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June 2, 2014

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PUBLIC SERVICE
COMMISSION

Via Hand-Delivery

Mr. Jeffrey Derouen
Executive Director
Kentucky Public Service Commission
P.O. Box 615
211 Sower Boulevard
Frankfort, KY 40602

Re: In the Matter of: Harold Barker; Ann Barker and
Brooks Barker v. East Kentucky Power Cooperative, Inc.
PSC Case No. 2013-00291

Dear Mr. Derouen:

Enclosed please find for filing with the Commission in the above-referenced case an original and ten (10) copies of East Kentucky Power Cooperative, Inc.'s Direct Testimony. Please return a file-stamped copy to me. Please note that only a copy of the verification of EKPC witness Dr. Kenneth Foster is attached to his testimony. The original signed and notarized verification will be filed once it is received from him.

Do not hesitate to contact me if you have any questions.

Very truly yours,

David S. Samford

Enclosures

M:\Clients\4000 - East Kentucky Power\1350 - Harold Barker Complaint - PSC Case No. 2013-00291\Correspondence\Ltr. to Jeff Derouen - 140602

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

RECEIVED
JUN 2 2014
PUBLIC SERVICE COMMISSION

IN THE MATTER OF:

HAROLD BARKER; ANN BARKER AND BROOKS BARKER	)	
COMPLAINANTS	)	
V.	)	**Case No. 2013-00291**
EAST KENTUCKY POWER COOPERATIVE, INC.	)	
DEFENDANT	)	

DIRECT TESTIMONY OF MARY JANE WARNER, P.E.
ON BEHALF OF EAST KENTUCKY POWER COOPERATIVE, INC.

Filed: June 2, 2014

I. INTRODUCTION

Q. PLEASE STATE YOUR NAME, TITLE AND BUSINESS ADDRESS.

A. My name is Mary Jane Warner. I am the Director of Production Engineering & Construction for East Kentucky Power Cooperative, Inc. ("EKPC"), 4775 Lexington Road, Winchester, KY 40391.

Q. PLEASE DESCRIBE YOUR EDUCATION AND PROFESSIONAL EXPERIENCE.

A. I have a BSCE from the University of Kentucky, and I am a Licensed Professional Engineer, in Kentucky. My electric utility experience spans 34 years, with 28 years in Transmission and 6 years in Production. During my time in Transmission my professional experience ranged from substation and transmission line design through progressively more responsible roles in management and leadership. My Production experience began with a 4 year Project Manager assignment for a large pollution control retrofit project, and then a transition to my current position.

Q. PLEASE DESCRIBE YOUR JOB DUTIES AS DIRECTOR, PRODUCTION ENGINEERING & CONSTRUCTION.

A. My job description requires that I provide effective leadership, vision, direction and accountability for engineering services related to a high degree of availability, reliability, operational efficiency, effective project management and major construction management for existing and planned generating facilities. I am responsible for project management, engineering management and construction management of all major capital generation and major maintenance projects for the Cooperative.

Q. PLEASE DESCRIBE THE PURPOSE OF YOUR TESTIMONY.

A. The purpose of my testimony is to respond to the issues identified by the Public Service Commission ("Commission") in its April 7, 2014 Order in this case and to various claims and statements made by the Complainants ("Barkers") in their complaint, direct testimony and responses to data requests.

Q. ARE YOU FAMILIAR WITH THE ORDER ENTERED BY THE PUBLIC SERVICE COMMISSION ("COMMISSION") ON APRIL 7, 2014 IN THIS PROCEEDING?

A. Yes. I have reviewed the Commission's Order. The Commission dismissed certain claims made by the Barkers that were beyond the scope of the Commission's jurisdiction over rates and service. The Commission then indicated that there were two primary issues over which it had jurisdiction. First, the Commission said that it would determine "whether EKPC was required to obtain a CPCN prior to beginning its transmission line upgrade project." In providing further discussion of this primary issue, the Commission's Order set forth two subordinate questions of "whether: (1) a CPCN is required for an entire transmission line project when one or more segments that equal or exceed one mile in length are not replacements or upgrades; or (2) a CPCN is only required for those segments of a transmission line project which equal or exceed one mile in length that are not replacements or upgrade of an existing transmission line." Second, the Commission said it would determine, "...if a CPCN was required, whether the proximity of the upgraded line to Complainants' premises presents health and safety concerns."

Q. ARE YOU FAMILIAR WITH THE COMPLAINT, TESTIMONY, AND RESPONSES TO DATA REQUESTS FILED BY THE BARKERS IN THIS PROCEEDING?

A. Yes, I am.

II. THE SMITH-NORTH CLARK TRANSMISSION LINE PROJECT

Q. WHAT WAS YOUR ROLE IN DEVELOPING AND IMPLEMENTING THE SMITH-NORTH CLARK TRANSMISSION LINE PROJECT ("PROJECT")?

A. At the time of this Project, I was the Manager of Power Delivery Expansion, which included responsibility for the planning, design, and construction of all transmission projects. My personal involvement in the Smith-North Clark Transmission Line Project was participation in planning the project (including regulatory and permitting), routing the line, the open house, and limited right of way negotiations.

Q. PLEASE PROVIDE A GENERAL DESCRIPTION OF PROJECT.

A. The Smith-North Clark Transmission Line Project was an upgrade/rebuild of an existing transmission line to provide a 345kV circuit from EKPC's existing J.K. Smith Generating Station ("Smith") to a needed junction in the existing Spurlock – Avon 345kV transmission line in order to reconfigure the transmission network to manage critical power flow congestion. The Project upgraded the existing Smith-Hunt-Sideview transmission line to a double circuit transmission line carrying the 345kV circuit above the lower voltage circuit currently operated at 69kV. The structures and lower circuit are designed with the necessary clearances to operate at 138kV, if the need should ever arise for such a change. The replacement structures are weathering steel two and three pole structures with connecting horizontal members. The 345kV circuit has three sets of conductor paired bundles and the 69kV circuit has three individual conductors. The line is protected by 2 overhead ground wires, one encasing fiberoptic cable for EKPC system communication purposes.

Q. PLEASE DESCRIBE THE TRANSMISSION LINE THAT EXISTED PRIOR TO THE PROJECT.

A. The Smith-Hunt-Sideview 69kV transmission line was located on 100 ft. wide right of way, and was constructed primarily of wooden H-frame structures, with some three pole structures. The single circuit line was built in the 1950's and consisted of 3 conductors and 2 overhead ground wires.

Q. IS THERE ANY PORTION OF THE PROJECT WHICH WAS NOT A REPLACEMENT AND UPGRADE OF THE EXISTING TRANSMISSION LINE?

A. There were several locations where the circuits had to separate to reach their voltage appropriate junctions or terminations. Those locations were at Hunt 69kV substation, where the 69kV circuit enters and exits the existing substation, and North Clark, where the circuits separate and the 69kV terminates at the existing Sideview 69kV substation and the 345kV circuit terminates at the new North Clark 345kV Substation. Maps of the Hunt substation area are attached as Exhibit

MJW-1 and MJW-2 and a map of the North Clark/Sideview substation area is attached as Exhibit MJW-3. The total length of the new 345kV circuit that enters the North Clark substation after diverging from the replaced 69kV circuit that runs into the Sideview substation is 3,755 feet. Of this, 1,800 feet of the new 345 kV circuit is located on property owned by EKPC. In the final configuration at Hunt, the centerline was shifted and all but 559 ft. of the deviation was a replacement of the existing 69kv line, and upgrade of that line for the 345kV circuit. Only the new segment of 345kV between structures UT19 and UT20 was not a replacement or upgrade of the existing line. Thus, the only portion of the Project that was not a replacement or an upgrade of the existing line was a total of 4,314 (3,755 + 559) feet of new 345 kV circuit not co-located with the replaced 69 kV line.

Q. WHY WAS THE PROJECT NECESSARY?

A. There were 3 primary reasons why system improvements were needed in the Spurlock/Avon/Smith area of EKPC's transmission network: 1) frequent overloading of the Avon 345/138kV, 450 MVA autotransformer in the June – August 2005 time period and expected future overloading; 2) potential instability of the existing combustion turbines at Smith; and 3) risk reduction of economic impact due to a loss of the Avon 345/138kV transformer. The Avon Transformer average power flow exceeded its summer continuous rating on numerous occasions in the period from May 1 – August 29, 2005. The actual redispatch costs to EKPC for this period alone was over $3.8 million and, without relief, the situation was forecast to continue and to worsen. In 2003, a brief transient stability screening analysis indicated unacceptable stability of the Smith Combustion Turbine Generating Units when evaluated against NERC criteria. Previously, EKPC had been willing to accept the risk of losing one or more of the Smith Units due to their quick start capabilities, and the relatively low total generating capacity at risk. Over time, the generation added at Smith and the diminished certainty of power import capability resulted in greater vulnerability to a disturbance caused by instability. Such an event could have resulted in the sudden loss of over 800MW instantaneously, which far exceeded the contingency provisions EKPC had at the time through the ECAR Automatic Reserve Sharing Program. In the event of a failure of the Avon transformer, the time required for replacement was estimated to be 1 – 18 months, and resulting redispatch costs (to shift generation from Spurlock to Smith) were estimated at $14 million to $22 million per month. Mitigation measures were taken to reduce the overload and risk, but none acceptably alleviated the Avon transformer constraint during times of heavy north to south flows on the transmission system, as a result of off-system contract power purchases. The construction of additional networked 345kV facilities was necessary to provide long-term relief for the overload and a robust solution for sustaining power flows without the disruption to generator dispatch for the long-term.

Q. WHY DID EKPC SEEK AN ADVISORY OPINION FROM THE COMMISSION'S STAFF REGARDING WHETHER A CPCN WOULD BE NEEDED FOR THE PROJECT?

A. During the route selection process and consideration of best alternatives, the project team considered a rebuild/upgrade of the existing Smith-Hunt-Sideview 69kV line and was reasonably confident that it met both the spirit and the letter of the recently adopted changes to KRS 278.020(2) as a replacement or upgrade of an existing transmission line or that any new circuit would be under 5280 feet in length. However, it seemed appropriate to seek confirmation that our interpretation was consistent with that of the PSC experts. This request provided us the opportunity to state our circumstances and logic and receive further input or confirmation.

Q. AT THE TIME THAT EKPC SOUGHT THE ADVISORY OPINION, HAD THE PROJECT ROUTE BEEN FIRMLY ESTABLISHED?

A. No. At the time that EKPC sought the advisory opinion, routes were being evaluated via the siting process described later in this testimony, and EKPC was making preparations to take a proposed corridor to the open house on November 10, 2005. EKPC was inquiring about a particular alternative which was eventually selected as the proposed route. Recent PSC Orders had clearly indicated a preference for locating transmission lines along existing corridors, rather than establishing new green field routes. In Case No. 2005-00089, the Commission stated, "The Commission does caution East Kentucky Power and all other electric utilities, however, that future applications should comprehensively consider the use of existing corridors in planning future transmission.") EKPC had already begun to inquire in the general vicinity of the Sideview Substation about property owner interest in the potential sale of their land for the substation, and to pursue the purchase of options if possible. At the time that EKPC sought the advisory opinion, the proposed route included less than 4000 feet that was not within the existing 100 ft. wide right of way, or not on EKPC property.

Q. **PLEASE PROVIDE A GENERAL DESCRIPTION OF THE PROCESS THAT EKPC CURRENTLY EMPLOYS IN DETERMINING WHERE TO SITE A TRANSMISSION LINE.**

A. EKPC uses the Kentucky Transmission Line Siting Methodology developed by EPRI in conjunction with Georgia Transmission Corporation (GTC), and Photo Science, Inc. The model was originally developed with input from stakeholders in Georgia, but later calibrated to embody values and weights as determined by a representative group of Kentucky stakeholders at a workshop held in Lexington on February 28, 2006. The methodology employs an optimizing model that includes land use and feature data over a large area to identify and rank paths of least impact. The best of those route alternatives are then compared to select a preferred or proposed alternative.

Q. **WITHIN THE CONTEXT OF EKPC'S SITING PROCESS, WAS THERE ANYTHING ABOUT THIS PARTICULAR PROJECT THAT SHOULD BE NOTED?**

A. This Project was in the first group of projects for which EKPC had used the EPRI/GTC Siting Methodology. The use of existing corridors was very strongly suggested by the Commission in CPCN Orders immediately prior to this Project, and the need for EKPC to expediously construct a solution to solve the transmission system constraints was critical. Consideration of these two factors was crucial to the selection of the proposed route. Five distinct routes emerged as the best options, and the EKPC project team conducted the expert judgment evaluation, which is the final step in the EPRI/GTC Siting Methodology, consisting of a professional collaboration guided by study results to select the proposed route. As the siting process was culminating, EKPC began to inquire about property purchases to piece together a viable substation site near the existing Sideview Substation. Eventually, this effort resulted in successfully assembling the property that is now the North Clark Substation site. The purchases and agreements were all negotiated without necessity for condemnation in fee, which was one of our goals in securing the substation site in any location.

Q. WERE ANY ALTERATIVE ROUTES THAT WOULD HAVE BYPASSED ALL OR A LARGE PORTION OF THE EXISTING TRANSMISSION LINE'S RIGHT-OF-WAY CONSIDERED FOR THE PROJECT?

A. Yes – Using the EPRI/GTC Siting Methodology, Photo Science generated route corridors and evaluated a total of 166 alternative routes that were scored according to the weighted impacts as described above. Some of those alternatives were located within existing corridors, and others were largely "green field" routes, although every alternative generated was co-located with the Smith – Hunt-Sideview line for a portion of the route.

Q. WHY WERE THOSE ALTERNATIVES REJECTED?

A. The best of the distinct alternatives were taken to the final step of the EPRI/GTC Siting Methodology ("Expert Judgment") where the project team performed a refined impact evaluation. That evaluation was based on Visual Issues (5%), Community Issues (40%), Rights-of-Way Schedule (25%), Construction/Maintenance Accessibility (5%), and Regulatory Issues (schedule & cost) (25%). The evaluation concluded the proposed route resulted in the least impact, and was therefore the preferred route.

Q. WERE THERE ANY DEVIATIONS FROM THE EXISTING RIGHT-OF-WAY THAT WERE MADE AS PART OF THE PROJECT?

A. Yes, but let me first clear up a potential point of confusion. A deviation from the existing right-of-way only means that the new transmission line is physically located in a different location than the original line. Saying that a line deviates from the existing right-of-way does not necessarily mean that the deviating portion of the transmission line is somehow a new transmission line. Whether any given segment of a new transmission line is a replacement or an upgrade of an existing transmission line depends upon a comparison of the nature and purpose of the lines and not a strict determination of whether the right-of-way has changed. The proximity of a deviation in right-of-way to the pre-existing right-of-way is one factor that could be taken into account in determining whether a project is a replacement and upgrade project or a whole new construction project, but that cannot be the sole determinative factor.

With this in mind, and as set forth in EKPC's response to Request No. 1 of Commission Staff's Initial Request for Information, dated November 7, 2013, there were three deviations from the existing right-of-way. The lengths of those deviations after negotiations with property owners concluded, were: 1) 6,975 feet at the Hunt Substation, although only 559 feet for the new non, co-located 345 kV circuit was not a replacement or upgrade; 2), 1,875 feet at the North Clark entry south of Donaldson Road, none of which was a replacement or upgrade, and 1,880 feet at the North Clark entry north of Donaldson Road on EKPC property, none of which was a replacement or upgrade. Thus, while the Project had deviations from the pre-existing right-of-way that totaled 10,730 feet, the majority of the construction within those deviations was still an obvious replacement and upgrade of the pre-existing line. Only 4,314 feet of the Project on a deviated right-of-way could fairly be considered as anything other than a replacement and upgrade of the existing transmission line.

Q. WHY WERE THESE DEVIATIONS MADE?

A. Since the 345kV line would not connect electrically with the 69kV Hunt Distribution Substation, the proposed double circuit transmission line was planned to separate at that location so the 345kV line could "jump around" the substation and the 69kV line could be unchanged in order to maintain the two way feed to the existing substation. The affected property owners subsequently requested a change in the location of the line that resulted in a favorable outcome for all parties. EKPC was able to successfully negotiate a restated easement and the change was made in the final design. On the northern end of the proposed route, the properties EKPC was able to purchase for the 345kV substation fronted Donaldson Road, and were oriented such that a realignment of the 345kV substation entrance was more attractive than the originally proposed route for that area, which extended past the Sideview Substation and affected three additional property owners.

Q. IS EKPC ALWAYS ABLE TO ACCOMMODATE REQUESTS FROM LANDOWNERS TO DEVIATE FROM THE EXISTING CENTERLINE IN REPLACING AND UPGRADING A TRANSMISSION LINE?

A. No, there are a number of factors that must be balanced to successfully implement an accommodation. We sometimes receive requests that are not feasible to meet when considering all factors.

Q. WHAT ARE SOME OF THE FACTORS THAT MUST BE BALANCED IN DETERMINING WHETHER A REQUEST TO MAKE A DEVIATION FROM AN EXISTING RIGHT-OF-WAY MAY BE ACCOMMODATED?

A. After a proposed route has been selected and landowners are invited to attend an open house, the process of negotiation with property owners begins. Property rights cannot be negotiated for a linear project all at once and it is not prudent to "link" the preferences of each property owner as we move along the line, so our goal is always to begin with a proposed route that is the least impactful as a whole. This enables us to use impact weighting endorsed by public input in the development of the proposed route, without putting the rights/preferences of any individual above those of another. Acting in an unarbitrary manner is a crucial element in the obligation of a utility. So, the first balancing point is whether or not we have the legal right to make the accommodation, and whether or not it negatively impacts another property owner. We must also evaluate the cost of a requested accommodation, which will flow to our Members. Requests that significantly increase the construction, maintenance, or operational cost of a facility or the schedule for implementation are not typically accommodated.

Requests are occasionally made that are inconsistent with good design practices, and cannot be implemented, or have a negative environmental impact that is insurmountable. In any event, if an accommodation cannot be successfully achieved, negotiations fail, and condemnation is the only remedy, EKPC has followed an objective, structured development of the proposed route in such a manner as to assure that it is the best route for the project.

Q. DID THE DEVIATIONS THAT WERE MADE RESULT IN A NET INCREASE OR A NET SAVINGS IN THE TOTAL COST OF THE PROJECT?

A. The deviation at Hunt resulted in a net savings, however there was an error in EKPC's prior Response 1b. to PSC Request 1. EKPC did compensate the Violet Foley Estate in the amount of $30,000. The revised net savings, based on EKPC's prior calculations, are $116,500 for Hunt and $26,700 for North Clark for a total of $143,200 for all deviations compared to the originally proposed route.

Q. IN LIGHT OF THESE DEVIATIONS, DO YOU BELIEVE THAT THE PROJECT COULD NO LONGER BE CONSIDERED A REPLACEMENT AND UPGRADE PROJECT?

A. No. As I mentioned earlier, there is a distinction between a deviation in right-of-way and the functional question of whether a new transmission line replaces or upgrades an old transmission line. With the exception of 559 feet of new 345kV line at the Hunt substation and 3755 feet of new 345kV line entering the North Clark substation, the entire project was a replacement and upgrade of the pre-existing line despite the deviations in right-of-way. The deviations made in the

Project's total 18 1/2 miles are minor, they were necessary in support of the use of an existing corridor, they were made via productive negotiations with property owners who had the right to refuse EKPC's offers, they resulted in net savings over the estimated cost or the original route and they resulted from circumstances that could not have been predicted when the proposed route was finalized.

Q. **IF THE COMMISSION INTERPRETED KRS 278.020(2) IN SUCH A MANNER THAT A CPCN WAS REQUIRED FOR THE ENTIRETY OF A TRANSMISSION LINE PROJECT WHEN ONE OR MORE SEGMENTS THAT EQUAL OR EXCEED ONE MILE IN LENGTH ARE NOT REPLACEMENTS OR UPGRADES, WHAT PRACTICAL RAMIFICATIONS WOULD RESULT?**

A. If the Commission said that an entire project was subject to a CPCN if any right-of-way deviation, or combination of right-of-way deviations, exceeded one mile and could not be considered as a replacement or upgrade, it would be very harmful to utilities, ratepayers and affected landowners. Utilities would, in essence, be punished for working with landowners to make reasonable accommodations for right-of-way deviations if any such deviation, or the sum of all such deviations, was to exceed a mile. If one deviation caused an entire project to be subject to the CPCN requirements, the utility's customers would ultimately have to bear the expense associated not only with the CPCN proceeding itself, but also with the delay of the project – which could be quite substantial. If multiple deviations were considered together as exceeding one mile, then the utility would have to arbitrarily pick and choose which deviations it might be willing to accept and which it would reject in order to stay within the confines of the statutory safe harbor, or to summarily reject all deviations to assure consistent treatment for property owners. The utility's interest in saving its customers from the costs of avoidable regulatory proceedings and project delays would create a strong disincentive to working with landowners.

Q. IF THE COMMISSION INTERPRETED KRS 278.020(2) IN SUCH A MANNER THAT A CPCN WAS REQUIRED FOR ONLY THOSE SEGMENTS OF A TRANSMISSION LINE PROJECT THAT EQUAL OR EXCEED ONE MILE IN LENGTH THAT ARE NOT REPLACEMENTS OR UPGRADES OF AN EXISTING TRANSMISSION LINE PROJECT, WHAT PRACTICAL RAMIFICATIONS WOULD LIKELY RESULT FROM SUCH AN INTERPRETATION?

A. The same disincentives I described before would still be present. Utilities would be very cautious about working with landowners to make reasonable accommodations for fear that their customers would be subject to additional costs arising from the CPCN proceeding and the potential delay of a project. Nevertheless, to the extent that a single segment may exceed one mile in length and not be considered a replacement or upgrade, then a CPCN would be required for that segment, as I understand the law. The statute appears to be silent as to whether the CPCN requirement is triggered when a single, non-replacement/non-upgrade segment exceeds a mile or whether the sum of all such segments may trigger the CPCN requirement even though no single segment may be one mile or more in length. The former interpretation would appear to serve the interests of landowners, customers and utilities without being contrary to the intent behind the statue as I understand it. Regardless, in this case, the total length of the new 345 kV that was not an upgrade of the existing line is significantly less than one mile when looked at individually and cumulatively.

Q. DID THE DEVIATIONS, IN ANY WAY, HAVE AN IMPACT TO THE SEGMENT OF THE PROJECT WHICH CROSSES THE BARKERS' PROPERTY?

A. No. The Hunt deviation is 8.5 miles away, and the North Clark deviation is 5 away.

Q. WHY WERE THE THREE ACTUAL DEVIATIONS NOT DESCRIBED IN THE OCTOBER 7, 2005 LETTER FROM EKPC'S COUNSEL REQUESTING AN ADVISORY OPINION AS TO WHETHER A CPCN WAS REQUIRED FOR THE PROJECT?

A. As described earlier in this testimony, some deviations were anticipated in the vicinity of the Hunt and Sideview substationss, but the circumstances had not yet arisen that gave rise to the actual deviations that were eventually adopted. They were a product of interaction with property owners, successful negotiations, and the evolving effort to lessen impact of the Project where possible. While the total length of the deviations was 10,730 feet, only 4,314 feet of the construction does not represent a replacement and upgrade of the existing line. That amount is relatively close to the approximate 4,000 feet estimated in EKPC's 2005 request for an advisory opinion.

Q. IN HINDSIGHT, DO YOU BELIEVE THAT EKPC SHOULD HAVE UPDATED COMMISSION STAFF REGARDING THESE DEVIATIONS?

A. Yes. As stated in EKPC's Response to PSC Information Request, Response 4, EKPC recognizes that this deviation should have been communicated to the Commission in 2006.

Q. ONCE THE FINAL ROUTE WAS DETERMINED, DID YOU STILL BELIEVE THAT THE STAFF ADVISORY OPINION WOULD APPLY TO THE SITUATION AND THAT NO CPCN WAS REQUIRED?

A. Yes. The deviation in the vicinity of the Sideview/North Clark substation (depicted in Exhibit MJW-3) amounted to 3,755 feet of new 345 kV conduit that diverged from the 69 kV circuit. Clearly this segment of brand new line on a brand new right-of-way was under the one mile threshold set forth in KRS 278.020(2) and half of that new line was in fact on EKPC's own property. I had no reason to think that this segment of the Project – after even taking into account the portion on EKPC's own property – would require a CPCN. The other deviation was located in the vicinity of the Hunt substation, which is depicted in Exhibits MJW-1 and MJW-2. While the total length of the deviation from the right-of-way was 6,975 feet, all but 559 feet of this was very clearly part of the replacement and upgrade of the existing line. The only new facilities consisted of the 559 feet of new 345 kV line.

In summary, the Project included, 10,730 feet of deviations from the pre-existing right-of-way. However, only 4,314 feet of this represented actually new construction that could not be considered a replacement and upgrade of the existing line. And of this new construction, only 2,434 feet of the new 345 kV line was not located on EKPC's own property. Thus, we determined that the deviations did not amount to more than one mile of new electric transmission line of 138 kV or above that could not be fairly and accurately described as a replacement and upgrade of the existing line and that the Commission Staff's guidance was still applicable. Therefore, we concluded that no CPCN was required before we moved forward with the Project.

III. ISSUES RAISED BY THE BARKERS

Q. PLEASE DESCRIBE WHAT EFFORTS EKPC UNDERTOOK TO EDUCATE AFFECTED LANDOWNERS OF THE PROJECT PRIOR TO THE COMMENCEMENT OF CONSTRUCTION.

A. An open house was held on November 10, 2005 and notices were published in the Winchester Sun on 10/31/05, 11/3/05, 11/5/05, and 11/7/05, advertising the event. On October 28, 2005 EKPC sent information packets to 250 addresses including affected property owners (identified by PVA records) and public officials for information about the project, and invitation to the open house. 93 individuals representing 98 parcels of land and 3 public officials attended the open house where they were encouraged to have one-on-one interaction with the Project team and other EKPC personnel to learn about the Project. There were exhibits and materials at the open house for inspection by the public and some information was provided to take home with them. In the months following the open house, EKPC made contacts and interacted with the public and affected landowners through the Project team and contract right-of-way agents.

Q. HOW DOES EKPC APPROACH THE TOPIC OF ELECTRIC AND MAGNETIC FIELDS WHEN DISCUSSING TRANSMISSION LINE PROJECTS WITH LANDOWNERS?

A. Since this concern arose in the late 1970's, EKPC has communicated openly with its Member Cooperatives, employees, property owners and the public that live and work in the vicinity of our transmission lines. We have long promoted education about EMF by providing literature, references, measurements, and personal interaction. EKPC has consistently encouraged the public to seek answers to their questions.

Q. WHAT IS THE DEPARTMENT OF ENERGY'S RAPID BROCHURE?

A. In the 1990's, the U.S. National Institute of Environmental Health Sciences (NIEHS) of the National Institute of Health and the U.S. Department of Energy (DOE) conducted a major study of EMF. The evaluation was called the Electric and Magnetic Fields Research and Public Information Dissemination (EMF RAPID) Program. As stated in the booklet titled "EMF, Electric and Magnetic Fields Associated with the Use of Electric Power, Questions & Answers", it was a "six-year project with the goal of providing scientific evidence to determine whether exposure to power-frequency EMF involves a potential risk to human health." And further, "This booklet explains the basic principles of electric and magnetic fields, provides an overview of the results of major research studies, and summarizes conclusions of the expert review panels to help you reach your own conclusions about EMF-related health concerns." It was originally printed in

1995, then updated and republished in 2002. The Barkers have acknowledged that they received a copy of this brochure at the open house.

Q. **DO YOU HAVE ANY REASON TO BELIEVE THAT THE PROXIMITY OF THE UPGRADED LINE TO THE BARKERS' PREMISES PRESENTS HEALTH AND SAFETY CONCERNS, DUE TO EMF?**

A. In regard to EMF exposure, EKPC has always taken the position that we will not attempt to interpret what should and should not be a health concern, leaving those determinations instead to medical and subject matter experts like Dr. Mezei and Dr. Foster, who have filed testimony in this case. We have consistently provided information and assisted people in measuring and understanding field exposure, and have assured them that we will meet all applicable requirements regarding transmission line design and construction.

Q. **ON PAGE 11 OF THEIR DIRECT TESTIMONY, THE BARKERS CLAIM THAT EKPC CONSTRUCTED THE 345 KV TRANSMISSION LINE THAT CONNECTS TO THE NEW NORTH CLARK SUBSTATION PRIOR TO ACQUIRING THE LAND FOR THE SUBSTATION. IS THAT CORRECT?**

A. The Barkers' statement is not correct. All options for the purchase of substation property were signed by April of 2006. Line construction commenced in July 2006. The final decision to make the deviation from the proposed route at the north end of the line was based on our level of success in acquiring property for the North Clark Substation , and the judgment of the Project team that the replacement and upgraded alternative was the best alternative for the Project.

Q. IN RESPONSE NO. 1 TO EKPC'S DATA REQUESTS, THE BARKERS STATE THAT EKPC NEVER INFORMED THEM THAT THEIR RESIDENCE WAS IN EKPC'S RIGHT-OF-WAY. IS THE BARKERS' RESIDENCE LOCATED WITHIN EKPC'S RIGHT-OF-WAY?

A. No. The corner of their detached garage was constructed approximately 6 feet into EKPC's pre-existing right-of-way, and a corner of the carport roof was built approximately 3 ft into EKPC's pre-existing right-of-way, but no portion of the actual residence has ever been within the right-of-way. In fact, the Barker's testimony specifically states on page 2 that the "…ROW goes through the middle of the front yard, part of the attached carport and garage/candy shop." The additional easement width necessary for the Project was normally acquired at 25 feet on either side of the existing easement. However, the additional 50 feet was acquired on only the side away from the Barker's home to avoid further encroachment.

Q. MR. PFEIFFER INDICATES IN RSPONSE NO. 16 TO EKPC'S DATA REQUESTS THAT HE HAS NEVER PERSONALLY DESIGNED, ROUTED, BUILT OR BUDGETED A TRANSMISSION LINE. BASED UPON YOUR PROFESSIONAL EXPERIENCE, ARE THERE ANY DIFFERENCES BETWEEN THE TYPE OF WORK MR. PFEIFFER INDICATES HE HAS PERFORMED AND THE WORK ASSOCIATED WITH THE PROJECT?

A. Yes. After a network is evaluated, voltage and conductor size are selected, transmission line design is primarily structural, and implementation of the design is heavy construction in the civil discipline. The curriculum vitae provided by Mr. Pfeiffer, indicates he has no training or experience in either structural design or heavy construction. Overall, the observations and calculations he provided for this Project appear drawn from general reference materials, his personal opinion, and topics he may have researched for the first time specifically related to this report. The specific shortcomings of his report and conclusions will be addressed by Dr. Dolloff and Dr. Cotts, who have filed testimony in this case.

Q. DO YOU DISPUTE THE COST ESTIMATES PROVIDED BY MR. PFEIFFER REGARDING THE COSTS OF MOVING THE SEGMENT OF THE PROJECT THAT CROSSES THE BARKERS' PROPERTY?

A. Yes. Mr. Pfeiffer suggests that his Option 1 would have cost $1,848.35 and his Option 2 would have cost $4,044.64 more than the existing line as it is today, if these options had been implemented at the time of the replacement and upgrade. However, if properly designed, the two options suggested by Mr. Pfeiffer would have cost approximately $69,000 and $72,000, respectively, based on average actual labor and material cost data from the Project. Mr. Pfeiffer incorrectly assumes there would be no additional right of way cost. The line is both shifted and the length slightly increased on an adjacent property owner and per standard configuration on a medium angle structure for this Project, would require the addition of 13 guy wires and 13 anchors at the new angle structure on the adjacent property owner and the two new angles on the Barker property. In order for his assumption of zero right-of-way cost to be correct, neither the adjacent land owner nor the Barkers would receive compensation for these deviations. My experience with designing, constructing and acquiring right-of-way for transmission lines does not support that assumption.

Q. WHAT REQUESTS WERE MADE BY THE BARKERS WITH REGARD TO THE SITING AND DESIGN OF THE TRANSMISSION LINE SEGMENT THAT CROSSES THEIR PROPERTY?

A. The first issues raised were the trees in the front yard that were to be cut, and the location of Structure UT79, which the Barkers' requested to move to the back of the house, along the adjusted centerline. There were discussions about whether or not the line could be moved away from the house, but when EKPC's constraints related to cost and impact to adjacent property owners were relayed to the Barkers, they did not accept the premise that any move would have to avoid an adverse cost impact to the Project, and must be acceptable to other affected land owners. Any such move would have required a negotiated resolution with the Barkers and potentially with adjacent land owners. EKPC was unable to make any progress in pursuit of a mutually acceptable solution.

Q. WHAT STEPS DID EKPC TAKE TO TRY AND ACCOMMODATE THE BARKERS?

A. EKPC offered to leave the front yard trees if the Barkers would commit to keep them below a specified height so as not to risk growth into the clearance zone for the line. The Barkers did not agree to that arrangement and EKPC later offered to pay the Barkers a replacement cost for the trees that were eventually cut by mutual agreement. EKPC redesigned the line to eliminate Structure UT79 (the structure closest to house), which required that we raise Structure UT80 which was designed to be on the Barker property, but well behind the home, and raise and move Structure UT78 to the North along the centerline on an adjacent property. The Barkers agreed to this change, and the line was constructed in this configuration. Evidence of the Barkers agreement is the fact that they voluntarily entered into the Agreed Interlocutory Judgment in the Clark Circuit Court proceeding. A copy of this order is attached as Exhibit MJW-4. During right-of-way clearing, EKPC agreed to leave felled timber in whole tree lengths for the Barkers use.

Q. WERE THERE ANY ADDITIONAL OFFERS MADE BY EKPC TO THE BARKERS, EITHER DIRECTLY OR THROUGH COUNSEL, BEYOND THOSE LISTED IN THE BARKERS' RESPONSE NO. 10 TO EKPC'S DATA REQUESTS?

A. As noted in the Barkers' response, a number of financial offers were made for the expanded easement during the Spring of 2006, culminating in a final offer of $37,800 prior to EKPC filing a condemnation suit in Clark Circuit Court on July 7, 2006. Over the time between then and now there have been numerous offers to either the Barkers or their attorney, to discuss resolution involving moving the house, buying the Barker property or portions thereof, and similar strategies. All such offers were rejected.

Q. DO YOU BELIEVE THAT EKPC HAS BEEN AS RESPONSIVE AS POSSIBLE TO THE CONCERNS RAISED BY THE BARKERS?

A. Yes. Although there were many meetings and discussions with the Barkers, EKPC was never able to successfully negotiate an acceptable outcome either before or after the condemnation suit was filed. Over the past 8 years, there were even attempts including mediation and an offer of settlement at the outset of this case. The difficulty we experienced in attempts to resolve this situation is exemplified by the Barkers refusal to negotiate at the Settlement Conference held by the Commission Staff in February, 2014.

IV. SUMMARY

Q. Did you sponsor any exhibits that are attached to your testimony?

A. Yes. Exhibit MJW-1, Exhibit MJW-2 and Exhibit MJW-3 were all developed by EKPC Staff working under my supervision and direction. Exhibit MJW-4 is a public record that may be found in the record of the condemnation proceeding currently pending the Clark Circuit Court. I ask that all of these Exhibits be incorporated into my testimony.

Q. Would you like to summarize your testimony?

A. The Smith-North Clark Project was critically needed to provide reliable service and avoid significant redispatch costs to EKPC's Members. The replacement and upgrade of an existing 69kV transmission line was a prudent and reasonable choice by EKPC to provide an effective solution, in a responsive time frame, at a reasonable cost, and in accordance with the strong desire by the PSC and the public to use available corridors for transmission line projects. All of the line construction except 2,434 feet (559 feet at Hunt plus 1,875 feet. at North Clark south of Donaldson Road) is either a replacement or upgrade of the existing line, or located on EKPC property. I do not believe that a CPCN was necessary for the Project or for the deviations that became part of the Project. The Barkers were given appropriate notice and information about the Project and EKPC made extensive efforts, in good faith, to negotiate a successful outcome regarding the rebuilt and upgraded line on their property. The line was constructed in accordance with good engineering practice and all applicable standards and codes.

Q. Does this conclude your testimony?

A. Yes.

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

HAROLD BARKER, **ANN BARKER, and** **BROOKS BARKER**	)	
COMPLAINANTS	)	**CASE NO.** **2013-00291**
V.	)	
EAST KENTUCKY POWER COOPERATIVE, INC.	)	

AFFIDAVIT

STATE OF KENTUCKY)
)
COUNTY OF CLARK)

Mary Jane Warner, being duly sworn, states that she has read the foregoing prepared testimony and that she would respond in the same manner to the questions if so asked upon taking the stand, and that the matters and things set forth therein are true and correct to the best of her knowledge, information and belief.

Mary Jane Warner

Subscribed and sworn before me on this 2nd day of June, 2014.

Gwyn M. Willoughby #500144
Notary Public

GWYN M. WILLOUGHBY
Notary Public
State at Large
Kentucky
My Commission Expires Nov 30, 2017

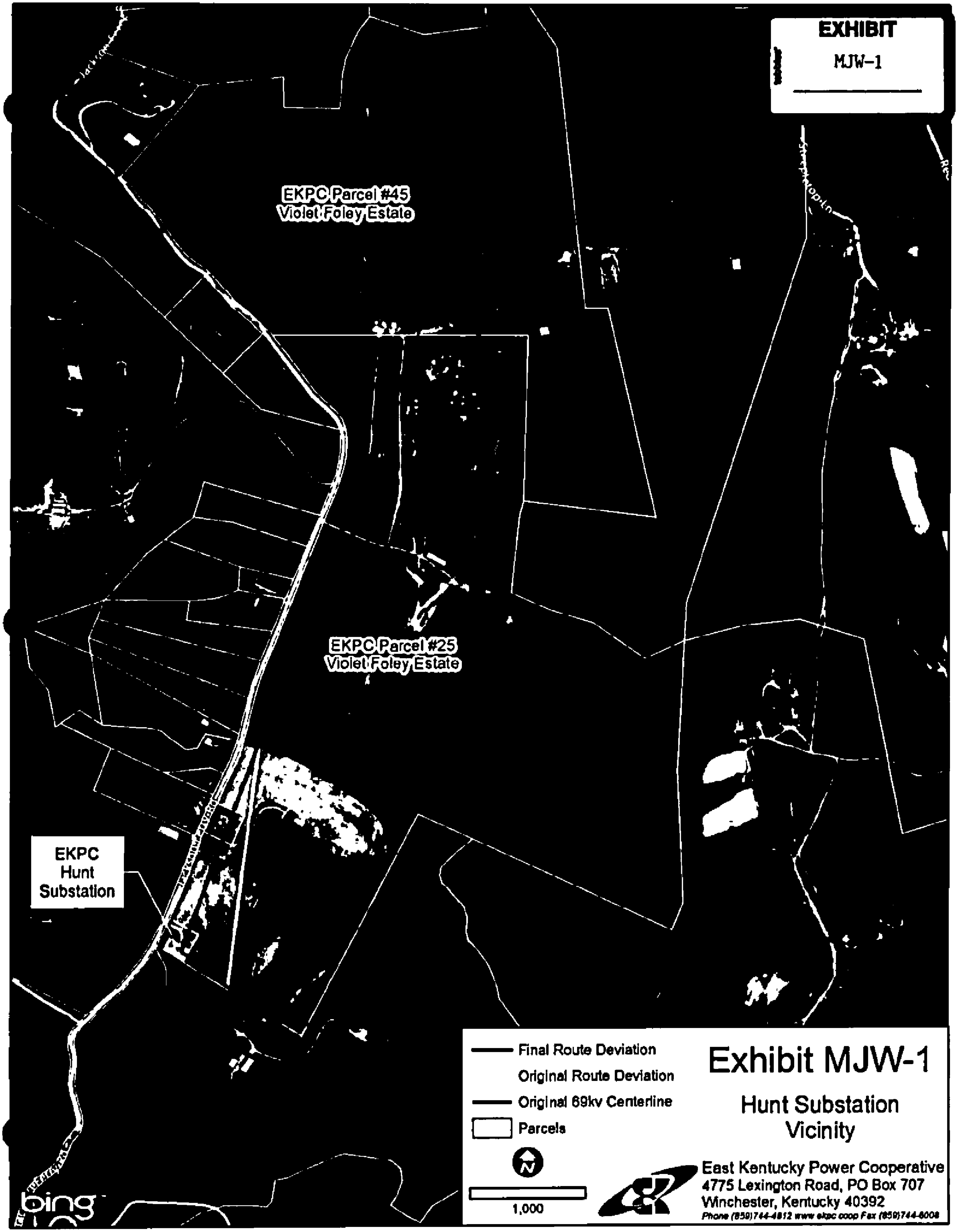
EXHIBIT
MJW-1
EKPC Parcel #45
Violet Foley Estate
EKPC Parcel #25
Violet Foley Estate
EKPC
Hunt
Substation
Final Route Deviation
Original Route Deviation
Original 69kv Centerline
Parcels
1,000
Exhibit MJW-1
Hunt Substation
Vicinity
East Kentucky Power Cooperative
4775 Lexington Road, PO Box 707
Winchester, Kentucky 40392
bing

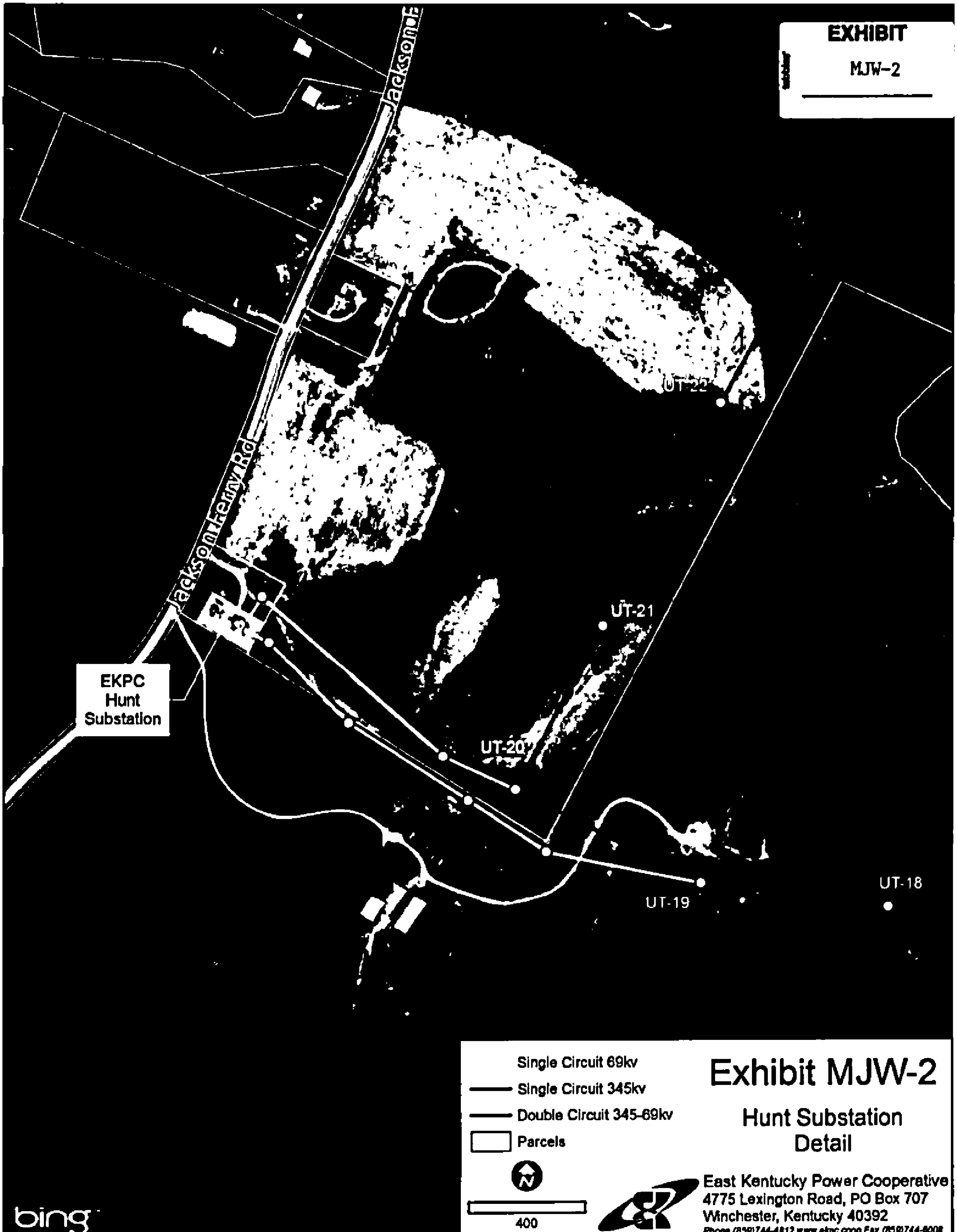
EXHIBIT
MJW-2
Jackson Ferry Rd
Jackson F
EKPC
Hunt
Substation
UT-22
UT-21
UT-20
UT-19
UT-18
Single Circuit 69kv
Single Circuit 345kv
Double Circuit 345-69kv
Parcels
400
Exhibit MJW-2
Hunt Substation
Detail
East Kentucky Power Cooperative
4775 Lexington Road, PO Box 707
Winchester, Kentucky 40392
bing

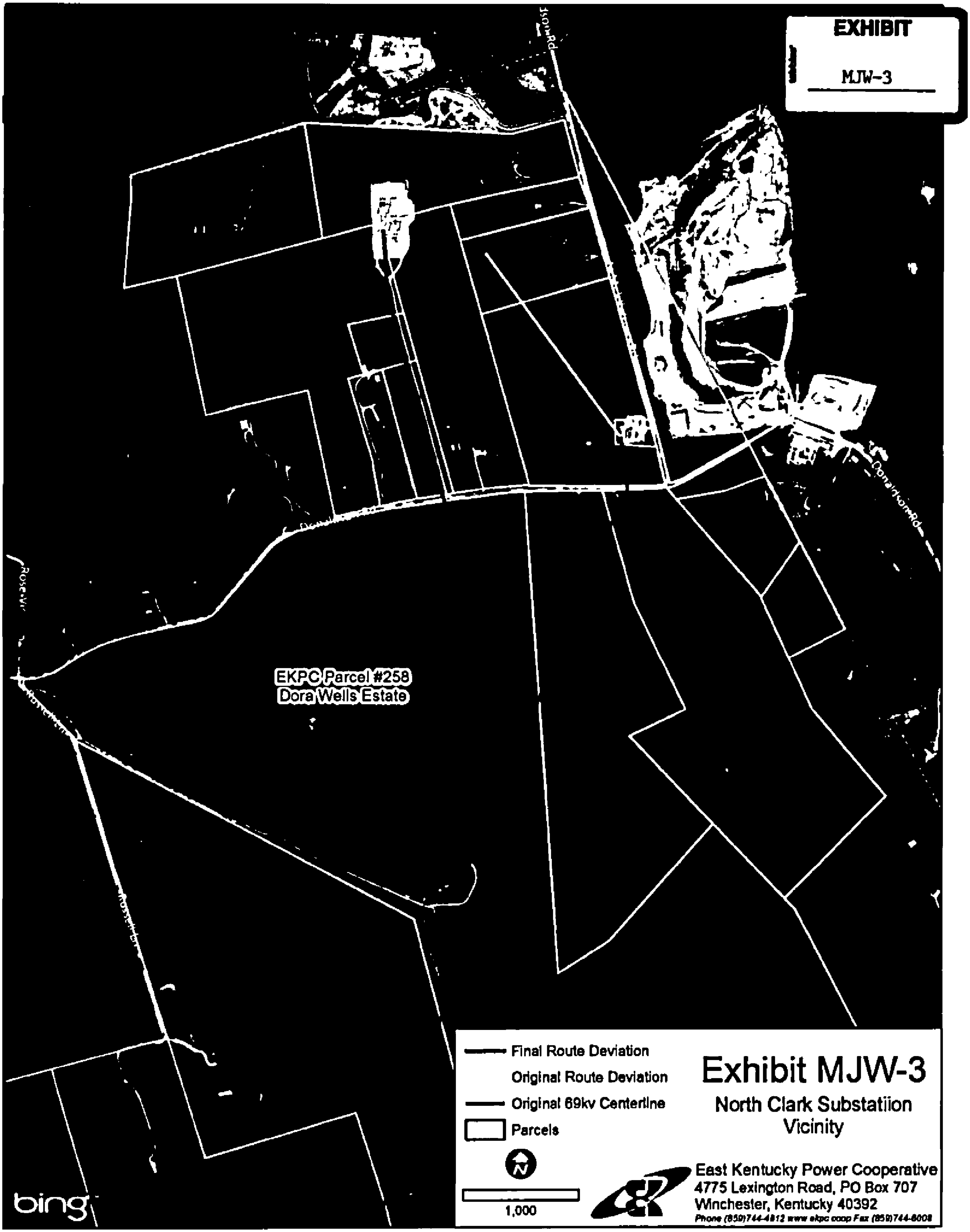

EXHIBIT
MJW-3
EKPC Parcel #258
Dora Wells Estate
Final Route Deviation
Original Route Deviation
Original 69kv Centerline
Parcels
1,000
Exhibit MJW-3
North Clark Substatiion
Vicinity
East Kentucky Power Cooperative
4775 Lexington Road, PO Box 707
Winchester, Kentucky 40392
bing

ENTERED 11-17-06
DAVID N. HUNT
CLARK CIRCUIT/DISTRICT COURT
BY [signature] D.C.

COMMONWEALTH OF KENTUCKY
CLARK CIRCUIT COURT
CIVIL ACTION NO. 06-CI-00419
DIVISION II

EAST KENTUCKY POWER COOPERATIVE, INC.,
A KENTUCKY CORPORATION — PLAINTIFF

VS: **AGREED INTERLOCUTORY JUDGMENT**

HAROLD BARKER, et al — DEFENDANTS

* * * * * * * * *

Upon examining the record herein, the Court finds:

1. That all the necessary parties hereto have been duly served with summonses and/or are before the Court; that the Defendants have not questioned the right of the Plaintiff to condemn the property or the use and occupation thereof.

2. That the Report of the Commissioners conforms to the provisions of KRS 416.580 and other applicable law.

3. IT IS, THEREFORE, ORDERED AND ADJUDGED that the Plaintiff under the provisions of KRS 279.110 and KRS 416.540 through 416.680 (the Eminent Domain Act of Kentucky) has the right and is entitled to condemn the lands and materials hereinafter described, and that the Plaintiff may take possession of said lands and materials for the purpose set forth in the petition upon the payment of the amount awarded by the Commissioners, which is $12,000.00 to the Clerk of this Court.

4. It is further ordered and adjudged that upon final determination of exceptions, or if no exceptions are taken within thirty (30) days from the entry of this Interlocutory Judgment, this Court shall enter a Final Judgment, and the Master Commissioner is appointed Special Commissioner of this Court for the sole purpose of conveying the title to the Plaintiff from the following lands and materials and for the following uses and purposes:

EXHIBIT
MJW-4

a. A certain tract of real property consisting of approximately 200 acres located approximately 5 miles east of the town of Winchester, lying on the north side of Mount Sterling Road, in Clark County, Kentucky and is more particularly described as follows:

<u>Property #1</u>

Beginning in the center of said Pike, corner to tract allotted to George Lewis; thence along same North 03°30' East 2123 feet to a post, corner to same; thence North 73° 00' East 98 feet to a post, corner to Ratliff; thence South 07° 14' East 18.5 feet to a fence post; thence North 72° 45' East 766.26 feet to corner to Ratliff; thence South 03° East 2455 feet to center of Mt. Sterling Pike, corner to Ratliff; thence along the center of said Pike North 84° 30' West 400 feet; thence North 87° 30' West 230 feet; thence North 84° 35' West 451.5 feet to the place of beginning, containing 50 acres, more or less.

Subject to any and all easements now of record including the existing Winchester-Mt. Sterling Road, U.S. Route 60, and applicable zoning restrictions.

Being the same property conveyed from Brooks Barnes and Elizabeth Barnes, husband and wife, to Ann Brooks Barnes Barker, a two-thirds (2/3) undivided interest, by deed dated December 28, 1973, recorded in Deed Book 212, at page 133, and of record in the Clark County Clerk's office; and being a part of the same property which Brooks Barnes and Elizabeth Barnes, his wife, conveyed an undivided one-third (1/3) interest to Ann Brooks Barnes Barker, by deed dated August 7, 1970 and of record in Deed Book 195, at page 530, also of record in the Clark County Clerk's office.

<u>Property #2</u>

A certain tract of land located on the north side of the Winchester-Mt. Sterling Turnpike, in Clark County, Kentucky, bounded and described as follows: Beginning at figure 11 on the map, a point in the middle of said turnpike a corner to the land sold by John Judy's heirs to George O. Graves (Williams land); thence with the middle of the pike S 88 49 E 58 poles to 12, a point in the middle of the road corner to Lot #3 in the line of Etta Clark's heirs, a stone on the north side of the road, a pointer; thence with the line of Lot #3 N 10 52 E 161.7 poles to 13 corner to Lot #3 and W. O. Brock; thence with the Brock line N 3 E 79.84 poles to 14 a stone corner on the south side of the stone fence; thence N 85 52 W 98.14 poles to the beginning of the 85 ½ acre tract of land conveyed by John D. Gay and wife to H. F. Judy on the east side of Cabin Creek and corner to W. O. Brock and Henry Besuden; thence with the Besuden line S 43 3 W 73.92 poles to 16 a stone corner to Mrs. Laura Williams; thence with her line S 1 E 54.32 poles to 17; thence N 73 5 E 46.44 poles to 18 a corner to Williams land; thence S 3 37 E 149.1 poles to the beginning, containing 150 acres of land, subject to all legal highways, easements and applicable zoning restrictions.

Being the same property conveyed to Brooks Barnes and Elizabeth Barnes, his wife, by Rodney Haggard, an unmarried man by deed dated January 13, 1951, and of record in Deed Book 140, page 539; of which the same property was conveyed by Brooks Barnes, et ux, an undivided 1/3 interest in same to Ann Brooks Barnes Barker, by deed dated August 7, 1970 and of record in Deed Book 195, page 530. The undivided 1/3 interest was further conveyed from Ann Brooks Barnes Barker and Harold F. Barker, her husband, back to Brooks Barnes and Elizabeth Barnes by deed dated December 28, 1973 and of record in Deed Book 212, page 130. Upon the death of Brooks Barnes and Elizabeth Barnes, the said property was then acquired by Ann Brooks Barnes Barker by virtue of the Last Will and Testament of Brooks Barnes dated June 13, 1975 and of record in Will Book 12, page 557 and the Last Will and Testament of Elizabeth Barnes dated October 26, 1993 and of record in Will Book 28, page 472; all of record in the Clark County Clerk's office.

b. It is further ordered and adjudged that Plaintiff, its successors and assigns, acquire the right to enter upon said property of the Defendant to construct, inspect, operate, repair, rebuild and maintain its electric transmission line and related facilities, including OPGW (optical ground wire) for electric utility purposes, along and upon the right-of-way herein described, together with the right of ingress and egress over said property of the Defendant while in the exercise of the rights and privileges granted herein, provided, however, that in exercising such right of ingress and egress the Plaintiff will, if reasonably accessible, confine said right of ingress and egress to the easement itself, and if not then whenever practicable to do so, use regularly established highways or farm roads.

c. Plaintiff shall also include the right to cut, fell, or otherwise control any and all trees and other vegetation and remove any structures or other obstructions, except gates and fences, located upon said easement, or any and all trees which are of such height that, in the opinion of the Plaintiff, might come in contact with said line or system; and it is understood that all merchantable wood shall remain the property of the Defendant and will be cut in lengths specified in writing by the Defendant, except that none shall be cut shorter than eight and one-half (8-1/2) feet, with said timber and any other cuttings to be left on or alongside said easement for the use of the Defendants; however if not specified as to length as provided above, then it is to be cut in lengths determined by the Plaintiff.

d. Plaintiff shall acquire the duty to restore and repair the area affected by said easement to a reasonable condition and within a reasonable time after final completion of said construction.

e. The Plaintiff shall pay the Defendants for any and all damages that may be caused to fences, gates, crops, animals and other property, including the land not actually occupied by the poles and anchors as a result of it constructing, inspecting, repairing, operating, or rebuilding said line and related facilities, except that it is specifically understood that the Plaintiff shall not be liable for cutting or trimming trees, or otherwise controlling trees and other vegetation and removing any structures or other obstructions in the manner and to the extent hereinabove specified; and Plaintiff shall also remain liable for any damages sustained because of its negligence in the operation and maintenance of said line and related facilities.

f. The Defendants, their successors, heirs, or assigns, are free to use and enjoy the property crossed by said easement, except, however, that such use shall not conflict with any rights or privileges herein granted to the Plaintiff, and that it is specifically understood that no buildings, signs, towers, antennas, swimming pools, or any other structures, except gates and fences shall be erected, maintained or moved upon the right of way described herein, nor shall any changes in the grade be made to the lands crossed by this easement without written permission from the Cooperative; and it is further understood that all poles, wires, and other related facilities installed on the herein described property at the Cooperative's expense, shall remain the property of the Cooperative and removable at the sole option of the Plaintiff.

5. It is further ordered and adjudged that Plaintiff takes and acquires hereby a transmission line easement across the above-described property and that said transmission line and related facilities are to be constructed and located according to the plat, marked "Verified Petition Appendix B," showing the centerline of survey, distance and bearings of said line and the location and number of poles and anchors thereon, and that said plat is made by reference a part hereof to the same extent as if copied in full herein. Said specific easement right-of-way which is necessary that Plaintiff acquire over and upon said property of Defendants, the centerline of which being described as follows:

> Beginning at a point between the subject land herein noted and the land of U.S. Highway 60 at Kentucky State Plane, South Zone Coordinate (hereinafter called KSP, SZC) N:2262200, E:2113466, and running thence N18°50'59"E, for a total distance of approximately 519 feet to a point in the line where line turns at KSP, SZC N:2262691, E:2113634, and running thence N17°48'03"E, for a total distance of approximately 2235 feet to a point in the line where line turns at KSP, SZC N:2264819, E:2114317, and running thence N14°54'29"E, for a total distance of approximately 1359 between the subject property and the land of Gerald Rogers at KSP, SZC N:2266132, E:2114667.

6. It is finally ordered and adjudged that the Sheriff of this county is hereby authorized and directed to evict or otherwise restrain Defendants if they attempt in any manner to keep Plaintiff from exercising its said rights after Ptaintiff has complied with all costs and payments as noted in paragraph 3 herein; and said Defendants shall pay for all costs and expenses of said eviction or other related action and for which cost and expense execution shall issue. All other costs in this case shall be paid by Plaintiff.

Dated this the 16th day of November, 2006.

[signature]

JUDGE, CLARK CIRCUIT COURT

SEEN AND AGREED TO BY:

ROGER R. COWDEN
Counsel for Plaintiff

MICHAEL ALEX ROWADY
Counsel for Defendants

CIRCUIT COURT CLERK'S CERTIFICATION

I, Lois Trimble, D.C., Circuit Court Clerk, do hereby certify that a copy of this Interlocutory Judgment was mailed to the Defendants named in this suit at the address as shown on the subject summons on this 17th day of November 2006.

CLERK, CLARK CIRCUIT COURT

By: Lois H. Trimble D.C.

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

IN THE MATTER OF:

HAROLD BARKER; ANN BARKER AND BROOKS BARKER	)	
COMPLAINANTS	)	
V.	)	**Case No. 2013-00291**
EAST KENTUCKY POWER COOPERATIVE, INC.	)	
DEFENDANT	)	

DIRECT TESTIMONY OF PAUL A. DOLLOFF, Ph.D.
ON BEHALF OF EAST KENTUCKY POWER COOPERATIVE, INC.

Filed: June 2, 2014

Q. PLEASE STATE YOUR NAME, BUSINESS ADDRESS, AND OCCUPATION.

A. My name is Paul A. Dolloff. I am an Electrical Engineer for East Kentucky Power Cooperative, Inc., 4775 Lexington Road, Winchester, KY 40391. I am also on the Adjunct Faculty of the University of Kentucky College of Electrical and Computer Engineering, 453 F. Paul Anderson Tower, Lexington, KY 40506-0046.

Q. PLEASE STATE YOUR EDUCATION AND PROFESSIONAL EXPERIENCE.

A. I have a B.S. in Electrical Engineering from Tennessee Technological University, a M.S. in Electrical Engineering from Virginia Polytechnic Institute and State University, a Ph.D. in Electrical Engineering from Virginia Polytechnic Institute and State University, and an M.B.A. from Morehead State University. I have worked for eighteen years with East Kentucky Power Cooperative (EKPC) and eleven years with the University of Kentucky

Q. PLEASE PROVIDE A BRIEF DESCRIPTION OF YOUR DUTIES AT EKPC.

A. I am a member of the Reliability Team in the Power Delivery Maintenance Department. The Reliability Team is primarily responsible for investigating all power outages on the EKPC bulk transmission system. The team also recommends process improvements to mitigate power outages and improve restoration efforts to increase system reliability.

Q. **WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?**

A. The purpose of my testimony is to describe my visits to the Barkers' residence during which I took measurements of the electric and magnetic fields associated with the North Clark to J.K. Smith 345 kV and the Hunt to Sideview 69 kV transmission lines and to describe the results of these measurements. I will also describe existing electric field and magnetic field standards from various states around the country that apply to high voltage power lines. Finally, I will discuss some specific issues that I noted in reviewing the Barkers' direct testimony and responses to data requests.

Q. **ARE YOU SPONSORING ANY EXHIBITS?**

A. Yes. I am sponsoring three memoranda that I wrote to document various visits to the Barkers' residence. These memoranda are designated as PAD-1, PAD-2 and PAD-3, respectively. In addition, I am sponsoring an exhibit which illustrates the electric field and magnetic field readings and modeled results taken by myself and others at the Barkers' residence, with a comparison to applicable standards that have been adopted by those few states with applicable standards. This exhibit is designated as PAD-4.

Q. **DID YOU VISIT THE BARKERS' HOME AND TAKE ELECTRIC FIELD READINGS?**

A. Yes, I visited the Barkers' home and took electric field readings.

Q. **WHEN DID YOU VISIT THE BARKERS' HOME AND TAKE THE ELECTRIC FIELD READINGS?**

A. During a site visit to the Barkers' home, I oversaw the measurement process of electric field readings on Friday, December 5, 2008.

Q. WHY DID YOU VISIT THE BARKERS' HOME AND TAKE ELECTRIC FIELD READINGS?

A. Chuck Caudill, manager of EKPC's Envision Services and Rick Drury, manager of Power Delivery Maintenance, requested that I take electric field readings at the Barkers' home.

Q. WHAT TYPE OF METER DID YOU USE TO TAKE THE ELECTRIC FIELD READINGS?

A. To take electric field readings I used the EMDEX II meter manufactured and calibrated by the Enertech Consultants company of Campbell, CA.

Q. WHEN WAS THE METER CALIBRATED?

A. Prior to the field measurements taken at the Barkers' home, the EMDEX II meter was calibrated on August 31, 2001.

Q. WHY DID YOU USE THIS PARTICULAR TYPE OF METER?

A. During the 1990's, the Electric Power Research Institute (EPRI) undertook an instrumentation development program to develop a personal meter with data-logging capability so that extremely low frequency magnetic fields (ELF-MF) exposures could be measured. EPRI partnered with the Enertech Consultants company of Campbell, CA to produce electromagnetic field (EMF) meters. This partnership resulted in the Electric and Magnetic Field Digital Exposure System, which led to the development of the EMDEX II handheld EMF exposure meter. As a member of EPRI, EKPC supported this program and purchased EMDEX II meters when production models became available in 1990. Being supported by EPRI, Enertech Consultants is internationally recognized as the manufacturer of choice for utility class EMF meters. Because the EMDEX II meter uses a three-axis probe, has a tight bandwidth (tuned to 40 to 800 Hz), is accurate to ±2%, and has a refresh rate of 1.5 to 10 seconds (depending upon configuration) this meter is superior to other EMF meters. Commercially available today, the cost of the EMDEX II is $2,900. Calibration services are available at a cost of $275.

The measurement taking process of power frequency electric fields is different than when taking magnetic field readings. Because most objects will perturb the electric field within a measurement area, an electric field meter cannot be kept close to a person or placed near an object without distorting the electric field readings. A kit (E-Probe) is available for the EMDEX II such that the meter can take electric field measurements. The E-Probe kit consists of a fiberglass extension pole deigned to isolate the user from the actual sensor. The kit also includes a software add-on, which allows the EMDEX II to display electric field readings.

The recognition of the EMDEX II meter by industry leaders coupled with the E-Probe kit that allows the EMDEX II to take and display electric field readings are reasons why I chose to use this particular meter.

Q. DID YOU LATER RETURN TO THE BARKERS' HOME AND TAKE MAGNETIC FIELD READINGS?

A. Yes, I later returned to the Barkers' home and took magnetic field readings.

Q. **WHY DID YOU RETURN TO TAKE THE MAGNETIC FIELD READINGS?**

A. During my conversation with the Barkers regarding EMFs, it seemed appropriate to offer to take magnetic field measurements as is routinely done by EKPC. The Barkers accepted this offer.

Q. **WHAT TYPE OF METER DID YOU USE TO TAKE THE MAGNETIC FIELD READINGS?**

A. To take magnetic field readings I used the EMDEX II meter manufactured and calibrated by the Enertech Consultants company of Campbell, CA.

Q. **WHY DID YOU USE THIS TYPE OF METER?**

A. Please see previous responses. Using a single meter to measure both electric and magnetic fields provides consistency to the measurement process and ultimately to the results.

Q. **WHEN WAS THE METER CALIBRATED?**

A. Prior to the field measurements taken at the Barkers' home, the EMDEX II meter was calibrated on August 31, 2001.

Q. **TO YOUR KNOWLEDGE, DOES THE FEDERAL GOVERNMENT HAVE ANY EMF STANDARDS?**

A. To my knowledge, the federal government does not have any EMF standards. Quoting the Electric and Magnetic Fields Research and Public Information Dissemination (EMF RAPID) Program booklet published in 2002 by the U.S. National Institute of Environmental Health Services (NIEHS) and the U.S.

Department of Energy (DOE), "In the United States, there are no federal standards limiting occupational or residential exposure to 60-Hz EMF."

The webpage, http://www.epa.gov/radtown/power-lines.html, from the U.S. Environmental Protection Agency website states, "In the U.S., there are no federal standards limiting occupational or residential exposure to power line EMF."

Quoting the "Power Frequency Magnetic Fields and Public Health" by William F. Horton and Saul Goldberg, ISBN: 0-8493-9420-1, 1995 by CRC Press Inc., "To date, no national standards exist for the regulation of magnetic fields based on long-term health effects. Nor does a federal agency have a clear mandate or specific authority to regulate."

Q. TO YOUR KNOWLEDGE, DOES THE STATE OF KENTUCKY HAVE ANY EMF STANDARDS?

A. To my knowledge, the state of Kentucky does not have any EMF standards.

Q. TO YOUR KNOWLEDGE, DOES RUS HAVE ANY EMF STANDARDS?

A. To my knowledge, the Rural Utilities Service (RUS) does not have any EMF standards.

Q. TO YOUR KNOWLEDGE, DO ANY OTHER STATES HAVE EMF STANDARDS?

A. To my knowledge, other states do have EMF standards.

Q. TO YOUR KNOWLEDGE, WHAT ARE THE EMF STANDARDS IN OTHER STATES?

A. Quoting the EMF RAPID Program booklet, "At least six states have set standards for transmission line electric fields; two of these also have standards for magnetic fields (see table below)." The table referenced in the above quote is given below and was taken directly, in its entirety, from the 2002 EMF RAPID booklet.

State Transmission Line Standards and Guidelines

	Electric Field		Magnetic Field	
State	**On R.O.W.***	**Edge R.O.W.**	**On R.O.W.**	**Edge R.O.W.**
Florida	8 kV/m[a] 10 kV/m[b]	2 kV/m	—	150 mG[a] (max. load) 200 mG[b] (max. load) 250 mG[c] (max. load)
Minnesota	8 kV/m	—	—	—
Montana	7 kV/m[d]	1 kV/m[e]		
New Jersey	—	3 kV/m		
New York	11.8 kV/m 11.0 kV/m[f] 7.0 kV/m[d]	1.6 kV/m	—	200 mG (max. load)
Oregon	9 kV/m	—	—	—

*R.O.W. = right-of-way (or in the Florida standard, certain additional areas adjoining the right-of-way). kV/m = kilovolt per meter. One kilovolt = 1,000 volts. [a]For lines of 69-230 kV. [b]For 500 kV lines. [c]For 500 kV lines on certain existing R.O.W. [d]Maximum for highway crossings. [e]May be waived by the landowner. [f]Maximum for private road crossings.

The webpage, http://www.epa.gov/radtown/power-lines.html, from the U.S. Environmental Protection Agency website states, "About seven states set standards for the width of right-of-ways under high-voltage transmission lines because of potential for electric shock." This website does not provide the names of these seven states and does not provide EMF exposure limits as set by these same states.

The February 1993 edition of The Electric Light & Power magazine contained an article entitled "EMF Avoidance Starts Even with the Lack of Evidence." This article states that the following seven (7) states regulate EMF exposure: Florida, Minnesota, Montana, New Jersey, New York, North Dakota, and Oregon.

The following table taken from "Power Frequency Magnetic Fields and Public Health" by William F. Horton and Saul Goldberg, ISBN: 0-8493-9420-1, 1995 by CRC Press Inc. indicates that eight (8) states have electric field limits.

State	Electric Field Limit
California	1.6 kV/m at edge of ROW*
Florida	10 kV/m for existing 500 kV transmission lines 8 kV/m for existing 230 kV transmission lines 2 kV/m for new transmission lines at edge of ROW
Minnesota	8 kV/m for existing 230 kV transmission lines
Montana	1 kV/m at edge of ROW in residential area 7 kV/m at edge of ROW at road crossing 2.5 to 3.5 kV/m in areas such as parking lots
New Jersey	3 kV/m at edge of ROW
New York	1.6 kV/m in ROW
North Dakota	9 kV/m at edge of ROW
Oregon	9 kV/m in ROW 7 kV/m at edge of ROW at road crossing

* Right of Way

4-1 Electric Field Limits by State [1-2]

Note that the 1.6 kV/m in ROW is in conflict with the table published in the EMF RAPID booklet. Data in EMF RAPID booklet is more comprehensive and has been verified as correct. With that, the 1.6 kV/m exposure limit in New York given in the above table should correctly state at the "edge" of the ROW, not "in" the ROW.

The following table taken from this same book indicates that two (2) states have magnetic field limits.

State	Magnetic Field Limit
New York	200 milligauss at edge of ROW* for lines of over 125 kV and more than 1 mile in length.
Florida	200 milligauss at edge of ROW for single circuit 500 kV lines. 250 milligauss at edge of ROW for double circuit 500 kV lines. 150 milligauss at edge of ROW for lines of 230 kV or less.

*Right of Way

Table 9.4-3 Magnetic Field Limits by State [1]

Q. DO THE READINGS YOU OBTAINED AT THE BARKERS' HOME COMPLY WITH THE STANDARDS SET IN OTHER STATES?

A. Yes. For those states with EMF standards, exposure limits may be given for on the right-of-way (ROW) and/or at the edge of the ROW. Considering exposure limits for electric fields, the most conservative electric field exposure limit for "on-the-ROW" is 8 kV/m as set by Minnesota. Note that Montana and New York have an on-the-ROW electric field exposure limit of 7 kV/m but these limits only apply to highway crossings. The highest on-the-ROW electric field reading taken at the Barkers' home is 0.997 kV/m, which is well below the most conservative state exposure limit of 8 kV/m.

Considering exposure limits for electric fields, the most conservative electric field exposure limit at the "edge-of-the-ROW" is 1 kV/m as set by Montana. The electric field reading taken at the edge-of-the ROW at the Barkers' home is 0.621 kV/m, which is below the most conservative state exposure limit of 1 kV/m. Note that the reading of 0.257 kV/m taken at the Barkers' home is considered suspect, and therefore disregarded, because the eaves of the home's carport likely provided partial shielding of the electric field emanating from the transmission lines to the meter's location.

Only two states (Florida and New York) have exposure regulations for magnetic fields and both states only give exposure limits at the "edge-of-the-ROW." The most conservative magnetic field exposure limit at the "edge-of-the-ROW" is 200 mG as set by New York. Note that the magnetic field exposure limit of 150 mG as set by Florida applies to transmission line voltages of 69 to 230 kV. As a reminder, the transmission lines at the Barkers' home are both 69 and 345 kV; therefore, the 150 mG exposure limit as set by Florida does not apply. The magnetic field reading taken at the edge-of-the ROW at the Barkers' home is 23.6 MG, which is well below the most conservative state exposure limit of 200 kV/m.

Q. DID EKPC DO ANY INTERNAL MODELING WITH RESPECT TO THE ELECTRIC OR MAGNETIC FIELDS ON THE BARKERS' PROPERTY?

A. Yes. Modeling was performed for both electric and magnetic fields.

Q. WHAT TYPE OF COMPUTER PROGRAM WAS USED TO COMPLETE THIS MODELING AND WHY WAS IT CHOSEN?

A. EMF modeling was performed using the Power Line Systems – Computer Aided Design and Drafting (PLS-CADD) software package from Power Line Systems, Inc. Recognized as an industry leading transmission line design and analysis software package, PLS-CADD has been adopted by more than 1,600 organizations in over 125 countries. PLS-CADD was chosen to perform EMF modeling for a number of reasons:

1. PLS-CADD is used by EKPC;
2. There is a high degree of experience with PLS-CADD at EKPC;
3. EKPC transmission line models have a high degree of accuracy within the PLS-CADD models: Structure design and 3-d landscape models;
4. PLS-CADD includes an EMF calculator based on the EPRI Red Book methodology;
5. PLS-CADD can perform EMF analysis with models containing multiple transmission lines (as is the case with this particular situation).

Q. WAS THE INTERNAL MODELING RESULTS CONSISTENT WITH THE ACTUAL READINGS TAKEN AT THE BARKERS' HOME?

A. Yes, the modeling results for both the electric and magnetic fields were consistent with the actual readings I took at the Barkers' home. For each of the on-site measurement visits, the actual loading conditions on both of the transmission lines were recorded. This recorded loading data was later used in the EMF modeling efforts. Following accepted industry practices, both the measured readings and the modeled results were taken at a height of 3.28 feet (1 meter) above the surface of the ground.

Electric Fields

Electric field readings were taken at the Barkers' home on Friday, December 5, 2008 between the hours of 12:20 p.m. and 1:10 p.m.[1] Loading conditions at the time the measurements were taken are given in Table One.

[1] See Exhibit PAD-1 for a memo giving complete electric field measurement results.

Table One Loading Conditions during Electric Field Measurements

Transmission Line	Voltage (kV)	MW	MVAr	Current (calculated)
N. Clark to JKSmith: 345kV	351.9 kV	254.0	25.0	418.7 amps
Hunt to Sideview: 69kV	71.0 kV (estimate)	17.0	2.1	139.3 amps

Table Two gives the measured and the modeled electric field values.[2] The model assumed the loading conditions given in Table One.

Table Two Electric Field Measurements and Modeling Results

	Electric Fields	
	On ROW	**Edge of ROW**
Measured	0.997 kV/m	0.621 kV/m
Modeled	1.515 kV/m	1.167 kV/m

Magnetic Fields

Magnetic field readings were taken at the Barkers' home on Tuesday, October 20, 2009 between the hours of 1:45 p.m. and 2:00 p.m.[3] Loading conditions at the time the measurements were taken are given in Table Three.

[2] See Exhibit PAD-4 for additional comparisons.

[3] See Exhibit PAD-3 for a memo giving complete magnetic field measurement results.

Table Three Loading Conditions during Magnetic Field Measurements

Transmission Line	Voltage (kV)	MW	MVAr	Current (calculated)
N. Clark to JKSmith: 345kV	350.4	527.0	16.0	868.7 amps
Hunt to Sideview: 69kV	69kV (assumed)	7.0	0.4	58.7 amps

Table Four gives the measured and the modeled magnetic field values.[4] The model assumed the loading conditions given in Table Three.

Table Four Magnetic Field Measurement and Modeling Results Comparisons

	Magnetic Fields	
	On ROW	Edge of ROW
Measured	61.4 mG	23.6 mG
Modeled	70.847 mG	30.931 mG

Q. **IN YOUR OPINION, WHAT WOULD BE THE LIKELY IMPACT OF USING THE EXISTING 69 KV TANSMISSION LINE AT A HIGHER 138 KV RATING?**

A. Electric field modeling was performed with the underbuilt transmission line at 69 kV and also at 138 kV. For the models, the 69 kV line was assumed to be at 71.0 kV, the 138 kV line was assumed to be at 138 kV, and the 345 kV line was assumed to be 352 kV. Table five gives the results of this modeling exercise.

[4] See Exhibit PAD-4 for additional comparisons.

Table Five Electric Field Modeling Results at 69 kV and 138 kV

	Electric Fields	
	On ROW	**Edge of ROW**
Line at 69 kV	1.515 kV/m	1.167 kV/m
Line at 138 kV	1.298 kV/m	1.063 kV/m

The electric field is slightly greater when the line is at 69 kV as compared to when the line is at 138 kV. Therefore, the magnitude (strength) of the electric field will decrease should the existing 69 kV line ever be energized at 138 kV.

By increasing the voltage of the 69 kV transmission line to 138 kV, the amount of current flowing in this transmission line will likely decrease. A decrease in the amount of current will result in a reduction in magnitude (strength) of the magnetic field.

Q. HAVE YOU REVIEWED THE TESTIMONY AND RESPONSES TO DATA REQUESTS PROVIDED ON BEHALF OF THE BARKERS IN THIS MATTER?

A. Yes, I have reviewed the testimony and responses to data requests provided on behalf of the Barkers in this matter.

Q. DO YOU HAVE ANY CONCERNS WITH ANY OF THE STATEMENTS CONTAINED WITHIN THE TESTIMONY OR THE RESPONSES TO DATA REQUESTS?

A. Yes, I have concerns with a number of the statements contained within the testimony and responses to data requests.

Q. **WHAT CONCERNS DO YOU HAVE WITH STATEMENTS CONTAINED WITHIN THE BARKERS' TESTIMONY OR RESPONSES TO DATA REQUESTS?**

A. The Complainants' Response to question 26(c) of the Defendant's Data Request is:

> **c. Phase rotation only matters in respect to the relationship between the 345 kV line and the 69 kV line. This relationship is either additive or subtractive and both cases have been considered.**

I agree that both the electric and the magnetic fields can be additive and subtractive based on phase rotation. Considering the electric field, the additive effect of the electric fields from each transmission line will be greatest if the phases are oriented such that the common phases of each transmission line are placed directly above one another as shown in Figure One.

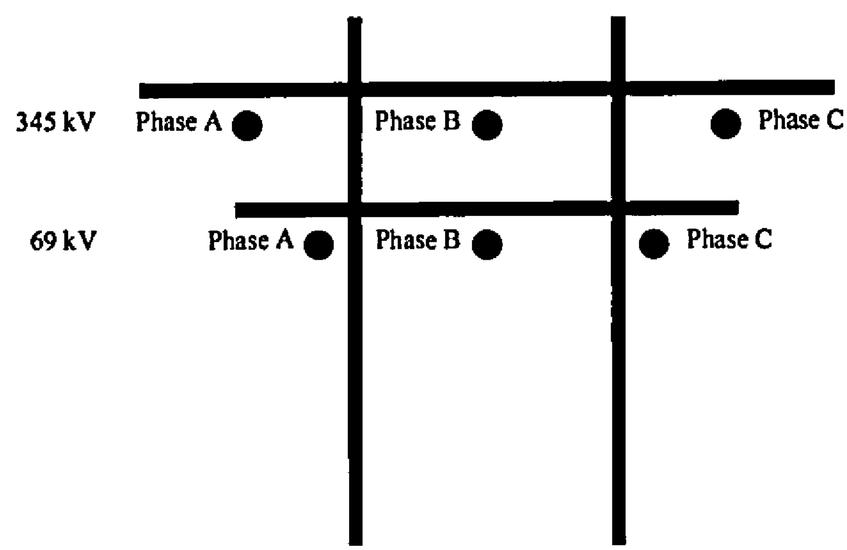

Figure One: Phase Rotation with Like-phases in Common Orientation

The resultant electric field from the interaction of the phase voltages from the two transmission lines is reduced if the phases are rotated as shown in Figure Two.

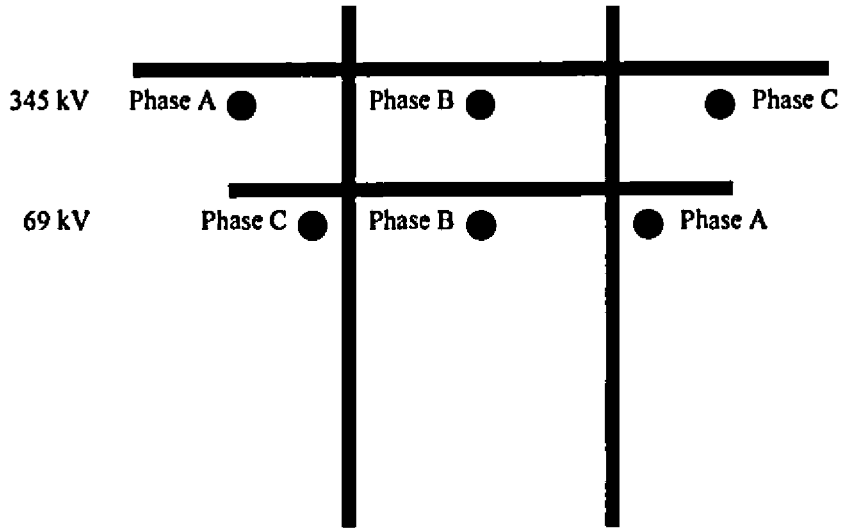

Figure Two: Phase Rotation to Reduce the Resultant Electric Field

It is important to note that the actual phase orientation of the two transmission lines in this matter is as given in Figure Two.

As can be imagined, there are multiple phase placement options between these two transmission lines. Though Mr. Pfeiffer's assertion that "both cases have been considered" implies that there are only two possible phase orientations is suspect, more importantly is the fact that Mr. Pfeiffer should have only considered the actual phase placement, as shown in Figure Two, for his electric field modeling efforts.

Phase rotation has the same effect on the additive and subtractive nature of the magnetic fields. However, unlike the resultant electric field, the resultant magnetic field is also dependent upon the direction of the current flow in each of the transmission lines with respect to one another.

The magnitude of the resultant magnetic field will be greatest when the phase rotation is given as shown in Figure One and the current flow in each transmission line is in the same direction. Mr. Pfeiffer should have only considered the actual phase placement as shown in Figure Two. It is unknown if Mr. Pfeiffer modeled the currents flowing in each transmission line to be in the same direction or in opposite directions. Still further, he should have used reasonable current magnitudes for his magnetic field modeling efforts instead of currents based on when the conductors reach minimum sag and maximum operating temperature. For this last point, please refer to the "Next-Contingency" discussion later in this testimony.

Q. WHAT OTHER CONCERNS DO YOU HAVE WITH MR. PFEIFFER'S TESTIMONY?

A. On page 76 of Mr. Pfeiffer's Investigation Report prepared on April 24, 2014 for the Barkers states:

- **Increasing the energy transmission levels will increase the sag, which will increase the electric fields.**

An increase in sag will not result in an increase in the electric field; however, an increase in sag will increase exposure to the transmission line's induced electric field at ground level because the distance to the energized conductors is reduced.

Q. DO YOU HAVE MORE CONCERNS WITH THE COMPLAINANTS' RESPONSES TO DATA REQUESTS?

A. Yes. The Complainants' Response to question 30 of the Defendant's Data Request states that he is quoting RUS Bulletin 1724E-203, as follows:

Nominal Line (kV)	ROW Width (Meters)	ROW Width (Feet)
69	23-30	75-100
115	23-38	75-125
138	30-46	100-150
161	30-46	100-150
230	**46-61**	**150-200**

continued...

345	**Has to be calculated**	

The circled text in the above quote is actually NOT part of RUS Bulletin 1724E-203 as purported by Mr. Pfeiffer. The actual table is silent beyond 230 kV as shown in a faithful quote:

RUS Bulletin 1724E-203
Page 6

Nominal Line (kV)	ROW Width (Meters)	ROW Width (Feet)
69	23-30	75-100
115	23-38	75-125
138	30-46	100-150
161	30-46	100-150
230	46-61	150-200

In this particular instance, it appears that Mr. Pfeiffer has, at the very least, taken liberties whilst quoting RUS Bulletin 1724E-203.

Q. IN ADDITION TO WHAT YOU HAVE ALREADY DESCRIBED, ARE THERE ADDITIONAL PROBLEMS WITH MR. PFEIFFER'S INVESTIGATION REPORT?

A. On page 41 of Mr. Pfeiffer's Investigation Report prepared on April 24, 2014 for the Barkers (hereafter referred to as Report) states that the minimum right-of-way (ROW) necessary for the 345 kV transmission line should be 166 feet as shown:

WOR = W = 166 feet

Mr. Pfeiffer's assertion that a ROW of 166 feet, minimum, is re-stated in the response to question 30 in the Complainants' Response to the Data Requests served by the Defendant:

Based on calculations using the RUS formula the Right-Of-Way width should have been 166 Ft.

Close inspection reveals that Mr. Pfeiffer's calculations are fraught with errors. Specifically, Mr. Pfeiffer's calculations have:

1. Math Error;
2. Unit Conversion Error;
3. Incorrect Assumptions and/or Missing Data;
4. Formula Misapplication and Incorrect Formula.

Math Error:

On page 41 of the Report, the following calculation is given:

WOR = W = 54 +2(10 +32.3).9129+ 2x13.4
WOR = W = 166 feet

Correctly performing the mathematical computations in the third line of this quote results in:

WOR = W = 158 feet.

Mr. Pfeiffer made a math error and incorrectly calculated a value of 166 instead of 158.

Unit Conversion Error"

On page 40 of the Report, Mr. Pfeiffer estimated the conductor swing-out angle, ϕ, to be 20 degrees:

$$\Phi = 20 \text{ Degrees (estimated)}$$

When used in the formula given on page 41 of the Report, the sine of ϕ must be taken. As can be seen, Mr. Pfeiffer incorrectly calculated the sine of 20 degrees to be .9129 as given on page 41 of the Report:

$$W = A + 2(l_i + S_f)\sin\phi + 2\delta + 2x$$

$$X = 7.5 + .4(V_{L\text{-}G} - 22)/12 = 13.4$$

$$WOR = W = 54 + 2(10 + 32.3)(.9129) + 2\times 13.4$$

$$WOR = W = 166 \text{ feet}$$

Correctly taking the sine of 20 degrees results in:

$\sin\phi = \sin(20) = 0.3420$[5]

Mr. Pfeiffer made a unit conversion error and incorrectly calculated the sine of 20 degrees to be 0.9129 instead of 0.3420.

[5] When using Excel to perform his calculations, Mr. Pfeiffer forgot to convert degrees to radians prior to using the SIN function. The correct formula in Excel is =SIN(RADIANS(20)).

Incorrect Assumptions and/or Missing Data:

In order to calculate the minimum right-of-way necessary for a 345 kV transmission line as outlined by the Rural Utilities Service Bulletin 1724E-200, certain configuration parameters and associated formulae are necessary:

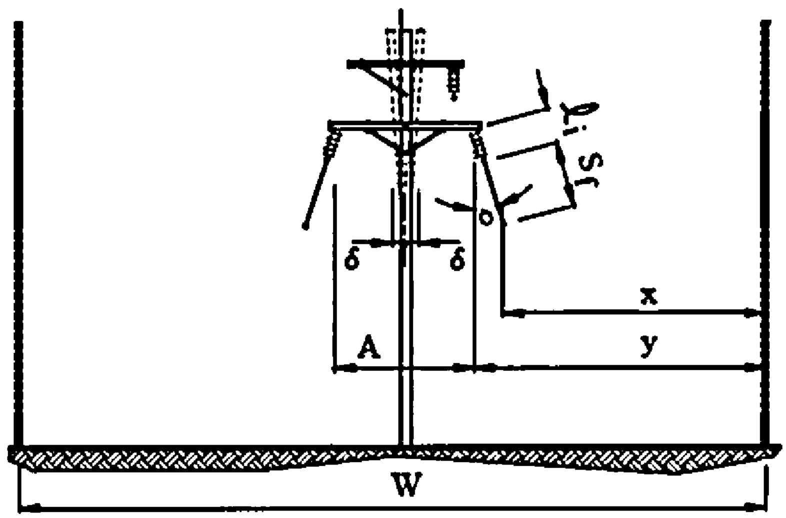

FIGURE 5-9: ROW WIDTH FOR SINGLE LINE OF STRUCTURES

$$W = A + 2(\ell_i + S_f)\sin\phi + 2\delta + 2x \qquad \text{Eq. 5-3}$$

where:

W = total right-of-way width required

A = separation between points of suspension of insulator strings for outer two phases

x = clearance required per Table 5-1 and appropriate clearance derived from Table 5-2 of this bulletin (include altitude correction if necessary)

y = clearance required per Section 5.2.1 and Table 5-1 and appropriate clearance derived from Section 5.2.2. and Table 5-2 of this bulletin (include altitude correction if necessary)

Other symbols are as previously defined. In some instances, clearance "x" may control. In other instances, clearance "y" may control.

In Mr. Pfeiffer's attempt to calculate W, the "total right-of-way width required," incorrect assumptions were made. Table Six gives correct values as provided by EKPC and Mr. Pfeiffer's assumed values to these and other necessary parameters.

Table Six Necessary ROW Calculation Parameters with Correct EKPC Provided and Pfeiffer Assumed Values

Parameter	EKPC Value	Pfeiffer Value	Definition
A	54	54	Separation between points of suspension of insulator strings for outer 2 phases
x	12.2	13.4	Required clearance for 345 kV displaced by wind
L_i	11	10	Insulator string length
S_f	28.28	32.3	Conductor final sag at 60° F with 6 psf of wind
ϕ	22.4	20	Conductor swing out angle in degrees under 6 psf of wind
δ	2.2	0	Structure deflection with a 6 psf wind

Mr. Pfeiffer assumed the correct value for A at 54 feet, his only correct assumption. Mr. Pfeiffer incorrectly assumed the insulator string length, L_i, to be 10 feet instead of the correct value of 11 feet. Mr. Pfeiffer incorrectly assumed the conductor final sag at 60° F with 6 psf of wind, Sf, to be 32.3 feet instead of the correct value of 28.28 feet. Mr. Pfeiffer incorrectly assumed the conductor swing out angle in degrees under 6 psf of wind, ϕ, to be 20 degrees instead of the correct value of 22.4 degrees. Mr. Pfeiffer incorrectly assumed the structure deflection with a 6 psf wind parameter, δ, to be 0 feet instead of the correct value of 2.2 feet.

Formula Misapplication:

Mr. Pfeiffer has incorrectly calculated the value of x to be 13.4 feet. The correct value for x is 12.24 feet. To correctly calculate x, the first step is to calculate the NESC Horizontal Clearance as stated in RUS Bulletin 1724E-200:

Conductors displaced by 6 psf wind:
NESC Horizontal Clear. = NESC Basic Clearance (Table 234-1) + .4(kV_{L-G} − 22)/12

One of the keys is to correctly obtain the "NESC Basic Clearance (Table 234-1) value. As given on page 41 in the Report, his assumption for this parameter of 7.5 feet is incorrect as shown:

$$X = 7.5 + .4(V_{L-G} - 22)/12 = 13.4$$

Although Mr. Pfeiffer accessed the correct table as indicated by his highlighted section on page 37 of the Report, he selected the "At rest" value instead of the "Displaced by wind" value as shown below:

2. From buildings, walls, projections, guarded windows, windows not designed to open, balconies, and areas accessible to pedestrians								
At rest	(NESC Rule 234C1a)	7.5	9.2	9.7	10.6	11.1	11.5	12.9
Displaced by wind	(NESC Rule 234C1b)	4.5	6.2	6.7	7.6	8.1	8.5	9.9

Being in an outdoor environment exposed to the elements, the 345 kV line is expected to be subjected to wind; therefore, the "Displaced by wind" value should be selected. With that, the value for the NESC Basic Clearance (Table 234-1) parameter should be chosen to be 4.5 feet. Mr. Pfeiffer incorrectly selected NESC Basic Clearance (Table 23401) parameter to be 7.5 feet instead of the correct value of 4.5 feet. Another mistake made by Mr. Pfeiffer in calculating x involves the "kV_{L-G}" variable in the formula for the NESC Horizontal Clearance. Specifically, Mr. Pfeiffer did not consider the voltage range that utilities are required to stay within during normal operating conditions as stated in standard ANSI C84.1-1995, Range A. For voltages greater than 600v, utility service voltages must stay within -2.5% and +5% during normal operating conditions. For a 345kV transmission line, these percentages translate to a voltage range of 336.38kV to 365kV during normal operating conditions. To correctly use this NESC formula, the highest allowable voltage during normal operating conditions must be used.

Mr. Pfeiffer incorrectly used a voltage of 345kV instead of the correct value of 362.25kV. Using a value of 4.5 feet for the NESC Basic Clearance (Table 234-1) parameter and $kV_{L\text{-}G} = 362.25kV/\sqrt{3}$, the correct calculation for the NESC Horizontal Clearance becomes:

$$\text{NESC Horizontal Clearance} = \text{NESC Basic Clearance(Table 234-1)} + .4(kV_{L\text{-}G}-22)/12;$$

$$\text{NESC Horizontal Clearance} = 4.5 + .4(362.25kV/\sqrt{3} - 22)/12;$$

$$\text{NESC Horizontal Clearance} = 10.74 \text{ feet.}$$

<u>Incorrect Formula</u>:

Mr. Pfeiffer incorrectly assumed that the NESC Horizontal Clearance is the same as the x value in the RUS clearance calculation. To correctly calculate the RUS Recommended Clearance, x, the following formula taken from RUS Bulletin 1724D-200 must be used:

Recommended Clearance = NESC Horizontal Clearance + Adder

RUS recommends that utilities add an additional 1.5 feet to the NESC Horizontal Clearance; thus, the adder in the above formula is 1.5 feet. Applying the previously calculated value for NESC Horizontal Clearance and the RUS recommended adder, the formula for x becomes:

$$\text{Recommended Clearance} = x = 10.74 + 1.5$$

$$x = 12.24 \text{ feet}$$

Mr. Pfeiffer incorrectly calculated a value of x to be 13.4 feet instead of the correct value of 12.24 feet.

<u>Formula Misapplication</u>:

Mr. Pfeiffer misapplied the formula for the ROW width as given in RUS Bulletin 1724E-200 and incorrectly arrived at a ROW width of 166 feet instead of the correct value of 112.74 feet. Correctly applying correct parameter values and correct sub-calculation values, the formula for the total ROW width, W, as given in RUS Bulletin 1724E-200 yields:

$$W = A + 2(Li + Sf) \sin \phi + 2\delta + 2x$$

$$W = 54 + 2(11 + 28.28) \sin (22.4) + 2(2.2) + 2(12.24)$$

$$W = 112.82 \text{ feet}$$

Mr. Pfeiffer incorrectly calculated a minimum ROW to be 166 feet instead of the correct value of 112.82 feet. As a reminder, EKPC currently has a 150 foot ROW, which is well above the RUS recommendation minimum of 112.82 feet.

Q. **WHAT ELSE ABOUT MR. PFEIFFER'S RESPONSES TO DATA REQUESTS STOOD OUT TO YOU?**

A. The Complainants' Response to question 38 of the Defendant's Data Request contains the following statement:

I have not located a definition of "next-contingency".

Without having a full understanding of the "next-contingency" concept, it is not possible to understand power line loading considerations, which has led Mr. Pfeiffer to make incorrect power flow assumptions on the two transmission lines under consideration. Quoting the North American Electric Reliability Corporation (NERC) document "Reliability Concepts, Version 1.0.2:

> **Credible contingencies are events (including disturbances and equipment failures) that are likely to happen.**

Electric utilities (system operators) under the jurisdiction of NERC (as is EKPC) are required to adhere to NERC rules and regulations. One such regulation requires electric utilities to design the bulk transmission system to safely and reliably operate should credible contingencies occur. Quoting NERC:

> **We have historically thought of our operating reliability criteria as being able to withstand an "n-1" event—that given some part of the Interconnection with "n" elements, we can reliably operate following the failure of any one of them. But given the many different kinds of credible contingencies, "n-1" is not always correct. Rather, our reliability criteria should be based on being able to withstand the next credible contingency, which may include multiple elements.**
>
> **Therefore, the system operator monitors the actual flows on its facilities and controls these flows so that they are within acceptable limits (System Operating Limits and Interconnection Reliability Operating Limits.) Keeping the actual flows within the SOL and IROL (and assuming those limits were calculated correctly) will help ensure the contingency flows (the flows that would result if the contingency occurs) will also be within acceptable limits.**

With these NERC definitions and directives, the "Next-Contingency" concept becomes clear – the system operator must have the ability to safely and reliably operate the bulk transmission system in the event of the "next" credible contingency; hence the term "Next-Contingency." To illustrate this concept, assume every single transmission line under the control of a single utility is operating at full capacity. Now, further assume a credible contingency occurs during which a transmission line is unexpectedly taken out of service. The power that was flowing on this lost transmission line prior to its removal from the system must now find alternative paths on which to deliver its power. If all other transmission lines are at full capacity, then the addition of the power from the lost transmission line would translate to over load situations on those transmission lines still in service. Obviously, creating overloads on transmission lines is not an acceptable consequence due to the loss of a single transmission line. For this very reason, utilities never intentionally operate individual transmission lines at full capacity. With this understanding, it follows that transmission line conductors will rarely, if ever, reach their maximum operating temperatures.

Transmission planning engineers recognize that transmission lines experience outages and design the entire transmission system to accommodate the loss of transmission lines without causing overloading scenarios. With that, neither of the transmission lines in question will ever be loaded to maximum capacity and the conductors will never reach maximum operating temperatures under normal operating conditions. This fact has two major implications:

1) The conductor sag will rarely, if ever, reach its minimum sag;
2) The magnitude of the magnetic field will rarely, if ever, reach its maximum magnitude.

Because Mr. Pfeiffer is unfamiliar with the "next-contingency" concept and is unaware of EKPC's operating strategy to meet this requirement has led to him making incorrect assumptions such as the following quote taken from page 85 of Mr. Pfeiffer's Investigation Report prepared on April 24, 2014 for the Barkers:

> Next, we determined what current would be flowing in each line at worse case conditions. For this we used EKPC's maximum conductor operating temperature values and their corresponding currents 3258 amps and 1468 amps for 345kv and 69kv lines in the winter.

Though each of these transmission lines may be capable of carrying these amounts of current, operating constraints to accommodate next contingency requirements would never allow either of these lines to come anywhere close to carrying these current magnitudes under normal operating conditions.

Q. WHAT ADDITIONAL CONCERNS DO YOU HAVE WITH MR. PFEIFFER'S INVESTIGATIVE REPORT?

A. On page 74 of the Report, Mr. Pfeiffer states:

> As the lower line's voltage is raised it will cause the electric fields to rise.

Mr. Pfeiffer restates this point on page 76 of the Report:

- Increasing the voltage of the 69kV line to 138kV will increase the electric fields.

As the electric field modeling given earlier in this testimony shows, the resultant electric field will actually decrease should the lower transmission line's voltage be raised from 69 kV to 138 kV.

Q. ARE YOU FAMILIAR WITH THE TYPE OF METERS THAT WERE USED BY THE BARKERS OR THEIR EXPERTS WHEN TAKING ELECTRIC OR MAGNETIC FILED READINGS?

A. I have no firsthand experience with these meters but I have gained a working knowledge of these meters by reading those sections of the manufacturers' websites describing these meters. The meter used by Mr. Pfeiffer is the UHS AC model manufactured by Alpha Lab. This meter is a 3-axis device with a ± 3% accuracy. Using the Alpha Lab UHS AC meter to measure magnetic field strength, the meter must be set to read magnetic fields ranging in frequencies from 13 to 75,000 Hz. Though this meter is no longer available, its replacement, model UHS2, retails for $310. Calibration services are available for this meter at a cost of $90.

The Barkers own the EMF/ELF meter manufactured by Extech Instruments. This meter is a single-axis device with a ± 4% accuracy. The EMF/ELF meter measures magnetic field strength for frequencies ranging from 30 to 300 Hz with a sampling rate of 2.5 readings per second. Being a single-axis device, the meter must be precisely oriented to obtain correct readings. This meter retails for $129.99.

Q. ARE THE METERS THEY USED COMPARABLE TO THE METER YOU USED TO TAKE YOUR READINGS?

A. No.

Q. WHAT ARE THE DIFFERENCES IN THE METERS?

A. The Barkers' EMF/ELF meter is not a three-axis device. This means that the readings obtained by this meter are highly dependent upon the direction of the incoming EMFs in relation to the orientation of the meter. Rotating this meter, both horizontally and vertically, will dramatically alter the meter's reading.

John Pfeiffer's meter has a very large measureable bandwidth. In particular, the meter simultaneously captures magnetic fields ranging from 13 to 75,000 Hz. As a reminder, magnetic fields emanating from transmission power lines are based on 60 Hz. Therefore, this meter will measure any and all magnetic fields in this 13 to 75,000 Hz range, resulting in readings that cannot be solely attributed to the 60 Hz power lines.

By comparison, the EMDEX II meter is recognized as the industry standard by researchers, scientists, and the electric utility industry. The overwhelming majority of EMF and health affects research spanning decades was based on the technology developed by EPRI and Enertech Consultants and deployed within the EMDEX II EMF meter.

The Barkers' EMF/ELF meter is accurate to ±4%. Mr. Pfeiffer's UHS AC meter is accurate to ±3%. EKPC's EMDEX II meter is accurate to ±2%.

Q. WOULD YOU LIKE TO SUMMARIZE YOUR TESTIMONY?

A. There are no Federal, State, or Rural Utilities Service regulations that provide 60 Hz based electric field exposure limits to which utilities serving in the Commonwealth of Kentucky must adhere. Likewise, there are no Federal, State, or Rural Utilities Service regulations that provide 60 Hz based magnetic field exposure limits to which utilities serving in the Commonwealth of Kentucky must adhere. The electric field exposure limits at the Barkers' home is within the exposure limits set by all of those states with electric field exposure regulations. The magnetic field exposure limits at the Barkers' home is within the exposure limits set by all of those states with magnetic field exposure regulations.

Moreover, with no previous utility experience – particularly in the areas of transmission planning, transmission line design, utility class system protection, and the lack of utility grade and industry recognized software, and with so many miscalculations and incorrect assumptions, false conclusions, coupled with the lack of the basic understanding of power system operation and utility planning criteria – Mr. Pfeiffer's ability to calculate accurate results in the area of power systems is significantly called into question.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes it does.

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

HAROLD BARKER, **ANN BARKER, and** **BROOKS BARKER** **COMPLAINANTS** **V.** **EAST KENTUCKY POWER COOPERATIVE, INC.**	)))))))))	**CASE NO. 2013-00291**

A F F I D A V I T

STATE OF KENTUCKY)
)
COUNTY OF CLARK)

Paul A. Dolloff, being duly sworn, states that he has read the foregoing prepared testimony and that he would respond in the same manner to the questions if so asked upon taking the stand, and that the matters and things set forth therein are true and correct to the best of his knowledge, information and belief.

Subscribed and sworn before me on this 2nd day of June, 2014.

Gwyn M. Willoughby #500144
Notary Public

GWYN M. WILLOUGHBY
Notary Public
State at Large
Kentucky
My Commission Expires Nov 30, 2017

EAST KENTUCKY POWER COOPERATIVE

inhouse mail

TO: Sherman Goodpaster

FROM: Paul A. Dolloff, Ph.D.
Research and Development

DATE: December 8, 2008

SUBJECT: Ann Barker: Electric Field Measurements

On Friday, December 5, 2008, Tom Hayes and I visited the home of Ms. Ann Barker to make electric field measurements. The meter used is the EMDEX II manufactured and calibrated by Enertech Consultants, Campbell, CA. The EMDEX II is a utility grade electric and magnetic field measuring instrument (EMF meter). In the 1980's, Enertech Consultants was contracted by the Electric Power Research Institute (EPRI) to design, develop, and manufacture an EMF meter specifically for the electric utility industry. As a result, the EMDEX II is recognized as the industry standard for EMF measurements in the electric utility industry.

East Kentucky's EMDEX II EMF meter was retrofitted with an electric field probe and associated software provided by Enertech Consultants. The EMDEX II was calibrated on August 31, 2001 and the electric field probe was calibrated on October 24, 2008. Figure One shows Tom Hayes (EKPC employee) at the Barker home demonstrating the correct method for using the EMDEX II when collecting electric field measurements.

EXHIBIT

PAD-1

Kentucky's
Touchstone Energy Cooperatives

Figure One Tom Hayes Demonstrating Correct Use of the EMDEX II

A 100 foot tape measure was stretched in a straight line from the corner of the Barker's home to the transmission line and beyond as shown in Figure Two.

Figure Two 100 Foot Measurement Line

Along this 100 foot line, electric field measurements were taken every 5 feet. These measurements are given in Table One where zero feet is at the house.

Measurement	Distance from House (ft)	Measured E-Field (kV/m)	Notes
1	0	0.257	Under carport eave
2	5	0.621	
3	10	0.878	On driveway
4	15	0.964	On driveway
5	20	0.996	Just off driveway
6	25	0.997	
7	30	0.953	
8	35	0.814	Within 5' of fence
9	40	0.771	Within 5' of fence
10	45	0.685	
11	50	0.589	
12	55	0.466	
13	60	0.326	
14	65	0.225	
15	70	0.166	
16	75	0.176	Center of power lines
17	80	0.225	
18	85	0.310	
19	90	0.407	
20	95	0.492	
21	100	0.632	100' from house

The measurements were taken between 12:20 p.m. and 1:10 p.m. on Friday, December 5, 2008. At 1:10 p.m., the ambient temperature was 27 F with a constant breeze. At 1:10 p.m., the EKPC 24-hour dispatch center was contacted to obtain the loading conditions of the both the 345kV and the 69kV transmission lines. This data is given in Table Two.

Transmission line	Voltage (kV)	MW	MVar
North Clark to J.K. Smith: 345 kV	351.9	254.0	25.0
Hunt to Sideview: 69 kV	71.0	17.0	2.1

C: Tom Hayes
Chuck Caudill
Rick Drury
Mark Brewer

EAST KENTUCKY POWER COOPERATIVE

inhouse mail

TO: Sherman Goodpaster

FROM: Paul A. Dolloff, Ph.D.
Research and Development

DATE: December 19, 2008

SUBJECT: Ann Barker: Electric Field Standards

Currently, there are no federal standards limiting occupational or residential exposure to 60 Hz electric or magnet fields (EMF). However, some states do have exposure limits. In June 2002, the Department of Energy (DOE) published a booklet entitled, *EMF, Electric and Magnetic Fields Associated with the Use of Electric Power*. On page 46 of this booklet, a table gives the limits for those states with EMF exposure limits. Table One, given below, is a reproduction of this table.

Table One EMF Exposure Limits for those States with Regulations

State Transmission Line Standards and Guidelines

State	Electric Field On R.O.W.*	Electric Field Edge R.O.W.	Magnetic Field On R.O.W.	Magnetic Field Edge R.O.W.
Florida	8 kV/m[a]	2 kV/m	—	150 mG[a] (max load)
	10 kV/m[b]			200 mG[b] (max load)
				250 mG[c] (max load)
Minnesota	8 kV/m	-	--	--
Montana	7 kV/m[d]	1 kV/m[e]		
New Jersey	—	3 kV/m		
New York	11.8 kV/m	1.6 kV/m	—	200 mG (max load)
	11.0 kV/m[f]			
	7.0 kV/m[d]			
Oregon	9 kV/m	—	—	---

*R.O.W. = right-of-way (or in the Florida standard, certain additional areas adjoining the right of way). kV/m = kilovolt per meter. One kilovolt = 1,000 volts. [a]For lines of 69-230 kV. [b]For 500 kV lines. [c]For 500 kV lines on certain existing R.O.W. [d]Maximum for highway crossings. [e]May be waived by the landowner. [f]Maximum for private road crossings.

Time was spent researching the internet to determine if any of the standards given in Table One have been updated since the June 2002 publication date of the DOE EMF booklet. Apart from Florida, no updates were found.

EXHIBIT
PAD-2

Kentucky's
Touchstone Energy Cooperatives

In Florida, the Electric and Magnetic Fields Chapter of the Florida Department of Environmental Protection adopted a Rule entitled *Electric and Magnetic Field Standards* with an effective date of 6/1/2008. A copy of this rule can be found at: http://www.dep.state.fl.us/legal/rules/siting/62-814.pdf.

Though EMF standards exist in some other states, Kentucky has no 60 Hz EMF exposure limits. These standards are provided to give perspective to the measurements taken at the Barker's home. Note that different exposure limits may be given for two different locations: On the right-of-way (R/W) and on the edge of the R/W. When two exposure limits are given, the exposure limits are greater when located on the R/W as compared to when located at the edge of the R/W. The reason for two exposure limits is to clearly recognize that one should expect an increased field strength when on the R/W as compared to when located off of the R/W.

A 100 foot tape measure was stretched in a straight line from the corner of the Barker's home to the transmission line and beyond. Along this 100 foot line, electric field measurements were taken every 5 feet. These measurements are given in Table two where zero feet is at the house.

Table Two E-Field Measured Data Taken at the Barker Home

Measurement	Distance from House (ft)	Measured E-Field (kV/m)	Notes
1	0	0.257	Under carport eave
2	5	0.621	
3	10	0.878	On driveway
4	15	0.964	On driveway
5	20	0.996	Just off driveway
6	25	0.997	
7	30	0.953	
8	35	0.814	Within 5' of fence
9	40	0.771	Within 5' of fence
10	45	0.685	
11	50	0.589	
12	55	0.468	
13	60	0.326	
14	65	0.225	
15	70	0.166	
16	75	0.176	Center of power lines
17	80	0.225	
18	85	0.310	
19	90	0.407	
20	95	0.492	
21	100	0.632	100' from house

It is important to note that all of the electric field measurements at the Barker's home were taken on the R/W. As a reminder, the EKPC easement for this line is 150 feet, 75 feet to each side of the transmission line's center-line.

Of the published 60 Hz electric field exposure limits given in Table One, the on R/W exposure limit ranges between 7.0 kV/m and 11.8 kV/m.

Of the published 60 Hz electric field exposure limits given in Table One, the edge of R/W exposure limit ranges between 1.0 kV/m and 3.0 kV/m.

Of the published 60 Hz electric field exposure limits given in Table One, the exposure limits for Montana are the most restrictive where the on R/W limit is 7.0 kV/m and the edge of R/W limit is 1 kV/m.

Looking at the electric field measurements taken at the Barker's home, the maximum reading was 0.997 kV/m.

Figure One is a plot of the electric field measurements taken at the Barker's home. In addition, the graph shows Montana's on and edge of R/W limits, the most restrictive of the published exposure limits.

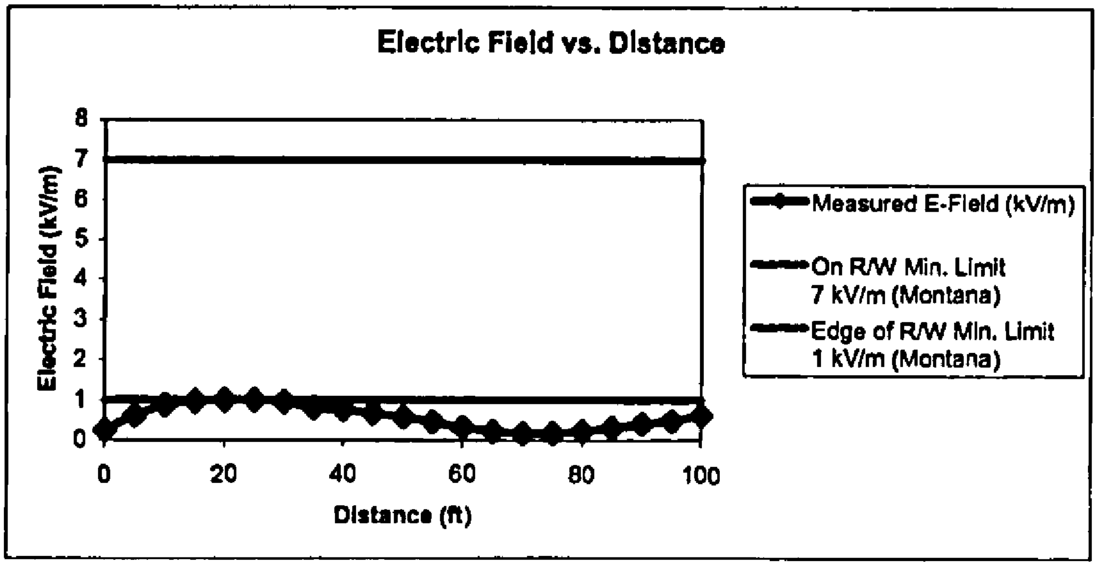

Figure One Measured E-Field Data from the Barker Home and State's Exposure Limits

The Barker's driveway is located on the EKPC, 150 foot, R/W easement. The minimum 60 Hz electric field exposure limit from those published as given in Table One is 7.0 kV/m. With a maximum measured reading of 0.997 kV/m, the Barker's exposure limit is below this minimum standard limit of 7.0 kV/m.

Even though the Barker's driveway is located on the EKPC, 150 foot, R/W easement, the maximum measured reading of 0.997 kV/m is below the minimum standard limit of 1.0 kV/m for on R/W.

The electric field exposure at the Barker's home is beneath both the on R/W and edge of R/W of all published 60 Hz electric field exposure limits from those states with electric exposure limits.

C: Tom Hayes
Chuck Caudill
Rick Drury
Mark Brewer

EAST KENTUCKY POWER COOPERATIVE

Inhouse mail

TO: Sherman Goodpaster

FROM: Paul A. Dolloff, Ph.D.
Research and Development

DATE: October 27, 2009

SUBJECT: Ann Barker: Magnetic Field Measurements

On Tuesday, October 20, 2009, Tom Hayes and I visited the home of Ms. Ann Barker to take magnetic field measurements. The meter used was the EMDEX II manufactured and calibrated by Enertech Consultants, Campbell, CA. The EMDEX II is a utility grade electric and magnetic field measuring instrument (EMF meter). In the 1980's, Enertech Consultants was contracted by the Electric Power Research Institute (EPRI) to design, develop, and manufacture an EMF meter specifically for the electric utility industry. As a result, the EMDEX II is recognized as the industry standard for EMF measurements in the electric utility industry. The EKPC EMDEX II was calibrated on August 31, 2001.

Figure One shows the Barker's house, carport, driveway, and the EKPC transmission line.

Figure One Barker Home and EKPC Transmission Line

EXHIBIT
PAD-3

Kentucky's Touchstone Energy Cooperatives

A tape measure was stretched in a straight line from the centerline of the transmission line to the nearest corner of the Barker's home. Along this straight line, magnetic field measurements were taken every 5 feet. These measurements are given in Table One.

Table One Magnetic Field Measurements Versus Distance from House

Measurement	Distance from House (ft)	Measured B-Field (mG)	Notes
1	0	23.6	Against the house
2	5	25.6	
3	10	28.0	
4	15	32.0	Comer of Carport
5	20	31.4	On driveway
6	25	25.2	
7	30	32.8	
8	35	40.0	
9	40	44.2	
10	45	47.6	
11	50	50.6	House side of fence
12	55	53.6	Field side of fence
13	60	56.4	
14	65	58 2	
15	70	60 2	
16	75	61.4	
17	80	61.0	
18	85	80.4	
19	90	60.0	Center of power lines

Magnetic field measurements were taken at various other locations outside the home as indicated in Table Two. Note: Measurements within the home were not requested.

Table Two Magnetic Field Measurements at Various Locations

Measurement	Measured B-Field (mG)	Location
1	23.0	Door under carport
2	22.0	Candy shop door
3	26.6	Garage door
4	34.6	Middle of driveway
5	14.8	Front door

The measurements were taken between 1:45 p.m. and 2:00 p.m. on Tuesday, October 20, 2009. During the visit, the weather was clear and the ambient temperature was 68 F with little to no breeze. At 2:05 p.m., the EKPC 24-hour dispatch center was contacted to obtain the loading conditions of the 345kV transmission line. Loading data at the time of the inspection for the 69kV line was obtained later. This data is given in Table Three.

Table Three Transmission Loading Data During Inspection

Transmission line	Voltage (kV)	MW	MVAr
North Clark to J.K. Smith: 345 kV	350.4	527.0	16.0
Hunt to Sideview: 69 kV		7.0	0.4

C: Tom Hayes
Chuck Caudill
Rick Drury
Mark Brewer

Jurisdiction/Agency	Electric Field Standard		Magnetic Field Standard	
	On ROW	**Edge of ROW**	**On ROW**	**Edge of ROW**
United States	NONE	NONE	NONE	NONE
Kentucky	NONE	NONE	NONE	NONE
Rural Utilities Service	NONE	NONE	NONE	NONE
California[1]	NONE	1.6 kV/m	NONE	NONE
Florida[2]	8 kV/m[a] 10 kV/m[b]	2 kV/m	NONE	150 mG[a] (max. load) 200 mG[b] (max. Load) 250 mG[c] (max. Load)
Minnesota	8 kV/m	NONE	NONE	NONE
Montana	7 kV/m[d] 2.5 to 3.5 kV/m[1,g]	1 kV/m[e]	NONE	NONE
New Jersey	NONE	3 kV/m	NONE	NONE
New York	11.8 kV/m 11.0 kV/m[f] 7.0 kV/m[d]	1.6 kV/m	NONE	200 mG (max. load)[h]
North Dakota[1]	NONE	9 kV/m	NONE	NONE
Oregon	9 kV/m	7 kV/m[1,d]	NONE	NONE
OBSERVED MEASURES[5]	1.1 kV/m	0.9 kV/m	10.7 mG	4.2 mG
OBSERVED MEASURES	0.997 kV/m[3]	0.621 kV/m[3]	61.4 mG[4]	23.6 mG[4]
EKPC MODELED MEASURES	1.515 kV/m[3]	1.167 kV/m[3]	70.847 mG[4]	30.931 mG[4]

[1]Not included in the EMF RAPID Program Booklet
[2]In the Florida, the standard applies to certain additional areas adjoining the ROW
[3]Taken during and modeled with 351.9kV on the 345kV line; 71.0kV (estimated) on the 69kV line
[4]Taken during and modeled with 868.7 amps on the 345kV line; 58.7.0 amps (estimated) on the 69kV line
[5]Measurements taken by independent consultant, Dr. Benjamin Cotts
[a]For lines of 69-230 kV
[b]For 500 kV lines
[c]For 500 kV lines on certain existing ROW
[d]Maximum for highway crossings
[e]May be waived by landowner
[f]Maximum for private road crossings
[g]In areas such as parking lots
[h]For lines over 125 kV and more than 1 mile in length[1]

EXHIBIT
PAD-4

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

IN THE MATTER OF:

HAROLD BARKER; ANN BARKER AND BROOKS BARKER COMPLAINANTS	)	
V.	)	Case No. 2013-00291
EAST KENTUCKY POWER COOPERATIVE, INC. DEFENDANT	)	

DIRECT TESTIMONY OF GABOR MEZEI, M.D., Ph.D.
ON BEHALF OF EAST KENTUCKY POWER COOPERATIVE, INC.

Filed: June 2, 2014

Q. **PLEASE STATE YOUR NAME, BUSINESS ADDRESS, AND OCCUPATION.**

A. My name is Gabor Mezei, M.D., Ph.D. I am employed by Exponent, Inc., located at 149 Commonwealth Drive, Menlo Park, California, 94025.

Q. **PLEASE STATE YOUR EDUCATION AND PROFESSIONAL EXPERIENCE.**

A. I am a Senior Managing Scientist at Exponent, a scientific research and engineering consulting company headquartered in Menlo Park, California. I work in Exponent's Health Sciences Practice in the Center for Epidemiology and Computational Biology. I have over 20 years of experience in health research including the conduct of epidemiologic studies of both clinical outcomes and environmental and occupational health issues. I have considerable experience in conducting complex health assessment and exposure characterization studies related to power-frequency and radiofrequency electric and magnetic fields ("EMF"). Prior to joining Exponent, I was responsible for leading a multidisciplinary scientific research program at the Electric Power Research Institute, a not-for-profit independent research organization. The research program's scientific work was aimed at addressing potential human health effects associated with residential and occupational exposure to power-frequency and radiofrequency EMF. I have appeared as an EMF health expert before the California Public Utilities Commission, the Alberta Utilities Commission, and the Joint Committee for Transport and Communications of the Parliament of Ireland. I also have worked as an epidemiologist at the Toronto Western Hospital, University of Toronto, and as a physician and epidemiologist at the National Institute for Dermatology in Budapest, Hungary. I trained as a medical doctor (M.D.) at the Semmelweis University of Medicine in Budapest, Hungary, and as an epidemiologist (Ph.D.) at the School of Public Health of the University of California in Los Angeles ("UCLA"). I have previously lectured at the UCLA School of Public Health, at Stanford University, and at the Electrotechnical Committee of the Hungarian Academy of Sciences, and I have been an affiliate associate professor in the Department of Environmental and Occupational Health Sciences of the University of Washington in Seattle and a visiting scientist at the Hungarian National Research Institute for Radiobiology and Radiohygiene. I was the recipient of Fogarty and Fulbright Fellowships. I am an author or co-author of over 50 scientific publications and book chapters on topics related to epidemiology of environmental and occupational exposures (with a focus on EMF exposure) and chronic diseases.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

A. The purpose of my testimony is to authenticate and incorporate by reference the expert opinion report that I have authored on behalf of East Kentucky Power Cooperative, Inc. ("EKPC").

Q. ARE YOU SPONSORING ANY EXHIBITS?

A. Yes. The expert opinion report that I prepared in association with this case is attached hereto and incorporated herein as Exhibit GM-1. It includes a copy of my curriculum vitae.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes it does.

VERIFICATION

Comes now, Gabor Mezei, M.D., Ph.D., and after being duly sworn does hereby state that the foregoing testimony is true and correct to the best of my knowledge and belief as of this 27 day of May, 2014.

Gabor Mezei, M.D., Ph.D.

STATE OF _______________

COUNTY OF _____________

The foregoing was subscribed and sworn to before me, the Notary Public, on this the __ day of May, 2014.

NOTARY PUBLIC

My Commission expires: ___________

CALIFORNIA JURAT WITH AFFIANT STATEMENT

☑ See Attached Document (Notary to cross out lines 1–6 below)
☐ See Statement Below (Lines 1–5 to be completed only by document signer[s], *not* Notary)

1

2

3

4

5

6

Signature of Document Signer No. 1 | Signature of Document Signer No. 2 (if any)

State of California

County of SAN Mateo

Subscribed and sworn to (~~or affirmed~~) before me on this 27TH day of MAY, 2014, by
Date | Month | Year

(1) GABOR MEZEI,
Name of Signer

proved to me on the basis of satisfactory evidence to be the person who appeared before me (.) (A

(and

(2) ________________,
Name of Signer

proved to me on the basis of satisfactory evidence to be the person who appeared before me.)

SUSAN L. DIXON
Commission # 1999032
Notary Public - California
San Mateo County
My Comm. Expires Dec 20, 2016

Signature Susan L. Dixon
Signature of Notary Public

Place Notary Seal Above

OPTIONAL

Though the information below is not required by law, it may prove valuable to persons relying on the document and could prevent fraudulent removal and reattachment of this form to another document.

Further Description of Any Attached Document

Title or Type of Document: Deposition

Document Date: MAY 27, 2014 Number of Pages: 4

Signer(s) Other Than Named Above: ________________

RIGHT THUMBPRINT OF SIGNER #1	RIGHT THUMBPRINT OF SIGNER #2
Top of thumb here	Top of thumb here

Exponent

Health Sciences Practice

Report of Gabor Mezei, M.D., Ph.D.

Barker v East Kentucky Power Cooperative Matter

EXHIBIT

GM-1

Report of Gabor Mezei, M.D., Ph.D.

Barker v East Kentucky Power Cooperative Matter

Prepared for

Sherman Goodpaster, Esq.
Senior Corporate Counsel
East Kentucky Power Cooperative, Inc.

Prepared by

Gabor Mezei, M.D., Ph.D.
Exponent
149 Commonwealth Drive
Menlo Park, CA 94025

May 30, 2014

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Contents

List of Tables

Acronyms and Abbreviations

µT	Microtesla
ACGIH	American Conference of Governmental Industrial Hygienists
BIR	BioInitiative Report
CENELEC	European Committee for Electrotechnical Standardization
EHC	Environmental Health Criteria
ELF	Extremely low frequency
EMF	Electric and magnetic fields
G	Gauss
GHz	Gigahertz
Hz	Hertz
IARC	International Agency for Research on Cancer
ICES	International Committee of Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
OSHA	Occupational Safety and Health Administration
kHz	Kilohertz
kV	Kilovolt
kV/m	Kilovolts per meter
mG	Milliguass
MHz	Megahertz
NIEHS	National Institute of Environmental Health Sciences
V/m	Volts per meter
T	Tesla
SCENIHR	Scientific Committee of Emerging and Newly Identified Health Risks
WHO	World Health Organization

Limitations

At the request of counsel for East Kentucky Power Cooperative, Inc., Exponent prepared this report that provides an overview of the scientific literature on potential health effects of power frequency electric and magnetic fields and evaluates whether exposure to electric and magnetic fields from the 345,000-volt transmission line owned and operated by East Kentucky Power Cooperative, Inc., near the Barker family property, presents any health risk to the Barker family. The findings presented herein are made to a reasonable degree of scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, and through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein for other purposes are at the sole risk of the user. My opinions are expressed herein to a reasonable degree of scientific certainty. I reserve the right to revise my opinion as more information becomes available.

Introduction

On July 7, 2013, a Complaint was filed on behalf of Harold Barker, Ann Barker, and Brooks Barker (the Barker family) at the Kentucky Public Service Commission against East Kentucky Power Cooperative, Inc. Among other complaints, the Barker family alleges health risks due to exposure to electric and magnetic fields (EMF) from the 345,000-volt (345 kilovolt [kV]) transmission line that East Kentucky Power Cooperative, Inc., owns and operates near the Barker family's property.

On April 30, 2014, I was asked by counsel for East Kentucky Power Cooperative, Inc., to evaluate materials related to the *Barker v East Kentucky Power Cooperative, Inc.*, matter. I was specifically asked to provide an overview of the scientific literature on potential health effects of power frequency EMF, evaluate whether exposure to EMF from the 345-kV transmission line owned and operated by East Kentucky Power Cooperative, Inc., near the Barker family property presents any health risks to the Barker family and provide a scientific evaluation of the testimony of David O. Carpenter submitted in this matter. This report summarizes my findings and opinions based on my professional qualifications, work experience, knowledge of the scientific literature on EMF exposure assessment and EMF epidemiology, and based on the reviewed documents related to this matter. The specific materials received from East Kentucky Power Cooperative, Inc., in this matter, and which I reviewed, are as follows:

1. Complaint
2. Testimony of Ann Barker and Brooks Barker
3. Testimony of David O. Carpenter
4. Report from Pfeiffer Engineering Co., Inc.
5. Report of Benjamin Cotts

My opinions are expressed herein to a reasonable degree of scientific certainty. I reserve the right to revise my opinions as more information becomes available.

Background and Qualifications

I am a Senior Managing Scientist at Exponent, a scientific research and engineering consulting company headquartered in Menlo Park, California. I work in Exponent's Health Sciences Practice in the Center for Epidemiology and Computational Biology. I have over 20 years of experience in health research including the conduct of epidemiologic studies of both clinical outcomes and environmental and occupational health issues. I have considerable experience in conducting complex health assessment and exposure characterization studies related to power-frequency and radiofrequency EMF.

Prior to joining Exponent, I was responsible for leading a multidisciplinary scientific research program at the Electric Power Research Institute, a not-for-profit independent research organization. The research program's scientific work was aimed at addressing potential human health effects associated with residential and occupational exposure to power-frequency and radiofrequency EMF. I have appeared as an EMF health expert before the California Public Utilities Commission, the Alberta Utilities Commission, and the Joint Committee for Transport and Communications of the Parliament of Ireland.

Previously I also worked as an epidemiologist at the Toronto Western Hospital, University of Toronto, and as a physician and epidemiologist at the National Institute for Dermatology in Budapest, Hungary. I trained as a medical doctor (M.D.) at the Semmelweis University of Medicine in Budapest, Hungary, and as an epidemiologist (Ph.D.) at the School of Public Health of the University of California in Los Angeles (UCLA). I lectured at the UCLA School of Public Health, at Stanford University, and at the Electrotechnical Committee of the Hungarian Academy of Sciences, and I was an affiliate associate professor in the Department of Environmental and Occupational Health Sciences of the University of Washington in Seattle and a visiting scientist at the Hungarian National Research Institute for Radiobiology and Radiohygiene. I was the recipient of Fogarty and Fulbright Fellowships. I am an author or co-author of over 50 scientific publications and book chapters on topics related to epidemiology of environmental and occupational exposures (with a focus on EMF exposure) and chronic diseases. A copy of my curriculum vitae is provided in Appendix A. Exponent, my employer, currently charges $350 per hour for my consulting services.

Overview of Electric and Magnetic Fields

In our modern society, we are surrounded by both manmade and natural sources of EMF. Natural sources include the earth's static magnetic field and the electric fields present in the atmosphere. Biological processes and life are also dependent on electricity. Brain and nerve functioning and movement of skeletal and heart muscles are all driven by electric impulses. Manmade sources, among others, include the electricity that we use in our homes and radio waves used for communication purposes.

Electricity is associated with two types of fields: electric fields and magnetic fields. Electric fields are created when there is a difference in voltage between two points. Electric field strength is measured in the units of volt per meter (V/m). Higher electric field levels are expressed in kilovolts per meter (kV/m); where 1 kV/m is equal to 1,000 V/m. The magnitude of natural electric fields at ground level is around 100 V/m in fair weather, but can increase to very high levels resulting in lightning during thunderstorms.

Magnetic fields are created by the flow of electric current (i.e., by the flow of electrical charges). The international unit of measurements of magnetic field strength (flux density) is Tesla (T). Levels of magnetic fields common in our environments are expressed in microtesla (μT); where 100,000 μT is equal to 1 T. The earth's magnetic field, depending on geographic location, varies between 25 and 65 μT. An alternative unit of measurements for magnetic fields, commonly used in the United States, is Gauss (G) or milligauss (mG), where 1,000 mG is equal to 1 G and 10 mG is equal to 1μT.

Both electric fields and magnetic fields diminish quickly with distance from the source. While electric fields are effectively blocked by conducting objects (e.g., trees, shrubbery, fences. buildings, and even the human body), magnetic fields are not effectively blocked by conducting objects.

Electromagnetic Spectrum

The electromagnetic spectrum encompasses a wide range of electromagnetic energy forms, which are characterized by wavelength and frequency. Frequency is expressed in Hertz (Hz) and multiples of Hz, such as kilohertz (kHz), megahertz (MHz) or gigahertz (GHz), and represents the number of times the electromagnetic energy and fields change direction and make a full cycle. Wavelength is inversely related to frequency, that is, low frequency is associated with long wavelength. The electromagnetic spectrum spans from 0 Hz (or static fields) through non-ionizing fields up to ionizing forms of radiation. The energy level of electromagnetic fields and their potential for interaction with biological tissues and living organisms is dependent on the frequency and wavelength of the fields. High frequency fields have high energy and are able to ionize atoms, or dislodge electrons from their path around their atomic nucleus (e.g., X-ray). This may potentially result in damage in living cells. Frequencies in the radio wave and microwave range (which is used, for example, in microwave ovens) may be able, at very high levels, to result in tissue heating. On the other hand, lower frequency fields, such as extremely low frequency (ELF) EMF, have very little energy and have no ionizing or tissue heating effects. Electricity generated, transmitted, distributed and used in the United States is alternating current with a frequency of 60 Hz, generating 60 Hz EMF. Power frequency or 60 Hz EMF is part of the very low energy, ELF segment of the electromagnetic spectrum.

Sources of ELF EMF

Electricity is integral to our modern society and has increasingly become part of our daily life over the past century. Sources of common ELF EMF exposure are the wiring in homes and buildings, electrical appliances, tools and equipment used in the home or in work environments, the transmission lines that carry electricity over larger distances from generating stations to substations, and the distribution lines that deliver power locally within communities.

Table 1. Typical magnetic field levels in proximity of electrical appliances

	Magnetic Field Levels at Various Distances from the Source* (mG)		
	6 inches	1 foot	2 feet
Hair dryer	300	1	-
Blender	70	10	2
Can opener	600	150	20
Toaster	10	3	-
Iron	8	1	-
Vacuum cleaner	300	60	10
Power saw	200	40	5

Source: EMF Questions and Answers (NIEHS, 2002, pp. 33-35)
*The values listed are the median mG at each distance.

EMF Levels at the Barker Property

Based on modeling work of Dr. Benjamin Cotts (as presented in his report submitted in this matter), the long-term average magnetic-field levels in the center of the Barker residence as a result of the nearby transmission line is anticipated to be approximately 3.3 mG (0.33 μT). The electric-field levels at the edge of the right-of-way nearest to the Barker residence is expected to be, on average, 0.9-1.0 kV/m, with a maximum of 1.3 kV/m. All of these values are well below accepted and scientifically-based international exposure limits, as discussed later in this report. Based on a national residential magnetic-field exposure survey conducted by the Electric Power Research Intsitute, the average measured magnetic fields levels are expected to be above 3.3 mG in approximately 4% of all residences in the United States (Zaffanella, 1993).

Scientific Review Process

Since the late 1970s a large body of scientific literature has accumulated related to potential health effects of ELF EMF, which includes the publication of peer-reviewed scholarly manuscripts reporting on numerous research studies from diverse scientific disciplines. According to the World Health Organization (WHO), "*[d]espite the feeling of some people that more research needs to be done, scientific knowledge in this area is now more extensive than for most chemicals.*"[1] The WHO currently also states on its website that "*[b]ased on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields.*"[2]

Given the large amount of scientific (and unscientific) information available on this topic, however, and the difficulty it may present to synthesize the available information to draw scientifically valid conclusions, it is important to review generally accepted methods scientists use to evaluate evidence on whether an exposure is causally related to adverse health outcomes. The purpose of this section is to provide an overview of the scientific review process.

Scientists worldwide use the process of health risk assessment, a standard scientific method, to determine whether exposure to physical, chemical or biological agents in our environments may result in any risk to human health. Health risk assessments are typically conducted by multidisciplinary expert panels convened by governmental, health, or scientific agencies. A key step in health risk assessment is hazard identification, a standard scientific process that entails a thorough and systematic *weight-of-evidence* evaluation of the relevant cumulative scientific literature. No single study or a selected sample of studies should be used to draw scientific conclusions on a potential cause-and-effect relationship; rather, the totality of the evidence needs to be considered.

[1] http://www.who.int/peh-emf/about/WhatisEMF/en/index1.html
[2] Ibid.

Sources of Scientific Evidence

The first step in a weight-of-evidence review is a systematic search of the scientific literature to identify relevant research studies that may provide evidence for consideration of a potential causal relationship between exposure and human health outcomes. Typically, three main types of scientific studies are considered in human health risk assessment: 1) epidemiologic studies conducted in human populations, 2) experimental laboratory studies of humans or laboratory animals (*in vivo* studies), and 3) laboratory studies using tissues and cells (*in vitro* studies). These types of studies have their own strengths and limitations and they provide different but complementary information on a potential interaction between exposure and a biological organism. Thus, these three lines of evidence need to be considered together.

Epidemiologic studies are mostly observational (i.e., non-experimental) studies that are conducted in human populations to measure the statistical relationship between people's exposure status and health conditions. The two main types of epidemiologic studies most commonly encountered in the scientific literature are case-control studies and cohort studies. Case-control studies compare the exposure distribution among a sample of cases of the specific diseases of interest (e.g., a certain type of cancer) to the exposure distribution of subjects free from that disease (e.g., a sample of healthy individuals). Case-control studies are typically retrospective and are more economical to study rare diseases. Cohort studies are follow up studies of individuals free of the specific disease under investigation at the start of the study, which compare the frequency of new disease occurrence among those exposed to a specific agent to the disease frequency among those not exposed to that agent. The magnitude of statistical association is measured by relative risk or risk ratio (comparing the risk of disease among exposed to that among unexposed in cohort studies) and odds ratio (comparing the odds of being exposed among the cases to that among controls in case-control studies). In most epidemiologic studies, investigators are not in control of the exposure under study due to the observational nature of these studies. Exposure distribution in the study population may be limited and the full potential range of exposure levels may not be adequately studied. This frequently results in statistically less powerful studies even in large study populations, for example, if the overwhelming majority of the study subjects are not exposed. Other study design features, such as the methods used to select and recruit study subjects, may also result in inadvertent distortion of results (e.g., selection and participation bias if study participants have inherently different characteristics compared to non-participants). Co-occurrence of two potentially harmful exposures in certain members of the population (for example, smoking and alcohol consumption) may result in mixing or masking the effects of one exposure by the effect of the other exposure. This phenomenon, called confounding in epidemiology, may results in overestimation or underestimation of the true association between exposure and health outcome. Approaches used to classify exposures or health outcomes in epidemiologic studies may also result in errors (e.g., exposure or disease misclassification). In spite of these limitations, epidemiologic studies are very valuable and typically provide the most weight in a human health risk assessment process because they study humans, the species of interest, at their typical environmental exposure levels and no interspecies or dose-related extrapolations are required.

In vivo research conducted with laboratory animals, most commonly rodents, evaluate whether animals exposed to higher levels of the agent of interest develop more or more severe diseases and symptoms compared to animals that are not exposed or exposed to lower levels of the agent of interest. Researchers in this type of study are in control of the exposure and all other environmental factors that may influence disease development. Investigators can determine exposure levels with high accuracy in an experimental study and may expose animals to much higher exposure levels than may be observed in human populations. The differences in physiology, metabolism, size, and longevity between laboratory animals and humans, however, require interspecies extrapolation, and findings from animal studies may not be directly applicable to humans in all cases. *In vivo* laboratory research conducted with human volunteers may typically contribute to our scientific understanding of only short term but not long term effects. In addition, known toxic or carcinogenic agents may not be tested on humans due to ethical considerations.

Researchers conducting *in vitro* studies with isolated cells and tissues may examine if exposure could result in certain biological changes, which may help our understanding of the biophysical mechanisms that may result in disease processes. Since responses observed in isolated cells and tissues, however, may be very different than responses that may occur in intact organisms, living animals, or humans, conclusions scientists can draw from *in vitro* studies are severely limited. For this reason, *in vitro* studies are considered secondary to epidemiologic and laboratory animal studies and provide less weight in a health risk assessment process.

Weight-of-Evidence Evaluation

Each relevant scientific study identified through the systematic literature search then individually undergoes an assessment as to its strengths and limitations and to its overall quality. Studies with higher quality contribute more weight to the overall assessment. Studies with severe limitations or flaws may not contribute any weight at all. Quality of the studies is assessed by evaluating the number of study subjects, the employed study design, the methods used to collect and analyze the data, and the potential for any biases, and systematic or random errors in the study. In epidemiologic studies, it is important to assess how study subjects were identified and recruited, what fraction of the eligible subjects participated in the study, whether there are any systematic differences between participants and non-participants, how exposure and outcome status were determined and ascertained, and whether the association observed in the study may be influenced by any systematic error, such as confounding, bias, classification error, or random variability. In laboratory studies, important considerations include the number of animals and exposure levels, whether the assignment of the animals to various exposure groups was random, and whether the outcome assessment and statistical analyses were blinded. (Blinding means that the investigators are not aware of the animals' exposure status when the outcome is assessed or when the analysis is conducted, but only when the results are final.)

Once each study is individually evaluated and weighed by its overall validity and quality, the totality of evidence is then considered, using standard guidance, for and against a cause-and-effect relationship between a particular exposure and health outcome. Generally accepted guidance for weighing the overall epidemiologic evidence is provided by the now seminal manuscript of Sir Austin Bradford Hill published in 1965 (Hill, 1965). In his paper, Hill outlined nine criteria (strength of association, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy) that can be used to assess whether the associations observed in epidemiologic studies might be causal. Although, as Hill himself cautioned, none of these criteria represent "*hard-and-fast rules*" and none of these criteria are "*sine qua non*" of causality, the more the epidemiologic evidence meets these guidelines, the more persuasive the evidence is for a potential causal relationship. Per Hill's recommendations, these guidelines are to be applied when chance could be ruled out with reasonable certainty as a potential explanation for the observed association. Similar guidance is applied for laboratory animal studies, and may include whether the specific health effects are demonstrated by two or more independent laboratories, or in two or more species, or under different laboratory protocol. Independent replication is crucial in both laboratory and epidemiologic studies.

Weight-of-Evidence Evaluation of Carcinogenicity

The International Agency for Research on Cancer (IARC), the cancer resarch agency of the WHO, is considered one of the leading international organizations for cancer risk assessment. IARC regularly assembles multidisciplinary expert panels to systematically review the scientific literature on exposure to various physical and chemical agents to determine their potential for carcinogenicity to humans. In its evaluations, IARC considers two main streams of evidence—epidemiologic and laboratory animal (*in vivo*) studies. While epidemiologic studies play a key role in the IARC's determination of carcinogenicity of various exposures, the Preamble to the IARC Monograph series on carcinogenicity evaluation includes the following statement with respect to the role and importance of laboratory animal studies, "*[a]ll known human carcinogens that have been studied adequately for carcinogenicity in experimental animals have produced positive results in one or more animal species*" (IARC, 2006). In addition, IARC considers *in vitro* studies to provide additional input on potential mechanism of effects and exposure assessment studies to better understand potential impacts of the exposure in our daily life. IARC, based on a weight-of-evidence review, classifies the overall evidence from epidemiologic and *in vivo* animal studies into one of the following three categories.

- The evidence is considered **sufficient** when a causal relationship can be established between exposure and cancer; in epidemiology studies, a positive relationship has been observed between the exposure and cancer in studies in which chance, bias, and confounding could be ruled out with reasonable confidence; and for *in vivo* animal studies, increased incidence of cancer was observed in high quality studies in at least two species or from two independent laboratories.

- The evidence is **limited** if a credible positive association is observed but chance, confounding, or bias could not be excluded as explanations in epidemiology studies, and if the association is limited to one experiment or there are unresolved questions regarding adequacy of design features in laboratory animal studies.

- The evidence is **inadequate** if there is insufficient quality, consistency, or statistical power in epidemiology studies, and if there are major qualitative or quantitative limitations or lack of data from *in vivo* studies.

In vitro research provides ancillary information and, therefore, is used to a lesser degree in evaluating carcinogenicity; it is classified simply as strong, moderate, or weak.

Based on the above assessments, the agents are then classified into five overall categories (listed from highest to lowest risk): (1) carcinogenic to humans (known carcinogens), (2) probably carcinogenic, (3) possibly carcinogenic, (4) non-classifiable, and (5) probably not carcinogenic to humans. The "possibly carcinogenic" category typically denotes exposures for which there is limited evidence of carcinogenicity in epidemiology studies, and *in vivo* studies provide limited or inadequate evidence of carcinogenicity. IARC has reviewed over 900 substances and exposure circumstances to evaluate their potential carcinogenicity. Over 80% of exposures fall either in the possibly carcinogenic (28%) or non-classifiable (53%) category. This occurs because in science it is nearly impossible to prove the absence of an effect (i.e., that exposure to something is completely safe). Few exposures show a clear-cut or probable risk, so most agents will end up in either of these two categories. To date, IARC has classified only one agent as probably not carcinogenic , which illustrates the conservative nature of the risk evaluation process for suspected carcinogens and the difficulty in proving the absence of an effect beyond all doubt.

Weight-of-Evidence Reviews of ELF EMF Health Studies

Numerous international and national governmental, health, and scientific agencies have conducted thorough weight-of-evidence reviews of the available scientific literature to evaluate whether exposure to ELF EMF may result in potential adverse health effects. These reviews were performed by expert panels assembled and appointed by these agencies and composed of experts in multiple scientific disciplines (e.g., epidemiology, toxicology, exposure assessment) with expertise and experience in ELF EMF research. These weight-of-evidence evaluations represent scientifically based consensus opinions that provide guidance for governmental and standards setting agencies to establish exposure limits or regulations to protect the health and safety of the public, and guide future scientific research by identifying potential research gaps and priorities.

In the past 15 years or so, a number of major scientific reviews have been completed, including those by the National Institute of Environmental Health Sciences (NIEHS), IARC, WHO, the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the European Commission's Scientific Committee of Emerging and Newly Identified Health Risks (SCENIHR), which I briefly review below. None of these reviews concluded that there is sufficient evidence to suggest that ELF EMF causes any adverse health outcomes, including cancer and neurodegenerative diseases.

National Institute of Environmental Health Sciences (1998)

The NIEHS is one of 27 research institutes and centers that comprise the U.S. National Institutes of Health. The chief mission of the NIEHS is to discover how the environment affects people in order to promote healthier lives. The NIEHS conducted a comprehensive review of the scientific literature on potential ELF EMF health effect as part of the Electric and Magnetic Fields Research and Public Information Dissemination Program mandated by the U.S. Congress in the 1992 Energy Policy Act. The NIEHS expert working group report included a thorough weight-of-evidence review of the literature on both cancer and non-cancer outcomes. The NIEHS followed the working procedures and evaluation methods of IARC. While reviewing epidemiologic studies of humans, the NIEHS working group found only limited evidence of a statistical association from studies of residential exposure to ELF EMF and childhood leukemia and from occupational studies of ELF EMF and chronic adult leukemia. As the NIEHS working group report explains, however, "*limited evidence*" implies that systematic errors, such as bias, confounding, and exposure or outcome misclassification cannot be ruled out as an explanation for the observed findings. Based on this limited evidence, the NIEHS working group classified ELF EMF as possibly carcinogenic, in a decision that the NIEHS called "*conservative.*" For all other cancer and non-cancer adverse health outcomes, the NIEHS expert working group found only inadequate, weak, or no evidence from human epidemiologic and laboratory animal studies.

International Agency for Research on Cancer (2002)

The IARC, the cancer research agency of the WHO, and a leading scientific and health authority on cancer research and cancer causation, reviewed the literature to evaluate potential carcinogenic effects of ELF EMF in 2002. The IARC expert working group classified ELF magnetic fields as possibly carcinogenic (Group 2B) based on limited evidence from childhood leukemia epidemiologic studies. The evidence was classified as inadequate for all other childhood and adult cancers from human epidemiologic studies and for all cancers from laboratory animal studies for ELF magnetic fields. Evidence for all cancers was inadequate for ELF electric fields.

World Health Organization (2007)

The WHO conducted a comprehensive weight-of-evidence evaluation of the scientific literature on ELF EMF and all cancer and non-cancer health outcomes and published its findings in their Environmental Health Criteria (EHC) in 2007. For ELF electric fields at the levels generally encountered by members of the public, the EHC concluded that there are no substantive health issues and did not recommend future epidemiologic research related to electric fields.

For ELF magnetic fields and cancer outcomes, the EHC concluded that recent studies did not change the IARC classification of ELF magnetic fields as "possibly carcinogenic" based on limited epidemiologic evidence and inadequate evidence from *in vivo* studies. The WHO expert panel acknowledged the statistical association between childhood leukemia and estimates of exposure to high average levels of magnetic fields, but could not rule out the possible effect of other factors (chance, bias, and confounding) on these results. Thus, when limited epidemiologic data were considered along with the largely negative findings from experimental studies, the WHO panel found that the cumulative evidence was not strong enough to conclude that magnetic fields are a known or probable cause of childhood leukemia. For all other cancers and non-cancer health endpoints, including potential effects on the neuroendocrine system, reproductive effects, and neurodegenerative diseases, the available evidence were deemed inadequate. For cardiovascular diseases and breast cancer specifically, the EHC concluded that the evidence does not support an association with ELF magnetic fields.

International Commission on Non-Ionizing Radiation Protection (2010)

The ICNIRP is the preeminent scientific organization for setting guidelines to protect the public from potential harmful effects of ELF EMF exposure, and the formally recognized organization for providing guidance on standards for non-ionizing radiation exposure for the WHO. The ICNIRP conducted its most recent review in 2010. It concluded that the existing ICNIRP guidelines are protective of the well-established acute effects of ELF EMF exposure, which are due to direct stimulation of nerves and muscles, induction of retinal phosphenes, and surface electric charges that may occur at field levels much higher than those the public may encounter. In agreement with conclusions from IARC and WHO, ICNIRP also concluded that other than the limited epidemiologic evidence from studies of childhood leukemia and ELF EMF, the evidence for other diseases are inconclusive or not in support of a potential causal association. With respect to the childhood leukemia literature they conclude that "*the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukemia is too weak to form the basis for exposure guidelines*." When evaluating the epidemiologic evidence on cancer development, ICNIRP states that "*[i]n general, the initially observed associations between 50–60 Hz magnetic fields and various cancers were not confirmed in studies designed to see whether the initial findings could be replicated*." With respect to potential effects on laboratory animals, ICNIRP concludes that "*the animal cancer data, particularly those from large-scale lifetime studies, are almost universally negative.*"

Scientific Committee on Emerging and Newly Emerging Health Risks (2013)

SCENIHR is made up of independent scientific experts assembled to provide advice on public health and risk assessments to the Department of Health and Consumer Protection of the European Commission. SCENIHR provides opinions on emerging or newly-identified health and environmental risks and on broad, complex, or multidisciplinary issues requiring a comprehensive assessment of risks to consumer safety or public health and related issues not covered by other Community risk assessment bodies. The mandate of SCENIHR includes the evaluation of potential health effects of EMF, as well. SCENIHR's most recent report, "*Preliminary Opinion on Potential health effects of exposure to electromagnetic fields (EMF),*" dated December 12, 2013, was released for public consultation on February 4, 2014. The overall conclusions of SCENIHR are consistent with those of IARC and WHO, and recognize the indication of a statistical association in some of the epidemiologic literature on childhood leukemia, for which chance, bias, and confounding cannot be ruled out as explanation. In addition, the limited epidemiologic evidence is not supported by the overall negative laboratory animal studies. The recently released SCENIHR report (2013) reiterates that "*no mechanism has been identified that could explain these findings,*" which, along with the lack of supportive laboratory animal data, prevents causal interpretation. With respect to recent epidemiologic studies of neurodegenerative diseases, the SCENIHR concludes that "*they do not provide support for the previous conclusion that ELF MF [magnetic field] exposure increases the risk for Alzheimer's disease.*"

Exposure Standards and Guidelines

Exposure standards and guidelines are developed by scientific organizations to protect against known health effects. Guideline development includes a thorough review and evaluation of the relevant scientific research using an objective weight-of-evidence approach. One of the main objectives of these reviews is to identify the lowest exposure level below which no health hazards have been identified (i.e., threshold level). Exposure limits are set well below the threshold level established by these reviews to take into account individual variability and sensitivity that may exist in susceptible populations, and are therefore quite conservative in nature.

Federal Exposure Standards

In the United States, there are no federal limits for exposure to 60 Hz EMF. The Occupational Safety and Health Administration (OSHA) of the United States Department of Labor currently has no standards on limiting exposure to power-frequency EMF in the workplace; however, there are national and international consensus guidelines that may be referenced by OSHA under a general duty clause citation (OSHA, 2014).

For 60 Hz magnetic fields, the only effects known to be produced in humans are seen at very high field levels, which the average person would not be expected to encounter even in occupational settings. These effects are short-term, immediate, perceptible reactions to the electrical stimulation of the muscle, the nervous system, and visual phosphenes (ICNIRP, 2010). Exposure to 60 Hz electric fields at high levels may results in perception, annoyance, and small electric discharges (microshocks). These effects are not severe and are reversible.

Guidelines for exposure 60 Hz electric and magnetic fields have been developed by ICNIRP. ICNIRP is an independent organization of scientists assembled from around the world from various disciplines with expertise in the field of non-ionizing radiation. Its guideline recommendations for non-ionizing radiation are formally recognized by the WHO, the International Labor Organization, and the European Commission. Other organizations that have developed scientifically-based consensus guidelines on magnetic field exposures include the International Committee on Electromagnetic Safety (ICES), and the American Conference of Governmental Industrial Hygienists (ACGIH). Exposure guideline values of these organizations are presented in Table 2 and Table 3.

Table 2. Guidelines for 60 Hz magnetic field exposure

Organization (Year)	Limit Value
ICES (2002) – General public	9,040 mG
ACGIH (2009) – Occupational limit	10,000 mG
ICNIRP (2010) – General public	2000 mG

Table 3. Guidelines for 60 Hz electric field exposure

Organization (Year)	Limit Value
ICES (2002) – General public	5 kV/m*
ACGIH (2009) – Occupational limit	25 kV/m
ICNIRP (2010) – General public	4.17 kV/m

*There is an exception within transmission line rights of way, where the limit is 10 kV/m, because people do not spend a substantial amount of time in these locations and very specific conditions are needed before a response is likely to occur (i.e., a person must be well insulated from ground and must contact a grounded conductor) (ICES, 2002, p. 27).

State Exposure Standards

There are six states in the United States with numeric limits for transmission line related EMF (Table 4), as outlined in the NIEHS Question and Answers Brochure on EMF. As NIEHS states, in most cases the limits represent "*the maximum fields that existing lines produce at maximum load-carrying conditions,*" that is, they aim to preserve *status quo* for exposure levels, and the limits are not based on specific health effects. In some states, there are electric field limits at road crossings to ensure that induced currents in large metallic objects, such as trucks and buses, do not represent an electric shock hazard.

Table 4. State standards and guidelines for transmission lines and substations

State	Electric Field: On right-of-way*	Electric Field: Edge of right-of-way	Magnetic Field: On right-of-way*	Magnetic Field: Edge of right-of-way
Florida	8 kV/m[a] 10 kV/m[b]	2 kV/m		150 mG[a] (max. load) 200 mG[b] (max. load) 250 mG[c] (max. load)
Minnesota	8 kV/m			
Montana	7 kV/m[d]	1 kV/m[e]		
New Jersey		3 kV/m		
New York	11.8 kV/m 11.0 kV/m[f] 7.0 kV/m[d]	1.6 kV/m		200 mG (max. load)
Oregon	9 kV/m			

*In the Florida standard, certain additional areas adjoining the right-of-way. [a]For lines of 69-230 kV. [b]For 500 kV lines. [c]For 500 kV lines on certain existing right-og-way [d]Maximum for highway crossings. [e]May be waived by the landowner. [f]Maximum for private road crossings.

Source: NIEHS, 2002, p. 46

Some additional states (e.g., California, Connecticut, and Iowa) and local jurisdictions have regulations related to specific setback distances for transmission lines in areas where there are residences, schools, hospitals, playgrounds, and other similar facilities.

ELF EMF Health Research

Since the 1979 publication of the first epidemiologic study investigating a potential association between electric distribution line characteristics in the vicinity of the residence and childhood cancer, a large amount of scientific evidence has accumulated about potential cancer and non-cancer health effects and exposure to residential and occupational sources of power-frequency EMF.[3] While a broad range of health effects have been investigated, most of the research focused on childhood leukemia and to a lesser extent on other childhood and adult cancers and adult onset neurodegenerative diseases. In the following sections, I will provide a brief overview of relevant literature for these health outcomes. I will also discuss potential interference with implanted medical devices. Despite extensive research conducted to date and the characterization by WHO that "*scientific knowledge in this area is now more extensive than for most chemicals,*" adverse effects of long term exposure have not been identified. The current scientific consensus as exemplified by the conclusion of the WHO is that the "*current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields.*"

Childhood Cancer

Childhood leukemia, while it is the most common malignancy among children, is a rare disease occurring among approximately 4 per 100,000 children per year (Ross and Spector, 2006). Despite significant improvements in treatment of childhood leukemia over the past few decades, little is known about what causes childhood leukemia. Ionizing radiation, such as X-rays, exposure to certain chemicals, such as chemotherapy and benzene, and certain genetic predispositions remain the only known risk factors for childhood leukemia, but these risk factors explain only a small fraction of childhood leukemia cases.

Childhood leukemia is one of the most researched diseases in the ELF EMF health literature. The first study by Wertheimer and Leeper in 1979 suggested a statistical association between

[3] While in North America, alternating current electricity with a frequency of 60 Hz is used, in most other parts of the world, 50 Hz electricity is used. Research results conducted in both frequencies are discussed together, as there is no reason to assume that any potential effects would be materially different for the two frequencies.

certain electric distribution wiring characteristics near the home and childhood cancer. A number of subsequent studies attempted to improve on various study design features, such as exposure assessment, case ascertainment, control selection, assessment of confounding and analytical techniques. When original data from a number of relevant studies were combined in one analysis (i.e., a pooled analysis), no association was apparent at lower exposure levels, but small statistical differences were noted in the proportion of children with and without leukemia that had average exposure above 0.3-0.4 μT (3-4 mG) (Ahlbom et al., 2000; Greenland et al., 2000). Inherent limitations of observational epidemiology studies, make them insufficient to draw causal inference and provide only limited epidemiologic evidence, because chance, bias, and confounding cannot be ruled out with reasonable confidence. In addition, laboratory animal studies that exposed rodents during their entire lifetime to significantly higher fields than those near transmission lines, did not show that EMF can induce or promote cancer and no accepted biophysical mechanism exists to explain a carcinogenic effect.

More recent epidemiology studies on childhood leukemia and ELF EMF have not materially changed the overall scientific evidence. In 2010, my colleagues and I conducted a pooled analysis of childhood leukemia studies published between 2000 and 2010 (Kheifets et al., 2010). The main objective was to evaluate if studies published following the two pooled analyses (Ahlbom et al., 2000; Greenland et al., 2000) discussed earlier provide any new scientific insight. In our new pooled analysis, the association with exposure levels above 0.3 and 0.4μT was statistically not significant and weaker than in the previous pooled analyses.

A number of recently published epidemiologic studies of childhood leukemia focused on distance between residential address and nearby power lines. These studies overall provide no new evidence for an association. In France, Sermage-Faure et al. (2013) examined residential distance to transmission lines among children with and without leukemia using geographic information systems. Overall no association was observed. The authors, however, also reported a statistically not significant association in a sub-analysis based on a small number of cases (n=9). A similar but smaller study in Denmark, Pedersen et al. (2014) reported no statistically significant association between childhood leukemia and residential proximity to power lines. In the largest study to date, Bunch et al. (2014) updated and extended an earlier study in the United

Kingdom published by Draper et al. in 2005 (Draper et al., 2005; Kroll et al., 2010). The new study extended the study period by 13 years (1962-2008), included lower voltage lines (132 kV) in addition to 275/400 kV lines, and included Scotland in addition to England and Wales in their analyses. Bunch et al. (2014) included over 53,000 childhood cancer cases and over 66,000 healthy control children and reported no overall association with residential proximity to power lines for leukemia or any other cancer among children. The statistical association reported by the earlier study was not apparent in the extended analysis

In another recent pooled analysis that my colleagues and I conducted (Schüz et al., 2012), we tested whether earlier findings (Foliart et al., 2006, Svendsen et al., 2007) on exposure to ELF magnetic fields and survival of children diagnosed with leukemia could be replicated. We pooled original data from Canada, Denmark, Germany, Japan, the United Kingdom, and the United States and combined data on more than 3,000 cases of childhood leukemia in one analysis. Our results showed no association between exposure to ELF magnetic fields and survival or risk of relapse among children with leukemia (Schüz et al., 2012).

For childhood brain cancer, ELF EMF epidemiologic studies reported no consistent associations. The main ELF EMF health risk reviews discussed above, including the assessments by IARC and WHO, concluded that the evidence for an association with childhood brain cancer is inadequate. To enable better assessment of the overall epidemiologic evidence, my colleagues and I conducted both a meta-analysis and a pooled analysis of the available studies (Mezei et al., 2008; Kheifets et al., 2010).[4] Our pooled analysis of childhood brain cancer studies was conducted following up on recommendations in the WHO ELF EMF research agenda. It included primary data from 10 studies on a total of over 8,000 children diagnosed with a brain tumor. No consistent risk increase or exposure-response relationship was observed regardless of the type of exposure metrics, cutpoints, adjustment for confounders, exclusion of particular studies, and analytical methods used.

[4] While a meta-analysis combines published results from scientific peer-reviewed articles, a pooled analysis combines primary data obtained from the investigators of the original studies.

Adult Cancer

In modern industrialized societies, about one-half of adult males and one-third of adult females are expected to develop some type of cancer during their lifetime (Siegel, 2013); thus, due to their public health importance adult cancers also have received substantial scrutiny in ELF EMF health research. Most attention was given to breast cancer, brain cancer, and leukemia. The general lack of supportive animal studies and the absence of known biophysical mechanisms for any potential carcinogenic effects are just as relevant for adult cancers as they are for cancers among children. Epidemiologic studies of ELF EMF and adult cancers have examined exposure to both residential (power lines, appliances) and occupational sources. Since occupational exposure levels could be substantially higher than those from residential sources, a large part of the ELF EMF epidemiologic literature on adult onset diseases are occupational studies. Overall, based on the totality of the scientific evidence, the review panels, such as those of the IARC and WHO, concluded that there is no conclusive or consistent evidence to suggest that ELF EMF is the cause of any type of adult cancer.

Initially, a biologically-based hypothesis was proposed for a potential link between EMF exposure and breast cancer and some of the earlier epidemiologic studies could not exclude the possibility of an association. Larger and better designed studies that followed up on the initial findings, however, tended to show no association (e.g., Forssen et al., 2005). Based on the available evidence the WHO concluded that the evidence overall was not in support of an association for breast cancer. More recent, large and well-conducted epidemiologic studies did not provide support for an association between breast cancer and residential proximity to power lines (Elliott et al., 2013) or occupational exposure to ELF EMF (Sorahan, 2012).

Adult leukemia and brain cancer, the most studied diseases in ELF EMF epidemiology, were also the focus of a large number of occupational epidemiologic studies showing varying results. Meta-analyses, which statistically combine results of published studies, if appropriately done, may be useful tools to understand patterns and trends in studies that are frequently difficult to interpret individually. Earlier meta-analyses conducted for occupational ELF EMF studies of adult leukemia and brain cancer (Kheifets et al., 1995; Kheifets et al., 1997) were consistent with a statistical association. In a more recent updated meta-analysis that my colleagues and I conducted (Kheifets et al., 2008) in response to recommendations in the WHO EHC, we combined relevant published studies on occupational ELF EMF exposure and adult leukemia and brain cancer. While small statistical associations were detected for leukemia and brain cancer, these were weaker in the more recent and methodologically improved studies. In addition, there was no clear dose-response pattern with increasing exposure levels and there was a lack of consistency across disease subgroups, overall providing no consistent support for a hypothesis that ELF EMF exposures are responsible for the observed excess risk (Kheifets et al., 2008).

The recent large case-control study of residential proximity to power lines and adult cancer in the United Kingdom, mentioned earlier, reported no association with either adult leukemia or brain cancer (Elliott et al., 2013). The occupational exposure study by Sorahan (2012), examining cancer incidence in a cohort of 81,842 electricity generation and transmission workers, reported no excess risk of leukemia or brain cancer with estimated occupational exposure to ELF EMF.

Neurodegenerative Diseases

In addition to various types of cancer, neurodegenerative diseases and their potential association with ELF EMF were extensively researched. Among the neurodegenerative diseases, Alzheimer's disease and amyotrophic lateral sclerosis (ALS), also known as Lou Gehrig's disease, have received the most attention in the ELF EMF research literature. Some of the earlier studies showed an association with Alzheimer's disease. These studies, however, were predominantly clinic-based occupational epidemiologic studies recruiting subjects at treatment centers and assessing job-related ELF EMF exposure based on the study subjects' recall; study design features that are all prone to result in bias. Later occupational epidemiologic studies that examined workers of electric utility companies or studies that used census-based information to identify occupations with exposure to ELF EMF, could not consistently confirm the association. Most of these studies, however, relied on death certificates to identify cases of neurodegenerative diseases, which is also a potential limitation in these studies.

My colleagues and I have recently conducted a meta-analysis (Vergara et al., 2013) to statistically combine the results of the large number of previously published occupational epidemiologic studies on ELF EMF and neurodegenerative diseases and to assess potential reasons for the variable results. While the combined results showed a moderate association between Alzheimer's disease and estimated magnetic-field levels, there was a statistical indication of publication bias that is likely to, at least partially, explain the results. Publication bias is a known tendency that favors the publication of positive results in the scientific literature. The analyses also indicated that higher quality studies were less likely to show an association.

Recent studies from Switzerland and Denmark assessed the relationship between residential proximity to power lines and neurodegenerative disease (Huss et al., 2009; Frei et al., 2013). The Swiss study (Huss et al., 2009) examined the occurrence of death due to neurodegenerative disease with distance of the home to the nearest high-voltage power lines. A statistically significant association was reported for Alzheimer's disease among those who lived within 50 meters (164 feet) of the nearest 220-380 kV transmission line. The association was stronger with longer duration of residence within 50 meters. The study conducted in Denmark, which I also co-authored, significantly improved on the design compared to the Swiss study, as it used hospital discharge records to identify newly-diagnosed cases of neurodegenerative disease as opposed to relying on death certificates (Frei et al., 2013). In our study, no association was observed between neurodegenerative disease, including Alzheimer's disease, and residential proximity to high-voltage power lines. Neither the Swiss nor the Danish study estimated actual magnetic-field levels but relied on distance to power lines as an approximation, a clear limitation in both studies.

The WHO in its EHC (2007) observed that the higher quality studies do not indicate an association with Alzheimer's disease and no biological mechanism has been established that can explain a potential ELF EMF effect on neurodegenerative disease development. According to the overall conclusion of the WHO (2007), the evidence for an association with neurodegenerative diseases is inadequate. According to the more recent SCENIHR (2013) conclusion, new studies do not provide convincing evidence for an increased risk of neurodegenerative diseases related to ELF-EMF exposure.

Implanted Cardiac Devices

The normal functioning of the heart is controlled by naturally occurring electric impulses. Implanted cardiac devices, most commonly pacemakers and implantable cardioverter defibrillators (ICD), are designed to sense and respond to the heart's electric signals. Pacemakers are used to maintain regular heart rhythm in the physiologic range. ICD are used to sense when potentially life-threatening irregular heartbeats develop and deliver an electric shock to bring the heart functioning back to normal. Outside electrical signals (e.g., from appliances, radio communication technologies, industrial equipment, and medical equipment such as magnetic resonance imaging) may potentially interfere with the normal operation of these cardiac devices. Most sources of EMF, however, are too weak to affect a pacemaker or an ICD. No cases were identified in the medical literature that reported accidental interference with a patient's pacemaker or ICD. Magnetic fields from transmission lines are generally too weak to cause interference, while electric field strength decreases rapidly with distance and is shielded by conductive objects, such as trees, building, fences, vehicles, and even the human body.

The probability of interference is dependent of several factors including the type, design and the settings of the device, the strength of the signal, the distance from the source of the signal, the signal's duration and frequency, and the patient's orientation. Most modern devices incorporate many technological and design features that minimize the potential for interference. These include bipolar sensing, shielding by titanium casing, electrical filtering of signals, switches and programmable settings of sensitivity, mode, and polarity (Dyrda and Khairy, 2008).

A number of recent experimental and observational studies examined pacemaker and ICD functioning in high fields. For example, Korpinen and colleagues tested of 31 pacemakers placed in human shaped phantoms directly under a 400-kV transmission line (Korpinen et al., 2012). No interference was observed with bipolar sensing and interference with only one unipolar pacemaker at an electric-field level between 6.7-7.5 kV/m. Souques and colleagues (2011) investigated electric utility workers with ICDs at electric substations in France. No interference with ICDs was observed with a magnetic field as high as 650 μT (6,500 mG) and electric fields as high as 12.2 kV/m.

While the American Conference of Governmental Industrial Hygienists (ACGIH, 2001) recommended that exposure for workers with implanted cardiac devices should be below 1 kV/m for electric fields and 100 μT (1,000 mG) for magnetic fields, these are general recommendations and do not specifically address modern devices with technological and design improvements that are more immune to potential interference. ACGIH recommends that patients consult their physicians and the respective pacemaker manufacturers before following these guidelines.

More recently, the European Committee for Electrotechnical Standardization (CENELEC) has developed specific procedures to assess potential risks to workers with active implantable medical devices (EN 50527-1, 2010). CENELEC has determined that these devices are expected to function without interference below the reference levels of 5 kV/m and 100 μT (1,000 mG) for ELF electric fields and magnetic fields, respectively, which are based on European Council Recommendation 1999/519/EC. The European Standards document also states that "*[f]or higher fields the voltage can cause electromagnetic interference effects but often this is not clinically significant ... and transient exposure can be permitted*" (EN 50527-1, 2010).

Evaluation of the Testimony of Dr. Carpenter

When I was requested to provide an expert report on ELF EMF health research, I was also asked to provide an evaluation of the testimony of Dr. David O. Carpenter, dated April 25, 2014, and submitted in the *Barkers v East Kentucky Power Cooperative, Inc.* matter. The testimony of Dr. Carpenter is a six-page document, not including references and attachments, that provides details of his qualifications and background, includes a cursory review of selected publications, and expresses an opinion that there is "*strong evidence in humans*" in support of health effects of ELF EMF and that the magnetic fields from the 345-kV power lines represent "*a real and significant health risk to the residents*" of the Barkers' home.

Dr. Carpenter's testimony on the potential health effects of ELF EMF is flawed for several reasons, including the selective reporting of studies with positive outcomes; the failure to consider the entirety of the relevant scientific literature; the failure to consider recent scientific publications; the failure to consider the limitations of individual studies; the lack of clearly identified methods to arrive to his conclusions; and the inconsistency of his conclusions with generally accepted scientific consensus opinions expressed by a number of national and international, multi-disciplinary expert panels, such as the ones of IARC, ICNIRP, WHO, and SCENIHR. In this section, I will discuss examples of the specific shortcomings of Dr. Carpenter's testimony.

Inconsistency with the Consensus Opinions of National and International Expert Panels

Dr. Carpenter references three expert panel reviews (NRC 1997, IARC 2002, WHO 2007) and highlights that these reviews reported a statistical association with childhood leukemia. Dr. Carpenter, however, fails to mention that these reports characterize this association as "weak" or "limited." According to the IARC and WHO evaluations, "limited" evidence implies that "chance, bias or confounding" could not be ruled as an explanation. Dr. Carpenter also fails to mention that these same panels also concluded that *in vitro* laboratory studies and whole animal *in vivo* studies do not provide evidence for an association and that none of these expert panels concluded that ELF EMF is a cause of any adverse health effects. For example, the overall conclusion of the National Research Council panel is that "*[t]he body of evidence, in the committee's judgment, has not demonstrated that exposure to power-frequency electric and magnetic fields is a human health hazard.*" The WHO panel stated that the cumulative evidence was not strong enough to conclude that magnetic fields are a known or probable cause of childhood leukemia and the WHO website currently states "*[b]ased on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields.*"

Dr. Carpenter also refers to the BioInitiative Report (BIR) (www.bioinitiative.org), he co-authored, as a source of documentation of adverse health effects. The BIR has been widely criticized in the scientific community for not following generally accepted scientific methods, such as the well-established weight-of-evidence assessment, when reviewing the scientific literature on EMF health effects. The organizations that criticized the BIR include the Health Council of the Netherlands and the Australian Centre for Radiofrequency Bioeffects Research (HCN 2008, ACRBR 2008). The scientific shortcomings of BIR include the selective citing of positive studies in support of their views without adequate consideration of the quality of studies and the heavy reliance on *in vitro* studies, as opposed to *in vivo* and epidemiologic research. These flaws explain why their conclusions are largely inconsistent with the conclusions of other national and international expert risk assessment panels. The critiques of BIR also have pointed out that the conclusions expressed in BIR do not appear to be consensus opinions, but rather they are individual opinions of the authors of various chapters.

Selective Reporting of Positive Studies

In his testimony, Dr. Carpenter selectively highlights studies that show associations with some of the investigated health outcomes. He fails to mention studies, however, that were conducted later as a follow up to the earlier studies and that subsequently did not report an association with the same outcomes. For example, Dr. Carpenter references the childhood leukemia studies of Foliart et al. (2006) and Svendsen et al. (2007) that—based on small number of study subjects—report a statistical association with survival, but fails to mention a much larger study that includes more than 3,000 children with leukemia and shows no association between ELF EMF exposure and survival of children diagnosed with leukemia (Schuz et al., 2012). Dr. Carpenter references the study by Huss et al. (2009) that reports an association for Alzheimer's disease among subjects who reside near power lines, but does not mention a later study that, with improved methodology, did not find an association between residential proximity to power lines and Alzheimer's disease (Frei et al., 2013). As another example, Dr. Carpenter mentions the study by Draper et al. (2005), but fails to mention the recently published updated analysis by Bunch et al (2014). While the Draper study reported a moderate association, the Bunch study, which provided substantial extension and update to the former study both in study period and geographic locations, no longer reported an overall association for leukemia or any other cancers among children.

Lack of Consideration of Study Quality

Dr. Carpenter references several studies that seem to support his conclusion without due consideration of the limitations of those studies. For example, Dr. Carpenter mentions the Yang et al. (2008) study and claims that its findings may explain the mechanism of cancer development. The Yang study has several limitations that prevent us from drawing scientific conclusions. First, it is currently unknown whether the specific DNA repair genes examined in the study play any role in childhood leukemia development. Second, the study relied on distance to electric installations to estimate exposure, which is known to be a poor proxy for actual ELF EMF levels. Finally the study was a case only design and no control group was included. Without a comparison group, it is impossible to tell what the expected distribution of the gene variation was in the general population.

General Disregard of Negative Laboratory Animal Studies

In vivo laboratory animal studies are considered key contributors to human health risk assessment. Although animal studies require interspecies extrapolation, they are invaluable in informing the risk assessment process, as they serve as excellent models for potential human health effects. In laboratory animal studies, researchers can expose animals to exposure levels substantially higher than exposures observable in human populations. Researchers in animal studies can also randomly assign and carefully control exposure levels and other factors, thus eliminating potential confounding effects, frequently impossible or difficult to control for in epidemiologic studies. The key role of animal studies is underlined by the following statement in Preamble of the IARC Monographs for evaluation of carcinogenicity: "*[a]ll known human carcinogens that have been studied adequately for carcinogenicity in experimental animals have produced positive results in one or more animal species.*" Since the potential carcinogenic effects of ELF EMF have been extensively studied in animals, including lifetime bioassays that expose the animals throughout their entire lifespan, it is very unlikely that any effects were missed.

In summary, Dr. Carpenter has not followed any generally accepted scientific process for arriving to his conclusion that there is "strong evidence of harm." His conclusions are not supported by the entirety of the available scientific evidence and are inconsistent with the conclusions of the comprehensive risk assessments and weight-of-evidence evaluations that have been conducted by numerous national and international expert panels on behalf of governmental, health, and scientific agencies across the globe in the past decade and a half.

Summary and Conclusion

In summary, a large body of scientific literature has accumulated over the past 40 years about exposure to ELF EMF and potential health effects associated with ELF EMF. This area has been extensively studied and the literature includes a variety of scientific studies, including epidemiologic studies of human populations, experimental studies of laboratory animals and humans (*in vivo* studies), and laboratory studies of cells and tissues (*in vitro* studies). As the WHO states, "*scientific knowledge in this area is now more extensive than for most chemicals.*"[5] The available scientific literature has been periodically and repeatedly reviewed by multidisciplinary expert panels convened by a number of national and international governmental, health and scientific agencies to evaluate the overall scientific evidence on whether ELF EMF at levels typically encountered in our environment, including the environment near transmission lines, pose any risk to human health. None of these expert panels has concluded that environmental exposure to ELF EMF causes any adverse health effects, including cancer and any other chronic diseases.

The estimated long-term average magnetic field values within the Barker residence due to the nearby transmission lines are well below internationally accepted, scientifically based exposure guidelines, such as those set by ICNIRP. These exposure levels are also well within the range that was measured in a national representative survey of households in the United States

Based on my knowledge and familiarity with the relevant literature, and the scientific reviews conducted by a number of international multidisciplinary expert panels, as described in this report, it is my opinion that a causal relationship between environmental exposure to ELF EMF and adverse chronic human health effects is not established and the magnetic field exposure that is anticipated in the Barker home as a result of the nearby transmission lines does not represent any proven health risk.

[5] http://www.who.int/peh-emf/about/WhatisEMF/en/index1.html

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Appendix A

Curriculum vitae of Gabor Mezei, M.D., Ph.D.

Gabor Mezei, M.D., Ph.D.
Senior Managing Scientist

Professional Profile

Dr. Gabor Mezei is a Senior Managing Scientist in Exponent's Health Sciences Center for Epidemiology and Computational Biology. Dr. Mezei has over 20 years of experience in health research including epidemiological studies of both clinical outcomes and environmental and occupational health issues. He has considerable experience in conducting complex health assessment and exposure characterization studies related to power frequency and radiofrequency electric and magnetic fields (EMF). Previously, at the Electric Power Research Institute, he was responsible for leading a multidisciplinary scientific research program aimed at addressing potential human health effects associated with residential and occupational exposure to power frequency and radiofrequency EMF. Dr. Mezei oversaw studies on potential EMF effects on animal health and welfare and directed occupational health and safety research focusing on injury surveillance, ergonomics evaluations of electric utility workers' tasks, and occupational exposure assessments within the electric power industry. Earlier, as a research associate at the Toronto Western Hospital, University of Toronto, he conducted studies on adverse outcomes and hospital readmissions following ambulatory surgery. Dr. Mezei trained as a medical doctor (M.D.) at the Semmelweis University of Medicine in Budapest, Hungary, and as an epidemiologist (Ph.D.) at the School of Public Health of the University of California in Los Angeles. He was the recipient of Fogarty and Fulbright Fellowships. He is currently an affiliate associate professor in the Department of Environmental and Occupational Health Sciences of the University of Washington in Seattle, Washington. Previously, he was a visiting scientist at the Hungarian National Research Institute for Radiobiology and Radiohygiene in Budapest, Hungary.

Dr. Mezei is an author or co-author of over 50 scientific publications and book chapters on topics related to epidemiology of environmental and occupational exposures and chronic diseases (such as cancer and neurodegenerative diseases), adverse clinical outcomes following ambulatory surgery, and environmental exposure assessment.

Academic Credentials and Professional Honors

Ph.D., Epidemiology, University of California, Los Angeles, 1995
M.D., Medicine, Semmelweis University of Medicine, Hungary, 1990

Fogarty Fellowship, 1992–1995
Fulbright Fellowship, 1994–1995

Languages

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Academic Appointments

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Peer-Reviewed Scientific Publications

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Editorial Board Member

- Journal of Exposure Science and Environmental Epidemiology (2008 to present)

Peer Reviewer

- American Journal of Epidemiology (2005, 2007, 2008, 2009)
- Bioelectromagnetics (2004, 2007, 2008, 2012, 2013)
- Environmental Health Perspectives (2005)
- Epidemiology (2006)
- European Journal of Pediatrics (2007)
- International Journal of Cancer (2008)
- Journal of Exposure Science and Environmental Epidemiology (2006)
- Pediatric Blood & Cancer (2006)

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

IN THE MATTER OF:

HAROLD BARKER; ANN BARKER AND BROOKS BARKER	)	
COMPLAINANTS	)	
V.	)	Case No. 2013-00291
EAST KENTUCKY POWER COOPERATIVE, INC.	)	
DEFENDANT	)	

DIRECT TESTIMONY OF BENJAMIN COTTS, Ph.D.
ON BEHALF OF EAST KENTUCKY POWER COOPERATIVE, INC.

Filed: June 2, 2014

Q. PLEASE STATE YOUR NAME, BUSINESS ADDRESS, AND OCCUPATION.

A. My name is Benjamin R.T. Cotts, Ph.D. I am a Manager in the Electrical Engineering and Computer Science Practice at Exponent, Inc. a scientific research and engineering consulting company located at 17000 Science Drive, Suite 200, Bowie, Maryland 20715.

Q. PLEASE STATE YOUR EDUCATION AND PROFESSIONAL EXPERIENCE.

A. I have a Bachelor of Science degree in Electrical Engineering from the University of Portland in Oregon, as well as Master of Science and Doctor of Philosophy degrees in Electrical Engineering from Stanford University in California.

I have more than 12 years of experience relating to research and evaluation of electric and magnetic fields, particularly in the extremely low frequency (ELF) (3-3,000 Hertz [Hz]) and very low frequency (3,000-30,000 Hz) portion of the electromagnetic spectrum. I am a member of several technical organizations, including the Institute of Electrical and Electronics Engineers (IEEE) and the International Council on Large Electric Systems (CIGRÉ). I am also a member of CIGRÉ's working group C4.32, Understanding of the Geomagnetic Storm Environment for High Voltage Power Grids, as well as a member of the International Committee of Electromagnetic Safety (ICES), Committee TC95.

I have previously testified before the Connecticut Siting Council and in regard to litigation on the nature of EMF in general and specifically to transmission lines and substations. I routinely perform EMF assessments of overhead alternating current (AC) and direct current (DC) transmission lines and EMF assessments for federal agencies, utilities, and construction developers. I have also performed electromagnetic compatibility assessments and site surveys for patients with pacemakers, ICDs and other implantable medical devices. I am the author of numerous peer-reviewed papers and conference presentations on the topic of electromagnetic waves and the earth's geomagnetic field.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

A. The purpose of my testimony is to authenticate and incorporate by reference the expert report which I have authored on behalf of East Kentucky Power Cooperative, Inc. ("EKPC").

Q. ARE YOU SPONSORING ANY EXHIBITS?

A. Yes. The expert report that I prepared in association with this case is attached hereto and incorporated herein as Exhibit BC-1. It includes a copy of my curriculum vitae.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes.

VERIFICATION

Comes now, Benjamin Cotts, and after being duly sworn does hereby state that the foregoing testimony is true and correct to the best of my knowledge and belief as of this 29th day of May, 2014.

Benjamin Cotts

STATE OF Maryland

COUNTY OF Anne Arundel

The foregoing was subscribed and sworn to before me, the Notary Public, on this the 29th day of May, 2014.

NOTARY PUBLIC

My Commission expires: 5/26/18

Elizabeth C. Keller
NOTARY
PUBLIC
Anne Arundel Co., MD

Exponent

Electrical Engineering and Computer Sciences Practice

Report of Benjamin Cotts, Ph.D.

Barker v East Kentucky Power Cooperative Matter

EXHIBIT

BC-1

Report of Benjamin Cotts, Ph.D.

Barker v East Kentucky Power Cooperative Matter

Prepared for

Sherman Goodpaster, Esq.
Senior Corporate Counsel
East Kentucky Power Cooperative, Inc.

Prepared by

Benjamin Cotts, Ph.D.
Exponent
17000 Science Drive
Bowie, MD, 20715

June 2, 2014

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Acronyms and Abbreviations

µT	Microtesla
A	Amperes
AC	Alternating current
ACGIH	American Conference of Governmental Industrial Hygienists
CIGRÉ	International Council on Large Electric Systems
DC	Direct current
EKPC	East Kentucky Power Cooperative, Inc.
ELF	Extremely low frequency
EMF	Electric and magnetic fields
EPRI	Electric Power Research Institute
G	Gauss
ICD	Implantable cardiac defibrillators
ICES	International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
kV	Kilovolt
kV/m	Kilovolt per meter
mG	Milligauss
NESC	National Electric Safety Code
OSHA	Occupational Safety and Health Administration
PECI	Pfeiffer Engineering Company, Inc.
pF	Picofarad
rms	Root mean square
ROW	Right of way
T	Tesla
TVL	Threshold limit values
V	Volt
V/m	Volt per meter

Limitations

At the request of East Kentucky Power Cooperative, Exponent performed measurements and modeling of electric and magnetic fields. The scope of our services was determined by the circumstances associated with this case as well as applicable codes, rules, and regulations. Any re-use of this report or the findings, conclusions, or recommendations presented herein for any other purpose are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation.

The findings presented herein are made to a reasonable degree of engineering and scientific certainty. I have made every effort to perform an accurate and thorough investigation. If new data become available or there are perceived omissions or misstatements in this report regarding any aspect of those conditions, we ask that they be brought to our attention as soon as possible so that we have the opportunity to fully address them.

Introduction

On July 7, 2013, a Complaint was filed on behalf of Harold Barker, Ann Barker, and Brooks Barker at the Kentucky Public Service Commission against East Kentucky Power Cooperative, Inc. (EKPC). Among other complaints, the Barkers allege health risks due to exposure to electric and magnetic fields (EMF) from the 345,000-volt (V) (345-kilovolt [kV]) transmission line that EKPC owns and operates near the Barker property.

I was asked by counsel for EKPC to evaluate materials related to the *Barker v East Kentucky Power Cooperative, Inc.* matter. I was specifically asked to assess the EMF levels associated with the 69-kV and 345-kV transmission lines owned and operated by EKPC near the Barker property and to provide a scientific evaluation of the testimony of Mr. John C. Pfeiffer submitted in this matter. This report summarizes my findings and opinions based on my professional qualifications, work experience, knowledge of the scientific principles governing electric fields and magnetic fields and based on the reviewed documents related to this matter. The specific materials received from EKPC in this matter, and which I reviewed, are as follows:

1. Complaint
2. Testimony of Ann Barker and Brooks Barker
3. Report from Pfeiffer Engineering Company, Inc. (PECI)
4. Response of Complainants To Data Requests Served By Defendant
5. Plan/Profile drawings of 69 kV transmission line
6. Plan/Profile drawings of as-built 69-kV / 345-kV configuration
7. Plan/Profile drawings of original 69-kV / 345-kV design
8. Loading information from May 22, 2014

Additional materials that I reviewed in the preparation of this report include:[1]

1. IEEE Standard 644-1994
2. IEEE Standard 644-1308
3. IEEE Standard C95.3.1-2010
4. EPRI Transmission Line Reference Book: 345 kV and Above
5. National Electrical Safety Code
6. EMDEX II User Manual Version 3.1 (March 2008)

My opinions are expressed herein to a reasonable degree of engineering and scientific certainty. I reserve the right to revise my opinions as more information becomes available.

[1] IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines (IEEE Std. 644-1994). New York: IEEE, 2002; IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters – 10 Hz to 3 kHz (Std.1308-1994). New York: IEEE, 2001; IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 100 kHz (Std. C95.3.1-2010). New York: IEEE, 2010; General Electric. EPRI Transmission Line Reference Book: 345kV and Above, Second Edition. Palo Alto, CA: Electric Power Research Institute, 1982; American National Standards Institute. National Electrical Safety Code, C2-2007. New York, NY: IEEE, 2007.

Professional Background and Qualifications

I am a Manager in the Electrical Engineering and Computer Science Practice at Exponent, a scientific research and engineering consulting company. I have a Bachelor of Science degree in Electrical Engineering from the University of Portland in Oregon, as well as a Master of Science and Doctor of Philosophy degrees in Electrical Engineering from Stanford University in Califomia.

I have more than 12 years of experience relating to research and evaluation of EMF, particularly in the extremely low frequency (ELF) (3-3,000 Hertz [Hz]) and very low frequency (3,000-30,000 Hz) portion of the electromagnetic spectrum. I am a member of several technical organizations including the Institute of Electrical and Electronics Engineers (IEEE) and the International Council on Large Electric Systems (CIGRÉ). I am also a member of CIGRÉ's working group C4.32, Understanding of the Geomagnetic Storm Environment for High Voltage Power Grids, as well as a member of the IEEE's International Committee of Electromagnetic Safety (ICES), Committee TC95.

I have previously testified before the Connecticut Siting Council and in regard to litigation on the nature of EMF in general and specifically to transmission lines and substations. I routinely perform EMF assessments of overhead alternating current (AC) and direct current (DC) transmission lines and EMF assessments for federal agencies, utilities, and construction developers. I have also performed electromagnetic compatibility assessments and site surveys for patients with pacemakers, implantable cardiac defibrillators (ICD), and other implantable medical devices. I am the author of numerous peer-reviewed papers and conference presentations on the topic of electromagnetic waves and the earth's geomagnetic field, which are listed in my curriculum vitae provided in Appendix A. Exponent, my employer, currently charges $280 per hour for my consulting services.

During this investigation, I have relied on my education, training, and experience in performing the analysis and formulating my opinions.

Technical Background

The electrical power system in the United States generates AC electricity at a frequency of 60 Hz, meaning that the electrical current flowing in a transmission line's phase conductors changes magnitude continuously in a cycle that repeats 60 times each second. This electricity generates EMF in the ELF range of the electromagnetic spectrum (i.e., 3 to 3,000 Hz), and is often referred to as power-frequency EMF. While the transmission lines that carry electricity from generating stations to substations and the distribution lines that carry electricity from substations to our homes, businesses, factories, and schools are sources of EMF, so too are all things connected to the electrical system—the wiring in our buildings and all electrical appliances and machines. Although the fields generated by electricity are commonly referred to collectively as EMF, these fields have different properties, as follows:

Electric fields

In an electrical power system, electric fields are produced by voltage applied to electrical conductors and equipment and, in general, the strength of the electric field will increase with higher voltage. Electric fields are generated even if an appliance or equipment is turned off if it is still plugged into the power source. Electric fields emanate radially outward from the source, the levels of which drop rapidly with distance. In addition, electric fields are effectively blocked or attenuated by any conducting object, such as trees, fences, walls, or buildings. Electric fields are measured in units of volts per meter (V/m) or kilovolts per meter (kV/m); 1 kV/m is equal to 1,000 V/m.

Magnetic fields

Magnetic fields result from electric current flowing through wires and electrical devices. The strength of the magnetic field generally increases with higher current, but the magnetic-field level is also determined by the characteristics of the source. The magnetic field generated by transmission lines, for example, depends on the arrangement of the conductors and their separation from one another. Similar to electric fields, magnetic fields diminish rapidly with distance from the source; but, unlike electric fields, they are not easily blocked by conducting objects. In North America, magnetic fields are typically expressed as magnetic flux density in units of Gauss (G) or milligauss (mG); in Europe and elsewhere, magnetic fields are commonly expressed in units of Tesla (T) or microtesla (μT), where 0.1 μT is equal to 1 mG.

Transmission line phase conductors

Transmission lines typically operate with three different phase conductors designated A, B, and C. As described above, the electrical current that flows in each phase conductor changes magnitude continuously in a cycle that repeats 60 times each second; but, in each of the three conductors in a transmission line it changes magnitude at different *times*. An illustration of this concept is presented in Figure 1, which shows that the current and voltage of each of the three phase conductors reaches a maximum (positive), zero, or minimum (negative) value at a different time. This offset in time is referred to as a phase difference between the various conductors. The phase difference between each of the transmission line conductors means that the EMF level associated with each conductor will also have phase differences, reaching maximum, zero, and minimum levels at different times. Properly accounting for the phase offset of each conductor is a critical component in accurately determining the levels of EMF associated with a transmission line.

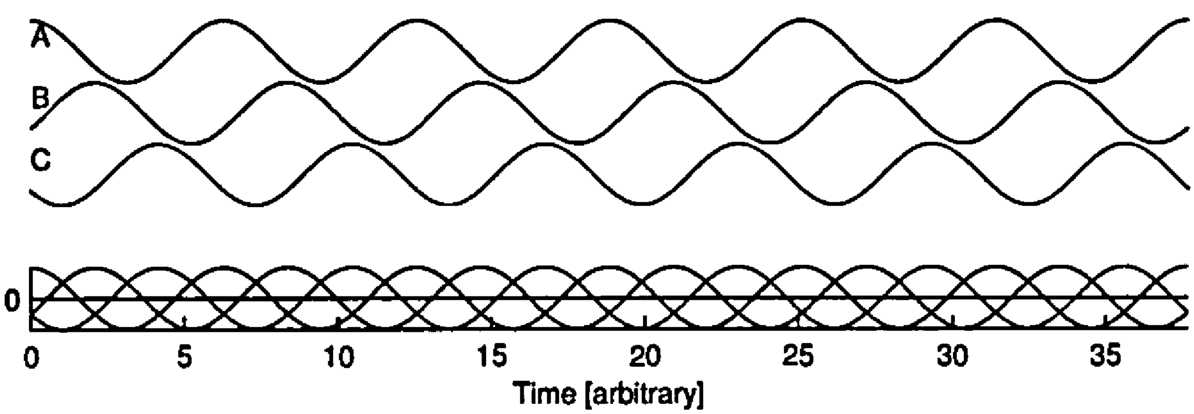

Figure 1. Transmission Line Phasing.

In this illustration the 'A' phase conductor starts at maximum value and decreases, the 'B' phase conductor starts at a slightly negative value and increases and the 'C' phase conductor starts at the same slightly negative value as 'B' and decreases.

Vector property of EMF

The vector nature of EMF means that depending on how the transmission lines are constructed, the EMF from different phase conductors can either reinforce to produce a larger field or oppose one another (cancellation) to produce a smaller field. This concept is shown in Figure 2.

In Figure 2a, two EMF vector fields are generally oriented in the same direction, so the total field is calculated by vector addition, and results in higher field levels. In Figure 2b, two EMF vector fields are oriented in a generally opposing direction, so the total field is calculated by vector subtraction, and results in reduced field levels. For three-phase transmission lines, the location and phase of each conductor relative to all other conductors will determine whether the resulting EMF from different conductors will add to or subtract from one another at any given location.

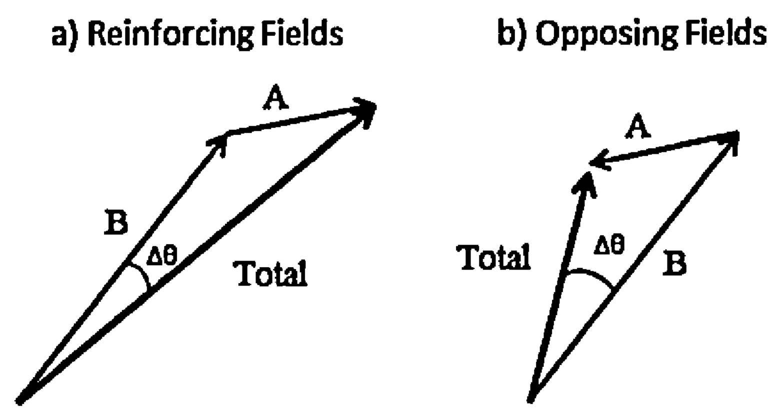

Figure 2. EMF field vector addition and vector subtraction

The design and construction of a particular transmission line influences the EMF levels at a particular location. In the case of the JK Smith to North Clark and Miller Hunt to Sideview transmission lines, the design and construction result in EMF cancellation, as described above, and generally lowers the EMF levels on the transmission line right-of-way (ROW) and beyond.

Miller Hunt to Sideview and Smith to North Clark transmission line characteristics

The AC transmission lines owned by EKPC operate at 69-kV and 345-kV. The 69-kV line connects the Miller Hunt and Sideview Substations (Miller Hunt to Sideview) and the 345-kV line connects the JK Smith and North Clark Substations (Smith to North Clark). These lines run overhead on a ROW across the driveway and by the east side of the residence located at 5450 Mt. Sterling Road in Winchester, Kentucky, which is owned by Mr. Harold Barker and Mrs. Ann Barker (Barker Residence).

An aerial photograph showing the relative locations of the transmission line ROW and the Barker property is provided in Figure 3.

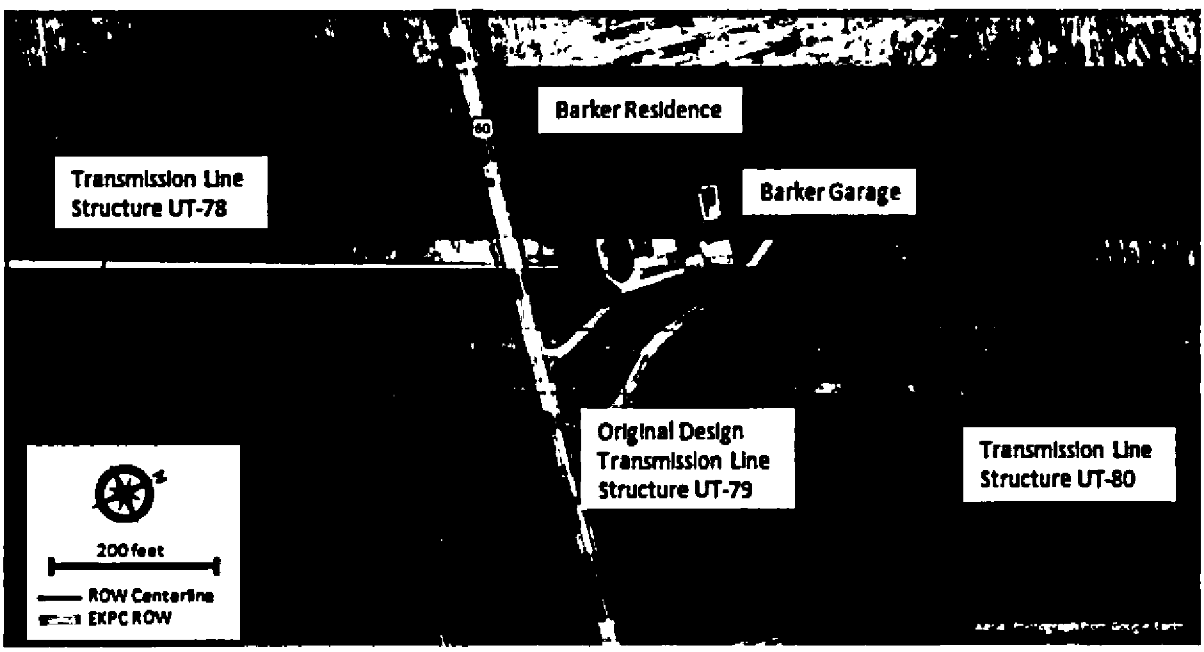

Figure 3. Aerial photograph indicating the relative locations of the transmission line ROW, structures UT-78, UT-79, and UT-80 and the Barker Residence and garage.

UT-79 was not constructed, but its planned location is shown for reference

A 69-kV transmission line (Miller Hunt to Sideview), consisting of three electrical phase conductors (identified by the letters A, B, and C), was constructed on H-frame structures (Figure 4a) prior to the construction of the Barker Residence and remained in that configuration until

2006. At that time, the 69-kV transmission line (69-kV Configuration) was upgraded with new phase conductors and constructed on a double-circuit H-frame structure with a new 345-kV transmission line and relocated a distance of 25 feet to the east of the centerline of the 69-kV Configuration (As-Built Configuration). The double-circuit structures supporting the transmission lines in this configuration are shown in Figure 4b. In addition, the original design of the double-circuit 69-kV/345-kV structures called for a structure to be located on the ROW to the east of the Barkers' driveway (Original Design Configuration). At the request of the Barkers, EKPC removed this structure (Structure UT-79) and increased the height of the adjacent structures (UT-78 to the south and UT-80 to the north) to maintain the required line clearance above the ground. Had the transmission line been constructed with Structure UT-79 in place, the line clearances in the vicinity of the Barker Residence would have been higher. Although it was not included in the final design, the Original Design Configuration is included in this report for further analysis.

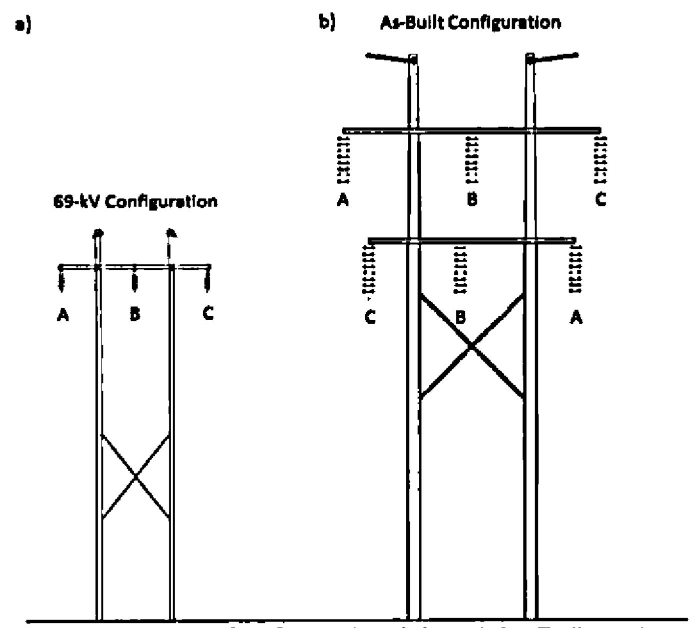

Figure 4. 69-kV Configuration (a) and As-Built and Original Design Configuration (b)[2,3,4]

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2 Conceptual drawings for visual reference only (not to scale); modified from information provided by EKPC.

3 Differences between the As-Built and Original Design Configurations are not evident in this figure. The primary difference is the height and location of various structures and the resulting differences in the minimum ground clearance of the transmission line conductors on the ROW adjacent to the Barker property.

4 The phasing arrangement shown in Figure 4b, with the conductors arranged A-B-C on top and reversed to C-B-A on bottom is known as the optimal phasing, which results in the lowest EMF levels at ground.

At the request of EKPC, I measured the EMF associated with the As-Built Configuration near the driveway (Barker Driveway), near the garage (Barker Garage) and along Bert T Combs Mountain Parkway (Mountain Parkway). In addition, I modeled the EMF associated with the 69-kV Configuration, the As-Built Configuration, and the Original Design Configuration. I have performed this assessment to describe the change in levels of EMF that resulted from the upgrade and construction of the transmission lines and to put the resulting field levels in the context of national and international standards and safety limits.

Methods

Measurement methodology

At each measurement location, the centerline of the ROW was identified by the center conductor of the overhead 345-kV transmission line. The ROW edges were then identified using a 100-foot measuring tape, which was also used to identify measurement locations relative to the center of the ROW. EMF measurements were recorded at a height of 1 meter (3.28 feet) above ground in accordance with standard methods for measuring EMF near power lines.[5] Magnetic-field levels were measured in units of magnetic flux density (mG) with a data-logging EMDEX II[6] 3-axis magnetic-field meter with survey wheel and were recorded as the total (resultant) root-mean square (rms) magnetic field and the magnetic field along the vertical axis, as well as parallel and perpendicular to the path of the transmission line ROW.[7] The survey wheel allows the EMDEX II to simultaneously record magnetic-field levels as well as distance from the starting location, thus providing accurate location information. This function enables an accurate comparison of measured magnetic-field levels with modeling results.

Electric fields were measured in units of kV/m with a single-axis sensor accessory for the EMDEX II meter. The axis of the electric-field sensor was successively oriented in the vertical, parallel, and perpendicular orientations relative to the ROW to measure vectors from which the resultant electric-field level is computed at particular points. These instruments meet the IEEE instrumentation standard for obtaining accurate field measurements at power-line frequencies.[8] The meters and the electric-field probes were calibrated by the manufacturer by methods described in IEEE Standard 644-1994.

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5 IEEE Std. 644-1994.

6 Manufactured by Enertech Consultants of Campbell, California.

7 EMF measurements along the vertical, parallel to the transmission line, and perpendicular to the transmission line were recorded as root-mean-square magnitudes. Root-mean-square refers to the common mathematical method of defining the effective voltage, current, or field of an AC electrical system.

8 IEEE Std.1308-1994.

Modeling methodology and software

Computer algorithms developed by the Bonneville Power Administration (BPA), an agency of the U.S. Department of Energy, were used to calculate EMF levels.[9] The BPA's computer algorithms are based on fundamental laws of physics and experimental evidence; they incorporate the simplifying assumptions that the transmission line's phase conductors are parallel to a flat earth and their extent are infinite.[10] The BPA's computer algorithm has been proven to accurately model EMF levels near transmission lines.[11] Both electric fields and magnetic fields were calculated as the resultant of x, y, and z fields at 1 meter (3.28 feet) above ground in accordance with standard methods as recommended by IEEE in Standard C95.3.1-2010.[12]

Modeling inputs

The important parameters needed to determine levels of EMF associated with transmission lines include voltage of the conductors, the amount of current flowing in the conductors, the arrangement of conductors, the height above ground, and the number, diameter, and separation of conductors used for each phase. A summary of the important transmission line configuration parameters incorporated in the model for six separate configurations is shown in Table 1. Three models were generated for comparison with measured EMF levels near the Barker Residence as well as along a nearby span and are referred to below as validation models. Three additional models are generated to compare the EMF levels that existed beneath the 69-kV Configuration with those in the As-Built Configuration and those which would have been in place had the Original Design Configuration been left as originally planned. These models are referred to below as Comparative Models

[9] Bonneville Power Administration (BPA). Corona and Field Effects Computer Program. Bonneville Power Administration, 1991.

[10] The terrain in some locations is clearly not flat; however, measurements in those locations are consistent with a downward sloping terrain and correspondingly lower field levels

[11] Chartier VL and Dickson LD. Results of Magnetic Field Measurements Conducted on Ross-Lexington 230-kV Line. Report No. ELE-90-98. Bonneville Power Administration, 1990.

[12] IEEE Std. C95.3.1-2010.

Validation models

The purpose of these models is two-fold. First, they provide a reference point to understand how the EMF levels vary from one side of the ROW to the other, as well as how these levels change with varying distance along the ROW. The second purpose of these models is to provide a validation for the modeling methodology used. These models are constructed based upon the conditions present at the time of measurements including measurements of conductor line height and conductor loading. Comparison of measured and modeled EMF levels using the same configuration is a useful tool in demonstrating the accuracy and efficacy of the model as well as demonstrating its limitations. The results of these models are presented below.

Comparative models

All comparative model configurations are evaluated using the conductor height at minimum ground clearance (taking into account both conductor sag and terrain change). The conductor sag is calculated based upon maximum temperature (212 degrees Fahrenheit). In order to compare the most similar scenarios, the 69-kV transmission line was modeled at an estimated average load of 150 amperes (A) for all configurations and the 345-kV transmission line was modeled at an estimated average load of 300 A.[13] Since each model is constructed assuming the minimum ground clearance anywhere along the ROW adjacent the Barker Residence, the calculated field values represent the maximum levels that would be expected to occur anywhere on the property for the given loading. The minimum ground clearances for each of the configurations are described in Table 1 and shown for reference in Figure 5

[13] Average loading was provided by EKPC as representative of annual average loading expected for these two transmission lines.

Table 1. Transmission line configuration and model inputs

Parameter	69-kV Configuration (Average)	As-Built Configuration - 69-kV and 345-kV (Average)	Original Design Configuration - 69-kV and 345-kV (Average)	Comparison to Measurements Barker Driveway[a]	Comparison to Measurements Barker Garage[a]	Comparison to Measurements Mountain Parkway[a]
Voltage (kV)	69	69/345	69/345	69/345	69/345	69/345
Loading (A)	150	150/300	150/300	54/104	62/111	68/178
Structure type	H-Frame	Dual-Circuit H-Frame	Dual-Circuit H-Frame	Dual-Circuit H-Frame	Dual-Circuit H-Frame	Dual-Circuit H-Frame
Structure distance to west ROW edge (feet)[b]	50	75	75	75	75	75
Conductor Height (feet)	38.49	33.68 49.85	41.85 58.64	44.2[c] 61.8[c]	54.6[c] 72.2[c]	37.3[c] 55.0[c]
Horizontal Phase Spacing (feet)	10.5	19.5/23.5 27.0	19.5/23.5 27.0	19.5/23.5 27.0	19.5/23.5 27.0	19.5/23.5 27.0
Phase Arrangement	A-B-C	A-B-C C-B-A	A-B-C C-B-A	A-B-C C-B-A	A-B-C C-B-A	A-B-C C-B-A
Number and diameter of Conductors (# x inches)	1x0.563	1x1.108 2x1.196	1x1.108 2x1.196	1x1.108 2x1.196	1x1.108 2x1.196	1x1.108 2x1.196
Conductor Separation (inches)	N/A	N/A 18	N/A 18	N/A 18	N/A 18	N/A 18

[a] Loading information for the two transmission lines was recorded by EKPC at 1-minute intervals during the time measurements were taken and are incorporated into the model accounting for both active (Megawatt) and reactive (Megavolt ampere reactive) contributions to the power (not shown here). .

[b] The centerline of the 69-kV Configuration was offset by 25 feet to the west (closer to the Barker Residence) than the As-Built and Original Design Configurations. The 69-kV Configuration was also situated on a 100-foot wide ROW compared to a 150-foot wide ROW for the As-Built and Original Design Configurations.

[c] Measurement of minimum line height was performed using a SupraRule T30 Thermometer.

Analysis

The purpose of my analysis is to describe the change in levels of EMF that resulted from the upgrade and construction of the transmission lines and to put the resulting field levels in the context of national and international standards and safety limits.

EMF measurements on the ROW

On May 22, 2014, between the hours of approximately 2:00 PM and 6:30 PM, I visited the transmission line ROW and made measurements on the ROW near the driveway of the Barker Residence and by the Barker Garage. These measurement locations are indicated in Figure 5. I performed both electric-field and magnetic-field measurements along the indicated paths in accordance with the methodology described above. Magnetic field measurements were performed along a continuous line from one side of the ROW to the other, while electric-field measurements were performed at discrete locations indicated below by blue dots along the measurement path.

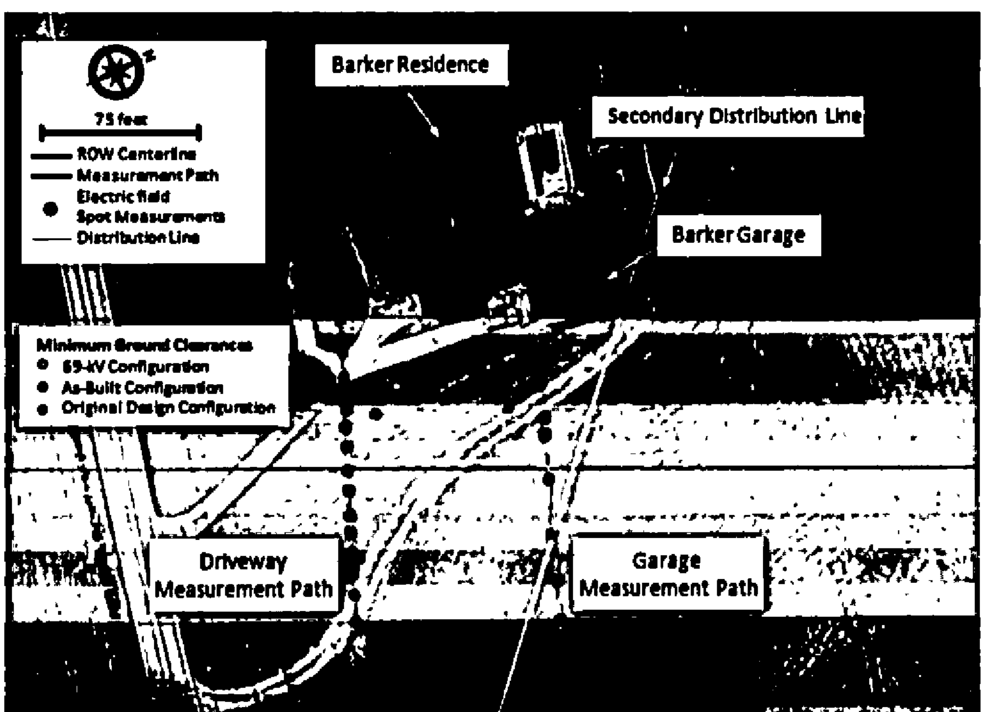

Figure 5. Aerial photograph of the Barker Residence with overlay of terrain, location of EMF measurements, and locations of minimum ground clearance for the 69-kV, As-Built, and Original Design Configurations.

Measurement results and model validation

Barker Driveway

The path along which magnetic-field levels were measured near the Barker Driveway is shown by a light blue line to the south of the Barker Residence in Figure 5. The measurements and the corresponding modeling results (calculated using parameters specified in Table 1) are shown by the blue '+' symbols and the green line, respectively, in Figure 6. The measurements are in reasonable agreement with modeling results.[14] As expected from modeling results, the highest magnetic-field level recorded occurred approximately beneath the center conductor of the 345-kV transmission line.

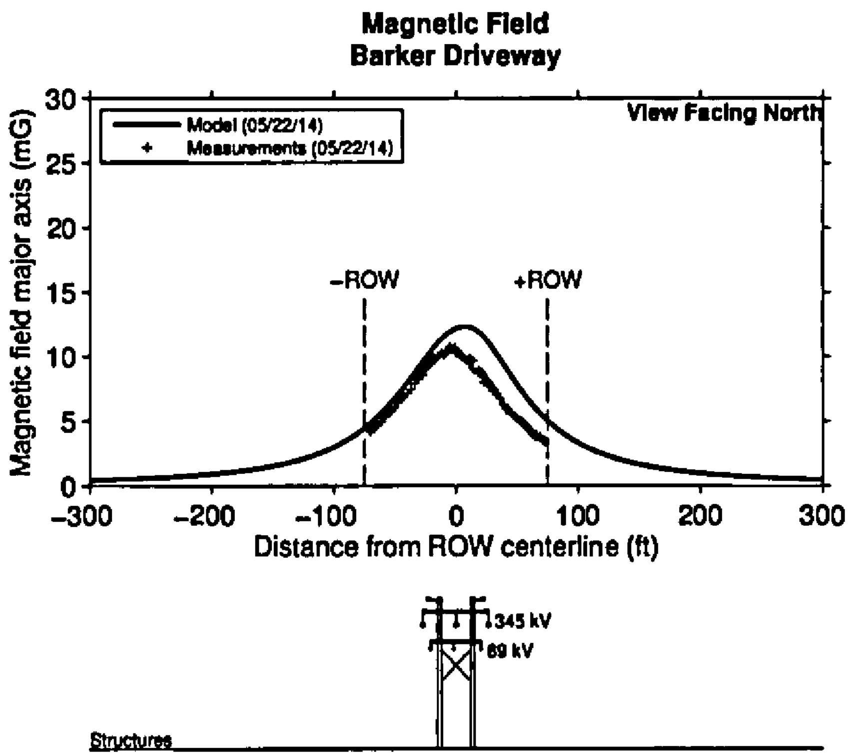

Figure 6. Comparison of magnetic-field modeling and measurement results near the Barker Driveway.

[14] It is typical for magnetic-field modeling results to be somewhat higher than measurement results, due to the assumption of infinite conductors over a flat earth, which increases field levels near the ground.

Electric-field measurements were performed along the same path as magnetic-field measurements, but at discrete locations, indicated by the blue dots in Figure 5. The data corresponding to these measurement locations is shown by the blue '+' symbols in Figure 7. Similar to the magnetic-field measurements, the agreement between measured and modeled results is good, particularly away from conducting objects.[15] As expected from modeling results, the highest electric-field level recorded occurred on the ROW just beyond the outside conductors of the 345-kV transmission line.

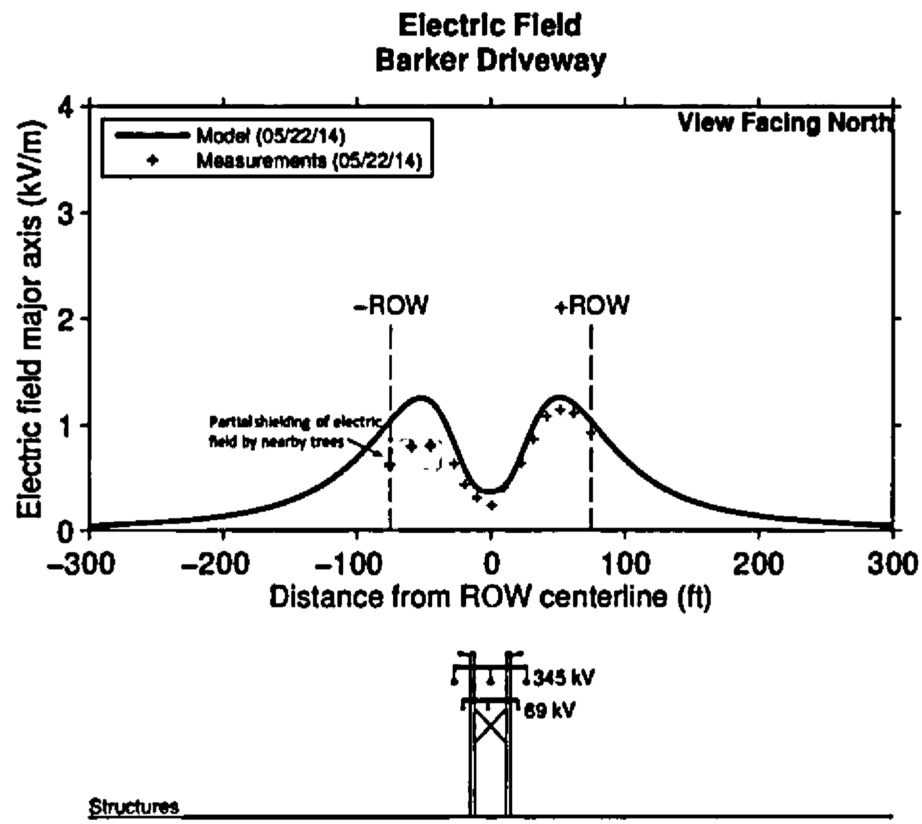

Figure 7. Comparison of electric-field modeling and measurement results near the Barker Driveway

Barker Garage

The path along which magnetic-field levels were measured near the Barker Garage is shown by a second light blue line, starting at the southeast comer of the garage, as shown in Figure 5. The

[15] Electric-field measurements near the west ROW edge were likely partially shielded by nearby trees in those locations. This effect, known as "shadowing" is characteristic of the influence any conductive object (including trees, walls, fences, cars, and even people) can have on an electric field. Further from the influence of these conductive objects, both the magnitude and general shape of measurements matches quite well with modeled results.

measurements and the corresponding modeling results (calculated using parameters specified in Table 1) are shown by the blue '+' symbols and green line, respectively, in Figure 8. Once again, the measurement and modeling results are in good agreement. The terrain drops off sharply to the east of the dirt road shown in Figure 5, and a corresponding decrease in measured magnetic-field levels was expected at these locations. At a distance of approximately 50 feet to the east of the ROW centerline, however, there is a slight increase in the magnetic-field level. This increased magnetic-field level corresponds to the location of the overhead secondary distribution line (shown as the yellow line in Figure 5) bringing electricity to the Barker Residence and is not associated with either the 69-kV or 345-kV transmission line.[16] The effect of the magnetic fields from the distribution line masks the reduction in magnetic-field levels, which would otherwise be expected. As expected from modeling results, the highest magnetic-field level recorded occurred approximately beneath the center conductor of the 345-kV transmission line.

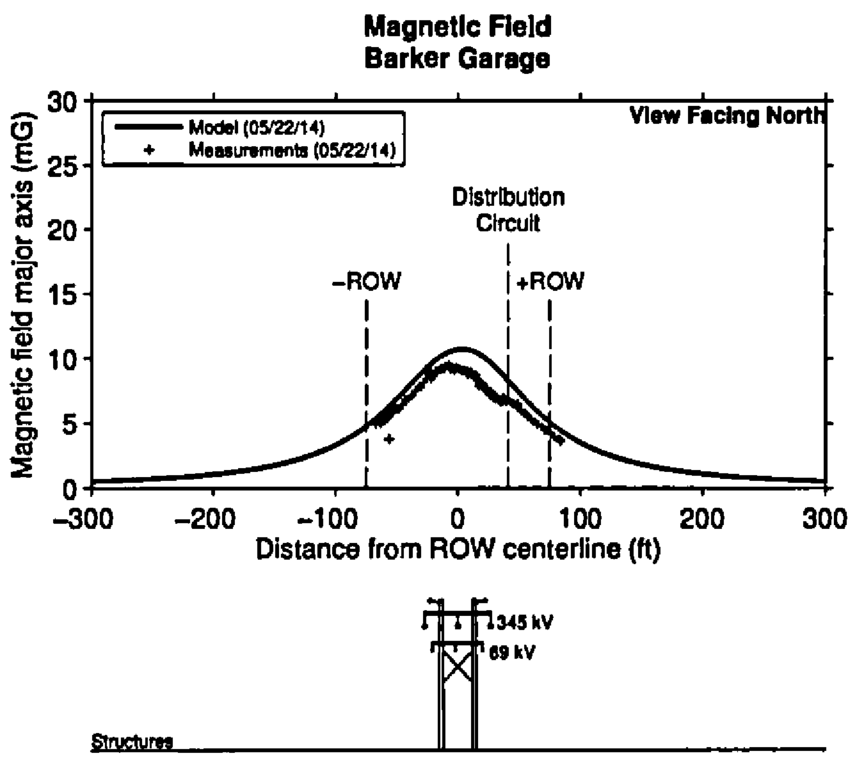

Figure 8. Comparison of magnetic-field modeling and measurement results near the Barker Garage.

[16] As will be shown in subsequent sections the magnetic-field from this distribution line was also likely measured by Mr. Pfeiffer, and interpreted incorrectly to be due to the transmission lines.

Electric-field measurements were performed along the same path as magnetic-field measurements, but at discrete locations, indicated by the blue dots in Figure 5. The data corresponding to these measurement locations is shown by the blue '+' symbols in Figure 9. Similar to the magnetic-field measurements, away from conducting objects the agreement between measured and modeled results is good.[17,18] The increased ground clearance at this location also reduces electric-field levels compared to the Barker Driveway profile. As expected from modeling results, the highest recorded electric-field level occurred just beyond the outside conductor of the 345-kV transmission line.

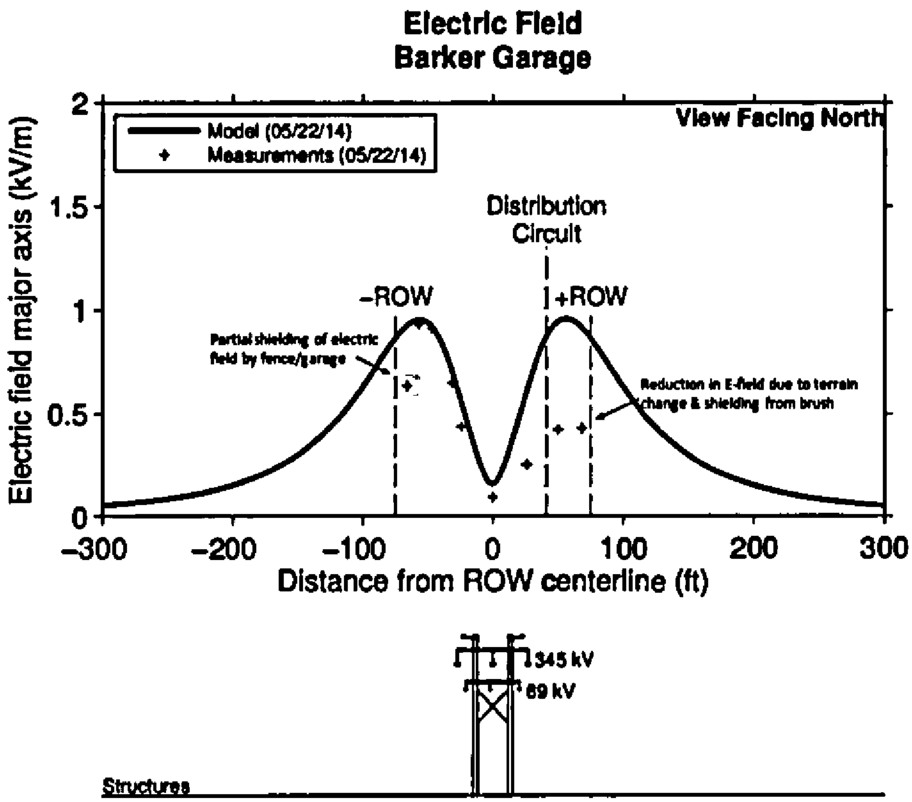

Figure 9. Comparison of electric-field modeling and measurement results near the Barker Garage.

[17] Electric-field measurements near the east ROW edge were likely reduced both due to a decrease in terrain height at these locations and also some 'shadowing' from the very tall brush in these locations. Away from the influence of these conductive objects and terrain changes, both the magnitude and general shape of measurements matches quite well with modeled results.

[18] There is no observable effect of the distribution circuit in the electric-field measurement. This is expected due to the much lower voltage of the distribution circuit relative to either overhead transmission line.

Mountain Parkway

As described briefly above, the verification of the model using measurements of EMF near the Barker Residence involves some differences in the measured configuration compared to the 'idealized' model. These differences are primarily based upon the terrain changes, conducting objects, and additional sources of magnetic fields in the vicinity of the Barker Residence, which result in deviations from the 'standard' magnetic-field level models, but nonetheless are readily explainable through application of sound engineering principles. The best location for performing EMF measurements is over flat ground, perpendicular beneath the midspan sag of an overhead transmission line, as this configuration most closely matches the idealized assumptions of the model. Since no such location was readily accessible at the Barker Residence, I performed measurements at an additional location approximately 2.5 miles to the southeast of the Barker Residence, along Mountain Parkway as shown in Figure 10.

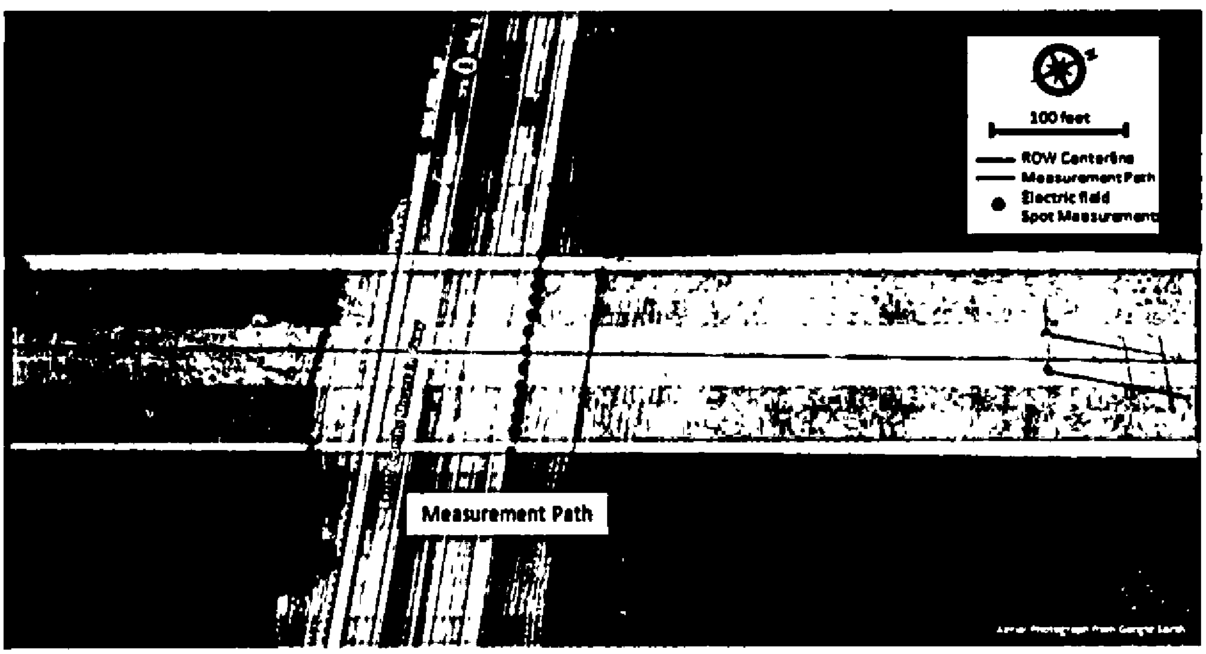

Figure 10. Aerial photograph with overlay of terrain and location of EMF measurements taken at Mountain Parkway.

The path along which both electric- and magnetic-field levels were measured is shown along the shoulder of Mountain Parkway by a light blue line, starting west of the transmission line ROW and proceeding east. The measurements and the corresponding modeling results (calculated using parameters specified in Table 1) are shown by the blue '+' symbols and green line, respectively, in Figure 11. The modeling at this location matches more precisely than in previous measurement cases, due to the relatively flat road beneath the midspan of the transmission line conductors. Small overestimates in the magnetic-field level near the center of the ROW are once again expected due to the sag of the conductors (i.e., conductors are not infinite in extent as assumed by the model). Magnetic-field levels at this location are higher than in either measurement location at the Barker Residence due to 1) higher loading of the 345-kV transmission line at the time of this measurement and 2) lower conductor ground clearance at this location.

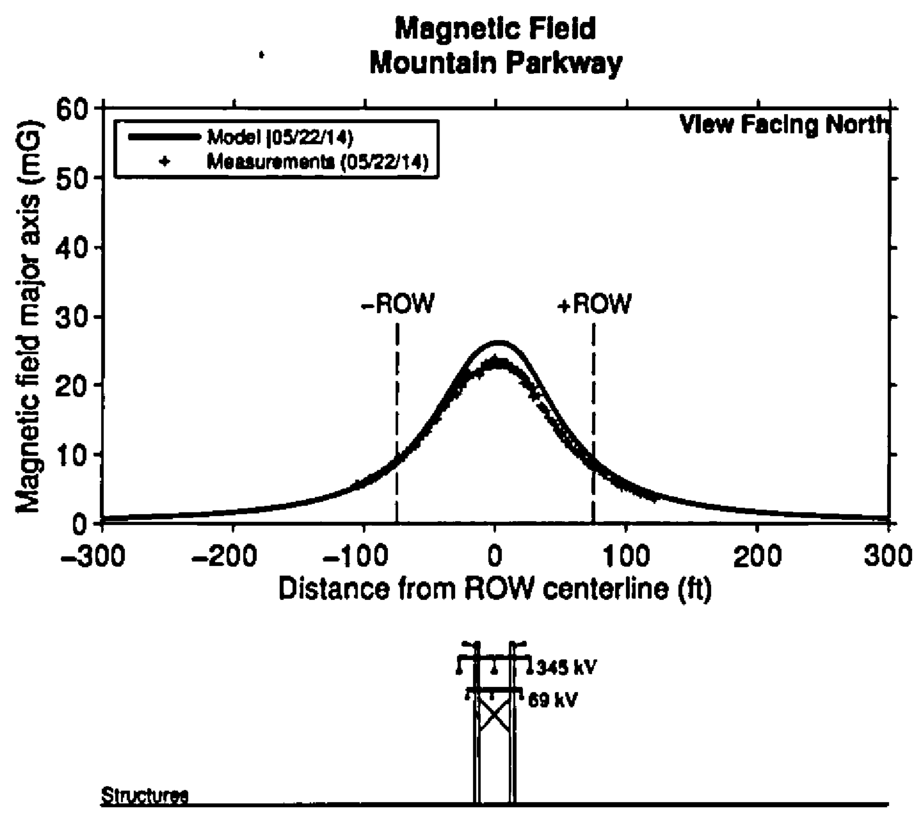

Figure 11. Comparison of magnetic-field modeling and measurement results along Mountain Parkway.

Electric-field measurements were performed along the same path as magnetic-field measurements, but at discrete locations, indicated by the blue dots in Figure 10. The data corresponding to these measurement locations are shown by the blue '+' symbols in Figure 12.

As in the case of the magnetic-field measurements, the lack of terrain changes and the absence of any nearby conducting objects (that would otherwise alter the local electric field) resulted in very good agreement between modeled and measured electric-field levels.

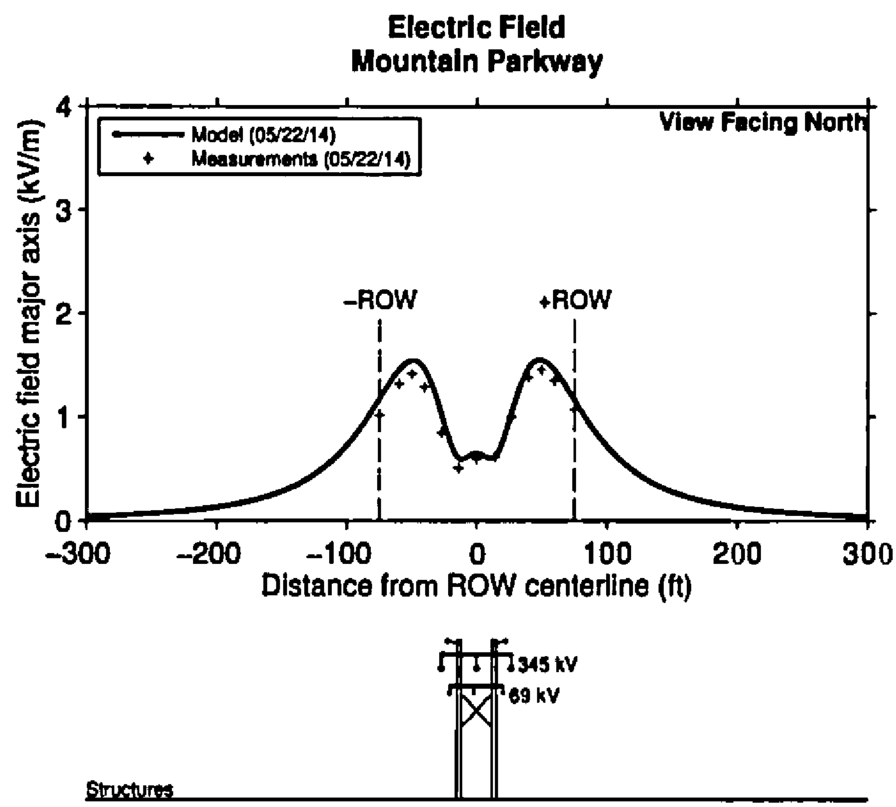

Figure 12. Comparison of electric-field modeling and measurement results along Mountain Parkway.

Modeling Results

Having verified the accuracy of the model, I then modeled the EMF associated with the 69-kV Configuration, the As-Built Configuration, and the Original Design Configuration. All configurations are evaluated using the conductor height at minimum ground clearance (taking into account both conductor sag and terrain change). The conductor sag is calculated based upon maximum temperature (212 degrees Fahrenheit). In order to compare the most similar scenarios, the 69-kV Configuration was modeled at an estimated average load of 150 A for all configurations and the 345-kV transmission line was modeled at an estimated average load of 300 A.

- 69-kV Configuration: The 69-kV design centered on a 100-foot ROW. The location of minimum ground clearance along the transmission line span passing by the Barker Residence was approximately 21 feet south of the original structure Y-102 as shown in Figure 5.

- As-Built Configuration: The as-built 69-kV and 345-kV double-circuit structures are centered on a 150-foot ROW, whose centerline is 25 feet further east from the original 69-kV Configuration ROW. The location of minimum ground clearance (shown in Figure 5) along the transmission line span passing by the Barker Residence is 430 feet south of existing structure UT-80.[19]

- Original Design Configuration: In the original design, the 69-kV and 345-kV double-circuit structures were centered on the same 150-foot wide ROW as the As-Built Configuration. The location of minimum ground clearance along the transmission line span passing by the Barker Residence would have been approximately 68 feet north of proposed structure UT-79 as shown in Figure 5.

The magnetic-field and electric-field results for all three modeled configurations are shown in Figure 13 and Figure 14, respectively. These figures are presented to show a direct comparison of the resulting EMF for these three configurations using similar assumptions.

As shown in Figure 13, the mutual cancellation of magnetic fields from the two transmission lines in the As-Built and Original Proposed Configurations result in magnetic-field levels that are only somewhat higher than the magnetic-field levels from the 69-kV Configuration, particularly on the west portion of the ROW nearest the Barker Residence. The largest change in magnetic-field levels is near the ROW centerline where the magnetic-field levels in the As-Built Configuration are approximately 60% higher than those in the 69-kV Configuration. As can be seen, however, if the Original Proposed Design had been constructed, it would have resulted in a maximum magnetic-field level increase of only approximately 4%. At the western (-) ROW edge, the differences among all configurations are less because the field levels

[19] Structure UT-79 was removed at the request of the Barkers; the location of minimum ground clearance for the As-built Configuration is within approximately 10 feet of the minimum ground clearance location for the 69-kV Configuration.

decrease rapidly with distance from the transmission line.[20,21] In particular, at a distance of 125 feet from the ROW centerline (the approximate center of the Barker Residence) the magnetic-field levels for the 69-kV, As-Built, and Original Proposed Configurations are 1.6 mG, 3.3 mG, and 3.1 mG, respectively. At all locations, magnetic-field levels are far below international standards for exposure to 60-Hz magnetic fields as discussed in greater detail in the Discussion section.

[20] Magnetic-field levels for all three configurations would be expected to vary with changes in load demand. Differences among the different configurations, however, would be expected to be similar to that described here, assuming similar changes in loading. Additional calculations (not shown) indicate that even under operation at a winter conductor thermal rating, magnetic-field levels are far below international exposure standards.

[21] There would be no corresponding increase in magnetic-field levels due to increased conductor sag at higher loading as the maximum sag (i.e., minimum ground clearance for 212 degrees Fahrenheit) is already included in these models.

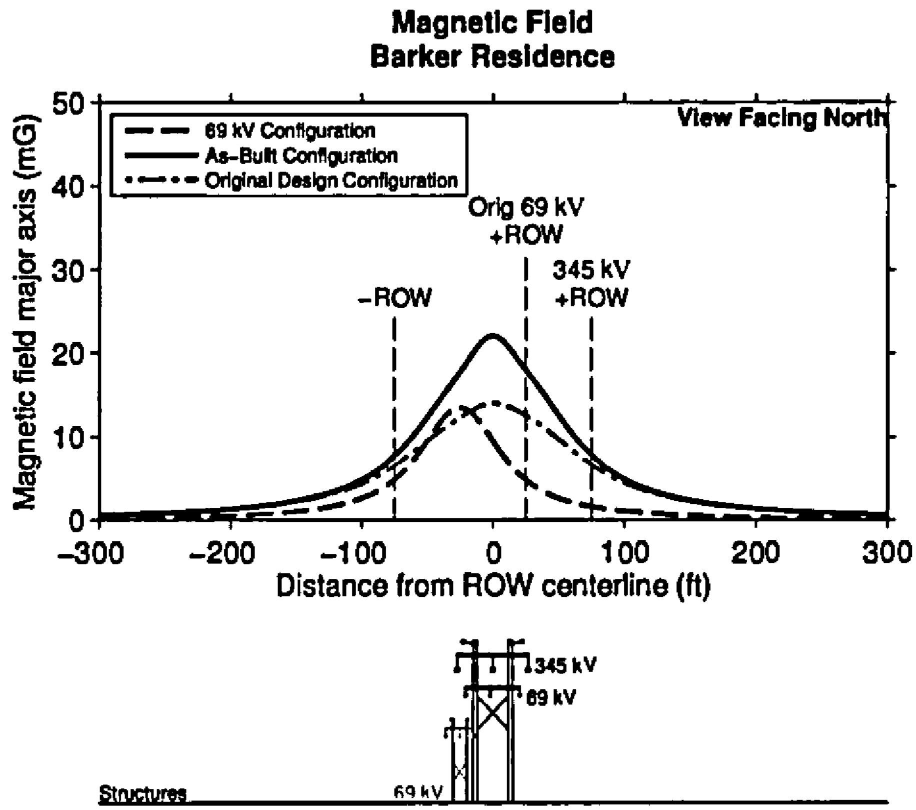

Figure 13. Comparison of the magnetic-field levels from the 69-kV Configuration, the As-Built Configuration, and the Original Design Configuration.

A similar comparison of the electric-field levels associated with the three modeled configurations is shown in Figure 14. As expected, the electric-field level at all locations on the ROW is increased in the As-Built and Original Proposed Design Configurations relative to the 69-kV Configuration. Electric-field levels remain at relatively low levels, however, with the maximum electric-field level for the As-Built and Original Proposed Design Configurations of only 1.8 kV/m and 1.4 kV/m, respectively (compared to 0.3 kV/m for the 69-kV Configuration).[22] These electric-field levels are representative of the highest that are expected to occur anywhere on the ROW adjacent the Barker Residence, regardless of future changes in loading. This is because electric-field levels have already been calculated at minimum ground clearance and would be less for any loading scenario in which conductor sag is reduced, either through decreased sag associated with decreased loading or through increased distance from the

[22] At the ROW edge, the electric field levels are lower; 1.3 kV/m, 1.1 kV/m, and 0.2 kV/m for the As-Built, Original Proposed Design, and 69-kV Configurations, respectively.

conductors as one moves away from the location of minimum ground clearance. In all locations, including the location on the ROW where electric-field levels are highest, the electric-field levels are far below those of international standards for exposure to 60-Hz electric fields, as discussed in greater detail in the Discussion section.

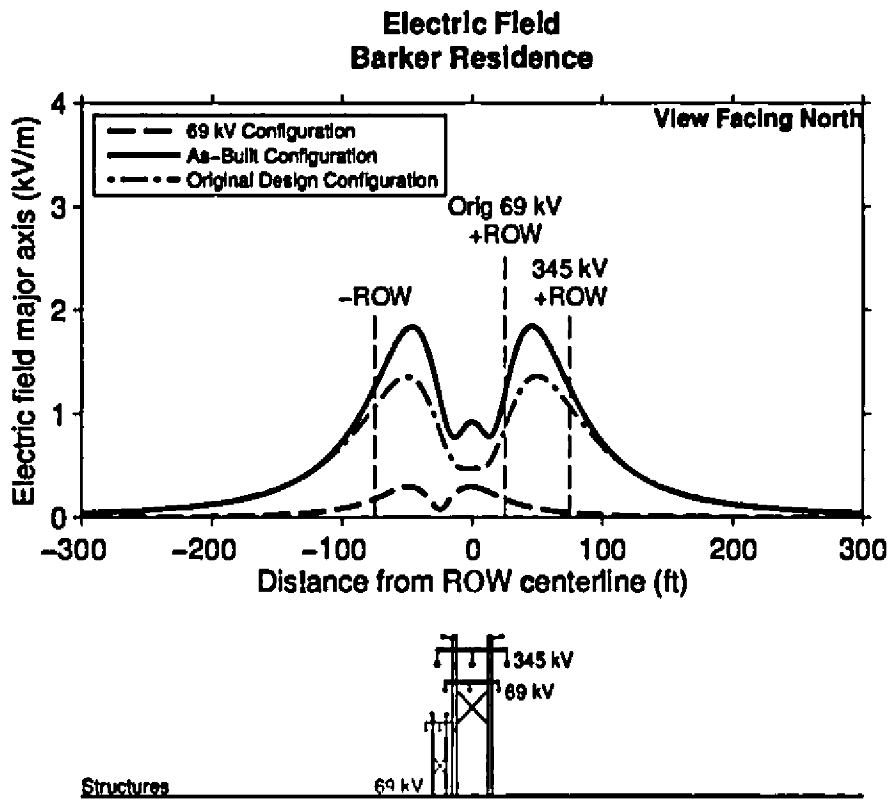

Figure 14. Comparison of the electric-field levels from the 69-kV Configuration, the As-Built Configuration, and the Original Proposed Design.

Discussion

Relevant standards

Health-based EMF standards

There are no federal health-based EMF standards in the United States, nor has the state of Kentucky enacted standards or guidelines for 60-Hz EMF that result from any part of the electrical power system—including generating stations, substations, transmission lines, and distribution lines. While some states, such as Florida[23] and New York,[24] have statutes or guidelines that apply to fields produced by new transmission lines, these are not health-based guidelines. These statutes were enacted to limit fields from new transmission lines to levels produced by existing transmission lines to maintain the *status quo*.

Exposure limits recommended by scientific organizations are more relevant than the various state-enacted guidelines. These exposure limits are based on evaluations of relevant health research and extensive weight-of-evidence reviews of that research, such as the limits developed the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and ICES.[25]

The guidelines limiting exposure to very high levels of EMF based on the avoidance of established acute effects developed by ICNIRP and ICES are provided in Table 2, which summarizes the reference levels established for the general public at which or below which exposure is ensured to not exceed limits on electric fields in the body.

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23 Florida Department of Environmental Regulation (FDER). Electric and Magnetic fields. Chapter 17-274. Department of Environmental Regulation Rules, March, 1989; Florida Department of Environmental Protection (FDEP). Chapter 62-814 Electric and Magnetic Fields, 1996.

24 New York Public Service Commission (NYPSC). Opinion No. 78-13. Opinion and Order Determining Health and Safety Issues, Imposing Operating Conditions, and Authorizing, in Case 26529, Operation Pursuant to Those Conditions. Issued June 19, 1978; New York Public Service Commission (NYPSC). Statement of Interim Policy on Magnetic Fields of Major Transmission Facilities. Cases 26529 and 26559 Proceeding on Motion of the Commission. Issued and Effective: September 11, 1990.

25 International Committee on Electromagnetic Safety (ICES). IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields 0 to 3 kHz (Std. C95.6-2002). Piscataway, NJ: IEEE, 2002; International Commission on Non-ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Phys 99: 818-836, 2010.

Table 2. Reference levels for whole body exposure to 60-Hz fields: general public

Organization	Magnetic Fields	Electric Fields
ICNIRP	2,000 mG	4.2 kV/m
ICES	9,040 mG	5 kV/m 10 kV/m*

*This is an exception within transmission line ROWs because people do not spend a substantial amount of time in ROWs, and very specific conditions are needed before a response is likely to occur (i.e., a person must be well insulated from ground and must contact a grounded conductor) (ICES, 2002, p. 27).

As part of its ongoing EMF Program, the World Health Organization recommends that governments adopt ICNIRP's guidelines for short-term exposure to ELF EMF in both occupational settings and for the general public.[26]

Implantable medical device standards

Manufacturers of implantable medical devices such as pacemakers and ICDs typically follow national and international standards that set electromagnetic compatibility requirements for such devices. As discussed by Dr. Mezei in his report in this matter, one of the more recent standards (EN 50527-1, 2010) "has determined that these devices are expected to function without interference below the reference values of 5 kV/m and 100 μT (1,000 mG) for ELF electric fields and magnetic fields, respectively, based on European Council Recommendation 1999/519/EC. The European Standards document also states that "*[f]or higher fields the voltage can cause electromagnetic interference effects but often this is not clinically significant ... and transient exposure can be permitted*" (EN 50527-1, 2010)."[27]

[26] World Health Organization (WHO). Environmental Health Criteria 238: Extremely Low Frequency (ELF) Fields. Geneva, Switzerland: World Health Organization, 2007.

[27] Report of Gabor Mezei, M.D., Ph.D., Barker v. East Kentucky Power Matter. Exponent, Inc., May 30, 2014, p. 27. The standard referenced by Dr. Mezei is: European Committee for Electrotechnical Standardization (CENELEC). Procedure for the Assessment of the Exposure to Electromagnetic Fields of Workers Bearing Active Implantable Medical Devices – Part 1 – General. EN 50527-1. Brussels: Cenelec, 2010.

Standards for electrostatic induction

At a fundamental level, electrostatic induction is the redistribution of charges in an electrically-neutral object due to the presence of an electric field. Electrostatic induction may occur in the vicinity of transmission lines, and under specific conditions it can result in nuisance shocks.

In his report, Mr. Pfeiffer includes information regarding measurements of induced voltages on a Dodge pickup truck at the Barker Residence.[28] In particular, as reported by Mr. Pfeiffer, the Barkers have measured voltages of 250 V and as high as 330 V between the wheel lug of the vehicle and ground.

Such induced voltages are a well-understood phenomenon. These voltages come about because the electric fields from the transmission lines couple to objects, driving current in those objects. These currents, in tum, give rise to an induced voltage that can be measured, as in the case at the Barker Residence. The Electric Power Research Institute (EPRI) has published documents demonstrating how to calculate the voltage induced on objects, including vehicles. They show that voltages on the order of a few hundred volts are relatively common and correspond to an induced current of a few tenths of a milliampere.

I have carried out my own calculations, taking into account the measured electric fields from the transmission lines and the approximate geometry of the Barker's pickup truck. The results of my calculations are documented in Appendix B of this report, and show that voltages up to 439 V may be induced for measured electric fields of 1 kV/m. I have verified that this corresponds to an induced current of 0.16 mA. This value can be compared to the 5 mA limit imposed by the National Electrical Safety Code (NESC) for AC transmission lines:

> For voltages exceeding 98 kV ac to ground, either the clearances shall be increased or the electric field or the effects thereof shall be reduced by other means, as required, to limit the steady-state current due to electrostatic effects to 5 mA, rms, if the largest anticipated truck, vehicle, or equipment under the line were short-circuited to ground. The size of the anticipated truck, vehicle, or equipment used to determine these clearances may be less than but need not be greater than that limited by federal, state,

[28] Investigation report for Mr. & Mrs. Barker, prepared by John C. Pfeiffer. Pfeiffer Engineering Co., Inc., April 24, 2014, p. 65.

> or local regulations governing the area under the line. For this determination, the conductors shall be at a final unloaded sag at 120 °F (50 °C).[29]

For comparison, I also calculated the induced current and voltage for the largest anticipated truck as referenced by NESC above. This corresponds to a regulation-sized truck as defined by the American Trucking Association.[30] The state of Kentucky also defines maximum allowed dimensions for vehicles (though not trucks specifically) that are comparable.[31] I found that for vertical electric field strength of 1 kV/m, the induced current was approximately 0.52 mA, approximately 10% of the NESC limit. This is larger than for the Dodge pickup by a substantial margin since the latter has less surface area to interact with the electric field. I also calculated an induced voltage of approximately 1,540 V.[32]

In order to evaluate the potential effect of these short-circuit currents (i.e., if one were to touch a vehicle parked underneath an EMF source), I compared my calculated values to the Occupational Safety and Health Administration's (OSHA) guidelines.[33] OSHA states that one of the primary factors that affects the severity of a shock is the amount of current flowing through the body. In particular, a current level of about 1 mA correspond to human perception levels, and a slight tingling sensation may be felt as a result.[34] If the resistance of the human body changes (e.g., due to wet skin), the maximum amount of current that can flow still corresponds to the calculated value (e.g., 0.16 mA for the case of the pickup). These levels are significantly lower than the threshold level for sensation.[35]

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[29] National Electrical Safety Code, Section 1, Subsection 013.C.1.c.

[30] EPRI Transmission Line Reference Book, p. 357.

[31] See also state of Kentucky motor vehicle dimension limits that provide similar dimensions (though not identical) to EPRI at http://www.lrc.state.ky.us/kar/603/005/070.htm.

[32] While this voltage may at first appear to be quite high it is important to note that it is the current level, not the voltage, which determines the strength of a shock. To place the magnitude of this voltage into context, the well-known phenomenon of 'carpet shocks' involve the buildup of static (DC) voltages which have been measured to be as high as 4 kV to 8 kV (EPRI Transmission Line Reference Book, p. 373.).

[33] https://www.osha.gov/SLTC/etools/construction/electrical_incidents/eleccurrent.html

[34] For current induced by electrostatic induction associated with transmission lines, the amount of current is limited and will not exceed the calculated short-circuit current under any scenario.

[35] Spark discharges may also occur as a result of electrostatic induction; however, according to EPRI, "[s]park discharges appear to be a secondary concern from a safety standpoint" while "[r]esponses to steady-state currents are used to establish safety limits" EPRI Transmission Line Reference Book, p. 373-374.

I also investigated the direct effect of the presence of electric fields on the human body. EPRI references a study where 136 persons were tested for their response to various electric-field levels as measured 1 meter above ground. Since a person's perception can vary, the result was a distribution that indicates the percentage of people likely to perceive the presence of a field, and as the field gets stronger, to feel a physiological annoyance associated with the field. For an electric field level of 1 kV/m, about 30% of the tested population was able to perceive the field, but less than 1% of the tested population felt an annoyance.[36] These percentages pertain to wet skin—for dry skin the percentage of the tested population that felt an effect is even lower, with less than 10% of the tested population able to perceive the field's presence.

Summary of calculated EMF

The calculated levels of both electric and magnetic fields are summarized in Table 3 for all three modeled configurations at average loading. Results of the highest electric- and magnetic-field levels are presented as well as field levels at the ROW edge and at a distance of 50 feet to either side of the ROW edge (i.e., 125 feet from the centerline).

As shown in Table 3, the electric- and magnetic-field levels in all configurations are far below health-based standards published by international organizations and recommendations by the World Health Organization. Field levels are also well within compliance with the NESC for induced currents and electrostatic induction as demonstrated above.[37]

[36] EPRI Transmission Line Reference Book, p. 374 and Figure 8.10.16.

[37] Though not explicitly presented here, both electric-field and magnetic-field levels from the transmission lines are below national and international limits for various other operational scenarios such as operation of the 69-kV line at 138-kV; operation of both lines at a winter thermal conductor rating; operation of the 69-kV line alone at a winter thermal conductor rating, and operation of the 345-kV line alone at a winter thermal conductor rating. These scenarios include the highest EMF levels that could conceivable be associated with the transmission lines as currently built but will occur only rarely in practice if ever.

Table 3. Calculated electric and magnetic-field values for average loading conditions and minimum ground clearance

		Location				
Configuration	Field	-125 feet from centerline	- ROW edge (-75 feet)	Max on ROW	+ROW edge (+75 feet)	-125 feet from centerline
69-kV*	Magnetic (mG)	1.6	4.9	13	1.6	0.8
	Electric (kV/m)	0.0	0.2	0.3	0.0	0.0
As-Built	Magnetic (mG)	3.3	7.7	22	7.8	3.3
	Electric (kV/m)	0.4	1.3	1.8	1.3	0.4
Original Design	Magnetic (mG)	3.1	6.5	14	6.7	3.1
	Electric (kV/m)	0.4	1.1	1.4	1.1	0.4

*The ROW width in the 69-kV Configuration was only 100-feet wide situated such that the west (-) ROW edge remains in the same location for all three configurations. The east (+) ROW edge for the 69-kV Configuration was technically a distance of only +25 feet from the As-Built Configuration centerline. Results in this table are presented at the same locations (as indicated) for all configurations for consistency even though values on the 69-kV Configuration +ROW edge would be higher than reported here.

Evaluation of the Testimony of Mr. Pfeiffer

In my review of the facts associated with this case and my associated modeling and measurements, I have also been asked to provide an evaluation of the testimony of John C. Pfeiffer, P.E., dated April 24, 2014, and submitted in the *Barkers v East Kentucky Power Cooperative, Inc.* matter.

Inaccurate calculations of ROW width (Section 5)

In Section 5 of his report (pp. 40-41), Mr. Pfeiffer states that the minimum width of the ROW allotted by EKPC was insufficient, and he attempts to demonstrate this conclusion with established equations for the recommended horizontal clearances of conductors.[38] From these equations and assumptions for certain parameters, such as the conductor final sag, Mr. Pfeiffer calculated that the minimum width of the ROW should be at least 166 feet.

The equation Mr. Pfeiffer used in this calculation is repeated below

$$W = A + 2(\ell_i + S_f)\sin\phi + 2\delta + 2x$$

As shown in this equation, Mr. Pfeiffer needed to determine the sine of the conductor sway angle (ϕ), which Mr. Pfeiffer assumed to be 20°. Mr. Pfeiffer, however, erroneously calculated the sine of the sway angle in radians rather than in degrees; thus resulting in a substantial overestimation of the minimum width of the ROW.[39,40] Using the accurate value for the sine of the sway angle in the equation reveals an effective minimum width of the ROW of about 110 feet. Therefore, the width of 150 feet set by EKPC for the transmission line is well above the effective minimum width recommended.

[38] U.S. Department of Agriculture (USDA). Design Manual For High Voltage Transmission Lines, Bulletin 1724e-200. USDA, Rural Utilities Service Electric Staff Division, 2009 (rev.).

[39] sin(20°) = 0.3420, while sin(20 rad) = 0.9129.

[40] Other mathematical errors and missing or incorrect assumptions were also noted but their effects are less and are not detailed here

Incorrect measurements of distances from the property to the transmission line (Section 5)

The reported distances from the transmission line conductors to the residence presented in Mr. Pfeiffer's report were sufficiently different from design specifications that I undertook a similar task to check the accuracy of the reported values. I investigated the distances between the transmission line and the same points on the property using Google Earth, similar to the investigation undertaken by Mr. Pfeiffer, as presented in his report. Figure 15 shows a sketch of the Barker Residence relative to transmission and distribution lines in the vicinity.

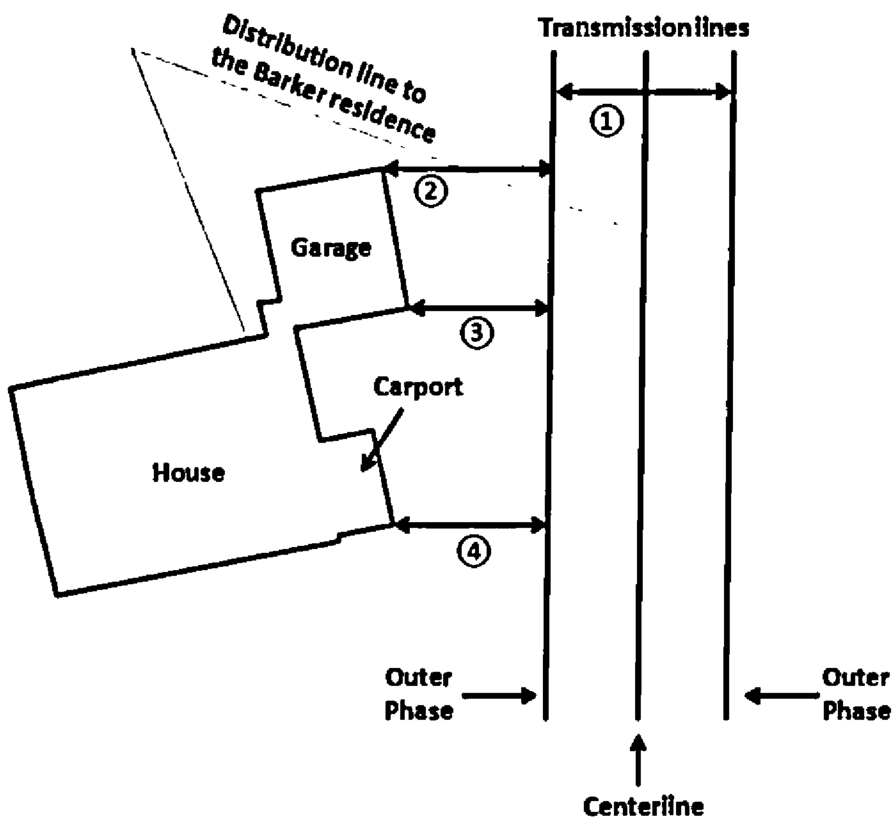

Figure 15. Sketch of the Barker Residence relative to distribution and transmission lines, showing various distances measured.

The measurements are shown in Table 4, along with Mr. Pfeiffer's measurements, and measurements from the land survey conducted by EKPC using LIDAR.[41]

Table 4. Comparison of the measured distances from the designated locations on the Barker's property to the transmission lines

	Calculated Measurements (feet)		
Measured location	**PECI - Google Earth**	**Exponent - Google Earth**	**EKPC LIDAR Survey**
Outside conductor to outside conductor	54	54	-
Northeast corner of the garage to outside conductor	34	46	-
Southeast corner of the garage to outside conductor	31	39	42[a]
Southeast corner of the house to outside conductor	47	55	-
Southeast corner of the garage to the center conductor	58[b]	65	69
Southeast corner of the carport to the center conductor	-	68	72

[a] Calculated by subtracting the outer conductor design width from the LIDAR-measured value (69-27=42)
[b] Calculated by adding the outer conductor design width to PECI-measured value (31+27=58)

Figure 16 shows that my measurement of the distance from conductor A to conductor C is 54 feet, which is the same as Mr. Pfeiffer's measurement as well as the distance indicated in the transmission line design drawings. Figure 17 shows that Exponent's measurement of the distance from the northeast corner of the garage to conductor A is about 12 feet greater than Mr. Pfeiffer's reported measurement, while Figure 18 and Figure 19, which show measurements from the southeast corner of the garage to conductor A, and from the corner of the house to conductor A, respectively, are both about 8 feet greater than Mr. Pfeiffer's measurements. The EKPC LIDAR measurements from both the southeast corner of the garage and the southeast corner of the carport are about 4 feet greater than my measured distances, indicating that the distances from Google Earth are sufficiently similar to design specifications so as to determine that the transmission line was, indeed, constructed in accordance with those specifications and with sufficient horizontal clearances from the residence. Given the relative ease with which I was able to demonstrate a reasonable match between Google Earth measurements and the design specifications of the transmission line, it is difficult to understand the significant

[41] LIDAR is similar to radar, but uses light waves rather than radiofrequency waves.

differences in Mr. Pfeiffer's estimates of the various distances, which are 12 to 20 feet less than the design values.

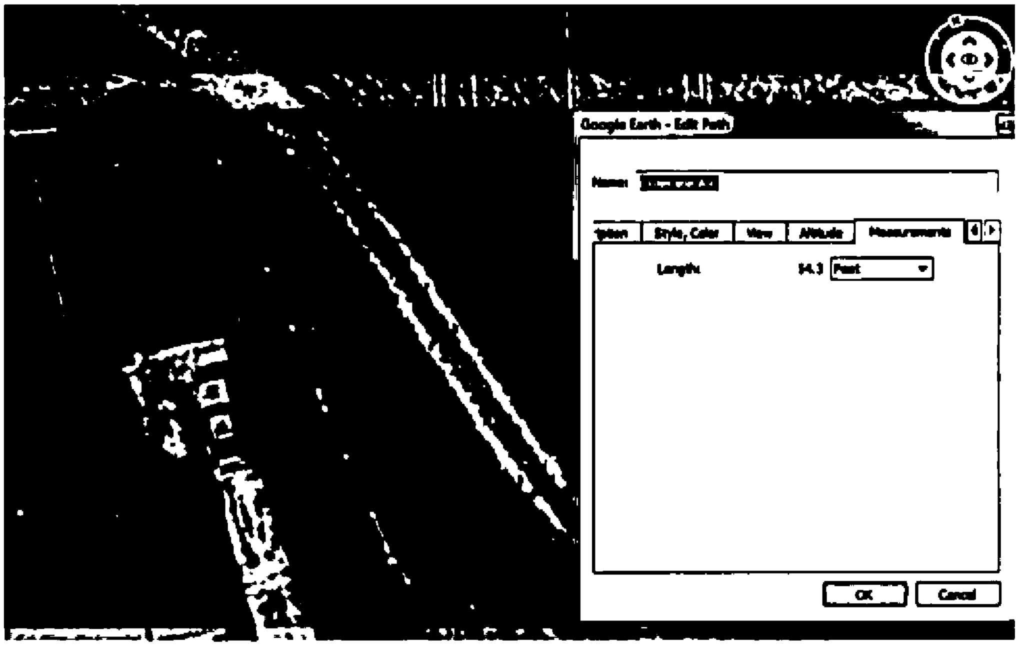

Figure 16. Exponent's Google Earth measured distance of outside conductor to outside conductor.

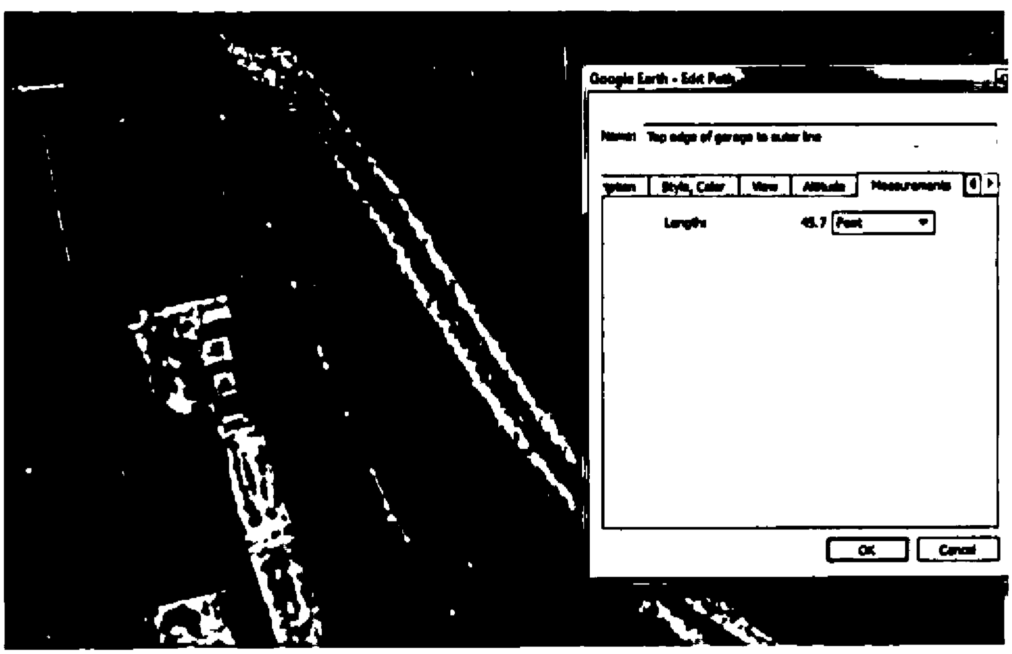

Figure 17. Exponent's Google Earth measured distance from the northeast corner of the garage to outside conductor.

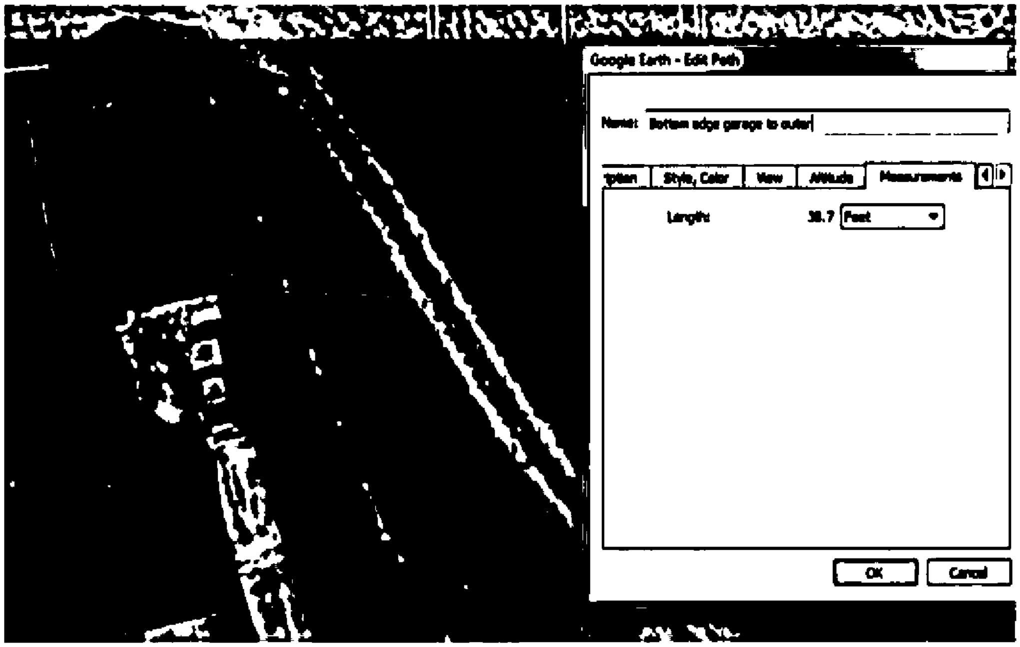

Figure 18. Exponent's Google Earth measured distance from the southeast corner of the garage to outside conductor.

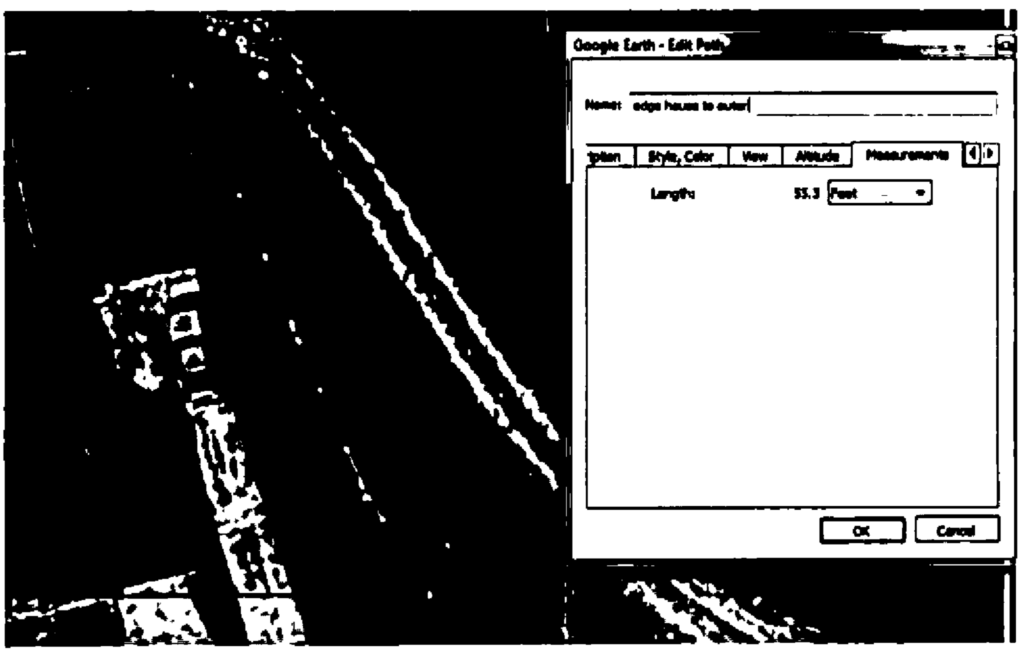

Figure 19. Exponent's Google Earth measured distance from the corner of the house to outside conductor.

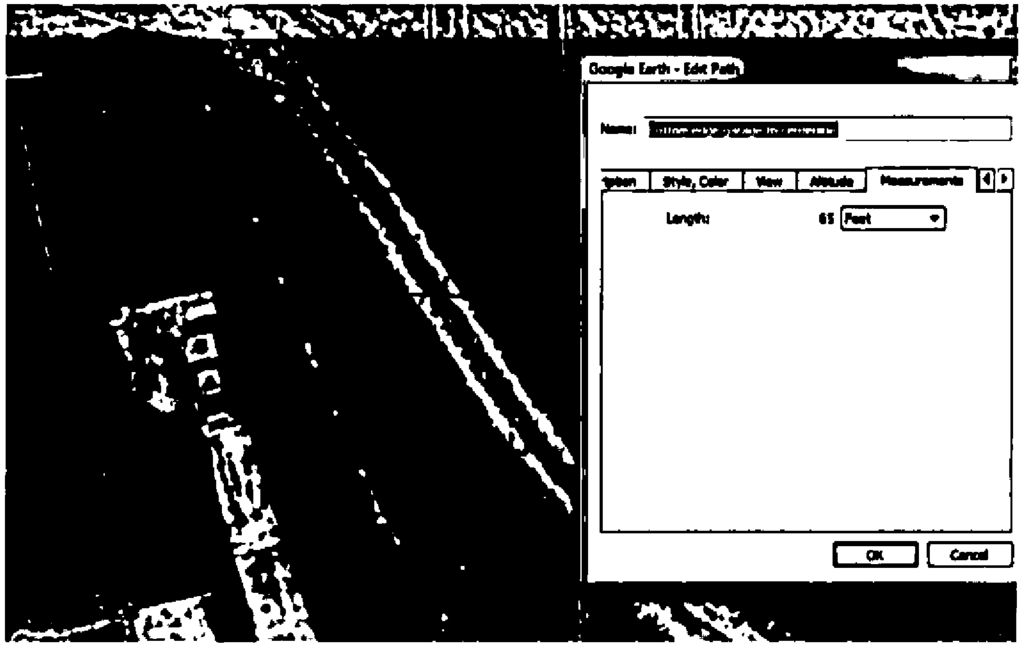

Figure 20. Exponent's Google Earth measured distance from the southeast corner of the garage to the center conductor.

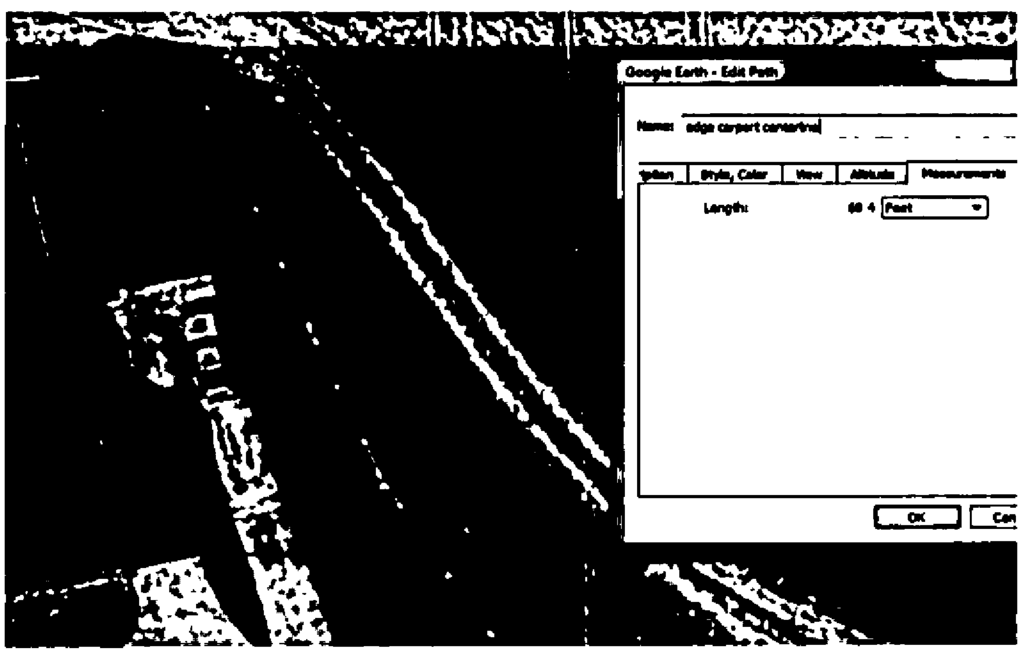

Figure 21. Exponent's Google Earth measured distance from the southeast corner of the carport to the center conductor.

Copying of various sources for background of EMF and associated health effects (Section 6)

In Section 6 of his report, titled "Medical Concerns," Mr. Pfeiffer provides information on the characteristics of EMF and some various effects as well as information on some of the relevant standards. The majority of the information he conveys in this section has been copied directly from a number of articles, reports, and websites. Most of the information does not include a reference or quotation marks to indicate that these are not his words or opinions, and in the sections that do include a reference, quotation marks are often missing, as summarized in Table 5. According to the *Chicago Manual of Style*, while quoting without permission is considered "fair use," the legal concept of fair use requires that the author give appropriate credit, specifically "With all reuse of others' materials, it is important to identify the original as the source. This not only bolsters the claim of fair use, but also helps avoid any accusation of plagiarism."[42] In fact, the National Grid EMF information website from which Mr. Pfeiffer has extracted a substantial amount of material states, "You must not pass the content off as your own material, and you must acknowledge the source of the Content by including an appropriate attribution statement and, where possible, provide a reference and/or link to this Website."[43]

Table 5. Pfeiffer text in Section 6 missing appropriate references

Start of Copied Text and Text Missing Quotation Marks	Actual Source	Comment
"Electric fields arise from electric charges ... "[full paragraph] (p. 48)	Health Physics Society (http://hps.org/hpspublications/articles/elf infosheet.html)	No reference or quotation marks; copied verbatim.
"Magnetic fields arise from the motion of electric charges ... " [full paragraph] (pp. 48-49)	Health Physics Society (see link above)	No reference or quotation marks; copied verbatim with very slightly modification.
"C. Induced currents" through "Effects of Induced Currents on the Body" (pp. 49-50)	National Grid's EMF Information Website (http://www.emfs.info/The+Science/highfi elds/Inducedcurrents)	Referenced in footnote 25, but copied verbatim with no quotation marks.
"E. Electric Fields" [full paragraph] (p. 54)	NIEHS Booklet - Electric and Magnetic Fields Associated with the Use of Electric Power (p. 46) (http://www.niehs.nih.gov/health/assets/d ocs_p_z/results_of_emf_research_emf_ questions_answers_booklet.pdf)	No reference or quotation marks, copied verbatim with vary slight modification.

[42] The Chicago Manual of Style, 16th Edition. Chicago: University of Chicago Press, 2010, pp. 188-190.

[43] http://www.emfs.info/legal/terms.htm

Start of Copied Text and Text Missing Quotation Marks	Actual Source	Comment
"Two organizations ... " through "... dangerous levels" (p. 55)	NIEHS Booklet (p. 47). See link above.	No reference or quotation marks, copied verbatim.
"F. Does EMF affect people with pacemakers ..." through "... or interference from EMF" (pp. 56-57)	NIEHS Booklet (pp. 47-48). See link above.	No reference or quotation marks, copied verbatim.
"G. Effects on equipment ..." [entire section] (pp. 57-58)	National Grid's EMF Information Website (http://www.emfs.info/The+Science/highfields/equipment/)	No reference or quotation marks; copied verbatim.
"H. Microshocks ..." through "J. The 2010 ICNIRP Guidelines ..." [entire sections (pp. 58-60)	National Grid's EMF Information Website (http://www.emfs.info/The+Science/highfields/Microshocks/Microshocks.htm) and (http://www.emfs.info/Related+Issues/limits/5060.htm)	Section H has a footnoted citation on the section heading, but the text is copied verbatim without quotation marks. Sections I and J are copied verbatim without a reference or quotation marks.
"K. Considerations Regarding Possible Long Term Effects ..." [entire section] (pp. 60-61)	Guidelines for limiting exposure to time-varying electric and magnetic fields (ICNIRP, 2010), p. 83 (http://www.icnirp.de/documents/LFgdl.pdf)	This section is referenced in the section heading; however, the text is copied verbatim from the Health Physics Journal article with no quotations.
"L. Cardiac Pacemakers ..." [entire section] (p. 61)	CapX2000 Factsheet (www.capx2020.com)	This is referenced just below the section heading; however, the text is copied verbatim from this organization's fact sheet with no quotations.

Incorrect Interpretation of measured magnetic field levels (Section 7)

Mr. Pfeiffer performed magnetic-field measurements on the ROW on January 19, 2012, and a figure displaying his measurement results are repeated several times throughout his report (e.g., Figure 21, Figure 30, and Figure 44). His measurements were not performed according to applicable standards that specify a measurement height of 1 meter above ground.[44] Nonetheless Mr. Pfeiffer used the measurements as a basis for interpreting the contributions of the transmission lines to the magnetic-field levels on the ROW. Mr. Pfeiffer makes several statements with regard to the measurements that are inconsistent with proper interpretation of the measurement results. In Section 7E, Mr. Pfeiffer states "...as we go past the first cable of the transmission line the measurements are distorted by the fields from all the cables interacting. Thus the data becomes [*sic*] complex and some of it has to be discarded." In reference to Figure

[44] IEEE Std. 644-1994.

44, Mr. Pfeiffer further states "The data points from -120ft to -60 ft. is [*sic*] the only good data as the remaining data is [*sic*] under the transmission lines."

Based upon the information provided in his report regarding the location of his measurements, I have performed a measurement assessment that explains the "unusual looking plots" described by Mr. Pfeiffer.[45] Mr. Pfeiffer's magnetic-field measurement path was defined by a line starting at the northwest comer of the garage and proceeded parallel with the northem edge of the garage out into the adjacent field and beneath the transmission lines.[46] An aerial photograph depicting the path along which Mr. Pfeiffer performed measurements as well as the locations of the transmission line centerline and the local distribution line bringing electricity to the Barker Residence are shown in Figure 22. Also shown overlaid on this photograph are the approximate locations of measurements performed by Mr. Pfeiffer and a shaded area depicting the portion of measurements Mr. Pfeiffer designated as "Good Data."[47]

Contained within the so-called "Good Data" is a 10.3 mG peak in the magnetic field level measured by Mr. Pfeiffer. As can be seen by a comparison of the location of the measurement points in Figure 22 with the data in Figure 44 of Mr. Pfeiffer's report, it is apparent that this peak occurred very near the distribution line feeding into the Barker Residence and away from the transmission lines. A correct interpretation of the data, however, demonstrates that this peak in the magnetic-field data is due to the distribution lines and not the transmission lines.[48] Since Mr. Pfeiffer incorrectly attributed this peak in the data to the transmission lines and based all subsequent magnetic-field calculations on both the shape and magnitude of this apparent peak, all of Mr. Pfeiffer's analysis and conclusions inferring magnetic-field values due to the transmission lines, are unfounded.

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[45] Pfeiffer Report, p. 68

[46] Ibid., pp. 68.

[47] Ibid., pp. 84, Figure 44.

[48] As shown in Figure 8 of this report, I too observed an effect from the distribution line on measured magnetic-field levels. Along the Barker Garage measurement path, I encountered the effects of the distribution line just past the outside phase conductor on the eastern portion of the ROW. This distribution line resulted in a localized increase in the magnetic-field level, as expected,

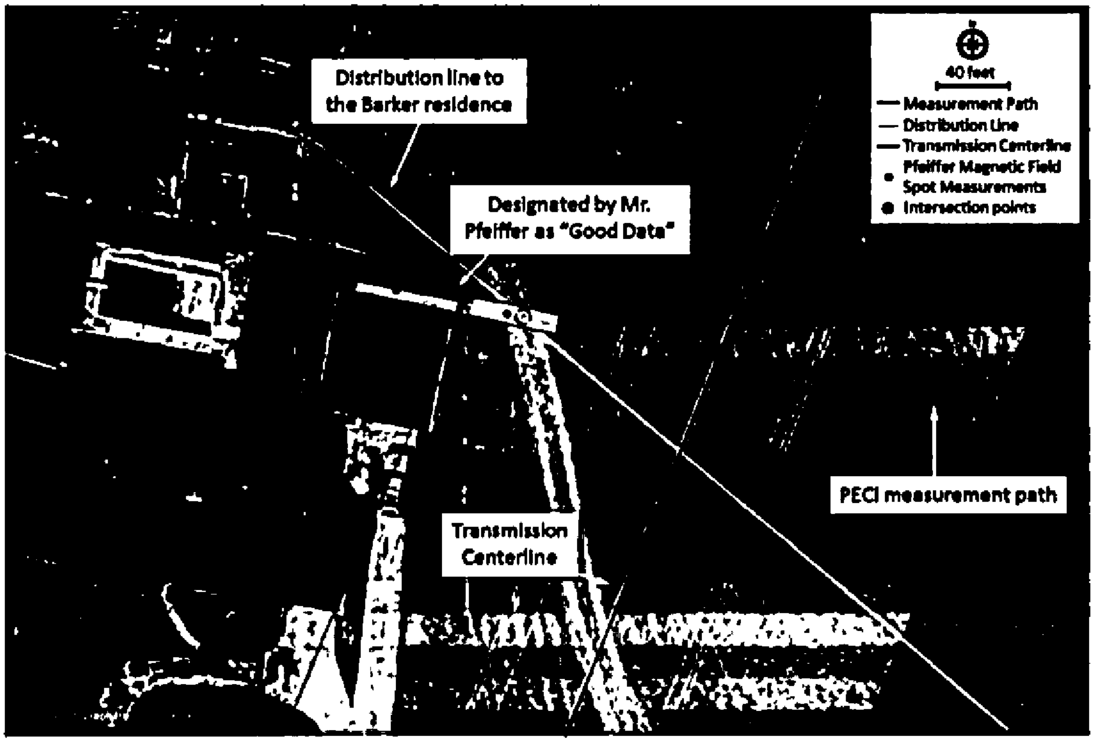

Figure 22. Aerial photograph showing the estimated location of Mr. Pfeiffer's measurement path and the intersection points of this measurement path with the overhead distribution line and the centerline of the transmission line.

Incorrect calculations of EMF levels (Section 7)

I have also reviewed the methodology, calculations, and results presented in Section 7 of Mr. Pfeiffer's report to assess the accuracy of his calculations. As described above, the basis for his comparison of modeling results was the peak magnetic-field value measured below the distribution line. Even without this error, it is clear from the presented analysis that levels of both electric and magnetic fields calculated by Mr. Pfeiffer are based on simplifying assumptions, which are invalid, and therefore result in incorrect EMF levels. There are a number of inadequacies in Mr. Pfeiffer's model, a few of which are highlighted here.

The primary deficiency in Mr. Pfeiffer's calculation method of EMF from transmission lines is suggested by his response to Question 26 in "Response of Complainants To Data Requests Served By Defendant" Case No. 2013-00291, May 12, 2014." In that response, Mr. Pfeiffer states "[p]hase rotation only matters in respect to the relationship between the 345 kV line and the 69 kV line." This is a valid statement; however, he continues, "[t]his relationship is either additive or subtractive and both cases have been considered." This statement implies that Mr. Pfeiffer believes the electric or magnetic field from the three phases of each transmission line all either add or all subtract. There are, in fact, 36 different ways in which the phase conductors of the two transmission lines can be varied.[49] An example of some of these different phase combinations are shown in Figure 23. In this example, the phases for the 345-kV line are fixed at A-B-C, while the phases for the 69-kV line are rotated six ways (shown in red). In addition, because the 345-kV phases could also be rotated 6 ways, there are a total of 36 combinations and not just 2 as implied by Mr. Pfeiffer.

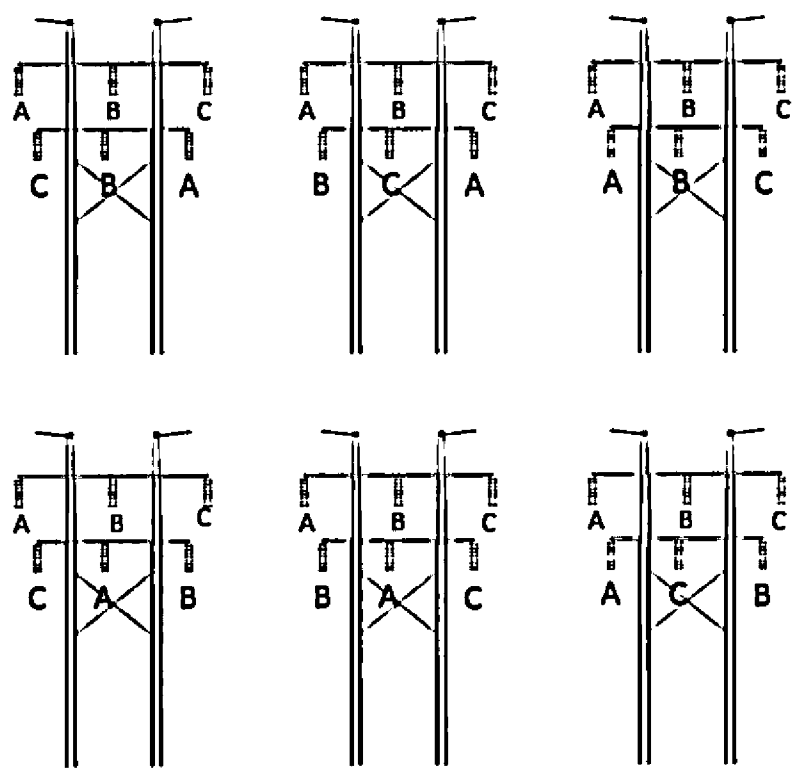

Figure 23. Example of different phase permutations for the double-circuit H-frame structures.

In this particular example the phasing of the 345-kV line is held fixed as A-B-C and the 69-kV line is allowed to rotate phases. There are six different possibilities in which to arrange the three conductors of the 69-kV transmission line. The six possibilities are: C-B-A, C-A-B, B-C-A, B-A-C, A-B-C, and A-C-B.

[49] For the case in which all currents are modeled with balanced currents without reactive power flow the possibilities reduce to six independent combinations.

In accurately calculating EMF levels, it is imperative to correctly account for the phase angle and position of all three conductors in a three-phase transmission line. Mr. Pfeiffer's exclusion of the phase angles and conductor spacing in his calculations is demonstrated by his spreadsheet attached in response to Question 23 in "Response of Complainants To Data Requests Served By Defendant" Case No. 2013-00291, May 12, 2014." I have analyzed Mr. Pfeiffer's spreadsheet presented in response to Question 23 and determined the methodology that he employed in performing his calculations. In performing his magnetic field calculations, Mr. Pfeiffer has:

1. calculated the magnetic-field level from only one phase conductor of each transmission line (instead of all three);
2. neglected any information about the phase of the transmission line conductors relative to one another, and;
3. incorrectly accounted for the vertical and horizontal distance from the conductor to his calculation location.

The results of the above calculation are then scaled by an arbitrary factor Mr. Pfeiffer designates simply as 'X' in order to match the desired measurement point at a single location (i.e., the magnetic-field level he measured beneath the overhead distribution line and incorrectly attributed to the transmission lines, as discussed above). As discussed in the "Transmission line phase conductors" portion of this report, any calculation of electric-field or magnetic-field values that exclude the information about the phases of the transmission line conductors are incorrect. This is because both pieces of information are necessary to know whether the EMF from multiple conductors will add together or subtract from one another, as discussed in the "Vector property of EMF" portion of this report.

I have identified only some of the primary shortcomings in Mr. Pfeiffer's calculations of magnetic-field levels. The application of this methodology to calculate magnetic-field levels is flawed and any results based upon these methods are uninformative. Assuming that Mr. Pfeiffer did not properly apply the concept of conductor phases (and other identified shortcomings in his methodology) to his calculations of electric-field levels, the results of these calculations are also incorrect and uninformative.

Unfounded conclusion of "danger" at specific EMF levels

Mr. Pfeiffer expresses the opinions that "there is a real danger for people with implanted medical heart devices when they are in close proximity of [*sic*] the Barker house" and that "[t]here is a potential health risks [*sic*] due to the magnetic and electric fields."[50] The former opinion appears to be primarily based upon the 2001 American Conference of Governmental Industrial Hygienists (ACGIH), Occupational Threshold Limit Values (TLV) for 60-Hz EMF that lists 1 kV/m for electric fields.[51] Immediately preceding the table detailing the TLV, however, Mr. Pfeiffer provides a quote stating that "The TLVs for 60-Hz EMF shown in the table are identified as guides to control exposure; they are not intended to demarcate safe and dangerous levels."[52] Furthermore, more recent standards (e.g., EN 50527-1, 2010) reference 5 kV/m and 1,000 mG as levels below which these devices are expected to function without interference.[53] The basis for the latter opinion regarding magnetic-field levels is not entirely clear from his report, but Mr. Pfeiffer does rather arbitrarily designate levels of 1.371 kV/m and 191 mG as "Potential Danger."[54] There is no basis from any internationally recognized organization for these field levels to be considered dangerous. To the contrary, the ICNIRP and ICES EMF reference levels (which themselves provide a wide safety margin to known health effects) are at least 4.17 kV/m and 2,000 mG, far above the levels labeled as "Potential Danger" by Mr. Pfeiffer. Furthermore, the potential for induced current from electrostatic induction effects of the electric field is far below the 5 mA safety limit imposed by NESC for AC transmission lines.

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50 Pfeiffer Report, pp. 9-10.

51 American Conference of Government Industrial Hygienists (ACGIH). Documentation of the Threshold Limit Value and Biological Exposure Indices, 7th Edition. Publication No. 0100. Cincinnati, OH: American Conference of Government Industrial Hygienists, 2001.

52 Pfeiffer Report, p. 55. This quote from Mr. Pfeiffer's report is copied directly from National Institutes of Health Sciences (NIEHS), Electric and Magnetic Fields Associated with the Use of Electric Power: Questions and Answers, NIEHS, 2002, p. 47.

53 European Standard, EN50527-1, 2010, p. 28.

54 Pfeiffer Report, pp. 88-89.

Summary and Conclusion

At the request of EKPC, I performed measurements of 60-Hz electric fields and magnetic fields along the ROW adjacent the Barker Residence as well as along a nearby portion of the same transmission line corridor. These measurements were performed to assess the EMF associated with the 69-kV and 345-kV transmission lines owned and operated by EKPC. Using the precise transmission line configuration and loading present at the time of my measurements, I also developed a model of the EMF levels on the ROW for each of the measured conditions. Comparison of the modeled field levels to measured levels are in good agreement confirming the accuracy and applicability of the modeling approach. I then modeled the EMF associated with the transmission lines for the 69-kV Configuration, the As-Built Configuration, and the Original Design Configuration assuming the minimum conductor clearance to ground anywhere along the Barker Residence.

Based upon the results of these calculations, as well as my knowledge and familiarity with the scientific principles involved in the calculation, measurement, and evaluation of EMF, it is my opinion that the EMF levels present at the Barker Residence are well below international standards of exposure to EMF such as those set by ICNIRP. In addition, the electric fields from the transmission lines are at such low levels that they do not present a safety hazard due to electrostatic coupling, induced voltage, or induced current according to the standards set out by the NESC for overhead transmission lines. These conclusions pertain both to the transmission lines as they are constructed and operated at the present time as well as for future operational scenarios such as contingency operation, operation at maximum rated current, or operation of the 69-kV transmission line at 138 kV, that may arise in the future without the need for a physical change to the conductors or structures comprising the transmission lines.

Appendix A

Curriculum Vitae of Benjamin Cotts, Ph.D.

Exponent
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Suite 200
Bowie, Maryland 20715

telephone 301-291-2500
facsimile 301-291-2599
www.exponent.com

Benjamin R. T. Cotts, Ph.D.
Manager

Professional Profile

Dr. Benjamin Cotts is a Manager in Exponent's Electrical Engineering and Computer Science practice. Dr. Cotts is experienced in both applied and theoretical electromagnetics and plasma physics including space weather, geomagnetic storms, and earth's radiation belts as well as in the initiation, field effects, and propagation of lightning discharges. Dr. Cotts is an expert in modeling and measurement studies of power system (AC and DC) electric and magnetic fields, as well as modeling of audible noise and radio noise for clients including federal agencies, utilities, and construction developers. He also performs electromagnetic compatibility assessments and site surveys for patients with pacemakers, ICDs and other implantable medical devices. Other areas of experience include electrical failures and standard-related performance analysis of consumer electronics including heating pads, magnetic induction heating devices, personal computers, electric utility RF smart meters and fire-related electrical failures.

Dr. Cotts has been a leading figure in coordinating scientific outreach to developing countries through the United Nations International Heliophysical Year (IHY) and International Space Weather Initiative (ISWI) programs and has organized and led multiple conferences on atmospheric and space science.

In one of his principal investigations, Dr. Cotts combined remote sensing measurements of ionospheric disturbances with numerical modeling of atmospheric, ionospheric, and magnetospheric interactions to determine the role of global lightning on the removal of radiation belt electrons. These radiation belt electrons are a critical factor in space weather for determining the effective lifetime of spacecraft, the electronics of which can be irreversibly damaged over time by these radiation belt electrons. Dr. Cotts was also involved in designing and building an interferometer to test the phase stability of the Main Drive Line at the Stanford Linear Accelerator Center in preparation for the LINAC Coherent Light Source.

Additionally, Dr. Cotts is experienced in the use of Matlab and has experience in C, C++, Mathematica, COMSOL as well as both Windows and Linux operating systems.

Academic Credentials and Professional Honors

Ph.D., Electrical Engineering, Stanford University, 2011
M.S., Electrical Engineering, Stanford University, 2004
B.S., Electrical Engineering, University of Portland (*summa cum laude*), 2002

Outstanding Student Paper Award, AGU Fall Meeting, San Francisco, California, 2004
Tau Beta Pi Engineering Honor Society
Delta Epsilon Sigma, National Scholastic Honor Society

Professional Affiliations

- Institute of Electrical and Electronics Engineers
- CIGRÉ

Peer Review

- Referee for Journal of Geophysical Research – Space Physics
- Referee for Annals Geophysicae
- Referee for Radiation Protection Dosimetry

Peer Reviewed Publications

NaitAmor, S, Cohen MB, T. Cotts BR, Ghalila H, AlAbdoadaim MA, Graf K. 2013. Characteristics of long recovery early VLF events observed by the North African AWESOME Network. Journal of Geophysical Research: Space Physics. 2013. 10.1002/jgra.50448

Haldoupis, C, Cohen M, Arnone E, Cotts B, Dietrich S. The VLF fingerprint of elves: Step-like and long-recovery early VLF perturbations caused by powerful ±CG lightning EM pulses. Journal of Geophysical Research: Space Physics, 2013. doi: 10.1002/jgra.50489.

Haldoupis C, Cohen M, Cotts B, Arnone E, Inan U. Long-lasting D-region ionospheric modifications, caused by intense lightning in association with elve and sprite pairs. Geophysical Research Letters 2012; 39:L16801. doi:10.1029/2012GL052765.

Salut MM, Abdullah M, Graf KL, Cohen MB, Cotts BRT, Kumar S. Long recovery VLF perturbations associated with lightning discharges. Journal of Geophysical Research 2012; 117:A08311. doi:10.1029/2012JA017567.

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Cotts BRT, Inan US, Lehtinen NG. Longitudinal dependence of lightning-induced electron precipitation. Journal of Geophysical Research 2011; 116:A10206. doi:10.1029/2011JA016581.

Cotts BRT. Global quantification of lightning-induced electron precipitation using very low frequency remote sensing. Doctoral Dissertation, Stanford University, 2011.

Haldoupis C, Amvrosiadi N, Cotts BRT, Van der Velde O, Chanrion O, Neubert T. More evidence for a one-to-one correlation between Sprites and Early VLF perturbations. Journal of Geophysical Research 2010, 115:A07304. doi:10.1029/2009JA015165.

NaitAmor S, Al Abdoadaim MA, Cohen MB, Cotts BRT, Neubeurt T, Soula S, Chanrion O, Abdelatif T. VLF observations of ionospheric disturbances in association with TLEs from the Eurosprite-2007 Campaign, Journal of Geophysical Research 2010; 115:A00E47. doi:10.1029/2009JA015026.

Cotts BRT, Inan US. VLF observation of long ionospheric recovery events. Geophysical Research Letters 2007; 34:L14809. doi:10.1029/2007GL030094.

Reports

Long RT, Blum AF, Bress TJ, Cotts, BRT. Best practices for emergency response to incidents involving electric vehicle battery hazards. Fire Protection Research Foundation Report, 2013.

Selected Conference Presentations

Cotts BRT, Inan US, Lehtinen NG. Theoretical prediction of longitudinal dependence of electron precipitation due to lightning. AGU Fall Meeting, San Francisco, CA, December 14–18, 2009.

Inan US, Cotts BRT, Lehtinen NG. Long recovery early/fast events as possible evidence of persistent ionization by Giant Blue Jets. IUGG, Perugia, Italy, July 2–13, 2007.

Cotts BRT, Inan US, Lehtinen NG. Long recovery early/fast events as possible evidence of persistent ionization by Giant Blue Jets. URSI, Ottawa, Canada, July 22–26, 2007.

Cotts BRT, Inan US. Observation of daytime perturbations of VLF transmitter signals. ICAE, Beijing, China, August 13–17, 2007.

Cotts BRT, Inan US. Daytime early VLF perturbations exhibiting long recoveries and wide-angle scattering. AGU, San Francisco, CA, December 10–14, 2007.

Cotts BRT, Inan US. VLF observation of long ionospheric recovery events. AGU, San Francisco, CA, December 11–15, 2006.

Cotts BRT, Inan US, Pasko VP. Ray tracing techniques applied to sky wave observations of lightning-induced ionospheric effects on short range VLF paths. URSI, Boulder, CO, January 5–8, 2005.

Cotts BRT, Inan US. Ray-based modeling of lightning-induced ionospheric effects on short range VLF skywave signals. AGU, San Francisco, CA, December 5–9, 2005.

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Cotts BRT, Inan US, Golkowski M. Lightning-induced electron precipitation measurements with VLF and the Arecibo Radar. PARS Summer School, Arecibo, PR, August 10–21, 2004.

Cotts BRT, Inan US, Selser E. ELF/VLF near-field imaging of modulated auroral-electrojet currents using a VLF interferometer. PARS Summer School, University of Fairbanks Alaska, August 11–21, 2003.

Cotts BRT, Inan US. Precipitation of energetic electrons by Magnetospherically Reecting (MR) Whistlers. AGU, San Francisco, CA, December 8–12, 2003.

Prior Experience

Post Doctoral Scholar, University of Colorado, Denver, 2011
International Science Outreach Manager, Stanford University, 2007–2011
Research Assistant, Stanford University, 2002–2011
Energy Research Fellow, Stanford Linear Accelerator Center, 2001

Appendix B

Calculation of Electrostatic Induction Effects.

Mr. Pfeiffer includes measurements of induced voltages on a Dodge pickup truck at the Barker Residence in his report.[55] In particular, voltages of 250 V and as high as 330 V were measured between the wheel lug of the vehicle and ground. The report does not specify the conditions for these measurements (i.e., the electric field strengths near the vehicle at the time of measurement nor does it specify the weather conditions). Induced voltages are a well-known and well-understood phenomenon. In particular, theoretical frameworks have been developed to calculate the induced voltages that might be expected in situations such as this one.

EPRI provides formulae to calculate the voltage induced on an object in an area with an electric field (electrostatic induction). The EPRI formulae provide methodology for calculating both the maximum current that flows from the object to ground (i.e., called the short-circuit current, I_{SC}). Based upon this induced short-circuit current it is then possible to calculate the voltage on that object relative to ground (i.e., called the object voltage-to-ground, V_{og}), which will depend both on the detailed geometry and construction of the object as well as the strength of the electric-field source.

The magnitude of the short-circuit current depends on the frequency (ω) and the rms amplitude of the source (E), as well as the effective charge-collection area[56] on the object (S)

$$I_{SC} = \omega \epsilon E S$$

The amplitude of the source is the vertical component of the electric field, measured in units of volts per meter at a height of about 1 meter from the ground. The frequency is given by expression $\omega = 2\pi f$, where f in this case is 60 Hz. Finally, ϵ is known as the permittivity of free space, and has a value of 8.85×10^{-12} Farads per meter. The effective charge collecting area of a vehicle is approximated in EPRI by treating the vehicle as a rectangular object, but it is not simply the surface area of a rectangular object that is of importance. For a particular geometry, the effective collection area has been empirically determined by EPRI, as illustrated

[55] Pfeiffer Report, p. 65.

[56] EPRI Transmission Line Reference Book, pp. 348 and Eq. 8.8.3..

in Figure 8.8.2 of the EPRI Transmission Line Handbook.[57] That reference provides curves for S normalized to the lateral dimensions A and B (length and width) of an object such as a vehicle. The curves are presented as a function of the ratio of the length to the width (A/B), and as a function of the ratio of the height of the vehicle (H) to width (B). A geometry must then be specified to calculate the short-circuit current and ultimately the induced voltage on the vehicle.

Table A-1. Summary of parameters used to calculate induced short-circuit current.

Vehicle	Length x Width x Height (A x B x H)	S/AB	S	Isc (for E= 1kV/m)
Regulation Truck (Kentucky)	10.67 x 2.44 x 3.81m	6	156 m^2	0.52 mA
Dodge RAM 1500	5.18 x 2.02 x 1.83m	4.5	47.1 m^2	0.16 mA

For reference, the maximum size of a truck in the state of Kentucky, as defined by the American Trucking Association,[58,59] is given by length of 35 feet (10.67 meters), a width of 8 feet (2.44 meters), and a height of 12 feet and 6 inches (3.81 meters). For the truck, the value of A/B = 4.375 and H/B = 1.56. For these values, Figure 8.8.2 of the EPRI reference indicates that S/AB = 6, and by extension that S = 1680 ft^2 (156.2 m^2). By comparison, a 2001 Dodge RAM 1500 (regular cab) pickup truck, similar to the one at the Barker Residence, has a length of 5.18 meters, a width of 2.02 meters and a height of 1.83 meters.[60] For this vehicle, A/B = 2.6 and H/B = 0.9. This yields S/AB = 4.5 and S = 47.1 m^2. I have summarized these values in Table A-1.

Using these values, I then calculated the induced current for both a 2001 Dodge RAM 1500 and a regulation-sized truck to be approximately 0.16 mA and 0.52 mA, respectively, for a vertical electric field strength of 1 kV/m. The associated voltage on the vehicle (sometimes called the object-to-ground voltage) is given by the expression:

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57 EPRI Transmission Line Reference Book, p. 350.

58 EPRI Transmission Line Reference Book, p. 357.

59 See also state of Kentucky motor vehicle dimension limits that provide dimensions similar (though not identical) to EPRI at http://www.lrc.state.ky.us/kar/603/005/070.htm.

60 See http://autos.msn.com/research/vip/Spec_exterior.aspx?year=2001&make=Dodge&model=Ram+1500.

$$V_{OG} = I_{SC} \,/\, \omega C$$

Here, I_{SC} is the computed short-circuit current, ω is the frequency defined as it was above, and C is the capacitance between the vehicle and the ground. The latter depends once again on the geometry of the vehicle and can be computed for vehicles in general by approximating the vehicle as a cylinder that sits a particular height off the ground. The formula for the capacitance is given by:

$$C = 2\frac{\pi\epsilon}{\ln\left(\frac{h+\sqrt{h^2-r^2}}{r}\right)}(L+2r)$$

Here, h is the average height of the vehicle from the ground, L is the length of the vehicle, and r is the average of two quantities: the half-width of the vehicle and half the distance from the lowest conductive point on the vehicle (e.g., metallic wheels) to the top of the vehicle. EPRI has shown, by comparing the results of this approximation to actual measurements that these formulas yield excellent results.[61]

The length, width, and height for a 2001 Dodge RAM 1500 are summarized in Table A-1. The lowest conductive point on the vehicle is the bottom edge of the metallic wheel, which is approximately 0.169 meters above ground. This was determined using the nominal tire size (225/75R16), which has a width of 225 millimeters and a sidewall height of about 75% of the width. These parameters yield $h = 1$ meter and $r = 0.92$ meters, resulting in a capacitance of about 947 picofarads (pF). This is slightly larger than the value of 800 pF reported in the EPRI reference for a sedan (Chevrolet Nova).[62] This result is combined with the computed short-circuit current to obtain an induced voltage of about 439 V. Recall that this voltage corresponds to an electric field strength of 1 kV/m, and scales linearly with the electric field (a 25% smaller electric field would yield 330 V).

[61] EPRI Transmission Line Reference Book, p. 358.

[62] EPRI Transmission Line Reference Book, p. 356.

This value can be compared to the maximum value of 330 V reported by PECI. Neither the precise location of the vehicle nor the line load conditions were reported by PECI. The quality of the ground contact and the type of terrain (e.g., soil, asphalt, etc.) also has an effect on the magnitude of the induced voltage. The formulae in EPRI are idealized and hence tend to overestimate the open-circuit voltage compared to what might be expected in a real-world scenario and the value of 439 V is also likely an overestimate. The general agreement however illustrates that the short-circuit currents on the order of a few tenths of a milliAmpere are reasonable as well. For reference, these currents are an order of magnitude smaller than the 5 mA requirement imposed by the NESC, described as follows:

> For voltages exceeding 98 kV ac to ground, either the clearances shall be increased or the electric field or the effects thereof shall be reduced by other means, as required, to limit the steady-state current due to electrostatic effects to 5 mA, rms, if the largest anticipated truck, vehicle, or equipment under the line were short-circuited to ground. The size of the anticipated truck, vehicle, or equipment used to determine these clearances may be less than but need not be greater than that limited by federal, state, or local regulations governing the area under the line. For this determination, the conductors shall be at a final unloaded sag at 120 °F (50 °C).[63]

The short-circuit current for the largest anticipated vehicle, in this case the maximum allowable size of a truck, is also within the NESC limit with a value of 0.52 mA. I also calculated the induced voltage corresponding to this induced current, using the values laid out in Table A-1 and assuming that the lowest conductive point on the vehicle is about 0.3 meters above the ground (consistent with EPRI calculations). I found that such a vehicle has a capacitance of 894 pF, and that approximately 1,540 V is induced on the vehicle relative to the ground for a vertical electric field of 1 kV/m.

[63] NESC, Section 1, Subsection 013.C.1.c.

Appendix C

Calibration Certificate for EMDEX II - Magnetic Field Measurement System

Certificate of Calibration

The calibration of this instrument was controlled by documented procedures as outlined on the attached Certificate of Testing Operations and Accuracy Report using equipment traceable to N.I.S.T. , ..ISO 17025, and ANIZ540-1 COMPLIANT

Instrument Model : Emdex II

Frequency : 60 Hz

Serial Number : 3363

Date of Calibration : 12 / 03 / 2013

Re-Calibration suggested at one year from above date.

etc

ENERTECH Consultants
494 Salmar Ave. Suite 200
Campbell, California 95008
(408) 866-7266 FAX : (408) 866-7279

Calibration Inspector

1403273 000 - 7233

Appendix D

Calibration Certificate for SupraRule T30 Thermometer

suparule

Lonsdale Road,
National Technology Park,
Limerick, Ireland.

Tel: +353 (0) 61 201030
Fax: +353 (0) 61 330812

Email: info@suparule.com
Web: www.suparule.com

Calibration Certificate

MODEL	***600E***
Serial No.	***A44142***
Date of Calibration	***11th April 2014***
CHM Calibration Due Date	***11th April 2015***

Equipment used:

Model	Serial No.	Control No.	Calibration Due Date
SupaRule T30 Thermometer	8310412	CAL ID 041	31st March 2015

Instrument calibrated to a national or international standards to better than ± 0.15°C (T30).

Method: After temperature stabilisation, readings taken are as follows:
Actual Temperature: 22.2°C
Temperature reading before adjustment: 22.5°C

Adjustment made.
Waveform calibrated.

Calibration accuracy:

After calibration the instrument will have an accuracy of ± 0.5% +/- 2digits provided that the displayed temperature is within ± 0.5°C of the ambient temperature. (Temperature range = 0°C to 35°C), as per its specification.

Test Title	*Tolerance*	*Actual Cable Height*	*UUT Reading*	*Pass/Fail*
5M	35mm	5 013	5 020	Pass
10M	60mm	10 009	10 025	Pass
12M	70mm	11 996	12 025	Pass

Eoin O Loughlin

Approved Signatory
Eoin O'Loughlin

Directors: J. McDonnell, M.Meehan, B. O'Donoghue,
Suparule Systems Ltd., Registered in Ireland. Company No. 152205. Registered Office is at the above address

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

IN THE MATTER OF:

HAROLD BARKER; ANN BARKER AND BROOKS BARKER	)	
COMPLAINANTS	)	
V.	)	**Case No. 2013-00291**
EAST KENTUCKY POWER COOPERATIVE, INC.	)	
DEFENDANT	)	

DIRECT TESTIMONY OF KENNETH R. FOSTER, Ph.D.
ON BEHALF OF EAST KENTUCKY POWER COOPERATIVE, INC.

Filed: June 2, 2014

Q. PLEASE STATE YOUR NAME, BUSINESS ADDRESS, AND OCCUPATION.

A. My name is Kenneth R. Foster. I am Professor of Bioengineering at the University of Pennsylvania, Department of Bioengineering, University of Pennsylvania, 240 Skirkanich Hall, 220 S. 33rd Street, Philadelphia, Pennsylvania, 19104-6392. In this matter, I am not representing the University of Pennsylvania. Instead, I am offering testimony as an independent expert on issues related to health and safety of electromagnetic fields ("EMF"), as permitted by the University.

Q. PLEASE STATE YOUR EDUCATION AND PROFESSIONAL EXPERIENCE.

A. I have a B.S. in physics (with honors) from Michigan State University (1967), a M.S. in physics from Indiana University (1968) and a Ph.D. in physics from Indiana University (1971). From 1971 through 1976, I served as a Lieutenant in the U.S. Naval Reserve, doing research on biological effects of EMF with the Navy. Since 1976, I have been with the University of Pennsylvania. My research related to the interaction of EMF with biological systems, ranging from biophysical mechanisms of interaction to exposure assessment. I have been involved for many years with organizations involved with health effects of EMF, including a year spent at the EMF Project with the World Health Organization in Geneva, which is concerned with possible health effects of electromagnetic fields, including in power line fields and radiofrequency energy. I have had long-standing members (since 1998) on the IEEE International Committee on

Electromagnetic Safety (ICES) which sets limits for human exposure to EMF. In addition, I serve on the Physical Agents Committee of the American Conference of Governmental Industrial Hygienists, which sets exposure limits for EMF, and have served on the National Council on Radiation Protection and Measurements, the IEEE Committee on Man and Radiation and other organizations involved with health and safety issues related to exposure to EMF. I have also served on the Advisory Board of the EMF program of the Electric Power Research Institute. I am a Fellow of the IEEE and of the American Institute of Medical and Biological Engineering and I served as President of the IEEE Society on Social Implications of Technology from 1996-1998. I am presently a Distinguished Lecturer for that Society. I have published more than 100 scientific papers in peer reviewed journals on a broad range of issues related to this topic as well as to medical applications of EMF. Finally, I am a Registered Professional Engineer in the State of Pennsylvania (PE-030018-E).

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

A. The purpose of my testimony is to provide an expert opinion regarding whether the EMF exposure levels associated with the 69 kV/345 kV transmission line operated by East Kentucky Power Cooperative, Inc. poses any sort of health or safety risk to the Complainants. I will also respond to various issues raised by the Complainants or their experts.

Q. ARE YOU SPONSORING ANY EXHIBITS?

A. Yes. My curriculum vitae is attached hereto and incorporated herein as Exhibit KRF-1. An expert opinion report that I prepared in association with this case is attached hereto and incorporated herein as Exhibit KRF-2.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes it does.

VERIFICATION

Comes now, Kenneth R. Foster, Ph.D., and after being duly sworn does hereby state that the foregoing testimony is true and correct to the best of my knowledge and belief as of this _2_ day of June, 2014.

Kenneth R Foster

____
Kenneth R. Foster, Ph.D.

STATE OF ___Pennsylvania____________

COUNTY OF ____Delaware_________

The foregoing was subscribed and sworn to before me, the Notary Public, on this the __ day of June, 2014.

____
NOTARY PUBLIC

My Commission expires: ____________

CURRICULUM VITAE

NAME	Kenneth R. Foster	
DATE/PLACE OF BIRTH	July 21, 1945 Baltimore, Maryland	
NATIONALITY	United States Citizen	
EDUCATION	1967	B.S.(Honors) Physics Michigan State University
	1968	M.S. (Physics) Indiana University
	1971	Ph.D. (Physics) Indiana University

POSITIONS HELD

1971-1976	Lieutenant, Medical Service Corps, U.S. Naval Reserve (assigned as a Biophysicist to the Naval Medical Research Institute, and Armed Forces Radiobiology Research Institute, both in Bethesda, Maryland)
1976-1977	National Institutes of Health Research Service Award, Bioengineering Department, University of Pennsylvania, Philadelphia, PA 19104
1977-1983	Assistant Professor Department of Bioengineering University of Pennsylvania
1983-	Associate Professor Department of Bioengineering University of Pennsylvania
1985	(during sabbatical leave) Visiting Professor Department of Electrical Engineering University of Ottawa, Canada
1999-	Professor Department of Bioengineering University of Pennsylvania
2000	(during sabbatical leave) Consultant, EMF Project, World Health Organization, Geneva, Switzerland

EXHIBIT

KF-1

OTHER UNIVERSITY APPOINTMENTS

1992-	(secondary Appointment) Department of Electrical Engineering University of Pennsylvania
1992 -	Member, Steering Committee, Institute for Environmental Studies, University of Pennsylvania
2000	Faculty advisory committee, Center for Bioethics, University of Pennsylvania

HONORS/DISTINCTIONS

Indiana University Physics Department Award for Excellence in Teaching, 1970.

National Science Foundation Traineeships, 1967-1969 and 1970-1971.

Defense Nuclear Agency Certificate of Achievement, 1976.

National Institutes of Health Research Service Award, 1976-1977.

Professional Engineer in the State of Pennsylvania 1981 (Certificate Number: PE-030018-E).

Fellow, Institute of Electrical and Electronics Engineers, 1987.

Member, Electromagnetics Academy, "For distinguished achievements and leadership in the field of electromagnetics and its various applications," 1990.

2000 IEEE Millennium Award

MEMBERSHIP IN SCIENTIFIC AND PROFESSIONAL SOCIETIES

AAAS
Biophysical Society
Bioelectromagnetics Society (Member Technical Program Committee, 1981 Member, Board of Directors, 1983-85), Chair, Awards Committee (1983-5).
American Physical Society
Sigma Xi
IEEE (Fellow)
Society for Risk Analysis

MAJOR CONFERENCE ORGANIZATION

Meeting Chairman, 13th Annual Northeast Bioengineering Conference, Philadelphia, 1987. (250 papers presented)

Technical Program Chairman, IEEE Engineering in Medicine and Biology Society, Boston MA, 1987. (1200 papers presented)

Steering Committee, Northeast Bioengineering Conference, 1986-1990.

Steering Committee, International Symposium for Technology and Society, 1997,1998,1998

MAJOR SERVICE TO PROFESSION

IEEE:

IEEE Engineering in Medicine and Biology
Chair, Philadelphia Chapter, Section on Engineering in Medicine and Biology (1980-1981); Member of IEEE-EMBS Administrative Committee, 1984-6, 1989-91), Awards Committee, IEEE Philadelphia Section (1988-), Chair, IEEE-EMBS Committee on Ethics and Professional Responsibility (1988-9), Chair, IEEE EMBS Technical Interest Profiles Committee (1989-), Distinguished Lecturer 1991-

IEEE Society on Social Implications of Technology (2000 members)
Treasurer, 1994
Vice President 1995-1997, 2009-11
President 1997-1998

IEEE EMBS Committee on Man and Radiation (COMAR)
Member 1990-; Vice Chair (Chair-Elect) 1995-7 ; Chair 1997-9.

IEEE Medical Technology Policy Committee 1995-

Accreditation Board for Engineering and Technology Accreditor, 1991-1995. Evaluated Bioengineering programs at 5 major universities.

Society of Risk Analysis, Philadelphia Section, President 1996-7.

Editor in Chief, Biomedical Engineering Online, 2005-

Physical Agents Committee, American Conference of Governmental Industrial Hygienists 2012-

RESEARCH EXPERIENCE AND DIRECTION

Since receipt of the Ph.D. in 1971, Dr. Foster has been engaged in studies on the interaction of nonionizing radiation and biological systems. The major emphasis of this work has been on the biophysical principles of interaction. Other significant interests have been on biomedical applications and health effects of electromagnetic fields and risk assessment with emphasis on possible health risks of nonionizing electromagnetic energy.

TEACHING EXPERIENCE

1974-1976	Lecturer (part-time), Physics Department, Montgomery College, Rockville, MD.
	<u>Courses taught at the University of Pennsylvania</u>
Spring 1977	BE 99 Independent study: Supervised Readings in

Neurophysiology.

Fall 1978	BE 352 Applied Physical Chemistry (with M. Litt).
Spring 1978-81 1988-	BE 310 Bioinstrumentation Laboratory. This is a lecture and laboratory course (3 hours lecture, 3 hours laboratory per week) that was reorganized and equipped by Dr. Foster.
Fall 1979-	BE 465 Bioelectric Instrumentation. This is a required senior design course for BE seniors who areminoring in instrumentation
Fall 1991-	BE 565 Biomedical Instrumentation. Elective introductory graduate course emphasizing microcomputer applications in medical instrumentation.
Spring 1983-1987	BE 511 Introduction to Bioengineering. Application of linear systems theory to biomedical engineering.
Spring 1987-8	BE 201 Introduction to Bioengineering. Application of linear systems theory to biomedical engineering (core sophomore course for Bioengineering majors)
Fall 1995-	BE 222 (Physical Principles of Living Systems)
Fall 1997 -	BE 615 (Case Studies in Biomedical Engineering)

Other: Developed and had approved Environment and Technology program in SEAS (dual-degree program with the College) 1997.

Undergraduate Curriculum Chair, Bioengineering, 1998-

DISSERTATIONS/THESES SUPERVISED

Ph.D. Theses

1981	Jonathan L. Schepps (Microwave dielectric properties of tissues)
1982	Benjamin R. Epstein (Dielectric studies on micro-emulsions)
1983	Jeffrey D. Kosterich (Dielectric properties of fluid saturated bone) (with S. R. Pollack) Present position: independent consultant.
1986	James W. Baish* (Models of heat transport in tissue) with P. S. Ayyaswamy)
1988	Erik Cheever (Imaging capabilities of microwave radiometry)
1990	Jonathan B. Leonard (Noninvasive measurement of subsurface tissue temperatures with microwave

*NSF Presidential Young Investigator Award, 1990

	radiometry)
1991	Amanda J. Osborn (Dieletric and electrooptic properties of suspensions)
1991	Susan Rae Smith (Dielectric properties of tissues)
1992	Mark S. Mirotznik (Helical antenna for catheter ablation)
1998	Isaac Chang (Electrical characterization of myocardium for microwave ablation)

UNIVERSITY ADMINISTRATIVE RESPONSIBILITIES

	Bioengineering Department
1978,1986	Seminar Chairman
1978-1991	Graduate Admissions Committee
1980-1981	Undergraduate Curriculum Co-chairman
1981-1984; 1998-	Undergraduate Curriculum Chairman in Bioengineering (organized successful Department preparation for the first accreditation visit by the Accreditation Board for Engineering Training)
	School of Engineering and Applied Science
1979-1980	Library Committee
1980-1981	SEAS Computer Utilization Committee
1981	Alternate Member, SEAS Academic Freedom and Responsibility Committee
1987-	Academic Performance Committee, SEAS
1988	Faculty Secretary, SEAS
1989	Chair, Electrical Engineering Department Chair Search Committee
	Other
1992-	Graduate Group, Center for Energy and the Environment
1992 -	Chair, ad-hoc committee to plan President's Symposium on Development and the Environment
1982 -	Steering Committee, Institute for Environmental

Studies, University of Pennsylvania

1998 -1999 Faculty Associate, Ware College House

1998 - Undergraduate curriculum chair, Bioengineering Departement (responsible for undergraduate program with 265 students).

EDUCATIONAL DEVELOPMENT Developed and had approved a new dual-degree program Environment and Technology (1997) between the School of Engineering and Applied Science and School of Arts and Sciences, University of Pennsylvania

CONSULTING ACTIVITIES

K. Foster has consulted extensively with government and industry on health and safety issues related to electromagnetic fields, and medical applications of radiofrequency energy, including:

Government: NIH Diagnostic Radiology Study Section (several times), various NIH Ad-Hoc Study Sections, US Army, US Air Force, Food and Drug Administration.

Industry: Pillsbury Co., Urologix, Oregon Medical Systems, Motorola, Bell Atlantic Mobile, Comcast Metrophone, Sprint Spectrum, Omnipoint Cellular Communications, Electric Power Research Institute, Information Ventures Inc.

International: World Health Organization, Government of Mexico

Referee for Journals

Aviation, Space, and Environmental Medicine
Bioelectromagnetics
Biophysical Journal
IEEE Transactions (IM, MTT, BME)
Journal of the American Chemical Society
Journal of Clinical Nutrition
Journal of Colloid and Interface Science
Journal of Microwave Power
Journal of Physical Chemistry
Nature
Physics in Medicine and Biology
Science

EDITORIAL RESPONSIBILITIES

Associate Editor, IEEE Transactions on Biomedical Engineering, 1985 - 1989.

Editorial Board Memberships

Bioelectromagnetics (1983-)
Journal of Microwave Power (1981-6)
Editor in Chief Biomedical Engineering Online (2006 -)

PATENTS

Patent Number 5,447,529, Method of using endocardial impedance for determining electode-tissue contact, appropriate sites for arrhythmia ablation and tissue heating during ablation. D. Panescu, D. K. Swanson, M. S. Mirotznik, D. S. Schwartzman, I. Chang, K. R. Foster. (Sept. 5, 1995).

Patent Number 5,562,721, Method of using endocardial impedance for assessing tissue heating during ablation. F. E. Marchlinski, D. S. Schwartzman, M. S. Mirotznik, C. D. Gottlieb, I. Chang. (Oct. 8, 1996).

Patent Number 5,673,704 Method of using endocardial impedance for determining electrode-tissue contact. F. E. Marchlinski, D. S. Schwartzman, M. S. Mirotznik, K. R. Foster, C. D. Gottlieb, I. Chang (Oct 7, 1997).

Patent Number 6,256,540 Systems and methods for examining the electrical characteristic of cardiac tissue Inventors: D. Panescu, D. K. Swanson, M. S. Mirotznik, D. S. Schwartzman, K. R. Foster (July 7, 2001).

Patent Number 6,370,435 Systems and methods for examining the electrical characteristic of cardiac tissue. D. Panescu, D. K. Swanson, M. S. Mirotznik, D. S. Schwartzman, K. R. Foster (April 9, 2002)

Patent Number 6,597,955 Systems and methods for examining the electrical characteristic of cardiac tissue D. Panescu, D. K. Swanson, M. S. Mirotznik, D. S. Schwartzman, K. R. Foster

SEMINARS/LECTURES/PRESENTATIONS

The state of water in tissue as determined by microwave dielectric spectroscopy. Baylor University, Department of Physiology, September 1980.

Dielectric properties of tumor and normal tissues. University of Ottawa, Department of Electrical Engineering, July 1981.

Dielectric properties of tissues and heterogeneous suspensions. Talk presented to the Bureau of Radiological Health, Food and Drug Administration, Rockville, MD, December 1981.

On the possible hazards of VLF radiation. Talk presented to a Workshop on VLF Radiation Hazards, Naval Medical Research and Development Command, Bethesda, MD, December 1981.

Dielectric properties of dispersed systems. Rice University, Department of Physics, May 1982.

Dielectric properties of biological materials at microwave frequencies. Drexel University, Center for Bioengineering, January 1983.

Mixture theory and transport properties of phantom tissue materials. HPC Working Group Meeting on Hyperthermia Phantoms, Allegheny Hospital, Pittsburgh, PA, February, 1984.

Transport properties of heterogeneous systems. NATO Advanced Research School, Erice, Sicily, September 1984 (Invited paper).

The microwave debate. Center for Bioengineering, Drexel University, January

1985. (Also presented at Dartmouth College, Swarthmore College, Johns Hopkins University, Universities of Arizona, Illinois, Ottawa, Pennsylvania, Purdue, Rhode Island, Rochester, Utah, Tucuman (Argentina), Victoria (British Columbia), Washington University)

Transport properties of heterogeneous systems. (Invited Speaker) Argentine Dielectrics Discussion Group, La Plata, Argentina, August 1985.

Heat transport in tissues. Univ. of Maryland School of Medicine 1986.

Dielectric properties of tumor and normal tissues (Plenary Lecture). Radiation Research Society Annual Meeting, Las Vegas NV, 1986.
Dielectric properties of tumor and normal tissues. Thomas Jefferson University Hospital, Department of Radiation Therapy, 1986.

Distinguished Faculty Lecturer, School of Engineering, Bucknell University, 1988. (presented several lectures and seminars).

Dielectric properties of water in biological and other suspensions Gordon Research Conference on Dielectrics, 1986.

Dielectric properties of tumor and normal tissues. Thomas Jefferson University Hospital, Department of Radiation Therapy, 1986.

Currents of death: Controversy about health effects of electromagnetic fields. K. R. Foster. 16th Northeast Bioengineering Conference, State College, PA March 1990. (Plenary Lecture).

Spiraled-helix antenna for catheter ablation of myocardial tissue using microwave energy. M. S. Mirotznik, D. K. Bogen, and K. R. Foster. 16th Northeast Bioengineering Conference, State College, PA March 1990.

Dielectrophoresis and levitation of cells: How are they related and what do they show? K. R. Foster. International Conference on Biophysics of Transmembrane Electric Fields, Baltimore MD 1990.

Powerline fields and cancer? Thomas Jefferson University Hospital, 1990. (also presented at Temple University, Department of Radiology, University of Pennsylvania)

Health effects of nonionizing electromagnetic fields: what is the problem and what should we do about it? Harvard School of Public Health, January 1991

Health effects of electromagnetic fields - scientific basis and policy implications. Program for Assessing and Revitalizing the Social Sciences, Environmental Risk and Public Policy Seminar, University of Pennsylvania, February 22, 1990.

Health effects of nonionizing electromagnetic fields (University of New Hampshire, April 1991).

Health effects of nonionizing electromagnetic fields. Seminar at Allied Chemical Company, Philadelphia PA April 1991.

Powerline fields and cancer? IEEE Philadelphia Section, April 1991.

Currents of death? -- controversy about health effects of electromagnetic fields, Temple University Department of Physics, December 1991.

Currents of Death? - Controversy about Health Effects of Electromagnetic Fields, Engineers' Week Special Lecture, Morristown NJ, February 1992.

Currents of death? - Controversy about health effects of electromagnetic fields. IBM Watson Laboratory, April 1992.

Health effects of electromagnetic fields - a biophysical perspective University of Maryland School of Medicine, Biophysics Department, Baltimore MD, May 1992.

Currents of death? - Controversy about health effects of electromagnetic fields. MIT Lincoln Laboratories, May 1992.

Journalistic standards in reporting on science and health (participant in a panel discussion sponsored by Manhattan Institute, New York, July 1992)

Health Effects of Powerline Fields. IEEE Puerto Rico and Caribbean Section, San Juan PR May 1993.

Biological effects and medical applications of millimeter waves. Temple University Center for Biomedical Physics, Philadelphia PA September 1993.

Phantom Risk: What we cannot know about environmental risk. Commonwealth Club, San Francisco CA, October 1993.

Health effects of powerline fields. Seminar presented at Pennsylvania State University Sept. 1994, also presented at IEEE Susquehenna Section Nov. 1994. Biological effects of powerline fields. University of Minnesota, Minneapolis MN, March 1995.

Radiofrequency interference with medical equipment: how great is the risk? University of Minnesota March 1995.

Radiofrequency interference with medical equipment. IEEE Engineering in Medicine Society meeting, Philadelphia PA May 1995.

Science and nonscience, science and junk science: defining the boundaries. Manhattan Institute symposium, Washington DC June 1995.

Currents of death? The controversy about potential health effects of electromagnetic fields. Department of Physics, University of Toronto, Sept. 1995.

Health effects of wireless communications systems: what are the issues? University of Texas Health Sciences Center, San Antonio Sept. 1995.

Health effects of electromagnetic fields: real or phantom risk? Bioengineering Dept. Northwestern Univ. March 1996.

Science, junk science, and the law. Manhattan Institute, New York. Feb. 1996

Science and the Law, Manhattan Institute, New York, June 1997.

How do we know it works? Columbia University, The Center for Biomedical Engineering, May 1998.

Health and safety implications of wireless communications. Seminar at IEEE Section Morelia, Mexico, Oct. 1998

More heat than light: exposure standards for protection of the public against microwave radiation. University of Texas Health Sciences Center, Oct. 1998

Electromagnetic fields and Cancer. Columbia University, Center for Bioengineering, January 1999.

Health Effects of Electromagnetic Fields. University of Girona, Girona Italy, July 2000.

Health effects of mobile telephones, European Patent Office, Den Haag, August 2000.

Health effects of mobile telephones, Columbia University, Center for Bioengineering, September 2000.
How safe are cell phones? New Jersey Junior Science Symposium (featured talk at a symposium for high school students) Monmouth NJ April 2001

Risks of wireless communications. IEEE Distinguished Lecturer, IEEE Birmingham Section, Birmingham AL April 2001. Similar lectures at Rose Hulman Institute, Terre Haute IN and Drexel University, Philadelphia PA (Oct. 2001), Columbia University (Nov. 2001)

What makes medical technology work? University of Waterloo (Waterloo Ontario) Oct. 2001.

Peering into the Brain. Lecture sponsored by IEEE History Center and Edward J. Bloustein School of Planning and Public Policy, Rutgers University, Nov. 13, 2003

Peering into the Brain: Better Lie Detection through Neuroscience? Dickinson College, Feb. 20, 2004; Loyola Marymount Univ. Dec. 3, 2005

Thermal models for microwave-tissue interaction. COST 281 meeting, Paris, September 2005

Modulation as a factor in biological effects of radiofrequency fields, COST 281 meeting, Zurich, February 2005

Mechanisms of Interaction of ELF Fields with Biological System: Can the Physics and Biology be Reconciled?; Ultrawideband Pulses: Interaction Mechanisms in the Time Domain UNESCO/WHO Seminar and NATO Advanced Research Workshop, Yerevan Armenia March 2005

New methods of polygraph analysis: perils and promises. University of Wisconsin, April 2005

Health Effects of Nonionizing Radiation. Old Dominion University, May 2006

Peering into the Brain. Hale Ethics Lecture, Rochester Institute of Technology, Jan 2008.

Series of three lectures on health effects of electromagnetic fields, Gazi University, Ankara Turkey March 2007

Peering into the Brain: Nonmedical Uses of Neuroscience. Robert M. and Mary Haythornwaite Foundation Distinguished Lecture Series, Temple University, November 2009

Health effects of wireless communications. ASSOCHAM conference on mobiles and health, New Delhi, Feb. 2012

PAPERS PRESENTED AT PROFESSIONAL MEETINGS

The electrical resistivity of aqueous cytoplasm. K. R. Foster, J. M. Bidinger and D. O. Carpenter. Presented at the Biophysical Society 20th Annual Meeting, Seattle, WA, February 1976.

Bounds on bound water: transverse and rotating frame NMR relaxation in barnacle muscle. H. A. Resing, A. N. Garroway, and K. R. Foster. Presented at the American Chemical Society Centennial Meeting, San Francisco, CA, September 1976.

Free water and the microwave conductivity of tissue. H. P. Schwan and K. R. Foster. Presented at the USNC/URSI Annual Meeting, Amherst, MA, October 1976.

Effect of surface cooling and blood flow on the microwave heating of tissue. H. N. Kritikos, K. R. Foster and H. P. Schwan. Presented at the IEEE Microwave Symposium, San Diego, CA, June 1977.

Temperature rise in tissue spheres induced by microwave radiation: a Greens function approach. H. N. Kritikos, K. R. Foster and H. P. Schwan. 1978 Symposium on Electromagnetic Fields, Ottawa, Canada, June 1978.

Auditory responses in cats produced by pulsed ultrasound. K. R. Foster and M. J. Wiederhold. Presented at the 1978 meeting of the Acoustical Society of America, Providence, RI, May 1978.

Dielectric properties of brain tissue between 0.01 and 7 GHz. K. R. Foster, R. D. Stoy and H. P. Schwan. URSI Meeting, Helsinki, Finland, August 1978.

Tissue impedance measurements using the microwave network analyzer. J. L. Schepps, A. W. Friend, Jr. and K. R. Foster. URSI National Radio Symposium, Seattle, WA, June 1979.

Microwave dielectric absorption of muscle tissue: evidence for multiple absorption mechanisms between 1 and 18 GHz. K. R. Foster, J. L. Schepps and H. P. Schwan. International IEEE Symposium, Seattle, WA, June 1979.

The state of water in tissues as indicated by microwave dielectric spectroscopy. K. R. Foster, J. L. Schepps and H. P. Schwan. International Conference on Water and Biological Systems, Bucharest, Romania, June 1980.

UHF and microwave dielectric properties of tissues: variation in tissue dielectric properties with water content. K. R. Foster and J. L. Schepps. Second Annual Meeting of the Bioelectromagnetics Society, San Antonio, TX, September 1980.

Microwave dielectric studies on tissues and heterogeneous materials. Symposium Honoring H. P. Schwan's 65th Birthday, Philadelphia, PA, November, 1980.

Heat transfer in surface-cooled objects subject to microwave heating. K. R. Foster, P. S. Ayyaswamy, T. Sundararajan and K. Ramakrishna. Third Annual Meeting of the Bioelectromagnetics Society, Washington, DC, August 1981.

UHF and microwave dielectric properties of normal and tumor tissues. J. L. Schepps and K. R. Foster. IMPI 16th Annual Symposium, Toronto, Canada, June 1981.

Anisotropic impedance properties of skeletal muscle. B. R. Epstein, R. G. Settle and K. R. Foster. 9th Annual Northeast Bioengineering Conference, Piscataway, NJ, March 1981.

Dielectric dispersion studies on nonionic microemulsions. K. R. Foster, P. C. Jenin, B. R. Epstein and R. A. Mackay. Colloid and Surface Symposium, Cleveland, OH, June 1981.

The effects of high power microwave pulses on red blood cells. S. L. Gartner, A. W. Friend, K. R. Foster and H. Howe Jr. IEEE-MTT Symposium, Los Angeles, CA, July 1981.

Dielectric properties of bone under near-normal physiological conditions. J. D. Kosterich, K. R. Foster and S. R. Pollack. First Annual Bioelectric Growth and Repair Symposium, Philadelphia, PA, September 1981.

Dielectric studies on ionic and nonionic microemulsions. B. R. Epstein, K. R. Foster and R. A. Mackay. 56th National Colloid and Surface Science Symposium, Blacksburg, VA, June 1982.

Dielectric properties of fluid saturated bone. J. D. Kosterich, K. R. Foster and S. R. Pollack. Fourth Annual Meeting of the Bioelectromagnetics Society, Los Angeles, CA, July 1982.

Dielectric studies on ionic and nonionic microemulsions. B. R. Epstein, K. R. Foster and R. A. Mackay. Fourth Annual Meeting of the Bioelectromagnetics Society, Los Angeles, CA, July 1982.

Dielectric properties of DNA at microwave frequencies. K. R. Foster, M. A. Stuchly and A. A. Kraszewski. Fourth Annual Meeting of the Bioelectromagnetics Society, Los Angeles, CA, July 1982.

Dielectric properties of fluid saturated bone: the effects of fluid conductivity. J. D. Kosterich, K. R. Foster and S. R. Pollack. 29th Annual Orthopaedic Research Society Annual Meeting, Anaheim, CA, March 1983.

Perfused phantom tissue models for hyperthermia research. J. W. Baish, P. S. Ayyaswamy and K. R. Foster. 31st Annual Meeting of the Radiation Research Society, San Antonio, TX, February 1983.

Dielectric absorption of bound water and its relation to other transport properties of polymer solutions. E. Cheever, K. R. Foster, J. B. Leonard and F. D. Blum. 5th Annual Meeting of the Bioelectromagnetics Society, Boulder, CO, June 1983.

Transport properties of O/W microemulsions. K. R. Foster, E. Cheever, J. B. Leonard, F. Blum, and R. A. Mackay. American Chemical Society Annual Meeting, Washington, DC, August 1983.

Multicomponent diffusion in microemulsions. E. Cheever, K. R. Foster, F. Blum, and R. A. Mackay, American Chemical Society Annual Meeting, Washington, DC, August 1983.

Thermal properties of tissue-equivalent electromagnetic phantoms. J. B. Leonard, K. R. Foster, and T. Whit Athey, 5th Annual Meeting of the Bioelectromagnetics Society, Boulder, CO, June 1983.

Dielectric properties of water in biological systems. H. P. Schwan and K. R. Foster, Conference on Biophysical Correlates of Cellular Function, Woodlands, TX, June 1983.

Mixture theory and transport properties of phantom tissue materials. K. R. Foster, HPC Working Group Meeting on Hyperthermia Phantoms, Allegheny Hospital, Pittsburgh, PA, February 1984.

Perfused phantom tissue models for microwave research. J. W. Baish, P. S. Ayyaswamy, and K. R. Foster, HPC Working Group Meeting on Hyperthermia Phantoms, Allegheny Hospital, Pittsburgh, PA, February 1984.

Electrical properties of low water content tissues. S. R. Smith and K. R. Foster, Sixth Annual Meeting of the Bioelectromagnetics Society, Atlanta GA, July 1984.

Development of phantom tissue models for hyperthermia research. J. W. Baish, K. R. Foster, and P. S. Ayyaswamy, Eleventh Northeast Bioengineering Conference, Worcester MA, March 1985

Myocardial regional perfusion rate measurements with microwave heating and radiometry, J. B. Leonard, J. W. Baish, D. K. Bogen, and K. R. Foster, Eleventh Northeast Bioengineering Conference, Worcester MA, March 1985

Thermal modeling of vascular tissues subject to microwave heating. J. W. Baish, P. S. Ayyaswamy, and K. R. Foster, Seventh Annual Meeting of the Bioelectromagnetics Society, San Francisco CA, June 1985 (Best Student Paper Award).

Sensitivity of microwave radiometry for detection of subcutaneous targets. E. Cheever and K. R. Foster, Seventh Annual Meeting of the Bioelectromagnetics Society, San Francisco CA, June 1985.

Dynamic phantom design: principle and practice. J. W. Baish, P. S.

Ayyaswamy, and K. R. Foster. IEEE Engineering in Medicine and Biology Meeting, Chicago IL, Sept. 1985.

Radiation patterns from ridged waveguide antennas in lossy media. J. B. Leonard, E. Cheever, and K. R. Foster. 13th Northeast Bioengineering Conference, Philadelphia PA March 1987.

Low frequency relaxation of suspensions of charged particles in electrolyte solution. C. Grosse and K. R. Foster, 13th Northeast Bioengineering Conference, Philadelphia PA March 1987.

The use of coaxial probes for precise dielectric measurements: a reevaluation. B. R. Epstein, M. A. Gealt, and K. R. Foster. IEEE-MTT-S Microwave Symposium, Las Vegas NV, June 1987.

Thermal response of ethanol-fixed perfused kidney using microwave radiometry J. B. Leonard, D. K. Bogen, and K. R. Foster. IEEE Engineering in Medicine and Biology Ninth Annual Conference, Boston MA, November 1987.

The dielectric properties of canine normal and neoplastic splenic tissues. J. C. Astbury, M. H. Goldschmidt, S. Evans, G. W. Neibauer, and K. R. Foster. 14th Northeast Bioengineering Conference, Durham NH, March 1988.

Sensitivity analysis of microwave radiometry for the detection of tumors. E. A. Cheever and K. R. Foster. IEEE Engineering in Medicine and Biology Tenth Annual Conference, New Orleans LA, November 1988.

On the selection of a bioheat equation for modeling hyperthermia treatments. J. W. Baish, K. R. Foster, and P. S.Ayyaswamy, Ninth Annual Meeting of the North American Hyperthermia Group, Seattle WA, March 1989 (Invited Paper)

Currents of death: Controversy about health effects of electromagnetic fields. K. R. Foster. 16th Northeast Bioengineering Conference, State College, PA March 1990. (Plenary Lecture).

Myocardial electrical resistivity mapping in ischemic sheep hearts and healing aneurisms. M. A. Fallert, M. S. Mirotznik, D. K. Bogen, S. W. Downing, E. B. Savage, K. R. Foster, and M. E. Josephson. 63rd Scientific Sessions of the American Heart Association, Dallas TX November 1990 (abstract published in Circulation, Vol 82: pp 451-451 (1990)

Dielectrophoresis and levitation of cells: How are they related and what do they show? K. R. Foster. International Conference on Biophysics of Transmembrane Electric Fields, Baltimore MD 1990.

Dielectrophoresis and levitation techniques for measuring the dielectric properties of colloidal particles. K. R. Foster and H. P. Schwan, IEEE Engineering in Medicine and Biology Annual Meeting, Phila. PA November 1990.

What is an "effect"? - Assessing causation in bioeffects studies. K. R. Foster, IEEE Engineering in Medicine and Biology Annual Meeting, Phila. PA November 1990.

Interaction of electromagnetic fields with biological systems. K. R. Foster.

(Invited Paper). Electro/91 April 1991.

Impedance mapping of myocardial tissue during ischemia. M. S. Mirotznk, M. A. Fallert, D. K. Bogen, and K. R. Foster, 17th Northeast Bioengineering Conference, Hartford CT, April 1991.

Health effects of low-level electromagnetic fields - a challenge to the standards setting process. K. R. Foster. American National Standards Institute Public Conference, Reston VA April 1991.

Biological effects of low-frequency electromagnetic fields: science and its limits in risk assessment (Invited Presentation) American Physical Society, Washington DC (April 1991).

Biological effects of low-frequency electromagnetic fields: science and its limits in risk assessment (Invited Presentation) American Physical Society Spring Meeting, Washington DC (April 1991).

Biological effects of nonionizing electromagnetic fields (Invited presentation). Electromagnetic Energy Policy Alliance, Washington DC April 1991.

Heating characteristics of thin helical antennas. M. S. Mirotznik, N. Engheta, and K. R. Foster. Northeast Bioengineering Conference, Kingston RI, March 1992,

Heating characteristics of thin helical antennas with conducting cores. M. S. Mirotznik, N. Engheta, and K. R. Foster. 1993 IEEE Antennas and Propagation Society/URSI Radio Science Meeting, Ann Arbor MI June 1993.

Radiofrequency energy-induced myocardial lesion growth characteristics using constant power. D. Schwartzman, I. Chang, T. Kamplain, A. Cowen, A. A. Adas, M. S. Mirotznik, K. R. Foster, and C. D. Gottlieb. 1993 American Heart Association Conference, Atlanta GA, November 1993.

Radiofrequency energy-induced myocardial lesion volume and formation rate is increased using a new electrode design. D. Schwartzman, I. Chang, A. A. Adas, M. S. Mirotznik, I. Shai, K. R. Foster, C. D. Gottlieb, F. E. Marchlinski. 1993 American Heart Association Conference, Atlanta GA, November 1993.

Myocardial impedance changes with radiofrequency energy application: effects of temperature and electrode geometry. D. Schwartzman, I. Chang, T. Kamplain, A. Cowen, I. Shai, K. R. Foster, C. D. Gottlieb, 1993 American Heart Association Conference, Atlanta GA, November 1993.

Effect of chronic infarction on myocardial impedance and impedance changes induced by application of radiofrequency energy, D. Schwartzman, I. Chang, K. R. Foster, C. D. Gottlieb, F. E. Marchlinski. 1993 American Heart Association Conference, Atlanta GA, November 1993.

Effect of thermistor location on radiofrequency energy-induced myocardial lesion formation. D. Schwartzman, I. Chang, A. A. Adas, K. R. Foster, F. E. Marchlinski. 1993 American Heart Association Conference, Atlanta GA, November 1993.

What happens to a fusion zone after fusion pores are created in it? Y. K. Wu, R. A. Sjodin, K. R. Foster, and A. E. Sowers, 1992 Annual Meeting of the Biophysical Society (Biophys. J. 64: A 190 (1993).

Analysis of EMF bioeffects relevant to exposures associated with Maglev and conventional electric rail transportation. R. B. Goldberg, W. A. Creasey, K. R. Foster. Annual Review of Research on Biological Effects of Electric and Magnetic Fields from the Generation, Delivery, and Use of Electricity, Savannah, GA. Oct. 1993.

Potential biological effects of electromagnetic fields associated with Maglev and other mass transit electric rail systems. R. B. Goldberg, W. A. Creasey, and K. R. Foster. Presented at Workshop on Safety Research Related to High-Speed Rail and Maglev Passenger Systems, Federal Railroad Administration, Itasca IL Oct. 1993.

Radiofrequency energy delivery results in nonuniform heating patterns. I. Chang, M. S. Mirotznik, D. Schwartzman, C. D. Gottlieb, F. E. Marchlinski, K. R. Foster. 43rd Ann. Scientific Session, American College of Cardiology.

Left ventricular catheter endocardial mapping during sinus rhythm in chronic myocardial infarction: Correlation of electrograms with electrical impedance. D. Schwartzman, I. Chang, M. S. Mirotznik, C. D. Gottlieb, K. R. Foster, F. E. Marchlinski, 43rd Ann. Scientific Session, American College of Cardiology (1994).

Radiofrequency ablation in chronic infarction: an in vitro investigation of endocardial lesion formation and tissue electrical characteristics. D. Schwartzman, I.Chang, M. S. Mirotznik, C. D. Gottlieb, K. R. Foster, F. E. Marchlinski, 43rd Ann. Scientific Session, American College of Cardiology.

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Prediction of myocardial lesion dimensions resulting from application of radiofrequency energy using a numerical model. M. S. Mirotznik, D. Schwartzman, I. Chang, C. D. Gottlieb, F. E. Marchlinski, K. R. Foster, 1994 North American Society of Pacing and Electrophysiology (NASPE).

Epicardial impedance changes with radiofrequency energy application in a porcine model. D. Schwartzman, I. Chang, M. S. Mirotznik, C. D. Gottlieb, K. R. Foster, F. E. Marchlinski, 1994 North American Society of Pacing and Electrophysiology (NASPE).

Electrical resistivity properties of normal and chronically infarcted ovine myocardium. I. Chang, M. S. Mirotznik, D. Schwartzman, C. D. Gottlieb, F. E. Marchlinski, K. R. Foster. Proc. Southeast Bioengineering Conference, April 1994.

Membrane skeleton functional properties can be probed from a new approach to the external application of controlled microforces. A. E. Sowers, J. D. Rosenberg, and K. R. Foster. American Society for Cell Biology 1994 Annual Meeting.

Measurements of permeability and tortuosity in calcaneal trabecular bone. M. J. Grimm, K. R. Foster, and J. L. Williams. 41st Ann. Meeting Orthopaedic Research Society, Feb. 13-16, 1995.

Radiofrequency field surveys in hospitals, S. Arnofsky, P. Doshi, K. R. Foster, D. Hanover, R. Mercado, D. Schleck, and M. Soltys, 21st Northeast Bioengineering Conference, Bar Harbor ME May 1995.

Computer Controlled Multielectrode Impedance Measurement System. I. Chang, C. Helfinstine, R. Gonzalez Garza, K. R. Foster, 21st Northeast Bioengineering Conference, Bar Harbor ME May 1995.

Radiofrequency interference with medical equipment: how big is the threat? Pennsylvania Society for Hospital Safety and Security and Pennsylvania Association of Health Care Risk Management, Hershey PA May 4, 1995.

Wireless communications systems: what are the risks? New Jersey Public Health Association meeting, New Brunswick NJ March 1996.

Mechanisms of Interactions Between Electric Fields and Cells
K. R. Foster and A. E. Sowers, Third Michaelson Conference, Colorado Springs CO Aug. 1996.

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Mechanisms of Interaction of Radiofrequency Fields with Biological Systems As Related to Modulation. Presented at WHO-Sponsored Conference on Biological Effects of Non-Thermal Pulsed and Amplitude Modulated RF Electromagnetic Fields and Related Health Risks, Munich, Germany, November 1996. Published in Non-Thermal Effects of RF Electromagnetic Fields, International Commission on Non-Ionizing Radiation Protection, May 1997, pp. 47-64.

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P J Riu, K R Foster, M S Mirotznik and Leon Axel, "FDTD simulations of induced fields and SAR in the body from MRI scanners", IFMBE Meeting, Nice, France, September 1997. Published in Medical & Biological Engineering & Computing, vol. 35 Supplement Part 2, pp. 767, 1997.

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A múltichannel multielectrode switching system computer controlled for bioelectrical impedance measurements. R. Gonzalez-Garza, J. Delgado-Romero, I.

Chang, and K. R. Foster, X International Conference on Electrical Bio-Impedance, Barcelona, Spain, April 1998.

Whither Bioelectromagnetics? Bioelectromagnetics Society Annual Meeting, St. Petersberg FL, June 1998.

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K. R. Foster, Thermal models for microwave hazards and standards setting. NATO workshop, Slovenia, Oct. 1998.

K. R. Foster, Setting Limits for Electromagnetic Field Exposures: Scaling Considerations Based on Mechanisms. Presented at WHO-Sponsored Conference on Biological Effects of Electromagnetic Fields 300 Hz - 1 MHz, Maastricht The Netherlands, June 1999.

K. R. Foster, E. R. Adair, and K. S. Mylacraine , Thermal modeling of extended (45 minute) exposure of human subject to 2.45 GHz microwave energy. Bioelectromagnetic Society Annual Meeting, Long Beach CA, June 1999.

K. R. Foster, The mechanism paradox: constraints on interactions between rf fields and biological systems, eleventh International Conference on Radiation Research, Dublin, Ireland July 1999. (Paper to appear in Radiation Research).

K. R. Foster and E. R. Adair Heat Transport in Tissues and Thermal and Spatial Averaging of Laser and Microwave Exposures, Second Workshop on Infrared Lasers and Millimeter Waves, Cloudcroft NM, Aug. 1999.

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Health effects of cellular telephones: recent scientific developments. K. R. Foster and J. E. Moulder, Polish GSM Conference, Warsaw, May 2000.

Biological effects and hazards of RF fields. International School of Plasma Physics, Varenna Italy May 2000.

Mechanisms of interaction of RF fields with biological systems, K. R. Foster and J. W. Baish, COST 244-bis workshop, Munich 10 June 2000.

Precautionary approaches to EMF regulation. Air Force symposium on electromagnetic field exposure guidelines. Munich 11 June 2000.

Health issues related to electromagnetic field exposure. Bluetooth conference, Monte Carlo 14 June 2000.

Electromagnetic Field Exposure Standards: Unresolved Issues. 15 International Wroclaw Symposium on Electromagnetic Compatibility, Wroclaw June 2000. Precautionary Approaches to EMF Regulation. International Symposium on Social Implications of Technology (ISTAS), Rome, September 2000.

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What science does not know about environmental risk. National Association of Environmental Law Societies, Houston TX, March 2001.

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Dosimetric studies on electrosurgical units. B. Liljestrand, K. H. Mild, C. Ly, and K. R. Foster, Bioelectromagnetics Society Annual Meeting, Minneapolis, June 2001.

Addressing the Risks of Wireless Communications. High Tech Forum on Communications Engineering, Zhuhai, China June 2001.

The Precautionary Principle. WHO Conference on the Precautionary Principle, Rome, June 2001.

Bioimpedance - Where to Next? XI International Conference on Bio-Impedance, Oslo, Norway June 2001.

Powerline Fields are Possible Carcinogens: Two Recent Reports by Health Agencies. Eighth Annual Michaelson Conference, Kalispell MN August 2001.

Mobile phones and cancer. Portugese Electrical Engineering Association, Lisbon, Dec. 2001

Limits on microthermal heating from microwave energy. FGF forum on mechanisms of interaction of nonionizing radiation and biological systems, Dresden, Dec. 2001

K. R. Foster Thermal modeling of human subjects exposed to microwave energy. Ninth Annual Michaelson Conference, Portland ME August 2002

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K. R. Foster, Can electromagnetic fields trigger application of the precautionary principle? WHO/European Commission Meeting, Luxembourg January 2003

K. R. Foster, Electrochemical treatment of tumors. Michaelson Research Conference, West Yellowstone MT, August 2003

K. R. Foster, Precautionary Principle and Electromagnetic Fields. Michaelson Research Conference, West Yellowstone MT, August 2003

K. R. Foster, Hot Topics in Non-Ionizing Radiation, American Industrial Hygiene Association, Atlanta, May 2004 (invited talk)

K. R. Foster, Internationalism, national security concerns, and scientific societies. IEEE Society on Social Implications of Technology conference (ISTAS), Worcester MA June 2004

K. R. Foster, Thermal models for RF - tissue interaction.

Q Balzano, AR Sheppard, KR Foster, ML Swicord, Field and temperature gradients in tissues near resonant short wires. Bioelectromagnetics Society Annual Meeting, Washington DC June 2004

K. R. Foster, Bioelectromagnetics and Microwaves, International Microwave Power Symposium, Toronto CA July 2004 (keynote talk)

L. Sheikh and K. R. Foster, The Left Ventricular Assist Device: A Multicultural Look at an Expensive Medical Technology 20th Annual IASTS Conference, Baltimore MD. Feb. 2005

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K. R. Foster, Search for new mechanisms of interaction of radiofrequency fields with tissue, URSI conference, Coherence and Electromagnetic Fields in Bioplogical Systems, Prague, Czech Republic, July 2005.

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K. R. Foster, More heat than light: separating thermal from nonthermal effects of radiofrequency energy on biological systems. COST 281 conference on Subtle Thermal Effects of RF-fields, Stuttgart Nov. 2005

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Should children use mobile phones? FGF conference, Stuttgart, Germany, Dec. 2006

K. R. Foster Mechanisms of Interaction of RF Fields With Biological Systems as Related to Modulation, FGF conference, Rostock Germany, September 2006

K. R. Foster, health effects of powerline fields (three lectures). Brasilia,Brazil, Aug 2006

K. R. Foster. One third of a century of research on the biological effects of radiofrequency energy: what have we learned? Workshop on RF dosimetry, Tokyo August 2006

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K. R. Foster, Ethical Implications of New Neuroscience Techniques As Applied to Homeland Security. Fifth International Conference on Ethical Issues in Biomedical Engineering, New York April 2009

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J. S. Sun, M. Doherty, K. R. Foster. Humanitarian Engineering after Katrina, Univ of PA April 2009

K. R. Foster, Fifty years of RF bioeffects research - what have we learned? FGF conference, Stuttgart Germany, Nov. 2009

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K. R. Foster. Malintent: (mis) application of technology for homeland security. Forum on Philosophy, Engineering and Technology, Golden CO May 2010

K. R. Foster Electromagnetic- thermal transduction, International Society For Magnetic Resonance in Medicine, Stillwater MN (Oct. 2010) invited presentation.

K. R. Foster, Murderous Microwaves - Health Effects of Mobile Telephones. Seminar at Univ. of DE 3/16/11.

K. R. Foster and D. Langleben, New Technologies for Homeland Security: What are their ethical implications? 6th Int. Conf. on Homeland Security, April 2011.

K. R. Foster, Present State of Science Regarding Possible Health Risks of Exposure to RF Energy, Andescom, Quito EQ Nov. 2012

K. R. Foster, A World Awash With Wireless Devices, Andescom, Quito EQ Nov 2012

K. R. Foster, Radiofrequency Fields and Health, Colombian Engineering Society, Bogota Colombia May 2013

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FOREWORD

The purpose of this report is to summarize the levels of public exposure to electric and magnetic fields and address health concerns arising from the installation in 2006 of a 345 kV/69 kV East Kentucky Power Cooperative (EKPC) transmission line. The line crosses Mt. Sterling Road, Winchester, Kentucky in a generally north-south direction. The line crosses property owned by Harold and Ann Barker, 5450 Mount Sterling Road, Winchester, KY whose house and garage are located immediately to the western edge of the right of way (ROW). The corner of the garage, a portion of the driveway and some parking areas on the property are located within the ROW.

My discussion will include:

- Summary of the levels of exposure to 60 Hz electric and magnetic fields from the proposed line, a summary of data provided to me by Dr. Benjamin Cotts, Exponent Failure Analysis Associates, 17000 Science Drive Suite 200, Bowie, MD.
- Summary of major international exposure limits and limits in effect in various states.
- A summary of opinions by expert committees under the auspices of health agencies or other internationally recognized bodies about possible health effects of exposure to powerline fields
- A review of the possible links between powerline fields and childhood leukemia, which has been a source of frequent public comment in other proceedings of a similar nature.
- Review of concerns about possible interference from powerline fields and implanted medical devices, in particular cardiac pacemakers, which were raised in the report of John C. Pfeiffer, P.E., an engineer hired by the Barkers.
- Summary of all recent (2010 and later) epidemiology studies published in the peer reviewed scientific literature related to health and residence near high voltage transmission lines.

Executive Summary

There is no applicable state or federal exposure limits to power frequency electric or magnetic fields that would apply in this case. However, the calculated and measured levels to electric and magnetic fields from the line at any place on the Barker property are far below major intemational limits, and below limits that are in effect in other states.

Numerous expert reviews of the possible health effects of powerline fields have failed to identify clear evidence of health problems from power frequency fields at levels that an ordinary citizen would encounter in nonoccupational and nearly all occupational settings, including at levels associated with the EKPC line that is subject of the present case. For the one issue that has prompted the most discussion among the public and health agencies, an association reported in some epidemiology studies between long term exposures to power frequency magnetic fields and childhood leukemia, numerous reviews by health agencies have concluded that the scientific evidence for this effect is limited and not sufficient to conclude that exposure to such fields at levels below intemational safety limits actually or probably does cause such health problems.

A review of recent epidemiology studies on health as related to living near high voltage lines has uncovered no new evidence that would be likely to affect the views of health agencies about the issue.

Extensive research has concluded that calculated and measured field strengths from the line fall well below anticipated thresholds for causing interference to cardiac pacemakers, and no interference is anticipated to other implantable devices as well.

1. Background

East Kentucky Power Cooperative (EKPC) has expanded the right of way (ROW) of an existing 69 kV power transmission line that runs in a north-south direction across the Barker property, and installed an additional 345 kV line within the ROW. The driveway including some parking areas are located within the right of way (ROW) of the line, and the house and garage are close to the westem edge of the ROW; one comer of the garage falls within the ROW.

Power transmission lines (as well as electrical installations of all sorts) produce both electric and magnetic fields, which for practical purposes can be considered to be separate entities at powerline frequencies. In the United States, power transmission lines carry current at 60 Hz (cycles per second). The fields that these lines produce belong to the extremely low frequency (ELF) part of the electromagnetic spectrum. These fields are commonly referred to as EMF (a generic term that applies to electric and magnetic fields in many different frequency ranges) or as ELF fields (which is refers to fields in a frequency range that includes 60 Hz).

Electric fields are associated with the presence of electric charges on the surface of electrical conductors that are held at high potential. Power lines produce electric fields in their surroundings regardless of the amount of current that is flowing through them. The strength of electric fields is measured in volts per meter (V/m) or thousands of volts per meter (kilovolts per meter, kV/m). The fields are strongest directly beneath a transmission line and fall off rapidly with increasing distance from the line. Building materials and trees provide effective shielding for electric fields, and consequently electric field levels measured within a residence or close to trees will be considerably below those calculated for the line in the absence of such structures.

Magnetic fields result from the flow of electric current through the line. The strength of a magnetic field depends on how much current is carried by a conductor, not its voltage, as well as the distance of the conductors above ground and other design parameters of the line. In the scientific literature and in most countries that rely on the metric system, the standard unit of measure of such fields is the tesla (T) or microtesla (μT, one-millionth of a tesla)[1]. An alternative measure that is more commonly used in the United States is the Gauss (G) or milliGauss (mG, one thousandth of a Gauss). One μT = 10 mG. Magnetic fields from a transmission line fall off rapidly with distance from the line. However, building materials do not shield ELF magnetic fields, and magnetic field strengths inside a residence from a power transmission line would be approximately the same as that measured immediately outside the residence.

2. Fields Produced By the Line

I was provided with an analysis by Mr. Benjamin Cotts, Ph.D., of Exponent Failure Analysis Associates, Bowie, MD on behalf of EKPC concerning electric and magnetic field levels produced by the line, both in its "as built" configuration (345/69 kV) and in the previous (69 kV only) configuration. Dr. Cotts also provided a set of measurements of field strengths at the site which agree with the calculated field levels.

Exponent Failure Analysis Associates is a highly experienced firm in this kind of work. The fields were calculated using the program BPA CAFE, which is a standard program used for such calculations and is regarded as highly reliable. Consequently I am confident that the calculated and measured field levels that he provided to me are accurate as of the time of his analysis. The calculations were done using average loading of the line (150/300 A for the two lines) according to information supplied to him by EKPC.

Table 1 below (from data supplied by Dr. Cotts) shows the maximum calculated levels of electric and magnetic fields within the ROW and at its edge. Measurements by Dr. Cotts are in general agreement with these calculations, although in one area of the driveway the measured electric fields were substantially lower than the calculated fields due to shielding by a nearby tree.

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[1] Technically, gauss and Tesla are measures of magnetic flux density; the more familiar term "field strength" is used here.

Table 1. Calculated electric and magnetic fields near and within the ROW of the line (from data supplied by Dr. Cotts, Exponent Failure Analysis)

Configuration	Field	Max on ROW	Western edge of ROW (+75 ft from centerline) (edge of ROW closest to Barker house)	West of ROW, 125 ft from centerline (roughly the center of Barker house)
69-kV (previous to construction of 345 kV line)	Magnetic (mG)	13	4.9	1.6
	Electric (kV/m)	0.3	0.2	0.0
As-Built (69/345 kV lines)	Magnetic (mG)	22	7.7	3.3
	Electric (kV/m)	1.8	1.3	0.4

These results show that the maximum magnetic field at the western edge of the ROW, which corresponds approximately to the eastern edge of the Barkers' house, are 7.7 mG (with the present configuration of the line) vs. 4.9 mG (previous configuration). At a distance that corresponds roughly to the center of the house, the calculated magnetic field is 3.3 mG (present configuration), compared to 1.6 mG (previous).

The corresponding values for the electric field, neglecting shielding effects of the house, increased from 0.2 to 1.3 kV/m at the edge of the ROW. Electric field strengths inside the house would be much lower because of the shielding effect of the building.

The calculated magnetic field levels in Table 1 are comparable to those reported by Mr. Pfeiffer (8 mG at the edge of the house, based on his measurements on Jan. 19, 2012). The calculated electric field strength in Table 1 (1.3 kV/m) at the western edge of the ROW is somewhat higher than those that Mr. Pfeiffer measured (0.257 kV/m), possibly due to shielding effects of the building.

3. Levels of Exposure to ELF Fields to the Population

Everybody in modern society is exposed to EMF from a variety of sources at highly variable levels. Most of the discussion of possible health effects of powerline fields pertains to magnetic field exposure and I focus my discussion on magnetic fields.

Major sources of exposure to ELF magnetic fields include:

a. Near appliances: Electrical appliances, in particular those containing motors, produce relatively strong magnetic fields in their immediate vicinity. Gauger (1985) reported an extensive survey of 100 appliances of 25 different kinds. Within a foot or so of appliances such as electric ranges, microwave ovens, can openers, vacuum cleaners, electric shavers, hair dryers, the peak magnetic fields were typically above 10 mG. Closer to the appliances magnetic fields are much higher, for example 10,000 mG an inch from an electric can opener or 20,000 to 30,000 mG an inch from an electric hair dryer or electric shaver measured in the study. These fields fall off quickly with distance, typically reaching levels below 1 mG at distances greater than 1-3 m from the appliance.

b. In the home, away from appliances: Most of the magnetic field exposure that an individual receives in his/her home, averaged over time, is produced as a result of net currents flowing through household wiring. One survey of 218 single unit detached houses located away from power lines reported a median magnetic field exposure of 0.5 to 0.7 mG in the homes, with 5% of the homes having magnetic field levels above 3 mG (Rankin 2002)[2]. These fields arise from current flowing in wiring in the house and vary depending on the wiring system used in any particular house.

   However, some residential areas have considerably higher ambient field levels. In rooms in apartment buildings that are located close to distribution transformers within the buildings or whose walls contain power distribution lines embedded in them, the magnetic field levels can be relatively strong. One recent survey in Switzerland reported average field levels in some rooms in apartments that were located close to in-building power transformers that were in the range of 6 to 10 mG (Röösli 2011)[3].

c. Near neighborhood distribution lines: These lines carry current typically at voltages between 4-34 kV, between electric substations and distribution transformers that supply individual homes with current at 120-240 V. These lines, which in the United States often run along city streets, may carry currents that are similar in magnitude to those that will be carried by the proposed line, i.e. 100-200 amperes. A primary distribution line carrying 100 amperes of current will produce magnetic field levels of 1 mG at distances more than 50m (160 ft) from the line, depending on the net current that flows along them (Kaune 1993).[4].

As a result of multiple sources of power frequency fields, everybody in modern society is constantly exposed to EMF at highly variable levels. The average levels in the home, away from appliances, are typically around 1 mG but when an individual is in close proximity to appliances or other sources of electric current, the exposures can be far higher. In typical occupational settings, magnetic fields can be considerably higher. For example, Kaune (1993) reported that the mean magnetic field exposure of electrical workers (a rubric that included electronic assemblers, electricians, and equipment repair people) was 5 mG[4].

To give an example of the high variability in a person's exposure to ELF magnetic fields, the website of National Grid[5] (a UK power company) shows the variation in a person's

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[2] Rankin, Richard F., et al. "Results of a multisite study of US residential magnetic fields." Journal of exposure analysis and environmental epidemiology 12.1 (2002): 9-20.
[3] Röösli, Martin, et al. "Extremely low frequency magnetic field measurements in buildings with transformer stations in Switzerland." Science of the Total Environment 409.18 (2011): 3364-3369.
[4] Kaune, W. T. "Assessing human exposure to power-frequency electric and magnetic fields." Environmental health perspectives 101.Suppl 4 (1993): 121.
[5] http://www.emfs.info/Sources+of+EMFs/exposure/

exposure to 50 Hz magnetic fields during the course of a day, as measured by a personal dosimeter worn by the individual. Field levels inside the home of that particular individual, away from appliances, were about 0.5 mG while those in his office at work were about ten times higher, about 5 mG. That individual's peak exposure during that day was 1490 mG during use of an electric drill, while his average exposure during the day was 1.1 mG.

The point of this discussion is that exposures to ELF magnetic fields in ordinary environments are highly variable. The magnetic fields from the 69/345 kV line are somewhat higher than from the previous configuration (69 kV only) but they are still within the range of exposures that Americans encounter in their ordinary environments.

4. Science-Based Exposure Limits for 60 Hz Electric and Magnetic Fields

While they have no legal force in the present case, a variety of exposure guidelines are in effect in other jurisdictions, and several states have "prudent avoidance" policies aimed at implementing low-cost measures to reduce public exposures to magnetic fields from electrical transmission facilities. Neither Kentucky nor the US federal government has exposure limits for 60 Hz electric or magnetic fields that would be relevant to the present case and neither entity has adopted prudent avoidance policies.

Science based limits set by recognized international agencies

Two internationally recognized organizations have established exposure limits for fields at 50/60 Hz. These have no legal force in the United States but provide an indication of conclusions by internationally recognized bodies about exposure limits that are sufficient to protect against all known adverse effects of ELF fields. These limits were based on extensive reviews of the relevant biological literature by expert committees.

1. International Commission on Nonionizing Radiation Protection (ICNIRP)[6]. ICNIRP is the formally recognized non-govemmental organization for setting exposure limits for nonionizing electromagnetic fields by the World Health Organization. Its recommendations are adopted by many countries throughout the world.

   ICNIRP provides two sets of limits: (a) basic restrictions, which provide the maximum electric field strength that are permitted within the body, which is considered to the biologically significant measure of exposure. (b) Reference levels, which are guidelines intended to ensure that the induced electric fields within the body are below the basic restrictions, with an additional safety factor above that incorporated into the basic restrictions.

[6] ICNIRP (International Commission on Non-Ionizing Radiation Protection), "Guidelines for limiting exposure to time-varying electric and magnetic fields (1 KHz to 100 kHz)." Health Physics, vol. 99, no. 6, pp. 818-836, 2010.

The rationale for the ICNIRP limits is described at length in the documentation for the guidelines. The guidelines are designed to protect against all identified hazards of ELF fields, which are associated with electrical stimulation of body tissues. These are acute phenomena that appear immediately after exposure is begun and disappear after exposure is terminated. Electric shock is an example of such an effect which is, moreover, a clear hazard.

The effect that ICNIRP considered to be well established and to occur at the lowest threshold are magnetophosphenes, which are flashes of light that a person experiences when his or her retina is stimulated by small electrical currents that are induced by ELF fields. ICNIRP based its limits on the threshold for this effect even though this effect is not hazardous. Life threatening effects of ELF fields, such as cardiac arrhythmias, require far higher exposure levels than those sufficient to produce magnetophosphenes.

The reference levels are not firm limits, but rather serve as guidelines for exposure levels above which a more detailed evaluation would be needed to ensure compliance with basic restrictions. These reference levels were set by engineers under "worst case" assumptions that consequently lead to overestimates of induced fields within the body under most actual exposure situations. Consequently, ICNIRP guidelines would allow an individual to be exposed to fields considerably above the reference levels provided that the basic restrictions are complied with.

The reference levels set by ICNIRP for public exposure to 60 Hz fields are 2000 mG (magnetic field) and 4.2 kV/m (electric field).

2. The IEEE (formerly called the Institute of Electrical and Electronics Engineers) has adopted a set of limits that are generally similar to ICNIRP but with some differences. For the general public, the limits for 60 Hz magnetic fields (reference levels) are 9040 mG to the head or torso for indefinite durations; limits for arms and legs are considerably higher. The limit for 60 Hz electric field in the ROW of power lines is 10 kV/m.[7]

Both the ICNIRP and IEEE limits are based on similar rationales and aim to protect against all established hazards of EMF, which in most cases are associated with electrical stimulation of tissues in the body. Both limits were designed to avoid magnetophosphenes, which are visual sensations produced when electric fields excite the retina; the effect itself is not hazardous. (The IEEE limit for electric fields beneath power lines protects against excessive electrical currents that might be induced in a

[7] IEEE C95.6, IEEE Standard for Safety Levels Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz. (2002)

person who touches a large conductive object such as a truck that is located in a very strong electric field such as might exist beneath a high voltage power line.) The differences between the ICNIRP and IEEE limits in part arises from different assumptions about the thresholds of electrical stimulation of the retina under different exposure conditions and different assumptions in calculating reference levels. Both sets of limits are far higher than the potential exposure at any place of public access from the Project.

There has been considerable public controversy over the past three decades about possible health effects from long-term exposures to EMF, in particular the possible link between long-term exposures to magnetic fields and childhood leukemia. Both the ICNIRP and IEEE committees considered possible adverse effects of long-term exposure to ELF magnetic fields but concluded that the scientific evidence for such effects was not adequate to establish limits. For example, the IEEE standard (2002) states:

> Established human mechanisms fall within the category of short-term effects. Such effects are understood in terms of recognized interaction mechanisms. Exposure limits defined in this standard are not based on the potential effects of long-term exposure because:
> a) There is not sufficient, reliable evidence to conclude that long-term exposures to electric and magnetic fields at levels found in communities or occupational environments are adverse to human health or cause a disease, including cancer.
> b) There is no confirmed mechanism that would provide a firm basis to predict adverse effects from low-level, long-term exposure.

The ICNIRP (2010) document states:

> It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukemia is too weak to form the basis for exposure guidelines. In particular, if the relationship is not causal, then no benefit to health will accrue from reducing exposure.

As I discuss below, health agencies that have evaluated the literature have arrived at similar conclusions. In the words of the National Radiological Protection Board of the U.K. (now part of Public Health England, a governmental health agency)[8]:

> the overall evidence for adverse effects of EMFs on health at levels of exposure normally experienced by the general public is weak. The least weak evidence is for the exposure of children to power frequency magnetic fields and childhood leukaemia.

State limits

[8] AF McKinlay et al., Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0-300 GHz). Documents of the NRPB: Volume 15, No. 3. Available on the Internet at http://www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1254510622253

Kentucky does not have limits for exposure to electric or magnetic fields that would be relevant to this Project.

New York and Florida have set limits for magnetic fields at the edge of the ROW of high voltage power lines, while six states have limits for electric fields at such locations. The limits for magnetic fields in the two states are 150-200 mG depending on the line voltage. These limits go back a number of years, to the 1980s and 1990s and are not new.

These limits, based on documentation that accompanies them, were not based on expert reviews of the scientific evidence (i.e. the limits are not science-based) and are not designed to prevent identifiable sources of injury. Rather, these limits were established for precautionary reasons. For example, the Florida limits for magnetic fields were based on "status quo cap criteria", i.e. they were put in place to ensure that new transmission technologies do not result in higher magnetic field exposure levels than those from present transmission line technology.

Table 2 summarizes limits adopted by the states that have adopted them.

Table 2. State limits on fields near high voltage transmission lines.

State	Area where limits applies		Field	Limit
Florida	Edge of right-of-way		Electric	2 kV m^{-1}
		230 kV lines or less	Magnetic	150 mG
		500 kV lines		200 mG
	On right of way or adjoining areas	69-230 kV lines	Electric	8 kV m^{-1}
		500 kV lines		10 kV m^{-1}
Minnesota	On right of way		Electric	8 kV m^{-1}
Montana	Edge of right-of-way	May be waved by landowner	Electric	1 kV m^{-1}
	Road crossings		Electric	7 kV m^{-1}
New Jersey	Edge of right-of-way		Electric	3 kV m^{-1}
New York	Edge of right-of-way		Electric	1.6 kV m^{-1}
			Magnetic	200 mG
	Public road crossings		Electric	7 kV m^{-1}
	Private road crossings		Electric	11 kV m^{-1}
	On right of way		Electric	11.8 kV m^{-1}

Oregon	**On right of way**	**Electric**	**9 kV m^{-1}**

Based on data provided to me by Dr. Cotts, the line as built complies with virtually all of these limits. The calculated electric field strength along the western edge of the ROW (1.3 kV/m) is 30% higher than the Montana limit.

In conclusion, with only one exception (Montana), the line as built complies with limits that are in effect in all other states. It complies with major international science-based limits by a very large margin.

Comments on report by Mr. Pfeiffer Mr. Pfeiffer cites other "standards" but he does not discuss the legal basis of these "standards" or the considerations related to their formulation or enforcement.

For example, he cites a "California Safety Limit for Public Schools" of 1.2 mG. I could not find any such regulation. The California Department of Health Services has a setback requirement for schools from power lines. According to a 2001 statement by the Department, "these distances are not based on biological evidence of a health hazard associated with electric and magnetic fields, but rather on the knowledge that magnetic fields strength decreases to background levels with increasing distance."[9,10] These guidelines were not designed to protect against any identified hazard of ELF fields but are precautionary in nature. Moreover, the regulations apply to the siting of schools and are not relevant to the present case.

5. Interference with Medical Devices

In his report, Mr. Pfeiffer raises concerns about possible interference of powerline fields with cardiac pacemakers, and cites a limit by the American Conference of Industrial Hygienists (ACGIH) that individuals with pacemakers should not be exposed to ELF fields above 1 kV/m. I serve on the Physical Agents Committee of ACGIH that originally developed this limit (but was not a member of the Committee when this particular limit was developed) and am closely familiar with ACGIH limits.

The actual statement in the ACGIH document says[11]:

> "Some models of cardiac pacemakers have been shown to be susceptible to interference by power-frequency (50/60 Hz) electric fields as low as 2 kV/m. It is recommended that, lacking specific information on electromagnetic interference from the manufacturer, the exposure of pacemaker and medical electronic device wearers should be maintained at or below 1 kV/m."

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[9] Electric and Magnetic Fields in California Public Schools, California Electric and Magnetic Fields Program 2001, www.dhs.ca.gov/ps/deodc/ehib/emf

[10] California Code of Regulations, Title 5, Division 1, Chapter 13, Subchapter 1 – School Facilities Construction.
Article 2 - School Sites, Paragraph 14010 - Standards for School Site Selection, Item c.

[11] ACGIH Threshold Limit Value statement "Sub-Radiofrequency (30 kHz and Below) And Static Electric Fields", ACGIH, Cincinnati OH 2010.

The basis for this recommendation is a 26 year old review[12] that reported that a small fraction of pacemakers were susceptible to interference when their wearers were in ELF fields above 2 kV/m (however due to fail-safe features in their design, even then the wearer would be protected from injury, by default to a fixed-pacing mode of operation).

I examined the FDA MAUDE database[13] (a database of reports of malfunctions in medical devices, which are required to be submitted to FDA by federal law) for instances of interference to pacemakers, over the data 1/1/1990 – 4/30/14. I uncovered 58 reports of interference to pacemakers, none of which were associated with power lines. (Most of the reported incidents involved device failure of some sort or interference from equipment used during medical procedures.) I also searched through the current medical literature on the possible effects of ELF fields on pacemakers. I could find no reports of <u>any</u> cases of harmful interference to cardiac pacemakers from electric fields beneath high voltage power lines.

There is some literature on possible interference from powerline fields to cardiac pacemakers, and that shows that field levels above that from the EKPC line are needed. For example, Silny and Scholten (2001) studied the immunity levels of pacemakers to electromagnetic interference, and concluded that under "worst-case" assumptions, external field strengths of 3.1 kV/m would be needed to cause interference in the most sensitive pacemaker that they considered. However, it should be noted that observation of interference to a pacemaker in a laboratory study does not imply that a patient would be endangered if such interference occurred in real life. Pacemakers are designed to "fail safe", i.e. default to a fixed pacing mode, to protect the patient in the very unlikely event that interference is produced.

The authors conclude "Thus, it is unlikely that a [cardiac pacemaker] patient has to fear interference with cardiac pacemakers from an electric field in everyday life," specifically including fields in the range of 1 kV/m[14].

A very wide variety of implanted medical devices are currently in use, and this class of devices is expanding rapidly, and it is not possible to examine the immunity characteristics of all implanted devices in use. Moreover, the range of settings that is possible with devices is wide.

However, as a practical matter, manufacturers must design implanted devices with a high level of electromagnetic immunity in view of the many sources of electric and magnetic fields in the environment. The field levels beneath the EKPC line are typical of those encountered beneath power lines and in other environments. The expectation of device manufacturers and regulatory bodies is that "[active implanted medical devices] are

[12] Griffin JC: Cardiac Pacemakers: Effects of Power Frequency Electric and Magnetic Fields. Presented at International Utility Symposium, Health Effects of Electric and Magnetic Fields, Toronto, Canada September 16–19, 1986.
[13] http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfMAUDE/search.cfm
[14] Silny, A. Scholten, J. "The interference threshold of unipolar cardiac pacemakers in extremely low frequency magnetic fields." Journal of medical engineering & technology 25.5 (2001): 185-194.

expected to work uninfluenced as long as the General Public Reference levels of 1999/519/EC are not exceeded."[15]. These limits are the same as ICNIRP limits, i.e. 4.2 kV/m for 60 Hz electric fields, which are considerably above electric field levels beneath the EKPC line.

All active implanted devices are subject to government approval (in the U.S. premarket approval by the FDA) which in turn requires that the device be tested according to immunity standards (IEC 60601-1-2 or ANSI/AAMI PC69:2007). These would ensure that the devices will function correctly at field levels well above 1 kV/m.

From the above discussion, I conclude that it is highly unlikely that a person who has an implanted device will suffer adverse effects from exposure to the electric and magnetic fields beneath the line. Nevertheless, patients with implanted devices should follow recommendations of their physicians and device manufacturers. Unfortunately, recommendations by device manufacturers are often overly general and nonspecific, such as advice to "avoid power lines" without stating maximum allowable field strengths (Mr. Pfeiffer cites some examples). But that does not imply that exposure levels at the levels produced by the EKPC line are actually hazardous to individuals with implanted devices; by all available evidence the actual risks are very small.

6. Conclusion

I conclude from the above analysis that the electric and magnetic fields produced by the EKPC line at the residence of the Barkers are well below major science-based exposure limits for the general population. Moreover, health agencies, in their expert reviews of the scientific literature, have not concluded that any hazards exist from such exposures.

Appendix 1 Childhood Leukemia and Powerline Fields

The possible biological effects of 50/60 Hz electric and magnetic fields have been studied intensively for many years. Since the issue of a possible link between exposure to power frequency magnetic fields and cancer first came up in 1979, that has been the main focus of research, but other health endpoints have been discussed as well. One industry source[16] reports that the total amount of research funds spent on studies of possible biological or health effects of ELF EMF worldwide has been $US 500M.

The literature on biological and health effects of power frequency EMF presently consists of several thousand studies and is far too extensive to review in detail here. In addition to the primary scientific literature, there have been numerous expert reviews of the scientific evidence by expert panels under the auspices of health agencies or other respected agencies.

[15] CENELEC Standard EN 50527-1 "Procedure for the assessment of the exposure to electromagnetic fields of workers bearing active implantable medical devices - Part 1: General" Belgium 2010.
[16] http://www.emfs.info/The+Science/Research/ accessed 3 October 2013

Appendices 1 and 2 will summarize (a) recent assessments of the current scientific evidence by expert panels under the auspices of health agencies or other responsible agency, and (b) discussion of one issue, a possible link between childhood leukemia and power frequency magnetic fields, and (c) summary of very recent developments in this field focusing on epidemiology studies related to residence near power lines that have appeared from 2010 to the present.

Childhood leukemia associated with exposure to magnetic fields

The health concern that has received the most discussion, both by the public and health agencies, is the possible link between exposure to ELF magnetic fields and childhood leukemia. This was first reported in a 1979 paper by Wertheimer and Leeper[17], who reported an association between "wiring codes" (related to proximity of a child's home to neighborhood electric distribution equipment, not high voltage power lines). Leukemia is the most common cancer in children but it is nevertheless very rare, with incidence of acute lymphoblastic leukemia of about 3-8 per 100,000 person-years for children of 19 years or below.[18]

In response to health concerns raised by the Wertheimer-Leeper study, governments and industry around the world have supported extensive research, including dozens of epidemiologic investigations and numerous animal studies.

Virtually all of the epidemiology studies related to childhood leukemia and magnetic field exposures are case-control studies, in which the investigator selects "cases" (individuals with a particular disease) and a similar or larger number of "controls" (healthy individuals) and compares the two groups with respect to the exposure in question. When studying rare diseases, case-control studies are more practical than population-based studies, but they are subject to a number of biases and other errors.[19] This is in addition to the usual caveat about epidemiology studies, that statistical associations between exposures and disease do not necessarily mean that the exposures actually caused the disease.

Selection bias has been widely discussed in connection with the childhood cancer studies. Selection bias arises when a study chooses controls in a way that is not independent of the exposure of the subjects. Because case-control studies on childhood cancer as related to magnetic field exposure have frequently had to solicit far more people to volunteer as controls (had low participation rates) than actually agreed to serve as controls, any small tendency to pick up a disproportionally large number of such individuals from among low exposure groups would skew the results to appear that individuals in the high-exposure group had an increased incidence of disease.

[17] Wertheimer, Nancy, and E. D. Leeper. "Electrical wiring configurations and childhood cancer." American journal of epidemiology 109.3 (1979): 273-284.
[18] Graça M. Dores, Susan S. Devesa, Rochelle E. Curtis, Martha S. Linet and Lindsay M. Morton. Acute leukemia incidence and patient survival among children and adults in the United States, 2001-2007. Blood 2012 119: 34-43.
[19] A. Feinstein, Clinical Epidemiology, W. B. Saunders, Philadelphia 1985.

A second, and very serious problem, is the difficulty in assessing magnetic field exposure. Since childhood cancer is very rare, the only practical studies are retrospective in design, i.e. the investigators identify cases and controls, and try to determine the subjects' exposure to magnetic fields in the years before their disease was identified. Because of the highly variable nature of exposures to power frequency fields in the environment, this is a very difficult task.

Other problems in interpretation arise from the heterogeneity of the results. Some studies reported associations between magnetic field exposure and childhood leukemia risk, while others found no statistically significant associations. A "statistically significant" association means that, by the statistical test that the investigator conducted, the association was probably not a statistical artifact. However the question remains whether it reflects a true cause-effect relation or may have resulted from bias of some sort. For most of the studies that reported statistically significant associations, the associations were near the edge of statistical significance and potential sources of bias are difficult to rule out.

So far, three pooled analyses (which combine results of multiple studies) have been reported. Two of theses studies, which appeared in 2000, are discussed here. The third, by Kheifets et al, appeared in 2010 and will be discussed in a later section.

- Greenland et al[20] pooled data from 15 childhood leukemia studies. This extensively conducted analysis found an odds estimate of 1.52 (95% confidence interval 0.99-2.33) when comparing children living in homes with fields above 0.3 μT with those below 0.1 μT, implying a 50% increase in risk albeit the associations were at the edge of statistical significance.
- At about the same time, Album et al[21] published a pooled analysis of nine childhood leukemia studies, and obtained an estimated summary relative risk of 2.00 (1.27–3.13) for children with residential magnetic field exposures above 0.4μT.

Neither Greenland et al nor Ahlbom et al above argued strongly that this increase was causal (caused by exposure to the magnetic fields) and both investigators qualified their discussion by pointing to significant uncertainties in the interpretation of their results.

For example, Greenland et al (2000) noted:

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[20] Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA. A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Childhood Leukemia-EMF Study Group. Epidemiology 11: 624-34; 2000.
[21] Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, Linet M. McBride M, Michaelis J, Olsen JH, Tynes T, Verkasalo PK. In summary, for exposure up to 0.4μT our data demonstrate relative risks near the no-effect level. For the very small proportion (0.8%) of subjects with exposure above 0.4μT, the data show a two-fold increase, which is unlikely to be due to random vari-ability. The explanation for the elevated risk estimate is unknown, but selection bias may have accounted for some of the increase.Br J Cancer 83: 692-8; 2000

"In light of the above problems, the inconclusiveness of our results seems inescapable; resolution will have to await considerably more data on high electric and magnetic-field exposures, childhood leukemia, and possible bias sources...both our categorical and trend analyses indicate that there is some association comparing fields above 0.3 μT to lower exposures, although there are as yet insufficient data to provide more than a vague sense of its form and its possible sources."

Ahlbom et al likewise concluded:

"In summary, for exposure up to 0.4μT our data demonstrate relative risks near the no-effect level. For the very small proportion (0.8%) of subjects with exposure above 0.4μT, the data show a two-fold increase, which is unlikely to be due to random variability. The explanation for the elevated risk estimate is unknown, but selection bias may have accounted for some of the increase."

Based on these reviews, if there is an increase in risk, it becomes apparent at residential exposure levels in the range 0.2-0.4 μT (2-4 mG). However, neither Greenland et al nor Ahlbom et al argued strongly that the weak associations that they found were causal and both stressed the considerable difficulty in interpreting the results. Difficulties include major uncertainties in exposure assessment (due the variability of magnetic field exposures that an individual experiences over time), varying methodologies used in the studies that they pooled, and lack of knowledge of what parameters of exposure are significant.

One consideration that works against the conclusion that the statistical associations reported in these studies reflects an effect of the fields is the absence of a biophysical mechanism that could account for such effects, despite decades of investigation in search of such a mechanism. Robert Adair, a prominent physicist, presented a strong argument against the possibility of direct effects of ELF magnetic fields at ordinary ambient levels:

"An examination of the physical interaction of such fields with the body shows that such interactions are too weak to have a significant effect on human biology at the cell level. Because of the high electrical conductivity of tissues, the coupling of external electric fields in air to tissue in the body is such that the effects of the internal fields on cells is smaller than thermal noise. Static magnetic fields smaller than the earth's field of 50 μT [500 mG] and varying fields weaker than the 4-μT [40 mG] 60-Hz fields that are equivalent in effect to that from walking in the earth's field, cannot be expected to generate significant biological effects."[22]

A second factor is the general lack of supporting evidence from well designed animal studies of the sort that are conventionally used for carcinogen assessment. For example, a U.S. government funded National Toxicology Program study involving two year (essentially lifetime) exposures to groups of 100 rats at levels up to 10 G (which is more than 3000 times higher than those implicated in the epidemiology studies) concluded

"These data, when considered as a whole, are interpreted as indicating that chronic exposure to pure linearly polarized 60 Hz magnetic fields has little or no effect on cancer development in the F344/N rat."

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[22] Adair, Robert K. "Constraints on biological effects of weak extremely-low-frequency electromagnetic fields." *Physical Review A* 43.2 (1991): 1039.

National Toxicology Program studies are rigorous, well controlled (and very expensive) studies that carry great weight in the cancer risk assessment process of US and international health agencies. The negative results of this massively funded and meticulously conducted study reduces the likelihood that the weak epidemiology evidence points to a real effect of the magnetic fields.

These studies are concerned with estimates of relative risk, i.e. the risk (probability of developing a disease) in an individual who is comparatively highly exposed to magnetic fields compared to someone who is exposed at lower levels. Childhood leukemia is a very rare disease, and the absolute risk (likelihood of developing the disease for any child) is very low. For reasons discussed above, detecting small changes in these small risks is scientifically a very difficult problem.

Expert Reviews of Powerline Fields and Health

Since the issue of possible links between ELF magnetic field exposure and childhood cancer arose in 1979, a massive scientific literature has developed on this topic, ranging from meticulously performed and heavily funded research by major scientific groups, to poor quality research conducted with little or no funding.

The studies range widely in biological endpoint, exposure levels, relevance to health, scientific quality. As typically the case with risk research, the literature is inconsistent in many respects. Most of the studies do not support the conclusion that exposure to powerline fields causes health problems. However, there is a scattering of reports of biological effects, of varying significance to health, at exposure levels in the range of those of present interest, and a scattering of epidemiology studies that report associations of some sort between exposure to ELF fields and some kind of disease.

The most reliable assessment of this literature, with respect to possible health effect of power frequency magnetic fields, is provided by expert reviews under the auspices of health agencies or other credible body. The best of these reviews consider the full range of available evidence and assess the quality of individual studies and try to reconcile inconsistencies in the evidence.

IARC Carcinogen Assessment (2002)

In an extensive report (2002) the International Agency for Research on Cancer (IARC), a component of the World Health Organization, analyzed a large number of scientific reports relevant to possible links between ELF fields and cancer[23]. The IARC Working Group, consisting of epidemiologists, biological scientists, and engineers with varying specialties, considered more than a hundred epidemiological studies of various

[23] International Agency for Research on Cancer. Non-ionizing Radiation. Part 1, Static and Extremely Low-frequency (ELF) Electric and Magnetic Fields. Vol 80. Lyon, France: International Agency for Research on Cancer; 2002

description, together with many relevant animal and laboratory studies. The evaluation was done according to a rigorous procedure specified by IARC.

The IARC review found "limited evidence in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation to childhood leukaemia", "inadequate evidence" in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation to all other cancers, and "inadequate evidence" in experimental animals for the carcinogenicity of extremely low-frequency magnetic fields. (Quotation marks indicate terminology that has special meaning within the IARC decision process).

Based on these considerations, IARC concluded that ELF magnetic fields are "possibly carcinogenic to humans" (Group 2B), while ELF electric fields are "not classifiable as to their carcinogenicity to humans (Group 3).

The classification (2B) is the lowest of several that IARC uses to indicate the weight of evidence that an agent or exposure causes cancer in humans:

Group 1: The agent is carcinogenic to humans (an example is tobacco smoking). As of Aug. 2013, IARC has classified 111 agents or exposure conditions as carcinogenic.[24]

Group 2A: The agent is probably carcinogenic to humans (e.g., being a hairdresser or barber; working in shifts in a job in a way that disrupts regular sleep patterns) (66 agents or exposure conditions).

Group 2B: The agent is possibly carcinogenic to humans. (Example: talc-based body powder, magnetic fields, coffee) (285 agents or exposure conditions).

Group 3: The agent is not classifiable as to its carcinogenicity to humans (ex. tea) (505 agents or exposure conditions).

Group 4: The agent is probably not carcinogenic to humans. Only one substance of the nearly 1000 agents that IARC has evaluated is in this category, caprolactam (used in the production of nylon).

In the context of IARC's decision rules, the 2B ("possibly carcinogenic") designation indicates that the data support some level of suspicion but that the evidence is insufficient to support the conclusion that ELF magnetic fields actually or probably cause cancer in humans under real-world exposure levels.

WHO Environmental Health Criteria Document on ELF Fields (2007)

[24] http://monographs.iarc.fr/ENG/Classification/ accessed 22 Aug. 2013

In 2007 the World Health Organization released an Environmental Health Criteria document on ELF fields (hereafter denoted by ELF-EHC)[25]. This massive review of the literature consists of more than 400 pages and cites nearly 1000 references. It was assembled by a Task Group of experts, most of whom were employees of health agencies worldwide, with additional input and review contributed by 150 scientists from around the world. The review was conducted under an extensive protocol using a weight-of-evidence approach and was designed to provide "an evaluation of risks as far as the data will allow."

The ELF-EHC principally focuses on potential non-cancer risks, but it references and updates the earlier (2002) IARC review of possible carcinogenic effects of ELF fields.

The main conclusions of the ELF-EHC are as follows:

- "[T]here are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public."
- "In 2002, IARC published a monograph classifying ELF magnetic fields as 'possibly carcinogenic to humans'. This classification is used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals... The Task Group concluded that additional studies since then do not alter the status of this classification... However, the epidemiological evidence is weakened by methodological problems... Thus, on balance, the evidence related to childhood leukemia is not strong enough to be considered causal."
- "A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure... The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them."
- "Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukemia, the benefits of exposure reduction on health are unclear."

The EHC presented estimates of the fraction of childhood leukemia cases that might be attributable to exposures to ELF magnetic fields, *assuming* that the data show an increase in risk at exposure levels above 3-4 mG and this is a real effect of the fields. The EHC concluded that roughly 1 to 4% of US cases of childhood leukemia were possibly attributable to magnetic field exposures, *under the assumption* that there is a causal link between exposures to the fields and cancer. This corresponds to 40 to 70 new cases per year in children under 14 years of age throughout the entire country that might be

[25] World Health Organization. Environmental Health Criteria No. 238. Extremely Low Frequency Fields. Geneva, Switzerland: World Health Organization; 2007.

attributable to magnetic field exposure. These small numbers reflect both the low incidence of childhood leukemia (with incidence rates of roughly 5 per 100,000 children per year), and the small fraction of the population that lives in homes with background field levels greater than 3 mG.

In 2006 Greenland and Kheifets extended this analysis[26]. They estimated the "attributable fraction" (i.e., the fraction of all cases of childhood leukemia that might be attributed to exposure to ELF magnetic fields from power lines) and the number of cases in different countries. They estimated that 4.7% of childhood leukemia cases across the U.S. might be attributable to exposure to ELF magnetic fields greater than 3 mG (with confidence limits from 1.6-8.7%). This corresponds to approximately 121 additional cases (range 42-223) of childhood leukemia per year across the entire U.S. The authors estimated that a hypothetical reduction of all exposures by 50% would reduce the number of attributable cases to 26 (uncertainty range 9–49). "The fraction of childhood leukemia cases possibly attributable to ELF exposure across the globe appears to be small," they concluded, "but both no impact and a substantial impact remain possibilities in light of the available data."

Taken together, these two reports from WHO and IARC are undoubtedly the most authoritative assessments of the current scientific data relevant to possible health risks of ELF fields from power distribution and transmission lines. While the 2002 IARC evaluation concludes that the data support some level of suspicion that ELF magnetic fields cause cancer in humans, neither this review nor the 2007 WHO assessment concluded that such fields actually do cause cancer or any other health problem under real-world exposure conditions.

Other Expert Assessments

Many papers on possible health effects and/or biological effects of ELF fields continue to be published, and the literature is reviewed on an ongoing basis by health agencies. These reviews have resulted in a number of detailed reports by expert committees, as well as numerous fact sheets and statements by health agencies and other groups around the world. Virtually all of these assessments are in agreement.

Below is a summary of recent assessments of the scientific literature conducted by independent panels of experts. These reports were selected to provide independent assessment of the scientific evidence related to possible health hazards of powerline fields by expert groups under the auspices of health agencies or other recognized agencies. Fact sheets and other brief statements of opinion by health agencies are excluded, together with statements by industry or other sources.

The main conclusions of these reports related to possible health effects of power frequency fields are also summarized.

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[26]. Greenland S, Kheifets L, Zafanella LE, Kalton GW Leukemia attributable to residential magnetic fields: Results from analyses allowing for study biases, Risk Analysis 26:471 –482 (2006).

- Ireland (2007)[27] (review prepared under the auspices of the Department of Communications, Marine and Natural Resources of Ireland.

  "No adverse health effects have been established below the limits suggested by international guidelines."

- Sweden (2008)[28]. Report by a 9-person independent expert group under the auspices of Sweden's Radiation Protection Authority.

  "New data on childhood leukemia published during the last year does not change the overall conclusions of our previous report, but indicate that a follow-up of survival results [survival of children diagnosed with leukemia as related to ELF-EMF exposure] may be worthwhile. A review of cardiovascular studies concluded that it appears unlikely that ELF causes cardiovascular disease, which is consistent with the evaluation made by WHO EHC."

- European Commission (2009)[29] report of Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR).

  "The few new epidemiological and animal studies that have addressed ELF exposure and cancer do not change the previous assessment that ELF magnetic fields are a possible carcinogen and might contribute to an increase in childhood leukaemia. At present, in vitro studies did not provide a mechanistic explanation of this epidemiological finding. No new studies support a causal relationship between ELF fields and self-reported symptoms. New epidemiological studies indicate a possible increase in Alzheimer's disease arising from exposure to ELF. Further epidemiological and laboratory investigations of this observation are needed. Recent animal studies provided an indication for effects on the nervous system at flux densities from 0.10-1.0 mT [1000-10000 mG]. However, there are still inconsistencies in the data, and no definite conclusions can be drawn concerning human health effects."

ICNIRP International Commission on Non-Ionizing Radiation Protection (2010).[30] Update to guidelines by an international committee that are adopted in most countries around the world.

"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukemia is too weak to form the basis for exposure guidelines. In particular, if the relationship is not causal, then no benefit to health will accrue from reducing exposure.... a causal relationship between magnetic fields and childhood leukemia has not been established nor have any other long term effects been established."

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[27] Department of Communications, Marine, and Natural Resources, Republic of Ireland, Report of the Expert Group on the Health Effects of Electromagnetic Fields, 2007 available on the Internet at

[28] Recent Research on EMF and Health Risks: Fifth Annual Report from SSI's Independent Group on Electromagnetic Fields, Swedish Radiation Protection Agency, 2008. Available on the Internet at http://www.stralsakerhetsmyndigheten.se/Publikationer/Rapport/Avfall-transport-fysiskt-skydd2/2008/200812--Recent-Research-on-EMF-and-Health-Risks-Fifth-annual-report-from-SSIs-Independent-Expert-Group-on-Electromagnetic-Fields-2007/

[29] European Commission. Health Effects of Exposure to EMF, Scientific Committee on Emerging and Newly Identified Health Risks, Directorate-General for Health and Consumers, European Commission, Jan 19 2009. Available on the Internet at http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf

[30] Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz–100 kHz).Health Phys 2010;99(6)·818–36. See: http://www.icnirp.de/ documents/LFgdl.pdf

- Sweden (2010) Update report by an independent expert group under the auspices of the Swedish Radiation Protection Authority. [31]

"Current overall conclusion on epidemiology. For ELF magnetic fields and risk of childhood leukaemia, previous conclusions still hold: a consistent association has been observed, but a causal relationship has not been established. Evidence regarding breast cancer weighs against an increased risk. Little new information has become available concerning parental exposure and risk of childhood cancer. Some evidence for a possible association of Alzheimer's disease with ELF magnetic field exposure has been obtained and further research is warranted."

- European Health Risk Assessment Network on Electromagnetic Fields (EFHRAN)[32] (2010). This review by a committee of experts that was funded by the European Commission, states (with reference to ELF magnetic fields)

> "Although numerous studies have been completed in this field, the evidence remains ambiguous. The major reasons are that study results are inconsistent and many studies suffered from methodological shortcomings.
>
> "For none of the diseases [that the committee considered] is there sufficient evidence for a causal association between exposure to low frequency fields and the risk of the respective disease.
>
> There is limited evidence for an association between magnetic fields and the risk of leukaemia in children. This evaluation reflects the current state of knowledge that epidemiological studies have shown an association between residential exposures to power frequency magnetic fields at above approximately 0.3/0.4 μT [3-4 mG] and a two-fold risk of childhood leukaemia with some degree of consistency, but the observed association alone is not sufficient to conclude a causal relationship. This is because of three reasons:
> i) there is no known mechanistic explanation for the observed association and none of the hypotheses put forward to explain it has received any convincing support from data;
> ii) overall, experimental studies do not provide evidence that low frequency magnetic fields are carcinogenic;
> iii) a combination of chance, bias and confounding may well have produced a spurious association in the epidemiological studies.
>
> It is unlikely that further epidemiological studies of the same design as used earlier will provide any new insight. New concepts to identify cohorts of children with higher exposures may turn out to be promising. If the hypothesis of a poorer survival of children with leukaemia will be confirmed by other studies, this will increase the biological plausibility of a causal association. Conversely, further methodological work investigating the impact of possible biases in the childhood leukaemia studies may shift the evidence in the opposite direction."

An update to this report, issued in 2012[33], examined a handful of recent epidemiology and experimental studies related to health effects of ELF fields, and concluded "[f]or

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[31] Recent research on EMF and health risk. Report 2010:44; 2010. http://www.stralsakerhetsmyndigheten. se/Global/Publikationer/Rapport/Stralskydd/2010/SSM-Rapport-2010-44.pdf.
[32] Report on the analysis of risks associated to exposure to EMF: in vitro and in vivo (animals) studies, July 2010 http://efhran.polimi.it/docs/IMS-EFHRAN_09072010.pdf
Risk analysis of human exposure to electromagnetic fields, July 2010
http://efhran.polimi.it/docs/EFHRAN_D2_final pdf
[33] http://efhran.polimi.it/docs/D2_Finalversion_oct2012.pdf

none of the [examined] diseases is there sufficient evidence for a causal association between exposure to low frequency fields and the risk of the respective disease."

- Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten, SSM). Eighth report from SSM's Scientific Council on Electromagnetic Fields. 2014 Mar.[34]

  According to the SSM press release that accompanied the reportcht[35], "Epidemiological studies show a correlation between low frequency magnetic fields (such as from power lines) and a slightly increased risk of childhood leukemia. But the research has not been able to explain the connection. It could be affected by other environmental factors."

Health Council of The Netherlands (2012)[36]. This report of an expert panel on childhood leukemia under the auspices of Health Council of The Netherlands concludes that

> "[t]he epidemiological findings are insufficiently supported by results from experimental studies and by mechanistic insights into causality, which means that the plausibility of there being a biological mechanism should be considered low. Based on the available evidence from these two types of research, the Committee considers a causal relation between exposure to ELF magnetic fields and ALL [acute lymphocytic leukemia, the most common form of childhood leukemia] or childhood leukaemia in general as possible, whereas the existence of a causal relation between ELF magnetic fields and AML [acute myelogenous leukemia, the most common form of leukemia affecting adults] is unknown."

The committee also commented on the public health relevance of a possible causal relationship between ELF MF exposure and ALL:

> "...if a causal relation exists, and given a total of approximately 110 new ALL cases each year, the number of extra cases of ALL attributed to magnetic exposures from high voltage power lines in the Netherlands is estimated at 0.4-0.5 per year."

BioInitiative Report (most recent edition 2014)[37]

One report stands in significant disagreement with all of the other expert reports cited here. This report, the so-called BioInitiative Report (BIR) was written by a self-selected group of scientists, and considers the evidence to be quite strong that ELF fields at ordinary ambient levels of 2-3 mG actually cause disease. Whereas the 2002 IARC review and the 2007 WHO Environmental Health Criteria review state that there is "limited evidence" that ELF magnetic fields cause cancer, the BIR states: "There is little doubt that exposure to ELF [fields] causes childhood leukemia."

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http://www.stralsakerhetsmyndigheten.se/Publikationer/Rapport/Stralskydd/2014/201416/

[35] http://www.stralsakerhetsmyndigheten.se/Om-myndigheten/Aktuellt/Nyheter/Mobiltelefoni-ny-forskning-tyder-inte-pa-halsorisker/

[36] Health Council of the Netherlands, the Superior Health Council Belgium, and the European Science Advisory Network for Health. Childhood leukemia and environmental factors. 2012 Dec 6. http://www.gezondheidsraad.nl/sites/default/files/201233ChildhoodLeukeamia.pdf

[37] BioInitiative: A Rationale for a Biologically-based Exposure Standard for Electromagnetic Radiation www.bioinitiative.org/report/index.htm

Unlike reviews of the scientific literature conducted by expert panels under the auspices of health agencies, the purpose of the BIR is overtly advocacy, to "document the reasons why current public exposure standards for non-ionizing electromagnetic radiation are no longer good enough to protect public health." Consequently, the BIR is best regarded as an advocacy document rather than an impartial and considered analysis by an impartial agency such as the World Health Organization. .

Health agencies have criticized the BIR and the report has little credibility among health agencies. For example, the Health Council of the Netherlands issued a critique (of the initial 2008 version of the BIR) that concludes that this report "is not an objective and balanced reflection of the current state of scientific knowledge and does not provide any grounds for revising the current views as to the risks of exposure to electromagnetic fields".[38] Nevertheless, the BIR has received wide public attention and is widely cited in public debates about the siting of power lines and other facilities.

Comments on Report by Dr. Carpenter

In his report submitted for this case, Dr. Carpenter states that there is "clearly an elevated risk of a variety of diseases among those who live there". This point of view is also presented in the BioInitiative Report, of which Dr. Carpenter was a principal organizer.

This represents his own personal views, but these views are greatly different from conclusions of major health agencies in their reviews of the issue. These reviews consistently find no persuasive evidence of health hazards from ELF fields below international exposure limits.

Conclusion

The possibility that long term exposure to power frequency magnetic fields might increase risk of childhood leukemia has been debated by scientists, health agencies, and the public since the 1979 study by Wertheimer and Leeper first raised the issue. Now, nearly 35 years later, hundreds of studies have been conducted to address the issue as well as to search for other possible adverse health effects from such exposures.

Numerous reviews by health agencies, standards setting groups, and other expert panels have consistently failed to find evidence that is sufficient to conclude that exposures to 50/60 Hz magnetic fields above 3-4 mG are a "possible" carcinogen, implying some level of suspicion but falling short of concluding that such fields actually cause disease. Moreover, expert reviews by health agencies have concluded that evidence for other possible health effects that have been discussed in some scientific reports is weaker than for childhood leukemia.

[38] The BioInitiative Report, Health Council of the Netherlands, Publication U-5601/EvR/iv/673-LI Publication nr 2008/17E, Sep 2, 2008. Available on the Internet at http://www.gr.nl/en/publications/environmental-health/bioinitiative-report

Given the extremely rare nature of childhood leukemia, several studies have shown that the fraction of all cases of childhood leukemia that might be attributable to magnetic field exposures *even if* there were a causal connection is very low. Consequently the population impact of exposures would be very low even if the fields actually did cause the disease.

Perhaps for this reason, or perhaps because of a sense of diminishing returns after more than 30 years of research on the issue without resolving it, funding for research in this area from US and other Western health agencies has fallen off considerably after a peak during the 1980s. However as noted below a considerable amount of research is still underway on the issue around the world, largely by investigators outside the US and Europe.

Appendix 2 Current Scientific Results

I was asked to review recent scientific developments related to possible health effects of powerline fields. This is a difficult task for two reasons:

- The literature is extremely large. One database on the subject, EMF-Portal (http://www.emf-portal.de), lists more than 400 papers of all sorts related to biological effects of 50/60 Hz fields that were published between 2010-2013. Narrowing the search to only epidemiology studies that mention power lines results in 30 studies over the same period.
- The literature is extremely diverse and variable in quality. Many of the studies are exploratory in nature, of a design that makes them useful for generating hypotheses rather than testing hypotheses that were clearly articulated before the studies. While many of these studies report biological effects, of some sort, such results would need to be independently confirmed and extended to allow any assessment of the significance of the findings. This is the role of a careful weight-of-evidence assessment as would be conducted by an expert committee under the auspices of a health agency.

The following review summarizes all epidemiology studies that I could locate that appeared in the peer reviewed literature from 2010 through late in 2013, on health of individuals as related to exposure to fields from power lines or residential exposure to power frequency magnetic fields from other sources.

The rationale for this choice of papers is that such studies are likely to be most influential in changing the views of health agencies and government regulators about possible health effects of living near power transmission lines. Moreover, these papers are likely to be too current to have been included in expert reviews of the field.

The studies were identified from www.emf-portal.de and their abstracts are quoted from Pubmed. To the best of my ability, these are all of the epidemiology studies that have appeared over the defined time period related to residence near high voltage power lines and disease. Studies are excluded if they principally concemed methodological issues, exposure assessment, or occupational exposures.

The studies are divided between primary studies and meta-analyses/pooled studies. In each group, the studies are listed by descending date of publication.

1. Primary Studies

Adult cancers near high-voltage overhead power lines.
Elliott P, Shaddick G, Douglass M, de Hoogh K, Briggs DJ, Toledano MB (2013), Epidemiology 24 (2): 184 - 190
Aim: A case-control study was conducted in the UK to investigate risks of adult cancers in relation to distance and extremely low-frequency magnetic fields from high-voltage overhead power lines using National Cancer Registry Data in England and Wales, 1974-2008.
Endpoints: leukemia and lymphoma (leukemia); brain tumor (brain tumor and central nervous system cancer); breast cancer (female breast cancer); malignant melanoma
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

Extremely low-frequency magnetic fields are designated as possibly carcinogenic in humans, based on an epidemiologic association with childhood leukemia. Evidence for associations with adult cancers is weaker and inconsistent.

METHODS:

We conducted a case-control study to investigate risks of adult cancers in relation to distance and extremely low-frequency magnetic fields from high-voltage overhead power lines using National Cancer Registry Data in England and Wales, 1974-2008. The study included 7823 leukemia, 6781 brain/central nervous system cancers, 9153 malignant melanoma, 29,202 female breast cancer cases, and 79,507 controls frequency-mEKPChed on year and region (three controls per case except for female breast cancer, one control per case) 15-74 years of age living within 1000 m of a high-voltage overhead power line.

RESULTS:

There were no clear patterns of excess risk with distance from power lines. After adjustment for confounders (age, sex [except breast cancer], deprivation, rurality), for distances closest to the power lines (0-49 m) compared with distances 600-1000 m, odds ratios (ORs) ranged from 0.82 (95% confidence interval = 0.61-1.11; 66 cases) for malignant melanoma to 1.22 (0.88-1.69) for brain/central nervous system cancer. We observed no meaningful excess risks and no trends of risk with magnetic field strength for the four cancers examined. In adjusted analyses at the highest estimated field strength, ≥1000 nanotesla (nT), compared with <100 nT, ORs ranged from 0.68 (0.39-1.17) for malignant melanoma to 1.08 (0.77-1.51) for female breast cancer.

CONCLUSION:

Our results do not support an epidemiologic association of adult cancers with residential magnetic fields in proximity to high-voltage overhead power lines.

Comments (K. R. F.)

A well done study with negative results.

Association between Exposure to Electromagnetic Fields from High Voltage Transmission Lines and Neurobehavioral Function in Children.
Huang J, Tang T, Hu G, Zheng J, Wang Y, Wang Q, Su J, Zou Y, Peng X (2013), PLoS One 8 (7): e67284
Aim: A cross-sectional study was conducted in China to investigate the association between exposure to electromagnetic fields from high voltage transmission lines and neurobehavioral function in children.
Endpoints: neurobehavioral function
Exposure: electric field, magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

Evidence for a possible causal relationship between exposure to electromagnetic fields (EMF) emitted by high voltage transmission (HVT) lines and neurobehavioral dysfunction in children is insufficient. The present study aims to investigate the association between EMF exposure from HVT lines and neurobehavioral function in children.

METHODS:

Two primary schools were chosen based on monitoring data of ambient electromagnetic radiation. A cross-sectional study with 437 children (9 to 13 years old) was conducted. Exposure to EMF from HVT lines was monitored at each school. Information was collected on possible confounders and relevant exposure predictors using standardized questionnaires. Neurobehavioral function in children was evaluated using established computerized neurobehavioral tests. Data was analyzed using multivariable regression models adjusted for relevant confounders.

RESULTS:

After controlling for potential confounding factors, multivariable regression revealed that children attending a school near 500 kV HVT lines had poorer performance on the computerized neurobehavioral tests for Visual Retention and Pursuit Aiming compared to children attending a school that was not in close proximity to HVT lines.

CONCLUSIONS:

The results suggest long-term low-level exposure to EMF from HVT lines might have a negative impact on neurobehavioral function in children. However, because of differences in results only for two of four tests achieved statistical significance and potential limitations, more studies are needed to explore the effects of exposure to extremely low frequency EMF on neurobehavioral function and development in children.

Comments (K. R. F.)

This study involved comparing test scores in two groups of children ages between 9 and 13 enrolled in different schools. The schools differed somewhat in background levels of magnetic fields, with one school (called School B) having significantly higher background field levels (median values 2 mG for School B vs. 0.28 mG for School A) due to a 500 kV power line located 94 m from school B. The mean age of the groups from School A, the control school, was about 0.7 years older than the mean age of the group from School B), and other parameters related to age (e.g. height, total years of education) were also different. The investigators reported a statistically significant difference in scores of two of four tests that they conducted on the children, with children in School A (the older group) performing better on the two tests after correction for a number of variables using a multiple regression model.

This study is impossible to interpret as related to possible effects of field exposure, for two main reasons:

First, the best that the statistical analysis can show is that the difference in test scores between the groups of children from the two schools was, according to the statistical analysis conducted by the authors not likely to be due to random sampling error. But the schools were different, with different teachers and different educational experiences by the students. There is no reason to think that the differences in test scores had anything to do with magnetic field exposure as opposed to some other difference between the schools.

Second, the two groups of students had very similar (average) scores on all of the tests. It is difficult to tell from the study *how large* the differences in test scores were between the two groups of students after correction for the many other variables in the study, but surely the differences were small. It appears likely that the differences in test scores were too small to be of any practical significance.

For these reasons, the study should be considered to be a hypothesis generating study. Indeed, the authors concluded that "more studies are needed to explore the effects of exposure to extremely low frequency EMF on neurobehavioral function and development in children."

The effect of extremely low frequency electromagnetic fields on pregnancy and fetal growth, and development.
Mahram M, Ghazavi M (2013), Arch Iran Med 16 (4): 221 - 224
Aim: A cohort study was conducted in Iran to determine the effect of exposure to extremely low frequency electric and magnetic fields from high-voltage electricity towers and power lines on pregnancy, fetal growth and development in humans.
Endpoints: reproductive effects and pregnancy outcomes (preterm delivery, duration of pregnancy, caesarean section, cause for caesarean section, birth weight and length, head circumference at birth, congenital abnormalities)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line

Abstract (from Pubmed)

Exposure to electromagnetic fields (EMFs) and its effects at different frequencies on living beings has been investigated for decades. However, there are fewer studies that have been conducted on humans, thus this study aims to determine the effect of extremely low frequency (ELF) -EMFs on pregnancy, fetal growth and development in humans.

MATERIAL:

In this epidemiologic analytical cohort study, cases included pregnant women and their newborns. There were 222 women exposed to ELF-EMFs from high voltage electricity towers and cables during pregnancy and 158 women who had no exposure during pregnancy. Data that included pregnancy duration, neonatal birth weight, length, head circumference, gender and congenital malformations were collected through direct questions, measurements and referral to the registered data of related hospital or health center documents. Collected data was analyzed by SPSS-16. $P < 0.05$ was considered significant.

RESULTS:

No significant difference was found in pregnancy duration and preterm labor, neonatal birth weight, length, head circumference and congenital malformations in the two studied groups.

CONCLUSION:

Although the results of this study have shown no significant effects of ELF-EMFs on human pregnancy, fetal growth and development, taking precautionary measures to reduce exposure to EMFs by pregnant women seems logical. Conducting similar studies is strongly recommended.

Comments (K. R. F.)

Another negative study.

Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007.
Sermage-Faure C, Demoury C, Rudant J, Goujon-Bellec S, Guyot-Goubin A, Deschamps F, Hemon D, Clavel J (2013), Br J Cancer 108 (9): 1899 - 1906
Aim: A case-control study was conducted in France to investigate the hypothesis of an increased acute leukemia incidence in children living close to power lines (225-400 kV and 63-150 kV).
Endpoints: childhood leukemia (acute leukemia)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

BACKGROUND:

High-voltage overhead power lines (HVOLs) are a source of extremely low-frequency magnetic fields (ELF-MFs), which are classified as possible risk factors for childhood acute leukaemia (AL). The study was carried out to test the hypothesis of an increased AL incidence in children living close to HVOL of 225-400 kV (VHV-HVOL) and 63-150 kV (HV-HVOL).

METHODS:

The nationwide Geocap study included all the 2779 cases of childhood AL diagnosed in France over 2002-2007 and 30 000 contemporaneous population controls. The addresses at the time of inclusion were geocoded and precisely located around the whole HVOL network.

RESULTS:

Increased odds ratios (ORs) were observed for AL occurrence and living within 50 m of a VHV-HVOL (OR=1.7 (0.9-3.6)). In contrast, there was no association with living beyond that distance from a VHV-HVOL or within 50 m of a HV-HVOL.

CONCLUSION:

The present study, free from any participation bias, supports the previous international findings of an increase in AL incidence close to VHV-HVOL. In order to investigate for a potential role of ELF-MF in the results, ELF-MF at the residences close to HVOL are to be estimated, using models based on the annual current loads and local characteristics of the lines.

Comments (K. R. F.)

With one exception, the study found no statistically significant association between childhood leukemia and proximity of residence to a power line. However, one subgroup of subjects, children aged 0-5 years who lived within 50 m of a 225-440 kV line, had an elevated odds ratio of 2.6 that was at the edge of statistical significance (95% confidence interval 1.0–7.0). Given the large numbers of comparisons that the investigators made in this study, it is difficult to know whether this might be a statistical artifact (false positive result). According to the authors, if this increase is real "it is expected to induce an excess of less than one new case < 15 years per year in France, under steady conditions of residency close to [such high voltage lines]".

Stillbirth and residential proximity to extremely low frequency power transmission lines: a retrospective cohort study.
Auger N, Park AL, Yacouba S, Goneau M, Zayed J (2012), Occup Environ Med 69 (2): 147 - 149
Aim: The association between stillbirth and residential proximity to extremely low frequency power transmission lines was investigated in cohort study in Canada.
Endpoints: reproductive effects and pregnancy outcomes (stillbirth)
Exposure: magnetic

Abstract (from Pubmed)

OBJECTIVES:

The relationship between electromagnetic field exposure and stillbirth has not been evaluated. We assessed associations between residential proximity to extremely low frequency power transmission lines and stillbirth across gestational age.
METHODS:

Data included singleton live births (N=514,826) and stillbirths (N=2033) for 1998-2007 in metropolitan areas of Québec, Canada. Using power transmission line maps, the distances between lines and residential six-digit postal codes (<25, 25-49.9, 50-74.9, 75-99.9, ≥ 100 m) were calculated. Generalised estimating equations were used to compute ORs and 95% CIs for distance and stillbirth, accounting for individual and area characteristics. Early preterm (< 28 weeks), late preterm (28-36 weeks) and term (≥ 37 weeks) stillbirths were examined relative to fetuses-at-risk.
RESULTS:

There was no association between distance and preterm stillbirth. The odds of term stillbirth for <25 m were greater compared to ≥ 100 m (OR 2.25, 95% CI 1.14 to 4.45), but no dose-response pattern was apparent.
CONCLUSIONS:

A graded dose-response trend between distance to lines and odds of stillbirth was not found, but the likelihood of term stillbirth was elevated for residences within 25 m of power transmission lines. Residential proximity to transmission lines is unlikely to be associated with stillbirth, but more research is needed to rule out a possible link.

Comments (K. R. F.)

The authors concluded that their study "found little support for a relationship between residential proximity to power transmission lines and preterm stillbirth, or stillbirth due to fetal anomalies." The one positive finding (a slight elevation in stillbirths at term for women residing within 25 m of a power line was the only positive finding among the 20 comparisons that the investigators conducted. The investigators did not determine the magnetic fields to which the subjects were exposed. There was no dose response relation (no increase in stillbirths with decreasing distance from the line) and no increase in preterm stillbirths among the women living close to the line. This, coupled with the small number of stillbirths to women living near the line (16 stillbirths out of 2899 total births among such women) suggests that the one isolated finding might have been a statistical artifact. At best this is a hypothesis generating study that would need to be followed up by a separate, larger study.

Association between Childhood Leukaemia and Exposure to Power-frequency Magnetic Fields in Middle Europe.
Jirik V, Pekarek L, Janout V, Tomaskova H (2012), Biomed Environ Sci 25 (5): 597 - 601
Aim: A case-control study was conducted in the Czech Republic to investigate the association between exposure to extremely low frequency magnetic fields and childhood leukemia.
Endpoints: childhood leukemia
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, inhouse wiring, residential exposure

Abstract (from Pubmed)

OBJECTIVE:

Higher levels of exposure to extremely low-frequency magnetic fields (ELF-MF) are associated with a slightly increased risk of childhood leukaemia. Compared with more-developed Western countries, higher exposure levels are evident in the Czech Republic, probably because of the different types of housing. In light of this, we aimed to examine the association between ELF-MF exposure and childhood leukaemia in the Czech Republic.

METHODS:

We conducted a paired case-control study. The cases (children with leukaemia) were age- sex- and permanent residence-mEKPChed to controls (children without leukaemia). Although this limited potential bias and confounding, it also limited our number of participants.

RESULTS:

The mEKPChed analyses included 79 case-control pairs. No significant association between ELF-MF exposure and childhood leukaemia was observed for exposures over 0.2 μT (odds ratio [OR]=0.93, confidence interval [CI]=0.45-1.93), 0.3 μT (OR=0.77, CI=0.34-1.75), or 0.4 μT (OR=0.9, CI=0.37-2.22).

CONCLUSION:

Despite higher levels of exposure in Middle and Eastern Europe, no indication of an association between ELF-MF exposure and childhood leukaemia was determined. This in contrast to the findings of previous studies conducted in different countries.

Comments (K. R. F.) Another negative childhood leukemia study. However it was too small to have much statistical power.

A Prospective Study of In-utero Exposure to Magnetic Fields and the Risk of Childhood Obesity.
Li DK, Ferber JR, Odouli R, Quesenberry Jr CP (2012), Sci Rep 2: 540-1 - 540-6
Aim: A prospective cohort study was conducted in the USA to investigate whether prenatal exposure to magnetic fields increases the risk of childhood obesity.
Endpoints: childhood obesity
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, domestic appliance, personal exposure

Abstract (from Pubmed)

We conducted a prospective study to examine whether in-utero exposure to magnetic fields (MFs) increases the risk of childhood obesity. Participating women carried a meter measuring MF levels during pregnancy and 733 of their children were followed up to 13 years to collect clinically recorded information on growth patterns with 33 weight measurements per child on average. Prenatal exposure to high MF level was associated with increased risk of being obese in offspring than those with lower MF level (odds ratio = 1.69, 95% confidence interval: 1.01-2.84). The association demonstrated a dose-response relationship and was stronger (more than 2.3 fold increased risk) among children who were followed up to the end of the study. The association existed only for persistent obesity, but not for transitory (unlikely) obesity. Maternal exposure to high MF during pregnancy may be a new and previously unknown factor contributing to the world-wide epidemic of childhood obesity/overweight.

Comments (K. R. F.)

Very similar comments would apply to this study as for Li's earlier study on asthma (see below): the study had not initially been designed to assess this endpoint, and little information was available possible confounders such as amount of time spent indoors.

Maternal exposure to magnetic fields from high-voltage power lines and the risk of birth defects.
Malagoli C, Crespi CM, Rodolfi R, Signorelli C, Poli M, Zanichelli P, Fabbi S, Teggi S, Garavelli L, Astolfi G, Calzolari E, Lucenti C, Vinceti M (2012), Bioelectromagnetics 33 (5): 405 - 409
Aim: A case-control study was conducted in Italy to investigate whether maternal exposure to magnetic fields from high-voltage power lines during early pregnancy increased the risk of congenital anomalies in the offspring.
Endpoints: reproductive effects and pregnancy outcomes (birth defects)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

The issue of adverse human health effects due to exposure to electromagnetic fields is still unclear, and congenital anomalies are among the outcomes that have been inconsistently associated with such exposure. We conducted a population-based, case-control study to examine the risk of congenital anomalies associated with maternal exposure to magnetic fields (MF) from high-voltage power lines during pregnancy in a community in northern Italy. We identified 228 cases of congenital malformations diagnosed in live births, stillbirths, and induced abortions among women living in the municipality of Reggio Emilia during the period 1998-2006, and a reference group of healthy newborns was mEKPChed for year of birth, maternal age, and hospital of birth. We identified maternal residence during early pregnancy and used Geographic Information System to determine whether the residences were within geocoded corridors with MF ≥0.1 μT [1 mG]near high-voltage power lines, then calculated the relative risk (RR) of congenital anomalies associated with maternal exposure. One case and 5 control mothers were classified as exposed, and the RR associated with MF ≥0.1 μT was 0.2 (95% CI: 0.0-2.0) after adjusting for maternal education. While small or moderate effects may have gone undetected due to low statistical power, the results of this study overall do not provide support for major effects of a teratogenic risk due to exposure to MF during early pregnancy.

Comments (K. R. F.)

The study found no statistically significant association between magnetic field exposure from the power line and birth defects, even at the highest exposure level (>4 mG). However this was a small study with limited statistical power.

Extremely low-frequency magnetic fields and survival from childhood acute lymphoblastic leukemia: an international follow-up study.
Schüz J, Grell K, Kinsey S, Linet MS, Link MP, Mezei G, Pollock BH, Roman E, Zhang Y, McBride ML, Johansen C, Spix C, Hagihara J, Saito AM, Simpson J, Robison LL, Dockerty JD, Feychting M, Kheifets L, Frederiksen K (2012), Blood Cancer J 2: e98

Abstract (from Pubmed)

A previous US study reported poorer survival in children with acute lymphoblastic leukemia (ALL) exposed to extremely low-frequency magnetic fields (ELF-MF) above 0.3 μT [3 mG], but based on small numbers. Data from 3073 cases of childhood ALL were pooled from prospective studies conducted in Canada, Denmark, Germany, Japan, UK and US to determine death or relapse up to 10 years from diagnosis. Adjusting for known prognostic factors, we calculated hazard ratios (HRs) and 95% confidence intervals (CI) for overall survival and event-free survival for ELF-MF exposure categories and by 0.1 μT increases. The HRs by 0.1 μT increases were 1.00 (CI, 0.93-1.07) for event-free survival analysis and 1.04 (CI, 0.97-1.11) for overall survival. ALL cases exposed to >0.3 μT [3 mG] did not have a poorer event-free survival (HR=0.76; CI, 0.44-1.33) or overall survival (HR=0.96; CI, 0.49-1.89). HRs varied little by subtype of ALL. In conclusion, ELF-MF exposure has no impact on the survival probability or risk of relapse in children with ALL.

Comments (K. R. F.)

This is a major study that was designed to follow up two previous reports[39] [40]of poorer survival from childhood leukemia among children with relatively higher exposure to ELF magnetic fields. This study was larger than the previous two, and found no effect of ELF magnetic field exposure and survival probability of childhood leukemia patients.

[39] Foliart, D. E., et al. "Magnetic field exposure and long-term survival among children with leukaemia." British journal of cancer 94.1 (2006): 161-164.
[40] Svendsen, Anne Louise, et al. "Exposure to magnetic fields and survival after diagnosis of childhood leukemia: a German cohort study." Cancer Epidemiology Biomarkers & Prevention 16.6 (2007): 1167-1171.

The relationship between residential proximity to extremely low frequency power transmission lines and adverse birth outcomes.
Auger N, Joseph D, Goneau M, Daniel M (2011), J Epidemiol Community Health 65 (1): 83 - 85
Aim: The association between residential proximity to transmission lines and adverse birth outcomes was investigated in Canada.
Endpoints: reproductive effects and pregnancy outcomes (preterm birth, low birth weight, small-for-gestational-age birth, and infant sex)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

BACKGROUND:

Occupational exposure to electromagnetic fields has been linked to adverse birth outcomes. This study evaluated whether maternal residential proximity to power transmission lines was associated with adverse birth outcomes.

METHODS:

Live singleton births in the Montréal and Québec census metropolitan areas from 1990 to 2004 were extracted from the Québec birth file (N=707,215). Proximity was defined as residing within 400 m of a transmission line. Generalised estimating equations were used to evaluate associations between residential proximity to transmission lines and preterm birth (PTB), low birth weight (LBW), small-for-gestational age (SGA) birth and infant sex, accounting for maternal age, education, marital status, ethnicity, parity, period of birth, and neighbourhood median household income.

RESULTS:

There was no association between residential proximity to transmission lines and PTB, LBW and infant sex in unadjusted and adjusted models. A lower likelihood of SGA birth was present for some distance categories (eg, adjusted OR 0.88, 95% CI 0.81 to 0.95 for 50-75 m relative to ≥400 m).

CONCLUSION:

Residential proximity to transmission lines is not associated with adverse births outcomes.

Comments (K. R. F.) Another negative study on living in proximity to power lines and adverse birth outcome (i.e. no effects observed).

Occupational and residential exposure to electromagnetic fields and risk of brain tumors in adults: a case-control study in Gironde, France.
Baldi I, Coureau G, Jaffre A, Gruber A, Ducamp S, Provost D, Lebailly P, Vital A, Loiseau H, Salamon R (2011), Int J Cancer 129 (6): 1477 - 1484
Aim: A case-control study was conducted in France to investigate the possible association between residential and occupational exposure to electromagnetic fields and the risk of brain tumors in adults.
Endpoints: brain tumor (glioma, meningioma, acoustic neurinoma, and other brain tumor types)
Exposure: mobile phone, radio frequency field, magnetic field, 50/60 Hz (AC), power transmission line, occupational exposure, residential exposure, personal exposure

Abstract (from Pubmed)

The etiology of brain tumors remains largely unknown. Among potential risk factors, exposure to electromagnetic fields is suspected. We analyzed the relationship between residential and occupational exposure to electromagnetic field and brain tumors in adults. A case-control study was carried out in southwestern France between May 1999 and April 2001. A total of 221 central nervous system tumors (105 gliomas, 67 meningiomas, 33 neurinomas and 16 others) and 442 individually age- and sex-mEKPChed controls selected from general population were included. Electromagnetic field exposure [extremely low frequency (ELF) and radiofrequency separately was assessed in occupational settings through expert judgement based on complete job calendar, and at home by assessing the distance to power lines with the help of a geographical information system. Confounders such as education, use of home pesticide, residency in a rural area and occupational exposure to chemicals were taken into account. Separate analyses were performed for gliomas, meningiomas and acoustic neurinomas. A nonsignificant increase in risk was found for occupational exposure to electromagnetic fields [odds ratio (OR = 1.52, 0.92-2.51)]. This increase became significant for meningiomas, especially when considering ELF separately [OR = 3.02; 95 percent confidence interval (95% CI) =1.10-8.25]. The risk of meningioma was also higher in subjects living in the vicinity of power lines (<100 m), even if not significant (OR = 2.99, 95% CI 0.86-10.40). These data suggest that occupational or residential exposure to ELF may play a role in the occurrence of meningioma.

Comments (K. R. F.) This study considered occupational and residential exposure to ELF magnetic fields and brain tumors in adults. It reported statistically significant associations, at the edge of statistical significance, for one tumor with occupational exposure.

The study found no statistically significant association between residence near power lines.
The study was almost completely negative, with only one of 19 comparisons showing a "statistically significant" association. Because of the large number of comparisons reported in this study, the one "statistically significant" result may be a false positive, since one would expect one out of every 20 comparisons to be "statistically significant" due to chance alone. The study is a hypothesis generating study and would need to be followed up by a larger and more focused study.

Maternal exposure to magnetic fields during pregnancy in relation to the risk of asthma in offspring.
Li DK, Chen H, Odouli R (2011), Arch Pediatr Adolesc Med 165 (10): 945 - 950
Aim: A prospective cohort study was conducted in the USA to investigate the relationship between maternal exposure to magnetic fields during pregnancy and the risk of asthma in offspring.
Endpoints: asthma
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, domestic appliance, residential exposure, personal exposure

Abstract (from Pubmed)

To determine whether maternal exposure to high levels of magnetic fields (MFs) during pregnancy is associated with the risk of asthma in offspring.

DESIGN:

A prospective cohort study.

SETTING:

Kaiser Permanente Northern California.

PARTICIPANTS:

Pregnant Kaiser Permanente Northern California members in the San Francisco area.

MAIN OUTCOME MEASURES:

Asthma was clinically diagnosed among 626 children who were followed up for as long as 13 years. All participants carried a meter to measure their MF levels during pregnancy.

RESULTS:

After adjustment for potential confounders, a statistically significant linear dose-response relationship was observed between increasing maternal median daily MF exposure level in pregnancy and an increased risk of asthma in offspring: every 1-mG increase of maternal MF level during pregnancy was associated with a 15% increased rate of asthma in offspring (adjusted hazard ratio [aHR], 1.15; 95% confidence interval [CI], 1.04-1.27). Using the categorical MF level, the results showed a similar dose-response relationship: compared with the children whose mothers had a low MF level (median 24-hour MF level, ≤0.3 mG) during pregnancy, children whose mothers had a high MF level (>2.0 mG) had more than a 3.5-fold increased rate of asthma (aHR, 3.52; 95% CI, 1.68-7.35), while children whose mothers had a medium MF level (>0.3-2.0 mG) had a 74% increased rate of asthma (aHR, 1.74; 95% CI, 0.93-3.25). A statistically significant synergistic interaction was observed between the MF effect and a maternal history of asthma and birth order (firstborn).

CONCLUSION:

Our findings provide new epidemiological evidence that high maternal MF levels in pregnancy may increase the risk of asthma in offspring.

Comments (K. R. F.)

The discussion provoked considerable comment in the scientific community. In an editorial accompanying the paper, Yost and Burch[41] noted that

> "...since the study was not designed with asthma in mind, little information was available on possible confounders for asthma or respiratory disease, which limited the ability of Li et al to control for a long list of other known or potential asthma risk factors, such as allergens (pollen, cockroach or pet dander, mold, mildew), chemical sensitizers (cleaning products, fragrances), stress, diet, social contacts, or respiratory toxins such as air pollutants. Further, only a single 24-hour period was used to measure MF exposures, and it is not possible to carefully examine to what

[41] Yost, Michael G., and James Bradford Burch. "A Recurring Question: Are There Health Effects of Power-Frequency Magnetic Fields?" Archives of pediatrics & adolescent medicine 165.10 (2011): 959.

> extent the measured exposures came from various sources in the environment or to what extent the measured period was representative of the entire exposure interval during pregnancy.

Two subsequent letters to the editor in the same journal pointed to the possibility of confounding effects, by known associations of indoor magnetic fields and air pollution[42] and between childhood asthma and time spent indoors.[43] These possible confounding effects had not been considered by Li et al.

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[42] J. J. Villeneuve, JAMA Pediatrics, Jan 2012, Vol 166 (1):97

[43] J. D. Brain, R. Kavet and P. A. Valberg, "Observations on Power-Line Magnetic Fields Associated With Asthma in Children," Arch. Pediatr. Adolesc. Med., vol. 166, pp. 97-98, JAN, 2012.

Adult mortality from leukemia, brain cancer, amyotrophic lateral sclerosis and magnetic fields from power lines: a case-control study in Brazil.
Marcilio I, Gouveia N, Pereira Filho ML, Kheifets L (2011), Rev Bras Epidemiol 14 (4): 580 - 588
Aim: A death certificate based case-control study was conducted in Brazil to investigate the association between magnetic fields from power lines and adult mortality from leukemia, brain cancer, and amyotrophic lateral sclerosis.
Endpoints: leukemia and lymphoma; brain tumor; neurodegenerative diseases (amyotrophic lateral sclerosis)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line

Abstract (from Pubmed)

Recent publications renewed interest in assessing potential health risks for subjects living close to transmission lines. This study aimed at evaluating the association of both distance of home address to the nearest overhead transmission line and of the calculated magnetic fields from the power lines and mortality from leukemia, brain cancer, and amyotrophic lateral sclerosis. We carried out a death certificate based case-control study accessing adult mortality in the Metropolitan Region of São Paulo, in Brazil. Analysis included 1,857 cases of leukemia, 2,357 of brain cancer, 367 of amyotrophic lateral sclerosis, and 4,706 as controls. An increased risk for mortality from leukemia among adults living at closer distances to transmission lines compared to those living further then 400 m was found. Risk was higher for subjects that lived within 50 m from power lines (OR=1.47; 95% CI=0.99-2.18). Similarly, a small increase in leukemia mortality was observed among adults living in houses with higher calculated magnetic fields (OR=1.61; 95% CI=0.91-2.86 for those exposed to magnetic fields >0.3 μT). No increase was seen for brain tumours or amyotrophic lateral sclerosis. Our findings are suggestive of a higher risk for leukemia among subjects living closer to transmission lines, and for those living at homes with higher calculated magnetic fields, although the risk was limited to lower voltage lines.

Comments (K. R. F.)

The study on the whole was overwhelmingly negative, with weak, barely statistically significant, associations between leukemia and living within 50 m of power lines. The associations became statistically insignificant when the data were corrected for race, schooling, and marital status. There was no association between disease and calculated magnetic field exposure levels.

Exposure to magnetic fields and childhood acute lymphocytic leukemia in Sao Paulo, Brazil.
Wünsch Filho V, Pelissari DM, Barbieri FE, Sant Anna L, de Oliveira CT, de Mata JF, Tone LG, de M. Lee ML, de Andrea MLM, Bruniera P, Epelman S, Odone Filho V, Kheifets L (2011), Cancer Epidemiol 35 (6): 534 - 539
Aim: A case-control study was condueted in Brazil to investigate the effect of exposure to 60 Hz magnetie fields on the occurrenee of childhood acute lymphocytic leukemia.
Endpoints: childhood leukemia (acute lymphocytic leukemia)
Exposure: magnetie field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

Epidemiologieal studies have identified inereased risks of leukemia in children living near power lines and exposed to relatively high levels of magnetie fields. Results have been remarkably consistent, but there is still no explanation for this increase. In this study we evaluated the effect of 60 Hz magnetic fields on acute lymphocytic leukemia (ALL) in the State of São Paulo, Brazil.

METHODS:

This case-control study included ALL cases (n=162) recruited from eight hospitals between January 2003 and February 2009. Controls (n=565) mEKPChed on gender, age, and city of birth were selected from the São Paulo Birth Registry. Exposure to extremely low frequency magnetic fields (ELF MF) was based on measurements inside home and distance to power lines.

RESULTS:

For 24h measurements in children rooms, levels of ELF MF equal to or greater than 0.3microtesla (μT), compared to children exposed to levels below 0.1 μT showed no increased risk of ALL (odds ratio [OR] 1.09; 95% confidence interval [95% CI] 0.33-3.61). When only nighttime measurements were considered, a risk (OR 1.52; 95% CI 0.46-5.01) was observed. Children living within 200 m of power lines presented an increased risk of ALL (OR 1.67; 95% CI 0.49-5.75), compared to children living at 600 m or more of power lines. For those living within 50 m of power lines the OR was 3.57 (95% CI 0.41-31.44).

CONCLUSIONS:

Even though our results are consistent with the small risks reported in other studies on ELF MF and leukemia in children, overall our results do not provide support for an association between magnetic fields and childhood leukemia, but small numbers and likely biases weaken the strength of this conclusion.

Comments (K. R. F.) Another negative study, no statistically significant associations were found between living near power lines and childhood leukemia.

The authors concluded: " we did not observed an increased risk of ALL [acute lymphocytie leukemia] for children with ELF MF exposures equal or above 0.3 m T or above 0.4 m T compared to those exposed to levels lower than 0.1 m T. Increased risks were observed in some subgroup, but results were inconsistent, imprecise and included a null value."

Childhood cancer and magnetic fields from high-voltage power lines in England and Wales: a case-control study.
Kroll ME, Swanson J, Vincent TJ, Draper GJ (2010), Br J Cancer 103 (7): 1122 - 1127
Aim: The case-control study published by Draper et al (2005) investigating the association between childhood cancer and magnetic fields from power lines was reanalyzed applying another method of exposure assessment. In the cited study, exposure assessment was based on the distance from home address at birth to power lines whereas in the present study the magnetic fields of the home address at birth were calculated for each child.
Endpoints: childhood leukemia; childhood brain tumor/cns tumor; other childhood cancer
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

Epidemiological evidence suggests that chronic low-intensity extremely-low-frequency magnetic-field exposure is associated with increased risk of childhood leukaemia; it is not certain the association is causal.

METHODS:

We report a national case-control study relating childhood cancer risk to the average magnetic field from high-voltage overhead power lines at the child's home address at birth during the year of birth, estimated using National Grid records. From the National Registry of Childhood Tumours, we obtained records of 28,968 children born in England and Wales during 1962-1995 and diagnosed in Britain under age 15. We selected controls from birth registers, mEKPChing individually by sex, period of birth, and birth registration district. No participation by cases or controls was required.

RESULTS:

The estimated relative risk for each 0.2 μT increase in magnetic field was 1.14 (95% confidence interval 0.57 to 2.32) for leukaemia, 0.80 (0.43-1.51) for CNS/brain tumours, and 1.34 (0.84-2.15) for other cancers.

CONCLUSION:

Although not statistically significant, the estimate for childhood leukaemia resembles results of comparable studies. Assuming causality, the estimated attributable risk is below one case per year. Magnetic-field exposure during the year of birth is unlikely to be the whole cause of the association with distance from overhead power lines that we previously reported.

Comments (K. R. F.)

Another negative study -- the study found no statistically significant association between magnetic field exposure from power transmission lines and cancer. However it was too small to have much statistical power.

Exposure to magnetic fields and the risk of poor sperm quality.
Li DK, Yan B, Li Z, Gao E, Miao M, Gong D, Weng X, Ferber JR, Yuan W (2010), Reprod Toxicol 29 (1): 86 - 92
Aim: A population-based case-control study was conducted in China to investigate whether exposure to high magnetic field levels reduces sperm quality.
Endpoints: reproductive effects and pregnancy outcomes (fertility (sperm quality: volume, pH, vitality, morphology, motility))
Exposure: 50 Hz - 60 Hz, magnetic field, 50/60 Hz (AC), personal exposure

Abstract (from Pubmed)

We conducted a population-based case-control study among healthy sperm donors to study exposure to magnetic fields (MFs) and poor sperm quality. All participants wore a meter to capture daily MF exposure. After controlling for confounders, compared to those with lower MF exposure, those whose 90th percentile MF level > or = 1.6mG had a two-fold increased risk of abnormal sperm motility and morphology (odds ratio (OR): 2.0, 95% confidence interval (CI): 1.0-3.9). Increasing duration of MF exposure above 1.6 mG further increased the risk (p=0.03 for trend test). Importantly, the association and dose-response relationship were strengthened when restricted to those whose measurement day reflected their typical day of the previous 3 months (a likely period of spermatogenesis). Age-adjusted Spearman Rank Order Correlations showed an inverse correlation between MF exposure and all semen parameters. Our study provides some evidence for the first time that MF exposure may have an adverse effect on sperm quality.

Comments (K. R. F.)

Appears to be the first report of this kind of effect. The results on the whole are weak, most of the comparisons were not statistically significant, there appears to be a considerable amount of post hoc analysis of the data, and it does not appear that the study had been done blinded. Nevertheless the study raises questions that should be addressed by additional studies.

Risk of hematological malignancies associated with magnetic fields exposure from power lines: a case-control study in two municipalities of northem Italy.
Malagoli C, Fabbi S, Teggi S, Calzari M, Poli M, Ballotti E, Notari B, Bruni M, Palazzi G, Paolucci P, Vinceti M (2010), Environ Health 9: 16
Aim: A case-control study was conducted in Italy to investigate the association between magnetic fields exposure generated by power lines and the risk of leukemia and other hematological cancers in children.
Endpoints: childhood leukemia (acute lymphoblastic leukemia, all types of leukemia); childhood lymphoma (all malignant neoplasms of the lymphatic and hematopoietic tissue)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

BACKGROUND:

Some epidemiologic studies have suggested an association between electromagnetic field exposure induced by high voltage power lines and childhood leukemia, but null results have also been yielded and the possibility of bias due to unmeasured confounders has been suggested.

METHODS:

We studied this relation in the Modena and Reggio Emilia municipalities of northern Italy, identifying the corridors along high voltage power lines with calculated magnetic field intensity in the 0.1-<0.2, 0.2-<0.4, and > or = 0.4 microTesla ranges. We identified 64 cases of newly-diagnosed hematological malignancies in children aged <14 within these municipalities from 1986 to 2007, and we sampled four mEKPChed controls for each case, collecting information on historical residence and parental socioeconomic status of these subjects.

RESULTS:

Relative risk of leukemia associated with antecedent residence in the area with exposure > or = 0.1 microTesla [1 mG] was 3.2 (6.7 adjusting for socioeconomic status), but this estimate was statistically very unstable, its 95% confidence interval being 0.4-23.4, and no indication of a dose-response relation emerged. Relative risk for acute lymphoblastic leukemia was 5.3 (95% confidence interval 0.7-43.5), while there was no increased risk for the other hematological malignancies.

CONCLUSIONS:

Though the number of exposed children in this study was too low to allow firm conclusions, results were more suggestive of an excess risk of leukemia among exposed children than of a null relation.

Comments (K. R. F.)
A negative study, no statistically significant associations. However the study was small and of limited statistical power.

Power-frequency magnetic fields and childhood brain tumors: a case-control study in Japan.
Saito T, Nitta H, Kubo O, Yamamoto S, Yamaguchi N, Akiha S, Honda Y, Hagihara J, Isaka K, Ojima T, Nakamura Y, Mizoue T, Ito S, Eboshida A, Yamazaki S, Sokejima S, Kurokawa Y, Kabuto M (2010), J Epidemiol 20 (1): 54 - 61

Abstract (from Pubmed)

BACKGROUND:

The strength of the association between brain tumors in children and residential power-frequency magnetic fields (MF) has varied in previous studies, which may be due in part to possible misclassification of MF exposure. This study aimed to examine this association in Japan by improving measurement techniques, and by extending measurement to a whole week.

METHODS:

This population-based case-control study encompassed 54% of Japanese children under 15 years of age. After excluding ineligible targeted children, 55 newly diagnosed brain tumor cases and 99 sex-, age-, and residential area-mEKPChed controls were included in the analyses. The MF exposures of each set of mEKPChing cases and controls were measured in close temporal proximity to control for seasonal variation; the average difference was 12.4 days. The mean interval between diagnosis and MF measurements was 1.1 years. The weekly mean MF level was defined as the exposure. The association was evaluated using conditional logistic regression analysis that controlled for possible confounding factors.

RESULTS:

The odds ratios (95% CI) for exposure categories of 0.1 to 0.2, 0.2 to 0.4, and above 0.4 microT, against a reference category of <0.1 microT (1 mG), were 0.74 (0.17-3.18), 1.58 (0.25-9.83), and 10.9 (1.05-113), respectively, after adjusting for maternal education. This dose-response pattern was stable when other variables were included in the model as possible confounding factors.

CONCLUSIONS:

A positive association was found between high-level exposure-above 0.4 microT [4 mG] and the risk of brain tumors. This association could not be explained solely by confounding factors or selection bias.

Comments (K. R. F.)
Reports a (barely) statistically significant association between ELF MF exposure above 4 mG and childhood brain tumors, however the study was small with very limited statistical power. The appearance of a dose-response function strengthens the (otherwise weak) case that there may be a causal link here.

Living near overhead high voltage transmission power lines as a risk factor for childhood acute lymphoblastic leukemia: a case-control study.
Sohrabi MR, Tarjoman T, Abadi A, Yavari P (2010), Asian Pac J Cancer Prev 11 (2): 423 - 427
Aim: A case-control study was conducted in Iran to investigate whether living near power transmission lines is associated with an increased risk of childhood acute lymphoblastic leukemia.
Endpoints: childhood leukemia (acute lymphoblastic leukemia)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

This study aimed to investigate association of living near high voltage power lines with occurrence of childhood acute lymphoblastic leukemia (ALL). Through a case-control study 300 children aged 1-18 years with confirmed ALL were selected from all referral teaching centers for cancer. They interviewed for history of living near overhead high voltage power lines during at least past two years and compared with 300 controls which were individually mEKPChed for sex and approximate age. Logistic regression, chi square and paired t-tests were used for analysis when appropriate. The case group were living significantly closer to power lines ($P<0.001$). More than half of the cases were exposed to two or three types of power lines ($P<0.02$). Using logistic regression, odds ratio of 2.61 (95%CI: 1.73 to 3.94) calculated for less than 600 meters far from the nearest lines against more than 600 meters. This ratio estimated as 9.93 (95%CI: 3.47 to 28.5) for 123 KV, 10.78 (95%CI: 3.75 to 31) for 230 KV and 2.98 (95%CI: 0.93 to 9.54) for 400 KV lines. Odds of ALL decreased 0.61 for every 600 meters from the nearest power line. This study emphasizes that living close to high voltage power lines is a risk for ALL.

Comments (K. R. F.)
Did not determine the magnetic field exposures. At the distances considered in this study, the magnetic field levels from power transmission lines would be very small, probably below ambient levels from other sources.

2. Meta-Analyses/Pooled Analyses

A Meta-Analysis on the Relationship between Exposure to ELF-EMFs and the Risk of Female Breast Cancer.
Chen Q, Lang L, Wu W, Xu G, Zhang X, Li T, Huang H (2013), PLoS One 8 (7): e69272-1 - e69272-9
Exposure: magnetic field, 50/60 Hz (AC), power transmission line. in-house wiring, electric blanket, domestic appliance, occupational exposure, residential exposure, personal exposure

Abstract (from Pubmed)

To comprehensively analyze the relationship between exposure to extremely low frequency electromagnetic fields (ELF-EMFs) and the development of female breast cancer.

METHODS:

Reports of case-control studies published from 1990 to 2010 were analyzed. The quality effect model was chosen to calculate total odds ratio (OR) depending on the data in studies and quality scores. Subgroup analyses were also performed by the situation of menopause, estrogenic receptor and exposure assessment respectively.

RESULTS:

For all 23 studies the OR was 1.07, 95% CI=1.02-1.13, for estrogen receptor positive subgroup,OR=1.11, 95% CI=1.03-1.20; for premenopausal subgroup, OR=1.11, 95% CI=1.00-1.23. The results of other subgroups showed no significant association between ELF-EMF and female breast cancer.

CONCLUSION:

ELF-EMFs might be related to an increased risk for female breast cancer, especially for premenopausal and ER+ females. However, it's necessary to undertake better epidemiologic researches to verify the association between ELF-EMF and female breast cancer due to the limits of current study, especially the one on exposure assessment.

Comments (K. R. F.)

The investigators combined results from a number of different studies involving several different kinds of exposure to magnetic fields at varying levels (use of electric blankets, residential and workplace exposures) at different exposure levels (which were not stated). Indeed, in many of the studies, particularly occupational studies, the magnetic field exposure was not even determined. In addition, in the subset of 5 studies in the analysis that involved residential exposures to magnetic fields, there was no statistically significant association between magnetic field exposure and breast cancer

Extremely low-frequency electromagnetic fields exposure and female breast cancer risk: a meta-analysis based on 24,338 cases and 60,628 controls.
Chen C, Ma X, Zhong M, Yu Z (2010), Breast Cancer Res Treat 123 (2): 569 - 576
Aim: A meta-analysis was performed to evaluate the risk of female breast cancer associated with extremely low-frequency electromagnetic fields exposure.
Endpoints: breast cancer
Exposure: electric field, magnetic field, 50/60 Hz (AC), electric blanket, occupational exposure, residential exposure

Abstract (from Pubmed)

Exposure to extremely low-frequency electromagnetic fields (ELF-EMF) has been suggested to increase female breast cancer risk; however, the data have been inconclusive. In order to derive a more precise estimation of the relationship, a meta-analysis was performed. Medline, PubMed, Embase, the Cochrane Library and Web of Science were searched. Crude ORs with 95% CIs were used to assess the strength of association between ELF-EMF exposure and female breast cancer risk. A total of 15 studies published over the period 2000 to 2009 including 24,338 cases and 60,628 controls were involved in this meta-analysis. The results showed no significant association between ELF-EMF exposure and female breast cancer risk in total analysis (OR = 0.988, 95% CI = 0.898-1.088) and in all the subgroup analyses by exposure modes, menopausal status, and estrogen receptor status. This result is in accordance with the previous meta-analysis carried out by Erren in 2000. In conclusion, this meta-analysis suggests that ELF-EMF exposure has no association with the susceptibility of female breast cancer.

Comments (K. R. F.)

A negative study – this analysis shows no association between ELF-EMF exposure and female breast cancer.

Pooled analysis of recent studies on magnetic fields and childhood leukaemia.
Kheifets L, Ahlbom A, Crespi CM, Draper G, Hagihara J, Lowenthal RM, Mezei G, Oksuzyan S, Schüz J, Swanson J, Tittarelli A, Vinceti M, Wünsch-Filho V (2010), Br J Cancer 103 (7): 1128 - 1135
Aim: The association between extremely low-frequency magnetic fields and childhood leukemia was investigated in a pooled analysis of seven recent studies. Following studies conducted after the pooled analyses of Greenland et al (2000) and Ahlbom et al (2000) were included: Bianchi et al, 2000 (Italy), Schüz et al, 2001 (Germany), Kabuto et al, 2006 (Japan), Lowenthal et al, 2007 (Tasmania/Australia), Malagoli et al, 2010 (Italy), Kroll et al, 2010 (UK), and Wunsch Filho, Brazil (personal communication, 2009).
Endpoints: childhood leukemia (especially acute lympoblastic leukemia)
Exposure: magnetic field, 50/60 Hz (AC), power transmission line, residential exposure

Abstract (from Pubmed)

BACKGROUND:

Previous pooled analyses have reported an association between magnetic fields and childhood leukaemia. We present a pooled analysis based on primary data from studies on residential magnetic fields and childhood leukaemia published after 2000.

METHODS:

Seven studies with a total of 10,865 cases and 12,853 controls were included. The main analysis focused on 24-h magnetic field measurements or calculated fields in residences.

RESULTS:

In the combined results, risk increased with increase in exposure, but the estimates were imprecise. The odds ratios for exposure categories of 0.1-0.2 μT, 0.2-0.3 μT and ≥0.3 μT, compared with <0.1 μT, were 1.07 (95% CI 0.81-1.41), 1.16 (0.69-1.93) and 1.44 (0.88-2.36), respectively. Without the most influential study from Brazil, the odds ratios increased somewhat. An increasing trend was also suggested by a nonparametric analysis conducted using a generalized additive model.

CONCLUSIONS:

Our results are in line with previous pooled analyses showing an association between magnetic fields and childhood leukaemia. Overall, the association is weaker in the most recently conducted studies, but these studies are small and lack methodological improvements needed to resolve the apparent association. We conclude that recent studies on magnetic fields and childhood leukaemia do not alter the previous assessment that magnetic fields are possibly carcinogenic.

Comments (KRF)
This pooled analysis, focusing on studies published since 2010, found no statistically significant associations between magnetic fields and childhood leukemia. However, as the investigators pointed out, the total number of subjects was too low to allow the analysis to have much statistical power and the results, while negative, are nevertheless not sufficient to contradict two previous pooled analyses by Greenland and Ahlbom in 2000.

A Pooled Analysis of Extremely Low-Frequency Magnetic Fields and Childhood Brain Tumors.
Kheifets L, Ahlbom A, Crespi CM, Feychting M, Johansen C, Monroe J, Murphy MF, Oksuzyan S, Preston-Martin S, Roman E, Saito T, Savitz D, Schüz J, Simpson J, Swanson J, Tynes T, Verkasalo P, Mezei G (2010), Am J Epidemiol 172 (7): 752 - 761
Aim: The association between extremely low-frequency magnetic fields and childhood brain tumors was investigated in a pooled analysis of 10 studies. The following studies were included: Savitz et al. (1988), Feychting et al. (1993), Olsen et al. (1993), Verkasalo et al. (1993), Preston-Martin et al. (1996), Tynes et al. (1997), UK Childhood Cancer Study Investigators (1999), Schüz et al. (2001), Saito et al. (2010), and Kroll et al. (2010).
Endpoints: childhood brain tumor/cns tumor
Exposure: magnetic field, 50/60 Hz (AC), residential exposure

Abstract (from Pubmed)

Pooled analyses may provide etiologic insight about associations between exposure and disease. In contrast to childhood leukemia, no pooled analyses of childhood brain tumors and exposure to extremely low-frequency magnetic fields (ELF-MFs) have been conducted. The authors carried out a pooled analysis based on primary data (1960-2001) from 10 studies of ELF-MF exposure and childhood brain tumors to assess whether the combined results, adjusted for potential confounding, indicated an association. The odds ratios for childhood brain tumors in ELF-MF exposure categories of 0.1-<0.2 μT, 0.2-<0.4 μT, and ≥0.4 μT were 0.95 (95% confidence interval: 0.65, 1.41), 0.70 (95% CI: 0.40, 1.22), and 1.14 (95% CI: 0.61, 2.13), respectively, in comparison with exposure of <0.1 μT (1 mG). Other analyses employing alternate cutpoints, further adjustment for confounders, exclusion of particular studies, stratification by type of measurement or type of residence, and a nonparametric estimate of the exposure-response relation did not reveal consistent evidence of increased childhood brain tumor risk associated with ELF-MF exposure. These results provide little evidence for an association between ELF-MF exposure and childhood brain tumors.

Comments (KRF)

Another negative study – this careful pooled analysis provides no consistent evidence for a link between ELF-MF exposure and childhood brain tumors.

CONCLUSIONS

The studies summarized in this Appendix represent a similar mix of (weakly) positive and negative results that has characterized the literature in this field for many years. Several of the "positive" studies have easily identified and serious methodological problems, while several of the "negative" studies were too small, with insufficient statistical power, to add much to previously published literature on the questions that they addressed.

In my opinion, these results would not change the conclusions of health agencies about the lack of persuasive evidence for health effects of ELF fields to citizens produced by high voltage power transmission lines.