BLAIR
& ROWADY, P.S.C.
ATTORNEYS AT LAW

M. Alex Rowady
Kimberly Carter Blair

Of Counsel
Michael A. Rowady

212 South Maple Street
Winchester, Kentucky 40391
Telephone 859-744-3251/744-3272
Facsimile 859-745-0729

RECEIVED
MAY 12 2014
PUBLIC SERVICE
COMMISSION

May 12, 2014

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

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

Dear Mr. Derouen:

Enclosed please find for filing with the Commission in the above-referenced case an original and eight (8) copies of the Complainants' Response to the Data Requests served by the Defendant.

Very truly yours,

M. Alex Rowady

MAR/abh
Enclosures
David S. Samford, Esq. (with enclosure)

COMMONWEALTH OF KENTUCKY
BEFORE THE PUBLIC SERVICE COMMISSION
CASE NO. 2013-00291

HAROLD BARKER;	)	
ANN BARKER; and	)	
BROOKS BARKER,	)	
COMPLAINANTS	)	
	)	**RESPONSE OF COMPLAINANTS**
V.	)	**TO DATA REQUESTS SERVED**
	)	**BY DEFENDANT**
EAST KENTUCKY POWER	)	
COOPERATIVE, INC.,	)	
DEFENDANT	)	

* * * * * * * * * * * * * * * * * *

Come the Complainants, Harold Barker, Ann Barker and Brooks Barker, by counsel, and file the attached Response to Data Requests served by Defendant.

Respectfully submitted,

M. ALEX ROWADY, ESQ.
Blair & Rowady, P.S.C.
212 South Maple Street
Winchester, Kentucky 40391
(859) 744-3251
ATTORNEY FOR COMPLAINANTS

CERTIFICATE OF SERVICE

This is to certify that the original and eight true copies of the foregoing was hand-delivered to Kentucky Public Service Commission, P.O. Box 615, Frankfort, Kentucky 40602-0615 and a true copy was sent by first-class mail to David S. Samford, Esq., Gross Samford, PLLC, 2365 Harrodsburg Road, Suite B235, Lexington, Kentucky 40504, this 12th day of May, 2014.

M. ALEX ROWADY, ESQ.

COMMONWEALTH OF KENTUCKY
BEFORE THE PUBLIC SERVICE COMMISSION
CASE NO. 2013-00291

HAROLD BARKER; **ANN BARKER; and** **BROOKS BARKER,** **COMPLAINANTS**	)	
V.	)	**TESTIMONY OF ANN BARKER and BROOKS BARKER**
EAST KENTUCKY POWER COOPERATIVE, INC., **DEFENDANT**	)	

* * * * * * * * *

ANN BARKER and **BROOKS BARKER**, after being duly sworn, testify as follows:

1. They are Complainants in the above-styled matter.

2. Complainant Ann Barker, along with her husband, Complainant Harold Barker, own real property located at 5450 Mt. Sterling Road, Winchester, Kentucky. Defendant East Kentucky Power Cooperative, Inc. owns and operates a 345 kV/138 kV transmission line which runs through said property.

3. They have attached hereto a joint statement which they adopt as their testimony herein.

Ann Barker
ANN BARKER

Brooks Barker
BROOKS BARKER

STATE OF KENTUCKY)
) s.s.
COUNTY OF CLARK)

Subscribed and sworn to before me by **ANN BARKER** and **BROOKS BARKER**, on this 12 day of May, 2014.

My commission expires: 4/19/16.

NOTARY PUBLIC
STATE OF KENTUCKY AT LARGE

ASHLEY B. HOLLEY
NOTARY PUBLIC
ID NO. 404995
MY COMMISSION EXPIRES 4/10/2016
STATE AT LARGE, KY.

Prepared by:

M. ALEX ROWADY, ESQ.
Blair & Rowady, P.S.C.
212 South Maple Street
Winchester, Kentucky 40391
859-744-3251
ATTORNEYS FOR COMPLAINANTS

JOHN C. PFEIFFER

STATE OF KENTUCKY)
) s.s.
COUNTY OF JEFFERSON)

The foregoing is subscribed and sworn to before me by **JOHN C. PFEIFFER**, on this 9th day of May, 2014.

Notary Public, State at Large, KY

My commission expires: My Commission Expires Nov 28 2016.

NOTARY PUBLIC
STATE OF KENTUCKY AT LARGE

Prepared by:

M. ALEX ROWADY, ESQ.
BLAIR & ROWADY, P.S.C.
212 South Maple Street
Winchester, Kentucky 40391
859-744-3251
ATTORNEYS FOR COMPLAINANTS

DAVID O. CARPENTER

STATE OF NEW YORK)
) s.s.
COUNTY OF RENSSELAER)

The foregoing is subscribed and sworn to before me by **DAVID O. CARPENTER**, on this 12 day of May, 2014.

My commission expires: 8/26/2017.

NOTARY PUBLIC

THOMAS S. CUCINOTTA
Notary Public, State of New York
Qualified in Renesslaer County
Reg. No. 01CU6288103
My Commission Expires 8/26/2017

Prepared by:

M. ALEX ROWADY, ESQ.
Blair & Rowady, P.S.C.
212 South Maple Street
Winchester, Kentucky 40391
859-744-3251
ATTORNEYS FOR COMPLAINANTS

1. Refer to page 2 of the Barkers' testimony. Please produce any and all documentation confirming the assertion that EKPC approved the location of the Barkers' residence or detached garage.

ANSWER BY: The Barkers

In 1973, Brooks Barnes (Ann Barker's father) asked EKPC to stake it's ROW carrying the then-existing 69kv line in anticipation of building the home where the Barkers now reside. Two EKPC employees met with Brooks Barnes, Ann Barker and Arnold Brown (the builder) in October of 1973 and used the floor plan to stake the EKPC easement. At the conclusion of this meeting EKPC determined there was adequate room for the house to be built without interfering with EKPC's ROW. Unfortunately Brooks Barnes and Arnold Brown are both deceased.

Since 1973 there has been no mention that the house was in EKPC's easement until the construction of this 345kv/138kv transmission line.

*A correction should be made to this question number 1 and also throughout this document – the garage/candy shop are ATTACHED to the residence.

2. Refer to page 7 of the Barkers ' testimony. Please describe the procedure by which you obtained the measurements of the level of magnetic or electric fields. At a minimum, this should include:

a. An identification of the type of equipment used, including the brand name, manufacturer and serial number.

b. The date you acquired each and every piece of equipment identified in response to (a) above and the person(s) from whom you acquired each and every piece of said equipment.

c. The date(s) upon which you have each and every piece of equipment identified in (a) above calibrated, the method of calibration, the standard used for each calibration and person(s) performing the calibration.

d. The training you received to operate said equipment.

e. A step-by-step description of the process by which you obtained each measurement.

ANSWER BY: The Barkers

a.- The barkers own a EMF/ELF meter. It is an Extech Instruments brand electromagnetic field meter. Serial no. R125439.

b.- The Extech meter was purchased from Grainger of Lexington on Aug.14 2007. The Barkers also own a Fluke 79 series 2 multimeter- serial no. 58550751 and a Meterman 37XR multimeter – serial no. 030108169. The Fluke 79 meter was purchased in 1993 in Lexington Ky. The Meterman was purchased from MCM Electronics about 2004.

c.- All of the above meters were calibrated by the manufacturer. The Extech EMF Meter was compared against Paul Dolloff's EMF meter from EKPC at the time of our meeting in Dec. 2008. The Extech meter was again compared to John Pfeiffer's Alpha Lab meter model UHS AC on Jan.19, 2012 which confirmed our meters' accuracy.

d.- The Barkers were shown how to use the EMF field meter referenced in (a) above by Brooks Barker, a licensed electrician with over 20 years of electric/ electronic technology experience. Brooks Barker has many years of experience using the above mentioned meters.

Continued on next page.........

EMF field meter steps.

1. turn meter on to the Gauss setting.
2. align the sensor slowly towards the device being tested and read the LCD display. Then note the field intensity reading on the screen.

The multimeters are simply switched on to the A/C volts setting, the ground lead connected to earth ground and the positive lead connected to metal on the vehicle. This would give you the voltage reading induced on the vehicles from the transmission lines.

3. Refer to page 7 of the Barkers ' testimony, where it is stated that Dr. Carpenter testified in February 2010 before the Minnesota State Legislature. Please provide the outcome of that proceeding, including copies of any published reports and studies.

ANSWER BY: The Barkers

We have requested a copy of the outcome of this proceding but as of this date we have not received any reports. This requires a request through the open records act with the state of Minnesota. This was a CAPX2020 345kv transmission line from Brookings, South Dakota to Hampton, Minnesota. The applicants were Great River Energy and XCEL Energy. PUC Docket # ET2/TL-08-1474 OHH Docket # 7-2500-20283-2. The attorney was Paula MaccAbee. Ph. 651-775-7128.

4. Refer to page 9 of the Barkers' testimony. Please provide a detailed description of the underlying facts and reasoning supporting the conclusion that the 138kV circuit is unnecessary since it has been operated at 69 kV.

ANSWER BY: John Pfeiffer

In determining the need for a transmission line one needs to refer to "Siting of Electric Transmission Lines" Research Report No. 348, Adopted November 8, 2007 to determine if this line was unnecessary.

Page ix

Any transmission owner that uses federally guaranteed loans, which are usually administered through the Rural Utilities Service, must comply with the National Environmental Policy Act (NEPA) before those funds are released. This law requires that prior to taking any major action, the acting party must consider the environmental impact of that action. The NEPA process and Kentucky's CPCN process each requires that the applicant develop a centerline for the route of the proposed transmission line. There is no guarantee that a centerline approved under one process will be approved by the other. Some NEPA compliance issues may require transmission owners to mitigate the effects of a specific project by adjusting a transmission centerline to avoid or minimize potential impact to a cultural resource. Recent PSC orders, however, have required that approved transmission centerlines cannot be adjusted by more than 500 feet on either side of the centerline and then only by written agreement with the property owner."

Page 12

"Criteria for Approving Proposed Transmission Lines

Kentucky's criteria for granting a Certificate of Public Convenience and Necessity (CPCN) for new electric transmission lines derive from the interpretation of the meaning of "public convenience and necessity" in KRS 278.020. This interpretation was handed down in 1952 by the Court of Appeals of Kentucky, at that time Kentucky's highest court, in Kentucky Utilities Company v. Public Service Commission. That case established two elements that must be met by an applicant seeking to construct a new line: **1) need and 2) an absence of wasteful duplication of facilities.**

The first element has been mostly uncontested. **The second element** has been the subject of much discussion since the 2004 amendments to the statute, resulting in clarification through Public Service Commission cases. PSC has said that to demonstrate an absence of **wasteful duplication**, an applicant must establish that it has conducted a thorough review of all reasonable alternative routes and that its choice of the proposed route was reasonable (PSC Case No. 2005-00207, Oct. 31, 2005). To establish these two elements, an applicant must show that it comprehensively considered the use of existing utility corridors and other rights-of-way (PSC Case No. 2005-00089, Aug. 19, 2005)."

. continued on next page..........

“The second element required is the "absence of wasteful duplication" resulting from the construction of the new transmission lines. Duplication involves the following considerations:

• an excess of capacity over need;

• an excessive investment in relation to productivity or efficiency; and

• an unnecessary multiplicity of physical properties, such as rights-of-way, poles and wires.

> • An unnecessary multiplicity involves "inconvenience to the public generally, and economic loss through interference with normal uses of the land, that may result from multiple sets of rights-of-way and a cluttering of the land with poles and wires."

The Kentucky Court of Appeals in 1952 (Kentucky Utilities Co. v. PSC 252 S.W. 2d 885, Ky. 1952) emphasized however, that the "cost" factor in considering duplication is not to be given more consideration than the "need" for service. If it appears that an existing facility cannot or will not provide adequate service, it might be proper for some duplication and some economic loss to be suffered, so long as the duplication and resulting loss are not greatly out of proportion to the need for service.”

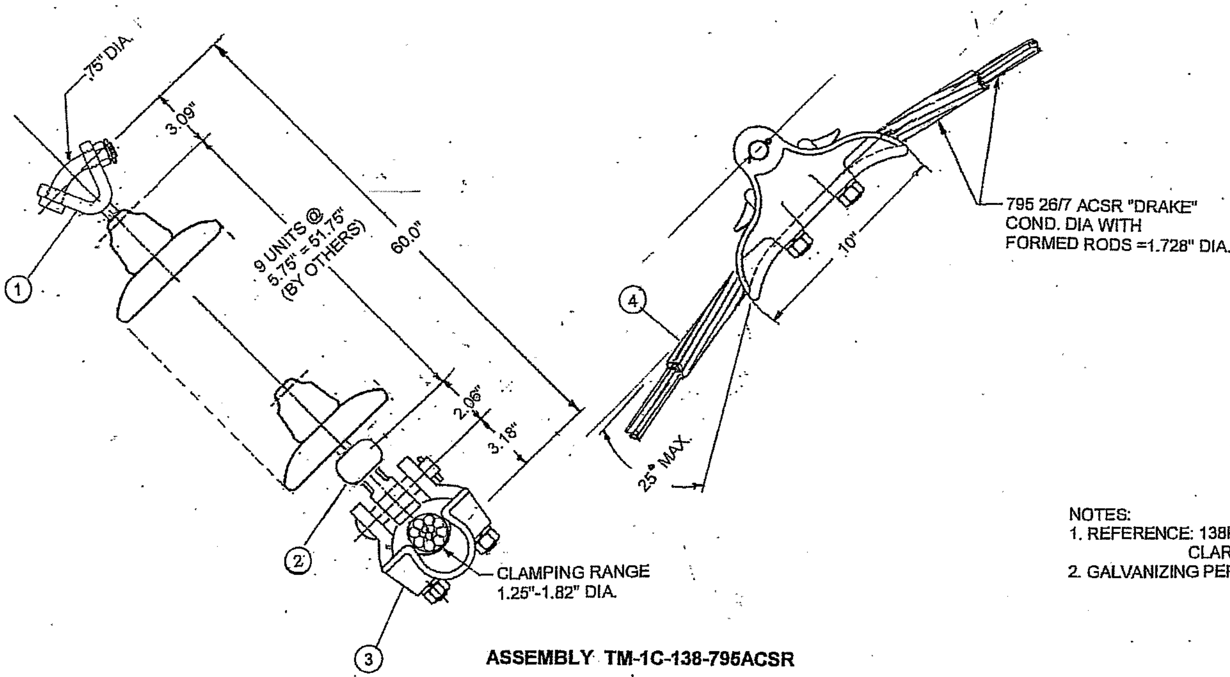
The lower transmission line was designed and built as a 138 kV line rather than a 69 kV line. The difference between the two types of line 69kv vs. 138 kV is the cost of the line supporting insulator and any lightning arrestors installed on the line.

If EKPC intended to only use the line as a 69 kV line then why did they spend the extra money to install a 138 kV line? This is clearly wasteful spending and a violation of the Siting requirements.

K

ITEM NO.	PART NO.	DESCRIPTION	MATERIAL	ULT. STR. LBS.	WT. (EA) LBS.	QTY. PER ASS'Y
1	YBC-30	Y BALL CLEVIS	GALV. STEEL	30,000	1.9	1
2	SA-16	SOCKET EYE	GALV. DUCT. IRON	30,000	1.8	1
3	HAS-182-N	SUSP. CLAMP	ALUMINUM	25,000	4.2	1
4	* AR-0141	ARMOR RODS	ALUMINUM	—	10.3	1

* OR EQUAL



ASSEMBLY TM-1C-138-795ACSR

NOTES:
1. REFERENCE: 138kv EAST KENTUCKY POWER COOP, SMITH/NORTH CLARK TRANSMISSION PROJECT.
2. GALVANIZING PER ASTM A153.

—	—	—	—
EC #	DATE	CHG BY	RESP ENG

DESC OF DWG —
—
—
—
REASON (S) FOR CHANGE —
DISPOSITION OF MAT'L —

ANDERSON

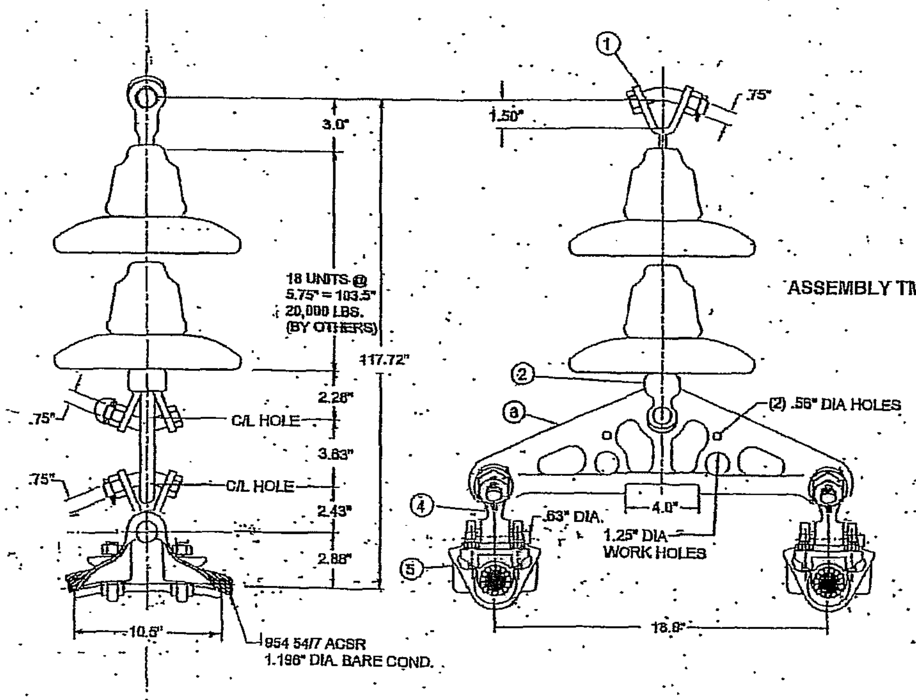
HUBBELL® POWER SYSTEMS

TITLE
138kv SINGLE STRING-SINGLE COND. (ANGLE) SUSPENSION ASSEMBLY

SIZE	DWG NO.	CAT / PART / ASSY NO.	REV
B	CC-17964	TAA-11-17964	R/0

DO NOT SCALE THIS DRAWING | DRN BY DG | DATE 4-04-'06 | SHEET 1 of 1

ITEM NO.	PART NO.	DESCRIPTION	MATERIAL	ULT. STR. LBS.	WT. (EA) LBS.	QTY. PER ASS'Y
1	YBC-30	Y BALL CLEVIS	GALV. STEEL	30,000	1.9	1
2	SYCS-30-90-SN	SOCKET Y CLEVIS	GALV. DUCT. IRON	30,000	2.5	1
3	YPD-30-18437-2	YOKE PLATE	GALV. DUCT. IRON	30,000	12.5	1
4	YCS-13-90	Y CLEVIS EYE	GALV. DUCT. IRON	30,000	2.25	2
5	CFS-139-10.5-N	SUSP. CLAMP	ALUMINUM	25,000	4.7	2



ASSEMBLY TM-1B-345-954ACSR

NOTES:
1. REFERENCE: 345kv EAST KENTUCKY POWER COOP. SMITH/NORTH CLARK TRANSMISSION PROJECT.
2. GALVANIZING PER ASTM A153

EC #	DATE	CHG BY	RESP ENG
—	—	—	—

DESC OF DWG
REASON (S) FOR CHANGE —
DISPOSITION OF MAT'L —

ANDERSON

HUBBELL® POWER SYSTEMS

TITLE
345kv SINGLE STRING
TWO COND. SUSP. ASSEMBLY

SIZE B | DWG NO. CC-17945 | CAT / PART / ASSY NO. TAT-21-17945 | REV R/0

DO NOT SCALE THIS DRAWING | DRN BY DG | DATE 3-08-'06 | SHEET 1 OF 1

5. Refer to the Barker Testimony, page 9. Please explain in detail how the Barkers concluded that the upgrade of the existing transmission line was connected with the possible addition of Warren Rural Electric Cooperative Corporation as a member of EKPC.

ANSWER BY: The Barkers

We believe that the construction of the 138kv/345kv Smith-Hunt-Sideview lines would not have been rushed through in the manner it was if EKPC had not been on a very tight timeline to get transmission lines and associated substations built for the connections to supply electric to Warren RECC. It is our belief that the construction of the numerous projects starting at this time and the magnitude of costs created a financial burden on EKPC which resulted in requests for three rate increases from Jan. 2007 to May 2010. This is also related to Clark Energy seeking an 11% residential rate increase in Dec.2009.

6. Refer to Response 5, page 12 of the Barkers' testimony. Please provide a copy of all surveys of the Barker Property undertaken for the purpose of ascertaining the precise area of the additional right of way easement.

ANSWER BY: The Barkers

Enclosed is the amended verified petition signed Dec.19 2006, accounting for the .03 acres of additional right of way. The attached amended exhibit (A) map on the following page mistakenly identifies the EKPC's electric transmission line as crossing the lands of Fred J. Farris. Whereas actually the land in exhibit (A) is the Barkers property and the KSPSZC numbers in the description are not consistent with the numbers on the map. Also attached on the following page is an e-mail from Mary Jane Warner verifying the amended verified petition to include the anchors and guy wires in the additional easement.

M. Alex Rowady

From: Mary Jane Warner [maryjane.warner@ekpc.coop]
Sent: Friday, November 10, 2006 3:27 PM
To: M. Alex Rowady
Cc: Roger Cowden; Bill Sharp; Sherman Goodpaster
Subject: RE: Harold and Ann Barker

Hi Alex -

Thank you for your quick response.

Issue #1

We will amend the Verified Petition to include the anchor and guy areas in the easement and will modify Exhibit #1 to the Verified Petition to show the offset in the easement for the guys and anchors. (P.S. - Roger looked over the case and you two may wish to discuss further for future reference, but we are willing to make this agreement regardless.)

Issue #2

We have had very limited success in assuming the responsibility for buying and planting trees to the satisfaction of property owners. We will pay the Barkers $3000 for them to use in planting whatever they desire to replace the front yard trees, subject to the rights acquired by EKPC for the transmission line. This sum will be separate and apart from any settlement or jury verdict resulting from the transmission line easement itself, but will be the final settlement on the issue of the front yard trees only. It is very important that the Barkers understand that, consistent with the rights EKPC is acquiring, any trees planted in or around the easement area are subject to trimming or cutting should they grow to a height which would create a problem with electrical clearance or could, when in falling, contact the conductors. In the alternative, the Barkers could either use the $3000 to plant trees away from the easement area so as not to risk the future problem, or choose trees from a list approved by EKPC. It must be understood that any tree that is deemed a danger to the line per the rights acquired by EKPC will be cut or trimmed.

Issue #3

I do not know the status of the felled trees on this property, but I will discuss with our inspector. Generally, we have no claim to the cleared trees and, pending my check and report back to you on the current status, we will leave them in place for the Barkers use.

Please respond to the Barkers as soon as you can and Roger or I will contact you on Monday to finalize this agreement.

Thank you very much for your attention to this matter.

Mary Jane

Mary Jane Warner, P.E.
Manager, Power Delivery Expansion
East Kentucky Power Cooperative
859-745-9344
FAX 859-744-6008

Please note my e-mail address change - maryjane.warner@ekpc.coop

-----Original Message-----
From: M. Alex Rowady [mailto:alex@blairrowadylaw.com]
Sent: Friday, November 10, 2006 2:30 PM
To: Mary Jane Warner
Subject: Harold and Ann Barker

Mary Jane: The only two issues we need to resolve are the guy wires and the trees. As for the former, there needs to be an "extention" of the easement to cover the air space between the poles and the ground and, of course, for the ground where the guy wires are anchored. As for the trees, the Barkers want EKPC to replace (at its expense) the front yard trees it intends to remove with a shorter species of the Barkers choosing. Also, the Barkers want to take possession of all trees felled (at any location on their farm) whether the wood is "merchantable" or not. Hopefully, this will clarify my clients' position for you. Thanks, Alex

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

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

VS: — AMENDED VERIFIED PETITION

HAROLD BARKER, et al — DEFENDANTS

* * * * * * * *

COMES the Plaintiff, East Kentucky Power Cooperative, Inc., by and through its duly authorized attorney, states that for its Verified Petition for condemnation filed herein, Plaintiff failed to include an Anchor Easement Area, consisting of an additional 0.03 acres that Plaintiff will acquire, that is 30' wide and extends an additional 45' from the edge of said transmission line easement, which is the subject of this action. Therefore, Plaintiff states that for its Amended Verified Petition for condemnation the following numbered paragraph 5 should hereby read as follows:

5. It is necessary for the Plaintiff to rebuild, enlarge, and double circuit the electric transmission line and system currently located upon the Defendant's property in accordance with the rights specifically described herein and to expand the existing 100' wide right-of-way by acquiring an additional 50' right-of-way boundary for a total width of 150 feet, and an anchor easement area, consisting of an additional 0.03 acres and extends 45' from the edge of the new easement (and 30' wide), as shown on the attached "Amended Exhibit A". The centerline of said right-of-way is 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:2262201, E:2113466, and running thence N18°50'57"E, for a total distance of approximately 518 feet to a point in the line where line turns at KSP, SZC N:2262691, E:2113634, and running thence N17°48'40"E, for a total distance of approximately 2236 feet to a point in the line where line turns at KSP, SZC N:2264819, E:2114317, and running thence N14°54'42"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.

Plaintiff hereby adopts, restates and reiterates each and every other allegation contained in the Original Verified Petition not in consistent herewith.

DALE W. HENLEY

ROGER R. COWDEN
SHERMAN GOODPASTER III
EAST KENTUCKY POWER
COOPERATIVE, INC.
P.O. BOX 707
WINCHESTER, KY 40392-0707
(859) 744-4812

ATTORNEYS FOR PLAINTIFF

VERIFICATION

STATE OF KENTUCKY)
) SCT.
COUNTY OF CLARK)

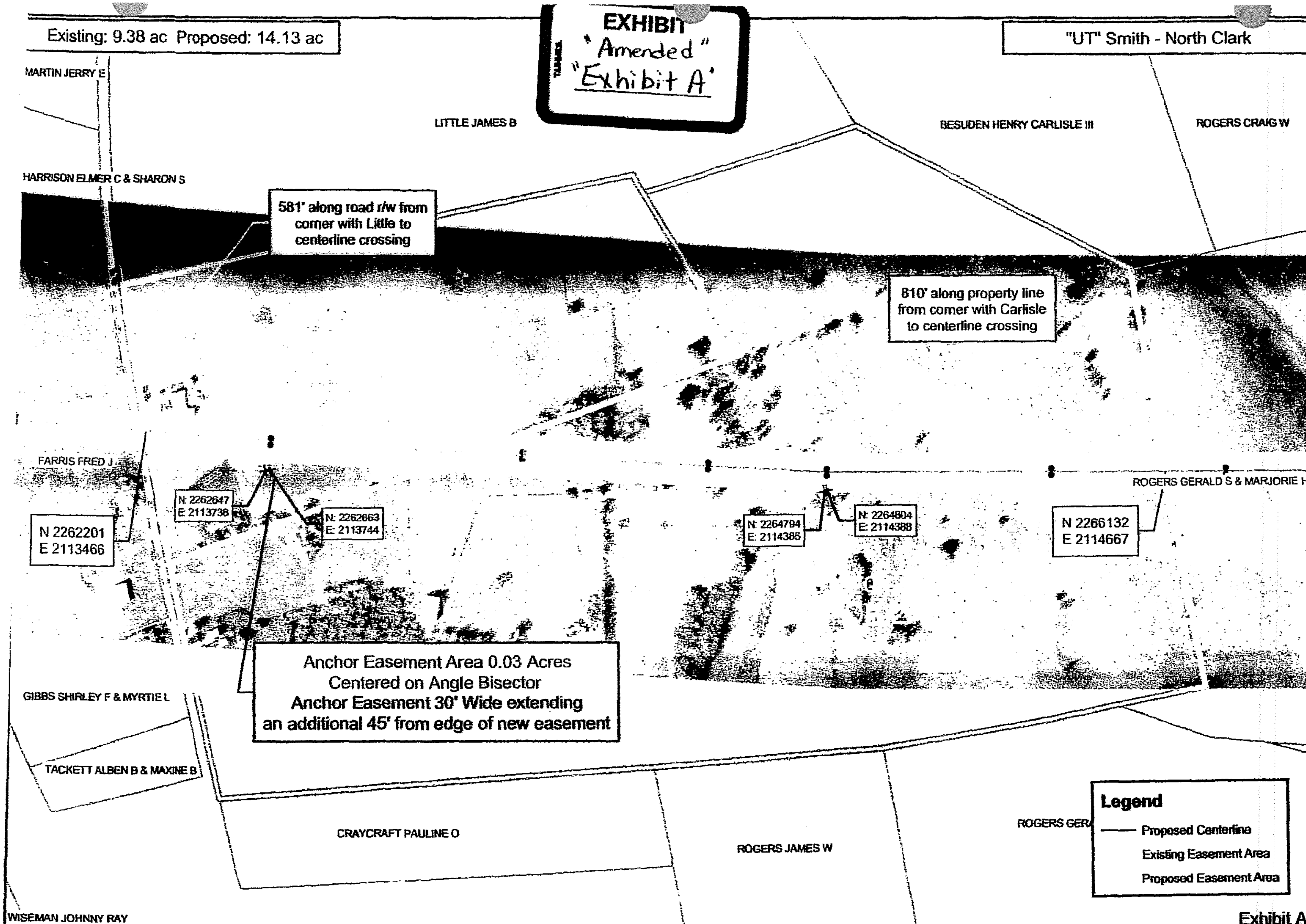
The affiant, Roger R. Cowden, states that he is Senior Corporate Counsel of the Plaintiff, East Kentucky Power Cooperative, Inc., and that this affiant has read the foregoing Petition and that the statements contained therein are true.

ROGER R. COWDEN

Subscribed and sworn to before me in the aforesaid state and county by Roger R. Cowden this the 19th day of December 2006.

My notarial commission expires: 12/20/08

NOTARY PUBLIC, KY
STATE-AT-LARGE



Data represented in this map was collected as a result of a centerline survey for the transmission line. Information regarding property lines was obtained from available sources, but is not intended to represent an official determination of property lines.

All coordinates listed are Kentucky State Plane, South Zone, NAD 1983.

East Kentucky Power Cooperative
4775 Lexington Road, PO Box 707
Winchester, Kentucky 40391
Phone (859)744-4812 www.ekpc.coop Fax (859)744-6008

Map showing approximate location of EKPC's electric transmission line crossing the lands of Fred J Farris in Clark County, Kentucky

1"=500'

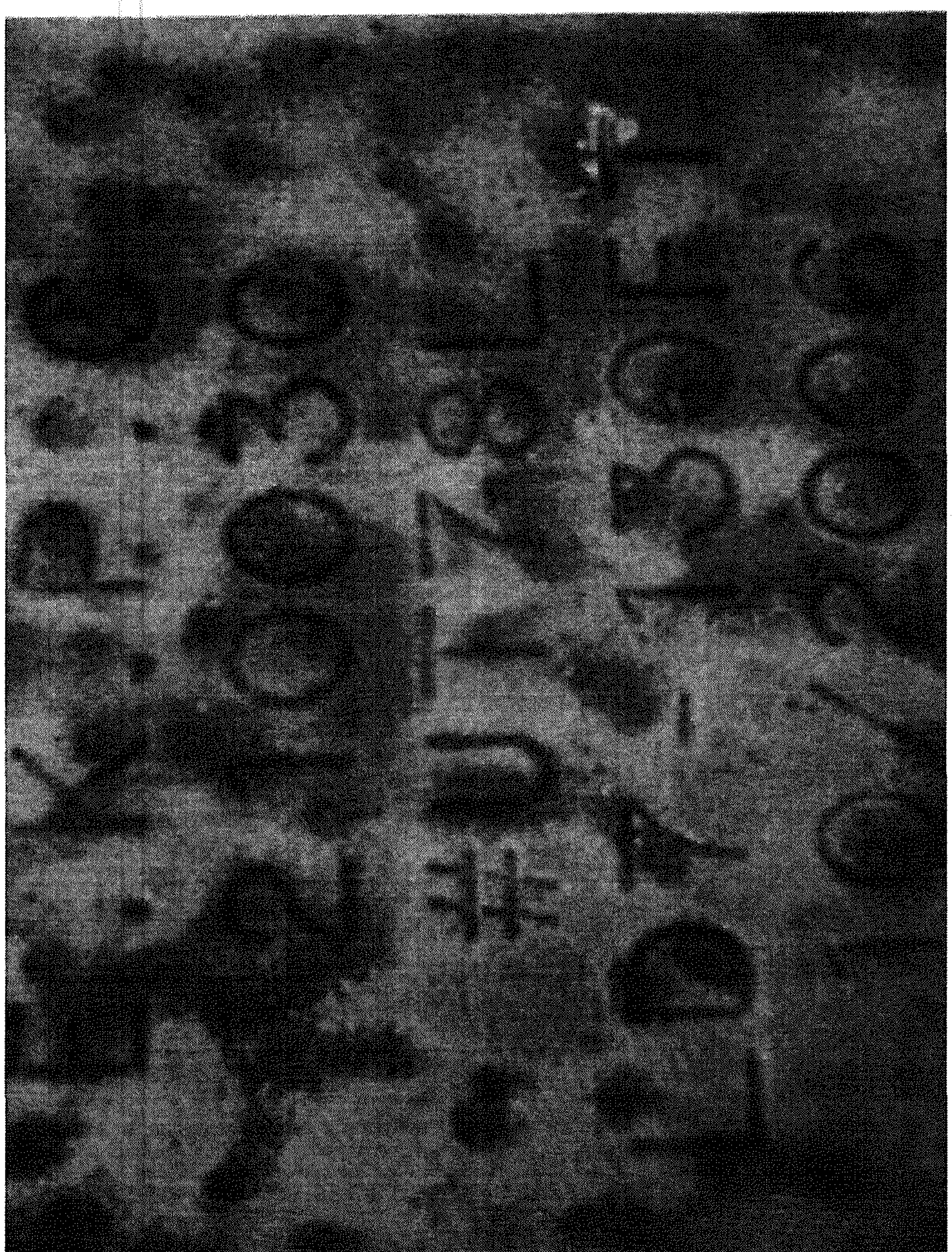
200 Feet

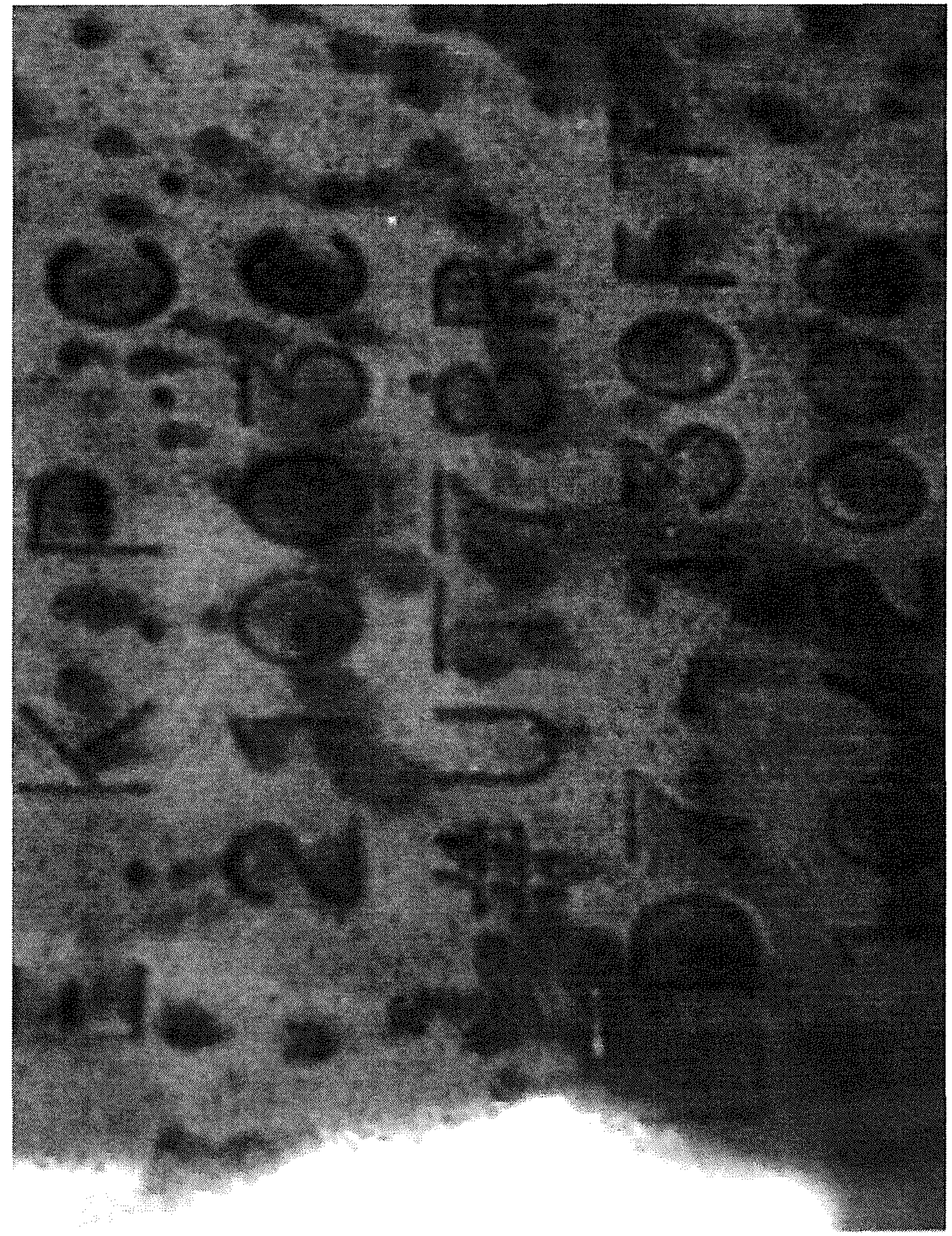
Map #
21461-09

7. Refer to Response 6b, page 12 of the Barkers' testimony. Please provide any and all facts supporting your statement that UT78 is 130 feet tall and not 140 feet tall.

ANSWER BY: The Barkers

When approaching the vicinity of the poles in question you can see that UT78 and UT80 appear to be of different heights. Also a metal plate is attached to each pole that states their height. See photos of ID plate on following page.





8. Please produce a copy of all recordings in the Barker's custody or control of any employees, representatives or agents of EKPC (whether audio or video) and a copy of any transcript of each such recording. For each such recording, please state:

a. The date of the recording.

b. The identity of the person making the recording.

c. The identities of each person recorded.

d. Whether each person recorded gave prior consent to the recording.

ANSWER BY: The Barkers

Dec .2008 Paul Dolloff from the Research and Development Dept. of EKPC came to our residence to provide a copy of and explain the measurements of the electric field data taken on Dec. 5^{th} 2008.

Brooks Barker made the audio recording.

Harold Barker, Ann Barker, Brooks Barker and Paul Dolloff were present.

Mr. Dolloff gave consent to be recorded since he had arrived early for the meeting and Ann Barker was working in Lexington Ky. on that date and could not be present at the beginning of the meeting.

Everyone at the meeting knew it was being recorded. Enclosed in the front of this folder is the cd of the entire meeting with Paul Dolloff and the Barkers.

9. Please provide a copy of all proposals, suggestions or offers made by the Barkers, directly or indirectly through counsel or other agents or representatives, to EKPC regarding the location of the transmission line on their property. If written copies of any such proposal, suggestion or offer do not exist, please provide a detailed description of the substance of each such proposal, suggestion or offer.

ANSWER BY: The Barkers

On March 20th 2006 the survey company staked the proposed new ROW on the Barker property and this was the first time we knew the easement would be going through the middle of the front yard and through the carport and attached garage/candy shop. Three days later on March 23rd 2006 the Barkers met with EKPC's Dominic Ballard, Mary Jane Warner, Mike Wells, Dan McNichol, Paul Dolloff and Rick Drury at the Barker residence to discuss this unnecessary ROW encroachment on our residence. This was totally unacceptable and it was obvious none of our requests voiced at the open house on November 10, 2005 had even been considered. The new poles were to be in the same location as the old ones-beside our front yard fence. The first set of old poles (near U.S.60) across the road on the Farris property were to be removed and not replaced. We showed EKPC all the land on the East and West side of our residence which we owned and asked that everything be moved away from the house.

After a month went by and the Barkers had not heard or received any further discussion on the matter the Barkers requested another meeting on April 27th 2006. At this meeting the Barkers met with Dominic Ballard, Paul Dolloff, Dan McNichol and Rick Drury. EKPC indicated that maybe the poles beside the front yard fence could be moved if Mr. Farris had not signed his easement on the property across the road.

After another month had gone by and the Barkers had not heard any further information on the matter, Ann Barker called EKPC and was informed that Mr. Farris had already signed his easement. We asked for another meeting on May 29 2006. At this meeting we informed EKPC that we knew they had went directly from our meeting on April 27th 2006 to Mr. Farris for the purpose of securing his easement. This appeared to be a deliberate attempt by EKPC to block any adjustments to the easement and poles on our property.

At the meeting on May 29 2006 EKPC indicated that maybe they could move the first set of poles next to the side yard to behind the garage and we would have to pay $10,000 each since they would be taller. We agreed on the price of the poles and asked that the lines be moved further east away from our residence. EKPC indicated that they put the additional 50 ft. of new ROW east of the old easement. Two weeks later EKPC called and said we would not have to pay for the poles. This was the ideal time for EKPC to move the lines totally away from the house since no construction had begun and they were in the process of adjusting the new 50 ft. portion of the easement. Continued on next page....................

Instead EKPC left the easement location where it was still encroaching on the carport and attached garage/candy shop. From the open house on November 10 2005 to this day the Barkers have been ardently trying to get these massive lines moved a safe distance from our home.

10. Please provide a copy of all proposals, suggestions or offers made by EKPC, directly to the Barkers or indirectly to their counsel, regarding the location of the transmission line on their property (including, but not limited to all alternative placement locations, variations in transmission line characteristics, offers to purchase right-of-way, offers to relocate the structures on the premises, etc.) that were rejected by the Barkers If written copies of any such proposal, suggestion or offer do not exist, please provide a detailed description of the substance of each such rejected proposal, suggestion or offer.

ANSWER BY: The Barkers

Refer to question 9 concerning the meetings and offers by EKPC and the Barkers regarding the relocation of the poles and easement on the Barker property.

May 8, 2006 Mike Wells ROW agent came with a formal offer of $14,000 for parcel 201 and $8,600 for parcel 200. We refused because we still had hope that EKPC would move everything a safe distance from our home. May 16, 2006 Mike Wells met Ann Barker in Applebee's parking lot and changed the offer on parcel 201 to $17,000 but left parcel 200 the same. We refused this offer because we still had not heard anything from EKPC concerning adjusting the easement. On June 28, 2006 William Sharp came with a final offer which he retracted after we brought to his attention a discrepancy in the linear feet of ROW. On June 29 2006 William Sharp brought the corrected offer which was $37,800 for both parcels. We rejected this offer because he indicated that EKPC was not going to do anything about adjusting the easement location. See attachments of offers on following page.

On September 14, 2011 the Barkers, their attorney Alex Rowady and Sherman Goodpaster (EKPC attorney) met at the firm of Pierce Hamblin for mediation which proved to be unsuccessful.

On July 31, 2012 EKPC requested that our attorney Alex Rowady, our engineer John Pfeiffer meet at their office with EKPC attorney Sherman Goodpaster and their engineers (which their engineers never showed up for)- the Barkers were asked not to come. No resolution came out of this meeting because their engineers failed to appear.

EAST KENTUCKY

POWER COOPERATIVE

COUNTY Clark

WORK ORDER #21461

PROJECT NO.

OFFER TO PURCHASE ADDITIONAL RIGHT OF WAY

Parcel No. 200

DATE: 5/8/06

Dear Mr. & Mrs. Barker:

A portion of your property is needed for construction of the subject project and has been valued on the basis of current market data. The compensation offered and set forth in this statement is not less than the amount approved by East Kentucky Power Cooperative (EKPC). This offer is for the acquisition of an additional right of way across your property. If accepted, EKPC will require an easement from all parties having an interest therein. All leases, mortgages, liens, taxes, and any other encumbrance will have to be released prior to payment of the consideration. Our offer for the additional 50' (Fifty Feet) of right of way and additional rights on the existing easement across your property is $8,600.00.

An allocation of the offer is:

Easement:	1.40 acres for $5,600.00
Damages:	$3,000.00
Total:	$8,600.00

Upon completion of successful negotiations, the signed easement will be processed for payment and the check will be delivered to you for final closing.

Every effort will be made to answer questions you may have regarding this acquisition and our procedures.

Very truly yours,

Michael Wells

East Kentucky Power Cooperative Representative

EAST KENTUCKY POWER COOPERATIVE	COUNTY Clark	WORK ORDER	#21461
	PROJECT NO.		

OFFER TO PURCHASE ADDITIONAL RIGHT OF WAY
Parcel No. 201

DATE: 5/8/06

Dear Mr. & Mrs. Barker:

A portion of your property is needed for construction of the subject project and has been valued on the basis of current market data. The compensation offered and set forth in this statement is not less than the amount approved by East Kentucky Power Cooperative (EKPC). This offer is for the acquisition of an additional right of way across your property. If accepted, EKPC will require an easement from all parties having an interest therein. All leases, mortgages, liens, taxes, and any other encumbrance will have to be released prior to payment of the consideration. Our offer for the additional 50' (Fifty Feet) of right of way and additional rights on the existing easement across your property is $14,000.00.

An allocation of the offer is:

Easement:	**3.31 acres for $11,585.00**
Damages:	**$2,000.00**
Total:	**~~$14,000.00~~** 17,000 DR

Upon completion of successful negotiations, the signed easement will be processed for payment and the check will be delivered to you for final closing.

Every effort will be made to answer questions you may have regarding this acquisition and our procedures.

Very truly yours,

Michael Wells

East Kentucky Power Cooperative Representative

EAST KENTUCKY POWER COOPERATIVE

June 29, 2006
RE: Final Offer
Smith – North Clark Project – W. O. #21461
Map #200, 201
Clark County, Kentucky

Harold and Ann Barker
5450 Mt. Sterling Road
Winchester, KY 40391

Dear Mr. And Mrs. Barker:

As Right of Way Agent for East Kentucky Power Cooperative, I have been unable to negotiate a settlement with you for a Transmission Line Easement and an Amended & Restated Transmission Line Easement across your property in Clark County, Kentucky.

An Evaluation by our Right-of-Way Department was made of the subject easements and it has been determined that the additional easement of fifty feet (50') wide, four thousand one hundred and thirteen feet (4113') long, containing 10 poles, 4 guys, would not depreciate your property value more than $37,800.00.

Please consider this offer and give your response to EKPC no later than July 5, 2006. Unless you have responded by the aforementioned date, EKPC will assume you have rejected the offer and do not wish to respond.

Thank you for your time and if you have any questions please call me at the number listed below.

Sincerely,

William A. Sharp, Right of Way Agent
East Kentucky Power Cooperative
P. O. Box 707
Winchester, Kentucky 40392-0707
(859) 745-9581

11. Please admit that the Barkers were offered a copy of the Department of Energy's RAPID brochure at the November 2005 open house.

ANSWER BY: The Barkers

Harold, Brooks and Ann Barker received a copy of the Dept. of Energy's RAPID brochure. The Barkers asked questions concerning the EMF levels at the open house but the person in charge of explaining this was not available to answer all our questions.

EAST KENTUCKY POWER COOPERATIVE

Transmission Line Siting Data List

Smith - Sideview 345kV

	COMMENTS
194 PALMER PALMER WILLIAM D & DEBORAH H	
195 VANSICKLE VANSICKLE RICHARD L	
196 BALDWIN BALDWIN WAYNE JOHN & CAROL SUE	
197 HARRISON HARRISON ELMER C & SHARON S	
198 MARTIN MARTIN JERRY E	
199 LITTLE LITTLE JAMES B	
200 BARKER 201 BARKER ANN BROOKS BARNES 859-744-1540 771-2282-C EXISTING LINE	Survey OK Please move away from house EMF Concerns
202 CRAYCRAFT CRAYCRAFT PAULINE O	
203 ROGERS ROGERS JAMES W	
204 ROGERS 205 ROGERS GERALD S & MARJORIE H EXISTING LINE	

12. Please provide a detailed description of any and all items in the Barkers' home, detached garage or elsewhere on their property that may create an electric or magnetic field.

ANSWER BY: The Barkers

In the Barkers home we have a computer, can opener, coffee pot, mixer, dishwasher, microwave, refrigerator, electric oven, electric range, washing machine, clothes dryer, tv, copier, digital clock, vacuum cleaner, air compressor. --- The fact remains the fields generated by these appliances decreases very very rapidly with distance away from the object. One example is the mixer has high readings 1 inch from the housing, however 12 inches away from it the reading is 0. All of the above listed items are not in constant use every minute of every day of the year. Whereas the EMF levels we are subjected to from the 345kv/138kv transmission lines ARE constant every minute, every day of the year throughout the entire house and will only increase once they are energized to full capacity.

13. If it is the Barkers' contention that they have been injured by the proximity of the transmission line to their residence or detached garage, please provide a detailed description of each such injury, including the date of injury or diagnosis and the facts supporting the contention that said injury has been caused by the proximity of the transmission line.

ANSWER BY: The Barkers

The Barkers currently are not aware of any illness or medical problems because of the transmission lines yet. We are a multi-generational household, Harold, Brooks, and Ann Barker live constantly with the high EMF levels while the Barkers daughter, grandchildren, and step great-grandchildren are exposed while visiting. According to experts and studies conducted on the hazards of high EMF levels and electric shock there is clearly an association and elevated risk of a variety of diseases/ illnesses such as the risk of cancer, alzheimers, ALS, and lateral sclerosis. According to studies every effort should be made to avoid long term exposures to magnetic fields above 2mg. The electric shock from vehicles which happens frequently should also be categorized as an injury as it is definitely an unpleasant feeling to receive.

14. Please provide a detailed explanation as to why the Barkers did not contact the Kentucky Public Service Commission ("Commission") subsequent to the November 2005 Open House and prior to the commencement of the replacement and upgrade project.

ANSWER BY: The Barkers

There never was any information provided by EKPC at the November 10, 2005 open house, or in their packet of information mailed to the affected land owners or advertised in the local newspaper on Oct.31, 2005, Nov 3, 5, 7, 2005 as to where you could contact any agency with your questions or concerns.
** See attachments following this question.

On July 10, 2006 a legal public notice was published in the Winchester Sun of EKPC's intent to hold a public scoping meeting and prepare an Environmental Assessment for the Madison/Garrard Co. transmission line. Ann Barker called and wrote a letter to Stephanie Strength of RUS concerning the Barkers problems with our easement situation.
**See attachments following this page.

It was not until EKPC put a notice in the Winchester Sun dated March 14, 2007 concerning the Notice Of Intent To Construct the 345kv transmission line through Madison/ Garrard counties that advertised a phone number and address for the PSC. Once the Barkers had that information Ann Barker then called the PSC on several occasions and at that time spoke with Helen Helton ext.244, Deputy Richard Raff ext.263, John Shupp ext.421, and Susan Dunn. Ann Barker was given a case number PSC 2008-02335 which she was to use in referencing her complaints.

Ann Barker spoke with Susan Dunn of the PSC on several occasions concerning the easement, EMF levels and the electric shock. Susan Dunn told Ann Barker she had tried to but was unable to resolve the issues and she would forward to Ann the last correspondence with EKPC's attorney Sherman Goodpaster.
**See attachments following this page

of Baghdad, the military said.

A similar bomb hit a patrol near Balad, 50 miles north of Baghdad, killing

killed.

Elsewhere, U.S. jets bombed two insurgent safe houses near the Syrian border today in an attack aimed

tractor and wounded six people, police said.

On Sunday, gunmen killed Ghalib Abdul-Mahdi, the brother of Shiite Vice Presi-

7-10-06 **Public Notice**

LEGAL
PUBLIC NOTICE

DEPARTMENT OF AGRICULTURE

Rural Utilities Service

East KY Power Cooperative; Notice of Intent to Hold Public Scoping Meetings and Prepare an Environmental Assessment

AGENCY: Rural Utilities Service, USDA.

ACTION: Notice of intent to hold public scoping meetings and prepare an environmental assessment (EA).

SUMMARY: The Rural Utilities Service, an agency which administers the U.S. Department of Agriculture's Rural Development Programs (USDA Rural Development) intends to hold public scoping meetings and prepare an environmental assessment related to possible financial assistance to East Kentucky Power Cooperative, Inc. (EKPC) of Kentucky for the proposed construction of approximately 35 miles of 345 kilovolt (kV) transmission line in Clark, Madison, and Garrard counties, KY. The proposed 345 kV transmission line project would be constructed within one of several alternative corridors under consideration. The alternative transmission line corridors originate at the J.K. Smith Power Station near the community of Trapp in Clark County, KY and terminate at the proposed location of a new 345 kV switching station. EKPC is requesting USDA RURAL DEVELOPMENT to provide financial assistance for the proposed project.

DATES: USDA RURAL DEVELOPMENT will conduct a scoping meeting in an open house format from 3 p.m. until 7 p.m. on Tuesday, July 11, 2006. The purpose of the meeting is to provide information and solicit comments for the preparation of an EA.

ADDRESSES: The public meeting will be held at the Best Western-Holiday Plaza located at 100 Eastern Bypass, Richmond, KY 40475 Phone: 859-623-9220.

A Macro Corridor Study will be available for public review at USDA Rural Development, Utilities Programs, 1400 Independence Avenue, SW., Washington, DC 20250–1571,; at the USDA Rural Development's Web site http://www.usda.gov/rus/water/ees/ea/htm; at EKPC"s headquarters office 4775 Lexington Road, Winchester, Kentucky 40391; and at the following Public Library locations:

Clark County Library
370 South Burns Avenue
Winchester, KY 40391
(859) 744-5661
Julie Maruskin, Director

Madison County Public Library
507 West Main St.
Richmond, KY 40475
(859) 623-6704
Sue Hays, Director

Garrard County Public Library
101 Lexington St
Lancaster, KY 40444

Written comments should be sent to: Stephanie Strength, Environmental Protection Specialist, USDA, Rural Development, Utilities Programs, Engineering and Environmental Staff, 1400 Independence Avenue, SW., Stop 1571, Washington, DC 20250–1571, or e-mail: stephanie.strength@wdc.usda.gov.

FOR FURTHER INFORMATION CONTACT:
Stephanie Strength, Environmental Protection Specialist, USDA, Rural Development, Utilities Programs, Engineering and Environmental Staff, Stop 1571, 1400 Independence Avenue, SW., Washington, DC 20250–1571, telephone (202) 720–0468. Mrs.Strength's e-mail address is stephanie.strength@wdc.usda.gov.

SUPPLEMENTARY INFORMATION: EKPC proposes to construct a 345 kV transmission line between a source substation at the J.K. Smith Power Station in Clark County and a proposed substation located near Lancaster. The proposed line would be constructed within one of several alternative corridors under consideration. The proposed corridors are located in Clark, Madison, and Garrard counties. The proposed corridors extend southwesterly from the J.K. Smith Power Station near Trapp, KY. From Trapp, the corridors will extend towards the communities of Union City, Redhouse, and White Hall to the north side of Richmond. From Richmond the corridors head in the southwesterly direction near communities such as Roundhill, Kirksville, Ruthton, Teatersville, Mcreary, Nina, and Three Forks towards the proposed location of a 345kV switching station. The proposed switching station would be located west of the community of Lancaster. The transmission line would require a right-of-way of 150 feet. Depending on which route is chosen the approximate length of the transmission line would be from 35 – 37 miles. It is anticipated that this transmission line would be in service in late spring to early summer of 2009.

Alternatives considered by USDA RURAL DEVELOPMENT and EKPC include: (a) No action, (b) alternative transmission improvements, and (c) alternative transmission line corridors.

An Electric Alternative Evaluation and Macro Corridor Study Report, prepared by EKPC will be presented at the public scoping meeting. The Report is available for public review at the addresses provided in this notice.

Government agencies, private organizations, and the public are invited to participate in the planning and analysis of the proposed project. Representatives from USDA RURAL DEVELOPMENT and EKPC will be available at the scoping meeting to discuss USDA RURAL DEVELOPMENT' environmental review process, describe the project, the need for the project, the macro corridors under consideration, and discuss the scope of environmental issues to be considered, answer questions, and accept oral and written comments.

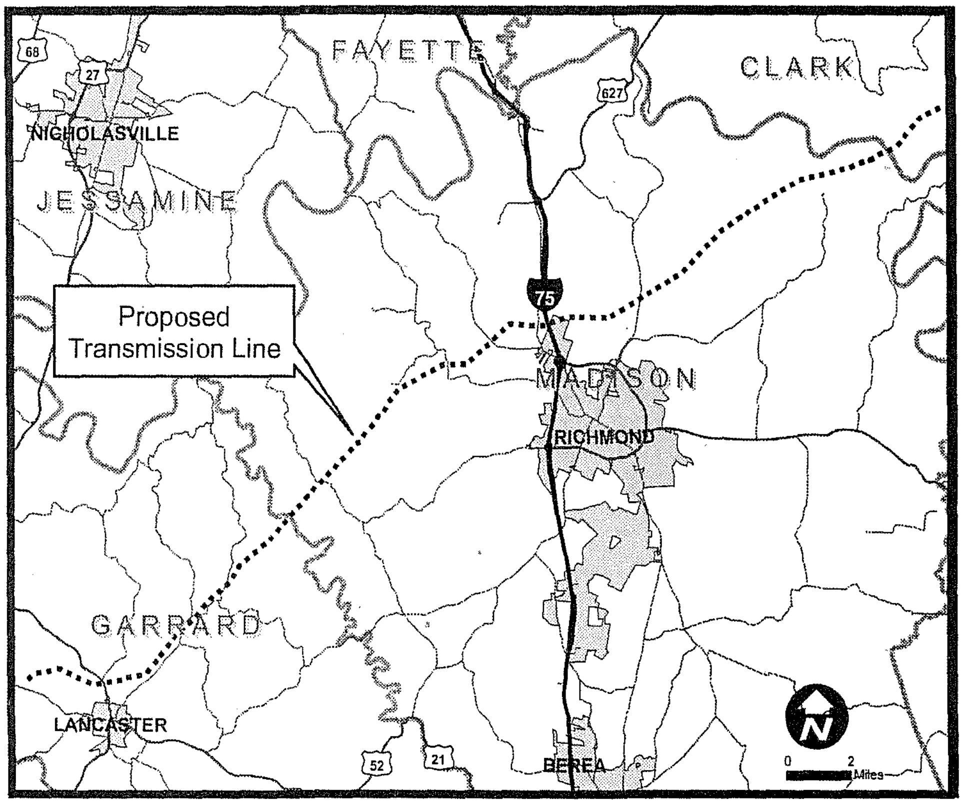
Questions and comments should be received by USDA Rural Development in writing by August 10, 2006 to ensure that they are considered in this environmental impact determination.
The comments received will be incorporated into the environmental analysis EKPC will submit to USDA RURAL DEVELOPMENT for review. USDA RURAL DEVELOPMENT will use the environmental analysis to determine the significance of the impacts of the project and may adopt it as its environmental assessment of the project. USDA RURAL DEVELOPMENT' environmental assessment of the project would be available for review and comment for 30 days. Should USDA RURAL DEVELOPMENT determine, based on the EA of the project, that the project would not have a significant environmental impact, it will prepare a finding of no significant impact. Public notification of a finding of no significant impact would be published in the Federal Register and in newspapers with a circulation in the project area. Any final action by USDA RURAL DEVELOPMENT related to the proposed project will be subject to, and contingent upon, compliance with environmental review requirements as prescribed by the Council on Environmental Quality and USDA RURAL DEVELOPMENT environmental policies and procedures.

Mark S. Plank,
Director, Engineering and Environmental Staff
USDA/Rural Development/Utilities Programs

July 10, 2006

Notice of Intent To Construct Proposed Transmission Lines

3/14/2007



East Kentucky Power Cooperative proposes to construct approximately 36 miles 345-kilovolt transmission line from J.K. Smith Station located in southern Clark County near Trapp, Ky., southwest through Madison County to the northwest of Richmond, Ky., to a new substation to be constructed in Garrard County west of Lancaster, Ky. That substation will tie the new line into an existing 345-kV line owned by Kentucky Utilities. Construction will consist primarily of two-pole, H-frame steel structures, with three-pole steel structures needed for some angles and dead-ends. The purpose of this line is to help EKPC accommodate load growth in Central Kentucky and improve the reliability of the regional transmission grid.

The transmission line will require a certificate of public convenience and necessity to be issued by the Kentucky Public Service Commission (PSC). This process will proceed on PSC Docket 2006-00463. You have the right to request a local public hearing. Interested persons, including property owners crossed by the line, have the right to intervene. Should you have any questions concerning this process, the Executive Director of the Commission is Elizabeth O'Donnell, Kentucky Public Service Commission, P. O. Box 615, 211 Sower Boulevard, Frankfort, Kentucky 40602-0615, telephone (502) 564-3940.

By working together we will arrive at the best solutions.

EAST KENTUCKY

PSC - 502-564-3940 Ruth Knowles x 451
PSC.KY.GOV

Dunn, Susan L (PSC)

From: Sherman Goodpaster [sherman.goodpaster@ekpc.coop]
Sent: Tuesday, December 23, 2008 3:07 PM
To: Dunn, Susan L (PSC)
Cc: David Smart; Ann Wood; Rick Drury; Chuck Caudill; Paul Dolloff
Subject: Update-Complaint 2008-02335-Ann Barker

Attachments: Ann Barker Memo 12-19-2008.pdf

Ann Barker Memo 12-19-2008.pdf...

Ms. Dunn,

I am attaching the December 19 report of Dr. Paul Dolloff which relates the electric field measurements taken on the Barker property to electric field standards in those states that have adopted such standards. I would point out that the six states listed in the report as having standards are the only states of which we are aware that have adopted these types of standards. If you or anyone on the Commission staff are aware of any other states with such standards, I would appreciate it if you could advise me of what these additional standards are so that our data base can be made current.

The report is essentially self-explanatory, and I will refrain from going through it point by point, except to state that the measurements taken on the property both on the right-of-way and at the edge of the right-of-way are well below any of the adopted standards.

Turning to mitigation, the transmission line that runs adjacent to the Barker property is a double circuit configuration with a 345 kV three phase circuit on the top of the structures and a 69kV three phase underbuild below it. The configuration of these circuits can have an impact on the strength of the electric field, and even though the measured electric field strengths are actually rather low, in order to further mitigate the electric field strengths, EKPC currently plans to "roll the phases" of the 69kV circuit. This involves reconfiguring the phasing of the 69kV circuit so that the "A" phase of the 69kV circuit lines up under the "C" phase of the 345kV circuit and the "C" phase of the 69kV circuit lines up under the "A" phase of the 345kV circuit. EKPC's modeling indicates that this should reduce the electric field strength to an even lower level. This work can be performed at the several substations along the route of the 69kV circuit, and at the present time, EKPC plans the undertake this reconfiguration during the upcoming spring when the 69kV circuit can next be taken out of service. EKPC also plans to consider this phasing for all future double-circuit transmission lines of like voltages.

Should you have any questions or need any further information, please advise.

<<Ann Barker Memo 12-19-2008.pdf>>

Sherman Goodpaster III
Senior Corporate Counsel
East Kentucky Power Cooperative
4775 Lexington Road
Winchester, Ky 40391
859-745-9375(Voice)
859-744-6008(Fax)
859-227-3600(Cell)
sherman.goodpaster@ekpc.coop

15. Please provide a copy of any and all reports, correspondence or other documents or recordings provided to the PSC by the Barkers or received by the Barkers from the Commission.

ANSWER BY: The Barkers

Along with all the reports, correspondence, documents, and recordings previously referenced in other questions The Barkers have attached additional e-mails to the PSC and their replies.

FW: East Kentucky Letter

Barker, Brooks [brooks.barker@fayette.kyschools.us]
Sent: Tuesday, June 11, 2013 7:35 PM
To: Aliciann Moberly
Attachments: SCN_20051019174807_001.pdf (141 KB)

From: Raff, Richard (PSC) [Richard.Raff@ky.gov]
Sent: Tuesday, June 11, 2013 1:49 PM
To: Barker, Brooks
Subject: FW: East Kentucky Letter

Attached is the October 7, 2005 letter from East Kentucky Power to the PSC requesting a Staff legal opinion relating to the proposed replacement/upgrading of a transmission line. Let me know if you need any additional information.
Richard Raff
(5020 782-2588

Barker, Brooks

From:	Barker, Brooks
Sent:	Wednesday, July 03, 2013 11:54 AM
To:	DeRouen, Jeff (PSC)
Subject:	RE: Filing Claim Regarding EKPC's 345kv/138kv transmission line per phone conversation on June 28th, 2013

Thank You.
Ann, Harold & Brooks

From: DeRouen, Jeff (PSC) [mailto:Jeff.DeRouen@ky.gov]
Sent: Wednesday, July 03, 2013 11:48 AM
To: Barker, Brooks
Subject: RE: Filing Claim Regarding EKPC's 345kv/138kv transmission line per phone conversation on June 28th, 2013

That should be no problem. I believe someone is going to try to contact you today or Friday.

Jeff Derouen
Executive Director
Kentucky Public Service Commission
211 Sower Boulevard
Frankfort, Kentucky 40601
(502) 564-3940

From: Barker, Brooks [mailto:brooks.barker@fayette.kyschools.us]
Sent: Wednesday, July 03, 2013 11:33 AM
To: DeRouen, Jeff (PSC)
Subject: RE: Filing Claim Regarding EKPC's 345kv/138kv transmission line per phone conversation on June 28th, 2013

Thanks so much for the form/process. We will be faxing the completed form back to you soon.
If possible could we get about a day notice of when the inspector will be coming?
Thanks again,
Ann, Harold & Brooks

From: DeRouen, Jeff (PSC) [mailto:Jeff.DeRouen@ky.gov]
Sent: Tuesday, July 02, 2013 2:50 PM
To: Barker, Brooks
Cc: Raff, Richard (PSC)
Subject: RE: Filing Claim Regarding EKPC's 345kv/138kv transmission line per phone conversation on June 28th, 2013

Thank you for your email and we enjoyed talking with you last week. As we discussed, we are going to send an inspector out to look at the safety aspects of the issues you have brought to us. During our conversation you expressed interest in filing a formal complaint regarding these matters. Attached is a form motion and procedure to follow.

Thanks.

Jeff Derouen
Executive Director

Kentucky Public Service Commission
211 Sower Boulevard
Frankfort, Kentucky 40601
(502) 564-3940

From: Barker, Brooks [mailto:brooks.barker@fayette.kyschools.us]
Sent: Monday, July 01, 2013 8:59 AM
To: DeRouen, Jeff (PSC)
Cc: Raff, Richard (PSC)
Subject: Filing Claim Regarding EKPC's 345kv/138kv transmission line per phone conversation on June 28th, 2013

July 1, 2013

Executive Director
Public Service Commission
Jeff Derouen

Dear Sir:

Harold, Brooks and I wish to thank you and Mr. Raff for your time and consideration on June 28th, 2013, regarding our problem with the EKPC 345kv/138kv transmission lines.

We believe, that Sherman Goodpaster's letter of October 7th, 2005 to the PSC requesting a staff opinion for the replacement & upgrading of the existing Smith-Hunt-Sideview electric transmission lines thru Clark Co. Ky. was misleading. EKPC indicated in their letter this would be a replacement & upgrade of their single-circuit 69kv line to a double circuit 345kv/69kv electric transmission line.

Also they indicated that in two locations it would be necessary to locate the 345kv circuit on a separate and new centerline, and these sections of the new centerline would be less than 4000 ft. in length.

Actually EKPC installed a double circuit 345kv/138kv line and moved three sections instead of the two indicated, to a new easement and created a new centerline of 14,697 ft. The first section was 3751 ft. on the northern end associated with the North Clark Co. Substation site. The second was a 6969 ft. section near the southern end on Jackson Ferry Rd. where the ROW was moved due to a property owners request. The third was a 3977 ft. section on the southern end located near the J.K. Smith property. All of the above mentioned facts- the 345kv/138kv upgrade and the moving of the ROW/lines is reported in the Gilpin Group Environmental Report required by RUS and published in May 2006.

According to KRS 278.020(1) & (2) as indicated in the PSC reply letter to EKPC dated October 26th 2005, an electric transmission line of 138kv or more, and is more than 5280 ft. in length shall not be considered an ordinary extension of an existing system and would require the issuance of a certificate of public convenience and necessity by the Commission. Senate bill 246 enacted in 2004 outlines the same requirements and procedures for a CPCN.

Since no certificate was required all land owners for this 18 miles of lines were denied the normal procedures & time to file any claims with the PSC. On October 31st 2005 (five days after your letter to EKPC) we received a notice of an open house on November 10th 2005 concerning the expansion on the transmission lines. At this meeting we told Bruce Murrey of EKPC that we were concerned about the large voltage increase and the location of the large steel poles so close to our home. EKPC indicated they did not know which route would be used for this expansion at this time. The next information of any kind from EKPC came in March 2006 when the surveyor staked their ROW. The easement is in the middle of our front yard and goes through the carport and garage of our home.
From this date of March 2006 forward, we have had numerous meetings, letters and phone conversations with EKPC concerning the movement of this easement away from our home- with no success. On June 9th, 2006, EKPC filed a condemnation suit against us in Clark Circuit Court- case no. 06-CI00419.

Currently the lines are at approximately 20 percent load capacity per EKPC and we receive a shock if you touch the metal on a vehicle in the driveway. The EMF levels have been as high as 23 milligauss inside the house. It is necessary to warn my customers who come to the Candy Shop that they are in a high electric/magnetic field in case they have a pacemaker or other implanted medical devices.

We believe if the PSC in the beginning had been given accurate details about the expansion, a certificate of public convenience and necessity would have been required. This would have given the PSC and all the land owners of these 18 miles, adequate time to investigate the expansion, file claims and have hearings with the PSC. The CPCN issued for the Clark-Madison-Garrard Co. lines appears to have given those land owners the ability to formally voice any concerns regarding the construction and easement issues of the lines.

It is due to the inaccurate information and the health & safety concerns of our family and the public, that we are filing this claim with the PSC. We appreciate your time and assistance in helping us to resolve an unhealthy and dangerous situation caused by these massive transmission lines being placed too close to our home.

Sincerely,

Ann Barker
Harold Barker
Brooks Barker

16. Concerning transmission lines,

a. Please identify how many miles of transmission lines Mr. Pfeiffer has personally routed, designed or built, including the voltage of such lines, where they were located and who owned them.

ANSWER BY: John Pfeiffer

With respect to this investigation I was not asked to design a transmission line but rather to evaluate an existing transmission line with respect to its proximity to the Barkers' house..

Next, we have to define what we consider a transmission line, there are many types. For simplicity we will call a transmission line a line of 60 Hz, 69,000 volts or higher and that the line transfers electrical energy between two substations where the voltage is raised or reduced. Next, when considering the design of a transmission line, one has to break the line into its components such as pole/tower, conductor, line ampacity, guying requirements and so on. Design of transmission line poles is primarily a mechanical engineering task since it has little to do with electricity. I normally will not size a pole but rather have a mechanical engineer perform the task even though I have had classes in college on subjects such as strengths of materials, and static and dynamic mechanical forces, all necessary areas of knowledge to design a transmission line. Likewise I am not a registered surveyor so I would not layout the final line of the right of way. Other areas of design are defining the load requirements of the transmission line, line voltage, thermo effects on the heating of the line and line sag. I have performed all of these types of tasks during my many years of experience. As an example I designed a 13,800 distribution system for Reynolds Aluminum in Louisville. The aerial cable system consisted of four three-conductor cables in metallic sheath. This aerial cable system had a much higher weight per foot then the transmission line in question. I defined the loads, laid out the route, specified the cable, performed the sag calculation and had a mechanical engineer design the needed steel poles, cross arms, and pole burial depth. While these four distribution cables are not considered a transmission line, I had to perform the same types of design activities.

Cable data:

13,800 Volts

4/0 to 350 kcmil

3 conductor cable, aluminum,

2.04 to 2.94 inch diameter, 2.226 to 6.182 lbs/ft. continued on next page……

Total weight per foot including messenger cables = 24.4 lbs/ft.

The 345,000 volt transmission line consisted of 6 cables with a total weight of approximately 7.4 lbs/foot

The 138,000 volt transmission line consisted of 3 cables with a total weight of approximately 3.6 lbs/foot

Note: Ice loading is not included in the above.

b. Has Mr. Pfeiffer ever been personally involved in the budgeting/estimating of a transmission line project? If yes, please identify the location, length, voltage, and owner of each project.

ANSWER BY: John Pfeiffer

Again, I have not been asked to design a transmission line and thus have not had the need to estimate the cost of a line. However, I have estimated the cost of distribution lines in industrial facilities as well as performed many design and construction cost estimates over the years. Cost estimating is not normally a part of an electrical engineering education but rather is a learned educational function through practical experience. Over my 45+ years of experience I have estimated many large projects with a high percentage of these projects where I personally was exposed to the full financial risk as the owner of an engineering company who also did design/build projects.

Cost estimating for this investigation consisted of obtaining actual material cost data and/or using established estimating data.

17. Please indicate how many electric and magnetic field evaluation reports Mr. Pfeiffer had prepared during the past ten years. Please explain why each report was prepared and please provide a copy of each such report.

ANSWER BY: John Pfeiffer

As in the majority of my engineering activities I am often involved in many engineering task that I haven't performed before. It is expected that an engineer has sufficient education to know how to obtain the required technical information needed to perform any particular project. Engineering education, training classes, etc. generally lag way behind technology Thus, engineering schools provide the engineer with a set of tools that will allow him/her to research new technologies as well as unfamiliar subject matter. An engineer is expected to do far more that just follow a cookbook in producing a design.

With respect to electric and magnetic fields my experience started in engineering school where 45 years ago this subject was a major subject of study. Since starting to work as an engineer, I have often been called upon to solve problems dealing with EMF in the form of electrical noise impacts on electronic/digital circuits. Although I have worked with the issue of EMF for years I have not produced a formal report on this subject.

18. Please provide the source(s) for all electrical and magnetic field documentation utilized in the Pfeiffer report. In addition, please provide a detailed explanation of how information based on 50 Hz power applies to 60 Hz power.

ANSWER BY: John Pfeiffer

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26. Power-line radiation and childhood leukemia: this cold case may finally be solved: Tekla Perry, December 16, 2008
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28. EMF Levels & Safety, Scantech
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34. Faulty DNA Repair May Explain EMF Role in Childhood Leukemia, Microwave News, December 15, 2008
35. Power-line radiation and childhood leukemia: this cold cast may be solved, IEEE spectrum, December 16, 2008
36. Lukemia & Lymphoma, Dec. 2008
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ANSWER BY: John Pfeiffer

In the United States and many other countries base their electrical system on a frequency of 60 Hz. Many other countries however, base their electrical system on a frequency of 50 Hz. When comparing 60 Hz measurement to 50 Hz measurement it's a simple multiplying factor. 100mG @ 50Hz = 83 mG @ 60Hz[1]

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[1] http://www.who.int/peh-emf/about/WhatisEMF/en/index3.html

19. Please refer to page 6 of Mr. Pfeiffer's report, Section V, part A. Mr. Pfeiffer states, "EKPC misrepresented critical distances where new right-of-way for the transmission line is required in addition to the existing right-of-way being used for the majority of the project." On page 37 of Mr. Pfeiffer's report he provides a summary of the line deviation segments; however he does not explain how the deviations were determined. Please provide a detailed explanation of the methods used by Mr. Pfeiffer to determine these deviations. Including all supporting workpapers, analyses and other documentation used to make the determination.

ANSWER BY: John Pfeiffer

The report attempted to show that EKPC continuously tried to mis-lead the PSC by constantly changing the ROW centerline distance. Due to the number of changes in EKPC numbers I used several methods to define property boundaries and the actual route of the transmission lines. The following is a list of information used.

1. Overview of the transmission line using Google Earth aerial maps.
2. Maps in the Gilpin Report, and from the Ky. Geological Department and Clark County PVA
3. Property deeds
4. Property option contracts

Continued on next page.............

In developing the various segment lengths I used various methods to make this determination. First, I tried to use EKPC data but this was very inconsistent.

Date	Source	ROW Locations	Deviation within property owned by landowners	Total deviation	
10/ 7/05	EKPC letter to PSC	2 locations where new ROW is needed		4000 ft.	
10/10/13	Answers from EKPC		8000 ft.	8000 ft.	
		North Clark SW Yard	2800 ft. leading to SW YD		
		North Clark SW Yard	2400 ft in SW YD	5200 ft.	
11/30/13	Answers from EKPC	North Clark SW Yard	2800 ft. leading to SW YD is now 1875 ft		
		North Clark SW Yard	2400 ft in SW YD is now 1880 ft.	3755 ft	EKPC claimed it was their property but was purchased for this project
		Shearer Estate	425 ft		
		Foley Estate	6550 ft	6975 ft	
		North Clark SW Yard	3755 ft.		
		Clark SB St	6975 ft	10730 ft.	

Continued on next page..........

Next, I obtained various maps and property deeds in order to determine the actual center line and where it deviated from the original center line of the existing ROW. I next confirmed all values by measuring the distance using Google Earth as shown below.

SUMMERIZATION of LINE DEVIATION SEGMENTS:

	Line Segment Distance in Feet **from Google Earth**	Total Line Segment Distance in Feet		Property Owners	Total Line Segment Distance in Feet	Total Line Segment Distance in Feet	Data Source
North Clark							
	1880			Stearns, Reffett, etc.	**1693**		**Gilpin pg 18**
	1875			Sword			
Segment Total Clark Substation		3755				**3755**	**PSC Request 1**
	557			Foley & Shearer			
	3051			Foley Property 1			
	3435			Foley Property 2			
Segment Total JK Smith Gen Station		7043			**6969**		**Gilpin pg 18**
						6975	**PSC Request 1**
	0			Haggard & Bower			
	3679			EKPC			
Segment Total		3679			**3977**	**3977**	**Gilpin pg 18**
Total Deviation from Existing ROW		14477			10946	**14707**	

The 14707 feet is the value that I am using as the official distance and is based upon EKPC documents.

20. Please refer to page 8 of Mr. Pfeiffer's report, Section V part H. Mr. Pfeiffer states, "These perceived health risk are also affecting the candy business that Mrs. Ann Barker runs out of her garage, as people are afraid to come to her business because of the close proximity to these lines." Please provide documentation covering the past 15 years to support this claim, such as business receipts records and income tax records for the candy business.

ANSWER BY: The Barkers

EKPC has misinterpreted John Pfeiffer's statement that, "people are afraid to come to her business because of the close proximity to these lines". Mr. Pfeiffer did not say this was a loss in revenue however this could occur and we would not have any knowledge of it unless they told us that they were avoiding the premises due to the close proximity of the lines. The way in which it is affecting the candy business is that some of our customers have to make arrangements to have their candy or supplies either delivered by the shop or arrange for someone else to pick up their order. This is because they have either a pacemaker or an (ICD) an implantable cardioverter defibrillator and have received instructions upon their release from the hospital to avoid being near high voltage, magnetic force fields, or radiation because these can cause pacemaker malfunction.

** See attachments after this page of dismissal instructions from hospitals.

IEEE Trans Biomed Eng. 2002 Mar;49(3):254-62.

Pacemaker interference by magnetic fields at power line frequencies.

Dawson TW, Caputa K, Stuchly MA, Shepard RB, Kavet R, Sastre A.

Department of Electrical and Computer Engineering, University of Victoria, BC, Canada.

Abstract

Human exposure to external 50/60-Hz electric and magnetic fields induces electric fields within the body. These induced fields can cause interference with implanted pacemakers. In the case of exposure to magnetic fields, the pacemaker leads are subject to induced electromotive forces, with current return paths being provided by the conducting body tissues. Modern computing resources used in conjunction with millimeter-scale human body conductivity models make numerical modeling a viable technique for examining any such interference. In this paper, an existing well-verified scalar-potential finite-difference frequency-domain code is modified to handle thin conducting wires embedded in the body. The effects of each wire can be included numerically by a simple modification to the existing code. Results are computed for two pacemaker lead insertion paths, terminating at either atrial or ventricular electrodes in the heart. Computations are performed for three orthogonal 60-Hz magnetic field orientations. Comparison with simplified estimates from Faraday's law applied directly to extracorporeal loops representing unipolar leads underscores problems associated with this simplified approach. Numerically estimated electromagnetic interference (EMI) levels under the worst case scenarios are about 40 microT for atrial electrodes, and 140 microT for ventricular electrodes. These methods could also be applied to studying EMI with other implanted devices such as cardiac defibrillators.

ID: 11876290 [PubMed - indexed for MEDLINE]

- Turn off large motors, such as cars or boats, when working on them (they may temporarily "confuse" your device).
- Avoid certain high-voltage or radar machinery, such as radio or television transmitters, arc welders, high-tension wires, radar installations, or smelting furnaces.
- If you are having a surgical procedure performed by a surgeon or dentist, tell your surgeon or dentist that you have a pacemaker or ICD. Some surgical procedures will require that your ICD be temporarily turned off or set to a special mode; however, this will be determined by your cardiologist. Temporarily changing the mode on your pacemaker can be performed noninvasively (no additional surgery is required), but should only be performed by qualified medical personnel.
- Always carry an ID card that states you have a pacemaker/ICD. It is recommended that you wear a medic alert bracelet or necklace if you have a device.
- You may have to take antibiotic medication before any medically invasive procedure to prevent infections.

Always consult your physician or device company if you have any questions ---cerning the use of certain equipment near your pacemaker/ICD.

ᴗan I participate in regular, daily activities with a pacemaker/ICD?

Once the device has been implanted, people with pacemakers/ICDs should be able to do the same activities everyone else in their age group is doing. When you have a pacemaker/ICD, you may still be able do the following:

- exercise moderately, upon advice from your physician
- drive your car or travel if cleared by your doctor
- return to work
- work in the yard or house
- participate in sports and other recreational activities
- take showers and baths
- continue sexual relationships

When involved in a physical, recreational, or sporting activity, a person with a pacemaker/ICD should avoid receiving a blow to the area over the device. A blow to the chest near the pacemaker/ICD can affect its functioning. If you do receive a blow to that area, see your physician.

ys consult your physician when you feel ill after an activity, or when you have __tions about beginning a new activity.

MERCY
Care you can believe in.

ɹischarge Instructions for Patients With ICD's

Cardiac Patient Care Handbook

General Instructions

- Carry your ID Card for your ICD with you at all times. This card will be given to you in the hospital or mailed to you.
- Medic Alert Bracelets are available from your pharmacist to wear at all times.
- Follow-up appointments with the ICD doctors will be discussed with you before discharge.
- Your family members should be trained in CPR. Mercy Health Partners, as well as other local organizations such as the American Heart Association provide this service.
- Carry your ID Card for your ICD with you at all times. This card will be given to you in the hospital or mailed to you.
- The ICD will bulge slightly under your skin. This bulge will decrease in size over the next few weeks. Please notify the doctor's office if you notice any of the following around your ICD site:

A bruise that does not go away.

Soreness or yellow, green, or brown drainage from the site.

Any swelling from the site.

If you have a fever of 100 degrees or higher that lasts for a few days.

- You do not need a dressing over site unless told otherwise.
- Leave steri-strips over your site until they start to fall off.
  Keep your incision clean and pat dry. Do not scrub. You may shower or bathe as long as your incision isn't submerged or directly sprayed upon until well healed.
  For comfort, wear loose fitting clothing.
- Report any signs of infection, fever, pain, swelling, redness, oozing, or heat at site especially if these symptoms increase after the first 3 to 4 days.

Activity Precautions

- Avoid activity that involves rough contact with the ICD site.
- The doctor will instruct you when you may resume driving.
- Avoid lifting your arm over your head on the ICD side or lifting over 10 pounds for 4 weeks.
- Do not carry objects by holding them against your ICD site.

Special Precautions

- You should avoid all strong magnetic fields, such as welding, large transformers, or large motors. Some ICD devices will beep if it detects a strong magnet. If this occurs, move out of the area.
- Treatments or surgery that require diathermy or electrocaudry should be discussed with your doctor before scheduled.
- Avoid radio frequency transmitters, including radar.
- Advise dentist or other medical personnel you see that you have an ICD.
- If you plan to move or take a trip to a new area, the doctor's office will give you a name of a doctor to contact for any problems.

:ial Instructions on Shocks

ɲ fy your doctor for any of the following:

- Anytime a shock is received in a 24 hour period. An office visit is not usually required for a single shock.
- Two or more shocks in a row. If you do not feel well, call the Rescue Squad, otherwise call your doctor. This may require an office visit.

Activity Guidelines

• You should limit use of your arm and shoulder where the pacemaker was placed for the first 1 to 3 months. You should NOT do any heavy pushing, pulling, or raising your arm above your shoulder until told otherwise by your cardiologist.

• Do not drive until advised by your cardiologist. This is usually 1 to 4 weeks

• You may do light housework such as washing dishes and cooking. Avoid vacuuming, lifting laundry, overhead cleaning, and activities that require frequent reaching.

• Ask your cardiologist before doing any sport activities such as golf, bowlin hunting, fishing or weight lifting.

Pacemaker Precautions

• Avoid being near areas with high voltage, magnetic force fields, or radiati because these can cause pacemaker malfunction. These areas may include high tension wires, power plants, large industrial magnets and arc welding machines. Symptoms of pacemaker malfunction are dizziness, lightheadedness or changes in heart rhythm. If symptoms occur, back up 10 feet and check your pulse.

• Pacemakers inserted today are not affected by microwave ovens. Pacemakers have built-in safety mechanisms protecting them from this electrical interference.

• When you go to an airport, always carry your pacemaker card with you. Because the pacemaker contains metal, it may trigger an airport metal detector. Explain to the airport attendant that you have a pacemaker so tha special arrangements can be made for a security check. The metal detector itself will NOT harm the pacemaker.

• Do not have an MRI (Magnetic Resonance Imaging) test because it can damage your pacemaker.

Call your cardiologist if you have:

• severe pain at your pacemaker site

• frequent or constant hiccups

• twitching of your abdominal muscles

• shortness of breath

• dizziness, lightheadedness or blackouts

21. Please refer to pages 12 and 13 of Mr. Pfeiffer's report which lists states in which there are limits for magnetic and electric fields. For each state identified, please provide:

a. The field strength(s) for both magnetic and electric field limits

b. The date that each limit was adapted by the state

c. The agency responsible for adapting each limit

d. the source(s) relied upon by Mr. Pfeiffer to make the claim about each state identified herein.

ANSWER BY: John Pfeiffer

Dr. Paul Dolloff's in-house mail letter to Sherman Goodpaster on December 19, 2008 states as follows: "Currently, there are no federal standards limiting occupational or residential exposure to 60 Hz electric or magnetic 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..." This is the same table shown as Figure 15 – State Transmission Line Standards and Guidelines, page 55 which was obtained from the same publication Dr. Dolloff referenced "EMF Electric and Magnetic Fields Associated with the Use of Electric Power, June 2002, National Institute of Health

Page 20 of "Siting of Electric Transmission Lines" Research Report No. 348, Adopted November 8, 2007 states:

"**Some States Have Standards for Allowable Electromagnetic Fields**. At least six states have standards for maximum electric fields in the rights-of-way and/or at the edges of rights-of-way of transmission lines: Florida, Minnesota, Montana, New Jersey, New York, and Oregon. At least four states have standards for magnetic fields at the edges of rights-of-way: Connecticut, Florida, Massachusetts, and New York (Commonwealth of Virginia 87; U.S. Dept. of Health. National. Electric 46). In 2004, the Connecticut General Assembly enacted into law the requirement that the Connecticut Siting Council adopt standards for best management practices for EMF. The law also establishes a presumption that transmission lines of 345 kilovolts or more located adjacent to residential areas and other specified areas should be buried. The law allows an applicant to rebut this presumption by showing the council that burial is technologically infeasible, taking into account the reliability of the state's electric grid."

Continued on next page.....

The determination of where in each state's legal system is the location of all statutes and rules dealing with EMF is a difficult task. Florida's statutes were found and follows. ......

Florida - 62-814.450. Electric and Magnetic Field Standards, Effective: Sunday, June 01, 2008. This regulation is a standard that was rewritten and applies to all transmission lines as of March 21, 1989.

Table of New Transmission Line and Substation Standards

KV Rating	Property Boundary of new Substation	Edge of Transmission Line Right-of-Way	On the Transmission Line Right-of-Way
<=230 kV	2.00 kV/m & 150 milliGauss	2.00 kV/m & 150 milliGauss	8 kV/m
<=500 kV and > 230 kV	2.00 kV/m & 200 milliGauss [1]	2.00 kV/m & 200 milliGauss [1]	10 kV/m
>500 kV	5.50 kV/m & 250 milliGauss	5.50 kV/m & 250 milliGauss	15 kV/m

http://www.ehib.org/emf/RiskEvaluation/riskeval.html

The fact that three references have been provided shows that these limits of EMF exposure do exist and can be verified later. The time limit for answering these questions do not allow for an exhaustive research which will require inquiries to each state be answered.

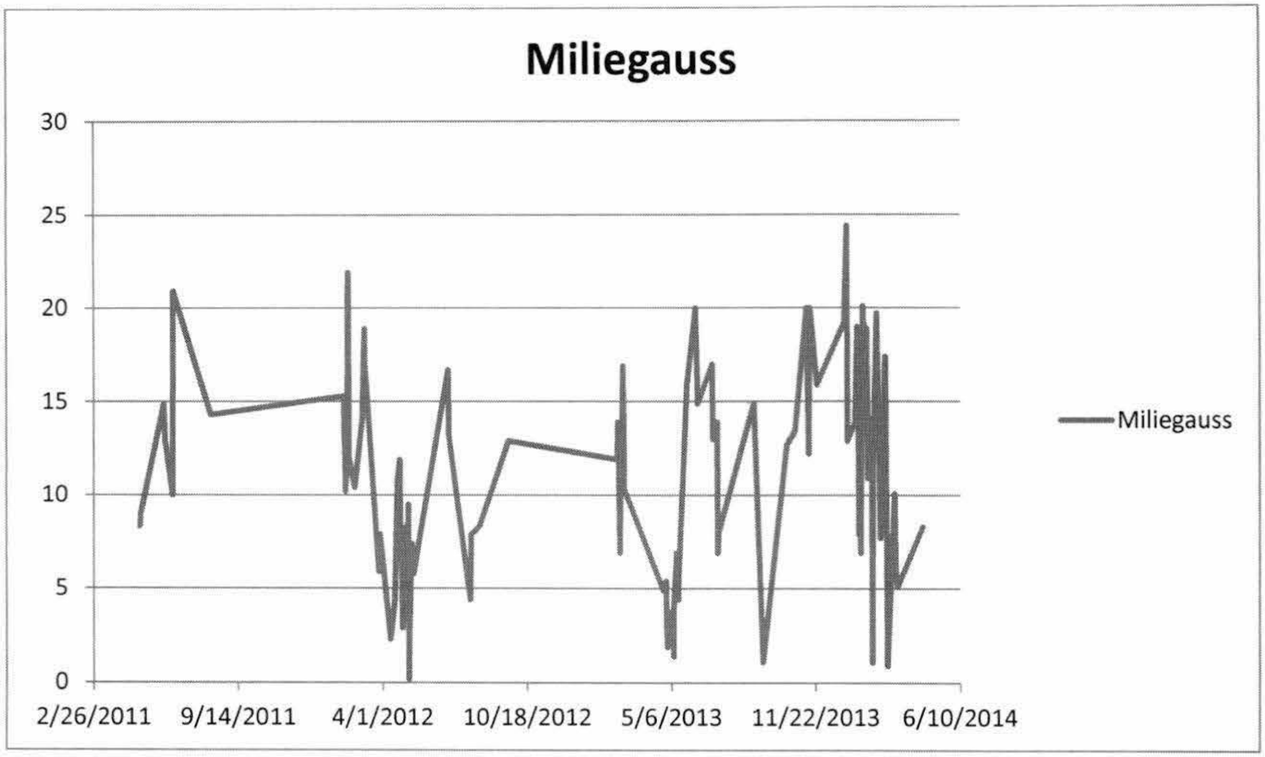
22. Please refer to page 13 of Mr. Pfeiffer's report, Item F. Mr. Pfeiffer states, "The power lines are being operated at far less than full capacity today." Please provide documentation supporting this statement.

ANSWER By: John Pfeiffer

The baseline for this statement is the energy levels that existed from January 19, 2012 when I made magnetic field measurements. The energy data was provided by Dr. Dolloff for this date. As stated in my report, page 74, the 345 kV line was operating at 13.1% of capacity and the 69 kV line was operating at 4.9% of capacity. The chart as shown in Figure 3 on page 13 shows the range of magnetic fields over time. On the baseline day my measurements magnetic fields at 90 feet from the centerline of the transmission line was 3.6 mg. 90 feet places the measurement in the kitchen of the Barker house. This is the same point represented by the chart below.

Based upon my projected emf levels for the line operating at full capacity the magnetic fields would be far greater than existing today.

Continued on next page........



Also, if EKPC does not intend to utilize the new transmission lines at or near their capacity then EKPC wasted the utilities money in building transmission lines with excess capacity that they never expect to use.

23. Please refer to pages 13 and 14, Item F of Mr. Pfeiffer's report. Please provide the basis and calculation for his estimate of magnetic fields and electric fields.

ANSWER BY: John Pfeiffer

Calculations of conductor sag and their effect on EMF have been developed for this location and is defined below.

I have estimated that the magnetic fields will be varying from 10 mG and to a high of 191 mG over time. Also the electric fields will vary from 0.997 kV/m to a high of 1.438kV/m over time.

The basis for these estimates is the lines capacities and the calculation of the amount of cable sag that will result as these lines reach capacity. By combining the increased sag and increased load the magnetic and electric fields can be predicted.

Line sag is calculated based upon IEEE sag formulas as illustrated in a IEEE Tutorial developed for the IEEE TP&C Line Design Subcommittee which is based upon a CIGRE WG B2.12 Technical Brochure. This tutorial was based around the SAG10 software program.

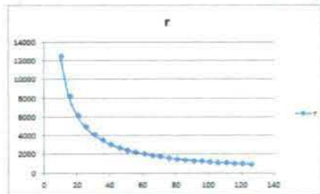
Instead of using the SAG10 program the formulas were entered into an Excel spreadsheet program. All calculations were verified by comparing the spreadsheet results against the SAG10 results.

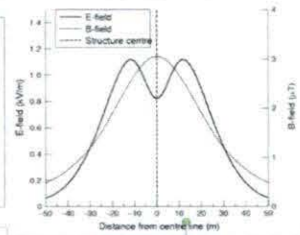
The first step in the analysis was to develop a spreadsheet model of typical electric fields. Spreadsheet 1 shows the model developed which has three curves based upon the distance from the center of the transmission line.

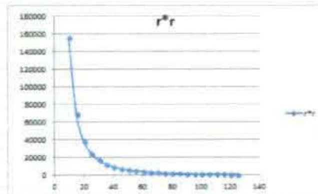
Continued on next page..........

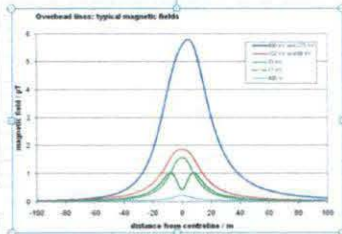
http://www.emfs.info/Sources+of+EMFs/Overhead+power+lines/Calculating/geometries/

e	r		r*r		
1000	125	125000	1000	125	15625000
1042	120	125000	1085	120	15625000
1087	115	125000	1181	115	15625000
1136	110	125000	1291	110	15625000
1190	105	125000	1417	105	15625000
1250	100	125000	1563	100	15625000
1316	95	125000	1731	95	15625000
1389	90	125000	1929	90	15625000
1471	85	125000	2163	85	15625000
1563	80	125000	2441	80	15625000
1667	75	125000	2778	75	15625000
1786	70	125000	3189	70	15625000
1923	65	125000	3698	65	15625000
2083	60	125000	4340	60	15625000
2273	55	125000	5165	55	15625000
2500	50	125000	6250	50	15625000
2778	45	125000	7716	45	15625000
3125	40	125000	9766	40	15625000
3571	35	125000	12755	35	15625000
4167	30	125000	17361	30	15625000
5000	25	125000	25000	25	15625000
6250	20	125000	39063	20	15625000
8333	15	125000	69444	15	15625000
12500	10	125000	156250	10	15625000

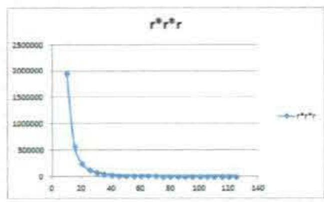








r*r*r		
1000	125	1953125000
1130	120	1953125000
1284	115	1953125000
1467	110	1953125000
1687	105	1953125000
1953	100	1953125000
2278	95	1953125000
2679	90	1953125000
3180	85	1953125000
3815	80	1953125000
4630	75	1953125000
5694	70	1953125000
7112	65	1953125000
9042	60	1953125000
11739	55	1953125000
15625	50	1953125000
21433	45	1953125000
30518	40	1953125000
45554	35	1953125000
72338	30	1953125000
125000	25	1953125000
244141	20	1953125000
578704	15	1953125000
1953125	10	1953125000

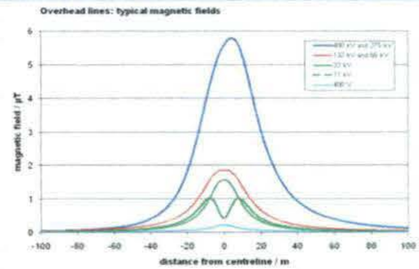


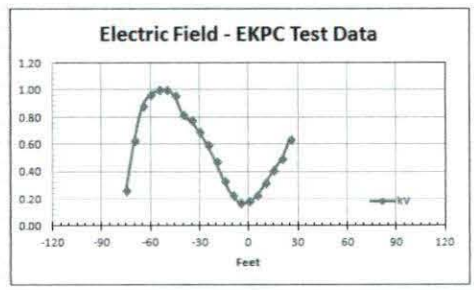
Spreadsheet 1 – Model of EMF Fields

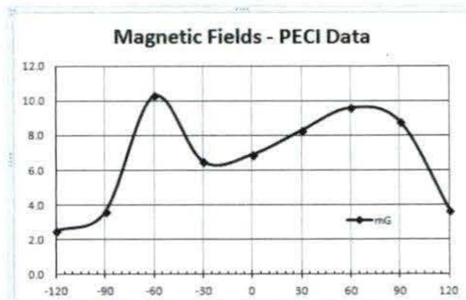
Continued on next page.........................

Next, the measured data was analyzed as shown in Spreadsheet 2.

	A	B	C	D	E	F	G	H	I	J
1										
2		EKPC Data								
3	0	-75	0.257		-120	0	2.5	-120	0	2.5
4	5	-70	0.621					-90	30	3.6
5	10	-65	0.878					-60	60	10.3
6	15	-60	0.964					-30	90	6.5
7	20	-55	0.996					0	120	6.9
8	25	-50	0.997					30	150	8.3
9	30	-45	0.953		-90	30	3.6	60	180	9.6
10	35	-40	0.814					90	210	8.8
11	40	-35	0.771					120	240	3.7
12	45	-30	0.685							
13	50	-25	0.589							
14	55	-20	0.466							
15	60	-15	0.326		-60	60	10.3			
16	65	-10	0.225							
17	70	-5	0.166							
18	75	0	0.176							
19	80	5	0.225							
20	85	10	0.31							
21	90	15	0.407		-30	90	6.5			
22	95	20	0.492							
23	100	25	0.632							
24	105									
25	110									
26	115									
27	120				0	120	6.9			
32	kV									
33	mG									
34	Feet									
35	Electric Field									
37	Magnetic Field - PECI Test									



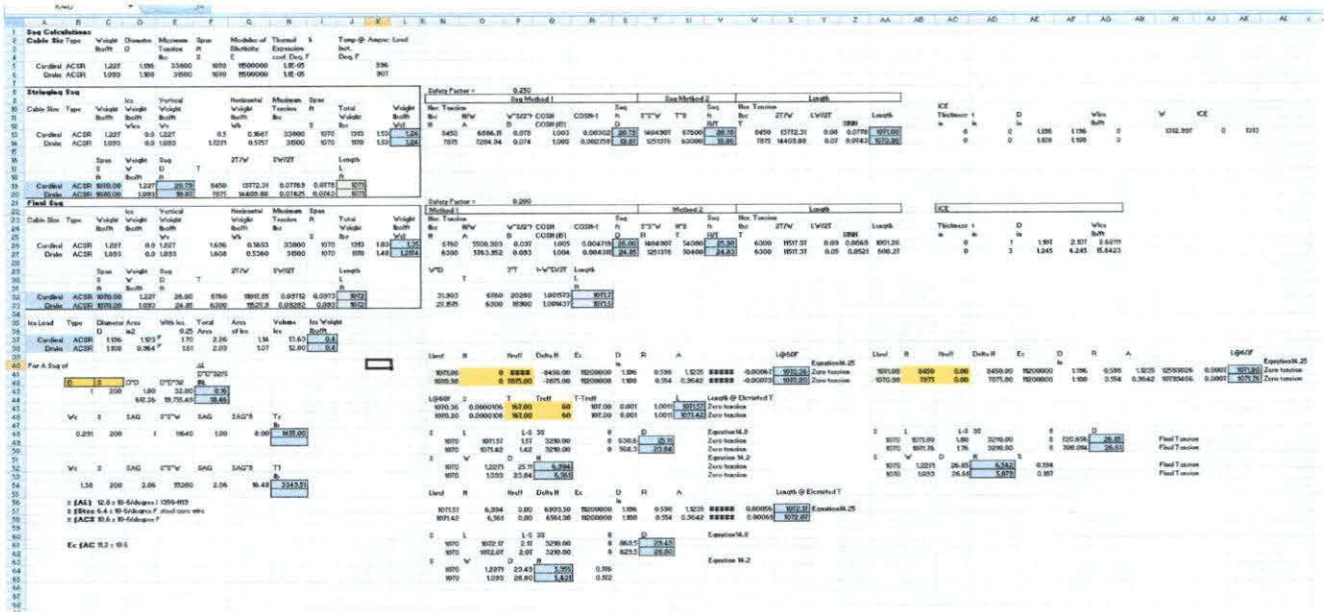




Spreadsheet 2 – Measurement Data

Continued on next page........

The third step was to calculate the cable sag using a spreadsheet I developed based upon the IEEE Tutorial.



Spreadsheet 3 – Cable Sag Calculations

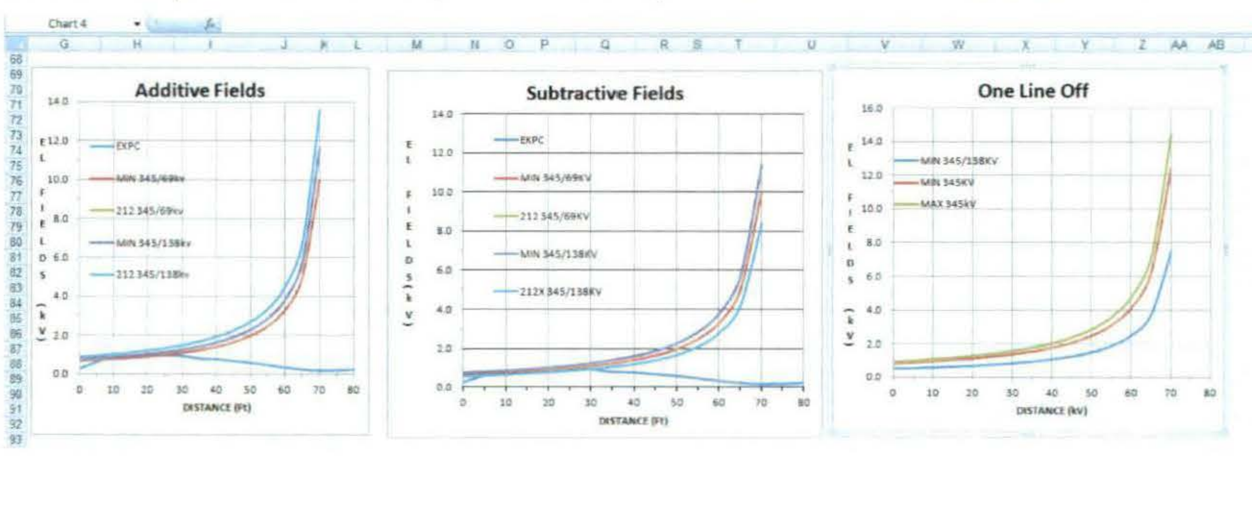
Continued on next page.....................

The final step was to develop spreadsheets combining the data above to study both the effects of additive and subtractive transmission lines. The additive spreadsheet follows.

	A	B	C	D	E	F	G	H	I	J	K	L	N	O	P	R	S	T
1	Magnetic Fields					Height above ground			ADDITIVE									
2	Top cross arm	117.50 A							345kv Min Sag	345kv 212 Sag	69kv Min Sag	69kv 212 Sag	345kv Min Sag	69kv Min Sag	Line Min Sag	345kv 212 Sag	69kv 212 Sag	Line 212 Sag
3	Below Insulator	10.50 B																
4	345kv min below	20.78 C			A-B-C	86.22												
5	345kv 167 below	29.49 D			A-B-D	77.51												
6	345kv 212 below	32.30 E				74.70		D	86.22	74.70	69.14	57.42						
7	Bot cross arm	23.00 F						P	60	60	60	60						
8	Below Insulator	5.50 G						Amps	47.59	3258	250.81	1468						
9	69kv min below	19.86 H			A-F-G-H	69.14		2I	95.18	6516	501.62	2936						
10	69kv 167 below	28.80 I			A-F-G-I	60.20	varaible	X	1.036	1.036	1.036	1.036						
11	69kv 212 below	31.58 J			A-F-G-J	57.42		2I*X	98.61	6750.58	519.68	3041.70						
12	Ground @ Pole	0.00					2I*X/P	B	1.64	112.51	8.66	50.69	10.30 B@ 60FT					
13								L	MIN D/MIN D	MIN D/212 D	MIN D/MIN D	MIN D/212 D						
14								L	1.00	1.15	1.00	1.20						
15					Magnetic			2I*X*L	98.61	7791.63	519.68	3662.54						
16					Field													
17		FT	Ft	Ft	Measurements			R1	B@R1	B@R1	B@R1	B@R1	B@R1*VR	B@R1*VR	SUM	B@R1*VR	B@R1*VR	SUM
18		0	0		2.5		2I*X*L/R1	120	0.822	64.930	4.331	30.521	0.822	4.331	5.152	64.930	30.521	95.451
19		5						115	0.857	67.753	4.519	31.848	0.857	4.519	5.376	67.753	31.848	99.601
20		10						110	0.896	70.833	4.724	33.296	0.896	4.724	5.621	70.833	33.296	104.129
21		15						105	0.939	74.206	4.949	34.881	0.939	4.949	5.888	74.206	34.881	109.087
22		20						100	0.986	77.916	5.197	36.625	0.986	5.197	6.183	77.916	36.625	114.542
23		25						95	1.038	82.017	5.470	38.553	1.038	5.470	6.508	82.017	38.553	120.570
24		30	30		3.60			90	1.096	86.574	5.774	40.695	1.096	5.774	6.870	86.574	40.695	127.269
25		35						85	1.160	91.666	6.114	43.089	1.160	6.114	7.274	91.666	43.089	134.755
26		40						80	1.233	97.395	6.496	45.782	1.233	6.496	7.729	97.395	45.782	143.177
27	At House	45		0				75	1.315	103.888	6.929	48.834	1.315	6.929	8.244	103.888	48.834	152.722
28		50		5				70	1.409	111.309	7.424	52.322	1.409	7.424	8.833	111.309	52.322	163.631
29	On driveway	55		10				65	1.517	119.871	7.995	56.347	1.517	7.995	9.512	119.871	56.347	176.218
30	On driveway	60	60	15	10.3			60	1.643	129.860	8.661	61.042	1.643	8.661	10.305	129.860	61.042	190.903
31	Just off driveway	65		20				55	1.793	141.666	9.449	66.592	1.793	9.449	11.242	141.666	66.592	208.258
32	grass	70		25				50	1.972	155.833	10.394	73.251	1.972	10.394	12.366	155.833	73.251	229.083
33	grass	75		30				45	2.191	173.147	11.548	81.390	2.191	11.548	13.740	173.147	81.390	254.537
34	Close to fence	80		35				40	2.465	194.791	12.992	91.563	2.465	12.992	15.457	194.791	91.563	286.354
35	Opposite side of fence	85		40				35	2.817	222.618	14.848	104.644	2.817	14.848	17.665	222.618	104.644	327.262
36	grass	90	90	45	6.5			30	3.287	259.721	17.323	122.085	3.287	17.323	20.609	259.721	122.085	381.806
37	Edge of Powerline	93						27	3.652	288.579	19.247	135.650	3.652	19.247	22.899	288.579	135.650	424.228
38		95		50				25	3.944	311.665	20.787	146.501	3.944	20.787	24.731	311.665	146.501	458.167
39		100		55				20	4.930	389.581	25.984	183.127	4.930	25.984	30.914	389.581	183.127	572.708
40		105		60				15	6.574	519.442	34.645	244.169	6.574	34.645	41.219	519.442	244.169	763.611
41		110		65				10	9.861	779.163	51.968	366.254	9.861	51.968	61.828	779.163	366.254	1145.417
42		115		70				5	19.721	1558.326	103.936	732.507	19.721	103.936	123.657	1558.326	732.507	2290.833
43	Center of Power Line	120	120	75	6.9			0										
44																		
45					Additive													
46					345	345												
47					69	138												
48					414	483												
49																		
50					0.167	0.286												
51					0.833	0.714												
52					Subtractive													
53					345	345												

Spreadsheet 3 – Transmission Line Additive model

The final step was to use the spreadsheets to produce a set of curves which follow.



24. Please refer to page 14, Figure 3 included in Mr. Pfeiffer's report. Please identify the person(s) who performed the measurements for this chart?

ANSWER BY: John Pfeiffer

Mrs. Barker and Brooks Barker.

25. Please refer to page 14 of Mr. Pfeiffer's report, Section G. Please provide all documentation Mr. Pfeiffer is aware of describing what other regulating utilities in Kentucky are doing with respect to electric and magnetic fields.

ANSWER BY: John Pfeiffer

I do not have information on other utilities in Kentucky

26. Please refer to the models used by Mr. Pfeiffer to calculate magnetic fields and electric fields on the Barkers' premises. Please indicate:

a. What software was used to perform the modeling

b. The basis for the dimensioning of the structure and phase locations used in the model.

c. The phase rotation assumptions used in the model.

d. The basis for loading (current, voltage) assumptions used in his model.

e. The basis for his conclusions that actual measurements are not given that the ground slopes downhill from the Barkers' residence toward the transmission line.

ANSWER BY: John Pfeiffer

First, there is no part or section referenced to the above questions. One has to assume that modeling is referring to projecting the EMF levels as the energy being transferred is increased.

a. Software used is Microsoft Excel
b. Dimensioning is based upon EKPC Pole Design drawing shown in Figure
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.
d. The basis on loading both voltage and current data provided by Dr. Dolloff of EKPC.
e. There is no assumption that all of the actual measurements are not valid but only that some cannot be used.

    The following graphs as shown in figures 36 and 37 of the report. These graphs are based upon measurements made on level ground. These profiles have been documented in many technical reports found and are used in the development of the reports analysis.

    Thus, since the Barkers' property slopes off to the East to such an extent that data in this sloped area cannot be used reliability. The only reason the magnetic fields were measured at the Barker house rather than at another location that is flat is that Dr. Dolloff's electrical field measurements were made in this location which is not ideal. In order to make a fair comparison with the Dolloff measurements we needed to make out measurements at the same approximate location as Dr. Dolloff. In doing so both sets of measurements are based upon the same cable distances above ground level. Cable/conductor height above ground is critical in making comparisons.

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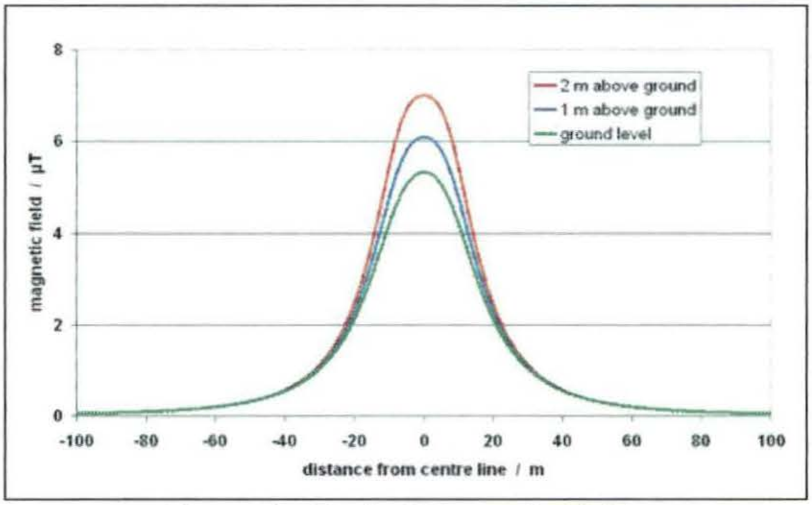

Figure 1 - Typical Magnetic Fields

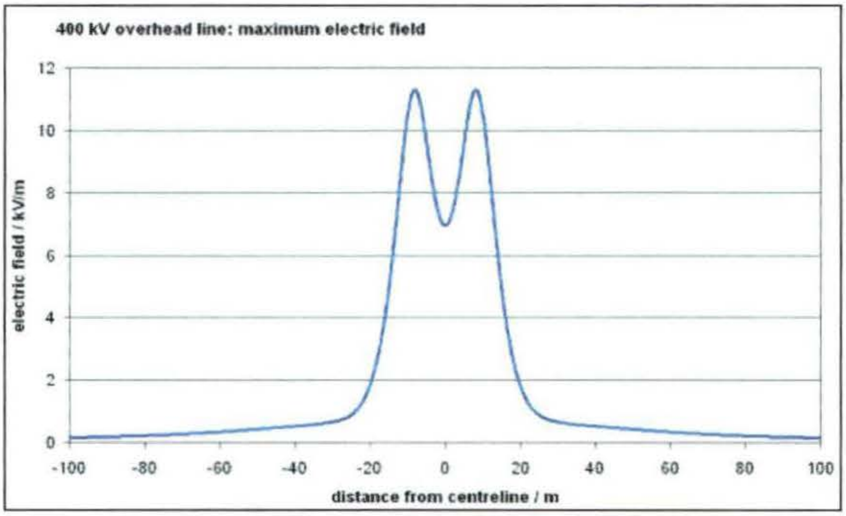

Figure 2 - Typical Electric Fields

27. Please identify all measurements of magnetic fields or electric fields personally taken by Mr. Pfeiffer. For each such measurement, please provide:

a. An identification of the type of equipment used, including the brand name, manufacturer and serial number.

b. The date he acquired each and every piece of equipment identified in response to (a) above and the person(s) from whom he acquired each and every piece of said equipment.

c. The date(s) upon which he had each and every piece of equipment identified in (a) above calibrated, the method of calibration, the standard used for each calibration and person(s) performing the calibration.

d. The training he received to operate said equipment.

e. A step-by-step description of the process by which he obtained each measurement.

ANSWER BY: John Pfeiffer

a. Measurements made by Pfeiffer Engineering Co., Inc. (PECI) were made on January 19, 2012 with the temperature at approximately 35 Degrees F. Pfeiffer Engineering used an Alpha Lab Model UHS ac milligauss meter as shown on page 67 of the report.
b. Purchase milli gause meter on 1/16/10 directly from Alpha Lab.
c. Alpha Lab Model UHS ac milligauss meter calibrated by manufacturer at time of assemble.
d. I read the instruction manual.
e. Measurement Methods as listed on page 67 through 69:

Continued on next page..........

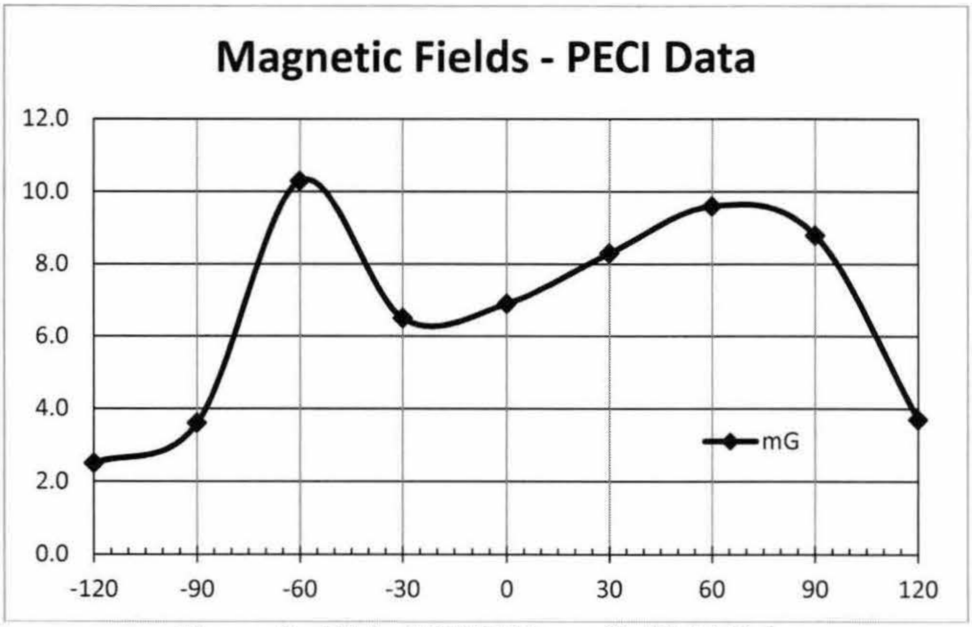

Figure 3 - Plot of PECI Magnetic Field Data

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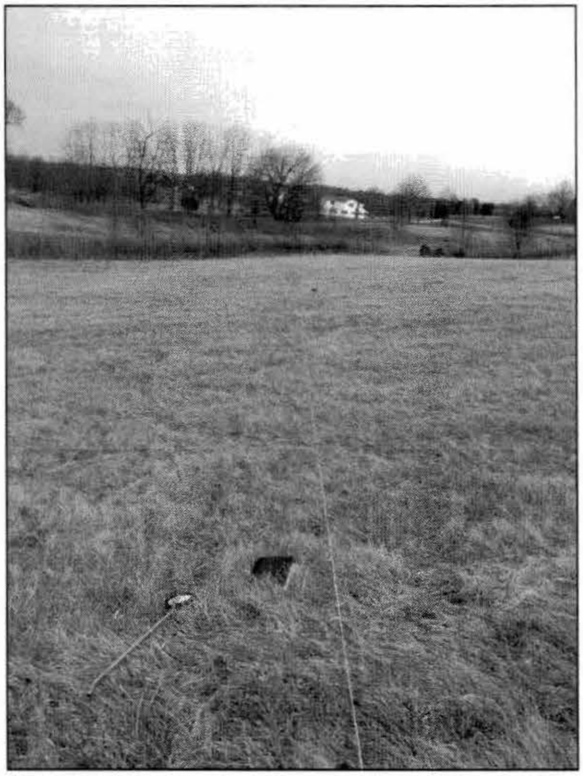


Figure 4 – Magnetic Fields Measurement Methods – Shows the line, measuring wheel and Flags

The method we used was to attach a line to the rear corner of the garage (North West) and run the line out into the field to a point past the transmission line. The line was moved until it was approximately parallel with the back side of the garage. It was also approximately perpendicular to the transmission line. Next, the center transmission line cable was located and marked with a flag. From that point measurement points were marked at 30 foot intervals and measurements were taken.

Measurements were taken from approximately 40 inches above the ground using a support stand. Measurements were made using a 3 axis measurement mode and also single axis measuring mode.

Continued on next page.............

Figure 5 – Magnetic Field Measurements – Note the Drop Off of the Land

Figure 6 – Magnetic Fields Measurements – Showing Where Measuring Line was Run

28. Please refer to page 20 of Mr. Pfeiffer's report, paragraph IX. Mr. Pfeiffer states, "Standards such as the National Electrical Code -NFPA 70 are adopted by the State Legislature every three years in order to make these standards a requirement." Please provide specific documentation as to the National Electrical Code's application to electric utilities.

ANSWER BY: John Pfeiffer

First the questioner appears to misunderstand what was stated. The following is the full statement.

"ENGINEERING EVALUATION of KRS 278:

In Kentucky as well as all states there are various standards that have to be interpreted on a daily basis by engineers in their performance of engineering work as defined by the State of Kentucky. Standards such as the National Electrical Code – NFPA 70 are adopted by the State Legislature every three years in order to make these standards a requirement. Engineering interpretation of portions of KSR 278 fall into the class where Engineering interpretation is a valid duty of an engineer and does not require the interpretation of a legal staff."

The purpose of the paragraph is to state the there is no attempt in the report for my opinion to extend from engineering opinion and into legal opinion. When dealing with certain Kentucky statutes such as where they extend into engineering sciences it is appropriate of an engineer to comment of such statutes.

With respect to the National Electrical Code (NFPA 70) electric utilities are only exempt from compliance with this code with respect to the actual generating equipment, transmission lines and distribution lines. Electric utilities are not exempt from adhering to standards such as NFPA 70 and OSHA for the construction of facilities such as EKPC's offices.

29. Please refer to page 49 of Mr. Pfeiffer's report, Figure 12. Please explain in detail how Mr. Pfeiffer calculated the dimensions shown on Figure 12.

ANSWER BY: John Pfeiffer

Page 46 not 49

The following EKPC drawing shows that the overall conductor separation as 54 ft. This dimension was used to develop the scaled figure using AutoCAD software. This AutoCAD figure became Figure 12 in the report.

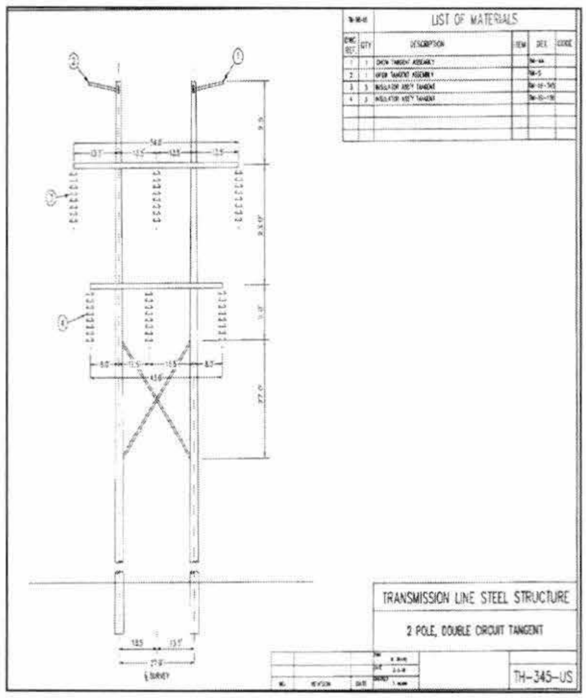


Figure 7 - EKPC Pole Design Drawing

continued on next page.........

Using the 54 feet as the cable separation it was then easy to scale a Google Earth photograph of the Barker farm. Figure 11 below shows the initial scaling of the figure.

Figure 8 - Google Earth Measurement of Width of Transmission Line – 54 Ft.

The cables shown in the Google Earth figure measured 54 Ft. as the overall cable separation which agreed with the EKPC drawing..

Continued on next page..........

Figure 4, EKPC aerial photograph shows the right-of-way defined and was used as a reference in developing figure 12.

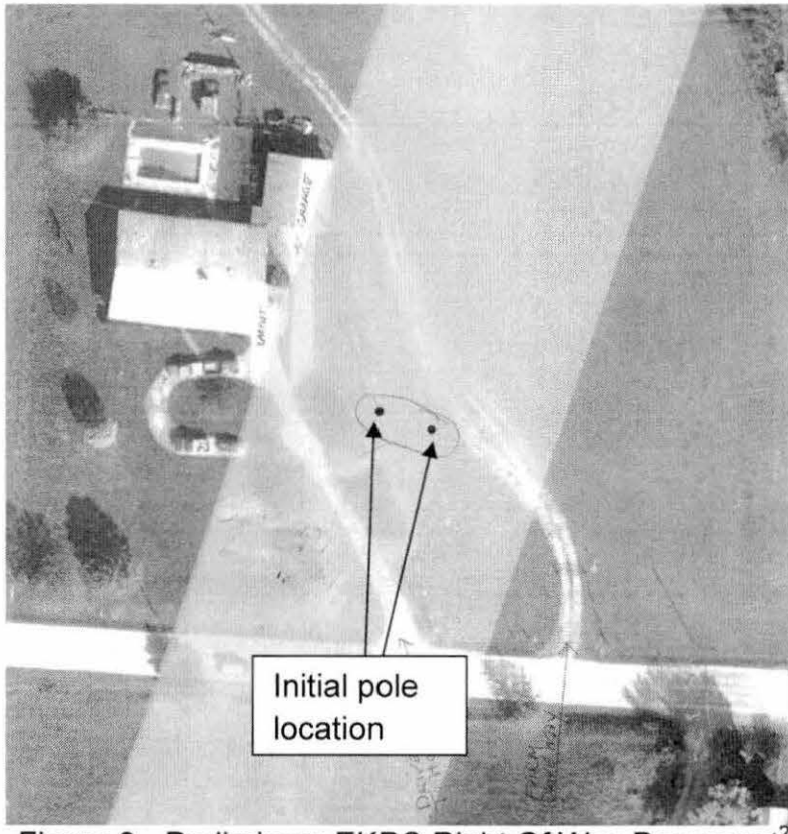


Figure 9 - Preliminary EKPC Right Of Way Document[2]

By using a printed picture is easy to use drafting dividers and a scale to measure all needed dimensions as they are in proportion to the cable separation. The dimensions were also collected from Google Earth software.

Continued on next page.........

2 EKPC presented this photograph at the public meeting on Meeting of 11/10/2005

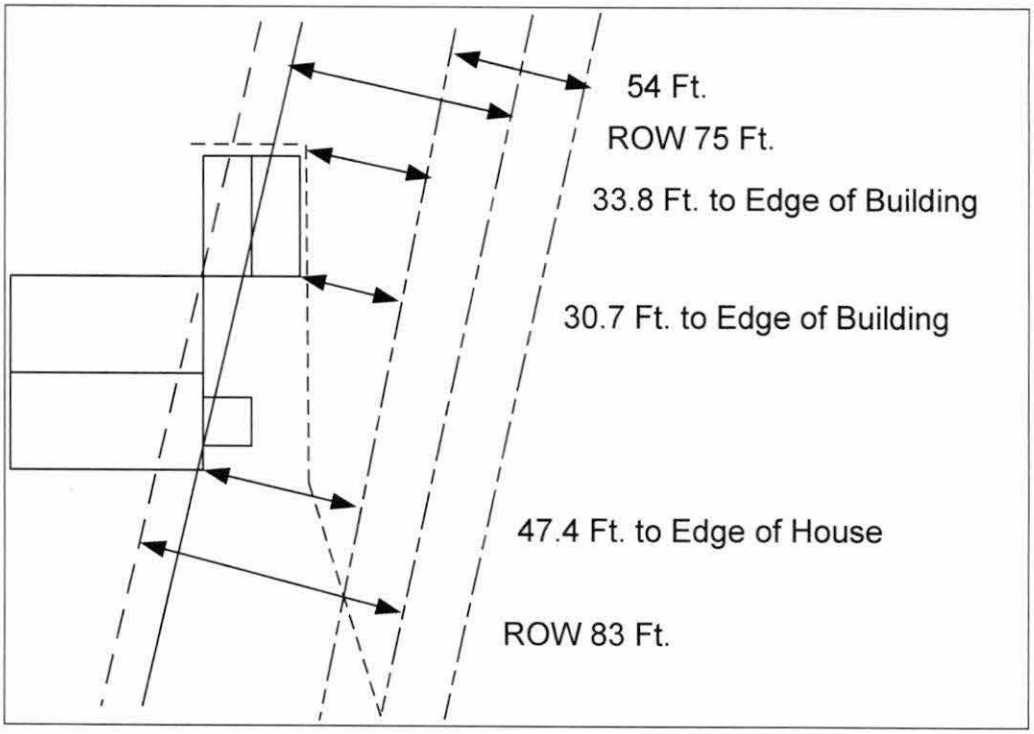


Figure 10 - Sketch of the Close Proximity of the Barkers' House to the Transmission Lines ROW

The above diagram was developed as a full scale drawing using AutoCAD software and the information described above..

30. Please refer to page 50 of Mr. Pfeiffer's report. Please provide specific citations to the RUS standards Mr. Pfeiffer is referencing in his statement concerning a violation of "the intent of the RUS standards."

ANSWER BY: John Pfeiffer

Page 50 has no such statement. The following is the statement from page 47.

"The above sketches confirm that the right of way does go through the Barkers' house and violates the intent of the RUS standards since this transmission was completely rebuilt. The existing transmission line and poles were removed before the new transmission line was constructed. Thus, the new line was required to comply with the right of way requirements."

RUS Bulletin 1724E-203 Guide for Upgrading RUS Transmission Lines states:

"3.2 Right-of-Way Width: One of the most important electrical clearance requirements is sometimes overlooked in procuring of right-of-way easements for transmission lines. The width of the right-of-way depends upon many factors, such as:

a. Structure configuration (phase spacing).

b. Conductor size and weight.

c. Structure span length.

d. Amount of conductor sag.

e. Amount of conductor blow out.

f. Operating voltage.

g. Elevation (MSL).

All of these factors should be considered before a transmission line is upgraded or converted. In the case of item "e" above, RUS Bulletin 1724E-200 discusses conductor blow out and ROW widths based on blow out calculations.

The following nominal right-of-way widths have been generally proven to be satisfactory and, in most instances, provide sufficient clearance for a fallen structure to remain within the right-of-way.

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**

"3.4 Analysis of Existing Lines and Structures: Before an existing structure or line becomes a feasible candidate for voltage conversion or improving the current rating, a thorough records search must be made, detailed field information obtained, and comprehensive engineering calculations made.

An in-depth review of the design parameters and construction methods used for the existing transmission line must be conducted at the beginning of any proposed line conversion or upgrading project. The purpose of such a thorough study is to clearly define the starting point and configuration before becoming committed to an expensive, time-consuming line modification."

3.4.2 "A survey....... An inventory of any changes to the physical features along the centerline should be recorded with corresponding elevations. Measurements should also include conductor attachment heights, obstructions, **right-of-way encroachments,** and check of span lengths. All wire crossing heights should be measured during the field survey."

3.4.3 Finally, the data should be analyzed to determine the optimal plan for improvement. **Any changes made to the existing line must, as a minimum, comply with the latest edition of the NESC...."**

Based on calculations using the RUS formula the Right-Of-Way width should have been 166 Ft. Whether you use my calculations of ROW or use EKPC's 150 Ft. ROW, EKPC did NOT maintain that ROW in rebuilding the new transmission line.

31. Please refer to page 68 of Mr. Pfeiffer's report, where it states, "two cables being considered are separated by1070 feet. .." Please identify what cables are separated by 1070 feet and whether this is a conceptual assertion or an assertion based upon actual conditions.

ANSWER BY: John Pfeiffer

From page 54 - 1070 Ft. of cable separation is referring to the span distance between the two H-Frame pole structures on either side of the Barker house. The 1070 ft. is the span length.

32. Please refer to pages 70 and 71 of Mr. Pfeiffer's report. Please provide a detailed description of why Mr. Pfeiffer chose to use EKPC's measurements for the electric field, but then used his own measurements (taken at a different date and time) for the magnetic field?

ANSWER BY: John Pfeiffer

Dr. Dolloff did not measure the magnetic fields.

33. Please refer to page 77 of Mr. Pfeiffer's report, paragraph F. Mr. Pfeiffer states, "This line, at the time of the measurements, was operated at 69 kV. Thus, the resultant EMF is lower that what can be expected in the future." Please provide all documentation and/or calculations that support this statement.

ANSWER BY: John Pfeiffer

Data provided by Dr. Dolloff of EKPC.

34. Please refer to page 78 of Mr. Pfeiffer's report.

a. Please provide a detailed description of how all equipment comprising the transmission system was considered in determining these capacities? In particular, how were the thermal ratings of equipment such as line switches and circuit breakers incorporated into the calculation of potential thermal loading capability?

b. Please provide a detailed description of whether the operating voltage of the line was considered in determining the capacities?

ANSWER BY: John Pfeiffer

In the examination of line load the purpose was in the determination of line sag and not overall transmission capacity which might include switches and circuit breakers. EKPC standards allow for operating temperatures at 176 degrees for normal operation and 212 degrees F on a contingency basis. I used these figures and assumed that the transmission lines in question were designed to EKPC line rating standards which would take into consideration the ratings of switches, circuit breakers and other such equipment.

The analysis was based upon EKPC's stated design voltages which were 345kV and 138kV. See page 78 just above figure 33 for a detailed explanation of the analysis.

35. Please refer to page 72 of Mr. Pfeiffer's report. Mr. Pfeiffer states, "Also 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 complex and some of it has to be discarded."

a. Please describe in detail how Mr. Pfeiffer determined what data should be retained and what data should be discarded.

b. Please provide all data discarded by Mr. Pfeiffer for his analysis.

ANSWER BY: John Pfeiffer

Page 68 shows how the land drops off at the point where the measurements were made and as shown below.

Please refer to question 26.

"Effects of the Land

Both sets of field measurements resulted in unusual looking plots. This is because, as we move from the house toward the center of the transmission line, the land falls off to the east. This causes the distance from the measuring point to the transmission line to be inconsistent. Also 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 complex and some of it has to be discarded.

Figure 11 – Magnetic Field Measurements – Note the Drop Off of the Land" cont...

Continued on next page........

The following are typical measurements produced by transmission lines.

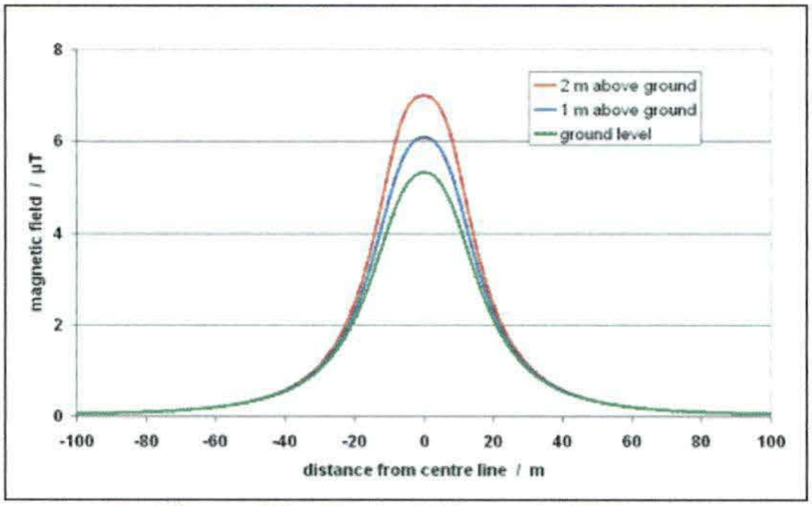


Figure 12 - Typical Magnetic Fields

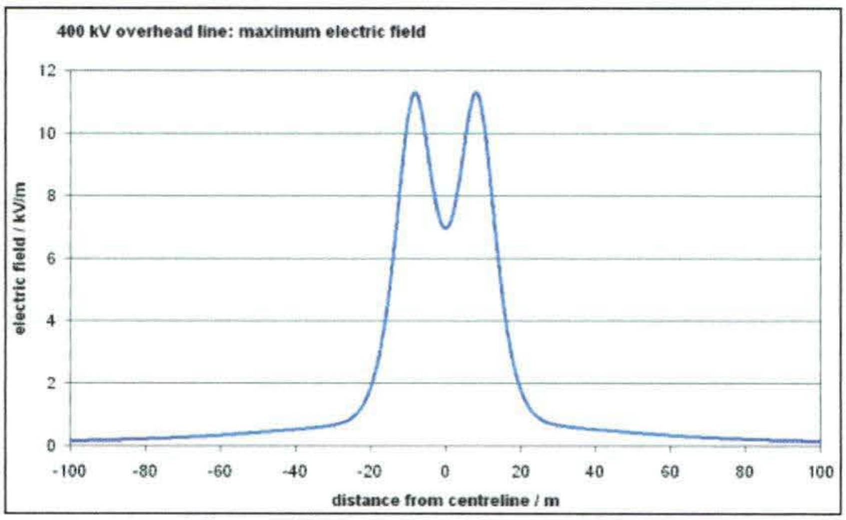
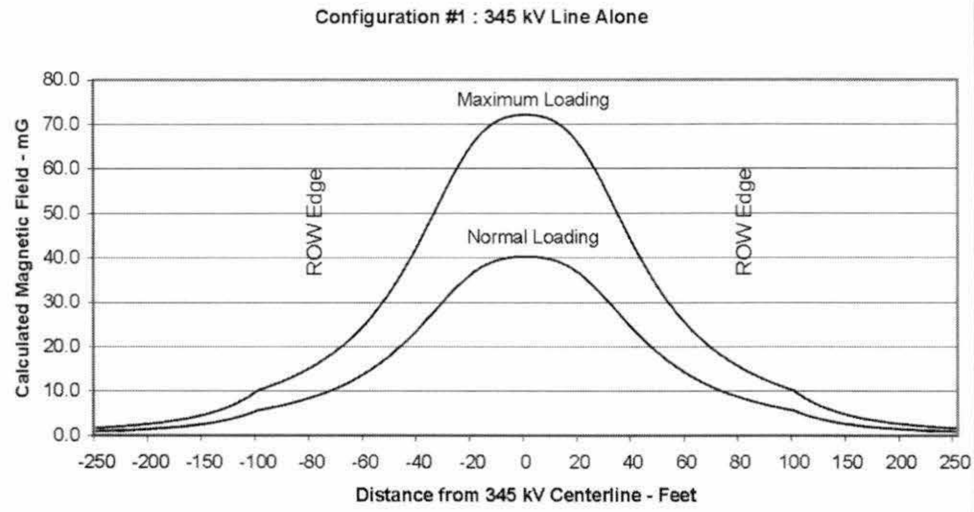


Figure 13 - Typical Electric Fields

Continued on next page.........

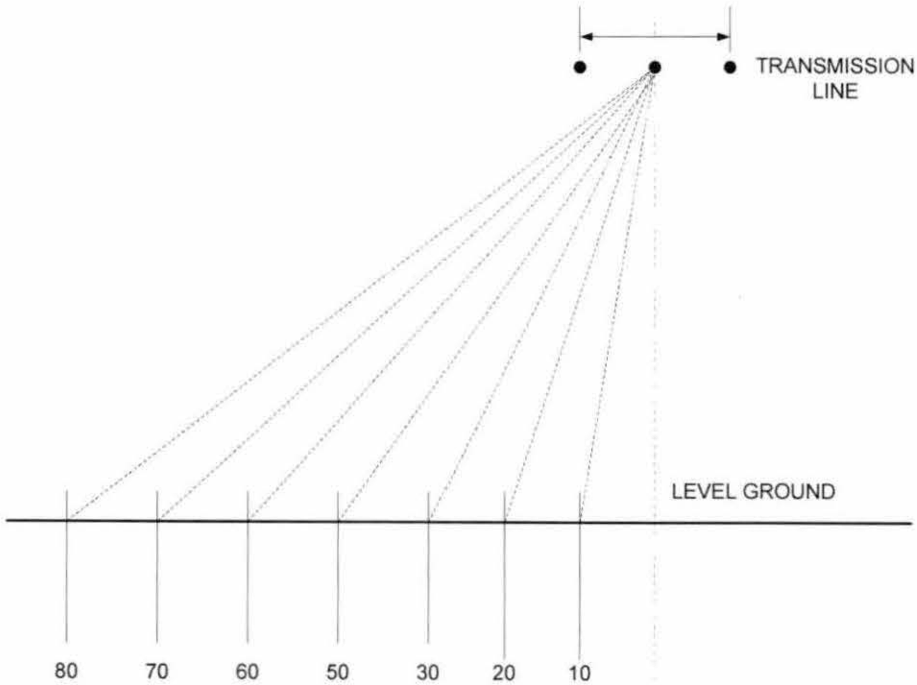
These transmission lines produce magnetic fields that are proportional to the amount of current flowing through the lines.

FIGURE 3.10-9: CALCULATED MAGNETIC FIELD PROFILE FOR THE PROPOSED 345 KV TRANSMISSION LINE ALONE



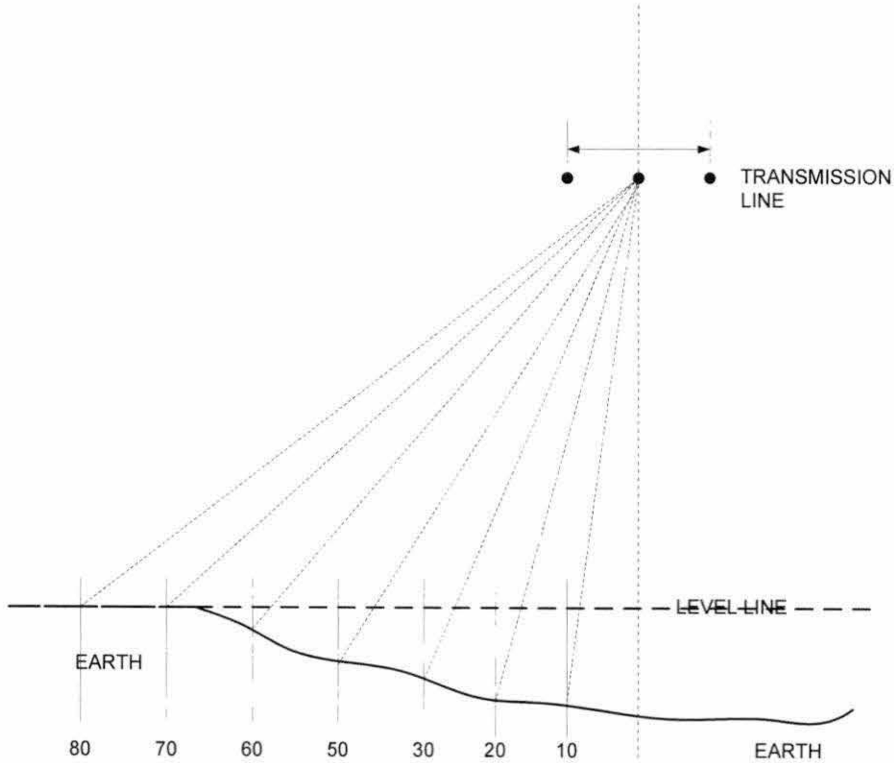
Continued on next page........

When we need to make measurements of magnetic or electric fields it's important that the measurements are made on level ground and at a uniform increment such as every 10 feet, as shown in the simulation sketch below. This approach will provide data that matches typical measurement curves as shown above.



Continued on next page..........

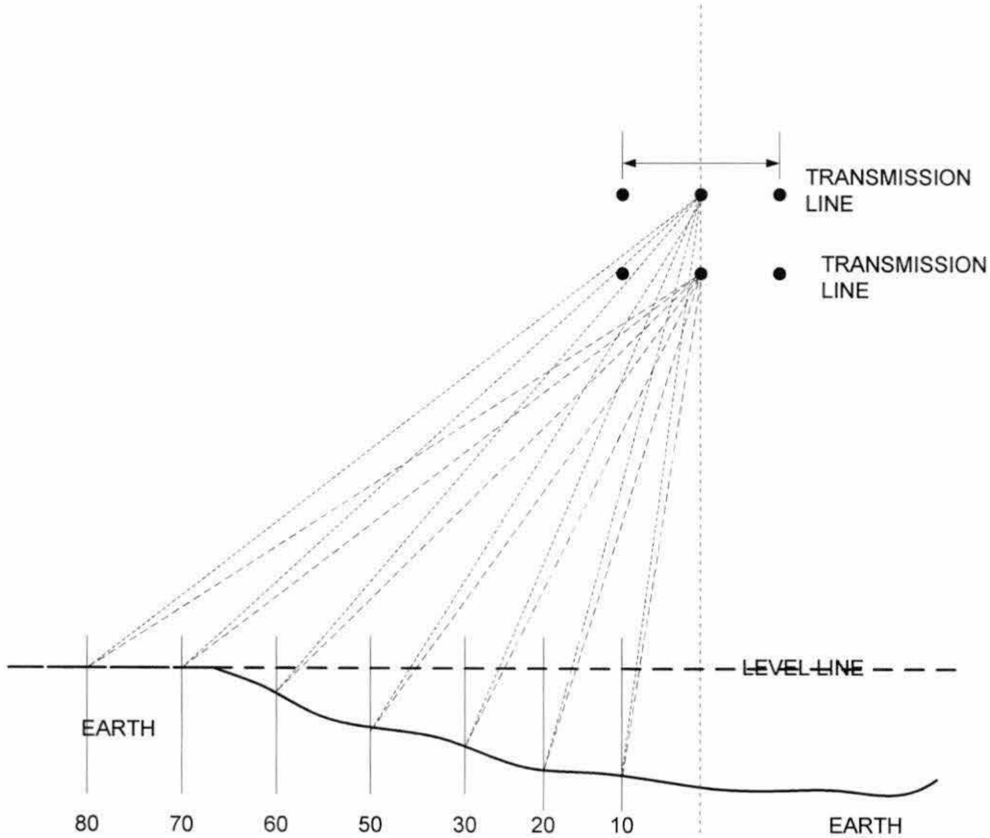
When you add complexity to the measurements such as where you do not have a level plain to work from as shown below the data is distorted.



When comparing the measuring distances between the two sketches you will find that the distances are not the same.

Continued on next page.........

Next, add additional complexity by having two transmission lines as shown below.



This makes for a very complex measurement.

In looking at the standard data profiles all the data no matter how complex it flattens out to a somewhat uniform level. By using only the outer most data points you can establish a reference point and then extrapolate that data based upon known standard data profiles. One can also make projections of levels of EMF based upon other conditions such as increased current load on the cables.

36. Please refer to page 78 of Mr. Pfeiffer's report. Mr. Pfeiffer states the actual operating conditions of the line during his measurements. Please provide the source of the actual operating conditions noted when Pfeiffer Engineering took its magnetic field measurements.

ANSWER BY: John Pfeiffer

Data was provided by Dr. Dolloff as to the current flow in each line on the date the test was performed.

37. Please refer to page 79 of Mr. Pfeiffer's report Please provide a detailed description of the basis for your opinion that all lines will approach design capacity sometime in the future?

ANSWER BY: John Pfeiffer

If EKPC designed these transmission lines to operate at less than they are capable of then EKPC is negligent in how they spend the funds of the owners of the company and the US Department of Agriculture if funds were all or partly provided by them.

Thus, I have assumed that the transmission lines were designed based upon expected future loads rather than assuming that EKPC is very wasteful with other people's money which I am sure they are not.

38. Please refer to page 79 of Mr. Pfeiffer's report regarding transmission line operating temperatures. Please describe your understanding of next-contingency operating requirements and whether you believe your report is consistent with these requirements.

ANSWER BY: John Pfeiffer

The rating for bare conductors:

Normal Operation

Emergency Operation

These ratings are also based on ambient temperature. Some cables are rated summer vs. winter while others are rated summer, fall winter, & spring

Rating, Emergency[3]: The rating as defined by the equipment owner (ATC) that specifies the level of electrical loading or output, usually expressed in megawatts (MW) or Mvar or other appropriate units, that a system, facility, or element can support, produce, or withstand for a finite period (2 hours). The rating assumes acceptable loss of equipment life or other physical or safety limitations for the equipment involved.

Rating, Normal: The rating as defined by the equipment owner (ATC) that specifies the level of electrical loading, usually expressed in megawatts (MW) or other appropriate units that a system, facility, or element can support or withstand through the daily demand cycles without loss of equipment life.

RUS 1724E-200 states:

9.4.3 Thermal Capability Considerations: When sizing a phase conductor, the thermal capability of the conductor (ampacity) should also be considered. The conductor should be able to carry the maximum expected long-term load current without overheating. Generally, a conductor is assumed to be able to heat up to 167°F without any long-term decrease in strength. Above that temperature, there may be a decrease in strength depending on how long the conductor remains at the elevated temperature. A conductor's ampacity depends not only upon its assumed maximum temperature, but also on the wind and sun conditions that are assumed."

EKPC Transmission System Planning Guide, October 13, 2011, table 2 defines Normal / Contingency as 212 degrees F. An older version of this guide lists 176 / 212 degrees F. continued on next page.............

3 OVERHEAD TRANSMISSION LINE AMPACITY RATINGS, CR-0061 v07, CR-0061 v07, American Transmission Company

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

Regulatory Documents:

National Electric Safety Code (NESC), ANSI-C2, as adopted by the respective state code

NERC Reliability Standard FAC-008-1, Facility Ratings Methodology

NERC, Glossary of Terms Used in NERC Reliability Standards, March 15, 2011

Industry Standards and Technical Bulletins

ANSI C119.4 -1998 American National Standard for Electrical Connectors. Connectors to Use Between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Conductors

The Aluminum Association, Aluminum Electrical Conductor Handbook, Third Edition, 1989

CIGRE Technical Bulletin 299, 2006

IEEE 738 – 2006 Standard for Calculating the Current-Temperature of Bare Overhead Conductors

Southwire Overhead Conductor Manual, Second Edition, 2007.

Standard Handbook for Electrical Engineers, McGraw Hill, various editions, (primarily for copper conductor properties)

39. Please refer to page 96 of Mr. Pfeiffer's report. Mr. Pfeiffer notes one option of reducing the effects of electric and magnetic fields is to increase the height of the poles.

a. Has Mr. Pfeiffer performed an analysis to determine if this option is a feasible solution to resolve the Barker's concerns? If yes, provide the results of that analysis.

b. Has Mr. Pfeiffer discussed this alternative with the Barkers? If yes, please provide the results of that discussion. If no, please explain why that option has not been presented to the Barkers.

ANSWER BY: John Pfeiffer

Page 92 of report.

This option to raise the poles has not been evaluated.

I believe it has been discussed but it did not get a favorable reaction from the Barker's. This would not be a cost effective option.

40. Please refer to page 102 of Mr. Pfeiffer's report. Please explain in detail why Mr. Pfeiffer believes the only cost to relocate the power line would be the cost of additional wire.

ANSWER BY: John Pfeiffer

The following from the report defines the cost detail however additional information is provided below.

"The options will reposition the lines resulting in moving the centerline of the transmission line 222 feet, option 1 or 309 feet, option 2 further away from the house. In doing this the length of the conductors will be increased. See the table below.

The cost of a section of the transmission line can be broken into the following:

- Design
- Right of Way expense
- Surveying
- Cable
- Poles
- Construction

At the time that EKPC decided to move the H-Frame poles from near the Barker's house on 5/8/06 to about 500 feet behind their house they had to do a redesign of this section of the transmission line. Thus, if at this time they would have also moved the line to the east or west a few hundred feet the primary additional cost would have been only the additional of cable.

There may have been a little additional surveying cost but that would have been less than $1,000.

.

	Centerline of line to the house	Increase in line length	Additional 345kV line	Additional 138kV line	345kV line Base cost of wire	138kV line Base cost of wire	Total Cost
Existing	55.6 ft	0					
Option 1	221.5 ft	54 Ft	324 ft.	162 ft	$1,389.38	$458.29	$1,848.35

Option 2	309 ft.	118 Ft	708 ft	354 ft.	$3,040.31	$1,004.33	$4,044.64

41. Concerning measurements of distance using Google Earth,

a. Would Mr. Pfeiffer admit that a ground survey will produce a more accurate measurement of distance than the use of Google Earth?

b. Has Mr. Pfeiffer actually measured the distances between the installed lines and the Barker house? If yes, please provide the results of his measurements. If no, please explain in detail why Mr. Pfeiffer has not taken the actual measurements.

ANSWER BY: John Pfeiffer

Yes, I agree that a survey performed by a registered land surveyor would probably be more accurate than using Google Earth.

No, survey quality measurements have not been made. The reason is that adequate measurements can be made using Google Earth for this investigation. This is based upon tests I have performed.

Test 1 – measured the distance between two utility poles in Massachusetts using Google Earth. Next, I visited the site and used a laser to confirm the distance between the two poles. They agreed within a few inches.

Test 2 – Measured the length and width of one runway at Louisville International Airport using Google Earth and then compared the results with official navigations maps and they agreed. During this investigation I am not designing or laying out a transmission line but making basic distance determinations which don't have to be accurate within 10^{th} or 100^{th} of an inch.

Goggle Earth Accuracy Test – The following is my comparison between Google Earth and FAA data:

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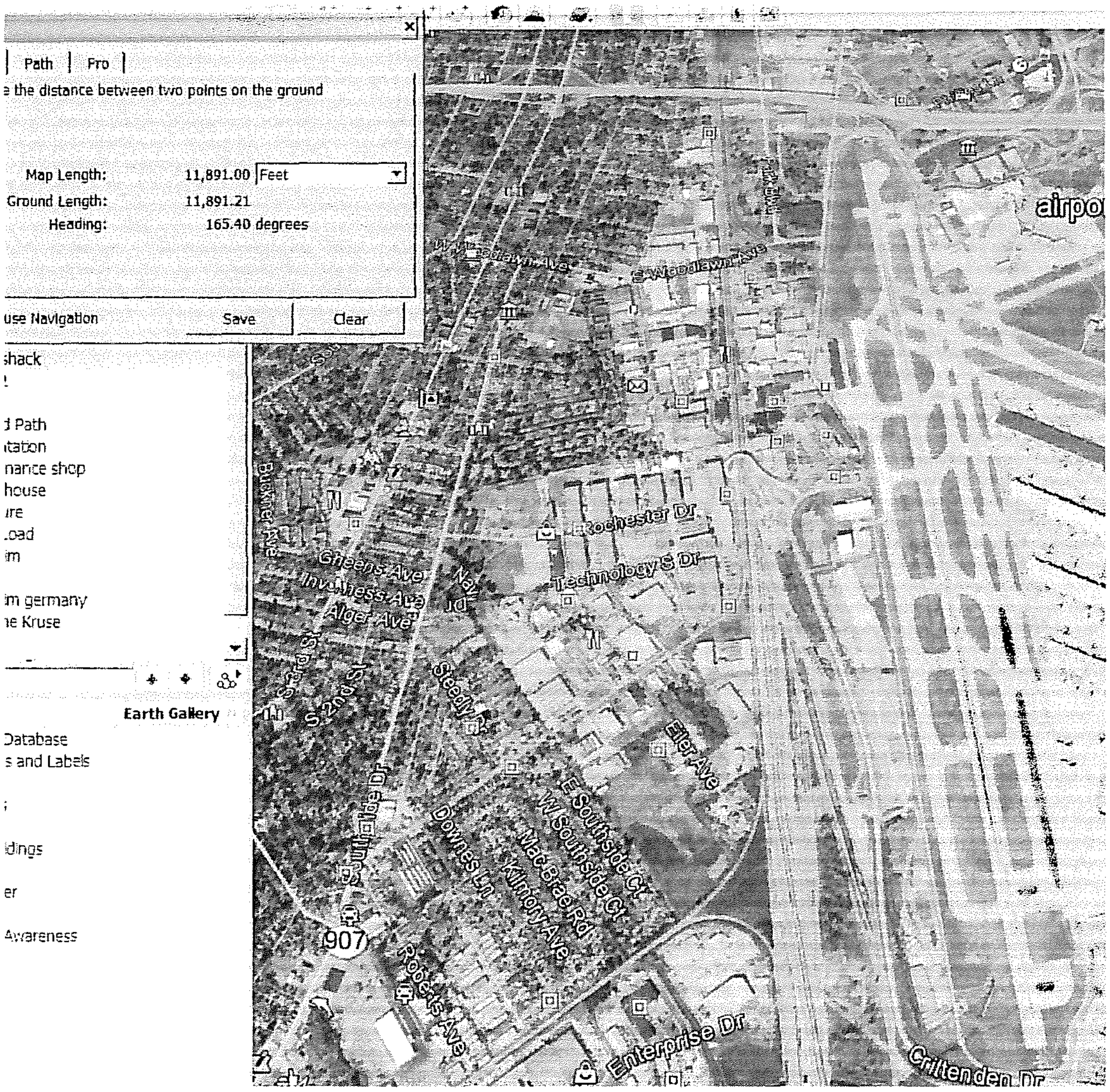

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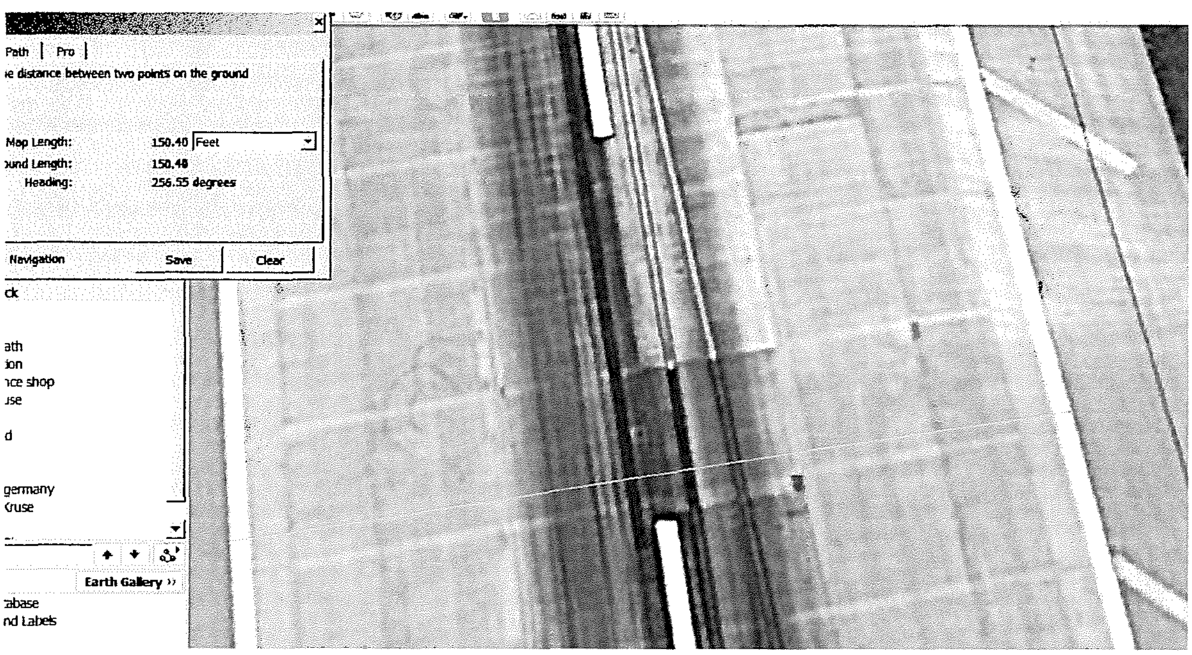
FAA data valid effective December 12, 2013 until February 6, 2014 (unless otherwise noted).

Summary | Airport | Runways | Comms | Terminal Procedures | Weather | Navaids | Remarks | NOTA

Runway Lengths and Distance for Louisvi

Runway 17R/3

Dimensions: (Length/Width)	11887 ft x 150 ft / 3623 m x 46 m
Surface	Bituminous Concrete (grooved), Good Condition
Weight Bearing Capacity	Single wheel: 75.0 Double wheel: 207.0 Double tandem: 360.0 Dual double tandem: 850.0
	17R
Latitude	38-11-13.1900N
Longitude	085-44-55.6300W
Elevation	489 ft
Traffic Pattern	left
True Bearing	165
Magnetic Variation	03W
Markings	Precision Instrument, Good condition
Crossing Height	75 ft
Displaced Threshold	850 ft
Declared Distances	TORA: 11095 TODA: 11095 ASDA: 11095



http://www.globalair.com/airport/apt.runway.aspx?aptcode=SDF

42. Please provide a list of all proceedings in which Dr. Carpenter has been permitted to offer his expert opinion and/or testimony and all proceedings in which Dr. Carpenter's proffered his expert opinion and/or testimony has not been permitted to be offered or has been excluded.

ANSWER BY: David O. Carpenter M.D.

DAVID O. CARPENTER, M.D.

PREVIOUS DEPOSITIONS AND TESTIMONY (past seven years):

Antonia Tolbert et al. vs. Monsanto Company, Pharmacia Corp., and Solutia Inc., deposed for the plaintiffs, 21-22 January 2003. Mark Englehart, Attorney 334-269-2343.

Aaron et al. vs. Chicago Housing Authority et al., deposed for the plaintiffs, 5-6 March 2003.

Kellum et al., vs. Kuhlman Corporation, deposed for the plaintiffs, 4 September 2004. Douglas Mercier, Attorney, 601-914-2882.

Allgood et al. vs. General Motors Corporation, deposed for the plaintiffs, 8-10 December 2004. Brian J. Leinbach, Attorney. 310-552-3800.

Maggie T. Williams et al. vs. Kuhlman Corporation, deposed for the plaintiffs, 1 February and 25 February 2005. Douglas Mercier, Attorney, 601-914-2882.

Solutia Inc. et al., Debtors, vs. Monsanto Company and Pharmacia Corporation; deposed for the plaintiffs, 12 September 2006. Samuel E. Stubbs, Attorney; 713-425-7345.

Charles W. Adams, et al., vs. Cooper Industries, Inc. et al., deposed for the plaintiffs, 28-29 September 2006. Donna Keene Holt, Attorney. 865-212-3294.

Arthur D. Dyer et al. vs. Waste Management et al., deposed for the plaintiffs, 2 November 2006. Mark L. Thomsen, Attorney. Cannon & Dunply, Brookfield, WI 53008.

Clopten et al. vs. Monsanto, deposed for the plaintiffs, 31 January 2007. Robert Roden, Attorney. 406-525-2665.

Marty Paulson et al. vs. Monsanto, deposed for the plaintiffs, 7 August 2007. Torger Oaas, Attorney. 406-525-2665.

John Edward Martinez and Gladys Yolanda Martinez vs. Entergy Corporation et al., deposed for the plaintiffs, 16 April 2008. Julie Jacobs, Attorney. 504-566-1704.

Fannie Wayne et al. vs. Pharmacia Corporation, et al., deposed for the plaintiffs, 29 October 2008. John E. Norris, Attorney. 205-541-7759.

Continued on next page......

Fannie Wayne et al. vs. Pharmacia Corporation et al., testified for the plaintiffs, 31 March-1 April, 2009. John E. Norris, Attorney. 205-541-7759.

Clement Passariello, et al., vs. CL&P, et al.; William Korzon, et al., vs. CL&P, et al.; Louis Gherlone et al., vs. CL&P, et al.; and William Ho, et al., vs. CL&P et al., deposed for the plaintiffs, 13 April 2009. Benson A. Snaider, Attorney. 203-777-6426.

Before the Pennsylvania Public Utility Commission, docket No A-2009-2082652, et al. Testified on behalf of the Saw Creek Estates Community Association, 2 September 2009. Paul M. Schmidt, Attorney. 215-569-2800 x161.

James Alford et al. v. Kuhlman Corporation, et al., pending in the USDC, Southern District of Mississippi, Deposed for plaintiffs, 20 August 2009. Shiela Bossier, Attorney. 601-352-5450

Fannie Wayne et al. v. Pharmacia Corporation. Deposed for plaintiffs, 23 September 2009, Timothy C. Davis, Attorney. 205-327-9115.

Before the Minnesota Public Utilities Commission in the matter of the route permit application by Great river energy and Xcel Energy for a 345 kV transmission line from Brookings County, South Dakota to Hampton, Minnesota. Testified for plaintiffs, 16 December 2009. Paula Maccabee, Attorney. 651-775-7128.

Highland Lakes Estates et al.v. Republic Services of Florida et al., Deposed for the plaintiffs, 23 April 2010. John W. Frost II, Attorney. 863-533-8985.

Zina G. Bibb, et al. v Monsanto Company et al. Deposed for plaintiffs, 28 April 2010. W. Stuart Calwell, Attorney, 304-343-4323.

Highland Lakes Estates et al., v. Republic Services of Florida et al., Testified for the plaintiffs, 13 May 2010.

Nora Williams, et al., v. City of Jacksonville, et al. Deposed for the plaintiffs.15 July 2010. Samuel W. Wethern, Attorney.

Ronald Cybart et al., Michael Campanelli, and Donald and Theresa Shea, et al.v. CL&P. Deposed for the plaintiffs. 15 July 2011. Benson A. Snaider, Attorney.

Maria Snoops vs. Lyon Associates, Inc. and Insurance Co of the state of Pennsylvania. Deposed for the plaintiff, 1 November 2011. Matthew J. Witteman, Attorney. 415-363-3106.

John Edward Martinez and Gladys Yolanda Martinez v. Entergy Corporation, et al., Deposed for the plaintiff, 19 December 2011. J. Patrick Connick, Attorney. 504-347-4535.

Continued on next page..........

AHM and David Mark Morrison vs. Portland Public Schools. Deposed for the plaintiffs, 25 January 2012. Shawn E. Abrell, Attorney. 503-224-3018.

Judy Prescott Barnett v Robert E. Carberry et al. Deposed for the plaintiff, 6 April 2012. Whitney North Seymour, Attorney . 212 455-7640.

Association Quebecoise de Lutte Contre La Pollution Atmospherique et al. vs. Hydro Quebec, et al. Testified for the plaintiffs, 17-18 May 2012. Domineque Neuman, Attorney. 514-849-4007.

FortisBC vs Citizens for Safe Technology. Testified for the plaintiff, 15 March 2013. David M. Aaron, Attorney. 250-551-6840.

John Edward Martinez and Gladys Yolanda Martinez v. Entergy Corporation et al., Deposed for the plaintiff, 21 June 2013. J. Patrick Connick, Attorney. 504-347-4535.

Village of Stillwater et al. and Saratoga County Water Authority v. General Electric Company. Deposed for the plaintiff, 10 April 2014. Donald Boyajian, Attorney. 518-463-7784.

Cases where Dr. Carpenter's testimony was not allowed: Allgood et al. v. General Motors, based on my presenting a medical monitoring program while not being licensed to practice medicine in Indiana.; Adams et al. v. Cooper Industries; and Lakey et al. v. Pugut Sound Energy Inc., which never got to the stage of a deposition.

43. Please refer to Dr. Carpenter's testimony. Please identify all applicable federal, state or local standards that have been enacted with regard to magnetic fields or electric fields. For each such standard, please identify:

a. The nature and characteristics of the standard.

b. The date that standard was adopted by the applicable state.

c. The agency responsible for adopting each limit.

d. The source(s) relied upon by Dr. Carpenter to demonstrate the adoption of such standard(s).

ANSWER BY: David O. Carpenter M.D.

Please see the attached chapter, especially . This article also shows magnetic fields around household appliances, which fall off rapidly with distance, unlike the situation around powerlines. I have no idea when these standards were adopted other than that for New York, where the magnetic field standard was adopted in I believe 1988 after our New York State Powerlines Project demonstrated elevations in risk of childhood cancer from exposure to powerline fields. The value was chosen because 200 mG was the largest value found in existing high voltage line and the state did not want to allow anything that was worse. I suspect all of these values were adopted by state public service commission or whatever the state agency was called. I do not believe that there are any federal standards.

Don W. Deno
David O. Carpenter

1

Sources and Characteristics of Electric and Magnetic Fields in the Environment

I. INTRODUCTION

This chapter discusses the full spectrum with an emphasis toward the ELF (extremely low frequency, 30 to 300 Hz) spectrum. This is in the spectrum below 100 kHz, where the electric and magnetic fields are usually analyzed more appropriately as separate and slowly time-varying electric or magnetic energy fields. Electric fields are described with the symbol **E**, a vector, in units of volts per meter, V/m. Magnetic fields are described with either the symbol **H**, a vector, in units of ampere per meter or the magnetic flux density with the symbol **B**, a vector in units of tesla. To be compatible with biological researchers, the magnetic flux density is often called magnetic field and described in milligauss. Units and conversions are described in Section II.B.1.

Above 100 kHz, the fields are usually more appropriately analyzed as coupled and propagating at the speed of light. They are called electromagnetic fields. At very high frequencies, such as light waves, the electromagnetic wave

TABLE I Frequency Spectrum[a]

Wavelength (m)	Frequency Hz	Frequency-band designations	
	3		Quasi-static field theory E and B do not propagate and are not coupled fields ↓
3×10^7	10		
	30		
3×10^6	100	ELF, extra low frequency	
	300		
3×10^5	1 kHz = 10^3 Hz	VF, voice frequency	
	3		
3×10^4	10	VLF, Very low frequency	
	30		
3×10^3	100	LF, low frequency	
	300		
3×10^2	1 MHz = 10^6 Hz	MF, medium frequency	E and B propagate as coupled fields ↓
	3		
30	10	HF, high frequency	
	30		
0.3	100	VHF, very high frequency	
	300		
3×10^{-2}	1 GHz = 10^9 Hz	UHF, ultrahigh frequency	
	3		
3×10^{-3}	10	SHF, superhigh frequency	
	30		
3×10^{-4}	100	EHF, extremely high frequency	
	300		

3×10^{-5}	1 THz = 10^{12} Hz	Å	μm		Infrared	
	3				↓	
3×10^{-6}	10	3×10^{5}	30		Visible light	
	30				0.70 to 0.40 μm	
3×10^{-7}	10^{2}	3×10^{4}	3		0.65 red	
	3×10^{2}				0.59 yellow	
3×10^{-8}	10^{3}	3×10^{3}	0.3		0.49 blue	
	3×10^{3}				↓	
3×10^{-9}	10^{4}	3×10^{2}	3×10^{-2}	Soft X rays	↓	
	3×10^{4}			↓	↓	
3×10^{-10}	10^{5}	3×10	3×10^{-3}	↓	↓	
	3×10^{5}			↓	↓	
3×10^{-11}	10^{6}	3	3×10^{-4}	↓	↓	
	3×10^{6}			↓	Ultraviolet	
3×10^{-12}	10^{7}	0.3	3×10^{-5}	↓	↓	
	3×10^{7}			↓	↓	Gamma rays
3×10^{-13}	10^{8}	0.03	3×10^{-6}	Hard X rays		↓

* Nomenclature: kHz, kilohertz; Mhz, megahertz; GHz, gigahertz; THz, terahertz; Å, angstroms (10^{-10} m of wavelength); μm, micrometer (10^{-6} m of wavelength).

analysis methods treat the propagating energy as oscillating bundles or particles of energy called photons. The full electromagnetic spectrum is discussed in this chapter to keep the ELF subject in perspective. Table I shows the spectrum and identifies the categories, the classifications, and the dominant properties.

Humans have no ability to directly detect electromagnetic radiation other than visible light, yet radiation such as γ and X rays can cause harm. Prolonged exposure to ultraviolet is known to cause sunburn and promote the occurrence of skin cancers. Until recently there have been few safety concerns about forms of electromagnetic radiation with lower energies. This is not to say that other forms of electromagnetic energy are not powerful. Obviously microwave radiation at high intensities is used to cause heating. The microwaves are absorbed by water molecules, which induces movement of the water molecules. This is the transformation of a field of energy to heat. We use nearly the same frequencies as in microwave ovens for our communications systems, but at intensities that are too low to cause tissue heating. Our whole world is bathed in electromagnetic radiation of various frequencies and energies. Life has evolved in the presence of electromagnetic fields and would be impossible as we know it without forms of radiation, such as heat and light. The degree of exposure and the dependence of any possible harm on specific properties of the fields are important.

How a low-level field might affect a biological system is imperfectly understood. It is generally believed that most actions must be through induced currents. Low-frequency oscillating magnetic fields penetrate the body and induce eddy currents. In contrast the electric field about a biological system, such as a human, is distorted considerably and induces surface charge and currents. The shape of the body is very important in describing how the field is perturbed. For ELF electric fields, the field within the body is very much reduced from the external field, because the air capacitive reactance to 60 Hz is 300×10^6 ohm-m, while conductive tissue is 10–100 ohm-m. Precise model analysis has been performed to trace the human body current distribution (Kaune and Gillis, 1981). Human electric field exposures are generally for short time periods (except for an electric blanket). The concept of induced current being the significant coupling is not practiced. If it was, the magnetic field derivative that induces current would be monitored. The practice has been to record only the magnetic field.

ELF magnetic fields are seldom attenuated and pose a more pervasive background than electric fields. Human magnetic field exposure commonly takes place over longer time periods than electric fields. A human body does not perceptibly distort the lines of flux for magnetic fields, because the impedance of the biological tissue to the oscillating magnetic field does not differ from air. The oscillating magnetic field does induce an electric field yielding a current in a conducting medium such as biologic tissues. If indeed induced currents are the basis of the biological effects of fields, then one might expect that similar effects would come from both electric and magnetic fields. This presents considerable difficulty in extrapolating from one animal species to another, especially to human who is both upright and bipedal.

Electric field-induced spark discharges are noticeable and disturbing. They cause an acute sensation of pain that is later accompanied by an exhaustion sensation. Benjamin Franklin described these sensations with his experiments. This problem can be experienced by (1) too many carpet sparks in succession, for example, 20 4-kV discharges, (2) being under a high-voltage power line where the electric field may exceed 8 kV/m causing many small irritating sparks from a person to ground, and (3) under a high-voltage line where spark discharges can come from the current induced on an ungrounded vehicle. Direct contact with appliances can lead to a current through a human. A current of 5.0 mA is the maximum safe let-go limit, while 0.5 mA current is the commonly held threshold of perception.

II. ELECTRIC FIELDS, MAGNETIC FIELDS, AND ELECTROMAGNETIC FIELDS

Electric field This is a form of stored energy. Electric field intensity is a vector quantity denoted by **E** in units of volts per meter. The electric field comes from the separation of charged particles. The electric field may exist completely separate from the magnetic field if the charge is motionless or "static." Charged particles in an electric field feel a force. Since matter consists of electrons, neutrons, and protons, electric fields can act to influence many substances. Accompanying the electric field is the displacement charge vector **D** in coulomb per square meter, $\mathbf{D} = \varepsilon\mathbf{E}$. The symbol ε denotes the dielectric property of the material that couples free charge to the electric field.

Magnetic field This is also a form of stored energy. Magnetic field intensity is a vector quantity denoted by **H** in units of ampere per meter. The magnetic field comes from current flow, the motion of charge. Moving charged particles in a magnetic field feel a force. Again, since matter consists of electrons, neutrons, and protons, and is almost always in some sort of motion, magnetic fields can influence many substances. Accompanying the magnetic field is the magnetic flux density vector (also referred to as the magnetic field) **B** in tesla (milligauss is often the unit used), $\mathbf{B} = \mu\mathbf{H}$. The symbol μ denotes the magnetic property of the material that couples the flux density to the magnetic field. It has been a practice to call both **B** and **H** the magnetic field.

Electromagnetic field This is a propagating coupled form of changing electric field and magnetic field. A changing displacement charge, **D**, gives rise to an induced magnetic field, **H**, and a changing magnetic flux, **B**, gives rise to an induced electric field **E**. The more rapidly the **D** or **B** field changes (the higher its frequency), the greater the induced **E** or **H** field, respectively. This mutual self-support of coupling (see Table II) exists even in a vacuum. At low frequencies the electric and magnetic fields contribute little to each other; therefore, they may be treated separately. The electric power frequency of 50–60 Hz is in this category.

There are many good textbooks on electric and magnetic fields. The following books and handbooks provide summaries:

- "Physics," Parts I and II, Halliday and Resnick (1966): This is a basic physics text including an introduction to electromagnetic fields.
- "Reference Data for Radio Engineers" (1992): This book has extensive information for propagating fields.
- Chapter 8.0 in the "EPRI Transmission Line Reference Book" (1982): This chapter summarizes ELF field coupling to the environment (Deno and Zaffanella, 1982).
- "Electronic Engineer's Handbook" (1989): This book contains back-

TABLE II Propagating Field Basic Equations

Speed of light in a vacuum

$$c_0 = 2.998 \times 10^8 \approx 3 \times 10^8 \quad \text{m/sec} \tag{1}$$

Dielectric constants of air

$$u \approx \mu_0 = 4\pi 10^{-7} \quad \text{H/m} \tag{2}$$

$$c = 3 \times 10^8 \approx c_0 = 2.998 \times 10^8 \quad \text{m/sec} \tag{3}$$

$$\varepsilon = 8.8537 \times 10^{-12} \approx \varepsilon_0 = 1/\mu_0 c_0^2 \quad \text{F/m} \tag{4}$$

Propagating waves have coupled electric and magnetic fields

$$c = 1/\sqrt{\varepsilon \mu} \quad \text{m/sec} \tag{5}$$

$$Z = \sqrt{\mu/\varepsilon} = 377 \quad \text{ohms} \tag{6}$$

P, Power flow for a cross section area
E, Electric field strength in volts per meter
H, Magnetic field strength in ampere per meter

$$P = \mathbf{E} \times \mathbf{H} \quad \text{W/m}^2\text{, propagating power flux vector} \tag{7}$$

$$P = \mathbf{E} \cdot \mathbf{E}/Z \quad \text{W/m}^2 \tag{8}$$

$$P = \mathbf{H} \cdot \mathbf{H}Z \quad \text{W/m}^2 \tag{9}$$

ground from an electronic engineer's point-of-view (Fink and Christianson, 1989).

- Electromagnetic Phenomena in "Van Nostrand's Scientific Encyclopedia," 7th ed. (1989): This section provides background in applying magnetic fields to biological systems (Considine and Considine, 1989).
- Standard Handbook for Electrical Engineers (Fink and Beaty, 1987): This book provides background from an electrical engineer's point-of-view.

The choice of the appropriate method of analyzing the interaction of an object with a field also depends upon the wavelength of the field relative to the object's size. If the wavelength is much larger than the object and the field penetration is larger than an object's cross section, then the analysis can be the same as for 60-Hz ELF calculations.

Magnetic field penetration is discussed in "Reference Data for Radio Engineers" (1992), Section 26-5. A table includes data of depth of penetration for energy to $1/e$ for $\sigma = 10^{-2}$ S and a relative dielectric constant of $\varepsilon = 10$. The data show 50 m at 10 kHz, 15 m at 100 kHz, 5 m at 3 MHz, and 2 m at 10 MHz. These are examples of earth soil, and although not equivalent to nonuniform biological tissue, they are useful for ballpark estimates of field penetration in biological systems. Propagating field analysis is usually applied at five times the wavelength away from the source. Propagating frequencies are usually thought of as starting at 100 kHz. (The low end of the AM broadcast band starts at 500 kHz). Analysis techniques overlap in spectrum depending on the subject. Examples are discussed further in this chapter.

A. Propagating Fields

The spectrum summarized in Table I shows radio, microwave, TV, and light as examples of propagating electromagnetic fields. Some of the most important properties of propagating fields are summarized in Table II. Most important in propagating fields relative to the ELF spectrum is the coupling of the electric and magnetic fields through the impedance of the medium. Vacuum and air without encumbrances are often called free space and have an impedance of 377 ohms.

High-frequency analysis often treats electromagnetic radiation as packets of energy called photons, with the energy described by $E = mC^2$. The photons have no rest mass. A familiar high-frequency form of electromagnetic energy is visible light, for which most forms of life have developed specialized receptors to be able to detect objects in the environment. Light wavelengths are from 0.40 to 0.70 μm (micrometers). Our eyes distinguish the different wavelengths as colors. The relationship between wavelength and energy for the radiated photon is described by Plank's law:

$$E = h\nu \qquad (10)$$

E is in joules, the photon energy
$h = 6.624 \times 10^{-34}$ J-sec, Plank's constant
ν is in Hertz, cycles per second.

This equation demonstrates that the photon energy is proportional to frequency, an important property of electromagnetic particles.

Visible light is usually specified by wavelength. Microwave and radio, however, are more often specified by frequency. The most energetic forms of electromagnetic radiation are γ rays and X rays. High-energy γ and X rays are usually characterized not by wavelength or frequency, but by energy, which is related to frequency as indicated in Eq. (1). These are very powerful packets of energy with very short wavelengths.

Chemical (electron) bond energy is typically 1 eV, electron volt. Thus photons must be ≥ 1 eV (1.602×10^{-19} J) to break a 1-eV covalent bond. This corresponds to radiation frequency of 242×10^{12} Hz, a wavelength of 1.24 μm. These high-frequency "ionizing" forms of electromagnetic radiation are sufficiently energetic to directly damage living organisms. "Ionizing radiation" can cause damage to DNA in living cells and break water molecules into charged and reactive elements called free radicals, which then cause further damage to the subcellular constituents of the cell.

The energies contained in lower-frequency forms of electromagnetic radiation contain insufficient energy to cause formation of "ions." Consequently, this part of the electromagnetic spectrum (everything below X rays) is often called "nonionizing radiation."

B. Quasi-Static Fields

Power line frequency and its harmonics are nonionizing radiation. The magnetic field from a power line has a wavelength of 5000 km and a frequency of 60 Hz. In comparison, visible light has wavelengths of 4×10^{-7} to 7×10^{-7} m and frequencies of $8 \times 10^{+14}$ to $4 \times 10^{+14}$ Hz. The earth's fields are essentially constant with small changes. These changes are not repetitive and are not characterized by a single frequency. These fields are at the lowest point of the electromagnetic spectrum.

At the low-frequency end of the spectrum, slowly changing electric and magnetic fields may be treated as if they were static or did not change. Electric and magnetic fields are described by vectors with a magnitude and direction at an instant in time. The E and B fields may be calculated separately as shown in Table III with Eqs. (11) to (14). The field calculations are made as if the field were not time varying. The induced current is the time rate of change, derivative, of the displacement charge. The induced voltage is the time derivative of the flux density.

TABLE III Maxwell's Electric and Magnetic Equations for Quasi-Static Analysis

$$\nabla \times \mathbf{H} = \mathbf{j}_c \quad \text{conduction current} \tag{11}$$

$$\nabla \times \mathbf{E} = -\partial \mathbf{B}/\partial t \tag{12}$$

$$\nabla \cdot \mathbf{D} = \rho \quad \text{electric charge on a surface} \tag{13}$$

$$\nabla \cdot \mathbf{B} = 0 \tag{14}$$

Electric field, E in volts per meter	Magnetic field, H in ampere per meter
$d\mathbf{E} = \frac{dq/\varepsilon}{4\pi r^2}\hat{r}$ (15)	$d\mathbf{H} = \frac{i}{4\pi r^2}\,d\mathbf{l} \times \hat{r}$ (16)

Stored energy per unit volume in joules per cubic meter

$\varepsilon E^2/2$, $\mu H^2/2$

In two dimensions, like a power line where conductors are straight for a long distance, then

$$\mathbf{E} = \frac{q/\varepsilon}{2\pi r}\hat{r}\ \text{V/m} \tag{17}$$

$$\mathbf{H} = \frac{i}{2\pi r}\hat{\mathbf{l}} \times \hat{r}\ \text{A/m} \tag{18}$$

Displacement charge density, **D** coulomb per square meter

$$\mathbf{D} = \varepsilon \mathbf{E}\ \text{C/m}^2 \tag{19}$$

Flux density, **B** tesla, weber per square meter

$$\mathbf{B} = \mu \mathbf{H}\ \text{T} \tag{20}$$

Time varying induction using quasi-static field theory

Current density across an area

$$\mathbf{i} = \partial \mathbf{D}/\partial t\ \text{A/m}^2 \tag{21}$$

Electric field around an area

$$\nabla \times \mathbf{E} = -\partial \mathbf{B}/\partial t\ \text{V/m}^2 \tag{22}$$

Current

$$I = \int \mathbf{i} \cdot d\mathbf{a}\ \text{A} \tag{23}$$

Voltage

$$V = \int \mathbf{E} \cdot d\mathbf{l}\ \text{V} \tag{24}$$

1. *Units*

The unit of measurement of electric fields is E in volts per meter. For magnetic fields, the comparable standard unit of measure is H in amperes per meter. The common ELF biomagnetic research unit of measurement is the magnetic flux density B in milligauss, mG. This is the magnetic flux density per unit area. The unit used by the Systeme International (SI) is the tesla (T), where 1 mG = 0.1 μT. Another unit sometimes used is the γ, where 1 γ = 1 nT. There is a lack of consistency in the usage of magnetic field units by different investigators. Table IV lists the conversion between the magnetic field units of measure. The relation of B, H, E, and D is given in Table III.

TABLE IV Magnetic Field and Magnetic Flux Density Unit Conversions in Air

$B = \mu_0 H$ in air, permeability, $\mu_0 = 4\pi \times 10^{-7} = 12.566 \times 10^{-7}$ H/m (25)

Multiply unit to convert into either ⟶ B Units of magnetic flux density ⟶ or H Unit of magnetic field intensity in air

Unit	Tesla (T)	Microtesla (μT)	Gauss (G)	milligauss (mG)	Ampere per meter (A/m)
B, units of magnetic flux density					
T		10^6	10^4	10^7	7.9577×10^5
$\mu_0 T$	10^{-6}		10^{-2}	10	0.8
G	10^{-4}	100		1,000	79.58
mG	10^{-7}	0.1	10^{-3}		7.9577×10^{-2}
H, units of magnetic field intensity					
A/m	$\mu_0 = 1.2566 \times 10^{-6}$	1.2566	0.012566	12.566	

$$0.012566 = 1/80$$

Equalities of less frequently used units:

Magnetic field intensity (oersted) $\text{Oe} \times 79.577 = \text{A/m}$ (26)

Magnetic flux density (weber per square meter) $\text{Wb/m}^2 \times 10^4 = \text{gauss}$ (27)

γ = nanotesla = nT = 10^{-9} T (28)

picotesla = pT = 10^{-12} T

Amount of magnetic flux (maxwells) $\text{Mx} = 10^{-8}$ Wb (29)

2. Methods of Quasi-Static Field Calculation

The exact procedure for calculating these fields is beyond the scope of this chapter. Suggested references for calculation are in the handbooks identified previously in this section. Quasi-static field analysis is based upon simplifying assumptions. The magnetic field is determined by the conduction currents. The electric field satisfies the voltage boundary conditions. Surface charge is distributed to satisfy the Maxwell's displacement charge at a conductive voltage boundary. Forms of these equations appear in Table III. These properties are calculated as in static field theory form for instantaneous values. For slowly varying ELF sinusoidal fields, the currents, voltages, and fields are treated as phasors, complex numbers representing magnitude and phase.

Both electric and magnetic fields are vectors having components in three spatial directions. Single-frequency (phase-locked) fields can be described as phasor vectors. If they are in phase, the vectors add and subtract directly, and therefore fields from multiple sources can add or subtract directly as vector addition. Usually two components from different sources are not in phase, the vectors are added as phasor vectors, and the fields will not have points of complete cancellation. This technology was used in analysis for the New York State Public Service Commission part of cases 26529 and 26559 [U.S. Department of Energy (USDOE), 1979]. The phasor analysis methods were reported in the closure part of the technical paper "Transmission Line Fields" (Deno, 1976).

Electric and magnetic fields differ in how they are generated, how they may be shielded, and how they act in biological systems. Electric fields are the forces that one charged particle exerts on another. They depend on charge transfer and do not require current flow. Experimentally an electric field can be produced between the two plates. The voltage between the two plates divided by the distance in meters between the plates yields the field in volts per meter. The magnitude of the electric field is directly proportional to the voltage. High-electric fields occur near equipment like high-voltage power lines. For example, common sources of ELF electric fields are power lines and lamps. An electric field is emitted from a device, whether it carries power or not. Household appliances are usually well shielded and emit little electric field. Household lamps are seldom shielded. The line cord will have a 110 Vac wire and a power ground wire. They average 55 Vac and couple strongly to the metal structure of a lamp. A lamp's metal structure is often about 40 Vac with modest 10- to 20-V/m electric fields close to a lamp. Power line ELF fields can be 5 kV/m under the low sag point of a span.

The magnetic fields are proportional to the current. There is no magnetic field from an appliance plugged in but not turned on. Depending on an appliance's switch, it can have the same electric field or even higher, when turned off. Electric and magnetic fields far from their source decrease with the inverse of the square of the distance from point sources like a lamp and inverse with the distance from a line source like a cable. An ELF magnetic field usually comes from point sources like appliances in a dipole pattern or from currents in a line from wiring, pipes, or a power line in a circular pattern about the current.

Electric fields are easily shielded by almost any object, including trees, windows, walls, and skin. Magnetic fields on the other hand are almost impossible to shield. Shielding is partially realized by using specialized materials, such as mu metal, or ferromagnetic materials, such as iron-containing metal.

3. Methods of Induced Current Calculation

In this section, the ELF spectrum is analyzed from the quasi-static point of view. The basic properties of these fields follow the equation forms in Table III. Table III emphasizes the similar structure of the basic electric and magnetic field equations in the quasi-static point-of-view.

a. Electric field-induced current An electric field, **E**, has a displacement charge, **D**, as described in Table III, that terminates on a surface. A change of the field and charge results in a current, $i = dD/dt$. This expression is directly valid for an area on a conductive surface terminating a uniform electric field. A hemisphere on such a surface will collect a current $i = j\omega\varepsilon E(3\pi r^2)$. An empirically determined formula for the current from a person to ground in the same situation is

$$i = 5.4 \times 10^{-9} \times h^2 \times E \quad \text{A} \tag{30}$$

h in meters
E in volts per meter.

An example of a person 1.7 m tall in a field of 1000 V/m would have a short-circuit current of 156 μA. The same current would be induced on a 0.71-m-radius hemisphere. For further detailed calculation procedures, see Deno and Zaffanella (1982).

b. Magnetic field-induced current A magnetic field, H, has a flux density, B, that is continuous and closes on itself. A change of the field and flux density results in an induced voltage around an area, $v = dB/dt$. For example, assume a cross section of the human body with cylindrical radius r, uniform resistivity ρ, and a flux density **B** perpendicular to the cross-section area. The magnetic field-induced current density i can be calculated as shown from Eq. (31–35). Area A of a circular section of radius r is

$$A = \pi r^2. \tag{31}$$

Flux in circular section of uniform field B perpendicular to the area is

$$\Phi = \pi r^2 B. \tag{32}$$

Induced voltage around the periphery of a circular area is

$$v = d\Phi/dt = j\omega\pi r^2 B, \tag{33}$$

where $j = \sqrt{-1}$. The distance around a circular area is $L = 2\pi r$. For example a human's waist could be $L = 0.813$ m (32 in.), which is a radius $r = 0.13$ m (5 in.). The resistance around the periphery of the circular area in units of ohms per square meter perpendicular to the radius of the circular area is

$$R = \frac{\rho L}{A} = \frac{\rho 2\pi r}{1\ \text{m}^2} = 2\pi r\rho\ \text{ohm/m}^2. \tag{34}$$

Current density around the circular area is

$$i = v/R = 0.5 j\omega r/\rho\ \text{A/m}^2. \tag{35}$$

The current density is proportional to the radius of a section. For example, if a person stands in a 5-mG vertical 60-Hz field with a body resistance of 10 ohm-m, an example calculation of the induced current density at the radius using Eq. (35) is

Chest radius $r = 17$ cm, $i = 1.6\ \mu\text{A/m}^2$

Head radius $r = 9$ cm, $i = 0.86\ \mu\text{A/m}^2$.

*c. **Induced current in humans*** The electric field-induced current calculation yields a total cross-section current based on an assumed homogeneous specific resistivity. The magnetic field-induced current calculation yields a current density at a radius around an area. Biological tissue such as a human is not homogeneous in resistivity. Resistivity parallel and perpendicular to muscular fiber is reported to be a 2.2:1 difference (Geddes and Baker, 1967). Most of the data came from dog experiments, because they are similar to humans. Human's resistances are reported to be lower than other biological systems. Examples are:

Cardiac muscle: $\sigma = 2.5$ mS/cm, $\rho = 4$ ohm meter

Skeletal muscle: transverse $\sigma = 0.6$ mS/cm
longitude $\sigma = 4.2$ mS/cm

Specific conductance: $\sigma = 1/\rho$ S

Specific resistance: ρ ohm-m.

Rush *et al.* (1963) report human blood to have a resistivity of 1 ohm-m, while animal experiments showed 1.6 ohm-m. The dog thorax mean resistance was 4.5 ohm-m. This reference reports a mean resistivity of 4.0 ohm-m for the outer thorax layer: skin, fat, muscle, and bone. These references have useful data on variations of resistivity. They emphasize how current densities vary within a tissue. Currents are concentrated into the more conductive tissue. It is suspected that on a microscopic level, the variations of resistivity could be much greater and currents could be more concentrated.

4. *Methods of ELF Field Measurement*

A complete measurement and description of ELF fields would be overwhelmingly complex. Gross simplifications must be made in supporting quantified ELF field measurement data for the biological research. The measurement compromises used in this chapter could be used until some new revelation on the biological effects is discovered. All of the data in this chapter were obtained from measurements of two methods: magnitude measurement and function of time recording. The ELF methods of field measurement rely on the rate of change in the field to induce a voltage or current that is proportional to the field.

a. Magnitude measurements The magnetic field sensor used throughout this chapter is a coil. It outputted a voltage proportional to the field rate of change. In the sensor there is a passive integrating filter that converts the coil output to a voltage proportional to the field intensity. The electric field sensor outputted a current proportional to the field rate of change. In the sensor was a passive integrator that converted the current to a voltage proportional to the field rate of change. Since the magnetic field sensed bandwidth is limited from 60 to 180 Hz, and the electric field was dominantly 60 Hz, the waveform does not have enough impulsive content for a difference between average calibrated rms detection and "true rms" detection. The variation in different device measurement data can come from the difference in their frequency response. The most extreme case can be examined in Figs. 12 and 13, the ELF magnetic field around a TV set. Comparing the square root of the sum of the squares shows a difference of 5% by including the fifth harmonic to the first and third. A selection of the frequency response and detection process must be made in making a measurement. Presently this selection is very arbitrary. Fortunately the practical differences are negligible compared to the spatial and time variations of ELF fields and the lack of a specific low-level ELF biological effect mechanism.

b. Time recordings (waveform capture) In this chapter the magnetic field measurements were made using a sensor coil with an output proportional to the magnetic field rate of change. The signal was recorded as a series of time function samples in a personal computer. The analysis proceeded to the

Fourier series, integrated in the frequency domain for the spectrum and reconstructed to the time domain for the function of time. This method of measurement has been used successfully.

c. ELF electric field measurement The electric field will terminate on a conductive surface with a surface charge equal to the permitivity times the electric field. This is called the Maxwell displacement charge. A field rate of change causes a surface charge current that is measured. Static fields are measured by chopping the field with a shield over a surface. ELF fields are measured using the frequency rate of change. Three basic configurations are used to make the measurement of this current that is proportional to the electric field. These three configurations have closed form solutions to precise shapes. Practical sensors have shapes that can be approximated to one of these solutions. Their precise calibration is performed in a known field.

1. A flat *conductive surface* termination of a field has a current that can be measured to interpret the average field over the surface by

$$i = j\omega\epsilon E(\text{Area}). \tag{36}$$

2. A *free body field meter* is a conductive object insulated in space, where the current between the top and bottom is measured and processed to yield a measure of the electric field. A shape can be approximated to be equivalent to a sphere split in the middle along the equipotential plane. The current between the sphere halves is proportional to the field according to

$$i = j\omega 3\pi r^2 \epsilon E. \tag{37}$$

3. *Space potential* can be measured at a location by measuring the current from an object shorted through a very small wire to ground. The isolated object can be approximated as an equivalent sphere of radius r to compute the capacitance to space, $4\pi\epsilon r$. Multiplying the capacitance by $j\omega$ yields the admittance $j\omega 4\pi\epsilon r$. The rms current is the rms voltage, V, times this admittance described by

$$i = j\omega 4\pi\epsilon r V. \tag{38}$$

d. ELF magnetic field measurement In the ELF spectrum, coils have good sensitivity performance for the low field strengths encountered. The induced voltage is proportional to the flux rate of change, according to

$$v = j\omega\Phi. \tag{39}$$

The total voltage is equal to the number of turns in the coil times the flux density times the area of the coil. The coil area is usually enhanced by a ferrite core to collect flux over a larger area and concentrate it through the coil. For an example, a ferrite core longer than the coil can increase the flux collecting area by a factor of 20. The coil voltage is proportional to the field strength and the frequency. An integrator can be added to attain a flat frequency response over a desired spectrum. The integration can be accomplished in the sensor or in a processing stage or computed after a recording.

Hall effect sensors are advantageously small like a pencil eraser. Their output is proportional directly to the field strength, not the rate of change like the coil. Hall effect sensors are less sensitive. Measurements below 1 G are dominated by the earth's field of 0.5 G.

Flux gate sensors have good sensitivity and operate well with constant geomagnetic fields through the ELF and V spectrum. Their output is proportional directly to the field strength. Flux gate sensors have saturation limitations.

III. NATURAL FIELDS

A. Geomagnetic Fields

The earth has a steady geomagnetic field that is large in magnitude as compared to the ac fields. This field is about 0.5 G and is relatively constant at any particular site. There are some sites with fields as high as 0.6–0.7 G at high latitudes and a low of about 0.23 G at low latitudes such as off the coast of Brazil. There are many smaller variations that arise as a result of the magnetic polarization variations from within the earth's crust (Hinze, 1985). The field is oriented like a bar magnet, although the poles do not correspond exactly to the geographic north and south poles. It is known that over the past 70 million years the geomagnetic field has reversed polarity at least 10 times. This field originates from submantle current flow. Life on earth has evolved in the presence of this geomagnetic field, which is large relative to most human-made sources.

The earth's field induces a current in a rotating body similar to a 60-Hz magnetic field-induced current in a stationary body except for the frequency. An example of equivalent induced current density is calculated here to provide a perspective and to show a method of calculation. Assume a rotation of 1 rad/sec (0.159 Hz, about 6 sec per revolution) in the earth's 500 mG magnetic field. An equivalent induced voltage and current from a 60-Hz field are calculated.

The induced voltage, according to Section II.B.3, is

$$v = d\Phi/dt. \tag{40}$$

The induced voltage around a biological tissue area is

$$V = j\omega(B \times \text{Area}). \tag{41}$$

The 60-Hz induced voltage is

$$V = j377(B_{60\ \mathrm{Hz}} \times \mathrm{Area}). \tag{42}$$

The earth's field of 500 mG with rotation of 1 rad/sec yields an induced voltage:

$$V = j(500\ \mathrm{mG} \times \mathrm{Area}). \tag{43}$$

Equating the induced voltage for an equivalent 60-Hz magnetic field yields

$$B_{60\ \mathrm{Hz}} = 1.33\ \mathrm{mG}_{\mathrm{peak}}. \tag{44}$$

Thus, a modest rotation in the earth's field at 1 rad/sec induces the same current density magnitude as a 0.94 mG rms 60-Hz magnetic field with the difference being the frequency and the 60-Hz induction being more constant over a relatively long period of time.

B. Ambient Atmospheric Electric Fields

The sky electric fields with a variety of frequencies arise primarily from atmospheric conditions and the sun. Thus the magnitude of the natural electric field is very dependent upon the weather. In fair weather, the earth has a constant electric field that is usually directed downward. This field is usually between 90 and 120 V/m (Clark, 1958). The field varies more than 50% over the time of day and tends to follow predictable patterns. There are also electric fields at various frequencies, but these are much smaller in amplitude and fall off rapidly with increasing frequency. Large and Wormell (1958) found, for example, that the field intensity at 5 Hz was 101 μV/m, while at 80 Hz it was 32 μV/m. There were only very small fields at frequencies over 300 Hz. The E field is much greater in storms. They can be as high as 5 to 20 kV/m in the vicinity of thunderstorms. These fields may also reverse polarity during severe weather. The 60-Hz component is normally in the order of 10^{-4} V/m.

Figure 1 shows an approximate typical space potential of the earth's electric field in the vertical plane. Measurements were made using a field-chopping sensor. The unperturbed measured field was about -100 V/m ($\mathbf{E} = -\nabla V$), $+100$ V at 1 m above the ground plane of a cut grass field. This is typical on a sunny windless day. Clouds can pass with strong fields of either polarity. Thunderstorms are accompanied by strong fields and strong transients. The outdoor atmospheric field is usually well behaved above the conductive ground potential moist vegetation. Inside dry houses in the winter, carpets and clothing will collect charge that can make the electric field similar to that shown in Fig. 1, except the field twists in unpredictable ways. An example of a high-local field distortion is clothing on people, where static sparking is evidence of field levels exceeding a megavolt per meter.

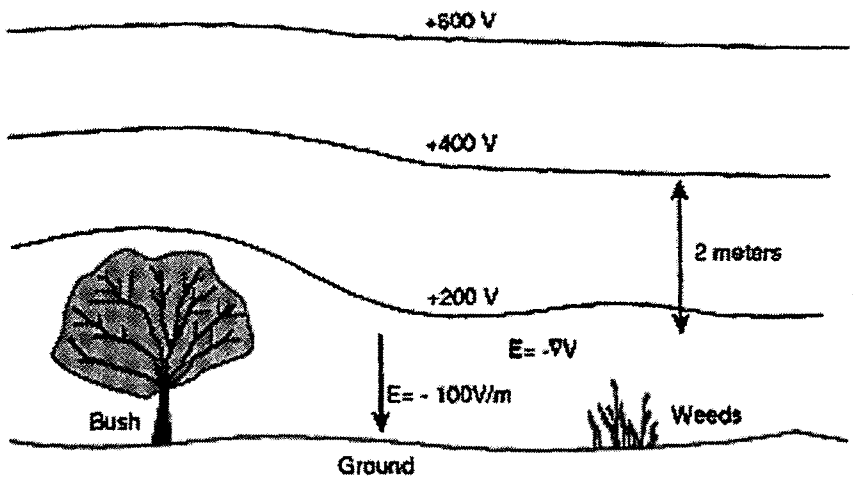


FIGURE 1 Earth's typical electric field on a warm sunny windless day.

C. Natural ac Magnetic Fields

Natural ac magnetic fields are superimposed on the geomagnetic field. These come from a variety of sources, particularly the sun and solar storms, and are in the range 0.04–0.4 pT (picotesla, 10^{-12} T), 0.4–4 μG, at 60 Hz (Chambers, 1967; Fraser-Smith and Helliwell, 1985a,b). The natural ac magnetic field is small compared to human-made magnetic fields.

Fraser-Smith and Bowen (1992) have recently recorded the natural 50- to 60-Hz magnetic fields at a variety of sites around the world. The sites were isolated from human-made electrical systems. At 50–60 Hz, the average ambient magnetic field arising from electric systems is 10^{+7} times that of the natural background. Thus while the human-made fields are small relative to the steady background, they are enormous relative to the background at comparable frequency. For example, sunlight includes the frequency of 3×10^{14} rad/sec (5×10^{13} Hz). The maximum radiated sun energy is around 1000 W/m^2. Assuming the sun-radiated energy flux is P = 1000 W/m^2 in sunlight, then the fields are calculated by

$$E = \sqrt{PZ} = 614 \text{ V/m} \tag{45}$$

$$I = \sqrt{P/Z} = 1.62 \text{ A/m}, 20.5 \text{ mG}. \tag{46}$$

Sunlight-radiated energy couples to human skin causing sunburn. The depth of penetration for this spectrum is very small. Propagating sunlight contains much more power for a given level of field than ELF that follows quasi-static field theory.

IV. ELF POWER LINE FIELDS

In North America, most electric power is 60 Hz; in the rest of the world it is 50 Hz. Electricity is transported from the site at which it is generated at high voltages for the purpose of transmission efficiency. In the United States, the largest voltages used for transmission lines at present is 765,000 V or 765 kV. After transport, a substation typically transforms the voltage to 5000–35,000 V in distribution lines. Step-down transformers in the secondary distribution lines feed individual businesses and homes with electricity at 115–230 V.

These power lines emit both electric and magnetic fields. They are usually analyzed using sinusoidal steady-state field theory in two dimensions. The two-dimension simplification over three dimensions assumes that the lines are straight and go for a sufficient distance toward infinity to make two-dimensional analysis valid. High-voltage lines are generally well balanced and sinusoidal. This usually leads to close correspondence between calculated and measured fields. At radial distances farther than about five conductor spacings along the ground, the degree of conductor current balance often dominates the cancellation of conductor current magnetic field. The field decreases proportional to $1/\text{rad}^2$ as long as the cancellation properties are dominant. A few percentage of ground return component can generate a dominant background field at large radial distances from the power line, decreasing proportional to $1/\text{rad}$ until the return path comes into play. Where more complicated configurations are encountered, such as in distribution systems, three-dimensional computations can be used, but are limited by undesired unbalance, unknown magnitude, and undesired unknown current return paths. For this reason it is usually preferable to measure the fields and not depend on calculations from insufficient data such as reading line current meters in a substation.

Three phase lines are intended to have balanced line frequency currents totaling zero at any instant. Practically, many power loads have significant third harmonic currents. The third harmonic current in the symmetrical three phases will be in phase, and their magnetic fields will be additive. The return current can be in ground circuits such as the lightning shield wires. Therefore, the fundamental 60-Hz fields from the three-phase conductors cancel, while the third harmonic fields at 180 Hz add. For this reason a dominant third harmonic field may be observed, especially about a distribution line.

The electric and magnetic field spectrum from high-voltage transmission power lines is usually very sinusoidal close to the line where the conductor currents dominate the field. At distances beyond five conductor spacings of the three-phase line, the contribution from the balanced conductor currents cancels significantly. At some further distance, the unbalanced currents become dominant, because they do not cancel. The currents and their magnetic field are usually not a sinusoid and contain a lot of harmonics. This is particularly true around distribution lines, where directly under the distribution line the distance to the conductors exceeds the five conductor spacings of the three-phase distribution line.

A. High-Voltage Power Line Fields

Extensive calculation and measurements were performed for the New York State Public Service Commission in 1975 for the 765 kV line from Massina to Marcy, NY. A report on some of this work appeared in (Deno, 1976). An existing lower-voltage situation was calculated and measured for comparison. Selected were two parallel 345-kV lines, the Rochester Gas and the Electric Rochester-Clay line West of tower 21. At 345 kV and 450 A, the maximum fields were 70 mG and 5 kV/m. The profiles were typical. The proposed 765-kV line was calculated extensively.

The vertical electric field with a ground clearance of 50 ft has a maximum of 9 kV/m. At 130 ft from the center line, the field is 2 kV/m. Both measured and calculated data on the 345 kV line at 450 A had maximum values of about 5 kV/m and 65 mG for the fields. Power lines at voltages above 115 kV have the largest 60-Hz electric fields in our normal environment. These fields were the subject of research papers "Calculating Electrostatic Effects of Overhead Transmission Lines" (Deno 1974), "Electrostatic Induction Formulae" (Deno 1975), and "Currents Induced In The Human Body" (Deno 1977). Most of this work is summarized in Chapter 8 in the EPRI Transmission Line Reference Book 2nd Ed. (Deno 1982).

Figure 2 displays some of the magnetic field phenomena. A cross-section drawing shows the configuration to scale with a ground clearance of 70 ft. The field can be described as a rotating vector at each point in space. The loci of these vectors are plotted on the cross-section drawing. In magnetic fields there are no zero boundary conditions as there are in electric fields. Therefore the ground-level magnetic field has an elliptical shape. At distances a few pole spacings from the line, the field is dominantly an oscillating vector with a negligible minor axis. At a ground clearance of 50 ft, the 765-kV line has a maximum under the line of 300 mG with 4000 A. At the more expected 1000 A, the field level would be 75 mG. At 130 ft from the center line, the field has reduced to 150 mG with the 4000 A. At the more expected 1000 A, the field level would be 38 mG.

A power line magnetic field may or may not dominate the background magnetic field in a residence. The dominant factors are (1) the line current (which is not obvious to a casual observer), (2) the separation of the residence from the power line, (3) the line configuration, and (4) the unbalanced current through a ground path. Figure 3 shows a plot plan with magnetic field magnitude contour levels around the house from measured data. The contour lines running essentially parallel to the power line indicate the power line as the source of the field dominating the residence.

Figure 4 is an example where an imposing looking power line and substation is next to a house, yet the power line and substation magnetic field is not dominating the residence. The conclusive evidence is the 0.5-mG contour line between the house and the power line substation. The magnetic field levels close to the house are higher, indicating local sources (within the house).

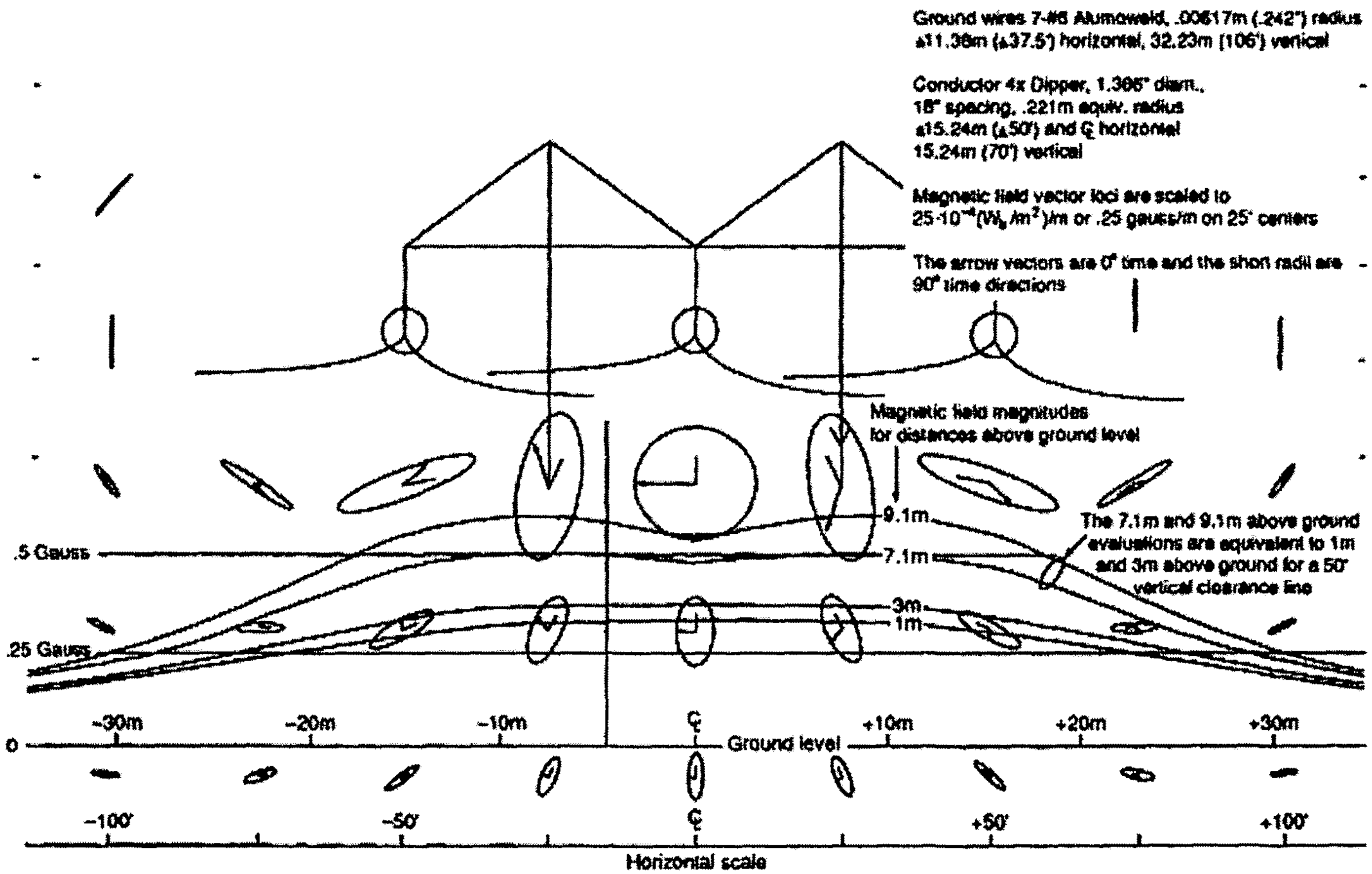


FIGURE 2 765-kV line magnetic field: A high voltage power line consists of three conductors separated horizontally and suspended by towers above ground. The three phases of voltage and current give rise to complex fields depicted here by ellipses.

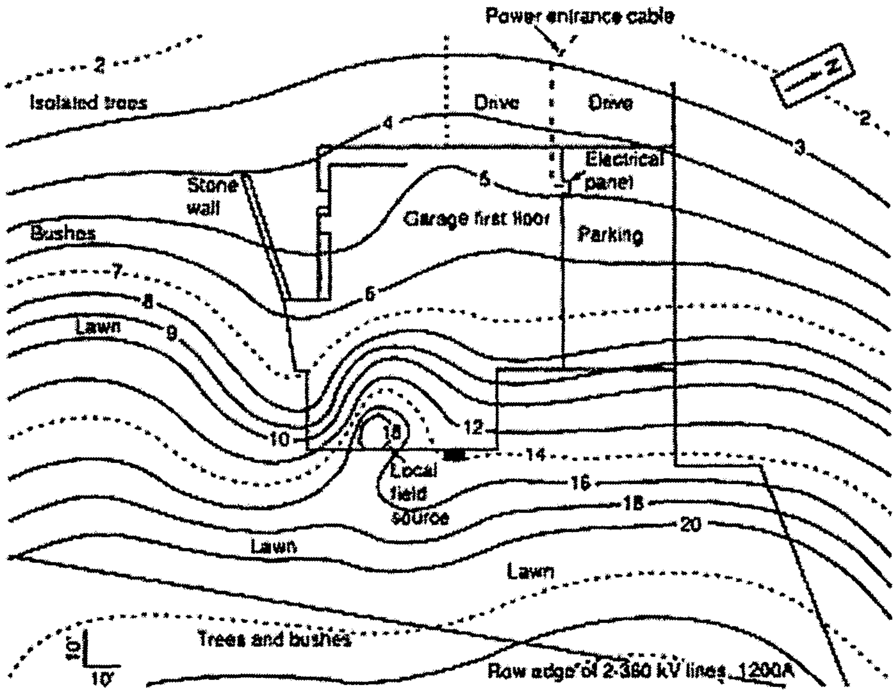


FIGURE 3 House background magnetic field coming from a power line. In this case, the 360-kV, 1200-A lines at the bottom of this figure create 20-mG fields in the lawn between the house and the line. A local source within the house is identified.

B. Distribution Lines

Electric fields produced by power lines are dependent upon the voltage at which the line is operated and the distance from the line. Distribution lines carry voltages up to 23 kV. Levels of 10 to 30 V/m are often found under distribution lines. The currents are variable depending on the local user loads, which can be 100 A. The magnetic field under distribution lines can have surprises from the user load current. The lightning neutral ground return circuit is not well controlled. It can have currents of a few ampere that generate local fields. Figure 5 (from Deno, 1984) shows how power return may deviate from the line drop. Current return through a large loop of a water system will also not cancel and can lead to dominant field sources. These currents concentrate at distribution circuit poles with transformers and poles with capacitors. The poles with capacitors conduct the harmonics to ground more than the poles with transformers.

The fields along distribution lines are best presented in their spatial form by showing their magnitude as a profile on a map. Taking and processing this data is described in the EmdexC 118 manuals (Deno and Deno 1991a, and

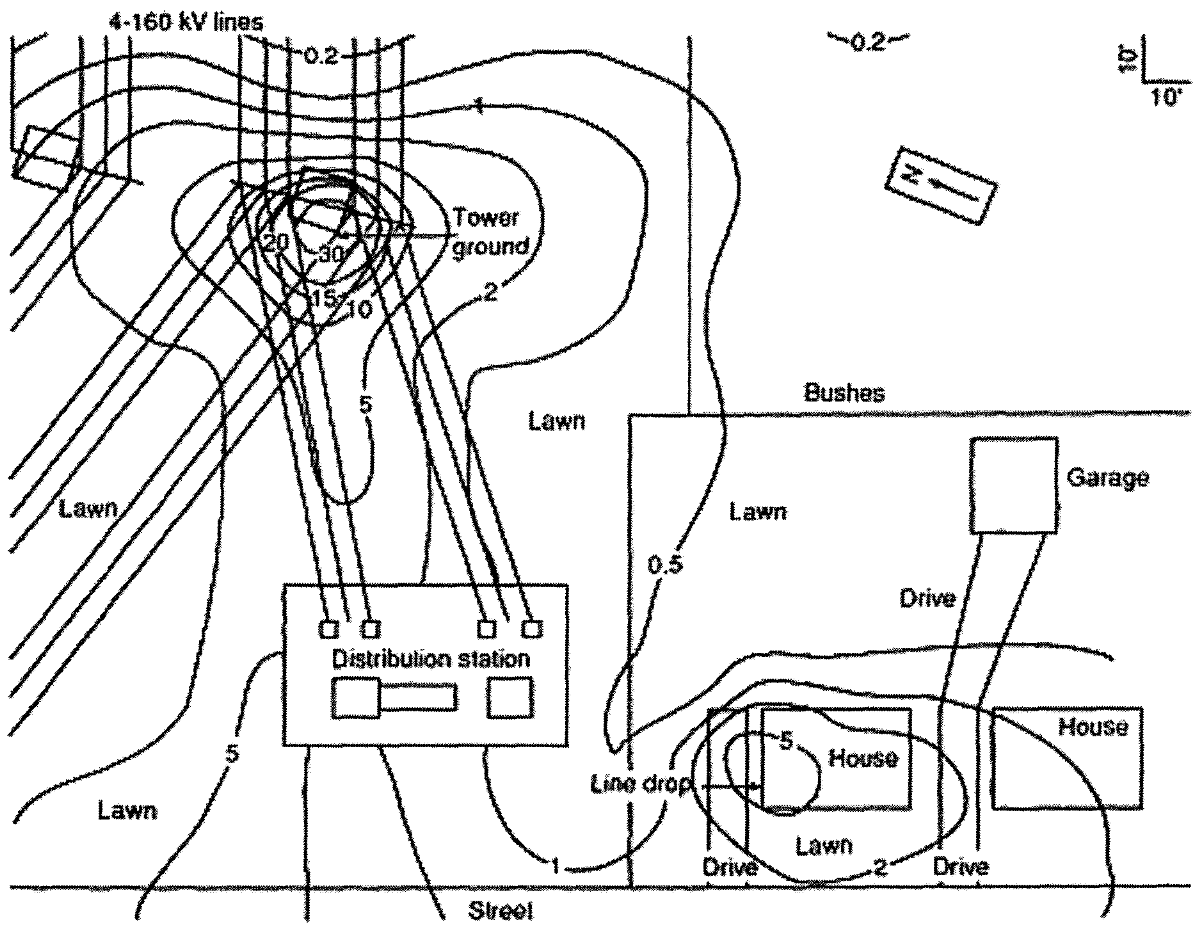


FIGURE 4 The house's background magnetic field does not come from the power line, since the 1-mG contour line lies between the house and the distribution station. The house has its own local sources of magnetic fields. Proximity to a power station is often accompanied by high levels of ELF magnetic fields.

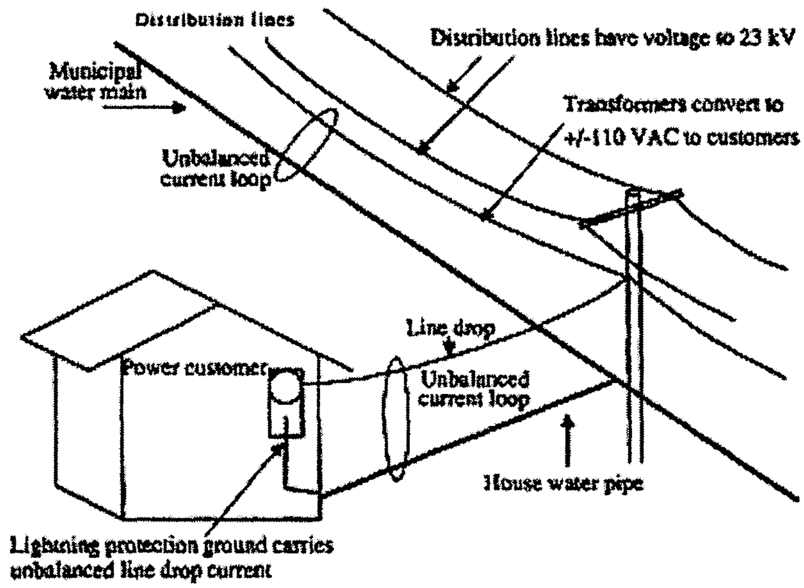


FIGURE 5 Power distribution common ground loop configuration. Not all ac power current returns via the power wires. Current pathways such as water pipes may also carry significant current in loops that create additional magnetic fields.

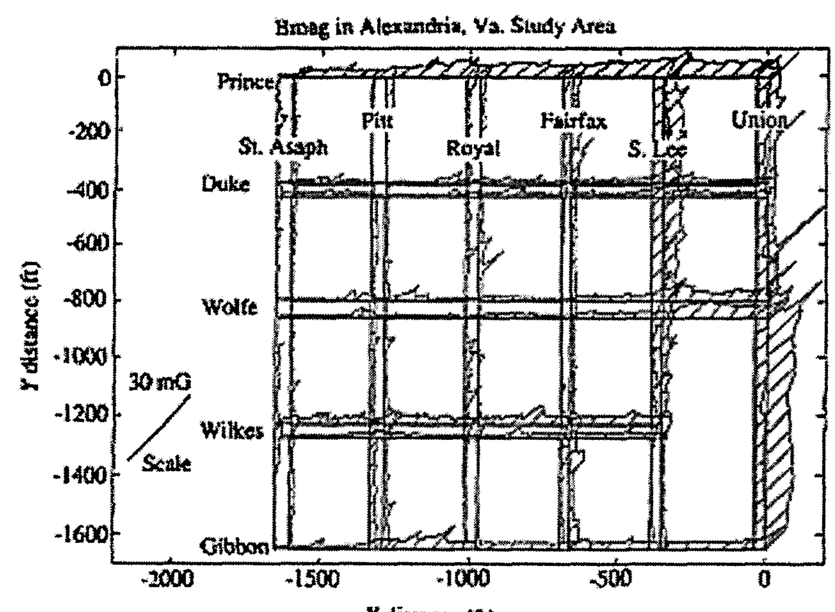


FIGURE 6 Magnetic field on streets of Old Alexandria, VA. The 30-mG scale bar is large compared to the values seen on most streets. The exception is Union Street at the far right, which has an electric power substation. (Obtained using EFM's EmdexC.)

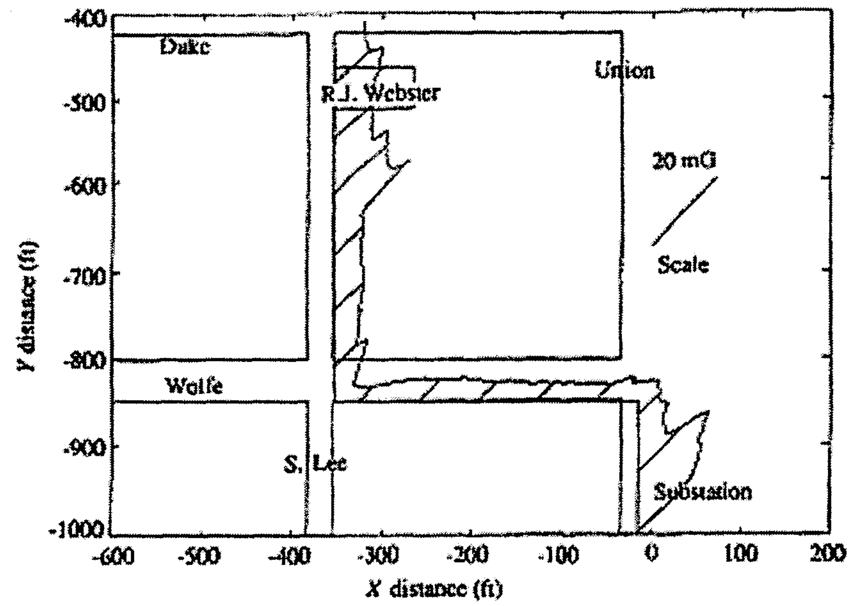


FIGURE 7 A single distribution line field along a street in Fig. 6. Data logging systems such as EFM's EmdexC facilitate collection and display of these sorts of data.

Deno and Deno 1991b). Figure 6 shows an example of a residential area where the distribution lines along the street created a measurable magnetic field. Note that the 30-mG scale bar allows quantitative translation of the path magnitude bars. The map was expanded about one distribution circuit showing the profile in Fig. 7. The power current in the line should decrease with distance from the substation. The higher magnetic field part way out from the substation indicates a dominance of local magnetic field causing currents from houses to distribution transformer secondary neutrals through paths other than the line drops. Much of these fields were contributed by power returning in the house lightning protection water system ground connection, as illustrated in Fig. 5. The neighborhood allowed the fields to be measured along the street. Inaccessible backyard field levels that were about 2 mG were not measured. Valid surface function and contour maps cannot be generated from such sparse data! The temporal variations are also a problem with any spatial presentation. The field magnitudes shown in Fig. 6 changed with the time of day from human lifestyle patterns such as temperature-influenced air conditioner loads.

Figure 8 shows the variation in magnetic field exposed to an individual on a trip. Data were taken by wearing an EmdexC magnetic data recorder while leaving the city of Old Alexandria, Virginia, City Hall and traveling to Washington, D.C. The first part of the plot was the walk to the city hall parking lot. Most of the fields were about 1 mG from the distribution lines. The higher

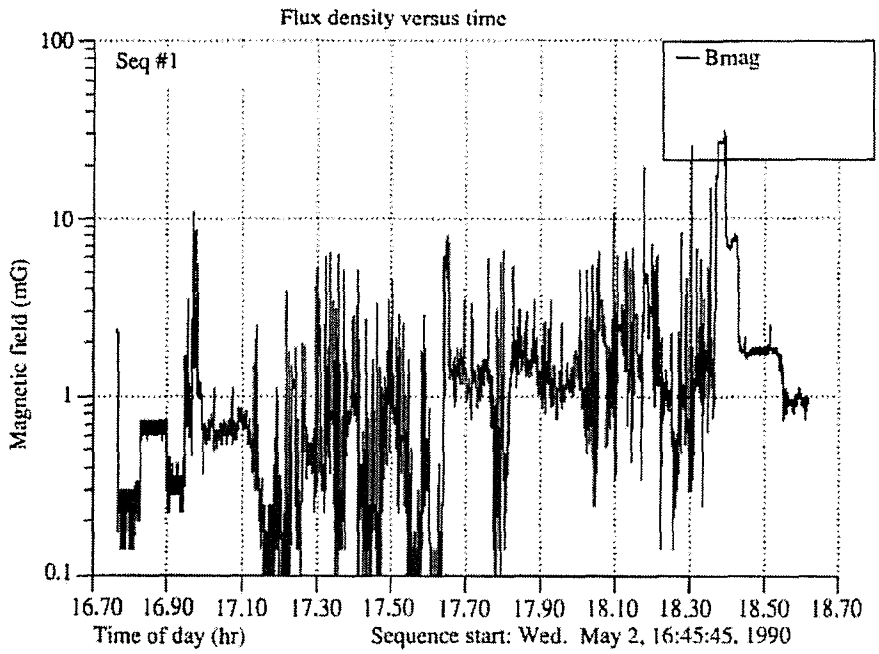


FIGURE 8 Magnetic field exposure plot of data used for Table V statistical summary. These data were collected during a 2-hr car trip from Old Alexandria, Virginia, to Washington, D.C. The highest level of exposure occurred at about 18:22 hr, when the data logger was brought near a computer to offload and process this data.

values occurred at the end of the exposure recording by using a computer. The plot of Fig. 8 typically leaves an impression of higher fields from the peaks than what was the real average. Table V shows the statistics for the recording that have a valid quantification of the average and mean recorded fields.

V. ELF HOUSEHOLD AND OCCUPATIONAL FIELDS

Feychting and Ahlbom (1992) provide statistics from Sweden in tables and figures showing fields common in Swedish households categorized into 0–0.09, 0.1–0.19, and from 0.2 μT (2.0 mG). These Swedish ELF magnetic field levels are similar to those found in the United States.

Household and occupational fields are usually made up of a lower level background field from a nearby cable with unbalanced current or a nearby power line. These fields are circular around the cable and decrease inversely with the radial distance. Appliance magnetic fields are highly localized and decrease proportional to the inverse square of the distance from the point of interest to the center of the source. Appliances with high-torque motors with

TABLE V Magnetic Field Exposure Statistics[a]

Statistic[b]	B_x (mG)	B_y (mG)	B_z (mG)	B_{mag} (mG)
Minimum	0.10	0.10	0.10	0.10
Maximum	29.00	20.30	22.70	30.70
Mean	0.93	0.83	0.63	1.58
Standard deviation	2.76	1.40	1.19	3.23
Geometric mean	0.42	0.47	0.35	0.83
Median	0.50	0.50	0.40	0.90

Percentile[b] (%)	B_x (mG)	B_y (mG)	B_z (mG)	B_{mag} (mG)
0.00	0.10	0.10	0.10	0.10
5.00	0.10	0.10	0.10	0.14
10.00	0.10	0.10	0.10	0.22
15.00	0.10	0.20	0.10	0.24
20.00	0.20	0.20	0.10	0.33
25.00	0.20	0.20	0.20	0.44
30.00	0.20	0.30	0.20	0.57
35.00	0.30	0.30	0.20	0.65
40.00	0.30	0.40	0.30	0.70
45.00	0.40	0.40	0.30	0.78
50.00	0.50	0.50	0.40	0.90
55.00	0.50	0.50	0.40	0.99
60.00	0.60	0.60	0.40	1.12
65.00	0.60	0.70	0.50	1.24
70.00	0.70	0.70	0.50	1.37
75.00	0.80	0.80	0.60	1.55
80.00	1.00	1.00	0.70	1.75
85.00	1.10	1.20	0.80	1.87
90.00	1.40	1.60	1.10	2.43
95.00	2.10	2.20	1.80	4.79
100.00	29.00	20.30	22.70	30.70

[a] These are the statistics of the data plotted in Fig. 8. These data were taken during a 2-hr trip from Old Alexandria to northeast Washington, D.C. The drive followed I-95 to U.S. 295 to Pennsylvania Avenue to East Capitol Street. Data started recording Wednesday, May 02, 16:44:42, 1990. Note that magnetic field magnitude is less than 2.43 mG 90% of the time and greater than 4.79 mG only 5% of the time.

[b] For 6674 frames.

little magnetic shielding, such as vacuum cleaners and small hand-held tools and appliances, generate high local fields. Since most appliances operate at low voltage, they have rather small associated electric fields. They may, however, draw considerable current and be close to people, and therefore the magnetic fields associated with their use may be significant.

A. Household

1. *Electric Blankets*

Florig and Hoburg (1991) have reported the fields associated with electric blankets. Electric fields vary from about 20 to over 100 V/m, depending upon the blanket manufacture, and the field decreases slowly with distance. They report magnetic fields at the blanket surface of several hundred milligauss, decreasing to about 10 mG at a distance of 10 cm. They calculate the average magnetic flux density within the whole body of an adult sleeping under an electric blanket separated from the body by 1 cm to be between 21.1 and 31.1 mG, depending upon the size and type of blanket used. The resultant average induced current would be 0.15 nA/cm^2, greatest at the body periphery and nearest the blanket. The resistive load of the heating wires results in a current proportional to the line voltage, very sinusoidal.

There have been reports of a new generation of electric blankets that use twisted pair heating wires that produce much less magnetic field. Clearly in those individuals who use electric blankets this exposure can be dominant from the time spent in the field. Other appliances, such as a hair dryer, may generate large fields, but rarely would an individual be in the field for long periods. One exception to this generalization is users of computer monitors.

2. *Contour Map of Living Room and Kitchen*

An example of living background fields is shown in Fig. 9. The data that were used to calculate the contours were taken at a time when none of the appliances noted on the map were operating. The 2- to 3-mG field across the center of the room was from a cable under the floor carrying a load to the second floor. The field magnitudes being parallel is a characteristic of line-carrying current that may be from a power line or a cable in a house. The field from an isolated cable decreases proportional to the inverse of the distance from the cable. The map shows the location of various household appliances. These appliances have magnetic fields that are very local. They decrease as the square of the distance from the source. The appliances noted on the map are described later in this section by their spectrum and a magnitude at a reference distance. This allows estimating the field by the rule of decreasing the field by the square of the distance from the source.

Household appliances differ from most power loads in their more nonsinusoidal wave shape and larger harmonic content. Large power loads are

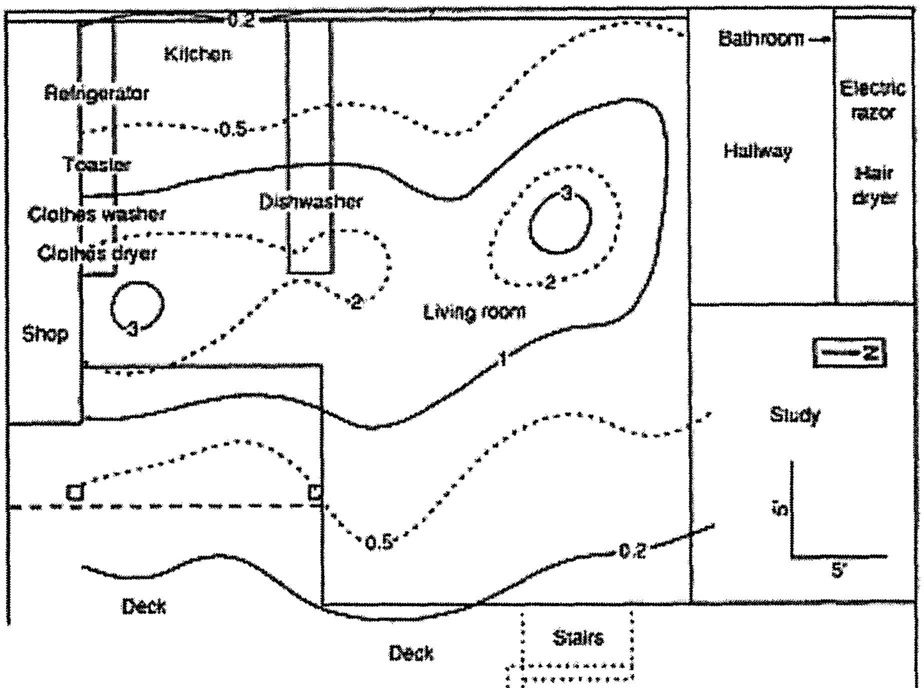


FIGURE 9 Household magnetic background field generated from within the house. At this point in time, the field intensities range from about 0.2 to 4 mG.

designed for efficiency, low-power factor, low vibration, and low noise. Appliances other than refrigerators and furnace blowers are generally designed for high power, low price, and small size. To do this the internal iron flux paths have very high-flux densities approaching saturation that results in high third harmonic load currents and emanating magnetic fields. The standard appliances are documented here with their field intensity versus distance, operating waveshape, and spectrum. The selection was made to show a representative set of household items.

3. *Television and Computer Monitor Fields*

Television sets and computer monitors are similar and can contribute to relatively long periods of exposure to the viewer and operator. The television or computer monitor dominantly cause the magnetic field from the deflection coils on the cathode ray tube (CRT). The vertical scan frequency of television and many computer monitor displays was chosen to be 60 Hz so that power frequency-interfering fields then cause a displacement that is much less bothersome to a viewer. A field as low as 125 mG is a detectable distortion level in this case, where the frequency difference is often 1 cycle/minute. If the vertical sweep or scan frequency differs from the power line frequency, and if the power line magnetic field is strong, the display will wiggle or appear fuzzy. There are a few computer monitor raster modes that are 50 and 70 Hz that react with a 60-Hz interference to have a troublesome 10-Hz displacement modulation (Deno and Baishiki, 1987). A power line field of 10 mG can be detected in this case. Any degradation of a display will cause fatigue to a viewer.

The horizontal scan frequencies are 15.36 kHz for the interlaced NTSC video (TV), and the 1993 computer monitors range from 30 to 60 kHz. The horizontal scan magnetic field is directed vertical to deflect the electron beam horizontally. The horizontal scan deflection coils are smaller on the inside of the deflection yoke. The smaller horizontal deflection coil has lower reactance that correlates with a lower magnetic field emanating around the CRT. For this reason the horizontal scan magnetic field is often one-third that of the vertical scan of 60 Hz. Recent 1993 monitors have been constructed with what is called a saddle yoke. The external fields have been reported to be reduced by a factor of three. The deflection coil saddle–toroidal and saddle–saddle winding methods are discussed with industry practices in an article by O'Connor (1991). The magnetic field reduction effects are compared with the rest of the industry.

A measure of the vertical sweep magnetic field at the power frequency is a good indication of the dominant magnetic field about the CRT. The horizontal scan field can be estimated from the 60-Hz field. The vertical scan field is horizontal, while the horizontal scan field is vertical about the CRT. Figure 10 shows the 60-Hz vertical scan field data versus distance from the screen.

The scan field is a ramp waveform. The retrace part is fast and produces the spread of the spectrum. Figure 11A shows the 60-Hz vertical scan magnetic field versus time, and Fig. 11B shows its spectrum for a television set.

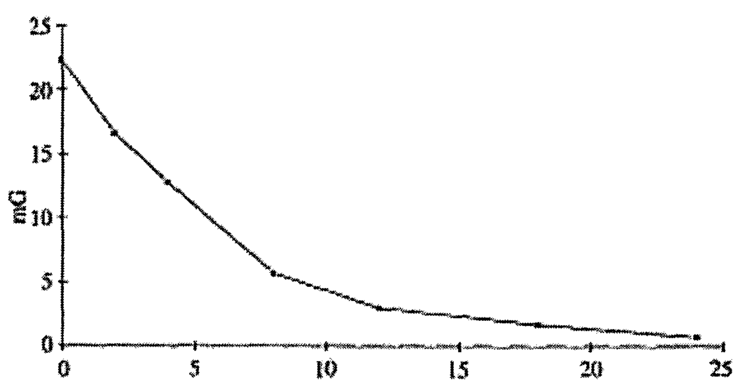


FIGURE 10 B_h, measured horizontal magnetic field magnitude versus distance from the center of the television set CRT screen. B_h is responsible for the vertical sweep.

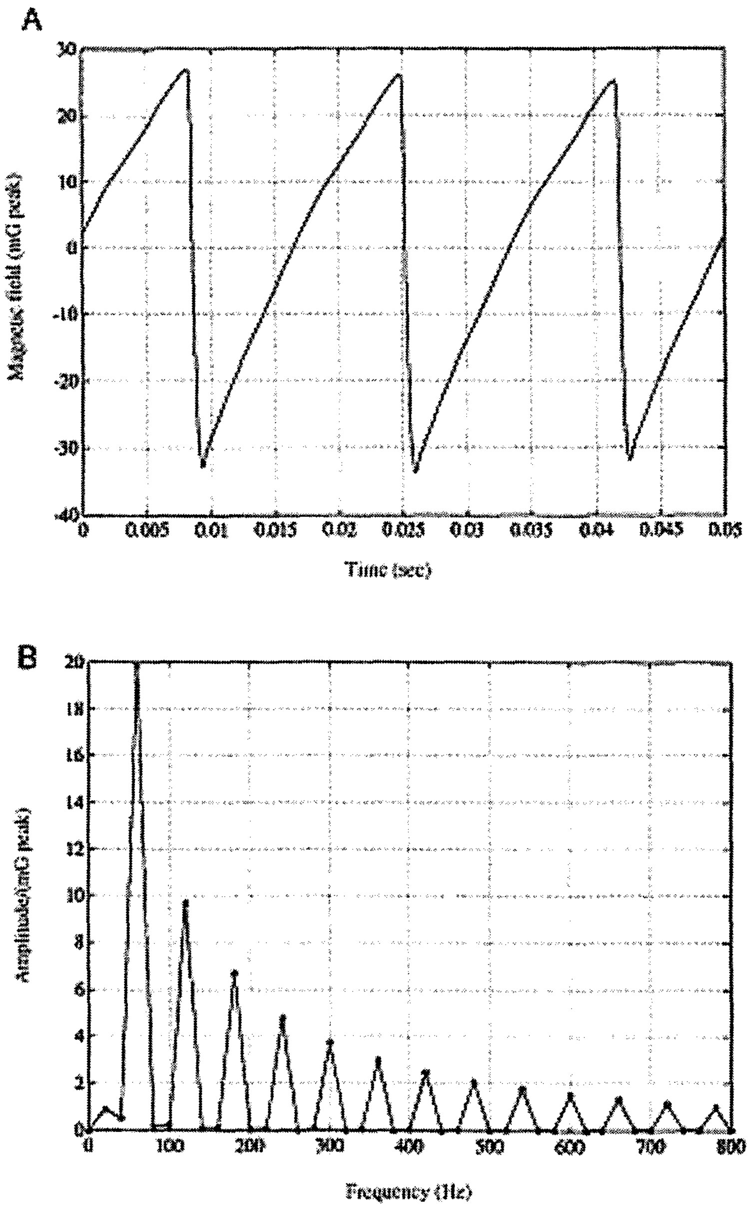
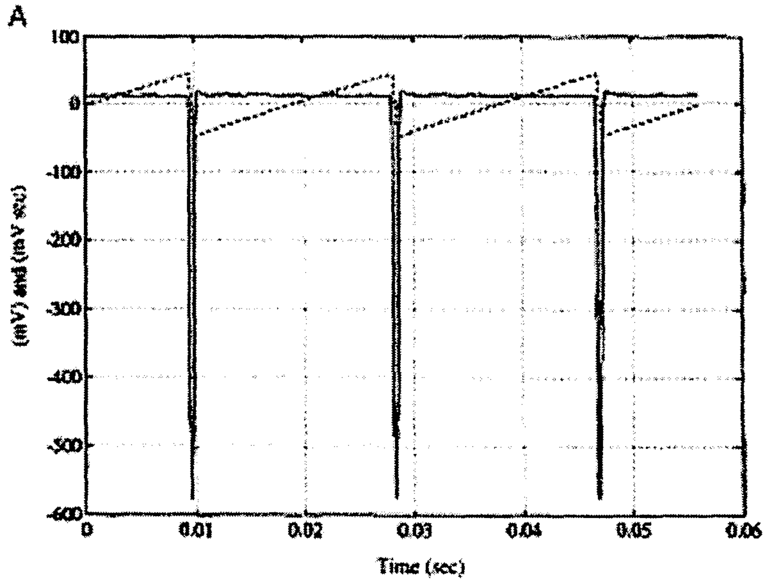


FIGURE 11 Horizontal measured magnetic field from TV set CRT vertical scan. (A) Measured horizontal magnetic field versus time from TV set CRT. (B) Measured magnetic field spectrum. The harmonics decrease proportional to the reciprocal of the harmonic number. This can be compared to Fig. 12B, where the impulse-like spectrum magnitude is more constant.



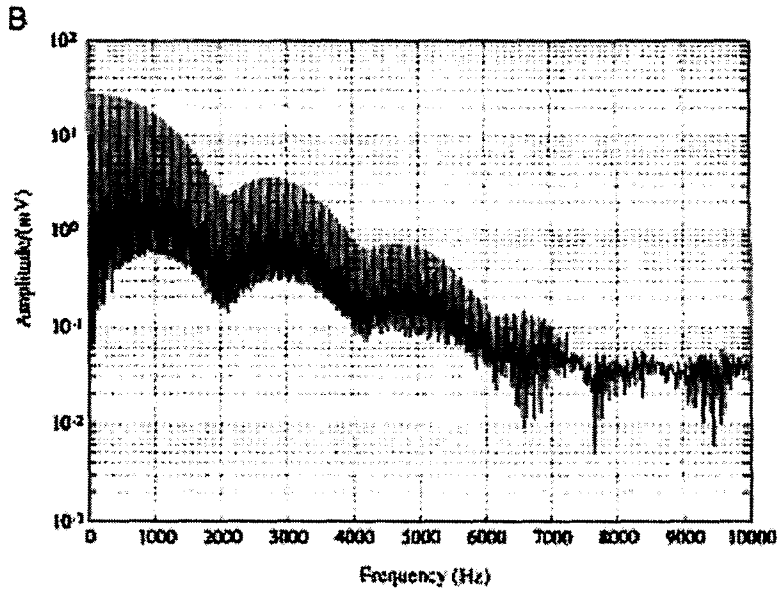


FIGURE 12 B_h, horizontal magnetic measured field from a computer monitor CRT vertical scan. (A) Vertical scan horizontal magnetic field (---) and derivative (—). (B) Vertical scan horizontal field derivative spectrum. This is similar to the TV set in Fig. 11. The derivative of the impulse-like retrace has the characteristic impulse harmonic series being constant. The Fig. 12B plot above 6000 Hz is not valid, being dominantly the digitizing error. The derivative spectrum is the induced current spectrum, which may turn out to be the important characterization.

Figure 12A shows the 60-Hz vertical scan magnetic field derivative versus time, and Fig. 12B shows the derivative spectrum for a computer monitor. These two devices have essentially the same 60-Hz magnetic field. Figure 12 shows that the retrace derivative resembles an impulse function with its harmonic spectrum levels resembling a constant level. A computer monitor's 30-kHz horizontal scan magnetic field is similar with more distortion from eddy currents in the monitor structure. Since a magnetic field induced a current proportional to frequency, for a 30-kHz horizontal scan the induced current is roughly $30{,}000/60 = 500$ times greater than the 60-Hz field.

The practice of the establishment has been to quantify the ELF magnetic field magnitude. If biological effects are from induced current, then the derivative would be the important characterization. Magnetic field bone healing treatment machines have proprietary waveforms that implicate a significance of the waveform. This opens the question of how standards of field magnitude are justified; the answer is beyond the scope of this chapter. It is important to appreciate the existence of the field derivative properties.

4. Clothes Washer

The clothes washer is mainly a running powerful single-phase induction motor and a few solenoid valves. The motor magnetic field from the operator

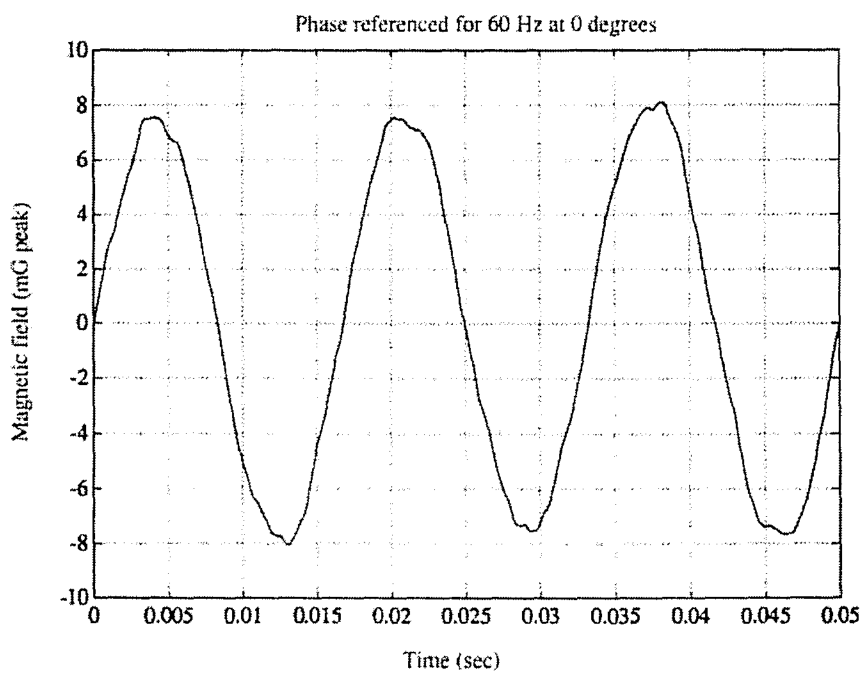


FIGURE 13 Clotheswasher-measured magnetic field versus time. The magnetic field is very sinusoidal with a peak amplitude of 8 mG.

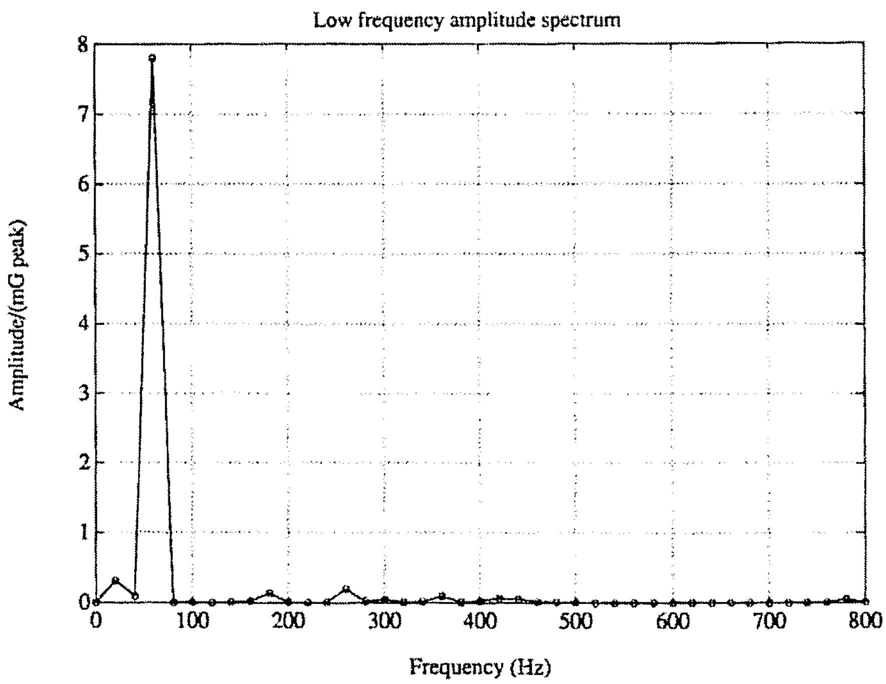


FIGURE 14 Clotheswasher-measured magnetic field spectrum. Compare with the time domain description of the field and note how small the non-60-Hz components are.

is toward the washer. The magnetic field at the operator's position is shown in Figs. 13 and 14. The field is close to a pure sine wave. The few ripples at the peak of the sinusoid are typical with induction motors.

5. Toaster

A toaster is a resistive heater load that draws current proportional to the power line 60-Hz sinusoidal voltage. These fields are characteristically a very smooth sinusoid.

6. Dishwasher

A dishwasher operates in a series of conditions during wash and rinse cycles. The magnitude was 4.6 mG over the dishwasher and 7.5 mG at the hip position of an operator. The field from the heater current is very sinusoidal from the power line voltage. The field from the induction motor current is similar to the clothes washer motor; see Figs. 13 and 14. The field from the solenoid current has a third harmonic similar to Figs. 19 and 20.

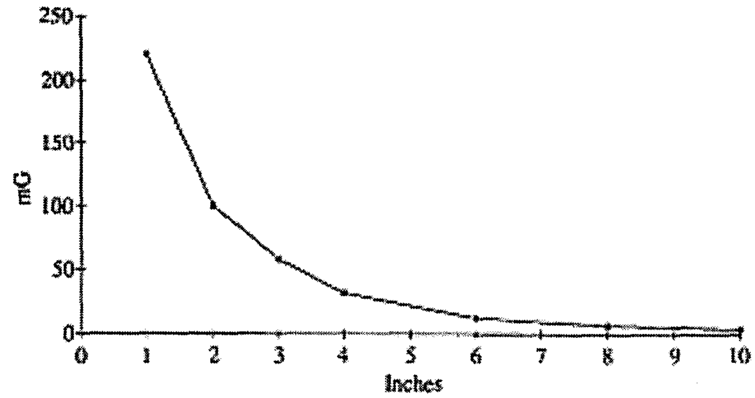


FIGURE 15 60 Hz through 180 Hz measured magnetic field from the hair dryer versus distance.

7. Vacuum Cleaner

A Eureka 3 horsepower vacuum cleaner was used in this evaluation. The field was longitudinal and circumferential about the motor, a point source. At 8 in. above the motor the field level was 16 mG. The high output power for the weight selects a series brush motor for vacuum cleaners similar to a hand circular saw motor. See Figs. 19 and 20 for waveform and spectrum.

8. Hair Dryer

Figure 15 shows the measured magnetic field magnitude versus distance from the hair dryer. Figure 16 shows the magnitude versus time field from a hair dryer. Figure 17 shows the spectrum and a dominant second harmonic present. The shape of the field waveform and the large second harmonic indicates an unusual half wave rectification. This type of changing field is unique to very small appliances that are designed for occasional use. The hair dryer is often used at distances from 2 to 6 in. from the person's head.

9. Razor

The razor studied was a Norelco 550TL. The field was measured perpendicular to the handle cutter surface. B_{max} was perpendicular to cutter surface. The razor is an example of a nonsynchronized power consumption. The spectrum showed a very dominant 360-Hz frequency. The razor is a relatively low-power device with accompanying modest stray magnetic fields. The razor is used a short time with only 14-mG field maximum at the surface of the skin and 2 mG at 2 in. from the cutter surface. The low field level and the short period of operation suggest that this appliance is not a significant source of exposure.

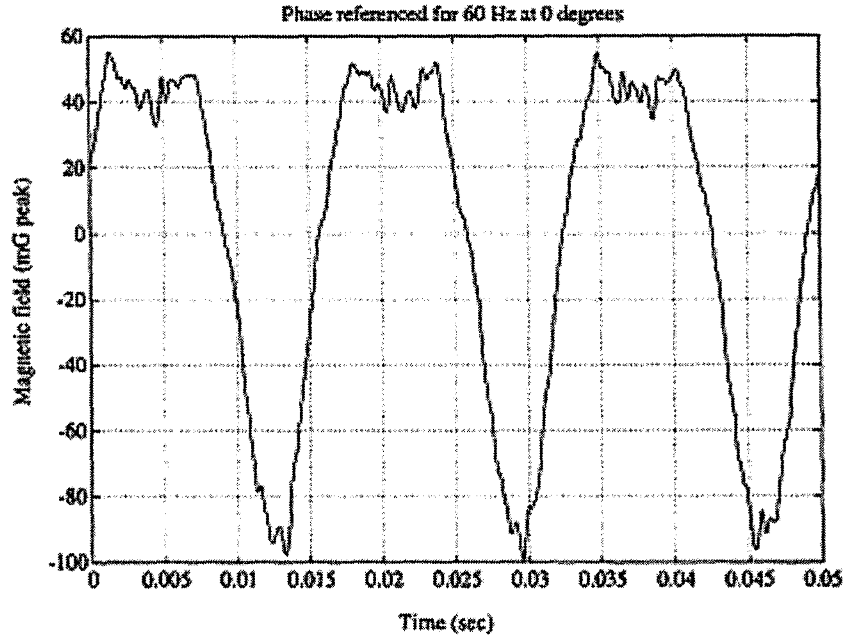


FIGURE 16 Hair dryer-measured magnetic field versus time. This field is 60-Hz periodic, not symmetric, and thus a large second harmonic. The peak strength is nearly 100 mG at the location of measurement.

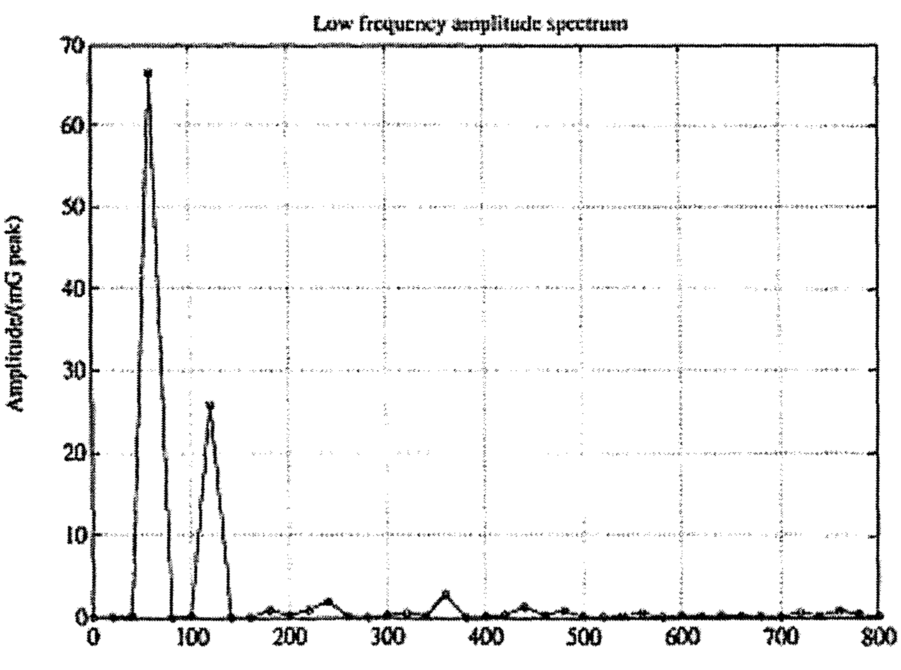


FIGURE 17 Hair dryer-measured magnetic field spectrum. The 60-Hz component is about 67 mG and the 120-Hz second harmonic is about 40%.

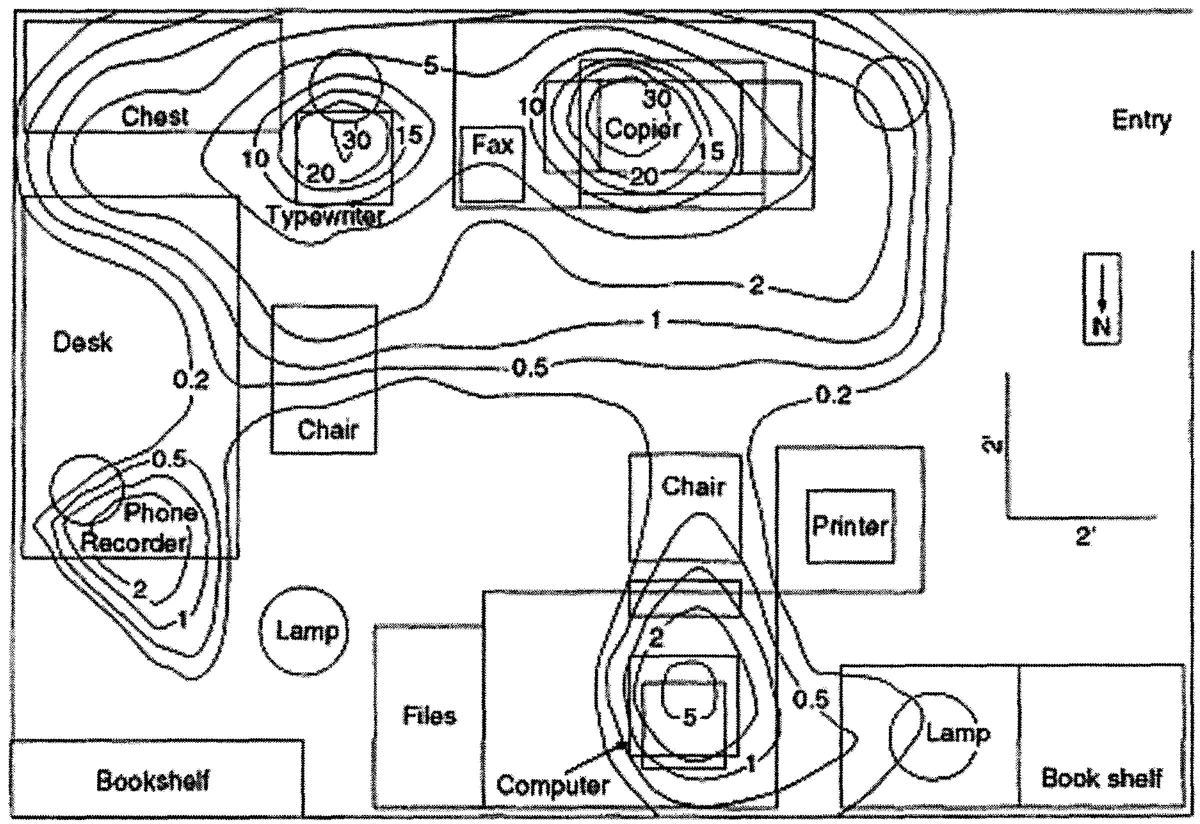


FIGURE 18 Spatial distribution of magnetic field in a real estate office. Note the general background field in most of the area is well below 1 mG in magnitude. The highest fields are at the copier, typewriter, and computer. Contours are shown for 0.1, 0.5, 1, 2, 5, 10, 15, 20, and 30 mG.

B. Occupational Exposure

Occupational exposures include household types, with additional special machines and standard office equipment. A typical real estate office with a superimposed contour plot of magnetic field intensity is shown in Fig. 18. It is an example of how office equipment influences the spatial distribution of the ELF magnetic field. The example shows a very low background level with local sources from energized office machines.

1. Hand Circular Saw

Figures 19 and 20 show the magnetic field of a hand circular saw. The field spectrum is a good example of a large third and fifth harmonic in a machine that works the internal iron flux density into partial saturation. This is characteristic in series brush-type motors that are designed for a high power to weight ratio. The vacuum cleaner motor is similar in design and has similar magnetic fields.

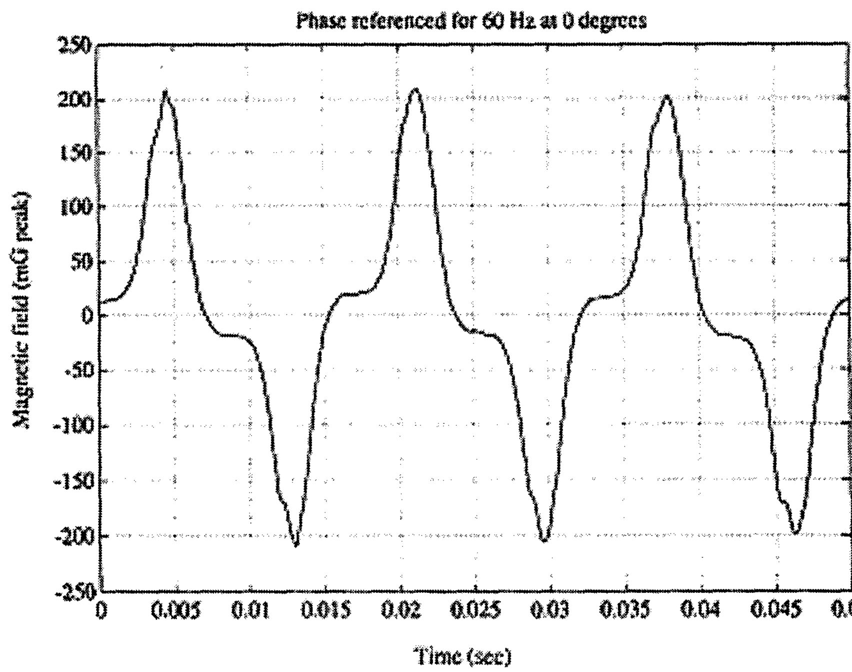


FIGURE 19 Hand-held circular saw-measured magnetic field versus time. This is a high-power-to-weight series wound motor similar to a vacuum cleaner motor. The low weight is attained by working the magnetic flux in the iron into saturation, which causes a third harmonic current component. Note that the peak magnetic field exceeds 200 mG and the nonsinusoidal nature of the field at this location.

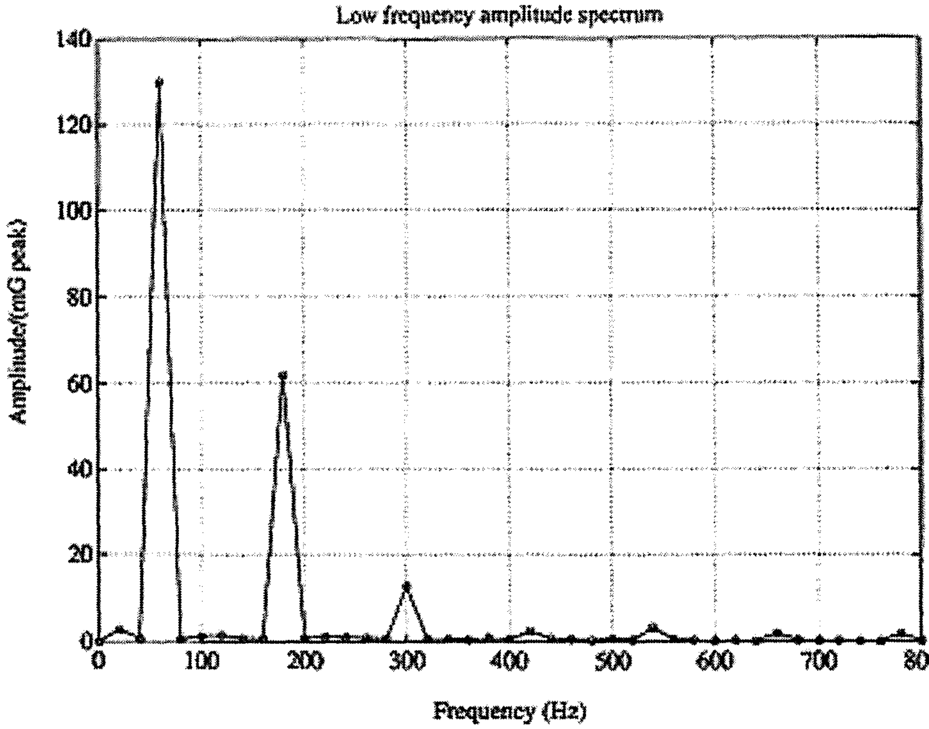


FIGURE 20 Hand-held circular saw-measured magnetic field spectrum. The 60-Hz component peak amplitude is 130 mG and the third harmonic is 62 mG. There are many odd harmonics. The odd harmonics are characteristic of the peaked function of time in Fig. 19.

2. *Copy Machine*

A Canon NP-1218 copy machine generated the magnetic field reported here. The field was recorded while ready to print. The field pulsed three times over 10 sec from 3 to 17 mG at the paper output location from the internal solid-state controller. The field pulsed 7 to 1.3 mG at the position of the operator. The operator's position in the ready to print status was dominated by pulses of $B_v = 1-3$ mG. The magnetic field at the operator's position is shown in Figs. 21 and 22. The magnitude and spectrum are characteristic of a mixture of motors and solid-state controllers in modern equipment. The variations suggest the complexity of quantifying field exposure.

3. *Small Gasoline Engines*

Small 2- and 4-cycle engines have ignition systems energized by a flywheel magnet assembly. In the flywheel, a magnet's motion creates a changing magnetic field in the region of a coil. The induced current that results is used to operate the ignition system to the spark plug. These assemblies emit a much

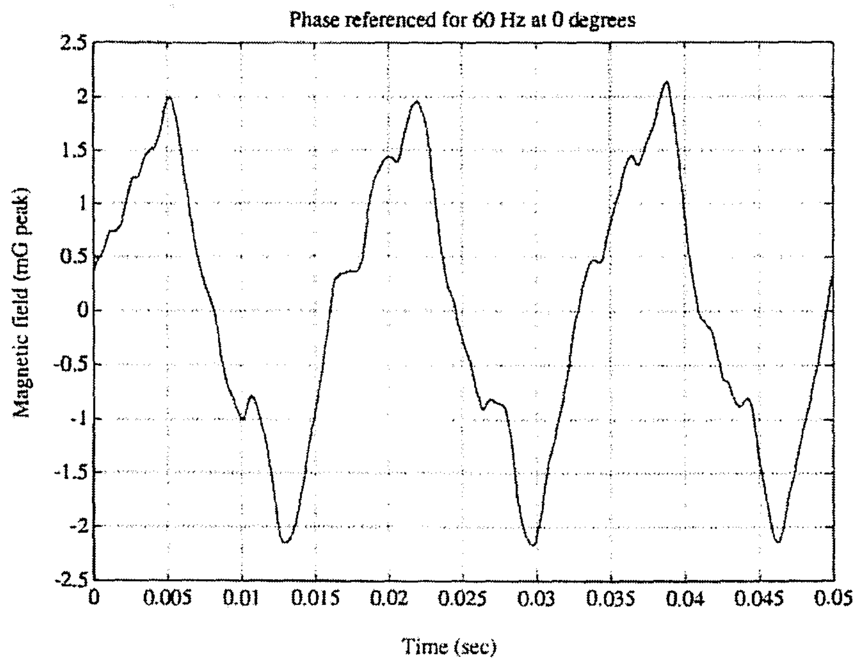


FIGURE 21 Copy machine-measured magnetic field versus time. Note the nonsinusoidal waveshape characteristic of complicated solid-state-controlled devices yielding harmonics to 60 Hz.

larger magnetic field than a generator or alternator that have a tightly controlled magnetic flux path through an armature. A professional chain saw operator may expose his genital area to this magnetic field for many hours a day due to his work position. Some of the newer solid-state ignition chain saws have a lower field. Measurements were made through a sensor filter with a bandwidth of 60 to 180 Hz. A Homelight Model 410 emitted 500 mG in idle and 550 mG at operating speed. A small Echo saw with solid-state ignition emitted 200 mG in idle and 150 mG at operating speed. These measurements emphasize the unappreciated phenomena that appliances do not have to be "plugged in" to generate magnetic fields. Engines and fans have steel parts that can chop the earth's magnetic field in the ELF spectrum. Battery-powered devices are designed for efficiency and have less emission of magnetic field.

4. Heavy Electrical Machinery

Most heavy machines have surprisingly modest 60-Hz fields for two reasons: they are designed to efficiently use the magnetic flux they create, and the regions of highest fields are in the interior of the machine away from human operators.

Higher fields will be experienced in welding. Welding is an example

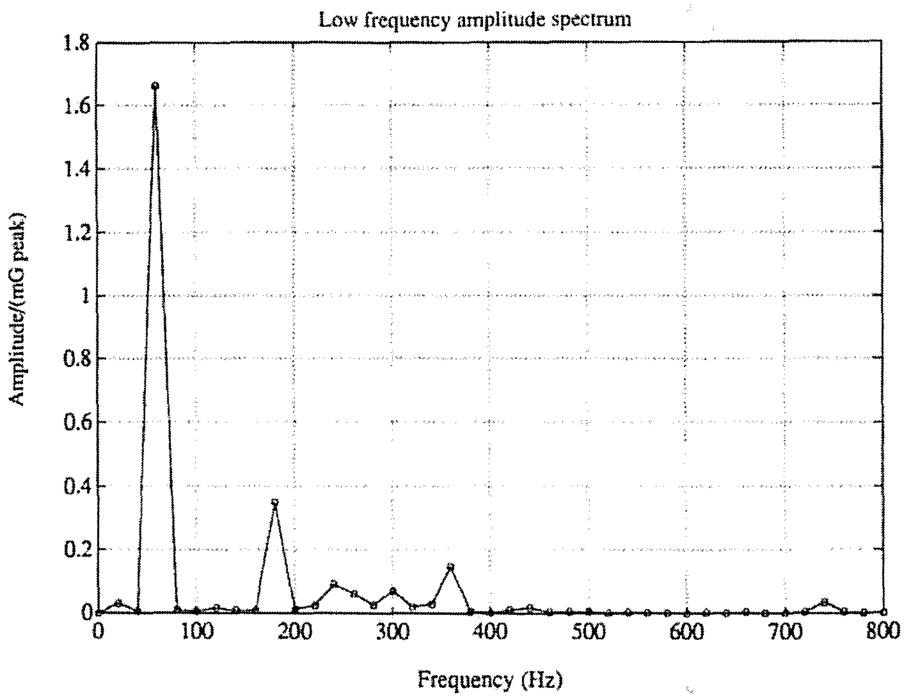


FIGURE 22 Copy machine-measured magnetic field spectrum. The 60-Hz component is about 1.7 mG at this location and the third harmonic at 180 Hz is almost five times smaller.

where the field comes from a simple conductor. The H vector is easily calculated and converted to milligauss by

$$H = I/(2\pi r) \tag{47}$$

and

$$B = 12.5\ H\ \text{mg} \tag{48}$$

in air. For example a welding current of 100 A at 30 cm from the operator would yield a field calculated as follows:

$$H = 100/(2\pi 0.3) = 53\ \text{A/m} \qquad (600\ \text{mG}). \tag{49}$$

This field is usually present for short periods of time.

C. Transients

Some biological researchers have expressed the opinion that occasional transients are less significant than repetitive cycles encountered in long exposure. Transients are difficult to measure and to describe. For example, switching a 110-Vac circuit to a motor has a continually changing current until the motor completes its start-up sequence and stabilizes to its operating speed. This often takes over a second. That means that difficult high-resolution, continuous recording is necessary for measurement and display of the data. A practicable concern is that the scaling must be preset correctly for the recording system. Iterative autoscaling cannot be used in a nonrepetitive transient.

Automobiles are a common but extreme cause of a series of difficult-to-describe transients. Current loops are switched with significant amperage for the starter motor, head lights, and fans. Since these resulting currents are fairly steady, the resulting constant magnetic field induces negligible steady-state currents. Furthermore, the steady state of dc fields produced seldom exceeds the earth's magnetic field. These are mostly transients and switched constant-current fields.

VI. EXPOSURES OTHER THAN ELF

A. Magnetic Resonance Imaging

Table VII provides a perspective of typical magnetic field levels. Magnetic resonance imaging (MRI) devices are the extreme of magnetic field intensity. Field magnitudes about MRI devices are reported with contour maps by Stuchly and Lecuyer (1987). A comprehensive reference on health effects is attributed to Tenforde (1981). Other biological health effects references are provided in the Stuchly and Lecuyer (1987) reference. The contour levels reported have ballpark characteristics of a point source proportional to $1/\mathrm{rad}^2$ with a level of 50 mT (500,000 mG) at 1 m from the center for a 1-T MRI device. The MRI 1-T magnetic field intensity device is a static field. If this field is switched rapidly, it will stimulate the nervous system directly.

B. Communications

AM radio signals are an example of a common propagating low-frequency-radiated wave. Their significant levels are usually found in the range of 1 μV/m to 1 mV/m. Since the induced current from an electric field is proportional to its frequency of oscillation, a 1-MHz radio signal at a field strength of 0.1 mV/m induces a current equivalent to a 60-Hz field of 1.6 V/m: (0.1 mV/m)(1 MHz/60 Hz) = 1.6 V/m. A similar relationship holds for the magnetic field. The radiofrequency magnetic field is related to its electric field by $H = E/Z$. The 0.1-mV/m radiowave then has a magnetic field of 0.26×10^{-6} A/m. The induced current magnitude-equivalent 60-Hz magnetic field is 0.0044 A/m, 0.055 mG. Table II includes the relation of propagating field strengths to radiated power density of watts per square meter perpendicular to the direction of propagation.

C. Magnetic Levitation Vehicles

Although magnetic levitation of vehicles is currently a research subject, it is significant from an environmental planning point-of-view. The fields about a magnetic levitation vehicle are the subject of a report [U.S. Department of Transportation (USDOT), 1992]. The report measured static (dc) fields and spectrum between 2.5 and 2500 Hz. The average field was 100 mG near the floor and 20 mG at a standing head level. The average static field near the floor was 835 mG. At the edge of the loading platform, 300 mG was measured as the vehicle passed.

VII. EXISTING STANDARDS FOR ELF ELECTRIC AND MAGNETIC FIELDS

The reference of Nair *et al.* (1989) includes a section entitled "Regulatory Activity and Exposure Standards," in which the regulatory status is well described: "The natural instinct of.. regulatory authorities.. is to implicitly assume that more is worse and impose field strength limits." The limits set are based on the maximum levels of existing power lines. Power lines are usually the first subject of regulation and controversy. They are obvious from the nature of their size. Power lines generate large fields. Power lines are more predictable than distribution lines. It is anticipated for the future that the concern will increasingly extend to distribution systems and home appliances.

A. State Regulations

States have regulated the field strength limits on transmission line rights-of-way. Table VI is a list of these regulations cited by Nair *et al.* (1989) with the NY 200-mG level at the edge of the ROW. This 200-mG application is based upon the mean field level for existing ROWs. The Public Service Commission wants to push utility transmission line design toward reduced fields in new construction. These field levels and their rationale will probably be revisited in the near future on the basis of health effects research. The controversy comes from recent epidemiological studies suggesting possible health hazards at low magnetic field levels.

B. Occupational Exposure

Occupational exposure limits have been recommended in the publication "Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices" (Industrial Hygienists, 1992–1993). The magnetic field limit over the spectrum is presented and provides a useful perspective by a group that has addressed the subject. The sections are entitled:

TABLE VI State-Regulated Field Levels along Transmission ROW

State	Field limit
Florida	500 kV lines
	10 kV/m in ROW
	2 kV/m at edge of ROW
	200 mG at edge of ROW
	250 mG at edge of ROW for double circuit
	230 kV lines and smaller
	8 kV/m in ROW
	2 kV/m at edge of ROW
	150 mG at edge of ROW
Minnesota	8 kV/m in ROW
Montana	1 kV/m at edge of ROW in residential areas
New Jersey	3 kV/m at edge of ROW
New York	1.6 kV/m at edge of ROW
	200 mG at edge of ROW
North Dakota	9 kV/m in ROW
Oregon	9 kV/m in ROW

- Radiofrequency/Microwave Radiation
- Static Magnetic Fields
- Sub-Radiofrequency (30 kHz and below) Magnetic Fields
- Sub-Radiofrequency (30 kHz and below) and Static Electric Fields
- Ultraviolet Radiation

In the 60-Hz ELF spectrum, it is stated that routine occupational exposure should not exceed B_{TLV} in mT = 60/f (f is in Hz). The reference goes on to cite cardiac pacemaker interference from magnetic fields as being as low as 0.1 mT (1.0 G).

C. Swedish Standard

Swedish ELF radiation standards have been distributed for video units. This is interpreted as applying to TV sets and computer monitors. A value of 2.5 mG is given for Band I, 5 Hz to 2 kHz. This is relevant to the vertical scan, horizontal field, and frequencies of 50–70 Hz that are in the ELF power spectrum. The standard describes for Band II, 2 kHz to 400 kHz, a recommended limit of 25 nT rms (0.25 mG). Band II covers the horizontal scan frequency, which commonly ranges from TV 15 kHz to 30 kHz in computer monitors. The horizontal scan magnetic field about a CRT is usually one-third that of the vertical and is oriented vertically. In Section V.A, Figs. 11, 12, and 13 describe the vertical scan field. Using the one-third rule for level of the horizontal scan relative to the vertical scan, the Band II field levels can be estimated.

VIII. SUMMARY

The ELF 30–300 Hz spectrum includes the electric power fields of 50 or 60 Hz and their main harmonics. The ELF spectrum is addressed in this chapter. The rest of the spectrum is discussed to provide a perspective. Background ELF fields are of biological research interest, because people are often exposed to them for long periods of time. The important characteristics of low-level ELF magnetic field to biological effects are not an established subject, which complicates quantitative exposure description. The ELF fields are analyzed by using simplifications referred to as quasi-static or quasi-steady-state analysis. In this case the propagation properties of electromagnetic fields are not used. Induced currents and voltages on nearby objects from sources of the fields are strongly influenced by frequency or rate of change. Thus, a 1-mG magnetic field at 180 Hz will induce three times the current of a 1-mG magnetic field at 60 Hz.

The earth's magnetic field of around 500 mG induces no current without rotation of an object. A typical human body rotational motion of 1 rad/sec in the earth's field induces a current magnitude equivalent to 1 mG of a 60-Hz field. Household appliances have higher local fields than ground-level high power lines. Appliances emit dipole fields that are very local, to which people tend to be exposed for short periods of time. Many appliances generate magnetic fields with frequency components greater than 60 Hz with time variations. The coordinate alignment of an appliance magnetic field is random. These qualities complicate a quantitative measure of magnetic field exposure even with the restriction of including only the ELF spectrum.

Table VII summarizes the fields over the entire spectrum in which we are immersed. In the ELF spectrum, a level of 1–2 mG is common. A switching transient such as a motor start and stop is assumed to be of such short duration that transients were not discussed in detail. Magnetic fields of long duration have been emphasized. Some of the complex magnetic field description problems are:

1. Appliances are turned on and off irregularly.
2. Low-level background fields change with time.
3. Local sources often have significant harmonic content in their emitted ELF magnetic field with unpredictable coordinate amplitude and phase components.
4. If a biological system is sufficiently sensitive to be affected by the low-level common background ELF magnetic field, the effect is not a statistical heating energy type of phenomenon. Spectral content and coordinate orientation could be significant characterization. Magnetic fields of long duration have been emphasized.

5. Harmonics, their individual coordinates, their phase relationship, and the change in time are too complex to completely characterize. Simplification examples are:

a. Harmonics are measured at a point in space and time,
b. statistical descriptors, such as field magnitude and recording field magnitude versus time increments, are used,
c. Spatial magnitude contours are determined on a horizontal plane at a point in time, over a reference space, and described by a map.
d. Field magnitude is measured at a point in time along a path of travel and presented spatially on maps.

TABLE VII Summary of Typical Electric and Magnetic Field Effects

Source	Frequency	Strength	60-Hz equivalent field for the same induced current	Comments on exposure
Electric				
Earth field	Constant in fair weather	+100 V around 1 m	Not applicable	Very low induced current
Clothing	Spark discharge	Up to voltage breakdown 3 MV/m	Not applicable	Variable with humidity Rubbing cloth can cause breakdown
Household	60 Hz	Max. 50 V/m	Same	Long periods of immersion
Power lines	60 Hz	5 kV/m max	Same	Short duration
Magnetic				
Earth field	Human motion	500 mG		Rotation
	0.2 rad/sec		0.2 mG	Walking
	1. rad/sec		1.0 mG	Active
Household	60 Hz	0.2 to 2 mG	Same	Background level
Powerlines	60 Hz	2 to 100 mG	Same	500 mG, max
MRI diagnostic imaging	Constant	1 T	Not applicable	Brief, clinical indication
Radiated field				
AM radio	1 MHz	0.1 mV/m 0.002 mG	1.6 V/m 0.043 mG	Constant exposure Quasi-steady state
Sunlight	$50\ 10^{14}$ Hz	632 V/m, 20 mG	Beyond breakdown	Assumed 1000 W/m^2

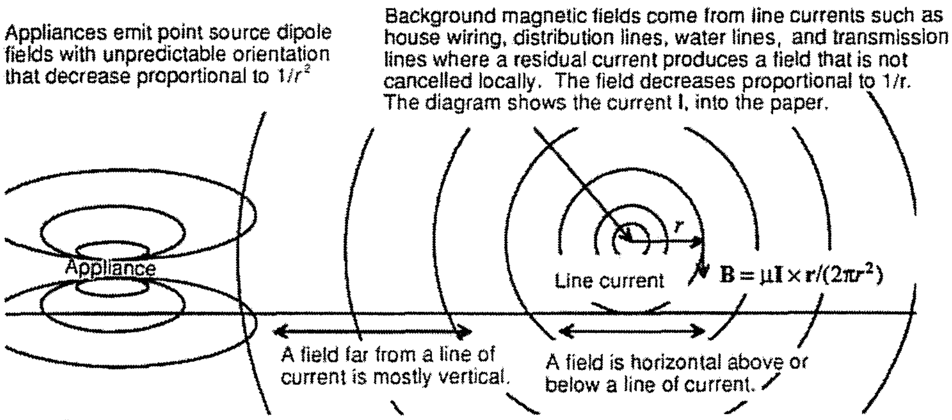


FIGURE 23 Characteristics of an ELF field spatial distribution in the environment.

Background ELF fields are usually vertical, because background sources tend to be currents in a conductor at a distance on a similar elevation. Figure 23 shows how the field is distributed about a line of current and why the similar elevation determines the magnetic field to be vertical. Line current fields decrease as $1/r$, where r is perpendicular to the current path. Appliances are point sources that have dipole fields. These fields are usually intense internal to the appliance, such as inside the motor. The externally emitted fields decrease proportional to $1/r^2$. Since appliance fields decrease so rapidly, they do not dominate a background field level in normal habitat. The distributed background level of magnetic field often has the greatest influence on ELF magnetic field exposure. An exception would be an electric blanket.

The important points discussed in this chapter were arbitrarily selected. Clearly any biological study should fully characterize the magnetic field used. The parameters of characterization should not be less than those described in this chapter. It is expected that new research will point out different and significant characterizations.

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44. Please provide quantitative data showing that EKPC has violated any electric field exposure limit to which utilities serving in the Commonwealth of Kentucky must adhere as approved and mandated by Kentucky law.

ANSWER BY: John Pfeiffer

There are no known Kentucky standards

45. Please provide quantitative data showing that EKPC has violated any magnetic field exposure limit to which utilities serving in the Commonwealth of Kentucky must adhere as approved and mandated by Kentucky law.

ANSWER BY: John Pfeiffer

There are no known Kentucky standards

46. Please provide quantitative data showing that EKPC has violated any federal electric field exposure limit to which utilities serving in the Commonwealth of Kentucky must adhere.

ANSWER BY: John Pfeiffer

I know of no federal electric field standards.

47. Please provide quantitative data showing that EKPC has violated any federal magnetic field exposure limit to which utilities serving in the Commonwealth of Kentucky must adhere.

ANSWER BY: John Pfeiffer

I know of no federal magnetic field standards.

48. Please provide quantitative data showing that EKPC has violated any Rural Utilities Service ("RUS") electric field exposure limit to which utilities serving in the Commonwealth of Kentucky must adhere.

ANSWER BY: John Pfeiffer

I know of no RUS electric field standards.

49. Please provide quantitative data showing that EKPC has violated any RUS magnetic field exposure limit to which utilities serving in the Commonwealth of Kentucky must adhere.

ANSWER BY: John Pfeiffer

I know of no RUS magnetic field standards.

50. If you provide any quantitative data in response to information requests 4 and 5 above, please provide a copy of the federal, state, or RUS standard(s) which support your response.

ANSWER BY: John Pfeiffer

Please see the answer to question 4

51. Please state whether Dr. Carpenter disagrees with the information contained in the Department of Energy's RAPID brochure? If the answer is "yes," please identify each such disagreement and provide a detailed descript ion of the nature of, reason for and facts supporting the disagreement.

ANSWER BY: David O. Carpenter M.D.

I have not seen this brochure, so cannot comment.

52. At the end of the next to last paragraph of his testimony, Dr. Carpenter states, "It is particularly onerous in that the utility did not have to run the line so close to their house, since there are open fields both to the east and the west." Please describe the analysis performed by Dr. Carpenter that established that the "open fields both to the east and the west" were viable and available alternative routes for the transmission line.

ANSWER BY: David O. Carpenter M.D.

Mrs. Barker reported to me that she and her family own lands both to the east and the west which were available to the utility.

53. In the last paragraph of his testimony, Dr. Carpenter states, "This must be a critical consideration when routes for a new high voltage powerlines are being considered, and this clearly did not occur when the present line was built." Please provide the analyses, studies, and documentation Dr. Carpenter relied upon to reach this conclusion.

ANSWER BY: David O. Carpenter, M.D.

The evidence is the fact that the line was placed so close to the house as to result in significantly elevated exposure to the residents. If the harm to the residents had been considered the line would not have been placed there.

54. Please provide the name, title, address and phone number of all experts with whom the Barkers have consulted regarding the effect of magnetic fields or electric fields. For each such expert identified, please provide copies of any reports, correspondence or other documents received.

ANSWER BY: The Barkers

John C. Pfeiffer, P.E.
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Dr. David O. Carpenter, M.D.
Director of the Institute for Health and the Environment at the University of Albany
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518-442-3300

Dr. Frank Barnes Ph.D
University of Colorado at Boulder
Boulder Co. 80309-0425
303-492-8225

55. If it is your contention that the transmission line project was not a replacement or upgrade of an existing transmission line, please provide a detailed description of the facts upon which such contention is based.

ANSWER BY: John Pfeiffer

This project is a replacement project.