APPENDIX C

SUBMITTED WRITTEN COMMENTS

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This Appendix presents the written comments submitted by participants and others during or after the symposium. They have not been peer-reviewed and represent the opinions of the writers.

Most comments are presented in order, below, as they relate to specific Topics (e.g., Topic #2: Field Parameters). One set of comments was keyed to the overall objectives of the RAPID Program and applied to more than one Topic; it is found at the end of this Appendix.

Topic #2: Field Parameters

<u>Comment #1: Yoshihisa Otaka</u>

[Narrowing the range of][1] field parameters seems to be unexpectedly complex even after the four EMF Symposiums. Polarization was included in the list of parameters of field. Although there are very few experiments reported using polarized fields, it seems that if researchers could determine whether polarization is an active magnetic field parameter (or not), the number of possible parameters—the "fractal problem"—would be simplified.

I think polarization as a field parameter conflicts with the induced current mechanism. Electric current is induced in human and animals in both circularly and linearly polarized magnetic fields, because they have round bodies and can move freely in the fields.

However, if biological effects are different, depending on polarization, this would support only the magnetite mechanism. (A magnetite micro-crystal rotates in a circularly polarized magnetic field but cannot start moving in a linearly polarized field.) As for the free radical and the resonance mechanisms, polarization makes no difference. Unpaired electron of a free radical can alter the spin without affecting chemical reactivity.

If circularly polarized magnetic fields are shown to have a different biological effect than linearly polarized fields, hazard would be limited to some geometrical area, and extrapolation of biological effects to another frequency based on calculated induced current would be erroneous.

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[1]The comment has been lightly edited for clarity.

If the magnetic field has a biological effect through induced current, experimental design using circularly polarized fields would be unnecessary.

Yoshihisa Otaka
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<u>Comment #2: Marcus Barnes</u>

The following is excerpted from a letter to the Symposium from Marcus Barnes of Aerodyne Laboratories:

I'm recommending that an appendix be included as an attachment to the symposium report [for purposes of technical clarity].

Here are a few relevant definitions I believe should be in included in such an appendix:

Exposure The measure of concentration or intensity of the environmental agent (EMF) in question

Dose That aspect, measure of concentration or intensity of the exposure that biologically interacts with the organism

(While we too frequently hear "exposure" and "dose" used interchangeably, we really don't know what "dose" is.)

Hazard A threat to a person or people and what they value

Risk The measure of a hazard's consequence expressed as a conditional probability of being hurt or harmed

Working Definitions as applied to and used in EMF:

RMS Root mean square: the <u>effective</u> value of an alternating electric or magnetic field (regardless of its waveshape)--i.e., the square root of the mean value of the periodic function over one complete cycle

TWA Time-weighted average: the mean of an alternating electric or magnetic field's RMS value, averaged over a specified time period, with a particular sampling rate

Peak (1.) The maximum instantaneous value of a periodic electric or magnetic field's waveshape or function during a specified time period

(2.) The maximum RMS value of an alternating electric or magnetic field during a specified time period

Transient an anomalous departure from an otherwise normal condition where an electric or magnetic field undergoes an extremely fast “rise” and/or “fall” time--transients may contain higher-order harmonics than would be present during the normal periodic function--so-called “spikes” are a category of transients

Parameter a characteristic feature(s) or property(s) of an electric or magnetic field--some examples would be: fundamental frequency, periodic waveshape, harmonic content, field strength, intermitency, modulation envelope, attendant transients and/or spikes, etc.

Only a beginning, the list could be expanded. It’s likely that you or other participants may have some terms in mind that could be appropriately added. Also, you (or others) could improve on what I’ve submitted.

Marcus Barnes
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Austin, Texas

<u>Comment #3: Kirby C. Holte</u>

Have we, as engineers and scientists, so complicated the study of possible associations between power lines and disease that meaningful risk assessments and response plans are impossible? The search for an EMF risk assessment and response plan has been bogged down for years due to the expanding list of metrics proposed as possible measures of “dose.” Table 1 includes 26 metrics loosely tied to four proposed mechanisms for biological coupling. The addition of other proposed mechanisms further expands the list and inclusion of EMF surrogates adds more complexity. Add non-EMF metrics, such as traffic, corona and ozone production (from power lines) and air pollution until, and the number of combinations and permutations reaches into the billions. Clearly there is neither sufficient time nor money available to study all proposed metrics.

Two approaches have been suggested to narrow the list. One approach, generally advocated by the engineers and physicists, examines all plausible mechanisms by which EMF and its various derivative metrics could cause or promote a cancer, identifies those metrics which are shown by the physics to be significant, and then sets fourth a protocol by which those metrics can either be measured or derived. The limitations of this approach are first, not enough is known about the mechanism to know which metrics are truly significant, and second, the approach tends to eliminate metrics which are not directly related to EMF.

The second approach, generally favored by the epidemiologists, starts with observation, for example Leukemia vs. Wiring Code, then look for measurable metrics which might reasonably associate with the observed effect. To be useful in developing a response strategy, metrics should be physically tied to the biological mechanism. Ultimately, this second approach leads to the identification of measurable metrics and their association to the power line. However, the two lists will differ significantly. Not all of the EMF related metrics from the first list would appear in the second list. On the other hand, the second list may contain metrics such as ozone, radio frequency noise, etc., which are not on the first list. The primary limitation to this approach is that the metrics selected may not be physically capable of producing a biological response sufficient to explain the observed effect.

There is a subset of this second approach, which has merit but must be treated with caution. It adopts one metric, most often TWA 60 Hertz rms magnetic field, and assumes that all other metrics are either not significant or are functionally proportionate to the selected metric. If, for example, one assumes that TWA rms, harmonics and intermittence are all significant; one accepts TWA as the metric by assuming that harmonics and intermittence are functionally proportional to TWA. One might take the approach one step further in designing the response strategy. That is, by assuming that an engineering design change, which reduces TWA rms magnetic field, will also reduce field harmonics and intermittence. The merit of this approach is that it is simple, both in terms of "exposure" quantification and for the design of field management options (strategic response). Its limitation is that no biological mechanism has been shown by which low level TWA or any other single metric can cause or promote cancer. Thus, a quantifiable risk assessment based on this method will be extremely difficult if not impossible.

A hybrid approach may be workable and deserves additional attention. I propose that a small group of engineers, physicists, epidemiologists, and biologists form a small task force to investigate further. Never the less, I am becoming increasingly convinced that the modified (single metric) approach using TWA may be the only practical approach. Once again, a small task force for further investigation is in order.

Ideally, the identification of significant metrics along with an understanding of how these metrics cause biological effects and ultimately, the degree to which these biological effects cause disease, would be used to establish a strategic response (regulation and/or mitigation plan). This may not be possible and, given the number of metrics and possible mechanisms, is, at this point, unlikely. The modified (single metric) TWA approach, as currently used in California's EMF Design Guidelines, provide an attractive and practical alternative.

These guidelines, developed through a California Public Utility Commission consensus committee and public hearings, require the utility to evaluate engineering and operating measures which materially reduce ground level magnetic fields for newly constructed or reconstructed power lines. Only those measures which meet all applicable safety and utility design standards need be evaluated and only those measures which materially reduce the magnetic field and add less than 4% to the total cost need be adopted. In recognition that design and operating standards vary between utilities, each utility operating within the state is responsible for the development and administration of their own EMF Design Guidelines. A "Field Management Plan" which describes the project, the field management options considered, and the reasons why the various options were accepted or rejected, is submitted to the PUC as part of the project approval process and is available for public review.

The California EMF Design Guidelines do not assume that power lines do or do not pose a health risk. If such a risk does exist, the guidelines do not implicitly assume that that health risk is function of either maximum or TWA rms magnetic field. Instead, the guidelines take a practical approach based on both the state of the science and public concern, both of which tend to focus on the reduction of rms magnetic fields. The practical result is that many new power lines can be designed with significantly lower magnetic fields. Reductions of 20 to 60% are not unusual. If, on the other hand, the guidelines required a reduction of all of the parameters listed in Table 1 (and a few others not listed in Table 1), many of the most effective field reduction measures would be eliminated.

Kirby C. Holte
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Walnut, CA

Topic #4: Exposure Systems

<u>Comment #1: Stuart Harvey</u>

We have found that some exposure systems described in the literature can only approximate the claimed field parameters. Any exposure system design benefits from precise field calculations (assuming that manufacturing tolerances are up to scratch), that will provide the exact magnitude and direction of the field at any point. This is particularly important where samples may be in a non-uniform field and the sensor tends to average over a significant volume, as the calculations are then more precise than the measured field. Computer aided design also allows theoretical designs reported in the literature to be optimized for practical experimentation.

As an example, a Helmholtz coil (and possibly a Merritt coil) is not optimized to produce the most uniform field over a given working volume, only to cancel a given moment at the centre. With computer design, the useful working volume can be optimized to fit a given sample space.

Are there general computer programs designed for this? We have used our own for a number of years and could make it available (subject to some user interface work) if there is a need.

I would also strongly recommend the general use of a laser vibrometer for vibration measurements when qualifying an apparatus. These instruments operate out of the field region, do not require any connection to the apparatus, and can work through small holes in incubators or mumetal shields. They are capable of measuring vibrations that are too small to be sensed by human touch (if not by mice).

Stuart Harvey
SAIC Canada
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Topic #7: Source and Environment Characterization

Comment #1: Stuart Harvey

For the class of periodic fields whose amplitude or direction changes slowly compared to the period, essentially complete characterization of the field at one point in space is readily achievable by periodic sampling with a 3-D waveform capture instrument. Has consideration been given to reducing the amount of data storage required by using some on-line processing?

As an example, the field at one point in time (actually several cycles) can be represented as a set of ellipses in real space, one for each harmonic. Each ellipse is completely specified by the major axis, minor axis, and relative phase, which may require a lot less space than the oversampled waveform. The evolution of each harmonic in space and time can then be followed by recording changes in these parameters.

With modern electronics, it should be possible to build a similar instrument for free-space electric field measurement using three electrically-short orthogonal dipoles and fibre-optic link. With FET preamplifiers, sensitivity to fields of the order of 1 V/m should not be a problem.

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Topics #8 and #9: Personal Exposure Characterization and Personal Exposure Modeling

Comment #1: Kent C. Jaffa

Calculated Historical Fields vs. Contemporary Spot Measurements

In the DOE Engineering Symposium, some presentations concluded that historical reconstruction of residential exposures is the best metric. In particular, Dana Loomis concluded that the Feychting and Ahlbom method is the “gold” standard as opposed to wire codes and measurements. Bill Kaune’s presentation on his analysis of the Swedish power line currents also supported this position. However, Kent Jaffa presented information which showed that these conclusions are suspect and that all findings relying on calculations or wire codes should be re-examined. Local EMF sources are ignored by these metrics and they appear to be more important to account for than historical power line changes at least in the Swedish study. If this is true for the Feychting and Ahlbom study, it may also be true for other studies using historical calculations or wire codes which neglect local sources.

Support for this premise is found by examining both the child and adult controls in the Feychting and Ahlbom study where these controls are divided into two time periods; 1960-1974 and 1975-1985. For calculated historical fields, there is little difference in the distribution of controls between these two time periods. If historical power line changes are important, than one would expect some difference with respect to time in the distribution of controls for calculated historical fields. On the other hand, there is a significant difference between the child controls for these two time periods for contemporary spot measurements. The earlier time period residences have significantly higher measured fields indicating that older homes in Sweden have higher local EMF sources. Thus, calculated historical fields appear to be the most flawed in earlier time periods contrary to previous viewpoints.

A direct comparison of the importance of local sources and historical power line changes can be made by an examination of the Swedish exposure observations. A comparison between contemporary spot measurements and calculations shows that 21.3% of the 1300 observations are classified differently with respect to the three primary exposure categories in the study. The misclassification difference between contemporary spot measurements and calculated historical fields is only 7% higher. On a smaller representative sample (660 observations) for which contemporary annual average calculated fields are available, the misclassification between contemporary and historical annual average calculated fields is only 15.6% which is less than the effect of contemporary local sources. Thus, contemporary local sources (21.3% misclassification) are more important than historical power line changes (15.6% misclassification).

In the Swedish study, it is reasonable to assume that the effect of historical local sources is in the same ballpark as contemporary local sources since the measurements were made under low power conditions with the power turned off to the residences. Under these conditions, local sources would include ground currents, other external sources not included in the calculations and calculation error. Thus, historical local sources appear to be more important to account for in the Feychting and Ahlbom study than historical power line changes.

In addition, historical calculations don't appear to be able to discriminate between residence type as there is little difference in the exposure distribution of apartments and single family homes. On the other hand, apartments have significantly higher measured fields than single family homes.

One other important factor is the accuracy of historical currents which were only known in 100 ampere increments. This is poor precision. The only requirement for spot calculations to accurately predict annual average calculations is that the spot current be in the same 100 ampere increment as the annual average current. Even if there is a difference in the current increment, current differences of 100 amperes wouldn't change the exposure category for some observations. Thus, the variability of spot currents isn't too problematic with this level of precision.

Kaune reported that historical current changes are important, however this is suspect as his findings are below the precision of the data. He reports a 3.8 ampere/year average load growth and a year-to-year variability of 55 amperes. Based on the average Swedish current of 300 amperes, this corresponds to a 1.3%/year load growth and a yearly variability of 18%. However, the precision of the data is 100 amperes or 33%. Thus, these findings are questionable because the reported findings are lower than the accuracy of the data.

In conclusion, an examination of the controls and observation data shows that contemporary local sources are as or more important to account for. These findings don't support the Loomis and Kaune presentations. Based on what is known, differences between groups and measurement practices can't account for this. In addition, these conclusions can't be explained away with non-differential misclassification arguments. Jaffa will be making a presentation on this at the next BEMS meeting and is planning on publishing his analysis. Jaffa believes that risk estimates based on wire codes and historical calculations can't be interpreted correctly without a better understanding of the role of local sources and power line changes in individual studies.

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Topic #13: Field-management Technologies

<u>Comment #1: Kirby C. Holte</u>

As so capably illustrated by EPRI and others, there are many engineering options available to reduce ground level magnetic fields produced by new or existing power lines and substations. In the case of new construction, many of these options can be implemented with no or very little additional cost to the project. In fact, electric utilities operating in California, have, since 1994, have achieved significant reductions in magnetic fields from new lines and stations while limiting added project costs to 4 percent or less.

Although much has been said and written about the 4 percent cost bench under the California program, other technical and personal safety issues tend to be far more important in evaluating field management options. These additional factors include, for example, structural integrity under maximum expected mechanical load; the ability to construct the line using standard utility tools and practices; the ability to safely maintain the line or substation; radio, audible, and television noise; induced currents and voltages; zero and negative sequence currents; etc.

Table 13-1 compares seven potential tower and conductor configurations utilizing the split phase technique to reduce ground level magnetic fields. The base case is a single circuit 220 kV line using horizontal construction. All seven split phase alternatives reduce the magnetic field by 52 to 87%. On the other hand, the two Cruciform design options have substantially increased zero and negative sequence currents which must be evaluated for their effect on the system. In addition, all of the alternatives have slightly increased radio, audible, and television noise which may be significant in areas with weak radio and TV signals.

Table 13-1: Engineering Evaluation – Magnetic Field Reduction for a 220 kV Transmission Line Using Split Phase Construction

220 kV Transmission Line Configuration	Phasing	Mag Field	Elec Field	Aud. Noise	Radio Noise	TVI	Zero Seq I	Neg. Seq I	Pos. Seq. Z
Base Case, Single Circuit Horiz.	abc	186	2.2	14.6	28.3	-6.4	0.8	2.4	33.8
SCE Double Circuit Lattice	abc-abc	89	1.5	18.9	32.6	-7.2	0.8	3.7	17.2
SCE Double Circuit Lattice	abc-cba	39	1.1	21.2	32.9	-3.0	0.8	1.0	15.3
SCE Double Circuit Compact	abc-abc	90	1.3	17.2	30.5	-9.0	0.8	4.1	17.5
SCE Double Circuit Compact	abc-cba	25	0.8	22.2	34.0	-1.4	0.8	0.1	14.7
EPRI Double Circuit Lattice	abc-cba	36	1.0	22.3	34.3	-2.1	0.3	1.4	14.9
EPRI Semi-Cruciform- mid span	Split	39	1.6	16.3	30.5	-5.6	3.0	3.6	18.2
EPRI Vertical Split Phase	Split	48	1.6	18.9	32.7	-4.4	3.1	5.6	19.9

In this example, the compact 220 kV double circuit design on tubular towers would appear to offer the lowest magnetic field and zero/negative sequence currents but the highest radio and audible noise. One might select this configuration in areas with good TV and radio coverage while selecting an alternative if the local signal strength is weak.

The California Public Utility Commission recognized that the selection of the "best" field management alternative required a thorough engineering analysis based on the specific conditions and each utility's operating and construction standards. As such, each utility was instructed to develop and publish an EMF Design Guide. These Design Guides provide the basis by which field management options are evaluated and ranked.

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Comments Keyed to Overall RAPID Objectives

<u>Comment #1: P. Sarma Maruvada</u>

The Symposium covered all EMF engineering aspects relevant to the ongoing risk assessment process related to the EMF-Health issue. The following comments address the four general categories of topics discussed at the Symposium.

1. *Technologies to measure and characterize magnetic fields*

- Existing techniques and instrumentation are quite adequate for measuring and characterizing all relevant aspects of power-frequency electric and magnetic fields.

- In the absence of any clear indication on which field parameter – or even a combination of parameters – is relevant to biological effects, a simple and relatively inexpensive approach should be recommended for field measurement and characterization. The resultant magnitude in the case of magnetic field and the magnitude of the unperturbed electric field appear to be the simplest and probably the most appropriate parameters to be recommended. Field parameters such as polarization or geomagnetic field components should be considered only for special laboratory studies.
- Analytical techniques are appropriate for characterizing the EMF of only simple configurations such as overhead transmission lines or underground cables. It is futile, for example, to attempt to calculate the magnetic fields in high-voltage substations or in a residential environment, because of the complexity and diversity of the configurations and equipment involved and the continuous variation of the magnitudes and phases of the currents. A statistical approach to characterizing EMF, based on detailed long-term measurements, is much more appropriate in such cases.
- Measurement protocols need to be simplified as much as possible to permit their widespread use in studies. It should be remembered that in some cases even a few spot measurements, made with a well-calibrated instrument, could provide a good characterization of the environment.
- Exposure systems used in recent in-vitro, in-vivo and human studies have been greatly improved, thanks in large part to the competent engineering contribution to these studies and to the comprehensive guidelines provided by organizations such as NIST. The important aspect of quality assurance is also being addressed right from the start in recent studies.

2. *Information on types and extent of human exposure in residential and occupational settings*

- Studies such as Rapid projects # 3 and # 6 have contributed valuable information on human exposures to EMF. Caution should be exercised, however, in extrapolating results, for example, from a 1000-person study to the entire population in the different regions of the U.S. In a recent Canadian study [1,2] of the magnetic field (MF) exposure of 200 persons in a residential environment, important differences were observed in the MF levels and exposures in two groups of houses (in two different municipalities), mainly due to differences in the water pipes used (plastic vs metallic).
- The statistical model developed in [2] can be a useful tool for evaluating population exposures (past and present) to MF in residential environments. The model takes into account the presence of any power transmission facilities in the vicinity and uses the information on the statistical distribution of currents, over any given period of time, in the transmission system. This tool is useful in estimating past exposures for epidemiological studies or in providing information required for public hearings on transmission projects.
- In recent epidemiological studies, appropriate instrumentation has been used to measure occupational exposures to MF and the data obtained has been used, along with other information, to predict past exposures, sometimes over periods of twenty to thirty years, for different job categories. The weak point of many of these studies, however, is the lack of other pertinent information and in some cases the methodology used. More engineering studies are needed therefore to improve the accuracy of prediction of past exposures, by

taking appropriate account of the past load variations as well as of any changes in technology or work practices which might have taken place over the years.

3. *Techniques to manage exposure/mitigate fields*

- It is appropriate to develop techniques for mitigating MF in buildings, mainly to eliminate possible interference to video display terminals. Existing technology has proven adequate for this purpose.
- However, the question of mitigation techniques for the purpose of reducing population exposure to fields is, at best, premature.
- Field management as a public policy issue needs to be examined carefully from different points of view: health effects, bio-ethics, engineering, economic, legal and public information. Such an examination has been carried out recently in Québec [3], which resulted in the adoption of a **prudent management** policy, based on continuing research, vigilance and public information.

4. *Dissemination of Information*

- Rapid project # 5 is very important for engineering studies all over the world. It is suggested, however, to encourage inclusion in this database of all EMF characterization studies carried out, not only in the U.S. but in other countries also.

References

[1] Maruvada, P.S., Turgeon, A., Goulet, D.L., Cardinal, C.U., “An Experimental Study of Residential Magnetic Fields in the Vicinity of Transmission lines” Paper No. PE-138-PWRD, 1998 IEEE/PES Winter Meeting, Tampa, Florida.

[2] Maruvada, P.S., Turgeon, A., Goulet, D.L., Cardinal, C.U., “A Statistical Model to Evaluate the Influence of Proximity to Transmission Lines on residential Magnetic Fields” Paper No. PE-136-PWRD, 1998 IEEE/PES Winter Meeting, Tampa, Florida.

[3] Cardinal, C., “Electric and Magnetic Field Effects: Reflections on How to Manage the Issue – A Utility’s Point of View” Presented at the Panel Session on “EMF Issue Management”, CIGRÉ Session, 1996.

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