A PROTOCOL FOR SPOT MEASUREMENTS OF RESIDENTIAL POWER FREQUENCY MAGNETIC FIELDS

A Report of the IEEE Magnetic Fields Task Force* of the AC Fields Working Group of the Corona and Field Effects Subcommittee of the Transmission and Distribution Committee

ABSTRACT

This paper describes a simple protocol for measuring power frequency magnetic fields in residences. The protocol should not be interpreted as an IEEE standard, but if followed, will provide a degree of procedural uniformity that currently does not exist. The measurement procedures are simple and not intended to characterize the temporal and spatial variability of magnetic field levels in residences. The protocol contains a structured component for measurements which are performed at specific locations, and an unstructured component for measurements which are performed at locations requested by the occupants. The protocol requires personnel performing the measurements to explain the metrology-related limitations associated with the measurement results. This paper also discusses terminology related to power frequency magnetic fields and their measurement, the meaning of measurement accuracy and variability within the context of residential magnetic field measurements, and examples of measurement approaches that characterize the variability of magnetic field levels.

Keywords: Accuracy, EMF, magnetic field, measurement protocol, power frequency, residential, spot measurements, terminology, variability.

1. INTRODUCTION

The recent interest in characterizing power frequency magnetic fields in homes has led to the development of a number of measurement protocols that differ in their objectives and corresponding complexity [1]. In addition, instrumentation with a range of capabilities is now commercially available [2-4], and measurements are being performed by people with different levels of expertise. Significantly different measurement results can be obtained using the different protocols and instrumentation. At the present time, there exists an IEEE standard for characterizing magnetic (and electric) fields near ac power lines [5], but as observed previously [2], this standard has a number of inadequacies if used alone for guidance during measurements of residential power frequency magnetic fields. These inadequacies occur, in part, because residential magnetic fields typically have unknown spatial distributions, can be as much as two orders of magnitude smaller than fields beneath power lines, and can contain large percentages of harmonics. Because of the above situation and the growing number of requests for residential magnetic field measurements, the AC Fields Working Group has prepared this paper as a "work-in-progress report" as part of an effort to establish uniform procedures for measurement of residential magnetic fields. Throughout this paper the term, magnetic field, will refer to the magnetic flux density which has the SI unit of tesla (1 tesla = 10^4 gauss). It is emphasized that the procedures described below do not represent an IEEE standard, and that the goals of the measurements are limited in scope. Specifically, this paper includes a description of a trial protocol for performing spot measurements of residential power frequency (and power frequency harmonic) magnetic fields. It is hoped that discussions of this paper will contribute to the eventual development of an IEEE standard. The protocol incorporates several features that are found in some of the references cited [1]. The goals of the protocol are to:

1. Provide for uniformity in measurement procedures by identifying specific measurement locations in and near residences,
2. Provide for an unstructured measurement component that addresses specific measurement-related questions raised by occupants of a residence,
3. Provide a prototype data sheet and plan view which should be filled out at the time of the measurements,
4. Identify the limitations associated with spot measurements.

The protocol is intended for use with hand-held survey meters consisting of a coil-type probe (single-axis or three-axis) and detector (signal processing circuit). The goals of the protocol can be expanded to include acquisition of information that is of a demographic nature (e.g., type of residence, reason for measurement request, etc.) by adding an appropriately designed questionnaire to the data sheet. The goals of the protocol do not provide for characterizing the polarization, spatial and temporal variations, or the harmonic content of the magnetic field. The characterization of wiring codes [6] also is not considered.

This paper also discusses some of the terminology associated with the instrumentation, measurement procedures, characteristics of the magnetic field, and the usefulness of a data base consisting of spot measurements. After this Introduction,

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the paper is organized into the following sections: Section 2 describes a spot measurement protocol using a "recipe" format and presents a sample data sheet for recording the data. Words that appear in **boldface type** are defined or discussed in Section 3. Section 4 discusses measurement uncertainty and variability within the context of residential magnetic field measurements, and suggests methods for better characterizing the range of magnetic field levels in a home. Concluding remarks are given in Section 5. It is assumed that the reader has an engineering or physics background and a basic understanding of the origin and characteristics of ac magnetic fields. Although it is recognized that the personnel performing the measurements may not have degrees in engineering or physics, these personnel should have received sufficient training in order to have a basic understanding of the origin and characteristics of ac magnetic fields. A number of booklets describing fields associated with power lines and appliances have been prepared for nontechnical audiences [7]. Providing occupants of residences with copies of one or more of these publications prior to a visit may aid in the exchange of information when measurements are performed.

2. MEASUREMENT PROTOCOL

A sample data sheet and residential plan view for recording **spot measurements** of the magnetic field are shown in Figure 1. Provision is made on the data sheet for indicating the address of the residence and important characteristics of the instrumentation that will be used, e.g., **frequency response**, **accuracy**, detector type (**true rms**, **average-sensing rms**, number of axes). When visiting a residence to perform measurements, the following procedures should be followed after initial contact with occupants of the residence:

- All lights and appliances should be left as found.
- A sketch, roughly to scale, of the rooms and outside perimeter of the house should be prepared as indicated in Figure 1. A separate plan view should be prepared for each level of the residence. Electric utility equipment in close proximity to the residence may be indicated on the plan view.
- The information called for at the top of the data sheet (i.e., date, time of measurements, temperature, meter model, etc.) should be recorded.
- All measurements should be performed at a height of about 1 m (39 inches or "waist high") above the floor (indoor measurements) or ground (outdoor measurements). In order to more clearly understand the measurement results, the occupants of the residence should be encouraged to observe the performance of the measurements.
- **Spot measurements** of the **maximum magnetic field** or **resultant magnetic field** should be performed in at least three rooms (e.g., bedroom, family room, kitchen) frequently used by the occupants. Measurements should be of the **ambient magnetic field** near the center of each room and away from appliances. The approximate location should be indicated on the plan view with a dot and a number, and the field value should be recorded on the data sheet with the corresponding number (Fig. 1). If fluctuations of the field reading occur during the measurements, an approximate average value over a 5 second interval may be recorded.

  Note: The **resultant magnetic field** is normally obtained directly with a field meter that employs a three-axis probe. However, a field meter with a single-axis probe can be used to measure the rms values of the three orthogonal spatial components in order to calculate the **resultant magnetic field** (see Section 3). To aid in this calculation, columns are provided on the data sheet for recording the rms values of the three orthogonal spatial field components. The z-component is normally in the vertical direction, and the x- and y-directions are arbitrarily chosen in the horizontal plane. Measurements of the resultant magnetic field with a single-axis probe may be expedited by using a platform and template to position the probe. This procedure can also reduce the measurement "jitter" for those field meters that are sensitive to motion of the probe in the earth's magnetic field and reduce operator error resulting from misalignment of the probe.

- Following the indoor measurements, **spot measurements** should be performed and recorded along the outside perimeter of the residence at roughly 3 m (10 feet) intervals beginning from a corner of the residence. A distance of about 1 m to 2 m (3 to 6 feet) should be maintained between the magnetic field probe and the outside wall of the building. It may be necessary to use more than one data sheet for the interior and exterior measurements. Outdoor perimeter measurements will in general not be possible for apartment dwellings.
- **Spot measurements** should be repeated in three rooms where occupants spend significant amounts of time, following the outdoor measurements. These repeat measurements provide limited information on the short-term stability of the field values (see Section 3).
- Upon completion of the above measurements, **spot measurements** should be performed and recorded at locations of interest to the occupants of the residence. The number of these measurements will be governed, in part, by the available time. If measurements are requested near power lines, procedures described in IEEE Std 644–1987 should be followed.
- Before leaving the residence, occupants should be informed that **spot measurements** represent a "snapshot" in time of the magnetic field level and do not provide information regarding its **temporal variation**. Similarly, it should be noted that **spot measurements** at the centers of the rooms provide very limited information on the **spatial variation** of the field (see Sections 3 and 4). Copies of the measurement results should be provided to the residents.

RESIDENT

Name ______________________

Address ______________________

City, State, Zip ______________________

Phone __________ Date __________

Time: Start __________ Stop __________

Outdoor Temperature (°F) __________

MAGNETIC FIELD METER DATA

Meter Model __________ S/N __________

Frequency Response __________

Detector (true rms, average rms,..) __________

Accuracy __________

Date of last calibration __________

Probe (Dia., No. axes) __________

Spot Measurement Data Recorded by __________

No.	B_{max}	x	y	z	Resultant	Location / Description
	B (μT_{rms} or mG_{rms})					
1					0.1 μT	Family Room
						Kitchen
						Bedroom
						Bedroom
						Bedroom

PLAN VIEW

Include outline of residence with rooms at each level and indicate measurement location with • and number.

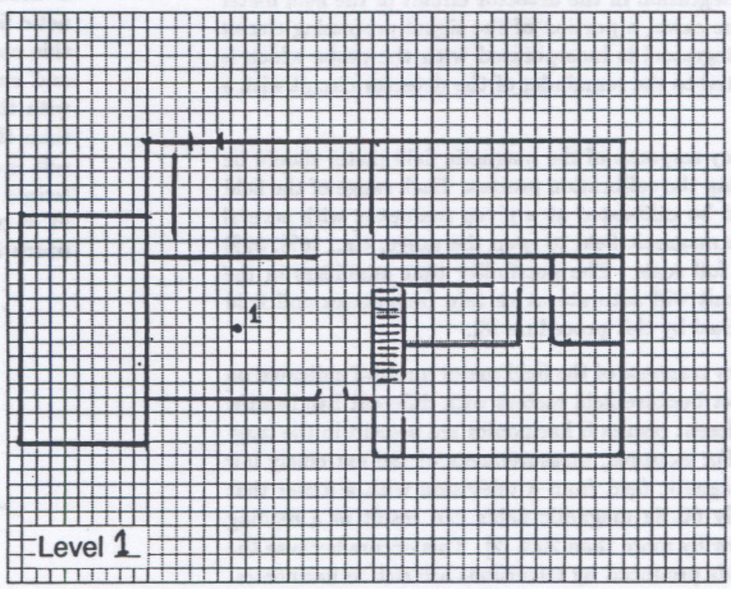

Figure 1. Data sheet with plan view.

3. TERMINOLOGY

In this section, the words that have appeared previously in bold face type are discussed in alphabetical order. The terms **maximum magnetic field** and **resultant magnetic field** are considered as part of a discussion of **magnetic field polarization.**

Accuracy: The accuracy of a field meter reading pertains to the amount of uncertainty in the measurement, which in turn is related to a calibration process. It should be noted that while calibrations of a field meter can be performed readily on its higher ranges [e.g., > 10μT (100 mG)] with a coil system [5], calibration of the more sensitive ranges [e.g., 0.2 μT (2 mG)] will normally be prevented by ambient fields of comparable magnitude in the laboratory. A voltage injection technique is one approach to overcoming this problem [8].

Ambient Magnetic Field: The ambient magnetic field at a point is the magnetic field at that point due to all sources near and far. **Spot measurements** of the ambient magnetic field are performed at the center of rooms to avoid significant contributions to the field from sources such as appliances. Magnetic fields from appliances decrease rapidly as a function of distance and typically are near background levels 1 or 2 meters from the appliance [9].

Average-Sensing RMS Detector (see also **True RMS Detector**): This refers to a detector circuit that rectifies the signal from the probe and is calibrated to give the correct rms value of a 60-Hz sinusoidal field. It should be noted that if there are harmonics in the magnetic field, a field meter with an average-sensing rms detector will not indicate the true rms value of the field. In this case, the magnitude of the error will depend in part on whether there is a stage of integration in the detector circuit. The error will also be a function of the phase relation between the harmonics and fundamental field components [4,10]. Indicating the type of field meter detector on the data sheet may help explain differences in measurement results.

Frequency Response (Bandwidth): Frequency response is defined as the change in response (reading) of the magnetic field meter to magnetic fields of constant amplitude but different frequencies. The range of frequencies over which the field meter response is constant to within 3 dB is often referred to as the bandwidth of the field meter. The constant response as a function of frequency is normally obtained by including a stage of integration in the detector circuit of the field meter [2,4]. In some cases, a portion of the signal processing circuit (e.g., the integrator) is incorporated with the probe which is then connected to the remainder of the detector circuit with a cable.

The frequency response of the magnetic field meter should be checked during the calibration process. Each range of the field meter should be calibrated at a given frequency with several values of the magnetic field to span the range, e.g., 10%, 50% and 90% of full scale. The possibility that amplifiers in the detector circuit will saturate at certain frequencies and field levels is checked by this procedure [8].

The frequency response of the field meter must be indicated on the data sheet because field meters with different bandwidths can yield different results if harmonics are present in the magnetic field. For example, measurements of the extremely low frequency magnetic field from a television with a meter that measures only 60-Hz magnetic fields can result in a reading that is too low by more than 20% [2]. This occurs because the magnetic fields produced by televisions are rich in harmonics.

Magnetic Field Polarization: Magnetic fields produced by three phase power lines are, in general, elliptically polarized [11]. This means that the magnetic field can be represented as a rotating vector that traces an ellipse for every cycle of the currents in the conductors, as shown schematically in Figure 2(a). The magnitude and direction of the semi-major axis, M, indicates the value and direction of the **maximum magnetic field**. Similarly, the magnitude and direction of the semi-minor axis, m, describes the minimum magnetic field. Because ambient magnetic fields in homes are typically produced by multiple current sources that are not necessarily in phase, elliptically polarized magnetic fields can occur in homes [12]. It should be noted that the present discussion regarding elliptical polarization assumes that the field has no harmonic content. The polarization state of fields which have significant harmonic content is more complicated [4].

Single-axis field meters may be used to measure the **maximum magnetic field** by orienting the probe until a maximum reading is indicated. Three-axis field meters measure the **resultant magnetic field** which is given by the expression

$$R = \sqrt{B_x^2 + B_y^2 + B_z^2}, \tag{1}$$

where B_x, B_y, and B_z are the rms values of the three orthogonal field components. It can be shown that the **resultant** is also equal to the rms value of the magnetic field magnitude [13]. The **maximum magnetic field** is less than or at most equal to the resultant magnetic field and the difference between the two quantities will depend on the degree of polarization. Two special cases of polarization indicate the extreme influences of polarization on the measurement results:

(i) When the semi-minor axis is zero, the magnetic field oscillates along a fixed direction as shown in Figure 2(b) and is said to be linearly polarized. For this case, the **maximum** and **resultant** field measurements will be equal.

(ii) When the semi-minor and semi-major axes are equal in magnitude, the magnetic field vector traces a circle as shown in Figure 2(c) and the magnetic field is said to be circularly polarized. For this case, the difference between the **maximum** and **resultant** field values will be the greatest, with the **resultant magnetic field** 41% greater than the **maximum magnetic field**. This result is readily seen by examining a circularly polarized magnetic field with unit magnitude, i.e., M = m = 1. The ratio of **resultant** to **maximum** is just $\sqrt{2}$.

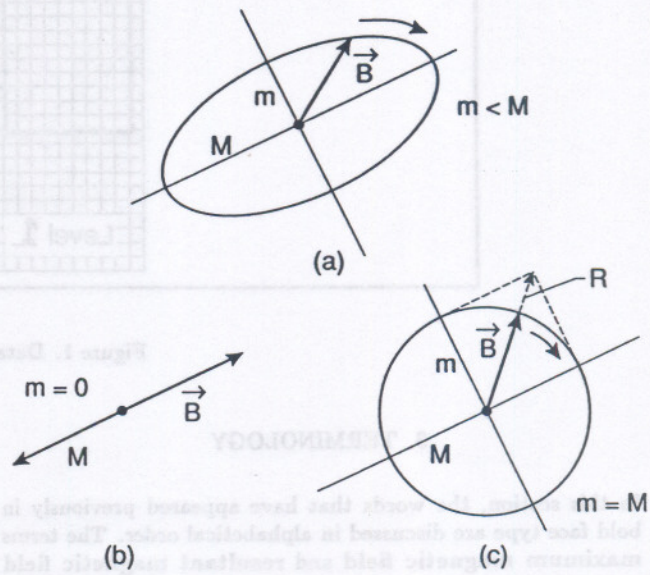

Figure 2. Degrees of polarization of power frequency magnetic field: (a) elliptical polarization m<M, (b) linear polarization m=0, (c) circular polarization m=M.

Two further observations are : (a) the **resultant magnetic field** can be determined with a single-axis probe by measuring the rms values of the three orthogonal field components and using Eq. (1); (b) comparison of **resultant** and **maximum magnetic fields** can provide information on the degree of polarization [12]. It is assumed that the magnetic field does not change significantly during the measurements.

Spatial Variation: Spatial variation refers to the change in magnetic field as a function of position. The spatial variation of residential magnetic fields typically is unknown because, unlike power line fields, the sources of the field are unknown. Spot measurements of the ambient magnetic field at the center of a room provide no information on the spatial variation and, unless there is a power line in close proximity to a residence, the magnetic field at the center of the room may or may not correlate well with field levels at other locations in the room. Figure 3 shows scatter plots of center-of-room measurements (vertical magnetic field, chest high) versus measurements at other points in living rooms and kitchens during a survey of 77 homes, as reported by Silva et al. [12]. While the homes were not randomly chosen and the field levels at different locations were not determined at the same instant, the data are indicative of possible spatial variations in the same room. Compared to living rooms (correlation coefficient = 0.789), the correlation between center-of-room measurements with measurements at other points is lower for kitchens (correlation coefficient = 0.642) in this limited survey. The larger dispersion in the kitchen scatter plot probably reflects the presence of appliances or other point sources in this type of room. Instrumentation and measurement techniques are available for characterizing spatial variations in rooms at approximately the same point-in-time [1(e)].

It should be noted that spatial variations near appliances are typically very large [9]. In addition, the variations are in general anisotropic. As a result, repeating or replicating measurements near appliances can be difficult [3] unless provision is made for positioning the probe at the same location very precisely.

Spot Measurement (Point-In-Time Measurement): A spot measurement, also referred to as a point-in-time measurement, is a measurement that is performed at some instant and does not provide information regarding the temporal or spatial variations of the magnetic field. Spot measurements of the magnetic field at the center of a room represent, as noted earlier, "snapshots" in time of the field levels and will depend on such things as load currents in nearby distribution lines, power consumption in the residence, number of service drops, and type of ground returns [12,13].

Temporal Variation: Temporal variation refers to the change in magnetic field level as a function of time at a particular location and represents one of the largest sources of variability for residential magnetic field measurements. Figure 4 shows 24 hour histories of the resultant magnetic field at the center of a living room on two days during which load currents varied significantly because of weather conditions. The data were obtained with a three-axis meter that recorded the true rms resultant magnetic field at a height of 1 m above the floor. The frequency bandwidth was adequate to characterize the fundamental and significant harmonic frequencies. Figure 4(a) shows measurements during a hot and humid July day in the metropolitan Washington area, when air conditioners were presumably in great use. The data were recorded every 15 seconds and the short term variations, which could last as long as several minutes, could not be attributed to any known sources in the residence. Field measurements at the same location during a cooler, less humid day in September [Figure 4(b)], reveal a significantly different range of values with an average field of about one-half as large as that during the July observations. It is noteworthy that a spot measurement performed near 11:30 a.m. during the cool September day [0.27 μT(2.7 mG)] would exceed nearly all daytime field levels observed on the hot July day and would be more than 10 times as large as many of the lower field values observed during the daytime hours of the

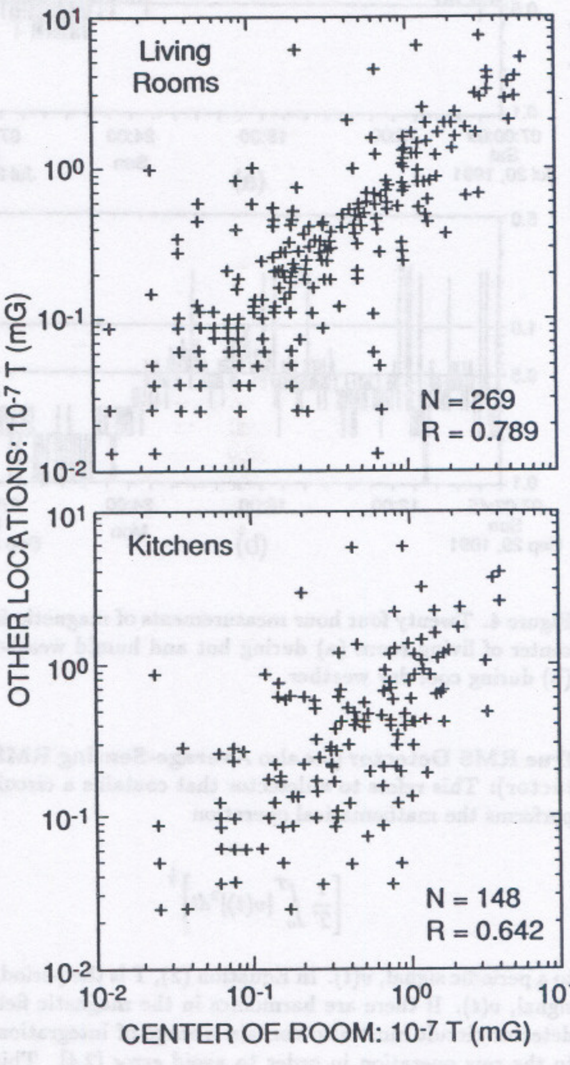

Figure 3. Scatter plots showing magnetic field at center of room versus other points in same room for living rooms and kitchens during survey of 77 homes [12]. Each datum point represents measurements at two locations in the same room. One measurement is performed at the center of the room (abscissa) and the other measurement is performed elsewhere (ordinate) with the location unspecified. There are 269 and 148 such pairs of measurements for living rooms and kitchens, respectively. The correlation coefficients are 0.789 and 0.642 for living rooms and kitchens, respectively. All of the data points would lie on the same diagonal line for a correlation coefficient of 1.

same day. Because the data in Figure 4 represent only two isolated 24 hour histories in one residence, the results should be regarded as anecdotal and not representative of houses in general. The data do exhibit a diurnal cycle as has been observed previously [12], with the lowest values generally occurring during the late night and early morning hours.

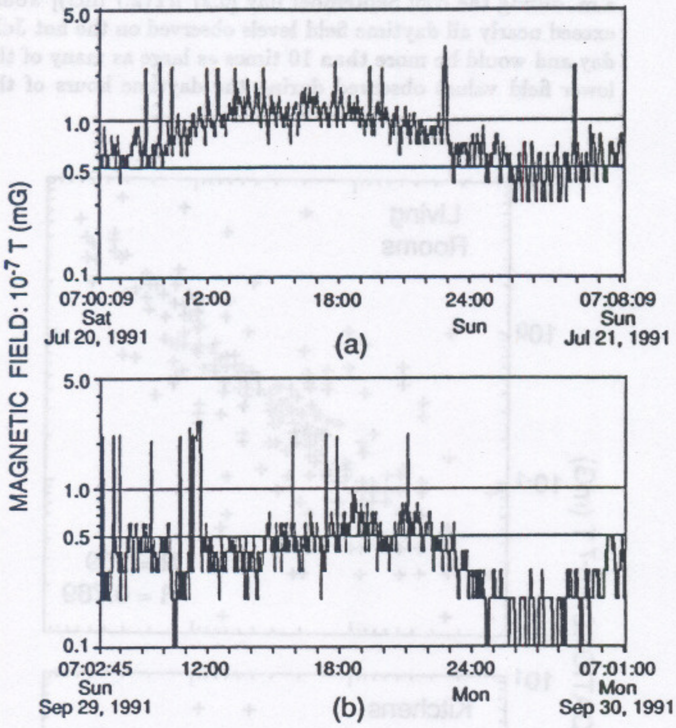

Figure 4. Twenty four hour measurements of magnetic field at center of living room (a) during hot and humid weather and (b) during cool dry weather.

True RMS Detector (see also **Average-Sensing RMS Detector**): This refers to a detector that contains a circuit that performs the mathematical operation

$$\left[\frac{1}{T}\int_o^T [v(t)]^2 dt\right]^{\frac{1}{2}} \quad (2)$$

to a periodic signal, $v(t)$. In Equation (2), T is the period of the signal, $v(t)$. If there are harmonics in the magnetic field, the detector circuit must also contain a stage of integration prior to the rms operation in order to avoid error [2,4]. This type of detector gives the rms value of a magnetic field containing harmonics provided that the frequency response of the detector is flat over the frequency range of interest. A true rms detector and an average-sensing rms detector will indicate the same value for a sinusoidal 60-Hz magnetic field.

4. MEASUREMENT ACCURACY AND VARIABILITY

As implied during the discussion of terms in Section 3, there can be many causes for uncertainty when characterizing residential magnetic fields with spot measurements and the protocol described in Section 2. The uncertainties can be grouped into two categories: (1) those associated with calibration and instrument design and (2) those associated with temporal and spatial variations [14]. The uncertainties in the first category are normally associated with measurement accuracy and can be reduced to small values (e.g., < 5%) by careful instrument design and calibration procedures. Reference [4] provides a detailed discussion of how different instrument designs (e.g., detectors with true rms, average rms, integrating, and nonintegrating circuit components) influence the measurement outcome. There is less control over the second category of uncertainty because residential magnetic fields have unknown spatial and temporal variations. The second category of uncertainty may be better referred to as measurement variability, distinct from measurement accuracy. Thus, while a spot measurement at some location may be performed with good accuracy, it will not be possible to specify with confidence what the variability will be without additional measurements. An examination of Figures 3–5 makes it abundantly clear that the uncertainties associated with temporal and spatial variations usually exceed by far the uncertainties associated with the calibration process and instrument design. It is for this reason that the last step of the protocol requires personnel performing the measurements to inform residents of the limitations associated with spot measurements.

Caution should be exercised in the use of any data base developed using the simple protocol described in this paper because the spatial and temporal variabilities associated with the measurements are not known. In addition, if the data are obtained primarily as a response to requests from occupants of residences, the sampling will not be random and the collected data will be subject to bias.

As magnetic field data obtained with more comprehensive measurement protocols during a national survey become available [1(b), 1(d)], it will be possible to develop a data base with statistical descriptions of such things as field levels (with national mean and median values), levels of harmonics, spatial and temporal variations, and degrees of polarization. References [12] and [13] represent early efforts to gather data of this type.

To describe magnetic field levels in an individual residence more fully, it will be necessary to use more sophisticated instrumentation, because of the possibly large spatial and temporal variations. For example, to better characterize the temporal variation of the magnetic field at a fixed location, measure-

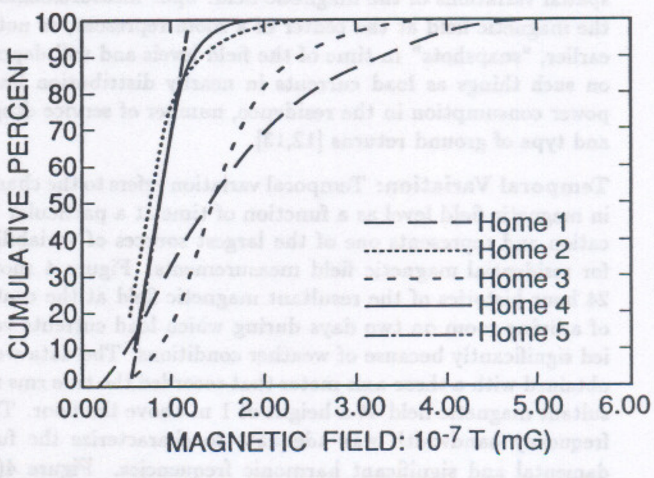

Figure 5. Cumulative frequency distributions of magnetic field at fixed points in five homes from reference [12]. The recording period for each house was twenty four hours.

ments of the resultant magnetic field can be recorded at regular time intervals for an extended period and the data can be displayed as shown in Figure 4. Another option, which is more statistical in nature, is to display data as a cumulative frequency distribution as shown in Figure 5. Figure 5 shows data recorded every five seconds for 24 hours in five homes [12]. The curves in Figure 5 express the percent of time (Cumulative Percent) that the resultant magnetic field is below a given level, e.g., for the measurement location in Home 1, the field is less than 2 mG 70% of the time. These results are valid for the 24 hour recording period, but may not reflect field levels at the same location on another day (e.g., Fig. 4). While a spot measurement in Home 2 on the same day may approximately reflect field levels because of the narrow range of field values, a spot measurement would not be a good indicator of field levels in Home 1 because of the broader range of field values.

A statistical approach to better characterize an electrical parameter with large temporal variations is not unique to residential magnetic fields. For example, because of the large variability of electrical parameters near high voltage dc transmission lines, due in large part to climatic conditions, it is necessary to record their values over periods of days, weeks and seasons to obtain realistic measures of their averages, medians, and ranges [15].

5. CONCLUSIONS

A measurement protocol has been described which provides for spot measurements of the maximum or the resultant power frequency magnetic field at specific locations in residences. The protocol is flexible in that it also allows for spot measurements to be performed at locations of interest to occupants of the residence.

The failure of spot measurements to provide information related to temporal and spatial variations of magnetic field levels was noted. The protocol requires that personnel performing the measurements inform the occupants of these limitations.

This paper also discussed terminology that is used to describe residential power frequency magnetic fields and terminology that describes the different operational modes of magnetic field meters. When, for example, the **magnetic field polarization** is elliptically or circularly polarized, the **resultant magnetic field** will always be greater than the **maximum magnetic field**. If magnetic field meters with different **frequency responses** are used to measure a field with significant harmonic content, different measurements results can be obtained.

The distinction was made between measurement accuracy and measurement variability. While accurate spot measurements can be made with simple survey meters, more complicated instrumentation and procedures are required for characterizing variability. Limits on temporal and spatial variations cannot be estimated from a relatively few spot measurements.

The scientific usefulness of a data base developed from the simple protocol described in this paper must be viewed with caution due to the highly variable temporal and spatial nature of the field. More extensive measurements involving additional locations in the residence and over longer periods of time can be made to better characterize the variability of the field. Information obtained that is of a demographic nature, e.g., reason for measurement request, may be of value to utilities for formulating policy.

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Discussion

K. B. Maracas (Salt River Project, Phoenix, Arizona): The Magnetic Fields Task Force of the IEEE AC Fields Working Group has made an important contribution to the myriad measurement practitioners who have sought some sort of procedural uniformity in conducting magnetic field surveys. As stated, the objectives of this protocol include the provision of a consistent measurement format and a discussion of the limitations associated with spot measurements. The protocol clearly meets those objectives.

In addition to these needs, electric utilities face unique challenges in attempting to provide spot measurements upon customer request. Many utilities are unable to dispatch technical staff members to conduct such measurements and consequently cannot appropriately discuss the metrology-related limitations of the results, or limitations related to the spatial and temporal variability of the fields themselves. Smaller utilities find it difficult to devote adequate resources to the development of expertise in these areas, and larger utilities are challenged with responding to the large volume of measurement requests they receive. From an industry perspective, the objectives of a protocol for measuring residential power frequency magnetic fields are consistent with, but perhaps broader than the IEEE protocol.

The intent of this discussion is to provide visibility to a national effort that is underway to develop a protocol that addresses the unique challenges that electric utilities face. The effort is administrated by the National EMF Measurement Protocol Group (NEMPG), an organization made up of representatives from several utilities and the three utility trade organizations: American Public Power Association (APPA), the Edison Electric Institute (EEI), and the National Rural Electric Cooperative Association (NRECA). NEMPG has also invited the input and participation of a broad array of interindustry and government advisors which includes representatives from the Electric Power Research Institute (EPRI), the National Institute of Standards & Technology (NIST), Electric Research & Management (ERM), the Environmental Protection Agency (EPA), the National Electrical Manufacturers Association (NEMA), and the IEEE AC Fields Working Group.

While the national industry protocol is being developed in close cooperation with the IEEE, its objectives are slightly different:

1. To be responsive to the needs of the utility consumer,
2. To provide a consistent measurement format so that useful scientific and demographic information can be extracted from its results, and
3. To provide a framework that is consistent with the needs and interests of regulatory officials.

It should be noted that the second objective is not intended to advocate that the measurement values themselves be analyzed or interpreted, but rather to find utility in the fact that collectively, electric utilities across the country are making tens of thousands of measurements per year. Providing a uniform framework for the measurement procedure enables utilities to track demographic trends and allows regulatory officials to oversee utility measurement programs consistently across the nation. However, recognizing the limitations imposed by the measurements themselves, the variability of the fields, and the fact that the data sources are not random samples, the development of "pooled" databases from resulting measurements is discouraged. In fact, strict caution is advised in interpretation of both the quantitative and demographic data.

For information about the national effort or NEMPG, contact Kate Maracas at (602) 236-2045.

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M. MISAKIAN, R.G. OLSEN, V.L. CHARTIER and T.J. MCDERMOTT (on behalf of the AC Fields Task Force): We thank K. Maracas for her comments and look forward to the eventual publication of the protocol being prepared by the National EMF Measurement Protocol Group (NEMPG). The objectives of the AC Fields Working Group and Magnetic Fields Task Force are very similar to the ones described by Ms. Maracas. For example, a major goal of the measurement protocol described in this paper is that it be useful to the utility industry, as well as commercial firms engaged in providing measurement services. The utility industry perspective was considered important in the development of the protocol and representatives of a number of utilities (e.g., Pacific Gas and Electric, Wisconsin Electric Power Company, Southern California Edison, New York Power Authority, and the Bonneville Power Administration) contributed to and reviewed the manuscript during its preparation. Indeed, many of the organizations mentioned by Ms. Maracas are represented in the Task Force and AC Fields Working Group.

K. Maracas makes the useful point that some utilities, because of their size, may not have the resources to provide technical staff with adequate technical expertise to conduct the residential measurements. How this problem will be dealt with in the NEMPG protocol is not known at this time because it is still in preparation. In our Introduction section, we urge that all personnel receive some training so they have a basic understanding of the origin and properties of ac magnetic fields. We believe that this approach has the greatest merit because, while some small utilities may benefit in the short term from a cost perspective by using untrained personnel, it may be more costly in the long term to undo misunderstandings that are created by metrology-related misinterpretations of the measurement results.

We would also comment that if the intent of the NEMPG is to develop a measurement standard, that it be done through a recognized standards writing organization such as the IEEE. The IEEE has functioned well in providing the utility industry, regulatory bodies, and commercial interests with guidance in the form of standards and recommended practices. We expect the issues regarding the proper measurement of magnetic fields in different environments to yield to this process as well. We invite any members of NEMPG who are not currently participating in the IEEE to join the AC Fields Working Group or one of the other IEEE groups actively involved in power frequency magnetic field issues.

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