Abstract for EMF RAPID Program Engineering Project #2: Recommendations for Guidelines for Environment-specific Magnetic-field Measurements

The purpose of this project was to document widely applicable methods for characterizing the magnetic fields in a given environment, recognizing the many sources co-existing within that space. The guidelines are designed to allow the reader to follow an efficient process to

(1) plan the goals and requirements of a magnetic-field study,
(2) develop a study structure and protocol, and
(3) document and carry out the plan.

The guidelines take the reader first through the process of developing a basic study strategy, then through planning and performing the data collection. Last, the critical factors of data management, analysis reporting, and quality assurance are discussed. The guidelines are structured to allow the researcher to develop a protocol that responds to specific site and project needs. The guidelines aim to help the user design a measurement protocol that will gather the most exposure-relevant information based on locations of people in relation to sources.

The report details the defining and documenting of a projected measurement protocol. Steps include determining and documenting study purpose; determining the environment classification and project resources; reviewing physical characteristics of the environment; selecting field parameters for measurement, selecting instrumentation; and developing a measurement strategy and data collection structure.

Once those parameters of the study are in place, more concrete steps are referenced, including gathering magnetic and non-magnetic data, gathering activity-pattern data, and so on. Of particular importance is the documenting of each step/piece of information, and ensuring quality in the data and findings.

Study Limitations

The pilot studies testing the guidelines were limited to measurements of three stand-alone environments. A test of the guidelines in a broader data-collection program would have been helpful, particularly with reference to systematically gathering and using activity-pattern data to develop the study plan.

The study took longer than expected to complete: by the time the study was completed, other researchers had published studies that used new measurement methods that were not considered in developing these guidelines.

The pilot studies were completed when the guidelines were in rough draft form, by researchers very close to the project. No third party tested the completed guidelines.

Areas for Future Research

Can the Environmental Classification Table, developed as part of this study, be successfully put into use to allow codification and stratification of environments studied, and to be helpful for meta-analysis and other data review?

If these guidelines were used by two investigators with identical study goals to plan and perform a measurement, how consistent would the measurement plan and resulting data be? What changes or adjustments could be made to the guidelines to ensure consistent data?

Source characterization is typically a subset of an environment-specific Measurement. Can the source characterization guidelines developed in RAPID Engineering Project #1 be implemented cohesively as part of these (RAPID Engineering Project #2) guidelines?

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Purpose and Focus

The purpose of this project was to document widely applicable methods for characterizing the magnetic fields in a given environment, recognizing the many sources co-existing within that space. The guidelines are designed to allow the reader to follow an efficient process to

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Because the RAPID program is based on exposure to magnetic fields and the potential health effects, the most important focus for these magnetic-field measurement guidelines is **relevance to exposure**. The assumed objective of an environment-specific measurement is to characterize the environment (given a set of occupants and magnetic-field sources) so that information about the exposure of the occupants may be inferred.

Ideally, the researcher seeks to obtain complete or "perfect" information about these magnetic fields, so that personal exposure might also be modeled perfectly. However, complete data collection is not feasible. In fact, it has been made more difficult as the research field has moved to expand the list of field parameters measured, increasing the cost and complexity of performing a measurement and analyzing the data.

The guidelines address this issue by guiding the user to design **a measurement protocol that will gather the most exposure-relevant information based on the locations of people in relation to the sources.** It is recommended that the "microenvironment" become the base unit of area in a study, with boundaries defined by the occupant's activity patterns and the field variation from the sources affecting the area. Such a stratification allows the researcher to determine which microenvironments are of most interest, and to focus the measurements methodically in those areas, in order to gather the most relevant set of data.

Tasks: Goals and Strategies

Developing the Basic Study Strategy

In developing a responsive protocol for performing magnetic-field measurements in a given environment, the first step is to design the research strategy to best characterize the exposures. This step will help to limit and optimize the measurement tasks. The strategy development must take into account the study purpose, the project resources, the physical characteristics of the environment, the field parameters desired for measurement, and the instrumentation to be used in the study. The guidelines describe the study strategy development in seven steps, summarized below.

Determine and document the study purpose. The investigators should develop a statement of purpose that can be understood by both themselves and the study sponsor or client. That statement should answer the following five questions:

(1) What is the goal of the study?
(2) Who is the audience?
(3) What circumstances initiated the study?
(4) What is the desired output of the study?
(5) How will the final data be used?

Documenting the study purpose will provide a basis for actions and help ensure that each task is optimized to provide the desired product.

Determine the environment classification. The guidelines present a method for classifying the environment type, based on Standard Industrial Classification code numbers for establishments. Such classification will encourage focus on the environment's properties, stratification within databases, and comparisons with similarly classified environments previously studied.

Determine the project resources. The scope of studies will almost always be limited by project resources. The financial resources, staff availability, instrumentation availability, and any time constraints should be assessed early in the planning process.

Review the physical characteristics of the environment. Preliminary information on the environment's characteristics and sources will highlight important features that should be considered in the measurement plan. These include features that may indicate what field parameters might be of interest, as well as the scope of measurements that might be necessary, based on the size and complexity of the environment.

Select field parameters for measurement. The dose metrics of magnetic-field exposure have not been defined. Therefore, depending on the needs of the study, the investigator will want to consider obtaining information on multiple parameters. The guidelines discuss parameters that may be selected for measurement, but leave choices open to the investigator, based on the study purpose, site characteristics, and practicality of measurement. The guidelines acknowledge that performing rms magnetic flux density measurements will continue to be a focus of environment-specific

measurements because this measurement is easy to perform, is readily understood by the research community and general public, and has been the focus of most previous studies.

Select instrumentation. The investigators should select instrumentation based on measurement and memory capabilities suited to the study goals, as well as on efficiency, reliability, convenience, and price. However, availability is usually the most prevalent factor. The guidelines discuss single-axis and three-axis rms meters and commercially available waveform capture systems, and the nature and potential functions of each class of instrument.

Develop a measurement strategy and data collection structure. Outlining a plan for data collection is the next step. The measurement strategy, a part of this plan, is the decision-making process by which it is ultimately determined where, when, and how magnetic-field data will be collected. The guidelines stress designing the measurements to gather only the most exposure-relevant information. They describe the use of the microenvironment to determine what information is most relevant.

The standard structure for performing magnetic-field characterization is suggested in a four-step process.

(1) Gather the basic information about sources, people, and other site information.

(2) Identify microenvironments.

(3) Weight the efforts to be spent in each microenvironment.

(4) Perform focused magnetic-field data collection.

The guidelines provide examples of data-collection structures, and the possible tasks that may be involved. Table 1, next page, shows examples of data-collection plans.

Table 1: Examples of Data-collection Plans Developed for Two Environment-specific Magnetic-field Studies

	Home Survey by Utility	**Characterization of an Industrial Facility**	**Outline for Your Study**
Source Identification	Make a quick walk-through of the house and yard to identify location of power facilities and typical sources. Question homeowner about specific sources, and any source of special interest to him/her.	Send pre-visit facility questionnaires, for informant to identify sources. Observe and document on pre-supplied maps during initial walk-through. Perform investigative measurements using hand-held meter or mapping wheel.	
Activity-pattern Data Collection	Assume that this home is like most others: e.g., occupants sleep in the bedrooms, occupy the living area frequently, use appliances most frequently in the kitchen, etc. Clarify any assumptions w/homeowner as necessary.	Use questionnaires to informants or observation using pre-designed forms and maps.	
Non-magnetic-field Data	Observe, or question homeowner about age of home, type of wiring, or other info.	Use questionnaires to informants, observation using pre-designed forms, or outside data from maps, drawings, and utility engineers.	
Micro-Environment Identification	Review notes about sources and uses to informally determine most exposure-relevant measurement points.	Compile and review information from activity-pattern maps and source identification maps. Develop sketches of the microenvironments. Confirm with notes and questionnaire responses.	
Selection of Points for Measurement	Per utility standard protocol, select center of rooms and corners of house. Choose other locations based on microenvironments of most interest, and as requested by homeowner.	Use a decision matrix identifying the occupancy and field types of each microenvironment in order to determine appropriate weighting	
Magnetic-field Data Collection	Use a hand-held rms meter to perform spot measurements at the selected locations.	Perform spot measurements using a waveform capture system at a sample rate appropriate to identify ultra-low frequency information. Station a meter to gather temporal data near a dominant source identified to fluctuate in time.	

Performing the Data Collection

The researcher next focuses on the specific steps of performing the data collection and determining the appropriate data to consider collecting. **Magnetic-field characteristics cannot be properly described by a single measurement or series of measurements.** Many factors, including the physical parameters of the environment; the location and operation of sources; the activity patterns of the occupants; and the spatial, temporal, frequency, and other parameters of the magnetic fields together paint a picture that characterizes magnetic-field exposure.

Develop the data-collection protocol. Before beginning data collection, the researcher must produce a written data-collection protocol. The protocol helps to ensure that relevant information is collected; that magnetic-field measurements are completed most completely, efficiently, and systematically; and that disruption to the environment is minimized. The guidelines provide examples of protocol formats, each organized in a chronological sequence. Objective, easy-to-use data-collection forms are the most reliable means to obtain and confirm a complete data set from the field. Their development is a part of generating the data-collection protocol. Examples of several forms have been included in the guidelines.

Carry out the data collection. The guidelines describe the specifics of data collection.

Identify magnetic-field sources. The guidelines describe methods of source identification, including visual inspection, gathering source information from an informant, performing exploratory measurements, performing field mapping, or using such tools as a clamp-on ammeter to identify sources of net current. The guidelines further detail methods for documenting the source locations, and defining the source characteristics such as source type, level of magnetic-field magnitude, and temporal characteristics.

Gather activity-pattern data. It is assumed that the goal of activity-pattern data collection is to provide the minimal data set of information required to properly include exposure-relevancy in the magnetic-field measurement study design. The guidelines describe methods of data collection (including interviews, questionnaires, and observation techniques) and outline the ways to choose the appropriate technique based on the study parameters. Recommendations are also given as to whether a site informant or the site's occupants are most appropriate providers of activity-pattern data. The guidelines furnish tips for constructing activity-pattern questions, as well as examples of data-collection tools, such as questionnaires and interview protocols.

Gather non-magnetic-field data. Other information about the environment and its sources may provide additional insight into the characteristics of magnetic-field exposure, painting a more complete picture of the environment's magnetic-field characteristics. The guidelines describe possible appropriate information, such as: site characteristics (i.e., building age); additional source information (i.e., sizes of motors); utility information (i.e., circuit loads); and occupant information (i.e., job descriptions and ages).

Plan and perform focused magnetic-field data collection. The three tasks described above provide the information required to plan further, more focused magnetic-field measurements. A magnetic-field measurement plan will aim to finalize the locations of measurements, timing of measurements,

measurement sampling rates, and the inclusion of temporal measurements. The guidelines direct the reader through the necessary steps:

(1) identifying microenvironments and weighting them for assessment,
(2) determining the number of measurements to perform and the locations of the measurements,
(3) determining the timing factors of measurements, and
(4) planning and performing temporal and other special measurements.

It is assumed that these data will comprise the substance of the report on magnetic-field data.

Managing, Analyzing, and Reporting Data

The report provides guidance for managing, compiling, analyzing, and reporting the collected data to the study audience. Data-management methods are described, including the following:

(1) protocols for documenting the measurement data,
(2) conventions for naming or labeling all data,
(3) structures for organizing the data for analysis, and
(4) plans for maintaining the integrity of the data.

Options for methods and tools for data analysis are discussed. The researcher should bear in mind that the choices of methods must be based on the questions the study has been designed to answer, and upon the study resources and parameters.

The project report should be a compilation of all effort expended in the study, presented in a format tailored to convey the information to the appropriate audience. The guidelines describe sample content for each report section. Three pilot study reports are included as examples of a report format.

Quality Assurance Methods

A quality assurance plan seeks to ensure that the data collected and reported are valid and consistent. The plan should be developed during the study planning process. Quality assurance steps can and should be specified for each phase of the study. The guidelines address nine steps for the investigator to follow in assuring quality.

(1) Minimize subjectivity throughout the project.
(2) Develop forms and checklists to assure completeness and consistency.
(3) Ensure that technicians have the appropriate expertise to perform data collection.
(4) Ensure the accuracy of the study instrumentation.
(5) Collect duplicate information.
(6) Clearly identify all information.
(7) Inspect and analyze data in a timely manner.

(8) Back-up everything.

(9) Perform pilot studies.

Summary

The guidelines provide flexible, widely applicable methods for performing exposure- relevant magnetic-field measurements. They may be used to produce a targeted, efficient, and useful study that collects, analyzes, and reports the data appropriate for the goals of the study.