Abstract for EMF RAPID Program Engineering Project #3: Environmental Field Surveys

Project #3 sought to obtain information on the levels and characteristics of different environments for which only limited data were available. These data could then be compared with magnetic-field data for the residential environment and for electric utility facilities, such as power lines and substations. It also investigated the contribution of various field sources in the surveyed environments. The report includes a review of other EMF surveys, including an evaluation of methods, protocols, and source identification and characterization.

The environmental field surveys used a protocol based on magnetic-field measurements and observation of activity patterns to estimate magnetic-field exposure by type of people and by type of sources. The data produced will form a part of the EMF measurement database.

Magnetic-field surveys were performed at four sites for each of five environments: schools, hospitals, office buildings, machine shops, and grocery stores. Field and exposure data were obtained separately for area fields and exposure points close to sources. Differences between average fields obtained at different sites in the same environment were significant in comparison to differences between environments. The relative contribution of each area source to area exposure was calculated. Main contributors to area fields were net currents (in schools, grocery stores, and hospitals), office equipment (in office buildings), and milling and welding equipment (machine shops). Analysis of exposure by person type found that welders had the highest exposure, followed by butchers and clerks/cashiers in grocery stores. Power lines were, generally, a minor source of magnetic-field exposure. A significant percentage of exposure, however, was caused by sources that could not be identified. Other findings include the following: that the third and fifth harmonics are the dominant ones in school environments; that spatial variability in field is much more important than the temporal variability in determining exposure; and, that transient fields greater than 0.3 mG were infrequent in the measured hospitals and schools.

Study limitations

Measurements were limited to only four sites of each type and to two geographical regions.

Areas for future research

Expand the measurements to additional environments and increase the number of sites in environments.

Compare personal exposure measurements at a site with estimated exposures based on the model.

EMF RAPID Program Engineering Project #3:
Environmental Field Surveys

Purpose and Focus

The purpose of this project was to obtain information on the levels and characteristics of different environments for which only limited data were available, especially for comparison with magnetic-field data for the residential environment and for electric utility facilities, such as power lines and substations. The project was also to provide information on the contribution of various field sources in the surveyed environments. The report includes a review of other EMF surveys, including an evaluation of methods, protocols, and source identification and characterization.

Tasks: Goals and Methods

There are many sources of magnetic fields in the environment. Most commonly discussed and studied are those from utilities' electric power lines (transmission and distribution) and facilities. However, there are numerous other sources present in the environment. Important questions remain concerning which occupational and public groups are exposed to magnetic fields and at what level these exposures might be occurring.

These environmental field surveys used a protocol based on magnetic-field measurements and observation of activity patterns. They were designed to provide estimates of magnetic-field exposure by type of people and by type of sources. The large amount of data produced will form a part of the EMF Measurement Database.

Magnetic-field surveys were performed at four sites for each of five environments:

- schools,
- hospitals,
- office buildings,
- machine shops, and
- grocery stores.

Of the 20 sites surveyed, 12 were located in the San Francisco Bay Area and 8 in Massachusetts.

Field and exposure data were obtained separately for areas and exposure points near sources. A site is composed of many areas where fields are measured. The area field is produced by "area sources" whose location and field distribution is in general not related to the location of the people in the area. An exposure point is a location where persons engage in fixed, site-specific activities near a local source that creates a significant increase in the area field (e.g., sitting in front of a desktop computer or standing at a lathe in a machine shop). Analyses were performed for area fields, exposure point fields, and combined area and point source fields.

The distribution of areas fields at a site was constructed using three different techniques: by weighting the fields from each area (1) equally, (2) by surface area, and (3) by exposure (i.e., by the

time spent in the area in person-minutes). The choice of weighting method did not significantly affect the overall distribution of area fields at a site. Differences between weighting methods were less significant than observed differences between sites and between environments.

Area Fields Weighted by Exposure

The averages of area fields across sites in an environment were found to range from high to low, as follows, for the different environments:

Environment	Average for the Four Sites
Grocery stores	1.93 mG
Machine shops	1.42 mG
Hospitals	1.27 mG
Schools	0.83 mG
Office buildings	0.72 mG.

The same ranking of environments was observed for the averages of the top 5th percentiles of the area fields across sites:

Environment	Average for the Four Sites
Grocery stores	7.5 mG
Machine shops	4.2 mG
Hospitals	3.7 mG
Schools	2.8 mG
Office buildings	2.5 mG.

Differences between area fields at different sites in an environment were significant in comparison to differences between environments. For example, the highest mean area field in an office building (i.e., in the environment with the lowest overall area field) was greater than the lowest mean area field in a grocery store (i.e., in the environment with the highest overall area field).

The relative contribution of each area source to area exposure was calculated. Main contributors to area fields were as follows:

- **net currents** in schools, grocery stores, and hospitals,
- **office equipment** in office buildings, and
- **milling and welding equipment** in machine shops.

Important contributors were as follows:

- **fluorescent lights** in grocery stores, office buildings, and hospitals, and
- **electrical panels** in machine shops.

Power lines were, generally, a minor source of magnetic-field exposure. A significant percentage of exposure, however, was caused by sources that could not be identified. Table A-6 shows the relative contributions of area sources in magnetic-field exposure.

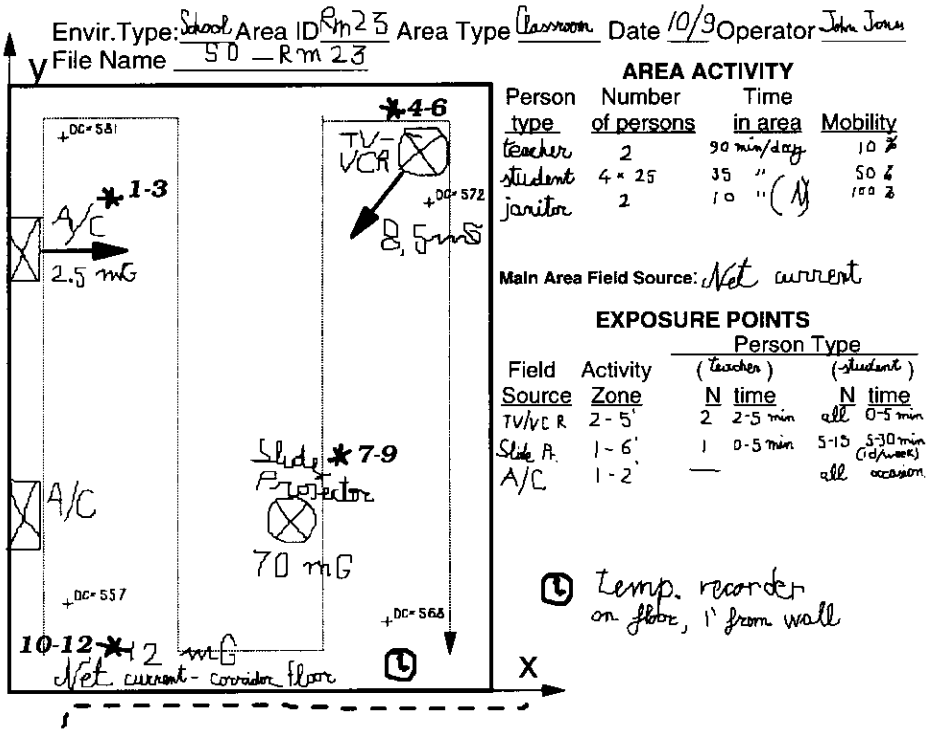
Table A-6: Relative Contribution of Area Sources to Magnetic-field Exposure

Area Source (Description)	Schools (%)	Grocery Stores (%)	Office Buildings (%)	Hospitals (%)	Machine Shops (%)
Power Lines	1.8	18.0	6.1	0.0	0.0
Power Supply Cables	2.1	0.0	2.6	2.9	0.0
Electrical panels	2.4	2.5	3.0	9.4	21.6
Net Currents	53.9	38.8	2.9	20.6	6.6
Air Conditioners	0.8	0.0	0.0	0.5	0.0
Fluorescent Lights	0.1	27.2	19.4	13.5	11.0
Transformers	0.0	0.0	0.0	0.9	21.9
Office Equipment, Appliances	14.6	0.6	33.8	13.1	8.2
Unknown	24.4	6.1	31.1	29.5	3.2
Laboratory Equipment	0.0	0.0	0.0	9.6	0.0
Vending Machines	0.0	0.0	1.1	0.1	0.0
Merchandising Equipment	0.0	6.8	0.0	0.0	0.0
Milling and Welding Equipment	0.0	0.0	0.0	0.0	27.4
	100.0	100.0	100.0	100.0	100.0

Exposure Points

Exposure at exposure points was characterized by defining a zone of activity (range of distances from a source) and an exposure duration (person-minutes), and by determining, through measurements, the field at different distances from the source. Figure A-2 illustrates the data recorded on an area sketch, after all data characterizing the environment had been identified through activity-pattern tracking and administration of a questionnaire.

Figure A-2: Area Sketch after execution of the DC measurements



Combined Area and Point Fields

Time-weighted-average (TWA) field exposures for an area were computed by combining area fields, point fields, and time activity information. Combined area and point fields showed only a modest increase over area fields weighted by exposure for schools (from 0.8 to 0.9 mG), for hospitals (from 1.3 to 1.4 mG), and for office buildings (from 0.7 to 1.0 mG). Combined fields showed a strong increase for grocery stores (from 1.9 to 2.7 mG) and, especially, for machine shops (from 1.4 to 3.9 mG), indicating a large effect of local sources in these two environments.

Exposure by Person Type

A time-weighted average and distribution of field exposure were calculated for each group of people. Results were as follows:

- **Office buildings:** Secretarial and support staff had a greater exposure than professionals.
- **Schools:** Teachers were slightly more exposed than students. Custodians and administrative staff were significantly more exposed than teachers and students.
- **Hospitals:** The medical staff and the maintenance staff were significantly more exposed than patients. Visitors were the least exposed.
- **Machine shops:** Welders had by far the largest exposure.

- **Grocery stores:** Clerks, cashiers, and butchers had much greater exposure than office staff and customers.

Results when groups of people were compared across environments were as follows. The highest exposures were as follows:

- **Welders in machine shops:** Highest exposure, both in terms of TWA and of top 5th percentile were (TWA 5.2 mG, top 5th percentile = 24.6 mG),
- **Butchers in grocery stores and clerks/cashiers in grocery stores:** Next highest exposures were: (Butchers: TWA 4.1 mG, top 5th percentile = 12.8 mG) (Clerks/cashiers: TWA 4.0 mG, top 5th percentile = 11.9 mG).

Groups with the lowest exposure were as follows:

- **Visitors in hospitals** (TWA = 0.8 mG, top 5th percentile = 2.4 mG),
- **Students in schools** (TWA = 0.9 mG, top 5th percentile = 2.9 mG),
- **Professionals in office buildings** (TWA = 0.9 mG, top 5th percentile = 2.6 mG).

These data refer to the average person of a given type. Individual people may have higher or lower exposures, and their exposure may vary significantly from day to day.

The percentage of total time spent above a field threshold was calculated for each type of person, for different field thresholds (2, 5, 10, 20, and 40 mG). It was found, for instance, that clerks / cashiers in grocery stores had the highest percentage of time (56%) spent above 2 mG and that professionals in office buildings had the lowest (14%).

Other Findings

For dc fields and combinations of ac and dc fields: The angle between dc and ac field was calculated and plotted versus the ac field magnitude. For both examples (a machine shop and a hospital), the distribution of these angles was found to be not significantly different from a random distribution of angles between two vectors in space.

For harmonics: When the waveshape of the magnetic field was recorded in different areas of a school site, the third and fifth harmonics were the most significant harmonics of 60 Hz present in the area field.

For polarization: The polarization of the 60-Hz magnetic field was calculated from the waveshape recordings at each school site. It was found that polarization decreases as the magnitude of the 60-Hz field increases.

For temporal variations: In the great majority of the cases, the geometric standard deviation of the spatial-temporal distribution is close to that of the spatial distribution. This means that an accurate knowledge of the temporal distribution adds little to the accuracy of exposure calculations.

For point source characterization: The dipole moments at 60 HZ and 180 Hz for sources were calculated based on field measurements. Sources for each environment were then ranked by dipole moment. The sources with the largest dipole moments were: a transformer, a welder power supply, an electric motor, an uninterruptible power supply, and an electric pencil sharpener.

For magnetic-field transients: At all sites, the maximum peak-to-peak value on a single-axis high-frequency channel was used to summarize transients. Machine shops as a group had the largest number of transients measured above 0.2 mG. Hospitals and schools had very few transients measured above 0.3 mG.

The report contains extensive appendices documenting results of the 20 site measurements.

Summary

Magnetic-field surveys were performed at four sites for each of five environments: schools, hospitals, office buildings, machine shops, and grocery stores. Field and exposure data were obtained separately for area fields and exposure points near sources. Differences between average fields obtained at different sites in the same environment were significant in comparison to differences between environments. Analysis of exposure by person type found that welders had the highest exposure, followed by butchers and clerks/cashiers in grocery stores. Power lines were, generally, a minor source of magnetic-field exposure. A significant percentage of exposure, however, was caused by sources that could not be identified. Other findings include the following: that the third and fifth harmonics are the dominant ones in school environments; that spatial variability in field is much more important than the temporal variability in determining exposure; and, that transient fields greater than 0.3 mG were infrequent in the measured hospitals and schools.