EM Site A.C. Magnetic Field Sources, Surveys and Solutions
Part V: Solutions!

Curt Dunnam, Linear Research Associates

This month's installment completes our primer series on magnetic fields by defining conditions where remedial EM site shielding is in fact technically feasible and by illustrating examples of both passive and active shielding methods for attaining lower site fields. For those readers who may have missed one or more previous articles, we have thus far presented some basic physics describing magnetic source fields (*Microscopy Today*, November, 1995), examined magnetic survey equipment and methods relevant to EM interference thresholds (*MT*, January, 1996), and, in Part IV ("Survey Data Analysis", *MT*, May, 1996), suggested techniques for interpretation of typical EM site survey data. Our continuing goal through this series is to educate the EM community about magnetic fields and how to measure, evaluate and cope with them. This final article completes the task with a look at technologies for reducing fields *in situ*.

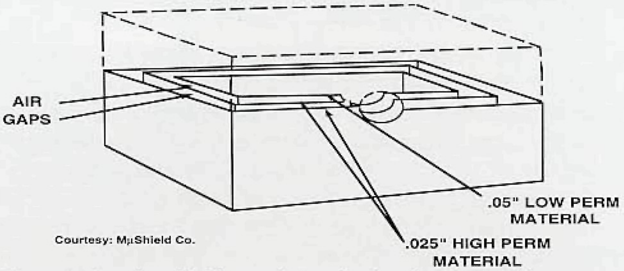
When magnetic shielding is required to bring a site into specification, knowledge of ambient field sources, levels and frequency characteristics is essential in specifying cost-effective field reduction. This month we will use ambient field information previously gathered at an example site as a basis for selecting and estimating costs of appropriate magnetic shielding for reduction of both localized and pervasive field sources.

First, it is useful to note that any source which generates a time-varying magnetic field within a frequency range of approximately 1 millihertz to 1 kilohertz at a magnitude exceeding 100 nanoteslas (1 milligauss) peak-to-peak may be considered a potential EM interference factor. Next, we need to segregate field resources into two types - those which are physically small to moderate-size and may be located in or very near the site, and those which are physically large and are situated relatively far from the site. Vaulted transformers, motors, video-display monitors and fluorescent lighting ballasts are examples of the former while large transmission lines, substations, pad-mounted transformers and major disturbers of the geomagnetic field (such as elevators and subway trains) are examples of the latter. For convenience, we will categorize the smaller, physically manageable sources as *localized* and the larger, incorrigible sources as pervasive (magnetic fields from the larger sources may be termed *pervasive* in the sense that their influence usually exceeds a building-sized volume).

Data available to us from our earlier Part III and IV survey activities will be used in preliminary source identification. Further, to better illustrate combined shielding techniques, let's add to our previous readings a large a.c. magnetic field (ACMF) contribution from a 20 KVA 480/208 stepdown transformer recently installed just down the hallway. As before, the EM room is divided into square cells A through F (corrected from Part IV to read sequentially A and B, C and D, E and F, from top to bottom, left to right; proposed EM column location at the junction of A, B, C and D). Initially, we look at sweep data taken with a hand-held teslameter and observe that readings at the proposed EM column location are approximately 4500 nTp-p (45 mGp-p) and also that the readings drop off rapidly as one moves away from the far corner of cell B. This is clearly a high-gradient field and a sign of a nearby localized source, and it is in fact an easy task to "home in" on the offending transformer with the hand-held teslameter. Once the source has been located, we can readily determine remaining ACMF fields at the EM site by switching the transformer power off for a short interval (in the early morning hours, if necessary!) in order to complete our measurements.

Noting at this point that worst-case magnetic fields measured in the site are approximately 36 times greater than the susceptibility threshold for our proposed FEG instrument, one may well wonder if the site can be salvaged for EM work.

Fortunately, it can. To arrive at a good solution, however, we first need to consider the shielding options available and their relative costs,. The two main categories of magnetic shielding - active and passive - may be used either separately or together as required. Passive shielding can be defined as surrounding a volume with sheet material of either high magnetic or electrical conductivity. At the relatively low frequencies which affect particle beam instruments such as EM's, however, it is most efficient to employ shielding material such as MuMetal® which exhibits high magnetic conductivity (i.e., permeability). Because passive shields may be constructed in a tiered fashion (Figure 1) using a combination of high saturation and high permeability Mu-Metal® materials, they are particularly effective at shunting elevated field levels near localized sources. Electronic, or active-feedback shielding, on the other hand, is most useful in reducing lower-level, low-gradient pervasive fields circulating from larger, distant sources. Its positive characteristics are relatively low cost per unit of shielded volume and physical unobtrusiveness, with tradeoffs of limited maximum field capability and attenuation coefficient. Active shielding is therefore a technique that works best for full-room shielding of affected instrumentation once strong local sources have been moved or passively shielded.



Courtesy: MμShield Co.

Figure 1. Passive shielding enclosure fror localized magnetic sources.
(shown with cover removed)

In our example EM site, we note from data analysis that the 4500 nTp-p ACMF reading is comprised of around 4300 nTp-p from the transformer source and 200 nTp-p of remaining low-gradient pervasive field. From our passive-shielding materials data sheet and close-in measurements of the transformer's leakage flux, along with supplemental engineering assistance from the shielding vendor, we find that a single-layer medium-permeability enclosure can be specified which provides a shielding factor of slightly grater than 120. This relatively high shielding coefficient reduces the transformer's contribution of time-varying magnetic field at the EM column to a negligible level. With this part of the solution in place, the remaining site magnetic fluctuations to be dealt with are two distinct lower magnitude contributions, the first at around 204 nTp-p in the "a.c." frequency range of 1.6 Hx - 1.0 KHz (mainly pervasive fields from neighborhood electrical power distribution equipment), and another at about 2900 nTp-p in the lower frequency range of 0.016 to 1.6 Hz (pervasive geomagnetic disturbances from elevators and vehicular traffic). To compensate these remaining fields, a 30 dB (attenuation factor of 32) active-feedback system covering a frequency range of 0.001 Hz to 1.0 KHz is specified with an installed configuration similar to that of Figure 2. Once the equipment is in place and activated, we note that maximum residual fields across the EM site are reduced to slightly less than 100 nTp-p, or about 80% of the FEG instrument's susceptibility threshold. Since the instrument manufacturer's published interference figure of 125 nTp-p is fairly conservative, a comfortable margin now exists between the compensated fields and the EM susceptibility threshold.

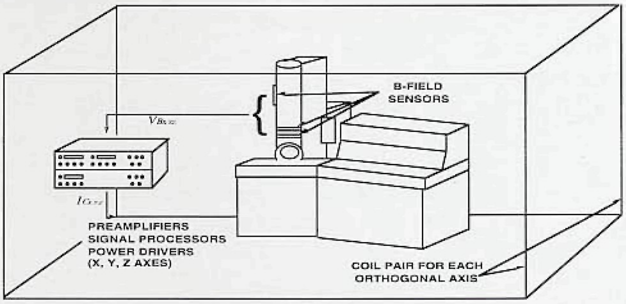


Figure 2. EM site equipped with active magnetic shielding system.

In sum, without too much effort and at a small percentage of the overall site cost, we have solved an atypical, worst-case interfering magnetic fields problem! In general, by applying a basic understanding of source characteristics, usseful survey data and a few key technical resources, it is possible to remedy most EM site magnetic field interference problems uickly and at reasonable cost.

Questions and/or comments relating to articles in this series are welcome and may be faxed to the author's attention at Linear Research Associates, Trumansburg, NY 14886, Fax: (770)368-8256. Assistance of the MuShield Company, Goffstown, NH, in the preparation of this article is gratefully acknowledged.