SELECTING RF/MICROWAVE INSTRUMENTATION FOR COMPLIANCE MEASUREMENTS

The radiation protection professional must choose RF/microwave instrumentation based on its ultimate operating environment.

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INTRODUCTION

During the past 20 years, awareness has increased in the health physics community of the potentially hazardous health effects of radiofrequency (RF) and microwave radiation. This article reviews the capabilities of past and present RF/microwave instrumentation and how their characteristics affect compliance measurements.

The average user is usually unaware of design limitations and compromises that different manufacturers have reached for their particular customer base or measurement philosophy. These compromises dictate how well an instrument will perform in a given RF/microwave environment.

HISTORY OF RF/MICROWAVE ENERGY AWARENESS

Approximately 20 years ago, the commercialization of microwave ovens generated a need for instrumentation operating at 915 and 2450 Megahertz (MHz) in order to obtain leakage information for manufacturers and repair organizations. Awareness of RF/microwave energy and its possible effects led to developments of broader frequency range monitors that, at first, were circularly polarized in an attempt to respond to all polarizations. These instruments were therefore not isotropic in their detection capability, and their effectiveness was markedly affected by geometric considerations. Without a priori knowledge of the field to be measured, a totally erroneous conclusion could have been made on the amount of RF/microwave energy present. These initial products were very broadband for their time, covering the spectrum from 1 to 14 Gigahertz (GHz) with the use of thermistor detectors. While the thermistor was very liner in its response, the receiving antenna design was not, necessitating multiple frequency calibrations to overcome polarization and frequency sensitivity errors of up to 10 decibels (dB). The next generation of these circularly polarized monitors incorporated thermocouple detectors, and improved antenna designs, which reduced frequency sensitivity errors to about 6 dB.

About 15 years ago, the first isotropic detection probes came on the market. Electric field probes became available covering the spectrum from 300 MHz to 18 GHz with a frequency sensitivity of only 3 dB, and a measuring range of 30 dB. During the early seventies the National Bureau of Standards (now the National Institute of Science and Technology, NIST) made many advances in calibration methods and procedures for quantifying RF/microwave fields. Near-field calculations and transverse electromagnetic (TEM cell) developments allowed for even higher calibration accuracies over a broad range of frequencies to uncertainties of +/-0.5 dB. Also in this time period, the development of magnetic field probes was accomplished, in part to measure the magnetic fields associated with high frequency (HF) communication systems. The impetus for the development of much of this isotropic instrumentation was the United States military, particularly the U.S. Air Force. The development of this broadband instrumentation overcame many of the problems associated with the earlier measurement equipment.

A discussion of the ability of the present generation of broadband isotropic instrumentation to perform compliance measurements is important. The 1974 American National Standards Institute (ANSI) Radiofrequency/Microwave Exposure Standard did not include frequency dependent criteria, nor did it differentiate between partial or whole body exposure. In 1982 the ANSI Standard was extensively revised to include frequency dependent exposure criteria. One of the most challenging changes to the standard for equipment manufacturers was the inclusion of these frequency dependent levels combined with the use of spatial and time averaging of exposure. Additionally, in certain situations, separate measurements of electric and magnetic fields were required. Clearly, past instrumentation with limited dynamic and frequency ranges had to be updated to meet new challenges, not only for standards compliance, but also to accommodate the proliferation of industrial, medical, scientific, and communications applications of RF/microwave energy.

NEW TECHNOLOGY

Presently, the instrumentation available must be able to meet the broadband needs of major users such as the military, but also be applicable to the narrowband customer whose needs must be met with a cost-effective solution. Therefore a proliferation has resulted of narrowband specialized products for 50/60 Hz fields, video display terminals, industrial heat sealers and induction heaters, and broadcast facilities. Broadband equipment has not gone without changes either. Instrumentation currently available on the market has traditionally utilized either diode or thermocouple based electric field detection. Uncompensated diode circuits, while providing higher dynamic ranges with excellent overload capabilities are nonetheless subject to large modulated signal and multiple emitter errors ranging from 1 to 30 dB. Early thermocouple based detectors exhibited excellent accuracy in complex, modulated field environments but were limited by overload specifications that a careless operator could exceed, thereby damaging or destroying these probes. Today, there is at least one manufacturer providing higher frequency probes that operate to 100 GHz based on thermocouple detection with 1000 percent overload specifications to guard against failure or modulation errors. At lower frequencies, between 300 kHz and 1000 MHz, probes employing compensated diode detection circuitries that all but eliminate signal and modulation errors are now on the market.

New technology has not been limited to electric field probes either, as shown by recent developments in magnetic field probes. Early magnetic field probes of certain designs were not truly isotropic. A phenomena known as "spatial shadowing" existed wherein one or more of the three orthogonally mounted detector loops did not allow the same flux lines to pass through all loops. This was caused by the three loops not having a common vertex. Later designs have corrected this source of error. Nonetheless, these probes were still difficult, if not impossible, to use in multiple emitter applications because of their erroneous response signals above their operating frequencies. Away from the controlled laboratory environment, where emitters are present throughout the frequency spectrum, large measurement errors are present when an out-of-band transmitter exists near a survey area. The 1982 ANSI Standard requested manufacturers to provide out-of-band response data; however, that only served to further complicate field measurements and to increase calibration costs. Newly designed magnetic field probes are available which greatly enhance the accuracy and operator confidence in magnetic field measurements.

MEASUREMENT TECHNIQUES

Currently, a new revision to the 1982 ANSI Standard has been drafted and may be enacted in 1990. Major changes include allowing the use of temperature probes and thermography to measure specific absorption rates (SAR's) of electromagnetic energy directly, rather than the use of calculations based on external field strengths. Provisions also are included for measuring induced body currents for radiofrequency fields below 30 MHz by standing an individual on a conductive plate electrode, and monitoring current flow to ground with an RF ammeter. In the draft revision, a major change has been made for external fields in the region of 3 kHz to 30 MHz. Presently, electric and magnetic fields are both measured and compared separately to the allowable exposure limit for the frequency being measured. In the draft revision, electric and magnetic field fractions will be summed and that sum will not exceed 100 mW/cm^2 at frequencies below 3 MHz. An interesting side note to this approach is that while many users have not embraced "equivalent power density" data for frequencies below 300 MHz, this concept is a common denominator which allows direct addition of contributing components, instead of the more cumbersome units that display squared electric and magnetic field strengths. Another change that affects the direction that new instrumentation will take is the use of time and/or spatial averaging. Although the use of such averaging was already permitted in the 1982 document, it has often been neglected in practice. The new revision will emphasize that, in certain conditions, a much more useful picture of the actual exposure situation will be obtained by using these techniques. The ANSI Standard exposure levels are averaged over a tenth of an hour and over the whole body. Therefore, in external field measurements, where highly localized fields exist, averaging techniques should be applied. In continuous field applications, like those found around RF induction sealers, measurements may be performed at different portions of the body and averaged together manually. In the case of a rotating radar where field levels are varying constantly, a time averaging module is the only way to truly measure and average the total exposure. Modules currently are available that can perform this averaging automatically, assisting in determining time averaged exposure. One system can perform spatial averaging over the body or workplace area. This system has a "pause" feature which allows horizontal and vertical scan averages to be summed so that one can determine averages in multiple planes or for cubic areas. Undoubtedly, continued advances in microprocessor technology will produce modules which will be able to perform all these functions, and, because of their small size, will produce minimal perturbations in the ambient electromagnetic field.

All of these newly available systems require comprehensive calibrations. The wide frequency ranges of modern probes require the use of multiple point calibrations with NIST traceability, both in and out of their frequency operating range. With the possibility of even more restrictive standards on the horizon, systems must not overestimate, or underestimate, these critical safety measurement levels. The latest ANSI recommended practice document lists various methods that have been approved to certify survey instruments that all manufacturers should be following. Users must know whether their units have been calibrated to respond correctly in a real world environment, or simply the controlled laboratory area. An example of an improved method of calibrating a meter and probe used in the environs of an AM radio station would be to understand what is occurring when the instrument is brought into the survey field. The potential field effect predominant in these low frequency applications requires that the meter and probe be physically calibrated together, as they would be used in the field, rather than simply calibrating the probe in a TEM cell without the meter present. Performance testing of survey instruments, similar to that which is now standard in the ionizing radiation community, is still only in its infancy for RF/microwave devices. As this area of radiation protection grows and matures, this type of independent testing by third parties will no doubt become standard.

SUMMARY

In conclusion, users must be aware of not only the strong points of a particular system but also its weak points. No single broadband instrument currently available will meet the needs of all users. Even though products might be specified similarly, their operation in a given environment may be significantly different. The radiation protection professional must be aware of these differences when choosing one for a particular application. ■

DISCLAIMER

This article was prepared when the author was an independent consultant. Any opinions, conclusions, or recommendations expressed in this article are therefore the author's own, and do not necessarily reflect the views of Battelle Pacific Northwest Laboratories.

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exists. Words such a "built to," "designed to," and "meets," usually followed by a reference to an agency standard or standards, guarantee nothing. Buyers of products described in this manner are at risk if they rely upon such statements to assure compliance. The use of such terms may range in effect from a genuine attempt at compliance to complete noncompliance. They may even refer to a product which met, at one point in time, the referenced standard.

The operative words one must search for are "Recognized," "Listed," "Certified," and "Licensed." These terms are usually supported by agency reports. When wrongly applied by vendors, they incur the wrath and legal pressures of the granting agency. Validity exists only as long as the product is compliant and for as long as the vendor maintains agreement with the agency. Covered products change daily which explain why the UL "Yellow Books," for example, are obsolete the day they are received. They are only useful as a guide. Vendors should be required to supply evidence of compliance and any changes in that status. ■