

American National Standard

recommended practice for the
measurement of hazardous
electromagnetic fields—rf and microwave

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Recommended Practice for the Measurement of Hazardous Electromagnetic Fields—RF and Microwave

1. Scope

1.1 Purpose. The purpose of this recommended practice is to specify techniques and instrumentation for the measurement of potentially hazardous electromagnetic fields¹ both in the near field and far field of the electromagnetic source. Thus, this recommended practice extends the specifications that are set forth in ANSI C95.3-1973 [2]² which deals with the measurement of potentially hazardous electromagnetic radiation at microwave frequencies, primarily in the far field.

Subcommittee I on Evaluation Techniques and Instrumentation was originally organized on April 7, 1960, to establish specifications for techniques and instrumentation used in evaluating hazardous radio-frequency radiation.

On January 8, 1963, the intent of the scope was clarified by specific reference to mankind, flammable volatile materials, and explosive devices; thus, the purpose was extended to establish specifications for techniques and instrumentation to be used in evaluating radio-frequency hazards to mankind, flammable volatile materials, and explosive devices.

Although the scope includes hazards to flammable volatile materials and explosive devices, the required specifications and definitions relating to the measurement of the quantities associated with hazards to fuel and ordnance are not yet available. Rather than wait for such specifications and definitions, it seems both necessary and desirable to prepare this recommended practice which, like ANSI C95.3-1973 [2], is devoted exclusively to personnel hazards. However, the measurement techniques

and instruments described herein are also applicable to the measurement of fields in the neighborhood of flammable materials and explosive devices, even though exposure standards for these situations have not been established. Further, this recommended practice includes leakage and near-field measurements and covers lower frequencies than ANSI C95.3-1973 [2].

1.2 Frequency Range. The techniques and instrumentation specified herein are useful over the frequency range of *approximately* 1 MHz to 100 GHz.³ This frequency range is an extension of that specified in ANSI C95.3-1973 [2], which pertains only to microwave frequencies, and of that specified in ANSI C95.1-1974 [1], which extends from 10 MHz to 100 GHz. No single measurement technique or instrumentation arrangement is valid over the wide frequency range covered by this recommended practice. In general, measurement techniques and instrumentation developed for use in the microwave range (that is, primarily above about 1 GHz) are not suitable for use at lower frequencies and vice-versa. Furthermore, most older instruments were not designed specifically for hazards purposes and are incapable of performing the accurate near-field measurements required to evaluate hazardous situations. For example, below 300 MHz, field strength measurement within one wavelength of the source are commonly required, and older instruments were designed primarily for far-field use.

1.3 Quantities and Parameters to be Measured. For frequencies above 300 MHz, and for mea-

¹It is beyond the scope of this recommended practice to define what constitutes a hazardous nonionizing electromagnetic field. For the present US Radiation Protection Guide, refer to ANSI C95.1-1974 [1]. It should be kept in mind that the limits given in these documents are under review and are subject to change as new information becomes available.

²The numbers in brackets correspond to the references listed in Section 2 of this recommended practice.

³These frequency limits should not be considered rigid, but are given as a general guide. Normally a given instrument does not abruptly become invalid at a specific frequency; rather its accuracy or sensitivity or both deteriorate over some frequency range until finally it is no longer usable. For example, an instrument designed for the lower frequencies may cover the entire broadcast band down to 0.5 MHz. One should be aware of the frequency limitations of a given instrument when using it.

measurements performed at distances from the source greater than a^2/λ with a probe whose dimensions are less than a , power density is usually a meaningful quantity (a is the largest dimension of the *effective aperture* of the source and λ is the wavelength). Unfortunately, power density has been almost universally adopted as a hazard indicator without regard to frequency, field configuration, ease of measurement, or the mechanisms which actually produce the biological damage. Furthermore, power density is difficult to determine, except in cases of stationary, single-component, plane-wave fields of known polarization. In fact, no existing instrument actually measures power density directly; they all measure one or more components of the electric field E or the magnetic field H , or both, and then infer a power density from the far-field, plane-wave relationship.

In many instances measurements will be required in the reactive or radiating near-field regions⁴ where reactive fields or standing waves exist. Under these more general conditions the time-average power density is not a reliable hazard indicator, even if practical probes could be developed for measuring power density. Insofar as hazards are due to energy absorption, the parameters $|E|^2$ and $|H|^2$ or the corresponding energy densities $U_E = \epsilon'|E|^2/4$ and $U_H = \mu'|H|^2/4$ are more reliable indicators of potential hazards [4]. Here ϵ' and μ' are respectively the real parts of the permittivity ϵ and magnetic permeability μ , $|E|$ and $|H|$ are the magnitudes of the electric and magnetic field vectors, and the energy density units are J/m^3 or pJ/cm^3 . Advantages of the energy density parameters are that the intensities of electric fields, magnetic fields, and electromagnetic fields can all be expressed in the same units, and energy absorption is conceptually easier to relate to units of energy per unit volume than to $(V/m)^2$ or $(A/m)^2$.

Since plane waves, all of the preceding parameters are simply related to power density, no loss of generality would occur with the use of these parameters for far-field measurements. Furthermore, most commercially available meters actually measure $|E|^2$ or $|H|^2$, while indicating *equivalent plane-wave power density*. Therefore, they do provide a valid indication

of potential hazards even though they may not indicate the actual power density at the point of measurement. Because rf-hazard equipment is currently not available to measure absolute peak values, only rms values will be considered. As the state-of-the-art advances, recommendations will be extended to include absolute peak quantities.

1.4 Types of Situations Covered. This recommended practice is intended for use in near- or far-field situations typified by the following:

- (1) Leakage fields
- (2) Radiation fields
- (3) Reactive fields

Leakage situations are generally interpreted as those involving the unintentional leakage of energy, whereas radiation situations are generally interpreted as those involving equipment designed to intentionally radiate electromagnetic fields. Reactive fields are present in the immediate vicinity of the sources of both leakage and radiation fields and tend to be stronger near inefficient radiators. Multipath interference due to the scattering and reflection of energy from other objects or surfaces is an additional complicating factor and is nearly always present to some degree in all three of the above situations. Accurate measurements must include procedures for estimating or avoiding these multipath effects; some useful techniques are given in 5.5.1, 6.3.1, and 6.3.4.

2. References

- [1] ANSI C95.1-1974, American National Standard Safety Level of Electromagnetic Radiation with Respect to Personnel
- [2] ANSI C95.3-1973, American National Standard Techniques and Instrumentation for the Measurement of Potentially Hazardous Electromagnetic Radiation at Microwave Frequencies
- [3] ANSI/IME 20-1978, Safety Guide for the Prevention of Radio Frequency Radiation Hazards on the Use of Blasting Caps
- [4] WACKER, P. F. and BOWMAN, R. R., Quantifying Hazardous Electromagnetic Fields: Scientific Basis and Practical Considerations. *IEEE Transactions on Microwave Theory and Techniques*, MTT-19. Feb 1971, pp 178–187.

⁴See definitions in Section 3.

3. Definitions

anechoic chamber. A room in which wave reflections from the boundary surfaces have been reduced to a negligible amount.

antenna. A device for radiating or receiving radio waves.

antenna array. A system of antennas coupled together for the purpose of obtaining directional effects.

antenna directivity. The ratio of the radiation intensity in a specified direction to the radiation intensity averaged over all directions.

NOTES: (1) The average radiation intensity is equal to the power radiated by the antenna divided by 4π steradians.

(2) In a particular system the directivity is fully realized only when the receiving polarization of the antenna is matched to that of the incident wave.

antenna effective aperture or effective area. In a given direction, the ratio of the power available at the terminals of a receiving antenna to the power density of a plane wave incident on the antenna from that direction, the wave being polarization-matched to the antenna.

NOTES: (1) A plane wave of given radiation intensity and from a given direction is polarization-matched to an antenna if its polarization is that which results in maximum power at the antenna terminals.

(2) The (total) effective aperture of an antenna may be decomposed into the sum of two partial effective apertures referred to two specified, orthogonal polarizations, respectively.

antenna effective height. (1) The height of the antenna center of radiation above the effective ground level. (2) In low-frequency applications, the term applies to loaded or non-loaded vertical antennas, and is equal to the moment of the current distribution in the vertical section divided by the input current.

antenna gain. See **gain of an antenna**.

antenna gain, relative. The ratio of the power gain of an antenna referred (relative) to a standard antenna.

NOTE: The relative gain may be in decibels or it may be a numeric. The standard antenna is usually a half-wave dipole or an isotropic antenna. The latter would be preferable if such an antenna existed.

antenna, parabolic. An antenna consisting of a parabolic reflector and a source at or near its focus.

antenna field regions. It is convenient to distinguish between the regions of small radiators (one wavelength or less) and large radiators (much larger than one wavelength).

(1) *Small Radiators:* The regions of small radiators (current elements and small linear radiators) are the electrostatic field region, the induction field region, and the radiation field region.

(2) *Large Radiators:* The regions of large radiators or aperture antennas are the reactive near-field region, the radiating near-field region, and the far-field region. The term induction field as defined for small antennas is not meaningful, but important vector field terms decaying inversely as higher powers of the distance than the first are usually called near-field terms.

antenna terminal impedance. The ratio of complex voltage to complex current at the terminals of a transmitting antenna, or the ratio of the open-circuit voltage to the short-circuit current at the terminals of a receiving antenna.

NOTE: Sometimes called antenna driving-point impedance.

aperture (unidirectional antenna). The part of a plane surface near the antenna perpendicular to the direction of maximum radiation through which the major part of the radiation passes.

athermal effect (nonthermal effect). Any effect of electromagnetic energy absorption exclusive of the production of heat.

attenuation. A general term used to denote a decrease in magnitude of a field quantity in transmission from one point to another.

NOTE: It may be expressed as a ratio, or, by extension of the term, in decibels.

average power ($\overline{P}$). The macroscopic time-average rate of energy transfer;

$$\overline{P} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t) dt$$

average power density. The power density integrated over the source repetition period.

average power output, amplitude-modulated transmitter. The radio-frequency power delivered to the transmitter output terminal averaged over a modulation cycle.

backward scatter. Scatter directed into the rear hemisphere with respect to the direction of incident energy.

beamwidth, half-power. In a plane containing the direction of the maximum of the lobe, the angle between the two directions in that plane about the maximum in which the radiation intensity is one-half the maximum value of the lobe.

bolometer. A device capable of absorbing radiant energy and of using the heat so developed to change its electrical resistance, thus indicating the amount of energy absorbed.

diode. As used here, a two-terminal semiconductor device that has the asymmetrical voltage-current characteristic exemplified by a single p-n junction; also a semiconductor device having two terminals exhibiting a non-linear voltage-current characteristic.

dipole. (1) Any one of a class of antennas producing the radiation pattern approximating that of an elementary dipole. (2) A straight radiator, usually fed in the center, producing a maximum of radiation in the plane normal to its axis. The length specified is the overall length.

NOTE: Common usage considers a dipole antenna to be a metal radiating structure which supports a line-current distribution similar to that of a thin straight wire, a half-wavelength long, so energized that the current has two nodes, one at each of the far ends.

directional pattern, antenna (radiation pattern). Graphical representation of the radiation or reception of the antenna as a function of direction.

NOTE: Cross sections in which directional patterns are frequently given are vertical planes and the horizontal plane or the principal electric and magnetic polarization planes.

driving-point impedance. At any pair of terminals of a network, the ratio of an applied potential difference to the resultant current at these terminals, all terminals being terminated in any specified manner.

duty cycle. Deprecated. See **duty factor**.

duty factor (duty ratio). Ratio of a wave composed of pulses that recur at regular intervals, the product of the pulse duration and the pulse repetition frequency.

duty ratio (duty factor). In a pulse radar or similar system, the ratio of average to peak pulse power.

effective aperture. See **antenna effective area**.

effective area. See **antenna effective area**.

electric field (general). A vector field of electric field strength or of electric flux density.

NOTE: The term is also used to denote a region in which such vector fields have a significant magnitude.

electric field strength (general). (1) At a given point, the vector Limit E of the quotient of the force that a small stationary charge at that point will experience, by virtue of its charge, to the charge as the charge approaches zero in a macroscopic sense.

(2) The magnitude of the electric field vector.

electric field vector. The force on a stationary positive charge per unit charge.

NOTE: This may be measured either in newtons/coulomb or in volts/meter. This term is sometimes called the *electric field intensity*, but such use of the word intensity is deprecated since intensity connotes power in optics and radiation.

electrical length. The length of any electrical conductor, such as an antenna or transmission line, expressed in wavelengths, radians, or degrees.

NOTE: When expressed in angular units, it is distance in wavelengths multiplied by 2π to give radians, or by 360 to give degrees.

energy density (electromagnetic field). The electromagnetic field energy contained in a given infinitesimal volume divided by that volume.

NOTES: (1) The term energy density may be used with prefatory modifiers such as instantaneous, maximum, and peak.

(2) In speaking of average energy density in general, it is necessary to distinguish between the space average (at a given instant) and the time average (at a given point).

far-field region. That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna.

NOTES: (1) If the antenna has a maximum overall dimension D which is large compared to the wavelength, the far-field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna, λ being the wavelength.

(2) For an antenna focused at infinity, the far-field region is sometimes referred to as the Fraunhofer region on the basis of analogy to optical terminology.

gain (antenna). The ratio of the radiation intensity, in a specified direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.

NOTES: (1) Gain does not include reflection losses arising from mismatch of impedance.

(2) The radiation intensity (power/unit solid angle) due to the isotropically radiated power is equal to the power accepted by the antenna divided by 4π steradians.

(3) If an antenna is without dissipative loss, its gain is equal to its directivity.

(4) The term *the gain* of an antenna is commonly used to designate the maximum gain as here defined.

horn antenna. An antenna having the shape of a tube whose cross-sectional area increases toward the open end and through which electromagnetic energy passes.

horn radiator. See **horn antenna**.

incident wave. A wave, traveling through a medium, which impinges on a discontinuity or a medium of different propagation characteristics.

insertion loss. The loss resulting from the insertion of a transducer in a transmission system. It is the ratio of the power delivered before the insertion to that part of the system following the transducer to the power delivered to that same part after the insertion, usually expressed in decibels.

NOTE: If more than one component is involved in the input or output, the particular components used must be specified.

ionizing radiation. Any electromagnetic or particulate radiation capable of producing ions directly or indirectly in its passage through matter. Examples are X-rays and gamma rays.

isotropic. Having the same properties in all directions.

isotropic antenna. A hypothetical antenna radiating or receiving equally in all directions.

NOTE: In the case of electromagnetic waves, isotropic antennas do not exist physically but represent convenient reference antennas for expressing directional properties of actual antennas.

liquid crystal. A state of matter having the characteristics of both liquid and crystal yet in fact being neither. Some liquid crystals exhibit a color effect at various phases within the mesophase caused by changes in temperature.

lobe (directional, radiation, antenna). A part

of the directional pattern bounded by one or two cones of nulls.

magnetic field strength (general). The magnitude of the magnetic field vector.

magnetic field vector (any point in a magnetic field). The magnetic induction divided by the permeability of the medium.

magnetic flux density (magnetic induction). That vector quantity B producing a torque on a plane current loop in accordance with the relation $T = IAn \cdot B$ where n is the positive unit vector normal to the loop and A is its area.

NOTE: The concept of flux density is extended to a point inside a solid body by defining the flux density at such a point as that which would be measured in a thin disk-shaped cavity in the body centered at that point, the axis of the cavity being in the direction of the flux density.

microwave region. See **microwaves**.

microwaves. A term used rather loosely to signify radio waves in the frequency range from about 1 GHz upward.

modulation. The process, or result of the process, whereby some characteristic of one wave is varied in accordance with another wave or signal.

NOTE: For the purpose of this recommended practice, continuous wave (cw) operation is considered to be a special form of modulation, that is, zero modulation.

multipath error. The error caused by the reception of a composite signal that arrives via two or more different paths.

multipath transmission (radio propagation). The propagation phenomenon that results in signals reaching the receiving antenna by two or more paths.

near-field region, radiating. That region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon distance from the antenna.

NOTES: (1) If the antenna has a maximum overall dimension which is not large compared to the wavelength, this field region may not exist.

(2) For an antenna focused at infinity, the radiating near-field region is sometimes referred to as the Fresnel region on the basis of analogy to optical terminology.

near-field region, reactive. That region of the field immediately surrounding the antenna wherein the reactive field predominates.

NOTE: For most antennas the outer boundary of the region is commonly taken to exist at a distance $\lambda/2$ from the antenna surface, where λ is the wavelength.

nonthermal effect. See **athermal effect**.

non-ionizing radiation. Any electromagnetic radiation incapable of producing ions directly or indirectly. Microwaves and *rf* waves are non-ionizing radiations.

peak power density. The maximum instantaneous power density occurring over a source repetition period.

peak power output. In a modulated carrier system, the output power averaged over a carrier cycle, at the maximum amplitude which can occur with any combination of signals to be transmitted.

peak pulse amplitude. The maximum absolute peak value of the pulse excluding those parts considered to be unwanted, such as spikes.

NOTE: Where such exclusions are made, it is desirable that the amplitude chosen be illustrated pictorially.

polarization (radiated wave). That property of a radiated electromagnetic wave describing the time-varying direction and amplitude of the electric field vector; specifically, the figure traced as a function of time by the extremity of the vector at a fixed location in space, as observed along the direction of propagation.

NOTE: In general, the figure is elliptical and it is traced in a clockwise or counterclockwise sense. The commonly referenced circular and linear polarizations are obtained when the ellipse becomes a circle or a straight line, respectively. Clockwise sense rotation of the electric vector is designated **right-hand polarization** and counterclockwise sense rotation is designated **left-hand polarization**.

power density. See **pynting vector**.

power gain. Of an amplifying device, the ratio of the power delivered to a specified load impedance to the power absorbed by its input.

NOTES: (1) It is usually expressed in decibels.

(2) If more than one component is involved in the input or output, the particular component used must be specified.

power level. At any point in a transmission system, the ratio of the power at that point to some arbitrary amount of power chosen as a reference. This ratio is usually expressed as decibels referred to 1 mW (dBm) or decibels referred to 1 W (dBW).

pynting vector. A vector P , defined as the vector product of the electric and magnetic fields at the point in question, that is, $P = E \cdot H$.

NOTE: It is expressed in units of watts per square meter and represents the electromagnetic field energy flow per unit area per unit time across a given surface element.

pulse repetition frequency. In a system using recurrent pulses, the number of pulses per unit of time.

pulse repetition rate. (See **pulse repetition frequency**.)

radar. A system that radiates electromagnetic waves and utilizes the reflection of such waves from distant objects to determine their existence or position.

NOTE: The name is derived from initial letters of the expression *radio detection and ranging*.

radiation intensity. In a given direction, the power radiated from an antenna per unit solid angle in that direction.

radiation protection guide (RPG). The radiation level that should not be exceeded without careful consideration of the reasons for doing so.

radio beam. A radio wave, most of whose energy is confined within a relatively small angle in at least one plane.

radio frequency (rf). A frequency that is useful for radio transmission.

NOTE: The present practicable limits of radio frequency are roughly 10 kHz to 100 GHz.

reflected wave. When a wave in one medium is incident upon a discontinuity or a different medium, the wave component that results in the first medium in addition to the incident wave.

NOTE: The reflected wave includes both the reflected rays of geometrical optics and the diffracted wave.

response time. The time required for a field-measuring instrument to reach 90% of the true value after being placed in the field to be measured.

scattering. The production of waves of changed direction, frequency, or polarization when electromagnetic waves encounter matter.

NOTE: The term is frequently used in a narrower sense, implying a disordered change in the incident energy.

standing wave. A wave in which, for any component of the field, the ratio of its instantaneous value at one point to that at any other point does not vary with time.

NOTES: (1) Commonly a periodic wave in which the amplitude of the displacement in the medium is a periodic function of the distance in the direction of any line of propagation of the wave.

(2) A standing wave results when the electric variation in a circuit takes the form of periodic exchange of energy between current and potential forms without translation of energy.

(3) Also termed stationary wave.

thermocouple. A pair of dissimilar conductors so joined at two points that an electromotive force is developed by the thermoelectric effects when the junctions are at different temperatures.

time averaged power density. The average power density integrated over the longest source period. This period can be as a result of rotational or directional characteristics of the source.

waveguide. (1) Broadly, a system of material boundaries capable of guiding electromagnetic waves. (2) More specifically, a transmission line comprising a hollow conducting tube within which electromagnetic waves may be propagated or a solid dielectric or dielectric-filled conductor for the same purpose. (3) A system of material boundaries or structures for guiding transverse-electromagnetic modes, often and originally a hollow metal pipe for guiding electromagnetic waves.

waveguide component. A device designed to be connected at specified ports in a waveguide system.

4. The Near-Field Measurement Problem

4.1 Characteristics of Nonionizing Electromagnetic (em) Radiation

4.1.1 Parameters Determined by the Source.

Sources of electromagnetic (em) radiation have widely different characteristics which impose a requirement for versatility upon the monitoring equipment. Pertinent characteristics are the following:

(1) **Modulation.** The specific characteristics of the signal in both the time and frequency domains are of prime importance.

(2) **Radiation Pattern.** In the near field, patterns change with distance from the source, whereas in the far field no significant change with distance occurs. At any given point in space, the field strength continually changes if either mechanical or electronic scanning techniques are used.

(3) **Frequency.** Energy may be present at frequencies spread over several decades, and may be predominately associated with either the *E* or *H* fields.

(4) **Polarization.** With respect to the far field, vertical linear, horizontal linear, elliptical, and circular polarizations are all in general use. However, in the near field, any one of these polarizations may exist at any given point.

4.1.2 Interference Patterns. The reflection features of both natural and man-made structures will result in nonuniform field intensities over any region of interest due to the establishment of standing waves or other interference patterns. This spatial variation of the electromagnetic field is caused by the interaction of the flow of rf energy from multiple sources or energy reflected from prominent features of the physical environment. These peaks in the electromagnetic distribution are separated by at least one-half wavelength, that is, they may be from a fraction of a centimeter to many meters apart, depending on the frequency of the source and the angles of arrival of the interfering waves. A change in frequency can result in a large change in energy distribution. Temporal variations can occur as a result of scanning antennas, moving vehicles, etc.

In a typical radar site or communications complex, for example, multipath interference often makes it difficult to obtain meaningful measurements. The region of concern may be illuminated from different directions by multiple sources with different characteristics and will encompass structures causing standing waves or coupling of fields. These complex conditions lead to complex field configurations with hot spots at different locations for different frequencies. Although a particular point in space may be in the far field or radiating near field of one piece of equipment, it may also be in the reactive near field of some other equipment. Furthermore, at least some of these emissions may be time dependent if mechanically scanned antennas or phased arrays are involved, or if time sequenced

operations are used such as with rf heat-sealing equipment. A typical phased array has several scanning functions which create entirely different electromagnetic field conditions both near to and far from the antenna. These different fields may exist either simultaneously or on a time sharing basis. Multipath interference can also affect the field polarization. Even when the polarization characteristics of all sources are known *a priori*, it is possible for certain types of structures (such as gratings or angled supports) to modify the polarization, and hence the interference pattern, in the region under investigation.

Furthermore, even when the physical environment is otherwise static, perturbations in the rf field will be caused by the introduction of test equipment or personnel to monitor its strength, or both. To ensure that safety requirements are met, it is imperative that any measurement program take account of the possibility of these and other variations. It should, therefore, include a sufficiently large sampling of data to preclude omission of hazardous combinations of conditions.

4.1.3 Radiation Leakage. Radiation leakage from electronic equipment presents special problems because the source of energy may not be clearly defined *a priori*. It could be coming from a crack in the shielding cabinet, or from poorly bypassed connecting cables. The polarization of the electromagnetic field and the location of the leak are not generally known ahead of time. This is a special case of the general near-field situation and the same problems can exist for all near-field measurements, whether the emitted fields are intentional or accidental. A completely general theoretical treatment of the leakage problem is very difficult and is beyond the scope of this recommended practice. The survey techniques differ from those associated with the radiation fields from antennas of radars and communication equipment. In the leakage case, the location of the source is found by trial and error. A nondirectional, nonpolarized detector is desirable in order to probe in the immediate vicinity of the equipment where directive pickup antennas would give poor readings because of their inability to respond to multipath signals and because of inaccurately known gain-reduction factors in the near field. However, a somewhat directive system consisting of a waveguide probe, thermistor,

attenuator, and power meter is easy to assemble, and may be useful for locating a source of leakage when accurate knowledge of the level is not required.

4.1.4 Reactive Near Field. The reactive near-field region of a given equipment exists close to the equipment where energy storage fields are important. In this region of space immediately surrounding the equipment, reactive components of the field predominate over the radiating near-field and radiating far-field components. Although the extent of the reactive region varies for different equipment, the practical outer limit is of the order of a few wavelengths. For example, at a distance of three wavelengths from an ideal dipole, all reactive components are less than 10% of the radiating components and the measurement error due to the reactive components would be less than 1 dB. Although the reactive components do not contribute to the net flow of radiated energy, they can couple into material and thus effect energy absorption. Consequently, it is important that the reactive field be measured in many situations. Furthermore, both electric and magnetic fields must be measured to fully evaluate the hazard since both are absorbed by biological subjects.

4.1.5 Other Considerations. In the near field, three orthogonal components of the electric field with arbitrary relative phases and amplitudes exist. Similarly, there are three orthogonal components of the magnetic field with arbitrary phases and amplitudes. The electric field is elliptically polarized in an arbitrary plane and the magnetic field, in general, is elliptically polarized in another plane. Consequently, in the near field, measurements of the phase and amplitude of each of the three components of the electric field give no information about the magnetic field at the point. Thus, use of instruments capable of measuring either the electric or the magnetic field and which respond to any arbitrary polarization is indicated. Field measurement devices utilizing three orthogonal dipoles or loops which detect the amplitude but not the phase of the electric or magnetic field, cannot provide complete information about the elliptically polarized field. Specifically, the maximum instantaneous field vector is not measured with these types of devices. Only an *averaged* total field strength is measured, with the averaging occurring over one cycle of the oscillation of