CHOOSING EMC ANTENNAS

A basic understanding of antenna structure, functions and applications aids in the choice of effective test antennas.

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INTRODUCTION

Choosing antennas can be one of the more difficult tasks which an EMC engineer must face. Very few electrical engineers whether digital designers, EMC specialists, or practitioners in other areas have the training or experience to understand the tradeoffs and compromises which the manufacturer of antennas must make in order to provide a useful, affordable product. The EMC engineer should not, however, be embarrassed by this lack of knowledge because most antenna engineers, though well-grounded in antenna principles and theory, are used to thinking only in terms of the requirements of communicators and other users of the RF spectrum. They simply do not understand the unique requirements of antennas for EMC measurements.

BASIC TERMINOLOGY AND PRINCIPLES

This examination of EMC antennas contains the basic assumptions that *receiving* refers to the measurement of undesirable, radiated emissions and that *transmitting* refers to the generation of electromagnetic fields for susceptibility testing. Several other key terms should be reviewed.

- Gain is the measure of an antenna's ability to concentrate a radiated signal in one direction or to receive a signal only from one direction, as opposed to all other directions. Gain is usually expressed in dB relative to a perfect isotropic radiator (dBi). Gain can be either positive or negative. Positive gain is achieved by focusing a signal in one direction much as a reflector focuses a flashlight beam. Negative gain results from losses in the antenna system and/or from the use of antennas which are "short" when measured in terms of the wavelength of the signal(s) of interest.

- Antenna factor (AF) is a measure of the relationship between the field strength of a signal (to which the antenna is exposed) and the voltage which that signal causes at the antenna terminals. AF is expressed in dB and is related to gain by the expression

$$G\,(\text{dBi}) = 20 \log (F) - 29.79 - AF\,(\text{dB})$$

where F is the frequency in MHz.

- Beamwidth is the number of compass degrees between the half-power points in the direction of the antenna's peak response. Beamwidth will have an E-plane and an H-plane component, which will not necessarily be the same (or even similar). For antennas which are designed to provide a positive gain, beamwidth and gain will usually have a reciprocal relationship.

- Bandwidth is the useful frequency range covered by the antenna. When expressed as a fraction of the antenna's nominal frequency, bandwidth is generally broader for non-resonant antennas than it is for resonant antennas. Bandwidth will be broader for low gain than for high gain antennas. For antennas which are designed to be broadbanded, the balun, or matching network, is frequently the factor which limits bandwidth rather than the antenna factor itself.

- Impedance is usually of little concern since virtually all EMC test equipment is designed to work into a 50-ohm load; and most, if not all, EMC antennas are designed and calibrated to present an impedance which is reasonably close to 50 ohms over their useful frequency band. One must, however, remain conscious of the possibility of impedance problems with antennas, particularly low frequency H-field loops. Antenna impedance will vary with frequency, and many low frequency loops do not have matching networks which will compensate for this variation.

- VSWR (Voltage Standing Wave Ratio) is an indirect measure of the impedance match of any two RF devices which transfer power from one to the other. VSWR is accorded too much importance by most users. This assertion is made based on a number of complicated reasons. Stated briefly, in the usual case, the apparent impedance of the feedline is a composite of the nominal impedance of the feedline and the impedance presented by the load; therefore, approximately equal mismatches will appear at both ends of the feedline. Most of the signal which is reflected from the load will, in turn, be reflected back along the feedline from the source. Nonetheless, VSWR can be a problem where very accurate measurements are required, where a signal source is unusually sensitive to impedance mismatches, or where significant feedline loss is apparent.

- Size is an important antenna characteristic. The necessity of handling and moving the antenna limits the practical size range. The need for using antennas within shielded enclosures restricts the maximum size. The need to minimize unwanted coupling to the ground plane or to surrounding objects also affects size. Conversely, good response at low frequencies, high gain, or large bandwidths creates a need for larger antennas.

SELECTION PROCESS

Bearing in mind the foregoing basic principles of antenna use, the EMC engineer begins the logical process of antenna selection by determining the particular use intended. Strictly speaking, any transmitting antenna can be used for receiving; however, in many receiving applications, the added sensitivity of an active antenna will almost surely convert the electronics into an open circuit!

The next decisive question which must be answered regards the frequency range of interest. For most EMC uses, the required frequency coverage will be too great to be accommodated by a single antenna. In actuality, because of the restrictions imposed by reasonable bandwidth and size, it is not uncommon to use as many as five antennas to cover all of the frequencies of interest.

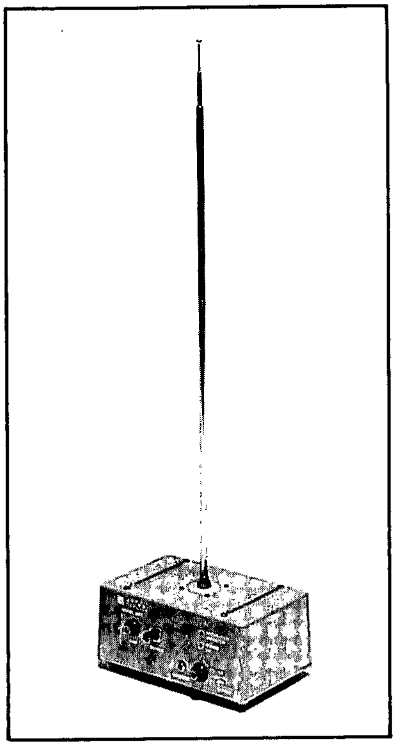

Figure 1. Active Rod E-field Antenna.

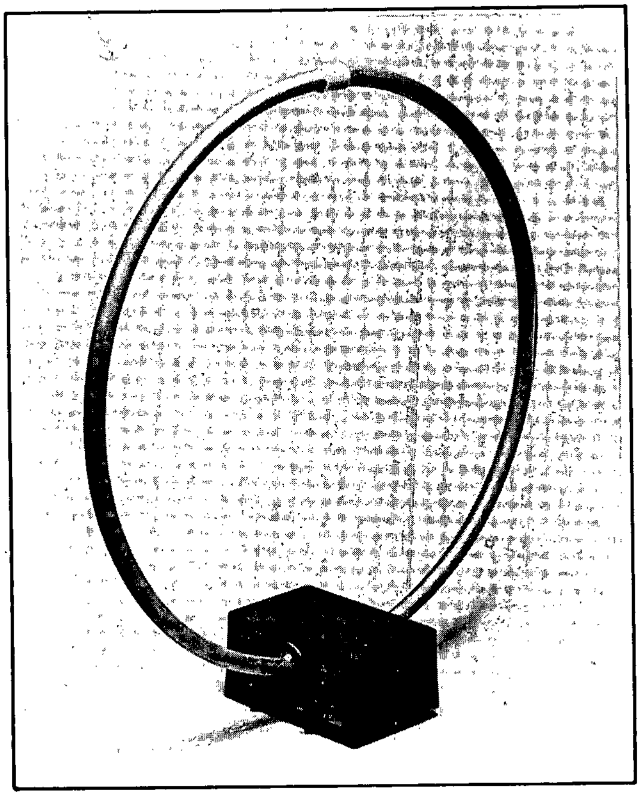

Figure 2. Active Loop H-field Antenna.

In many cases, the minimum frequency of interest will be low enough to require two antennas — one to be used in measuring the electric component of the field and one for the magnetic component. This combined usage is explained thusly. While measurement distances are usually in absolute units and usually specified by some regulation or standard, the makeup of an electromagnetic field is a function of the source impedance (perhaps unknown) and of the distance from the source in wavelengths. In the "far field" the EM field assumes the characteristics of a plane wave; whereas, the E-field component and the H-field component are related by the free space impedance of 377 ohms. One can therefore calculate the field power, the E field, or the H field given any one of the three. In the "near field" no such convenient relationship exists. The impedance of the wave at any point in the near field is somewhere between the unknown source impedance and the known free space impedance. As a result of this unknown impedance, it is necessary to measure both the E field and the H field and to compute power. (At this point it is also possible to compute the wave impedance and to extrapolate back to the source impedance. This calculation can be useful in diagnosing the actual cause of a troublesome emanation.) The thoughtful tester might ask why one cannot obtain just one or two antennas to cover extreme bandwidths. However, this option involves a number of tradeoffs as the following paragraphs will make clear.

THE IMPORTANCE OF GAIN

Every antenna has both positive and negative gain. The positive is good, and the negative is undesirable but necessary. Ideally every antenna used in EMC measurements should have as much positive and as little negative gain as possible. Taking into account the limits of practical antenna design, antenna gain almost always costs less than receiver sensitivity or amplifier power. Since it is always desirable to detect the smallest radiated emission or to generate the required susceptibility test field at the minimum cost, optimum antenna gain is always a plus.

With the usual exception of tuned dipoles, which are normally used only when required by regulation or by published procedure, most antennas used below 100 MHz are nonresonant and will exhibit negative gain (loss). The type of antennas usually used in this range are rod antennas for the very low frequency E-field measurements (Figure 1). Also special E-field generators are used for susceptibility testing. At these very low frequencies shielded loop antennas are used for H-field measurements, and loop antennas are used for H-field generation (Figure 2). Above 20 to 30 MHz the most common antennas are non-resonant dipoles, often in the biconical configuration (Figures 3 and 4). These antennas are used because as the frequency decreases, the size of a broadband resonant antenna increases and quickly becomes unmanageably large. The gain is negative because the antennas are small relative to the wavelengths involved. Tuned antennas are used only when absolutely required because of the considerable time necessary to complete a test if the antenna must be retuned at each frequency change.

In the 100 MHz to 200 MHz range, broadband resonant antennas begin to become practical and are used in many applications. They are still sufficiently large to be a problem in some uses so the relatively inefficient nonresonant antennas still have valid application in this range. Above 200 MHz, gain antennas are almost universal. Again size is one of the primary limiting factors. A log periodic dipole array, can be designed and built, at least theoretically, to cover almost any frequency range and to provide very high gain (Figure 5). However, as the bandwidth increases, so does the size. At very high frequencies, the short element lengths and resultant small boom requirements are incompatible with the mechanical strength required to support the larger low frequency elements. Other antenna types are also used at the higher frequencies, such as the double ridged waveguide horns. Because of the mechanical assembly involved and the high gain, these antennas are often preferred at frequencies above 1 to 2 GHz.

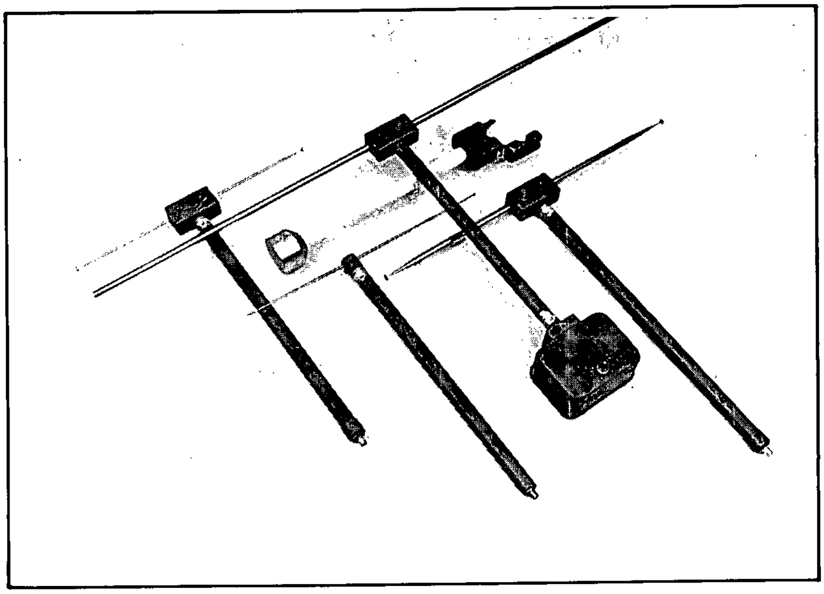

Figure 3. Adjustable Element Dipole Antenna Set.

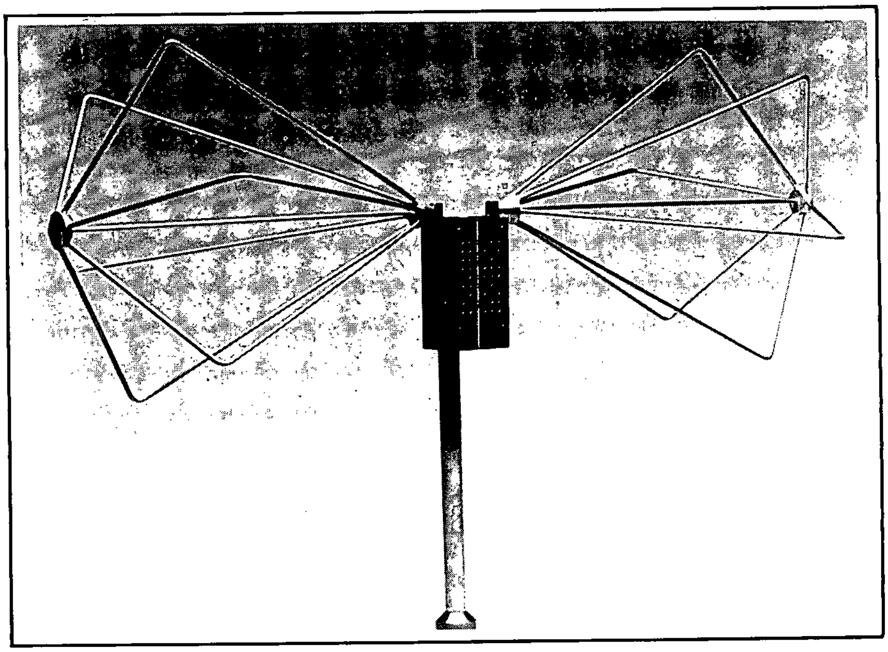

Figure 4. Biconical Dipole Antenna.

THE ROLE OF SIZE

The role of size as a significant limiting factor in EMC antenna design has already been mentioned. There are the obvious problems involved in handling a very large antenna. Also unwanted coupling of the antenna to the ground plane, to the unit under test, to the shielded room walls, and to any other surrounding objects must be minimized. Coupling will be less troublesome if the antenna elements are kept well clear of the

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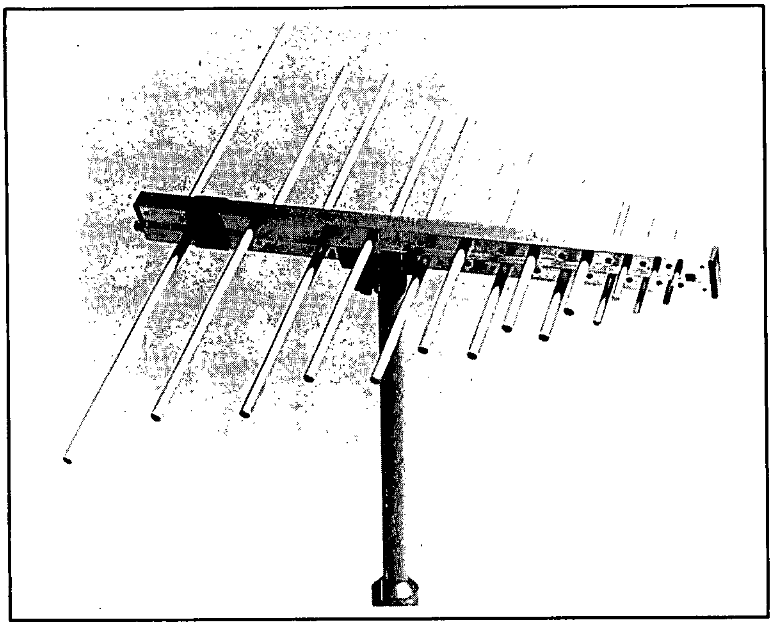

Figure 5. Log Periodic Antenna.

object which is to be avoided, and obviously it is easier to stay clear with a small antenna.

Beamwidth is another factor which must be "traded-off" against the gain. Antennas cannot create power! They can only focus it, much as the reflector behind a light or the lens of a telescope does. In other words, gain and beamwidth are reciprocals. As gain increases, beamwidth decreases and vice versa. The practical application of this phenomenon is to limit the area which can be "under test" at any one time. If the area illuminated by the susceptibility test field or the area "seen" by the emission test antenna is less than the size of the object under test, the test must be repeated as many times as necessary to insure that the whole unit is tested; and even then, the results may not be valid.

To summarize, gain, bandwidth, and size are all interrelated. Generally as gain increases, so does size. Similarly as bandwidth increases, so does size. The dilemma of multiple antennas has become fairly obvious. It is just not practical to build one or a very small number of antennas which will work efficiently over a large bandwidth. Essentially they would be too large.

SPECIFIC FACTORS IN ANTENNA SELECTION

Having considered all the foregoing facts, the EMC tester must consider some very specific data when choosing antennas. Exactly how flat is the gain (antenna factor) curve? Many times an antenna with a flat curve will be easier to use than one with the ultimate gain. How is the antenna factor (or gain) measured? Some vendors provide data at the distances at which an antenna is normally used while others play "specsmanship" and advertise only true (or calculated) far-field numbers which almost always look better but which may not be very useful. Are pads used when measuring the antenna factor? If so, they can introduce significant losses; and unless they are removable, they preclude the use of the antenna for transmitting. Are individual calibration curves or charts provided for each antenna? Is the would-be tester limited to calculated or "typical" data? Does the vendor provide a recalibration service? Antennas are precision instruments and that precision should be maintained.

Having ascertained basic antennas needs, the EMC test engineer should look to the reputation of the vendor or manufacturer. Are knowledgeable people willing and able to take the time to answer questions? Are custom or modified products available if those already in stock do not meet specific needs? Most importantly, since no one builds 100 percent perfect products, just how good is the warranty? Both actual wording and a reputation for reliability should be considered.

Finally there is the consideration of price, the last item on the list. Because the EMC antenna is a precision instrument, there is no such thing as a good cheap EMC antenna. However, antennas represent such a small portion of the total investment in an EMC facility, that price should not be the major factor when making antenna purchases. Obviously everyone appreciates the importance of thrift and the limitations on available funding. Nonetheless, price should be a deciding factor only after comparing the realities of antenna performance.

SUMMARY

In selecting antennas for EMC testing, one must first define the job to be done. Is the requirement for transmitting, receiving, or both? What is the required frequency coverage? What is the minimum acceptable gain? What is the maximum practical size? After he has resolved all these questions, just how many antennas will the tester require, and what will be the frequency range and gain of each antenna? Are the antennas individually calibrated? Will the data acquired meet the tester's needs? Are the results presented in the most suitable form? Are necessary help and a comprehensive warranty available from the vendor? What is the overall cost of the testing setup, and how does this figure fit into the testing budget? When these crucial questions have been resolved, the tester can fill out the purchase order with confidence! ■