

AEROSPACE INFORMATION REPORT

Submitted for recognition as an American National Standard

SAE AIR1509

Issued 1978-01
Cancelled 1999-01

EMC Antennas and Antenna Factors: How To Use Them

TABLE OF CONTENTS

1. SCOPE	2
2. INTRODUCTION	2
3. ANTENNA FACTORS VS. ANTENNA GAIN	3
3.1 Examples	6
4. TYPES OF ANTENNAS	7
4.1 Antenna Manufacturers	12
4.2 Magnetic Field Conversion Factors	13
5. ANTENNA FACTORS	14
6. REFERENCES	24

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

Copyright 1999 Society of Automotive Engineers, Inc.
All rights reserved.

QUESTIONS REGARDING THIS DOCUMENT:
TO PLACE A DOCUMENT ORDER:
SAE WEB ADDRESS

(724) 772-8510
(724) 776-4970
<http://www.sae.org>

FAX: (724) 776-0243
FAX: (724) 776-0790

Distributed under license from the IHS Archive



Documents
Document Sharing Hub

1. SCOPE:

This AIR discusses the use and application of EMC antennas and antenna factors. The relationships between antenna gain, antenna factor, power density (W/m^2), and field strength (V/m) are discussed. Some examples of their use are given. Illustrations of commercially available EMC antennas commonly used in performing EMI measurements are included. In addition to the illustrations, the antenna factors, frequency ranges, typical uses (applications), and the manufacturers of these antennas are also listed.

2. INTRODUCTION:

When measuring radiated electromagnetic fields such as electromagnetic interference, an antenna of some type is necessary to intercept or "pick up" the radiated signal. The antenna is connected to a receiver and the receiver measures the output voltage or power from the antenna. This voltage represents the magnitude of the field intercepted by the antenna. By knowing the antenna factor and the cable losses between the receiver and the antenna, the voltage measured by the receiver can be converted to field strength in volts per meter. If the receiver is calibrated in volts per megahertz the measured voltage can be converted to volts per meter per megahertz. If power measurements are desired instead of voltage the measured power can be converted to power density in watts per square meter, etc.

The principal point is that when a calibrated receiver is used to measure the output signal from an antenna, this measured signal (in volts) can be converted to field strength (volts per meter) by use of a factor which is called the antenna factor. The antenna factor converts the output signal from an antenna to field strength.

Often an antenna is used to generate a field instead of intercepting a field. In this case the power gain of the antenna is sometimes used to calculate the field strength generated at some distant point. The gain of an antenna and the antenna factor are not directly interchangeable, although there is a definite mathematical relationship whereby gain can be converted to antenna factor under certain conditions and vice versa. Likewise, power density can be converted to field strength. The conditions under which these conversions can be made and examples of the conversions are discussed later in this document.

3. ANTENNA FACTORS VS. ANTENNA GAIN:

Usually, antennas are calibrated for measurements of far fields only, i.e., uniform planewave fields in free-space. For such fields the magnitude of the electric vector, E , and the magnetic vector, H , are related to the power density, P , by the relationship $P = EH$, and $E/H = 120 \pi$. These conditions normally exist only in free-space and not under near field conditions that are often encountered when making measurements at low frequencies in shielded rooms or in close proximity to each other. When making EMI measurements under near field conditions, it is extremely important that properly designed antennas be used. These antennas must be designed and constructed for making near field measurements. Most antennas are designed for far field measurements only. The equations presented in this section for converting antenna factor to antenna gain, electric fields to magnetic fields, field strength to power density, etc., are valid for far field conditions only.

Antenna calibration data are usually given in terms of either antenna factor or antenna gain. The antenna gain is usually referenced to an isotropic radiator. If the calibration data are given in terms of antenna gain, these data can be readily converted to antenna factor or vice versa by the application of simple equations. Derivation of these equations follows.

Let,

P = Power density at antenna (W/m^2),

P_R = Received power (W),

V_R = Received voltage (V),

Z_R = Receiver input impedance (Ω),

E = Field strength (V/m),

G = Antenna gain (power ratio),

λ = Free-space wavelength (m),

f = Frequency (MHz),

K = Antenna factor (for converting to V/m), and

K_1 = Antenna factor (for converting to W/m^2).

$$P_R = PG \lambda^2 / 4\pi \text{ (Note 1)} \quad (1)$$

$$P = E^2 / 120\pi \text{ (Note 2)} \quad (2)$$

Combining (1) and (2) yields:

$$P_R = \frac{E^2 G \lambda^2}{480\pi^2} \quad (\text{Eq. 3})$$

3. (Continued):

Then, since

$$P_R = \frac{V_R^2}{Z_R},$$

$$\frac{V_R^2}{Z_R} = \frac{E^2 G \lambda^2}{480 \pi^2}$$

Or,

$$V_R = \sqrt{\frac{Z_R G}{480} \frac{E \lambda}{\pi}}.$$

And, since $\lambda = \frac{300}{f}$,

$$V_R = \sqrt{\frac{Z_R G}{480} \frac{300 E}{f \pi}}.$$

Note 1: "Reference Data for Radio Engineers," ITT sixth edition, page 27-42.

Note 2: ibid, page 27-7.

Simplifying,

$$V_R = \frac{75 E}{f \pi} \sqrt{\frac{Z_R G}{30}},$$

and rearranging

$$E = \frac{V_R f \pi}{75} \sqrt{\frac{30}{Z_R G}}.$$

3. (Continued):

Since Antenna Factor, K, is defined by $K = E/V_R$,

$$K = \frac{f\pi}{75} \sqrt{\frac{30}{Z_R G}},$$

Or in dB

$$K \text{ (dB)} = 20 \log f + 20 \log \frac{\pi}{75} + 1/2 (20 \log 30 - 20 \log Z_R G)$$

$$K \text{ (dB)} = 20 \log f - 10 \log Z_R - 10 \log G - 12.79 \text{ dB}$$

If $Z_R = 50 \Omega$

$$K \text{ (dB)} = 20 \log f - 10 \log G - 29.78 \text{ dB/m} \quad (4)$$

If it is desired to calibrate in terms of W/m^2 (or mW/cm^2), this can also be readily accomplished.

Since $P_R = PG\lambda^2/4\pi$, (equation 1)

$$P = P_R 4\pi/G\lambda^2,$$

and since $\lambda = 300/f$,

$$P = P_R 4\pi f^2/G(300)^2.$$

Then, since the desired factor, K_1 , is defined as $K_1 = P/P_R$,

$$K_1 = 4\pi f^2/G(300)^2$$

Or, in dB:

$$K_1 \text{ (dB)} = 10 \log (4\pi) + 20 \log f - 10 \log G - 20 \log (300),$$

$$K_1 \text{ (dB)} = 10.99 + 20 \log f - 10 \log G - 49.54, \text{ and} \quad (5)$$

$$K_1 \text{ (dB)} = 20 \log f - 10 \log G - 38.55 \text{ dB/m}^2.$$

3. (Continued):

Summary

Antenna factor K , for conversion to V/m from received voltage and antenna factor K_1 , for conversion to W/m² from received power, can be readily deduced from the isotropic gain of an antenna. In addition, it is apparent from the equations that conversion of units can be readily accomplished from V/m to W/m² or mW/cm², if the input impedance, Z_R , of the receiver is known.

3.1 Examples:

Antenna gain is given as 7 dB at 350 MHz.

From equation (3),

$$K \text{ (dB)} = 20 \log (350) - 7 - 29.78 = 14.1 \text{ dB/m},$$

and from equation (4),

$$K_1 \text{ (dB)} = 20 \log (350) - 7 - 38.55 = 5.3 \text{ dB/m}^2$$

In the first case, readings in dB μ V are converted to dB μ V/m by adding 14.1 dB, while in the second case, readings in dBW are converted to dBW/m² by adding 5.3 dB. Since 1 m² = 10⁴ cm², readings in dBm can be changed to dBm/cm² by subtracting 34.7 dB (5.3-40).

When the antenna, receiver, and connecting coaxial cables are designed for a 50-ohm system, conversion to the various units can be made very easily. The following equations can be used.

To convert the received voltage V_R in dB μ V to power density P in watts/m², use $P = K - 145.8 + V_R$,

where

P = power density in watts/m²,
 K = antenna factors in dB, and
 V_R = received voltage in dB μ V.

To convert the received voltage V_R in dB μ V to power density P in dBm/cm², use $P = K - 155.8 + V_R$,

where

P = power density in dBm/cm²,
 K = antenna factor in dB, and
 V_R = received voltage in dB μ V.

3.1 (Continued):

To convert the received power in dBW to field strength in dB μ V/m use $E = K_1 + 145.8 + P_R$,

where

E = field strength in dB μ V/m,

K_1 = antenna factor (for conversion to watts/m²), and

P_R = received power in watts.

4. TYPES OF ANTENNAS:

Various types of antennas are used in EMC testing depending on the frequency range and the particular application. Chart I on the following pages lists the various types of commercially available antennas available to perform EMI measurements. The chart lists typical frequency ranges, a sketch of the antenna, typical applications (emission tests or susceptibility tests), approximate antenna factors, and antenna manufacturers. The antenna factors in the chart are merely illustrative examples and should not be used for measurements. A more complete list of typical antenna factors for specific antennas is shown in the next section.

The table in 4.2 can be used to convert to various units commonly used in EMI measurements. The table lists conversion factors for the following units: microvolt per meter, gauss, picotesla, micro-ampere per meter, Weber per square meter, and gamma. Conversion from magnetic field units to another set of magnetic field units (gauss to picotesla) are valid for both far field and near field conditions if a magnetic antenna is used (such as a loop). However, conversions from magnetic field strength to electric field strength and vice versa are only valid for far field conditions regardless of the type of antenna used.

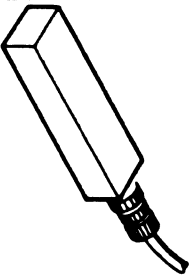
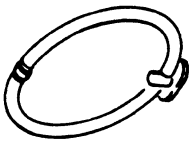
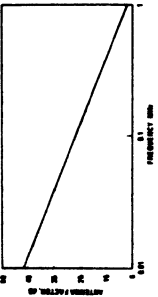
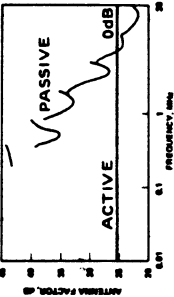
ANTENNA TYPE	TYPICAL FREQUENCY RANGE	TYPICAL ILLUSTRATION	TYPICAL APPLICATION	TYPICAL ANTENNA FACTOR	MANUFACTURER (CODE)
FERRITE LOOP	0.1 Hz TO 100 kHz		RADIATED EMISSION TESTS	ANTENNA FACTORS NOT AVAILABLE	8, 9, 19, 22
SHIELDED LOOP	20 Hz TO 35 MHz		RADIATED EMISSION AND RADIATED SUSCEPTIBILITY TESTS		7, 8, 10, 12, 15, 18, 19, 23, 4, 17, 20, 22, 4, 1
VERTICAL RODS	10 kHz TO 35 MHz		RADIATED EMISSION TESTS		7, 9, 10, 12, 15, 19, 23, 4, 8, 11, 16, 17, 22, 1
ACTIVE	10 kHz TO 35 MHz				4, 11, 19

CHART I