EMCO REFERENCE

ANTENNA TERMS
&
CALCULATIONS

EMC TEST SYSTEMS – An ESCO Company

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1 Definition of Antenna Factor

This term is traditionally tied to the recieve antenna factor, the ratio of field strength at the location of the antenna to the output voltage across the load connected to the antenna.

.❶ $$AF = \frac{E}{V}$$

where:

AF = Antenna Factor, meters^{-1}
E = Field Strength, V/m or µV/m
V = Load Voltage, V or µV

Converting to dB (decibel) notation gives:

.❷ $$AF_{dB(m^{-1})} = 20 \log \left(\frac{E}{V}\right)$$

or:

.❸ $$AF_{dB(m^{-1})} = E_{dB(V/m)} - V_{dB(V)}$$

The antenna factor is directly computed from:

.❹ $$AF = \frac{9.73}{\lambda \sqrt{g}}, 1\, m^{-1}$$

where:

λ = Wavelength (meters)
g = Numeric gain

In the same sense, for magnetic fields, as seen by loop antennas:

.❺ $$AF_{H\, dB(S/m)} = H_{dB(A/m)} - V_{dB(V)}$$

In terns of flux density (B-Field):

.❻ $$AF_B = AF_H + 20 \log (\mu)$$

.❼ $$AF_B = AF_H - 118, T/V$$

Loop antennas are sometimes calibrated in terms of equivalent electric field, where:

.❽ $$AF_{E\, dB(m^{-1})} = AF_{H\, dB(S/m)} + 20 \log \eta$$

.❾ $$AF_{E\, dB(m^{-1})} = AF_{H\, dB(S/m)} + 20 \log (120\pi)$$

where:

η = the impedance of free space
$= 120\pi\ \Omega$

2 Conversion of Signal Levels from mW to µV in a 50Ω System

Voltage and power are equivalent methods of stating a signal level in a system where there is a constant impedance. Thus:

.❶ $$P = \frac{V^2}{R}$$

where:

P = Power in Watts
V = Voltage Level in Volts
R = Resistance Ω

For power in milliwatts (10^{-3}W), and voltage in microvolts (10^{-6}V),

.❷ $$V_{dB(\mu V)} = P_{dBm} + 107$$

3 Power Density to Field Strength

An alternative measure of field strength to electric field is power density:

.❶ $$P_d = \frac{E^2}{120\pi}$$

where:

E = Field Strength (V / m)
P = Power Density (W / m^2)

Common Values:

E	P_D
200 V/m	10.60 mW/cm²
100 V/m	2.65 mW/cm²
10 V/m	26.50 µW/cm²
1 V/m	0.265 µW/cm²

4 Power Density at a Point

.❶ $$P_d = \frac{P_t G_t}{4\pi r^2}$$

In the far field, where the electric and magnetic fields are related by the impedance of free space:

P_d = Power Density (W / m^2)
P_t = Power Transmitted (W)
G_t = Gain of Transmitting Antenna
r = Distance from Antenna (meters)

5 Friis Transmission Formula

The Friss Transmission formula describes Power received by an antenna in terms of power transmitted by another antenna:

.❶ $$P_r = \frac{P_t G_t G_r \lambda^2}{(4 \pi r)^2}$$

where:

P_r = Power Received (W)

P_t = Power Transmitted (W)

G_r = Numeric Gain of Receiving Antenna

G_t = Numeric Gain of Transmitting Antenna

r = Separation Between Antennas (meters)

λ = Wavelength (meters).

6 Electric Field vs Power Transmitted (Far Field)

The electric field strength at a distance from a transmitting antenna such that the electric and magnetic field values are related by the impedance of free space is:

.❶ $$E_{V/m} = \frac{\sqrt{30 P_t G_t}}{r}$$

where the terms are as defined above.

For simple radiating devices having low gain, far field conditions exist when:

.❷ $$r \geq \frac{\lambda}{2 \pi}$$

where:

λ = Wavelength (meters)

For more complex antennas having higher gain values, far field conditions exist when:

.❸ $$r \geq \frac{2D^2}{\lambda}$$

where:

D = Maximum dimension of the antenna (m)

dB?

7 Relationship of Antenna Factor and Gain in a 50Ω System

.❶ $$G_{dB} = 20 \log \left(f_{MHz}\right) - AF_{dB(m^{-1})} - 29.79$$

8 Power Required to Generate a Desired Field Strength at a Given Distance when Antenna Factors are Known

.❶ $$P_{dB(W)} = 20 \log_{10} \left(E_{desired\,(V/m)}\right) + 20 \log_{10} \left(d_m\right) - 20 \log_{10} \left(f_{MHz}\right) + AF_{dB(m^{-1})} + 15$$

9 Relationship Between Frequency and Wavelength

.❶ $$f \lambda = c$$

where:

f = Frequency (Hz)

λ = Wavelength (meters)

c = Velocity of Light

= 3×10^8 m/s

a simpler relationship is:

.❷ $$\lambda = \frac{300}{f_{MHz}}$$

10 Decibel Formulas

A decibel is one tenth of a Bel, and is a ratio measure of relative amplitude. In terms of power, the number of decibels is ten times the logarithm to the base 10 of the ratio.

In terms of power:

.❶ $$dB = 10 \log_{10} \left(P_1 / P_2\right)$$

where P_1 and P_2 are in watts.

dB?

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$$r \geq \frac{2D^2}{\lambda}$$

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D = Maximum dimension of the antenna (m)

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$$P_{dB(W)} = 20 \log_{10} \left(E_{desired\,(V/m)}\right) + 20 \log_{10} \left(d_m\right) - 20 \log_{10} \left(f_{MHz}\right) + AF_{dB(m^{-1})} + 15$$

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In terms of power:

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$$dB = 10 \log_{10} \left(P_1 / P_2\right)$$

where P_1 and P_2 are in watts.

In a constant impedance system, power references can be made between different measurement points. They can also be related to voltage or current measurements:

.❷

$$\text{Power Ratio} = 10\log_{10}\left(P_1/P_2\right)$$

$$= 10\log_{10}\left(\frac{V_1^2/R_1}{V_2^2/R_2}\right)$$

$$= 20\log_{10}\left(\frac{V_1}{V_2}\right)$$

$$- 10\log_{10}\left(\frac{R_1}{R_2}\right)$$

for a constant impedance system.

.❸ $R_1 = R_2$

and:

.❹

$$\text{Pwr Ratio (dB)} = 20\log_{10}\left(\frac{V_1}{V_2}\right)$$

Also:

.❺ $G_{dB} = 10\log\left(g\right)$

.❻ $V_{dB(reference)} = 20\log\left(V/V_{reference}\right)$

.❼ $P_{dB(reference)} = 10\log\left(P/P_{reference}\right)$

where a typical reference for voltage is microvolts and a typical reference for power is milliwatts.

The reverse relationships are:

.❽ $g = 10^{G_{dB}/10}$

.❾ $V = 10^{V_{dB\,(reference)}/20}$

.❿ $P = 10^{P_{dB\,(reference)}/10}$

11 Transmit Antenna Factor

The transmit antenna factor of an antenna is computed from the gain or receive antenna factor, and is a measure of the transmitting capabilities of that antenna. It is valid under the conditions of measurement of the receive antenna factor, in a 50 Ω system.

.❶ $TAF_{dB(m^{-1})} = G_{dB} - 2.22 - 20\log_{10}\left(d_m\right)$

Where:

$TAF_{dB(m^{-1})}$ = Transmit Antenna Factor

G_{dB} = Antenna Gain of Transmitting Antenna

d_m = distance (m)

Alternatively:

.❷

$$TAF_{dB} = 20\log\left(f_{MHz}\right) - AF_{dBm^{-1}} - 32.0 - 20\log\left(r_m\right)$$

12 Computing Power Required for a Specific Field Intensity Given Power Required to Generate 1 Volt/meter

Antenna transmitting capabilities are often given in terms of the input power to an antenna to generate 1V/m at one or more distances. The input power required to develop a different electric field level value is found by:

.❶ $P_{dB(W)} = P_{dB(W)\,(1\,V/m)} + 20\log_{10}\left(E_{desired\,V/m}\right)$

Abbreviations & Symbols

SI Units

A/m	Ampere per meter
H	Henry
µA/m	Microampere per meter
T	Tesla
nT	Nanotesla
pT	Picotesla
Wb	Weber
S	Siemens
S/m	Siemens per meter

List of Equivalent SI Magnetic Units and Obsolete Units

$\mu_o = 4\pi \times 10^{-7}$ H/m

1 T = 1 Wm/m^2
1 T = 7.96 x 10^5 A/m
1 T = 10^4 gauss
1 T = 10^9 gamma

1 nT = 796 A/m
1 nT = 10^3 pT
1 nT = 10^{-5} gauss

1 µA/m = 1.256 x 10^{-3} nT
1 µA/m = 1.256 pT
1 µA/m = 1.256 x 10^{-8} gauss
1 µA/m = 1.256 x 10^{-3} gamma

1 pT = 0.796 µA/m
1 pT = 10^{-3} nT
1 pT = 10^{-8} gauss
1 pT = 10^{-3} gamma

1 gamma = 796 µA/m
1 gamma = 1 nT
1 gamma = 10^{-3} pT
1 gamma = 10^{-5} gauss

1 oersted = 1 gauss
0 dBµA/m = +2 dB(pT)

Gauss, oersted and gamma are obsolete terms, deprecated for modern usage.