RF and EMC Formulas and Charts

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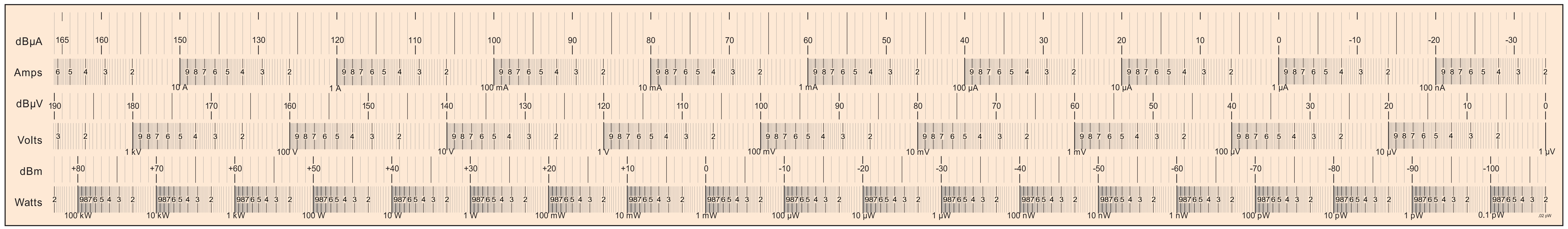
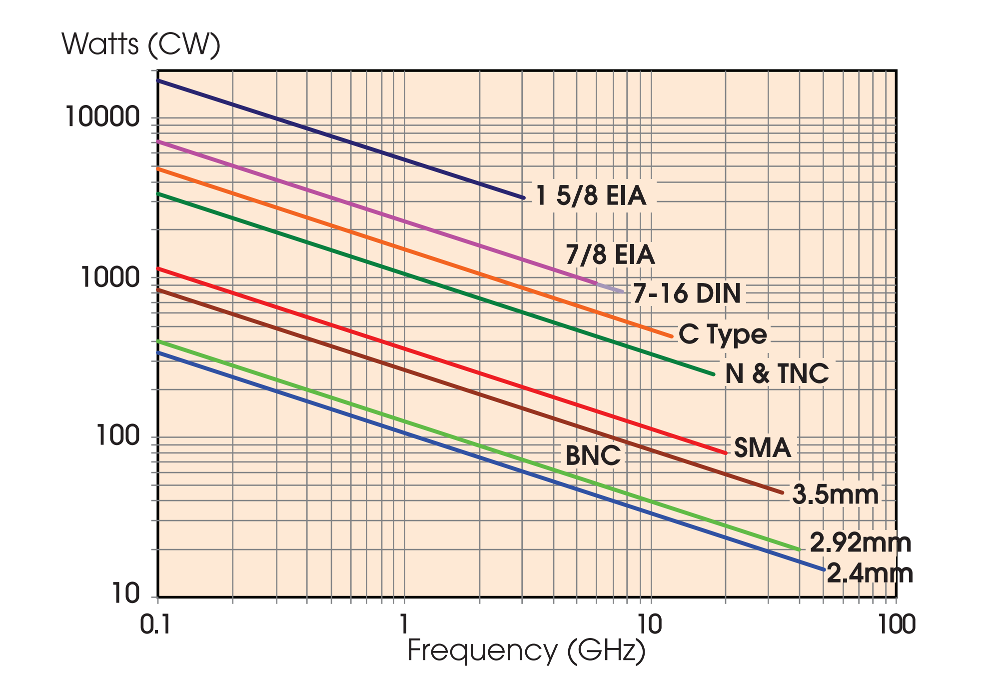
Conversions for 50Ω Environment



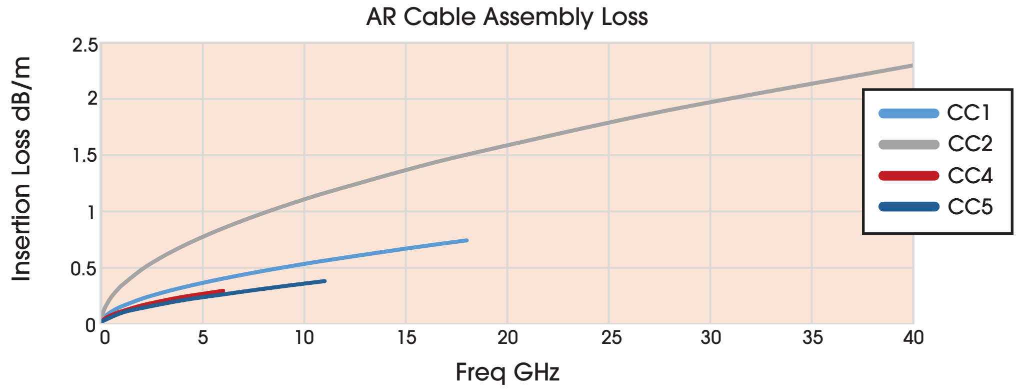
Connector Power Handling VS. Frequency



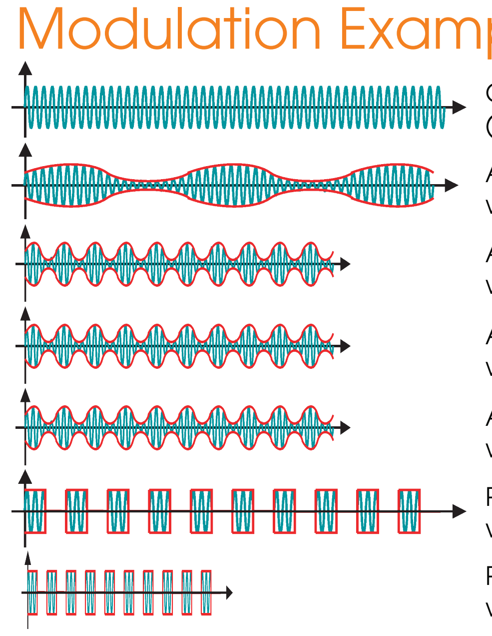
AR Cable Loss

AR offers a standard line of low loss microwave coaxial cables. The maximum operating frequency and power handling capability of the cable is determined by the lowest frequency or power connector.

AR Cable Assembly Loss



Modulation Examples



CW Continuous Wave (un-modulated signal)

AM (Medical equipments) with 2 Hz frequency and 80% modulation depth

AM (Telecom applications) with 1 kHz frequency and 80% modulation depth

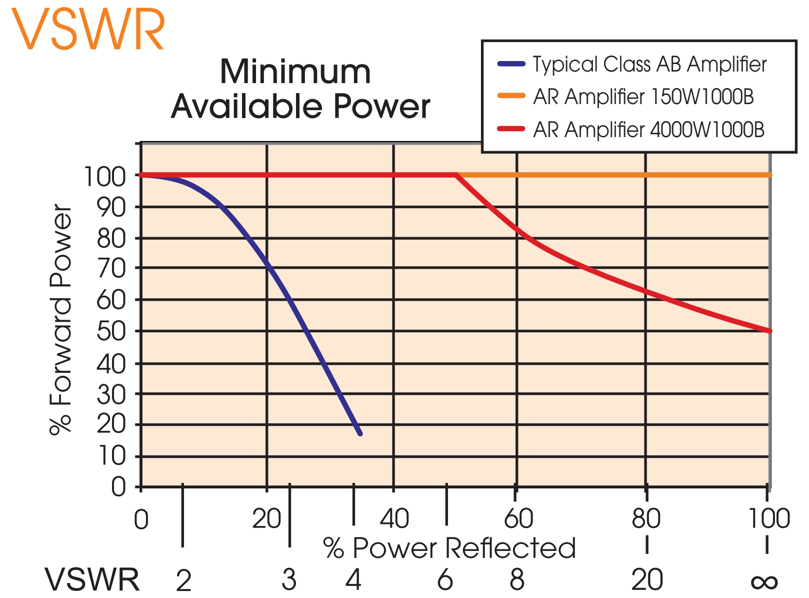
AM (IEC 61000-4-6) with 1 kHz frequency and 80% modulation depth

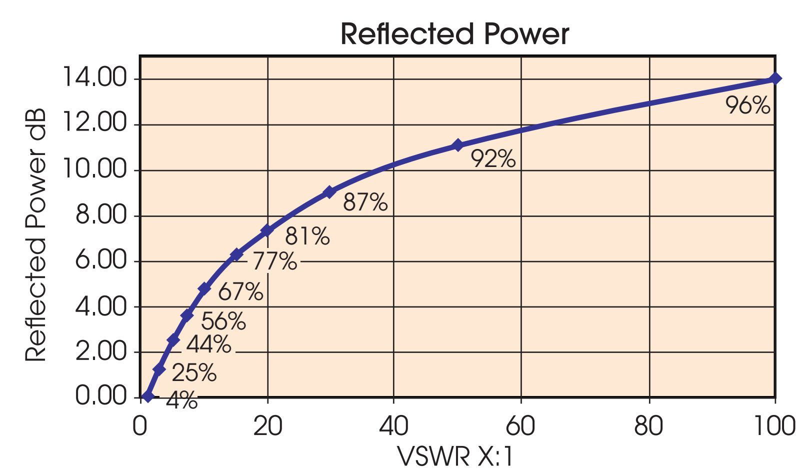
AM (ISO 11452) with 1 kHz frequency and 80% modulation depth

PM (alarm system components EN 50130-4) with 50% duty cycle and 1 Hz repetition

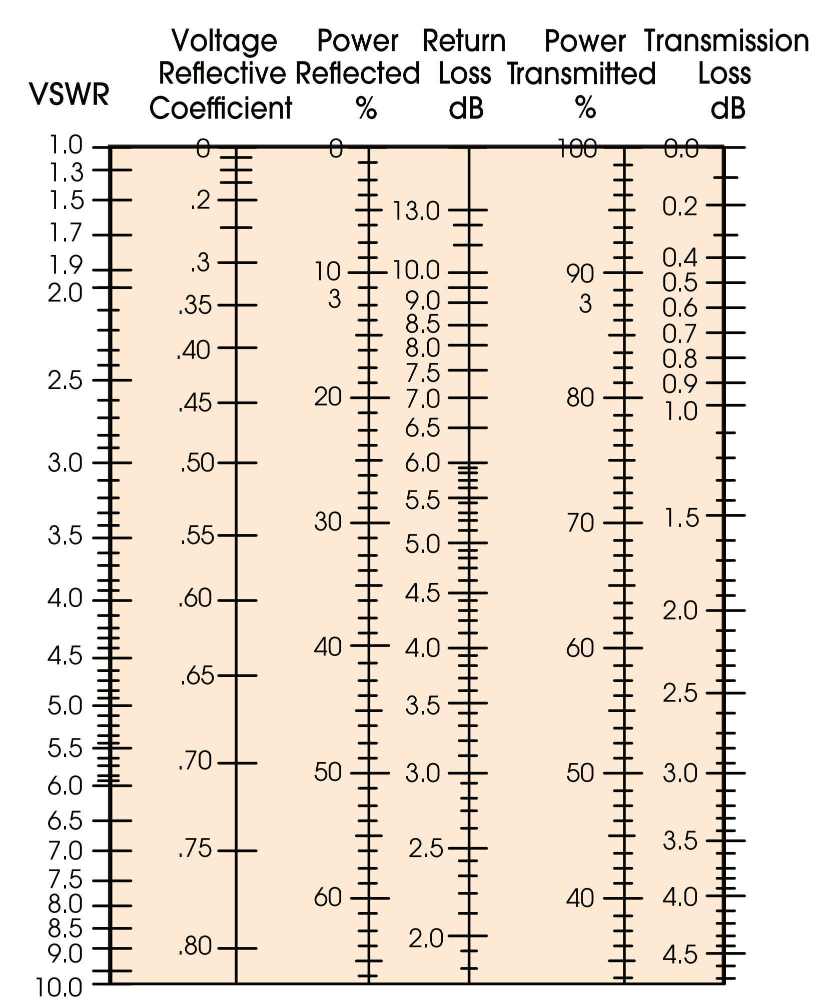
PM (MIL STD 461) with 50% duty cycle and 1 kHz repetition

VSWR





VSWR Conversion Chart



VSWR Calculations

VSWR = Voltage Standing Wave Ratio

$$VSWR = \frac{Emax}{Emin} = \frac{Vmax}{Vmin} = \frac{1+\rho}{1-\rho}$$

$$\frac{P_r}{P_f} = \left(\frac{VSWR-1}{VSWR+1}\right)^2$$

ρ = Reflection Coefficient

$$\rho = \left|\frac{Z_1 - Z_2}{Z_1 + Z_2}\right|$$

RL(dB)= Return Loss

$$RL(dB) = -20 \log(\rho)$$

ML(dB)= Mismatch Loss

$$ML(dB) = -10 \log(1-\rho^2)$$

$$\text{Power Reflected } \% = \rho^2 * 100$$

$$\text{Power Transmitted } \% = (1-\rho^2) * 100$$

Unit Conversions

Linear → Log

Volts to dBm	dBm = 20 * Log (Volts) + 13
Amps to dBm	dBm = 20 * Log (Amps) + 47
Watts to DbμV	dBμV = 10 * Log (Watts) + 137
Amps to DbμV	dBμV = 20 * Log (Amps) + 154
Watts to dBμA	dBμA = 10 * Log (Watts) + 103
Volts to dBμA	dBμA = 20 * Log (Volts) + 86

Linear → Log

Watts to dBm	dBm = 10 * Log (Watts) + 30
Volts to dBμV	dBm = 20 * Log (Volts) +120
Amps to dBμA	dBμA = 20 * Log (Amps) + 120
Ω to dB Ω	dBΩ = 20 * Log (Ω)

Log → Linear

dBm to Watts	$\text{Watts} = 10^{\left(\frac{dBm - 30}{10}\right)}$
dBμV to Volts	$\text{Volts} = 10^{\left(\frac{dB\mu V - 120}{20}\right)}$
dBμA to Amps	$\text{Amps} = 10^{\left(\frac{dB\mu A - 120}{20}\right)}$
dB Ω to Ω	$\Omega = 10^{\left(\frac{dB\Omega}{20}\right)}$

Log → Linear

dBμV to Watts	$\text{Watts} = 10^{\left(\frac{dB\mu V - 137}{10}\right)}$
dBμA to Watts	$\text{Watts} = 10^{\left(\frac{dB\mu A - 103}{10}\right)}$
dBm to Volts	$\text{Volts} = 10^{\left(\frac{dBm - 13}{20}\right)}$
dBμA to Volts	$\text{Volts} = 10^{\left(\frac{dB\mu A - 86}{20}\right)}$
dBm to Amps	$\text{Amps} = 10^{\left(\frac{dBm - 47}{20}\right)}$
dBμV to Amps	$\text{Amps} = 10^{\left(\frac{dB\mu V - 154}{20}\right)}$

Linearity/Gain

Linearity – an amplifier is said to be in its linear region when its output power is proportional to its input power and still capable of delivering additional power.

Gain – The ratio of amplifier output power to the input power.

1 dB compression point – this is the output power level where a 10 dB increase at the input produces a 9 dB increase in output power (10 dB – 9 dB = 1 dB).

3 dB compression point – the output power level where a 10 dB increase at the input only results in a 7 dB increase in output power (10 dB – 7 dB = 3 dB). Above this point the amplifier is said to be in "saturation."

Rated output power – the output power with a 0 dBm input.

Saturated power – here an increase in input power will have no increase in output power. At this point, the amplifiers is said to be in full saturation.

Input Power Levels

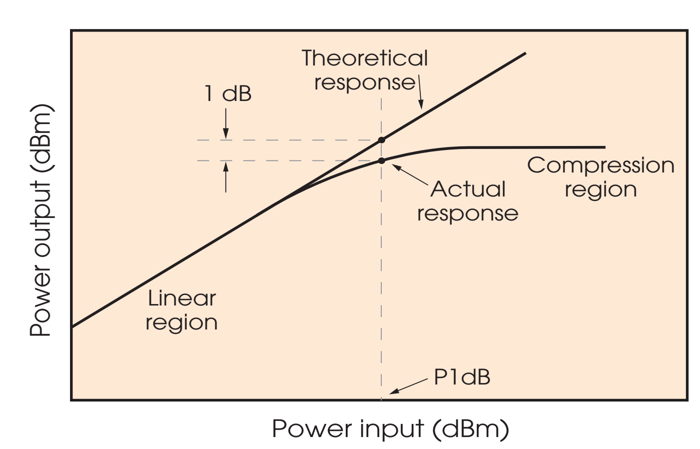
Signal Generator:	1 milliwatt which is equivalent to 0 dBm
Function Generator:	1 milliwatt or 224 millivolts rms into 50 Ω
Max input before damaging amplifier:	+13 dBm or 20 milliwatts (20 times more power than 0 dBm)

Gain

Frequently Used Decibel Conversions

dB	Power Ratio
0	1
1	1.26
3	2
6	4
10	10
13	20
17	50
20	100
30	1000

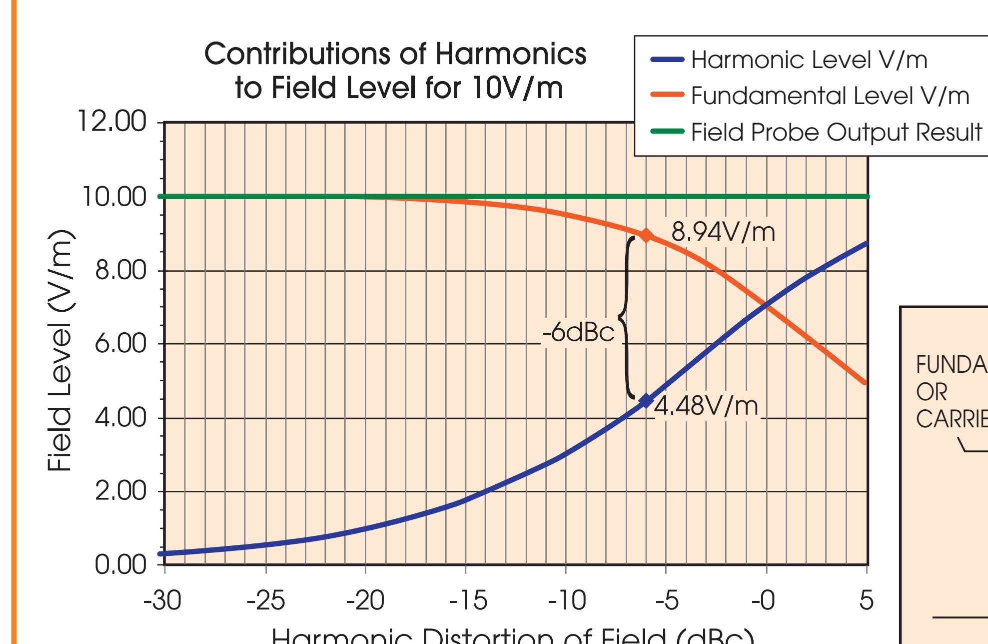
$$\text{Power Gain (dB)} = 10 \text{ Log}\left(\frac{\text{Output Power}}{\text{Input Power}}\right)$$

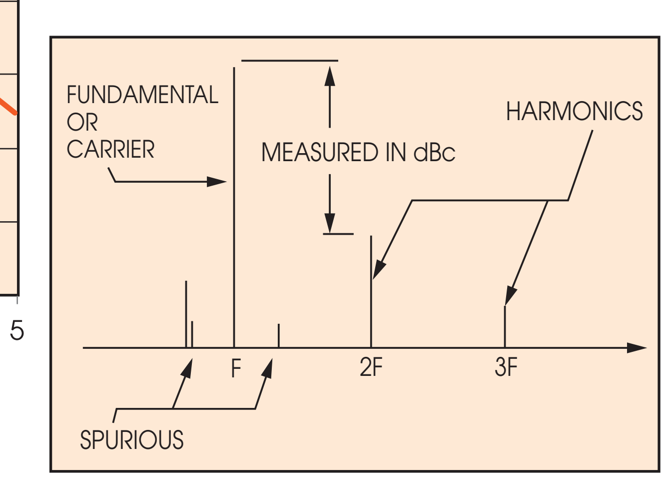


Harmonics

Harmonics are (usually unwanted) signals which are exact multiples of the operating frequency.

SPURIOUS are other unwanted signals. Amplifiers do not generate signals (other than IMD) unless they are unstable.





Note: dBc means dB below carrier.

Field & Power Calculations

Radiated Field Strength

dBμ V/m to V/m

$$V/m = 10^{\left(\frac{dB\mu V/m - 120}{20}\right)}$$

V/m to dBμ V/m

$$dB\mu V/m = 20 * \text{Log}(V/m) + 120$$

New V/m with dBΔ

$$V/m_{new} = 10^{\left(\frac{dB\Delta + 20*\text{Log}(V/m_{start})}{20}\right)}$$

$$V/m = \frac{\sqrt{30*\text{Watts}*\text{Gain}_{numeric}}}{\text{Meters}}$$

$$\text{Watts} = \frac{(V/m*\text{meters})^2}{30*\text{Gain}_{numeric}}$$

$$V/m = \frac{\sqrt{30*\text{Watts}*10_{numeric}^{\left(\frac{\text{Gain}_{dBi}}{10}\right)}}}{\text{Meters}}$$

$$\text{Watts} = \frac{(V/m*\text{meters})^2}{30*10^{\left(\frac{\text{Gain}_{dBi}}{10}\right)}}$$

Power Required for Field or Distance Change

Power required if gain remains constant (in far field using the same antenna and changing the field level or test distance)

For Field Change $\quad \text{Watts}_{New} = \text{Watts}_{Old} \frac{(V/m_{new})^2}{(V/m_{old})^2}$

For Distance Change $\quad \text{Watts}_{New} = \text{Watts}_{Old} \frac{(\text{Meters}_{New})^2}{(\text{Meters}_{Old})^2}$

Conducted Current Measurement Using a Current Probe

Where reading is in dBμV and probe factor is dBΩ or Ω

$$dB\mu A = dB\mu V - db\Omega$$

$$dB\mu A = dB\mu V - 20 * \text{Log}(\Omega)$$

Power Required for BCI Test

Power needed for BCI probe (50Ω) for given Insertion loss (IL(dB))

$$\text{Watts} = 10^{\left[\frac{IL + 10\cdot LOG\left(\text{Volts}^2/50\right)}{10}\right]}$$

$$\text{Watts} = 10^{\left[\frac{IL + 10\cdot LOG\left(\text{Amps}^2\cdot 50\right)}{10}\right]}$$

$$\text{Watts} = 10^{\left[\frac{IL + dB\mu A - 73}{10}\right]}$$

Power needed for BCI probe or EM Clamp (150Ω) for given Insertion loss (IL(dB))

$$\text{Watts} = 10^{\left[\frac{IL + 10\cdot LOG\left(\text{Volts}^2/150\right)}{10}\right]}$$

$$\text{Watts} = 10^{\left[\frac{IL + 10\cdot LOG\left(\text{Amps}^2\cdot 150\right)}{10}\right]}$$

Power Required for TEM Cell

Height of the TEM Cell

$$\text{Watts} = \frac{(V/m * \text{Height} * 0.5)^2}{Z_{(50\Omega)}}$$

Power Required for GTEM Cell

Height in meters

$$\text{Watts} = \frac{(V/m * \text{SeptumHeight})^2}{Z_{(50\Omega)}} * \text{flatness} * \text{modulation}$$

Antenna Equations

Far Field Distance Estimation
Dipole & Log-periodic antennas

$$\text{FarField} = \frac{\lambda}{2*\pi}$$

Horn Antennas

$$\text{FarField} = \frac{2*\text{aperature}^2}{\lambda}$$

Far Field Equations
Gain Over Isotropic

$$\text{Gain}_{Numeric} = 10^{\left(\frac{\text{Gain}_{dBi}}{10}\right)}$$

$$\text{Gain}_{dBi} = 10 * \text{Log}(\text{Gain}_{Numeric})$$

$$\text{Gain}_{Numeric} = \frac{(\text{Meters}*V/m)^2}{30*\text{Watts}}$$

$$\text{Gain}_{dBi} = 10 * \text{Log}\left(\frac{(\text{Meters}*V/m)^{20}}{30*\text{Watts}}\right)$$

$$\text{Gain}_{dBi} = 20 * \text{Log}(MHz) - AF - 29.79$$

Antenna Factor (AF)

$$AF = 20 * \text{Log}(MHz) - \text{Gain}_{dBi} - 29.79$$

$$AF = 20 * \text{Log}(MHz) - 10 * \text{Log}(\text{Gain}_{numeric}) - 29.79$$

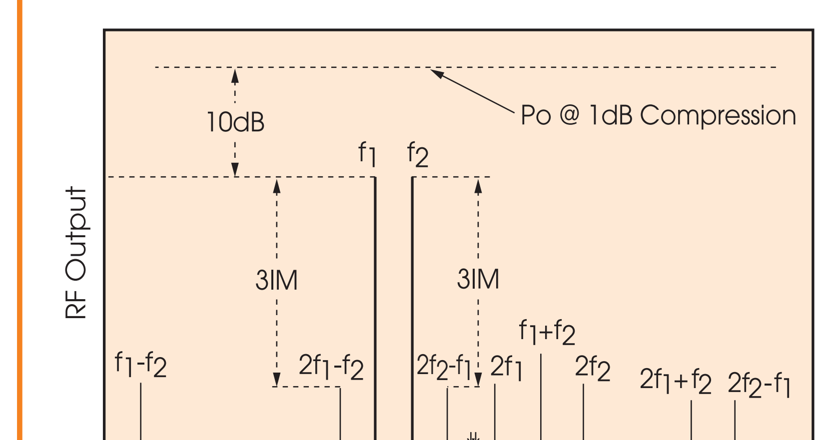
Find Antenna Spot Size, Beam Width and Distance

$$\text{Spot}_{meters} = 2 * \text{Distance}_{meters} \tan\left[\frac{\text{Angle}_{3\,dB}}{2}\right]$$

$$\text{Distance}_{meters} = \frac{\text{Spot}_{meters}}{2*\tan\left(\frac{\text{Angle}_{3\,dB}}{2}\right)}$$

$$\text{Angle}_{3\,dB} = 2 * \tan^{-1}\left[\frac{\text{Spot}_{meters}}{2*\text{distance}}\right]$$

Intermodulation Products (Multi-Tone)



Fundamental Tones and Intermodulation Products

$$IP_3 = \text{Power}(f_1 \,\&\, f_2) + \frac{3IM}{2},$$

where Power (f_1 & f_2) = the power in each fundamental signal, f_1 & f_2. (Note that $f_1 = f_2$)

In actual practice, to measure 3IM, the two fundamental tones are set at a level of 10dB below the 1dB compression point of the amplifier.

Thus, Power(f_1 & f_2) = Po (@ 1dB compression) – 10dB, where Po is the output power at the 1dB compression point of the amplifier.

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