# EMC Formulas

## Term Conversion in 50Ω Environment

### Log

**dBµV to dBm** $dBm = dB\mu V - 107$

**dBµA to dBm** $dBm = dB\mu A - 73$

**dBm to dBµV** $dB\mu V = dBm + 107$

**dBµA to dBµV** $dB\mu V = dB\mu A + 34$

**dBm to dBµA** $dB\mu A = dBm + 73$

**dBµV to dBµA** $dB\mu A = dB\mu V - 34$

### Log ⇦ Linear

**Volts to dBm** $dBm = 20 \bullet Log(Volts) + 13$

**Amps to dBm** $dBm = 20 \bullet Log(Amps) + 47$

**Watts to dBµV** $dB\mu V = 10 \bullet Log(watts) + 137$

**Amps to dBµV** $dB\mu V = 20 \bullet Log(Amps) + 154$

**Watts to dBµA** $dB\mu A = 10 \bullet Log(Watts) + 103$

**Volts to dBµA** $dB\mu A = 20 \bullet Log(Volts) + 86$

### Log ⇨ Linear

**dBµV to Watts** $Watts = 10^{\left(\frac{dB\mu V - 137}{10}\right)}$

**dBµA to Watts** $Watts = 10^{\left(\frac{dB\mu A - 103}{10}\right)}$

**dBm to Volts** $Volts = 10^{\left(\frac{dBm - 13}{20}\right)}$

**dBµA to Volts** $Volts = 10^{\left(\frac{dB\mu A - 86}{20}\right)}$

**dBm to Amps** $Amps = 10^{\left(\frac{dBm - 47}{20}\right)}$

**dBµV to Amps** $Amps = 10^{\left(\frac{dB\mu V - 154}{20}\right)}$

### Linear

**Volts to Watts** $Watts = \frac{Volts^2}{50}$

**Amps to Watts** $Watts = Amps^2 \bullet 50$

**Watts to Volts** $Volts = \sqrt{Watts \bullet 50}$

**Amps to Volts** $Volts = Amps \bullet 50$

**Watts to Amps** $Amps = \sqrt{\frac{Watts}{50}}$

**Volts to Amps** $Amps = \frac{Volts}{50}$

## Unit Conversion

### Log ⇦ Linear

**Watts to dBm** $dBm = 10 \bullet Log(Watts) + 30$

**Volts to dBµV** $dB\mu V = 20 \bullet \log(Volts) + 120$

**Amps to dBµA** $dB\mu A = 20 \bullet \log(Amps) + 120$

**Ω to dBΩ** $dB\Omega = 20 \bullet \log(\Omega)$

Used for the conversion of Voltage & Current

### Log ⇨ Linear

**dBm to Watts** $Watts = 10^{\left(\frac{dBm - 30}{10}\right)}$

**dBµV to Volts** $Volts = 10^{\left(\frac{dB\mu V - 120}{20}\right)}$

**dBµA to Amps** $Amps = 10^{\left(\frac{dB\mu A - 120}{20}\right)}$

**dBΩ to Ω** $\Omega = 10^{\left(\frac{dB\Omega}{20}\right)}$

## Term Conversion / Ohms law

### Log

**dBµV to dBm** $dBm = dB\mu V - 10 \bullet Log(\Omega) - 90$

**dBµA to dBm** $dBm = dB\mu A + 10 \bullet Log(\Omega) - 90$

**dBm to dBµV** $dB\mu V = dBm + 10 \bullet Log(\Omega) + 90$

**dBµA to dBµV** $dB\mu V = dB\mu A + 20 \bullet Log(\Omega)$

**dBm to dBµA** $dB\mu A = dBm - 10 \bullet Log(\Omega) + 90$

**dBµV to dBµA** $dB\mu A = dB\mu V - 20 \bullet Log(\Omega)$

### Linear

**Find Watts** $Watts = Amps^2 \bullet \Omega, \; Watts = \frac{Volts^2}{\Omega}$

**Find Volts** $Volts = Amps \bullet \Omega, \; Volts = \sqrt{Watts \bullet \Omega}$

**Find Amps** $Amps = \sqrt{\frac{Watts}{\Omega}}, \; Amps = \frac{Volts}{\Omega}$

### dB Calculations

**dB Δ Watts** $$dB = 10 Log\left(\frac{Watts_1}{Watts_2}\right)$$

**dB Δ Volts** $$dB = 20 Log\left(\frac{Volts_1}{Volts_2}\right)$$

**dB Δ Amps** $$dB = 20 Log\left(\frac{Amps_1}{Amps_2}\right)$$

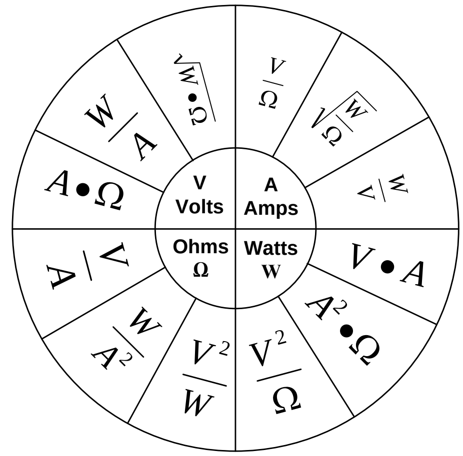
**New Watts w/dB Δ** $$Watts_{New} = 10^{\left(\frac{dB\Delta + 10 \bullet Log(Watts_{start})}{10}\right)}$$

**New Volts w/dB Δ** $$Volts_{New} = 10^{\left(\frac{dB\Delta + 20 \bullet Log(Volts_{start})}{20}\right)}$$

**New Amps w/dB Δ** $$Amps_{New} = 10^{\left(\frac{dB\Delta + 20 \bullet Log(Amps_{start})}{20}\right)}$$

dB Correction for distance change (antenna far field)

$$dB = 20 \bullet Log\left(\frac{\text{distance}_2}{\text{distance}_1}\right)$$




## Sine Wave

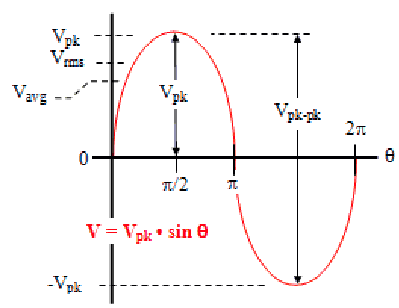
### Voltage levels for a sine wave

$$Volts_{peak} = \sqrt{2} \bullet Volts_{rms} = \frac{\pi}{2} \bullet Volts_{Avg}$$

$$Volts_{rms} = \frac{Volts_{peak}}{\sqrt{2}} = \frac{\pi}{2 \bullet \sqrt{2}} \bullet Volts_{Avg}$$

$$Volts_{avg} = \frac{2}{\pi} \bullet Volts_{peak} = \frac{2 \bullet \sqrt{2}}{\pi} \bullet Volts_{Avg}$$

$$Volts_{peak-peak} = 2 \bullet Volts_{peak}$$



## w/ Impedance of air = 377 Ω

**dBμV/m to dBm/m²** $dBm/m^2 = dB\mu V/m - 115.8$

**dBm/m² to dBμV/m** $dB\mu V/m = dBm/m^2 + 115.8$

**dBμA/m to dBμV/m** $dB\mu V/m = dB\mu A/m + 51.5$

**dBμV/m to dBμA/m** $dB\mu A/m = dB\mu V/m - 51.5$

**dBμA/m to dBpT** $dBpT = dB\mu A/m + 2$

**dBpT to dBμA/m** $dB\mu A/m = dBpT - 2$

**Watts/m² to V/m** $V/m = \sqrt{Watts/m^2 \bullet 377}$

**V/m to Watts/m²** $Watts/m^2 = \frac{{V/m}^2}{377}$

## Radiated Field

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

**V/m to dBμV/m** $dB\mu V/m = 20 \bullet Log(V/m) + 120$

**New V/m with dBΔ**

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

Interpolation values on a graph w/ Log of frequency
This equation works for finding all points on a test curve where test limit is sloping (i.e. DO 160F BCI testing)

$$value_{new} = \frac{Log\left(\frac{freq_{new}}{freq_{lower}}\right)}{Log\left(\frac{freq_{upper}}{freq_{lower}}\right)} \bullet (value_{upper} - value_{lower}) + Value_{lower}$$

## Current Injection

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

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

$$Watts = 10^{\left(\frac{IL + 10 \bullet LOG\left(Amps^2 \bullet 50\right)}{10}\right)}$$

$$Watts = 10^{\left(\frac{IL + dB\mu A - 73}{10}\right)}$$

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

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

$$Watts = 10^{\left(\frac{IL + 10 \bullet LOG\left(Amps^2 \bullet 150\right)}{10}\right)}$$

**Conducted current measurement using a current probe. Where reading is in dBμV and probe factor is dBΩ or Ω**

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

$$dB\mu A = dB\mu V - 20 \bullet Log(\Omega)$$

## Power needed for TEM Cell

$$Watts = \frac{\left(V/m \bullet Height \bullet 0.5\right)^2}{Z_{(50\Omega)}}$$

## Power needed for GTEM Cell

$$Watts = \frac{\left(V/m \bullet SpectrualHeight\right)^2}{Z_{(50\Omega)}} \bullet 1.08$$

## Wave length (λ)

$$\lambda[meters] = \frac{300}{MHz} \quad \tfrac{1}{4}\lambda[meters] = \frac{75}{MHz}$$

## Period

$$Time(s) = \frac{1}{Hz} \qquad Hz = \frac{1}{Time(s)}$$

# VSWR

### VSWR given Fwd/Rev power

$$VSWR = \frac{1 + \sqrt{\frac{Watts_{rev}}{Watts_{fwd}}}}{1 - \sqrt{\frac{Watts_{rev}}{Watts_{fwd}}}}$$

### VSWR given Return Loss (RL)

$$VSWR = \frac{1 + 10^{\left(\frac{-RL(dB)}{20}\right)}}{1 - 10^{\left(\frac{-RL(dB)}{20}\right)}}$$

### VSWR Given Impedance (Z)

$Z_O > Z_L$ $$VSWR = \frac{Z_O}{Z_L}$$

$Z_L > Z_O$ $$VSWR = \frac{Z_L}{Z_O}$$

### VSWR given reflection coefficient (Γ)

$$VSWR = \frac{1+\Gamma}{1-\Gamma}$$

## Reflection Coefficient (Γ)

$$\Gamma = \sqrt{\frac{Watts_{Rev}}{Watts_{Fwd}}}$$

$$\Gamma = \left|\frac{Z_{load} - Z_{Amp}}{Z_{load} + Z_{Amp}}\right|$$

$$\Gamma = \frac{VSWR-1}{VSWR+1}$$

$$\Gamma = 10^{\left(\frac{-RL(dB)}{20}\right)}$$

## Return Loss (RL) in dB

$$RL(dB) = -20 \bullet Log\left(\frac{VSWR-1}{VSWR+1}\right)$$

$$RL(dB) = 10 \bullet Log\left(\frac{Watts_{fwd}}{Watts_{rev}}\right)$$

$$RL(dB) = -20 \bullet Log(\Gamma)$$

## Transmission Loss (TL) in dB

$$TL(dB) = 10 \bullet Log\left(\frac{Watts_{fwd}}{Watts_{fwd} - Watts_{rev}}\right)$$

$$TL(dB) = -10 \bullet Log\left(1 - \Gamma^2\right)$$

$$TL(dB) = -10 \bullet Log\left(1 - \left(10^{\left(\frac{-RL(dB)}{20}\right)}\right)^2\right)$$

$$TL(dB) = -10 \bullet Log\left(1 - \left(\frac{VSWR-1}{VSWR+1}\right)^2\right)$$

## Antenna Equations

### Far Field Distance

**Dipole & Log-periodic antenna**

$$FarField = \frac{\lambda}{2 \bullet \pi}$$

**Horn antenna** $$FarField = \frac{2 \bullet apeture^2}{\lambda}$$

### Far Field Equations

**Gain over isotropic** $$Gain_{Numeric} = 10^{\left(\frac{Gain_{dBi}}{10}\right)}$$

$$Gain_{dBi} = 10 \bullet Log(Gain_{numeric})$$

$$Gain_{Numeric} = \frac{\left(Meters \bullet {}^{V}\!/_{m}\right)^2}{30 \bullet Watts}$$

$$Gain_{dBi} = 10 \bullet Log\left(\frac{\left(Meters \bullet {}^{V}\!/_{m}\right)^2}{30 \bullet Watts}\right)$$

$$Gain_{dBi} = 20 \bullet Log(MHz) - AF - 29.79$$

**Antenna Factor (AF)**

$$AF = 20 \bullet Log(MHz) - Gain_{dBi} - 29.79$$

$$AF = 20 \bullet Log(MHz) - 10 \bullet Log(Gain_{numeric}) - 29.79$$

**Find Antenna Spot size, Beam Width and Distance**

$$Spot_{meters} = 2 \bullet \text{Distance}_{meters} \tan\left[\frac{Angle_{3dB}}{2}\right]$$

$$\text{Distance}_{meters} = \frac{Spot_{meters}}{2 \bullet \tan\left(Angle_{3dB}/2\right)}$$

$$Angle_{3dB} = 2 \bullet \tan^{-1}\left[\frac{Spot_{meters}}{2 \bullet \text{Distance}}\right]$$

## Field Strength

$$V/m = \frac{\sqrt{30 \bullet Watts \bullet Gain_{numeric}}}{Meters}$$

$$V/m = \frac{\sqrt{30 \bullet Watts \bullet 10^{\left(\frac{Gain_{dBi}}{10}\right)}}}{Meters}$$

$$Watts = \frac{\left({}^{V}\!/_{m} \bullet meters\right)^2}{30 \bullet Gain_{numeric}}$$

$$Watts = \frac{\left({}^{V}\!/_{m} \bullet meters\right)^2}{30 \bullet 10^{\left(\frac{Gain_{dBi}}{10}\right)}}$$

**Power needed if gain remains constant (in Far Field) using same antenna and changing field level or test distance.**

**For Field Change** $$Watts_{New} = Watts_{Old} \frac{\left({}^{V}\!/_{m\,New}\right)^2}{\left({}^{V}\!/_{m\,Old}\right)^2}$$

**For Distance Change**

$$Watts_{New} = Watts_{Old} \frac{\left(Meters_{New}\right)^2}{\left(Meters_{Old}\right)^2}$$

### Power for given Amplitude Modulation %

$$Watts_{peak} = Watts_{CW} \bullet \left(1 + (\% \bullet 0.01)\right)^2$$

$$Watts_{avg} = \frac{Watts_{CW} \bullet \left(2 + (\% \bullet 0.01)^2\right)}{2}$$

$$Watts_{avg} = \frac{Watts_{peak} \bullet \left(2 + (\% \bullet 0.01)^2\right)}{2 \bullet \left(1 + (\% \bullet 0.01)\right)^2}$$

### Power for given Pulse Modulation Duty Cycle %

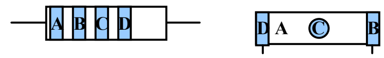
$$Watts_{peak} = \frac{Watts_{avg}}{\% \bullet 0.01}$$

## Useful conversions

1 in = 0.0254 m
1 ft = 0.3048 m
1 yd = 0.9144 m
1 in$^2$ = 0.00064516 m$^2$
1 ft$^2$ = 0.092903 m$^2$
1 yd$^2$ = 0.83612736 m$^2$
1 in$^3$ = 0.000016387064 m$^3$
1 ft$^3$ = 0.028316846 m$^3$
1 yd$^3$ = 0.764554858 m$^3$
1 lb = 0.45359237 kg
1 psi. = 6,894.7573 Pa (Pascal)
1 hp = 550 ft•lb/sec = 745.6999 Watts
°C = (°F-32)/1.8

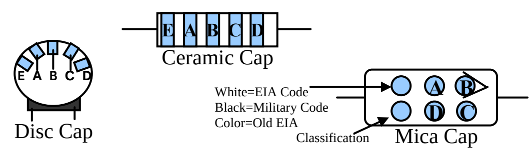
| | | |
|---|---|---|
| 1,000,000,000,000,000,000,000,000 = $10^{24}$ | yotta | Y |
| 1,000,000,000,000,000,000,000 = $10^{21}$ | zetta | Z |
| 1,000,000,000,000,000,000 $10^{18}$ | exa | E |
| 1,000,000,000,000,000 = $10^{15}$ | peta | P |
| 1,000,000,000,000 = $10^{12}$ | tera | T |
| 1,000,000,000 = $10^{9}$ | giga | G |
| 1,000,000 = $10^{6}$ | mega | M |
| 1,000 = $10^{3}$ | kilo | k |
| 100 = $10^{2}$ | hecto | h |
| 0.01 = $10^{-2}$ | centi | c |
| 0.001 = $10^{-3}$ | milli | m |
| 0.000001 = $10^{-6}$ | micro | µ |
| 0.000000001 = $10^{-9}$ | nano | n |
| 0. 000000000001 = $10^{-12}$ | pico | p |
| 0. 000000000000001 = $10^{-15}$ | femto | f |
| 0. 000000000000000001 = $10^{-18}$ | atto | a |
| 0. 000000000000000000001 = $10^{-21}$ | zepto | z |
| 0. 000000000000000000000001 = $10^{-24}$ | yocto | y |

## Resistor Color Codes




| 1st (A) | 2nd (B) | Multiplier (C) | Tolerance (D) | Color |
|---|---|---|---|---|
| 0 | 0 | 1 | 1% | Black |
| 1 | 1 | 10 | 2% | Brown |
| 2 | 2 | 100 | 3% | Red |
| 3 | 3 | $10^3$ | 4% | Orange |
| 4 | 4 | $10^4$ | | Yellow |
| 5 | 5 | $10^5$ | | Green |
| 6 | 6 | $10^6$ | | Blue |
| 7 | 7 | $10^7$ | | Violet |
| 8 | 8 | $10^8$ | | Gray |
| 9 | 9 | $10^9$ | | White |
| Gold | | 0.1 | 5% | |
| Silver | | 0.01 | 10% | |
| No color | | | 20% | |

## Capacitor Color Codes




Color Codes for Ceramic Caps

| Multiplier (C) | Tolerance (D) Above 10pf | Tolerance (D) Below 10pf | Temp Coef ppm/°C (E) | Color |
|---|---|---|---|---|
| 1 | 20 | 2.0 | 0 | Black |
| 10 | 1 | | -30 | Brown |
| 100 | 2 | | -80 | Red |
| 1000 | 3 | | -150 | Orange |
| | 4 | | -220 | Yellow |
| | 5 | 0.5 | -330 | Green |
| | 6 | | -470 | Blue |
| | 7 | | -750 | Violet |
| 0.01 | 8 | 0.25 | 30 | Gray |
| 0.1 | 10 | 1.0 | 500 | White |