



Useful RF Formulas & Relationships

Resistance (ohm):

$$R = \frac{l_c}{A} \cdot \delta; \quad \delta_{Cu} = \frac{1}{5.8 \cdot 10^7} \Omega \cdot m$$

l_c : Length of conductor
 A : Cross area of conductor (e.g. *Width · Height*, or $r^2 \cdot \pi$)
 δ : Conductivity

The capacitance of a plate capacitor (Farad):

$$C = \frac{A}{d} \cdot \epsilon_r \cdot 8.8541878176 \cdot 10^{-12}$$

A : Area, d : Distance, ϵ_r : Relative permittivity.

Voltage standing wave ratio:

$$VSWR = \frac{1 + |\gamma|}{1 - |\gamma|}$$

γ : Voltage reflection coefficient

Reflection coefficient:

$$|\gamma| = \frac{VSWR - 1}{VSWR + 1}$$

VSWR: Standing wave ratio

$$\gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Z_0 : Reference impedance, Z_L : Load impedance

Return loss (dB):

$$RL = -20 \cdot \log(|\gamma|)$$

γ : Voltage reflection coefficient

Load impedance (ohm):

$$Z_L = \frac{1 + \gamma}{1 - \gamma} \cdot Z_0$$

Z_0 : Reference impedance, γ : Voltage reflection coefficient.

VSWR improvement by inserting attenuation:

$$VSWR_{in} = \frac{1 + 10^{-A/10} \cdot \frac{VSWR_{out} - 1}{VSWR_{out} + 1}}{1 - 10^{-A/10} \cdot \frac{VSWR_{out} - 1}{VSWR_{out} + 1}}$$

A : Loss in attenuator [dB]. Positive number.
 $VSWR_{out}$: Standing wave ratio the load presents to the attenuator



Q's, L is inductance [H], R resistance [Ω], f frequency [Hz], C capacitance [F]:

Series connection

$$Q_L = \frac{2\pi \cdot f \cdot L}{R_s} \quad R_s = \frac{2\pi \cdot f \cdot L}{Q_L}$$

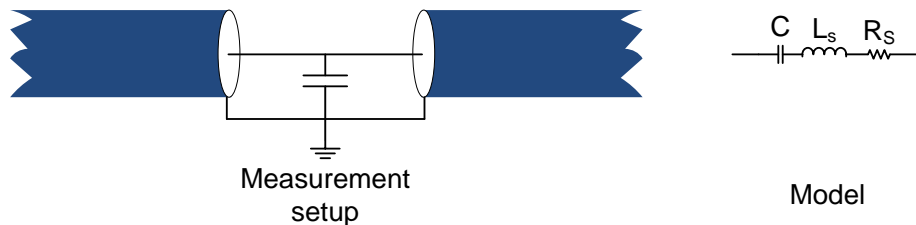
$$Q_C = \frac{1}{2\pi \cdot f \cdot C \cdot R_s} \quad R_s = \frac{1}{2\pi \cdot f \cdot C \cdot Q_C}$$

Parallel connection

$$Q_L = \frac{R_p}{2\pi \cdot f \cdot L} \quad R_p = 2\pi \cdot f \cdot L \cdot Q_L$$

$$Q_C = 2\pi \cdot f \cdot C \cdot R_p \quad R_p = \frac{Q_C}{2\pi \cdot f \cdot C}$$

Measuring capacitor model parameters using S21 measurements (C placed in parallel with transmission line):



Series resistance (ohm):

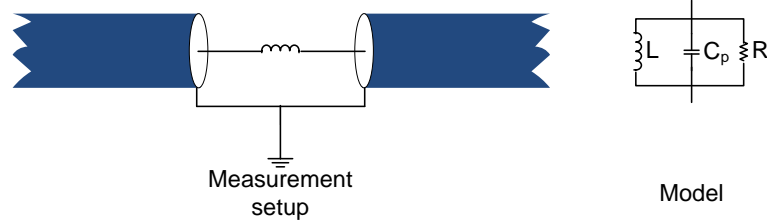
$$R_s = \frac{25 \cdot 10^{S21_{dB}/20}}{1 - 10^{S21_{dB}/20}} \quad S21_{dB}: S21 \text{ magnitude in dB.}$$

Series inductance [H]:

$$L_s = \frac{1}{C \cdot (2\pi \cdot f_{res})^2} \quad f_{res}: \text{Resonance frequency [Hz]}$$



Measuring inductor model parameters using S21 measurements (L placed in series with transmission line):



Parallel resistance (ohm):

$$R_p = \frac{100 \cdot (1 - 10^{S21_{dB}/20})}{10^{S21_{dB}/20}} \quad S21_{dB}: S21 \text{ magnitude in dB.}$$

Parallel capacitance [F]:

$$C_p = \frac{1}{L \cdot (2\pi \cdot f_{res})^2} \quad f_{res}: \text{Resonance frequency [Hz]}$$

European/US versus Japanese standard SMD component sizes:

“Inch”	≡	“mm”
01005	≡	0402
0201	≡	0603
0402	≡	1005
0603	≡	1608
0805	≡	2012
1206	≡	3216
1210	≡	3225