Subject: Effect of Pads on VSWR **Date:** March 20, 2012
Reference(s): **Author:** Jeff Crawford

$$\cosh(\alpha + j\beta) = \cosh(\alpha)\cos(\beta) + j\sinh(\alpha)\sin(\beta)$$
$$\sinh(\alpha + j\beta) = \sinh(\alpha)\cos(\beta) + j\cosh(\alpha)\sin(\beta)$$

$$\tanh(\alpha + j\beta) = \frac{1}{2}\frac{\sinh(2\alpha) + j\sin(2\beta)}{\cosh^2(\alpha)\cos^2(\beta) + \sinh^2(\alpha)\sin^2(\beta)}$$

$$\cos(\alpha + j\beta) = \cosh(\beta)\cos(\alpha) - j\sinh(\beta)\sin(\alpha)$$
$$\sin(\alpha + j\beta) = \cosh(\beta)\sin(\alpha) + j\sinh(\beta)\cos(\alpha)$$

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

If powers are measured at the same impedance level, then the dB ratio of voltages and currents becomes

$$Voltage\ dB = 20\log_{10}\left(\frac{V_1}{V_2}\right) \qquad Current\ dB = 20\log_{10}\left(\frac{I_1}{I_2}\right)$$

One should not attempt to convert dB voltage and current ratios to power ratios without knowledge of the impedances across which they are measured.

Attenuation in nepers: $N = \ln\left(\frac{V_1}{V_2}\right)$

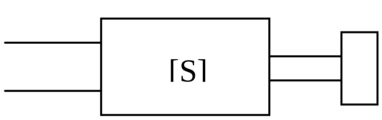
In terms of the ratio of input power to output power at the same impedance level: $N = \frac{1}{2}\ln\left(\frac{P_1}{P_2}\right)$

$$\alpha = \ln\left(\frac{V_1}{V_2}\right) \qquad e^{\alpha} = \frac{V_1}{V_2}$$

$$20\log_{10}\left(\frac{V_1}{V_2}\right) = 20\log_{10}\left(e^{\alpha}\right) \qquad dB = 20\,\alpha\log_{10}(e)$$

α is the attenuation in nepers

$$dB = 8.686\,\alpha$$



Load

$$S_{11}' = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L}$$

Power gain: $P = 10\log_{10}\left(|S_{21}|^2\right)$ *and* $|S_{21}| = |S_{12}|$ so: $|S_{21}| = |S_{12}| = 10^{P/20}$

Example:
A pad of 6 dB. Output VSWR to match is 1.65

$$\Gamma_L = \frac{VSWR-1}{VSWR+1} = \frac{1.65-1}{1.65+1} = 0.24528 \quad \Rightarrow 20\log_{10}\left(0.24528\right) = -12.21dB$$

For the 6 dB pad, $\left|S_{21}\right| = \left|S_{12}\right| = 10^{-6/20} = 0.501187$

Inserting into $S_{11}' = S_{11} + \dfrac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L}$

$$S_{11}' = S_{11} + \frac{\left(0.501187\right)^2 0.24528}{1-0} = 0.061612$$

Now translate this S_{11} term into VSWR:

$$VSWR = \frac{1+\left|S_{11}\right|}{1-\left|S_{11}\right|} = \frac{1+0.061612}{1-0.061612} = 1.1313$$

$$\text{Return Loss} = 20\log_{10}\left(\frac{VSWR-1}{VSWR+1}\right) = \; -24.2\ dB$$

Check: With the pad inserted the return loss should equal the original return loss at VSWR = 1.65:1, improved by twice the loss of the pad (2 * 6 dB).

Original return loss of 12.21 dB + 2 x 6 dB equals 24.21 dB return loss. Check

