Return Loss and VSWR

The **ratio** of the **reflected power** from a load, to the **incident power** on that load, is known as **return loss**.

Typically, return loss is expressed in **dB**:

$$R.L. = -10 \log_{10}\left[\frac{P_{ref}}{P_{inc}}\right] = -10 \log_{10} |\Gamma_L|^2$$

The return loss thus tells us the **percentage** of the **incident** power **reflected** by load (expressed in **decibels**!).

A larger "loss" is better!

For **example**, if the return loss is **10dB**, then **10%** of the incident power is **reflected** at the load, with the remaining **90%** being **absorbed** by the load—we "lose" 10% of the incident power

Likewise, if the return loss is **30dB**, then **0.1 %** of the incident power is **reflected** at the load, with the remaining **99.9%** being **absorbed** by the load—we "lose" 0.1% of the incident power.

➔ Thus, a **larger** numeric value for return loss **actually** indicates **less** lost power!

An **ideal** return loss would be $\infty \, dB$, whereas a return loss of 0 dB indicates that $|\Gamma_L| = 1$—the load is **reactive**!

> Return loss is helpful, as it provides a **real-valued** measure of load match (as opposed to the complex values Z_L and Γ_L).

Voltage Standing Wave Ratio

Another traditional real-valued measure of load match is **Voltage Standing Wave Ratio** (VSWR).

Consider again the **voltage** along a terminated transmission line, as a function of **position** z :

$$V(z) = V_0^+\left[e^{-j\beta z} + \Gamma_L\, e^{+j\beta z}\right]$$

Recall this is a **complex** function, the magnitude of which expresses the **magnitude** of the **sinusoidal signal** at position z, while the phase of the complex value represents the relative **phase** of the sinusoidal signal.

Let's look at the **magnitude** only:

$$\begin{aligned} |V(z)| &= |V_0^+|\ \left|e^{-j\beta z} + \Gamma_L\, e^{+j\beta z}\right| \\ &= |V_0^+|\ \left|e^{-j\beta z}\right|\ \left|1 + \Gamma_L\, e^{+j2\beta z}\right| \\ &= |V_0^+|\ \left|1 + \Gamma_L\, e^{+j2\beta z}\right| \end{aligned}$$

VSWR depends on $|\Gamma_L|$ only

It can be shown that the **largest** value of $|V(z)|$ occurs at the location z where:

$$\Gamma_L e^{+j2\beta z} = |\Gamma_L| + j0$$

while the **smallest** value of $|V(z)|$ occurs at the location z where:

$$\Gamma_L e^{+j2\beta z} = -|\Gamma_L| + j0$$

As a result we can conclude that:

$$|V(z)|_{max} = |V_0^+|\left(1 + |\Gamma_L|\right) \qquad |V(z)|_{min} = |V_0^+|\left(1 - |\Gamma_L|\right)$$

The ratio of $|V(z)|_{max}$ to $|V(z)|_{min}$ is known as the **Voltage Standing Wave Ratio** ($VSWR$):

$$\boxed{VSWR \doteq \frac{|V(z)|_{max}}{|V(z)|_{min}} = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|} \qquad \therefore \qquad 1 \le VSWR \le \infty}$$

VSWR = 1 if matched, bigger if not!

Note if $|\Gamma_L| = 0$ (i.e., $Z_L = Z_0$), then $VSWR = 1$.

We find for **this** case:

$$|V(z)|_{max} = |V(z)|_{min} = |V_0^+|$$

In other words, the voltage magnitude is a **constant** with respect to position z.

Conversely, if $|\Gamma_L| = 1$ (i.e., $Z_L = jX$), then $VSWR = \infty$.

We find for **this** case:

$$|V(z)|_{min} = 0 \qquad \text{and} \qquad |V(z)|_{max} = 2|V_0^+|$$

In other words, the voltage magnitude varies **greatly** with respect to position z.

A plot of the total voltage magnitude

As with **return loss**, *VSWR* is dependent on the **magnitude** of Γ_L (i.e, $|\Gamma_L|$) **only** !