

# 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  $\Gamma_L$ ).

## 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:

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

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

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

## 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:

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

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  $\Gamma_L$  (i.e.,  $|\Gamma_L|$ ) **only** !

