21.14: Standing Wave Ratio

Precise matching of transmission lines to terminations is often not practical or possible. Whenever a significant mismatch exists, a standing wave (Section 3.13) is apparent. The quality of the match is commonly expressed in terms of the *standing wave ratio* (SWR) of this standing wave.

> *Standing wave ratio* (SWR) is defined as the ratio of the maximum magnitude of the standing wave to minimum magnitude of the standing wave.

In terms of the potential:

$$\boxed{\text{SWR} \triangleq \frac{\text{maximum } |\widetilde{V}|}{\text{minimum } |\widetilde{V}|}}$$

SWR can be calculated using a simple expression, which we shall now derive. In Section 3.13, we found that:

$$\left|\widetilde{V}(z)\right| = |V_0^+| \sqrt{1 + |\Gamma|^2 + 2\,|\Gamma| \cos(2\beta z + \phi)}$$

The maximum value occurs when the cosine factor is equal to $+1$, yielding:

$$\max \left|\widetilde{V}\right| = |V_0^+| \sqrt{1 + |\Gamma|^2 + 2\,|\Gamma|}$$

Note that the argument of the square root operator is equal to $(1 + |\Gamma|)^2$; therefore:

$$\max \left|\widetilde{V}\right| = |V_0^+|\,(1 + |\Gamma|)$$

Similarly, the minimum value is achieved when the cosine factor is equal to -1, yielding:

$$\min \left|\widetilde{V}\right| = |V_0^+| \sqrt{1 + |\Gamma|^2 - 2\,|\Gamma|}$$

So:

$$\min \left|\widetilde{V}\right| = |V_0^+|\,(1 - |\Gamma|)$$

Therefore:

$$\boxed{\text{SWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}} \tag{21.14.1}$$

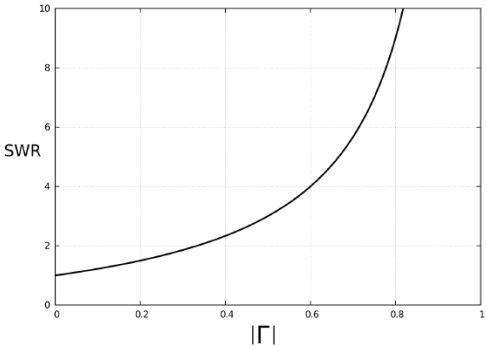

Figure 21.14.1 Relationship between SWR and $|\Gamma|$.

This relationship is shown graphically in Figure 21.14.1. Note that SWR ranges from 1 for perfectly-matched terminations ($\Gamma = 0$) to infinity for open- and short-circuit terminations ($|\Gamma| = 1$).

It is sometimes of interest to find the magnitude of the reflection coefficient given SWR. Solving Equation 21.14.1 for $|\Gamma|$ we find:

$$|\Gamma| = \frac{\text{SWR} - 1}{\text{SWR} + 1} \tag{21.14.2}$$

SWR is often referred to as the *voltage standing wave ratio* (VSWR), although repeating the analysis above for the current reveals that the current SWR is equal to potential SWR, so the term “SWR” suffices.

SWR < 2 or so is usually considered a “good match,” although some applications require SWR < 1.1 or better, and other applications are tolerant to SWR of 3 or greater.

Example 21.14.1: Reflection Coefficient for Various Values of SWR

What is the reflection coefficient for the above-cited values of SWR? Using Equation 21.14.2, we find:

- SWR = 1.1 corresponds to $|\Gamma| = 0.0476$.
- SWR = 2.0 corresponds to $|\Gamma| = 1/3$.
- SWR = 3.0 corresponds to $|\Gamma| = 1/2$.

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