

3.18: Measurement of Transmission Line Characteristics

This section presents a simple technique for measuring the characteristic impedance Z_0 , electrical length βl , and phase velocity v_p of a lossless transmission line. This technique requires two measurements: the input impedance Z_{in} when the transmission line is short-circuited and Z_{in} when the transmission line is open-circuited.

In Section 3.16, it is shown that the input impedance Z_{in} of a short-circuited transmission line is

$$Z_{in}^{(SC)} = +jZ_0 \tan \beta l$$

and when a transmission line is terminated in an open circuit, the input impedance is

$$Z_{in}^{(OC)} = -jZ_0 \cot \beta l$$

Observe what happens when we multiply these results together:

$$Z_{in}^{(SC)} \cdot Z_{in}^{(OC)} = Z_0^2$$

that is, the product of the measurements $Z_{in}^{(OC)}$ and $Z_{in}^{(SC)}$ is simply the square of the characteristic impedance. Therefore

$$Z_0 = \sqrt{Z_{in}^{(SC)} \cdot Z_{in}^{(OC)}}$$

If we instead divide these measurements, we find

$$\frac{Z_{in}^{(SC)}}{Z_{in}^{(OC)}} = -\tan^2 \beta l$$

Therefore:

$$\tan \beta l = \left[-\frac{Z_{in}^{(SC)}}{Z_{in}^{(OC)}} \right]^{1/2}$$

If l is known in advance to be less than $\lambda/2$, then the electrical length βl can be determined by taking the inverse tangent. If l is of unknown length and longer than $\lambda/2$, one must take care to account for the periodicity of tangent function; in this case, it may not be possible to unambiguously determine βl . Although we shall not present the method here, it is possible to resolve this ambiguity by making multiple measurements over a range of frequencies.

Once βl is determined, it is simple to determine l given β , β given l , and then v_p . For example, the phase velocity may be determined by first finding βl for a known length using the above procedure, calculating $\beta = (\beta l) / l$, and then $v_p = \omega / \beta$.

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