

## 21.6: Lumped-Element Model

It is possible to ascertain the relevant behaviors of a transmission line using elementary circuit theory applied to a differential-length lumped-element model of the transmission line. The concept is illustrated in Figure 21.6.1, which shows a generic transmission line aligned with its length along the  $z$  axis. The transmission line is divided into segments having small but finite length  $\Delta z$ . Each segment is modeled as an identical two-port having the equivalent circuit representation shown in Figure 21.6.2. The equivalent circuit consists of 4 components as follows:

- The resistance  $R'\Delta z$  represents the series-combined ohmic resistance of the two conductors. This should account for *both* conductors since the current in the actual transmission line must flow through both conductors. The prime notation reminds us that  $R'$  is resistance *per unit length*; i.e.,  $\Omega/\text{m}$ , and it is only after multiplying by length that we get a resistance in  $\Omega$ .
- The conductance  $G'\Delta z$  represents the leakage of current directly from one conductor to the other. When  $G'\Delta z > 0$ , the resistance between the conductors is less than infinite, and therefore, current may flow between the conductors. This amounts to a loss of power separate from the loss associated with  $R'$  above.  $G'$  has units of  $\text{S}/\text{m}$ . Further note that  $G'$  is *not* equal to  $1/R'$  as defined above.  $G'$  and  $R'$  are describing entirely different physical mechanisms (and in principle *either* could be defined as either a resistance or a conductance).
- The capacitance  $C'\Delta z$  represents the capacitance of the transmission line structure. Capacitance is the tendency to store energy in electric fields and depends on the cross-sectional geometry and the media separating the conductors.  $C'$  has units of  $\text{F}/\text{m}$ .
- The inductance  $L'\Delta z$  represents the inductance of the transmission line structure. Inductance is the tendency to store energy in magnetic fields, and (like capacitance) depends on the cross-sectional geometry and the media separating the conductors.  $L'$  has units of  $\text{H}/\text{m}$ .

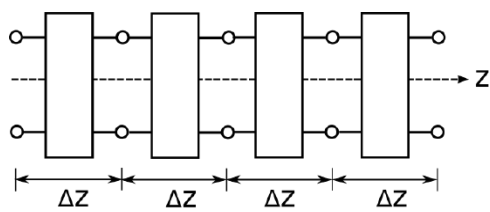
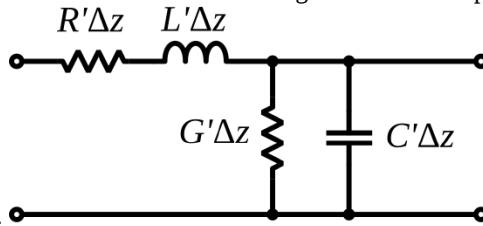


Figure 21.6.1 Interpretation of a transmission line as a cascade of discrete series-



connected two-ports. Figure 21.6.1 Lumped-element equivalent circuit model for each of the two-ports in Figure 21.6.2 (CC BY SA 3.0 Unported (modified))

In order to use the model, one must have values for  $R'$ ,  $G'$ ,  $C'$ , and  $L'$ . Methods for computing these parameters are addressed elsewhere in this book.

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