How to use SPICE transmission line models

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Why do SPICE users get unexpected results when using transmission lines? Because the SPICE model is a device that doesn't exist in the physical world.

What is a transmission line? There are lots of definitions available, for instance this typical one:

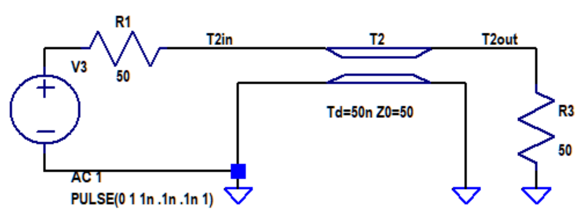
> a means for conveying electromagnetic energy between two points with a minimum of radiation (Electropedia.org, 726-01-01)

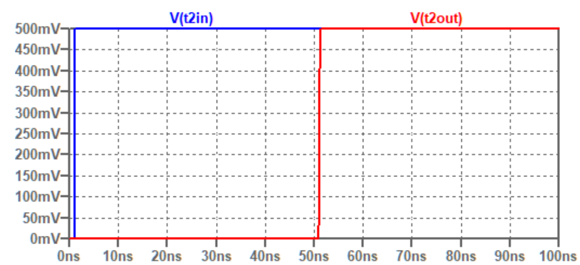
That tells us what a transmission *does*, but not what it *is*. For our purposes, a more useful definition is:

> A two-conductor structure with a homogeneous dielectric (MrAnalog)

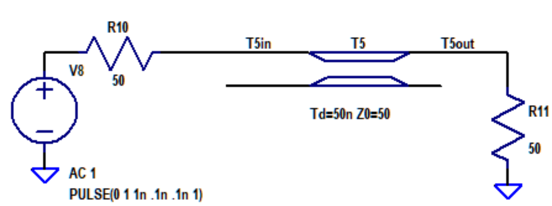
LTspice has three transmission line models - T (lossless), O (Lossy), and U (Uniform RC). We'll be covering how to use the T and O lines.

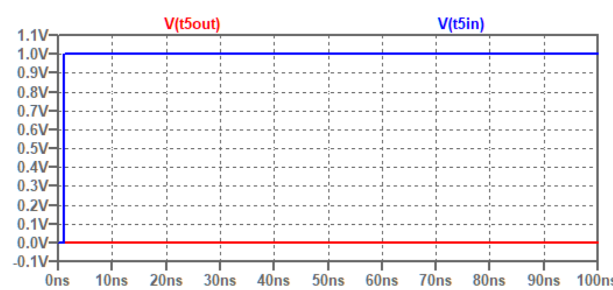
Let's test the SPICE T transmission line with a 50Ω impedance and a 50ns delay, with a matched driver and receiver. In this configuration, we expect the output of the line to be a delayed duplicate of the line's input.





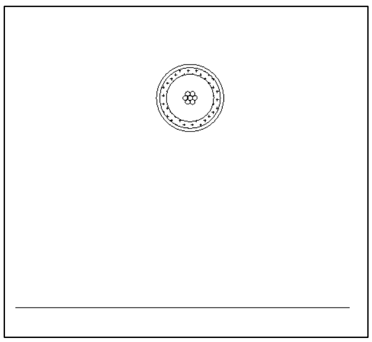
This is what we expect, an output having the same shape as the input but delayed from it. Now let's try disconnecting one of the two conductors.





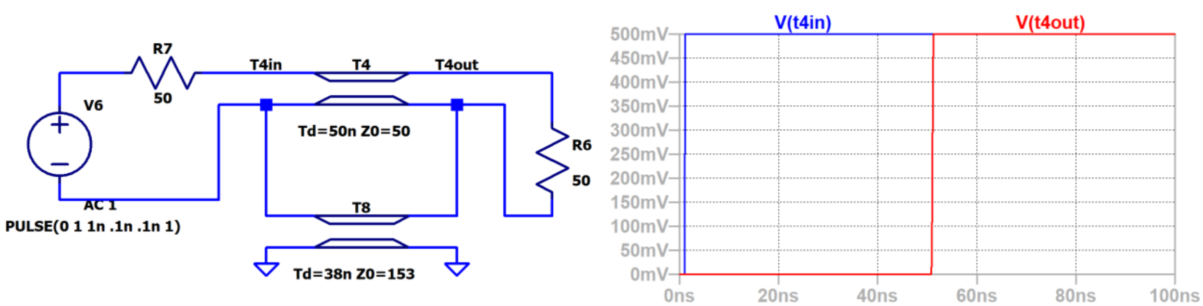
Now something's wrong. We are putting a voltage across two resistors and a wire in series, yet no voltage is dropping across the resistors, meaning that no current is being drawn. Apparently in SPICE, a transmission line is NOT a literal two-conductor structure.

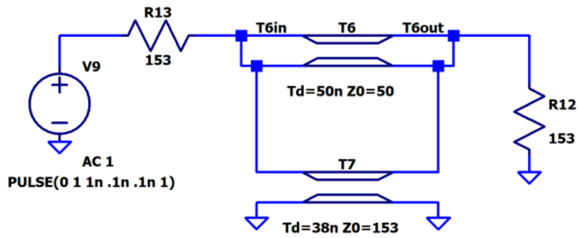
What we call a transmission line, like a coaxial cable, is actually TWO transmission lines. The center conductor and its shield form a (differential mode) transmission line. Also, the shield and its surroundings form a second transmission line (the common mode). Let's consider a 50Ω coax (RG8U) sitting one inch above a conductive table, shown below. Using an online calculator, we can find that the impedance of the common mode is 153Ω.

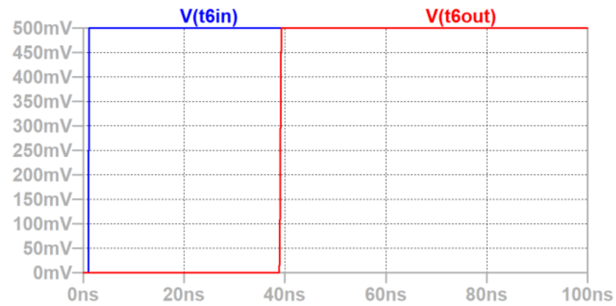


The SPICE T line is inherently a single mode differential device, conceptually sketched below. Clearly there is no conduction from one end to the other, as there would be an a real physical transmission line.

To represent a real coaxial line, two SPICE lines are used. The upper T line is the differential mode, and the lower one is the common mode. The two previous experiments are repeated below.



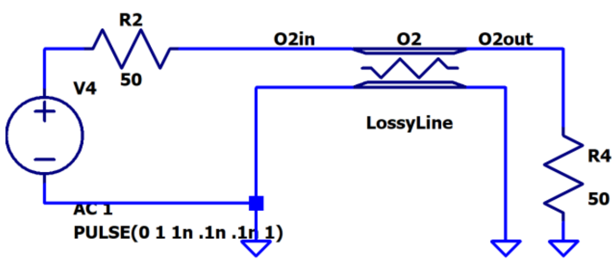


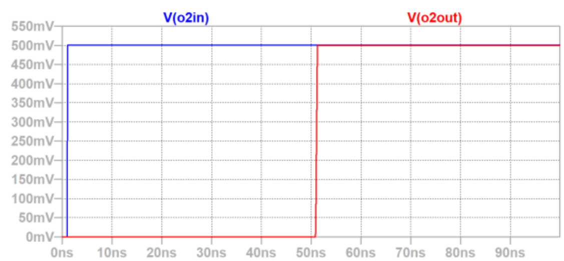


Both modes now behave as they should.

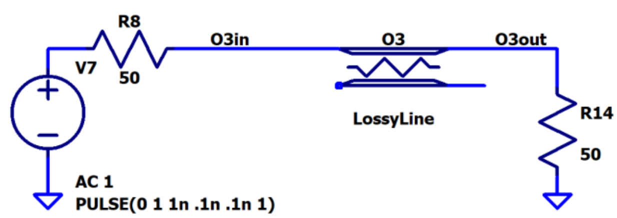
SPICE O lines

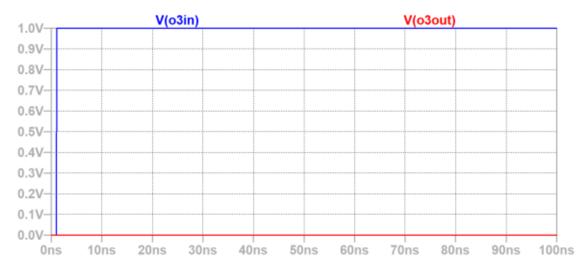
See the associated page “Types of SPICE Transmission Lines” for more detail on the three types of lines. Here we are interested in how to use these lines. The first two experiments are repeated here for O lines, with the O parameters selected to match the T line behavior.





.model LossyLine LTRA(len=49.2 R=0 L=50.9n C=20.3p)





The O line shows the same behavior as the T line. Thus both types of lines are differential models.