Grappling with The Saber Spice Transmission Line (spt)

Wesley Cardone, March 2020

INTRODUCTION: The following paper is a transcode from a paper I wrote for engineers at Ford's EESE organization regarding transmission lines for computer simulation. The computer simulation software used at ford is Symulink's Saber. Thus, substitute "LTSpice" where you see Saber mentioned. The Saber transmission line is the same one used by LTSpice.

> Working with the Saber implementation of the Spice Transmission line can be simple if you understand its fundamental operating principle.

First of all, what is the Spice Transmission Line all about? The model defines a loss in dB/meter which this paper is not going to address in any great detail. This has three parameters: 1. Attenuation constant in dB per meter (dB/m); 2. Frequency reference for loss; and 3. Highest frequency in MHz.

This paper is intended to address the transmission speed of electro-magnetic media through the wire. There are two parameters relative to this in the Spice transmission line model: 1. Velocity factor (vf); and 2. Wire length in meters. The Spice model also has a characteristic impedance parameter (Z_0) which will not be addressed in this paper since the Saber implementation is the same for it.

The velocity factor of the transmission line is the speed that electro-magnetic media travels through the wire relative to the speed of light in free space. If the speed of light in free space is 299.79246 e6 meters/second in free space and a given wire's velocity factor (vf) is 0.66, the speed that electro-magnetic media will travel through the wire at will be 197.863 meters per micro-second.

The second parameter of media speed is the length of wire. With this parameter the model can establish the delay of media from the input to the output. Thus, if a wire has a velocity factor of 0.66 and is 1 meter in length, it will take 2.2 nano seconds for electro-magnetic media to travel from the input to the output.

Looking at the problem from the above perspective, it appears that the Saber implementation of the transmission line complicates the specification of a transmission line. This is because the Saber implementation (except for characteristic impedance) has completely different parameters which describe the exact same characterization. Further, the Saber implementation has two methods to do this adding further complication. But if these parameters are understood, it is easy to grasp how to characterize the Saber implementation of the Spice transmission line.

BOTH METHODS: Both methods rely on specifying a delay as a component value, t_{ee}. That is, delay is not specified as a parameter per unit length but rather as a component length. If we have a sample wire that is 1234 mm in length, the delay will be from end-to-end of that 1234 mm long wire.

THE FIRST METHOD: The first method of characterization delay is with the "delay" parameter, t_d. In the earlier example we had a wire with a velocity factor of 0.66 that was 1 meter long. We found that the end-to-end delay was therefore 2.2 nano seconds. With the Saber implementation all we need do is specify a delay parameter of 2.2e-9 seconds. Further, specifying this parameter overrides the other parameters if they have been specified. This is the first of two methods in which the Saber implementation can be characterized.

THE SECOND METHOD: There are three parameters of interest: 1. Period in seconds or frequency in Hertz; 2. The speed of light; and 3. Velocity factor. These three parameters work in tandem to define an end-to-end delay in seconds. To understand the philosophy, it is critical to recognize that defining a

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frequency also defines a wave length, λ, in meters based on the speed of light in free space. With λ defined, it is now possible to normalize the wire length in terms of the wavelength.

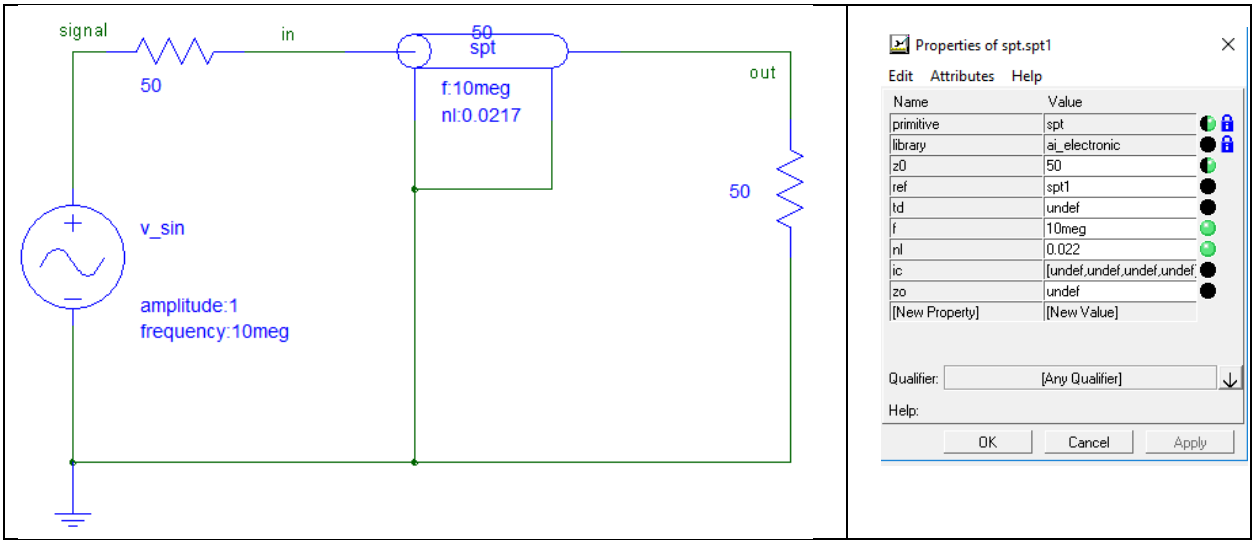
Let us suppose that we have a wire 1,234 mm in length with a velocity factor (vf) of 0.66. The time for the signal to travel end-to-end is therefore 2.72 nsec. How can we characterize this in the Saber implementation?

The time for end-to-end travel (t_d) becomes:

$$t_d = 1.234\ (m)\frac{1\ second}{299.79246\ e6\ (m)}0.66 = 2.7167\ nsec$$

The Saber characterization of the 1.234 meter wire having a velocity factor of 0.66 is therefore a product of:

- c = 299.792 e6 m/sec (speed of light in free space in meters/sec)
- vf = 0.66 (velocity factor, unitless)
- L = 0.0217 (wire length in meters)



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