# Total loop inductance/length in 50 Ohm transmission lines: Rule of Thumb #6

**Eric Bogatin** - February 07, 2014

This rule of thumb estimates the loop inductance per length in all 50 Ohm transmission lines in FR4.

$L_{Len}$ = 8.3 nH/inch

Remember: before you start using rules of thumb, be sure to read the Rule of Thumb #0: Use rules of thumb wisely.

Previous Rule of Thumb #5: Capacitance per length in all 50 Ohm transmission lines in FR4.

At low frequency, a transmission line, shorted at the far end, looks like an inductor. After all, it is just a conductor in a funny shaped loop, current going down the signal path and getting shorted to the return path, making its way back.

This is illustrated in the figure below which plots the input impedance of a shorted transmission line and the impedance of an ideal inductor. At low frequency, they predict exactly the same impedance.

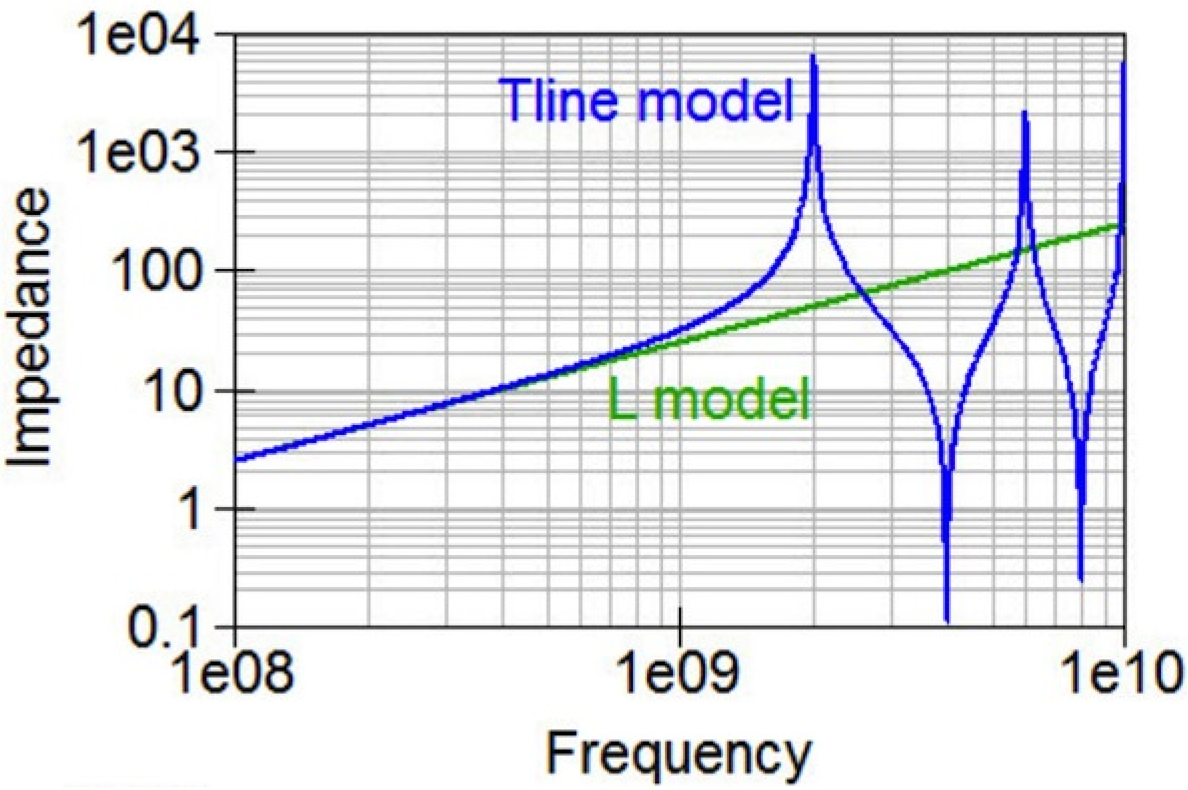


**Figure 1. Input impedance of a transmission line shorted at the far end and an ideal**

**inductor.**

To connect a transmission line with a total L and C value, we can approximate a real transmission line with an n-section LC model. Solving the circuit model, we get,

$$Z_0 = \sqrt{\frac{L}{C}} \quad \text{and} \quad TD = \sqrt{LC}$$

By taking the product, we get the total loop inductance as

$$L = TD \times Z_0$$

This is very reasonable. If the length of the line increases, so should the total loop inductance. If the characteristic impedance increases, like the line width decreases, then the total loop inductance should increase.

The time delay is related to the speed of the signal in the material and the physical length:

$$TD = \frac{Len}{c}\sqrt{Dk}$$ with c = speed of light in air, Dk = the dielectric constant of the materials.

This gives the total loop inductance in a transmission line as

$$L = TD \times Z_0 = \frac{Len}{c}\sqrt{Dk} \times Z_0$$

For the special case of FR4 with Dk = 4 and the speed of light in air as 12 inch/nsec, the total loop inductance per length of any transmission line is

$$\frac{L}{Len} = L_{Len} = \frac{\sqrt{Dk}}{c} \times Z_0 = \frac{\sqrt{4}}{12\,{}^{in}/_{nsec}} \times 50\Omega = 8.3\,{}^{nH}/_{in}$$

This says that ALL 50 Ohm transmission lines in FR4 have exactly the same loop inductance per length. If we make the line width wider, we have to make the dielectric thicker to preserve the 50 Ohms, and this keeps the loop inductance the same.

For example, a 50 Ohm line 2 inches long has a total loop inductance of about 16.6 nH.

Now you try it:

1. How much loop inductance does a surface trace have that is 0.2 inches long?

2. What is the total loop inductance in a long trace on a board, 5 inches long?

Next rule of thumb: RoT #7: Ground bounce in a connector.