How far is far enough? Signal line spacing for acceptable near end crosstalk: Rule of Thumb #20

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Near-end crosstalk is one of the three important sources of line-to-line crosstalk. It arises in both stripline and microstrip interconnects. The most important way of controlling it is by moving the lines father apart. This rule of thumb answers the question, how far apart.

Spoiler summary: To keep the worst case near-end crosstalk in 50Ω single-ended busses below 5%, keep the edge-to-edge spacing greater than two times the line width.

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

Previous: Rule of Thumb #19: How much crosstalk is too much?

Crosstalk is one of the most confusing topics in signal integrity. This is probably because many of the popular descriptions and discussions about crosstalk confuse the various terms and root causes, muddying the waters. If you really want to understand the principles and root cause of near-end crosstalk, far-end crosstalk, and ground bounce, check out Chapter 10 in Signal and Power Integrity-Simplified, or the EPSI course on the Signal Integrity Academy.

Near-end crosstalk arises in both microstrip and stripline transmission lines from the sum of the capacitively and inductively induced noise propagating in the backward direction on the victim line. The farther apart the signal lines, the less the fringe fields between the signal and return paths of the aggressor and victim lines.

The fringe field coupling depends most strongly on the dielectric thickness between the signal and return paths and the separation between adjacent signal lines. The closer the spacing between adjacent lines, the more fringe fields couple. The closer the return planes to the signal lines, the more tightly the fields couple to the planes, and the less they couple to the adjacent line.

To a good first order approximation, at a fixed characteristic impedance, the near-end crosstalk will scale with the ratio of the spacing to the dielectric thickness. This means that in 50Ω lines, the near-end crosstalk will be the same if the dielectric thickness and the spacing are both doubled, or both cut in half. This scaling means that for lines with a specific characteristic impedance, we don’t need to know the spacing, just the ratio of spacing to dielectric thickness.

But when we look at the traces on a board, it’s hard to judge what the dielectric thickness is.

Instead, it’s much easier to measure the line width and to judge the spacing in terms of the line width.

Of course, if we know the characteristic impedance, we know the ratio of line width to dielectric thickness. This is why crosstalk will also scale with the ratio of edge-to-edge separation and line width.

In the special case of 50Ω lines in FR4, we can use a field solver to explore design space and calculate how the near-end crosstalk changes with separation. Since crosstalk scales with the ratio of separation to line width, for a constant impedance, we can describe the separation in terms of how many line widths.

Figure 1 is the field solver-calculated near-end crosstalk for two adjacent 50Ω microstrip and striplines traces, plotted as we increase the separation. We would expect the near-end noise will decrease as the separation increases, but how quickly, and which has more crosstalk, stripline or microstrip? The field solver tells us.

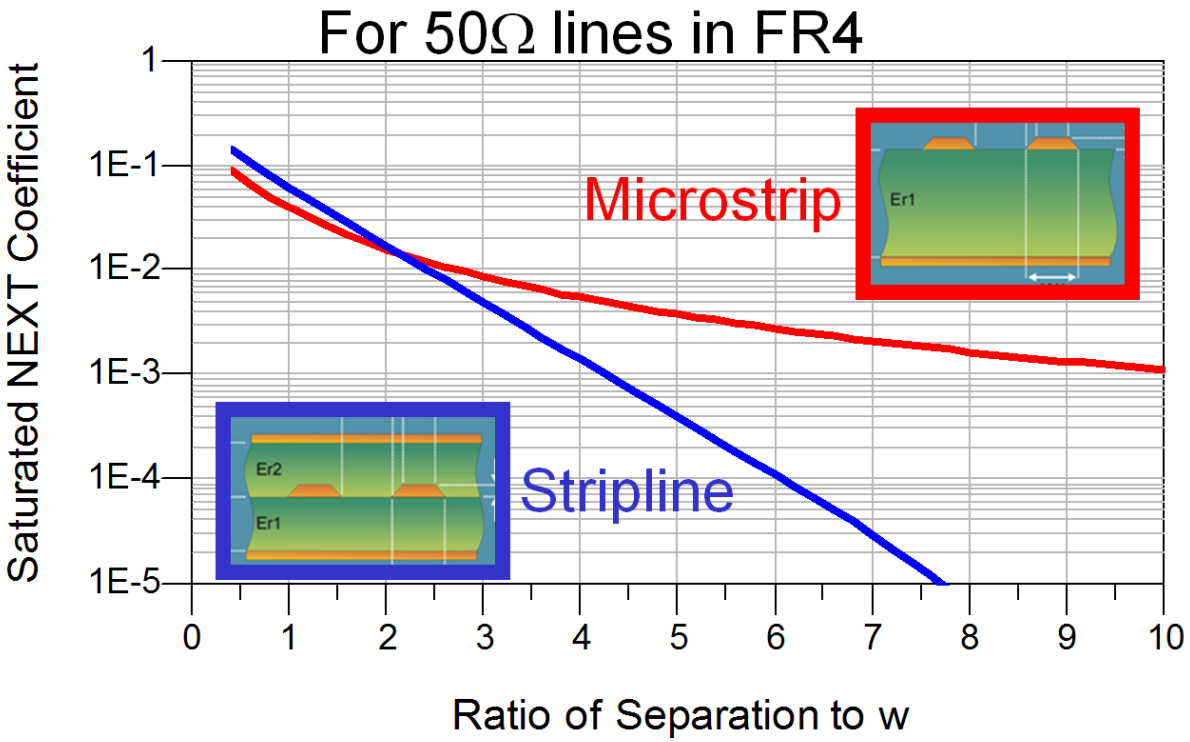

Figure 1

How much crosstalk is too much? If the noise budget allocates a total of 5% near-end crosstalk (see Rule of Thumb #19), and a victim line is between two aggressors, then we can tolerate about 2.5% near-end crosstalk between two lines.

Coincidently, for both microstrip and stripline, the near end crosstalk is about 2.5% when the spacing is 2× the line widths. This is the origin of the rule of thumb, for 50Ω lines in FR4, to keep near end crosstalk to an acceptable level, keep the line-to-line spacing twice the line width.

If you want higher interconnect density than a spacing of 2× the line width, it doesn't mean it won’t work, it means that you will probably have more than 5% near-end crosstalk and you better put in the numbers to make sure your design can handle it. And, if the impedance is higher than 50Ω, for

the same spacing, there will be more than 5% near-end crosstalk.

Now you try it:

1. You have a 50Ω stripline bus with line widths of 5 mils. The edge-to-edge spacing is 5 mils. Should you be concerned?
2. Your edge-to-edge spacing in a microstrip bus is twice the line width, but the impedance is 35Ω. Should you be concerned about the near-end crosstalk?

Next rule of thumb #21: How far apart should signal lines be for acceptable far end crosstalk?

Also see:

- Bogatin's Rules of Thumb
- Crosstalk: How much is too much?: Rule of Thumb #19

Additional information on this and other signal integrity topics can be found at the Signal Integrity Academy, www.beTheSignal.com.