Recently, there has been a lively discussion in the various EMC and signal integrity forums on guard traces and whether they are useful in reducing crosstalk between closely-spaced traces in your high-speed designs. My best “lawyer-like” answer is, “it depends”.

Another common question: “Do you terminate them in their characteristic impedance, ground them at one end or both ends, or not at all?” I think we can answer the last part of this easily, if we realize that a conductor with no connections (no current flow) will impact the outcome very little, if at all. In fact, a floating conductor situated between an aggressor and victim trace can actually couple noise from one to the other and make the coupling worse than if it wasn’t there at all!

Guard traces are typically grounded at both ends to the signal reference plane. There are certainly situations where guard traces can help. For example, for low-frequency audio - especially for two-sided board designs, guard traces can reduce crosstalk by an order of magnitude. However, on modern-day high-frequency digital designs, guard traces may help, but only if implemented correctly.

Crosstalk occurs when the magnetic lines of force pass from the aggressor trace under the victim trace. In other words, the lines of force must encircle the victim (Faraday’s Law). As the distance between the aggressor and victim traces increases, the coupling decreases, as you might expect. Henry Ott, in his latest book, Electromagnetic Compatibility Engineering (2009), summarizes succinctly when he states, “crosstalk between adjacent microstrip traces is proportional to the square of the trace height divided by the square of the separation distance.”

Clayton Paul has a whole chapter on crosstalk in his book, Introduction to Electromagnetic Compatibility (2006), where he has rigorously derived the crosstalk equations and modeled the crosstalk between two wires or microstrips. The example of a guard trace, of sorts, was using a ribbon cable, so the application is not quite what we experience with high-speed circuit boards.

What really prompted me to write this article was a recent white paper by signal integrity expert, Howard Johnson (http://www.sigcon.com/Pubs/news/15_02.htm), where he explained the mechanism for crosstalk using clear graphics and simulation plots - one of the best explanations I’ve seen for modern-day digital designs. He maintains that while separating traces enough to fit in a guard trace helps the most, the inclusion of the guard trace (grounded at both ends) only helps by about 2 dB, because the magnetic field lines of force merely pour over the top of it. Simply separating the traces reduces the coupling by 12 dB, so his position is, “why bother?”

Signal integrity expert, Eric Bogatin, in his book, Signal Integrity - Simplified, also has a full chapter on crosstalk. He agrees that simply spacing the aggressor and victim traces farther apart yields the most benefit. His rule of thumb for trace spacing is that a minimum of 10 mils creates less than 2% near-end crosstalk (NEXT). Therefore, the edge to edge spacing for signal traces should be at least
two times the trace width. He also adds that for far-end crosstalk (FEXT), increasing the spacing between signal traces from 1w (w=trace width) to 3w will decrease the far-end crosstalk by 65%.

But what about guard traces? Bogatin points out that separation may not be the only answer, especially for mixed signal circuitry or products with sensitive inputs, such as oscilloscopes or instrumentation amplifiers. In this case, we may need a noise level 100 dB down to avoid “self-interference” and guard traces used with microstrips won’t get you there.

When using guard traces, Bogatin suggests the trace should be as wide as will fit between the aggressor and victim traces, consistent with the fabrication design rules for spacing. Even so, he admits the guard trace really won’t help all that much for microstrip. The addition of multiple shorting vias along the guard trace will help reduce the FEXT even further through cancellation of the reflected wave.

But, for even more reduction in crosstalk, Bogatin recommends that stripline always be used. In stripline structures, there will be much less far-end noise and less need for multiple shorting vias along the guard trace. With striplines, a separation of just 30 mils between aggressor and victim can increase the isolation by three orders of magnitude.

So, it appears the bottom line is that when working with microstrip, guard traces offer little help, while with stripline, guard traces can help a great deal. I’ve asked both Howard and Eric to provide for us any additional views or thoughts regarding guard traces. Perhaps we can put this question “to bed”.