A few years ago, when I had recently joined a high-speed test equipment manufacturer, I was assigned to take a production-ready (and very promising) product through EMI scans. The product needed to undergo EMI compliance testing before being shipped.

This product, which was housed in a rack-mount 8U metal chassis, consisted of a control card, a communication card, and several line cards. Micro coaxial cables connected internal high-speed circuitry to external ICs under test.

Since this was not my design, I prepared for the EMI scans by studying the schematics, the layout of the boards and the backplane, the mechanical aspects of the chassis, and the seating of cards in the chassis for possible areas of EMI leakage. The product was designed to test ICs at several hundred megahertz and to capture the outputs of ICs containing hundreds of pins at 5-psec timing resolution. As a result, the line cards were full of high-precision clock circuitry, high-speed/low-skew clock and pin drivers, and high-speed ADCs and DACs.

One thing that stood out was that the product was not well-designed for passing EMI emissions test. The power-supply filtering on the line cards was highly inadequate, and the grounding was multi-point, with the entire front side of the chassis connected to signal_ground at different points on each line card. It was apparent that my EMI scan was going to involve a long fight.

An EMI pre-scan proved my suspicions. Radiated emissions exceeded FCC Class A requirements by 10 to 12 dB at various frequencies in the range 100 MHz through 1.5 GHz.

I tried the usual fixes—plugged and unplugged several line cards and cables, added ferrite clamps to power and other slower cables, wrapped high-speed input/output (I/O) cables around ferrites, and so forth—but none of these actions made any significant difference. I added more filtering to clock oscillators and drivers and changed single-stage filters to two-stage cascaded filters, and something interesting started to happen. As I doubled the filter stages, EMI levels would go down at some frequencies but shoot up at some other frequencies.

It got very frustrating and I spent several days and late nights in the EMI test lab trying to catch this moving target. When I attached long, hanging wires to the chassis to act as antennas, I saw no difference in electromagnetic radiation. It was possible that the entire chassis was somehow acting as one big antenna.
I knew that high-speed currents from multiple signal_ground connections were flowing along the front edge of the chassis. But why would they circulate all over the chassis instead of following the path of least impedance?

I removed all line cards and opened up the chassis. I noticed that the chassis and signal_ground of the backplane were shorted together even when no line cards were present.

Then I took out the plug-in power modules one at a time. There were two of them, one on either side of the chassis, plugged in from the back. When I took out both, the short between chassis and signal_ground was gone. This had to have serious EMI implications.

The two power modules were shorting the signal_ground to the chassis at two ends of the chassis that were 16 inches apart, near the backplane power connectors. The high-speed return currents in the signal_ground of the backplane were free to circulate not just along the front edge of the chassis but also along the back edge, or effectively throughout the entire chassis. The chassis had become an antenna and was radiating instead of shielding the internal circuitry.

Opening up a power module showed the cause of this. Return for 12V power (also the signal_ground for the backplane) was electrically attached to the inside of the metal housing of the power module. I disconnected these returns and plugged the power modules back in. There were no more shorts.

A subsequent EMI scan showed that the offending emissions were now down from 12 dB to 4 dB for all frequencies in the spectrum. My job was not over yet, but this was a good start. Over the next few days, I was able to reduce the EMI for a partially populated system down to acceptable limits.

Anoop Hegde is a hardware design engineer and consultant who works on system architecture, high-speed digital design, EMI, and microcontrollers. He designs circuits as an electronics hobbyist in his spare time.