Checking Cable Performance with Vector Network Analyzer

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In the column "Comparing Cable Shields " [1] we showed that poor cable shield can result in significant noise pickup from the air, which can easily mask a few mV of noise voltage that we need to measure on a good power distribution rail. We showed a quick comparison of cable shield quality with a signal source and an oscilloscope. In this column we look at the same cables in the frequency domain, using a pocket-size Vector Network Analyzer (VNA).

Figure 1: *The USB-connected miniVNA Pro pocket-size VNA.*

Vector Network Analyzers are similar to Time Domain Reflectometry (TDR) instruments that many digital engineers may be more familiar with: they both transmit a known signal into the Device Under Test (DUT) and measure the response. TDR instruments use a step waveform with a given rise time; VNAs use a sinewave source sweeping the frequency within a user-defined range. VNAs have long been popular in microwave engineering and more recently in high-speed digital engineering. They measure what are called scattering (***S***) parameters, which are the complex ratios of transmitted and reflected waves.

In recent years small, low-cost and portable VNAs have also become available. Measured data in this column was collected with a pocket-size VNA, called miniVNA Pro [2]. It operates over the 0.1 – 200 MHz frequency range. It is battery powered and has USB and Bluetooth connectivity. *Figure 1* shows the instrument. The DUT and DET SMA connectors are where we hook up a two-port DUT. The instrument injects sine-waves (swept from 0.1 to 200 MHz or in any user-defined sub-band of it) into the cable connected to the SMA labeled DUT, measures sine-waves propagating back from the DUT SMA (*Reflection*) and the DET SMA (*Transmission*) and compares the measured received sine-waves to the injected sine-waves to characterize Reflection (e.g. S_{11}) and Transmission (e.g. S_{21}). With this instrument we can measure the full ***S*** matrix of a two-port DUT, though to get the full matrix, we have to manually set up four independent measurements. The instrument comes with Open, Load and Short SMA calibration standards, shown on the lower left in *Figure 1*.

For a nominally symmetrical and reciprocal DUT with two connections, like our cables, there are only two parameters to measure: *Reflection* (S_{11}) and *Transmission* (S_{21}). If the DUT is really symmetrical, *Reflection* measured from either connection will be the same ($S_{11} = S_{22}$). Similarly, a reciprocal DUT will give us the same *Transmission* measurement result, regardless which direction we measure it ($S_{21} = S_{12}$).

Before any measurement is taken, we have to perform a calibration to the end of the connecting cables. *Figure 2* shows the *Through* calibration. The two short beige-colored cables are connected with an SMA through piece, also called SMA slug. After calibration, the residual *Transmission* reading by disconnecting the two cables is < -80dB, pretty good from a pocket-size instrument. The two short beige-colored cables have high quality and therefore we get the same noise floor reading regardless where we open the connection; whether we just remove the slug but leave the two cables connected to the VNA or if we remove the two cables as well.

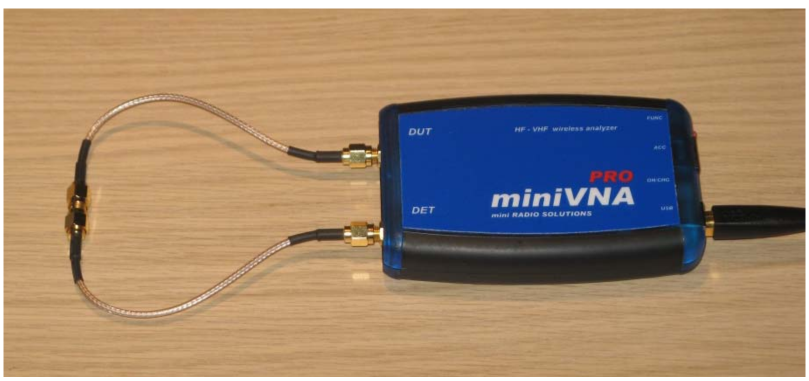

Figure 2*: Through calibration layout.*

To check further the shield quality of our coaxial cables, I connected the two cables under test to the VNA, leaving in place the short high-quality cables shown in *Figure 2* that were part of the *Through* calibration.

A poorly-shielded cable was connected to the DUT port to serve as the Aggressor. Several different Victim cables were connected, in turn, to the DET port. The Aggressor and Victim cables lay loosely near each other, as shown in *Figure 3*.

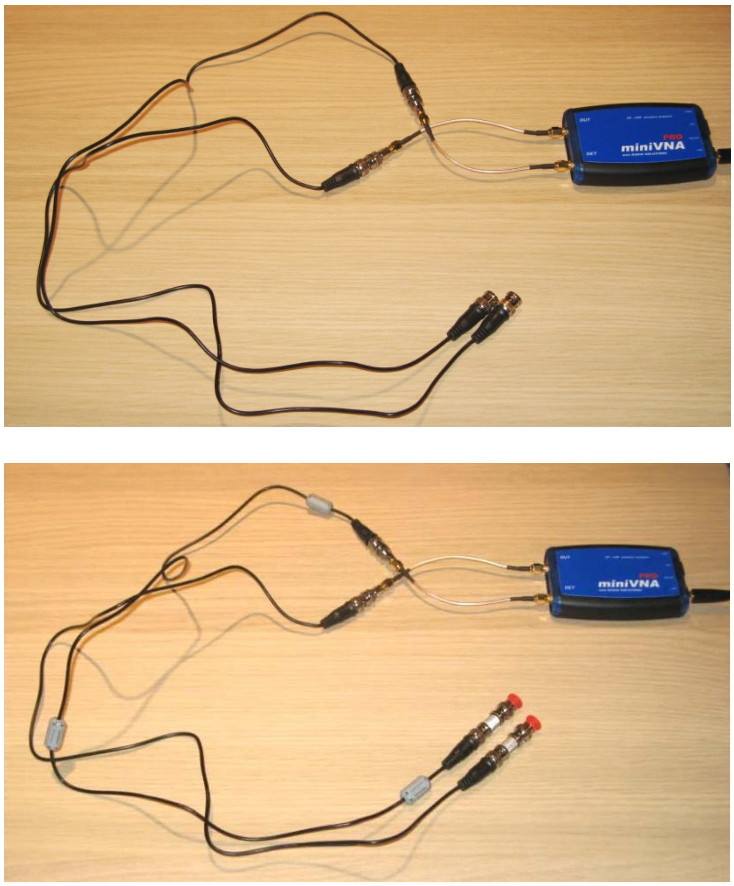

Figure 3: *Layout to measure the two poor-quality cables. Top: both cables with open end. Bottom: both cables terminated.*

The results measured for each Victim configuration are shown in *Figure 4*:

- Red Trace: High-quality, well-shielded Victim cable, with both cables open-ended.
- Blue Trace: Poorly-shielded Victim cable, with both cables open-ended.
- Green Trace: Poorly-shielded Victim cable, with both cables terminated.
- Grey Trace: Poorly-shielded Victim cable, with both cables terminated, with ferrite-absorbers on the Victim cable.

The upper photo in *Figure 3* shows both cables open-ended, and the lower photo shows both cables terminated and with ferrite absorbers on the Victim.

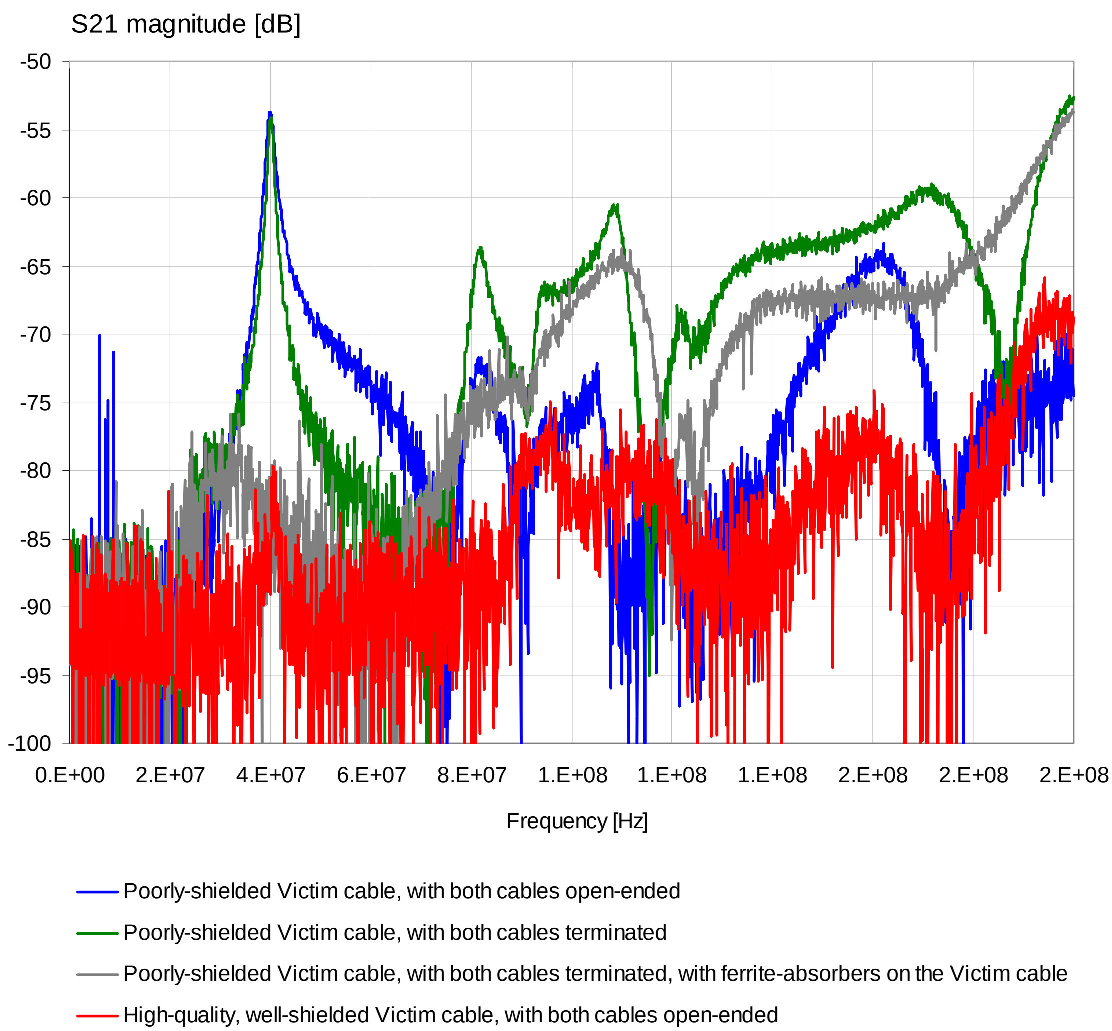

Figure 4*: Crosstalk through the cable braid and air for four different cable combinations.*

The VNA was set to measure *Transmission* (S_{21}), which in this case represents the crosstalk between the two cables through the cable braid and air. The two extremes are the blue and red traces: blue refers to the poorly shielded cable; the red trace shows the *Transmission* with the good-quality cable, both with open end. These correspond to the two cases described in [1]. The red trace is hardly above the noise floor of the instrument; the blue trace has multiple big peaks. The sharp 40-MHz peak is related to the quarter-wave resonance of the cables, which is one quarter of the inverse of the end-to-end delay. With termination at the far end (green trace) the crosstalk pattern changes, but only ever so slightly: it is somewhat lower in the 40 – 70 MHz frequency range, but it gets higher above 80 MHz. With the poor-quality cable, we can lower the 40MHz peak by putting absorbing ferrites around the cable (shown by the grey trace). The 40 MHz peak got lower by about 25 dB, and the higher-frequency resonances got also reduced by 5 to 10 dB.

This illustrates that when at least one of the two cables has good-quality shield, the coupling path between them is blocked, and the crosstalk gets much lower, regardless of how the far ends are terminated. When both the aggressor and victim cables have poor shielding, the crosstalk at the resonance frequencies is significant, though termination and ferrite absorbers can help a little. In an electromagnetic susceptibility scenario, such as the one we described in [1], we focus on the victim and may not even know where the aggressor is or what generates the aggressor signal. In those situations the quality of the cable shield makes a big difference.

References:

[1] "Comparing Cable Shields," QuietPower column, http://www.electrical-integrity.com/

[2] MiniVNA-Pro, http://miniradiosolutions.com/minivnapro