QuietPower columns
EDN SI/PI Masterclass

Simple Fixtures Made of SMA Connectors

Istvan Novak, Oracle, August 2018

In the previous blog post you saw a very simple home-made fixture [1]. It takes only two coaxial cables and some solder wick. The fixture is convenient for quick tests and for situations when a little error due to the contact resistance and due to the variable shape of the solder wick contacts is acceptable. If you want more accurate and consistent data, you need to use fixtures with fixed geometry and solder the component to it. Such fixtures are described here.

A fixed-geometry fixture offers the benefits of consistent and more repeatable results. For instance, we can make fixed-geometry fixtures out of certain connectors. For our typical bypass capacitor sizes the various flavors of PCB-mount SMA connectors are very convenient. These connectors have two distinct sides: the SMA side interfacing with the SMA connector on our cables and the PCB side that attaches to the printed circuit board. The SMA side comes with the choice of regular male or female, but there are also reverse-polarity SMA male and female connectors, so you need to pay attention when you buy these parts. Our common cables come with regular male SMA connectors, therefore a good choice for the fixture is to use regular female SMA. The PCB side also has a large variety of different geometries, dependent on how you want to mount the connector to the printed circuit board. If the mounting is perpendicular to the board, the four posts at the corners are soldered to the board either as surface-mount or through-hole connections. If you want to use the connector as edge-mount, the spacing between the posts are created such that it can straddle the board with its specified thickness. Some of these varieties are illustrated in *Figure 1*. From left to right you see SMA-female-to-surface-mount, SMA-male-to-narrow-base-vertical-through-hole-mount, SMA-female-to-wide-base-vertical-through-hole-mount, SMA-female-to-narrow-base-vertical-through-hole-mount, SMA-female-to-wide-base-edge-mount and SMA-female-to-narrow-base-edge-mount connectors.

Figure 1: *Some of the available choices for SMA-to-pcb connectors.*

For fixtures to measure bypass capacitors, the best choice is to use SMA-female edge-mount connectors, which are the last two connectors on the right. There is one more choice you have to make: the size of the base of the connector. The narrow-base connectors you see here have posts on a 5 mm grid and these connectors are best suited for smaller-size components, such as 0805, 0603 and 0402 capacitors. 1206 and 1210 components can also be attached to these fixtures. The wide-base edge-mount connector has posts on an 8 mm horizontal grid. You need them for bigger components, such as D-size (7.3mm x 4.3mm) packages.

To create a fixture, you have to solder two of these connectors back-to-back. You can connect both ends to SMA male cable connectors and you have to attach the bypass capacitor you want to measure to the center pin and ground frame in the middle of the fixture. A wide-base and narrow-base empty fixture are shown in *Figure 2*. *Figure 3* shows fixtures with 1210-size ceramic capacitors attached.

Figure 2: Wide-base and narrow-base empty SMA fixtures.

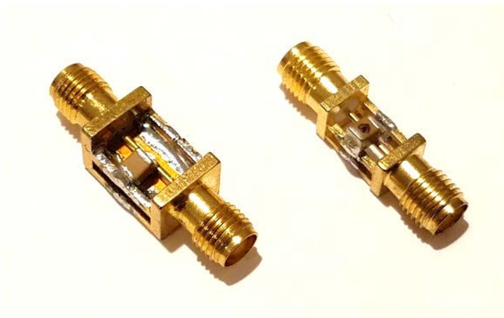

Figure 3: Wide-base and narrow-base SMA fixtures with bypass capacitor.

Before measurements are taken, you have to calibrate the system. Up to about 30MHz a simple Response Through calibration is usually sufficient. For the Response Through calibration you can simply use the empty fixture connected between Port 1 and Port 2 of the VNA. After the calibration, you have to solder the DUT between the center pin and ground frame of the fixture and take the reading. You can also create multiple fixtures with identical geometry and keep one just for the purposes of Response Through calibration and reserve the others for measuring DUTs. You measure the S_{21} transfer parameter with the network analyzer and from that you can calculate the complex impedance of the capacitor with the simple formula of

$$Z = \frac{Z_0}{2}\frac{S_{21}}{1 - S_{21}}$$

Where Z_0 is the port impedance of the Vector Network Analyzer, usually 50 Ohm. The network analyzer used for these measurements has an option available that does this transformation inside the instrument [2]. If you are interested in the derivation of the formula above, you can find it on page 132 of [3].

When you select the frequency range for the measurement, the tradeoff is between the start and stop frequencies and the nature of components you want to measure. If you want to start the sweep anywhere below 30 kilohertz ***and*** want to measure components with low impedance at low frequencies, such as low-ESR high-capacitance parts, you may run up against the cable-braid loop error, described in Section 7.1.1 of [3]. Dependent on how you reduce the cable-braid loop error, the chosen solution may come with its own limitations at high frequencies. For this article a home-made common-mode choke was used to reduce the effect of the cable braid resistance, with an upper bandwidth of approximately 50 MHz; the data was collected in the 300 Hz to 30 MHz frequency range.

Figure 4 shows the setup of this measurement without the common-mode toroid. The common-mode toroid and its use will be described in later blogs. *Figure 5* shows the measurement results for a 47uF 1210-size X5R capacitor. The excitation was set to -10dBm RF source power level and 0V DC bias.

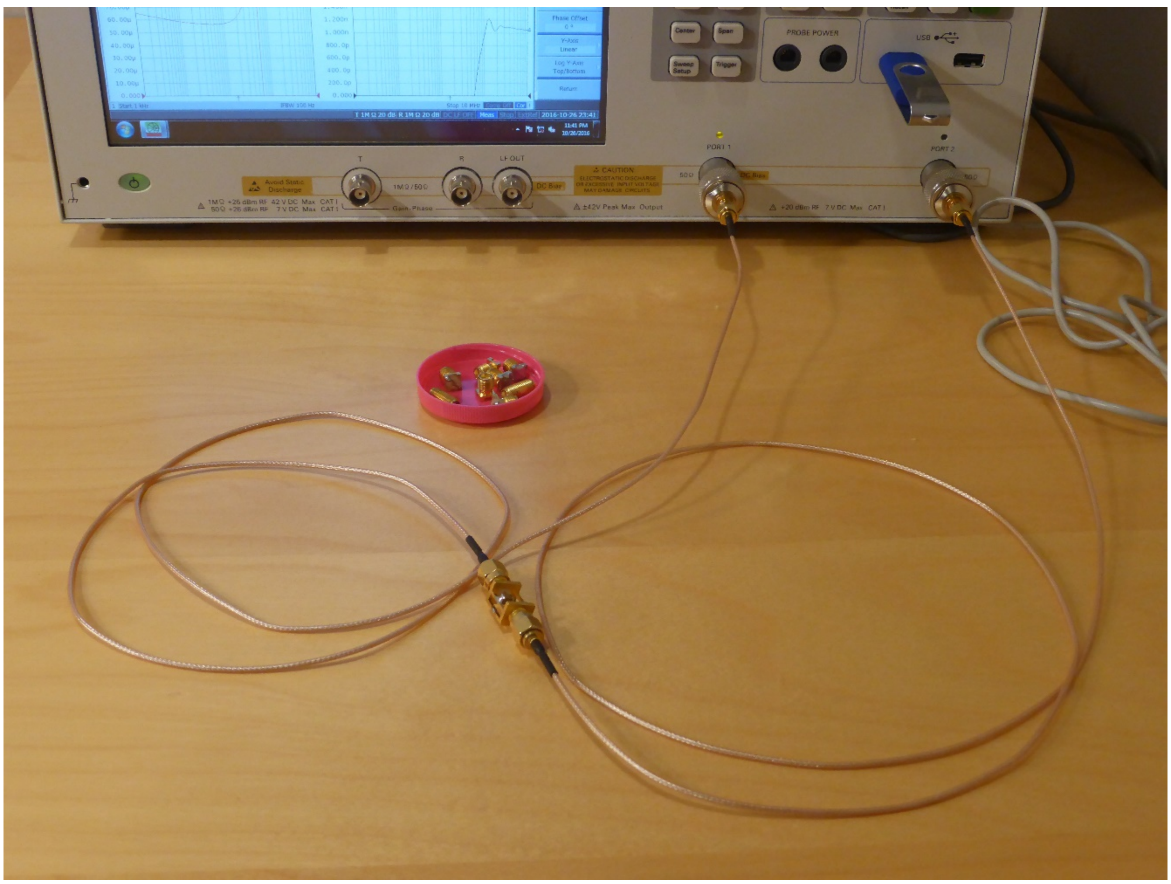

Figure 4.: *Measurement setup with network analyzer and a back-to-back SMA fixture. E5061B loaner VNA is courtesy of Keysight.*

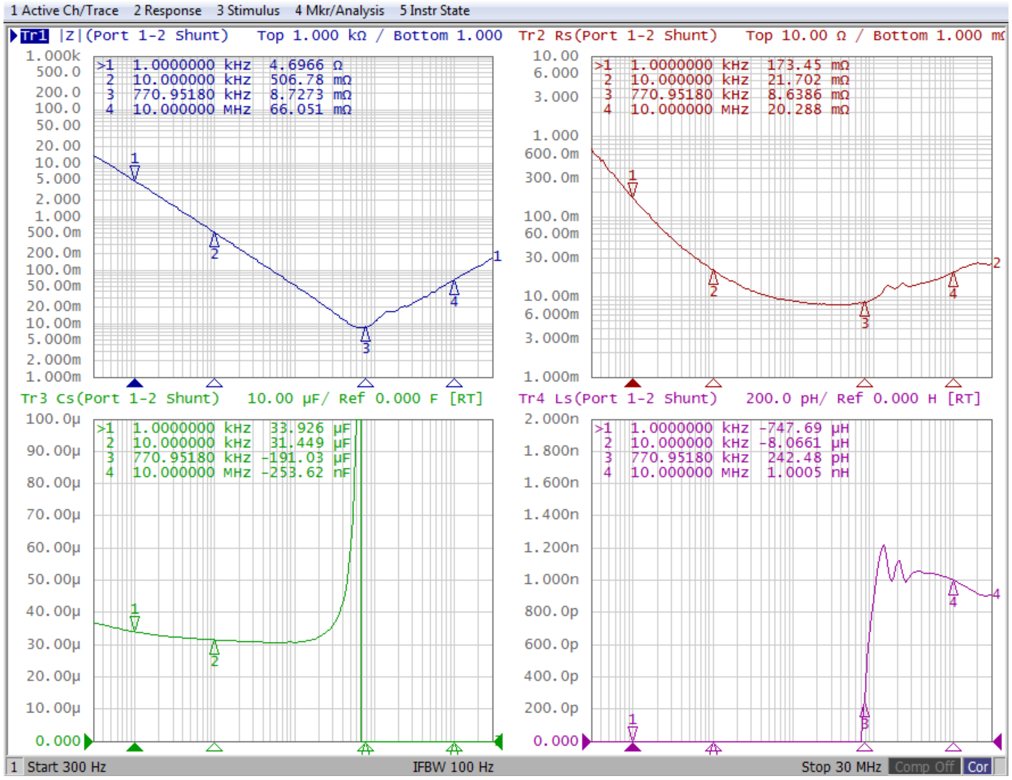

Figure 5.: *Measurement data of a 47 uF 1210 size ceramic multi-layer capacitor taken in a setup similar to the one shown in Figure 4. E5061B loaner VNA is courtesy of Keysight.*

On the instrument display by using the Impedance Analysis Option of the VNA [2], the screen is set up with four simultaneous traces: Impedance magnitude (upper left), Effective Series Resistance, Rs (upper right), Equivalent Series Capacitance, Cs (lower left) and Equivalent Series Inductance, Ls (lower right). The logarithmic horizontal scale starts at 300 Hz and ends at 30 MHz. The 70 Hz IFBW setting provides a good compromise between sweep speed and noise floor.

While these fixtures are still very simple to make and provide fixed and repeatable geometry, they do not have a planar structure with power and ground planes and therefore they do not represent our typical printed circuit board applications. For this reason you probably need to ignore the inductance in the measured data. For applications where you are looking only for the capacitance information and possibly also for the Equivalent Series Resistance (ESR) data, this simple fixture is an acceptable solution. If we really need the inductance also to be representative to our application, the best we can do is to create fixtures with the same or similar stackup as the final application and connect the DUT with escape patterns we plan on using on our board. These fixtures are tailored to our pcb geometry and therefore have more limited applications, but will best represent the DUT's performance in our real application over a wide frequency range. For such fixtures, see for instance *Figure 7.13* on page 206 of [3].

References

[1] Solder-wick trick characterizes bypass caps, EDN, May 9, 2018, https://www.edn.com/electronics-blogs/signal-integrity-collection/4460638/Solder-wick-trick-characterizes-bypass-caps

[2] Impedance Analysis for the E5061B ENA LF-RF Vector Network Analyzer (Option 005), http://literature.cdn.keysight.com/litweb/pdf/5991-0213EN.pdf

[3] Istvan Novak, Jason R. Miller: Frequency Domain Characterization of Power Distribution Networks. Artech House, Boston, 2007.