Monoblock RF Filter Testing
Recommended VNA Calibration Method

Introduction

Monoblock RF Filters come in all shapes and sizes and no JEDIC or equivalent standard exists for these parts. The size of the filter is dependent on the ceramic used, the filter characteristics, and the physical demands of the customer. Since most of these filters operate at 1 GHz to 6 GHz, the fixtures used to test the filters must have excellent 50 ohm match and proper grounding. Very small placement errors, as small as 0.001 inches (0.0254 mm) will cause the S-parameters measured to change.

CTS standardized a fixture type and test method for our array of Monoblock filters. This fixture is used in development of the product and later in the factory for manufacturing the product. Also, filters may be sampled on small coupons (a Printed Circuit Board) for customer evaluation. Both measurement methods have the VNA calibration method in common.

To achieve the highest measurement accuracy, the VNA must be calibrated with in a full 2-port mode using high quality 3.5 APC standards with a Load VSWR of 1.03 or better up to 6.0 GHz.

The Fixture Connection

The RF test fixture used by CTS to measure Monoblock filters, see Fig. 1, presents a problem for calibration. The connections on it are all SMA female. The 2-port calibration of S21 and S12 requires that the two cables be connected together and this in turn requires the use of a female-to-female adapter. The adapter introduces both phase and insertion loss which will affect the measured values of the filter.

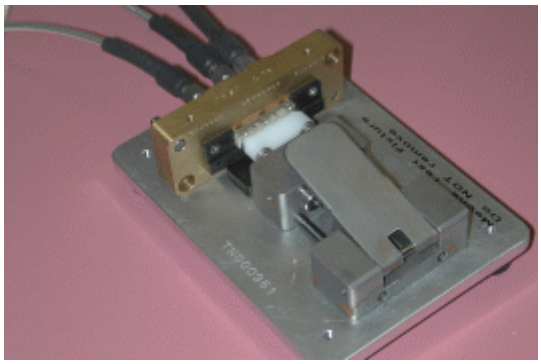

Figure 1 CTS Filter RF Test Fixture

Figure 2 Phase Matched Adapters

If a custom electronic calibration module is available (which has two female SMA connectors) then there is no issue and the calibration will be accurate. However, it is much more common to have to calibrate with physical standards from a calibration kit. For this reason we recommend the use of a phase-matched adapter (PMA) set to eliminate the error for the “Female Thru” see Fig. 2. Unfortunately, these do not usually come with the purchased calibration kit and the must be ordered separately. The female-to-male phase matched adapter must be in series with one of the cables on a simplex (2-port) filter or in series with the cable to the common or antenna port of a duplex (3-port) filter during filter testing.

As shown in Fig.1, the VNA is connected to the fixture with a set of flexible cables. The accuracy of the calibration is also dependent on the quality of the cables. The cables should be phase stable during the

flexing that will occur while attaching standards and finally the fixture. High quality cables from Gore are available with 3.5 APC male ends. We have found that a less expensive solution is to use a good quality commercial cable. Our spec for the cable requires a VSWR less than 1.10 and that the phase variance with a 45 degree 3-inch bend is less than 1.0 electrical degree.

VNA Setup

A Vector Network Analyzer like the Agilent 8753ES is configured with three ports and simplifies the testing of a duplex filter. Even though it is not a "True 3-Port" analyzer, the overlap of Rx and Tx bands for a typical duplex filter provides enough isolation so that the S-parameters are very close to those measured with a true 3-port analyzer such as the Advantest R3767CG and later models.

When using a VNA with only 2 ports, the third port on a duplex filter fixture must be terminated with a 50 Ω load. The 8753ES provides this load since the precision RF switches in the test set terminate the unused port. Likewise, for RxTx measurement the PMA must be moved to port 2 or port 3 during calibration and measurement.

The designations "Rx" band and "Tx" band are equipment dependent. For the Cellular CDMA Handset Market the Rx band is the High Band 1930-1990 MHz and the Tx band is the Low Band 1850-1910 MHz. However, a filter used in a CDMA Cellular Base Station would transmit on the High Band and Receive on the Low Band. The choice of S-parameter connections is arbitrary and for the purpose of this paper we will refer to a handset duplexer product and the CTS connection method.

We chose Port 1 to be connected to the common or antenna port on the filter so that the S-parameters would be S21 for the Rx and S31 for the Tx sections of the filter. The Rx-Tx isolation measurement would then be S32. Since the 8753ES is really only a 2-port analyzer, all three port combinations port 1-2, port 1-3 and port 3-2 require a calibration. Also, since there are only two channels in the VNA, the Isolation measurement setup needs to be stored in a separate register and recalled as required.

The VNA is a complex instrument with many choices. We normally set Channel 1 to S21 (Rx), Channel 3 to S11, Channel 2 to S13 (Tx), and Channel 4 to S33. The channels must be uncoupled to allow this combination. The directions are chosen to match the normal signal flow for a product. The calibration has to be done twice, once for each set of ports (1-2 and 1-3).

Starting with channel 1 (ports 1 and 2), set the Start and Stop Frequencies, the number of points, and the bandwidth, the VNA calibration can begin. Since the standards are 3.5 mm APC, this standard is selected from the menu and then a two-port cal. Since we are also using phase-matched adapters, start with the female-female adapter and the Transmission cal. The adapter can then be changed to the female-male and left in place on the port 1 cable for the remainder of the calibration sequence. Continue next with the Reflection standards and finally, Isolation (which is omitted for typical filters).

Next choose channel 2 and repeat the calibration this time on ports 1 and 3.

Before measuring any parts it is wise to do a verification. The proper way is to measure a known standard or a typical part that has already been measured. This insures that the data taken on the filters under test will be valid.

Conclusion

CTS standard practice for RF measurement of a Monoblock Filter has been described for a Duplex filter and typical Rx and Tx S-parameter setups. The most accurate 3.5 mm APC calibration method is used with phase matched adapters.

While the method is the most accurate and uses readily available standards, the fixture or coupon does add additional loss and phase error to the measurements.

Reference Equipment and Materials

VNA Agilent 8753ES Vector Network Analyzer
Cables CTS M0605 N-male to SMA male, 12 inch
Calibration Standards (Economy)
Agilent 85033-60017 3.5 mm Load
Agilent 85033-60019 3.5 mm Open
Agilent 85033-60021 3.5 mm Short
Phase Matched Adapters (Economy)
Agilent 83059C (85027-60006) 3.5 mm M-F Adapter
Agilent 83059B (85027-60005) 3.5 mm F-F Adapter

Bibliography

1. Agilent Application Note 1287-3, 5965-7709E, Applying Error Correction to Network Analyzer Measurements
2. Agilent Application Note 1287-9, 5968-5329E, In-Fixture Measurements Using Vector Network Analyzers.
3. CTS App Note AN1007 VNA 3.5mm APC Calibration Method

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