Improve Your Millimeter-Wave Spectrum Measurements

Spectrum measurements in the millimeter-wave region require extra care to obtain accuracy and repeatability.

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Making good spectrum measurements gets tougher as frequencies get higher, and there are special challenges in the millimeter-wave region. Nevertheless, you can make good millimeter-wave measurements with a minimum of trouble: Just combine good basic microwave measurement practice with a few procedures and techniques unique to these higher frequencies. Even if you are inexperienced, avoiding the most common pitfalls will allow you to make optimal measurements. Likewise, common errors in practice will yield poor measurements even from the best equipment.

What is millimeter wave? Definitions vary, but the term generally refers to frequencies of 26.5 GHz or 30 GHz and above. This is where signal wavelengths fall below approximately 10 mm, and thus the terminology changes from centimeters to millimeters. The techniques described below cover millimeter-wave measurements in coaxial environments to approximately 50 GHz.

Modern spectrum analyzers such as the new 44-GHz and 50-GHz PSA series are able to cover the entire range of design tasks for high-frequency applications well, handling frequencies from IF and RF through millimeter wave, so they are the ideal fundamental tools for designers in this frequency range. The following practices to improve your millimeter-wave spectrum measurements apply no matter what type of measurement you're making—signal power or frequency, noise level, distortion, or phase noise.

Use the Correct Cables and Adapters

You should use only cables and adapters designed for millimeter-wave frequencies. Accessories for millimeter-wave measurements are different (and generally more expensive) from those used in RF or microwave measurements. The materials, structures, and geometries of these cables and adapters are specifically designed for these frequencies, to provide more-consistent impedance and reduce signal loss. Avoid compromising the performance of an expensive test system with poor-quality or inappropriate cabling and accessories.

Use a Connector Saver

You should use a "connector saver" on the spectrum analyzer. The small size and precise geometry of millimeter-wave connectors mean that they are more delicate and more costly than the larger connectors used at lower frequencies. Millimeter-wave spectrum analyzers often use male connectors on the front panel to encourage users to semi-permanently attach a female-to-female adapter or dc block as a connector saver. Measurement cables are attached to this connector saver, which can easily be replaced after it becomes worn or damaged.

Always Use a Torque Wrench

You should use a torque wrench on all connections. Proper torque improves measurement repeatability and extends connector life. The tightening torque on connectors has a significant effect on measurements at millimeter-wave frequencies, and repeatable measurements require consistent torque from measurement to measurement and on all the connections in a setup **(figure 1)**. A torque wrench also avoids damage due to over-tightening and helps connectors achieve their rated lifetimes.

Use Consistent Cables, Connectors, and Cable Routing

You need to use the same cables, connectors, and cable routing for the most-consistent measurement results. Even the highest-quality cables and adapters have measurable insertion loss and affect imped-

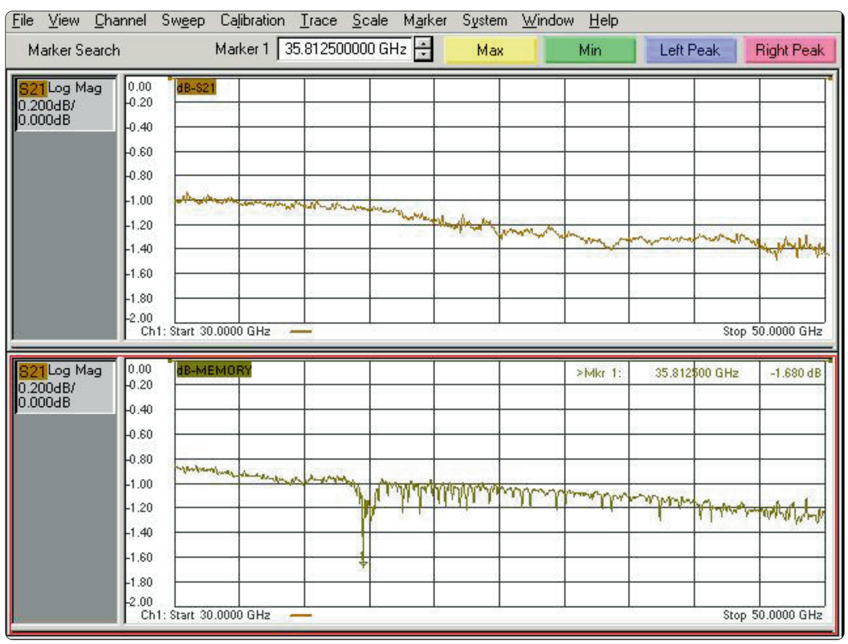

Figure 1. Consistent torque is important for accurate, repeatable measurements. The top trace shows the return loss of a measurement made using the correct torque on appropriate connectors. The bottom trace shows the same measurement, but with the connections casually hand-tightened..

ance (return loss) at millimeter-wave frequencies. Bending, kinking, and stretching cables can also affect results—in some measurements you can see a difference in real time just by flexing a cable while a measurement is in progress. Since repeatability is as important as absolute accuracy in many measurements, it's always a good idea to use the same cables and connectors in the same configuration from measurement to measurement. Not surprisingly, the use of semi-rigid coaxial cable can improve many measurements by reducing incidental movement and making more-consistent connections.

Do More Calibrations

You should perform calibrations and alignments frequently, and whenever measurement conditions change. Virtually all millimeter-wave analyzers have auto-calibration and auto-alignment functions in their firmware and hardware. Take advantage of these functions in each measurement to allow the analyzer to perform at its best. This is particularly important in the high measurement bands and where preselectors are used. Analyzers typically initiate calibrations and alignments on a timed basis, although they also may respond to detected changes in temperature. In general, the best measurements are made when the analyzer temperature has stabilized and a calibration or alignment is performed shortly before the measurement itself.

Know the Measurement Plane

You should understand the measurement plane and its characteristics and connect the analyzer to the circuit using the shortest, simplest, straightest path possible. Fewer connectors or adapters, and shorter cables reduce the chance for problems and minimize the non-ideal behavior of each element. When different connections are being made between measurements, and especially for relative measurements, it's important to understand the measurement plane. For this it is key to know what parts of the measurement connection change from measurement to measurement.

Review Specifications

You need to review instrument specifications and the individual measurement configuration to understand the actual level of performance you can expect. Major performance figures such as amplitude and frequency accuracy (or phase noise), flatness, noise level (or signal-to-noise ratio), and repeatability will not be as good at millimeter-wave frequencies. Analyzer architectural changes such as the use of higher-order harmonics and preselectors tend to widen the inherent bandwidth of measurements and reduce the dynamic range available at millimeter-wave frequencies. Cabling and connectors contribute to both signal loss and flatness variations due to impedance or return-loss uncertainty. These sources of error add to those from any uncertainties produced by the imperfect impedance of the source under test.

Be Careful!

Make your measurements carefully—begin with the best measurement practices that you would normally apply to RF and microwave measurements. Good practice at millimeter-wave frequencies is a superset of good practice at lower frequencies. All the factors that influence lower-frequency measurements are more difficult, sensitive, and variable at higher frequencies. Good measurements at these frequencies will take significantly more time and care. You need to inspect connections and cables frequently to detect wear or damage, and promptly replace gear that has reached the end of its rated life.

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Additional literature
8 Hints for Better Millimeter-Wave Spectrum Measurements
Application Note 1391
Literature number 5988-5680EN

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