Efficient Cable and Antenna Testing

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Efficient Cable and Antenna Testing

Ensure fast, accurate and efficient cable and antenna testing by using appropriate instrumentation and the right measurement techniques for verifying and troubleshooting cables, connectors and antennas in RF and microwave communications systems.

By Rolland Zhang

Faulty cables, connectors and antennas cause roughly 50 to 60 percent of cellular base station problems. Components may become damaged during installation, operation and maintenance of a telecommunications system or may suffer reduced performance as they age. Extreme weather may damage outdoor installations. Even sheltered installations can be problematic, potentially exposing components to mishandling, stress, heat, vibration and containments that can leak into the system. Such failures cause poor coverage and unnecessary handovers in the cellular system, making appropriate testing all the more critical. Cable and antenna measurements are often used to verify and troubleshoot the electrical performance of RF and microwave transmission systems and antennas. Key to ensuring fast, accurate and efficient cable and antenna testing (CAT) is use of appropriate instrumentation and the right measurement techniques.

Photo 1: Agilent's FieldFox combination microwave analyzer's base function is a cable and antenna analyzer, and it can be configured to include spectrum and network analysis. Offering amplitude accuracy of ±0.5 dB at power-up with no warm-up required, a frequency range up to 26.5 GHz, built-in calibration capabilities and ruggedized operation, the analyzer is suitable for a range of applications including satellite communications, microwave backhaul and military communications.

CAT basics

When verifying and maintaining the operation of RF and microwave transmission systems and antennas, measurements are often made along the coaxial cable connecting a transmitter to its antenna or between an antenna and its receiver. This process, line sweeping, measures signal attenuation or insertion loss and return loss as a function of frequency. Line sweeping is also used to estimate the physical location of a fault or damage along the transmission line using the distance-to-fault (DTF) measurement available on many RF and microwave signal analyzers. Testing transmission line performance is not limited only to coaxial cable. Systems using waveguide and twisted-pair cables may also be characterized, once the appropriate adapter is installed between the transmission line and the coaxial interface on the analyzer. In addition, antenna measurements in the form of signal reflection or return loss and voltage standing wave ratio (VSWR) may be used to verify the performance of an antenna at the installation site. When multiple antennas are required at a site, antenna-to-antenna isolation may also be verified.

In all cases, a modern handheld microwave analyzer configured for cable and antenna testing proves especially effective for making the required measurements (see Photo 1). Its performance, functionality and flexibility make it an extremely useful tool for quickly and accurately characterizing the entire transmission system and the performance of individual system components.

Tackling cable insertion loss

The insertion loss of transmission line or coaxial cable, often measured as a function of the intended operating frequency band, is the amount of energy dissipated in the cable and includes energy lost due to mismatch reflection between the source and load. Generally, the source (transmitter), transmission line (coaxial cable) and load (antenna) are all designed for the same characteristic impedance, Zo — usually 50 ohms or 75 ohms when using coaxial cable. Most modern RF and microwave analyzers are configured with 50-ohm test port impedances. When measuring 75-ohm cables and components, a 50-ohm to 75-ohm adapter is required.

Removing transmission line cables to verify their operation and troubleshoot cable failures once they have been installed in a system is costly and difficult. With long cable runs, gaining access to both ends of the cable at the same time is typically impossible, especially when attempting to connect the cable to the test instrumentation. Under these conditions, techniques for measuring cable insertion loss from one end of the cable are preferred.

Three techniques for measuring cable insertion loss with a modern RF and microwave analyzer in CAT mode are:

Two-port technique — Here, the cable-under-test is connected to two ports on the analyzer. The analyzer injects a test signal into the cable from its RF OUT port. As the signal passes through the cable, a small portion of the energy is absorbed by resistive and dielectric losses in the cable. Discontinuities from cable connectors, cable splices, damage and other factors reflect a portion of the energy back to the source resulting in an additional increase in measured insertion loss. The remaining signal exiting the cable is then measured by the analyzer at the RF IN port. The ratio between input and output signals represents the total insertion loss of the cable, usually expressed in decibels (dB).

One-port technique — This method measures cable insertion loss from only one end of the cable-under-test. One end of the cable is attached to the analyzer, while the other is left open or terminated in a short circuit (recommended for microwave frequencies). The analyzer injects a test signal into the cable from the RF OUT port. The signal passes through the cable, is completely reflected from the open (or shorted) end, passes through the cable a second time, and is measured by the analyzer using the same port. The analyzer then uses this information and a built-in model for coaxial cable dispersion to report cable insertion loss as a function of frequency. This technique is only available on analyzers configured with an internal factory-calibrated reflectometer for measuring reflected signals at the instrument's RF OUT port.

Power-meter technique — With this technique, the instrument is configured as a power meter connected to a USB power sensor. One end of the cable-under-test is connected to the analyzer's RF OUT port, while the other end is connected to the USB power sensor. The analyzer is configured to generate a CW signal at the RF OUT port. This test signal is transmitted along the cable and measured by the USB power sensor. If the cable ends are separated by a large distance, the sensor is connected back to the analyzer through a USB cable extender. Because this technique does not allow swept-frequency measurements, manual tuning of the analyzer's settings is required when changing test frequencies.

Calibrating Analyzer Test Ports

When making cable insertion loss, return loss and VSWR, antenna-to-antenna isolation, and DTF measurements, different test requirements often result in a variety of jumper cables and adapters being connected to the analyzer. The effects of these components can be removed from the measurements using the user calibrations available in most modern RF and microwave analyzers. The different types of user calibrations for accurately measuring the reflection characteristics and insertion loss of components and systems fall into two categories: mechanical calibration and analyzer-specific built-in calibration. One-port OSL (open, short, load), normalization, enhanced response and full two-port calibration are examples of mechanical calibration types available on a range of analyzers. CalReady, a factory calibration using standards traceable to NIST, and QuickCal, an industry-first function enabling hassle-free calibration without external accessories, are prime examples of built-in calibrations specific to the FieldFox analyzer.

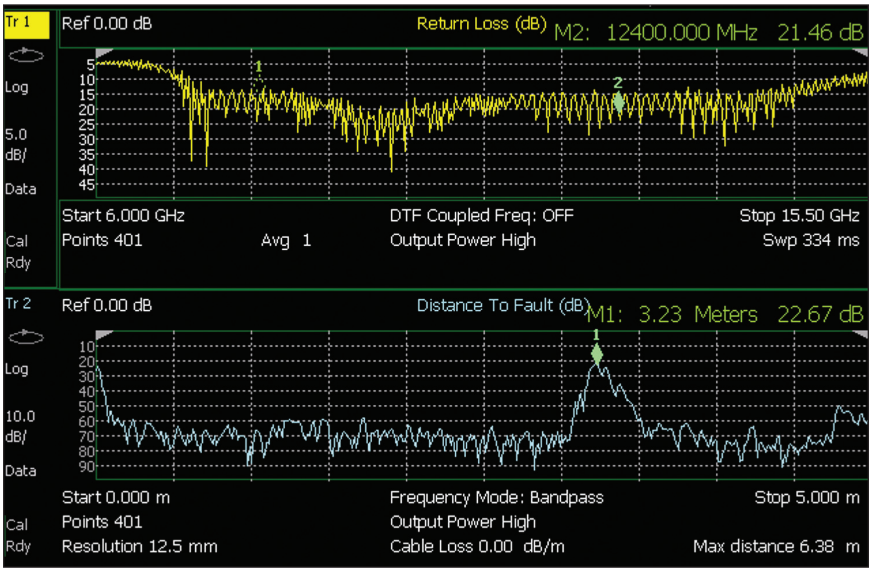


Photo 2: Shown here are the measured return loss (upper trace) and DTF (lower trace) for an X-band antenna and coaxial feed cable.

When measuring cables with high insertion loss, the displayed measurement trace may exhibit a high level of noise. In this case, the relative signal-to-noise ratio and associated measurement accuracy can be improved by setting the analyzer's output power to high-power mode. The displayed noise level can also be reduced by increasing the number of trace averages or decreasing the intermediate-frequency bandwidth setting.

Antenna return loss and VSWR

Antennas are specified by their gain factor and return loss or VSWR. Antenna gain measurements are typically performed in a special test facility (e.g., an anechoic chamber). Return loss and VSWR are standard measurements reported for most RF and microwave components and systems and can easily be measured with a modern microwave analyzer in the field or lab.

Once installed in a system, only an antenna's reflection properties are measured to determine whether or not it is faulty or damaged. The antenna's return loss and VSWR are used to characterize its performance. These one-port measurements are typically performed over the intended frequency band of interest.

A typical antenna with a return loss of 10 dB or higher represents a reasonably well-matched antenna. A 10-dB return loss is equivalent to having 90 percent of the incident energy radiated by the antenna and 10 percent of the energy reflected back to the transmitter. For applications where high efficiency is required (e.g., base station antennas) the return loss may be specified at 15 dB or higher. A 10-dB return loss is approximately equal to a VSWR of 2:1. While a conversion table can be used to find the relation between values of return loss and VSWR, some modern analyzers handle this conversion and can be easily configured to display the measured response as return loss or VSWR.

When interfacing the antenna to the analyzer, high-quality adapters can be used to improve measurement accuracy and repeatability. The adapter characteristics may be removed from the measured results using the analyzer's calibration feature (see the sidebar, "Calibrating Analyzer Test Ports"). The analyzer should also be attached as close to the antenna as possible so the insertion loss of the cable does not mask the antenna's true return loss.

Antenna-to-antenna isolation

When different wireless systems are collocated to share tower and shelter structures, antennas (either operating within the same system or between different systems) must be spaced far enough apart to maintain an adequate level of isolation. This prevents creation of intermodulation distortion in the transmit amplifiers or noise desensitization in the receivers.

Systems are typically designed with duplexing and other filters to reject signals from nearby transmitters and other interference, but system performance may require an antenna-to-antenna isolation of 60 dB or more. It is therefore necessary to sweep the antenna-to-antenna isolation across all frequency bands of interest. This can be done with a two-port insertion loss measurement in which each antenna is attached via a short jumper cable to the analyzer.

Locating faults

When cable insertion loss is higher than expected or return loss and VSWR are out of specification, finding fault locations along the transmission system becomes essential. The location is determined using the analyzer's DTF capability, which uses reflection measurements taken from the transmission line to calculate the individual amplitude response of any discontinuities as a function of distance.

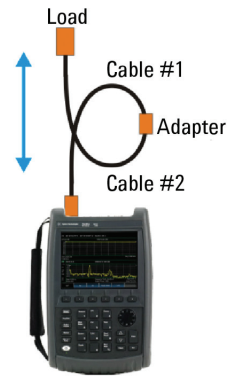
Photo 2 shows a dual display of the return loss as a function of frequency and associated DTF measurement from a section of coaxial cable connected to an antenna. When examining the DTF display, high-amplitude level signals are located at the points where discontinuities exist along the transmission line and at the load. The location of these high-amplitude signals provides an important troubleshooting tool when determining faults in the cabled transmission system.

A typical configuration for measuring DTF is shown in Figure 1. It is assumed that the load (e.g., the system antenna, a 50-ohm termination or just an open-ended cable) is connected to the analyzer through two sections of coaxial cables connected via an adapter. Figure 1 also shows a table of important cable specifications as supplied by the manufacturer. The specification for velocity factor (VF) is important to enter into the analyzer for the instrument to correctly display the distance to each cable discontinuity.

DTF measurements of transmission systems are primarily concerned with locating the physical position of faults along the line, and therefore, precise amplitude measurements of the return loss and VSWR may not be required. Accordingly, most applications only require that the cable's VF be entered into the analyzer's cable specification table. When the VF of a cable is unknown but the physical distance of the cable is known, it can be estimated using the DTF measurement.

Conclusion

Cable and antenna testing are critical to verifying and maintaining the operation of RF and microwave transmission systems and antennas. Use of appropriate measurement and calibration techniques, along with a modern RF and microwave signal analyzer configured for cable and antenna testing, provides the best means of accurately, quickly and effectively accomplishing this goal. Download Agilent's application note, "Techniques for Precise Cable and Antenna Measurements in the Field", to learn more. ■



Cable specifications

Velocity factor	0.66
Cable loss (dB/m) @ 50 MHz	0.04
Cable loss (dB/m) @ 100 MHz	0.06
Cable loss (dB/m) @ 500 MHz	0.17
Cable loss (dB/m) @ 1000 MHz	0.28

FieldFox DTF cable spec menu

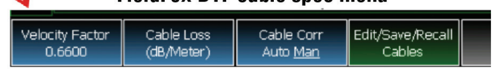


Figure 1. Shown here is the configuration for measuring the distance-to-fault in a system having two coaxial cables connected to a load; also shown are the specifications for the cables used in this example.

Rolland Zhang is the product manager for Agilent Technologies' FieldFox RF and microwave handheld analyzers. Previously, he served as business development manager for Agilent's Wireless Network Solutions Division. He has more than 20 years of experience in wireless infrastructure installation and maintenance, and wireless network engineering,