FLUKE®

Calibration

Choosing and using cables for RF calibration

Application Note

Coaxial cables are common throughout RF and microwave calibration, representing significant investment as precision cables can be very expensive. Choosing an appropriate cable type is often critical to successfully making accurate, repeatable measurements.

Figure 1. Typical cables and connectors: general purpose BNC and N-Type on the left; flexible and semi-flexible precision metrology grade in the middle; and phase-stable VNA testport cables on the far right.

Characteristics of the cable, the connectors, and the attachment of the connectors to the cable all contribute. The key characteristics are attenuation, phase shift (delay) and match, and their stability with time, temperature and flexing/movement of the cable and connectors. Maintaining the cable and connectors in good condition is essential to minimizing errors and uncertainties.

For less demanding applications such as distributing reference frequencies around the laboratory or between individual instruments within a system, typical general purpose RG58 cable using BNC connectors such as those shown in Figure 2 will suffice. However, these types of cables are not appropriate for metrology applications where signal level or phase accuracy and stability or impedance match is critical. Generally the BNC connector is not appropriate for calibration applications, but there are some higher quality BNC connectors available which are typically used with higher grade cables in oscilloscope calibration. The majority of oscilloscopes appearing in the calibration workload have BNC connectors, so use of a BNC connector is unavoidable.

Figure 2. General purpose coaxial cables.

At RF and microwave frequencies the cables and connectors are transmission lines. Using cable and connector types appropriate for the frequency range is essential in order to avoid excessive attenuation and other unwanted effects as the transmission line approaches its cutoff frequency. Coaxial connectors are described by the transmission line diameter (internal diameter of the outer conductor). At higher frequencies the smaller transmission line dimensions dictated by shorter wavelengths place greater demands on mechanical tolerances. Cables and connectors become smaller in diameter, more fragile, and require greater care in their use, handling and storage. The precision N-Type (7 mm) connectors common in many metrology applications are useable up to 18 GHz. Other types including PC3.5 mm, 2.92 mm (K), 2.4 mm, 1.8 mm (V), 1.0 mm, etc, are designed for higher frequencies (110 GHz for the 1.0 mm). Do not exceed manufacturer's frequency range specifications for the cables and connectors. Some of these connector types are non-destructively interconnectable, but doing so introduces excessive mismatch.

A few typical examples of flexible and semi-flexible metrology grade cables are shown in Figure 3. Unsurprisingly, the improved performance is accompanied by higher costs, typically an order of magnitude more expensive than general purpose cables, with the higher precision cables being even more expensive. The top two examples in Figure 3 are flexible "level stable" cables, with attenuation characteristics not significantly affected by variations in temperature and flexing. Good practice is to observe a minimum bend radius of around 100 mm. Kinked cables will have unpredictable performance and should be discarded to prevent inadvertent use.

Phase stable cable types, as their name implies, also maintain phase (delay) characteristics with time, temperature and flexing. Cable of this type is commonly used as Vector Network Analyzer (VNA) test port cables where good flexibility and immunity to bending and flexing are required. See Figure 4.

The manner in which the connector and cable are joined—crimped or clamped—is also important, both electrically and mechanically. Mechanical arrangements differ with connector design, with potential discontinuity of the transmission outer conductor through the termination resulting in variations in transmission line characteristic impedance and therefore contributes to match (mis-match) performance. In a crimped connector the cable outer conductor is secured by compression between a metal sleeve and the connector body. In a clamped connector there is a nut and ferrule securing the cable outer conductor to the connector body. Crimping has the potential to add further transmission line discontinuities if

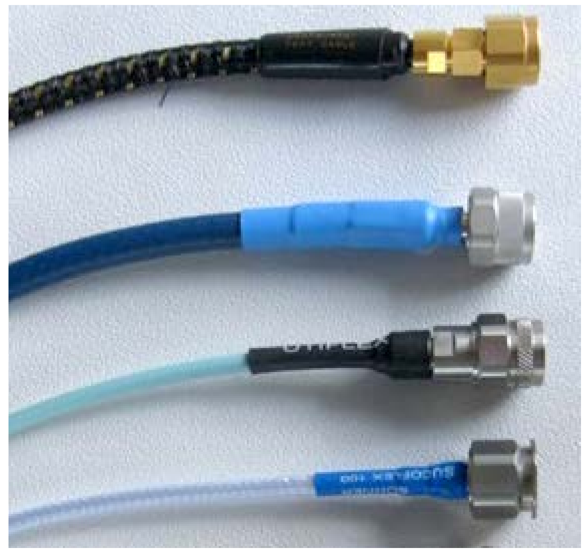

Figure 3. Precision metrology grade coaxial cables with N-Type connectors. Top two are level stable types.

Figure 4. Phase and level stable cables used for Vector Network Analyzer (VNA) test port connections.

the pressure applied to form the crimp distorts the cable or connector components. Clamping has the potential for a smoother transition of the transmission line outer conductor, and therefore better match. However, there is opportunity for loosening of the clamping nut with cable movement, etc, degrading the connection impacting attenuation and match performance, potentially in an intermittent fashion. Crimped and clamped terminations have different attributes and users should choose according to their needs.

It is good practice to consider cables much like any other calibrated item within the laboratory, including them within routine maintenance and calibration schedules, and to serialize or asset tag cables as a means of identifying individual items. Many higher grade cables are supplied with measured data for attenuation and match and users may make their own measurements, for example using VNAs. Regularly inspect cables and connectors for damage and any other degradation that might affect performance, monitoring characteristics, changes and where appropriate account for the characteristics during use.

For more information, please see "Making repeatable RF connections during RF calibration" on www.flukecal.com

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Printed in U.S.A. 8/2015 6005963b-en