Application Note

Accurately characterize loss and reflection of long, embedded coaxial transmission systems

What will be covered in this application note:

1. Introduction to common problems presented when coaxial transmission systems are permanently installed within an enclosed environment, and each end is separated by large distances.
2. The benefits of swept frequency measurements vs single or multiple CW frequency point measurements. Includes example of defective cable found only after performing swept measurement.
3. Detailed list of required items to perform the described measurements.
4. A step-by-step complete procedure from start to finish with detailed photos and instructions.
5. Supplemental information: Using dual screen mode for simultaneous measurements, and using DTF for troubleshooting defective cables.

Introduction:

Properly measuring end-to-end loss in coaxial and waveguide systems can present significant challenges once those systems are permanently installed (embedded) and their physical ends are located at far distances away from each other.

There are measurement options, but most are based on using a signal source and a power meter, making a single frequency (CW) measurement at a particular chosen or defined frequency. Measuring coaxial transmission systems like these using only a single CW frequency point, or perhaps a set of CW frequency points, could easily miss a problem in that transmission system that may lie somewhere between the measured CW points. Increasing the number of measurement points beyond 10 or 20 is cumbersome and time consuming since the signal generator and power meter needs to be normalized at every CW frequency point before a measurement at that point can be made.

If the transmission system only had to operate over a very narrow frequency range, you might be able to get a reasonable characterization of the system using multiple discrete points. The reality is that many of today's systems have to support multiple bands and wide bandwidth. For example, today's currently installed DAS systems are often required to cover multiple bands ranging from about 700 MHz to 3.5 GHz, with more and more bands being added as time goes on. As the bandwidth requirements continue to increase, the need for a better, more efficient solution becomes clearly obvious.

In the past, scalar analyzer systems were a good solution because they could easily sweep a range of frequencies and plot the system response as a continuous curve, which was advantageous and desirable, however they were large, bulky instruments, and required AC power at all times.

Traditional Vector Network Analyzer (VNA) instruments are not able to make these measurements since their measurement ports cannot be separated far enough physically to reach both ends of the transmission system under test.

Other typical measurement requirements for characterizing a coaxial transmission system include reflection measurements (Return Loss (RL) or VSWR) and reflection based distance-to-fault (DTF) for troubleshooting and fault location. The reflection measurements provide valuable information about the overall health of the system and the DTF measurement are essential to precisely identify the location of any faults if they exist within the system.

Luckily there is a solution. The Anritsu S820E is capable of performing all of the required reflection measurements including DTF. The S820E can also perform the loss measurements on coaxial transmission systems with the addition of a few external items available from Anritsu.

A typical in-building passive DAS configuration is shown below. The test signal is applied to the input of the tree feeding individual antennas on multiple branches of the system. The antennas are located throughout the building at strategically chosen locations to provide optimal coverage. Distances between antennas and test signal input increases as the size of the building increases, and can easily spread out over 70 meters or more. See ***Figure 1***.

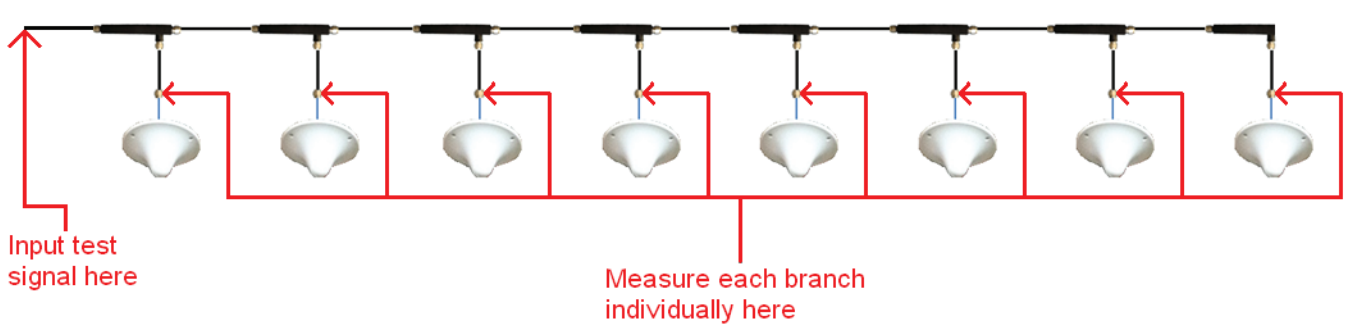


Figure 1. *Typical in-building passive DAS configuration. Number of antennas varies as needed, last antenna may be >70 meters away from the test signal input port.*

Other examples might also include 5.8 GHz WiFi, and there are countless other requirements such as coaxial cable systems embedded in aircraft wings and fuselage, these are often required to be measured from frequencies as low as possible and going typically up to 18 GHz, although there can be requirements well beyond 18 GHz depending on the system.

What you will need to measure 50 ohm coaxial based embedded transmission systems:

1. Standard 50 ohm coaxial based system:
   a. S820E instrument with required frequency range. There are 5 models covering 1 MHz to 8/14/20/30/40 GHz.
   b. Coaxial test port cable(s) with appropriate connectors
   c. Coaxial calibration kit such as TOSLN50A-18 (for the reflection measurement)
   d. Precision coaxial adapters as required for the transmission system being measured.
   e. SC-8268 USB Transmission Sensor or any MA24108A/MA24118A/MA24126A USB Power Sensor (for the transmission measurement). The example below uses the MA24118A.
   f. 2000-1717-R USB Extender
   g. 2300-1777 CAT 5e cable, 22.5 meter length, or any suitable length of CAT 5e (CAT 6 preferred) up to 85 meters

Example measurement procedure, N (m) to N (f) type transmission cable, 700 MHz to 3.5 GHz, 259 datapoints (default):

1. Ensure instrument is in Advanced Mode (Press “Menu” hardkey then select “Advanced Mode”) then preset instrument to obtain a known state.
2. Press “Freq/Dist” [Freq/Dist] main menu key (bottom row of keys, see Figure 2)
3. Press “Start Frequency (F1)” [Start Frequency (F1)] submenu key (vertical column of keys on right side of display, see ***Figure 2***) and set start frequency to 700 MHz. Set “Stop Frequency (F2)” [Stop Frequency (F2)] to 3.5 GHz.

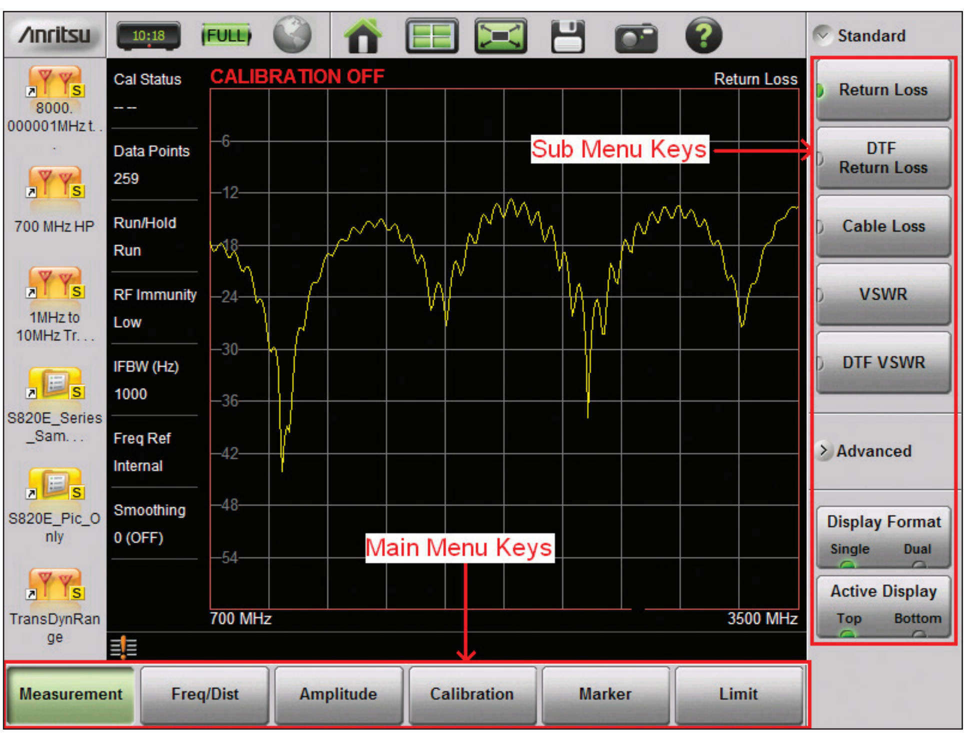
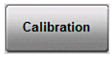


Figure 2*. Basic layout of menu and submenu keys*

Note: **Before proceeding with calibration, ensure USB transmission sensor (MA24118A in this example) is connected to instrument. Use USB extender and CAT5e cable as necessary.

4. Press “Calibration” 

main menu key to open Calibration sub menu. See ***Figure 3***.

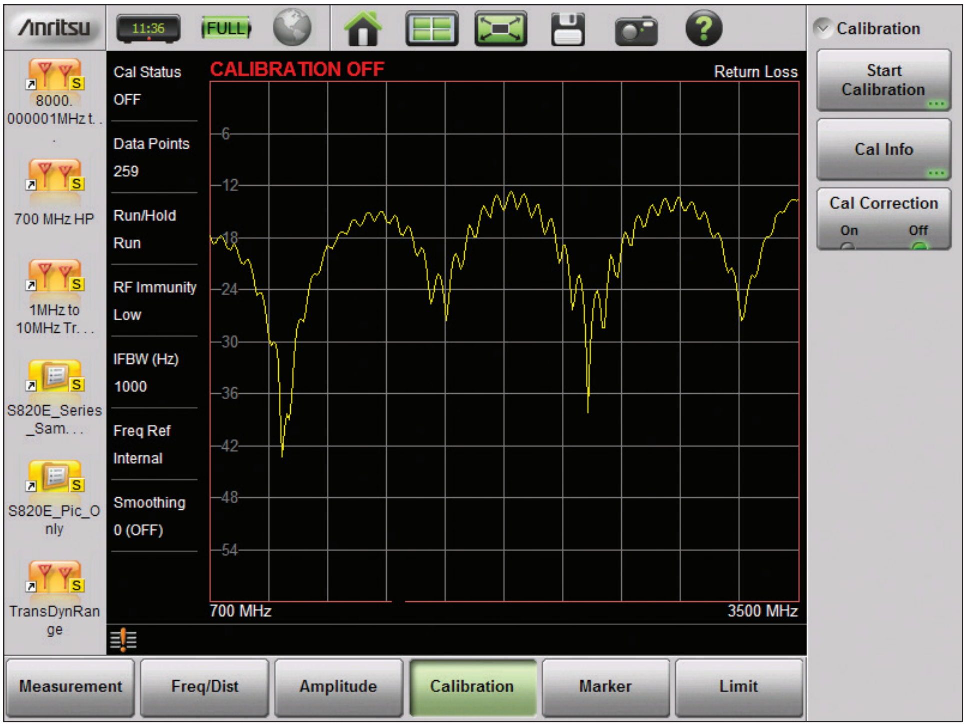
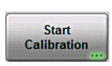


Figure 3. *Calibration sub menu*

a. Press “Start Calibration” 

sub menu key to initialize a new calibration sequence. See ***Figure 4***.

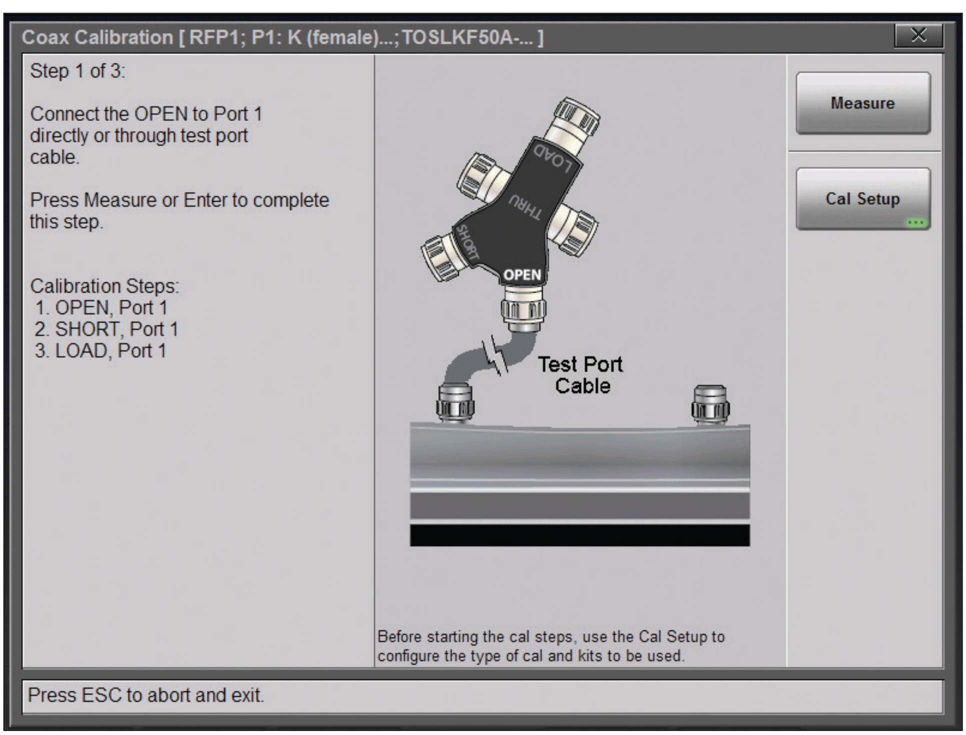
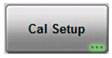


Figure 4. *Default Calibration Sequence*

b. Press “Cal Setup” 

key. See ***Figure 5***.

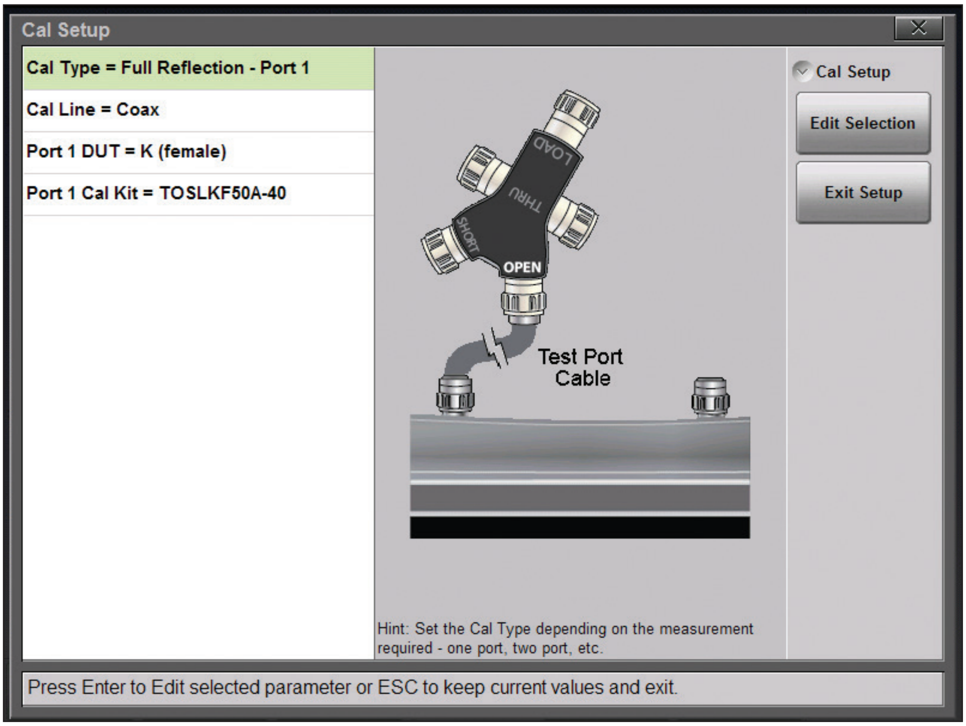
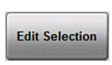
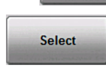


Figure 5. *Cal Setup*

c. Press “Edit Selection” 

key, scroll down to highlight “2PES: 1-Path 2-Port – Fwd path (Ext. Sensor)” then press “Select” 

. See ***Figure 6***.

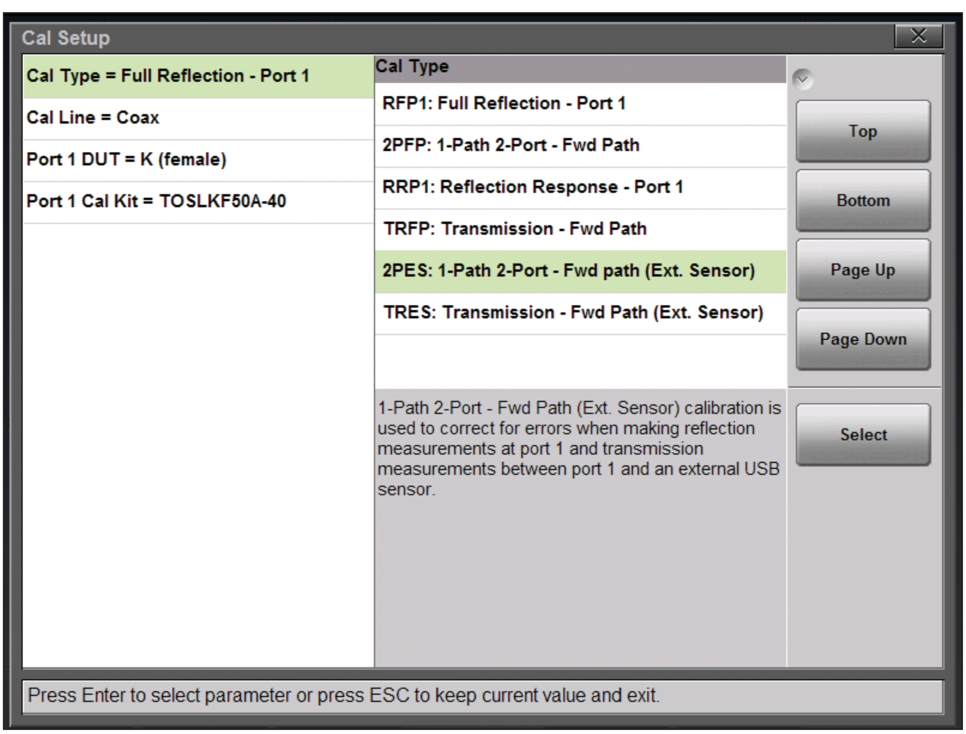


Figure 6. *2PES: 1-Path 2-Port – Fwd path [Ext. Sensor] highlighted*

d. Verify Cal Line = Coax. If Cal Line = Waveguide, press "Edit Selection" key and select "Coax"

e. Scroll down to highlight Port 1 DUT = K (female), press "Edit Selection", scroll to highlight N (male) and press "Select". See ***Figure 7***.

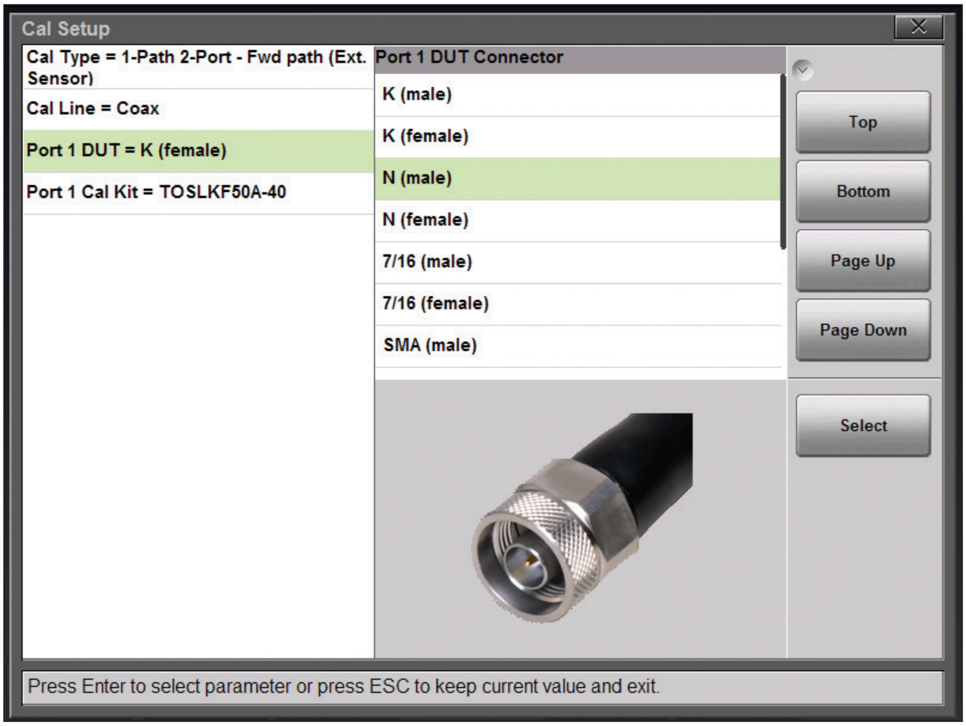


Figure 7. *N (male) highlighted*

f. Scroll down to highlight Port 1 Cal Kit = OSLN50A-18, press "Edit Selection" if different cal kit is being used. Highlight actual cal kit being used (TOSLN50A-18 in this example) then press "Select". See ***Figure 8***.

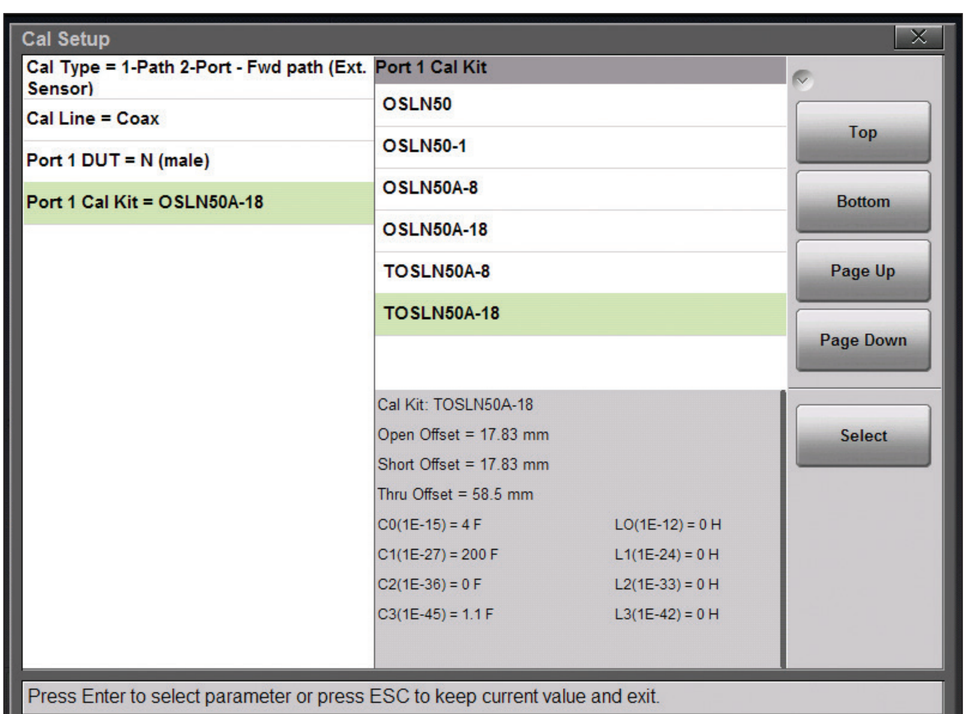


Figure 8. *TOSLN50A-18 Calibration Kit Highlighted*

g. Press “Exit Setup” [Exit Setup] to return to Calibration menu. Calibration menu should now look like ***Figure 9***.

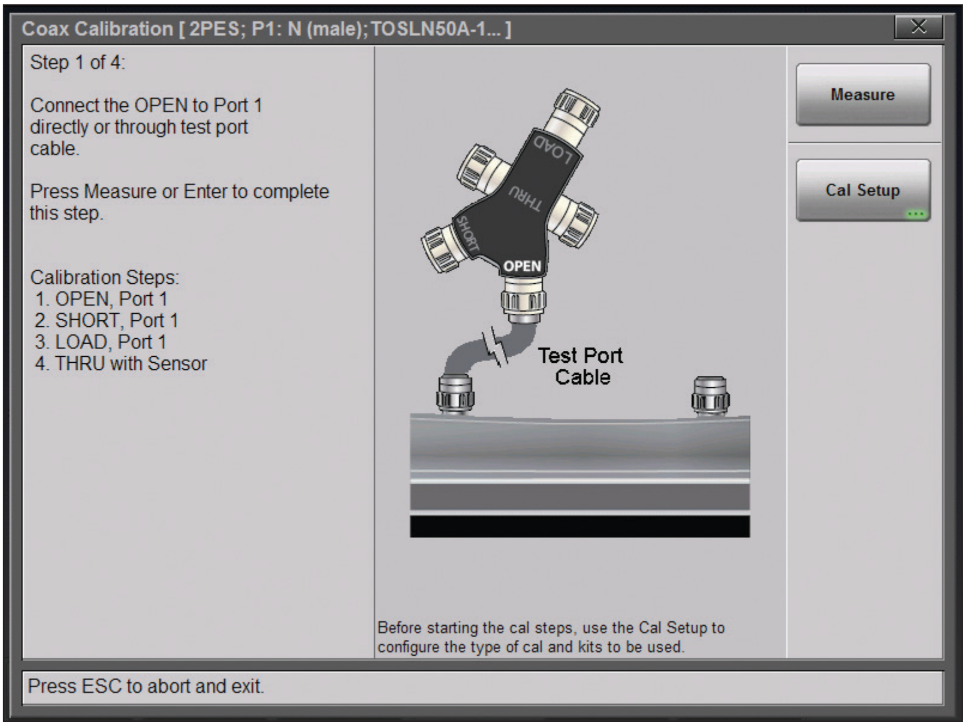


Figure 9. *Calibration settings complete. Ready to begin Step 1.*

h. Step 1. Connect Open to Port 1 (end of test port cable) then press “Measure” [Measure] to continue. Wait for instrument to complete step 1.

i. Step 2. Connect Short to Port 1 (end of test port cable) then press “Measure” [Measure] to continue. Wait for instrument to complete step 2.

j. Step 3. Connect Load to Port 1 (end of test port cable) then press “Measure” [Measure] to continue. Wait for instrument to complete step 3.

k. Step 4. Connect USB sensor to Port 1 (end of test port cable) then press “Measure” [Measure] to continue. This step of the calibration takes approximately 30 seconds to complete. Wait for instrument to complete step 4.

l. All steps are now complete but calibration is not yet applied. Press “Apply” [Apply] to complete calibration.

Your instrument screen should now look similar to the display below. USB sensor still attached to test port cable.

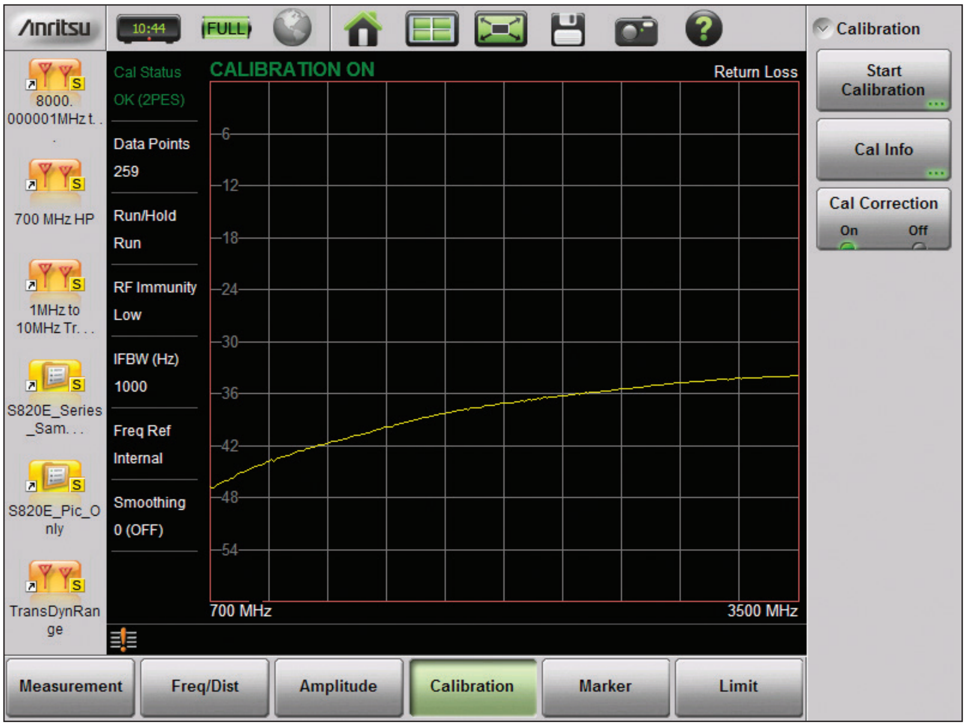
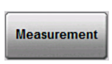


Figure 10. *Calibration completed. Ready to begin measurements*

Now in the following steps (5 to 11) we will measure the reflection (Return Loss) and end-to-end loss (Transmission [Ext. Sensor]) on the DUT. In this example we will measure these individually, but you will note that ***only one calibration is required.***

5. Press “Measurement” 

main menu key, Return Loss should already be selected and display should show Return Loss

6. Connect test port cable to one end of the coaxial transmission system (DUT), and place a ***calibration grade termination*** (load) at the other end of DUT. *Tip: Always use a calibration grade termination when measuring the DUT reflection (Return Loss or VSWR). A lesser quality termination may alter the actual DUT response, causing it to appear worse than it actually is.*

7. If limits or markers are required, activate them as needed. Consult the S820E user guide (built into instrument help menu) for details on limits and marker use. See ***Figure 11*** for example of Return Loss measurement on the DUT. Your measurement will be different.

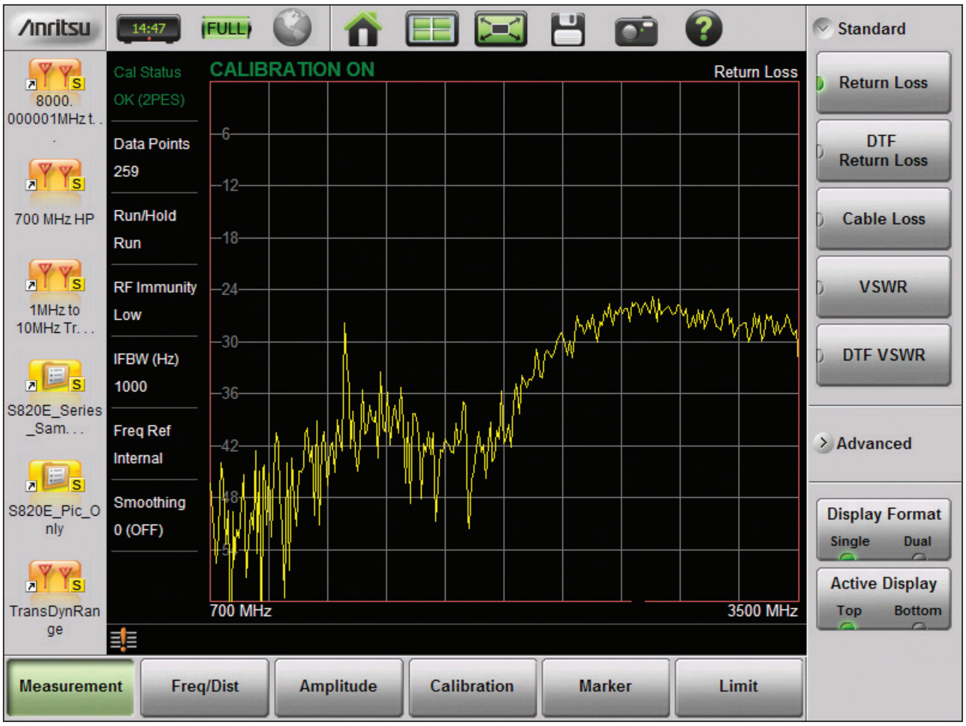


Figure 11. *DUT Return Loss measurement*

8. Save the measurement file as needed. Consult the S820E user guide for instructions on file saving if required.

9. Remove the termination from the end of the DUT and connect the USB sensor (MA24118A in this example) to the end of the DUT.

10. Press the" Advanced" Advanced submenu key, then press "Transmission [Ext. Sensor]" Advanced .

    Allow enough time for at least one sweep to complete. Use limits or markers as necessary. See ***Figure 12*** for example of end-to-end loss measurement on the DUT.

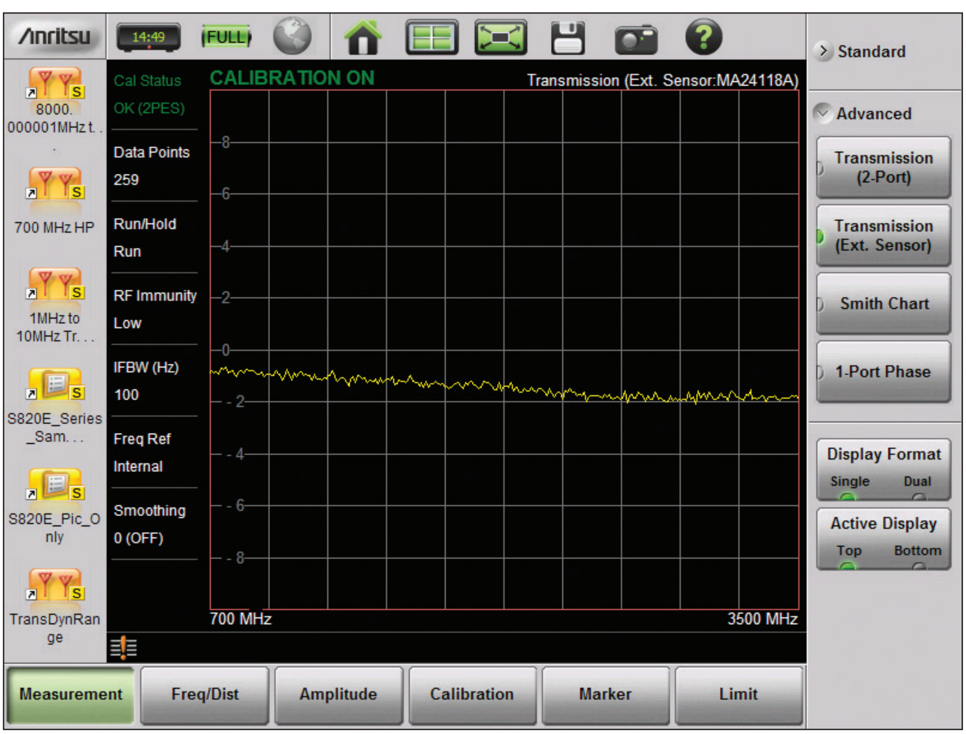


Figure 12. *DUT Transmission [Ext. Sensor] end-to-end loss measurement*

11. Save the measurement file as needed. Consult the user guide for information on file saving if required.

As mentioned in the beginning of this application note, using discrete CW frequency points, or a number of discrete CW measurement points is not adequate to accurately characterize the response of a coaxial transmission system. ***Figure 13*** shown below is a perfect example. This coaxial transmission system had been previously measured using only 10 discrete CW frequency points. The technician passed this coaxial transmission system based on the results, but the problems continued with communications being carried in this transmission system. Eventually the system was re-measured using the swept frequency method as outlined in this application note, the problem was immediately apparent, a significant dip in transmission amplitude around 12 GHz was found. This dip had been missed completely by the discrete CW point measurement method since it would only have been discovered if one of those discrete CW points happened to be at exactly the same frequency as the dip, the odds of a discrete CW frequency landing exactly where the fault lies is very unlikely in practice. Clearly the swept frequency measurement capability of the S820E proved to be invaluable. A detailed analysis of the transmission system tested revealed that at some point in its history, a cable had been accidentally cut and repaired. The repair involved cutting out the damaged section, installing new connectors on each end of the cut cable, and connecting the cable assembly via the new connectors. Unfortunately the new connectors used for the repair were not the correct type and they were being operated well beyond their mode-free design parameters.

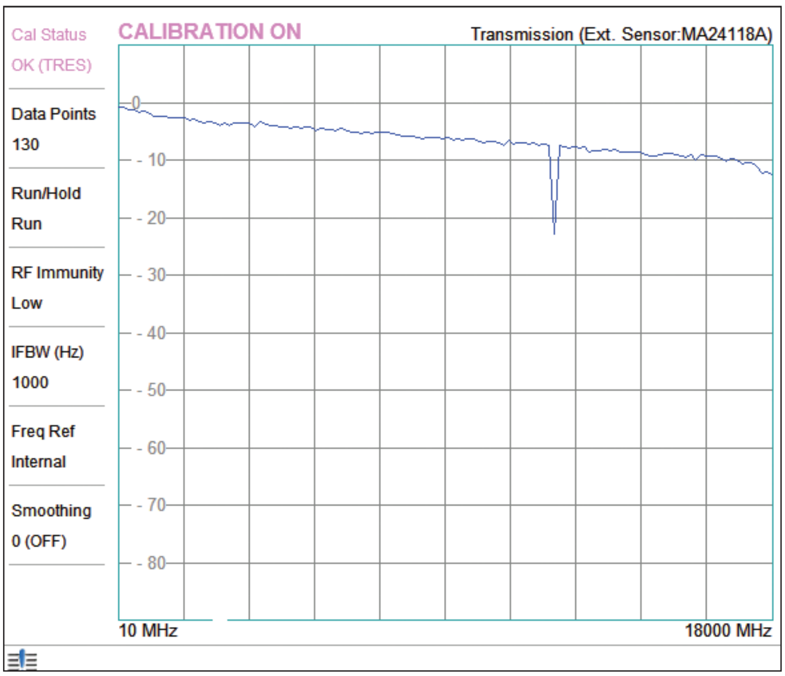
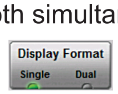


Figure 13. *Faulty connector(s) easily revealed using swept frequency measurement technique*

Conclusion:

In this application note we have shown how it is possible to easily and accurately measure end-to-end loss and reflection on embedded coaxial transmission systems using a swept frequency range, where each end of the system is separated by long physical distances. We have also demonstrated how the S820E is also capable of performing these measurements with only one calibration required. These measurements discussed in this application note can easily be adapted to other coaxial connector types. 75 ohm coaxial and rectangular waveguide systems can also easily be measured using appropriate calibration components and adapters.

Supplemental information:

1. If desired, both measurements covered in this application note may be measured and displayed simultaneously. To measure and display both simultaneously, based on the calibration previously made in step 5, simply press the “Display Format”  sub menu key until “Dual” is lit with the green indicator (***Figure 14.***)

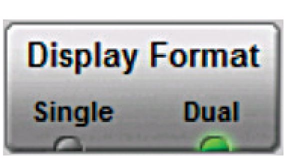


Figure 14. *Dual display indicator lit*

The screen will split into 2 graphs as seen in ***Figure 1***5, one graph will be highlighted with a red box, this is the “active” trace or measurement for parameter setting or measurement enhancements such as markers, limits, scale, etc. Select what to display for each active trace as you would if using the single display mode. You may mix and match any measurement combination that is supported by the current calibration. Each measurement trace will display Calibration On or Calibration Off depending on whether the current active calibration can support the selected measurement type. Please consult the S820E user guide for more information on Dual Display measurements.

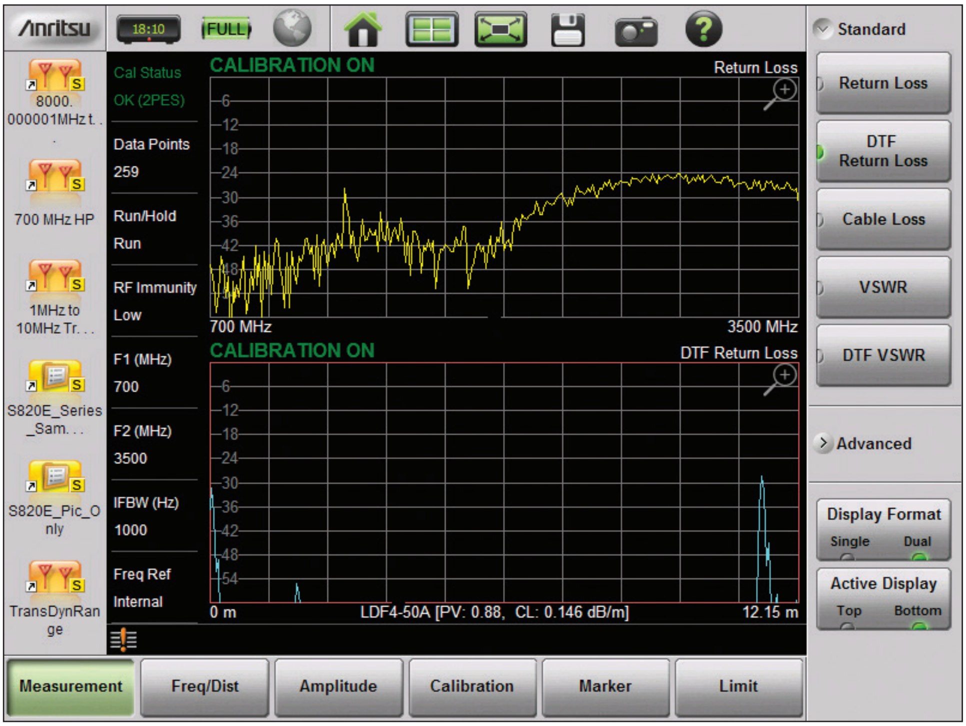


Figure 15. Dual display measurement with Return Loss and DTF-Return Loss displayed

2. Distance-to-Fault measurements are generally necessary and invaluable when a problem has been encountered in the transmission system. Finding the precise location of the fault(s) is easily done simply by selecting “DTF Return Loss” or “DTF-VSWR” after completing the Return Loss measurement described in step 6. Alternatively the user could simultaneously display both the Return Loss measurement and the DTF-Return Loss measurement using the Dual display format as noted above. See ***Figure 15***. Additional information regarding Distance-to-Fault measurements may be found in the S820E user guide as well as in the following application note titled “Distance To Fault” available from the library tab of the S820E web page located here http://www.anritsu.com/en-us/products-solutions/products/s820e.aspx

Additional Notes:

1. Be aware that if you choose to simultaneously measure and display reflection and end-to-end loss using the USB sensor, the reflection measurement will be worse while the USB sensor is connected at the end of the DUT. If the reflection measurement must pass a user defined limit for sweep verification, be sure to remove the USB sensor and replace it with a precision calibration grade termination at the end of the transmission system before judging and saving the measurement. Using a precision calibration grade termination for the reflection measurement will eliminate erroneous results.
2. The SC-8268 USB Transmission Sensor has been optimized to provide extended operation up to a maximum of 40 GHz, and starting as low as 1 MHz. Its sensitivity has also been optimized to provide an additional 10 dB of measurement dynamic range when compared to the MA241XXA series of USB sensors.
3. If you experience excessive trace noise while performing the USB sensor based transmission measurements, try reducing the instrument IFBW to 100 Hz and/or adding just 2 or 3% trace smoothing. These settings can be found in the Sweep menu.

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