APPLICATION NOTE

FlexCal™ Broadband Calibration and Measurement

Cell Master and Site Master

1.0 Introduction

This is a practical broadband calibration measurement procedures note. The objective of this note is to present measurement tips and procedures which will help a field technician troubleshoot and identify faulty antenna system components.

1.1 Problematic Cables, Connectors and Antennas are Primary Sources of Cell Site Problems

More than sixty percent of a typical cell site's problems are caused by problematic cables, connectors, and antennas. Faulty components are a primary source of overall antenna degradation and can result in dropped calls. This puts pressure on the field technician who must fix the problem while minimizing any delay in system operation. Quickly troubleshooting and identifying these problems offers Service Providers a way to improve quality, while reducing cost – an important differentiating factor for any company working in today's highly competitive wireless market. However, locating and fixing these problems, especially without the right equipment, can be a tricky and time-consuming proposition. Traditionally, it has been easier to simply replace the suspected cable or antenna system component.

This task is further complicated by the need to continually perform instrumentation calibration, using such techniques as the Open-Short-Load (OSL) calibration method, every time a change occurs in either start frequency and/or stop frequency – an action which would invalidate the calibration. Despite the difficulty, calibration is necessary in order to maintain the integrity of any measurement.

2.0 Identifying Faulty Cables and Antenna System Components

The Anritsu Cell Master and Site Master FlexCal™ broadband calibration feature is an OSL-based calibration method. It offers field technicians a simple and convenient way to troubleshoot and identify faulty antenna system components because it eliminates the need for multiple instrument calibrations and calibration setups. Field technicians can now perform a broadband calibration and change the frequency range after calibration without having to recalibrate the instrument. A zoom in/zoom out capability is available in Return Loss, Cable Loss or VSWR mode. Because the resolution and maximum distance are dependent on the frequency range, field technicians - in DTF mode - can even change the frequency range to produce the desired fault resolution and horizontal range needed for the measurement without performing additional calibrations.

The Site Master has a measurement range of 25 to 4000 MHz. When FlexCal is selected, Site Master is calibrated from 25 to 4000 MHz. FlexCal has the same accuracy as the OSL calibration method for this frequency range. For frequency ranges other than 25 to 4000 MHz, measurement uncertainty may degrade slightly due to calibration data interpolation. Therefore, it is recommended that you perform another OSL calibration to obtain the maximum possible measurement accuracy when the data is to be used for archiving and reporting.

3.0 Understanding OSL Cal and FlexCal

The OSL calibration method is the most widely used calibration technique for one-port calibration. The OSL cal provides accurate measurements over a fixed frequency range which can not be changed without performing another calibration. FlexCal broadband calibration is an OSL-based calibration method with a number of mathematical interpolation techniques that can be applied to measurements for adjusted frequency ranges

Figure 1 depicts the main errors in a 1-port measurement. These errors come from directivity, source match and frequency response. Directivity errors are a result of non-ideal directional devices which affect the isolation between the test and reference path. Source Match errors come from differences in impedance between the test port and the system. Frequency response errors are caused by differences in the response of the test and reference paths.

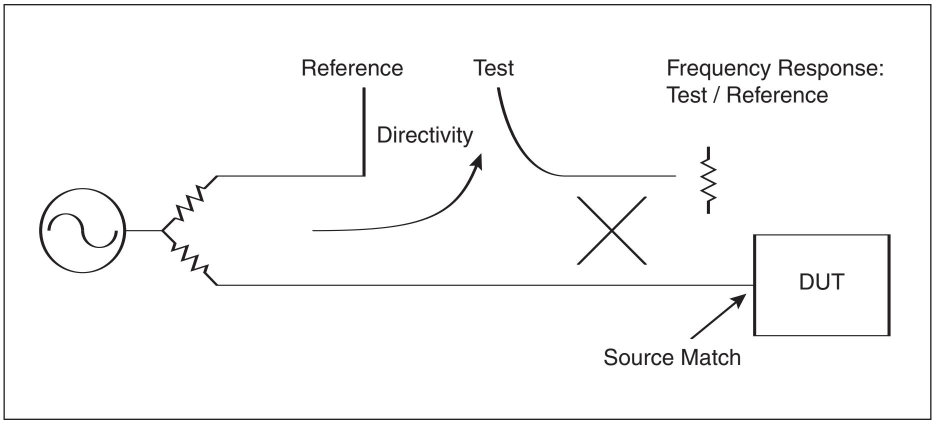


Figure 1. Shown here is a 1-port error model.

During the calibration, three measurements are made with three different reflection coefficients (Open-Short-Load) to solve for three unknown variables. All errors due to directivity, source match, and frequency response can then be mathematically removed to enable accurate vector-corrected measurements.

Mathematical interpolation allows you to adjust the frequency range. When the FlexCal feature is selected, the instrument will be calibrated from 25 MHz to 4 GHz. If the specified frequency changes – the calibration will still be from 25 MHz – 4 GHz and the frequency step size or display resolution will be 7.7 MHz for 517 datapoints.

Suppose you wanted to zoom in to the GSM 900 band. The frequency range could be easily adjusted from 890 to 960 MHz and would not require another calibration. The new 70 MHz frequency range will only use a fraction of the original calibrated points with the remaining data being derived from interpolation.

FlexCal can be very convenient and save a lot of time for both frequency measurements and Distance-To-Fault (DTF) measurements since frequency range can be changed after the calibration. This feature is in particular very useful for DTF measurements because fault resolution and maximum horizontal distance are dependent on the frequency range according to the following relationship:

$$\text{Maximum distance (meters)} = \frac{150\text{x(relative propagation velocity)x(datapoints - 1)}}{\text{F2 - F1}}$$

$$\text{Fault Resolution (meters)} = \frac{150\text{x(relative propagation velocity)}}{\text{F2 - F1}}$$

where the frequency values, F1 and F2, are in units of MHz.

These equations illustrate that while a wider range will produce better fault resolution, it will also impact the maximum distance. To find a solution that satisfies both parameters, you simply change the frequency range. Changing the frequency range will not necessitate another calibration if FlexCal is used.

This table shows the fault resolution and maximum horizontal distance for different frequency ranges. It assumes a relative propagation velocity constant of 0.87.

DataPoints		130	259	517
Frequency Span (MHz)	**Resolution (m)**	**Max Distance (m)**	**Max Distance (m)**	**Max Distance (m)**
50	2.610	336.7	673.4	1346.8
100	1.305	168.3	336.7	673.4
200	0.653	84.2	168.3	336.7
300	0.435	56.1	112.2	224.5
400	0.326	42.1	84.2	168.3
500	0.261	33.7	67.3	134.7
600	0.218	28.1	56.1	112.2
700	0.186	24.0	48.1	96.2
800	0.163	21.0	42.1	84.2
900	0.145	18.7	37.4	74.8
1000	0.131	16.8	33.7	67.3
1200	0.109	14.0	28.1	56.1
1400	0.093	12.0	24.0	48.1
1600	0.082	10.5	21.0	42.1
1800	0.073	9.4	18.7	37.4
2000	0.065	8.4	16.8	33.7
2200	0.059	7.7	15.3	30.6
2400	0.054	7.0	14.0	28.1
2600	0.050	6.5	12.9	25.9
2800	0.047	6.0	12.0	24.0
3000	0.044	5.6	11.2	22.4
3200	0.041	5.3	10.5	21.0
3400	0.038	5.0	9.9	19.8
3600	0.036	4.7	9.4	18.7
3800	0.034	4.4	8.9	17.7
3975	0.033	4.2	8.5	16.9

3.1 Variables Affecting Calibration Accuracy

The accuracy of a normal OSL calibration is affected by several variables. One variable to consider is directivity; typically the largest source of return-loss measurement uncertainty. Directivity performance is in large part determined by the quality of the directional device. Since the directivity varies for different connector types, the accuracy of the calibration will vary according to the connector type as well. With typical N connectors, it is common to expect directivity of 40 dB or better from 25 MHz to 4 GHz.

Another important variable to take into consideration is the cable's insertion loss. Cell Master and Site Master are excellent tools for 1-port insertion loss measurements. To make the measurement you must place a short or an open at the end of the cable. The Cable Loss mode can then be used to analyze the amount of energy that is lost in the cable. If the cable loss is too significant, the difference between the measured signal and the directivity may be small enough to affect the measurement and could significantly alter its accuracy.

For instance, if the residual directivity is 40 dB and the measured cable loss is 15 dB, then the measured return loss is 30 dB and the directivity error is only 10 dB below the measured level. The possible range of Return Loss values would range from 27.6 dB {$20\log(10^{-30/20} + 10^{-40/20})$} to 33.3 dB {($20\log(10^{-30/20} - 10^{-40/20})$}. To minimize directivity errors, a good rule of thumb is to make sure that the directivity of the test equipment and the cal components should be at least 15 dB better than the measurements you are trying to make. For maximum measurement accuracy, it is recommended that you use only precision components and minimize the use of adapters following calibration. The residual directivity of the Cell Master and Site Master using Anritsu's precision calibration components will nominally be on the order of 42 dB. Placing non precision adapters at the end of the phase stable cable after the calibration will introduce errors to the measurement and alter the accuracy of the measurement. For instance, using a non precision adapter with a specified directivity of 25 dB will affect the measurement range significantly and no cables with higher loss than 5 dB could be used with the 15 dB rule.

Figure 2 provides a look at measurement uncertainty after vector correction at room temperature.

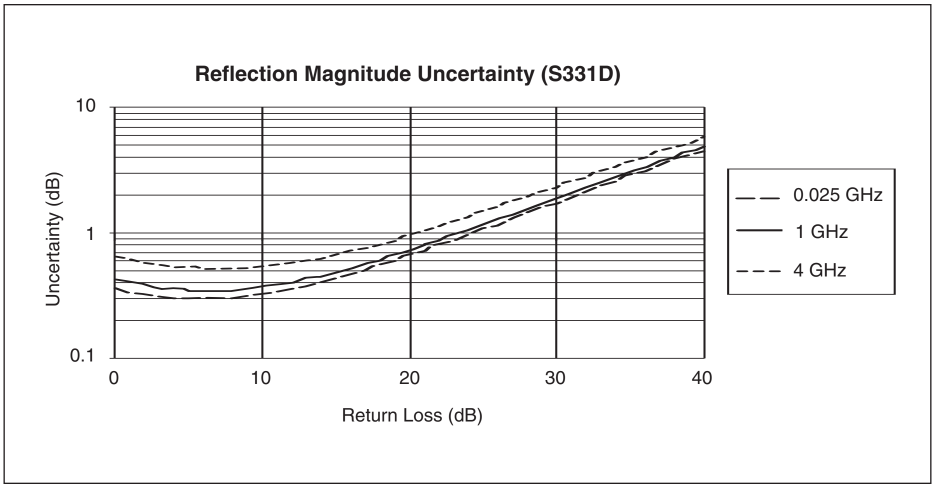
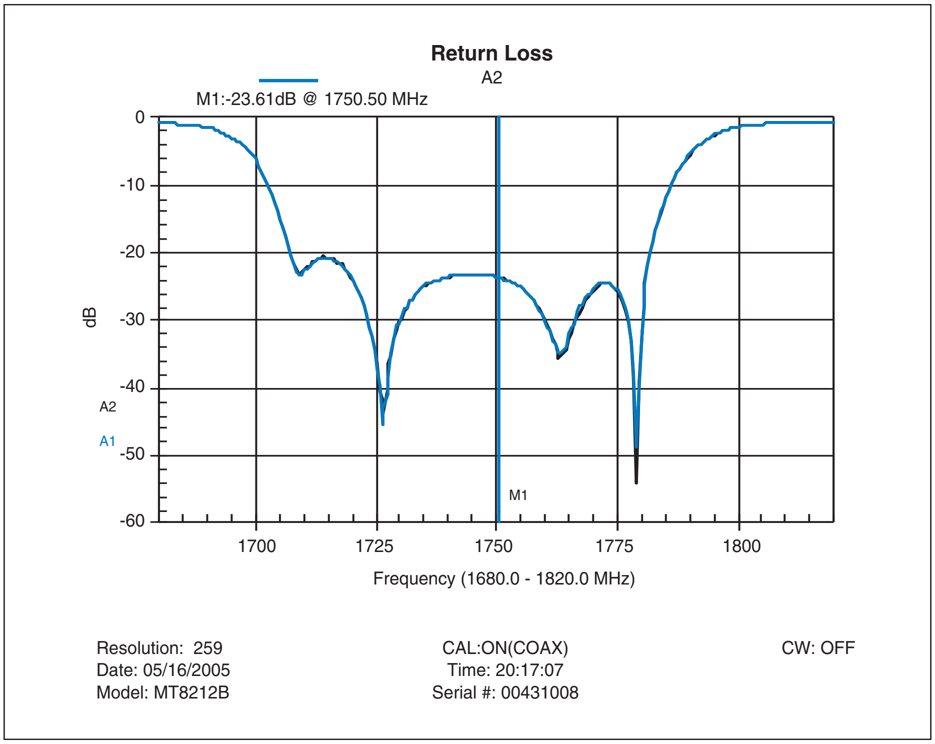


Figure 2. The Return Loss uncertainty was calculated taking source match, directivity, frequency response, dynamic range, and connector repeatability into consideration.

4.0 FlexCal Calibration Measurements

For accurate results, the Cell Master analyzer must first be calibrated prior to making any measurements. To do this, a phase stable cable is connected to Cell Master. The calibration is performed at the end of the phase stable cable. The phase stable cable may be moved or bent while making the measurement without causing any noticeable error. FlexCal can be activated in the options menu by pressing SYSTEM, followed by OPTIONS.

Figure 3 shows a measurement of a 1750 MHz bandpass filter. A termination is connected to the output of the filter to measure its return loss between 1650 MHz and 1850 MHz. The figure shows the return loss characteristics showing 25 dB or better return loss for the pass band. As can be seen in the figure, the difference between the OSL and FlexCal measurements is minimal implying that FlexCal calibration method can be used for zooming into frequency ranges that is about 20 times smaller than the original frequency range.



Resolution: 259
Date: 05/16/2005
Model: MT8212B

CAL:ON(COAX)
Time: 20:17:07
Serial #: 00431008

CW: OFF

Figure 3. Shown here is an overlay of the return loss of a bandpass filter taken with taken with OSLCal and FlexCal.

5.0 An Example of an Antenna System

Figure 4 shows the setup for a typical wireless-network antenna system including the cables, connectors, and the antenna. This particular network is known to have faults present. The FlexCal calibration method is used to show how easily the faults can be identified.

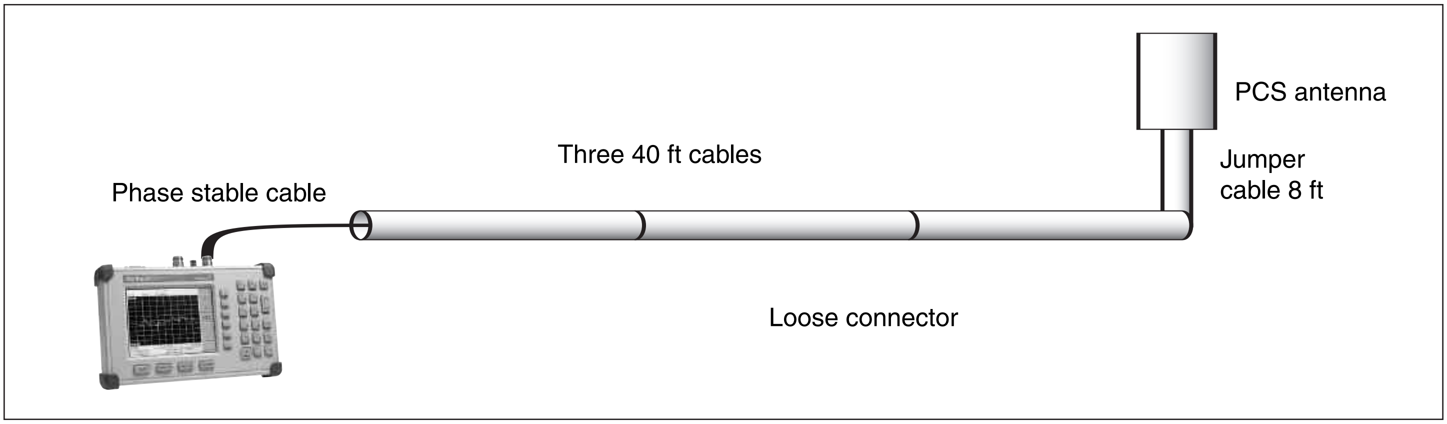


Figure 4. A typical setup for an antenna system.

This table shows typical return loss specifications, in the PCS band, for various antenna system components. Service providers may have different values based on their specific requirements.

TABLE 1

Component	Return Loss (dB)
Cable	<-20
Connector	<-30
Antenna	<-15 to -18 dB

The System Return Loss measurement is usually the one of the first measurements that is performed. The return loss of the antenna tend to be worse than the return loss of the cable and the connectors. Many operators expect a system return loss sweep of 15 dB ±3 dB. Figure 5 shows a return loss measurement in the PCS region of the antenna system. The overall return loss level is worse than normal and the ripple pattern also suggest that there could be some discontinuities in the path of this system.

Distance-To-Fault (DTF) can be very helpful in locating faults in the transmission line system. DTF sweeps the cable and system in the frequency domain and is then transformed to the time domain using mathematics. The DTF displays shows return loss values versus distance and faults can be found by looking at the return loss value.

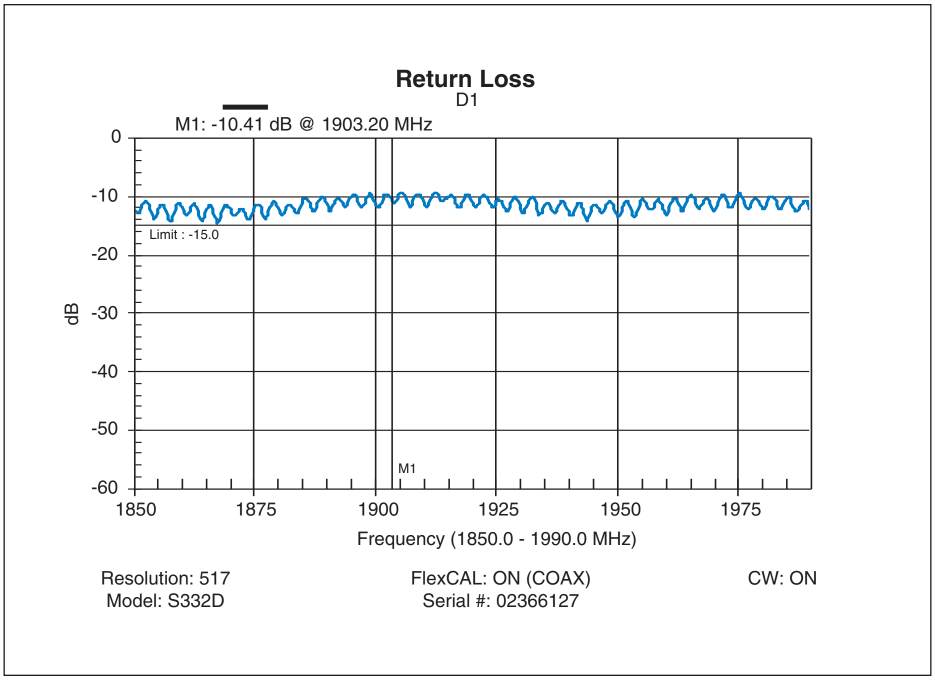


Figure 5. System Return loss measurement.

Figure 6 shows a DTF display of the system in Figure 4 swept from 1750 to 1990 MHz.

This display shows four distinct impedance variations. The first two located at about 40 ft and 80 ft show two good connectors and you can also see the connector of the 10ft jumper cable at about 120 ft and then end of the cable at 128 ft. The return loss value of the connector at 120 ft is a little worse than normal and this is an indication that something is wrong in this area. The maximum fault resolution for this frequency range, given a relative propagation velocity constant of 0.87, is 3.06 feet or:

$$0.93 \text{ meters} = \frac{150x0.87}{1990\text{-}1850}$$

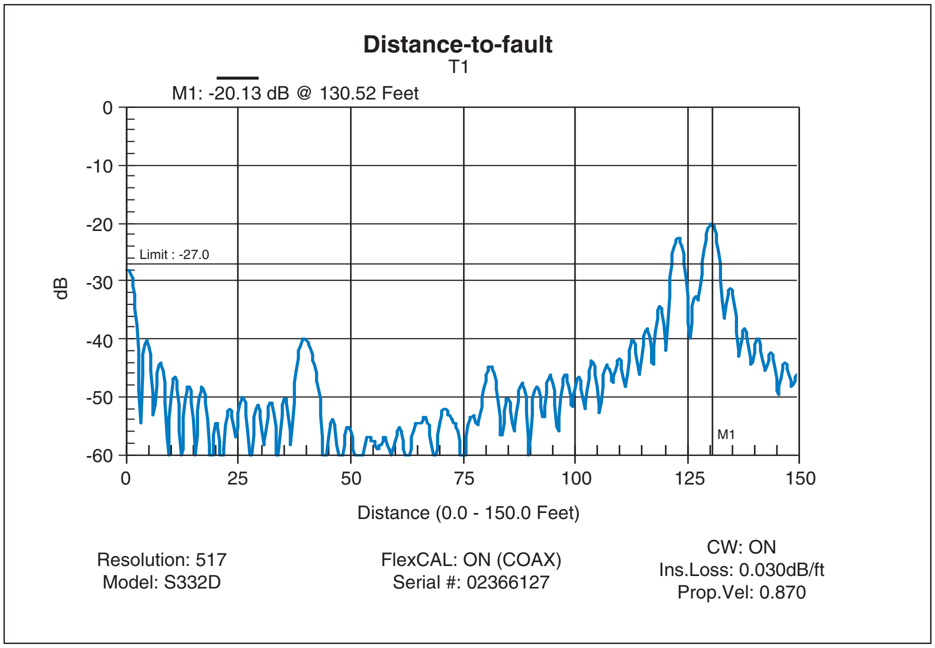


Figure 6. Distance-to-Fault measurement using the PCS frequency range.

In order to verify that there are no more faults present in the problematic area, the fault resolution has to be improved and the only way to do this is to sweep the system again with a wider frequency range. The black trace in figure 7 shows the resulting DTF display derived from sweeping the system from 1650 MHz to 2090 MHz and the blue trace shows the resulting DTF display obtained by sweeping the system from 1850-1990 MHz sweep. The resulting fault resolution or Site Master's ability to separate two closely spaced signals is about 3ft for the PCS frequency range and about 0.75 ft for the 1650 to 2090 MHz sweep. This clearly shows that the wider frequency range sweep has improved the fault resolution and the improved resolution reveals another problem close to the end of the cable. Note that the same difference between F1 and F2 over a different frequency range may not necessarily have shown the bump, as the antenna performance may mask the performance of the connector.

In a real-world scenario, you may have to change the frequency range several times in order to find a fault. In some antenna system, frequency selective devices such as filters or duplexers might be in the signal path and the system has to be swept in the correct frequency ranges to ensure that the signal is not reflected. Changing the frequency range several times can be very time consuming especially if you need to recalibrate every new frequency setting.

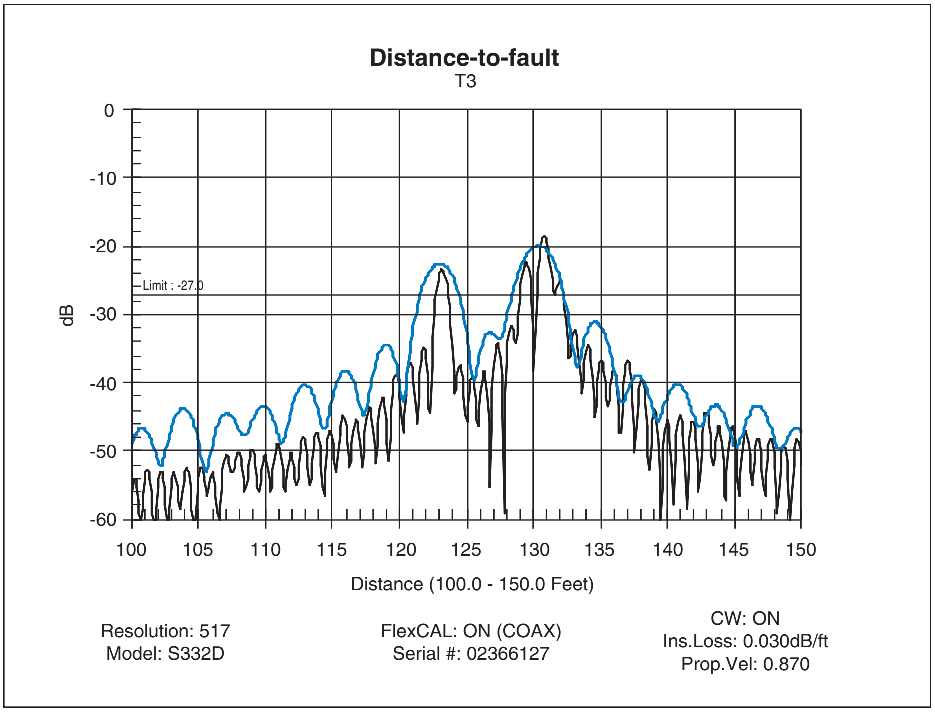


Figure 7. Distance-to-Fault measurement using both the PCS frequency range (blue trace) and the 1650 to 2090 MHz frequency range (green trace).

Figure 8 illustrates DTF measurements in the PCS frequency range. They were obtained using both the OSL and FlexCal calibration methods. The similarity of these two measurements validates the accuracy, and therefore the true benefit, of the FlexCal calibration feature for troubleshooting.

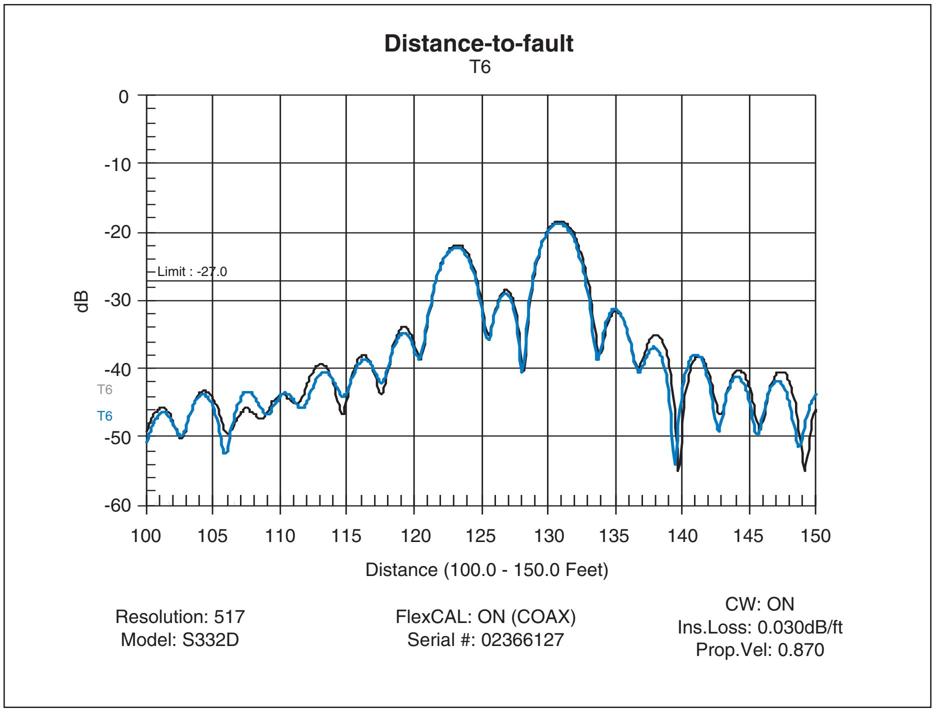


Figure 8. Distance-to-Fault measurement in the PCS band using the OSL and FlexCal calibration methods.

6.0 FlexCal Limitations

There are some limitations to the phase stable cable that can be used for FlexCal measurements.

1) FlexCal cannot be applied to phase stable cables longer than approximately 5 meters (16.4 ft). If you try to calibrate at the end of the cable using cables longer than 5m, the unit will inform you that “Flexcal is not suitable for this case.” In these situations, you should switch from Flexcal to OSL cal. Please note that this limitation only applies to the phase stable cable which is being calibrated.

2) FlexCal always calibrates the instrument from 25 MHz to 4000 MHz and the phase stable cable that is used to calibrate the instrument should be designed to cover the entire frequency range. Narrow frequency band phase stable cables should not be used. For instance, Flexcal should not be used if there is a narrow band filter before the calibration plane

7.0 Conclusion

The FlexCal broadband calibration method is an OSL-based method with interpolation to accommodate for adjusted frequencies. This calibration method is available in the Cell Master and Site Master cable and antenna analyzers. It provides a quick, easy and accurate method of troubleshooting and identifying faulty antenna system components without having to perform multiple calibrations. Field technicians can even change the frequency range after calibration; a useful capability in both the Return Loss and DTF modes. For traditional OSL calibration, a change in the frequency range would automatically invalidate the calibration and necessitate instrumentation recalibration.

With the FlexCal calibration method, field technicians can now realize a significant time savings, while more effectively dealing with the variables that typically affect measurement uncertainty and accuracy.

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