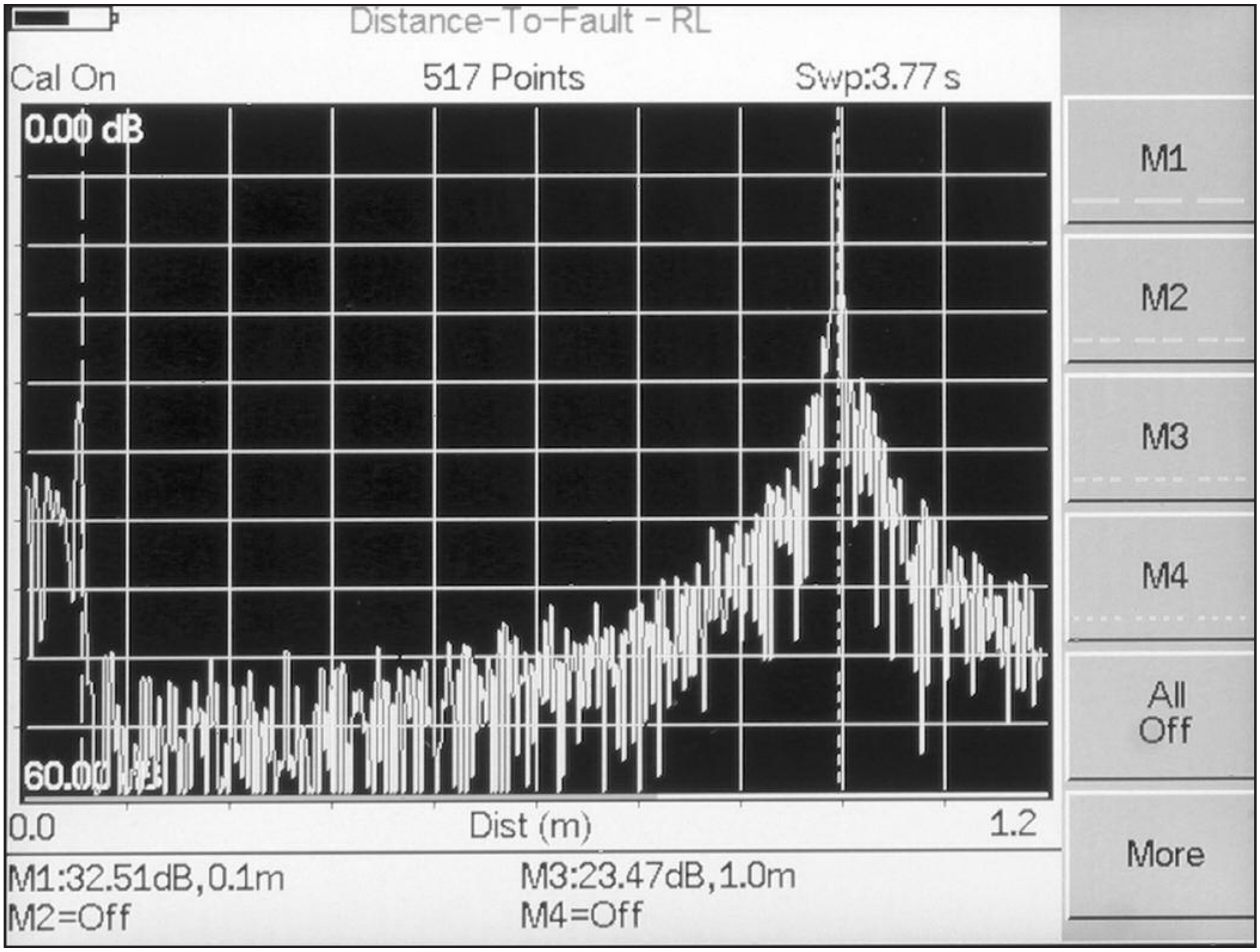
APPLICATION NOTE

Distance To Fault

Site Master™, Cell Master™, VNA Master™

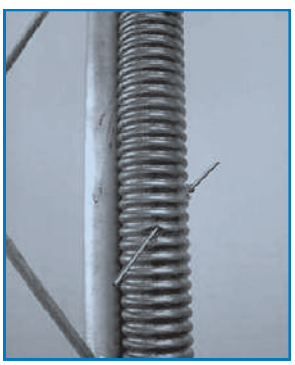


Distance To Fault Measurements for Cable and Antenna Installation and Maintenance

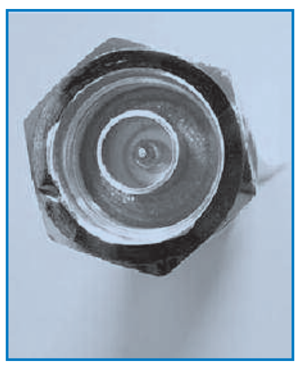
Introduction

Distance To Fault (DTF) is a performance verification and failure analysis tool used for antenna and transmission line service and maintenance. It uses the Frequency Domain Reflectometry (FDR) measurement technique. FDR is a transmission line fault isolation method which precisely identifies signal path degradation for coax and waveguide transmission lines. Although the acronyms are similar, FDR technology is different from traditional Time Domain Reflectometry (TDR) techniques. The FDR technique uses a swept RF signal instead of TDR DC pulses. FDR is far more sensitive than TDR and can precisely locate faults and degradation in system performance, not just DC open or short circuit conditions. This dual role of predicting future failure conditions and isolating existing problems makes DTF an important part of service and maintenance on transmission lines.

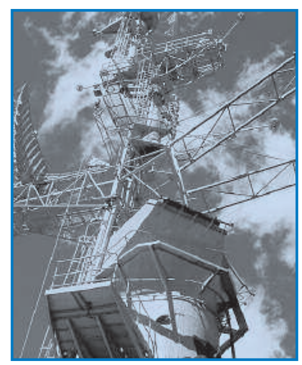
DTF displays RF return loss or VSWR data versus distance. The effects of poor connections, damaged cables, or faulty antennas are quickly identified. Since DTF automatically accounts for attenuation versus distance, the display accurately indicates the return loss or VSWR of the antenna.



Cable Problems
Cable Discontinuities
Damaged/Dented Ground Shield
Moisture and Corrosion
Fasteners Pinching Cables



Connector Problems
Corroded Connectors
Low Quality Connectors
Poor Center Pin Contact



Antenna Problems
Out of Specification
Storm/Shipping Damage
Damaged Lightning Arrestor

Typical Communication Systems Problems

Reduce Maintenance Time and Expense

For the majority of transmission lines and antennas, the absence of DTF capability severely impacts the time to repair transmission lines and renders preventative maintenance procedures impractical. RF failure conditions at the top of a tower or through a bulkhead frequently are not measurable with traditional tools such as TDR and spectrum analyzers with tracking generators. A TDR cannot detect small performance changes at RF frequencies, so it is not possible to monitor performance degradation between maintenance intervals with these traditional methods. Without FDR techniques, the "Fix after Failure" philosophy becomes the only alternative.

Many components can cause problems in a communication system. Transmission lines are typically the most common failure point. Tower mounted transmission lines are exposed to weather, and will degrade over time. Lightning can sever a portion of the antenna or damage the in-line lightning arrestor. Sunlight exposure can change the dielectric properties of the antenna housing, causing the antenna bandwidth to drift. Antennas and transmission lines used on-board ships and aircraft may be degraded due to salt water corrosion. These common problems can cause unwanted signal reflections. Poorly tightened connectors and poor environmental seals are exacerbated by acid rain corrosion. Eventually these problems cause intermittent outage and failures at exactly the times they are least welcome, such as during storms or during extreme periods of cold. With DTF available, the root causes of RF problems can be identified. For example, connector corrosion can be detected early and weather seals replaced before moisture destroys expensive cables. DTF finds these problems because the FDR technique can accurately detect very small performance changes within the transmission line.

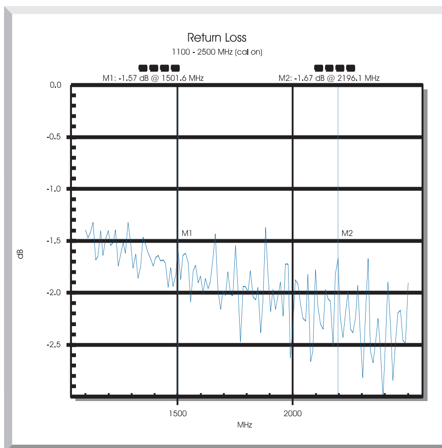
In a Wireless Communication System, tower mounted transmission lines and cables are replaced frequently, perhaps every five to ten years, in some cases. Usually, all the site's cables are replaced based upon the assumption that maintenance calls are imminent on other feeds in addition to the problem cable. This practice may be precipitated by the cable installer, who would likely make the same mistakes on each cable connection. Replacing all the cables frequently is an expensive proposition. It is much less expensive to monitor individual transmission lines for slight degradation and fix the problem early, before serious damage occurs.

Preventative maintenance has another set of benefits even more important than cost. Quality is improved. Uptime is maximized by preventing failures. Transmitter performance is optimized by eliminating poorly performing components. Cell coverage is more consistent. Hand off anomalies are reduced by eliminating ping-ponging between weak/strong base stations. Overall quality is improved giving greater customer satisfaction.

FDR Measurement Theory

The FDR measurement technique requires a swept frequency input to the transmission line. An inverse FFT (Fast Fourier Transform) is performed on the reflected signals transforming this information into the time domain. The distance is then calculated from this information by knowing the propagation velocity. The relative propagation velocity of a coax transmission line is required for distance calculation. The attenuation per foot or meter for the cable is also required in order to compensate for the attenuation versus distance. Likewise the cutoff frequency and waveguide loss are required for DTF, measurements of waveguide transmission lines. Thus, the actual return loss versus distance is shown in Figure 1. Anritsu Handheld products incorporating DTF include tables of many standard cables and waveguides to simplify DTF measurements.

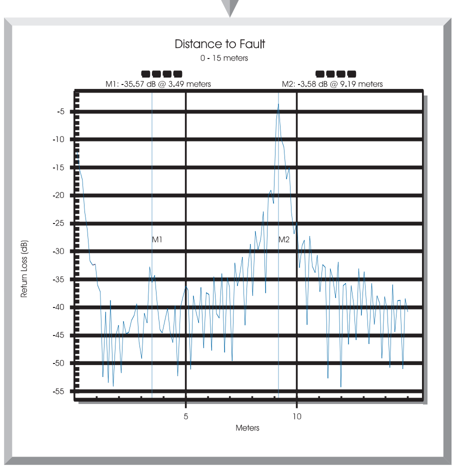
TEST TIP
Cable manufacturers specify the propagation velocity (Vp) of cables. If this specification is not available, it can easily be determined by measuring a known length of cable. The cable's average insertion loss can be verified at the same time. *See "Optimizing Frequency Range" on page 13 for a detailed procedure.*



Frequency Domain Data

$$f(t)=\sum_{n=-\infty}^{\infty} F_n \bullet e^{jn\omega_0 t}$$

Inverse FFT



Time (Distance) Domain Data

Figure 1. Actual Return Loss vs. Distance

FDR Versus TDR

FDR (Frequency Domain Reflectometry) and TDR (Time Domain Reflectometry) techniques are used for for similar purposes but are very different in their technical implementation.

TDR equipment sends pulsed DC or 1⁄2 sine wave signals into a copper pair and then digitizes the return response of reflected pulses. Pulse TDR was the original TDR methodology used to evaluate input impedance of components. It employs a fast rising DC pulse as the source and thus only a small amount of energy is sent. This technique is used for 50Ω transmission lines and typically covers distances of less than 200 feet with an accuracy of ±1%. Some recent TDRs use 1⁄2 sine typically for testing of telecom transmission lines. A 1⁄2 sine wave source servicing large amounts of energy is used, resulting in measurements over a longer distance. This technique is used for 50Ω and 75Ω transmission lines and can cover distances up to 50,000 feet with an accuracy of ±1%.

Distance To Fault with impedance information uses Time Domain Reflectometry (TDR pulse). This technique measures the impedance change of a cabling system versus distance using the cable propagation velocity (Vp). The precise location of potential sources of DC level failures are identified. However, no information regarding performance problems at actual operating RF frequencies is available.

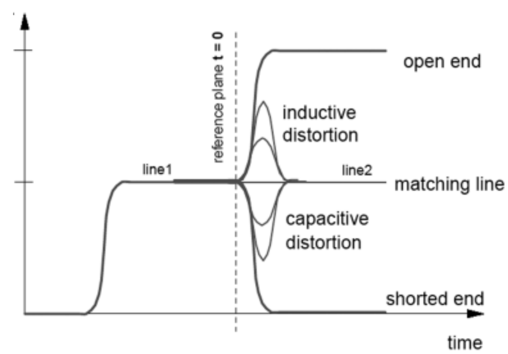


Figure 3. DTF with Impedance

The FDR technique requires a swept frequency RF signal. The Frequency Domain Reflectometry principle involves vector addition of the sources output signal with reflected signals from faults and other reflective characteristics within the transmission line.

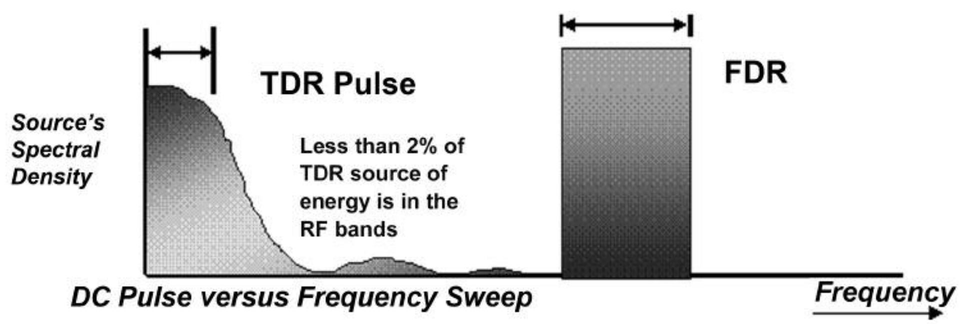
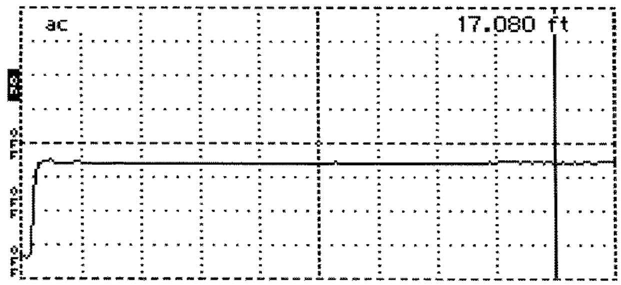
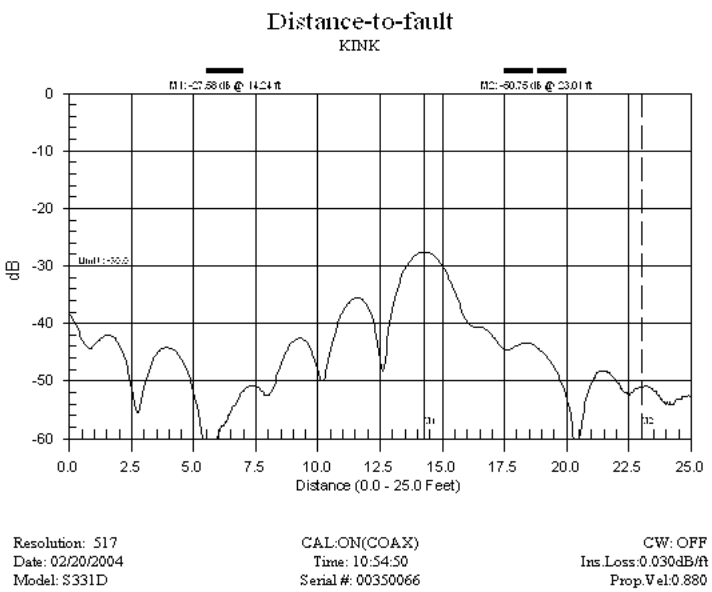


Figure 2. DC Pulse vs. Frequency Sweep

Historically TDRs have been less expensive than FDR based analyzers. While the price discrepancy is no longer true today, the technical differences remain. TDRs, for all practical purposes, do not measure RF performance, but rather identify opens or shorts in the conductors. Neither cables nor antennas can be tested to their RF specifications. The superior capability of FDR techniques has resulted in the obsolescence of many TDR devices. See Figure 4 for a sample comparison of TDR vs. FDR displays measuring a kink in a coax cable at 14.2 feet. The cable anomaly can be clearly seen using FDR techiques that cannot be seen using TDR.



TDR Presentation



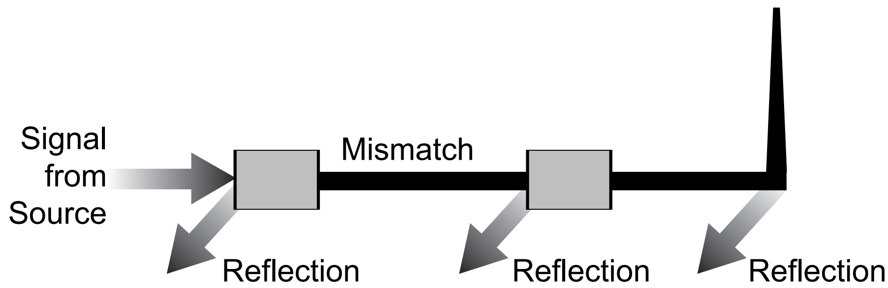
FDR Presentation

Figure 4. TDR vs. FDR Measurement

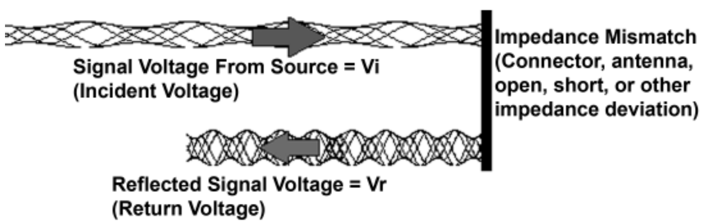
TDRs are limited because a corroded junction or over-crimped cable might easily pass a DC signal, but cause large reflections of RF power. Despite commercial claims of high equivalent bandwidth, pulse TDRs do not provide sufficient effective directivity for accurate RF frequency tests such as return loss. Sensitivity is not adequate to identify small changes in return loss characteristics. Further, TDRs frequently fail to measure in the presence of RF interference from nearby transmitters. Thus, TDR measurements support only catastrophic open and short circuit failure conditions.

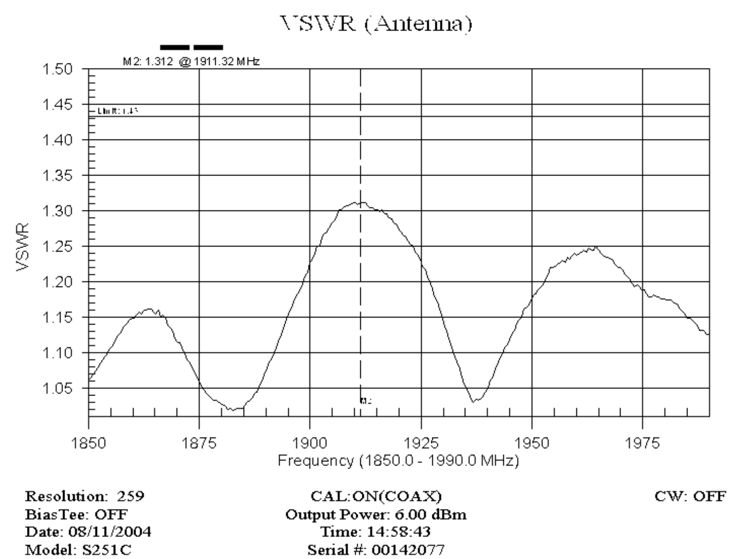
Some Measurement Fundamentals

In cable and antenna measurements signal reflections, which are a result of poor mismatch, are measured. These measurements can be viewed as VSWR or Return Loss with the Site Master.



VSWR (Voltage Standing-Wave Ratio)

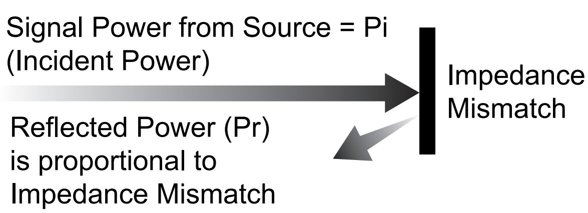




VSWR is the ratio of the maximum to minimun.

$$\text{VSWR} = \frac{V_i + V_r}{V_i - V_r}$$

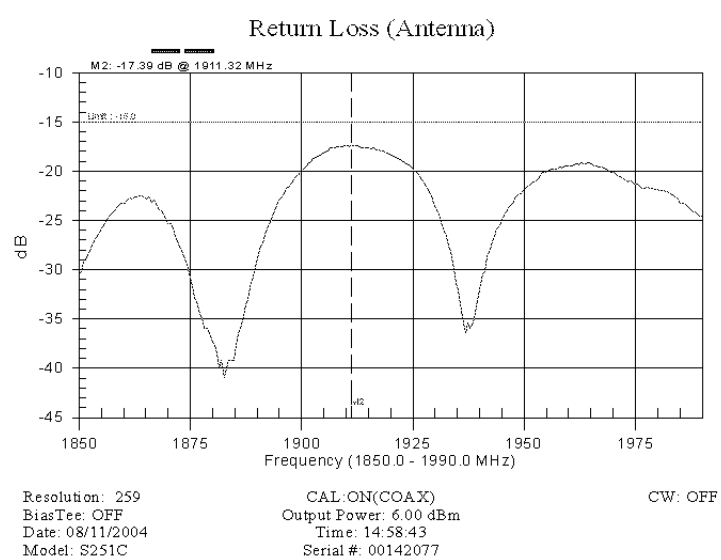
Return Loss



Reflection Coefficient = Γ (Rho) = Pr/Pi

Return Loss is the ration of the reflected signal to the incident signal.

$$\text{Return Loss} = -20 \log \left(\frac{\text{VSWR} - 1}{\text{VSWR} + 1} \right)$$



Cell Site Commissioning and Maintenance

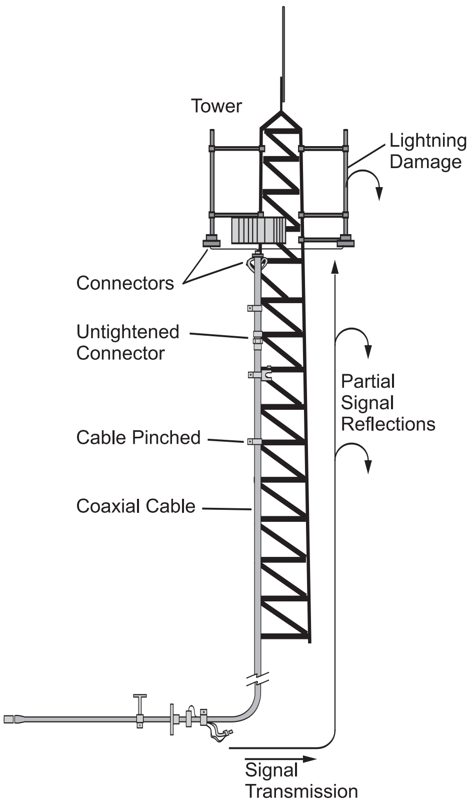


Figure 5. Signal Reflections

Site Master and Cell Master products are used in the cell site commissioning process and for maintenance service. These products play an integral role in the overall system maintenance and service plan. Both DTF and return loss measurements are based upon the same basic, signal reflection principles shown in Figure 5. No transmission line component is a perfect impedance match, as each will reflect some of the signal energy. The reflections are detected and analyzed using DTF.

In the site commissioning process, a return loss measurement is done to verify the system meets specification (with some margin). A baseline DTF measurement is taken. The return loss of the antenna can be verified with the DTF measurement. The location of any connectors, jumper cables and the antenna are noted and confirmed. This becomes the baseline DTF "signature" to which all subsequent measurements are compared.

1. Set up the instrument (select measurement mode, frequency range, amplitude, and resolution).
2. Calibrate and perform the return loss or VSWR measurement.
3. Store the display and the setup in internal memory for future use. Print a hard copy if required.
4. Set up the instrument for Distance To Fault (DTF) and perform a DTF measurement.
5. Store the display and the setup in internal memory for future use. Print a hard copy if required.
6. Download stored displays to a PC (using Handheld or Master Software Tools) for database updating and future analysis.

In maintenance service, the presence of a problem is easily detected by comparing a DTF measurement to the previous "DTF Signature" data. Performance monitoring consists of several specific steps.

1. Recall the instrument setup and calibration used during a previous maintenance service or during an initial installation and perform a DTF measurement.
2. Store the measurement display in internal memory.
3. Download the stored display to a PC (using Handheld or Master Software Tools). Print a hard copy if required.
4. Retrieve the "Baseline" DTF measurement data from the PC (stored on a hard drive or floppy).
5. Compare the measurement to the stored data using the overlay function in Software Tools.
6. Investigate any transmission line section showing a discrepancy from the base line data.
7. Repair any problems, then repeat the measurement and store the data for future analysis.
8. Follow the same steps (1-6) to compare Return Loss measurements to previous maintenance data.

Each cable/antenna tends to have a unique Distance To Fault (DTF) signature because varying cable electrical lengths, cable types, dielectric thickness variations, and the position of components (connectors, adapters, and lightning arrestors) will cause different reflections at differing positions in the transmission line. Reflections from the transmission line's various components are vector signals which will add or subtract depending upon their relative phases. The relative phases are dependent upon the individual characteristics of each device and their relative physical position in the transmission line. When measuring at the end of a transmission line, addition and subtraction of the various reflections create a nearly random pattern of ripples on the return loss display. The result is that each individual cable will have its own unique signature or "finger print." Variations in the measurements between maintenance intervals offer a good indication of degradation or damage causing conditions. A large change indicates a problem. Small changes may indicate aging, ultra-violet exposure, or dimensional changes due to seasonal temperature conditions.

Return Loss is the vector sum of all the reflections on the transmission line. Slight changes in the reflected signal from one component may not be apparent in a return loss measurement as illustrated in Figure 6. The return loss has degraded slightly at several frequencies but it is still meeting the –17 dB specification. In the DTF mode the reflections from each component along the transmission line are isolated. Changes in the performance of the transmission line or the components over time can be easily seen, as shown in Figure 6. The two DTF graphs are the same except for the return loss value at marker 1. The return loss at that point has degraded by approximately 5 dB.

While return loss analysis can be an ambiguous quality indicator, Distance To Fault (DTF) analysis highlights the problem clearly. In this case the problem was a loose connector. When it was tightened the DTF display again appeared as the plot on the left (the baseline data). If the connector remained loose, invasive moisture would eventually destroy the expensive antenna.

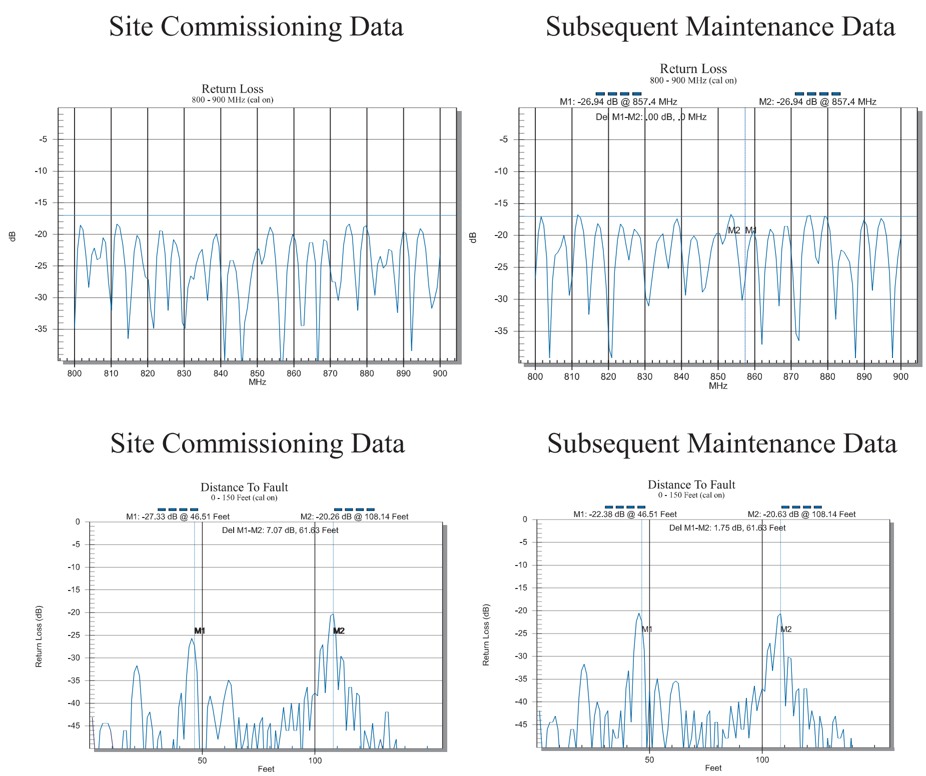


Figure 6. Sample Commissioning and Maintenance Data

DTF Measurement Procedure

Distance domain measurements, commonly known as Distance To Fault (DTF), are made over a selectable distance range. The maximum distance range is dependent upon the frequency range. See "Optimizing Frequency Range", on page 12, for further explanation. Distance To Fault capability is available in Anritsu Handheld products.

The following specific button presses are for the D-Series Site Masters. Although other Anritsu Handheld products that include DTF capability may have slightly different user interfaces and key presses, the concepts and practices remain the same.

Recalling a Setup

To use a previously stored setup:

Step 1. Press the **RECALL SETUP** key. Select the desired setup using the Up/Down Arrow key and press **ENTER**. (Both the measurement Setup and Calibration will be restored.)

OR

Selecting a Frequency Range and Resolution

Step 1. Press the **MODE** key and select either SWR or Return Loss and press **ENTER**.

Step 2. Press the F1 soft key from the ensuing soft key menu and enter the desired numerical value using the keypad or the Up/Down Arrow key. Press the **ENTER** key when data entry is complete.

Step 3. Press the F2 soft key from the soft key menu and enter the desired numerical value using the keypad or the Up/Down Arrow key. Press the **ENTER** key when data entry is complete. Check that the Freq scale at the bottom of the display area indicates the new frequency start and stop values.

Step 4. Press the **MEAS/DISP** button and select the RESOLUTION soft key. Select the desired resolution (number of points to be measured) from the sub-menu.

Performing a Calibration

CAUTION: The measurement system must be calibrated at the ambient temperature prior to making a measurement. If the temperature drifts outside a specified range an indicator appears (↕°C). A recalibration at the current temperature is recommended. Any time the frequency range is changed the appropriate calibration must be recalled or a new one performed.

Step 1. Press the **START CAL** key.

Step 2. Select **COAX** or **WAVEGUIDE** from the soft key menu and select the DUT connector type using the Up/Down Arrow key.

Step 3. Press **ENTER** when complete.

Step 4. Press the Start Cal soft key.

Follow the instructions on the display.

For Coax media: "Connect OPEN, Press **ENTER**," "Connect SHORT, Press **ENTER**," and "Connect LOAD, Press **ENTER.**" Connect the respective Open, Short, and Load component to the end of the Test Port Extension Cable if used. After each selection, a spinning hour glass appears while the measurement is in progress.

OR

For Waveguide media: "Connect 1/8 OFFSET SHORT, Press **ENTER**," "Connect 3/8 OFFSET SHORT, Press **ENTER**," and "Connect LOAD, Press **ENTER.**" Connect the respective Offset Shorts and Load component to the end of the Test Port Extension Cable if used. After each selection, a spinning hour glass appears while the measurement is in progress.

NOTE

For best calibration results (compensation for all measurement system uncertainties) ensure that the is calibration component is connected at the end of the test port or optional extension cable; that is at the same point that you will connect the device to be tested. If you require a Test Port Extension cable, use a phase stable cable. If you use a typical laboratory cable to extend the test port to the device-under-test, cable bending subsequent to the calibration will cause uncompensated phase reflections inside the cable. Cables which are not phase stable cause unacceptable measurement errors that are more pronounced as the test frequency increases. For optimum calibration, Anritsu recommends using precision calibration components.

Performing a DTF Measurement

Verify that **Cal On** appears in the upper left corner of the screen. If not, see page 10 for Performing a Calibration.

> ***NOTE***
> *The maximum allowable distance, based on the selected frequency span and number of points, will be displayed beneath the D2 data entry field.*

> ***NOTE***
> *Press the **SYS** button, then **Options**, then **Units** soft keys to toggle between feet and meters. Loss and relative propagation velocity values for many commonly used cable and waveguide types are listed in the Tables at the back of this document.*

Step 1. Press the **MODE** button and select the DTF–SWR or DTF-Return Loss soft key.

Step 2. Press the D1 soft key to select the start distance. Enter the desired numerical value using the keypad or the Up/Down Arrow key. Press **ENTER** when data entry is complete.

Step 3. Repeat the above step for **D2** to select the end distance.

Step 4. Press the MORE soft key to go to the DTF Sub-Menu.

Step 5. Press the CABLE soft key, then the SHOW ALL soft key to select a coaxial cable from the stored list of cables. If the cable under test is not shown, press the LOSS and PROP VEL soft keys to enter cable loss and relative propagation velocity parameters. Enter the desired numerical values using the keypad or the Up/Down Arrow key. Press **ENTER** when each data entry is complete.

If a Waveguide Calibration has previously been performed, the DTF Parameters in Step 5 will be changed to **WAVEGUIDE LOSS**, **CUTOFF FREQ**, and **WAVEGUIDE** type.

Step 6. Press the WINDOW soft key to select an alternative windowing type. For tips on Windowing see page 14.

Step 7. Press the BACK soft key to return to the previous menu.

Using the DTF AID Table

The **DTF AID** menu displays the current settings of the DTF Parameters. These parameters can be selected and changed as indicated above, or directly from the **DTF AID** menu, using the Up/Down Arrow key to select the desired parameter and pressing **ENTER**.

The DTF Aid Table can be accessed by selecting either DTF – SWR or DTF – Return Loss from the **MODE** key. The DTF AID soft key can then be selected.

Selecting the Maximum Distance

Enter the numerical value of the maximum desired distance using the keypad or the Up/Down Arrow key.
Press the **ENTER** key when data entry is complete.

Selecting the Frequency Range and Resolution

> ***NOTE***
> *Changing the Start or Stop Frequency will invalidate a previously performed calibration. A new calibration will need to be performed before making a DTF measurement.*

Step 1. Using the Up/Down Arrow key, select F1 (start frequency) and press **ENTER**. Enter the desired numerical value using the keypad or the Up/Down Arrow key. Press **ENTER** when data entry is complete.

Step 2. Repeat the above for F2 (stop frequency).

Step 3. Using the Up/Down Arrow key, select **RES** and press **ENTER**. Enter the desired numerical value using the keypad or the Up/Down Arrow key. Press **ENTER** when data entry is complete.

DTF AID Table Parameters

Step 4. Select the Windowing type to be used. See page 15 for tips on Windowing. Press the **ENTER** key when data entry is complete.

Step 5. Use the Up/Down Arrow key and the **ENTER** key to select the desired coaxial cable from the coaxial cable list. Alternatively, use the Up/Down Arrow key and the **ENTER** key to select **PROP VEL** and **LOSS** and enter the relative propagation velocity and cable loss parameters numerical value.

If a Waveguide Calibration has previously been performed, the DTF Parameters in Step 5 will be changed to **WAVEGUIDE TYPE**, **CUTOFF FREQ**, and **WAVEGUIDE LOSS**.

Change any DTF parameters in the DTF AID table display area by using the Up/Down Arrow key and the ENTER key.

After all desired parameters have been selected and changed, select **Keep Current Value – CONTINUE** and Press **ENTER**.

Using Markers

Step 1. Press the **MARKER** key to display the Marker Menu.

Step 2. Select any displayed Marker soft key. A Marker Sub-Menu will appear. Select the ON/OFF soft key to turn the Marker On. Press the EDIT soft key to update the value of the Marker. Enter the desired numerical value using the keypad, pressing **ENTER** when the data entry is complete or press the Up/Down Arrow key.

Step 3. Alternatively, press the MARKER TO PEAK soft key to put the selected Marker on the largest signal displayed. Select the MARKER TO VALLEY soft key to move the selected Marker to the lowest signal displayed.

Step 4. Press the BACK soft key to return to the main Marker Menu.

Step 5. Repeat Step 2 for each Marker as required.

Step 6. Press the MORE soft key to access additional Markers.

NOTE
The Marker values will be displayed at the bottom of the display area. During the editing of Marker values, the active marker will be highlighted in this area.

Scaling the Display

The display can be scaled automatically scale the display using the **AUTO SCALE** key.

Alternatively, scale the display by pressing the **AMPLITUDE** key, then selecting the TOP and BOTTOM soft keys. Using the keypad or Up/Down Arrow key, enter the desired value. Press **ENTER** when data entry is complete.

Using Limits

Limits may be set up for the measurement in the following way:

Step 1. Press the **LIMIT** key to display the Limit Menu.

Step 2. If a Single Limit (single value across the entire distance range) is required, press the SINGLE LIMIT soft key. Select the ON/OFF soft key to turn the Limit On. Press the EDIT soft key to update the value of the Limit. Enter the desired numerical value using the keypad. Press the Up/Down Arrow key.

The Limit line may be turned off by pressing the ON/OFF soft key.

Step 3. If more than one limit value across the entire distance range is needed, press the MULTIPLE LIMITS soft key. Select the SEGMENT 1 soft key. Press the ON/OFF soft key to turn on the first segment of the limit line. Press the EDIT soft key and enter the start distance using the numeric keypad and press **ENTER**. A new data entry display will appear. Enter the desired value of the limit at the start distance and press **ENTER**. A new data entry display will appear. Enter the desired end distance of the first limit segment and press **ENTER**. A new data entry display will appear. Enter the desired value of the limit at the end distance and press **ENTER**. This process can be repeated for each new segment by selecting the NEXT SEGMENT soft key. When each segment is selected information is displayed at the bottom of the display area. Pressing the PREV SEGMENT and NEXT SEGMENT will advance the displayed information to the previous or next segment.

Saving a Setup

Press the **SAVE SETUP** key. Using the Up/Down Arrow key, select an <Empty> location. Press **ENTER**. The measurement setup and calibration will be saved.

Saving a Trace

Press the **SAVE DISPLAY** key. Enter a trace name using the soft keys and press **ENTER** when data entry is complete.

Optimizing Frequency Range

Selecting the appropriate frequency range is not as obvious as it may seem. For return loss measurements, the specification usually calls out the frequency range over which the data is to be taken. For Distance To Fault analysis, the resolution and maximum distance range are dependent upon the frequency sweep range, the number of frequency data points and the relative propagation velocity of the cable being tested. Therefore, the frequency range must be chosen carefully. When checking the return loss of the antenna in DTF mode, the operating frequency range of the antenna should be used.

For checking transmission lines, a large frequency span is desirable to highlight potential faults or areas of performance degradation. However there is a constraint that limits the frequency range. The maximum distance is inversely related to the frequency range

$$\text{maximum distance (meters)} = \frac{1.5 \times 10^8 \times \text{relative propagation velocity} \times \text{Points} - 1}{(F2 - F1)}$$

(F1 and F2 are the start and stop frequency in Hz. Points is the number of frequency data points used during measurement)

The wider the frequency range, the smaller the maximum distance that can be measured. Graphs illustrating this relationship are shown in Figure 7.

There is also a relationship between resolution and frequency range. The wider the frequency range, the smaller the resolution. Wider frequency sweeps improve the resolution of DTF measurements.

Coax:

$$\text{resolution (meters)} = \frac{1.5 \times 10^8 \times \text{relative propagation velocity}}{(F2 - F1)}$$

(F1 and F2 in Hz)

Waveguide:

$$\text{resolution (meters)} = \frac{1.5 \times 10^8 \left(\sqrt{1-(Fc/F1)^2}\right)}{(F2 - F1)}$$

(Fc is waveguide cutoff in Hz, F1, F2 in Hz)

With adequate frequency sweep range, 0.6 centimeters can be resolved. Distance range can exceed 600 kilometers using narrow frequency sweeps.

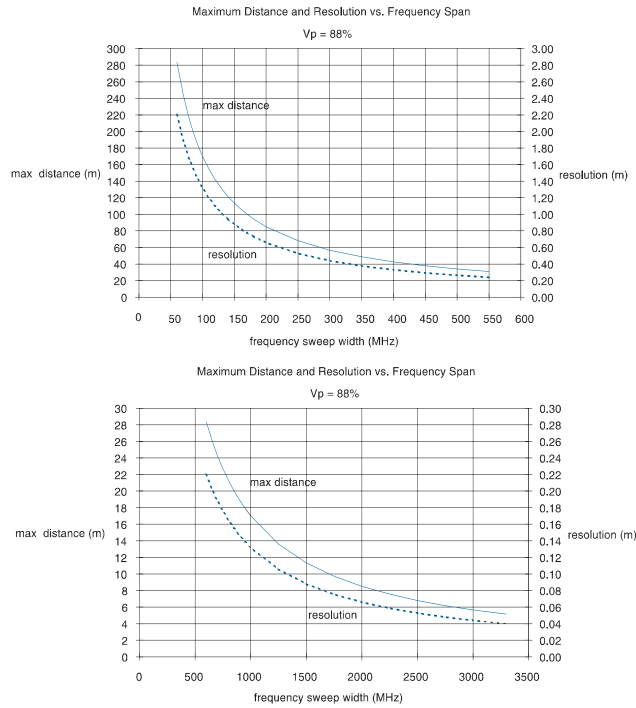


Figure 7. Frequency Range vs. Distance

Cable Characteristics

The insertion loss of a cable varies with frequency - the higher the frequency the greater the loss of a cable. Most cable manufacturers specify the loss of their cables at one or more specific frequencies. If the loss is not specified for your particular frequency range, or the loss of the cable is unknown, the DTF feature can be used to find the loss.

Using a small piece of the type of cable to be tested, connect it to the instrument with the other end open (not connected to anything). Perform a DTF measurement over the frequency range of operation. A spike in return loss should be visible where the open is located (at the end of the cable). An open circuit should have 0 dB return loss (full reflection). Adjust the cable loss parameter until the open at the end of the cable measures 0 dB return loss. Use the marker function to display the value.

The relative propagation velocity of a cable is equal to 1/[SQRT (relative dielectric constant)]. The dielectric constant is determined by several factors including the dielectric type of the transmission line and the diameter thickness of that dielectric. It is specified by the manufacturer of the cable. Flexible cables may have more than ±10% variation in dielectric constant along the cable's length due to manufacturing tolerances. Dielectric constant does not vary with frequency. If the correct relative propagation velocity is not used the distance calculation will be incorrect. If the relative propagation velocity is unknown it can be found using the DTF feature.

A known length of cable (the type being tested) can be used to determine the propagation velocity. Connect it to the instrument with the other end open (not connected to anything). Perform a DTF measurement. A spike in return loss should be visible where the open is located (at the end of the cable). An open circuit should have 0 dB return loss (full reflection). Adjust the relative propagation velocity parameter until the open at the end of the cable indicates the correct cable length.

DTF Performance

"DTF Instrumentation Accuracy" is better than 0.1%, but the more practical concern is "Measurement Accuracy." Return loss measurement accuracy is influenced by many factors; the quality of the calibration (including the calibration components and calibration method), the accuracy of the information entered by the user, and the quality of the cables being tested. Precision calibration components allow greater measurement accuracy. For accurate calibration results, all measurement system uncertainties need to be compensated for by ensuring that the calibration components are connected to same point that will be connected to the device being tested (at the end of any extension cables or adapters being used).

Distance calculations are based on the assumption of a specific propagation velocity value for the cable or transmission line. If the propagation velocity is set incorrectly, the fault location will be identified at the wrong distance. Relative propagation velocity is calculated as 1/[SQRT(relative dielectric constant)]. The dielectric constant is determined by several factors including the dielectric type of the transmission line and the diameter thickness of that dielectric. Cable manufacturers routinely have dielectric constant variations. The variation may be ±10% or more along the cable's length. Low cost cables generally have even greater variation in dielectric constant.

Further practical impediments to absolute distance accuracy include the various filters, diplexers, adapters, and differing cable types that are typical of most RF transmission lines. Despite the fact that the instrument itself is extremely accurate, the characteristics of the device under test confound attempts to specify absolute distance accuracy requirements for practical, in-service measurements. The net effect is that each transmission line will have its own "signature" or "finger print" on a DTF display. The ability to store DTF displays, download them to a computer and overlay traces makes analysis of these unique signatures simple. When historical data is compared to recent data, large changes in the "signature" indicate a serious problem. Small changes may indicate aging or dimensional changes due to seasonal temperature conditions.

Typical absolute measurement accuracy for tower mounted transmission lines is within one foot, slightly better than a technician's ability to measure physical length on a tower mounted cable. Further, most service problems are either physical damage or connector problems. Physical characteristics such as connectors, adapters and bends show up clearly on the DTF display. Thus, identifying a problematic transmission line section is straightforward. As compared to return loss measurements where test accuracy is critical because small performance changes may indicate big problems. Comparison of DTF "before" and "after" plots isolates problems quickly and easily.

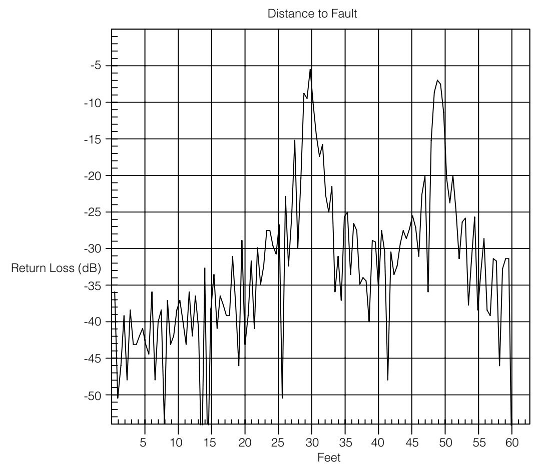
Windowing

When making a DTF measurements, the **FREQ/DIST** key provides access to the DTF Aid menu. The DTF Aid menu provides for setting the cable loss and relative propagation velocity of the coaxial cable. The Window key opens a menu of FFT windowing types for the DTF calculation. The theoretical requirement for inverse FFT is for the data to extend from zero frequency to infinity. Side lobes appear around a discontinuity due to the fact that the spectrum is cut off at a finite frequency. Windowing reduces the side lobes by smoothing out the sharp transitions at the beginning and at the end of the frequency sweep. As the side lobes are reduced the main lobe widens thereby reducing the resolution.

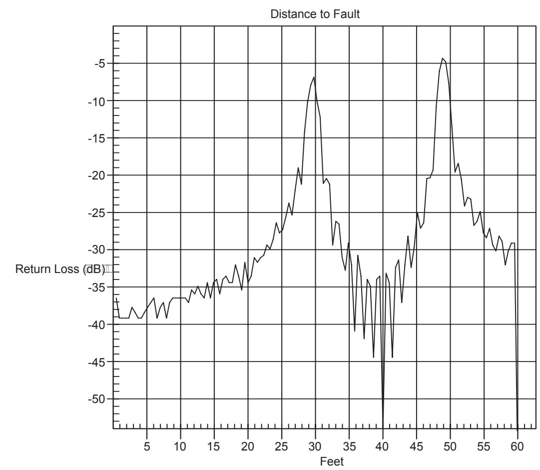
In situations where there may be a small discontinuity being masked by the side lobes of a larger one next to it, side lobe reduction windowing should be used. When distance resolution is critical, such as when two discontinuities of comparable levels are very close to each other, windowing can be reduced in order to distinguish between the two peaks presented by these discontinuities.

Examples

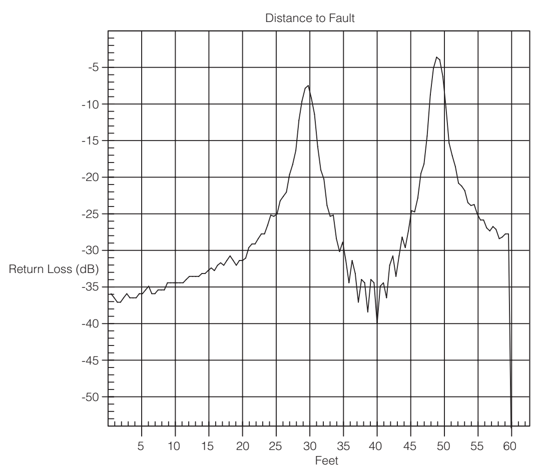
The types of windowing in order of increasing side lobe reduction are: rectangular, nominal side lobe, low side lobe, and minimum side lobe. The graphs are examples of these types of windowing.



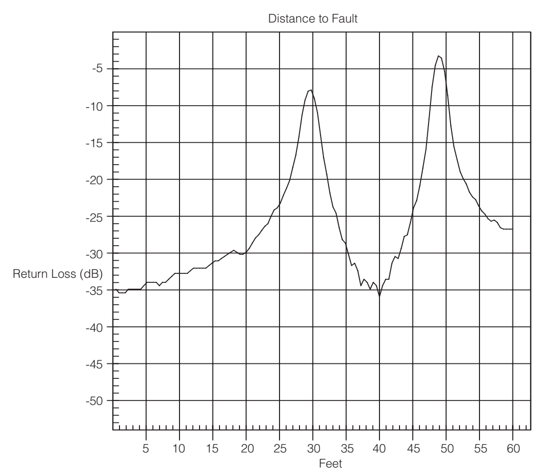
Rectangular Windowing



Nominal Side Lobe Windowing



Low Side Lobe Windowing



Minimum Side Lobe Windowing

Summary

Anritsu Site Master, Cell Master, and VNA Master Handheld products are precision analysis tools that measure Distance To Fault (DTF), Return Loss and VSWR on coax waveguide transmission lines. DTF and Return Loss (VSWR) measurements are accurate and repeatable, even in the presence of RF interference. As a troubleshooting tool, DTF analysis can pinpoint damage and impending failure conditions. Thus, small degradations to RF performance can be spotted before more serious damage occurs. For example, loose connectors and moisture intrusion can be detected before corrosion destroys the cable, saving thousands of dollars in material and re-installation costs. By contrast, previous TDR based fault location and spectrum analyzer based return loss measurements are error prone and susceptible to RF interference. TDR's can only find catastrophic faults. DTF finds potential problems quickly and reliably, allowing cellular service personnel to implement preventative maintenance plans and reduce cost per cell expenses. Since a large percentage of communication systems problems are caused by problematic cables, connectors, and antennas, Anritsu's Handheld products pay for themself quickly. Anritsu's Handheld products rugged construction and wide temperature operating range provide trouble-free operation in the field.

Coaxial Cable Technical Data

The following tables provide standard listings of common coaxial cables along with their Relative Propagation Velocity and Nominal Attenuation values in dB/m at 1, 2, and 2.5 GHz. (N/A indicates that the specification is not applicable to the listed cable.)

Coaxial Cable Technical Data

Manufacturer	Cable Type	Relative Propagation Velocity (Vf)	Nominal Attenuation dB/m at 1 GHz	Nominal Attenuation dB/m at 2 GHz	Nominal Attenuation dB/m at 2.5 GHz
Andrew	FSJ1-50A	0.84	0.197	0.285	0.313
Andrew	FSJ2-50	0.83	0.134	0.196	0.222
Andrew	FSJ4-50B	0.81	0.119	0.176	0.201
Andrew	LDF4-50A	0.88	0.073	0.107	0.121
Andrew	LDF5-50A	0.89	0.041	0.061	0.070
Andrew	LDF6-50	0.89	0.029	0.044	0.051
Andrew	LDF7-50A	0.88	0.024	0.037	0.043
Andrew	LDF12-50	0.88	0.021	0.033	N/A
Andrew	LDF4.5-50	0.89	0.054	0.08	0.091
Andrew	LDF5-50B	0.91	0.041	0.061	0.070
Andrew	HJ4-50	0.914	0.087	0.137	0.150
Andrew	HJ4.5-50	0.92	0.054	0.079	0.084
Andrew	HJ5-50	0.916	0.042	0.063	0.070
Andrew	HJ7-50A	0.921	0.023	0.034	0.040
Andrew	HJ12-50	0.931	0.019	0.029	N/A
Andrew	VXL5-50	0.88	0.045	0.066	0.075
Andrew	VXL6-50	0.88	0.032	0.048	0.055
Andrew	VXL7-50	0.88	0.024	0.037	0.043
Andrew	AVA5-50 7/8"	0.91	0.0376	0.0553	0.0627
Andrew	AVA7-50 1 5/8"	0.92	0.0225	0.0336	0.0384
Andrew	VXL5-50 7/8"	0.88	0.0446	0.0659	0.0750
Andrew	VXL6-50 1 1/4"	0.88	0.0320	0.0483	0.0560
Andrew	VXL7-50 1 5/8"	0.88	0.0243	0.0371	0.0427
Andrew	EFX2-50	0.85	0.0368	0.0541	0.0615
Andrew	HL4RP-50A	0.88	0.0226	0.0331	0.0376
Belden	RG8, 8A	0.659	0.262	N/A	N/A
Belden	RG9, 9A	0.659	0.289	N/A	N/A
Belden	RG17, 17A	0.659	0.180	N/A	N/A
Belden	RG55, 55A, 55B	0.659	0.541	N/A	N/A
Belden	RG58, 58B	0.659	0.558	N/A	N/A
Belden	RG58A, 58C	0.659	0.787	N/A	N/A
Belden	RG142	0.659	0.443	N/A	N/A
Belden	RG174	0.659	0.984	N/A	N/A
Belden	RG178B	0.659	1.509	N/A	N/A
Belden	RG188	0.659	1.017	N/A	N/A
Belden	RG213	0.659	0.292	N/A	N/A
Belden	RG214	0.659	0.292	N/A	N/A
Belden	RG223	0.659	0.535	N/A	N/A
Cablewave	HCC12-50J	0.915	0.087	0.126	0.137
Cablewave	HCC78-50J	0.915	0.041	0.061	0.066
Cablewave	HCC158-50J	0.95	0.022	0.031	0.033
Cablewave	HCC300-50J	0.96	0.015	N/A	N/A
Cablewave	HCC312-50J	0.96	0.013	N/A	N/A
Cablewave	HF 4-1/8” Cu2Y	0.97	0.010	N/A	N/A
Cablewave	HF 5” Cu2Y	0.96	0.007	N/A	N/A
Cablewave	HF 6-1/8” Cu2Y	0.97	0.006	N/A	N/A
Cablewave	FLC 38-50J	0.88	0.115	0.169	0.19
Cablewave	FLC 12-50J	0.88	0.072	0.11	0.134
Cablewave	FLC 78-50J	0.88	0.041	0.061	0.072
Cablewave	FLC 114-50J	0.88	0.033	0.05	0.059
Cablewave	FLC158-50J	0.88	0.025	0.038	0.042
Comscope	CR50 540 PE	0.88	0.069	0.103	0.116
Comscope	CR50 1070PE	0.88	0.037	0.055	0.064
Comscope	CR50 1873PE	0.88	0.022	0.0344	0.04
Eupen	EC4-50 1/2	0.88	0.074	0.109	0.124
Eupen	EC4.5-50 5/8	0.88	0.056	0.083	0.094
Eupen	EC5-50 7/8	0.88	0.041	0.061	0.069
Eupen	EC6-50 1-1/4	0.88	0.030	0.045	0.052

Coaxial Cable Technical Data, Continued

Manufacturer	Cable Type	Relative Propagation Velocity (Vf)	Nominal Attenuation dB/m at 1 GHz	Nominal Attenuation dB/m at 2 GHz	Nominal Attenuation dB/m at 2.5 GHz
Eupen	EC7-50 1-5/8	0.88	0.025	0.038	0.043
Eupen	EC12-50 2-1/4	0.88	0.022	0.034	0.039
NK Cables	RF 1/2” –50	0.88	0.0757	0.112	0.127
NK Cables	RF 1/2” –50 GHF	0.88	0.0757	0.112	0.127
NK Cables	RF 1/2” –50 BHF	0.88	0.0757	0.112	0.127
NK Cables	RF 5/8”–50	0.88	0.0518	0.0768	0.087
NK Cables	RF 5/8”–50 GHF”	0.88	0.0518	0.0768	0.087
NK Cables	RF 5/8”–50 BHF”	0.88	0.0518	0.0768	0.087
NK Cables	RF 7/8”-50	0.88	0.0413	0.062	0.07
NK Cables	RF 7/8”–50 GHF”	0.88	0.0413	0.062	0.07
NK Cables	RF 7/8”–50 BHF”	0.88	0.0413	0.062	0.07
NK Cables	RF 1 5/8” –50	0.88	0.0248	0.038	0.044
NK Cables	RF 1 5/8” –50 GHF”	0.88	0.0248	0.038	0.044
NK Cables	RF 1 5/8” –50 BHF”	0.88	0.0248	0.038	0.044
NK Cables	RF 2 1/4” –50	0.88	0.021	0.034	N/A
NK Cables	RF 2 1/4” –50 GHF	0.88	0.021	0.034	N/A
NK Cables	RF 2 1/4” –50 BHF	0.88	0.021	0.034	N/A
NK Cables	RFF 3/8” –50	0.81	0.147	0.218	0.25
NK Cables	RFF 3/8” –50 GHF	0.81	0.147	0.218	0.25
NK Cables	RFF 3/8” –50 BHF	0.81	0.147	0.218	0.25
NK Cables	RFF 1/2” –50	0.82	0.112	0.167	0.19
NK Cables	RFF 1/2” –50 GHF	0.82	0.112	0.167	0.19
NK Cables	RFF 1/2” –50 BHF	0.82	0.112	0.167	0.19
NK Cables	RFF 7/8” –50	0.84	0.052	0.078	0.089
NK Cables	RFF 7/8” –50 GHF	0.84	0.052	0.078	0.089
NK Cables	RFF 7/8” –50 BHF	0.84	0.052	0.078	0.089
Times	LMR100	0.80	0.792	1.15	1.31
Times	LMR200	0.83	0.344	0.49	0.554
Times	LMR240	0.84	0.262	0.377	0.424
Times	LMR400	0.85	0.135	0.196	0.222
Times	LMR500	0.86	0.109	0.159	0.18
Times	LMR600	0.87	0.087	0.128	0.145
Times	LMR900	0.87	0.056	0.086	0.098
Times	LMR1200	0.88	0.044	0.065	0.074
Times	LMR1700	0.89	0.033	0.049	0.056
-	310801	0.821	0.115	N/A	N/A
-	311201	0.82	0.180	N/A	N/A
-	311501	0.80	0.230	N/A	N/A
-	311601	0.80	0.262	N/A	N/A
-	311901	0.80	0.377	N/A	N/A
-	352001	0.80	0.377	N/A	N/A

Cable Type	Maximum Frequency (GHz)	Relative Propagation Velocity (Vf)	Nominal Attenuation dB/m at 6 GHz
FSJ1-50A	20.4	0.84	0.53
FSJ2-50	13.4	0.83	0.37
FSJ4-50B	10.2	0.81	0.35
EFX2-50	13.5	0.85	0.34
LDF1-50	15.8	0.86	0.31
LDF2-50	13.5	0.88	0.32
LDF4-50A	8.8	0.88	0.22
HJ4-50	10.9	0.914	0.26
HJ4.5-50	6.6	0.92	0.15

Waveguide Technical Data

Waveguide Offset Short* Specifications

Offset Short P/N	Frequency (GHz)	Length (mm)
24UM70	6.926	20,710 ± 0.08
24UM84	8.396	17,040 ± 0.05
24UM100	10.084	14,675 ± 0.05
24UM120	12.247	11,978 ± 0.04
24UA187	4.807	30,979 ± 0.11
24UA137	6.926	20,710 ± 0.08
24UA112	8.396	17,040 ± 0.05
24UA90	10.084	14,675 ± 0.05
24UA62	14.940	9,742 ± 0.04
24UA42	21.225	7,067 ± 0.03
24CMR187	4.807	30,979 ± 0.11
24CMR137	6.926	20,710 ± 0.08
24CMR112	8.396	17,040 ± 0.05
24CMR90	10.084	14,675 ± 0.05
24UER70	6.926	20,710 ± 0.08
24UER84	8.396	17,040 ± 0.05
24UER100	10.084	14,675 ± 0.05

* Offset shorts are 3/8 wave at the geometric mean frequency waveguide band and dimensionally accurate to <0.5 degree at the maximum operating frequency of the corresponding wavelength.

Waveguide Technical Data

Waveguide Type/Model	Start Frequency (GHz)	Stop Frequency (GHz)	Cutoff Frequency (GHz)	Mid-Band Loss (dB/m, GHz)
WR229 WG11A	3.300	4.900	2.577	0.0374
WR187 WG12	3.950	5.850	3.152	0.0515
WR159 WG13	4.900	7.050	3.711	0.0591
WR137 WG14	5.850	8.200	4.301	0.0738
WR112 WG15	7.050	10.000	5.259	0.1024
WR102	7.000	11.000	5.786	0.1083
WR90 WG16	8.200	12.400	6.557	0.1578
WR75 WG17	10.000	15.000	7.868	0.1913
WR67	11.000	17.000	8.578	0.2159
WR62 WG18	12.400	18.000	9.486	0.2411
WR51 WG19	15.000	22.000	11.574	0.3691
WR42 WG20	17.000	26.500	14.047	0.5200
		Andrew		
EW34	3.100	4.200	2.376	0.0223
EW37	3.300	4.300	2.790	0.0292
EW43	4.400	5.000	2.780	0.0289
EW52	4.600	6.425	3.650	0.0394
EW63	5.580	7.125	4.000	0.0453
EW64	5.300	7.750	4.320	0.0479
EW77	6.100	8.500	4.720	0.0584
EW85	7.700	9.800	6.460	0.1086
EW90	8.300	11.700	6.500	0.1010
EW127	10.000	13.250	7.670	0.1263
EW132	11.000	15.350	9.220	0.1581
EW180	14.000	19.700	11.150	0.1939
EW220	17.000	23.600	13.340	0.2822

Waveguide Technical Data, Continued

Waveguide Type/Model	Start Frequency (GHz)	Stop Frequency (GHz)	Cutoff Frequency (GHz)	Mid-Band Loss (dB/m, GHz)
		Cablewave		
WE37	3.600	4.200	2.830	0.0269
WE46	4.400	5.000	3.000	0.0354
WE61	5.925	6.425	3.600	0.0390
WE65	6.425	7.125	4.000	0.0453
WE70	7.125	7.750	4.300	0.0404
WE78	7.125	8.500	4.670	0.0446
WE108	10.500	11.700	6.570	0.0978
WE130	11.700	13.250	7.430	0.1142
WE150	14.000	15.350	8.600	0.1398
WE191	17.700	19.700	10.680	0.1952
		Hanover		
E38	3.100	4.200	2.320	0.0243, 3.6
EH36	4.400	5.000	3.080	0.0361
E54	5.000	6.000	3.870	0.0469, 5.4
E60	5.600	6.425	3.600	0.0354
E65	5.925	7.125	3.990	0.0456
E70	6.425	7.750	4.290	0.0479
EH78	7.700	8.500	4.650	0.0692, 8.2
E100	8.500	10.000	6.440	0.0889, 9.5
E105	10.700	11.700	6.600	0.0909
E130	10.950	13.250	8.400	0.1129
E150	14.000	15.350	10.490	0.1385
E185	17.300	19.700	11.100	0.1929
E220	21.200	23.600	12.900	0.3002, 22.5

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