Measuring Transmission Line Quality Prior to and During installation on a Tower

Tom Brinkoetter

RadioSiteTest.com

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Background (CV)

- 40 years of RF Test and Measurement Applications engineering
  - Anritsu Spectrum and Network Analyzers
  - Tektronix Spectrum Analyzers, Oscilloscopes
  - HP Spectrum and Network Analyzers

- Certifications
  - FAA sUAS Pilot License, October 2016
  - Drone Cell Tower Inspection Training, December 2016
  - Certified Climber /Rescuer, January 2017
  - Anritsu PIM Master Certification 2015
  - Network Associates Sniffer Certified Professional 2000
  - External PIM Testing 2018

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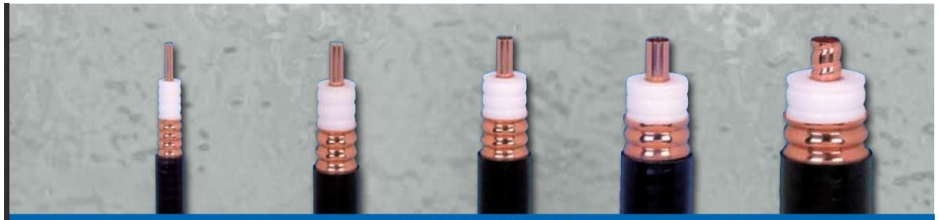
Transmission Lines are Critical to RF Site Performance

A transmission line's job is to transfer power from a source to a load



STANDARD SERIES

1/2"	5/8"	7/8"	1 1/4"	1 5/8"
Attenuation, dB/100ft Standard Conditions: VSWR 1.0; Ambient Temperature 68° F				
0.357	0.246	0.189	0.134	0.110
0.661	0.456	0.347	0.247	0.203
1.45	1.00	0.762	0.549	0.449
2.22	1.54	1.17	0.850	0.694
3.25	2.26	1.71	1.26	1.03
6.11	4.27	–	–	–
Average Power Rating kW, Standard Conditions: VSWR 1.0; Ambient Temperature 104° F Inner Conductor Temperature 212° F no solar loading				
6.73	9.27	14.60	21.24	28.27
3.64	5.00	7.89	11.44	15.22

We will show that transmission line testing can be accurately performed with Distance to Fault (DTF) measurement techniques.

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Problems in New Spools of Cable

- Manufacturing
  - Tears in Copper Shield
  - Wrong Impedance
  - Periodic Dents
  - Excessive Loss
- Transport & Storage
  - Forklift
  - Side
  - Water
- Installation
  - Sloppy work
  - Bumpers
  - Grounding Clamps

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Storage

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What is the Impact of Bad Cable?

- Costly Labor Hits
  - Rework Labor: Climbers--$2000/day
- Penalties
  - $thousands/day in some cases
- Loss of Reputation
  - Unreliable Integrators and Cable Mfgs Go Out of Business
- Less Reliable Networks if Issues Are Not Found

- Warehouse Test and Integration before Scheduling Crews

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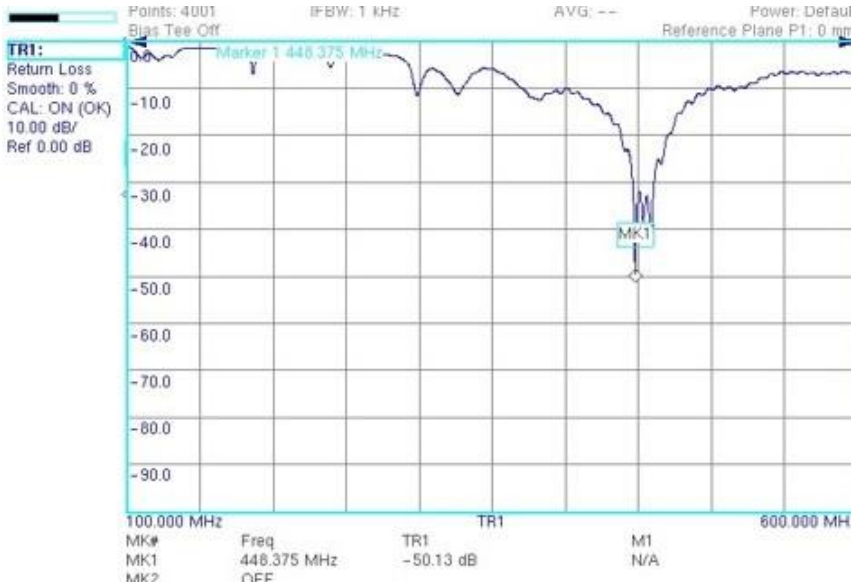
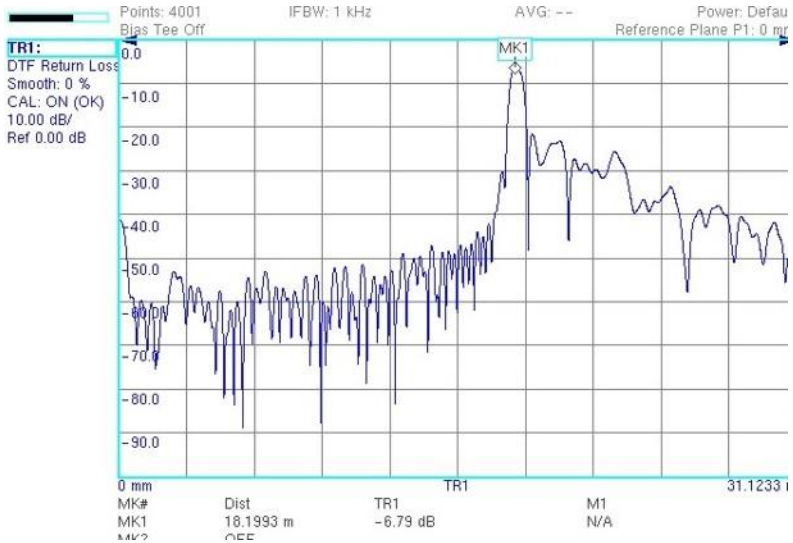
Testing for Dents, Kinks, Tears

- Return Loss
  - Each freq. all distance
- Distance-to-Fault
  - Each distance all freq.





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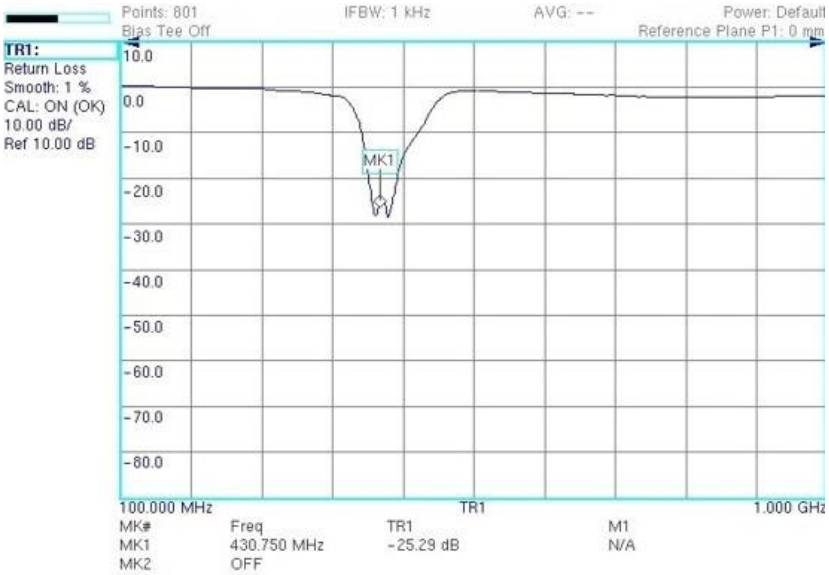
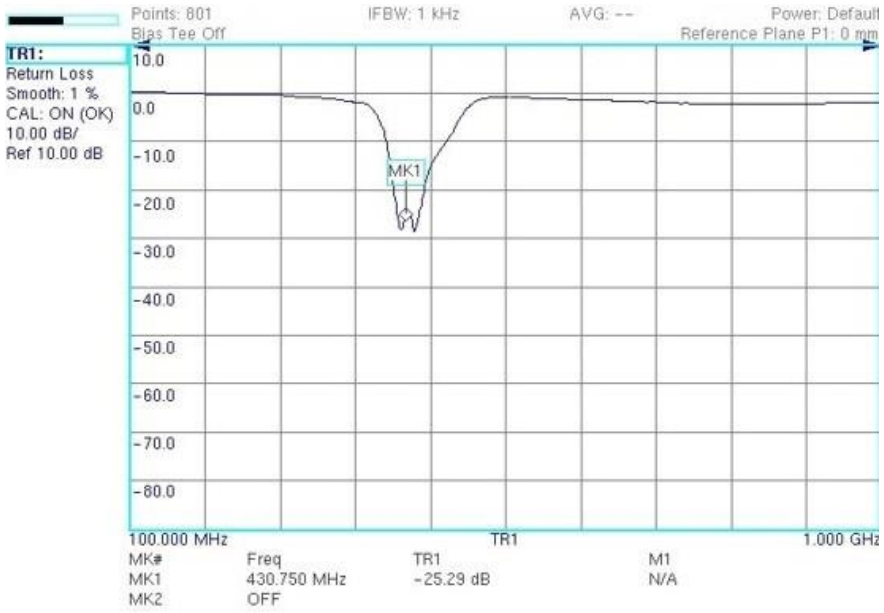
Testing an Antenna (Match RL or SWR)

- Return Loss vs. Frequency (0.1 to 1 GHz)
- 0 dB RL = full reflection
- 20 dB RL = 99/100 watts radiated.



Return Loss trace of the Antenna at the end of 600 Ft of LDF2

- No Mismatches in the system!



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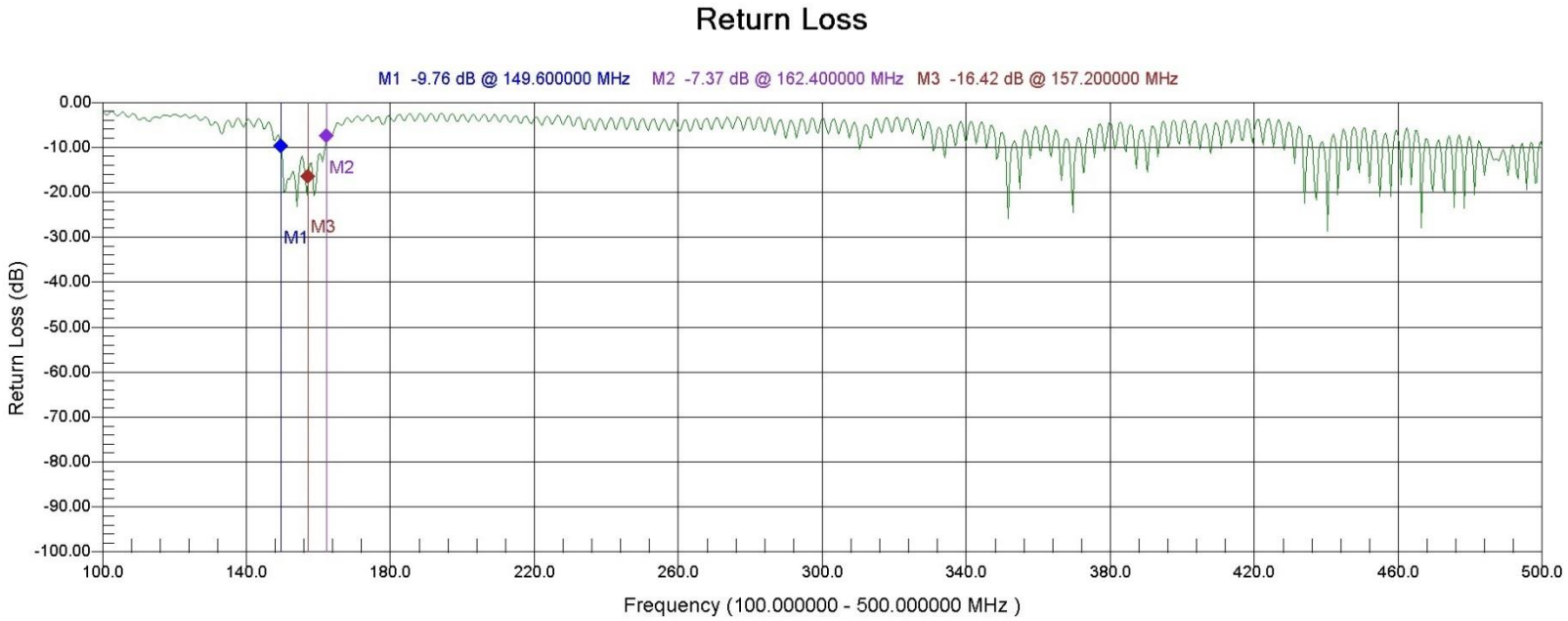
What if There are Dents, Kinks, Tears (Mismatches) In the Feedline?

- Buzz in Return Loss presented to the transmitter.
- Challenge Transmitters in Multi-Channel systems



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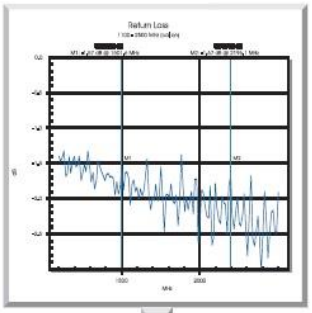
Distance-to-Fault (DTF) Mode Available on Many Cable/Antenna Analyzers

- Mathematically transforms Return Loss vs. Frequency to Return Loss vs. Distance

Looks at spectrum of RL trace.

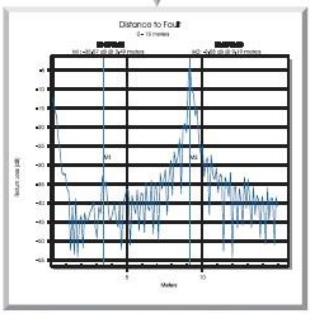
  - Faster the ripple = longer distance



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

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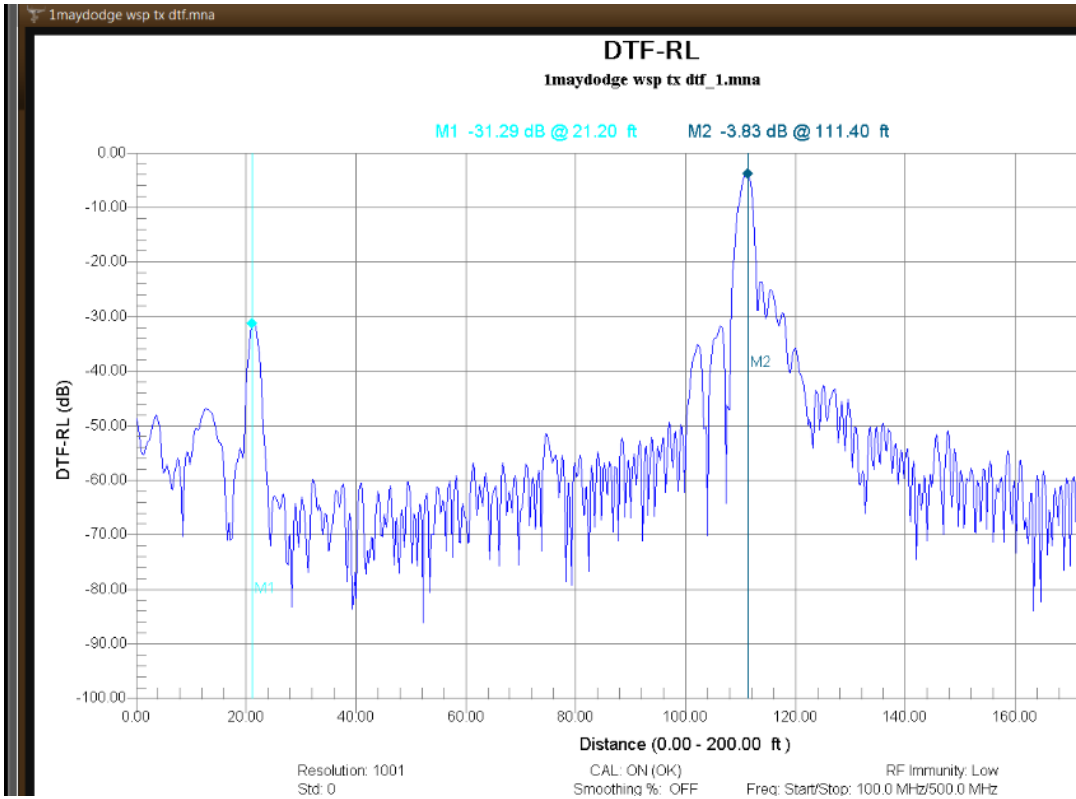
Using (DTF) Distance-to-Fault to Locate Problems

- Distance-to-Fault Transmitter Filtering to Antenna
- Damaged PolyPhaser



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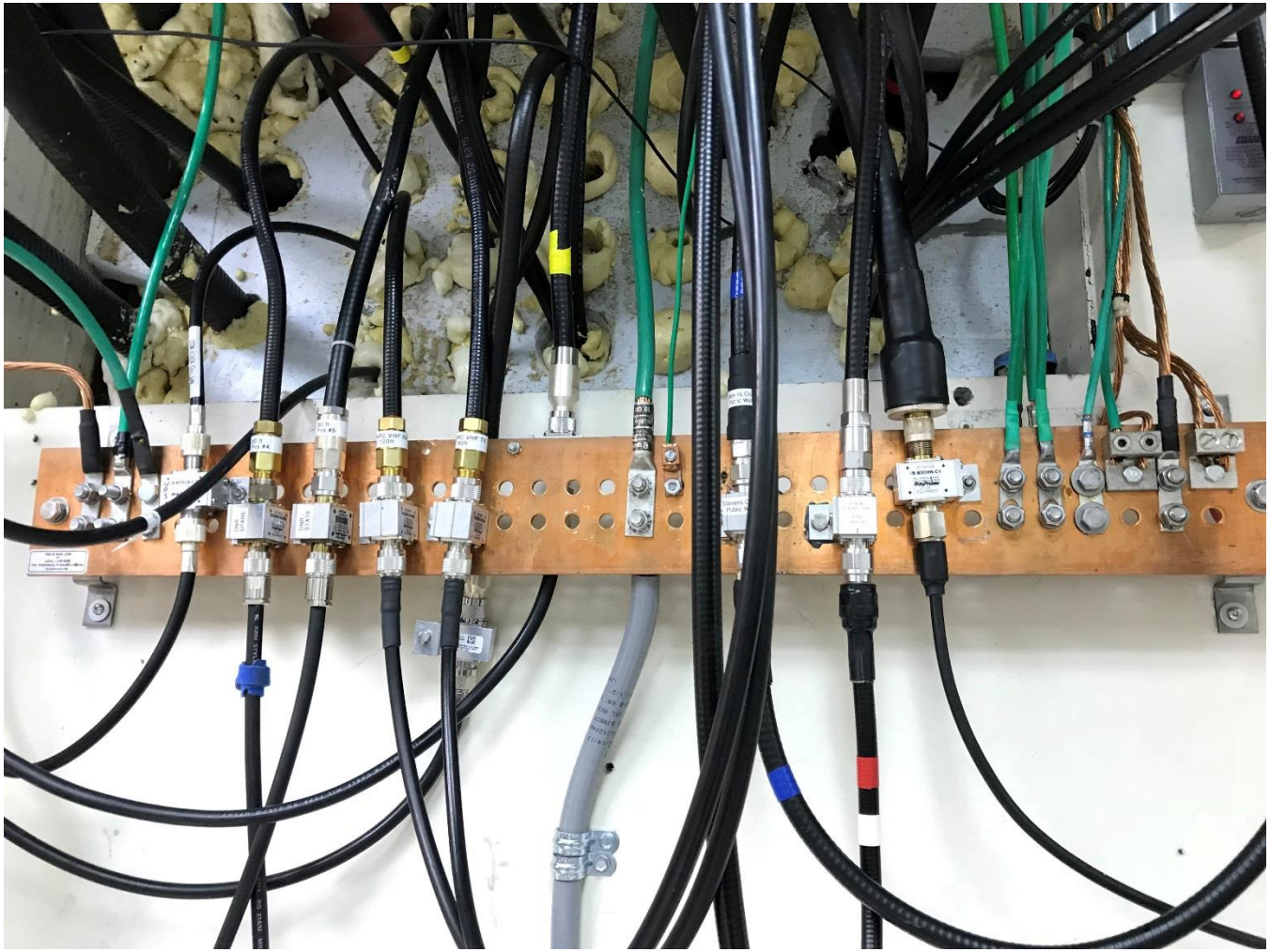
PolyPhaser Grounding



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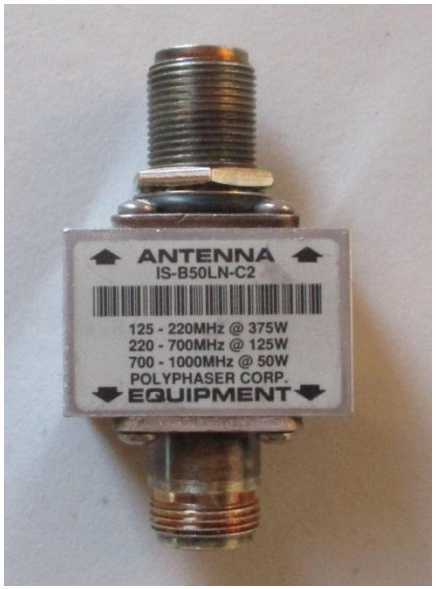
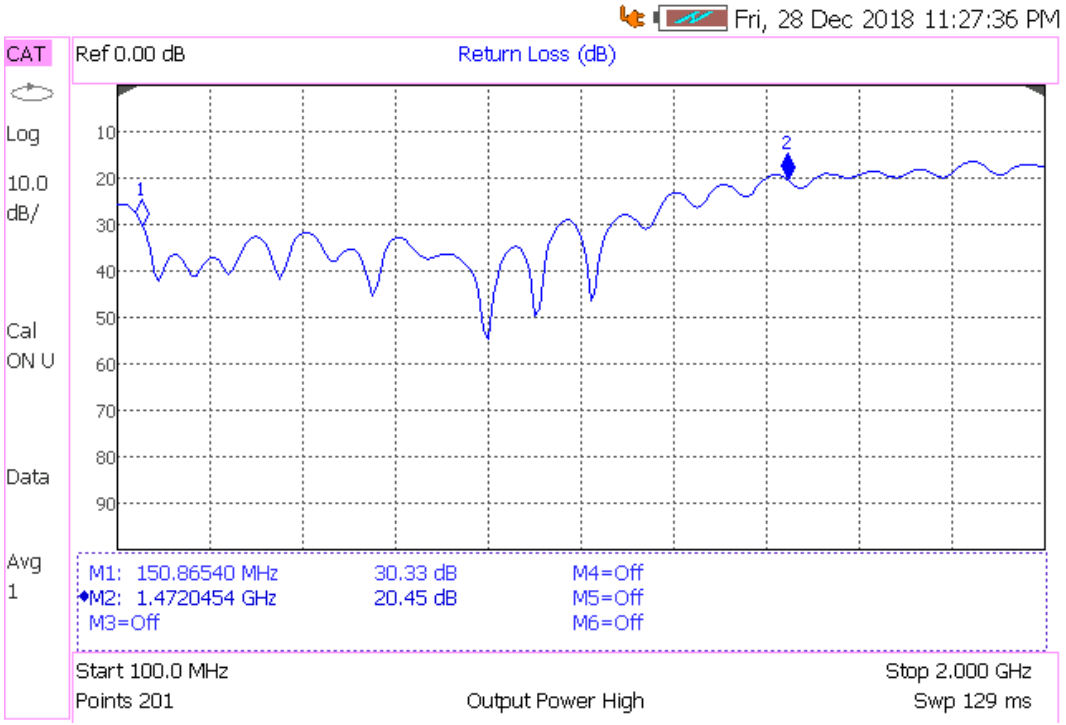
PolyPhaser Lightning Protection

- DTF Measurement frequency range 200 MHz to 1 GHz





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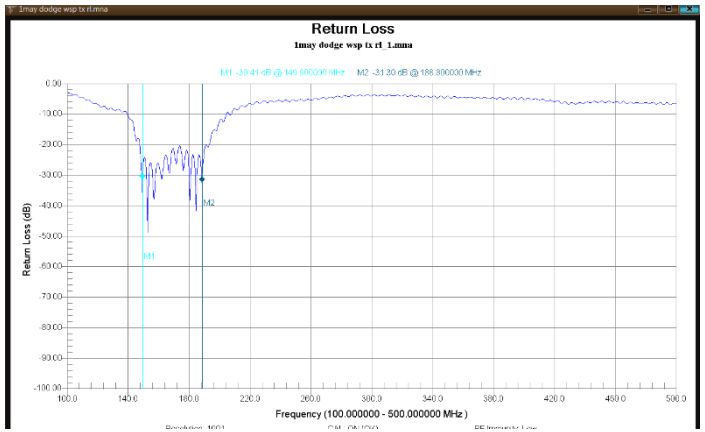
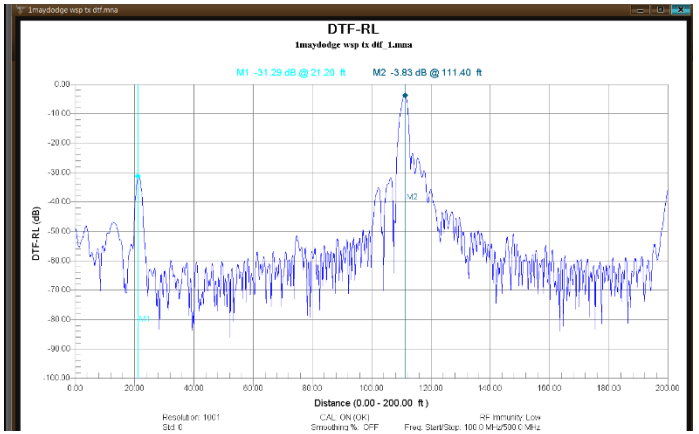
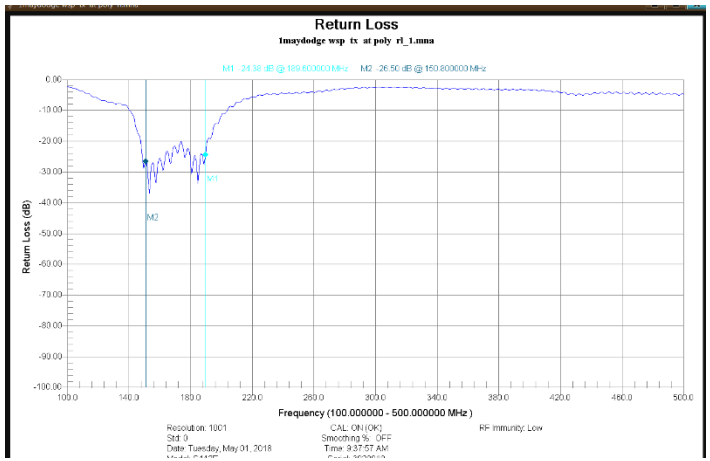
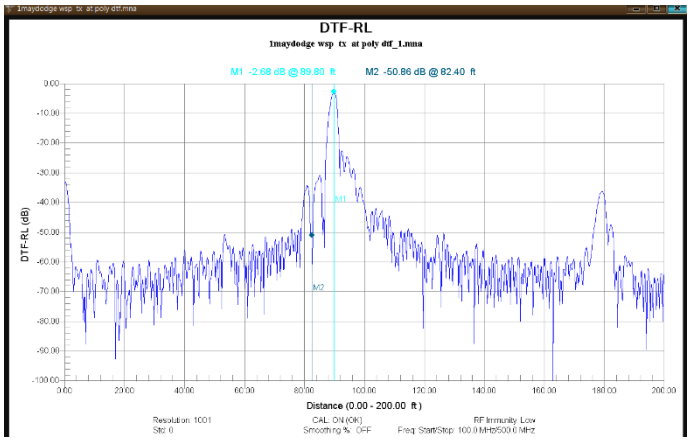
Measure Before and After Polyphaser

- Summary









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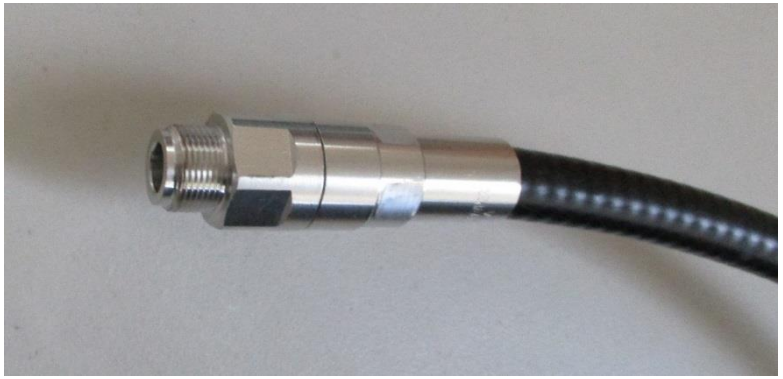
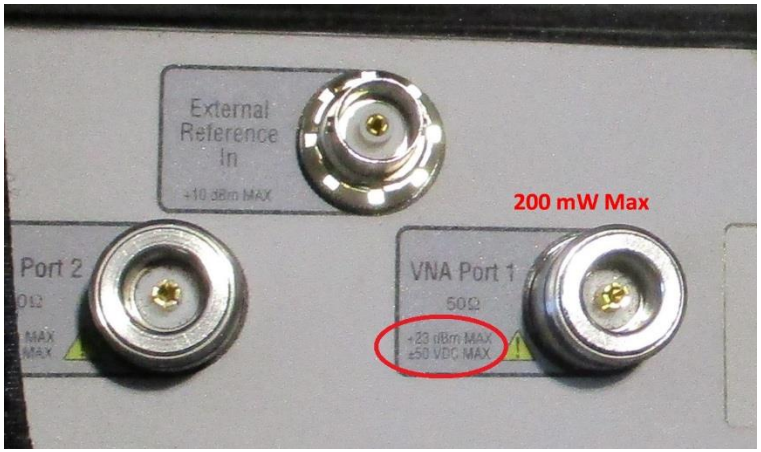
Test Equipment Burn Out Warning

- "Test this Antenna Please???
  - Difficult to trace cable



- VNA Ports can be burned out $$$$
  - Check total power on that cable
  - Switch to Spectrum analyzer mode then back to VNA mode
  - Use total power sensor first



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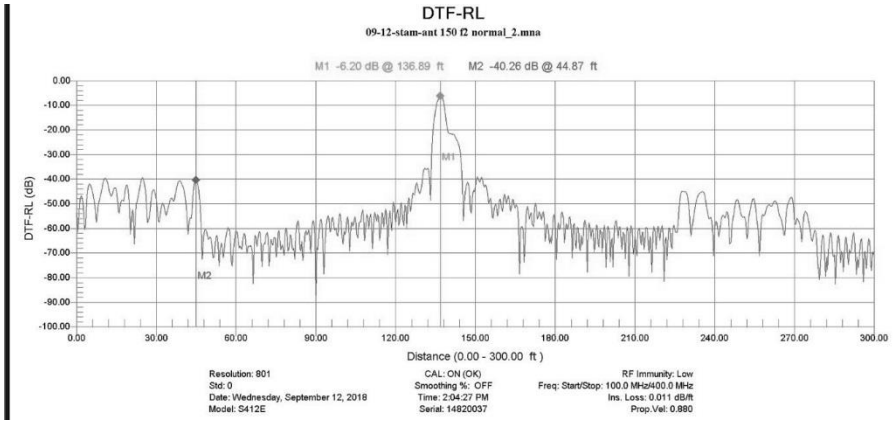
Distance to Fault Return Loss Accuracy

- DTF amplitude accuracy will not be good when:
  - Multiple cable types
  - Frequency limiting devices prevent wide frequency range
    - Still Useful for troubleshooting
- >> Frequency sweep = distance resolution
- >> Points = longer cable measurements

- LMR 400 with LDF 4-50



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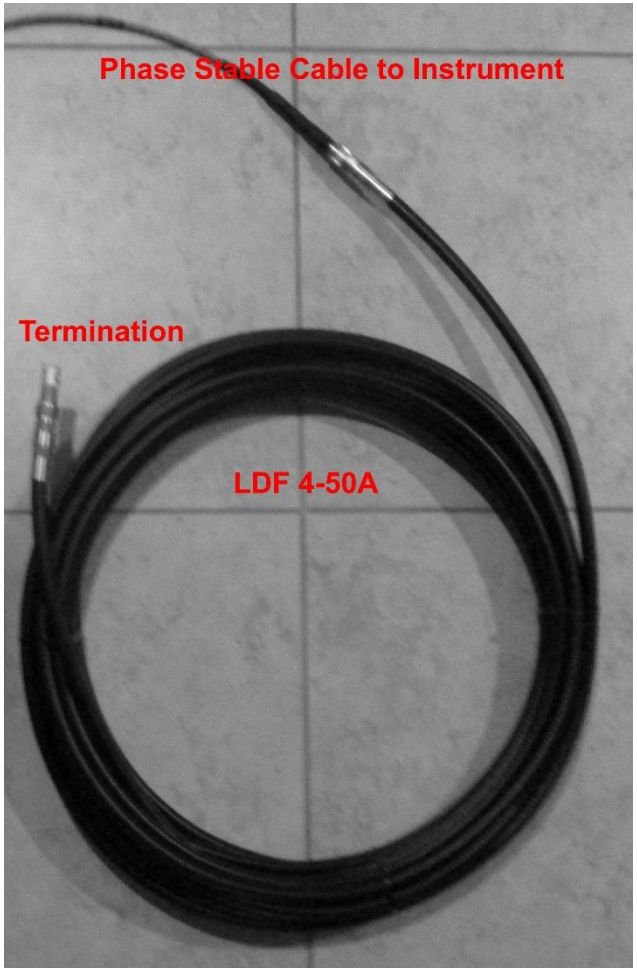
Distance to Fault Return Loss Accuracy

- A general rule of thumb is to assume 1 dB of uncertainty for every 10 dB of Return Loss measured.
- A feedline measured at 50 dB RL could have as much as 5 dB of uncertainty in the measurement result.
- LDF4 / AVA4 50 ohms +- 1 Ohm = 40 dB Return Loss



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Good Calibration

- Calibration sets reference distance (plane)
- Open Short and Termination are always offset from the mating location
  - Termination can't be made exactly at the mating location
- Cal Component connectors should be in new condition

- Cal component must match the analyzer math

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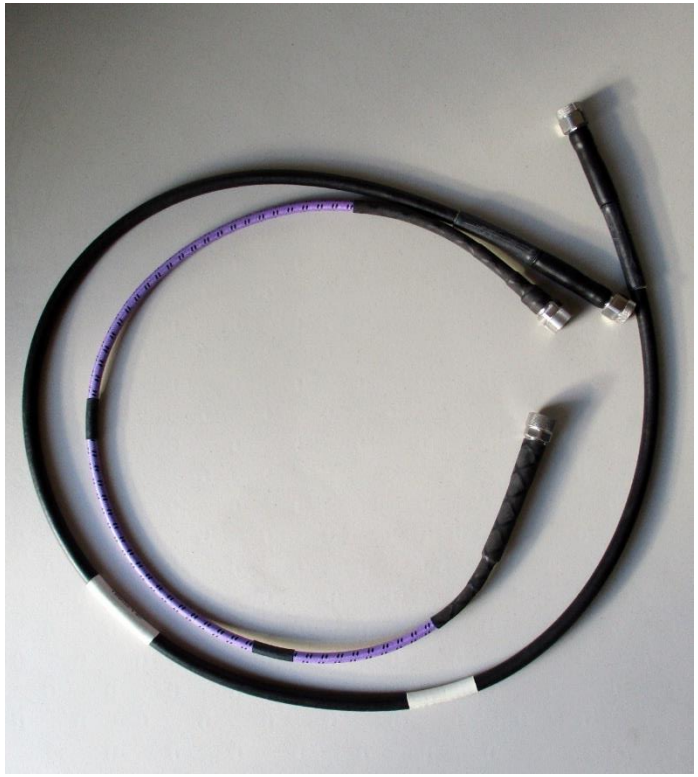
Phase Stable Test Port Cable

- Can’t connect stiff hardline directly to Test Port
- Ordinary flexible cable has phase and amplitude change when moved



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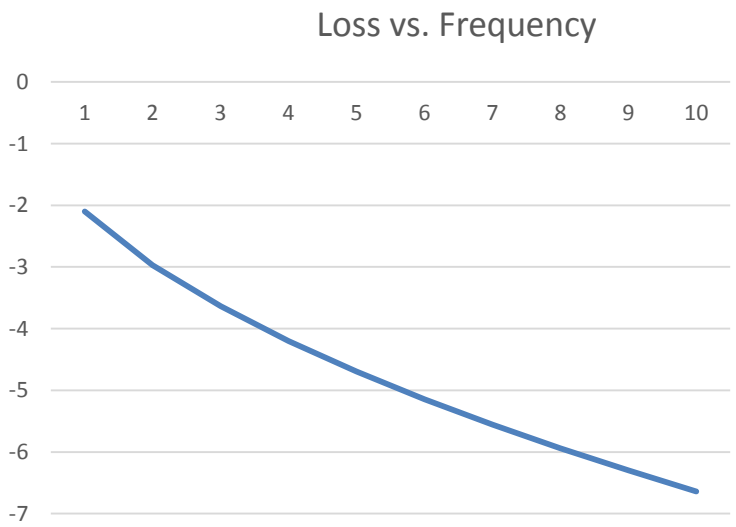
DTF Analyzer with State-of-the-Art Math

Loss at F2 =loss at F1 *SQRT(F2/F1)



- Best Accuracy for Return Loss vs. Location
- Cable type includes velocity factor and loss vs. frequency
- Measurement frequency range set by user.

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Cable Loss

Product Specifications

COMMSCOPE®

LDF4-50A

Attenuation

Frequency (MHz)	Attenuation (dB/100 m)	Attenuation (dB/100 ft)	Average Power (kW)
0.5	0.149	0.045	40.00
1	0.211	0.064	36.11
1.5	0.259	0.079	29.46
2	0.299	0.091	25.50
10	0.672	0.205	11.35
20	0.954	0.291	7.99
30	1.172	0.357	6.51
50	1.521	0.463	5.02
85	1.995	0.608	3.82
88	2.031	0.619	3.76
100	2.169	0.661	3.52
108	2.256	0.688	3.38
150	2.673	0.815	2.85
174	2.887	0.88	2.64
200	3.103	0.946	2.46
204	3.135	0.956	2.43
300	3.835	1.169	1.99
400	4.462	1.36	1.71
450	4.749	1.447	1.61
500	5.021	1.53	1.52
512	5.085	1.55	1.50
600	5.533	1.686	1.38
700	6.009	1.831	1.27
800	6.456	1.968	1.18
824	6.56	1.999	1.16
894	6.855	2.089	1.11
960	7.124	2.171	1.07
1000	7.284	2.22	1.05
1218	8.11	2.472	0.94
1250	8.226	2.507	0.93
1500	9.093	2.771	0.84
1700	9.744	2.97	0.78
1794	10.039	3.06	0.76
1800	10.058	3.066	0.76
2000	10.666	3.251	0.72
2100	10.961	3.341	0.70
2200	11.251	3.429	0.68
2300	11.535	3.516	0.66

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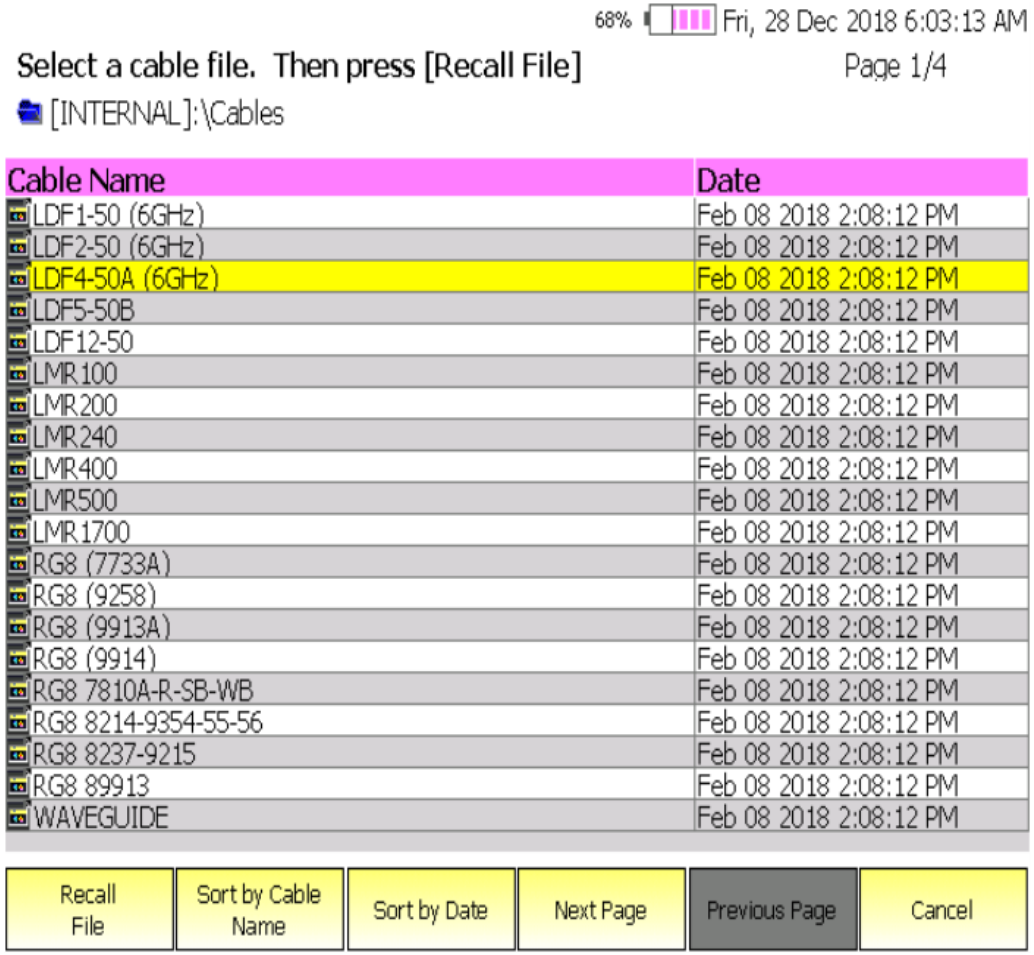
Example Instrument Cable Table



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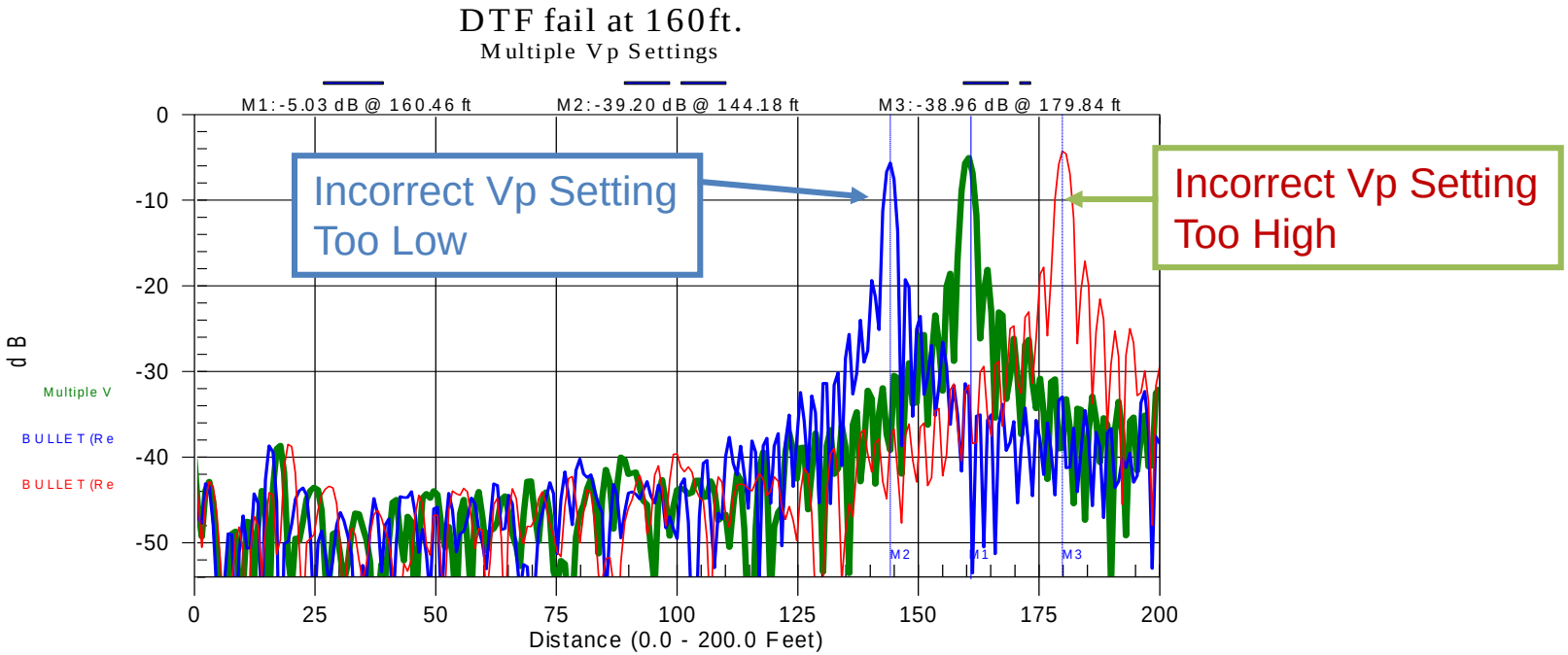
Distance to Fault

Distance to Fault Accuracy

- *Distance – Vp (Propagation Velocity) Setting*



Resolution: 259
Date: 04/14/2003
Model: S331C

CAL:ON(COAX)
Time: 09:32:33
Serial #: 00201068

CW: OFF
Ins.Loss:0.020dB/ft
Prop.Vel:0.890

An incorrect Vp setting causes incorrect distance reading

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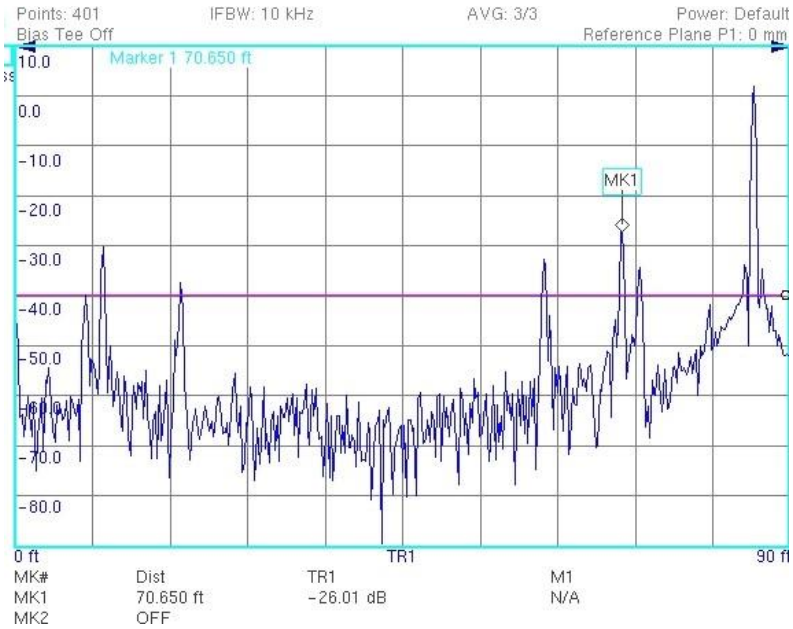
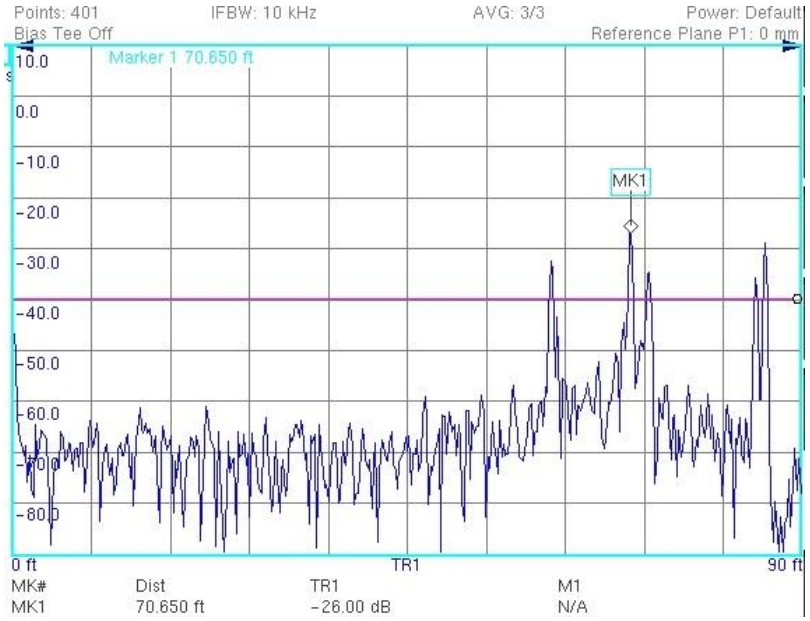
Cable with Dent With and Without Termination at End

- No Termination



- With Termination



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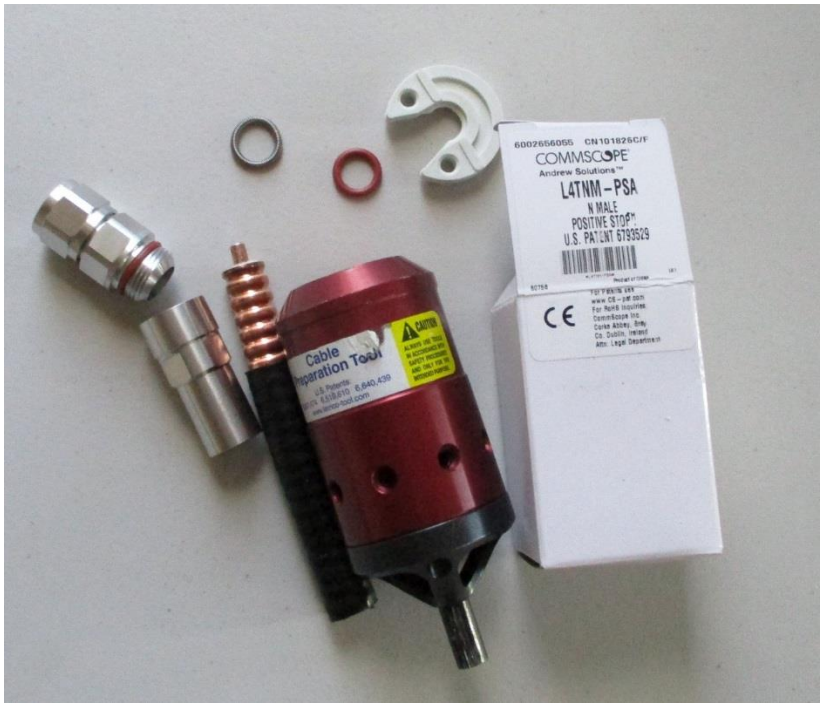
Installing a Connector and Termination

- Unspool the cable
- Square cut both ends of the cable
- Install a connector on both ends of the cable
  - $20 each and 30 minutes
- Connect a termination
  - $20
- Connect the instrument to the opposite end of the cable



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Installing Connectors and Termination

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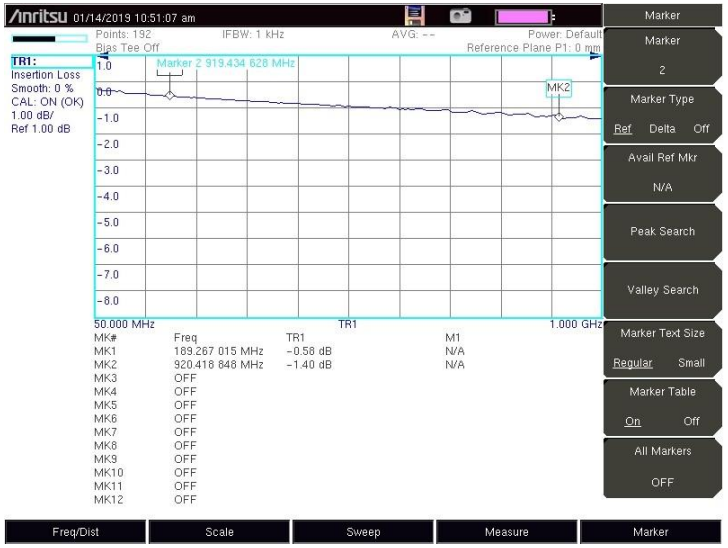
Excessive Loss

- 2 Port Analyzers
  - Connectors both ends of spool
  - “Press-on” Test Connector inside spool end



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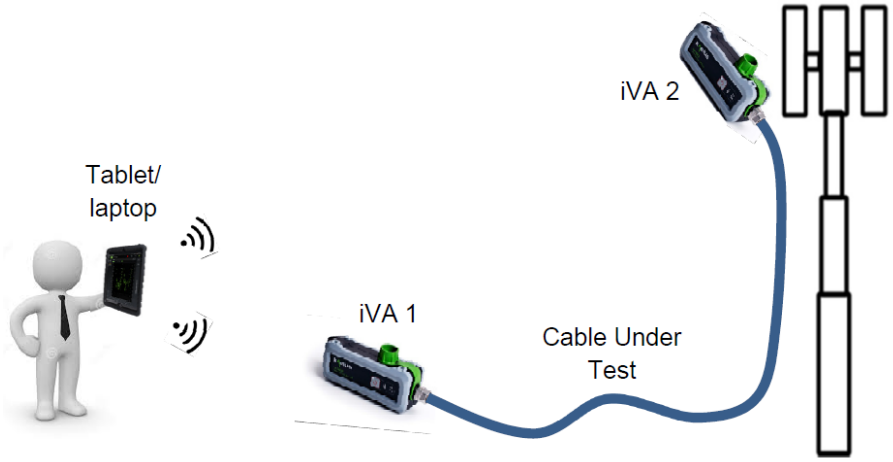
Excessive Loss

- Kaelus iVA Transmission Mode Option
  - 560 MHz to 2750 MHz



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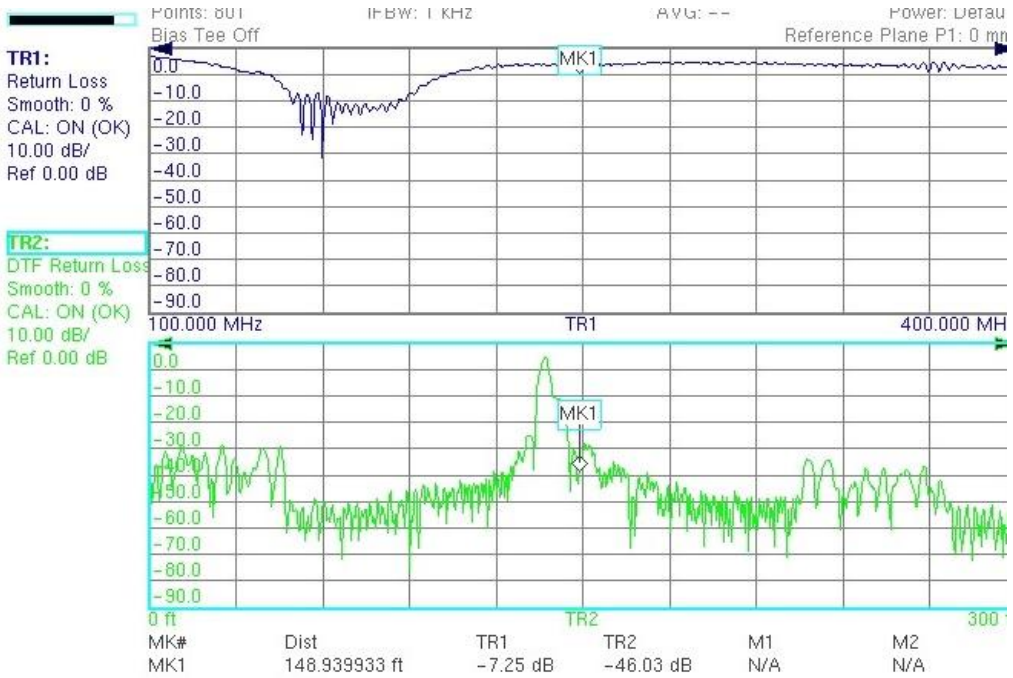
Excessive Loss

- 1 Port Insertion Loss Measurement
  - Full Reflection at Far end of spool
  - Cable loss ½ Return Loss at Frequency with full reflection



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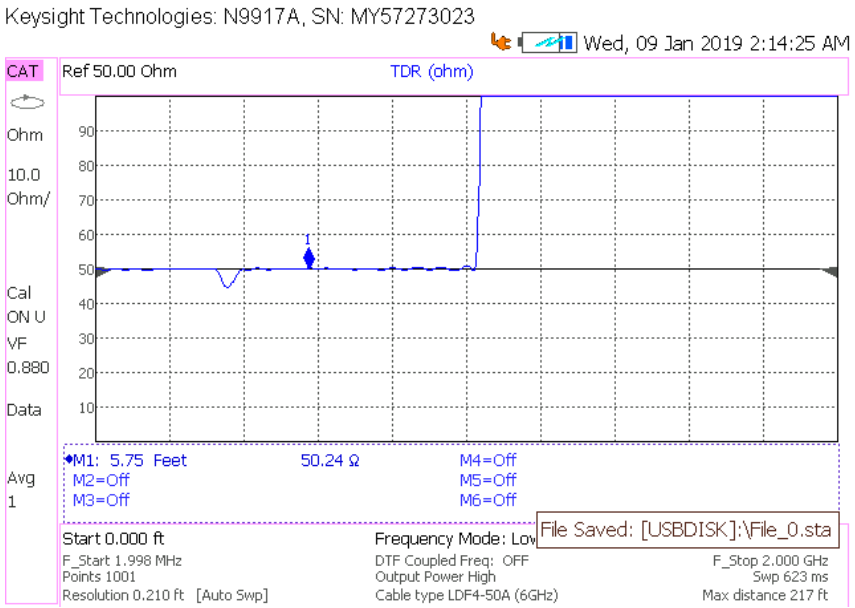
Wrong Impedance

- Distance-to-Fault is relative (to 50 ohms)
- TDR mode uses different math to show absolute ohms



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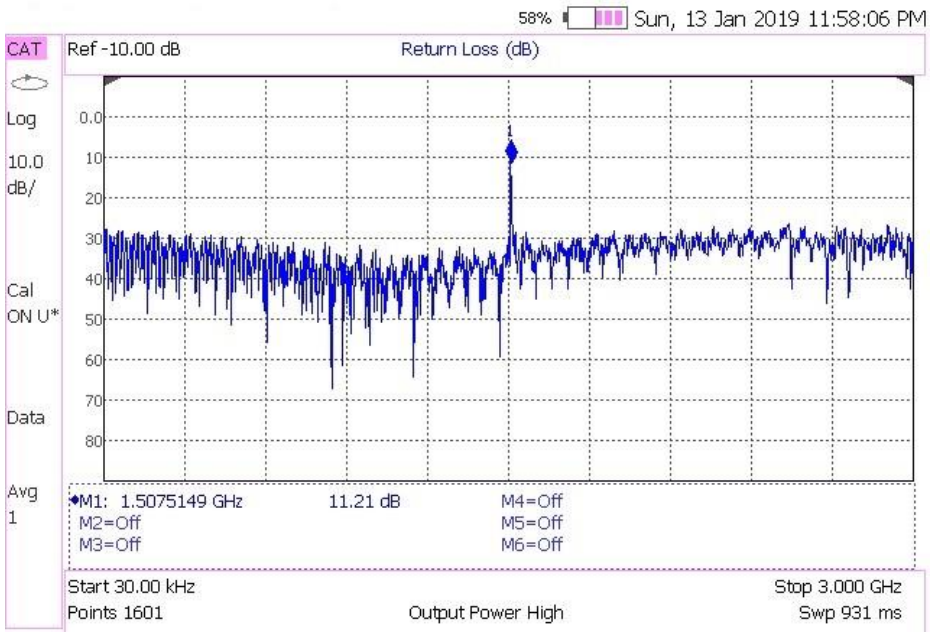
“Structural Return Loss” (periodic dents)

- Periodic dents
  - Manufacturing wheel
  - Forklift creases
- Very bad return loss at one frequency
- Need very high resolution (frequency) return loss measurement
  - 1601 point
  - Slows sweep time



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Theory to Practice

- Cable arrives at shop or site
- Inspect for physical damage

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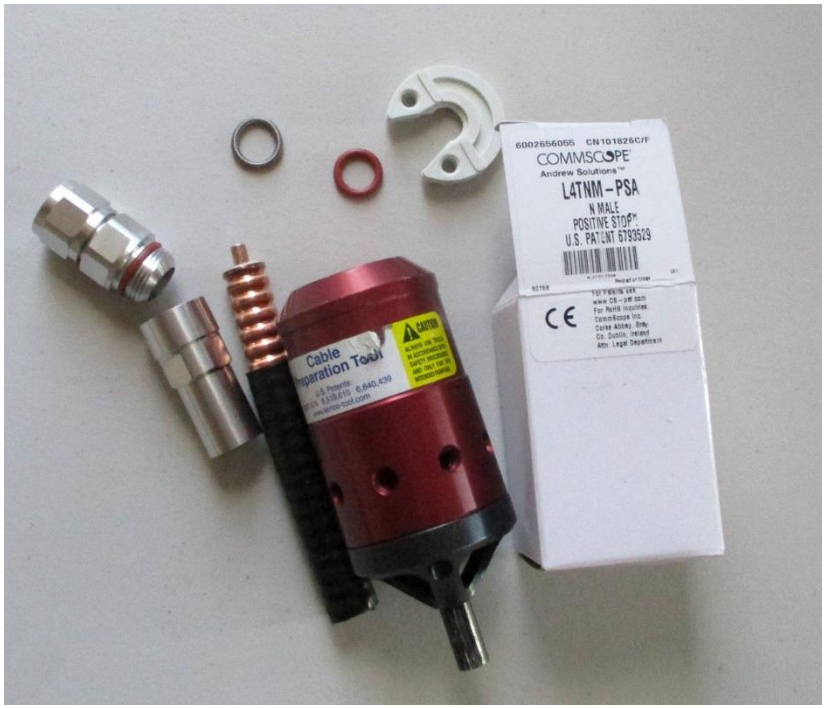
Theory to Practice

- Install Connector on outside end
  - Also inside end if possible



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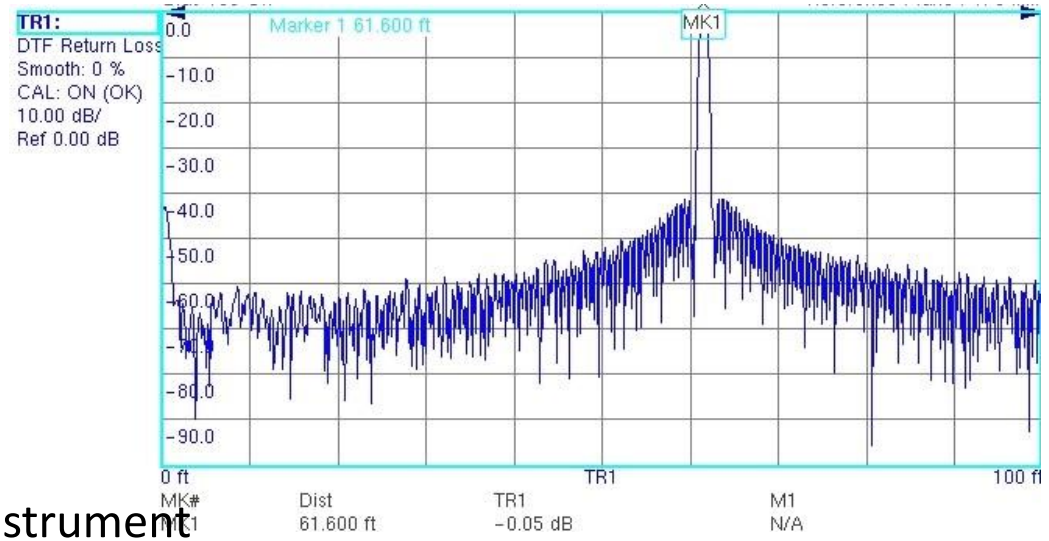
Theory to Practice

- Measure Distance-to-Fault from the connector to the open inside end of the spool
  - Cable type
    - Loss /vf
  - 0.1 to 1 GHz
  - 1001 points
    - 480 ft max
  - Careful Calibration
    - Cal component for instrument



- No termination on inside end of spool
  - Is distance correct?

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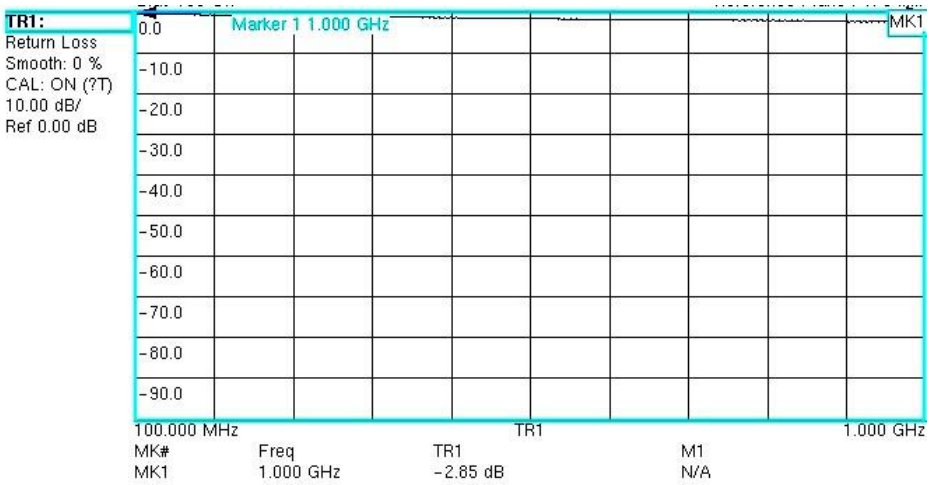
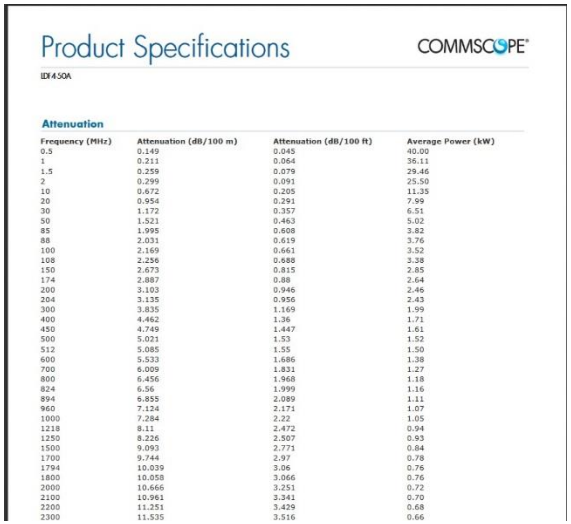
Theory to Practice

- Check for excessive loss
  - With open on inside end
  - One-way loss = ½ of return loss measurement
  - Compare with vendor spec




Product Specifications

COMMSCOPE

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204	3.135	0.956	2.43
300	3.835	1.169	1.99
400	4.462	1.36	1.71
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512	5.085	1.55	1.50
600	5.533	1.686	1.38
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800	6.456	1.968	1.18
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1500	9.093	2.771	0.84
1700	9.744	2.97	0.78
1794	10.039	3.06	0.76
1800	10.058	3.066	0.76
2000	10.666	3.251	0.72
2100	10.961	3.341	0.70
2200	11.251	3.429	0.68
2300	11.535	3.516	0.66

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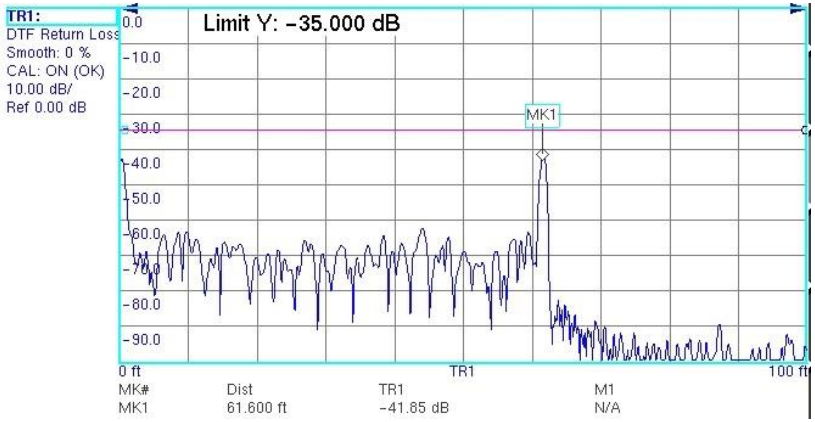
Theory to Practice

- Unspool cable / begin hauling up the tower
  - Low cost termination on the connector going up the tower

RadioSiteTest

Theory to Practice

- Thread cable into shelter and cut to exact length
- Install Connector on shelter end
- Measure DTF from shelter end to termination at top end
- Good example



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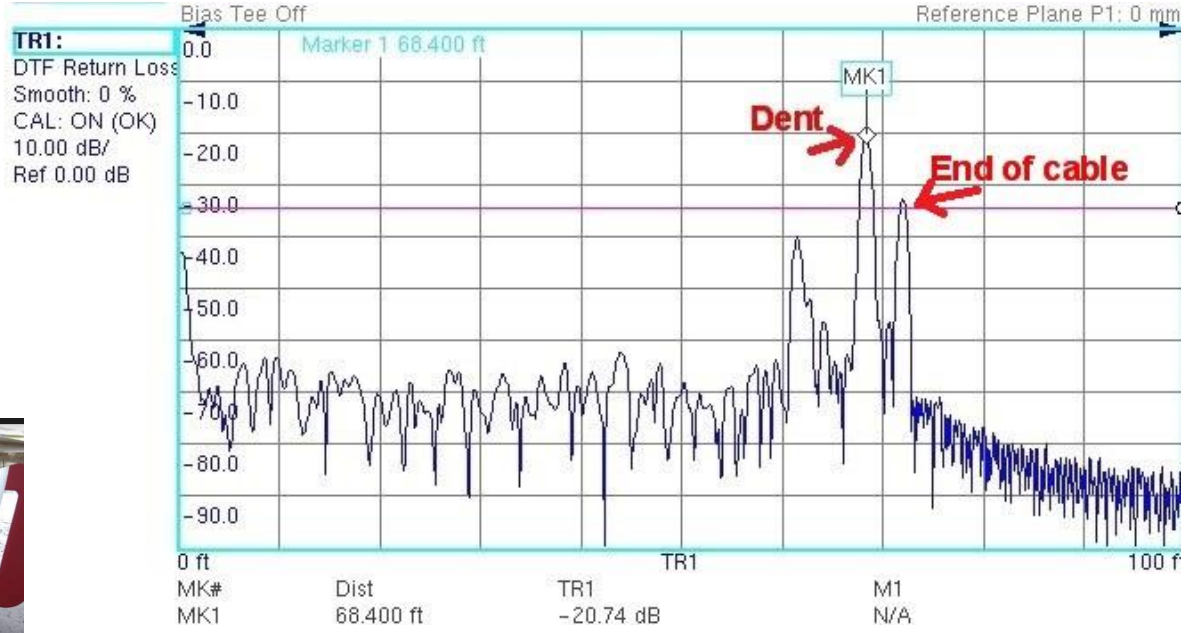
Theory to Practice

- Bad example



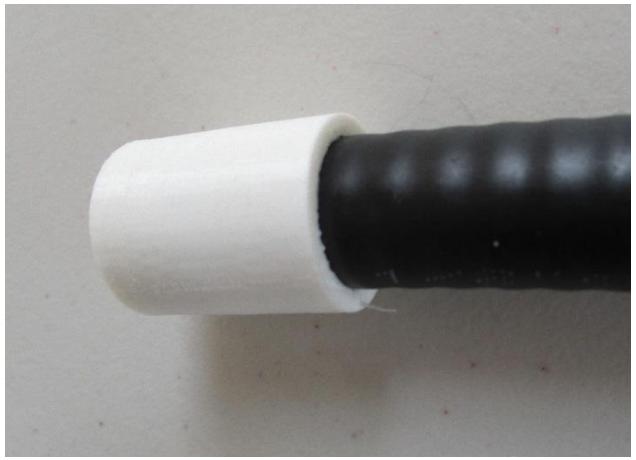
RadioSiteTest

A Better Way.. Press-on Termination

- Square cut the ends of the cable
- Press on Termination at the factory or distributor
- Inside of the spool

Theory to Practice with Termination cap on Inside of Spool (future)

- Cable arrives at shop or site
- 30 dB RL Termination cap on inside end of spool shipped from distributor
- Patented



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A Better Way.. Press-on Test Connector

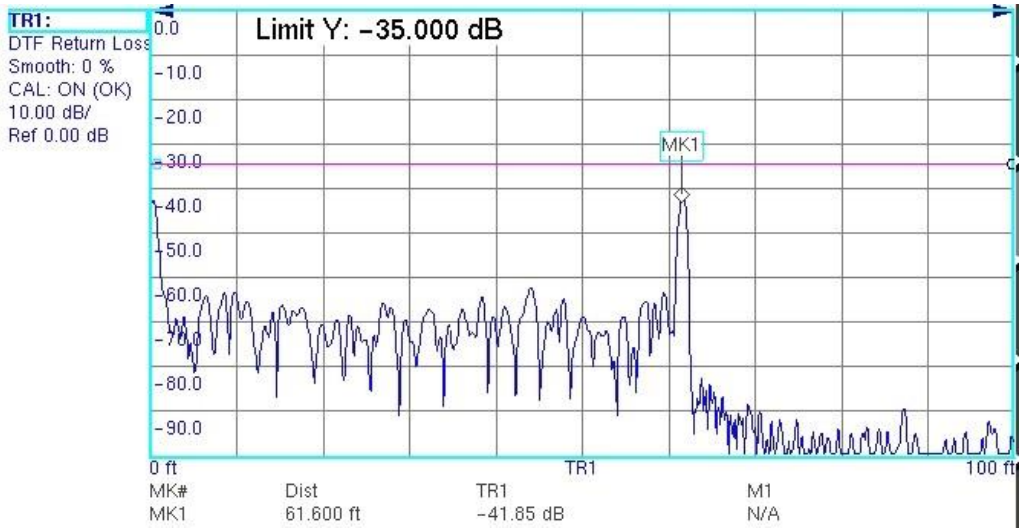
- Square cut the outside end of the cable
- Press on test connector
- Make measurements
- Remove connector

- Patent Pending

Theory to Practice with Termination cap on Inside of Spool and Press-on Test Connector (future)

- Cable arrives at shop or site
- Is distance correct?
- Is the cable good (<-35 dB RL)

- Cable good-bad without climber or installing a connector



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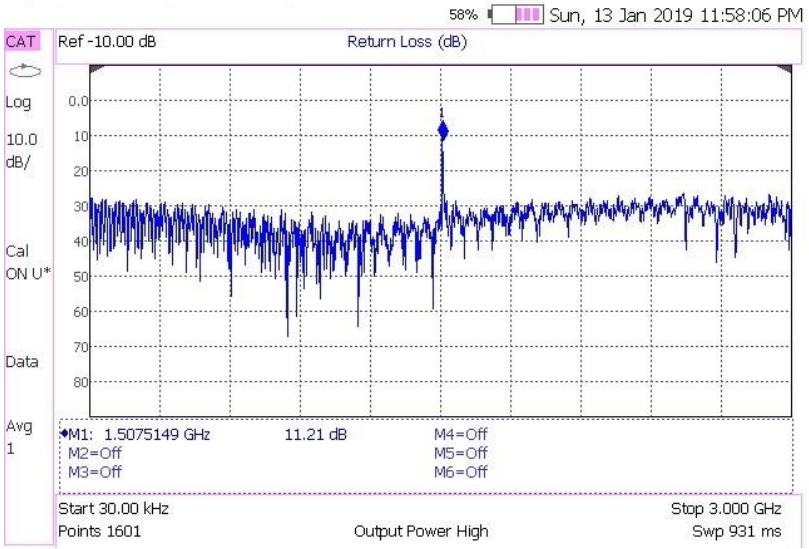
Theory to Practice with Termination cap on Inside of Spool and Press-on Test Connector (future)

- Check for structural problems
- Return loss vs. Frequency with 4001 points
- Cable good-bad without climber or installing a connector



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Measuring Transmission Line Quality Prior to and During installation on a Tower

- Kinking
- Crushing
- Water damage

It could be a manufacturer, distributor, shipper, or installer problem. The only way to know for sure is to test at handoff points.

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Q&A

- 10 dB Return loss @ 100 watt transmitter Radiated power?
- Cable damage to good antenna. Transmitter sees what?
- Why is it important to enter the cable type into the test equipment setup?
- What measurement is DTF with an open ended cable?
- T or F A good return loss at the transmitter output is always good?
- What should you consider when setting the frequency range for a DTF measurement?
- What should you consider when setting the # of points for a DTF measurement?
- Why should you terminate a spool of cable before determining if it is good or bad?
- Good cable is 50 ohms +- 1 ohm What is the return loss of the cable?
- How can you approximately measure the loss of installed cable?

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Questions / Contact Information

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Presentations and Papers

- Presentations:
  - Using Drones for Site Surveys, IWCE, March 2017
  - Testing Indoor Coverage, IWCE, March 2017
  - Measurement and Optimization of Talk-in Coverage for VHF and UHF TDMA Radio Systems, IWCE, March 2017
  - In-Building Distributed Antenna Systems (DAS) Planning for Public Safety, IWCE March 2016
  - Public Safety Distributed Antenna System (DAS) Measurements, Web seminar August 2015
  - Receiver Blocking Measurements, APCO WRC May 2015
  - Optimizing Simulcast Systems, IWCE March 2015
  - Using SINAD Coverage Mapping to Locate Receiver Blocking, APCO WRC 2015
  - Using a VNA to Tune N-Way Combiners, IWCE March 2014
  - P25 Receiver Testing, IWCE 2013
  - Fundamentals of Interference Analysis IWCE 2011
  - Session Chairman for Wireless Data Technical Session at the Wireless Design Trade Show from 1992 to 1999
- Application Notes / White Papers:
  - Solving mm-Wave Test Challenges, Microwave Journal March 2017
  - In-Building Propagation Measurements for 5G Communications August 2016
  - In-Building Mapping March 2016
  - Accuracy of DTF Measurements of New Spools of Transmission Line, December 2015
  - Measuring Antenna Pattern with the Anritsu S412E, November 2015
  - High Q Notch Filter Measurements; August 2015
  - Measuring Delay Through a Repeater or DAS, August 2015
  - Receiver Testing January, 2012
  - Mapping BER of P25 Radio Systems, May, 2015
  - Indoor Mapping, August 2010

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