

Techniques for precise cable and antenna measurements in the field

March 25, 2015

Gustaaf Sutorius
Application Engineer



Agenda

Techniques for precise cable and antenna measurements in the field

Cable & Antenna
Measurements March 2015,
Gustaaf Sutorius

- **Introduction Keysight Technologies**
- FieldFox Introduction
- Antenna Measurements
- Cable Loss Measurements
- Cable Fault Measurements



A Brief History of Keysight

1939–1998: Hewlett-Packard years

A company founded on electronic measurement innovation



1999–2013: Agilent Technologies years

Spun off from HP, Agilent became the World's Premier Measurement Company. In September 2013, it announced the spinoff of its electronic measurement business



2014: Keysight begins operations

November 1, Keysight is an independent company focused 100% on the electronic measurement industry

We believe in “Firsts”

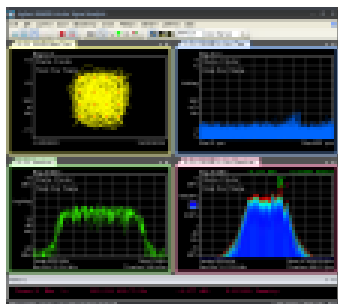
Bill Hewlett and Dave Packard's original vision launched Silicon Valley and shaped our passion for “firsts” 75 years ago. Today we are committed to provide a new generation of “firsts” – software-oriented solutions – that create value for our investors and valued insights for our customers.

Keysight Today: Unique Measurement Science

- At Keysight Technologies *Measurement Science* propagates faster
- Faster from Keysight R&D Labs to:
 - Actual Hardware (instruments)
 - Actual Software (EDA tools)
- Industry leading *Measurement Science* has been THE enabler for technical leadership in:
 - Oscilloscopes
 - Signal Generators
 - Spectrum Analyzers
 - Network Analyzers
 - HandHeld FieldFox

Keysight Measurement Science: Spectrum Analyzers

Performance



89600B VSA software
Premier signal analysis



CXA

9 kHz to 26.5 GHz, 25 MHz BW



EXA

10 Hz to 44 GHz, 40 MHz BW



MXA

10 Hz to 26.5 GHz, 160 MHz BW
Available with RTSA



PXA

3 Hz to 50 GHz, 160 MHz BW
Available with RTSA



UXA

3 Hz to 26.5 GHz, 510 MHz BW
Available with RTSA

100% code compatibility

Similar user experience

Price

Keysight Measurement Science: Vector Network Analyzers

Industry Broadest Price/Performance Choices



PXIe VNA

Drive down the size of test
300 k to 26.5 GHz

FieldFox

Carry precision with you
30 k to 26.5 GHz



E5080A

The next-generation ENA



E5071C, E5072A

High-performance RF NA



E5061B, E5063A

NA + ZA in one-box
Low cost RF NA

ENA Series

Drive down the cost of test
5 Hz to 20 GHz



PNA (N522XA)

High-performance Microwave NA



PNA-L (N523XA)

Economy Microwave NA



PNA-X (N524XA), NVNA

Most advanced & flexible
Microwave NA

PNA Family

Reach for unrivaled excellence
300 k to 1.1 THz



mm-wave Solution

Up to 1.1 THz



PNA-X Receiver

8530A Antenna
Replacement

Agenda

Techniques for precise cable and antenna measurements in the field

- Introduction Keysight Technologies
- **FieldFox Introduction**
- Antenna Measurements
- Cable Loss Measurements
- Cable Fault Measurements



FieldFox: Leveraging Measurement Science

FieldFox analyzers are the handheld extension of the best network and spectrum analyzers.



“FieldFox’s result is almost identical to my PNA. I want one of these for all of my engineers.”

-Senior calibration engineer from spacecraft research and development center.



2012 FieldFox microwave handheld analyzer



2001 PSA spectrum analyzer



2000 PNA vector network analyzer



2009 PXA X-Series signal analyzer



1984 8510A vector network analyzer



2007 PNA-X vector network analyzer



1978 HP 8566B spectrum analyzer

FieldFox in brief



- **Keysight Measurement Science** (PNA-X IP) in a much smaller form factor. A true Vector Network Analyzer with 4 Receivers.
- **Unique Calibration Science** (InstAlign, Calready etc.) makes FieldFox measurements consistent with lab benchtop instruments
 - **Calready**: Impossible to make uncalibrated measurements
 - **InstAlign**: No warmup time. No issues with changing ambient temperatures
- Designed From Scratch as Portable Instrument (15 Watt, no fan,etc)
- **Rugged**: No fans or vents. Designed for rain, dust, moisture, humidity, rapid temperature changes etc. 3-year warranty
- **Easy to use** (CAT mode for instance)
- Independent RF Source (generate a verification signal in the field)
- Channel Power Meter allows Frequency Banded Power Measurements

No Warmup time & No Calibration Required



FieldFox: “more difficult to perform wrong measurements”

- **Calready**: Impossible to make uncalibrated measurements
 - No need to calibrate for Cable & Antenna measurements
- **InstAlign**: No warmup time. No issues with changing ambient temperatures.
 - No need for waiting (warm-up time) for Spectrum and Channel Power Measurements

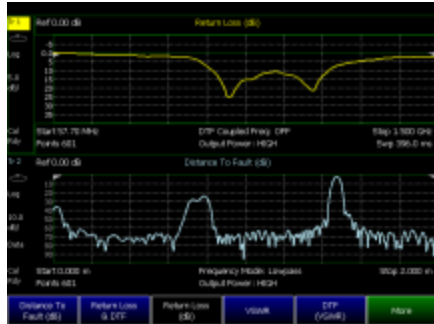
FieldFox: Precision RF&uWave Measurements in the Field

FieldFox replaces many Benchtop Instruments:

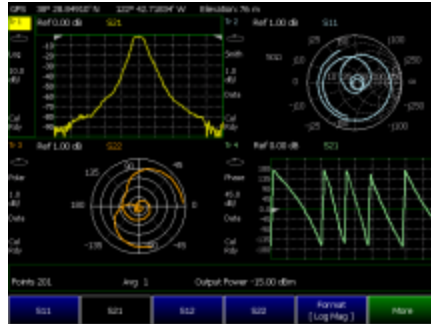
- FieldFox as Performance Vector Network Analyzer
- FieldFox as Cable & Antenna Analyzer
- FieldFox as Performance Spectrum Analyzer
- FieldFox as Interference Analyzer
- FieldFox as Vector Voltmeter
- FieldFox as DC Voltage Source
- FieldFox as Channel Power Meter
- FieldFox as Frequency Counter
- FieldFox as GPS Receiver
- FieldFox as Signal Generator



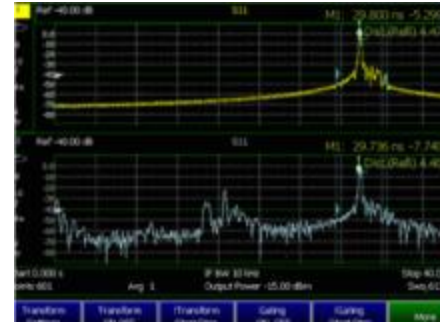
RF Toolbox with Laboratory Instrument Precision



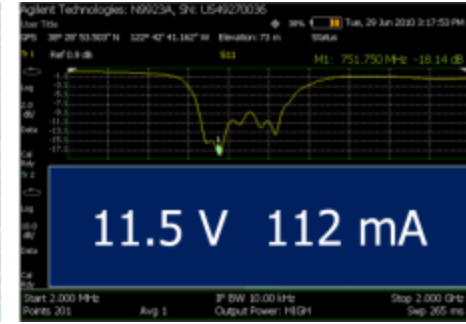
Cable and antenna analysis



Vector network analysis



Time domain



DC source & current monitor



Spectrum analysis

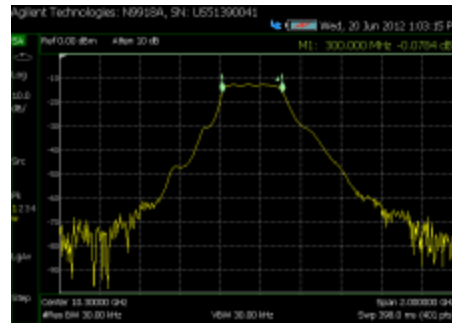
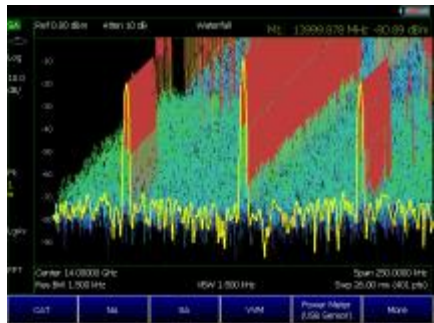
Plus:

Built-in GPS
Independent source
Full-band preamplifier
SA frequency counter

Light weight: 6.6 lbs (3.0 kg)
 Long battery life: 3.5 hrs
 Bright display: 6.5 inch TFT



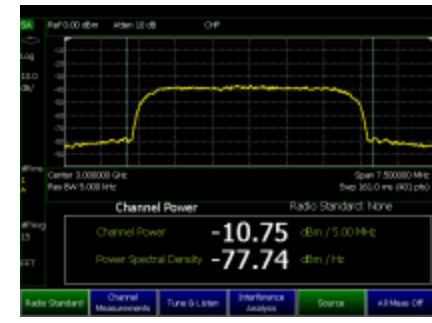
Built-in power meter



Full-band tracking generator



Vector voltmeter



Channel power measurement

Agenda

Techniques for precise cable and antenna measurements in the field

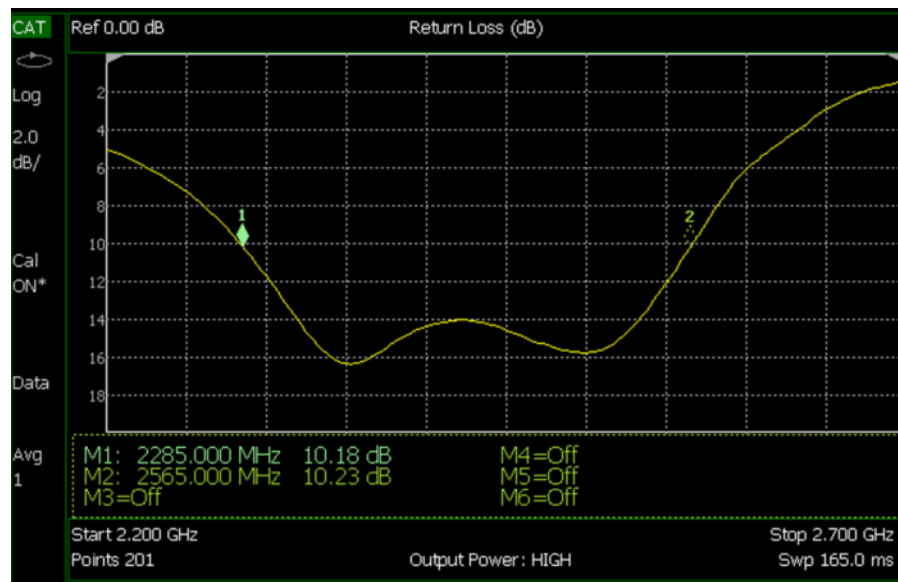
- Introduction Keysight Technologies
- FieldFox Introduction
- **Antenna Measurements**
- Cable Loss Measurements
- Cable Fault Measurements



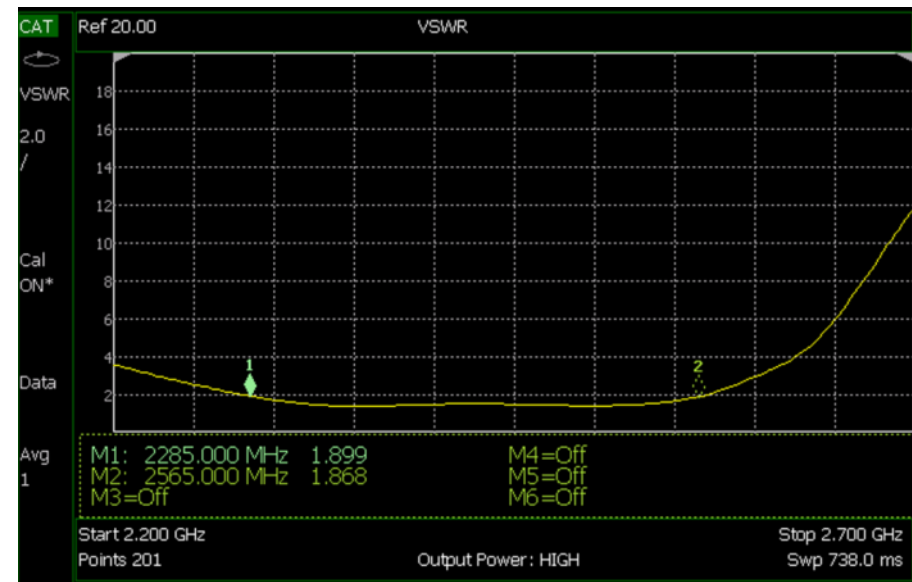
Antenna Measurements

- FieldFox
1. Return loss (dB)
 2. Voltage standing wave ratio (VSWR)
 3. Antenna-to-antenna Isolation
- Special equipment
- Gain
 - Efficiency

1: Return loss (dB)



2: VSWR



Antenna-to-Antenna Isolation

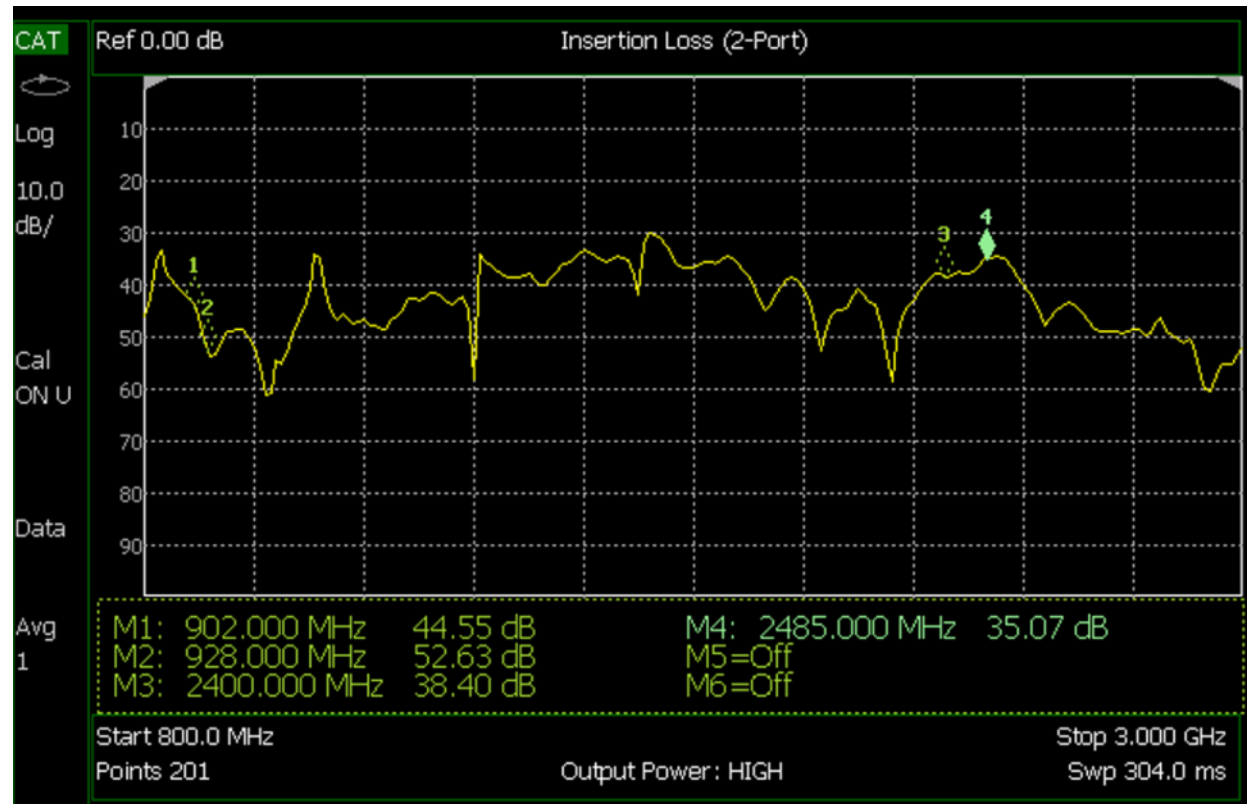


Copyright J M Briscoe and licensed for reuse under the Creative Commons License.



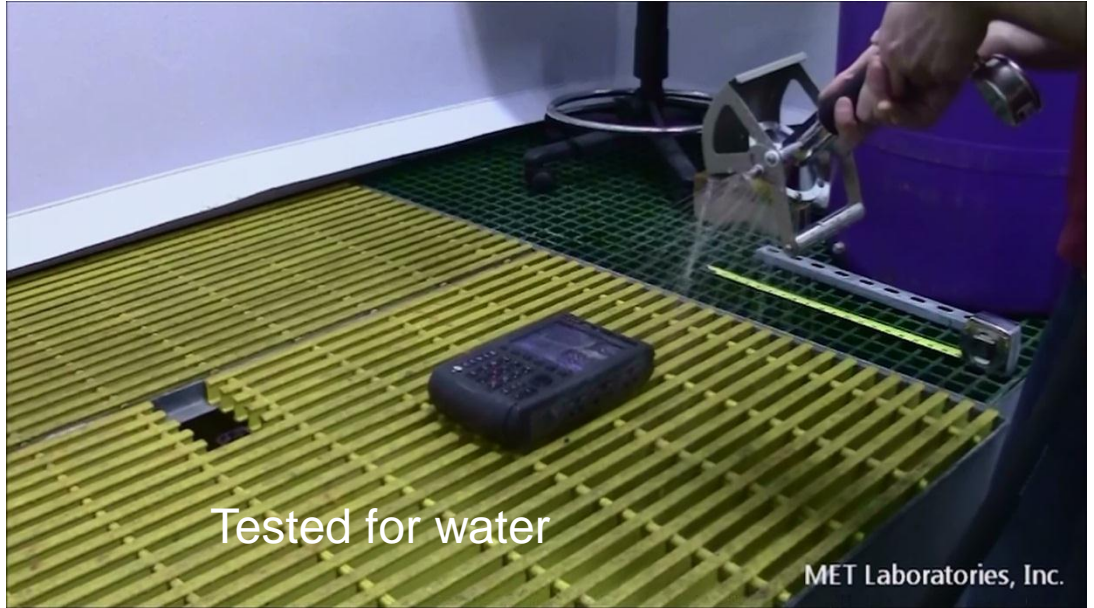
Antenna-to-Antenna Isolation Measurement

Insertion loss (2-port)



Antenna-to-antenna isolation is above 44 dB across the 900 MHz band but is only 35 dB in the 2.4 GHz band. In this case, the system spec calls for 40 dB of isolation.

FieldFox: protected for dust, spraying water, shock & vibration



Tested for dust



Agenda

Techniques for precise cable and antenna measurements in the field

- Introduction Keysight Technologies
- FieldFox Introduction
- Antenna Measurements
- **Cable Loss Measurements**
- Cable Fault Measurements

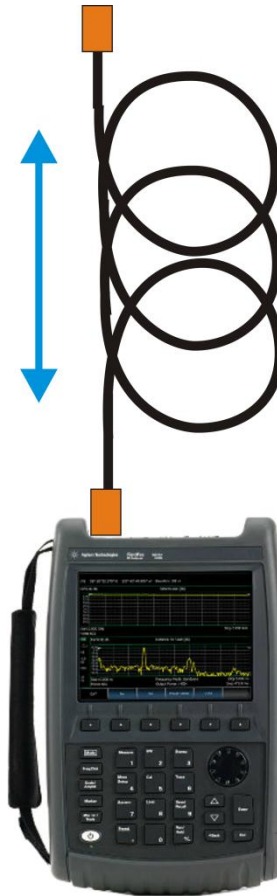


Cable Loss Measurement Techniques

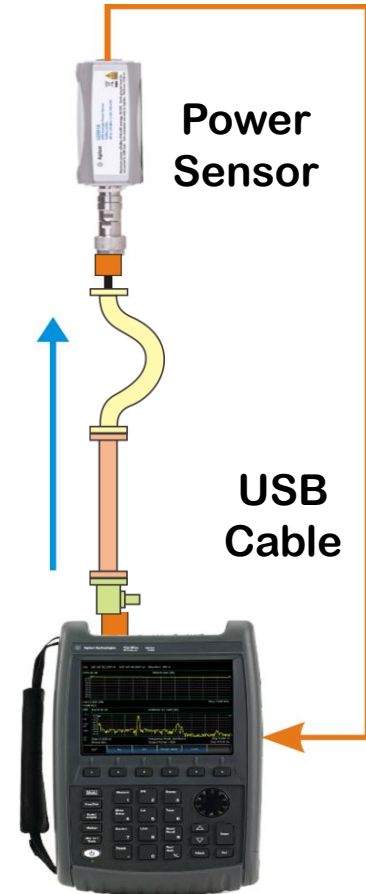
2-Port 'Transmission' Loss Measurement



1-Port 'Reflection' Loss Measurement

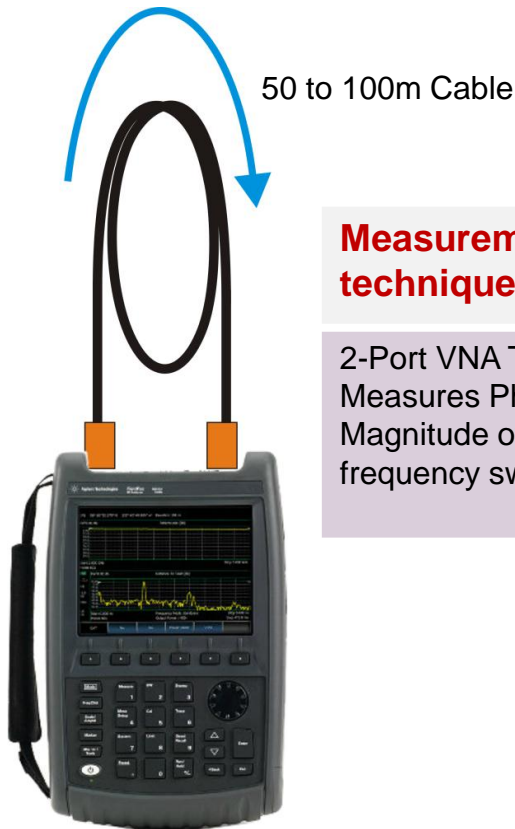


Frequency Offset Loss Measurement



Cable Loss Measurement Techniques - Transmission

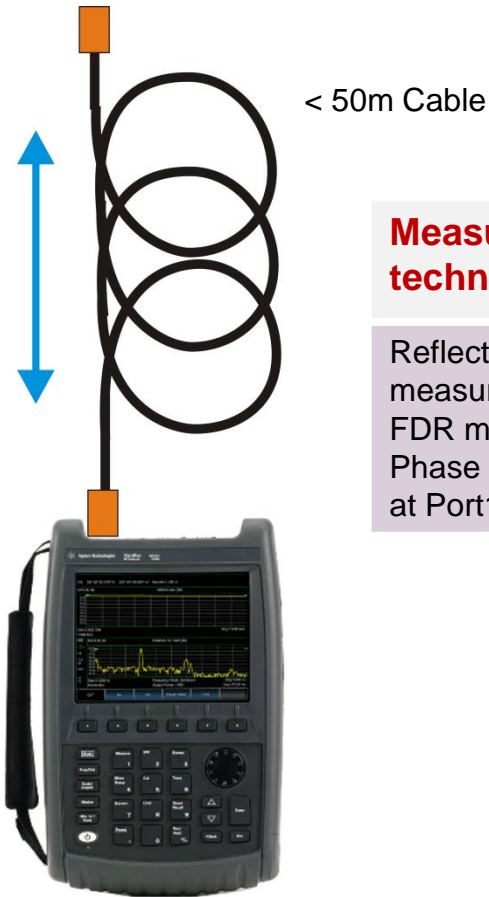
2-Port 'Transmission' Loss Measurement



Measurement techniques	Typical loss value	Cable length / installation method	Accuracy / comments
2-Port VNA Transmission Measures Phase and Magnitude over frequency sweep	80 to 100 dB depending on freq.(RF vs μ W)	50 to 100m depending on freq. 2 ends of Cable must be close enough to maintain good calibration	Most accurate method to measure Cable Loss

Cable Loss Measurement Techniques - Reflection

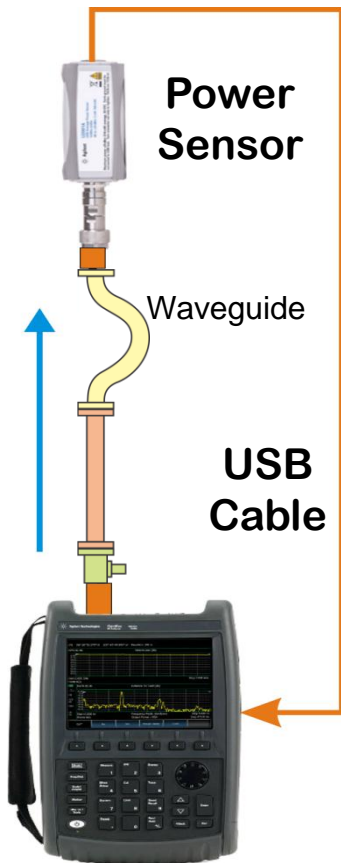
1-Port 'Reflection' Loss Measurement



Measurement techniques	Typical loss value	Cable length / installation method	Accuracy / comments
Reflection measurement using FDR measures Phase & Magnitude at Port1	20 to 25dB	<50m Cable installed with difficult /restricted access at other end.	Practical but less accurate (mismatch) with less dynamic range than 2-Port Transmission method

Cable Loss Measurement Techniques (Option-208)

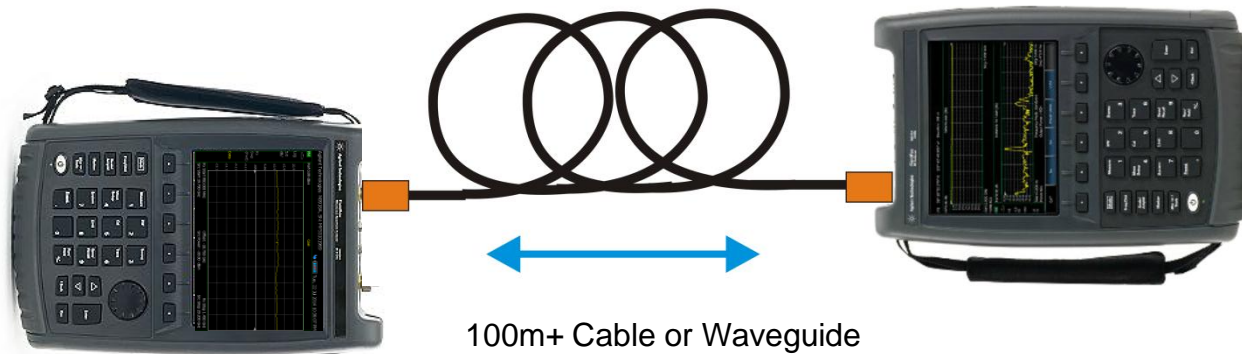
Frequency Offset Loss Measurement



Measurement techniques	Typical loss value	Cable length / installation method	Accuracy / comments
PS (power sensor) measures power difference between 2 ends of Waveguide.	Typically 20 - 25dB depending on PS dynamic range	<50m Waveguide installed with access to other end	Slow (settling time), subject to external interference, less dynamic range than 2-Port Transmission. Normalization required

Cable Loss Measurement Techniques (Option-209)

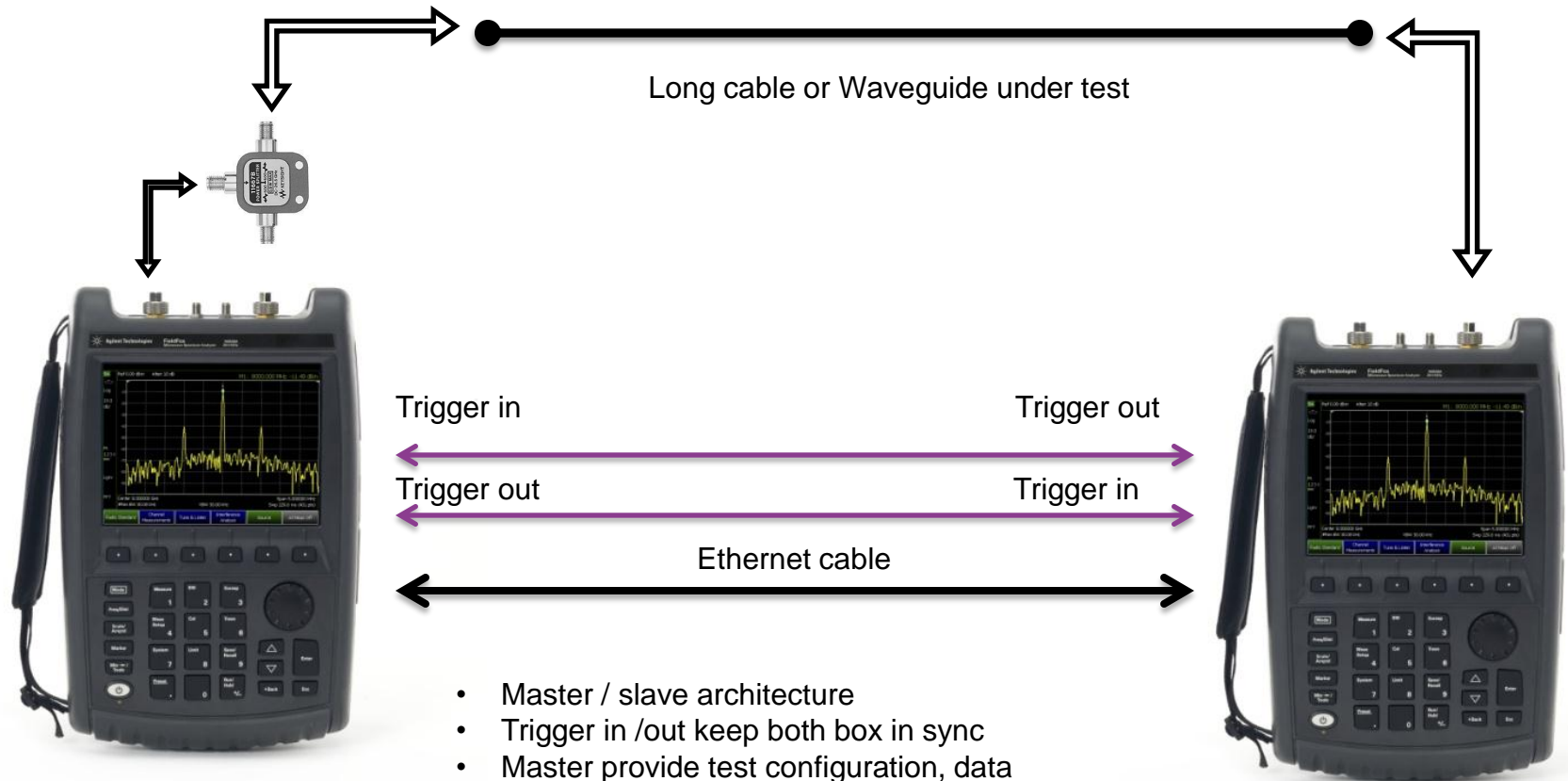
Source – Receiver 'Transmission' Loss Measurement



Measurement techniques	Typical loss value	Cable length / installation method	Accuracy / comments
One FFox is Source, other FFox is Receiver with InstAlign technique, 'ERTA' Extended Range Transmission Analysis	60 to 100+dB (or even higher) with Pre-amp	100m+ Cable installed with access to other end of Cable or Waveguide	No Warm-up No OSLT Calibration req'd (Normalization only) x3 to x10 faster than Power Sensor Loss measurement +/-0.5dB (-10 to +55°C)

Long Cable Loss Measurements (Option-209)

ERTA Measurement setup



Slave / source

Master / receiver

- Master / slave architecture
- Trigger in /out keep both box in sync
- Master provide test configuration, data transfer and final measurement presentation
- Each box can be locked with GPS timing to get better dynamic range and stability.
- Test / jumper cable loss can be measured using VNA and recalled as cable loss in ERTA mode

Overview of Cable Loss Measurement Techniques

Measurement technique	Dynamic Range	Accuracy	Calibration	Comments
2 Port 'Transmission' Loss measurement	Best	Best	Yes, mandatory 2-Port Cal (all systematic errors removed)	Access to both ends of Cable mandatory
1-Port 'Reflection' Loss measurement	Good - Poor	Good	Yes, mandatory 1-Port Cal (3 systematic errors removed)	Access to only one end of Cable
Power Sensor Loss measurement	Good	Good - Poor	Yes mandatory Normalization that removes only tracking (freq. response) errors	Access to both ends of Cable mandatory Results dependent on PS performance (dynamic range, settling time, etc..)
Source – Receiver Loss measurement Extended Range Transmission Analysis (ERTA)	Best	Best	Yes Normalization req'd	Access to both ends of Cable mandatory +/-0.5dB accuracy x3 to x10 faster than Power Sensor method

Agenda

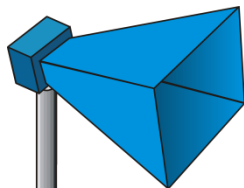
Techniques for precise cable and antenna measurements in the field

- Introduction Keysight Technologies
- FieldFox Introduction
- Antenna Measurements
- Cable Loss Measurements
- **Cable Fault Measurements**



Loss Measurements + CAT Distance-to-Fault (DTF)

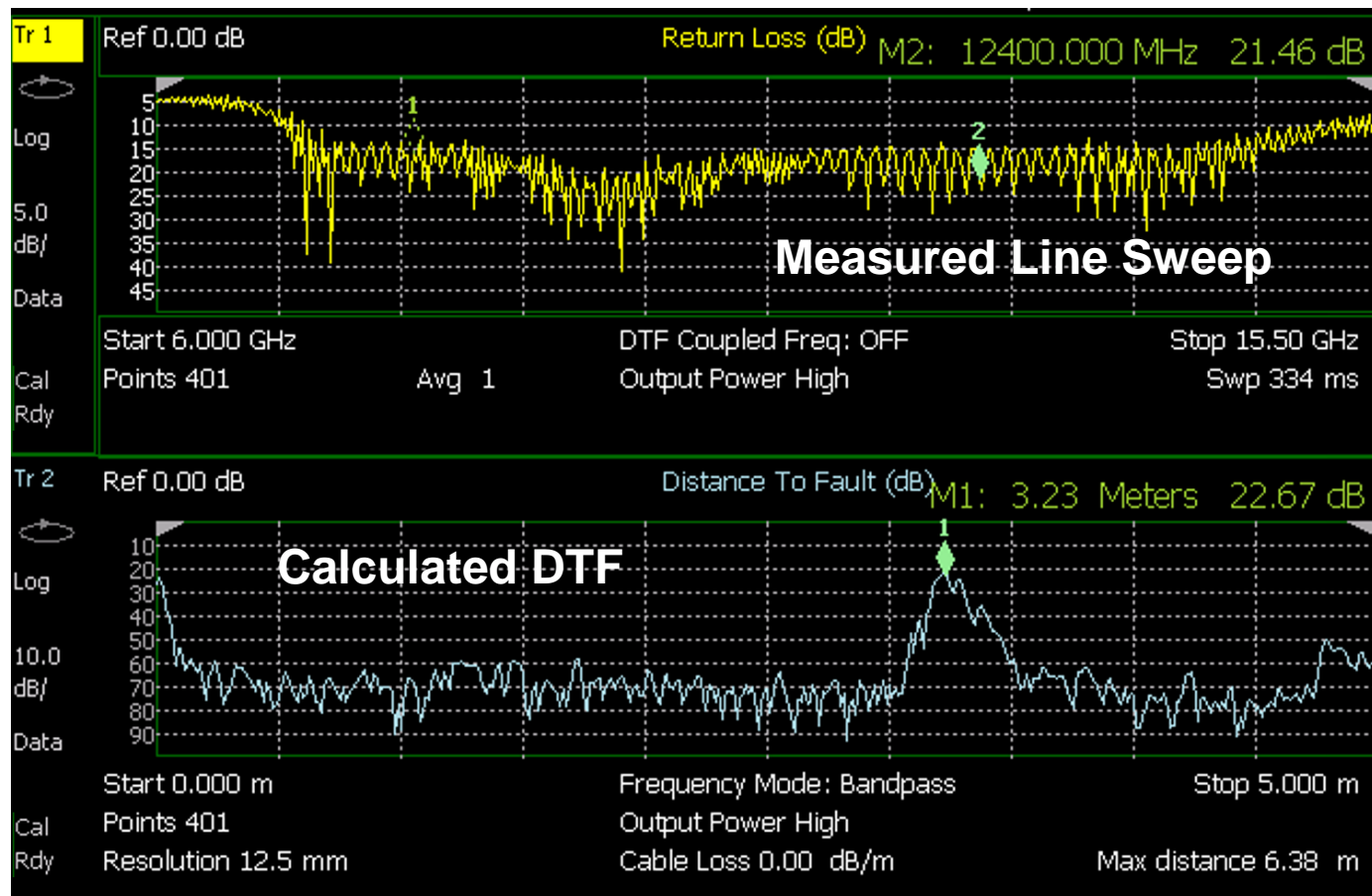
X-Band Horn
Antenna



Coaxial
Cable



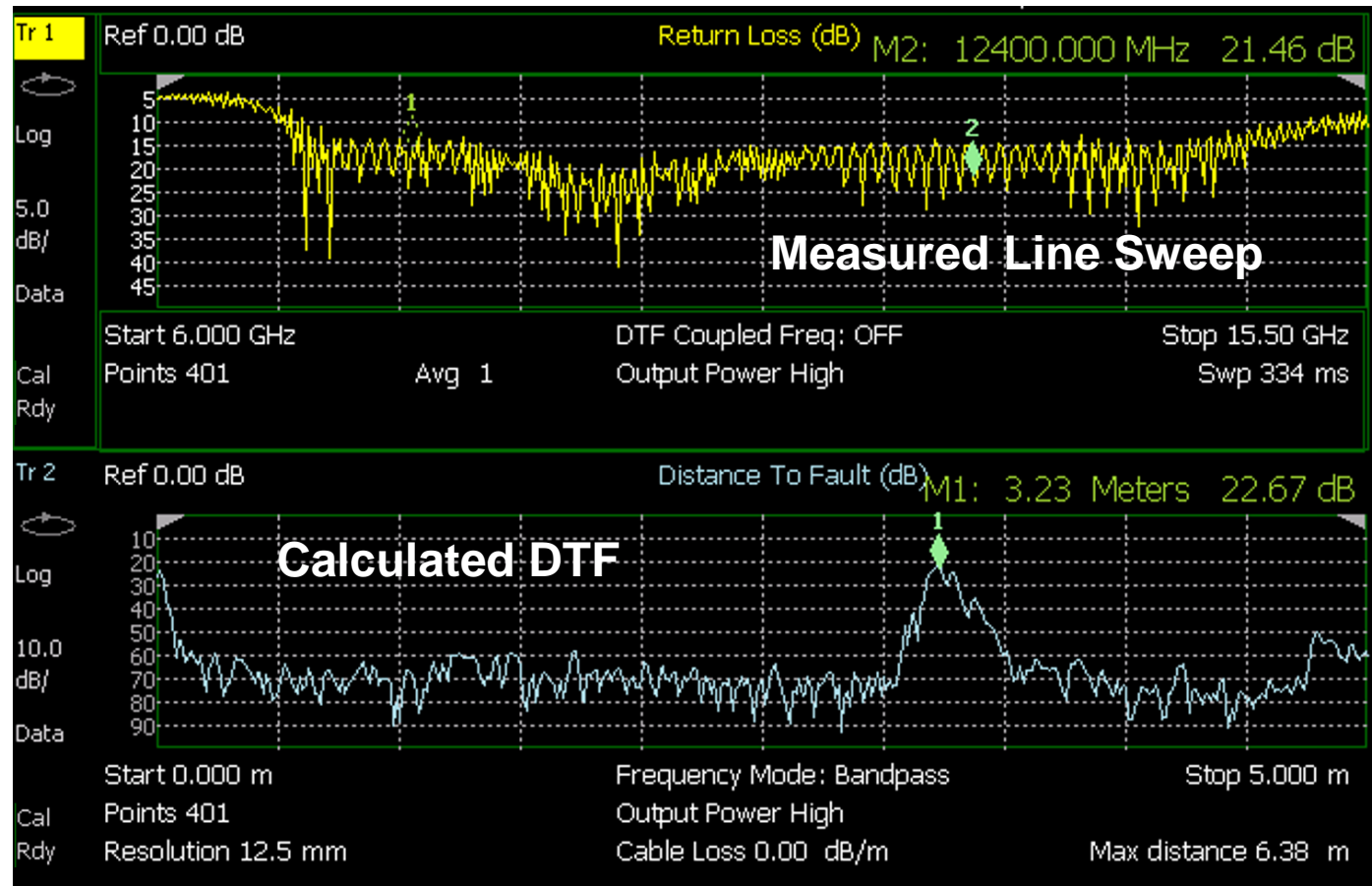
FieldFox
N9918A



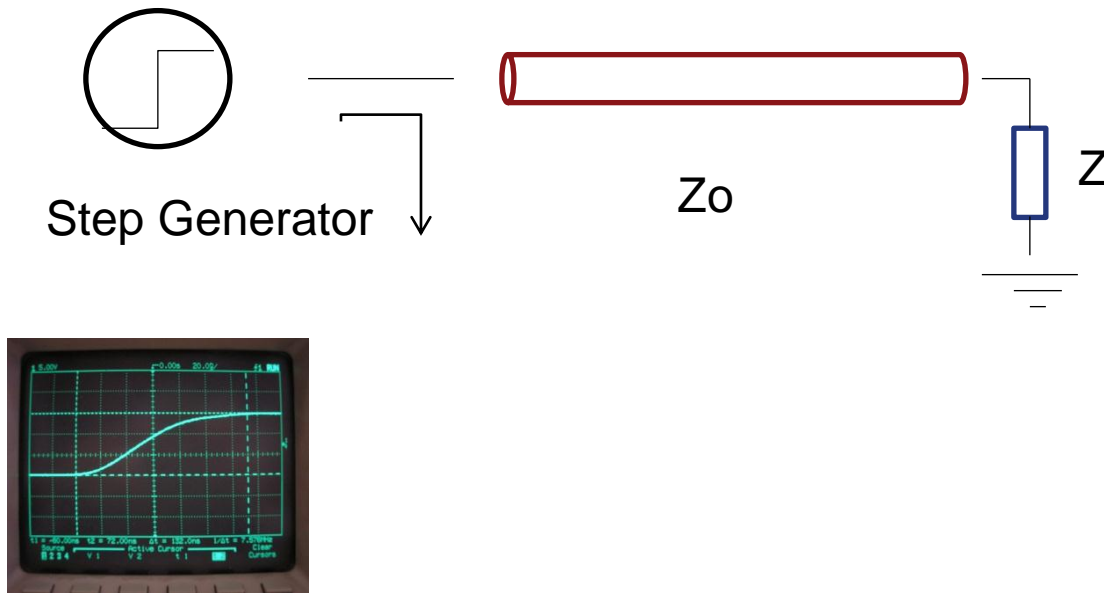
Demonstration: CAT Distance-to-Fault (DTF)



**FieldFox
N9918A**



New: Time Domain Reflectometry TDR (#215)



scope

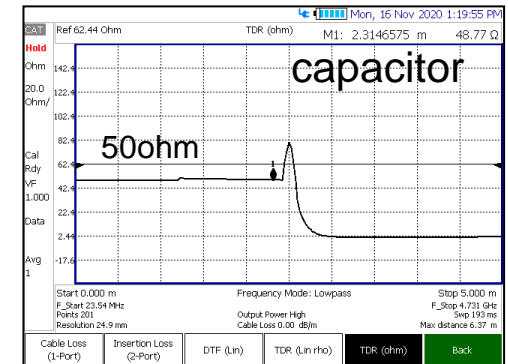
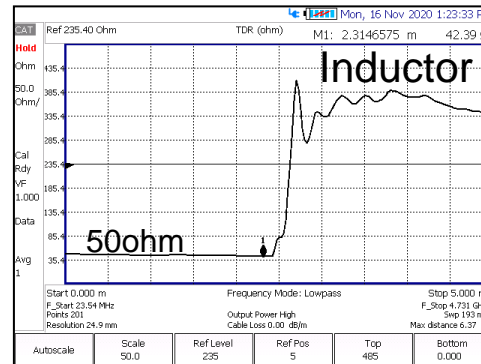
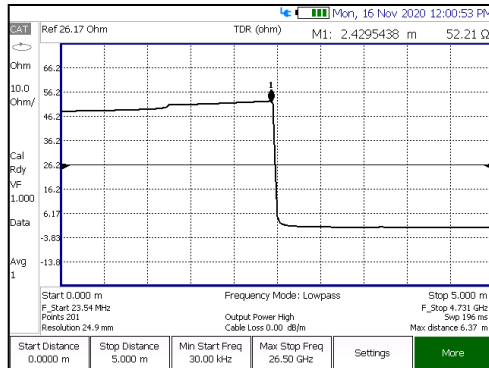
Legacy instruments operation:

- Generator injects a fast edge step signal into cable under test
- Scope records both injected and reflected signal.
- System rise determines the instrument resolution

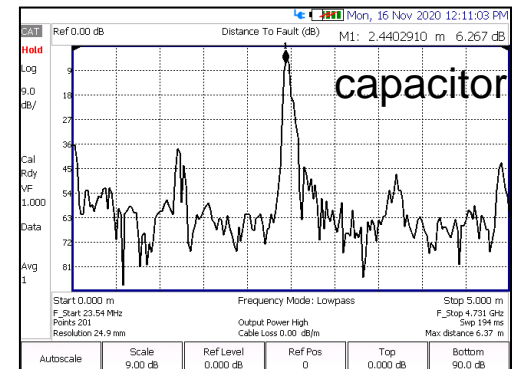
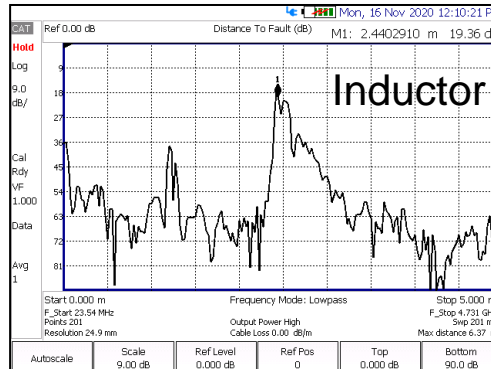
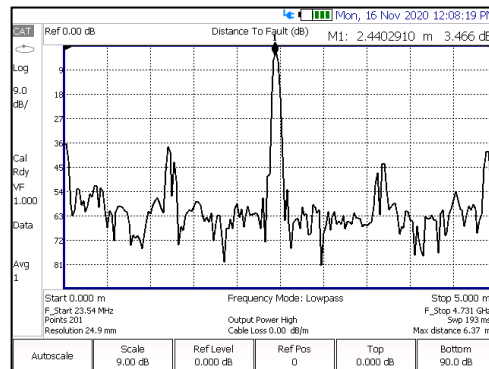
TDR: more “impedance” info on than CAT/FDR

TDR indicates “Impedance Type”: Inductive or Capacitive

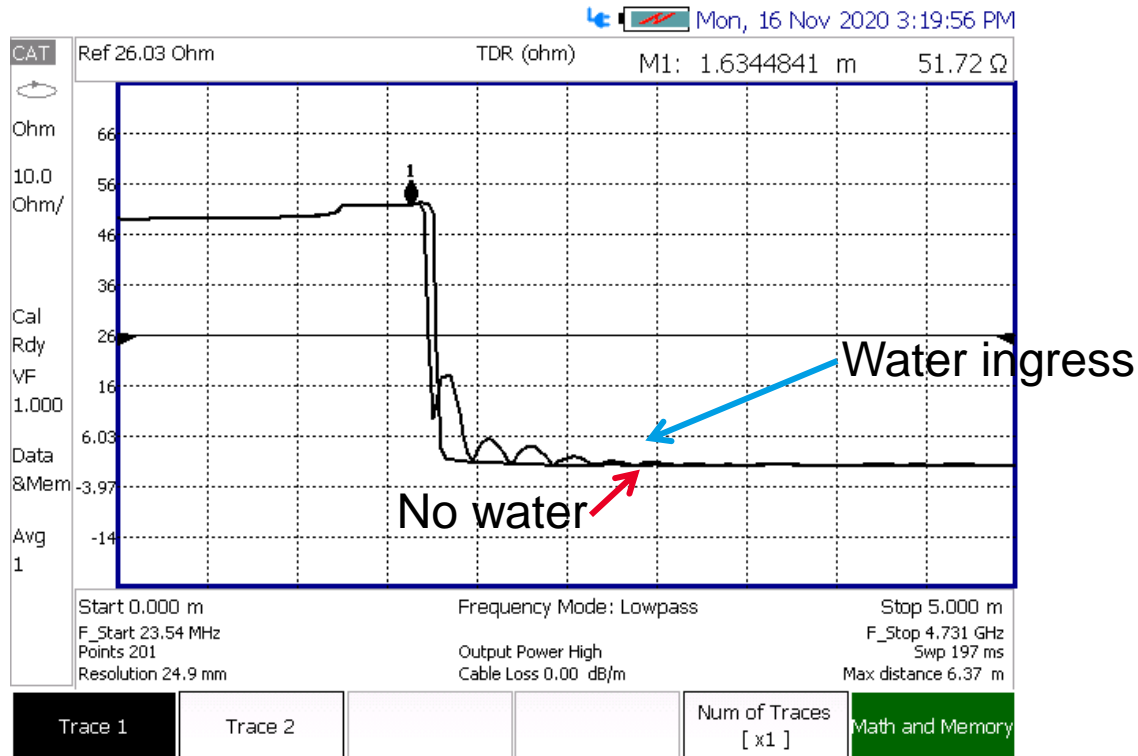
TDR



FDR



Water in transmission line using TDR

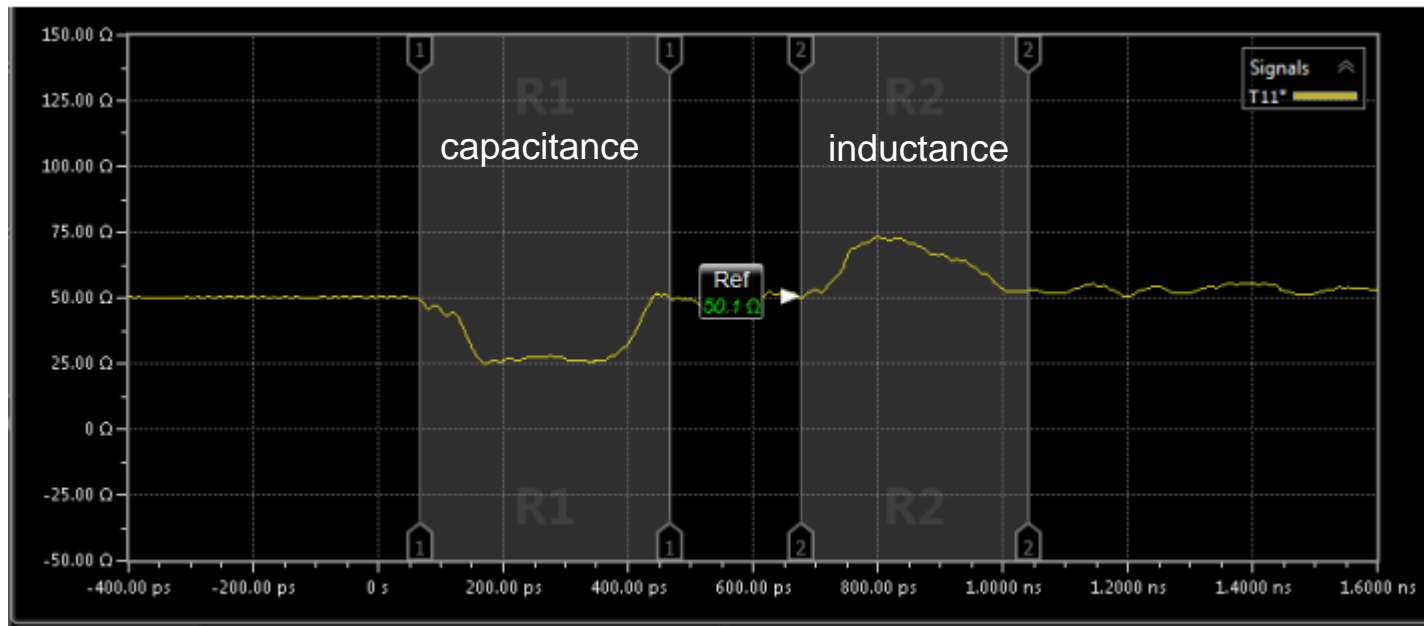


Provides information on faults detected by DTF: open or short circuit, water ingress.

TDR trace on 86100D DCA-X TDR Lab Instrument

Capacitive vs inductive

TDR trace with parasitic capacitance and inductance

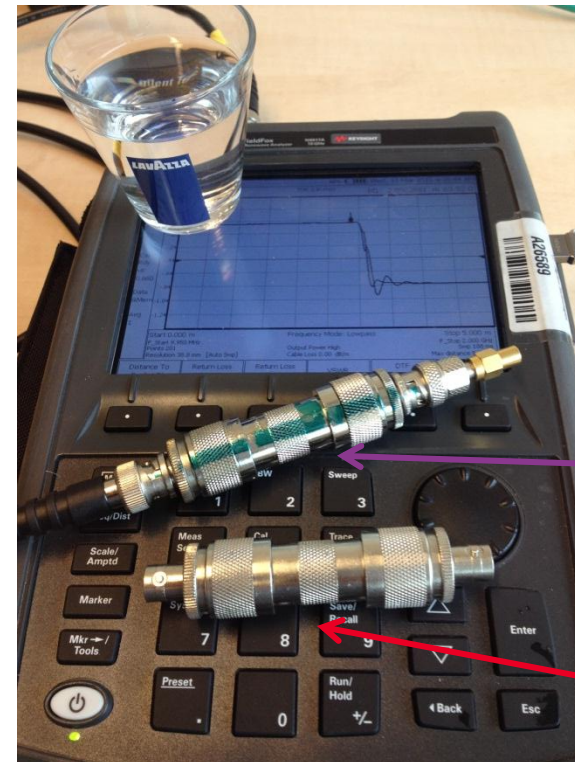


Shunt capacitance is negative going. Series inductance is positive going.

Demonstration: Water Poured in N-Type connector

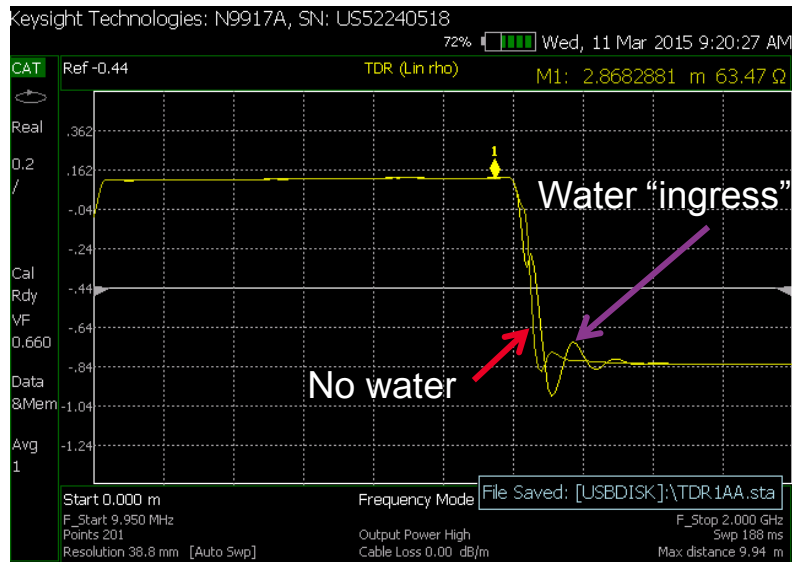
Demo Setup @ Keysight office Amsterdam

N-type connector + water: Capacitive or inductive?

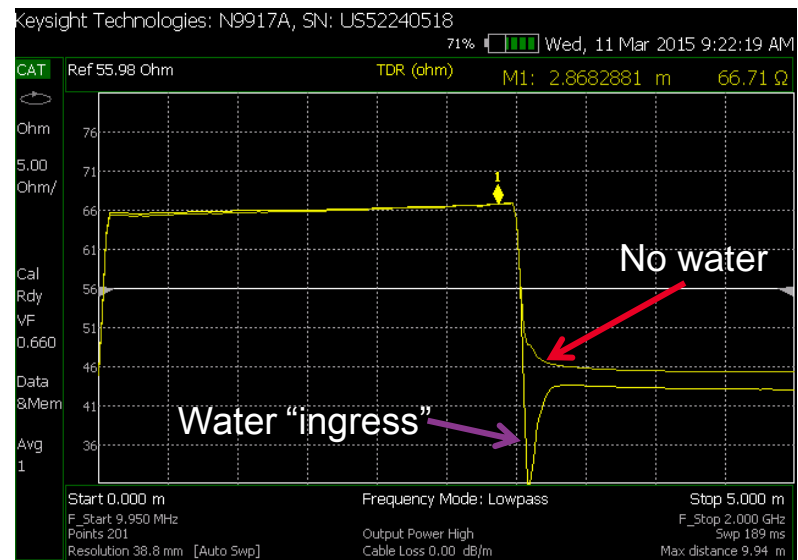


Demonstration: Water in N-Type connector

“N-type + water” vs “normal N-type” (no water)



Water ingress on FieldFox



Capacitive

Cable Test Reference Material

Web Page Cable Test : <http://www.keysight.com/find/fieldfox>

Application Note Cable Test : Precise Cable & Antenna Test in the Field
<http://literature.cdn.keysight.com/litweb/pdf/5991-0419EN.pdf>

YouTube Video Cable Test:

https://www.youtube.com/watch?v=ht_B_GMtG4I&list=PLWyOzUV26TwOXNHIL7Hb9Dnvti-LR5ZZy