# FieldFox Handheld Education Series Part 3: Calibration Techniques for Precise Field Measurements

**FieldFox Handheld Education Series**

- Interference Testing
- Cable and Antenna Measurements
- Calibration Techniques
- Time Domain Measurements
- Precise Power Measurements

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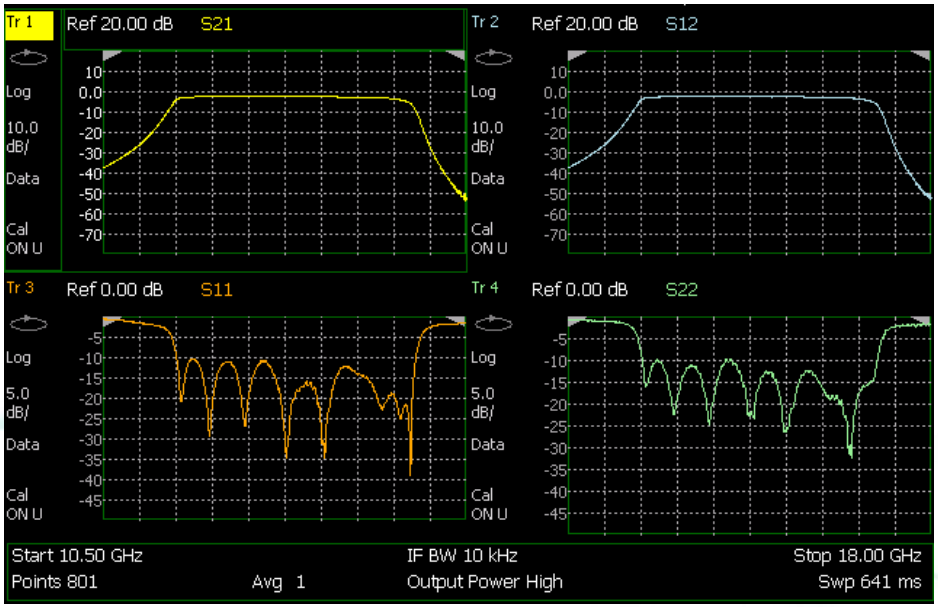
# Calibration Techniques for Precise Field Measurements



# Outline

- FieldFox VNA and CAT modes
- T/R and S-Parameter Test Sets
- Systematic Errors
- User Calibration Types
  - CalReady
  - QuickCal
  - Mechanical
- Advanced Topics
- Guided Calibration

*Image courtesy of John Arthur, Wireless EDGE*

# FieldFox Modes and Measurement Parameters

Vector Network Analyzer (VNA)

- S-parameters: S11, S21, S12, S22
- Time Domain

30 kHz to 26.5 GHz

Combination Analyzer

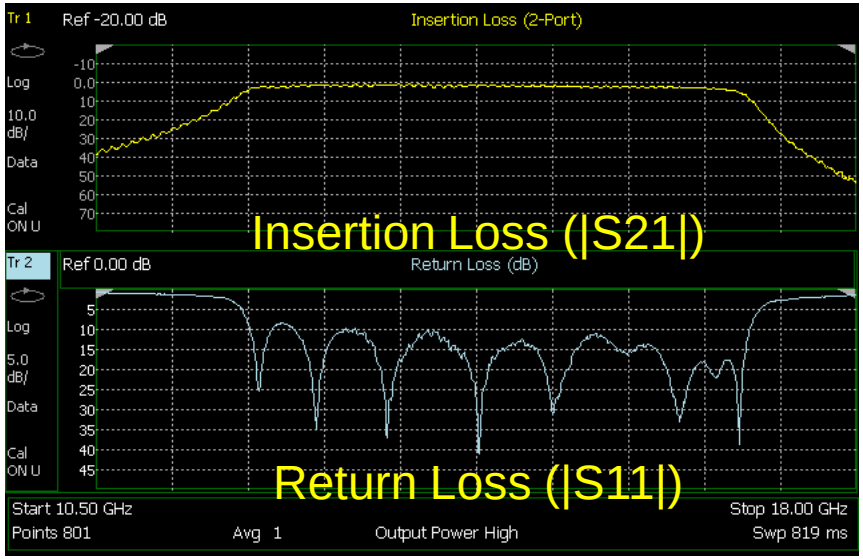
Cable and Antenna Test (CAT) Analyzer

- Return Loss and VSWR
- Insertion Loss
- Distance to Fault (Time Domain)

*Calibration techniques are the same for both modes*

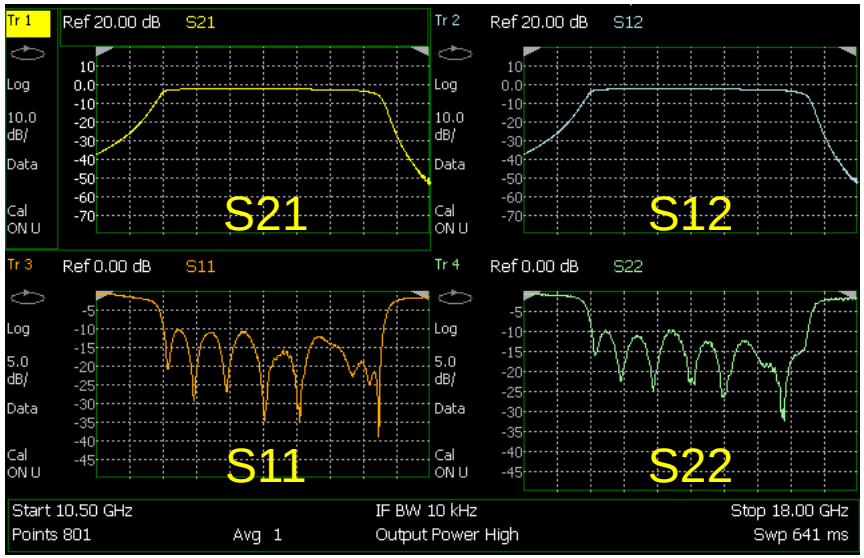
# CAT and VNA Display Comparison

## CAT Mode



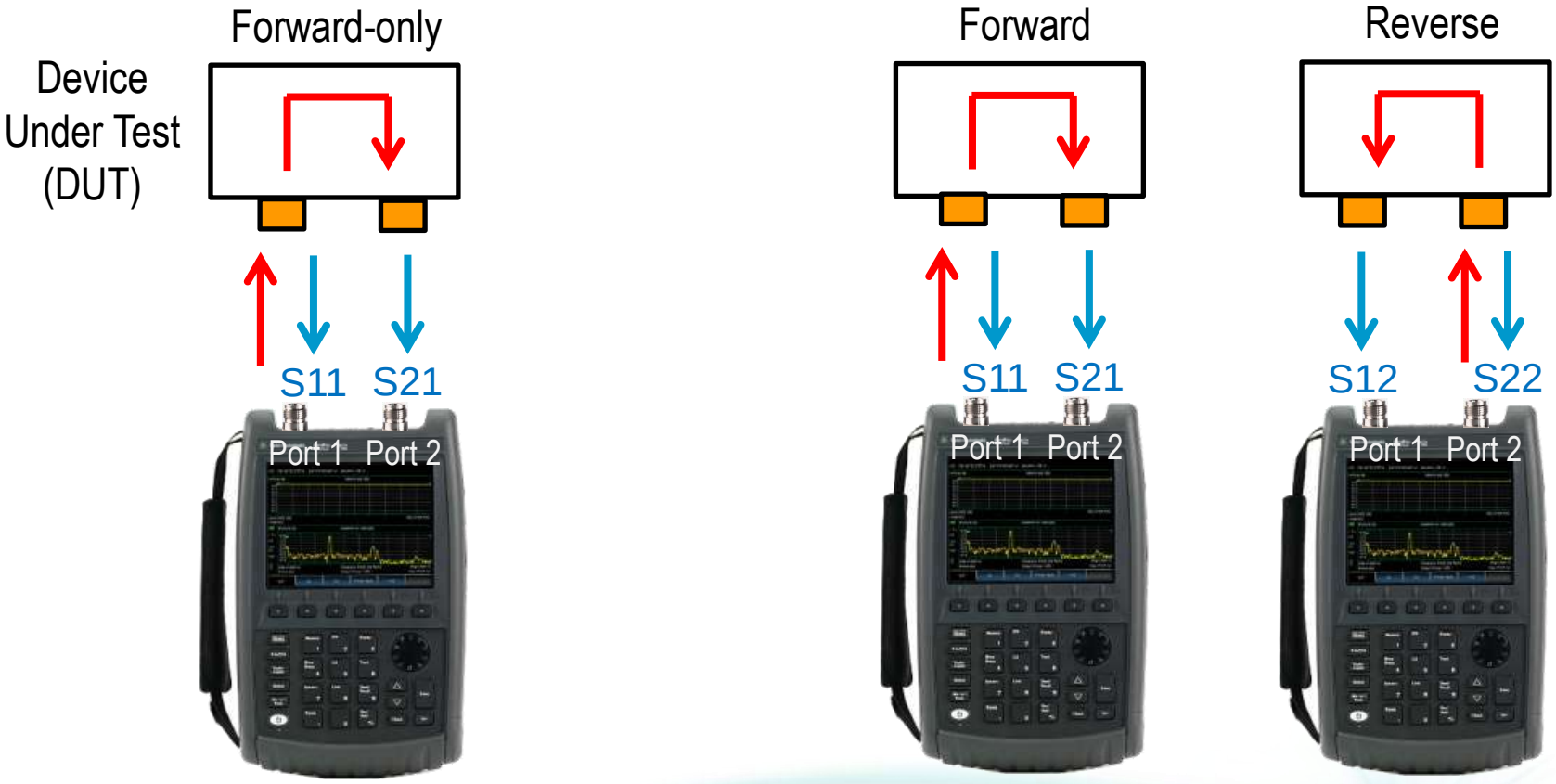

- Magnitude
- Reduced Error Correction
- CAT also includes 1-port Insertion Loss

## Full 2-port VNA Mode




- Magnitude and Phase
- Full 2-Port Error Correction Capability
- S-parameter and T/R Hardware Options

# Forward and Reverse Measurement Capability

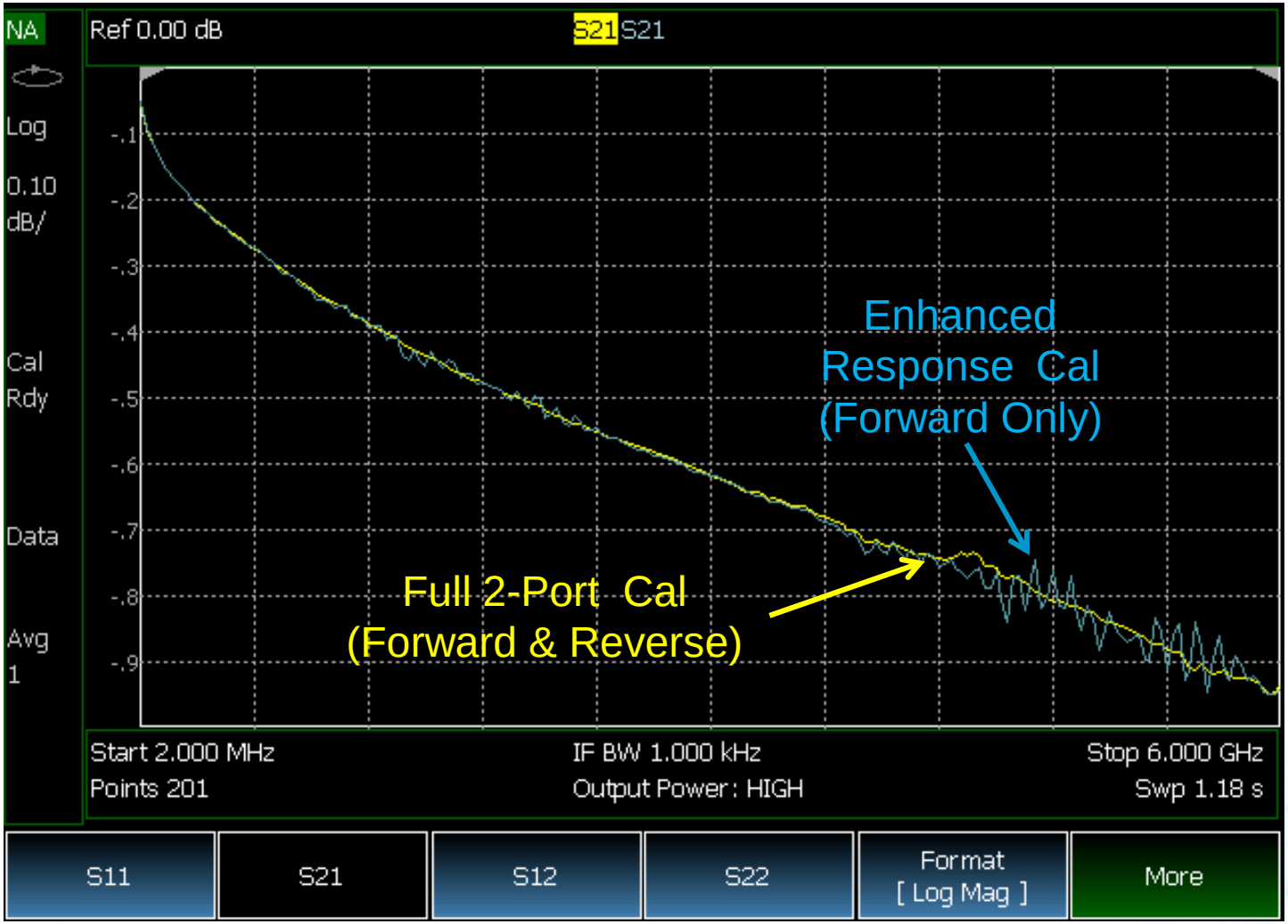



Transmission / Reflection, (T/R)

Full 2-Port S-parameter Configuration

*Improved measurement accuracy with Forward and Reverse capability*

# Measurement Comparison: Full 2-Port and Forward Only




Full 2-port calibration types correct for all systematic errors

# FieldFox Calibration Requirements

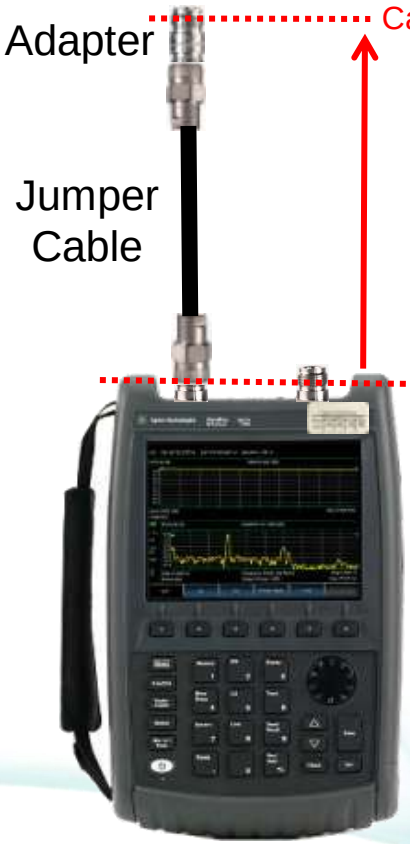
## Factory Calibration


Certificate of Calibration

*Re-calibration recommended 12 to18 months*

"CalReady" Error Coefficients Stored Internally

## User Calibration

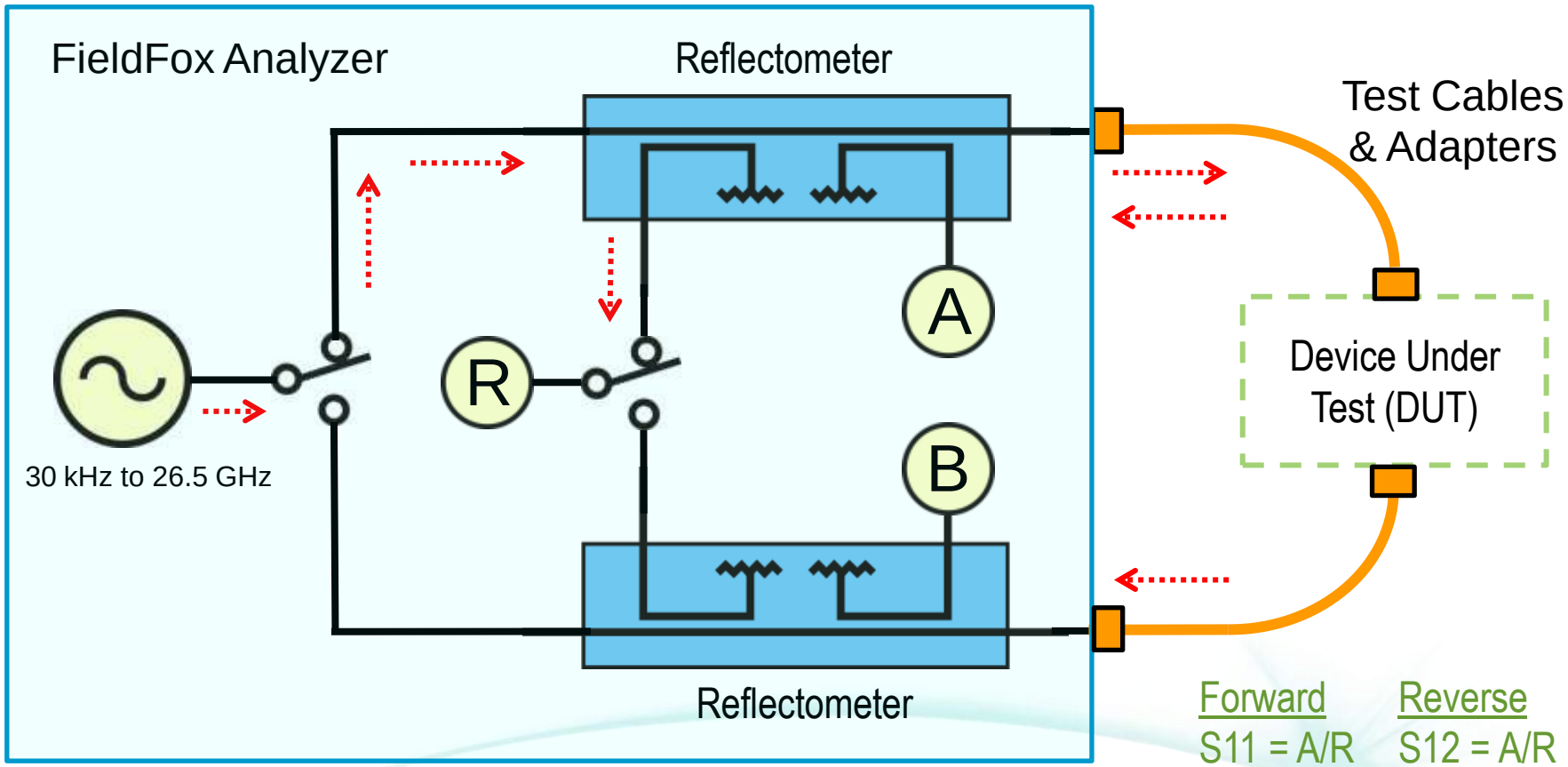



*Removes systematic errors*

*Frequent User Calibration*

# Sources of Systematic Errors

*Simplified Hardware Configuration*




Forward
S11 = A/R
S21 = B/R

Reverse
S12 = A/R
S22 = B/R

User Calibration
- Tracking Errors
- Mismatch Errors
- Directivity Errors

Other
- Random Errors
- Drift Errors

# User Calibration in the Field

## *Simple*

- No cal kit required
- Rapid calibration
- Full 2-port cal (at test ports)
- Compensate for cables & adapters

Cal Types

CalReady
QuickCal
Normalization

## *Advanced*

Calibration kit

- Requires cal kit
- Measure cal standards
- Full 2-port cal (all configurations)

Cal Types

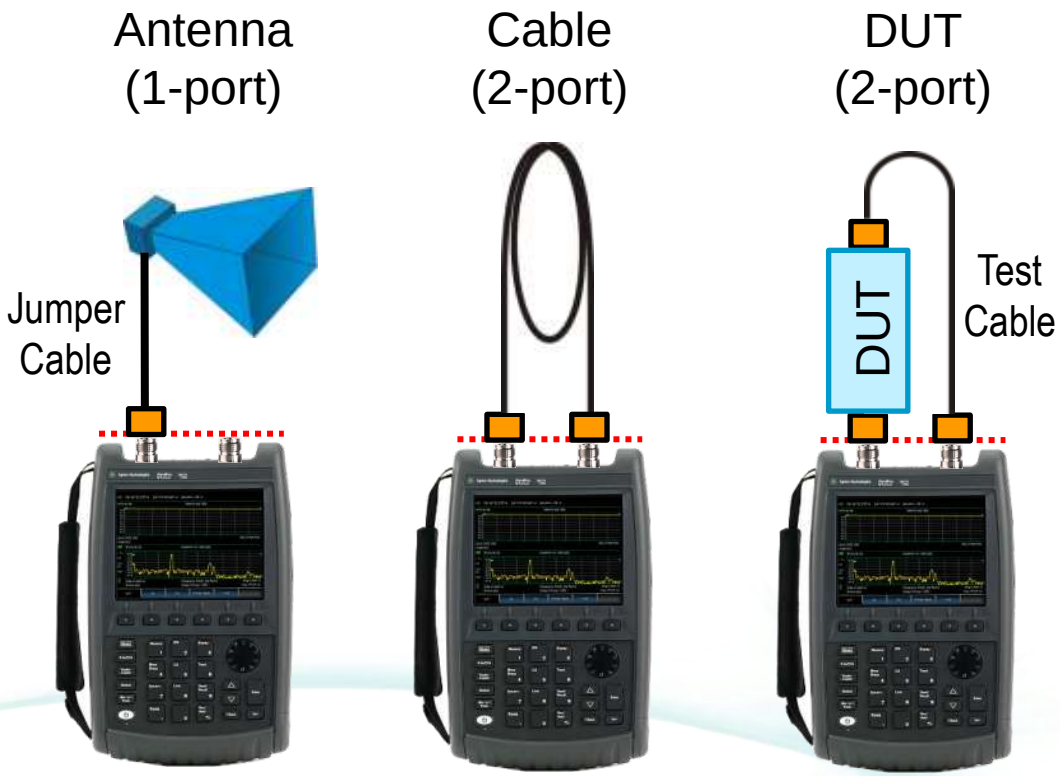
1-Port OSL
Full 2-port, SOLT
Full 2-Port, QSOLT
Enhanced Response

# CalReady

## Calibration

- Built-in
- Full 2-port Cal


## Test



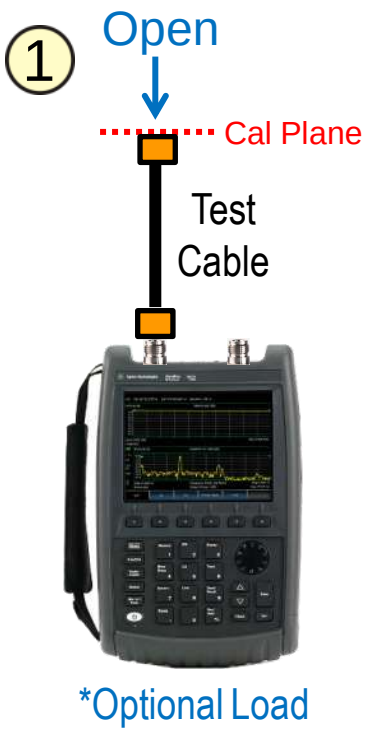

*Full 2-port error correction at FieldFox test ports*

# QuickCal

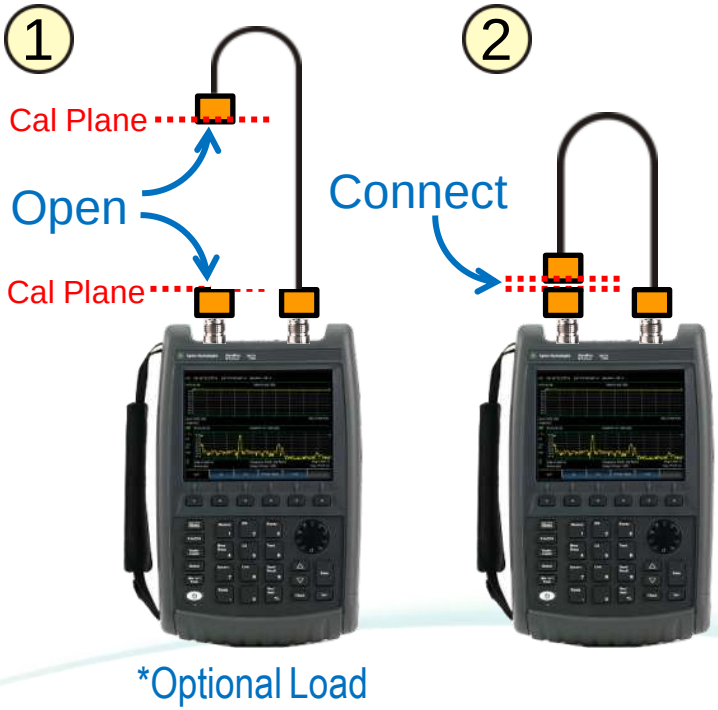
## Calibration

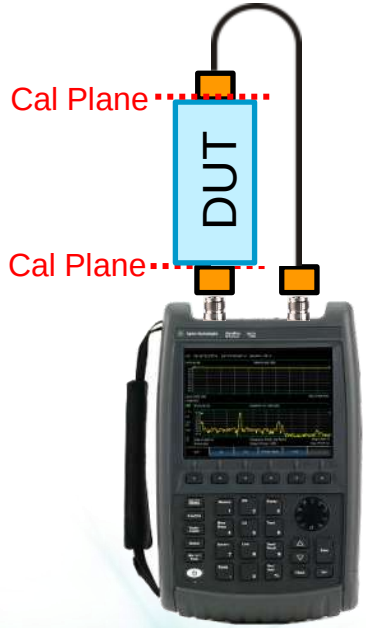
## Test

### 1-Port Quick Cal



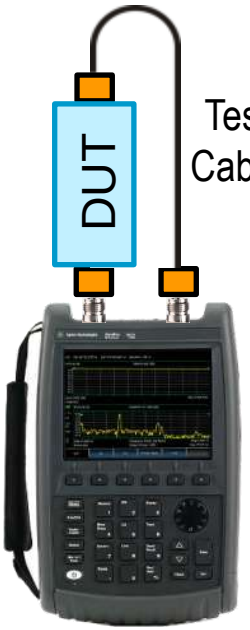

### 2-Port Quick Cal



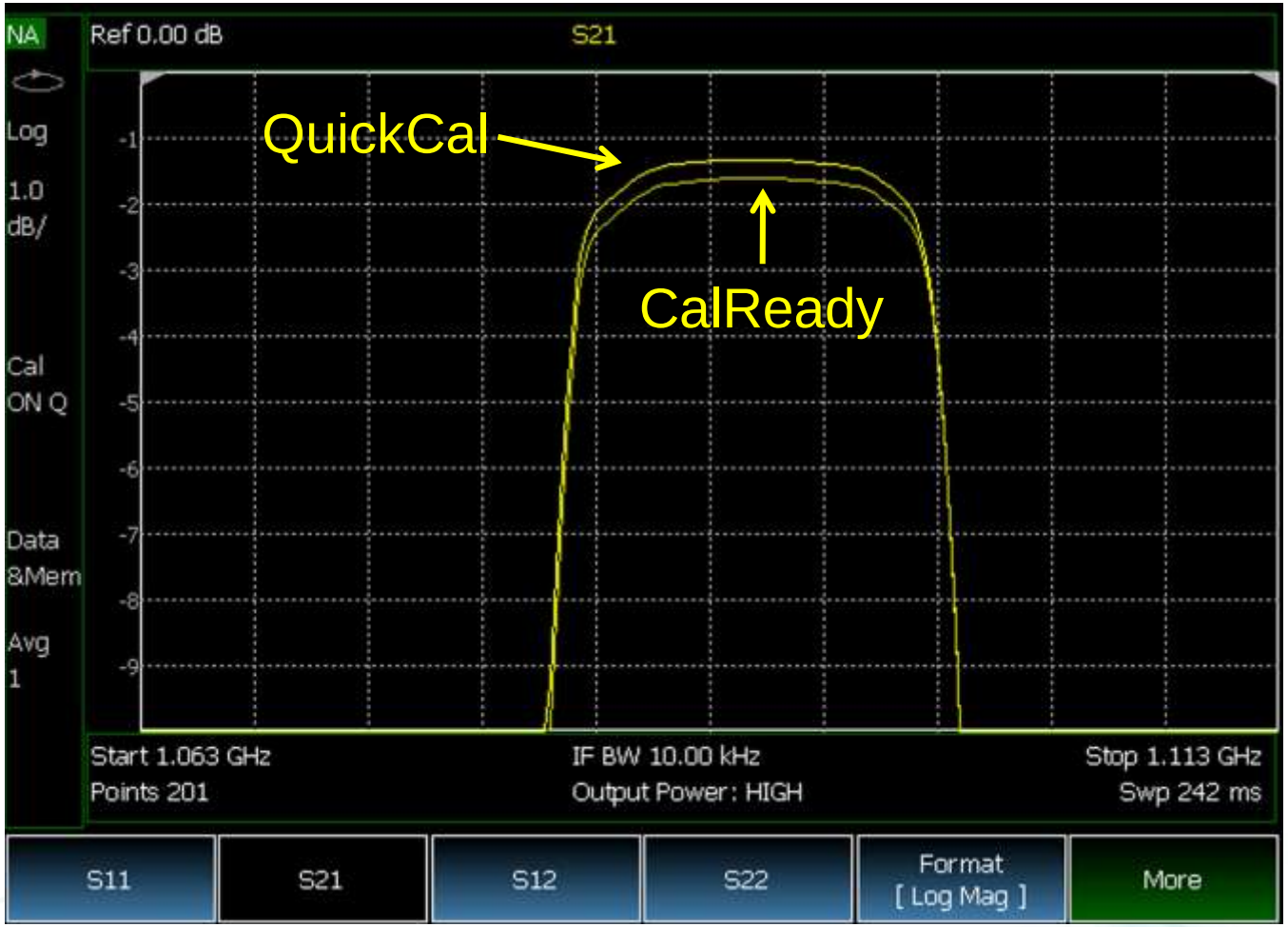




*Full 2-port error correction with cable and adapter compensation*

# Measurement Comparison: Rapid Calibration Types




DUT = Filter




*QuickCal compensates for test cables and adapters*

# Normalization & Response Calibration Types

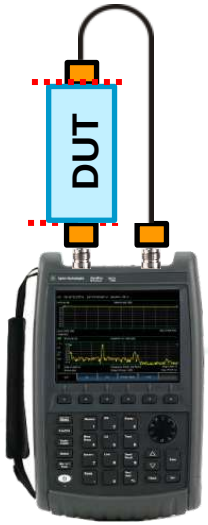
Calibration (Normalization)

Thru

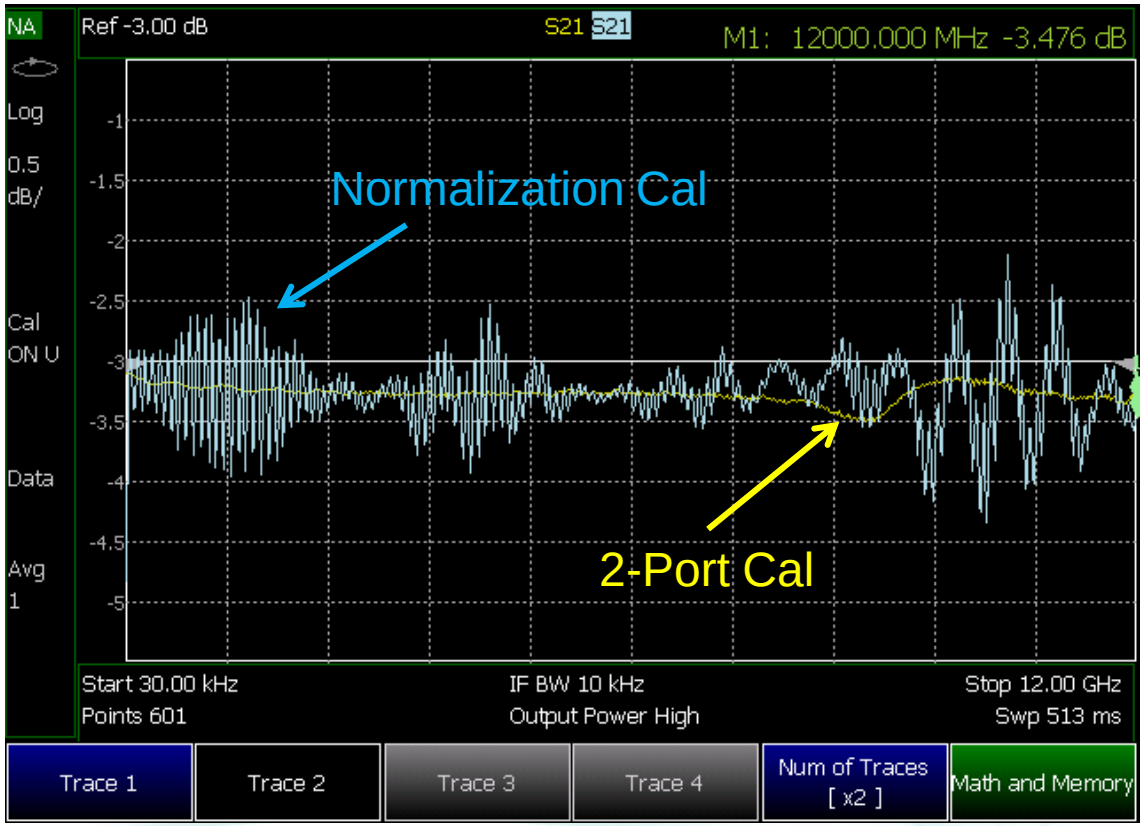
*Store measurement sweep*

Test

*Displays Test / Memory*

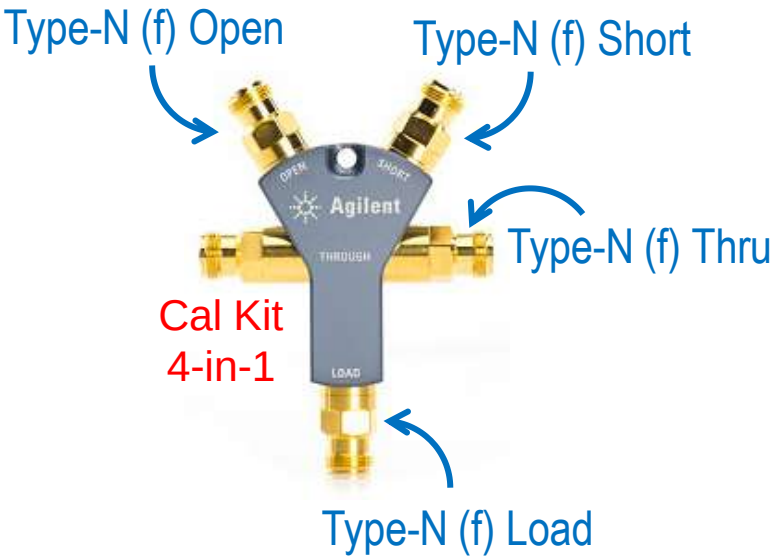



Measurement Comparison of a 3-dB Attenuator




- *Normalization* stores “Thru” sweep to memory
- Better to use *CalReady* or *QuickCal*

# Mechanical Calibrations




## 1-Port Calibration

Calibration Standards (OSL)
- Open
- Short
- Load

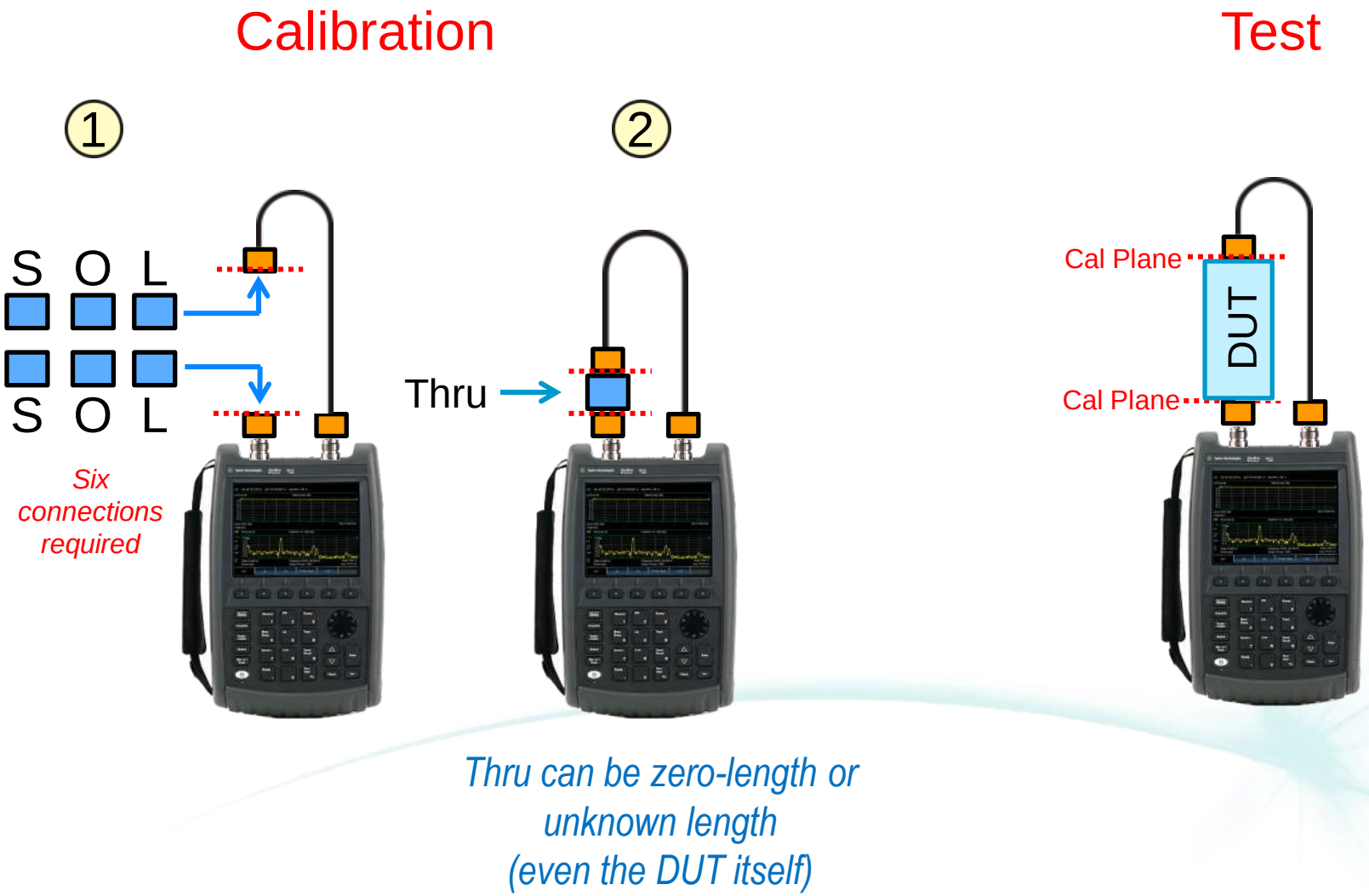
## 2-Port Calibration

Calibration Standards (SOLT)
- Short
- Open
- Load
- Thru

Cal Standards should match DUT ports

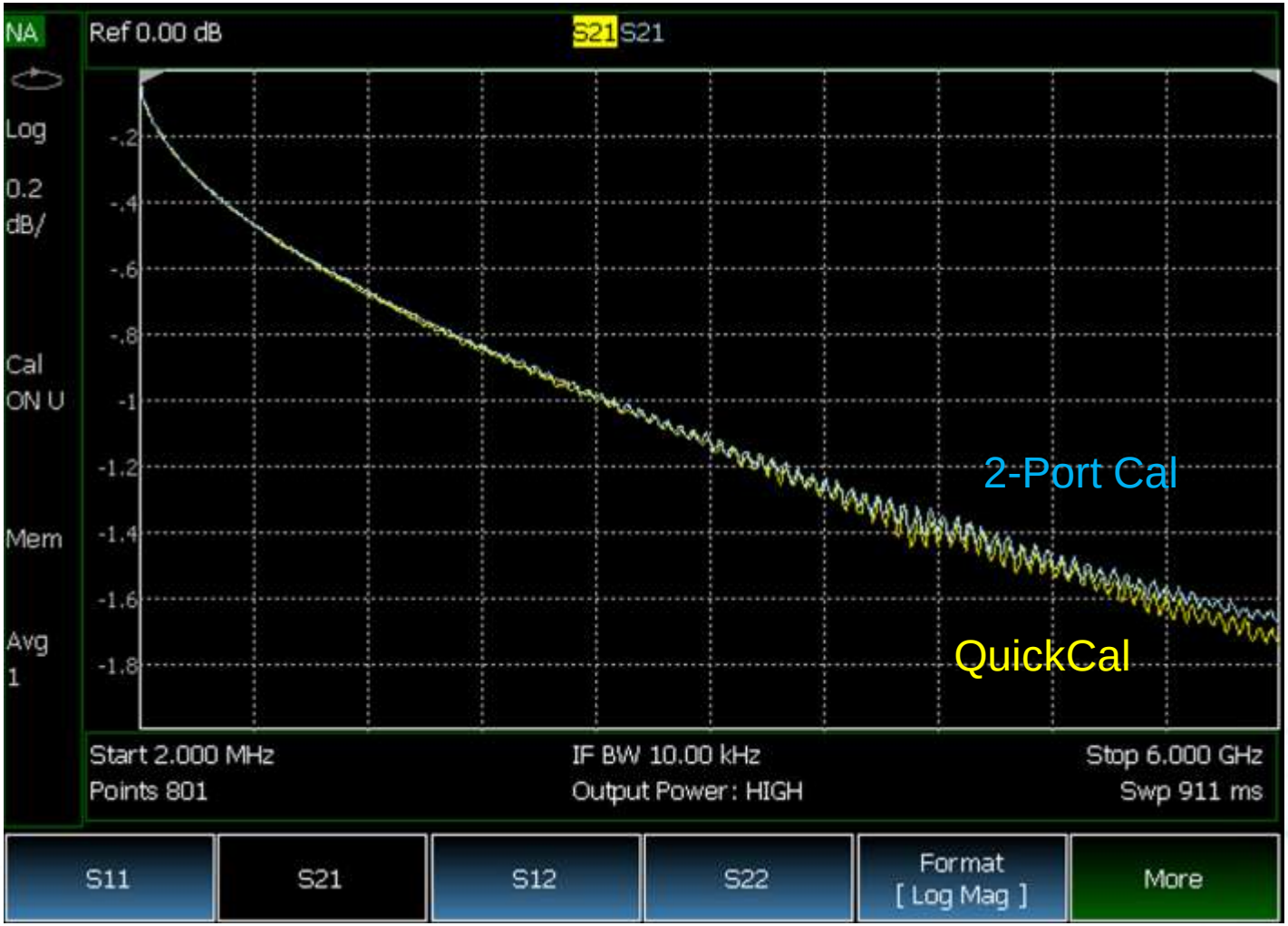

*Mechanical calibrations provide the highest level of measurement accuracy*

# Mechanical Calibration: Full 2-port (Forward & Reverse)



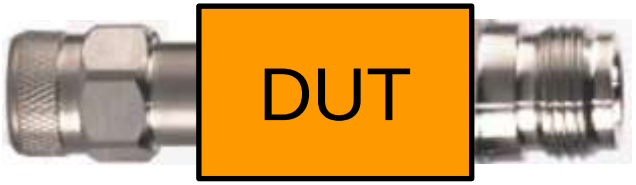
# Comparing QuickCal and Mechanical Calibrations

Measurement of a Coaxial Cable



# Advanced Concepts : Insertable and Non-Insertable DUTs

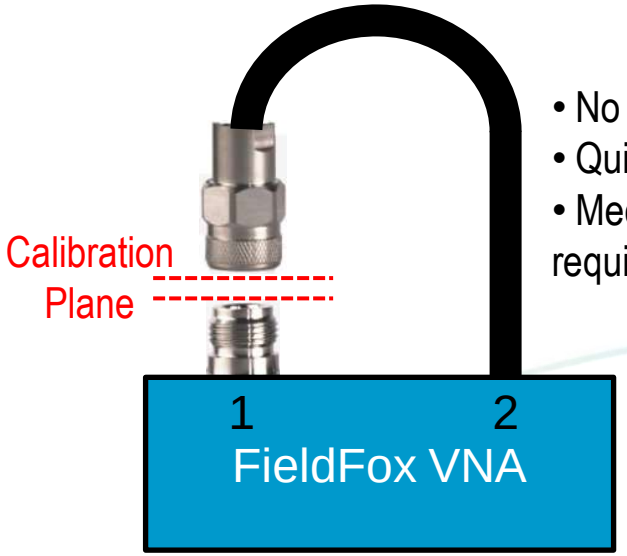
## Insertable




- *Same connector type*
- *Different gender*

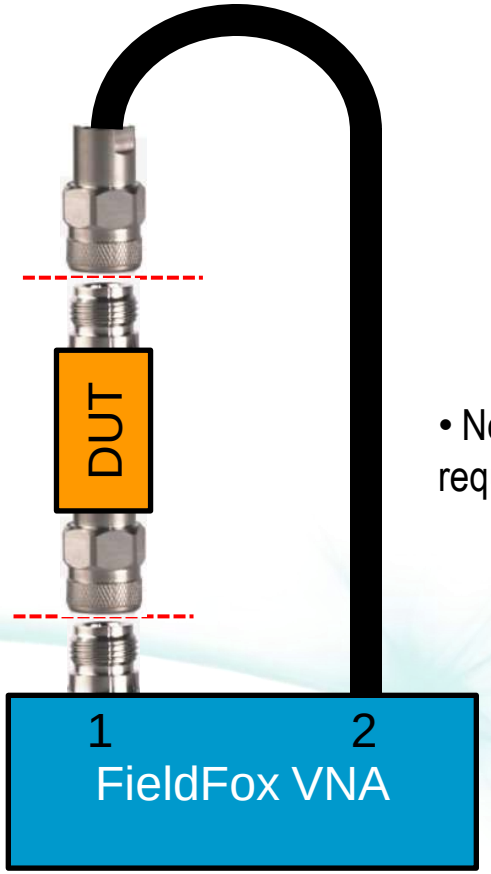
## Calibration

- No “Thru” adapter required
- QuickCal easy to implement
- Mechanical Cal; (m) & (f) kits required



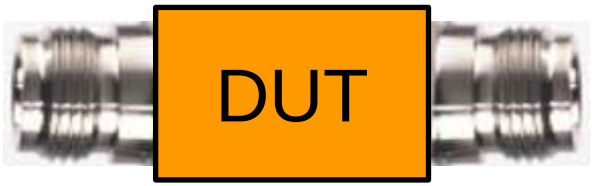

## Test

- No adapter(s) required



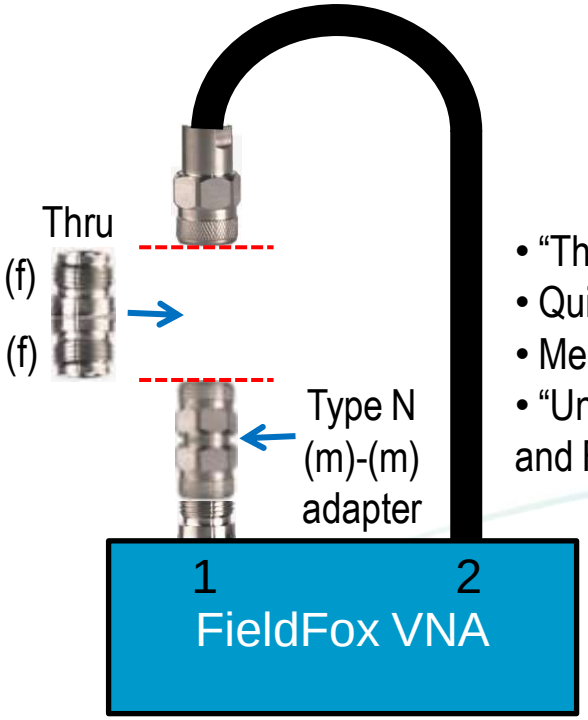
# Advanced Concepts : Insertable and Non-Insertable DUTs

## Non-Insertable




Type-N (f) Type-N (f)

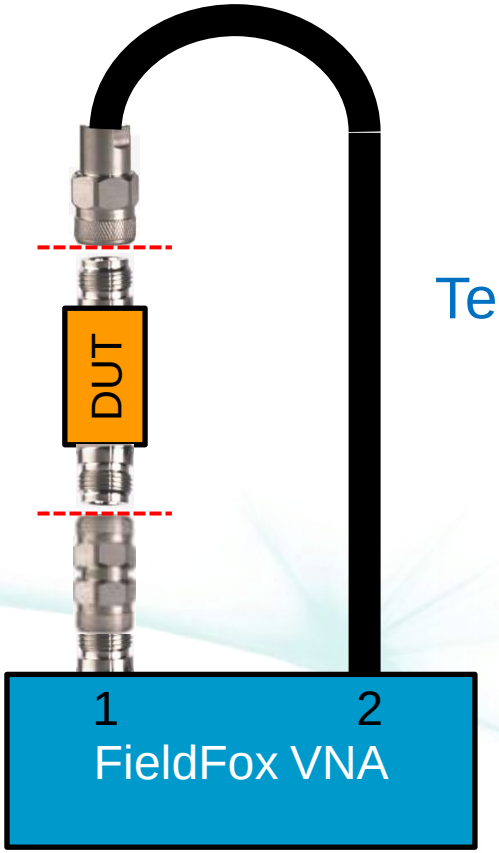
- *Same connector type and gender*
- *Different connector types*




## Calibration

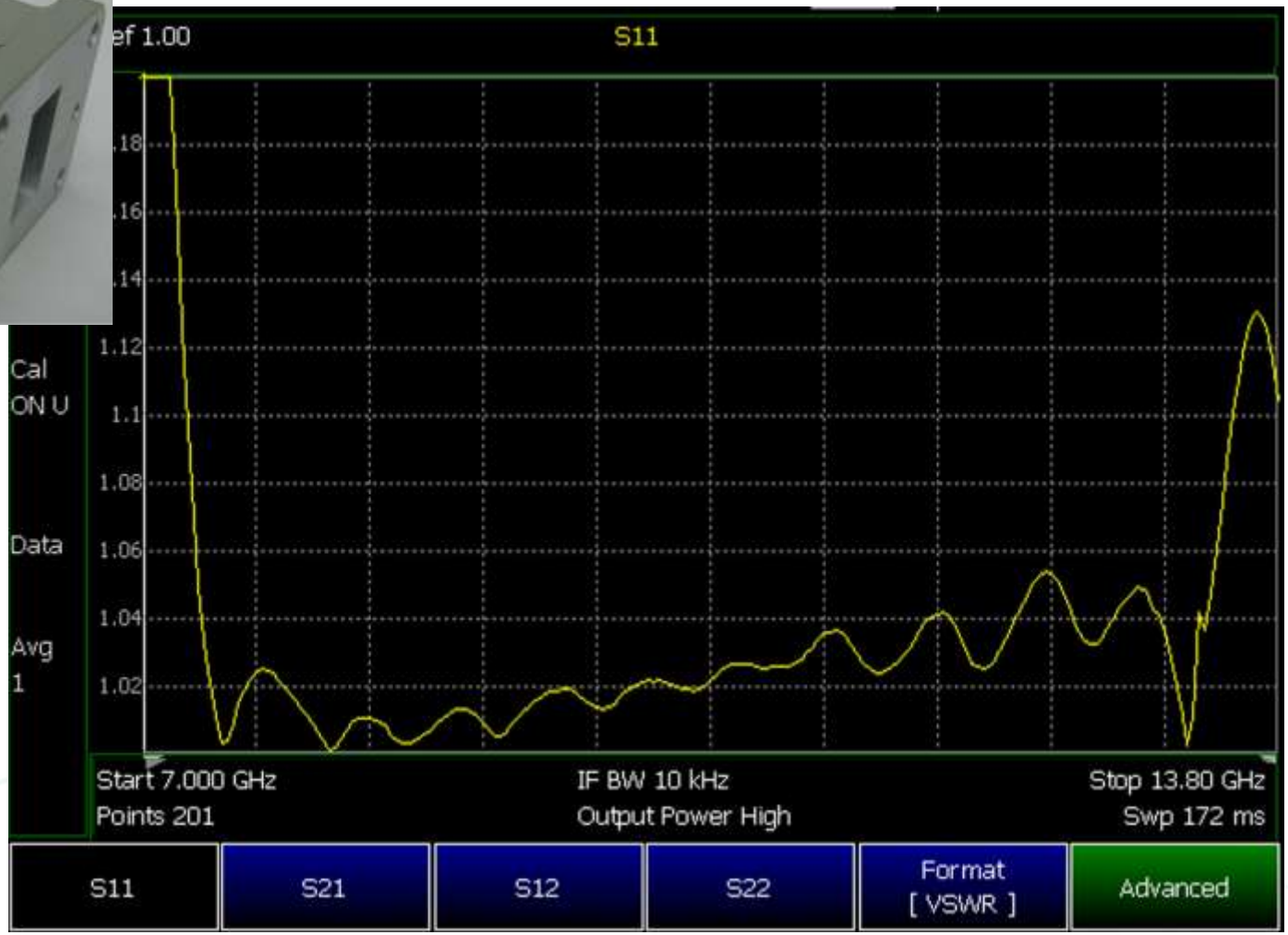
- "Thru" adapter matches DUT
- QuickCal easy to implement
- Mechanical Cal; (f) kit required here
- "Unknown Thru" available in QuickCal and Full 2-Port cal types.

## Test

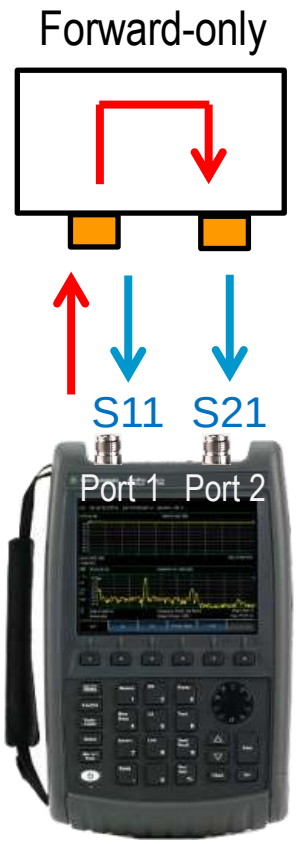


# Non-Insertable DUT Measurements


X-Band Waveguide-to-Coax Adapter



# Calibration Types for T/R Test Sets

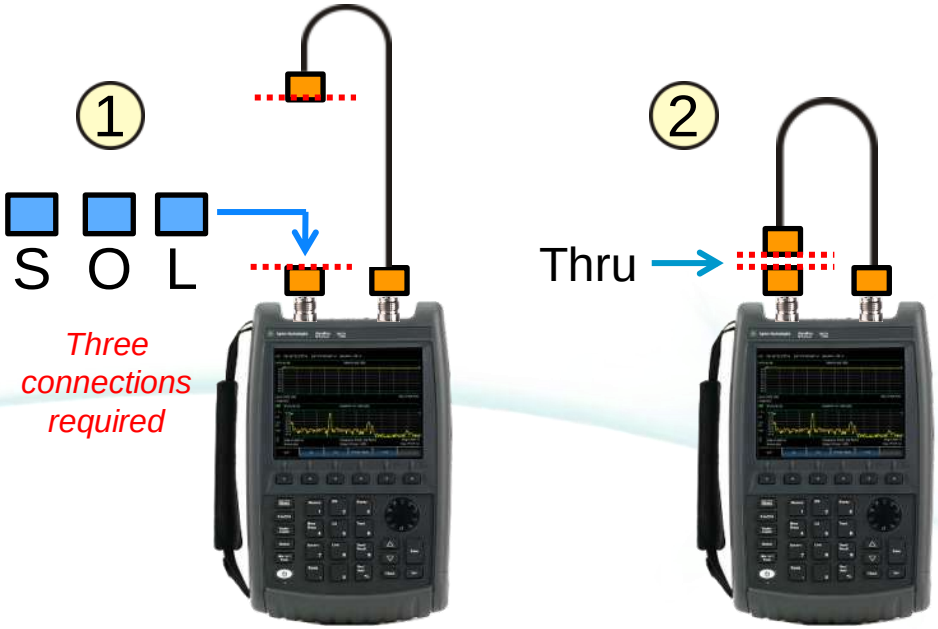



FieldFox with T/R

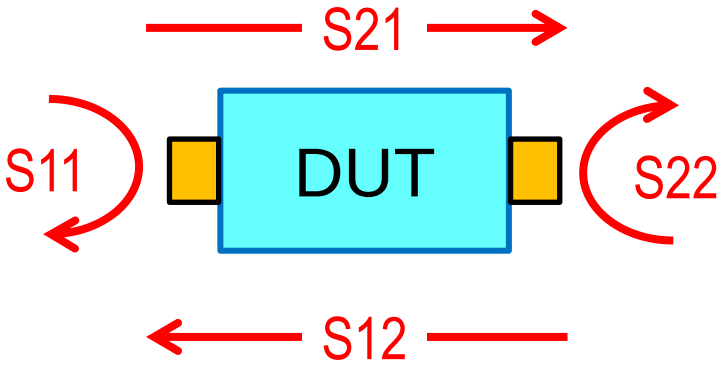
## T/R Cal Types

- Normalization/Response
- OSL (1-port)
- CalReady (Enhanced Response)
- QuickCal (Enhanced Response)
- Mechanical Enhanced Response

## Enhanced Response Cal Procedure



# Advanced Topics: Reciprocal and Non-Reciprocal DUTs




## Reciprocal

S21 = S12

Examples:

- Cables
- Filters
- Couplers
- Attenuators

*Use Reciprocal Enhanced Response Cal*

## Non-Reciprocal

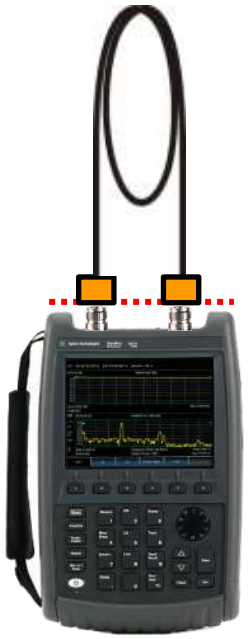
S21 ≠ S12

Examples:

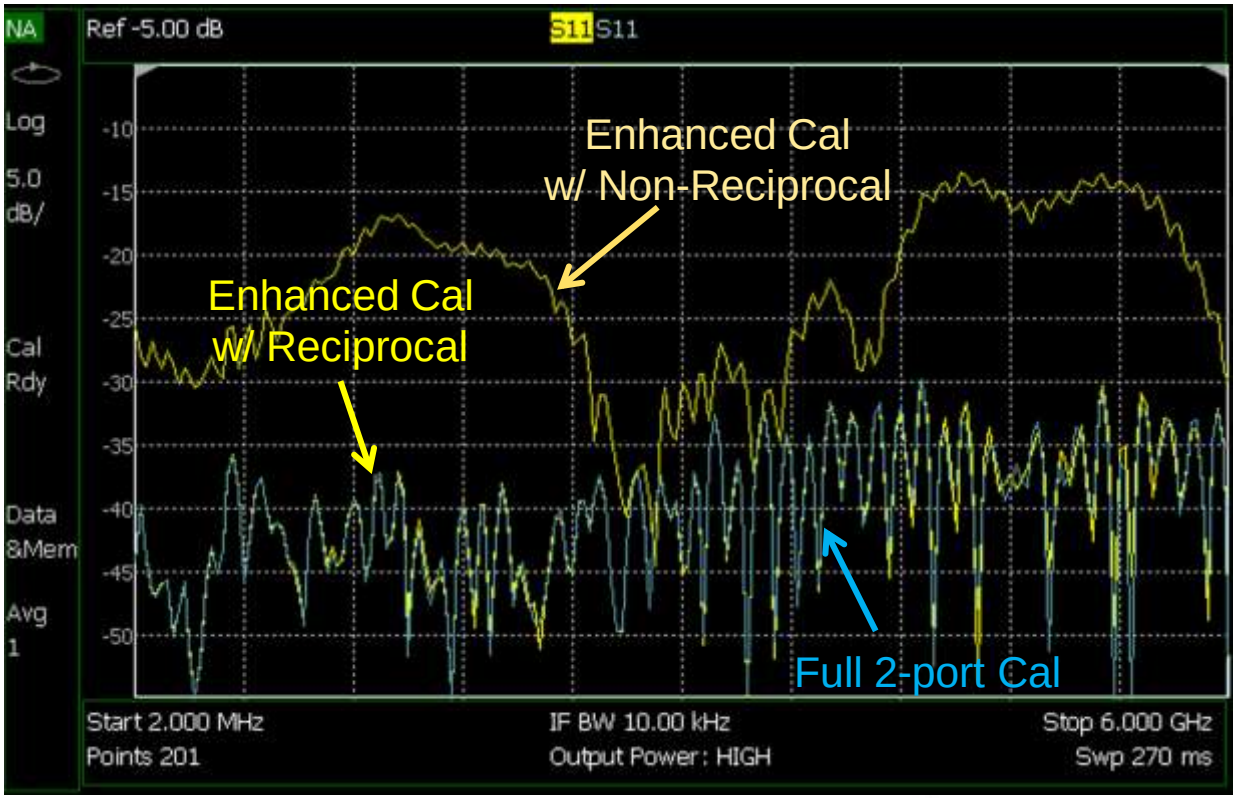
- Amplifiers
- Isolators
- Circulators

*Use Non-Reciprocal Enhanced Response Cal*

# Cable Measurement Comparison



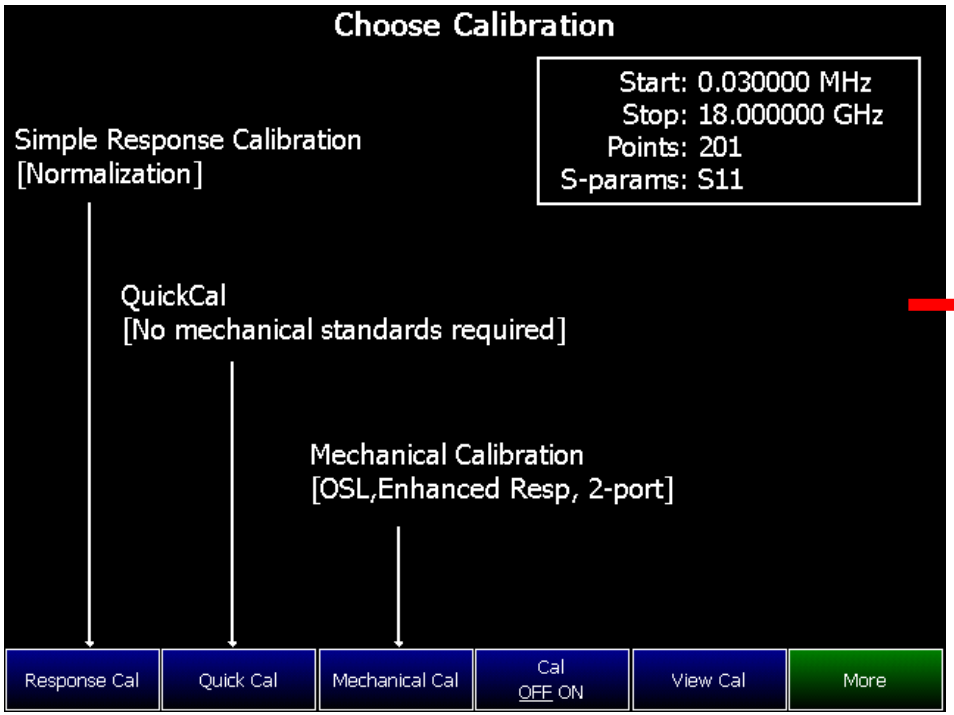
*CalReady*

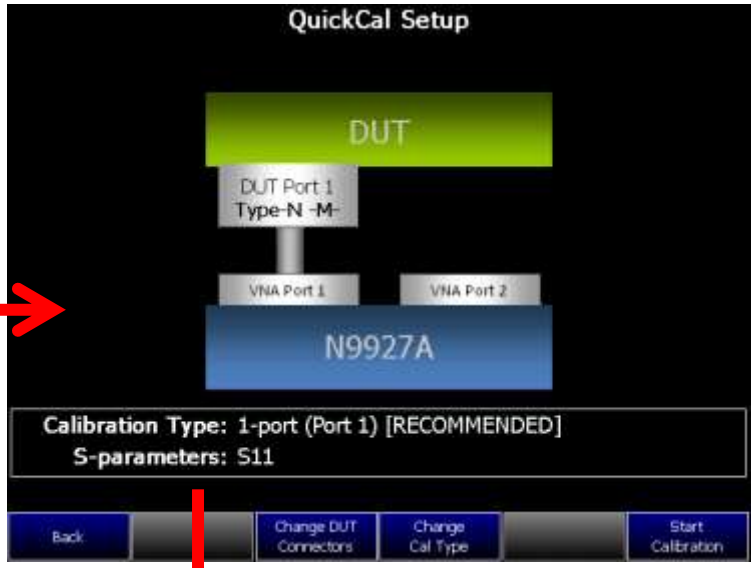



| DUT Type | Enhanced Response : Non-Reciprocal (default) | Enhanced Response: Reciprocal |
|---|---|---|
| Reciprocal (cable) | Good | Highest |
| Non-Reciprocal (amp) | Highest | Incorrect |

# Advanced Concepts: Optimizing Dynamic Range

# FieldFox Guided Calibration – *Cal Wizard*





- FieldFox recommends calibration type
- Simple setup process
- Cal Wizard for step-by-step connections

# FieldFox VNA Characteristics

- ***Carry precision with you -*** Agilent-quality measurements
- Best measurement stability over temperature and time
- 100 dB Dynamic Range
- Weather resistant, MIL-PRF-28800F Class 2 design
- 6.6 pounds (3 kg)
- 3.5 hour battery life

N9912A 4/6 GHz RF Analyzer

N9923A 4/6 GHz RF Vector Network Analyzer (VNA)

N9925A 9 GHz Microwave VNA

N9926A 14 GHz Microwave VNA

N9927A 18 GHz Microwave VNA

N9928A 26.5 GHz Microwave VNA

N9913/4/5/6/7/8A RF and Microwave Combination Analyzers

# FieldFox Accessories

## Calibration Kits

Coax, 4-in-1

3.5 mm, Type N

Coax, 3-in-1

Type N, 7/16

Waveguide

X-Band, P-Band, K-Band

*Other cal kits available*

## Phase Stable Test Cables

N9910X-704, type N(m) to TNC(f), 13 GHz

N9910X-709, 3.5 mm(f) to 3.5 mm(f), 26.5 GHz

N9910X-810, type N(m) to N(m), 6 GHz

# Conclusions

- Introduced S-parameters basics for measuring S11, S21, S12 and S22
- Discussed Full 2-Port and T/R hardware options
- Discussed error correction and user calibration
- Introduced CalReady, QuickCal and Mechanical cal types
- Reviewed advanced topics including insertable and non-insertable DUTs

# For More Information

**Web**: www.agilent.com/find/FieldFox

**Literature**:

- *Techniques for Precise Interference Measurements in the Field,* application note, literature number 5991-0418EN
- *Techniques for Precise Cable and Antenna Measurements in the Field,* application note, literature number 5991-0419EN
- *Techniques for Precise Measurement Calibration in the Field,* application note, literature number 5991-0421EN
- *FieldFox Handheld Analyzers*, brochure, literature number 5990-9779EN

**Third in a series of monthly application webcasts**

- ✓ Sept 26, 2012: Interference Testing
- ✓ Oct 24, 2012: Cable and Antenna Measurements
- ✓ Nov 28 2012: Calibration Techniques
- Jan 23 2013: Time Domain Measurements
- Mar 27 2013: Precise Power Measurements

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## Thank you for your time
## Questions?

# References


- Agilent Application Note: Network Analyzer Basics, Literature Number 5965-7917E, August 2004

- Agilent FieldFox Analyzers N9913A, N9914A, N9915A, N9916A, N9917A, N9918A, N9925A, N9926A, N9927A, N9928A, N9935A, N9936A, N9937A, N9938A, User's Guide, Literature Number N9927–90001, September 28, 2012

- Agilent Application Note: Techniques for Precise Cable and Antenna Measurements in the Field, Literature Number 5991-0419EN, August 27, 2012,

- Agilent Application Note: Techniques for Precise Measurement Calibrations in the Field, Literature Number 5991-0421EN, August 29, 2012