





Effectively maintain and troubleshoot military communication systems

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RF/MW hand held segment





Effectively maintain and troubleshoot military communication systems

Military communication systems include RADAR, SATCOM, VHF/UHF radio and microwave backhaul. Depending on the branch of military, these system can be installed on ground, vehicles, ships and aircraft. For these mission critical systems, it is key to effectively maintain optimum performance level.

Reduced system performance of failure can usually be traced to faulty components such as T/R modules, antennas, cable waveguide, filters and amplifiers.

This paper will discuss what needs to be tested and how to test and verify these systems. Key topics are RADAR field test and verification, SATCOM field test, microwave backhaul test, cable and antenna test, VNA calibration in the field, waveguide calibration and tests as well as radio environment characterization.

In the past, these tasks were performed using multiple bench top / lab grade instruments. With introduction of the Agilent FieldFox family, users can perform lab grade measurements in the field with great confidence in result, and at greatly reduced operation costs.

Agenda

- **Military and government communication system overview**
- **Challenges to maintain and troubleshoot the system**
- **test equipment to address field RF /MW issues**
- **Cable and antenna test**
- **VNA and its calibration**
- **RADAR test**
  - System overview
  - Key measurements
- **Satellite ground station**
  - System overview, key measurements
- **Microwave Backhaul**
  - System overview and key measurements
- **Summary**

Military communication system overview

RADAR system:

- *Target search, navigation aid, missile guidance, tracking*

SATCOM:

- *Long range telecommunication*

VHF/UHF Radio

- *Local communication*

Microwave link

- *Point to point backhauls, emergency communication*

GPS

- *Navigation*

Challenges to maintain and troubleshoot system

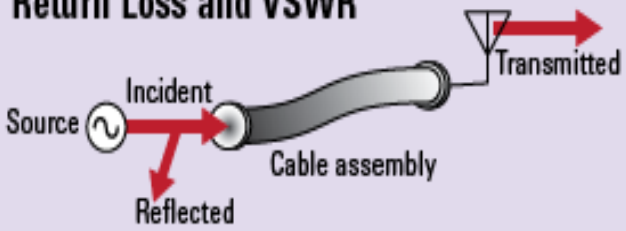
- Most of systems are unique configured to meet special needs, the test plans are different from system to system;
- Variety of components are built into the system, which need to be verified and tested, like diplexer, duplexer, cavity filter, LNA, PA, attenuator etc..
- Needs to perform many RF tests, which can traditionally be fulfilled by multiple bench top boxes in the bench, VNA, cable loss, DTF, power meter, spectrum monitoring etc..
- Accuracy and repeatability across temperature range are essential
- Location of the system are environmental challenging, for example, extreme temperature, dust, explosive environment, under direct sun light. and spurious RF signal sensitive area

All instruments in one package is a necessity, rather than nice to have

Cable and antenna test

Cable and Antenna Measurement Basics

Return Loss and VSWR



Return loss	VSWR
Ideal = Infinity	Ideal = 1.0
Good = 25 dB ➡	Equates to a VSWR = 1.12

An efficient use of power is required to transmit data from the BTS to a mobile phone:

- The transmission line system must be free of defects.
- Each transmission line imperfection, every connection, and the antenna itself will reflect some of the generated power back toward the source.
- Any reflected power will be absorbed by the transmission line system and source—this is an inefficient use of power.
- The integrity of the transmission line system, including the antenna, must be tested.

A common method to test the antenna feedline system:

- Send a known, incident signal through it and measure the signals (traveling waves) that are reflected back.
- Determine the reflection characteristics of the feedline system by measuring the amplitude ratios and phase differences between the incident and reflected waves.
- Measuring these reflections gives a figure of merit for evaluating the quality of the transmission feedline system called the reflection coefficient (Γ). From the reflection coefficient we can calculate the return loss and the voltage standing wave ratio (VSWR) according to the following formulas:

$$\Gamma = \left(\frac{V_{Reflected}}{V_{Incident}}\right)$$

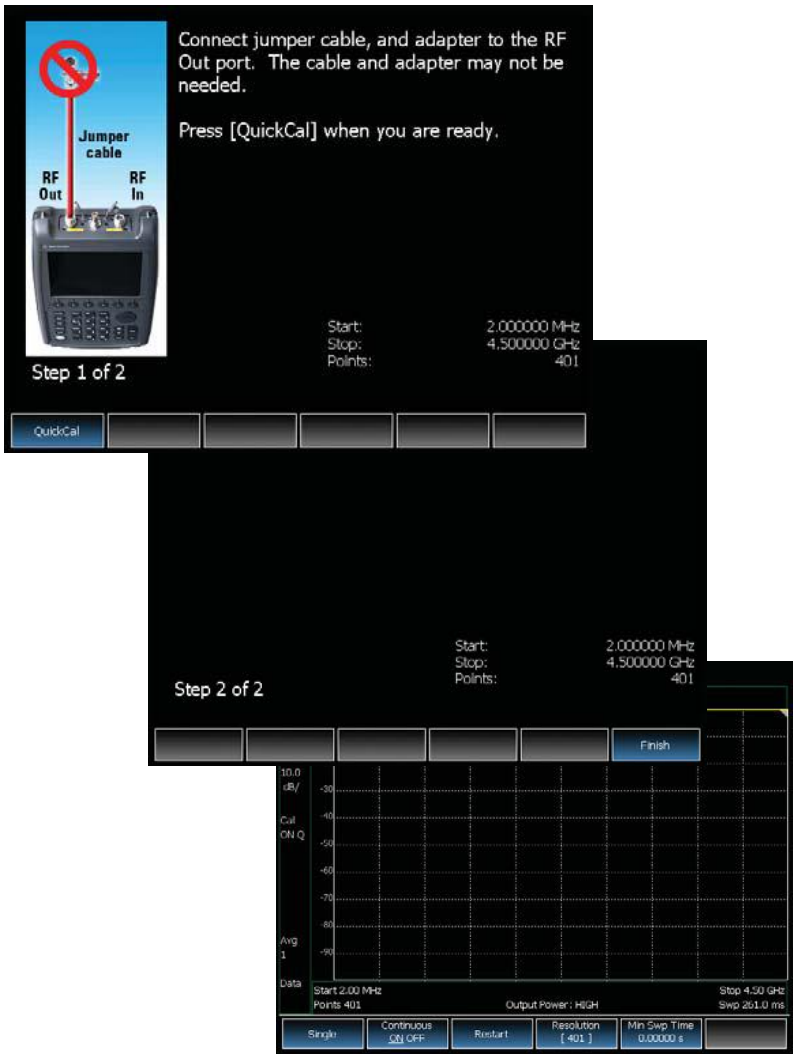
$$\text{Return loss} = -20 \times \log\Gamma$$

$$\text{VSWR} = \frac{(1+|\Gamma|)}{(1-|\Gamma|)}$$

Return Loss vs. VSWR Conversion Table

Return loss (dB)	VSWR	Return loss (dB)	VSWR
46.1	1.01	19.1	1.25
40.1	1.02	17.7	1.30
36.6	1.03	16.5	1.35
34.2	1.04	15.6	1.40
32.3	1.05	14.7	1.45
30.7	1.06	14.0	1.50
29.4	1.07	12.7	1.60
28.3	1.08	11.7	1.70
27.3	1.09	10.9	1.80
26.4	1.10	10.2	1.90
25.7	1.11	9.5	2.00
24.9	1.12	8.3	2.25
24.3	1.13	7.4	2.50
23.7	1.14	6.6	2.75
23.1	1.15	6.0	3.00
20.8	1.20	5.5	3.25

CalReady and QuickCal simplifies cable and antenna measurements



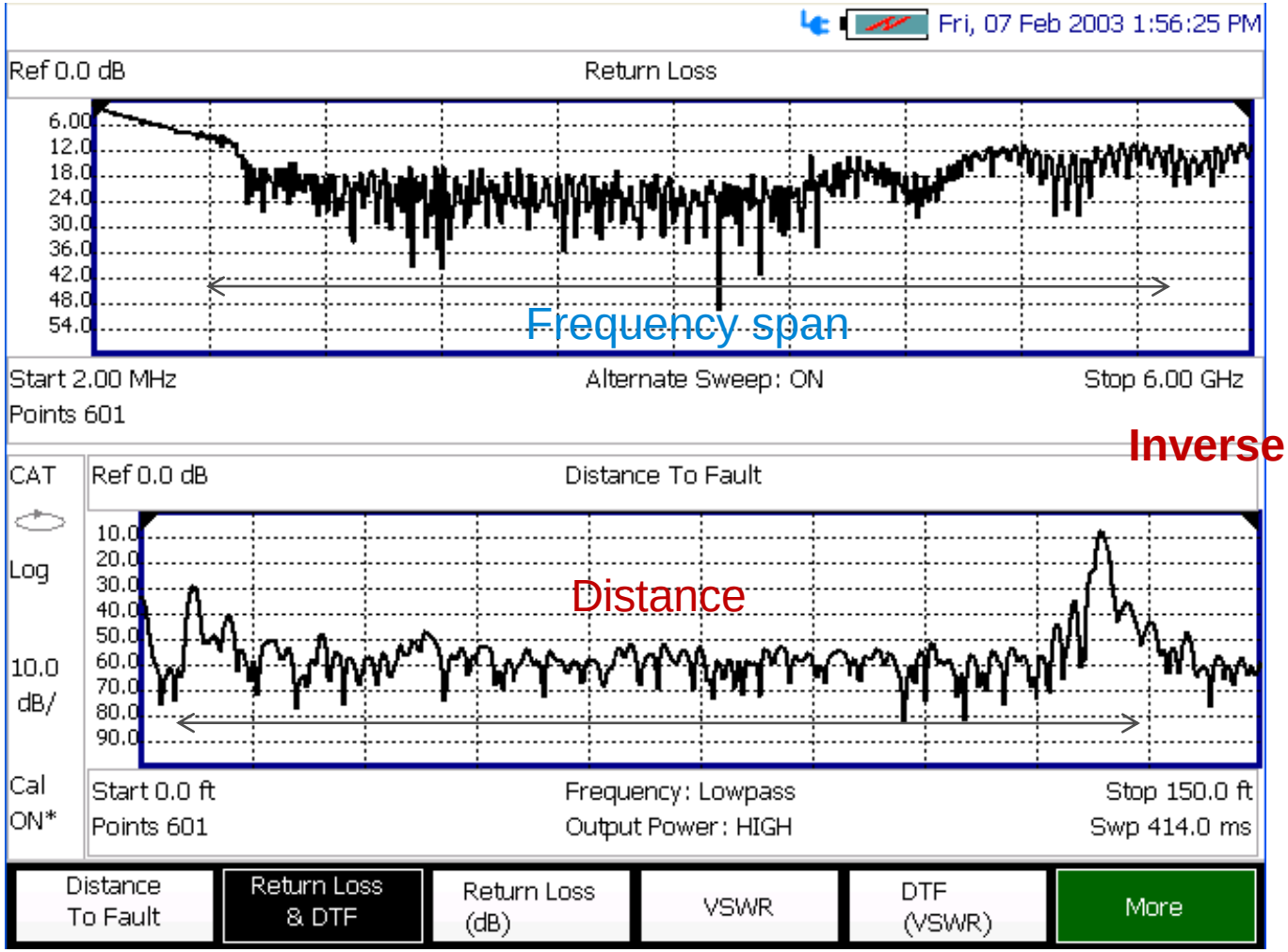
-Instrument is calibrated at power on with CalReady

- QuickCal allows user to change reference plane to end of cable or adapters

- works on any connector type, user doesn't have to bring different adapters for testing

- rugged and sealed unit greatly reduces temperature effects in the field

Distance to fault measurements



Return loss in Frequency domain

Inverse FFT

Return loss in Time domain

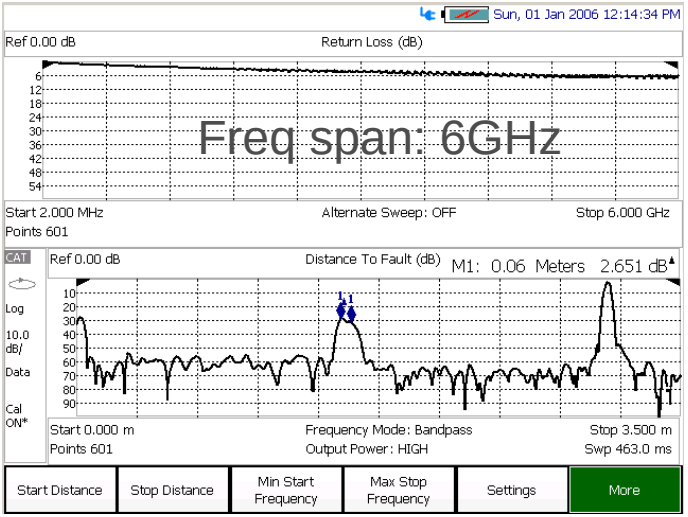
Distance to fault operating modes

- Band Pass Mode
  - Input: start and stop distance, start and stop frequency, cable type
  - Applications: band limited system

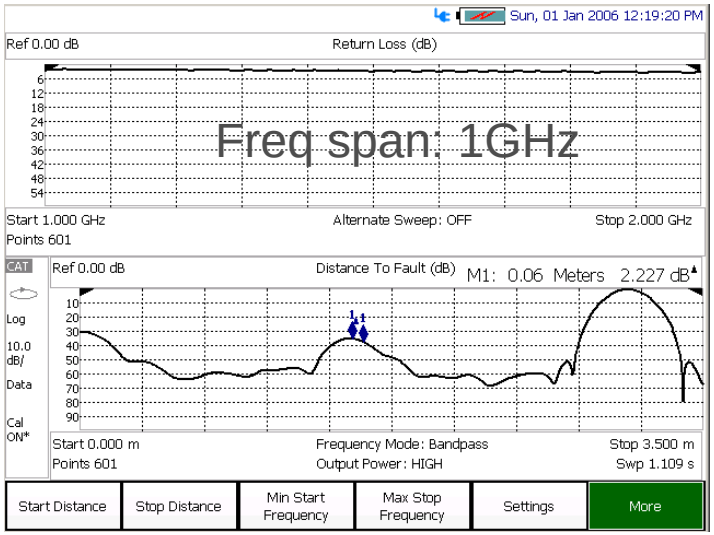
- Low Pass Mode
  - Input: start and stop distance, cable type
  - Applications: broad band system, like cable

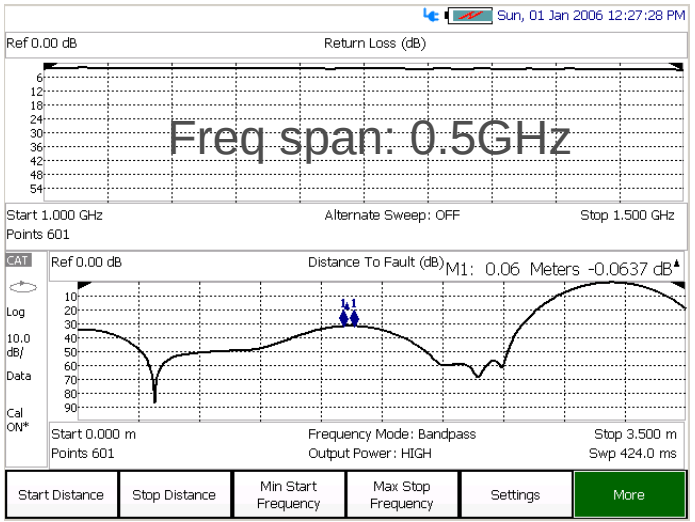
- In band pass mode, extra care needed to make sure proper start and stop frequency and range to avoid phantom peaks, Agilent FieldFox implements special algorithm to avoid such phantom peaks.

Frequency span impacts DTF measurements

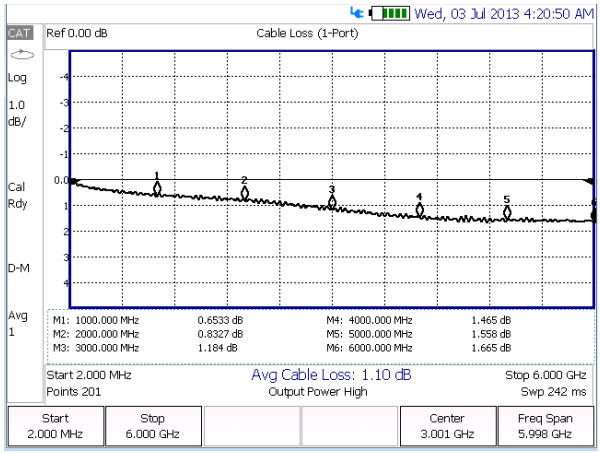


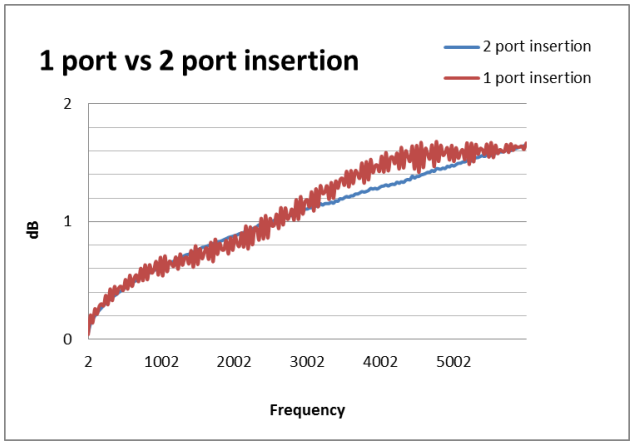
Cable under test:
2 x 1.5m with a
0.06 m barrel

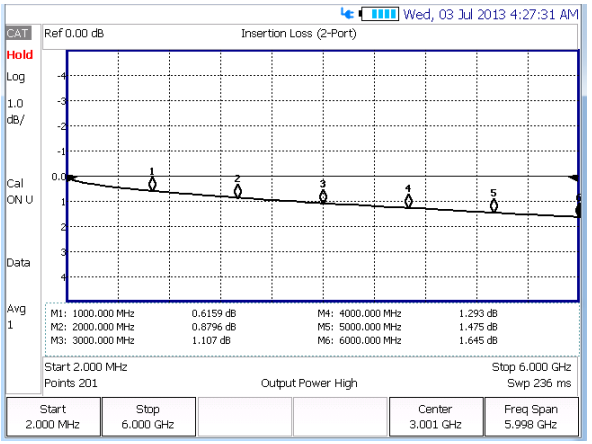




Cable loss: 1 port and 2 port insertion loss







1 port cable loss
- Cal ready
- Measure return loss of the cable and save it to memory
- Connect short or leave it open at end of cable
- Enable DATA-TRACE

2 port insertion is more accurate, but 1 port cable/insertion loss has adequate accuracy for long cable measurement where 2 port measurements cannot be performed

2 port insertion loss
- Mechanical 2 port cal
- Measure insertion loss

VNA

VNA Architecture and features

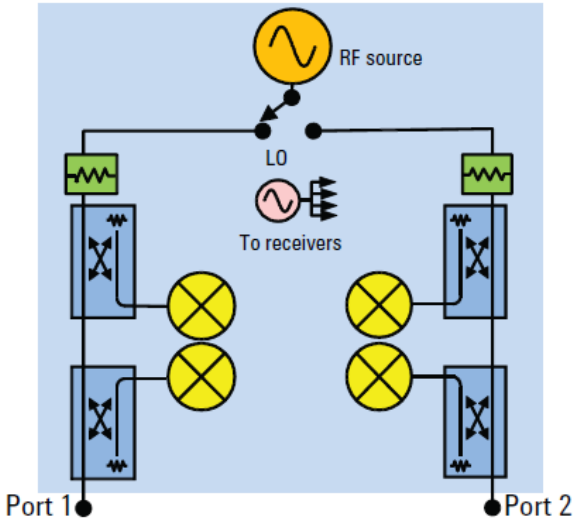
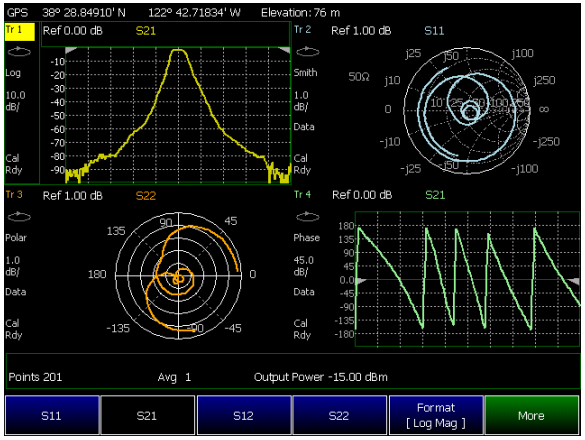
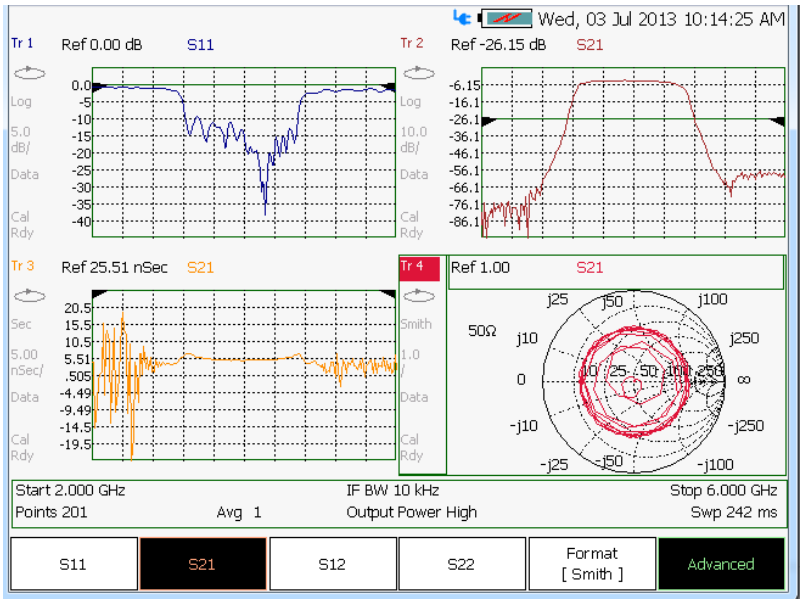


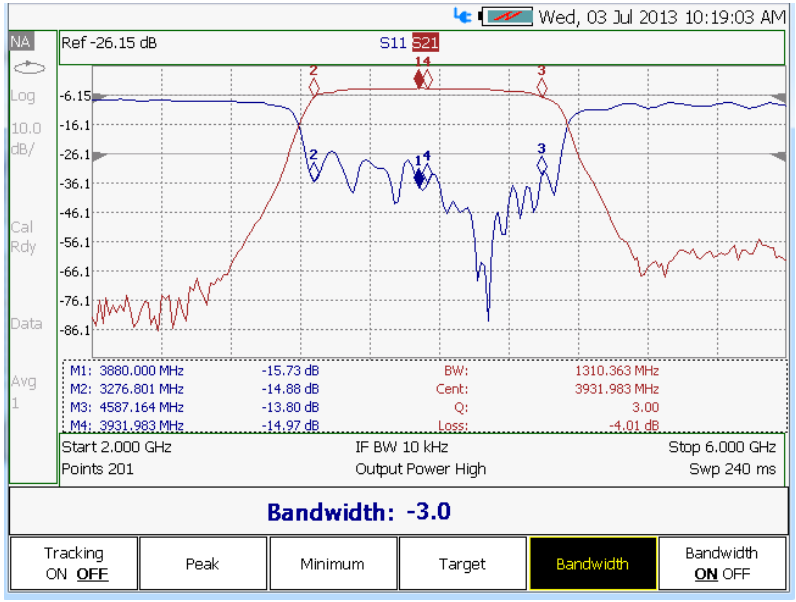
Figure 10: N9923A with option 122



- **4 receiver architecture**
- **Calibration supported:**
  - CalReady and QuickCal
  - 1 port calibration, Full 2 port calibration, unknown thru calibration, QSLOT, Waveguide Calibration and TRL
  - Response and enhanced response
  - User defined cal kit
- **Measurements:**
  - S parameters (mag and phase)
  - Group delay, electrical delay, port extension
  - Smith chart, polar chart, impedance

Filter / Diplexer Measurement



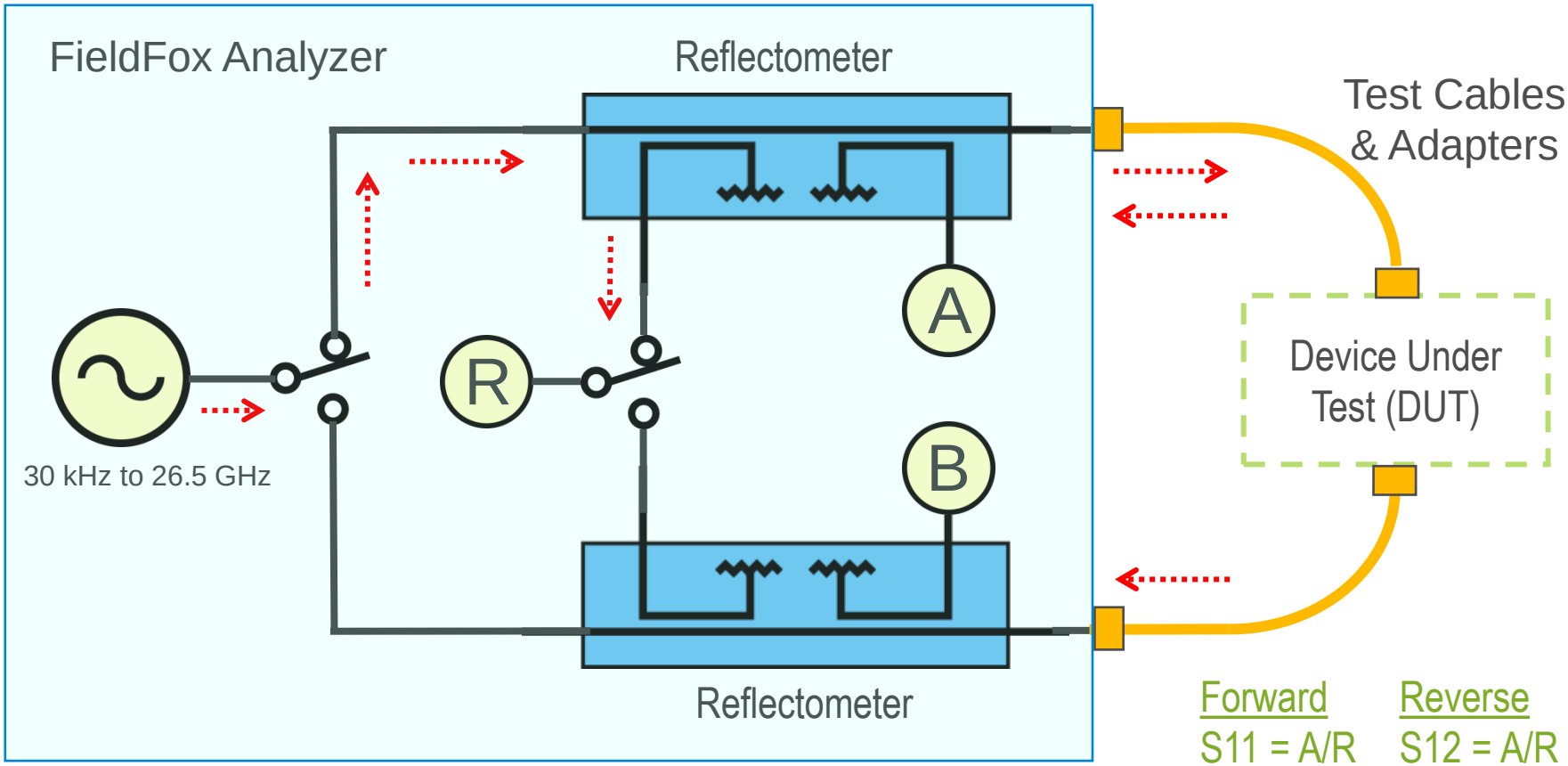


4 S-Parameter measurements

Filter bandwidth measurement

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

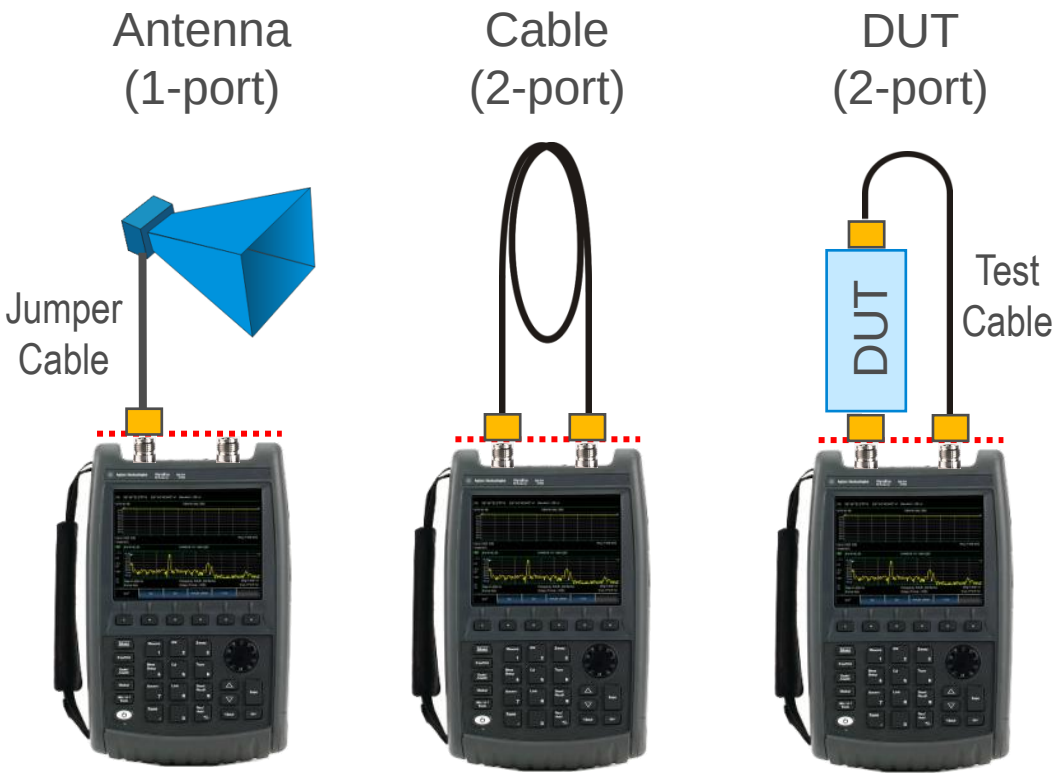
Other
- Random Errors
- Drift Errors

CalReady

Calibration

- Built-in
- Full 2-port Cal

Test



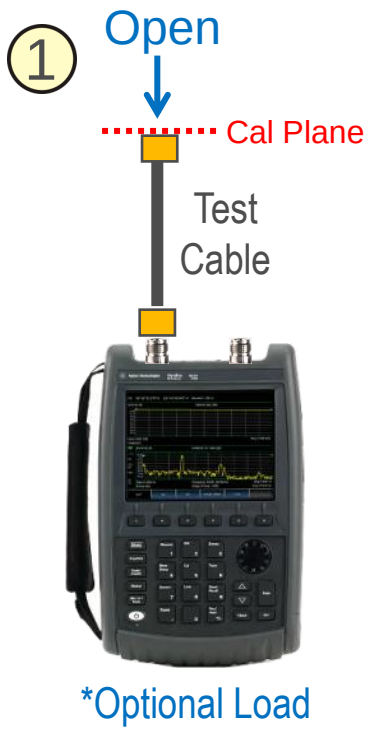
Full 2-port error correction at FieldFox test ports

QuickCal

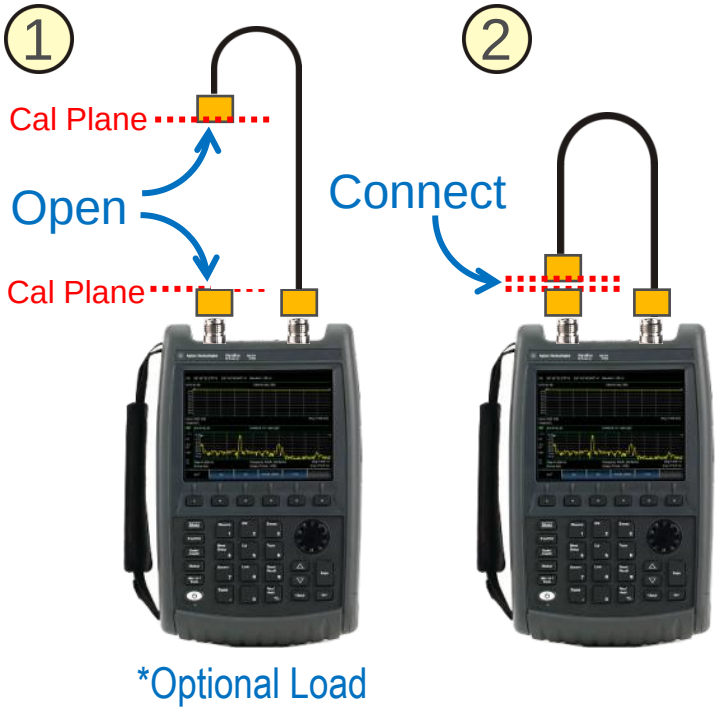
Calibration

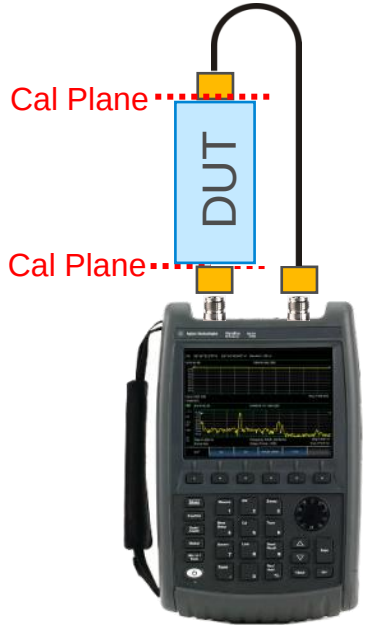
Test

1-Port Quick Cal



2-Port Quick Cal





Full 2-port error correction with cable and adapter compensation

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

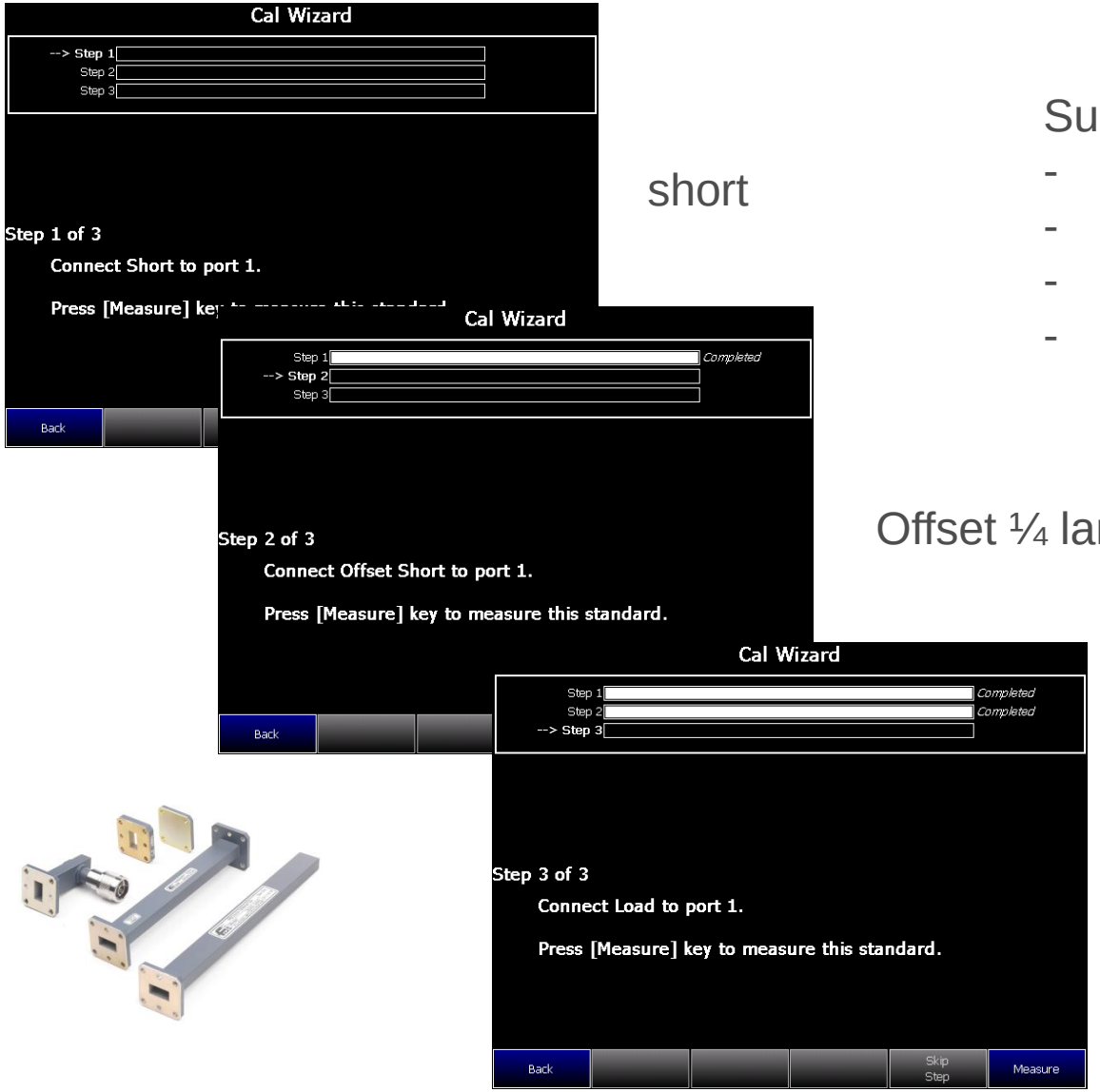
Calibration kit

- 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

Waveguide Calibration



short

Offset ¼ lambda + short

load

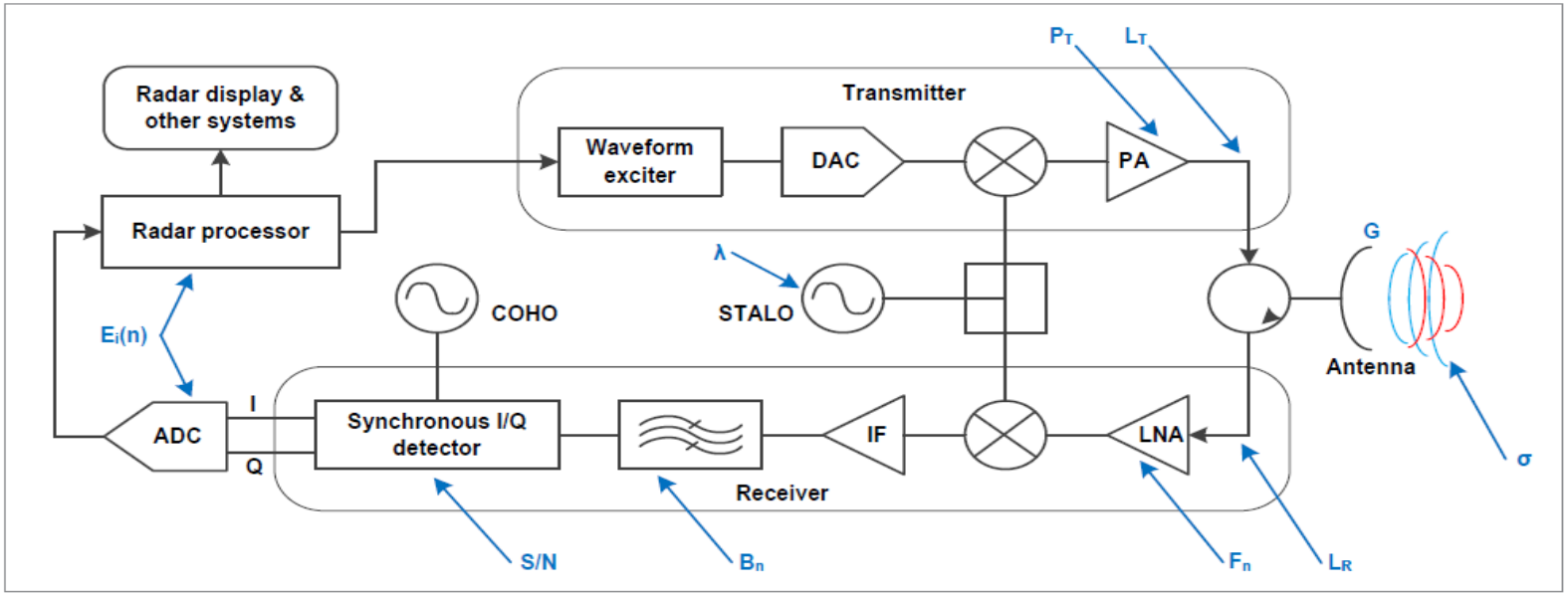
Supported waveguide kit

- WR137, 4 to 8GHz, C band
- WR90, 8 to 12GHz, X band
- WR62, 12 to 18GHz, Ku band
- WR42, 18 to 26.5GHz, K band

RADAR

RADAR system overview

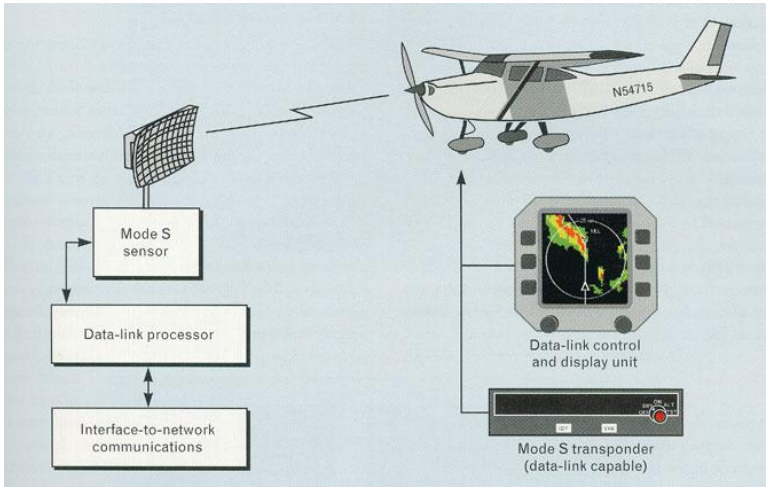
$$40\ \mathrm{Log}(R_{max}) = PT + 2G + 20\ \mathrm{Log}\lambda + \sigma + E_i(n) + 204\ \mathrm{dBW/Hz} - 10\ \mathrm{Log}(B_n) - F_n - (S/N) - L_T - L_R - 33\ \mathrm{dB}$$



Key RF components:

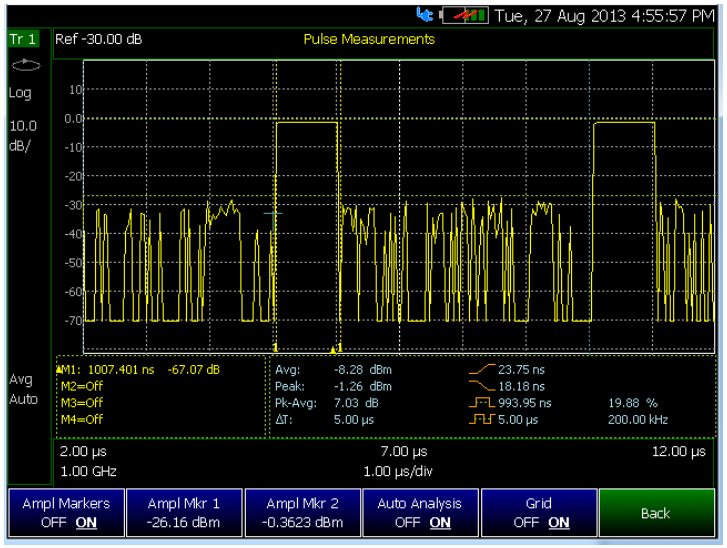
Antenna, coax cables, waveguide, duplexer, diplexer, PA, LNA, pulse generator STALO

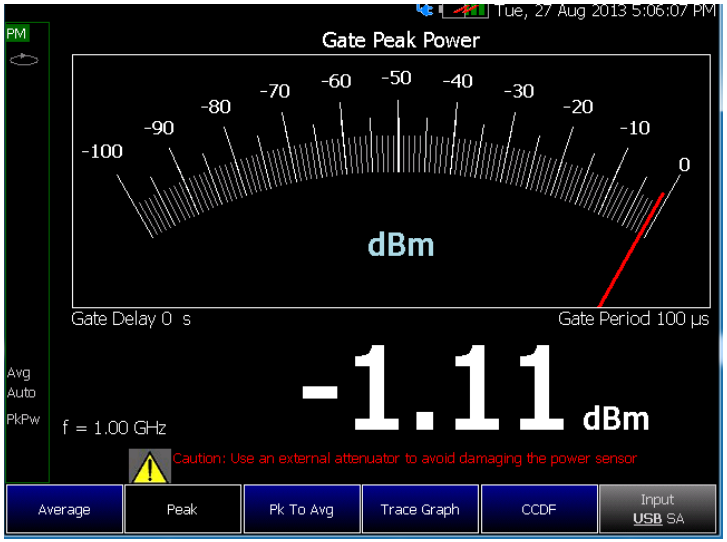
RF tests performed on RADAR



- Cable and antenna test
- RADAR pulse measurement
- Phase array antenna measurement (S21 mag and phase, VVM A/B)
- RF test target generation system test – channel alignment (VVM or VNA mag and phase)
- Diplexer verification
- Radio Frequency (RF) Receiver Stabilized Local Oscillator (Stalo) Signal Phase Alignment (VVM or VNA)
- Sigma and delta antenna port phase alignment (VVM A/B)
- Attenuator test (VNA S21 or S11)
- Waveguide test

Pulse Measurement



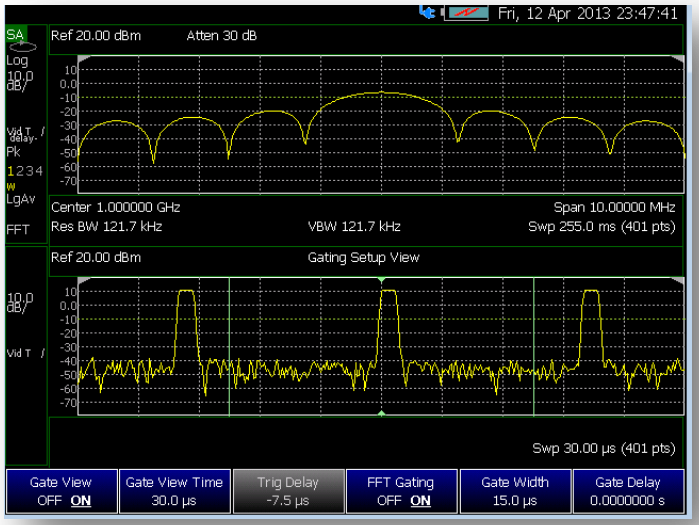


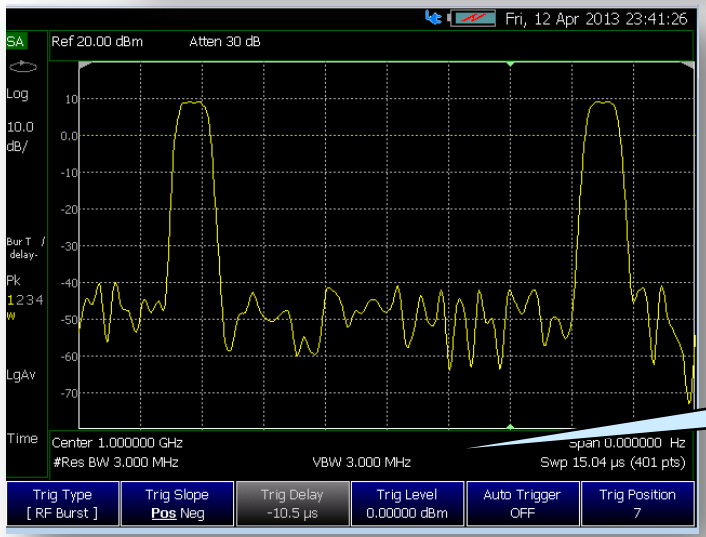
Use case:

- Allow user to use Agilent peak power sensor (U202x) to characterize RF/MW pulse up to 40GHz

Measurement summaries	Average power Peak power
	Pulse Profile: Pulse width, rise time, fall time, PRI, peak to average ratio
	Vertical and horizontal markers, marker table, gate setup, trigger, radio standards setup

Spectrum analyzer pulse measurements





Use case:

- Make RF pulse measurement like RADAR quicker and easier

Spectrum analyzer time gating (opt 238)

- Frequency domain and time domain views
- Adjustable trigger position
- Settable gate width and gate view time

Triggers:

- External, video, free run, burst trigger
- Trigger delay and pre-trigger
- Settable trigger position

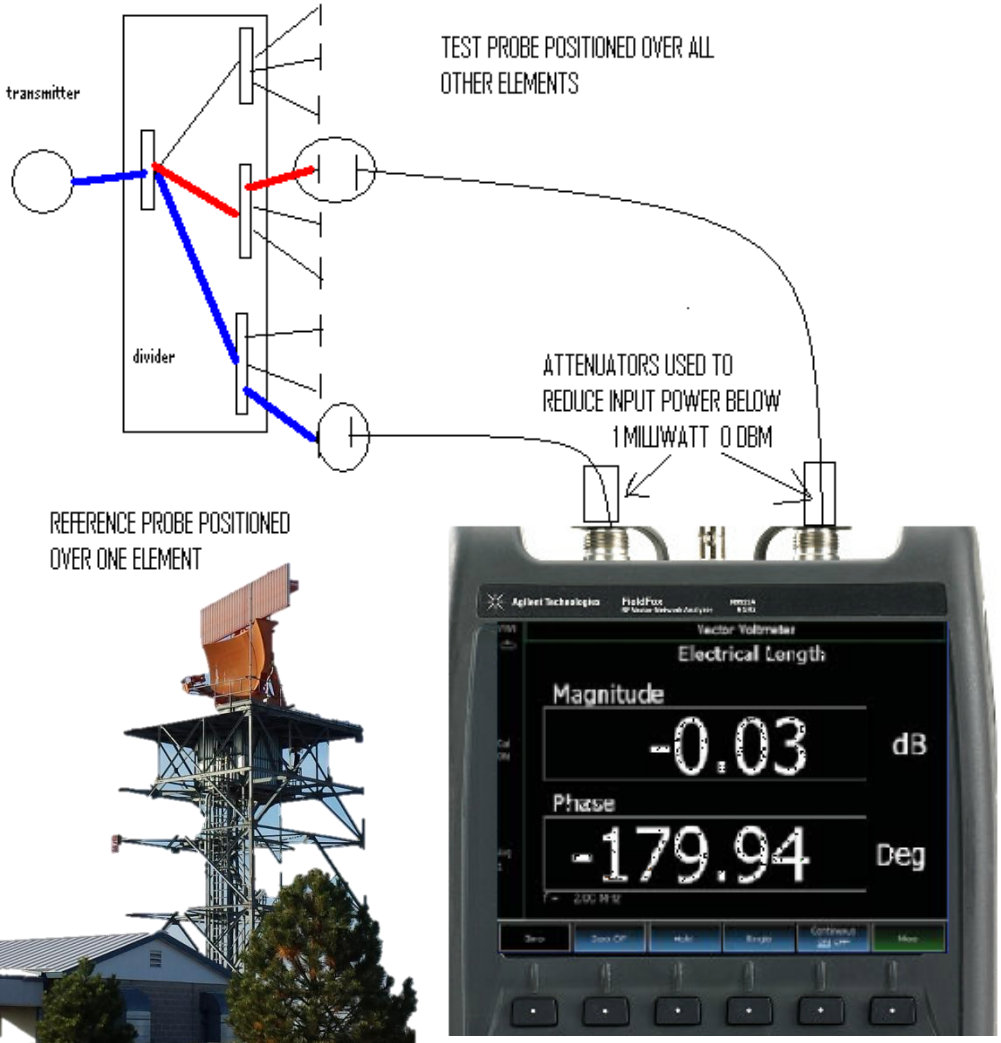
Others:

- 1 Hz and 3Hz RBW settings

Trigger delay: + xx is delay, -xx is pre trigger

Above features are not available for N9912A

FAA measurement examples: Phased array element test

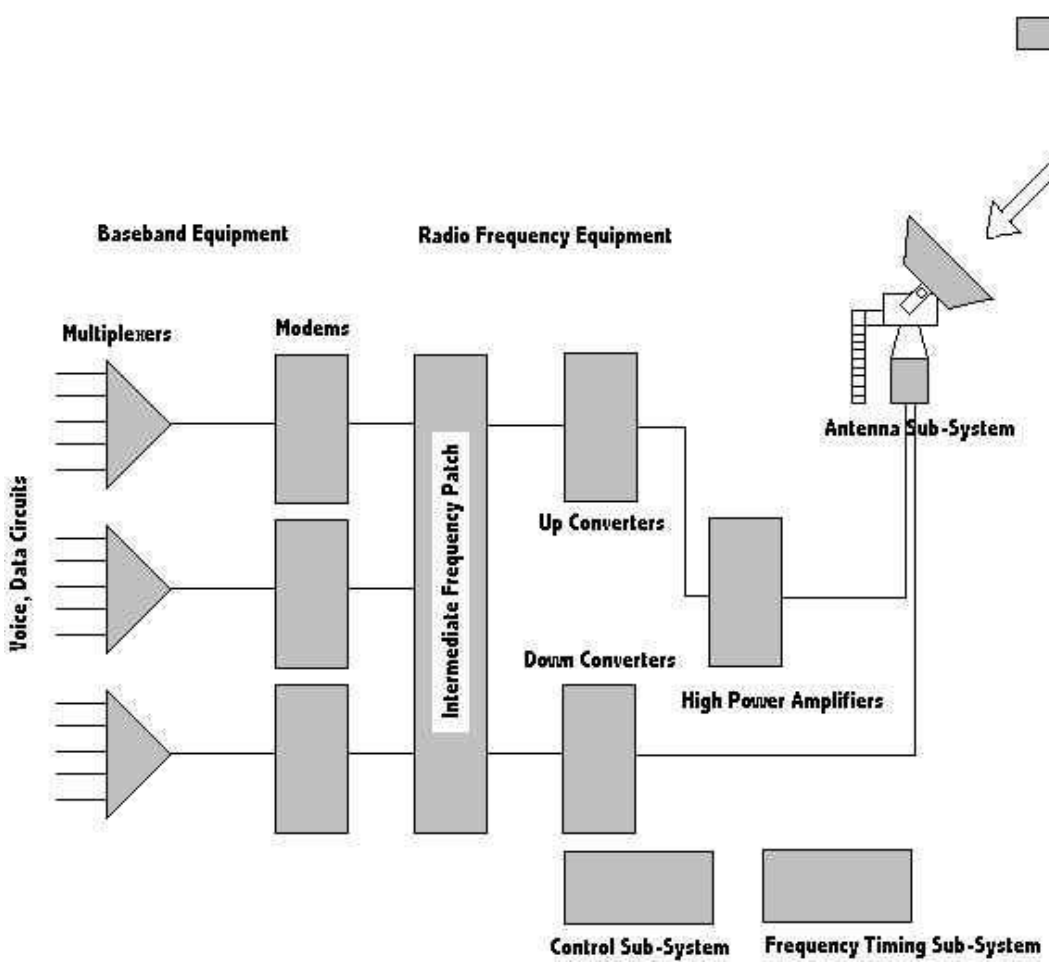


1. PRESET N9923A
2. MODE, VVM, B/A
3. FREQ DIST
4. SET FREQUENCY EQUAL TO TRANSMIT FREQUENCY
5. CONNECT REFERENCE PROBE TO CORRECT ELEMENT
6. CONNECT TEST PROBE TO FIRST ELEMENT
7. MEAS SETUP, ZERO
8. MOVE TEST PROBE TO ALL OTHER ELEMENTS AND VERIFY CORRECT AMPLITUDE AND PHASE ON EACH ELEMENT

SUSPECT LOOSE OR CORRODED CONNECTORS OR CABLES IN THE DIVIDER AND ANTENNA ELEMENTS

Satellite Ground Station

Satellite ground station



RF components:

- Antenna
- Duplexer
- Diplexer
- Waveguide
- Coax cable
- High power amplifier
- LNA
- Up / down converter
- Local oscillator

Key RF measurements for Satellite ground station

- Antenna return loss
- Cable loss
- Waveguide VSWR
- Receive band gain (LNA verification)
- Transmit band gain (HPA verification)
- Antenna pattern
- Up and down converter verification

Microwave backhaul

Microwave Radio Configuration

Waveguide

WG/Coax adapter

Combiner/Filter

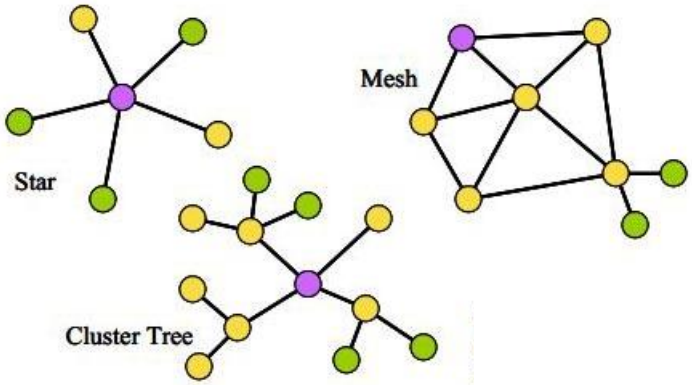
TX/RX

Base Band

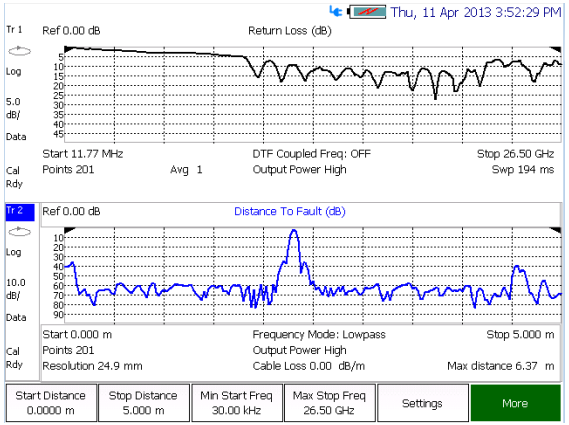
controller

Transport interface

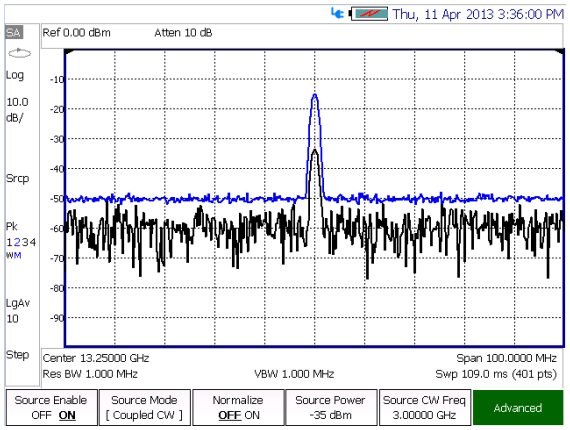
DS1, DS 3
SONET
Gig-Ethernet

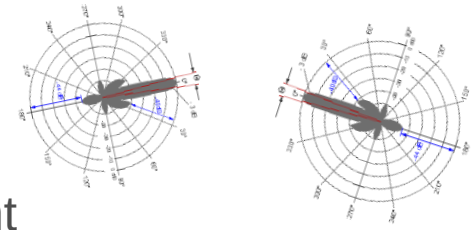


Tests for microwave backhaul

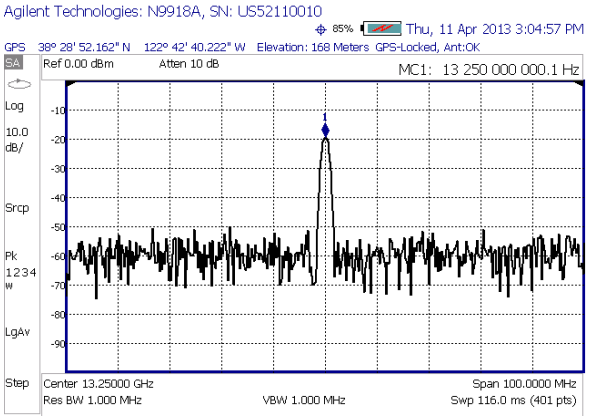


Waveguide test

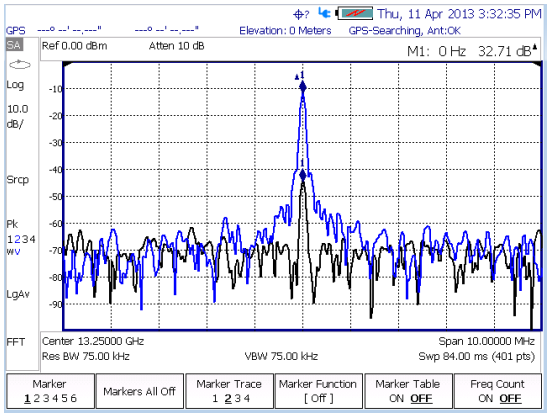




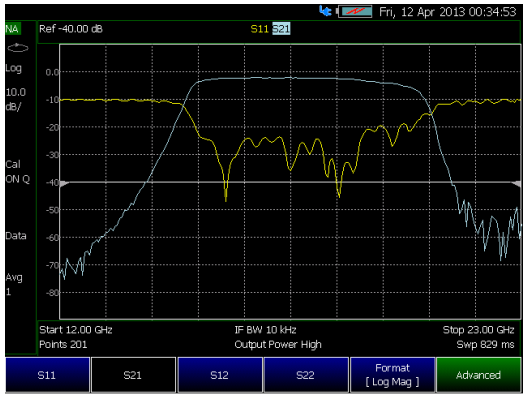
Antenna alignment



Frequency measurement



Path Loss Verification



Combiner tuning

Test During troubleshooting

- Received Signal Level
- Power measurement
- Path loss verification
- Signal analysis to find out if any interference
- Antenna/WG/Cable sweep
- Filter/Combiner verification
- TX/RX combiner verification, potentially tuning

FieldFox microwave analyzer: 10 Instruments in 1

Cable and antenna analyzer
30 kHz to 26.5 GHz

Full 2-port vector network analyzer with time domain analysis, 30 kHz to 26.5 GHz

Spectrum analyzer, with full-band tracking generator
5 kHz to 26.5 GHz

Power meter
5 kHz to 26.5 GHz

Built-in GPS receiver

Light weight: 6.6 lbs (3.0 kg)
Long battery life: 3.5 hrs
Bright display: 6.5 inch TFT
CISPR class B compliant
MIL-PRF-28800 F Class 2
MIL-STD-810G, 511.5, Proc 1
IP 53 type tested (dust/water)

Independent signal generator
30 kHz to 26.5 GHz

Vector voltmeter, 2-port
30 kHz to 26.5 GHz

Interference analyzer

Variable DC source and current monitor

Frequency counter

Summary

- Military communication system are unique, high accuracy and repeatable, comprehensive tests (SpecAn, VNA, frequency, power, timing etc..).
- Measurement results can be related easily with bench equipment.
- Systems are always installed in environmental challenging locations: remote, dusty, rainy, cold, hot.
- Agilent FieldFox provides multi functions, matching results with bench equipment and operates in tough environment.