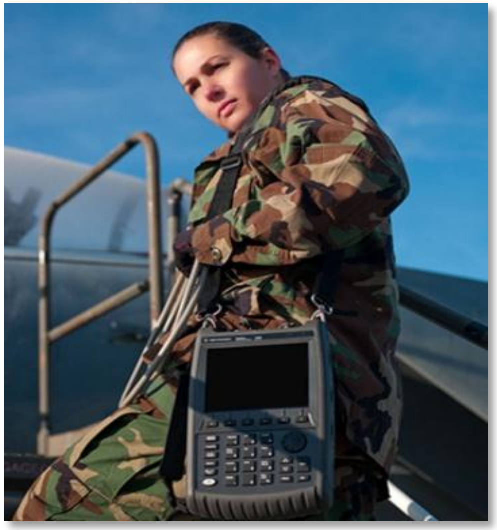
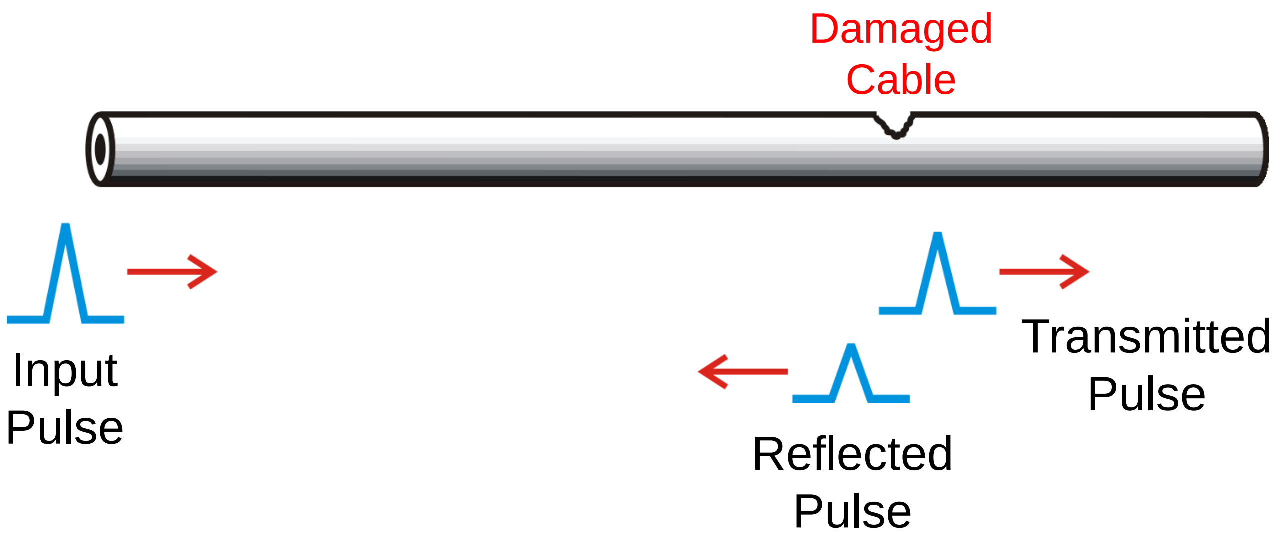
Part 2: Making Precise RF & µW Measurements in the Field

1. Introduce and demonstrate Distance to Fault (DTF) measurement and concepts
2. Application examples: Distributed Antenna System
3. Quick techniques for optimizing DTF accuracy in the Field
4. Introduce and describe higher precision, thanks to a Vector Network Analyzer
5. review of Vector Network Analyzers
6. End of Part 2



What is a Distance-to-Fault (DTF) Measurement?

Measurement technique to determine the location of problems along a cable or transmission line



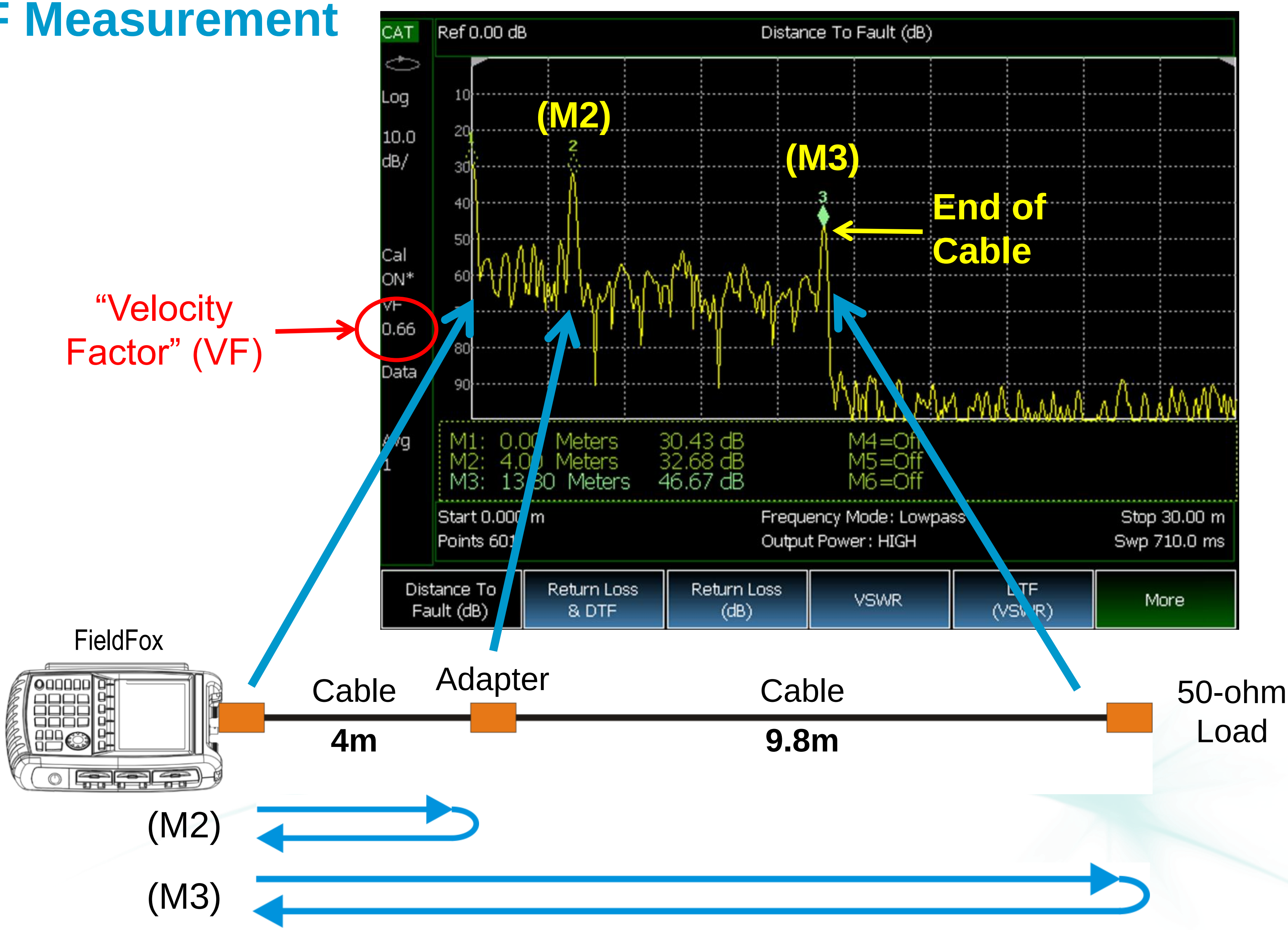
$$\mathrm{DTF(meters)} = \left[\frac{time_{\mathrm{roundtrip}}}{2}\right]\left[v_{\mathrm{cable}}\right] = \left[\frac{time_{\mathrm{roundtrip}}}{2}\right]\left[\frac{c}{\sqrt{\varepsilon_r}}\right]$$

$$\mathrm{VF} = \frac{v_{\mathrm{cable}}}{c} = \frac{1}{\sqrt{\varepsilon_r}} \quad (\leq 1)$$

$\mathrm{c} = \text{speed of light}$

$\varepsilon_{\mathrm{r}} = \text{relative dielectric constant of material}$

DTF Measurement



Demo – DTF Measurements in the Field

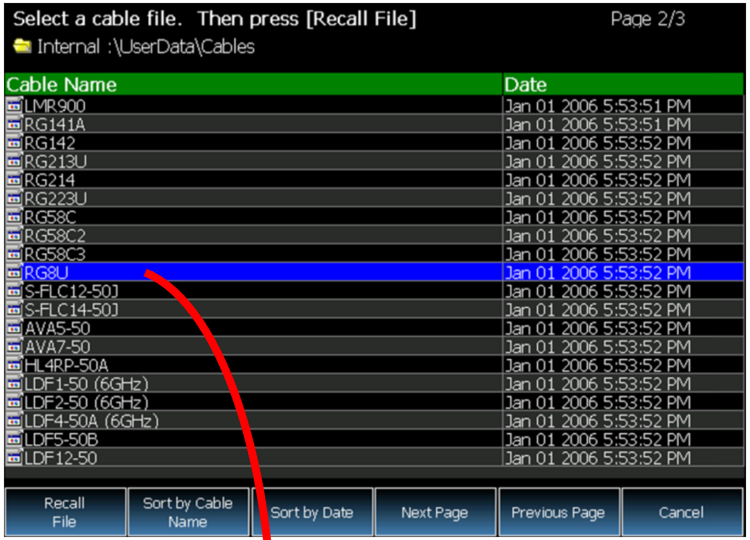
Entering Cable Parameters

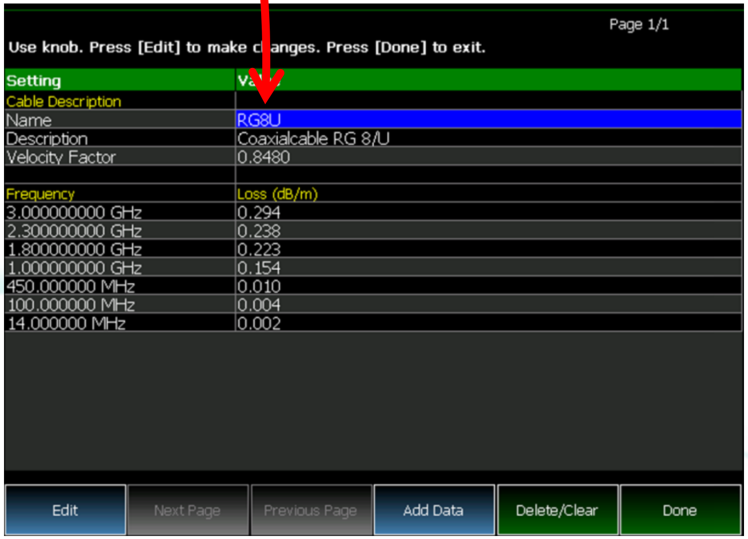
- Manual Entry
- Select/Create Cable File

RG8U Cable Specs

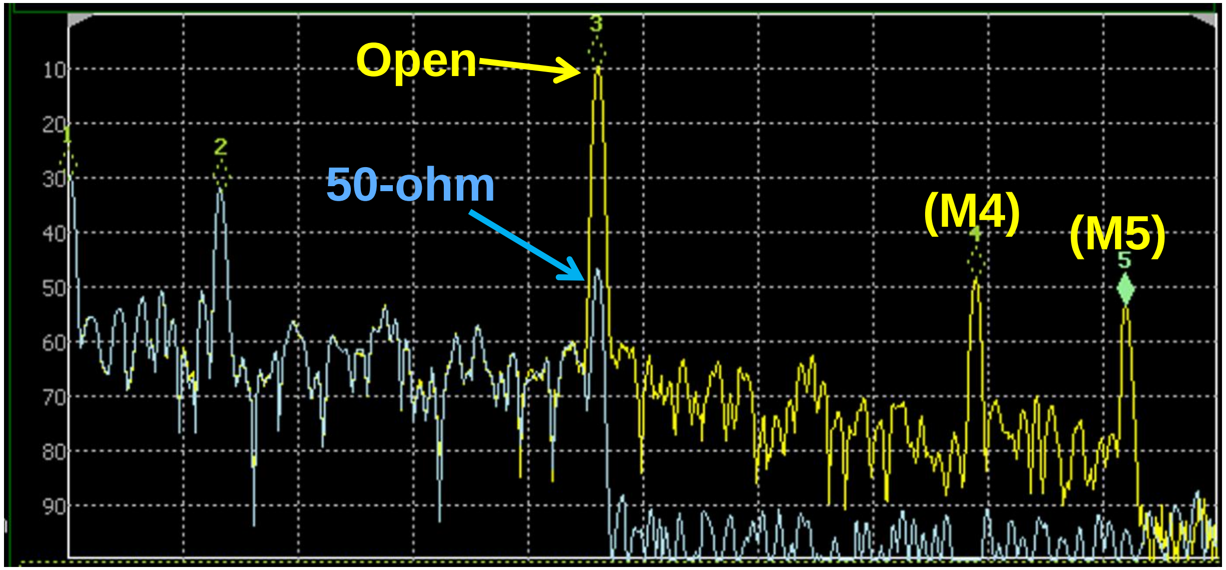
Velocity Factor	0.848
Cable Loss (dB/m) @ 100 MHz	0.004
Cable Loss (dB/m) @ 450 MHz	0.010
Cable Loss (dB/m) @ 1000 MHz	0.154
Cable Loss (dB/m) @ 3000 MHz	0.294

FieldFox DTF Cable Spec Menu

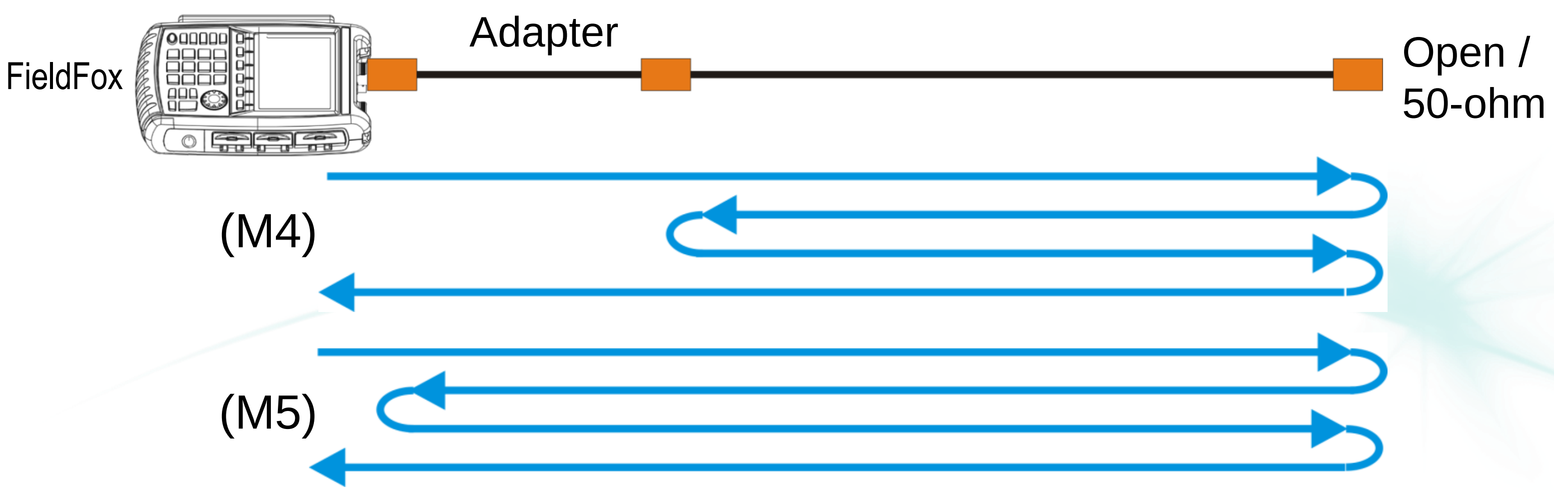




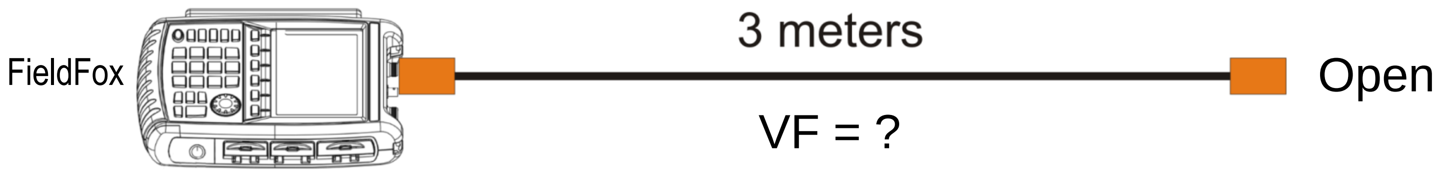
DTF Multiple Reflections

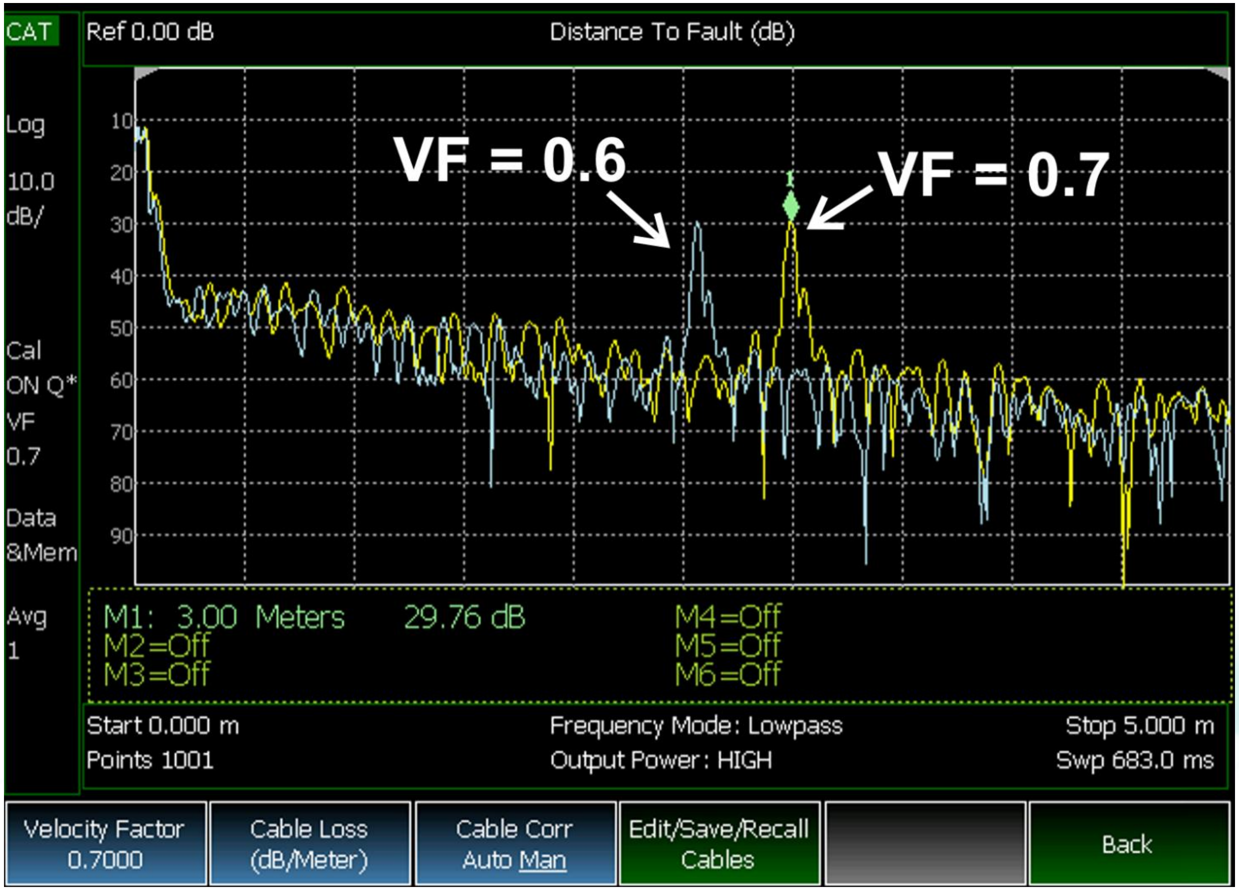


- Multiple reflections may create additional responses past the cable end
- Swap the load from Open to 50-ohm, observe changes in response

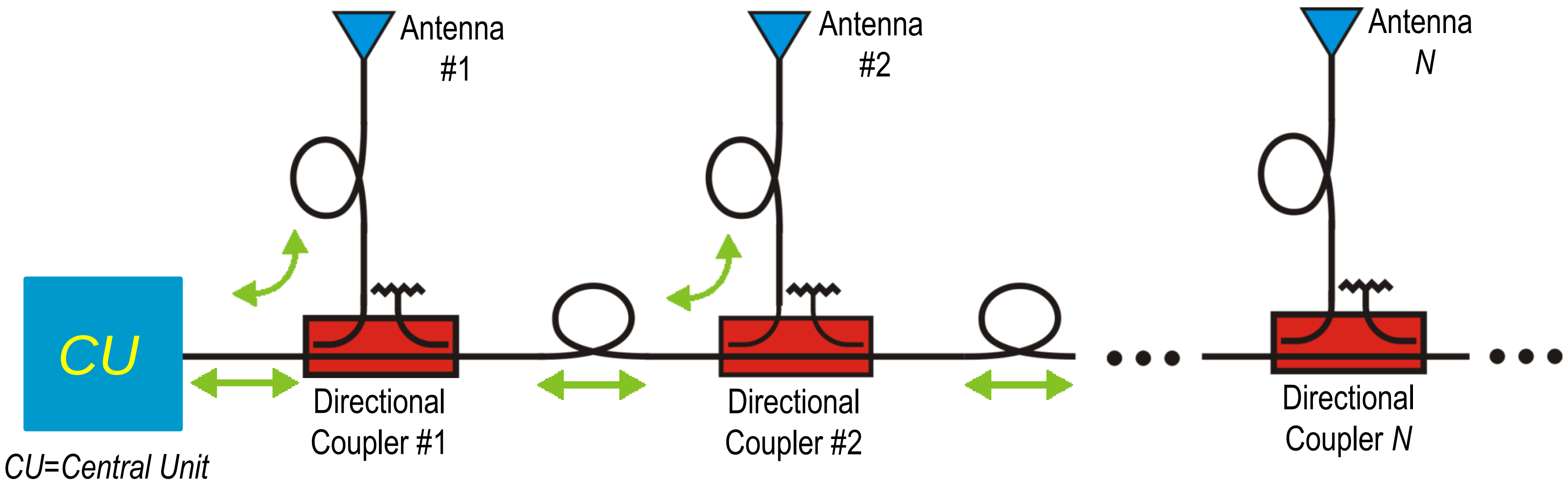


Application Example: Estimating Velocity Factor





Application Example: Distributed Antenna System (DAS)

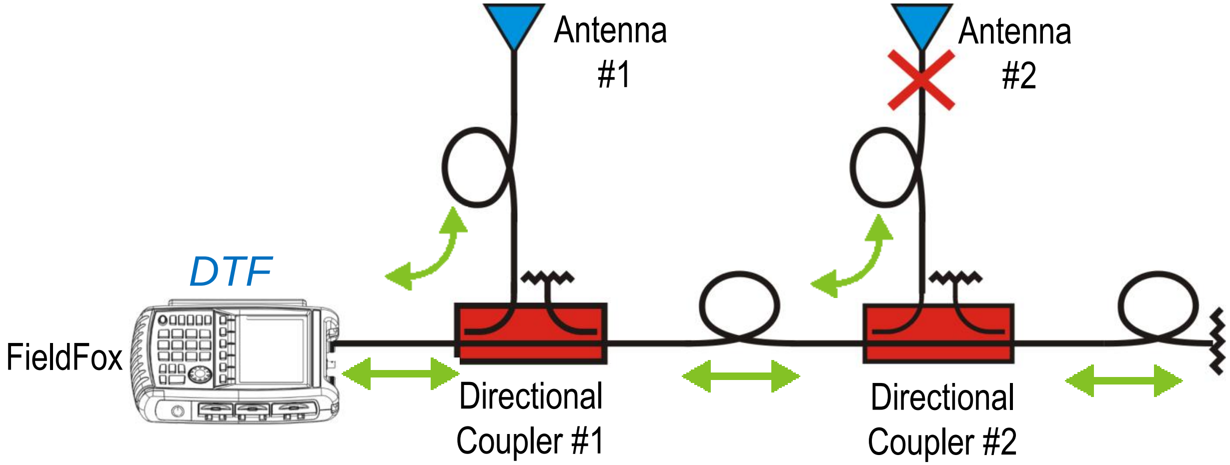


DAS techniques can

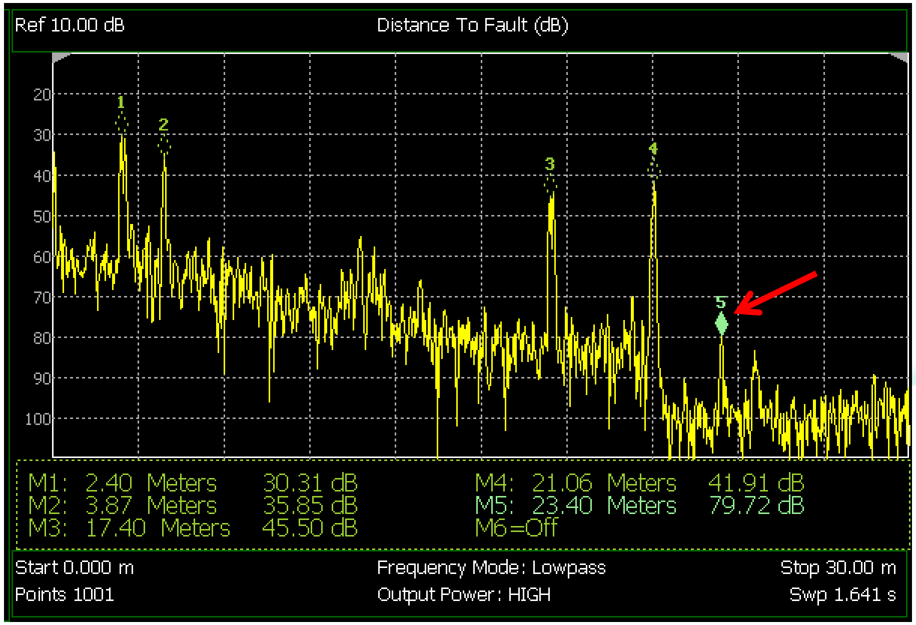
- Extend signal coverage
- Reduce signal fading
- Reduce system cost

DAS may results in complex DTF measurement displays

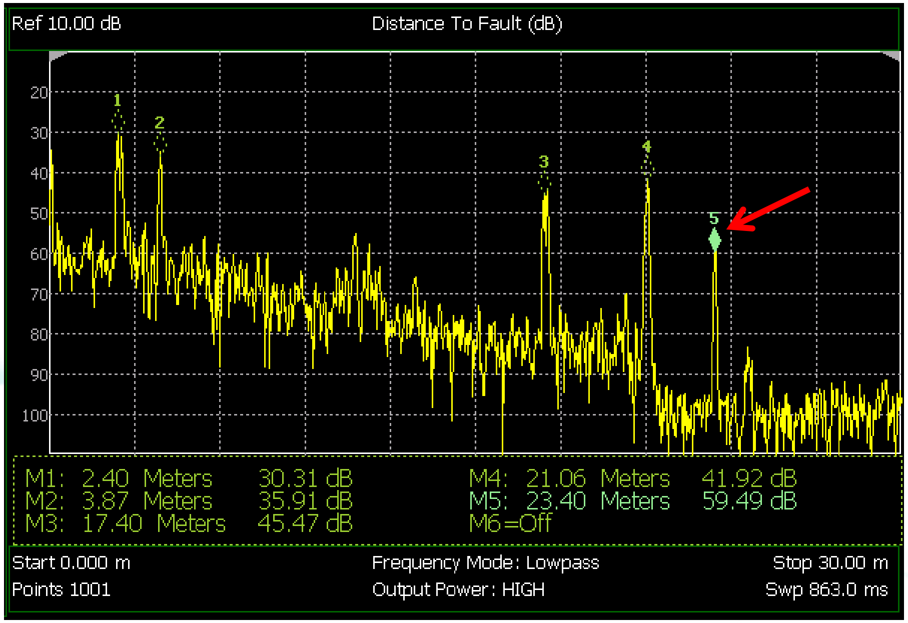
Application Example: DAS Measurement



Baseline

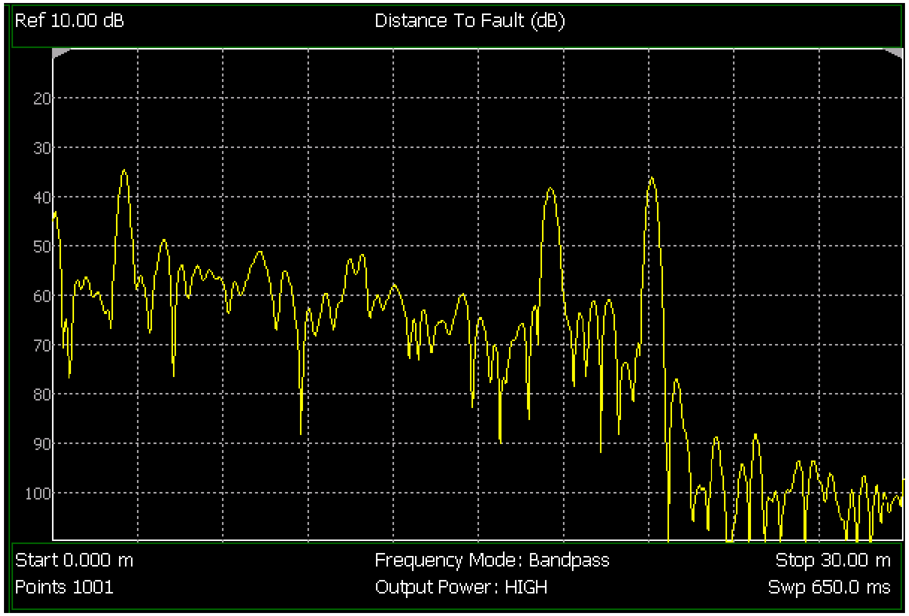


Reported Problem



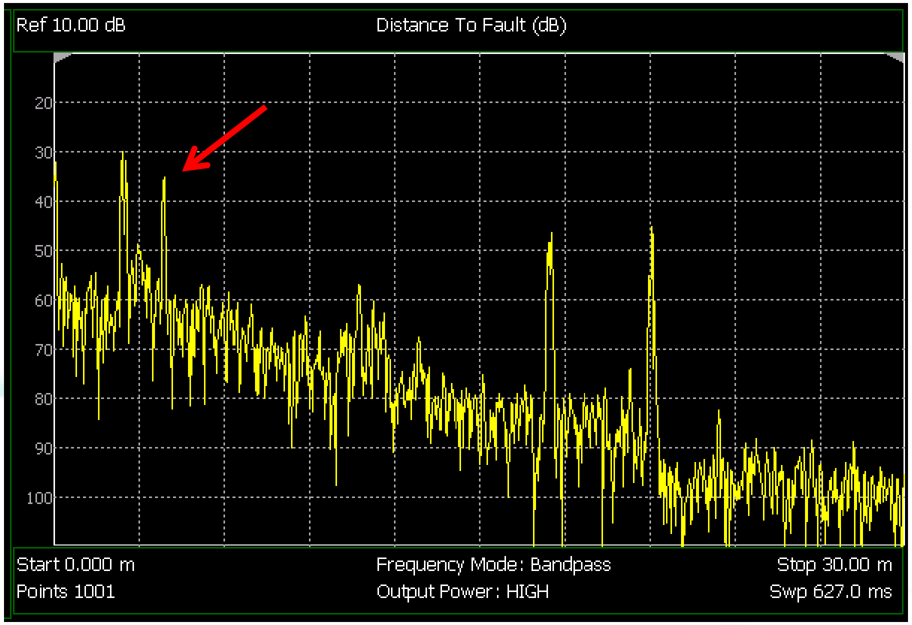
Measured Frequency Span and Resolution

DTF with 1GHz Span



Wide Frequency Span ↔ Improved Distance Resolution

DTF with 6GHz Span



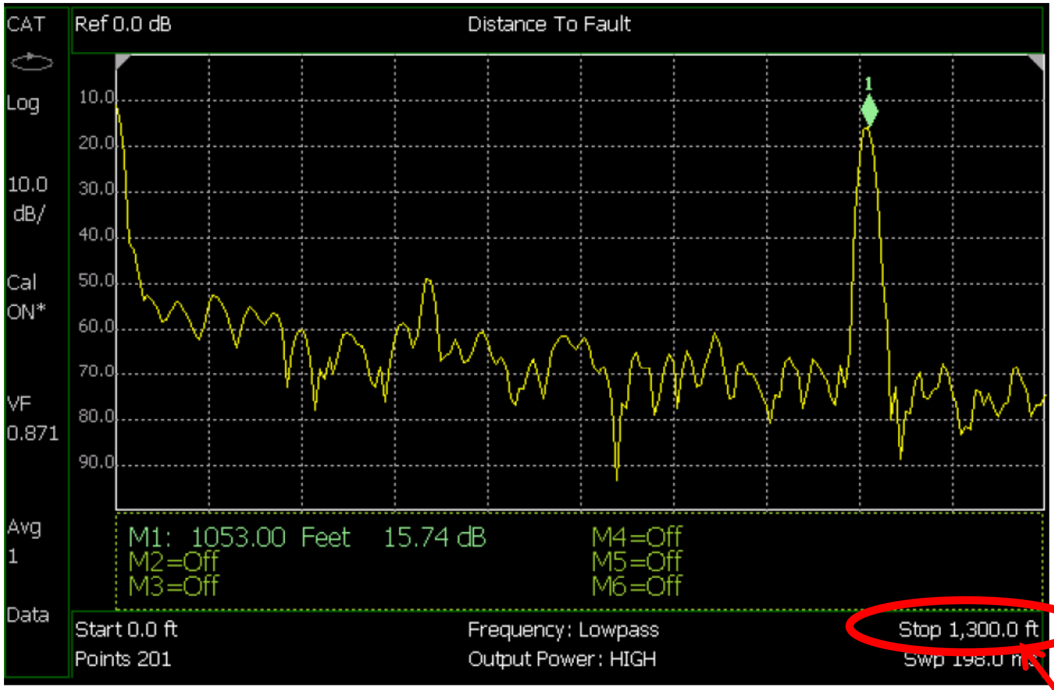
Lowpass Mode

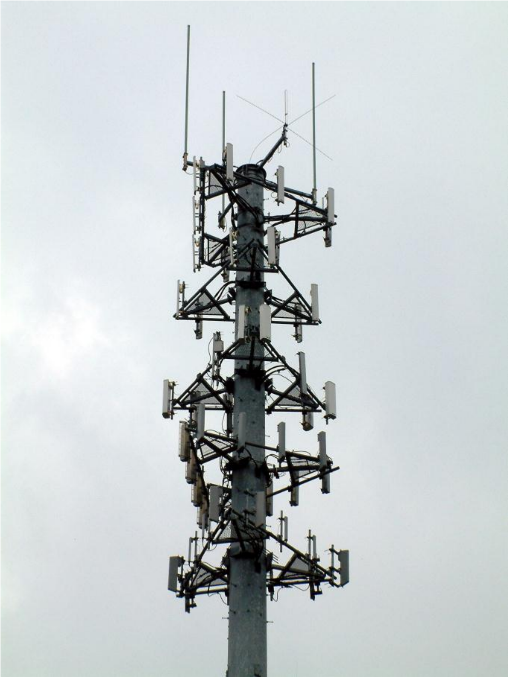
- Highest resolution
- Requires broadband DUT (i.e. cable)

Bandpass Mode

- Lower resolution
- Bandlimited DUT (filter, antenna)

Maximum DTF Distance





Set distance

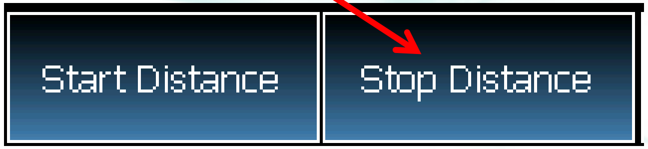
$$\text{Max. DTF Distance} = \frac{\text{VF} \times c \times \text{Points}}{2 \times \text{BW}}$$

$\text{VF} \equiv$ Velocity Factor

$c \equiv$ speed of light

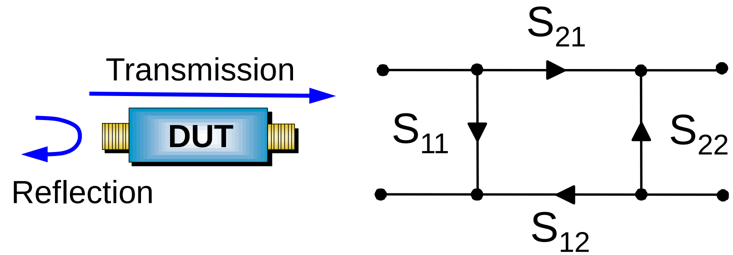
$\text{Points} \equiv$ # of data points

$\text{BW} \equiv$ frequency range



FieldFox Distance Menu

What Are Vector Network Analyzers?



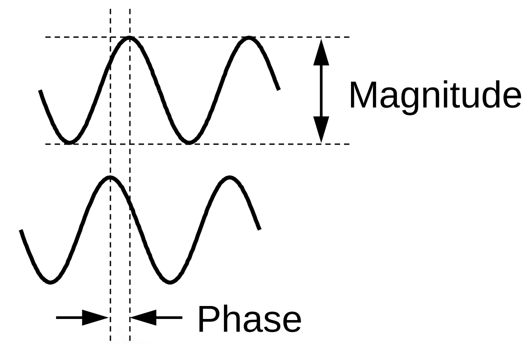
Are stimulus-response test systems

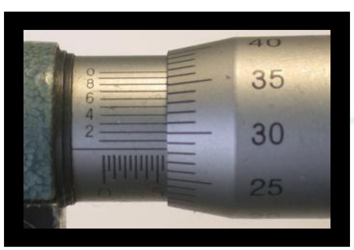
Characterize forward and reverse reflection and transmission responses (S-parameters) of RF and microwave components

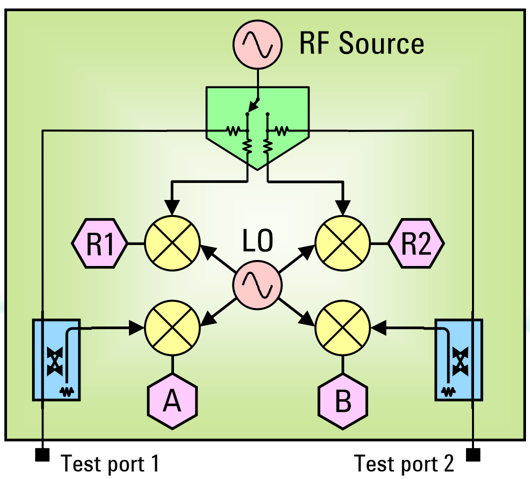
Quantify linear magnitude and phase

Are very fast for swept measurements

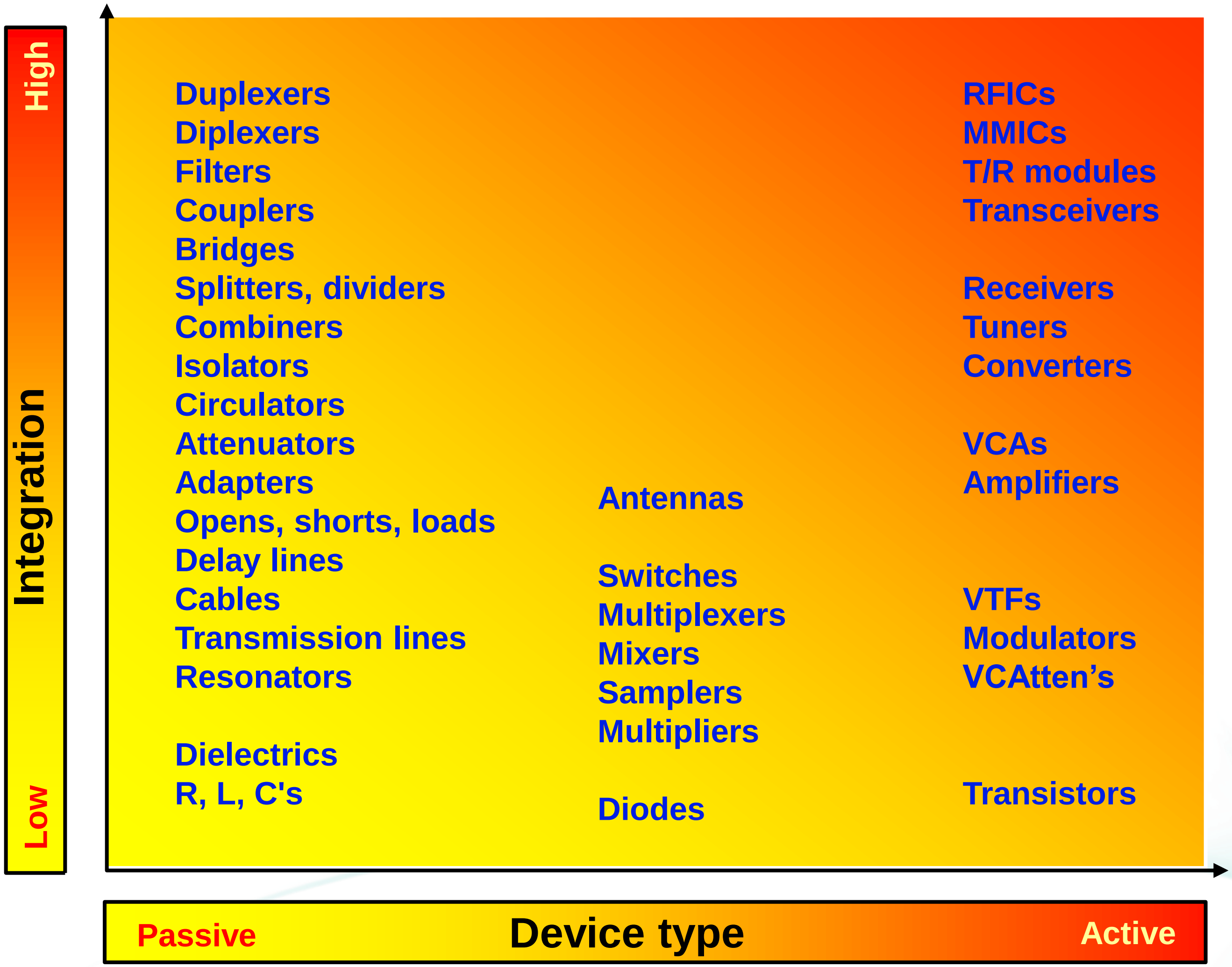
Provide the highest level of measurement accuracy







What Types of Devices are Tested?



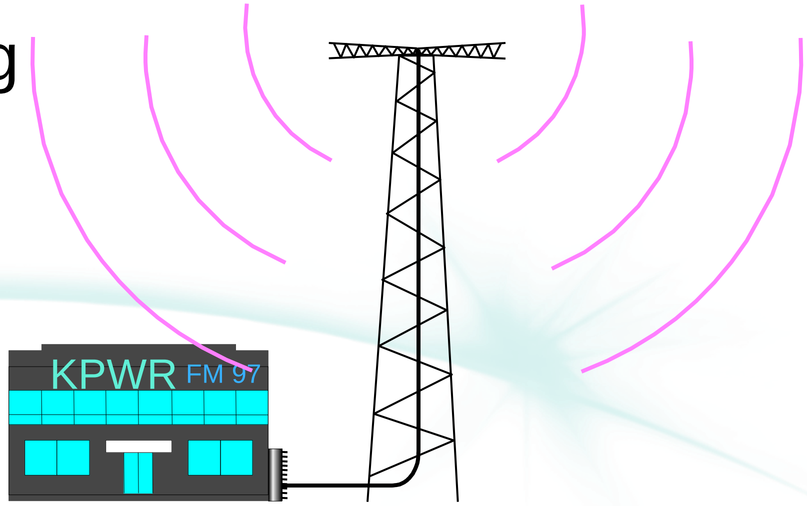
Why Do We Need to Test Components?

Verify specifications of "building blocks" for more complex RF systems

Ensure distortionless transmission of communications signals

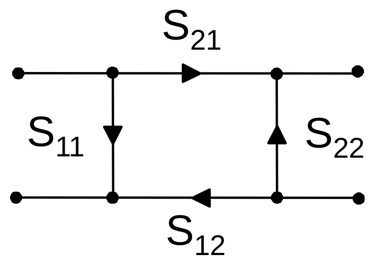
- Linear: constant amplitude, linear phase / constant group delay
- Nonlinear: harmonics, intermodulation, compression, X-parameters

Ensure good match when absorbing power (e.g., an antenna)

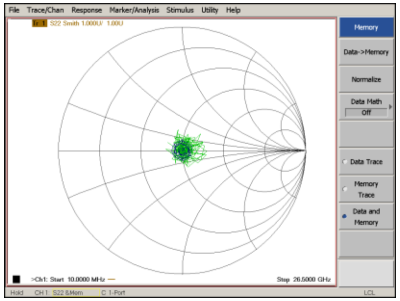


The Need for Both Magnitude and Phase

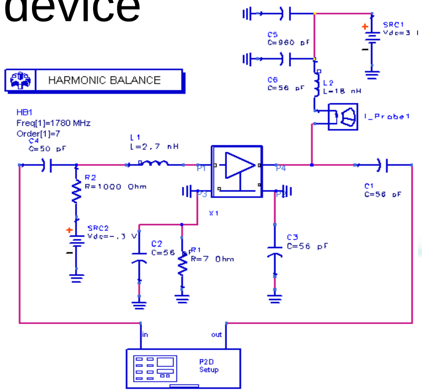
1. Complete characterization of linear networks



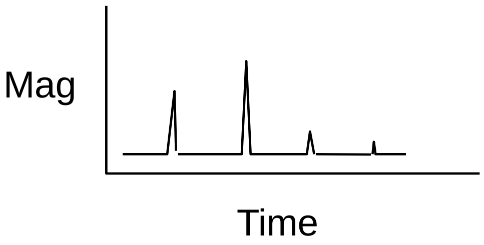
2. Complex impedance needed to design matching circuits



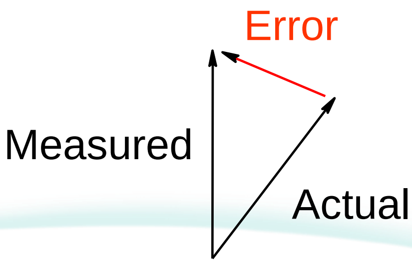
3. Complex values needed for device modeling



4. Time-domain characterization



5. Vector-error correction

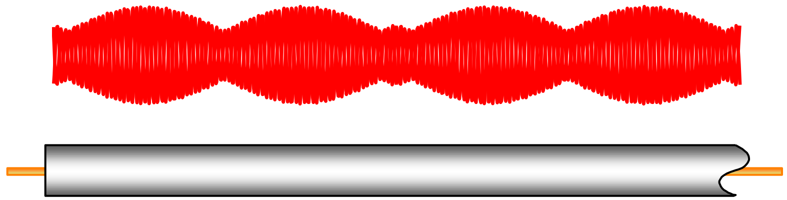


6. X-parameter (nonlinear) characterization

Transmission Line Basics

Low frequencies

- Wavelengths >> wire length
- Current (I) travels down wires easily for efficient power transmission
- Measured voltage and current not dependent on position along wire



High frequencies

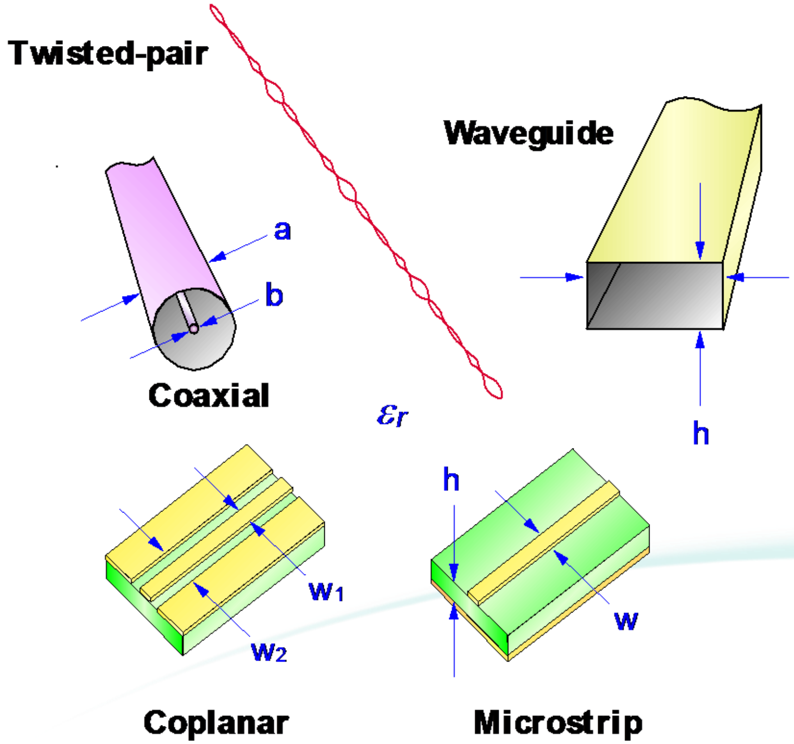
- Wavelength ≈ or << length of transmission medium
- Need transmission lines for efficient power transmission
- Matching to characteristic impedance (Z_o) is very important for low reflection and maximum power transfer
- Measured envelope voltage dependent on position along line

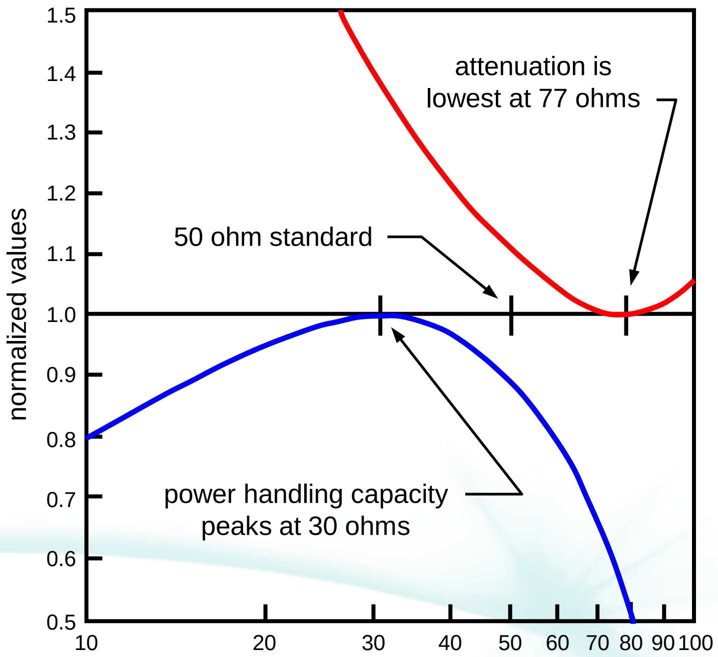
Transmission line Z_o

Z_o determines relationship between voltage and current waves

Z_o is a function of physical dimensions and ε_r

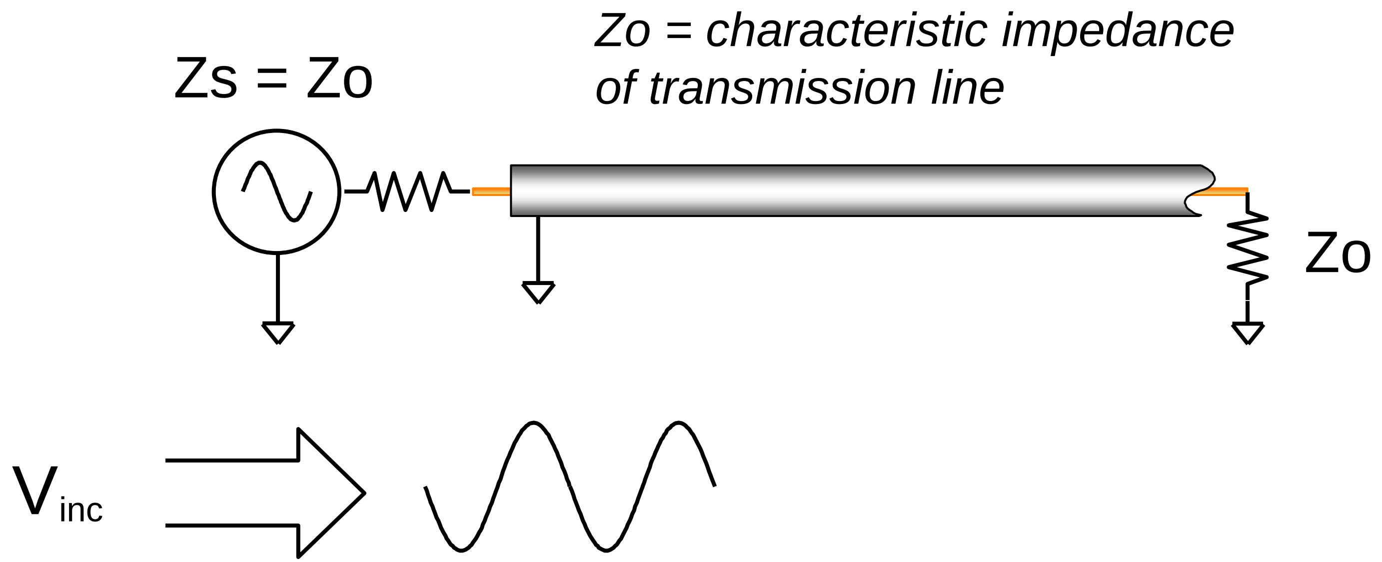
Z_o is usually a real impedance (e.g. 50 or 75 ohms)





Characteristic impedance for coaxial airlines (ohms)

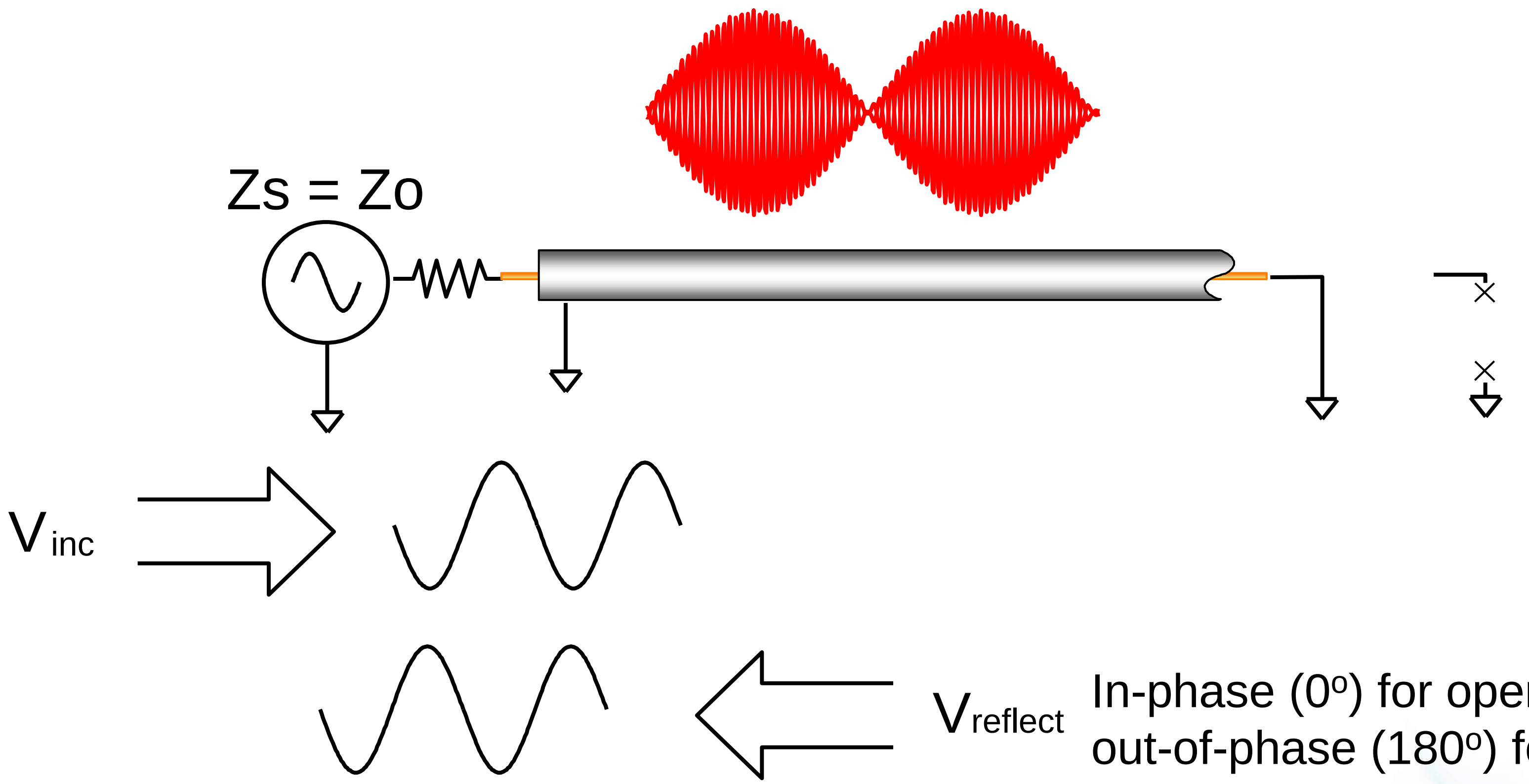
Transmission Line Terminated with Zo



$V_{reflect}$ = 0! *(all the incident power is transferred to and absorbed in the load)*

For reflection, a transmission line terminated in Zo behaves like an infinitely long transmission line

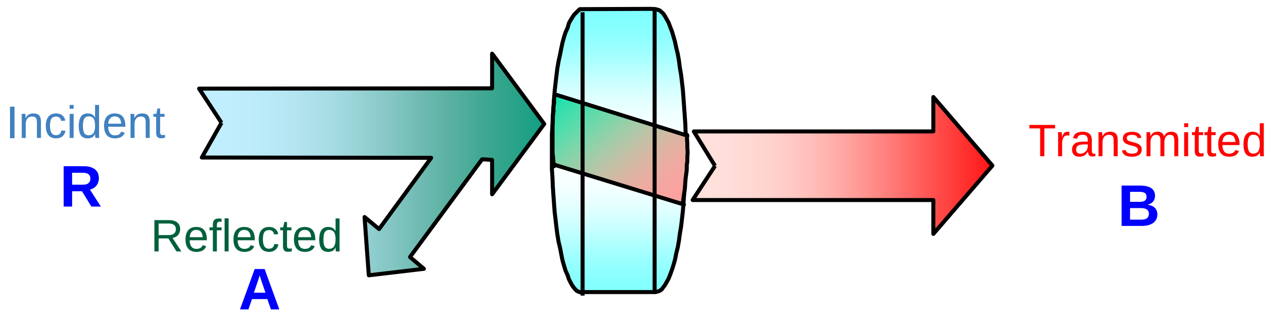
Transmission Line Terminated with Short, Open



In-phase (0º) for open,
out-of-phase (180º) for short

For reflection, a transmission line terminated in a short or open reflects all power back to source

High-Frequency Device Characterization



REFLECTION

$$\frac{\text{Reflected}}{\text{Incident}} = \frac{A}{R}$$

- VSWR
- S-Parameters S_{11}, S_{22}
- Reflection Coefficient Γ, ρ
- Impedance, Admittance R+jX, G+jB
- Return Loss

TRANSMISSION

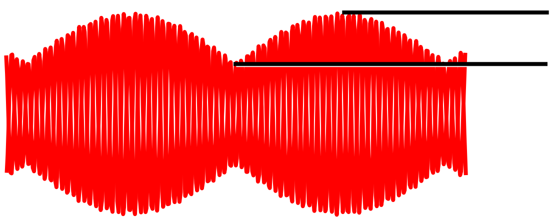
$$\frac{\text{Transmitted}}{\text{Incident}} = \frac{B}{R}$$

- Gain / Loss
- S-Parameters S_{21}, S_{12}
- Transmission Coefficient T, τ
- Insertion Phase
- Group Delay

Reflection Parameters

Reflection Coefficient $\Gamma = \dfrac{V_{reflected}}{V_{incident}} = \rho \angle \Phi = \dfrac{Z_L - Z_o}{Z_L + Z_o}$

Return loss $= -20 \log(\rho), \ \rho = |\Gamma|$



Voltage Standing Wave Ratio

$$\textbf{VSWR} = \frac{V_{max}}{V_{min}} = \frac{1 + \rho}{1 - \rho}$$

No reflection
(Z_L = Zo)

Full reflection
(Z_L = open, short)

0	ρ	1
∞ dB	**RL**	0 dB
1	**VSWR**	∞

FieldFox – Superior Integration & Precision

Ten Instruments in One (30kHz to 26.5GHz)

1. Cable Antenna Tester (CAT) with CalReady and QuickCal
2. Full 2-Port VNA for all 4 S-parameters, magnitude and phase
3. Spectrum Analyzer with unprecedented accuracy – no warm-up
4. Tracking generator, independent source and preamplifier covering full frequency range
5. Interference analyzer & recorder
6. Built-in power-meter
7. Power meter using ext. power sensor (to 40GHz)
8. Vector Voltmeter for cable trimming
9. Built-in GPS receiver
10. DC-bias supply & current monitor

Portable - Pick up FieldFox for its Ergonomics

Weighing 3.0 kg, practical for **one hand operation**

No fans or vents for a completely sealed instrument for harshest environments + **3-year standard warranty**

10 Instruments in One for less equipment in the field and *fastest time to First Measurement* for a field engineer

Bright, low-reflective display and **backlit keys** for easy viewing in darkness or direct sunlight

One-button measurements simplify complex setups and **Cal Wizard** ensures quick, accurate calibrations in the field without the need for a Cal kit

Take Precision With You
Measurements correlate with accuracy of bench top instruments

Li-Ion battery <3.5 hours with stand-by mode for +4 hours

…and Depend on its Durability

Specially designed connector bay protects connectors from damage due to drops or other external impacts

Gasketed doors protect connectors from dust and moisture

Transfer and archive data through LAN, USB and SD card

Type tested to **IP53** for resistance to dirt/dust and water ingress

Operation -10 to +55ºC
Storage: -51 to +71 ºC

Agilent Technologies

New: Remote control capability option-030 *FREE OFFER**

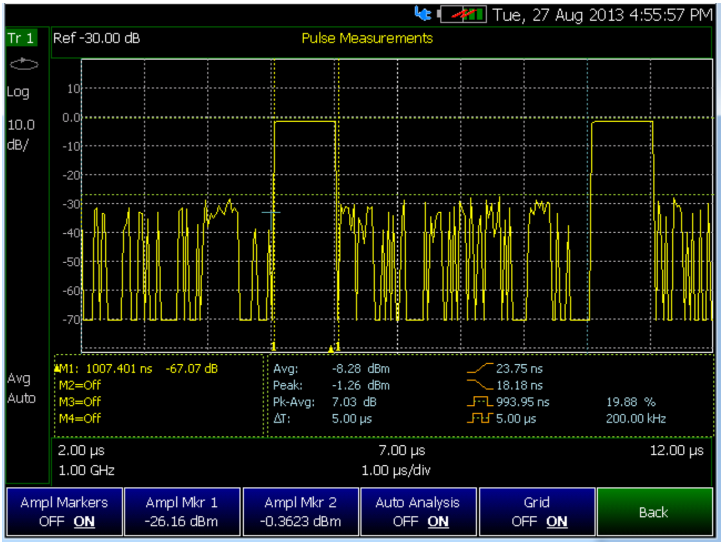
- Allows any user to deploy RF instrument to hard to reach location
- Monitor signals from various locations

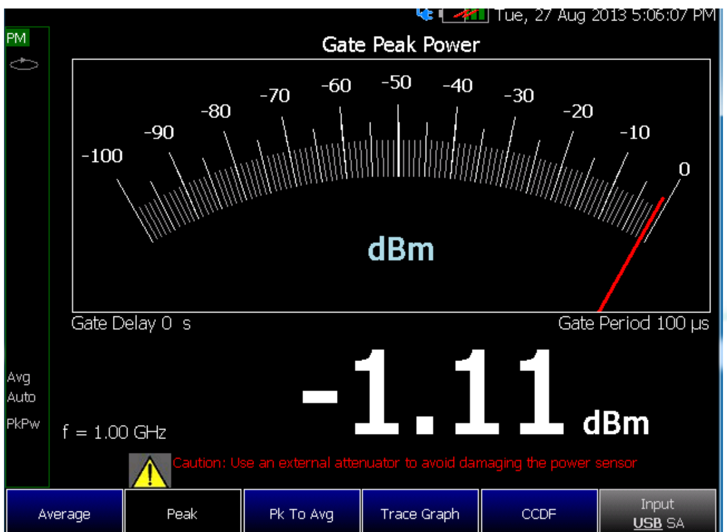
1. Remote control fieldfox via WLAN and cellular broadband data connection using iPad and iPhone
2. Access User Guides, data sheets and tutorial videos via Internet
3. The app is Free to download from Apple store.

For all FieldFox model

* Until Dec 31

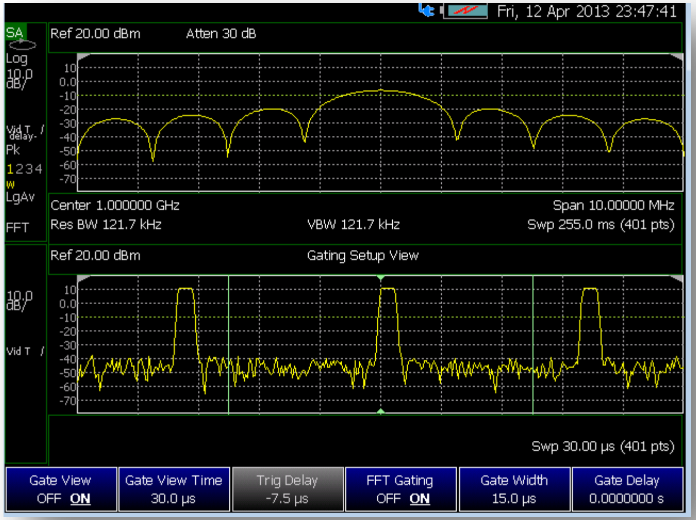
New: Pulse Measurement option - 330





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

New: Spectrum analyzer pulse measurements –option 238



- Capable of RF pulse measurements 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

New accessories: For Field Testing Faster and Easier

1. N9911X C, X, Ku and K band waveguide calibration kits
   - Supports both 1 port and 2 port calibrations

2. eCal support
   - Supports Agilent N4430, 85092 and N6490 series eCal modules

3. N9910X option 820 Handheld broadband directional antenna
   - Frequency: 400MHz to 27GHz

End of part 2