FieldFox Handheld Education Series Part 4: Techniques for Precise Time Domain Measurements in the Field

FieldFox Handheld Education Series

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

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Business Development Engineer

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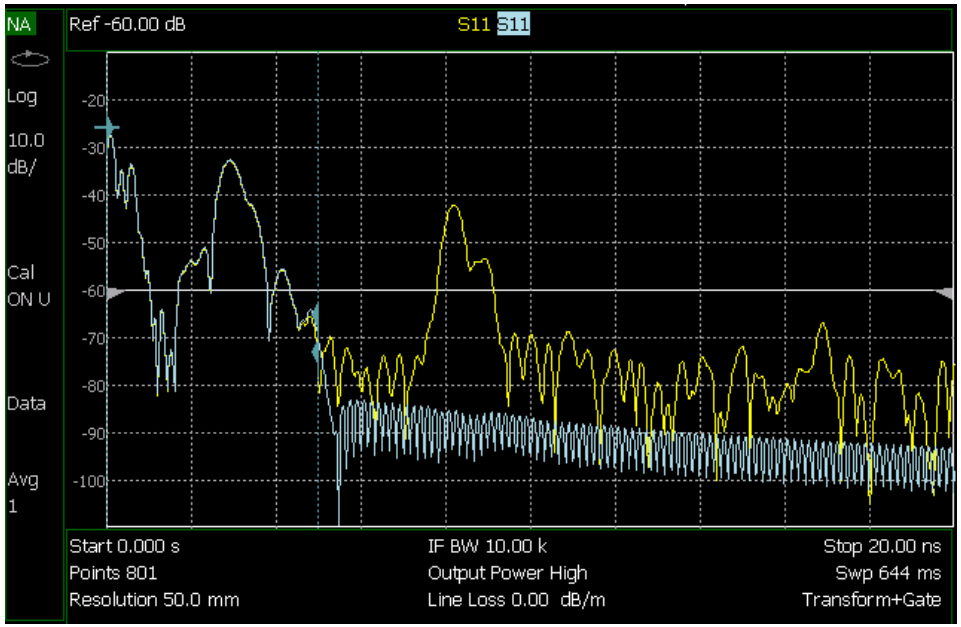
Techniques for Precise Time Domain Measurements in the Field

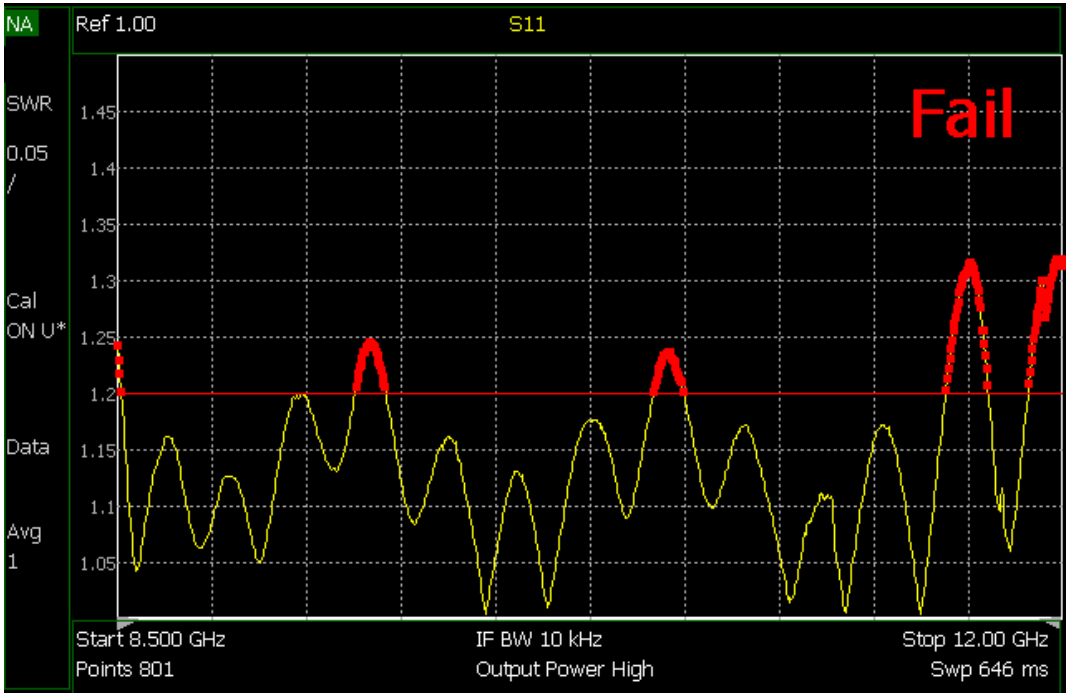


Outline

- Frequency and Time Domain Testing
- Instruments with Time Domain Capability
- Frequency to Time Transformation
- Time Gating
- Masking Effects
- Distance to Fault Calculations
- Optimizing Time Domain Measurements

Frequency Domain Response

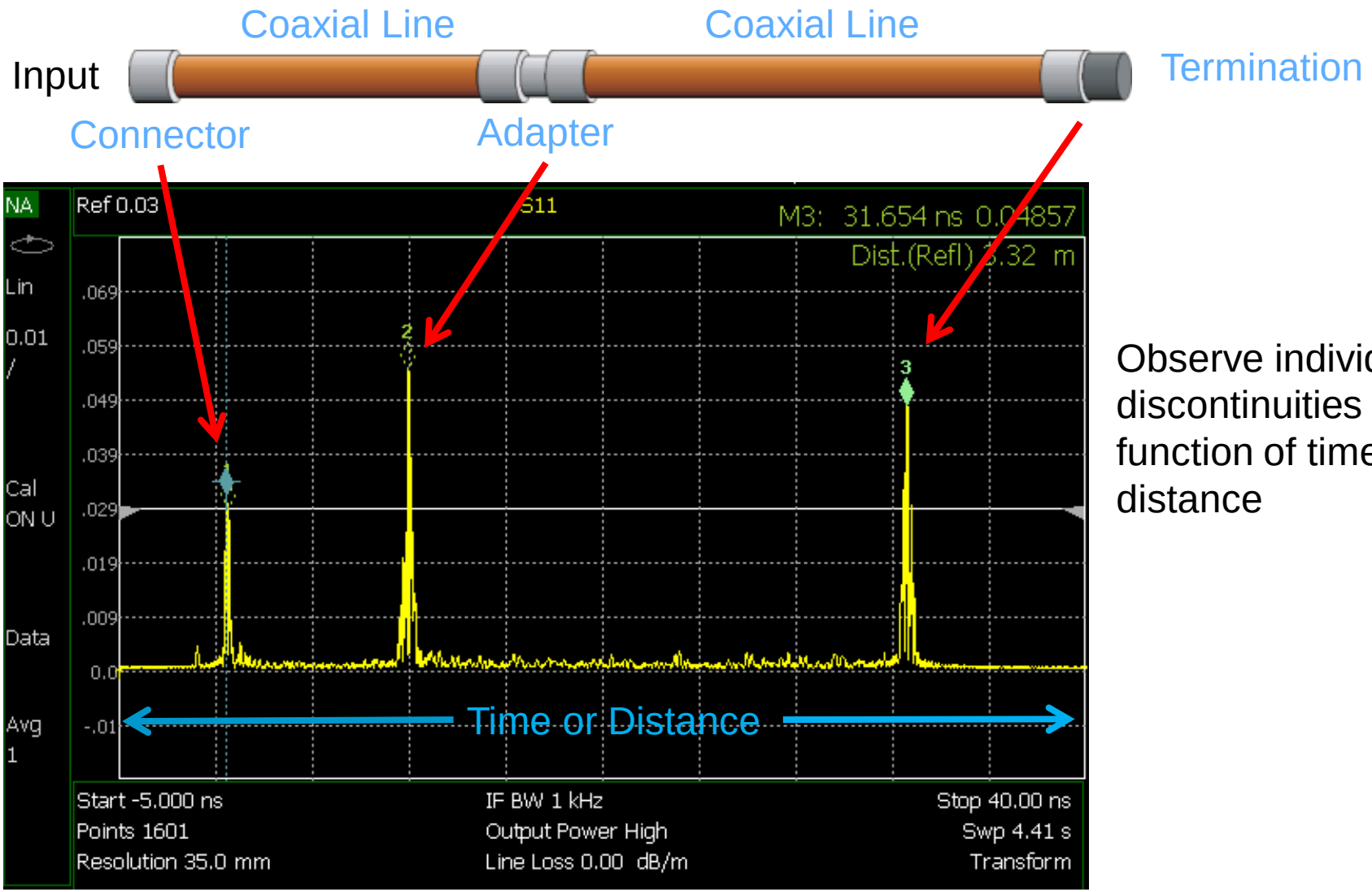
Measured VSWR of complete system



Which component is causing the problem ?

Where is the fault located ?

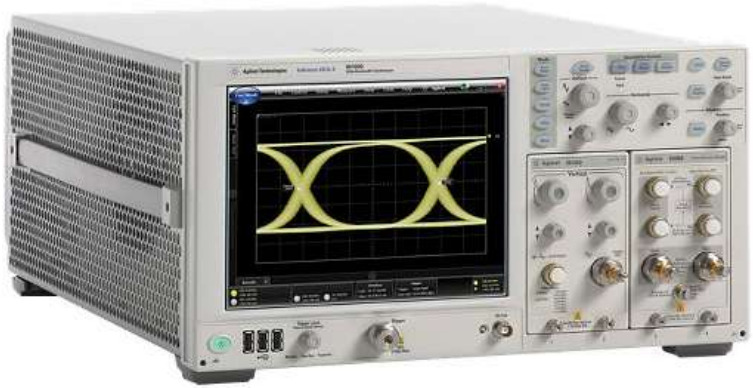
Time Domain Response



Observe individual discontinuities as a function of time or distance

Equipment Types with Time Domain Capability

Time Domain Reflectometer (TDR)



86100D DCA with 54754A TDR Module

- True time-sampled measurements
- Step Generator with fast rise time
- Oscilloscope-based

Vector Network Analyzer (VNA)

Cable and Antenna Test (CAT) Analyzer

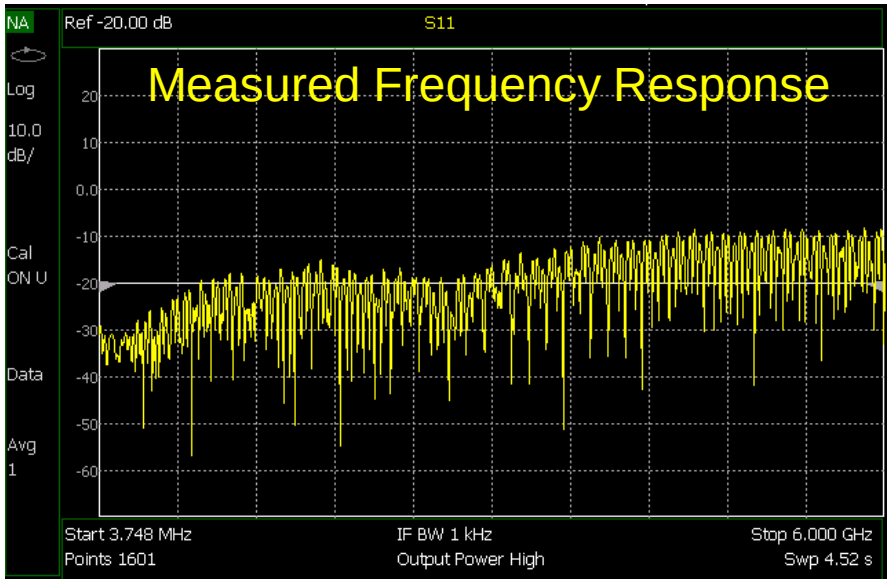
N9918A FieldFox
30 kHz to 26.5 GHz

- Swept frequency measurements
- Transform to time domain
- High dynamic range receiver
- Measure band-limited devices

Measured Frequency to Time Transformation

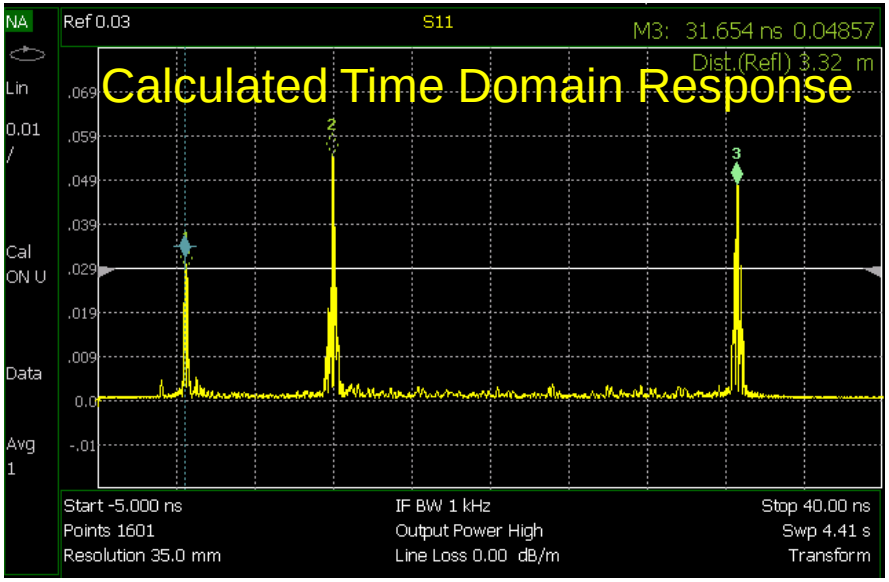
FieldFox
VNA or CAT

Device under test (DUT)

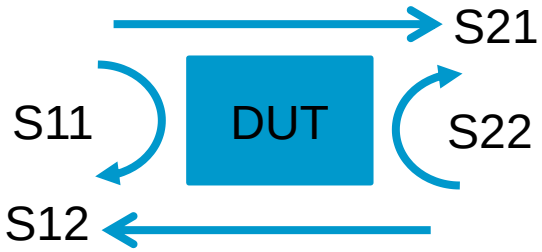


Measure S-parameter (e.g. S11 shown here)

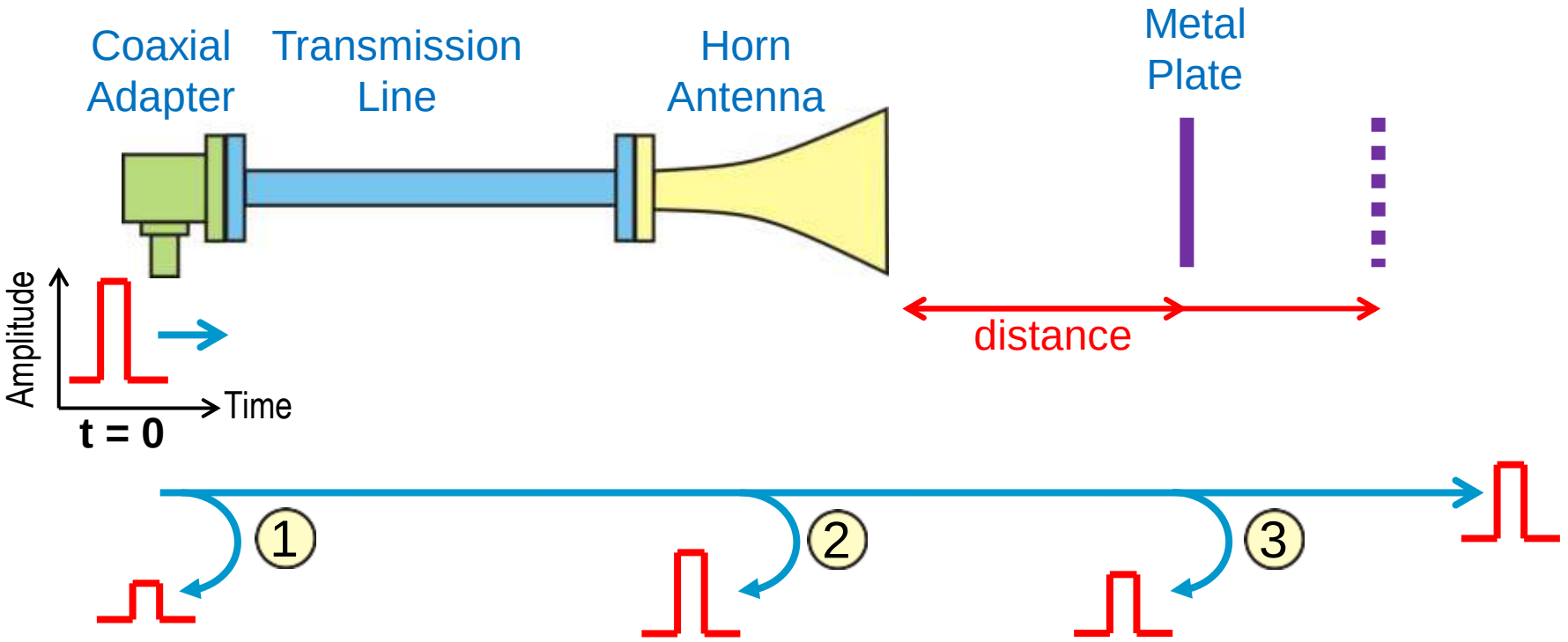
Activate Time Transform on VNA



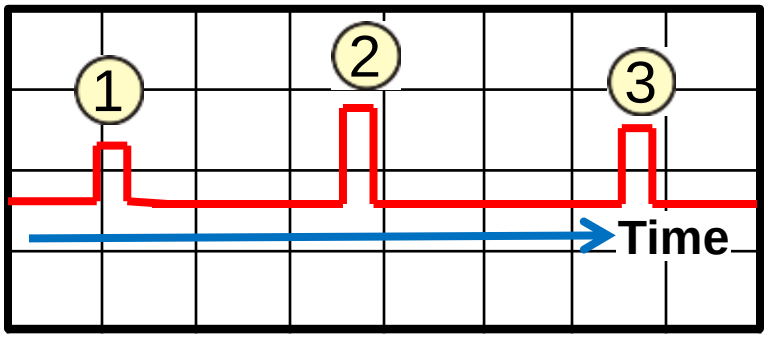
Perform Time Transform on any S-parameter



Time Domain Example



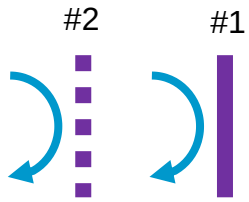
Time Domain Display

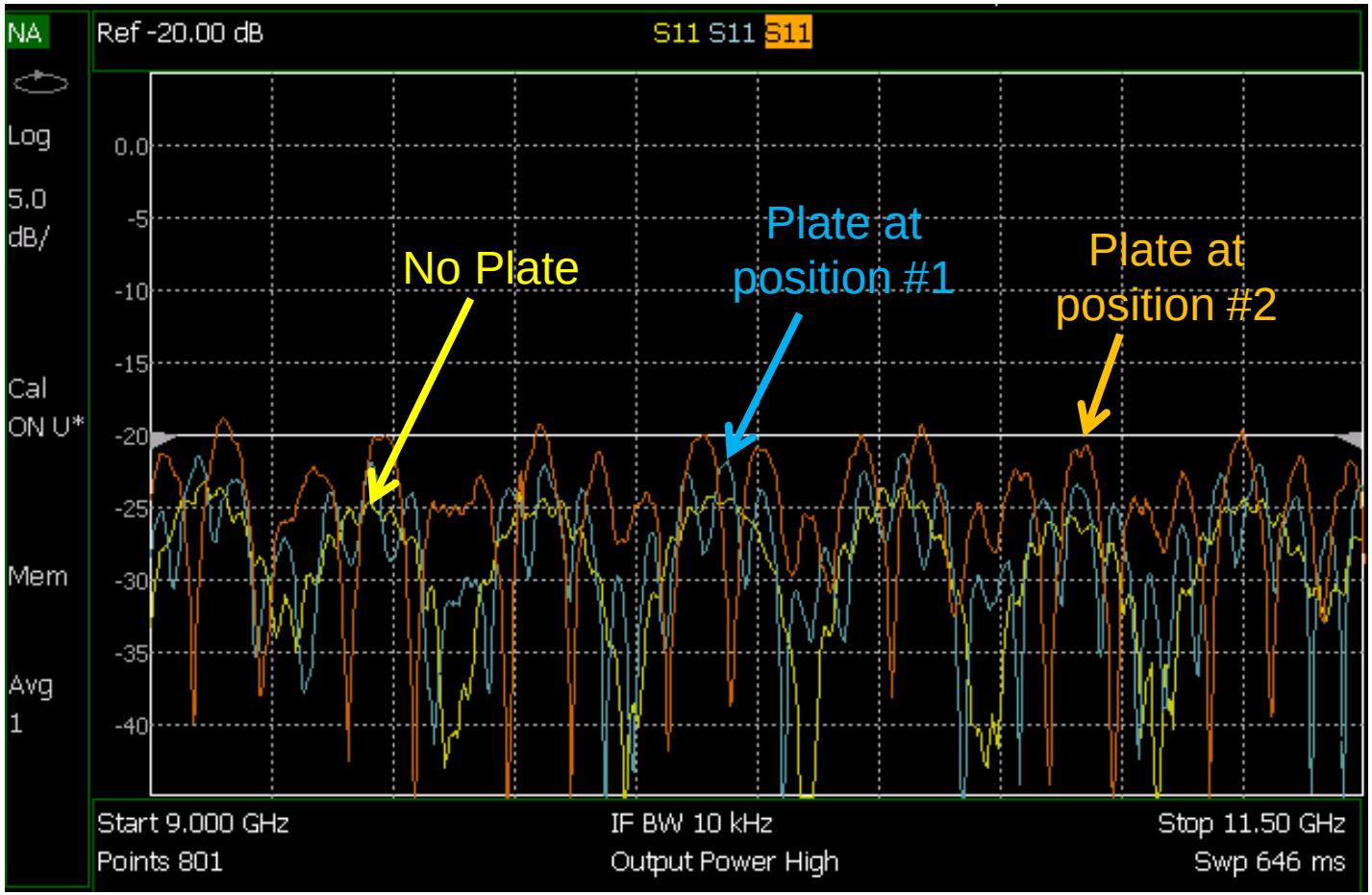


- Identify discontinuities
- Large reflections are typically the problem
- Time delay is round trip

Measured Frequency Response

Begin with the frequency response of S11

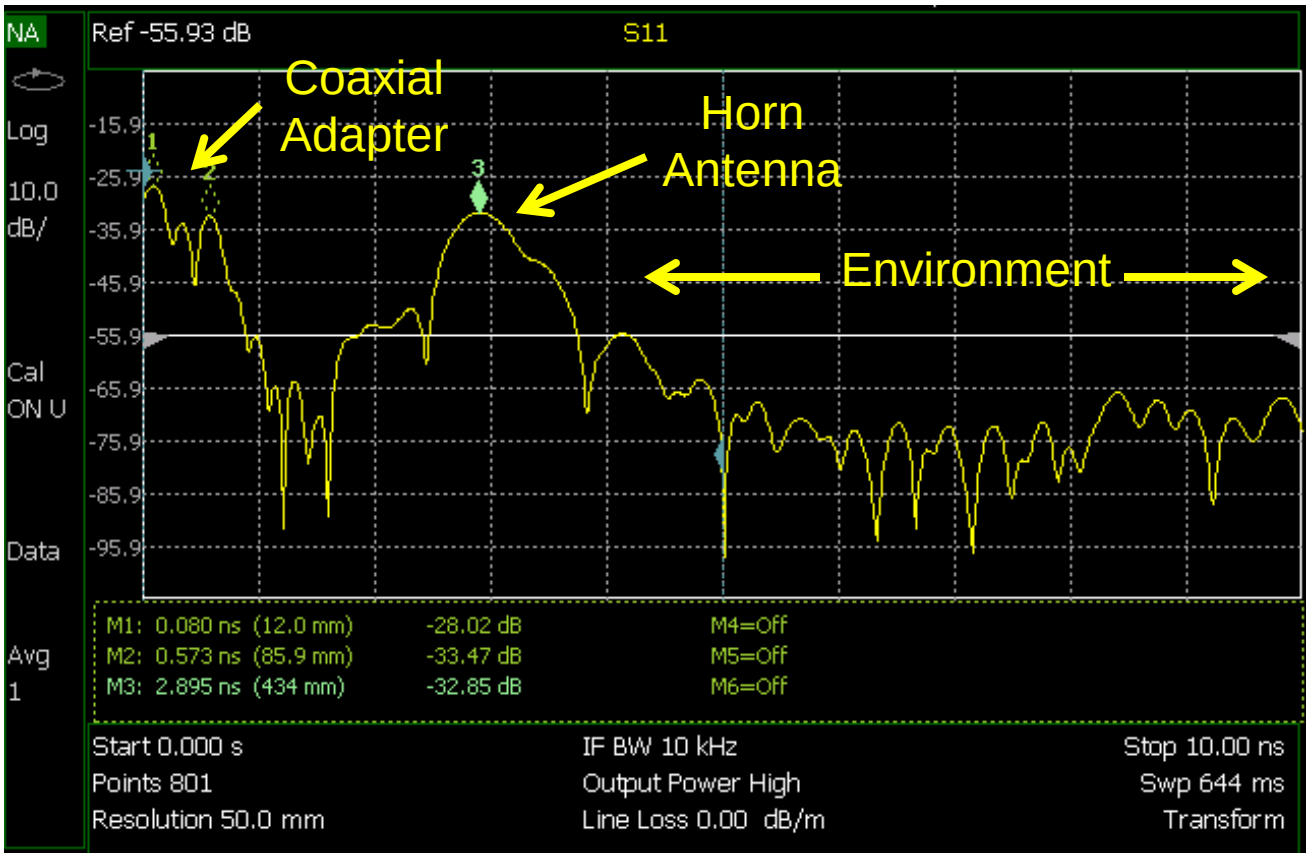




Reflections from environment create additional ripple in frequency response

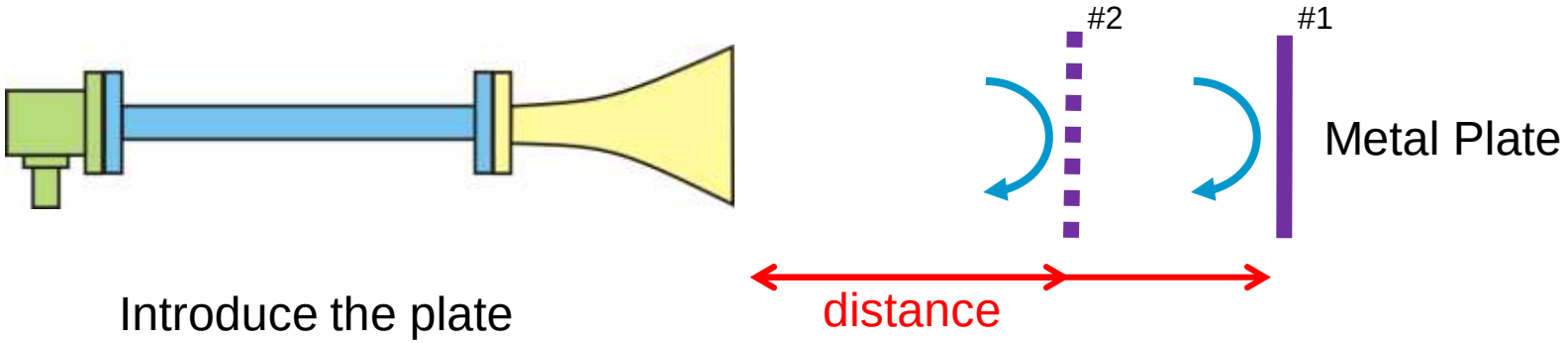
Time Domain Transform – No Plate

Transform into the time domain

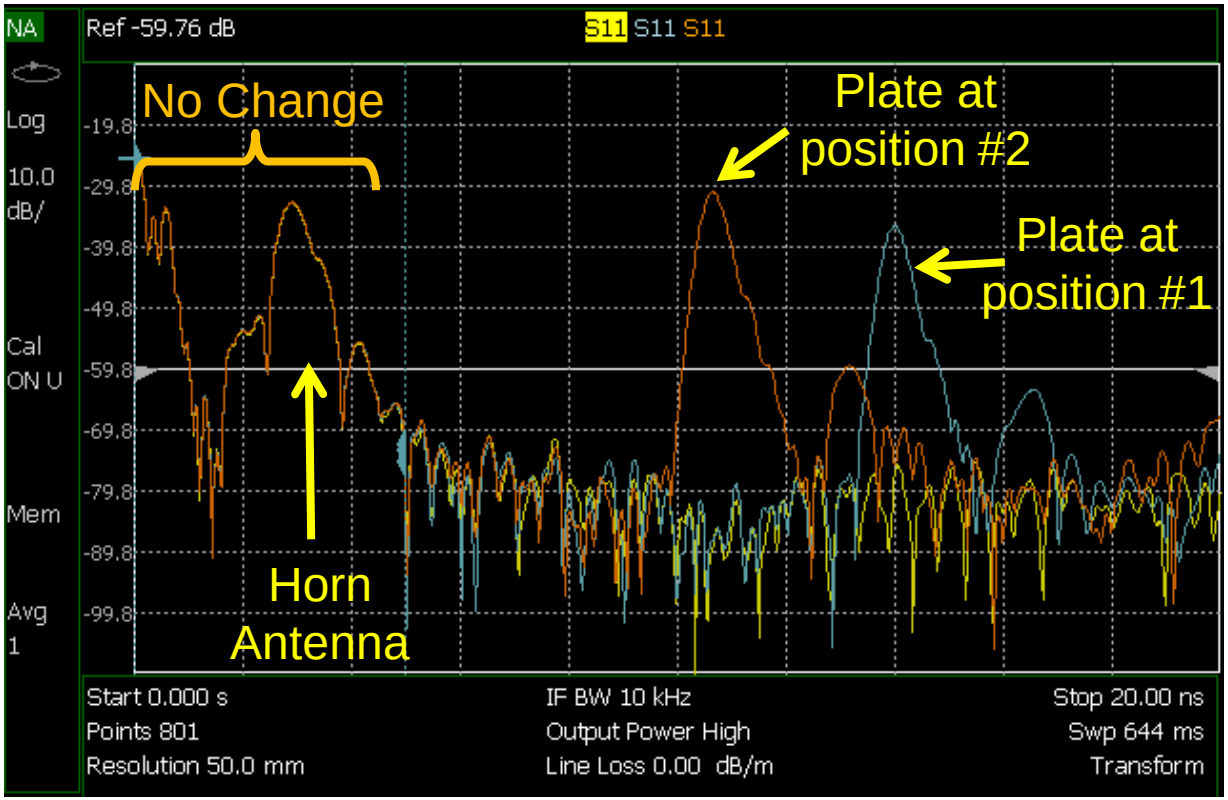


- Locate discontinuities as a function of time
- Time resolution is proportional to pulse width

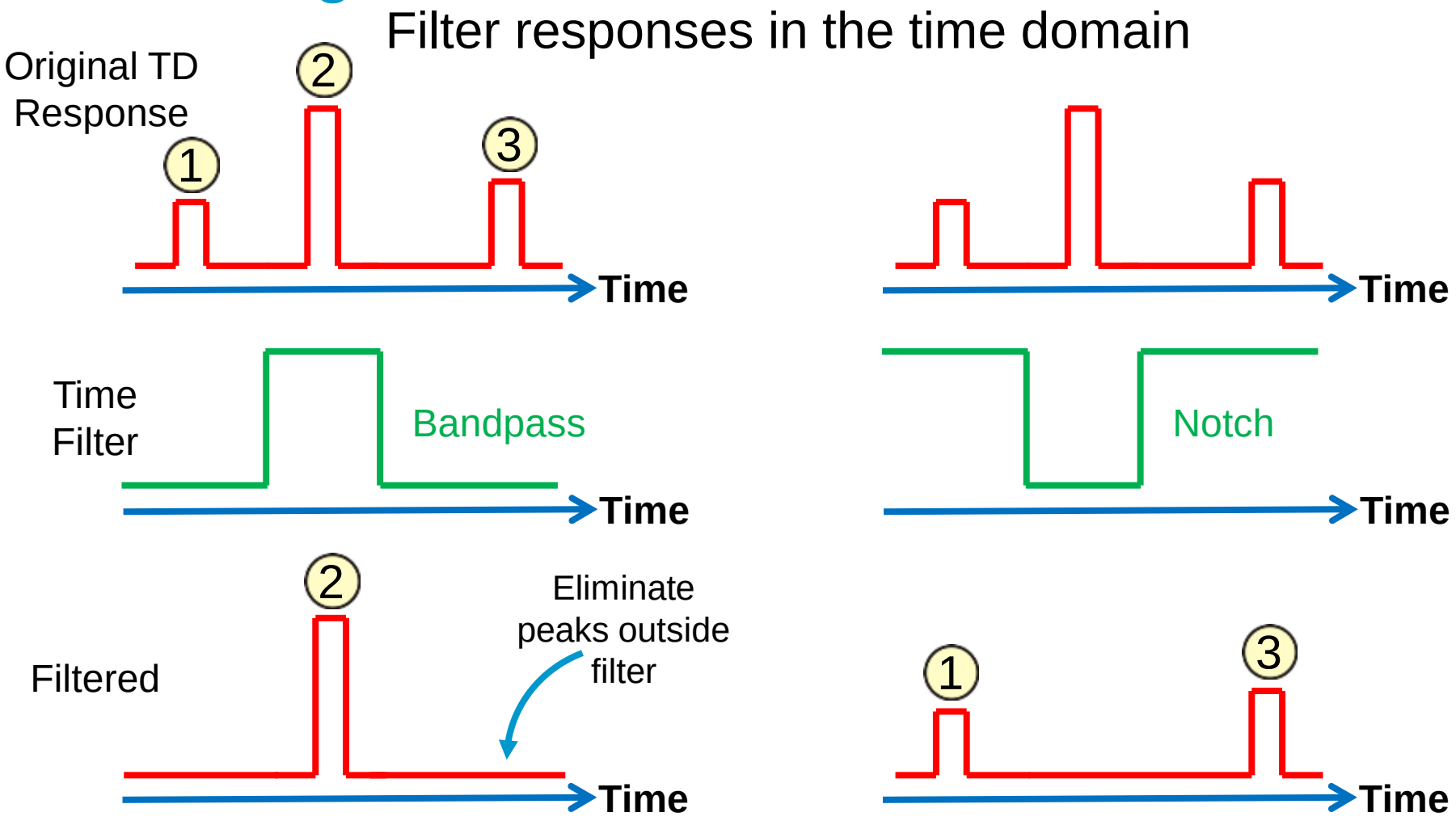
Time Domain with Environment Reflections



Introduce the plate

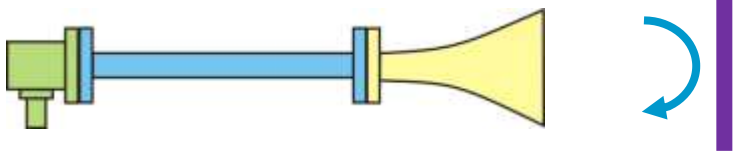


Time Gating

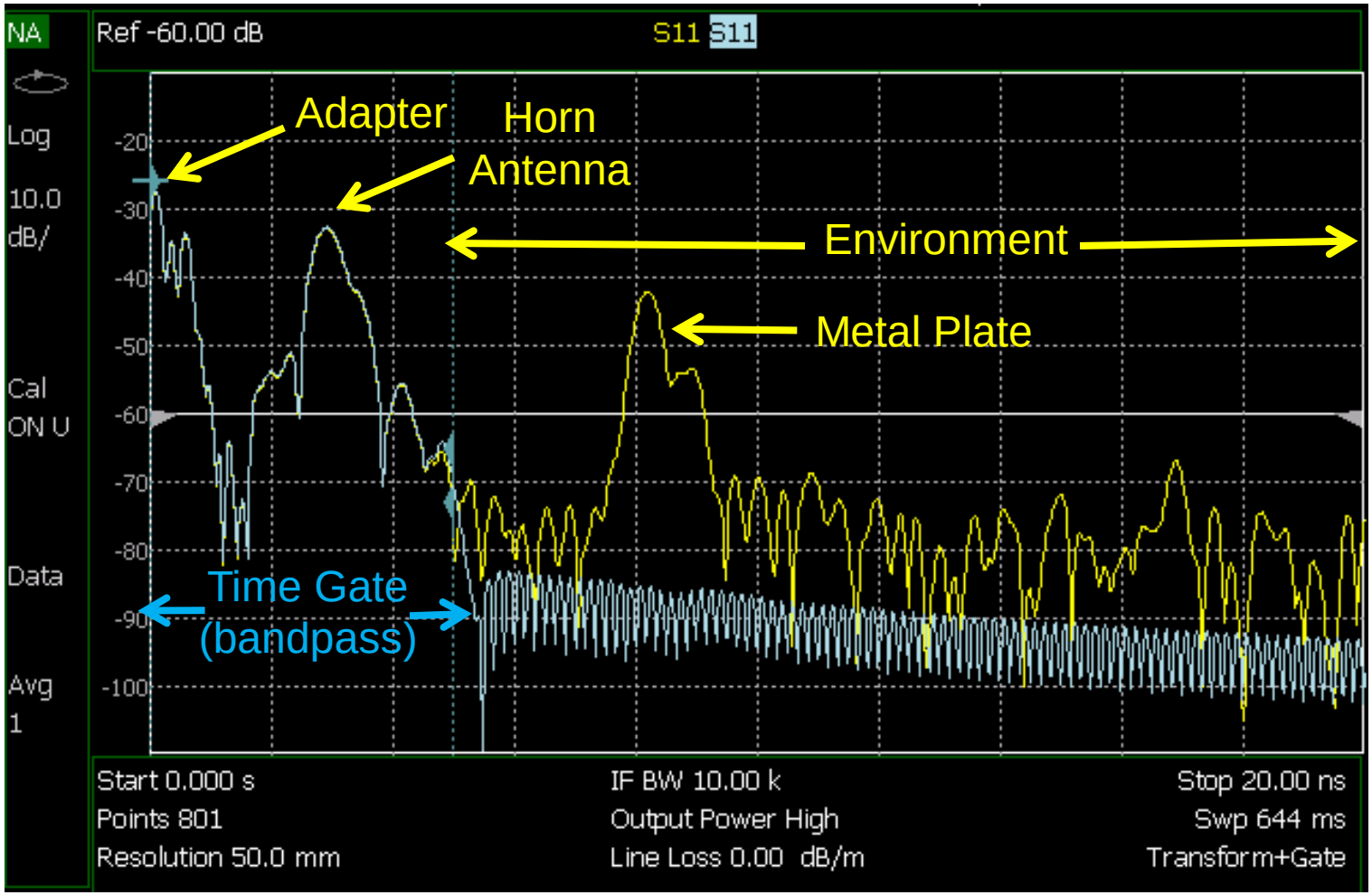


Examine frequency response of time filtered signal

Gating in the Time Domain

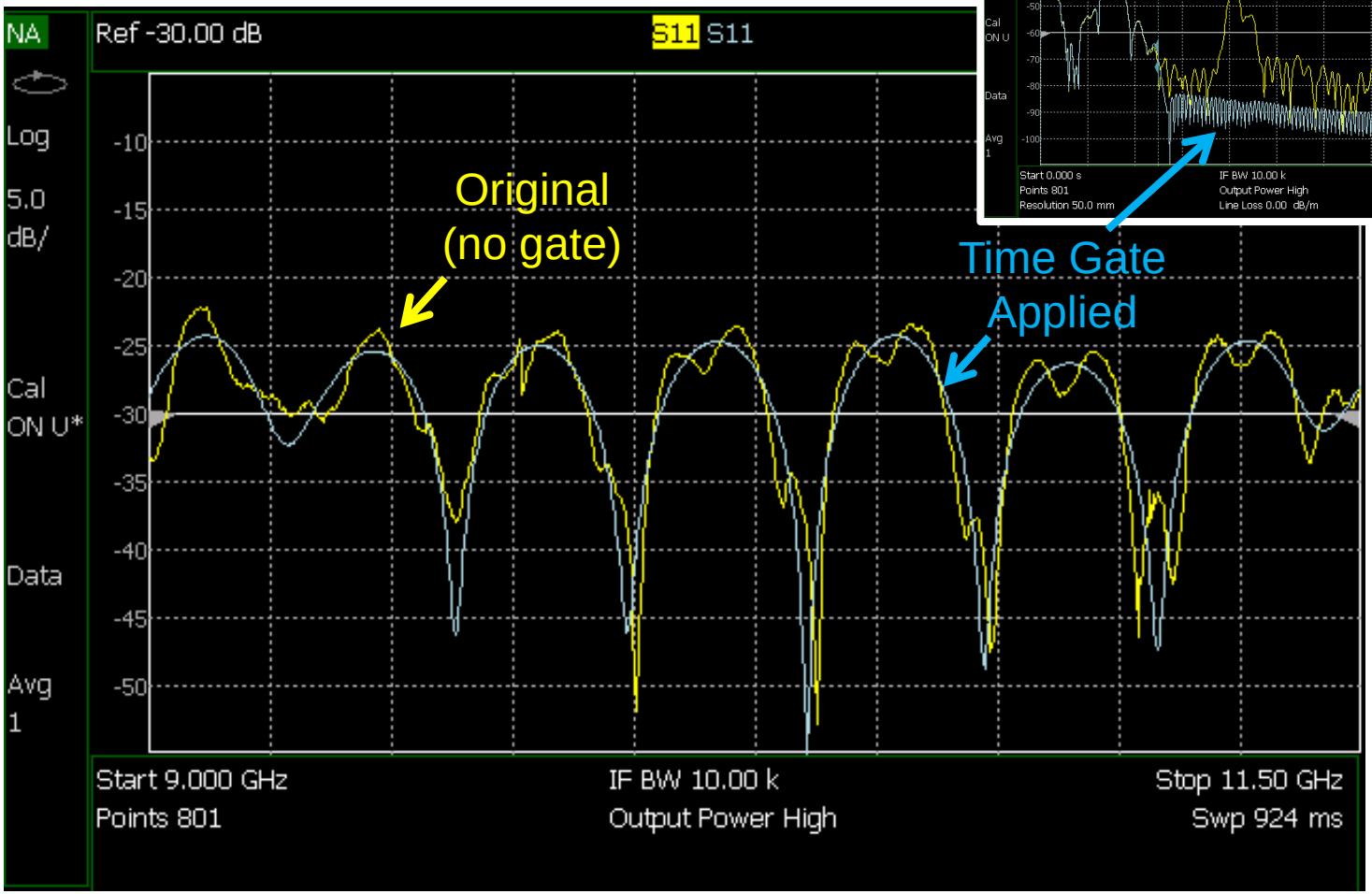


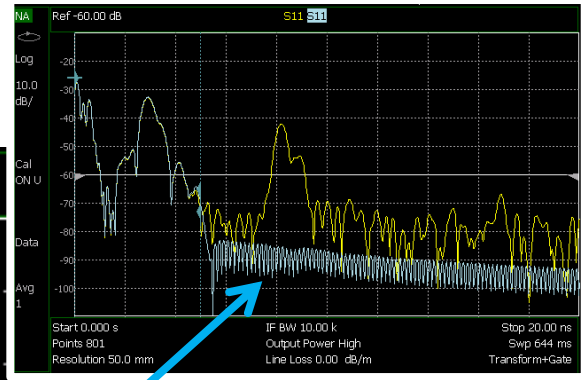
Filter unwanted reflections



Gating in the Frequency Domain

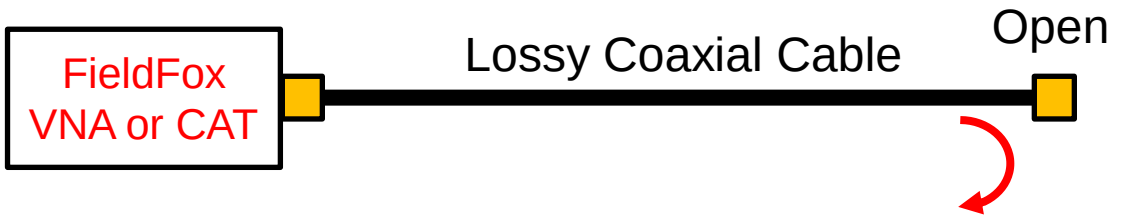
Return to frequency domain with gate active



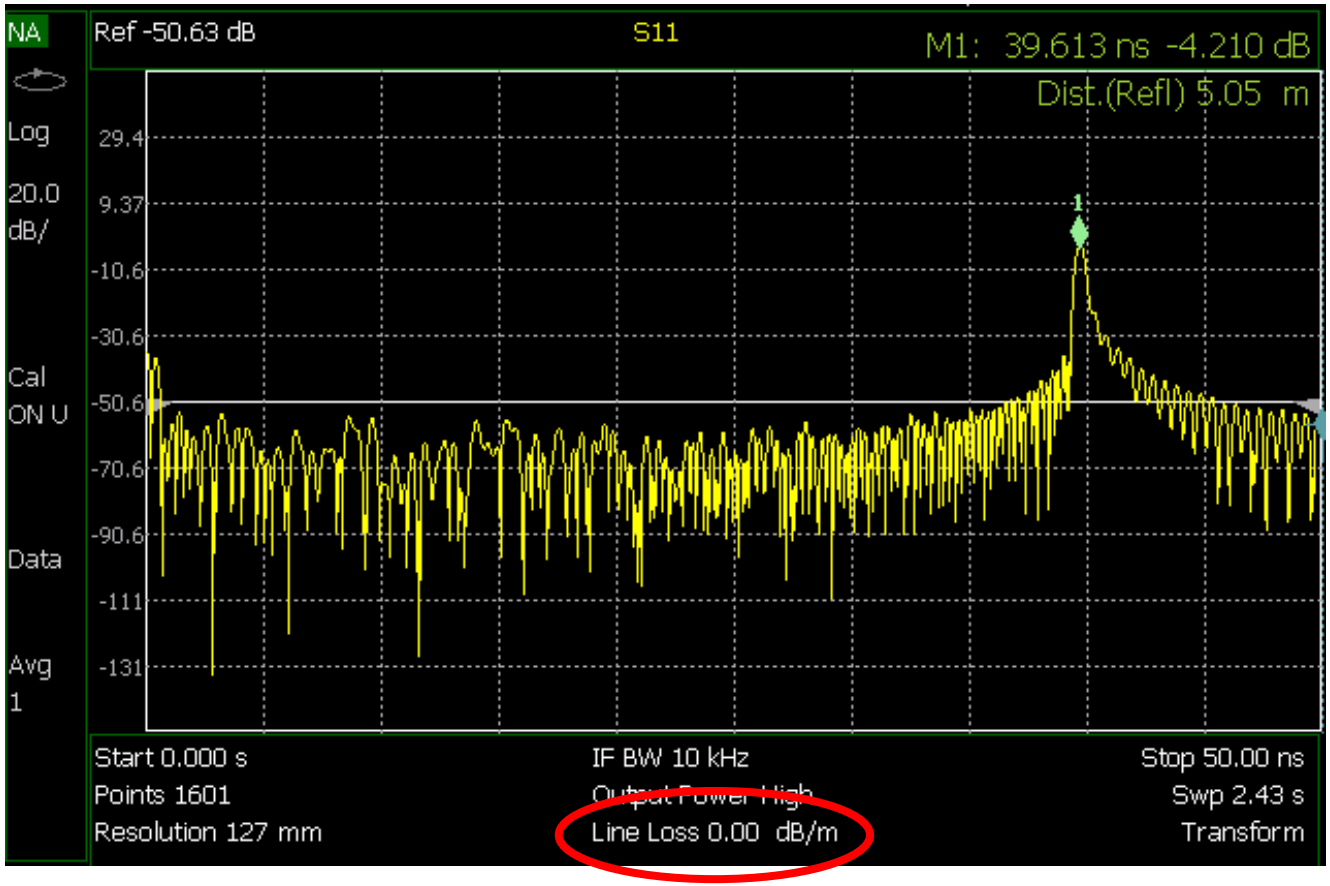


Remove undesired reflections from the frequency measurement

Masking in Coaxial Lines



Cable insertion loss reduces the amplitude of the measured signal

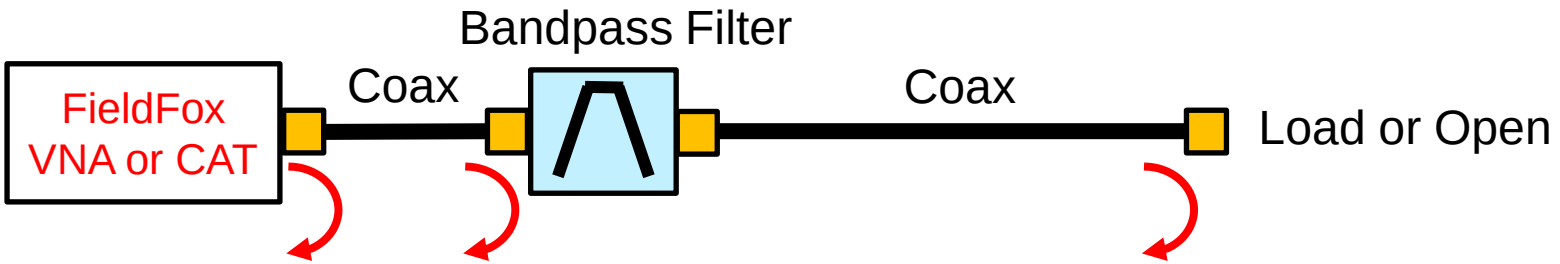


Enter average cable loss factor (db/m)

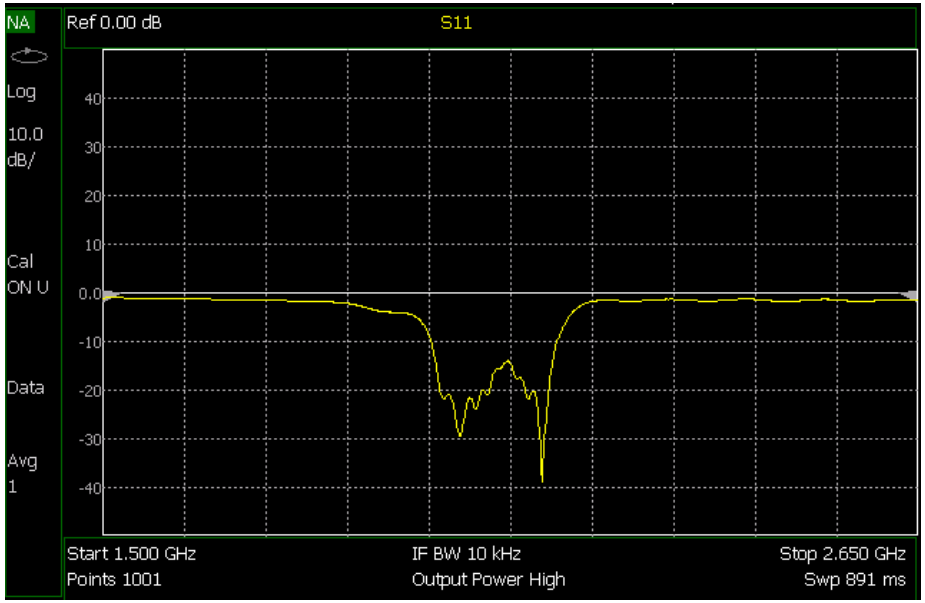
or

Select cable loss file (CAT mode)

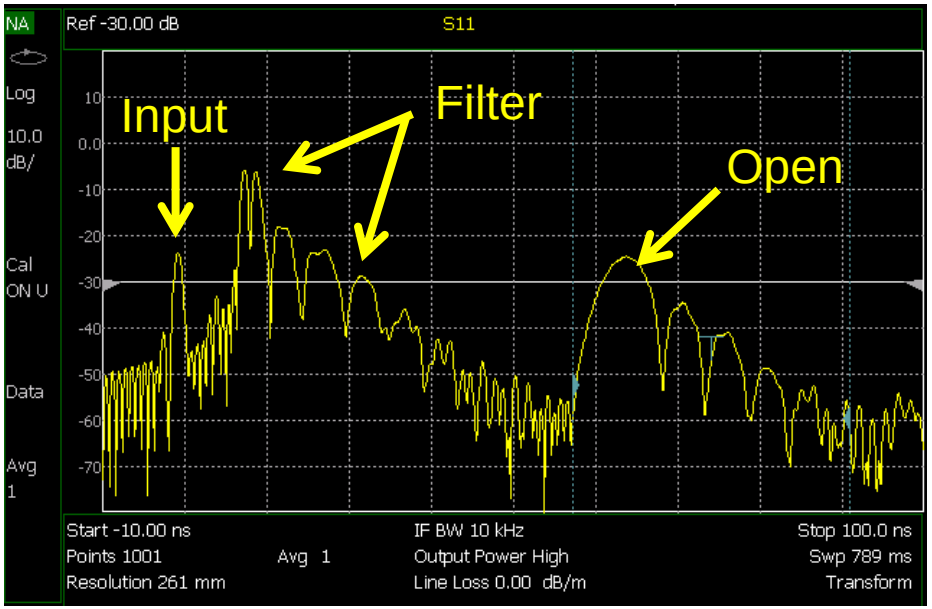
Time Domain with Filter



Frequency Domain: S11 → Time Domain: S11

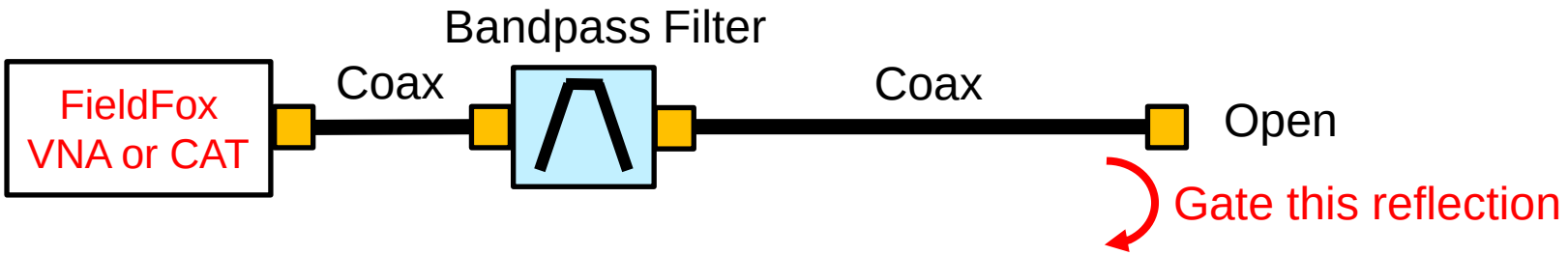


Terminated with 50-ohm load

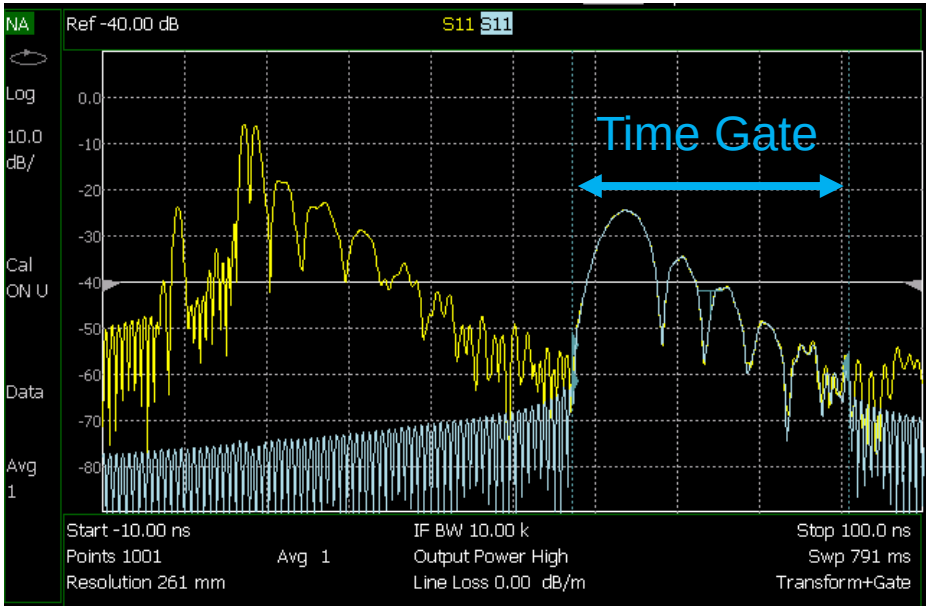


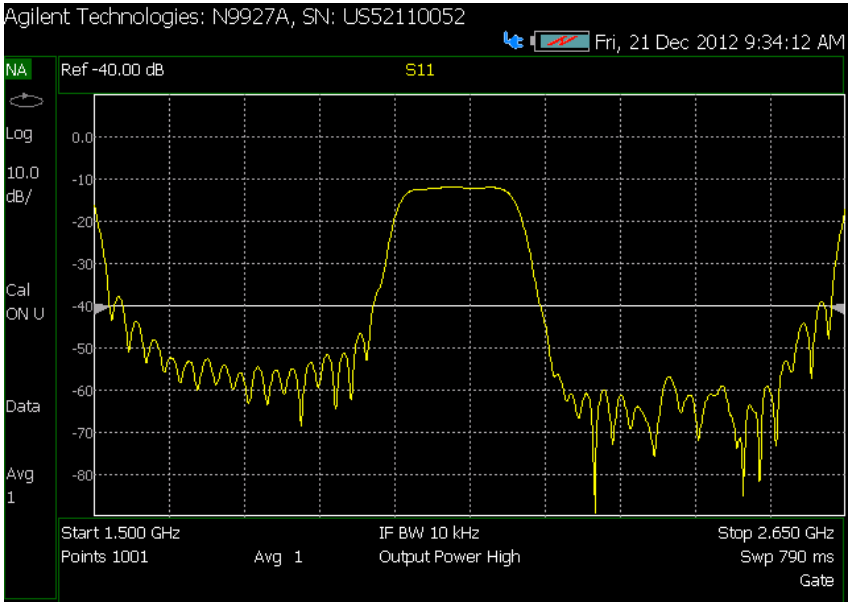
Terminated with open

Masking Effects with Filter



Time Domain Gating → Frequency Domain with Gating

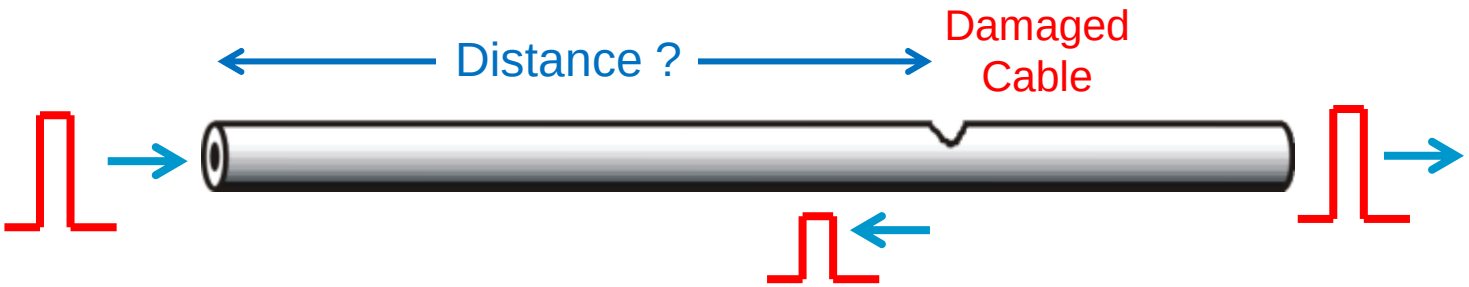




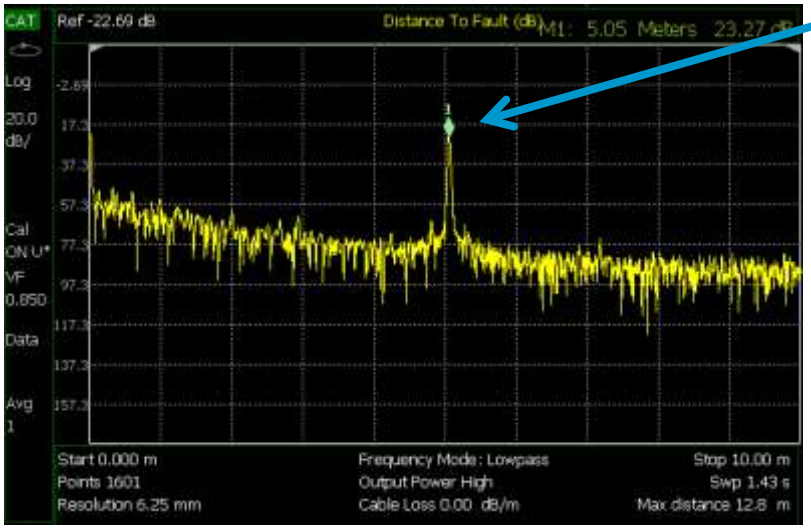
- Reflection from open includes *masking* effects of BPF
- Cable loss entry will not compensate for filter masking

Relating Time Measurements to Distance

What is the physical Distance to Fault (DTF) ?



S11 measurement



Enter Velocity Factor (VF) on VNA,CAT

Marker value = round trip travel time, t_{RT}

$$\mathrm{DTF(m)} = \left[\frac{t_{RT}}{2}\right]\left[v_{\mathrm{cable}}\right]$$

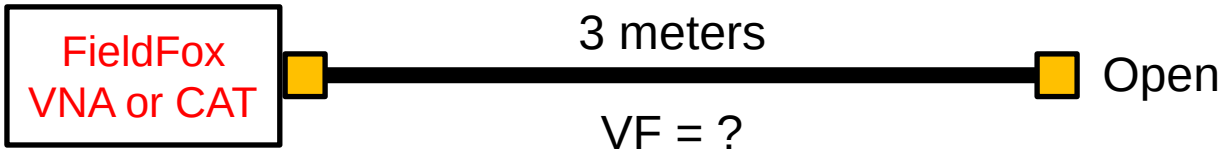
$$\text{where} v_{\mathrm{cable}} = (\mathrm{VF})(c)$$

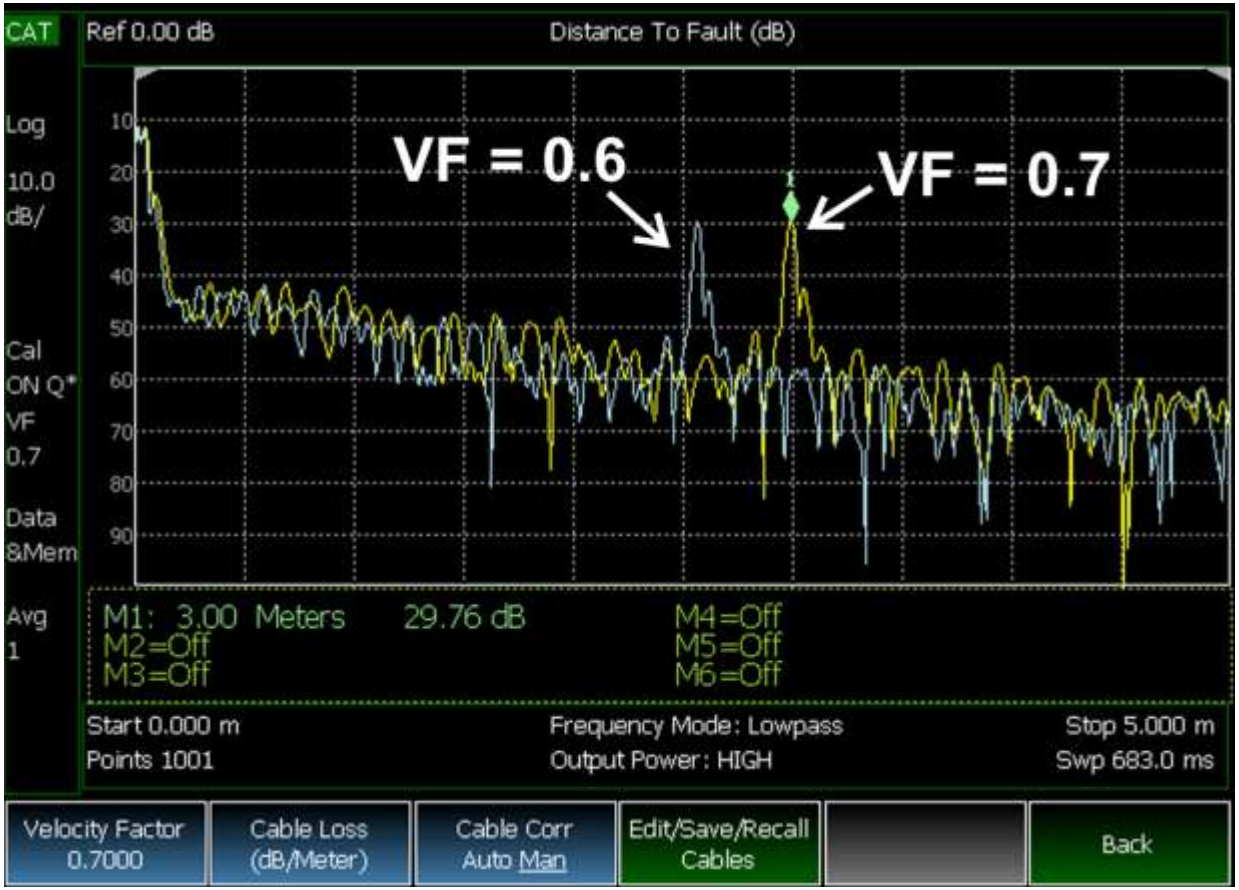
$$\mathrm{VF} = \frac{1}{\sqrt{\varepsilon_r}} \quad (\leq 1)$$

$c = \text{speed of light}$

$\varepsilon_r = \text{relative dielectric constant of material}$

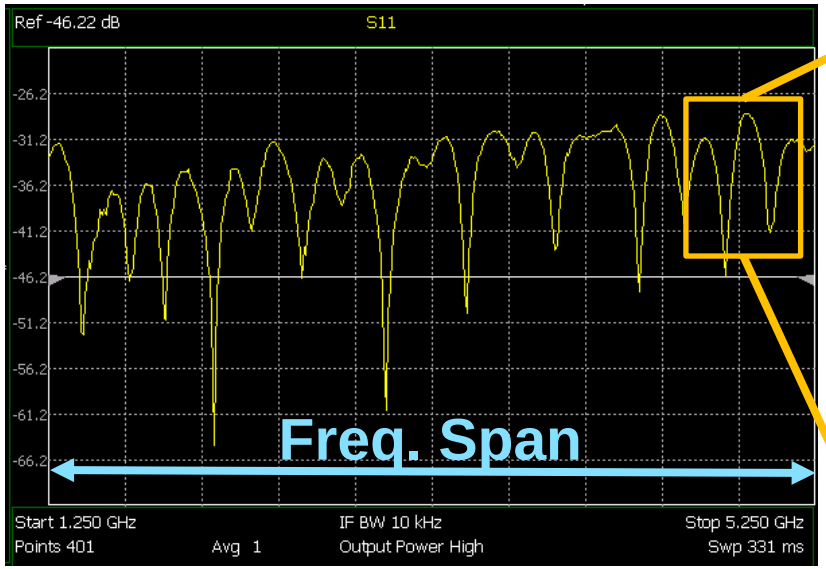
Estimating the Velocity Factor (VF)



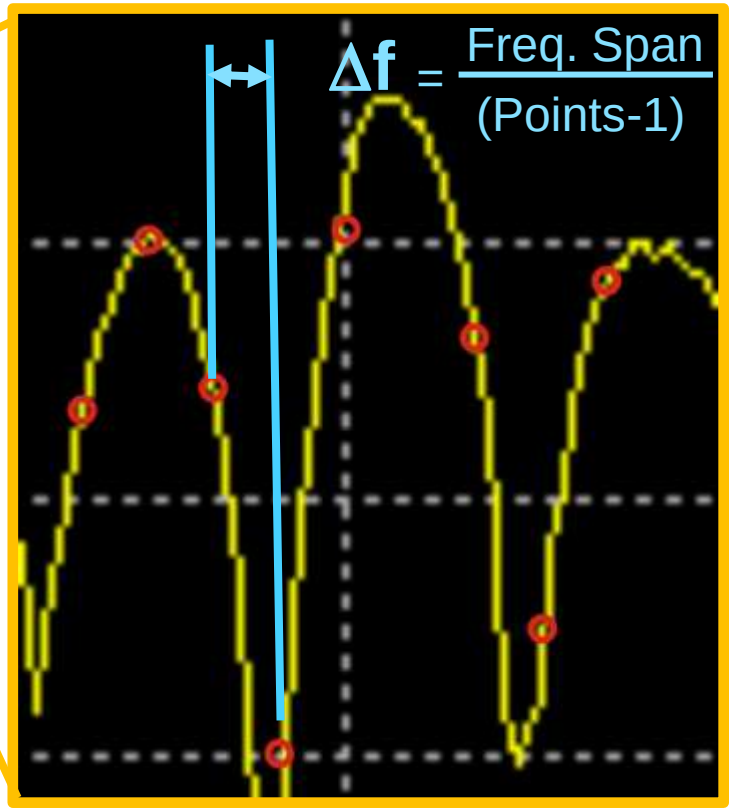


Configuring the Frequency Range and Points

Frequency Domain



Sampled Data



Not to scale

Time– Frequency Relationships

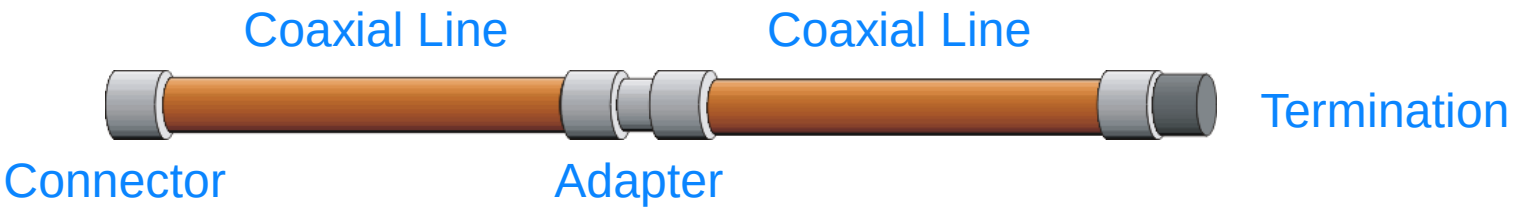
Pulse Width ~ 1/(Freq. Span)

Max. Time Span ~ 1/(2Δf)

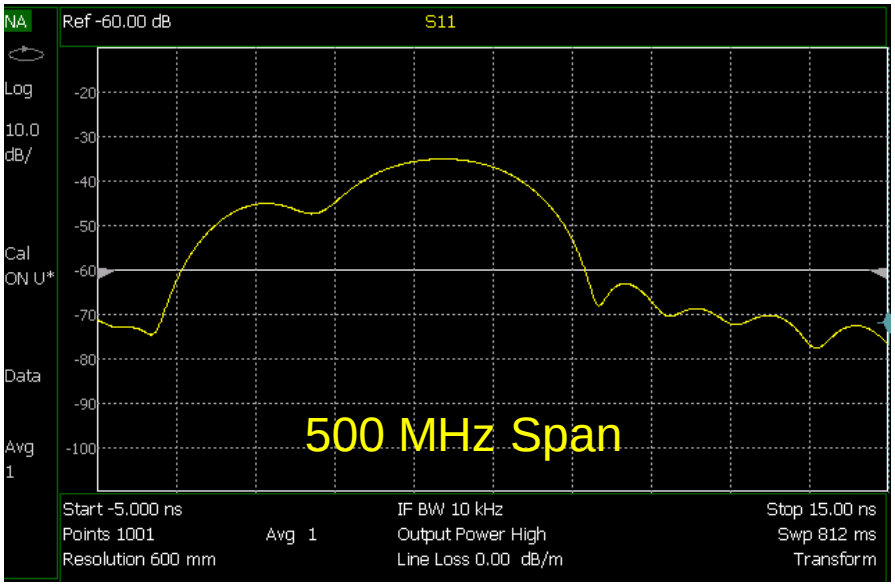
Points = 101 → 10,001

Frequency Span and Pulse Width

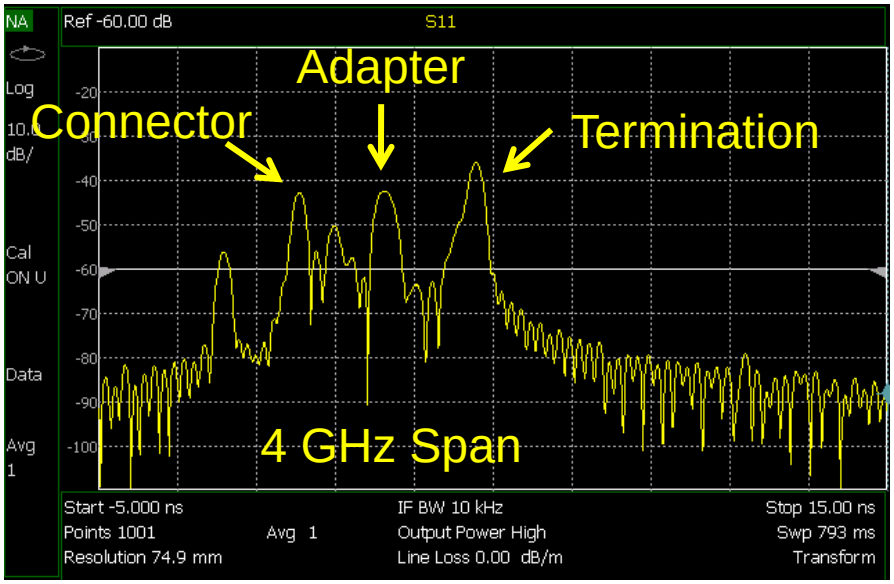
Pulse Width ~ 1/(Freq. Span)



Time Domain using 500 MHz Span

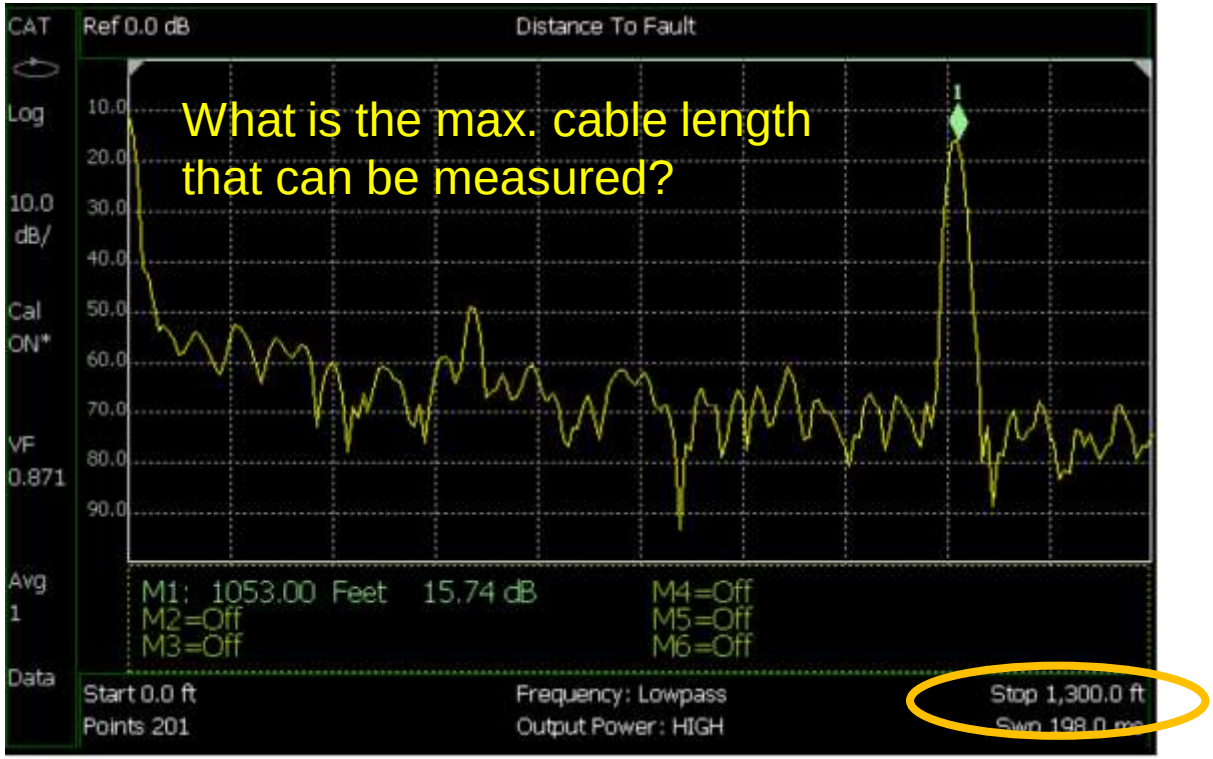


Time Domain using 4 GHz Span



Frequency Span and Time Span

$$\text{Max. Time Span} \sim 1/(2\Delta f) = \frac{(\text{Points}-1)}{2(\text{Freq. Span})}$$



VF=0.66
10,001 points

Span (GHz)	Max Time (μs)	Range (m)
2.5	2	395
5.0	1	198

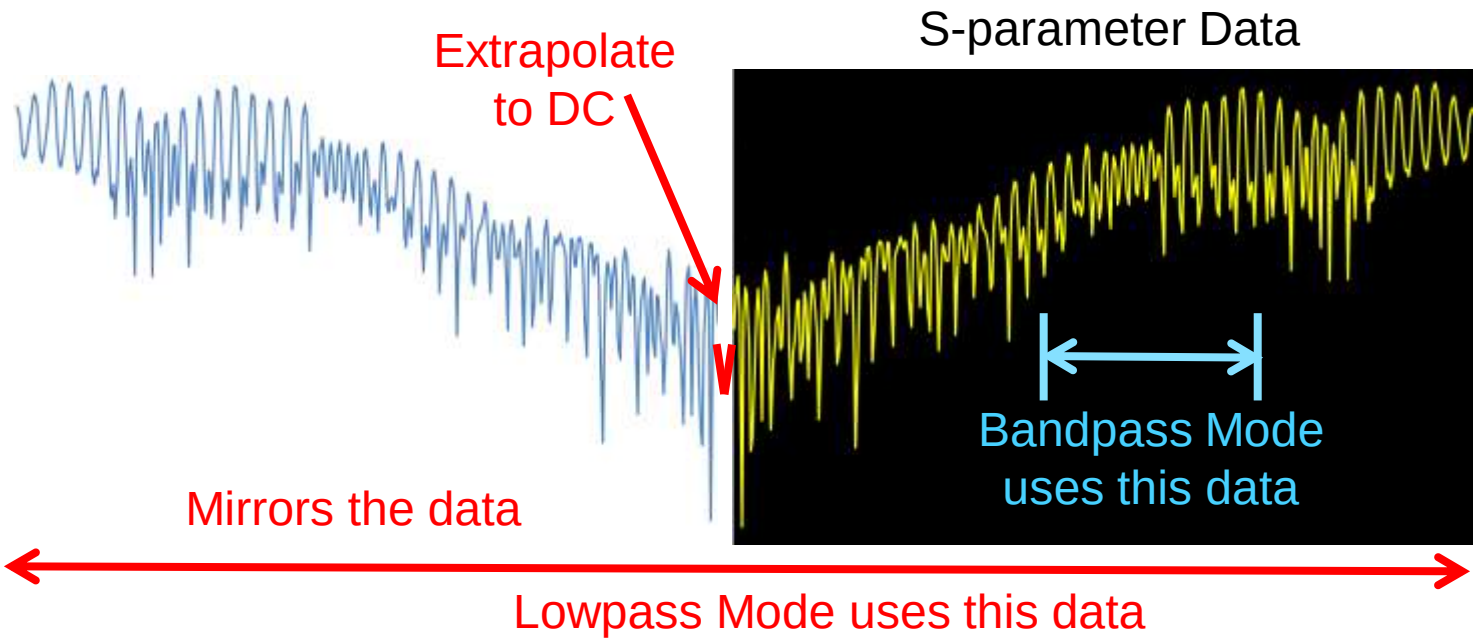
Configuring the Time Stimulus

Lowpass Mode

- Coaxial Cables
- Coaxial Adapters

Bandpass Mode

- Waveguide Components
- Couplers
- Filters
- Antennas



Other Applications Using Time Domain

- Filter tuning
- Transmission line impedance
- Mixer group delay
- SAW filter leakage
- Calibration verification using airlines and shorts
- Optimize time domain measurements using Window function
- Optimize gating using Window function

Conclusions

- Introduced the relationship between the frequency and time domains
- Discussed time domain as a verification and troubleshooting tool
- Discussed time gating for isolating discontinuities
- Investigated masking effects in the time domain
- Introduced instrument configurations for proper DTF testing
- Listed other interesting applications

FieldFox VNA and CAT Analyzer Characteristics

- ***Carry precision with you -*** Agilent-quality measurements
- Full amplitude accuracy of ±0.6 dB at turn-on, -10ºC to +55ºC
- Weather resistant, MIL-PRF-28800F Class 2 design
- 6.6 pounds (3 kg)
- Built-in GPS
- 3.5 hour battery life

N9912A 4/6GHz RF Analyzer

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

N9925A 9GHz Microwave VNA

N9926A 14GHz Microwave VNA

N9927A 18GHz Microwave VNA

N9928A 26.5GHz Microwave VNA

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

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
- *FieldFox Handheld Analyzers*, brochure, literature number 5990-9779EN

4th in a series of monthly application webcasts

- ✓ Sept 26, 2012: Interference Testing
- ✓ Oct 24, 2012: Cable and Antenna Measurements
- ✓ Nov 28 2012: Calibration and Alignment
- ✓ 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 1287-12, *Time Domain Analysis Using a Network Analyzer*, Literature Number 5989-5723EN, May 2012

- Agilent Application Note 1304-2, *Time Domain Reflectometry Theory*, Literature Number 5966-4855E, May 2006

- Agilent Application Note 1287-8, *Simplified Filter Tuning Using Time Domain*, Literature Number 5968-5328E, July 2000

- Agilent Application Note 1287-10, *Network Analysis Solutions Advanced Filter Tuning Using Time Domain Transforms*, Literature Number 5980-2785EN, March 2001

- Agilent Application Note, *Techniques for Precise Cable and Antenna Measurements in the Field*, Literature Number 5991-0419E, August 2012.