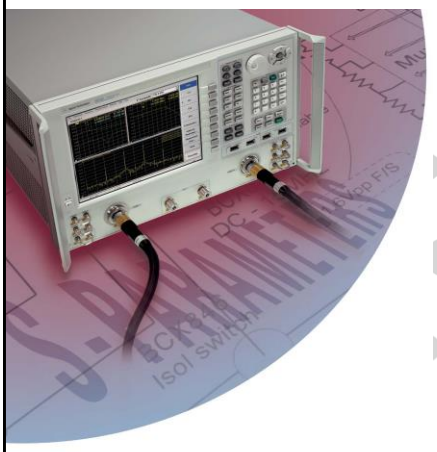
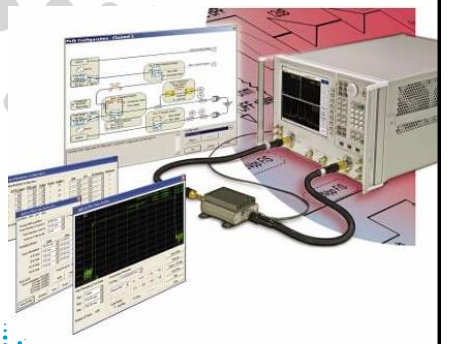
RF Network Analyzer Basic & Applications





Agilent RF Network Analyzer

cover the range from 10 Hz all the way up to 110 GHz.

Target: Component Test

Markets: R&D, design validation, Manufacturing
Apps: Amplifiers, mixers, filters, materials, etc.
Needs: single connection, multiple measurements, speed
Customers: Mini-Circuits, Samsung, Panasonic, etc.

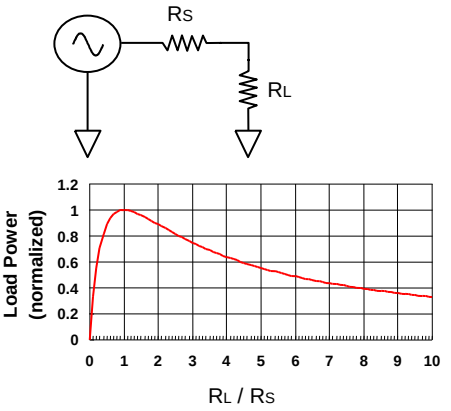
Design validation test set-up

mixer

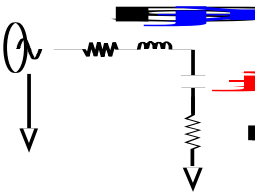
Low Noise Amplifier (LNA)

filters

Power Transfer Efficiency

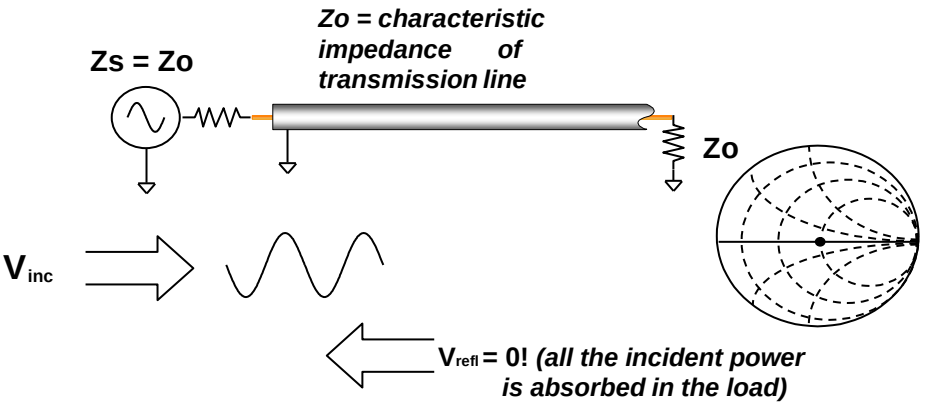


For complex impedances, maximum power transfer occurs when $Z_L = Z_S^*$ (conjugate match)



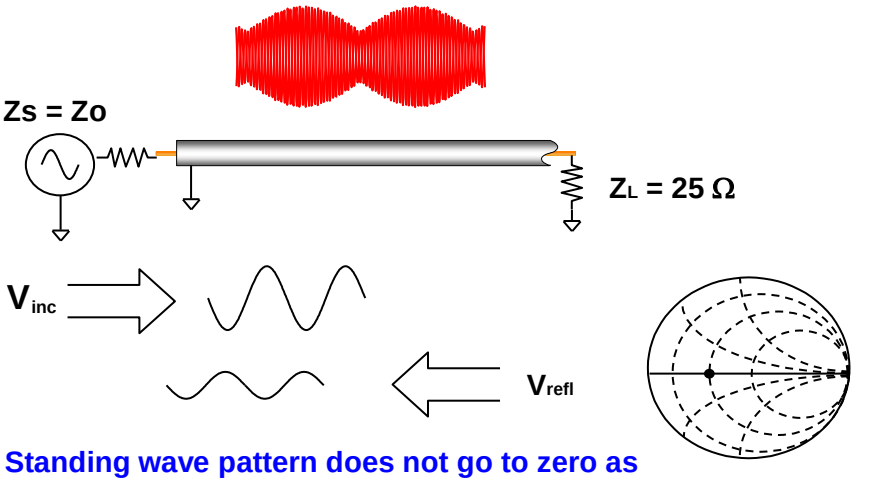
Maximum power is transferred when $R_L = R_S$

Transmission Line Terminated with Zo



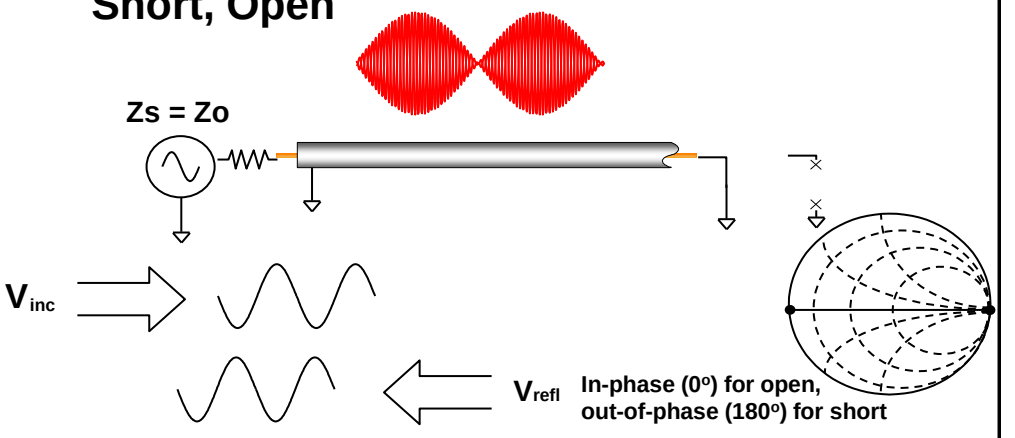
For reflection, a transmission line terminated in Zo behaves like an infinitely long transmission line

Transmission Line Terminated with 25 Ω



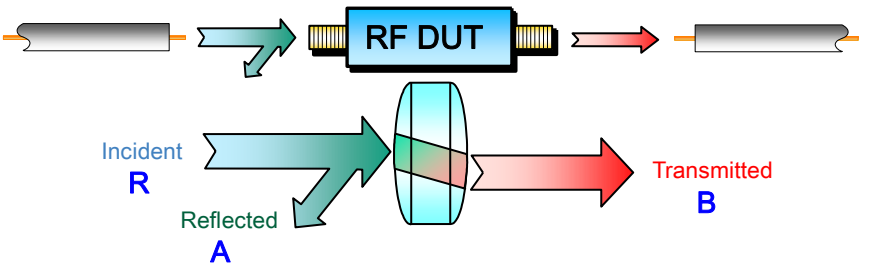
Standing wave pattern does not go to zero as with short or open

Transmission Line Terminated with Short, Open



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

High-Frequency Device Characterization



REFLECTION

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

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

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

Transmission Parameters

$$\text{Transmission Coefficient} = T = \frac{V_{\text{Transmitted}}}{V_{\text{Incident}}} = \tau \angle \phi$$

$$\text{Insertion Loss (dB)} = -20 \log \left| \frac{V_{\text{Trans}}}{V_{\text{Inc}}} \right| = -20 \log \tau$$

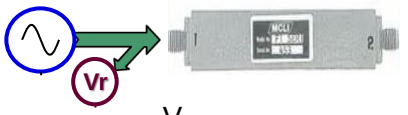
$$\text{Gain (dB)} = 20 \log \left| \frac{V_{\text{Trans}}}{V_{\text{Inc}}} \right| = 20 \log \tau$$

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

Reflected / Incident = A / R

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

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

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

Voltage Standing Wave Ratio

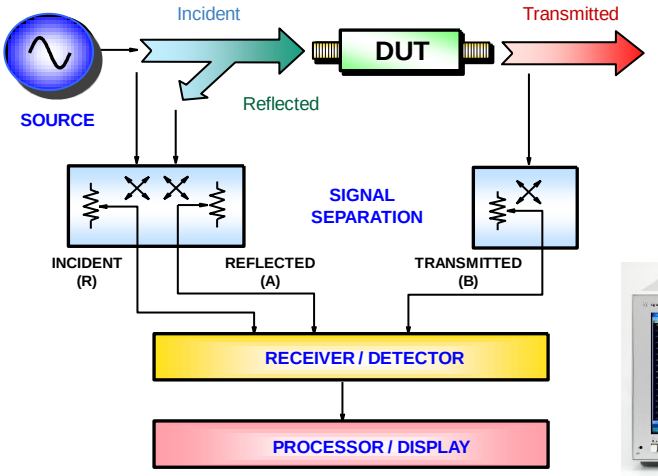
VSWR = Emax / Emin = $\frac{1+\rho}{1-\rho}$

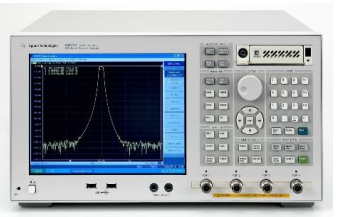
No reflection ***(Z_L = Zo)***

Full reflection ***(Z_L = open, short)***

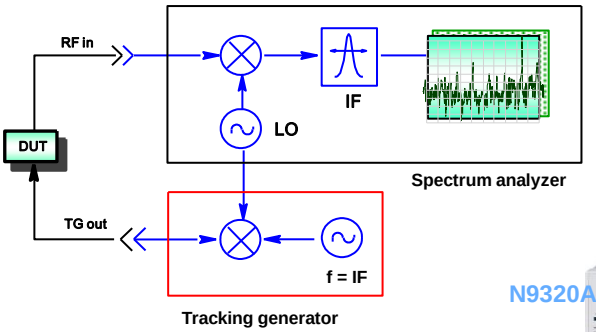
0	ρ	1
$-\infty$ dB	RL	0 dB
1	VSWR	∞

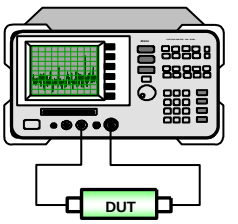
Generalized Network Analyzer Block Diagram

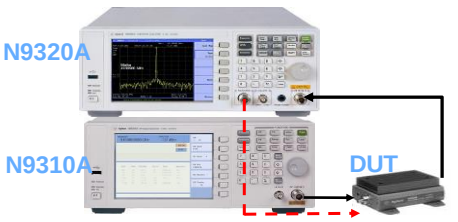




Spectrum Analyzer / Tracking Generator



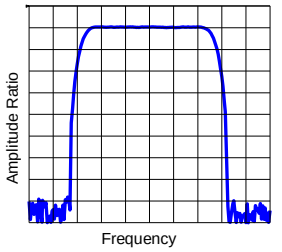


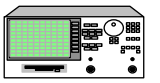


Key differences from network analyzer:

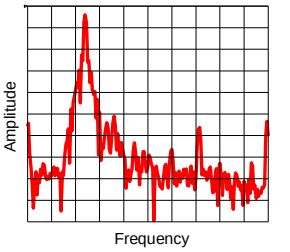
- one channel -- no ratioed or phase measurements
- More expensive than scalar NA Only error correction available is normalization.
- Less accurate
- Small incremental cost if SA is required for other measurements

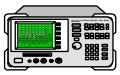
What is the Difference Between Network Analyzer and Spectrum Analyzers?





Measures known signal





Measures unknown signals

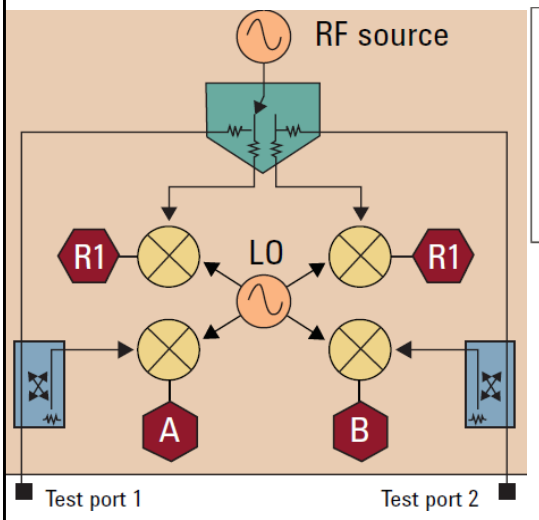
Network analyzers:

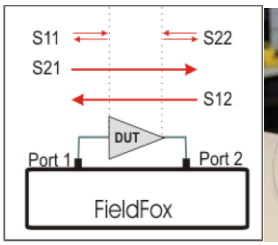
- measure components, devices, circuits, sub-assemblies
- contain source and receiver
- display ratioed amplitude and phase (frequency or power sweeps)
- offer advanced error correction

Spectrum analyzers:

- measure signal amplitude characteristics carrier level, sidebands, harmonics...)
- can demodulate (& measure) complex signals
- are receivers only (single channel)
- can be used for scalar component test (*no phase*) with tracking gen. or ext. source(s)

N9923A Full 2-port S-parameters





S_{21}

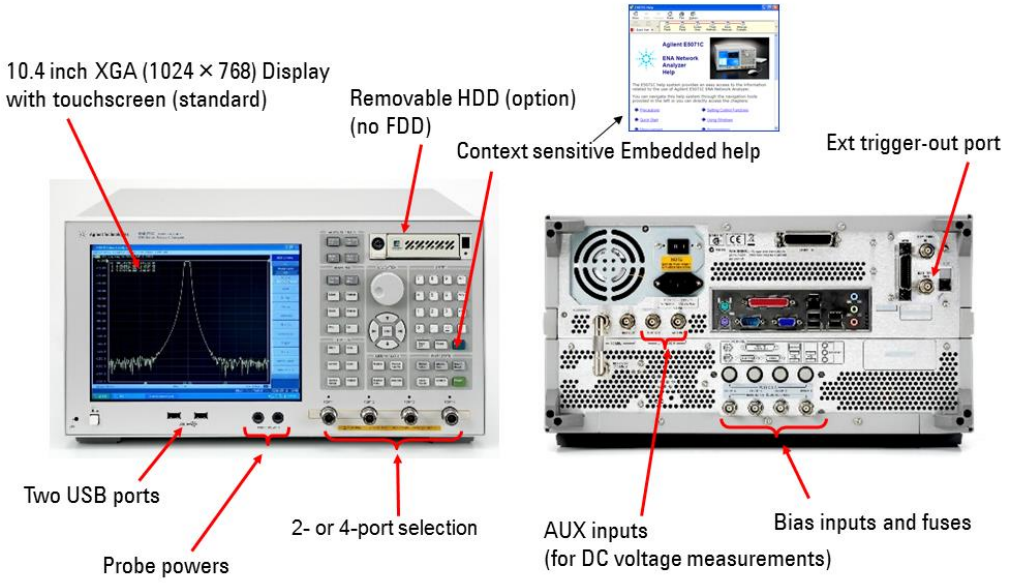
Signal Measured (Out of DUT)

Signal Incident (In to DUT)

S-Parameter Measurement Term:

- S11 : Return Loss ,Input Impedance
- S21 : Gain , Insertion Loss
- S12 : Isolation
- S22 : Output Impedance

E5071C Front & Rear View

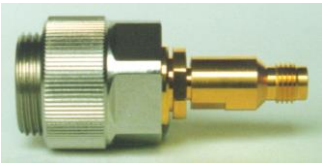


Protecting ENA System

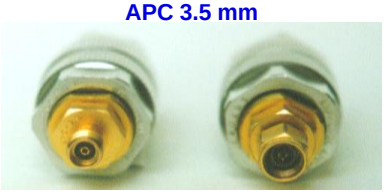
- **Do NOT Plug off Power Cable during Shutdown Process**
- Do NOT install a standard version of the Windows operating system on the ENA.
- Do NOT change advanced performance settings or group policies.
- Do NOT add or delete any hard disk drive partitions on the ENA.
- Do NOT delete the Agilent user account.
- Do NOT modify any of the Agilent software registry entries.
- Do NOT change the settings of Standards and Formats in Regional Options .
- **Install Antivirus Protection.**
- Run Error Check and Disk Defragmenter
- **Do NOT Modify or delete any Files and Folders in Drive other than D and E: Drive.**
- **Do not apply DC voltage or current to the test port. Applying DC voltage or current may lead to device failure.**
- **Precautions for Electrostatic Discharge (ESD)**
- Maintain working environment condition
- **Proper grounding prevents building-up of static charge which may be harmful to ENA.**

Connector Type

APC 7mm & APC 7 to 3.5mm Connector

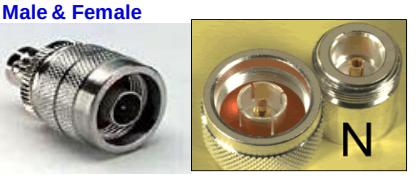


APC 3.5 mm

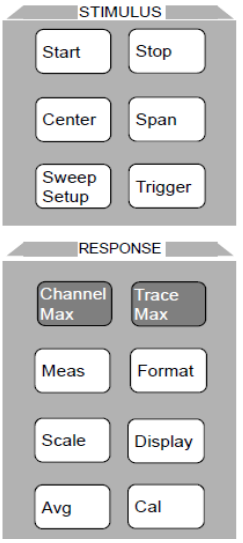


SMA Connectors

Connector Type N Male to BNC Male & Female



Basic Measurement Procedure: Overview



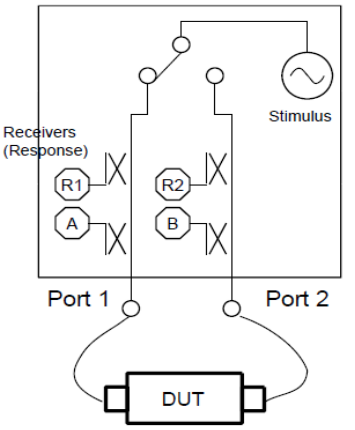
Preset
Set the ENA to the default setting

Set Stimulus
Frequency Range, Sweep Type, Source level,

Set Response
Measurement Parameter, Display format, averaging, Calibration, etc.

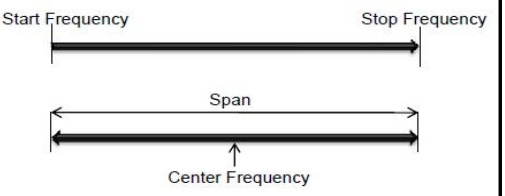
Measurement

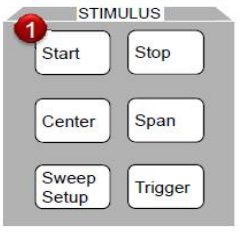
2-port S-parameter test set
Simplified block diagram

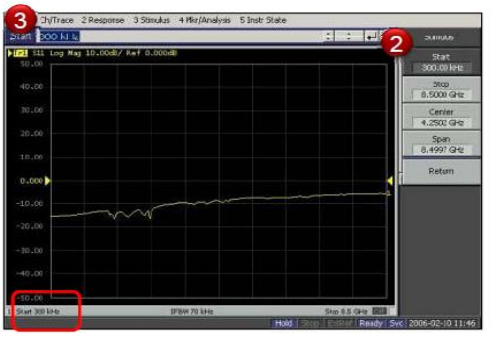


Setting Stimulus Frequency

Worming-up:
Set the frequency range as below…
Start: 4 GHz
Stop: 8 GHz

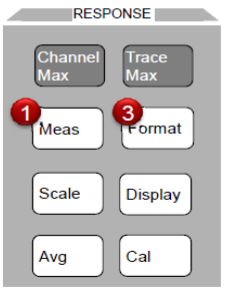


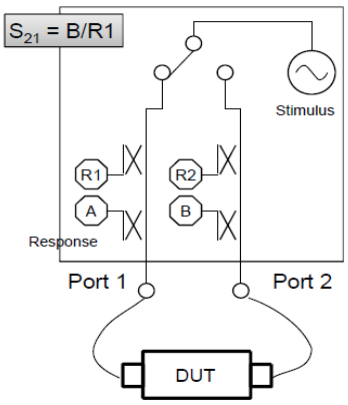




Setting Response Measurement Parameter, Format

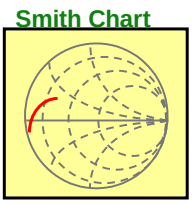
Worming-up:
Configure the Meas set up as below…
Meas: S21
Format: LogMag





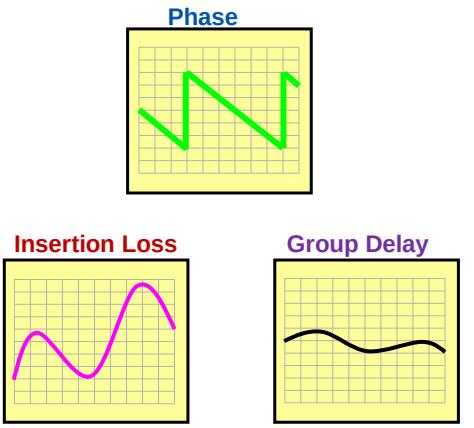
Common Display Formats for S_{11} (& S_{22})

- Log MAG (Return Loss)
- SWR
- Smith Chart
- Polar
- Other formats available for specific applications
  - Phase
  - Delay
  - Lin MAG
  - Real
  - Imaginary

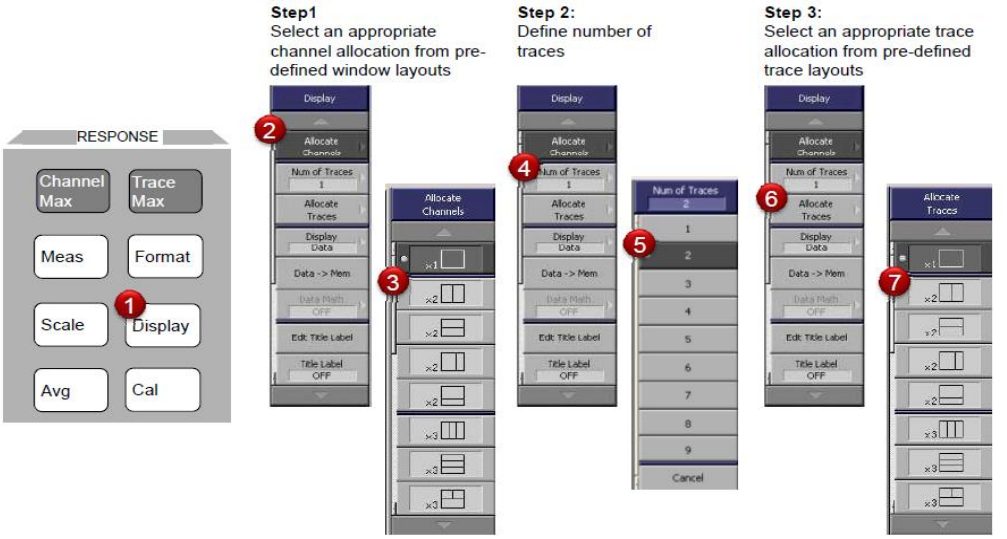


Common Display Formats for S_{21} (& S_{12})

- Log MAG (Insertion Loss)
- Phase
- Delay
- Other formats available for specific applications
  - Smith Chart
  - Polar
  - Lin MAG
  - SWR (not valid for S21, S12)
  - Real
  - Imaginary

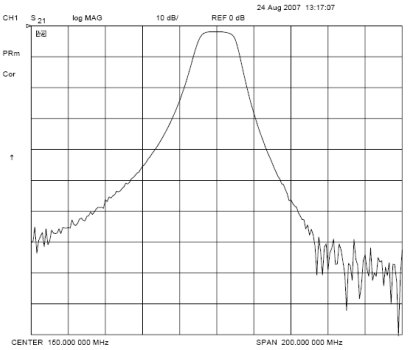


Channel & Traces
Allocate Channels & Traces

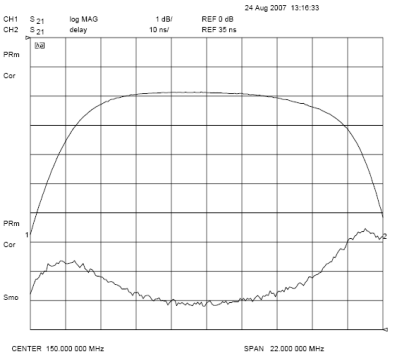


150MHz Band pass Filter

Parameter	Specification
Filter type	Bandpass
Center Frequency	150 MHz
Insertion Loss	< 3 dB (< 2 dB typical)
3 dB Bandwidth	20 MHz ± 2 MHz

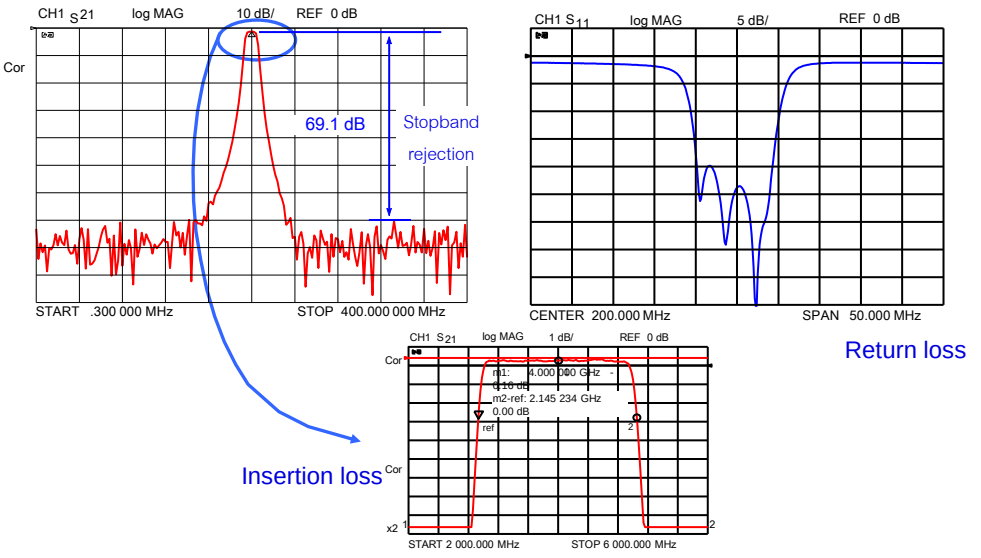


Over all response (10dB)



Band pass Amplitude & Group delay (1dB)

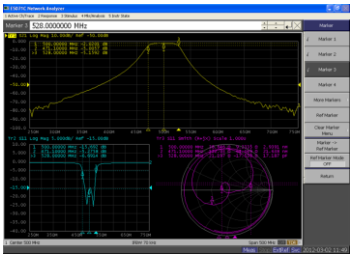
Frequency Sweep - Filter Test



Hand on BP Filter measurement

- **Connect the DUT**
- Port 1 : BP Filter Pin1
- Port 2 : BP Filter Pin2

Masure Parameter:
Insertion loss , Bandwitch



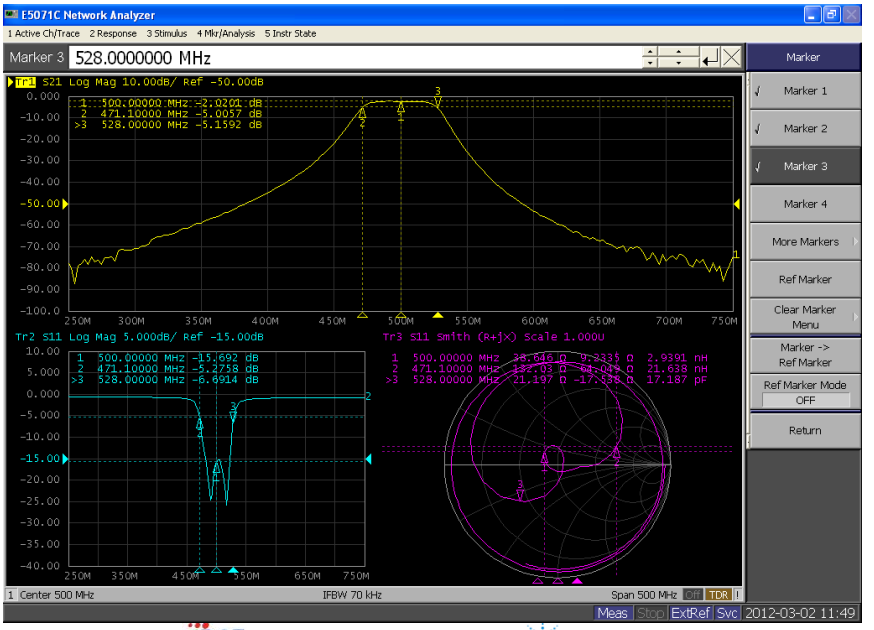
•Setup
- 1. Preset : OK
- 2. Stimulus: Center : 500MHz , Span : 500MHz
  or Start : 250MHz , Stop : 750MHz
- 3. Display : Number of Traces: 3
  Allocate Traces:
- 4. Select parameter & format as below:

Trace No	Meas	Format
1	S21	Log
2	S11	Log
3	S11	Smith(R + jX)

- 5. Scale : Auto Scale All
- 6. Place marker at : Marker 1 500MHz
  Marker 2 471MHz
  Marker 3 528MHz

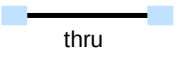
Insertion Loss = 2.02 dB
Calculate -3dB BW = Freq Marker 3- Freq Marker1
= 528 – 471 = 47 MHz
Save/Recall : Save State ,File Dialog: BPF500M

BP Filter 500MHz Test Data

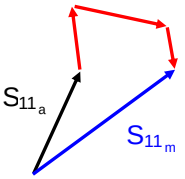


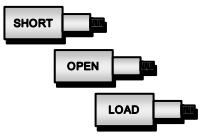
Types of Error Correction

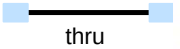
- **response (normalization)**
  - simple to perform
  - only corrects for tracking errors
  - stores reference trace in memory, then does data divided by memory



- **vector**
  - requires more standards
  - requires an analyzer that can measure phase
  - accounts for all major sources of systematic error





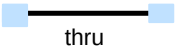


Errors and Calibration Standards

UNCORRECTED

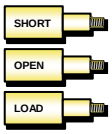
- Convenient
- Generally not accurate
- No errors removed

RESPONSE



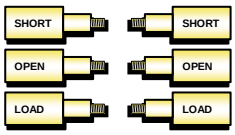
- Easy to perform
- Use when highest accuracy is not required
- Removes frequency response error

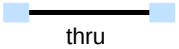
1-PORT



- For reflection measurements
- Need good termination for high accuracy with two-port devices
- Removes these errors:
  - Directivity
  - Source match
  - Reflection tracking

FULL 2-PORT



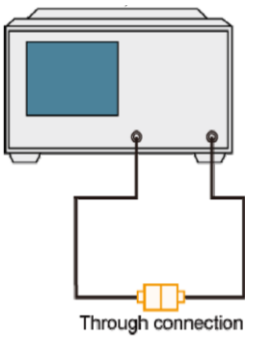


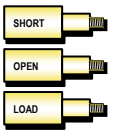
- Highest accuracy
- Removes these errors:
  - Directivity
  - Source, load match
  - Reflection tracking
  - Transmission tracking
  - Crosstalk

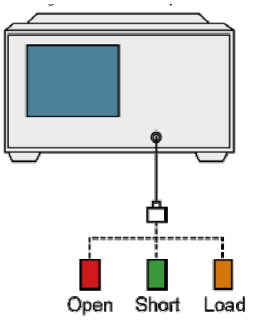
ENHANCED-RESPONSE

- Combines response and 1-port
- Corrects source match for transmission measurements

Thru Response and 1 Port Calibration

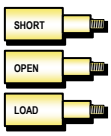




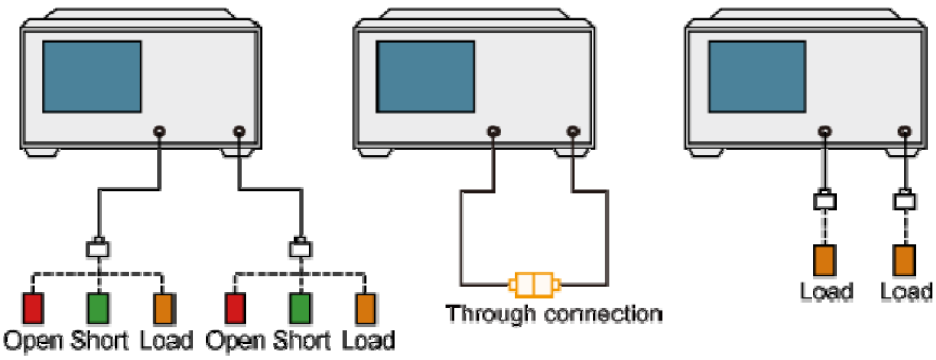


- **Removes these errors(3 Error Terms)**
  - Directivity
  - Source match
  - Reflection tracking

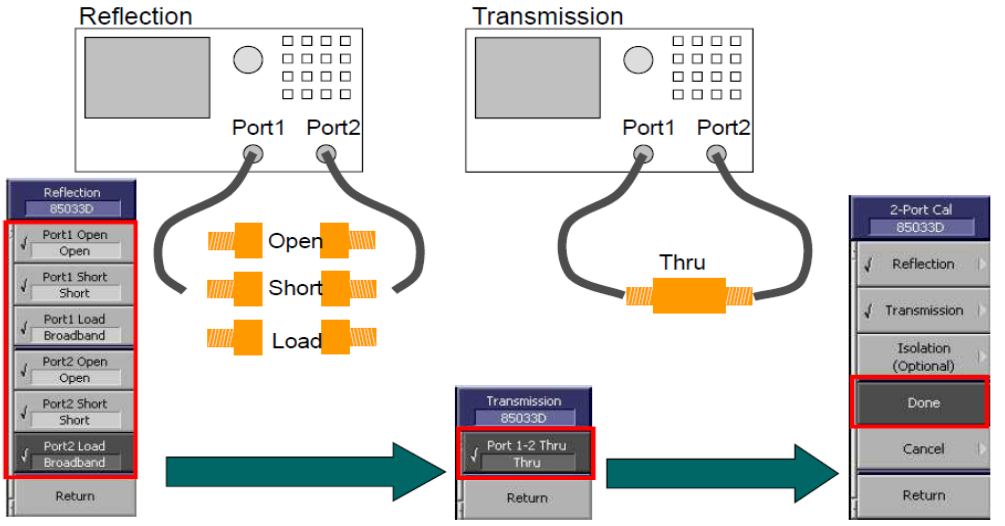
Full 2 Port Calibration



- **Removes these errors(12 Error Terms)**
  - Directivity x2
  - Source match x2
  - Transmission tracking x2
  - Combines response and 1-port x2
  - crosstalk x2
  - Load match x2
  - Reflection tracking x2
  - Isolator x2



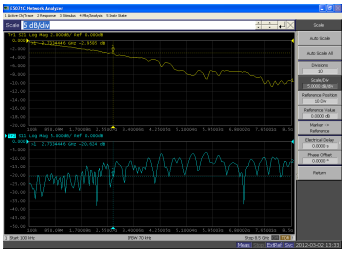
Calibration Basic Calibration Procedure (Mechanical Cal)



Hand on Cable measurement

- **Connect the DUT**
- Port 1 : RF Cable Pin1
- Port 2 : RF Cable Pin2

Masure Parameter:
Insertion loss , Bandwitch



Setup

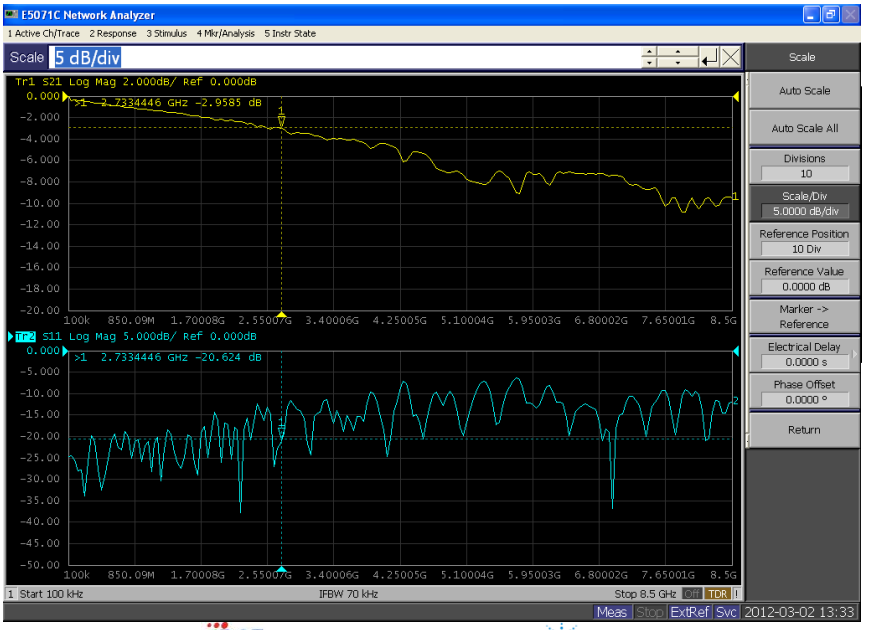
- 1. Preset : OK
- 2. Stimulus: Stop : 8.5GHz ,
- 3. Display : Number of Traces: 2
  Allocate Traces: 
- 4. Select parameter & format as below:

Trace No	Meas	Format
1	S21	Log
2	S11	Log

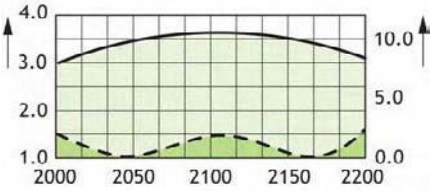
5. Scale : Auto Scale All
   TR1,TR2 Reference value = 0
   Reference Position = 10
6. Marker Search : Target ,Target value ,-3dB

   Cable -3dB BW = 2.73 GHz
   Return Loss = -20 dB

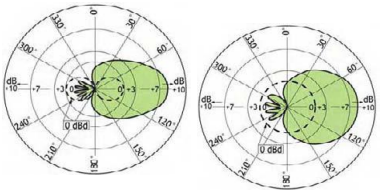
RF Cable test data



Antenna Measurements



Electrical properties	
Frequency range	2200 - 2500 MHz
Impedance	50 Ω
VSWR	< 2.0 (2200 - 2400 MHz) 1.5 (2400 -2500 MHz)
Polarisation	linear, vertical
Gain	16.5 dBi
3 dB beamwidth	horizontal: 85° / vertical: 6°
Downtilt	0°
Front to back ratio	25 dB
Max. power	100 W (CW) at 25°C



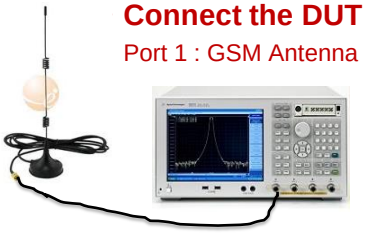
สายอากาศ มีคุณสมบัติ ดังนี้

- ค่า Return Loss จะต้องมีการสูญเสียจากการสะท้อนกลับน้อยที่สุด (ลบมาก ๆ)
- ค่า VSWR สายอากาศที่ดีจะต้องมีต่า VSWR (ค่าเข้าใกล้ ๆ 1 จะดี)

Hand on Antenna measurement

Connect the DUT

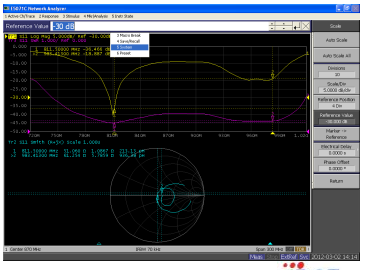
Port 1 : GSM Antenna



Masure Parameter:

-Frequency Response

-Retuen loss ,- VSWR , Z in



•Setup

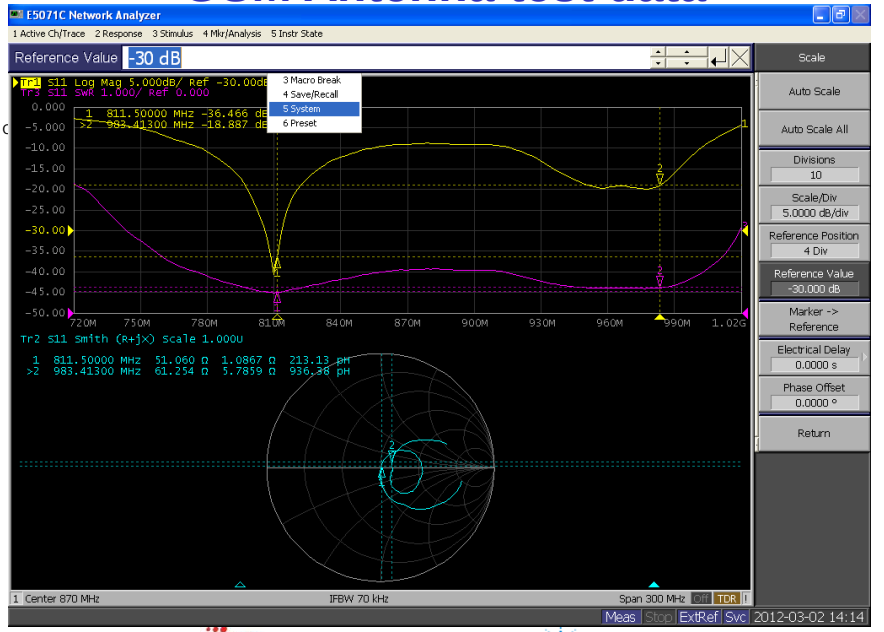
- 1. Preset : OK
- 2. Stimulus: Center : 870MHz , Span : 300MHz
  or Start : 720MHz , Stop : 1020MHz
- 3. Display : Number of Traces: 3
  Allocate Traces:
- 4. Select parameter & format as

Trace No	Meas	Format
1	S11	Log
2	S11	Smith (R + jX)
3	S11	SWR

- 5. Scale : Auto Scale All
- 6. Marker Search for Marker1 : min for Tr1 = 811MHz
- 7. Place marker at : Marker 2 = 982MHz

	Point1	Point2	
Antenna Frequency =	811	982	MHz
Return Loss =	-30	-19	dB
VSWR =	1.08	1.2	
Zin =	44.5	60	Ohm

GSM Antenna test data



Target Markets & Applications

- Active device characterization
- Metrology & cal lab

PNA-X, NVNA

- Wireless RF components
- High-volume mfg.
- High-speed digital

- Replace a rack of equipment with one instrument
- Complete linear & nonlinear active device characterization

PNA-L

- LF-RF components
- CATV/75-ohm

ENA

- S-parameters
- Signal integrity
- Material measurements

Mm-Wave

ENA-L

- Antenna

PNA-X Rece

- Broadband device characterization
- Wireless mm-wave
- Research in THz

- Installation & Maintenance
- A/D service/maintenance

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RF/uW Handheld Portfolio

Carry Precision with you!

26.5 GHz
18 GHz
14 GHz
9 GHz
6 GHz
4 GHz

N9330B
N9912A-104
N9912A-106
N9913A
N9914A
N9915A
N9916A
N9917A
N9918A
N9923A-104
N9923A-106
N9925A
N9926A
N9927A
N9928A
N9935A
N9936A
N9937A
N9938A
N9340B
N9342C
N9343C
N9344C

20 GHz
13.4 GHz
7 GHz
3 GHz

CAT only | Combo ANALYZER | VNA | SA | HSA

Network Analyzer Basics & Application

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