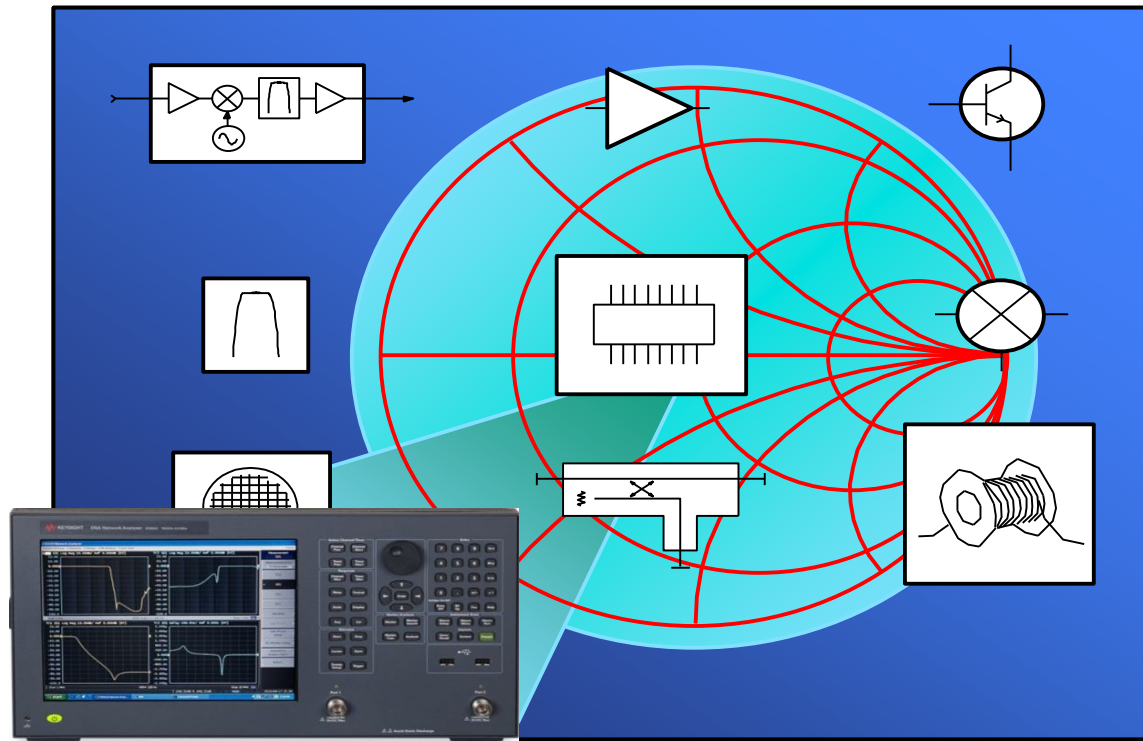


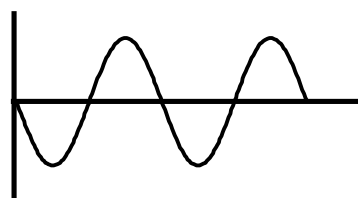
Network Analyzer 의 기초



RF(AC)신호의 측정

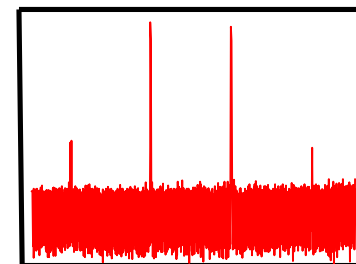
Fourier Transform

Oscilloscope

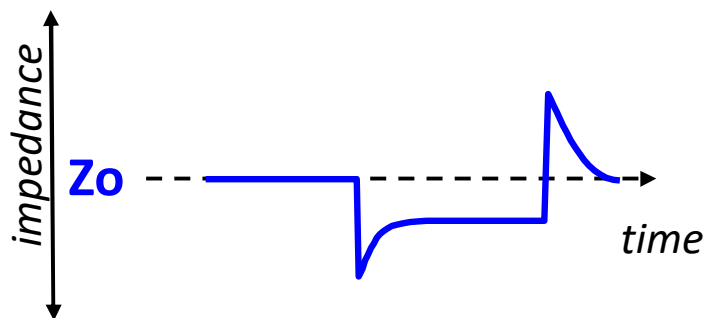


Period (주기)
Frequency
Voltage
Current

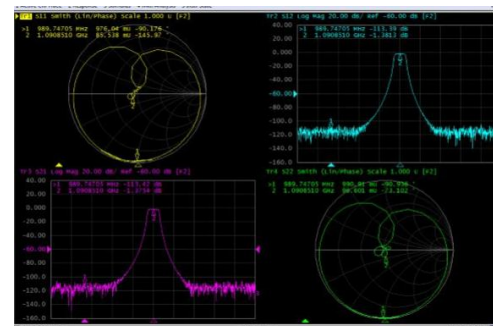
Spectrum Analyzer



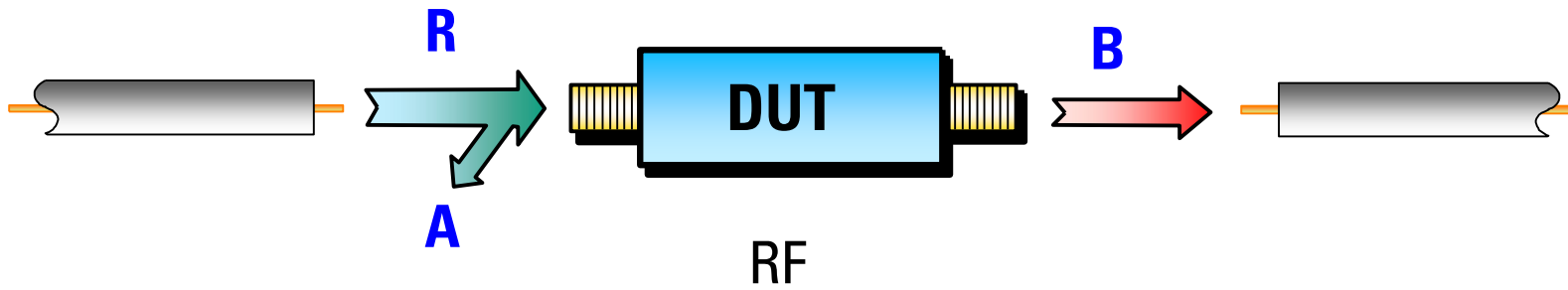
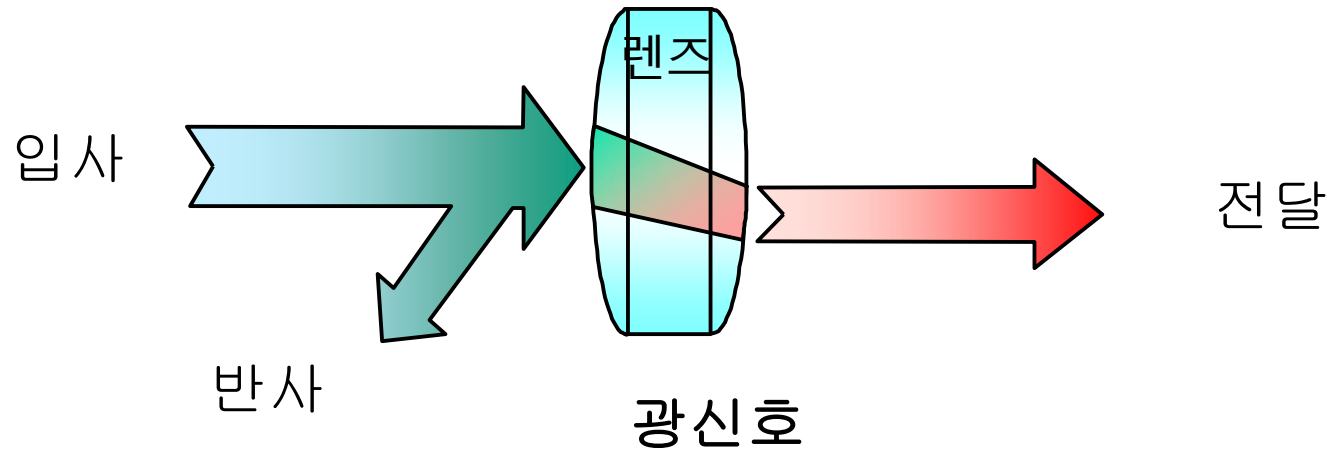
TDR



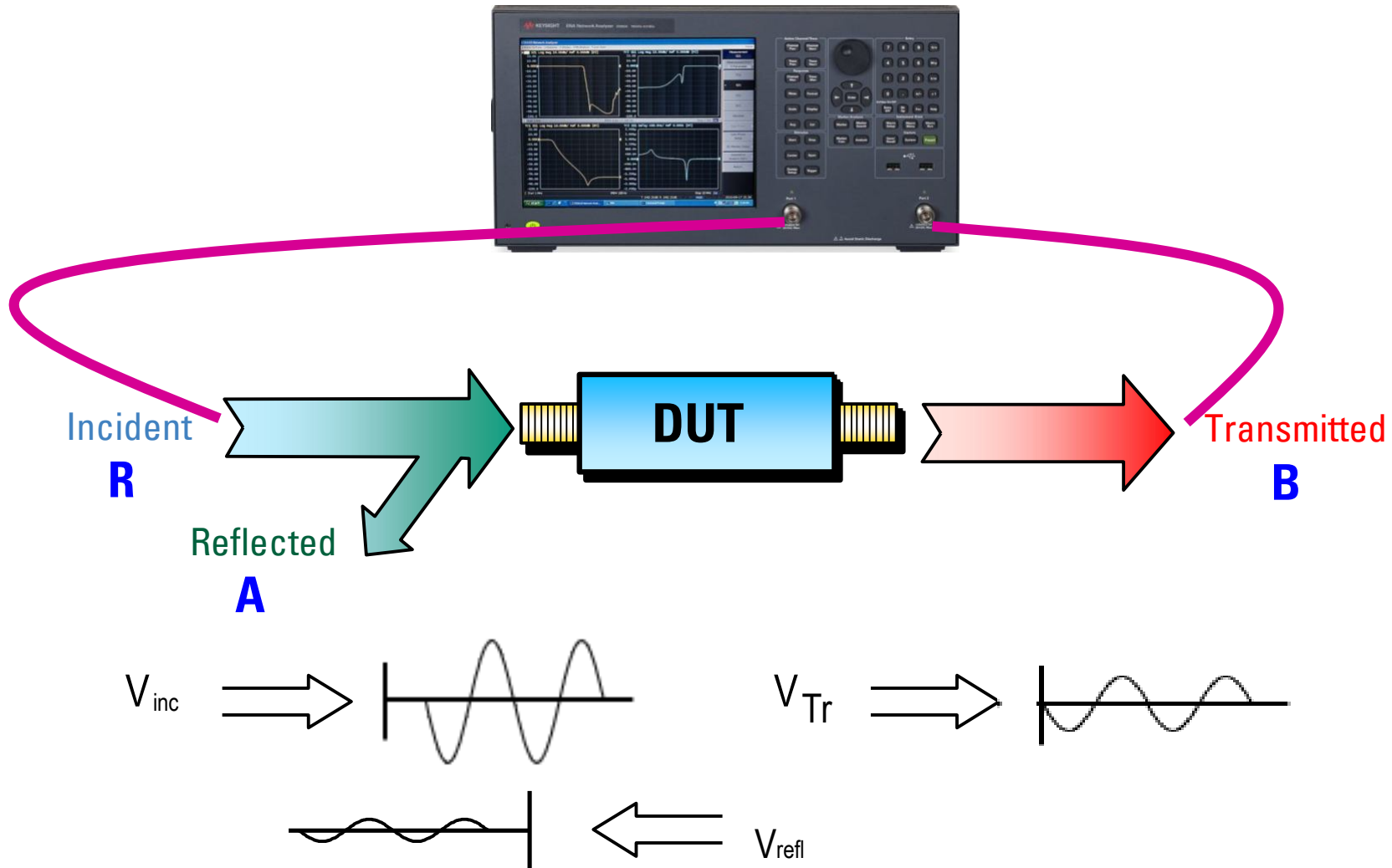
Network Analyzer



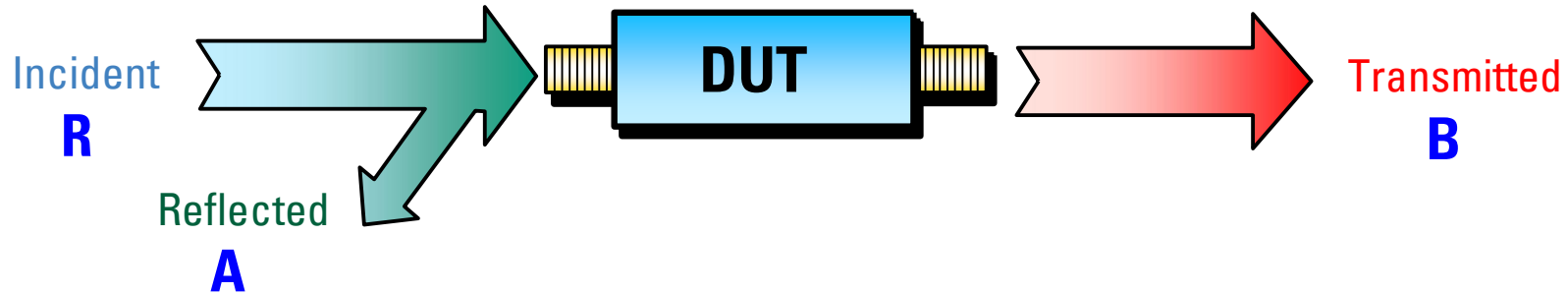
광신호와 RF 신호의 비교



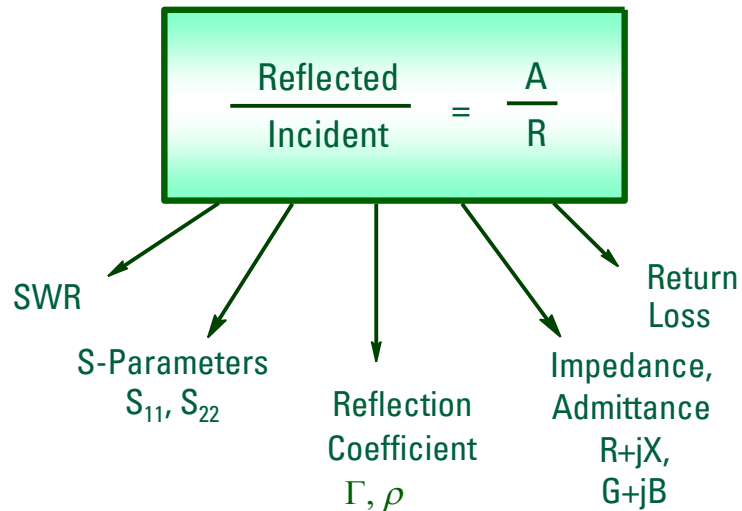
네트워크 분석기의 동작원리



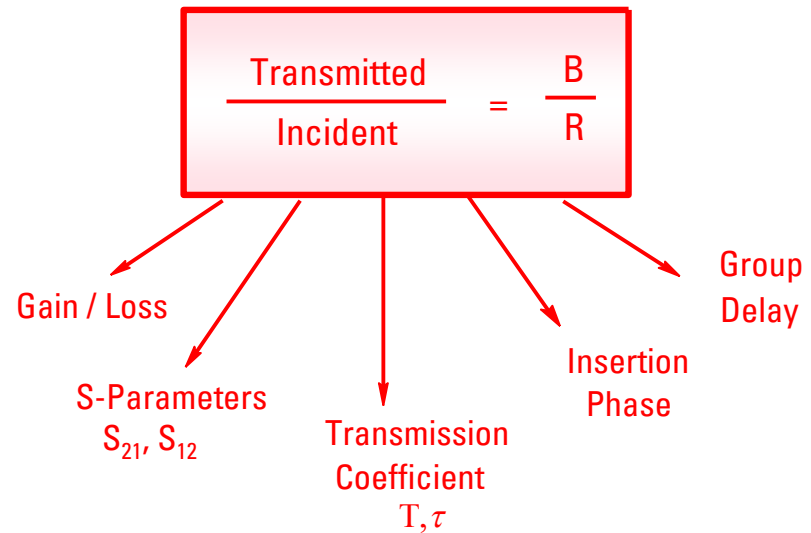
네트워크 분석기의 측정항목



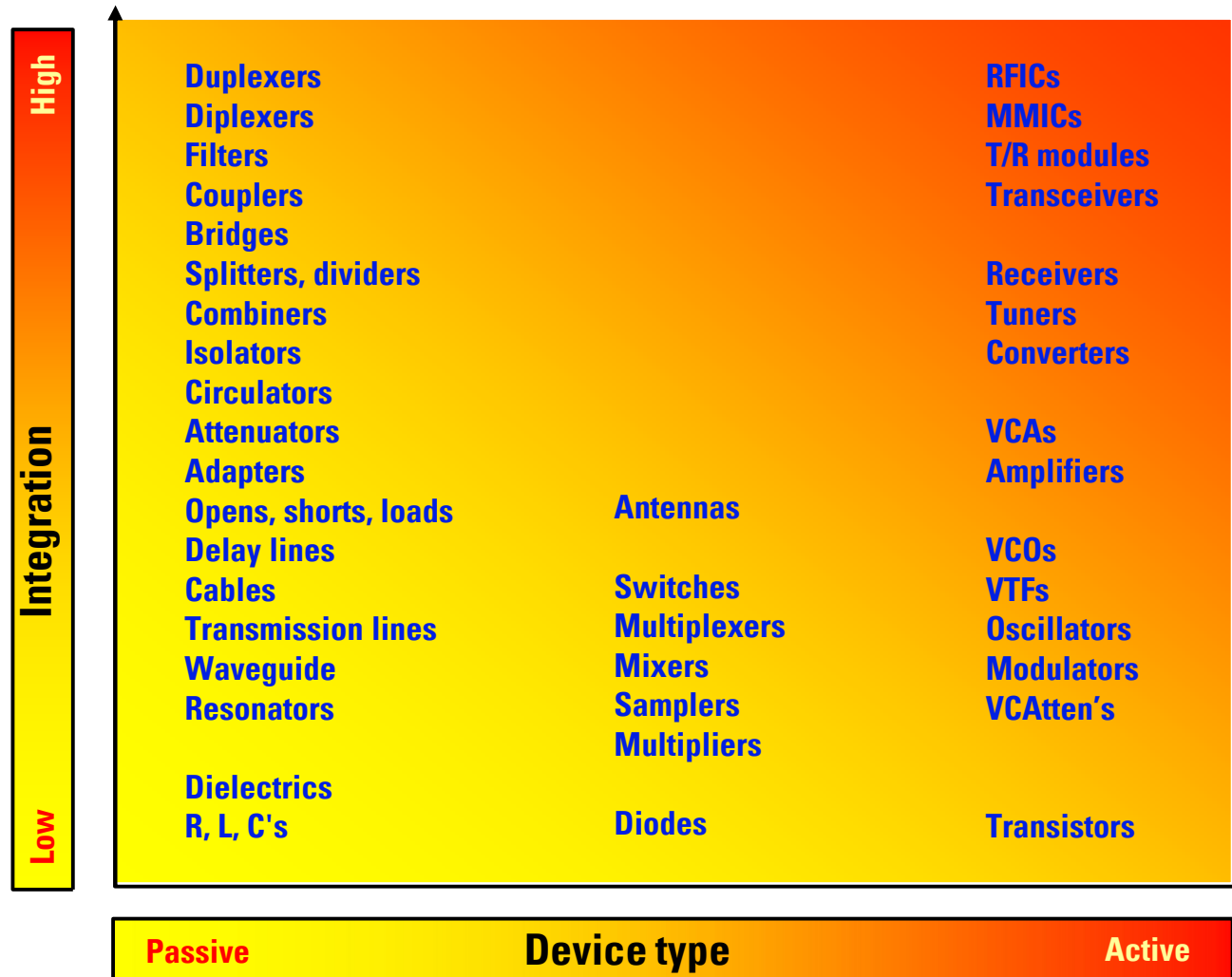
측정항목(REFLECTION)



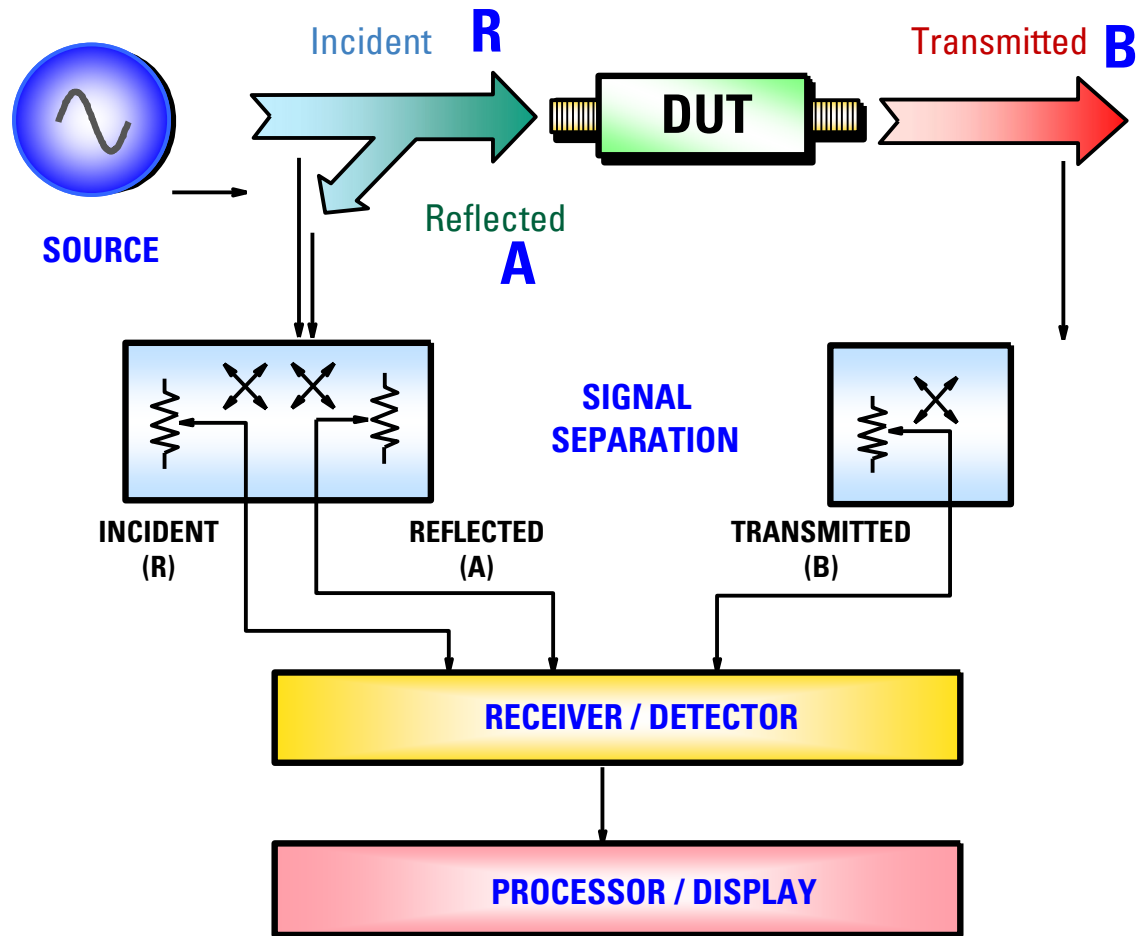
측정항목(TRANSMISSION)



What Types of Devices are Tested?

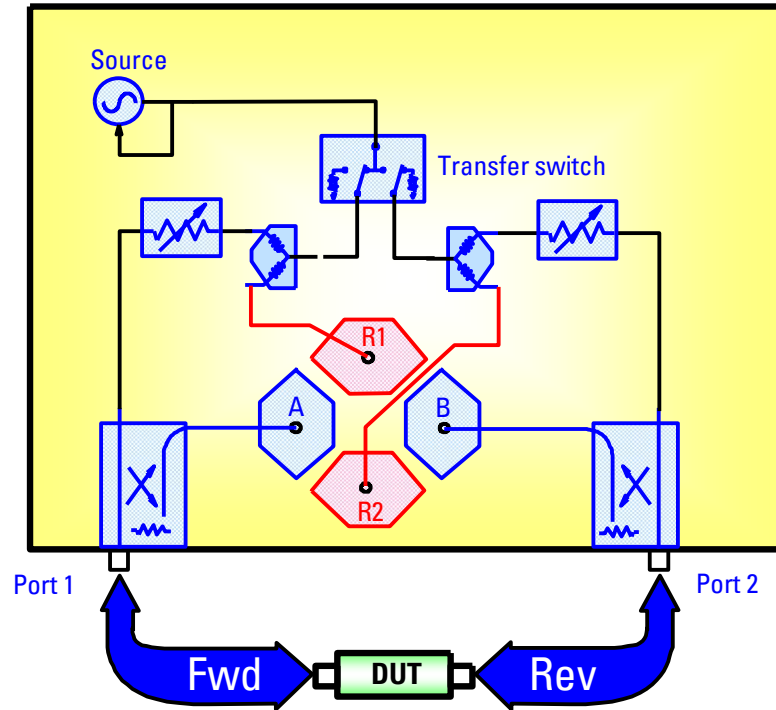


간략한 네트워크분석기의 구조



간략한 네트워크분석기의 구조

S-Parameter Test Set



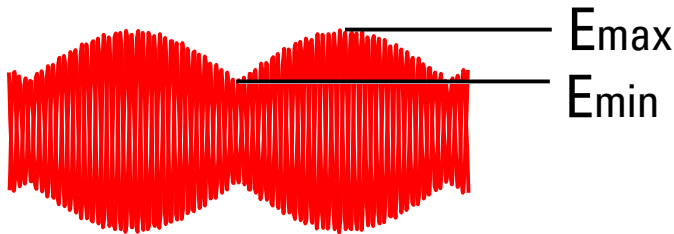
RF comes out port 1 or port 2
forward and reverse measurements
two-port calibration possible

반사와 관련된 측정항목

Reflection Coefficient
(반사계수)

$$\Gamma = \frac{V_{\text{reflected}}}{V_{\text{incident}}} = \rho \angle \Phi = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Return loss = $-20 \log(\rho)$
(반사손실)



Voltage Standing Wave Ratio

$$\text{VSWR} = \frac{E_{\text{max}}}{E_{\text{min}}} = \frac{1 + \rho}{1 - \rho}$$

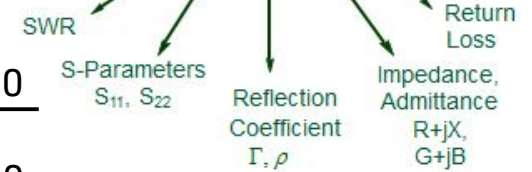
No reflection
($Z_L = Z_0$)

Full reflection
($Z_L = \text{open, short}$)

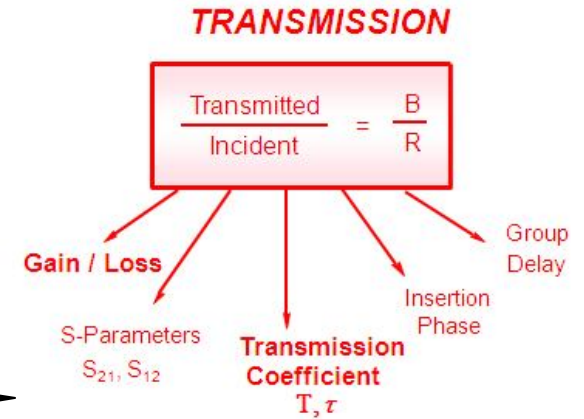
0	ρ	1
$-\infty$ dB	RL	0 dB
1	VSWR	∞

REFLECTION

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



전달과 관련된 측정항목



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

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

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

S-Parameters

S21

입력포트번호

출력포트번호



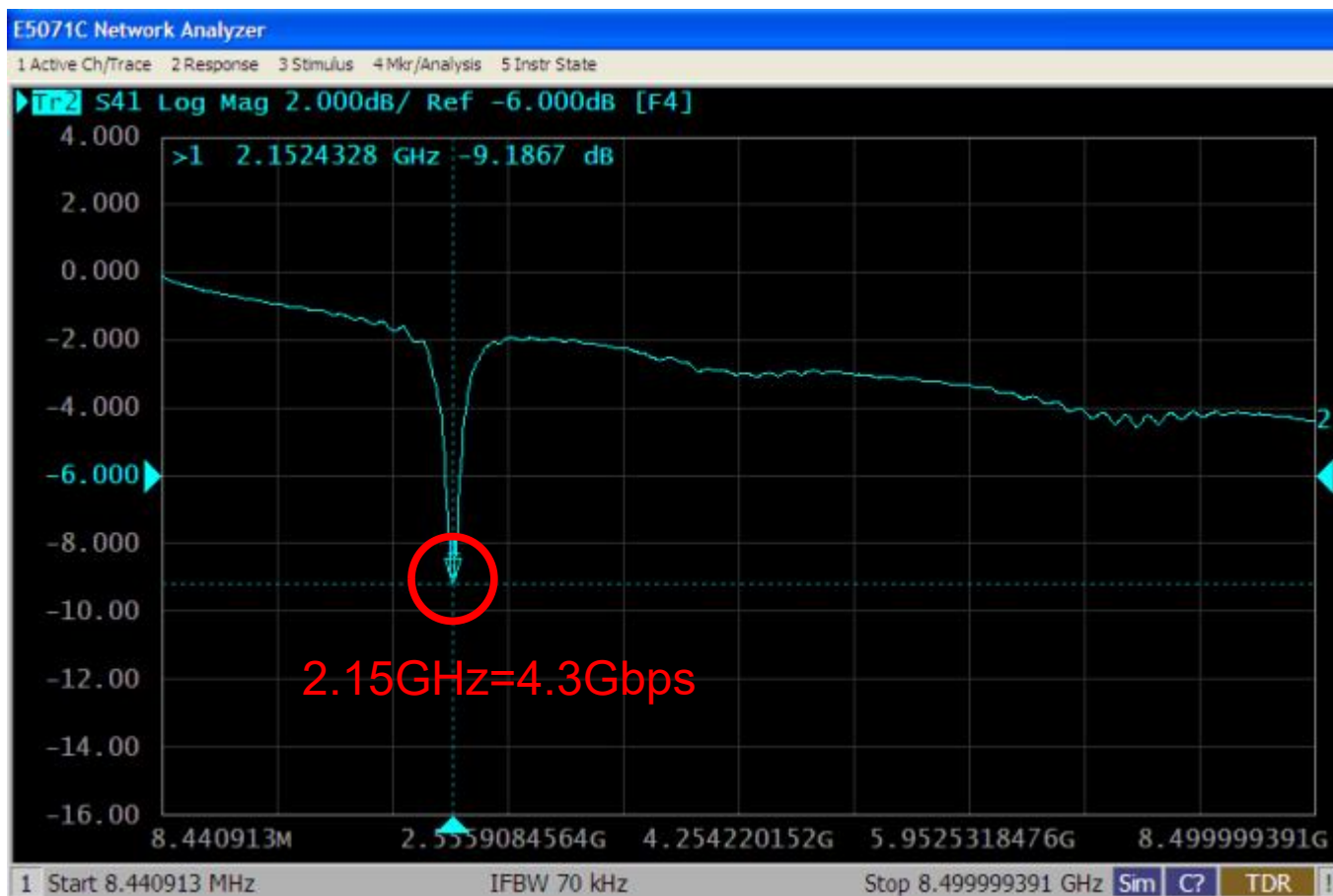
포트1

포트2

- S11** = forward reflection coefficient (*input match*)
- S22** = reverse reflection coefficient (*output match*)
- S21** = forward transmission coefficient (*gain or loss*)
- S12** = reverse transmission coefficient (*isolation*)

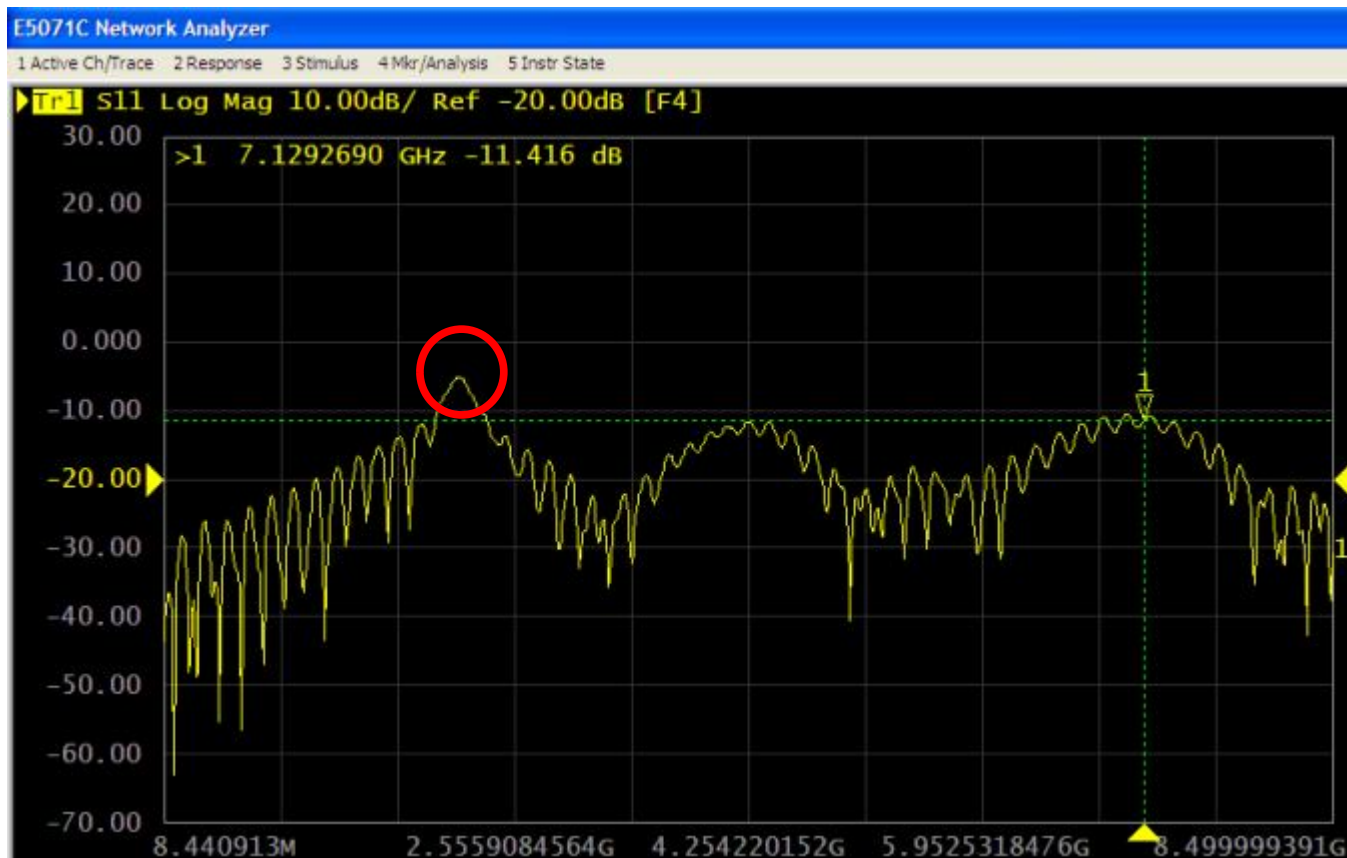
S-parameter (반사손실, 삽입손실)

삽입손실(Insertion Loss, S21)



S-parameter (반사손실, 삽입손실)

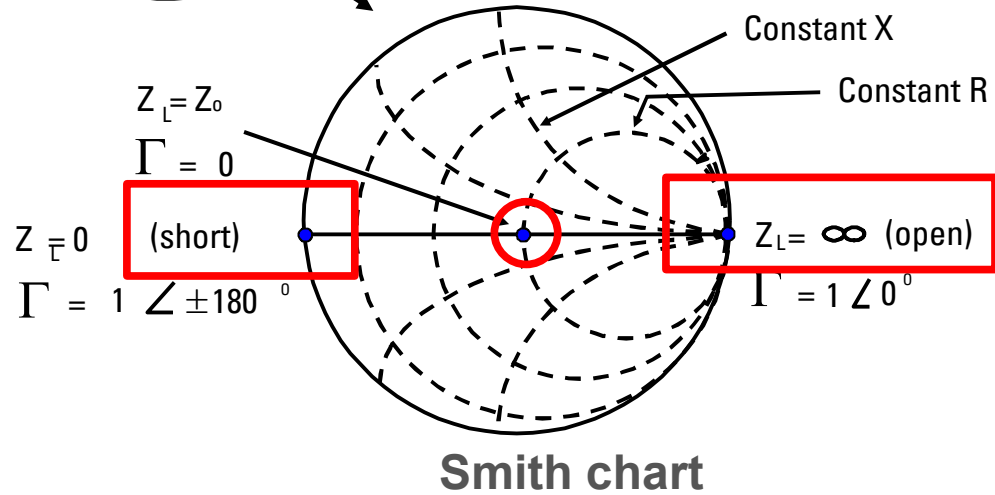
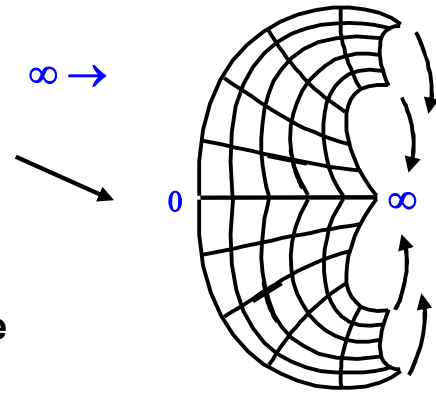
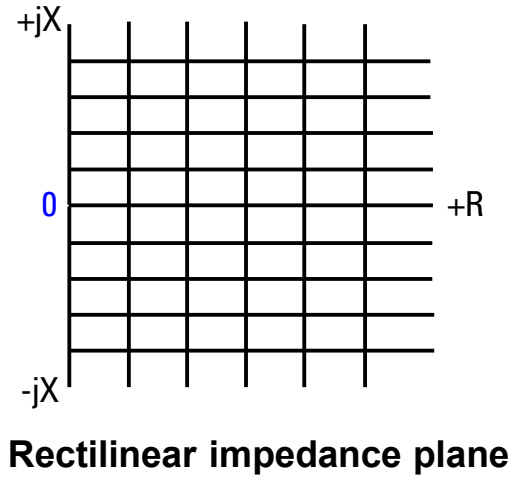
반사손실(Return Loss, S11)



VSWR(정재파비)



Smith Chart (스미스 차트)



스미스 차트는 직교 좌표계를 한쪽점을 기준으로 원좌표로 변환한 것

Measurement Error Modeling



Systematic errors

due to **imperfections** in the analyzer and test setup
assumed to be **time invariant** (predictable)



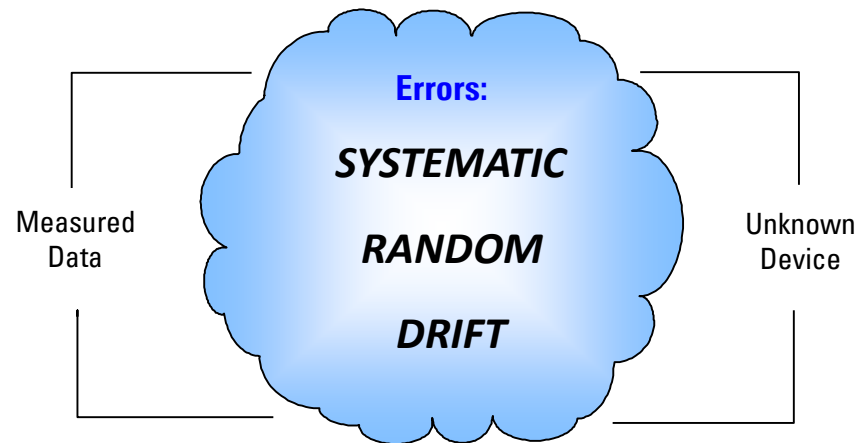
Random errors

vary with time in random fashion (unpredictable)
main contributors: instrument **noise**, switch and connector
repeatability

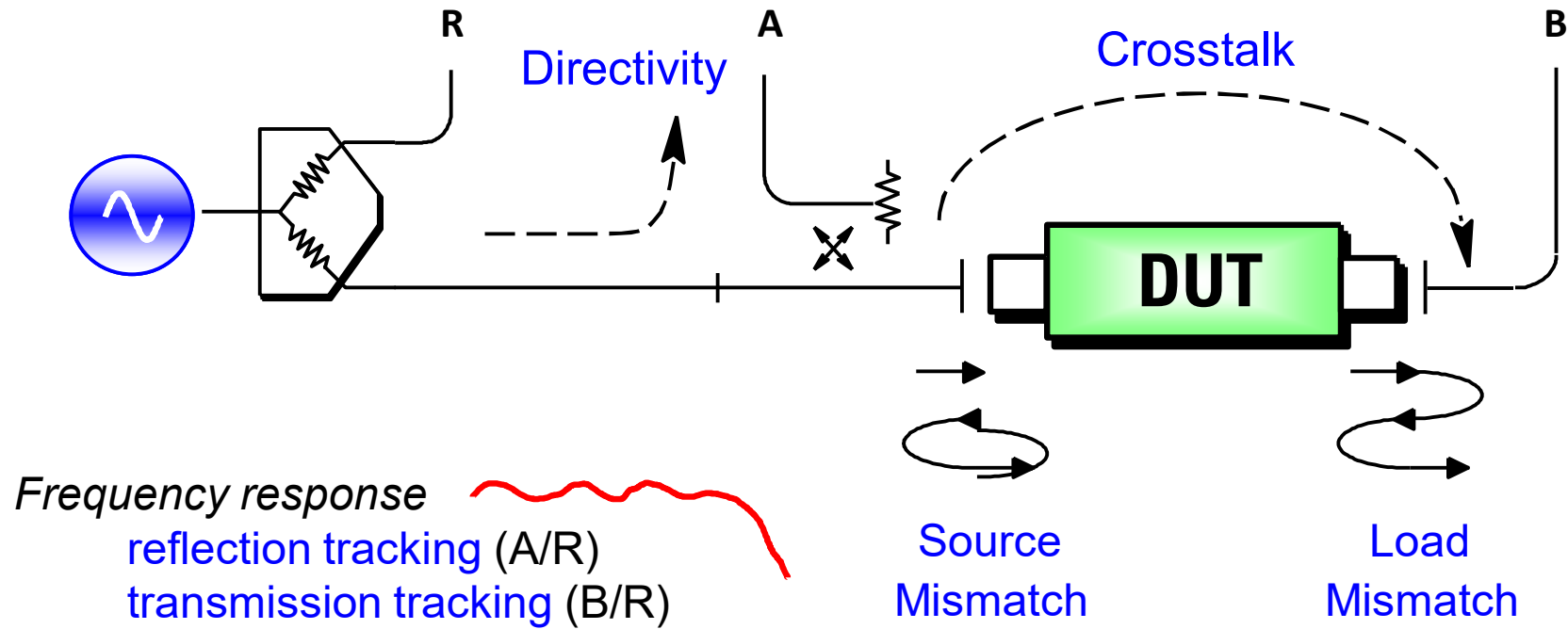


Drift errors

due to system performance changing **after** a calibration has
been done
primarily caused by **temperature variation**



Systematic Measurement Errors



***Six forward and six reverse error terms
yields 12 error terms for two-port devices***

Calibration

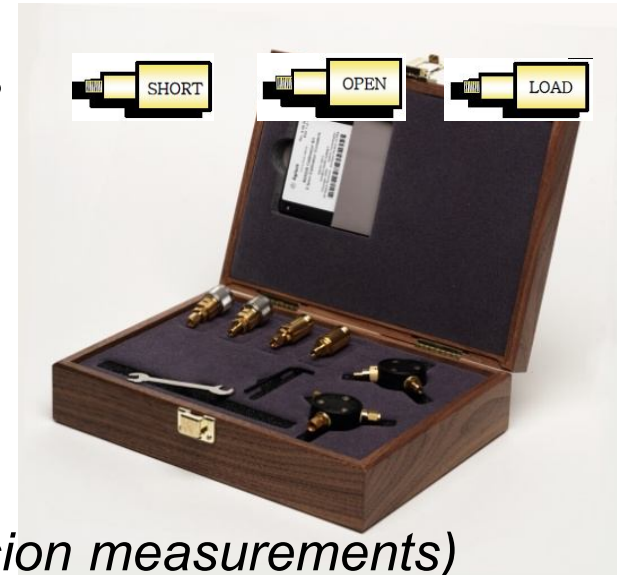
-Systematic Error를 보정하기 위한 표준시료를 이용하는것

Process of characterizing systematic error terms
measure **known standards**
remove effects from subsequent measurements

1-port calibration (*reflection measurements*)
only 3 systematic error terms measured
directivity, source match, and reflection tracking

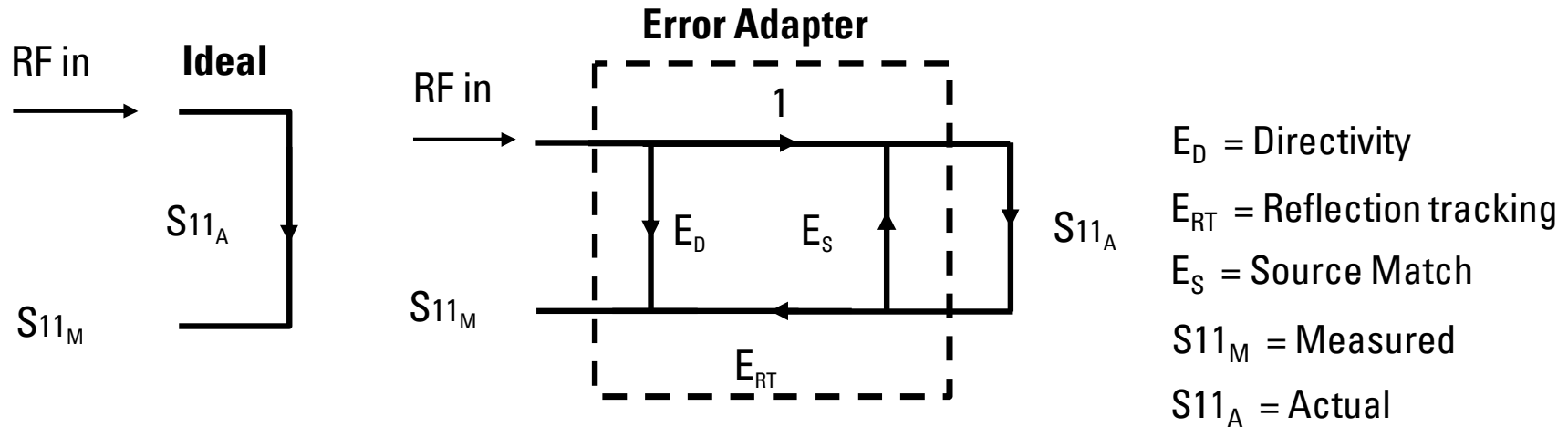
Full 2-port calibration (*reflection and transmission measurements*)
12 systematic error terms measured
usually requires 12 measurements on four known standards (SOLT)

Standards defined in **cal kit definition file**
network analyzer contains standard cal kit definitions
CAL KIT DEFINITION MUST MATCH ACTUAL CAL KIT USED!
User-built standards must be characterized and entered into user cal-kit



Calibration

-Reflection: One-Port Model



To solve for error terms, we measure 3 standards to generate 3 equations and 3 unknowns

$$S11_M = E_D + E_{RT}$$

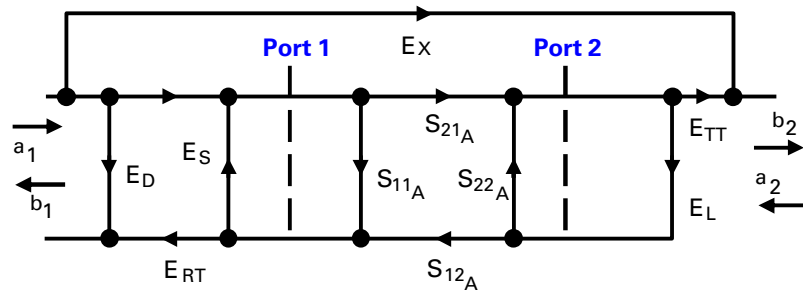
$$\left[\frac{S11_A}{1 - E_S S11_A} \right]$$

Assumes good termination at port two if testing two-port devices
 If using port 2 of NA *and* DUT reverse isolation is low (e.g., filter passband):
 assumption of good termination is not valid
 two-port error correction yields better results

Calibration

Two-Port Error Correction

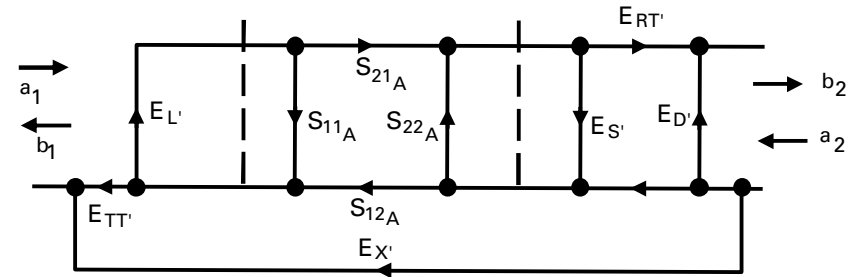
Forward model



- E_D = fwd directivity
- E_S = fwd source match
- E_{RT} = fwd reflection tracking
- $E_{D'}$ = rev directivity
- $E_{S'}$ = rev source match
- $E_{RT'}$ = rev reflection tracking
- E_L = fwd load match
- E_{TT} = fwd transmission tracking
- E_X = fwd isolation
- $E_{L'}$ = rev load match
- $E_{TT'}$ = rev transmission tracking
- $E_{X'}$ = rev isolation

Each actual S-parameter is a function of all four measured S-parameters
 Analyzer must make forward *and* reverse sweep to update any one S-parameter
 Luckily, you don't need to know these equations to **use** network analyzers!!!

Reverse model



$$S_{11a} = \frac{(\frac{S_{11m} - E_D}{E_{RT}})(1 + \frac{S_{22m} - E_{D'}}{E_{RT'}} E_{S'}) - E_L(\frac{S_{21m} - E_X}{E_{TT}})(\frac{S_{12m} - E_{X'}}{E_{TT'}})}{(1 + \frac{S_{11m} - E_{D'}}{E_{RT}} E_S)(1 + \frac{S_{22m} - E_{D'}}{E_{RT'}} E_{S'}) - E_L' E_L(\frac{S_{21m} - E_X}{E_{TT}})(\frac{S_{12m} - E_{X'}}{E_{TT'}})}$$

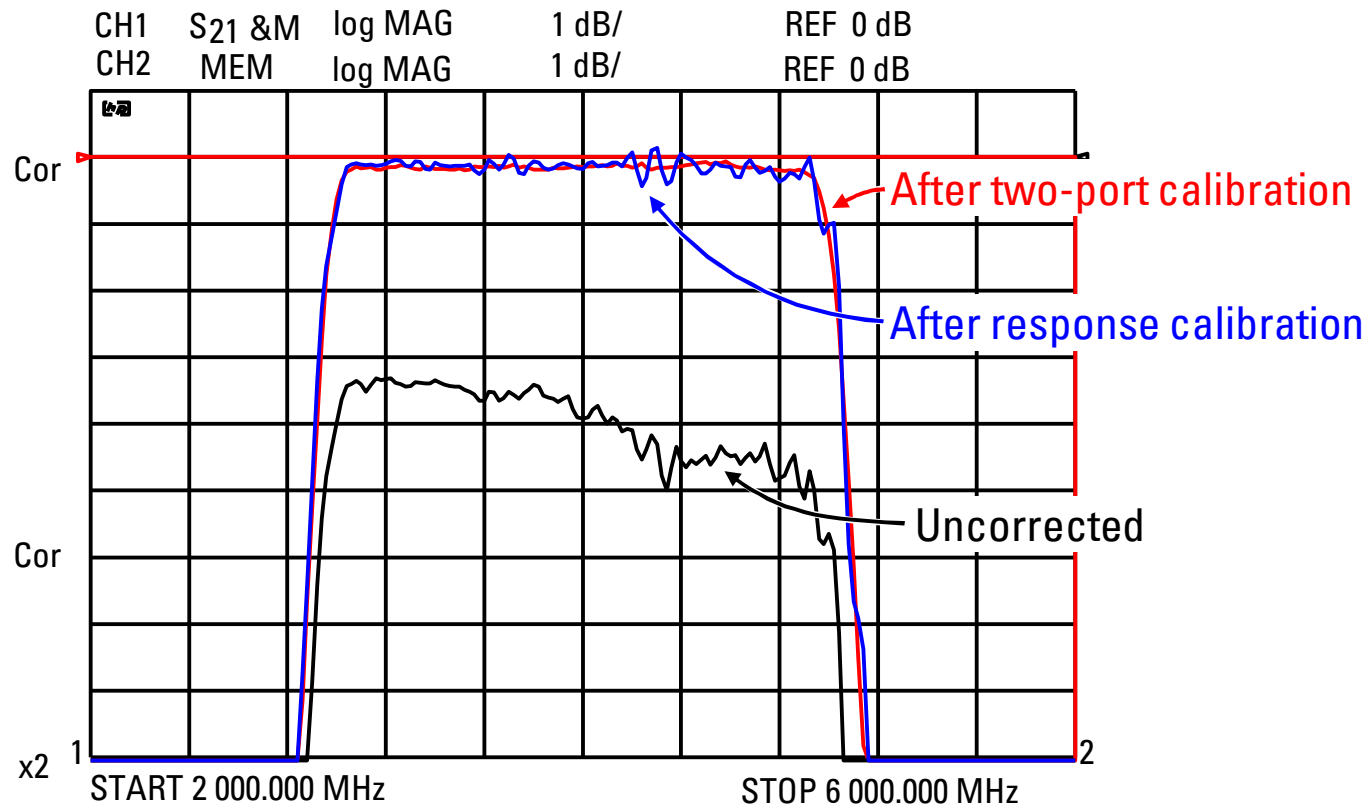
$$S_{21a} = \frac{(\frac{S_{21m} - E_X}{E_{TT}})(1 + \frac{S_{22m} - E_{D'}}{E_{RT'}} (E_{S'} - E_L))}{(1 + \frac{S_{11m} - E_D}{E_{RT}} E_S)(1 + \frac{S_{22m} - E_{D'}}{E_{RT'}} E_{S'}) - E_L' E_L(\frac{S_{21m} - E_X}{E_{TT}})(\frac{S_{12m} - E_{X'}}{E_{TT'}})}$$

$$S_{12a} = \frac{(\frac{S_{12m} - E_{X'}}{E_{TT'}})(1 + \frac{S_{11m} - E_D}{E_{RT}} (E_S - E_{L'}))}{(1 + \frac{S_{11m} - E_D}{E_{RT}} E_S)(1 + \frac{S_{22m} - E_{D'}}{E_{RT'}} E_{S'}) - E_L' E_L(\frac{S_{21m} - E_X}{E_{TT}})(\frac{S_{12m} - E_{X'}}{E_{TT'}})}$$

$$S_{22a} = \frac{(\frac{S_{22m} - E_{D'}}{E_{RT'}})(1 + \frac{S_{11m} - E_D}{E_{RT}} E_S) - E_L'(\frac{S_{21m} - E_X}{E_{TT}})(\frac{S_{12m} - E_{X'}}{E_{TT'}})}{(1 + \frac{S_{11m} - E_D}{E_{RT}} E_S)(1 + \frac{S_{22m} - E_{D'}}{E_{RT'}} E_{S'}) - E_L' E_L(\frac{S_{21m} - E_X}{E_{TT}})(\frac{S_{12m} - E_{X'}}{E_{TT'}})}$$

Calibration

Measuring filter insertion loss



ECal: Electronic Calibration

Control ECal directly from the PNA or ENA Network Analyzers via USB
Nine connector types available
Ideal calibration technique for manufacturing
Mixed-connectors available

- Type-N 50 ohm, 3.5 mm and 7-16
N4690 Series, 2-port Microwave ECal
85090 Series, 2-port RF ECal
N4431B, 4-port RF ECal



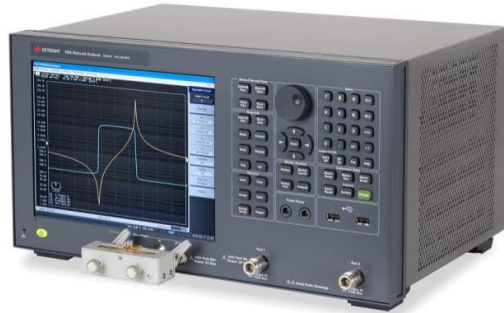
키사이트 네트워크 분석기



FieldFox

Handheld RF
Analyzer

5 Hz to
4/6/9/14/18//26.5/32
/44/50 GHz



E5061B:NA + ZA in one-box, 5 Hz to 3 GHz

**E5063A:Low cost RF VNA,100 kHz to 1.5/3.0 GHz, 4.5GHz,
13.5GHz, 18GHz**



Streamline, USB VNA

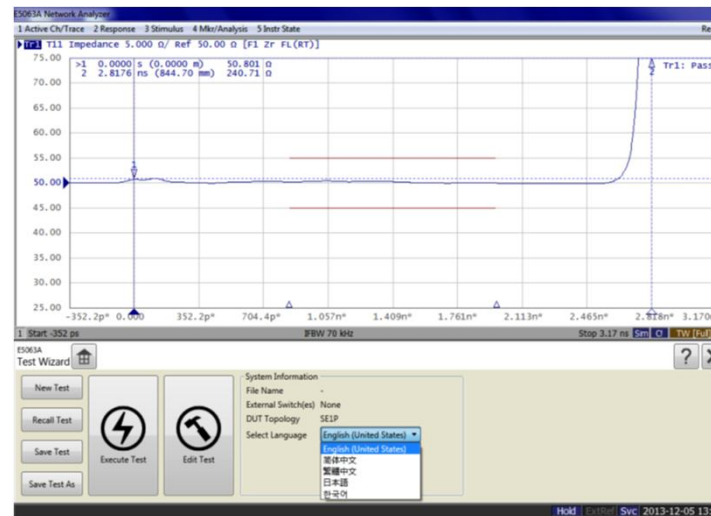
4.5/6.5/9/14/20/26.5GHz

기본 모델:E5063A



E5063A:Low cost RF VNA,
-100 kHz 0.5/1.5//3.0 GHz, 4.5GHz,
13.5GHz, 18GHz

TDR특성임피던스의 측정



핸드형 RF 및 마이크로웨이브 분석기(FieldFox)

FieldFox

Handheld RF Analyzer

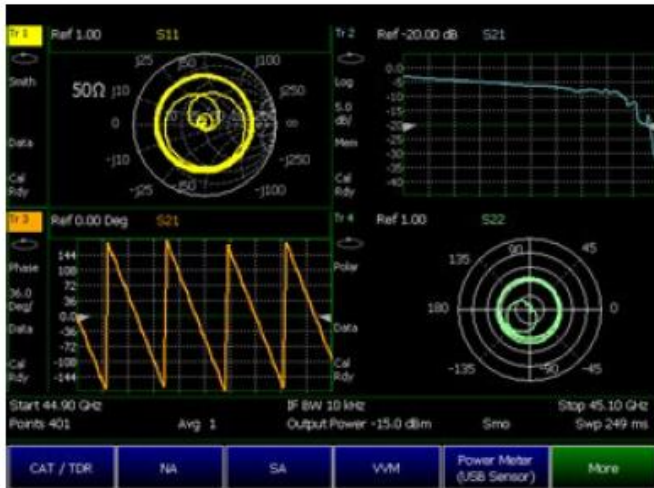
4/6/9/14/18/26.5/32/44/50 GHz



Option

- VNA
- SA
- CAT
- Power Meter

핸드형 RF 및 마이크로웨이브 분석기(FieldFox)



Vector network analyzer

- All four S-parameters, magnitude and phase
- Time-domain analysis, mixed-mode reflection S-parameters
- CalReady, QuickCal, full 2-port cal, TRL, waveguide cal, ECal support, and a Guided Calibration Wizard



Cable and antenna analyzer

- Distance-to-fault (DTF) and return loss/VSWR
- 1-port cable loss, 2-port insertion loss, and time-domain reflectometry (TDR)
- Integrated QuickCal up to 18 GHz for simple field measurements - no calibration kit required

핸드형 RF 및 마이크로웨이브 분석기(FieldFox)



Spectrum analyzer

- Unprecedented amplitude accuracy of ± 0.5 dB with InstAlign¹ - no warm-up required
- Tracking generator, independent source, and preamplifier covering the full frequency range
- Channel power (CHP), occupied bandwidth (OBW), spectrum emission mask (SEM), adjacent channel power (ACP)
- Interference analysis and analog demodulation

핸드형 RF 및 마이크로웨이브 분석기(FieldFox)

Model	CAT and VNA frequency	Spectrum analyzer frequency ¹	Test port connectors
RF & microwave (combination) analyzers			
N9913A	30 kHz to 4 GHz	100 kHz to 4 GHz	Type-N (f)
N9914A	30 kHz to 6.5 GHz	100 kHz to 6.5 GHz	Type-N (f)
N9915A	30 kHz to 9 GHz	100 kHz to 9 GHz	Type-N (f)
N9916A	30 kHz to 14 GHz	100 kHz to 14 GHz	Type-N (f)
N9917A	30 kHz to 18 GHz	100 kHz to 18 GHz	Type-N (f)
N9918A	30 kHz to 26.5 GHz	100 kHz to 26.5 GHz	3.5 mm (m)
N9950A	300 kHz to 32 GHz	9 kHz to 32 GHz	NMD 2.4 mm (m)
N9951A	300 kHz to 44 GHz	9 kHz to 44 GHz	NMD 2.4 mm (m)
N9952A	300 kHz to 50 GHz	9 kHz to 50 GHz	NMD 2.4 mm (m)
Vector network analyzers			
N9925A	30 kHz to 9 GHz	—	Type-N (f)
N9926A	30 kHz to 14 GHz	—	
N9927A	30 kHz to 18 GHz	—	
N9928A	30 kHz to 26.5 GHz	—	
Spectrum analyzers			
N9935A	—	100 kHz to 9 GHz	
N9936A	—	100 kHz to 14 GHz	
N9937A	—	100 kHz to 18 GHz	
N9938A	—	100 kHz to 26.5 GHz	
N9960A	—	9 kHz to 32 GHz	
N9961A	—	9 kHz to 44 GHz	
N9962A	—	9 kHz to 50 GHz	



1600-9545

jays@jays.co.kr

USB type 네트워크 분석기 (Streamline)



Frequency Range

Model number

Frequency range

P9370A	300 kHz to 4.5 GHz
P9371A	300 kHz to 6.5 GHz
P9372A	300 kHz to 9 GHz
P9373A	300 kHz to 14 GHz
P9374A	300 kHz to 20 GHz
P9375A	300 kHz to 26.5 GHz



2대의 Streamline을 이용한
4포트 VNA의 구현

네트워크 분석기, 간단측정절차

1.Set-up

Measure plane

2.Stimulus

주파수, Power, Number of point, IF BW (Sweep type...)

3.Calibration

Cal kit , Cal type , Cal, Verify

4.Measurement

Meas, Format, Scale/Div, Display, Marker

5.Measure result

Printing, Saving

DEMO

Demo Example

