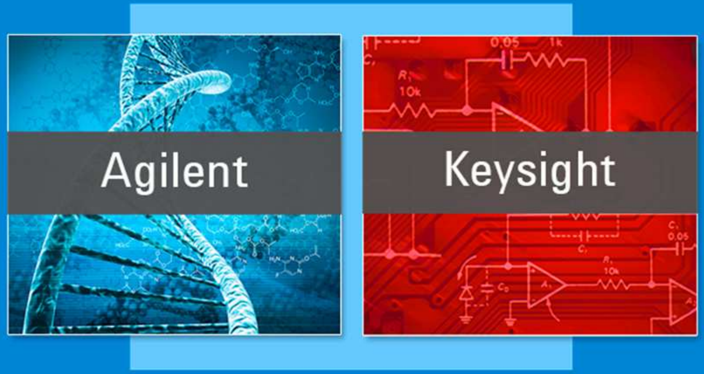
INTEGRIDAD DE SEÑAL

Analizador PCB – Altas Prestaciones, Bajo Coste



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91 631 3300

AGENDA

Unlocking Measurement Insights for 75 Years

- Traditional PCB Measurements
- PCB Market Trends
- Dedicated VNA for PCB Measurements
- Summary & Closure

AGENDA

- **Traditional PCB Measurements**
- PCB Market Trends
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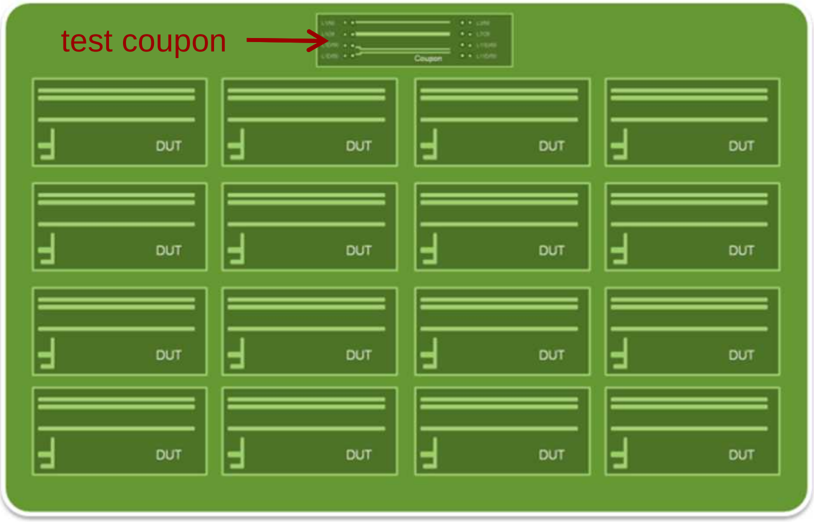
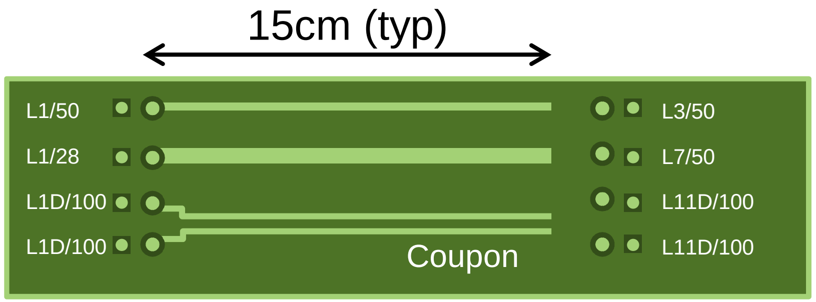
- Summary & Closure

Traditional PCB Measurements

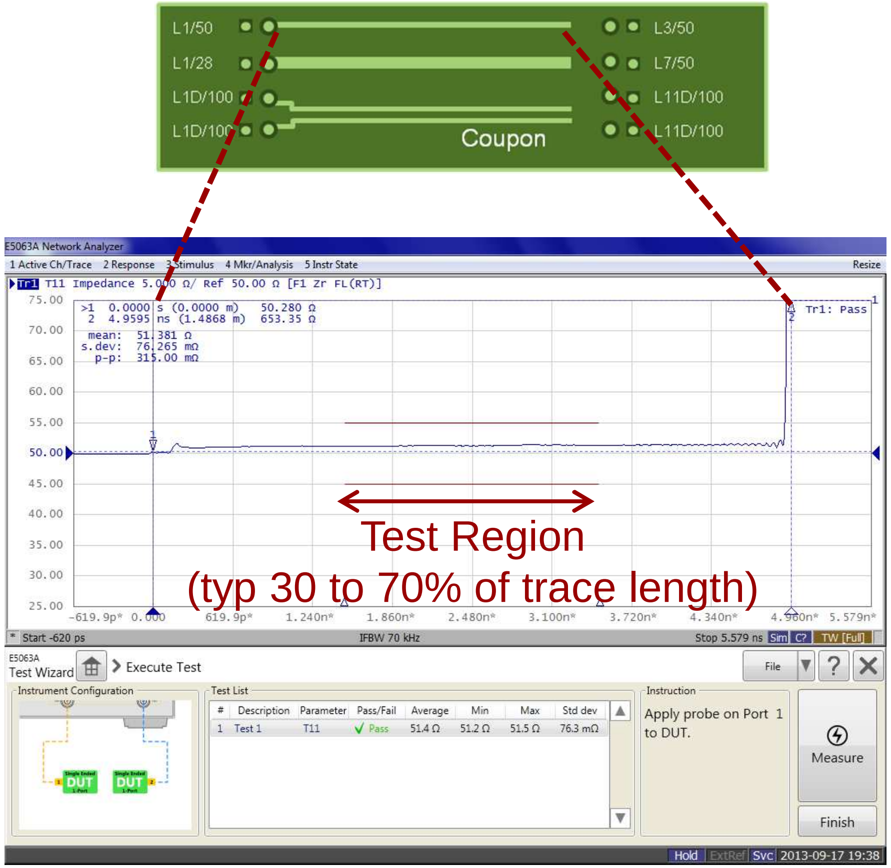


- Test Coupon Example:



- Parameters = Impedance (SE & DIFF)
- Required Tolerance = ±10%

- L1/50 trace measurement example



```
Tr1 T11 Impedance 5.000 Ω/ Ref 50.00 Ω [F1 Zr FL(RT)]
>1  0.0000 s (0.0000 m)    50.280 Ω
 2  4.9595 ns (1.4868 m)   653.35 Ω
  mean:   51.381 Ω
 s.dev:   76.265 mΩ
   p-p:   315.00 mΩ
```

Start -620 ps IFBW 70 kHz Stop 5.579 ns Sim C? TW [Full]

Test List

#	Description	Parameter	Pass/Fail	Average	Min	Max	Std dev
1	Test 1	T11	✓ Pass	51.4 Ω	51.2 Ω	51.5 Ω	76.3 mΩ

Instruction

Apply probe on Port 1 to DUT.

2013-09-17 19:38

Test Region

(typ 30 to 70% of trace length)

Manual Procedure on VNA

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

- ✓ Set Time Domain Parameters
  - Stimulus to Low Pass Step
  - Set Freq Low Pass
- ✓ Calibrate
- ✓ Fixture Compensation
- ✓ Enable Fixture Simulator: BalUn, Diff Z, Z Conv
- ✓ Enable Time Transform
- ✓ Format Lin Mag
- ✓ MRK1 Search Target 0.5 (probe open)
- ✓ MRK2 Search Target 0.5 (probe measuring)
- ✓ Set MEAS RANGE from 30%MRK1 to 70%MRK2
- ✓ Enable LIMIT TEST

L1D/100 trace measurement example

AGENDA

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PCB Market Trends

PCB

Antenna

Trends:
- Higher data rates
- Tighter impedance control

Measurements:
- Impedance (TDR)
- Sample or 100% testing
- Required tolerance = ±5%
- In-circuit test (non-coupon)

⇒Need more accurate and higher bandwidth instrument

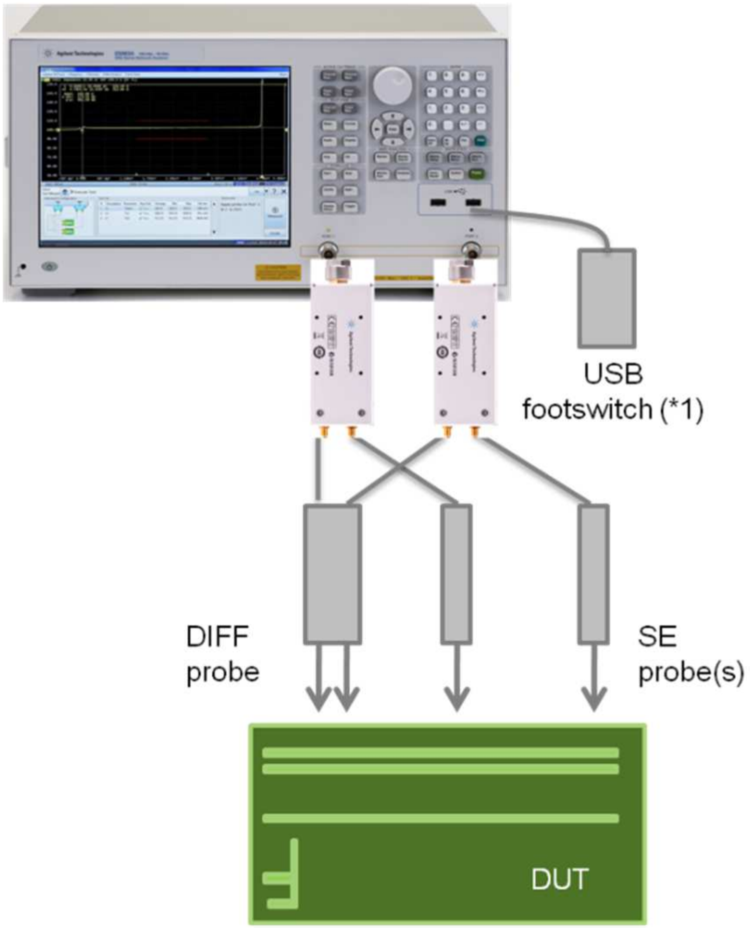
Trends:
- More PCB integrated antennas
- More PCB suppliers manufacture antennas

Measurements:
- Return loss (S-parameters)
- 100% testing

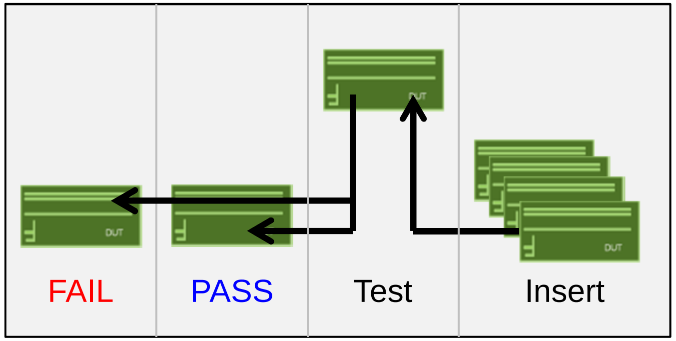
⇒Need to measure in both time and frequency domains

Use Models

Manual Testing



Automated Testing



AGENDA

Unlocking Measurement Insights for 75 Years

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E5063A PCB Analyzer

The Best Solution for PCB Manufacturing Test

Frequency Range	4.5/8.5/18 GHz
Number of Ports	2 or 4 w/ switch U1810B
Time Domain	YES
Frequency Domain	YES
Topology	SE & DIFF
PCB Dedicated GUI	YES
Error Correction	Deskew, Deskew&Loss, and Electronic Cal
ESD Robustness	YES

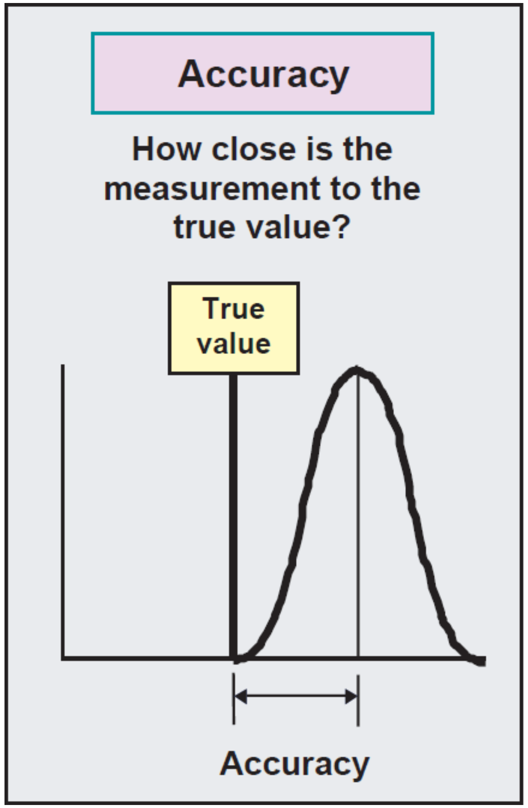
- **More Accuracy and R&R***
- **More ESD Robustness**
- **Dedicated GUI for PCB Measurements**
- **The lowest cost solution in the industry**

* Repeatability & Reproducibility

More Accuracy and R&R*

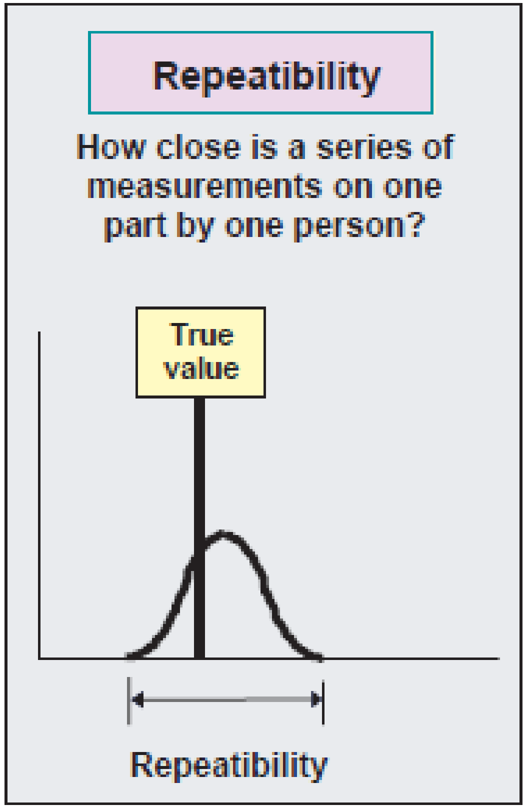
* Repeatability & Reproducibility

Definitions:



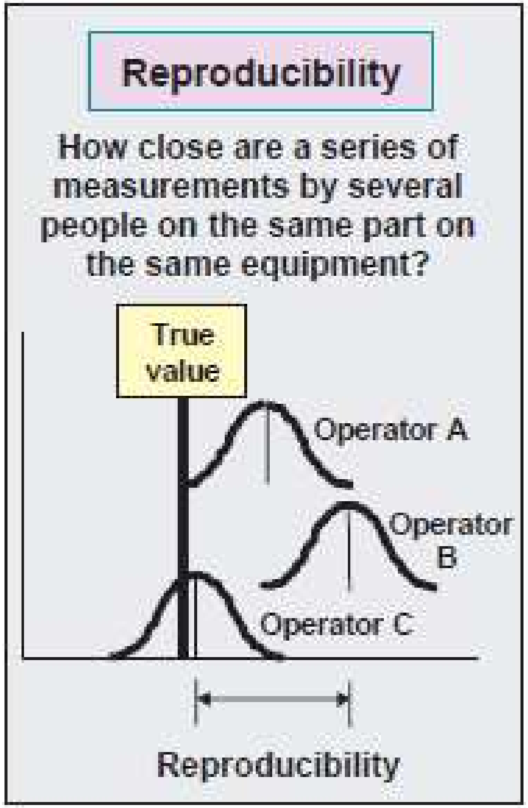
Accuracy

How close is the measurement to the true value?



Repeatibility

How close is a series of measurements on one part by one person?



Reproducibility

How close are a series of measurements by several people on the same part on the same equipment?

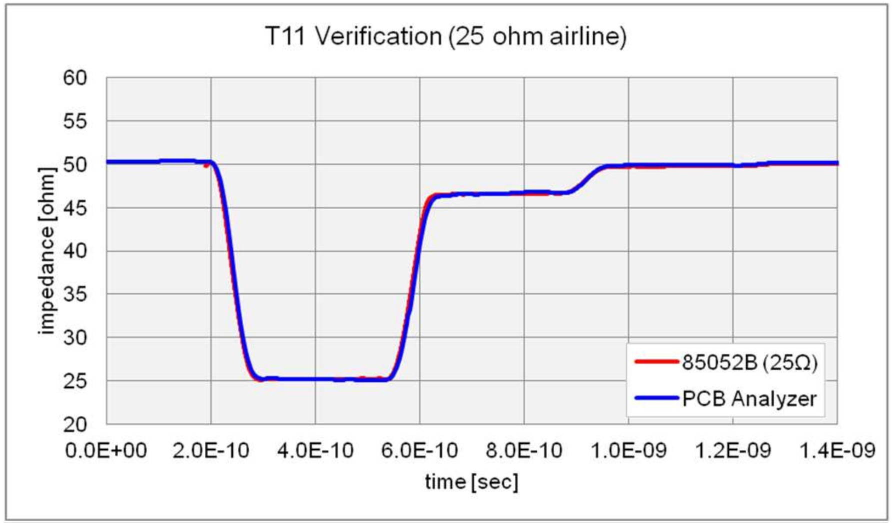
(Source: IPC-TM-650 Number 1.9 Measurement Precision Estimation for Variables Data)

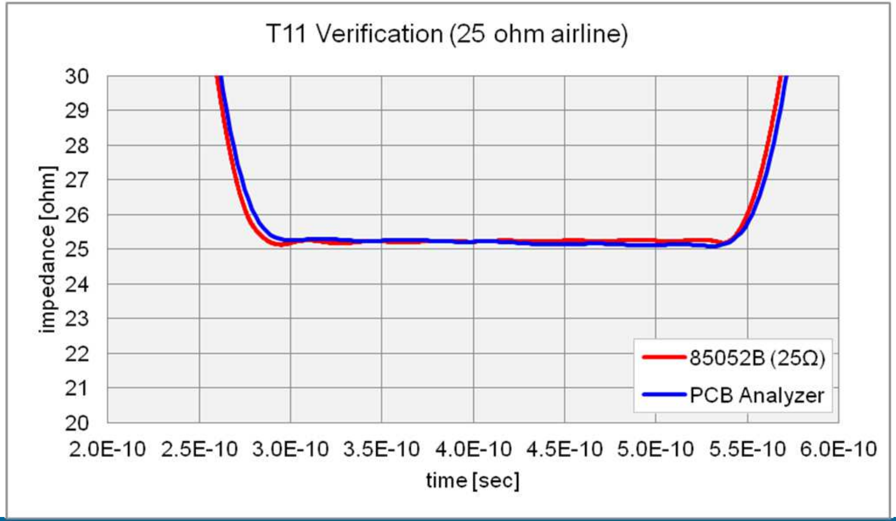
Accuracy Verification using a NIST Traceable Standard

Measurement results are within 0.1 ohm of 25 ohm airline standard.

DUT: 25 ohm airline
(85052B Verification Kit)

The verification kit includes measurement data and uncertainties which are traceable to National Institute of Standards and Technology (NIST).





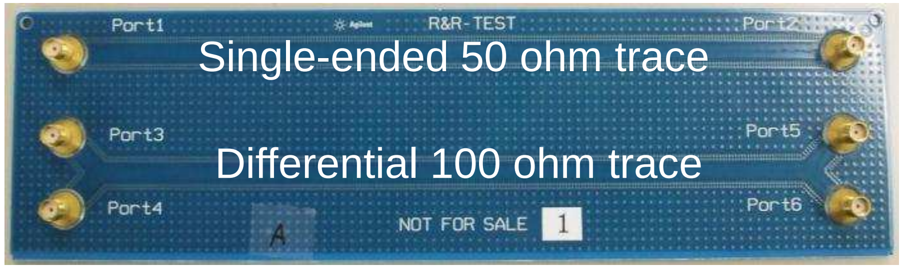
R&R Evaluation (Average and Range Method)

Unlocking Measurement Insights for 75 Years

	Single-ended	Differential
R&R	**0.010 ohm**	**0.020 ohm**

DUT: R&R Evaluation Board
(unused ports left open)

DUT Length = 22 cm

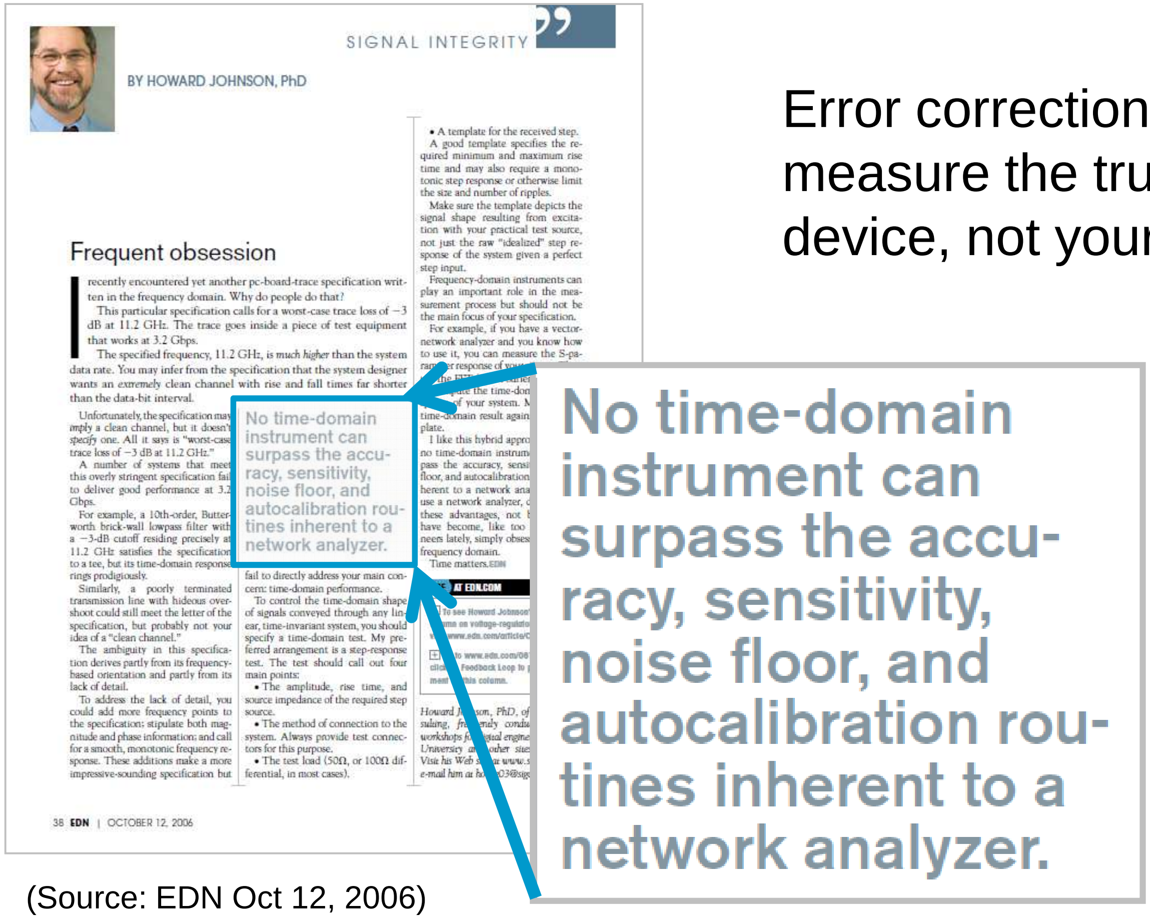


Test Conditions
- 3 operators
- 7 DUTs
- 3 measurements on each DUT
- Average impedance within 30-70% of the DUT length used for R&R calculations

Error Correction Techniques

KEYSIGHT
TECHNOLOGIES

Unlocking Measurement Insights for 75 Years



SIGNAL INTEGRITY

BY HOWARD JOHNSON, PhD

Frequent obsession

I recently encountered yet another pc-board-trace specification written in the frequency domain. Why do people do that?

This particular specification calls for a worst-case trace loss of −3 dB at 11.2 GHz. The trace goes inside a piece of test equipment that works at 3.2 Gbps.

The specified frequency, 11.2 GHz, is *much higher* than the system data rate. You may infer from the specification that the system designer wants an *extremely* clean channel with rise and fall times far shorter than the data-bit interval.

Unfortunately, the specification may *imply* a clean channel, but it doesn't *specify* one. All it says is "worst-case trace loss of −3 dB at 11.2 GHz."

A number of systems that meet this overly stringent specification fail to deliver good performance at 3.2 Gbps.

For example, a 10th-order, Butterworth brick-wall lowpass filter with a −3-dB cutoff residing precisely at 11.2 GHz satisfies the specification to a tee, but its time-domain response rings prodigiously.

Similarly, a poorly terminated transmission line with hideous overshoot could still meet the letter of the specification, but probably not your idea of a "clean channel."

The ambiguity in this specification derives partly from its frequency-based orientation and partly from its lack of detail.

To address the lack of detail, you could add more frequency points to the specification: stipulate both magnitude and phase information; and call for a smooth, monotonic frequency response. These additions make a more impressive-sounding specification but fail to directly address your main concern: time-domain performance.

> No time-domain instrument can surpass the accuracy, sensitivity, noise floor, and autocalibration routines inherent to a network analyzer.

To control the time-domain shape of signals conveyed through any linear, time-invariant system, you should specify a time-domain test. My preferred arrangement is a step-response test. The test should call out four main points:

- The amplitude, rise time, and source impedance of the required step source.
- The method of connection to the system. Always provide test connectors for this purpose.
- The test load (50Ω, or 100Ω differential, in most cases).
- A template for the received step.

A good template specifies the required minimum and maximum rise time and may also require a monotonic step response or otherwise limit the size and number of ripples.

Make sure the template depicts the signal shape resulting from excitation with your practical test source, not just the raw "idealized" step response of the system given a perfect step input.

Frequency-domain instruments can play an important role in the measurement process but should not be the main focus of your specification.

For example, if you have a vector-network analyzer and you know how to use it, you can measure the S-pa-ram[illegible]er response of you[illegible] [illegible] the FFT [illegible] [illegible]pute the time-dom[illegible] [illegible] of your system. M[illegible] time-domain result again[illegible] plate.

I like this hybrid appro[illegible] no time-domain instrum[illegible] pass the accuracy, sensi[illegible] floor, and autocalibration [illegible] herent to a network ana[illegible] use a network analyzer, [illegible] these advantages, not [illegible] have become, like too [illegible] neers lately, simply obses[illegible] frequency domain.

Time matters.EDN

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☐ To see Howard Johnson' [illegible] [illegible]umn on voltage-regulatio[illegible] [illegible] www.edn.com/article/C[illegible]

⊞ [illegible] to www.edn.com/061[illegible] click [illegible] Feedback Loop to p[illegible] ment [illegible] this column.

Howard J[illegible]son, PhD, of [illegible] sulting, fre[illegible]ently condu[illegible] workshops fo[illegible] [illegible]gital engine[illegible] University an[illegible] other sites [illegible] Visit his Web s[illegible] at www.s[illegible] e-mail him at ho[illegible]03@sig[illegible]

38 EDN | OCTOBER 12, 2006

No time-domain instrument can surpass the accuracy, sensitivity, noise floor, and autocalibration routines inherent to a network analyzer.

(Source: EDN Oct 12, 2006)

Error correction techniques enables you to measure the true performance of your device, not your measurement system.

Dedicated GUI for PCB Measurements

KEYSIGHT
TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Tr1 T33 Impedance 2.000 Ω/ Ref 50.00 Ω [F1 Zr FL(RT)]

```
>1   0.0000 s  (0.0000 m)     50.844 Ω
 2   2.8114 ns  (842.84 mm)   350.39 Ω
```

Tr1: Pass

Start -351 ps   IFBW 70 kHz   Stop 3.163 ns

Test List

#	Description	Parameter	Pass/Fail	Average	Min	Max	Std dev
1	L1/DIFF100	Tdd11	✓ Pass	100 Ω	100 Ω	101 Ω	128 mΩ
2	L1/SE50	T33	✓ Pass	50.1 Ω	49.8 Ω	50.3 Ω	94.9 mΩ
3	ANT	S44					

Instruction

Apply probe on Port 3 to DUT.

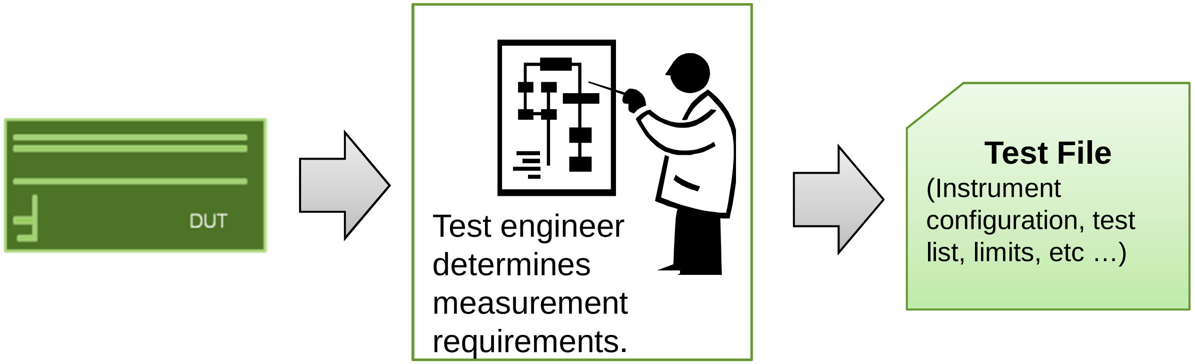
2014-01-10 14:41

Modes of Operation

Unlocking Measurement Insights for 75 Years

Edit Test Mode

- Define test parameters and generate test setup file.

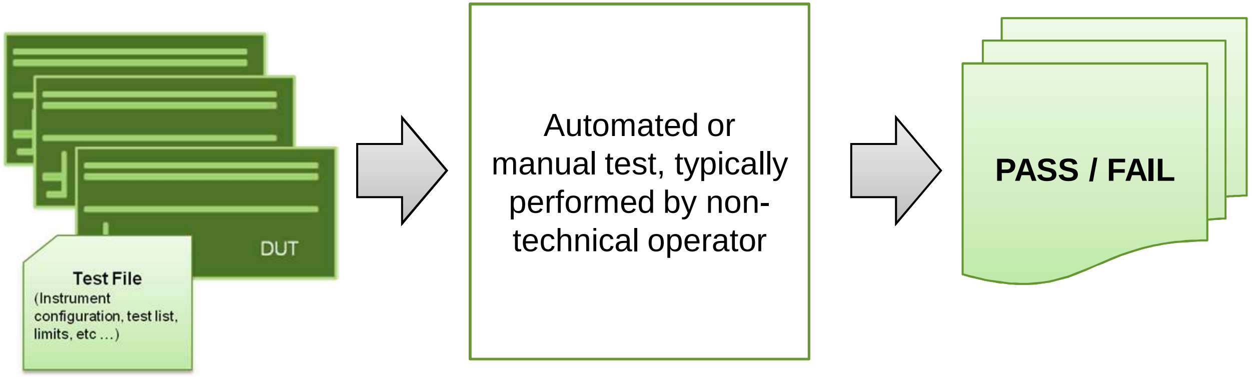


Test engineer determines measurement requirements.

Test File
(Instrument configuration, test list, limits, etc …)

Execute Test Mode

- Recall test setup file and execute test.



Test File
(Instrument configuration, test list, limits, etc …)

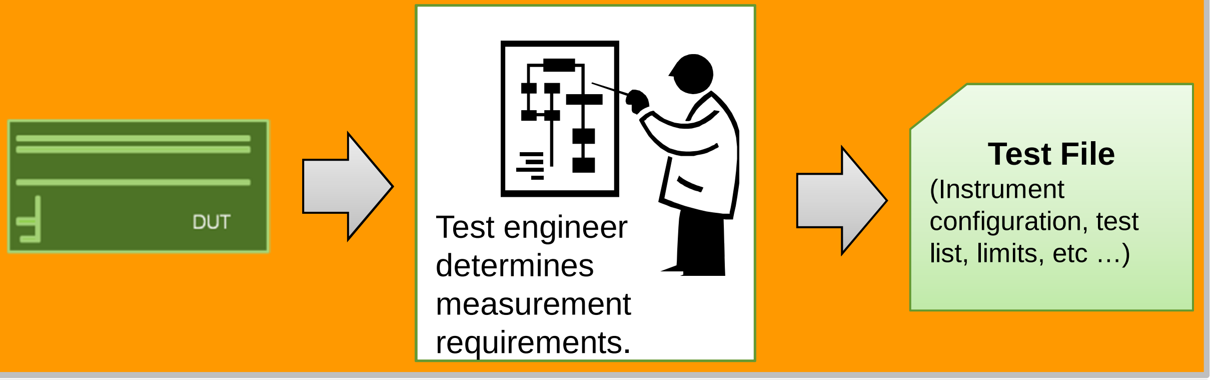
Automated or manual test, typically performed by non-technical operator

PASS / FAIL

Modes of Operation

Edit Test Mode

- Define test parameters and generate test setup file.

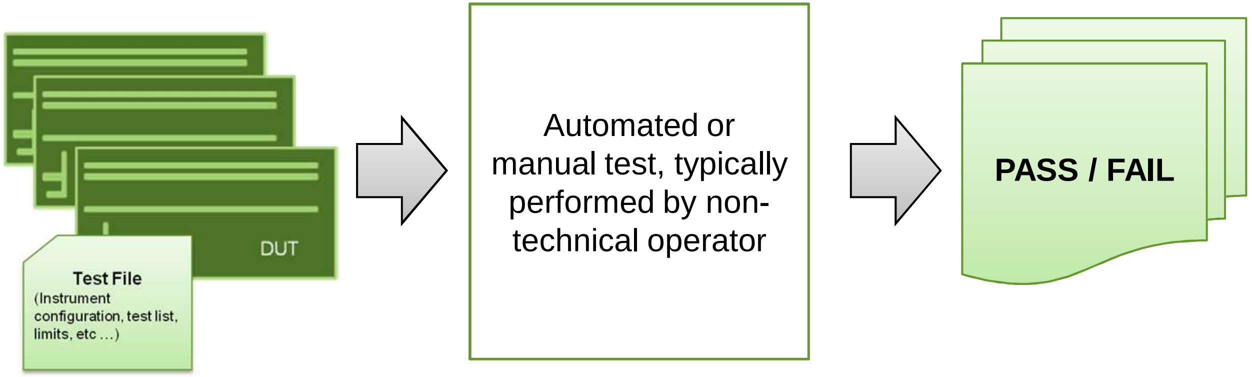


Test engineer determines measurement requirements.

Test File
(Instrument configuration, test list, limits, etc …)

Execute Test Mode

- Recall test setup file and execute test.



Test File
(Instrument configuration, test list, limits, etc …)

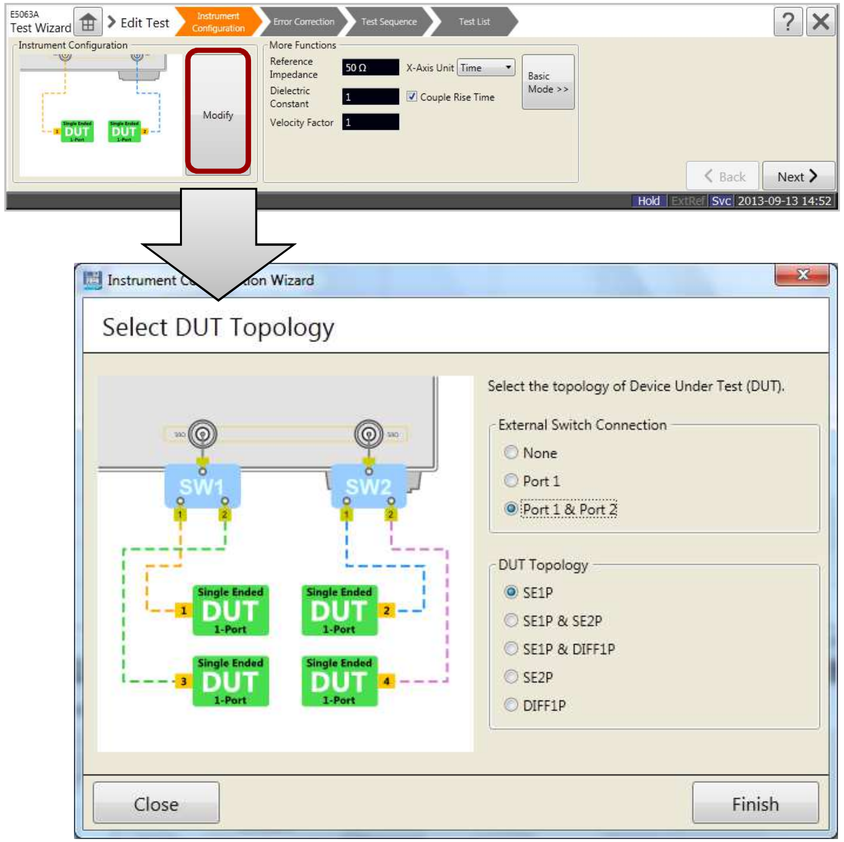
Automated or manual test, typically performed by non-technical operator

PASS / FAIL

Edit Test Mode > Instrument Configuration

KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights for 75 Years

The E5063A PCB Analyzer provides two ports for measurement. By connecting up to two U1810B USB Coaxial Switches (SPDT), the number of available ports can be extended up to four.



Reference Impedance: 50 Ω
X-Axis Unit: Time
Dielectric Constant: 1
☑ Couple Rise Time
Velocity Factor: 1

Select DUT Topology

Select the topology of Device Under Test (DUT).

External Switch Connection
○ None
○ Port 1
● Port 1 & Port 2

DUT Topology
● SE1P
○ SE1P & SE2P
○ SE1P & DIFF1P
○ SE2P
○ DIFF1P

Note:

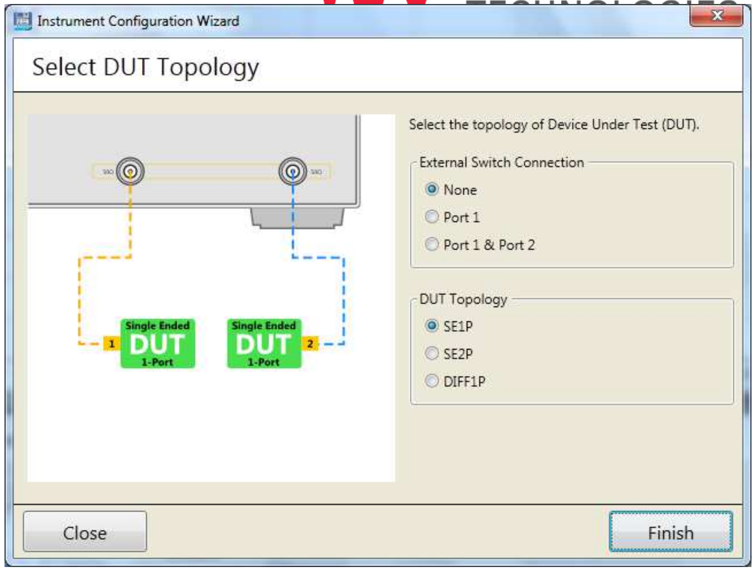
- When connecting only one switch, the switch must be connected to E5063A Port 1.
- When only one switch is connected and two switch configuration (Port 1 & Port 2) is selected:
  - In the Edit Test mode, a Warning message is generated, but edit test is possible.
  - In the Execute Test mode, an Error message is generated and test execution is not possible.

Edit Test Mode > Instrument Configuration

The available DUT Topology selections will depend on the number of switches selected.

Note:

- The switch port number is shown in yellow and the DUT port number is shown in orange.
- The DUT port number is used when defining measurement parameters (ex. TDR on Port 3 is T33).

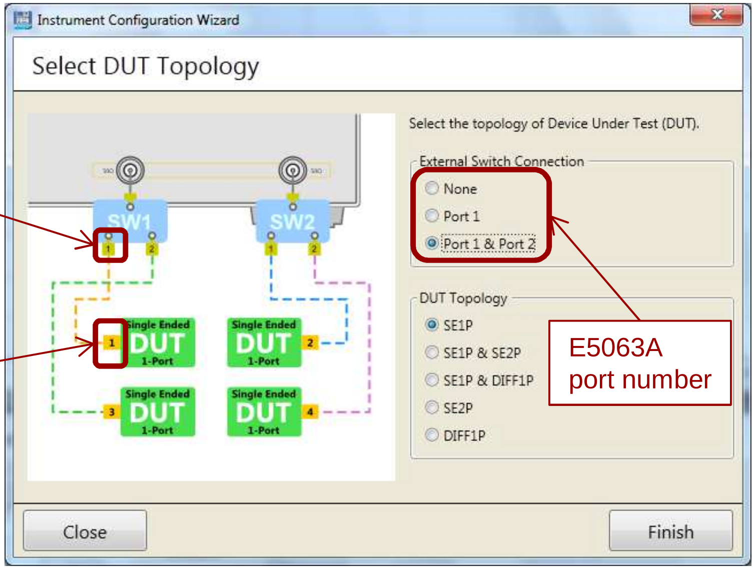


Select DUT Topology

Select the topology of Device Under Test (DUT).

External Switch Connection
- ● None
- ○ Port 1
- ○ Port 1 & Port 2

DUT Topology
- ● SE1P
- ○ SE2P
- ○ DIFF1P



Select DUT Topology

Select the topology of Device Under Test (DUT).

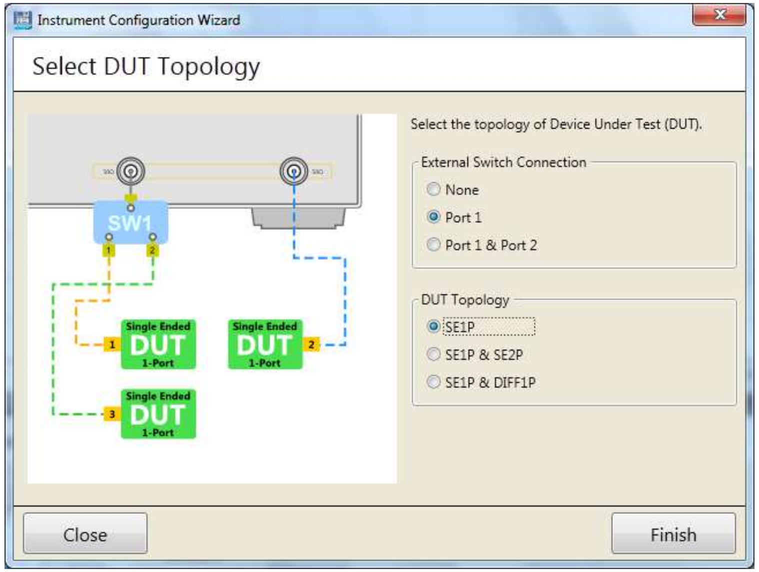
External Switch Connection
- ○ None
- ○ Port 1
- ● Port 1 & Port 2

DUT Topology
- ● SE1P
- ○ SE1P & SE2P
- ○ SE1P & DIFF1P
- ○ SE2P
- ○ DIFF1P

switch port number

DUT port number

E5063A port number



Select DUT Topology

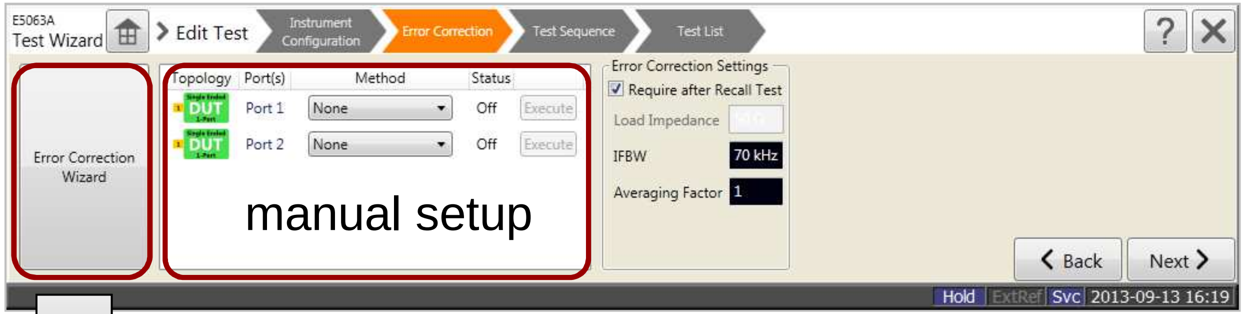
Select the topology of Device Under Test (DUT).

External Switch Connection
- ○ None
- ● Port 1
- ○ Port 1 & Port 2

DUT Topology
- ● SE1P
- ○ SE1P & SE2P
- ○ SE1P & DIFF1P

Edit Test Mode > Error Correction

The Error Correction Wizard (recommended) provides a step-by-step guide to perform error correction. Manual setup and execution is also possible by selecting the appropriate method in the Error Correction table.

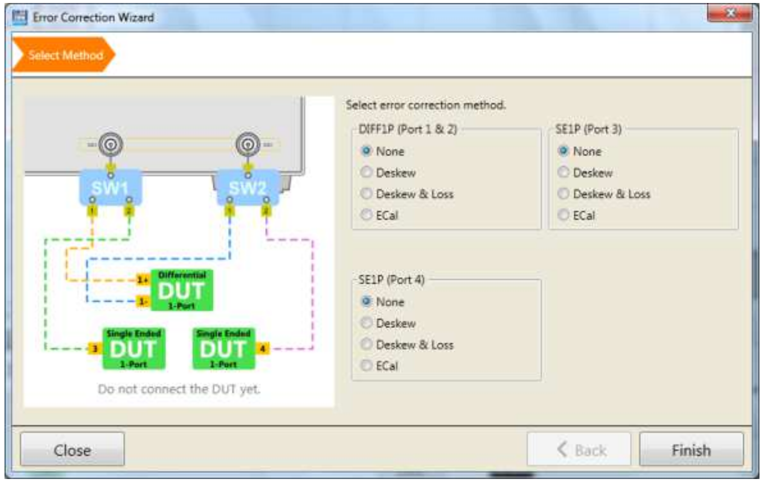


Topology	Port(s)	Method	Status	
DUT	Port 1	None	Off	Execute
DUT	Port 2	None	Off	Execute

Error Correction Settings
☑ Require after Recall Test
Load Impedance
IFBW 70 kHz
Averaging Factor 1

manual setup

Wizard



Do not connect the DUT yet.

Select error correction method.

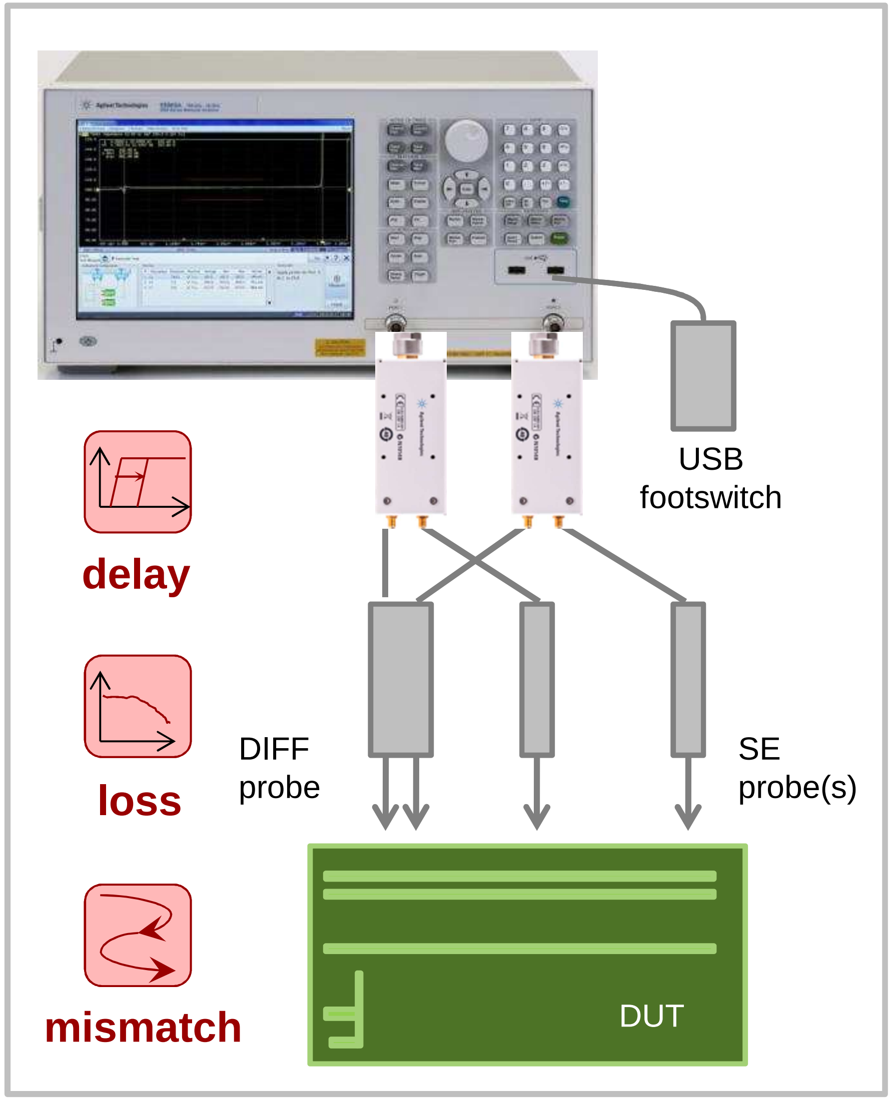
DIFF1P (Port 1 & 2)
● None
○ Deskew
○ Deskew & Loss
○ ECal

SE1P (Port 3)
● None
○ Deskew
○ Deskew & Loss
○ ECal

SE1P (Port 4)
● None
○ Deskew
○ Deskew & Loss
○ ECal

- The following error correction methods are available:
    - Deskew
    - Deskew and loss compensation
    - Full Calibration (ECal)

Why Error Correction?



Measure your device, not your measurement system.

Cables, probes, switches, and fixtures are no longer ideal at today's data rates.

To get the most accurate information about the device under test, you must account for errors introduced by your measurement system, such as **delay**, **loss**, and **mismatch**.

Error Correction Method Comparison

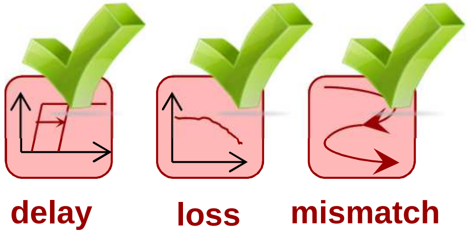
Two common types of error correction methods (FAST):

Deskew

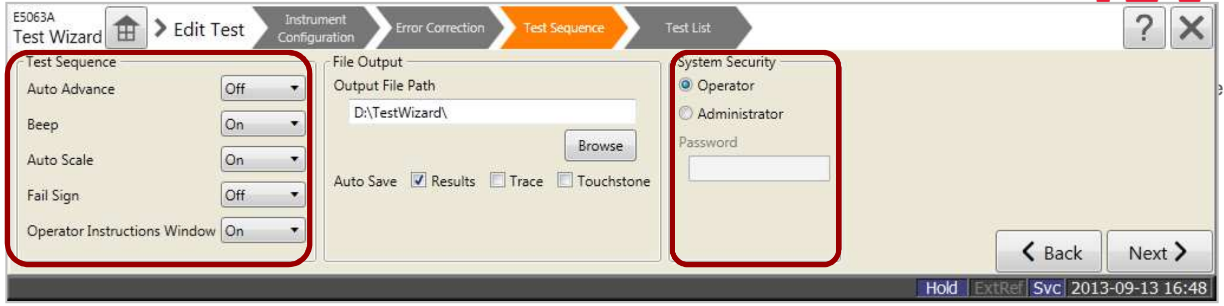
- Commonly used in time domain instruments
- Simple to perform
- Only corrects for delay

Full calibration (ECal)

- Commonly used in frequency domain instruments
- Requires more standards
- Accounts for all major sources of error



Edit Test Mode > Test Sequence



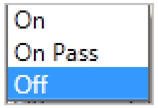
Test Sequence
Auto Advance Off
Beep On
Auto Scale On
Fail Sign Off
Operator Instructions Window On

File Output
Output File Path
D:\TestWizard\
Browse
Auto Save ☑ Results ☐ Trace ☐ Touchstone

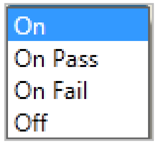
System Security
● Operator
○ Administrator
Password

Test Sequence

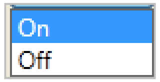
- Auto Advance



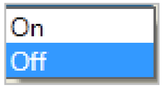
- Beep



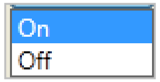
- Auto Scale



- Fail Sign



- Operator Inst Window



System Security

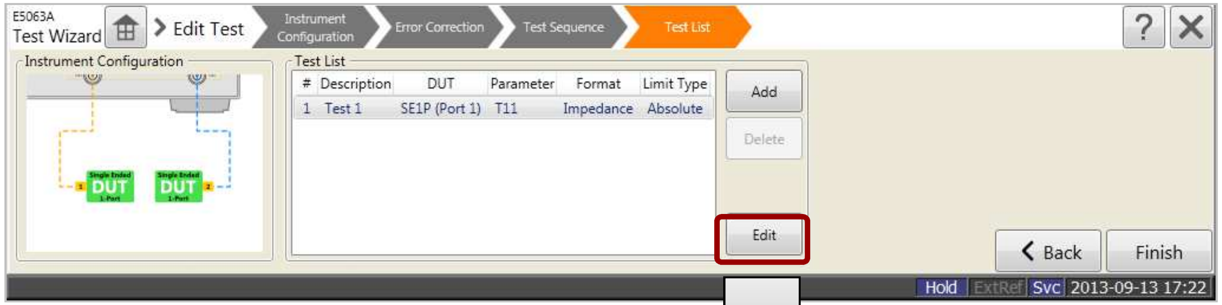
- Operator: access to Edit Test mode without password.

- Administrator: password required to enter Edit Test Mode

Edit Test Mode > Test List

KEYSIGHT TECHNOLOGIES

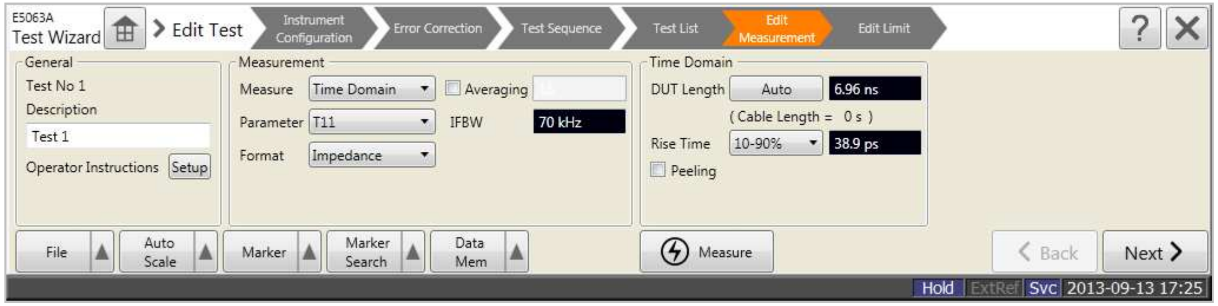
Unlocking Measurement Insights for 75 Years



Test List

#	Description	DUT	Parameter	Format	Limit Type
1	Test 1	SE1P (Port 1)	T11	Impedance	Absolute

- Edit Measurement

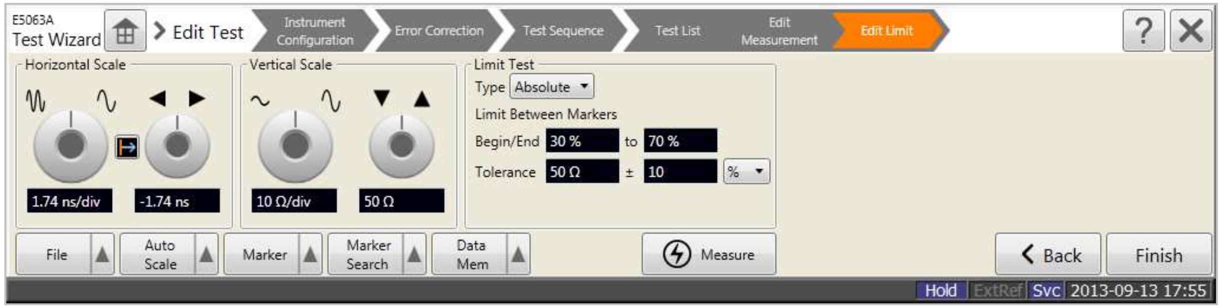


General
Test No 1
Description: Test 1
Operator Instructions Setup

Measurement
Measure: Time Domain
☐ Averaging
Parameter: T11
IFBW: 70 kHz
Format: Impedance

Time Domain
DUT Length: Auto 6.96 ns
(Cable Length = 0 s)
Rise Time: 10-90% 38.9 ps
☐ Peeling

- Edit Limit

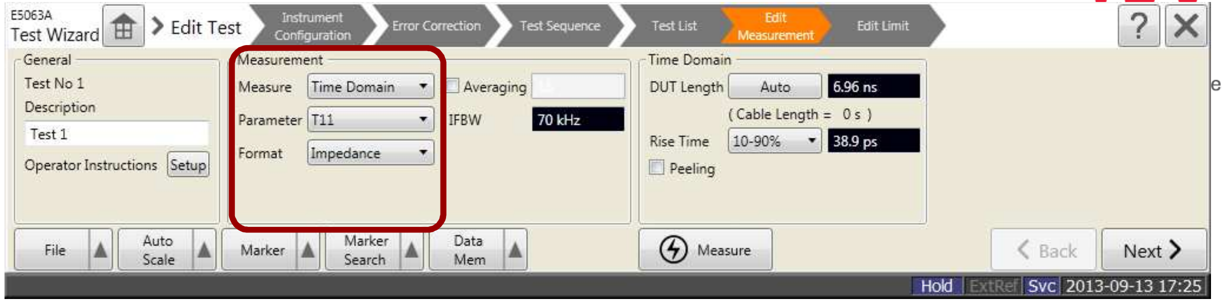


Horizontal Scale: 1.74 ns/div, -1.74 ns

Vertical Scale: 10 Ω/div, 50 Ω

Limit Test
Type: Absolute
Limit Between Markers
Begin/End: 30 % to 70 %
Tolerance: 50 Ω ± 10 %

Edit Test Mode > Test List > Edit Measurement



General
Test No 1
Description: Test 1
Operator Instructions Setup

Measurement
Measure: Time Domain
Parameter: T11
Format: Impedance
☐ Averaging
IFBW: 70 kHz

Time Domain
DUT Length: Auto 6.96 ns
(Cable Length = 0 s)
Rise Time: 10-90% 38.9 ps
☐ Peeling

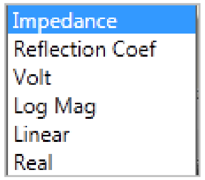
2013-09-13 17:25

- Measure

Time Domain
S-Parameter

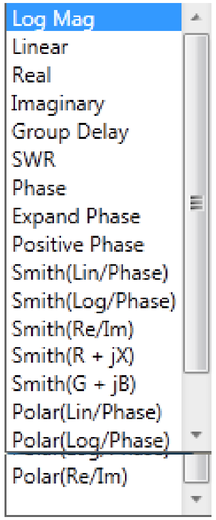
- Format

Time Domain



Impedance
Reflection Coef
Volt
Log Mag
Linear
Real

Freq Domain



Log Mag
Linear
Real
Imaginary
Group Delay
SWR
Phase
Expand Phase
Positive Phase
Smith(Lin/Phase)
Smith(Log/Phase)
Smith(Re/Im)
Smith(R + jX)
Smith(G + jB)
Polar(Lin/Phase)
Polar(Log/Phase)
Polar(Re/Im)

- Parameters

Available	Not Available

Topology: SE1P

T11	T12	T13	T14
T21	**T22**	T23	T24
T31	T32	**T33**	T34
T41	T42	T43	**T44**

Topology: SE2P

T11	**T12**	T13	T14
T21	**T22**	T23	T24
T31	T32	**T33**	**T34**
T41	T42	**T43**	**T44**

Topology: DIFF1P

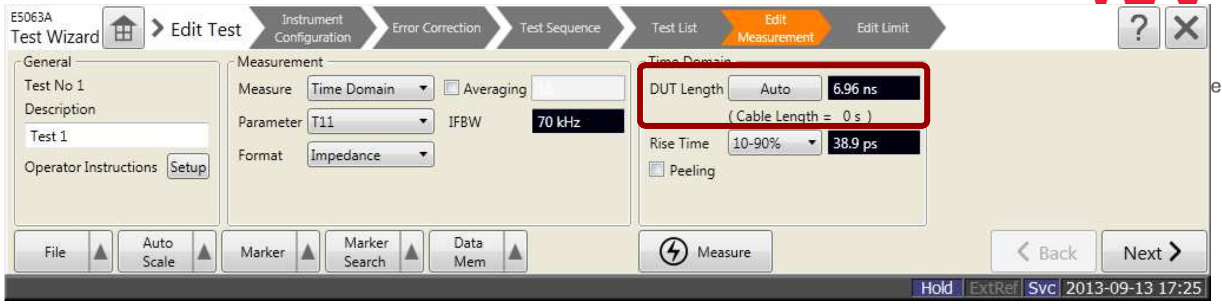
Tdd11	Tdd12	**Tdc11**	Tdc12
Tdd21	**Tdd22**	Tdc21	**Tdc22**
Tcd11	Tcd12	**Tcc11**	Tcc12
Tcd21	**Tcd22**	Tcc21	**Tcc22**

Note:

- Available parameters will depend on the selected instrument configuration. (ex. For Port 1 (one switch) and SE1P topology, T44 is not available.)
- Equivalent S-parameters are available when frequency domain is selected.

Edit Test Mode > Test List > Edit Measurement

easurement Insights for 75 Years



General
Test No 1
Description: Test 1
Operator Instructions Setup

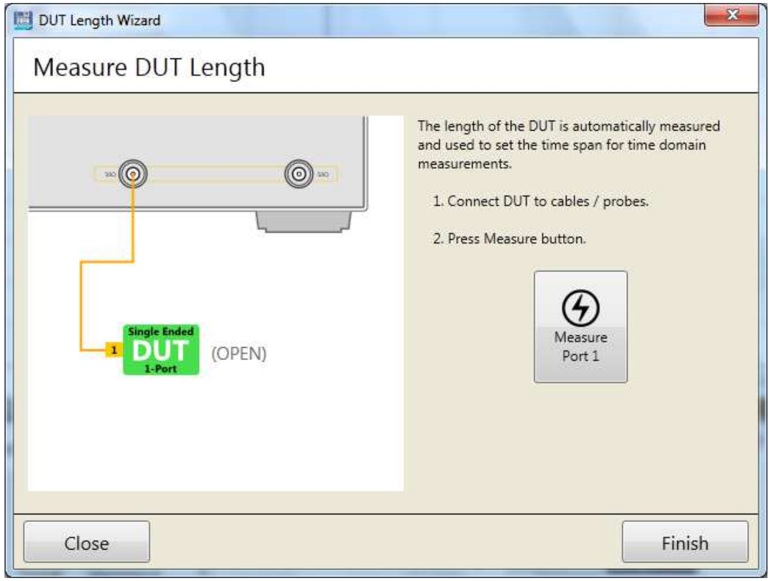
Measurement
Measure: Time Domain
☐ Averaging
Parameter: T11
IFBW: 70 kHz
Format: Impedance

Time Domain
DUT Length: Auto 6.96 ns
(Cable Length = 0 s)
Rise Time: 10-90% 38.9 ps
☐ Peeling

Hold ExtRef Svc 2013-09-13 17:25

•DUT Length
The DUT Length Wizard (recommended) provides an automatic measurement of the DUT length. Manual entry is also possible using the numeric entry box.

The DUT length setting is used to set the optimum time span for time domain measurements.

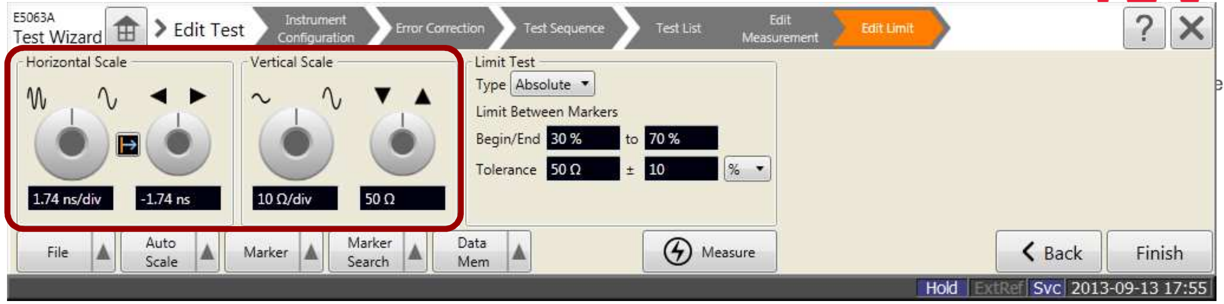


Measure DUT Length

The length of the DUT is automatically measured and used to set the time span for time domain measurements.

1. Connect DUT to cables / probes.
2. Press Measure button.

Edit Test Mode > Test List > Edit Limit



Horizontal Scale: 1.74 ns/div, -1.74 ns

Vertical Scale: 10 Ω/div, 50 Ω

Limit Test

Type Absolute

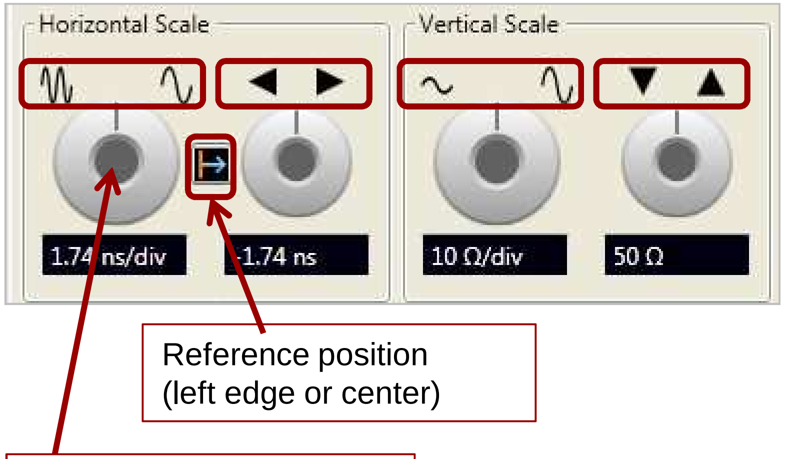
Limit Between Markers

Begin/End 30 % to 70 %

Tolerance 50 Ω ± 10 %

increase / decrease scale (1-2-5 step)   left   right

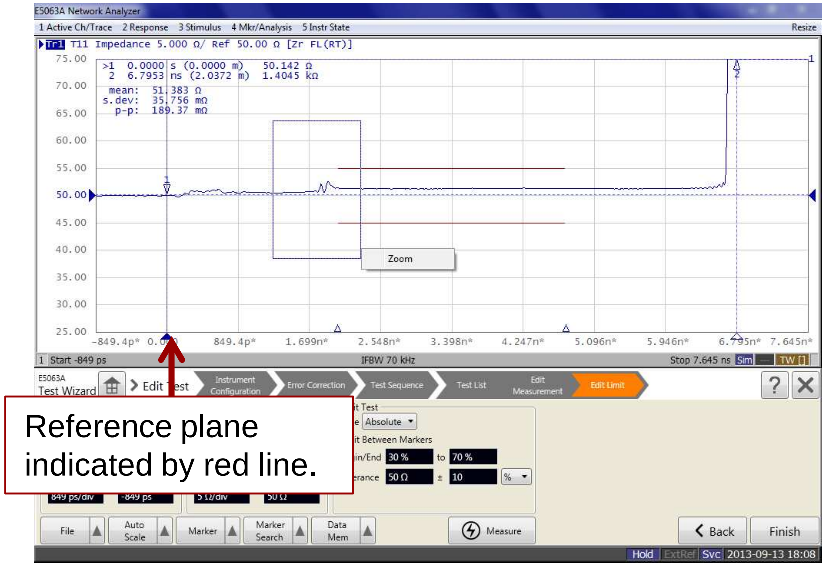
increase / decrease scale (1-2-5 step)   down   up



Reference position
(left edge or center)

Click on software knobs
to enable mouse wheel.

- By specifying an area with the mouse, it is possible to zoom in on specific sections of the response.



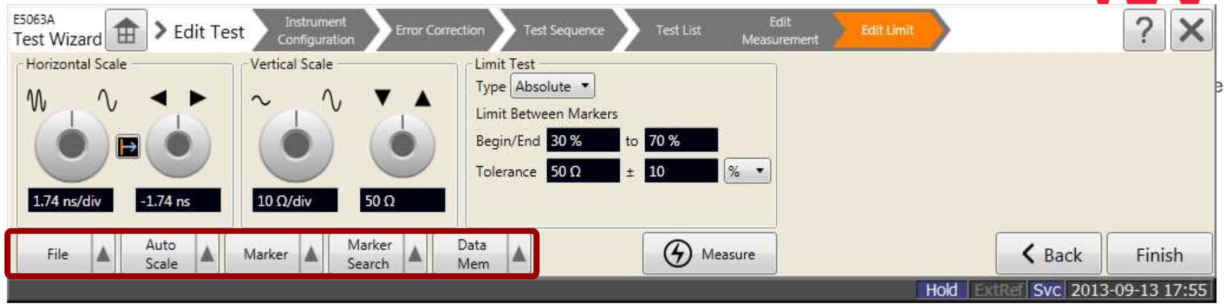
```
Tr1 T11 Impedance 5.000 Ω/ Ref 50.00 Ω [Zr FL(RT)]
>1  0.0000 s  (0.0000 m)    50.142 Ω
 2  6.7953 ns (2.0372 m)   1.4045 kΩ
  mean:   51.383 Ω
 s.dev:   35.756 mΩ
   p-p:   189.37 mΩ
```

1 Start -849 ps   IFBW 70 kHz   Stop 7.645 ns

Limit Test: Type Absolute; Limit Between Markers: Begin/End 30 % to 70 %; Tolerance 50 Ω ± 10 %

Reference plane
indicated by red line.

Edit Test Mode > Test List > Edit Limit



Horizontal Scale: 1.74 ns/div, -1.74 ns

Vertical Scale: 10 Ω/div, 50 Ω

Limit Test

Type: Absolute

Limit Between Markers

Begin/End: 30 % to 70 %

Tolerance: 50 Ω ± 10 %

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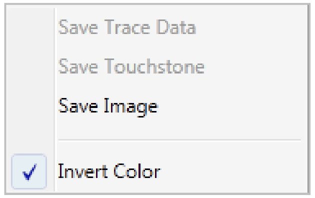
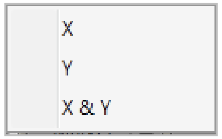
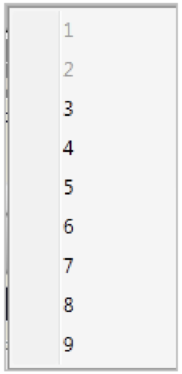
- File



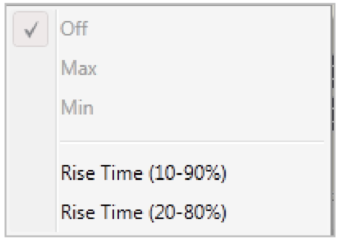
- Auto Scale



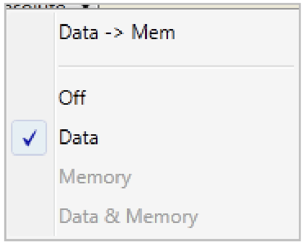
- Marker



- Marker Search



- Data Mem



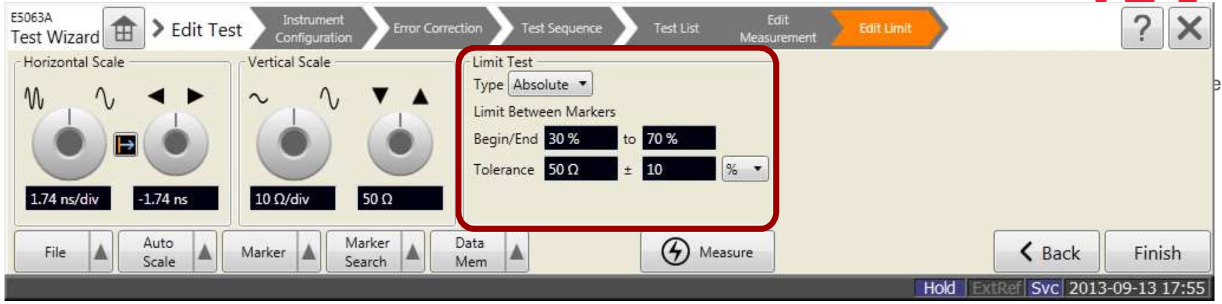
Note:

Markers 1 and 2 are reserved for defining the measurement range.

Edit Test Mode > Test List > Edit Limit

KEYSIGHT
TECHNOLOGIES

easurement Insights for 75 Years



Limit Test

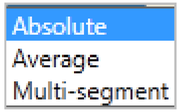
Type Absolute

Limit Between Markers

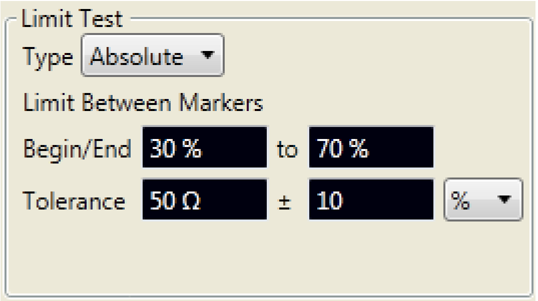
Begin/End 30 % to 70 %

Tolerance 50 Ω ± 10 %

- Type



- Absolute limit test will perform pass/fail judgment on each point in the defined test area.
- Average limit test will perform pass/fail judgment on the average impedance value in the defined test area.
- Multi-segment limit test will perform pass/fail judgment based on the limit line defined in the limit table.



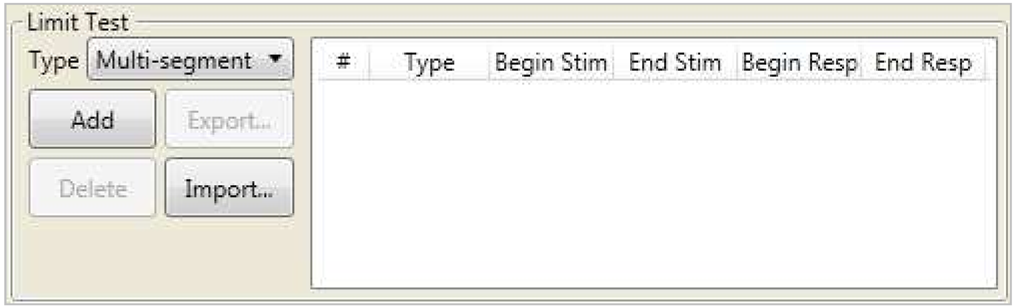
Limit Test

Type Absolute

Limit Between Markers

Begin/End 30 % to 70 %

Tolerance 50 Ω ± 10 %



Limit Test

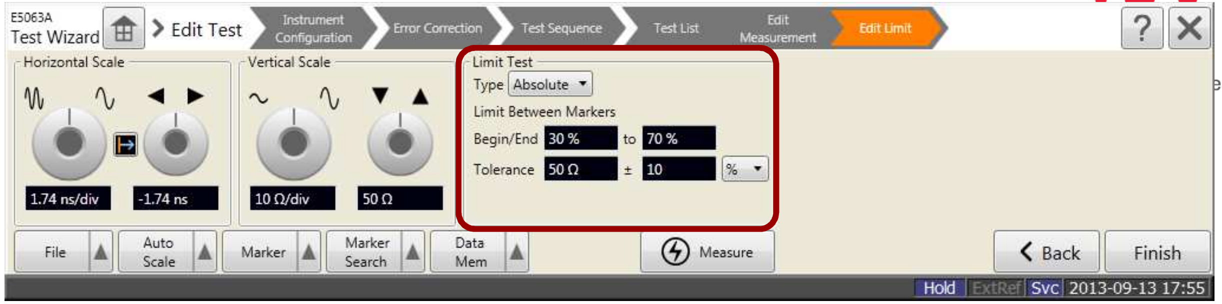
Type Multi-segment

#	Type	Begin Stim	End Stim	Begin Resp	End Resp

Edit Test Mode > Test List > Edit Limit

KEYSIGHT TECHNOLOGIES

easurement Insights for 75 Years



Horizontal Scale: 1.74 ns/div, -1.74 ns

Vertical Scale: 10 Ω/div, 50 Ω

Limit Test

Type: Absolute

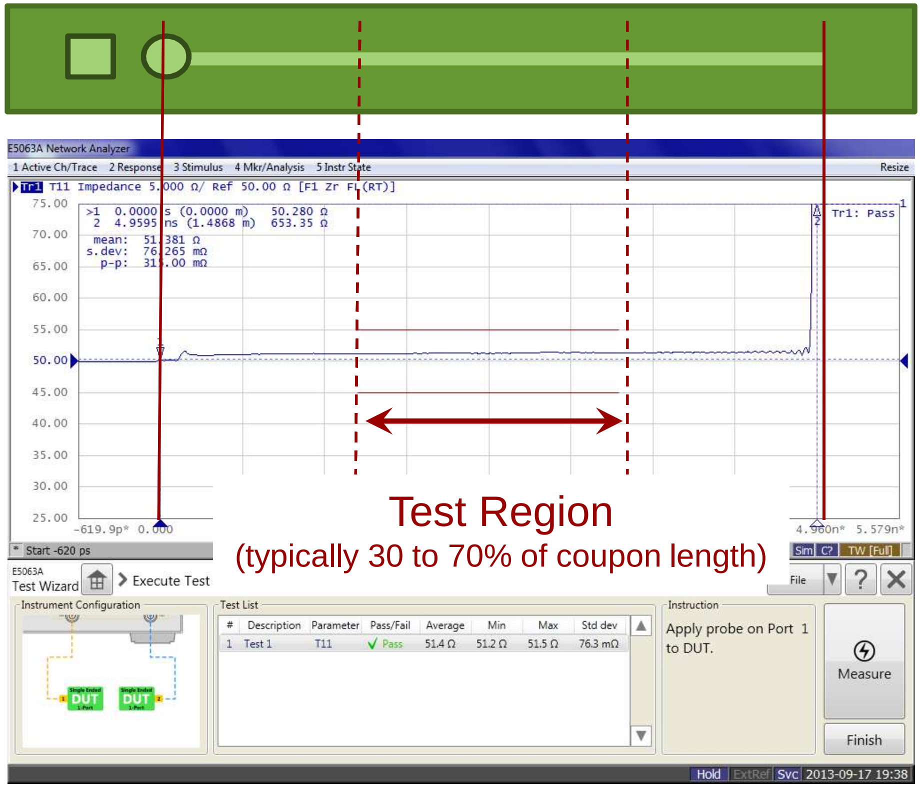
Limit Between Markers

Begin/End: 30 % to 70 %

Tolerance: 50 Ω ± 10 %

2013-09-13 17:55

- The **Limit Between Markers** feature enables users to specify the length of the trace to be tested.



Controlled Impedance Coupon

```
Tr1 T11 Impedance 5.000 Ω/ Ref 50.00 Ω [F1 Zr FL(RT)]
>1  0.0000 s (0.0000 m)    50.280 Ω
 2  4.9595 ns (1.4868 m)  653.35 Ω
   mean:  51.381 Ω
 s.dev:  76.265 mΩ
   p-p:  315.00 mΩ
Tr1: Pass
```

Test Region

(typically 30 to 70% of coupon length)

Test List

#	Description	Parameter	Pass/Fail	Average	Min	Max	Std dev
1	Test 1	T11	✓ Pass	51.4 Ω	51.2 Ω	51.5 Ω	76.3 mΩ

Instruction

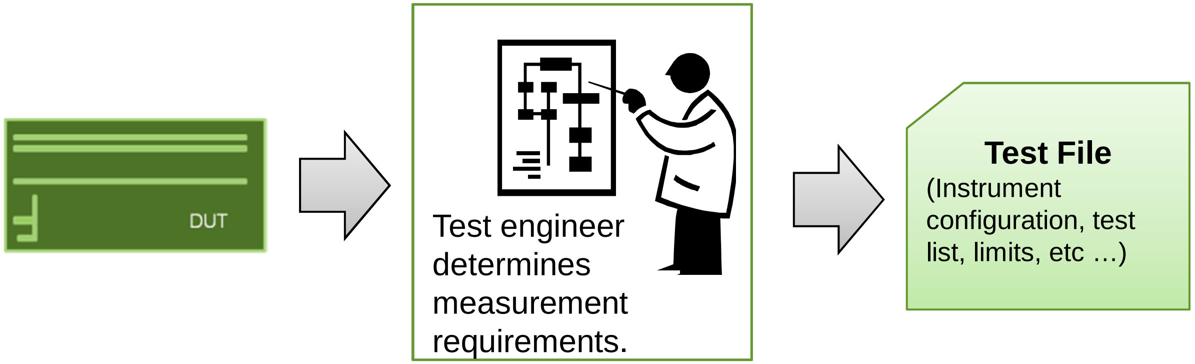
Apply probe on Port 1 to DUT.

2013-09-17 19:38

Modes of Operation

Edit Test Mode

- Define test parameters and generate test setup file.

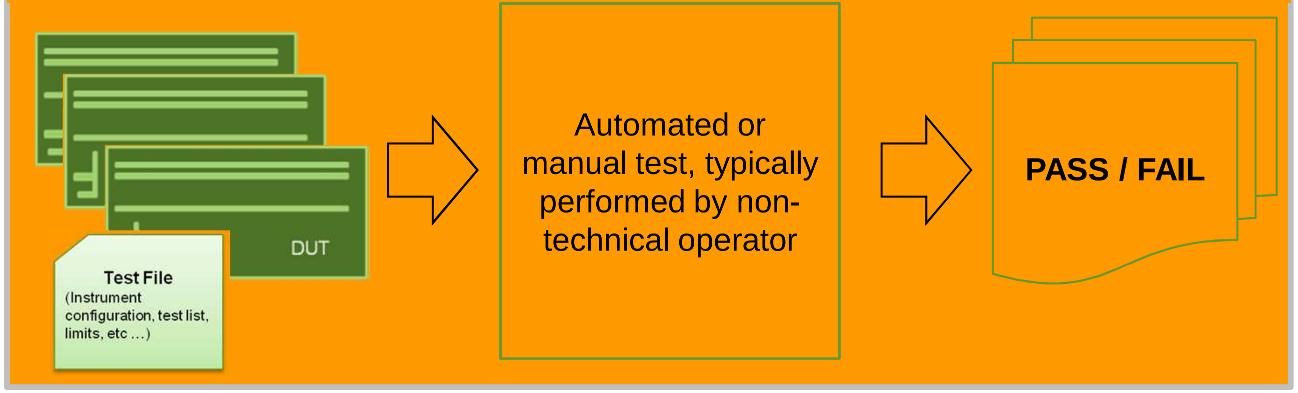


Test engineer determines measurement requirements.

Test File
(Instrument configuration, test list, limits, etc …)

Execute Test Mode

- Recall test setup file and execute test.

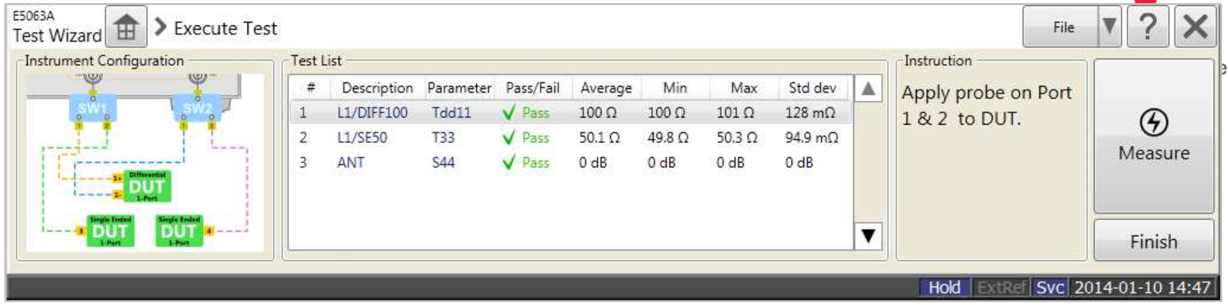


Test File
(Instrument configuration, test list, limits, etc …)

Automated or manual test, typically performed by non-technical operator

PASS / FAIL

Execute Test Mode



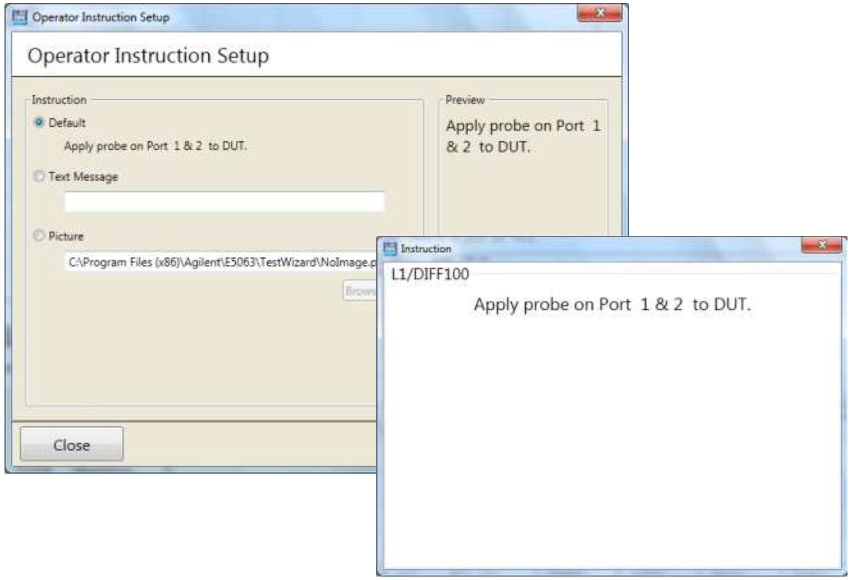
Test List

#	Description	Parameter	Pass/Fail	Average	Min	Max	Std dev
1	L1/DIFF100	Tdd11	✓ Pass	100 Ω	100 Ω	101 Ω	128 mΩ
2	L1/SE50	T33	✓ Pass	50.1 Ω	49.8 Ω	50.3 Ω	94.9 mΩ
3	ANT	S44	✓ Pass	0 dB	0 dB	0 dB	0 dB

Instruction
Apply probe on Port 1 & 2 to DUT.

Operator Instructions

Customize operator prompts as appropriate for your application.



Operator Instruction Setup

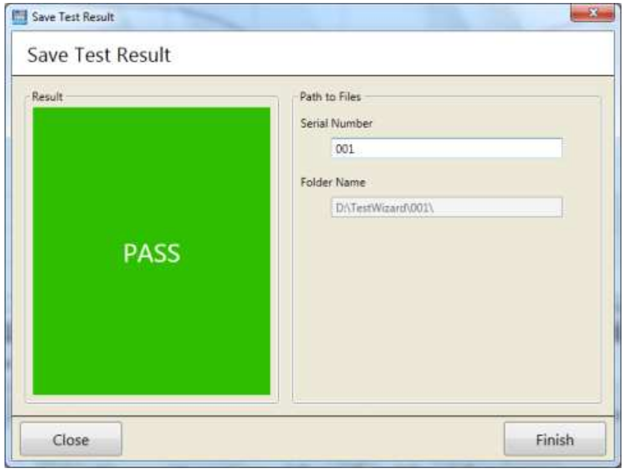
Instruction
● Default
Apply probe on Port 1 & 2 to DUT.
○ Text Message
○ Picture
C:\Program Files (x86)\Agilent\E5063\TestWizard\NoImage.p

Preview
Apply probe on Port 1 & 2 to DUT.

L1/DIFF100
Apply probe on Port 1 & 2 to DUT.

Saving Test Results

All test results are displayed on screen in waveform and statistical format for real-time analysis. Results can also be saved to file for later inspection.



Save Test Result

Result
PASS

Path to Files
Serial Number: 001
Folder Name: D:\TestWizard\001\

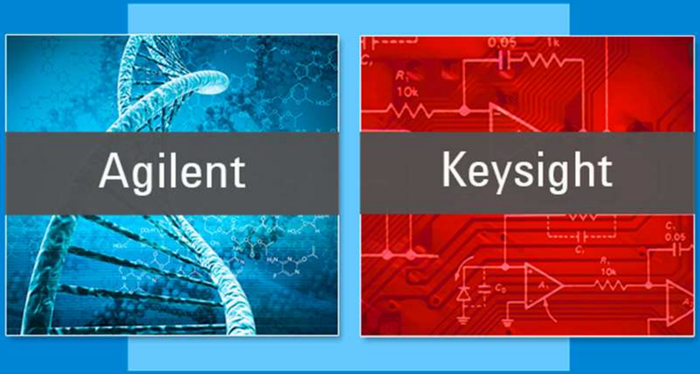
Demo: Tdd11 and Sdd11

AGENDA

Unlocking Measurement Insights for 75 Years

- Traditional PCB Measurements
- PCB Market Trends
- Dedicated VNA for PCB Measurements
- **Summary & Closure**

THANK YOU !



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