Interfacing ZVA/ZVB/ZVT with AWR® software for filter design and optimization

Application Note

Products:

- R&S® ZVA
- R&S® ZVB
- R&S® ZVT
- AWR® Microwave Office® (MWO) Software
- AWR® Visual System Simulator™ (VSS) Software
- AWR® Testwave™
- AWR® NuHertz™

This application note describes how to interface R&S® ZVA/ZVB/ZVT vector network analyzer with AWR® electronic design automation (EDA) software. Using AWR® Testwave™ option, measured data can be exported via GPIB/LAN and verified with simulated data. Basic filter design is simplified with AWR® NuHertz™ filter wizard, an optimization tool that can be introduced to correlate measured with simulated data.

ROHDE&SCHWARZ

Application Note

Matthias Beer/Fiyyaz Bin Rahim

10.2009- 1MA163_1e

Table of Contents

1 Introduction

1.1 Overview

For manufacturers of RF devices, reducing the timescale from design to validation is essential to realize shorter time-to-market forecasts for new designs. Particularly, for RF design and verification engineers, their efficiency has to be enhanced by changing the design flow. Serial design flow with validation loops can be replaced by a parallel design-validate flow.

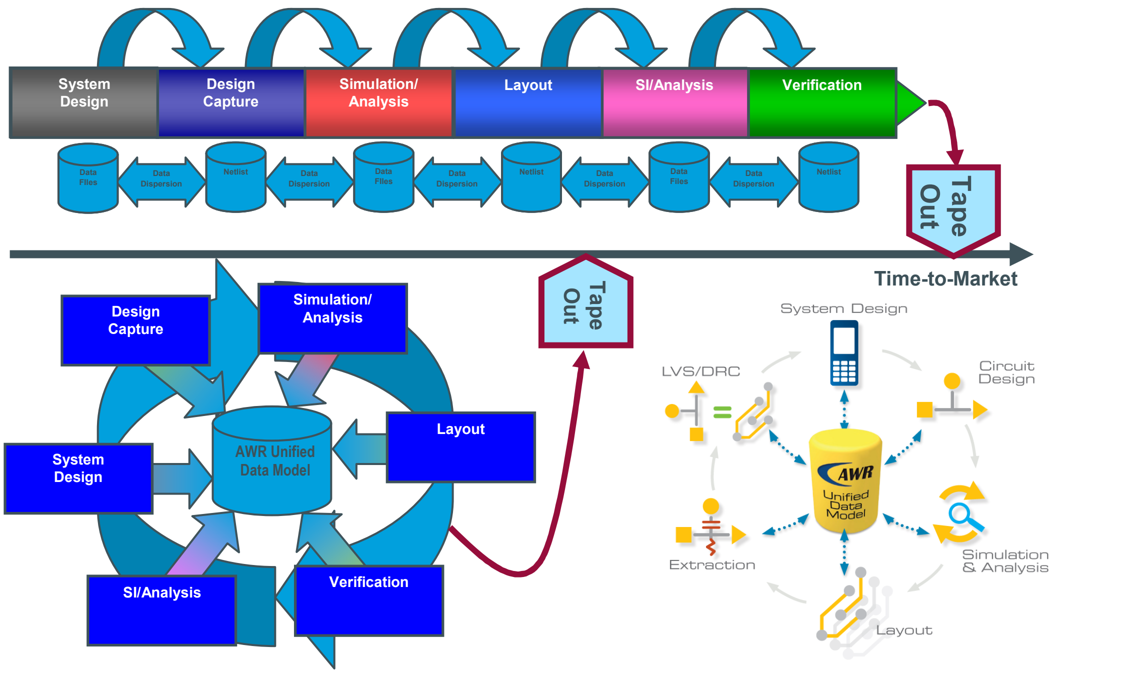


Figure 1: Parallel design-validate flow via AWR's unique Unified Data Model design environment/flow

AWR® employs the Unified Data Model™ (UDM) as the basis for parallel design-validate flow. This modern design platform enables real-time design concurrency across RF system, circuit, electrical and physical design phases. UDM, being a single data-set approach, allows multiple views of the circuitry and results in unparalleled tool interactivity and an enhanced throughput.

Furthermore, the AWR® design environment features an option, referred to as AWR® TestWave™ [1], which allows importing of real measurement data from R&S® Vector Network Analyzer ZVA/ZVB/ZVT for instance and utilize it for correlation or post-processing issues inside the simulation and design environment. Hence, designs from AWR® Microwave Office® (MWO) and AWR® Visual System Simulator™ (VSS) can be correlated with actual prototype measurements.

1.2 Setup

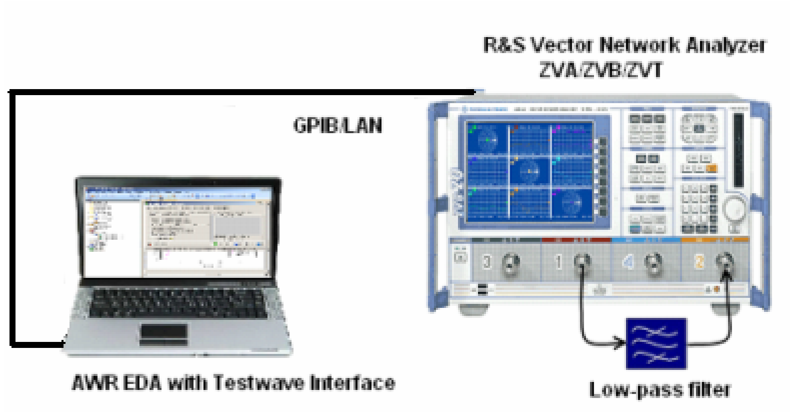


Figure 2: Simulate and validate setup

A simple design cycle of a filter is introduced from design and simulation to verification by a “golden unit” commercial-off-the-shelf (COTS) filter measured with R&S® Vector Network Analyzer ZVB. Enhanced option like AWR® NuHertz™ filter synthesis wizard [2] is briefly introduced to verify filter design. A standard optimization tool for tuning is also discussed.

Once a design cycle is in AWR® software, it needs to be validated with a prototype. AWR® TestWave™ interface option allows for integration with actual measured data from test and measurement instruments. In this application note, R&S® Vector Network Analyzer ZVB is used to measure filter characteristics such as return loss, pass band and cut-off frequency to be correlated with simulated design data from AWR® MWO and VSS software. Design optimization, based on the correlation of simulation and actual measured data, can now help to enhance the time- to-market flow and to reduce cost intensive design cycles. By providing successful designs and a reduced number of design cycles, resources can be more efficiently allocated and an earlier market release provides a competitive edge.

2 Simulation with AWR® software

2.1 Design

A fundamental passive component in RF circuitry would be a low-pass filter. Low-pass filters can be located after the RF front-end as a pre-selector or be transformed into a band-pass filter. A basic 4th order *Butterworth* low-pass filter with a cut-off frequency of 1.87 GHz and 50 Ω impedance rating for both ports will be designed. For this application note, instead of an early engineering sample or prototype, a COTS "golden unit" from Mini-Circuits® model NBLP-1870 [3] is measured with a R&S® Vector Network Analyzer ZVB and the data be correlated with the filter design done with AWR® MWO™.

Ideally, *Butterworth* filter has a gentle cut-off and no gain ripple due to flat amplitude response. Generally, the LPF cut-off frequency indicates the pass-band (rejection towards higher frequencies) and is typically specified by a 3dB insertion loss. A 4th order Low-pass *Butterworth* filter with series-shunt profile can be designed using capacitive and inductive lumped elements according to equations (1) and (2):

Equation (1) & (2):

$$C_i = \frac{1}{\pi F_c Z}\sin[\frac{(2i-1)\pi}{2n}] \quad \text{Where } i = \text{odd integers} \qquad (1)$$

$$L_j = \frac{Z}{\pi F_c}\sin[\frac{(2j-1)\pi}{2n}] \quad \text{Where } j = \text{even integers} \qquad (2)$$

Where, *F_c = Cut-off frequency,*
Z = Source or load impedance,
n = Order number.

The result of such calculations can be tabulated as in Table 1 below.

Table 1: Tabulation of inductive-capacitive elements

4th order Butterworth Filter	
Impedance Z = 50 ohm Cut-off frequency Fc = 1.87 GHz Order n = 4	
Element	
Inductive(j)	Capacitive(i)
(2) 7.86 nH	(1) 1.3028pF
(4) 3.257 nH	(3) 3.145 pF

2.1.1 Design of low-pass filter (LPF) with AWR® Microwave Office® (MWO) software

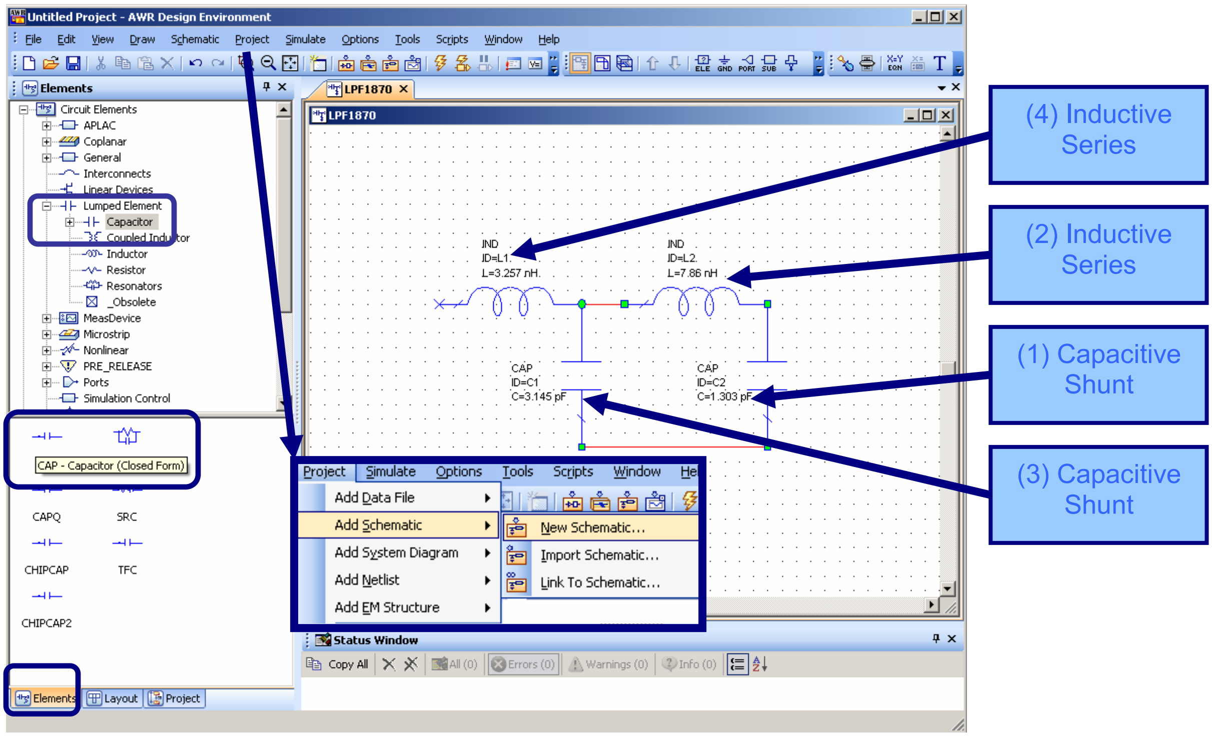


Figure 3: Adding lumped elements into a schematic with values calculated from Table 1

Starting a new LPF design from scratch, a new project and simulation schematic has to be created inside the AWR® MWO design environment: Select [Project] in the taskbar, [Add Schematic] and [New Schematic]. On the bottom left pane tab, switch to [Elements] tab and select under [Circuit Elements], [Lumped Element] as [Closed form capacitor and Closed form inductor]. Directly input the necessary values by left-clicking and dragging the elements onto the schematic. Add ground and ports from AWR® MWO taskbar by selecting [Draw].

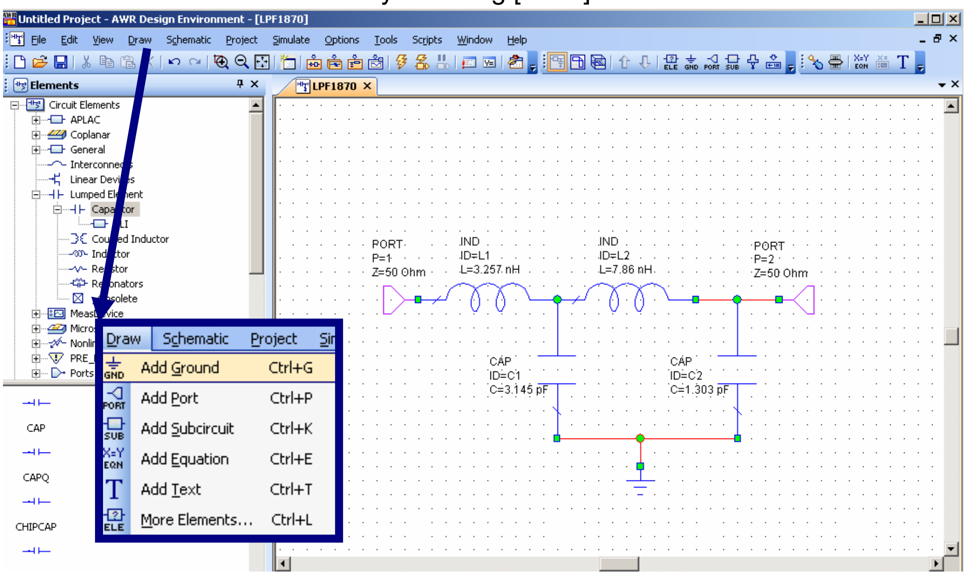


Figure4: Adding ground and ports to the circuit

2.1.2 Synthesis of low-pass filter (LPF) with NuHertz™ filter wizard option

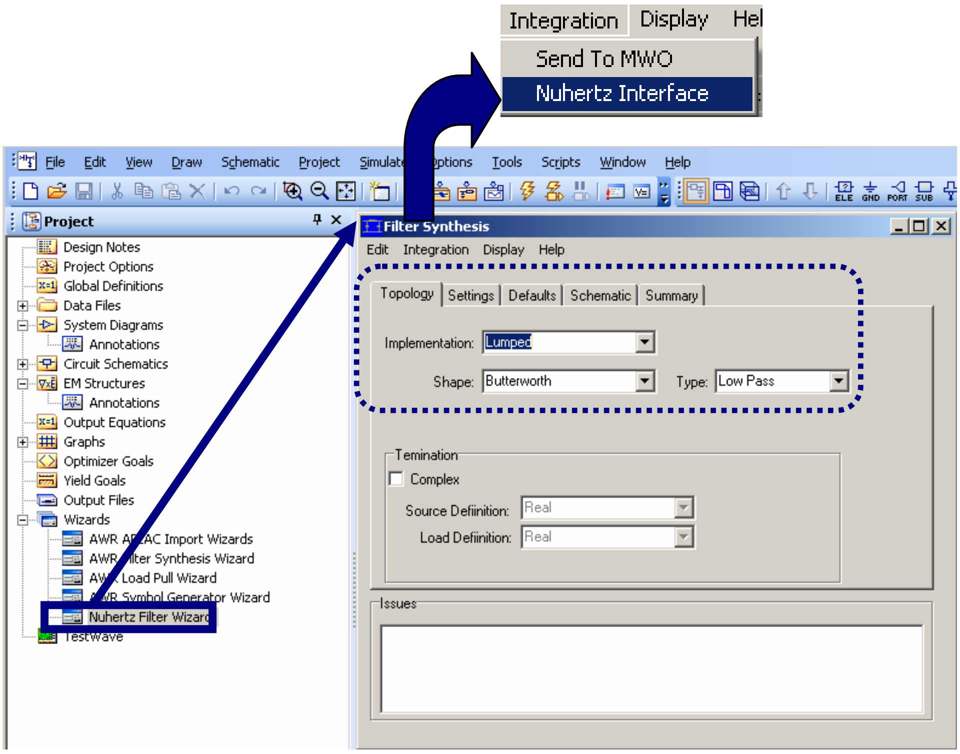


Figure5: AWR® NuHertz™ filter synthesis wizard option

Filter design is made simple with AWR® NuHertz™ filter synthesis wizard option. Without prior knowledge a filter can be designed, calculated and simulated by the option utilizing the given input parameters like filter type, class, frequency and order.

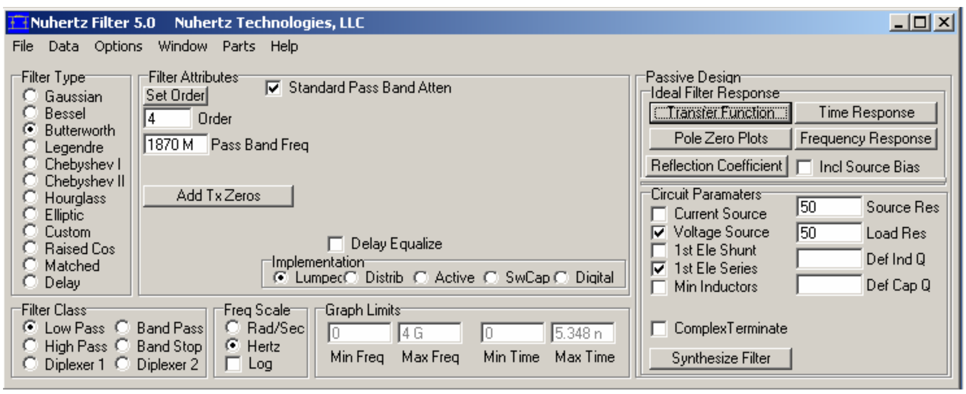
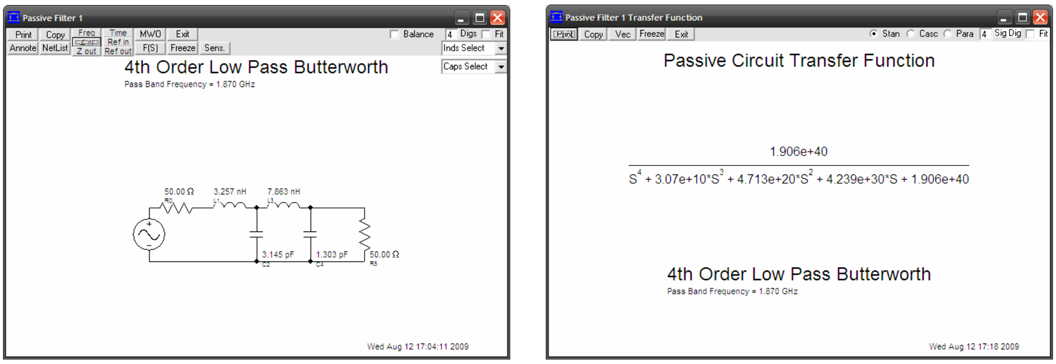


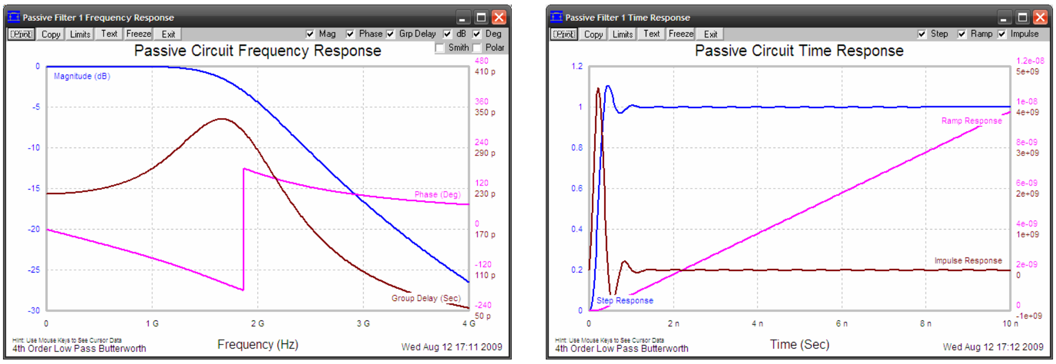
Figure 6: AWR® NuHertz™ filter synthesis wizard interface

A 4th order Butterworth lumped element low pass filter is shown prior to synthesis.

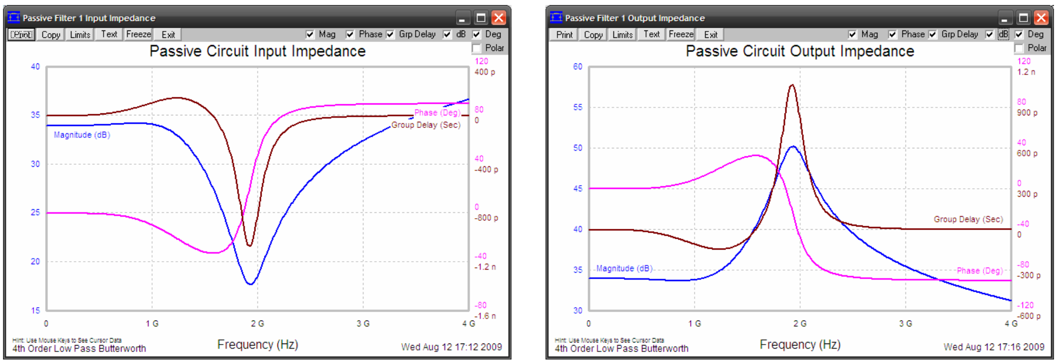
Subsequently some results from the automatic filter synthesis are given:



AWR® NuHertz™ result: 4th order butterworth LPF circuitry and transfer function



AWR® NuHertz™ result: Frequency and Time response



AWR® NuHertz™ result: Input and output impedance in magnitude, phase and group delay

Figure 7: AWR® NuHertz™ filter synthesis wizard results

Various filter types and classes can be rapidly synthesized accurately with AWR® NuHertz™. The filter order, cut-off frequency as well as Q factors of the lumped elements and other circuit parameters can be defined for the simulation. The results from the filter simulation can be displayed and evaluated and finally transferred into AWR® MWO as a new filter schematic. It is a quick and handy tool for RF designers who want to choose from a myriad of filter types and classes to incorporate into their designs and circuits.

2.2 Analysis

2.2.1 Simulated plots

AWR® NuHertz™ filter design wizard as an option allows for synthesis of filters. AWR® MWO simulation provides an analytical approach to verify the results. Furthermore, different variable scenarios and interdependence required for systems simulation can be simulated. Analysis and display of results is a seamless series of steps. Setup of graph properties prior to AWR® MWO simulation simplifies the analysis.

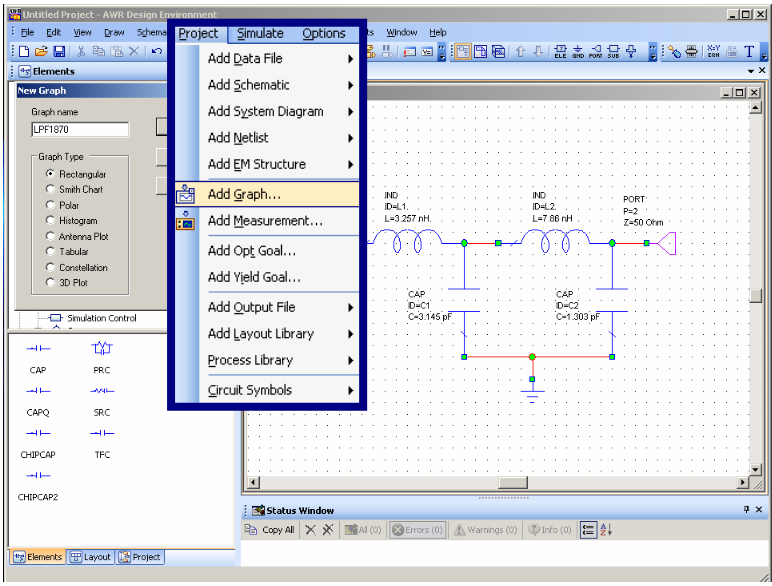


Figure8: Adding graphs and adding measurements to plot

From AWR® MWO taskbar, select [Project], [Add Graph] and [Name Schematic] as "LPF1870". For S_{11} and S_{21} measurements for low-pass filter, the rectangular graph is selected.

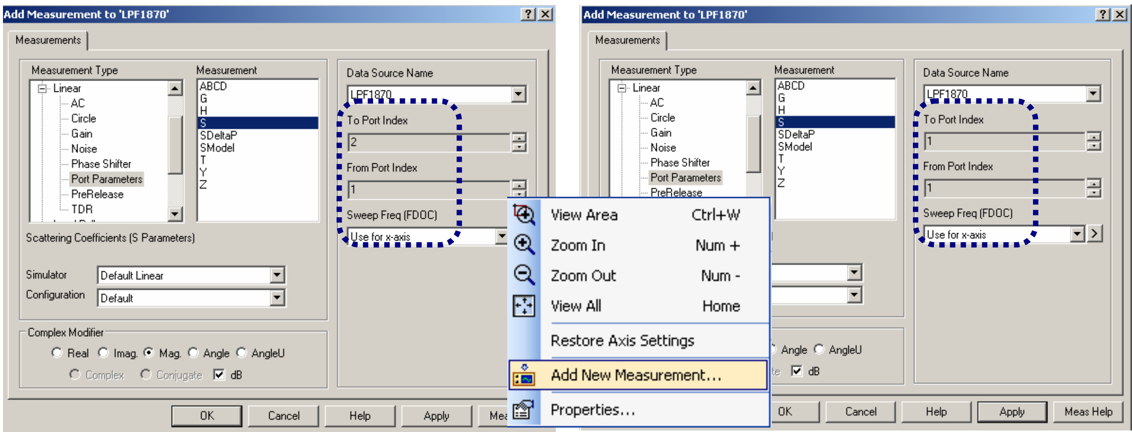


Figure 9: Adding new measurements into graph by right-click

By right-clicking on graph and select [Add New Measurement], S_{11} and S_{21} measurements can be selected and data source is taken from schematic data called "LPF1870".

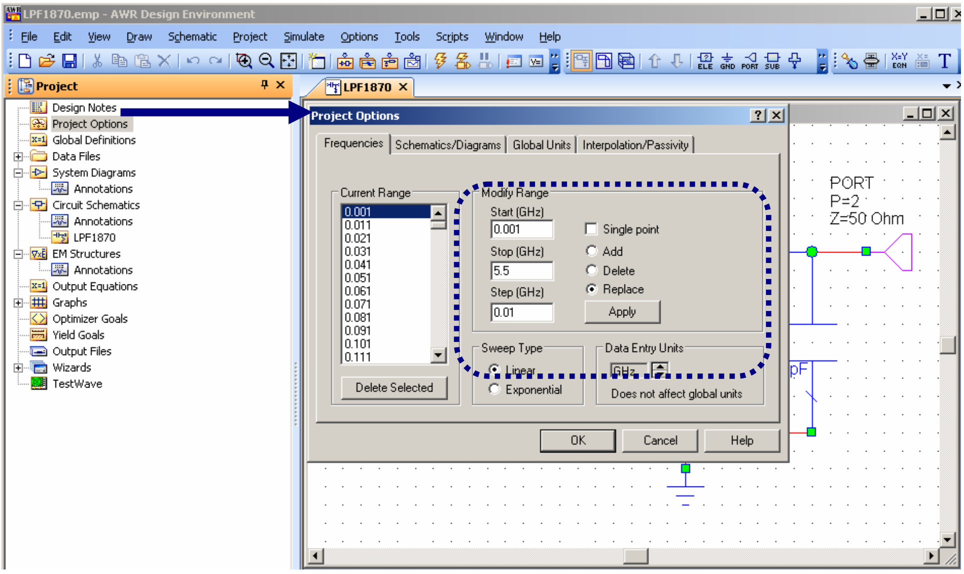


Figure10: Project options to set frequency range

In order to set a frequency range, on the bottom left pane tab, switch to [Projects] tab and select [Project Options]. Suppose we choose an operating frequency range between 0.001 to 5.5 GHz at steps of 10 MHz. Assume a linear sweep, proceed by setting the graph scaling. Once on graph tab, graph scaling is done by right-clicking and selecting [Properties].The y-axis can be set to “dB” and from a minimum of -70 dB to a maximum of 5 dB. The x-axis can be set to an operating frequency range coinciding with the linear sweep from 0 to 5.5 GHz.

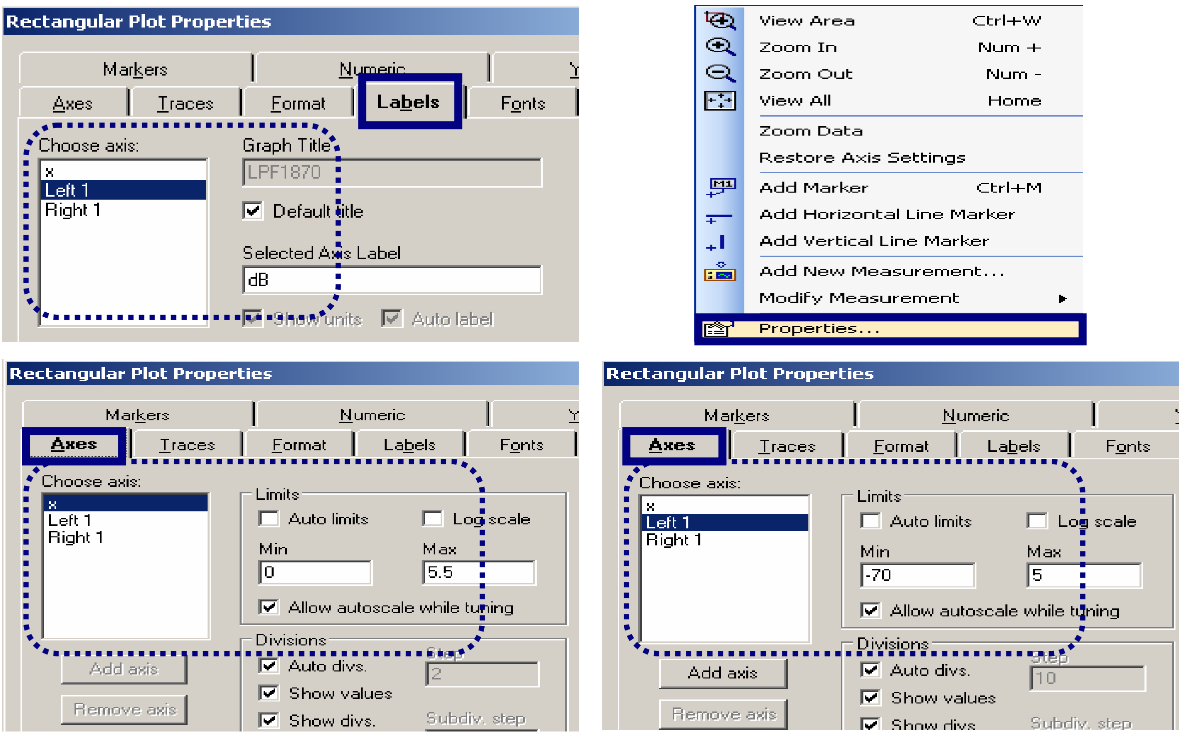


Figure11: Properties options to set axes scale

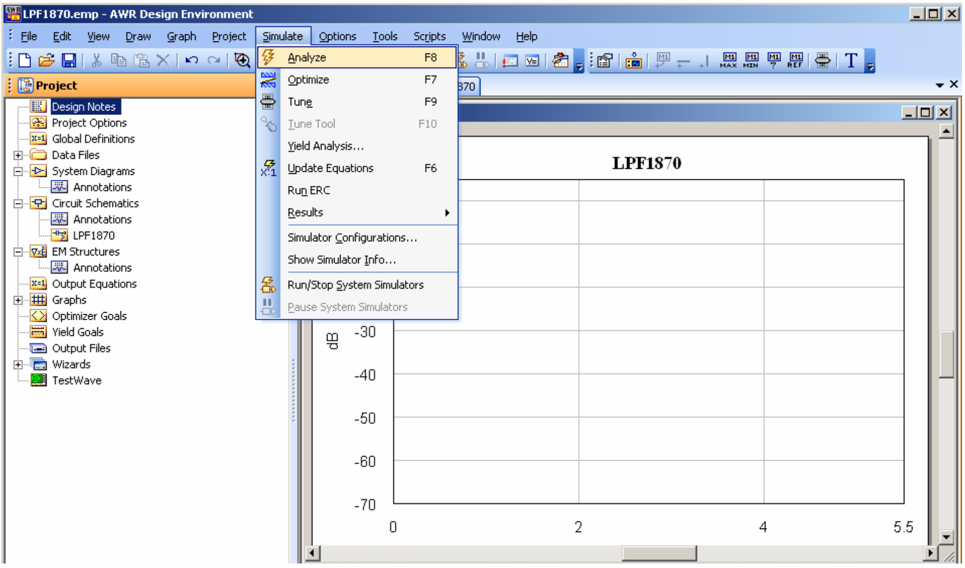


Figure 12: Analyzing the data into a rectangular plot

From AWR® MWO taskbar, select [Simulate], then [Analyze] for simulated plot. Both S_{11} and S_{21} measurements will be plotted consequently.

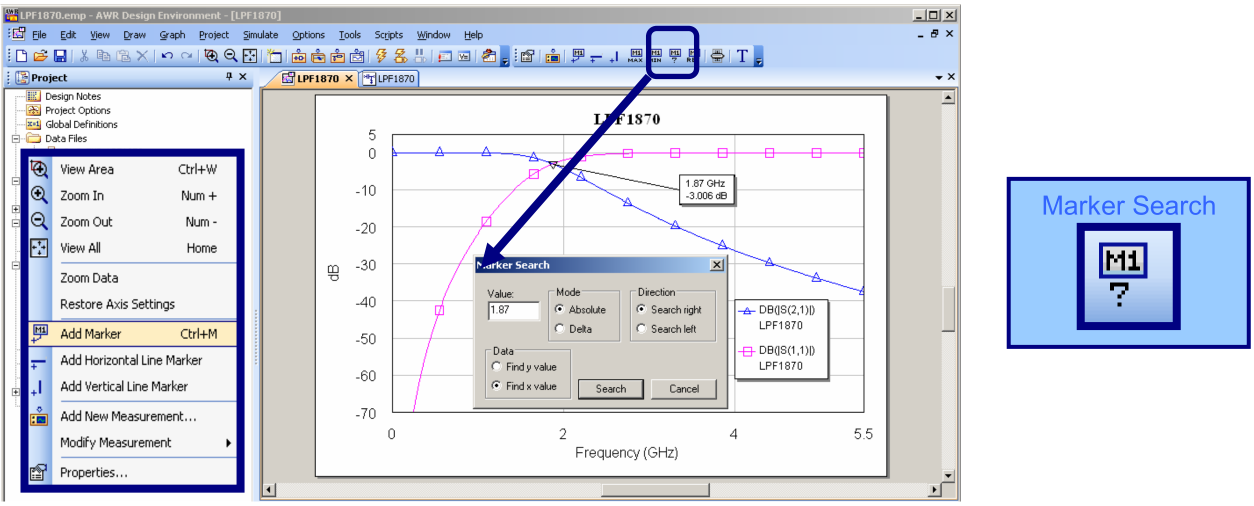


Figure 13: Adding marker and pointing markers to specified location via "Marker Search"

By right-clicking, select [Add Marker] and point the cursor to place a marker on the graph. On the right part of taskbar, a [Marker Search] icon allows for specific marker placement.

2.2.2 Tune tool for optimization

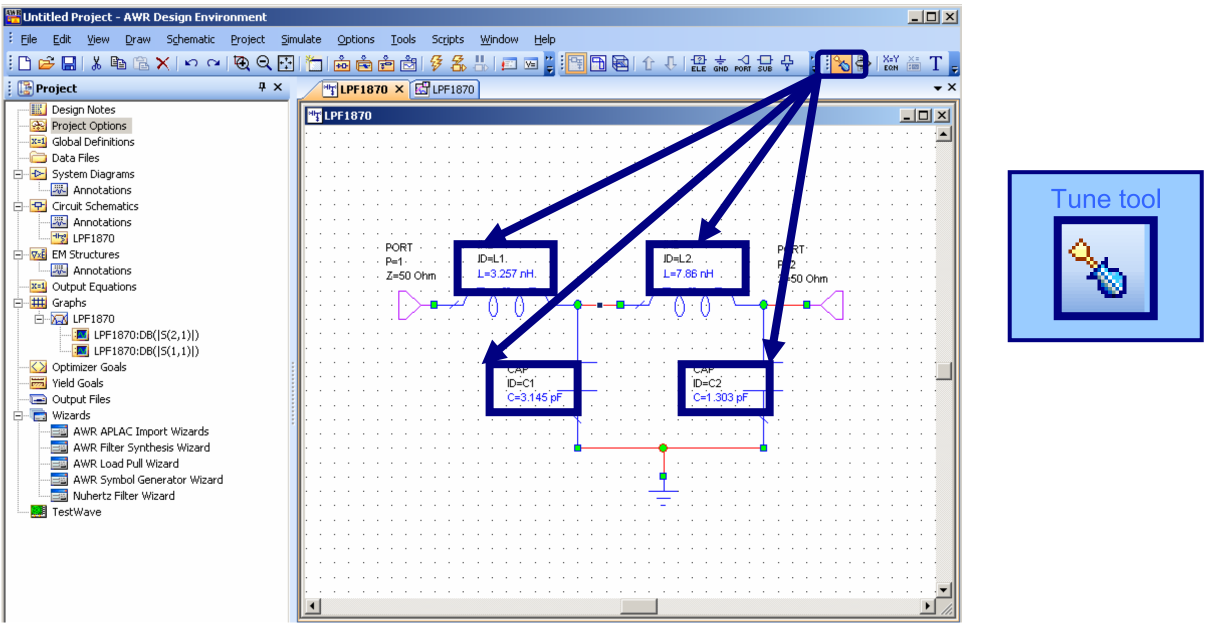


Figure 14: Tune tool for optimization

Switch to schematic format tab, then on the right part of taskbar, select [Tune tool]. Then point to lumped element and left-click to make the element variable to tune. Tunable elements will then be highlighted in **blue**.

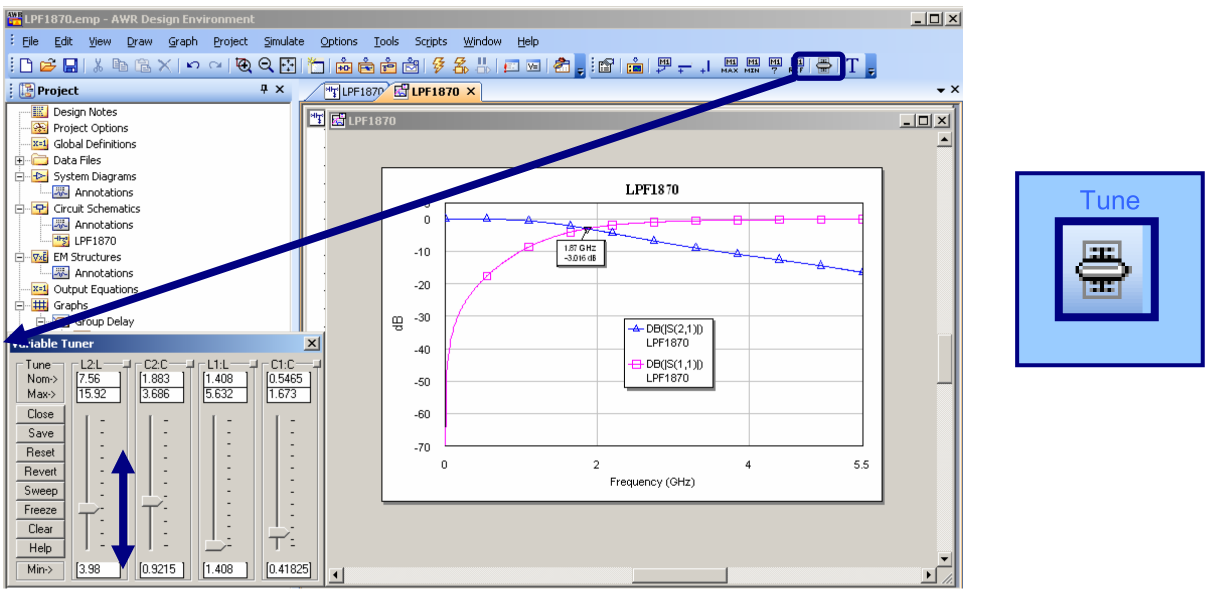


Figure 15: Real-time optimization of parameters

To optimize, select [Tune] on the right part of taskbar and a variable console will appear. This powerful tool performs optimization real-time without having to analyze or compile.

3 Verification

Verification involves correlation of simulated versus measured data. COTS "golden unit" from Mini-Circuits® model NBLP-1870 [3] actual data is measured using R&S® Vector Network Analyzer ZVB and correlated with the simulated filter design data from AWR® MWO. Prior to calibration, settings of the R&S® Vector Network Analyzer ZVB must be configured to optimum conditions for measurement (refer to Table 2).

Setting Parameter	Trade-off	Chosen setting
Start and Stop frequency	Narrow down span to skip range where data is irrelevant	Span between 0- 5.5GHz
Number of points	Higher number of points lead to better resolution at the expense of slower calibration time	501 points as an average
Measurement Bandwidth	Low Bandwidth for higher dynamic range at the expense of slower sweep time. High Bandwidth might lead to degraded dynamic range due to noise.	1kHz as an average
Power	Power level can be adjusted in the filter passband to avoid receiver entering its compression region	0dBm

Table 2: Optimum conditions for measurement

Various filter measurements are briefly discussed as a figures-of-merit in figure 16. This is not an exhaustive list but features just the main parameters.

Return Loss(S_{11})

RETURN LOSS

$= -10 * \log_{10} (Power_{reflected} / Power_{in})$

Where:

$Power_{reflected}$ = reflected power,
$Power_{in}$ = input power.

Return loss is a ratio of reflected power to incident power at the test port of a filter and is expressed in decibels(dB).
Return loss measurement is used to evaluate the impedance match of a filter.

Insertion Loss(S_{21})

INSERTION LOSS

$= 10 * \log_{10}(Power_{out} / Power_{in})$

Where:

$Power_{out}$ = outputpower,
$Power_{in}$ = input power.

Insertion loss is the difference in dB power between the signals at the filter input and filter output. It shows the filter passband as well as the 3dB cut-off frequency.

Standing Wave Ratio (SWR)

SWR

$= (V_i + V_r) / (V_i - V_r)$

Where
V_i =incident voltage,
V_r = reflected voltage.

VSWR (Voltage Standing Wave Ratio) is an alternative way for evaluating the impedance match of a filter. It is a measure of ratio of reflected voltage over incident voltage.
Values of typically 1-1.2 constitute a relatively good match.

Group Delay

Group delay is the time delay through a filter, which is related to phaselinearity.
The group delay is defined as the derivative of the phase shifts versus frequency. It is desirable to have a flat group delay as this indicates the linearity of the filter.

Figure 16: Scorecard for filter measurement

3.1 Calibration of R&S® ZVB vector network analyzer

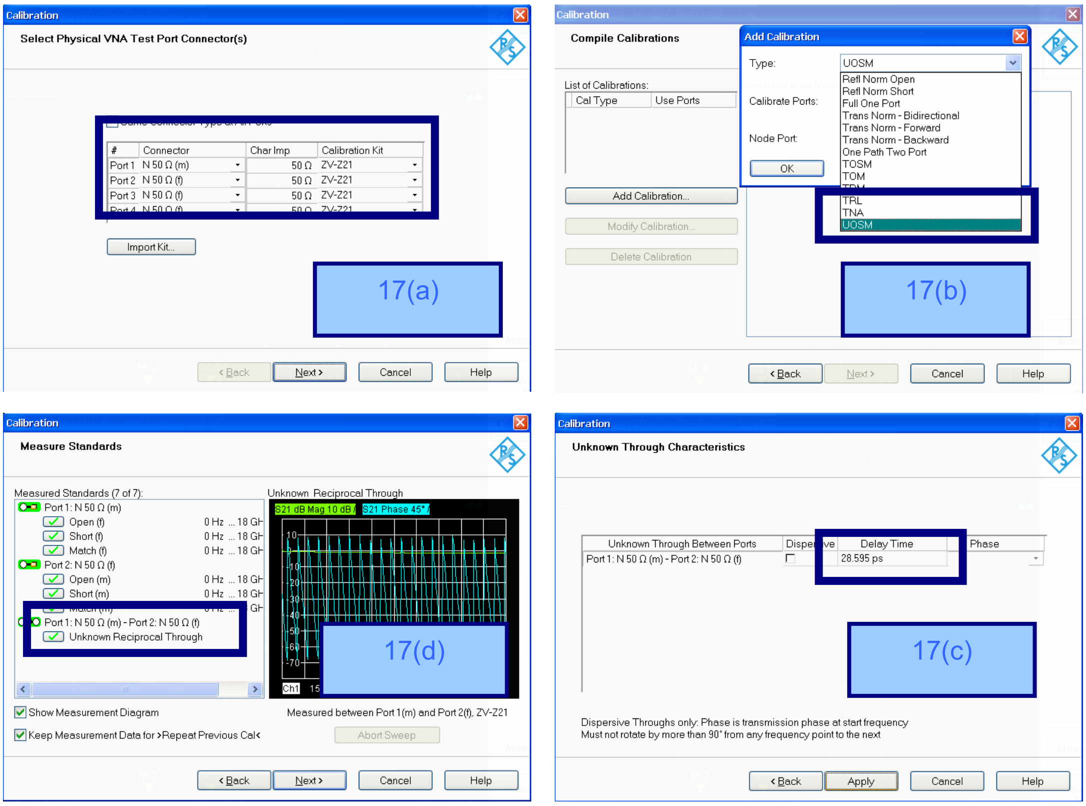


Figure 17: Calibration of R&S® ZVB vector network analyzer using UOSM method

A Vector Network Analyzer is only as useful as the accuracy with which it makes measurements, and this requires the instrument to be calibrated. Employing a technique called vector error correction, error terms are characterized using known standards so that errors can be removed from actual measurements.

R&S®ZV-Z21 calibration kit contains necessary precision N standards **T**hrough, **O**pen, **S**hort and **M**atch (male and female). In this application note, the COTS low-pass filter has both male and female ports. As such, the Unknown Through, (UOSM) method is used since different connector types are used at the test ports [4].From the soft-keys of *R&S®ZVB,* select [Cal], [Start Cal], [More (1/2)] and [Other]. Referring to Figure 17(a), select the necessary male/female for the ports and proceed with “Next”. Referring to Figure 17(b), select [add calibration] and select “UOSM”. Proceed with calibrating the reference planes and unknown through consisting of female-female N standard through connected to male-male N standard through. This unknown through has a delay time, as shown at Figure 17(c) and Figure 17(d).

3.2 Data transfer via AWR® TestWave™

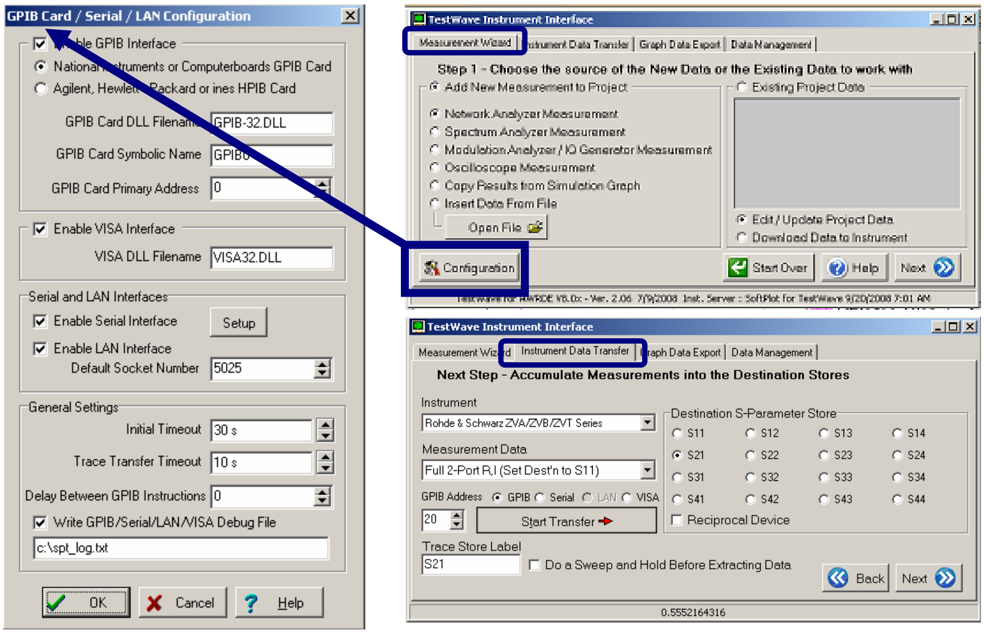


Figure 18: Configuration of transfer via GPIB and type of measurement

Testwave™ option allows for measured data to be transferred from test equipment into simulation environment for correlation or post-processing issues. Once installed, double-click icon at the bottom of the [Project Tree]. Under [Configuration], modes of data transfer such as GPIB or LAN can be chosen. Under [Measurement Wizard] tab, select the type of measurement. Proceed to [Interface Data] tab and select the make and model of equipment. Confirm the address and “Start Transfer” to import data from the test equipment.

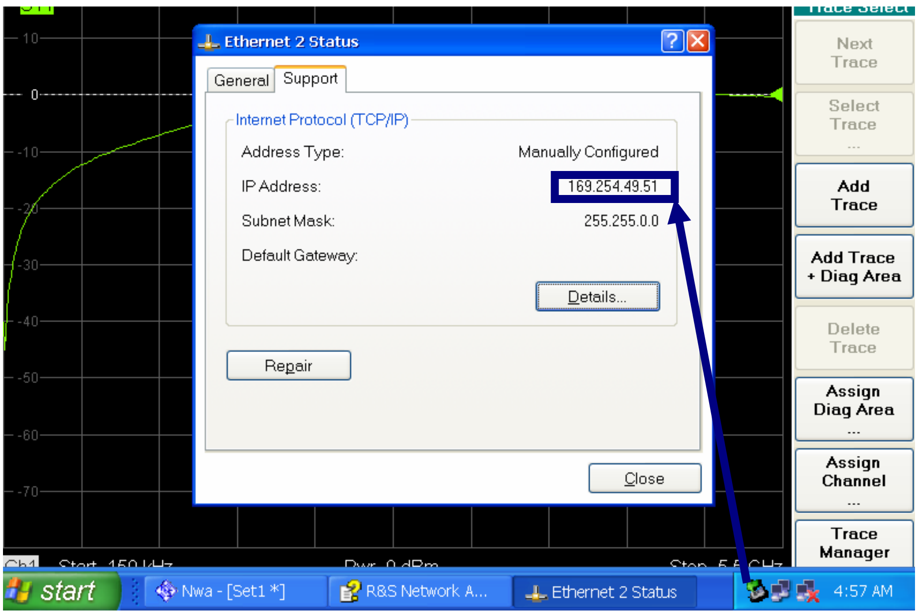


Figure 19: Acquiring IP address of R&S® ZVB

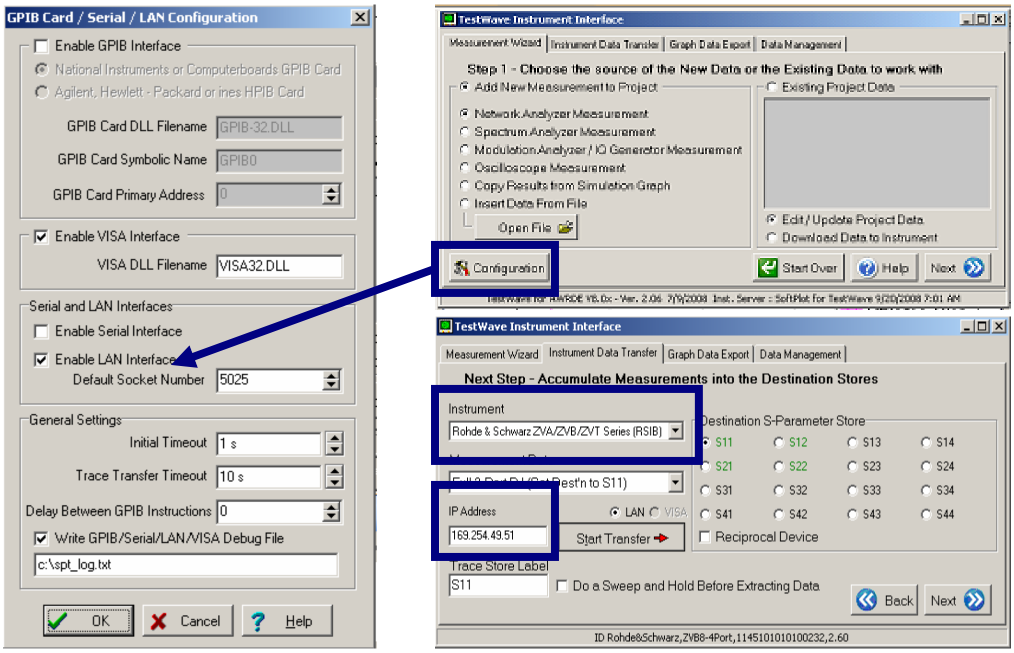


Figure 20: Configuration of transfer via LAN and type of measurement

For LAN setup, proceed to acquire the IP address of the equipment as shown in figure 19. Under Testwave™ option [Configuration], proceed to select [Enable LAN Interface] and [Enable VISA Interface]. At a default socket number of "5025", proceed to select instrument under make and model RSIB. Adopt the instrument IP address and press "Start Transfer" to acquire data as shown in figure 20.

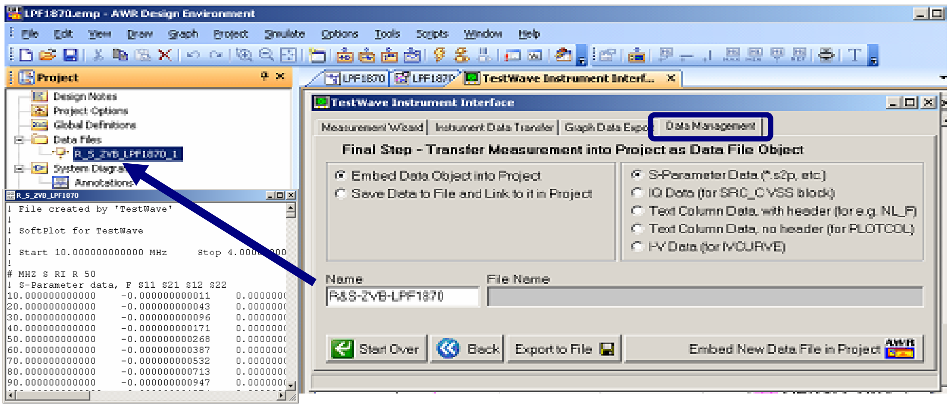


Figure 21: Embedding data into project as data files

Under [Data Management] tab, "S-parameters" are chosen to directly "Embed Data Object into Project". The name of data file will appear in the project tree and its content can be viewed by left-clicking it.

3.3 Simulated versus Measured plot

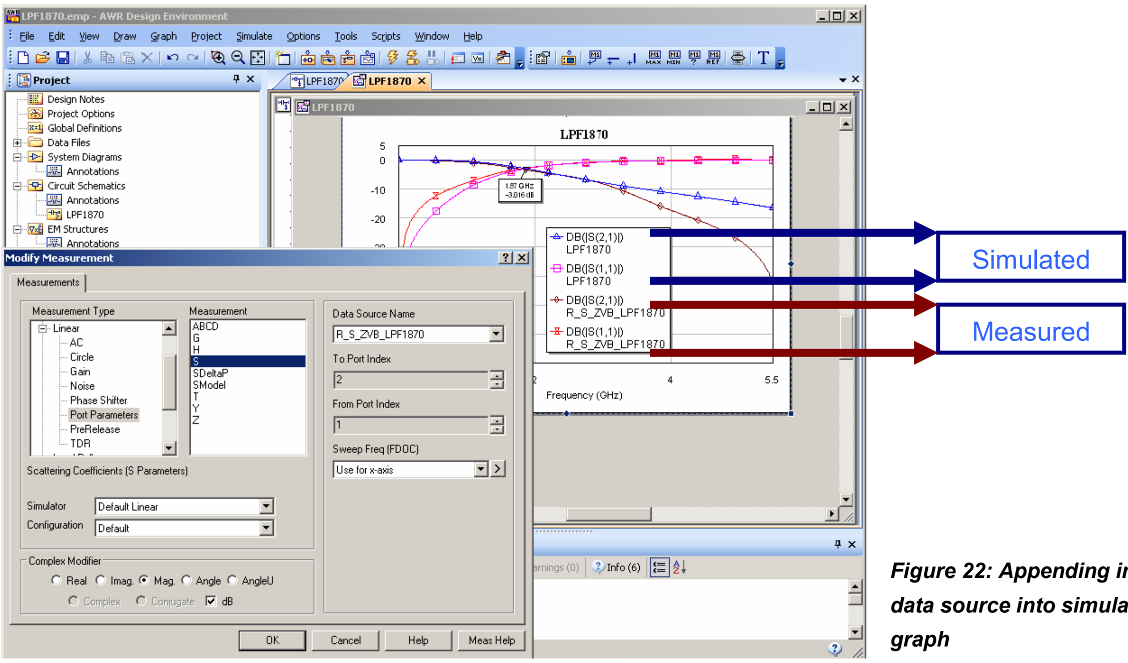


Figure 22: Appending imported data source into simulated graph

Right-click on the graph, [Add Measurement] and select name of data file to append. We select S_{11} and S_{21} measurements and “Analyze” again to generate measured plots.

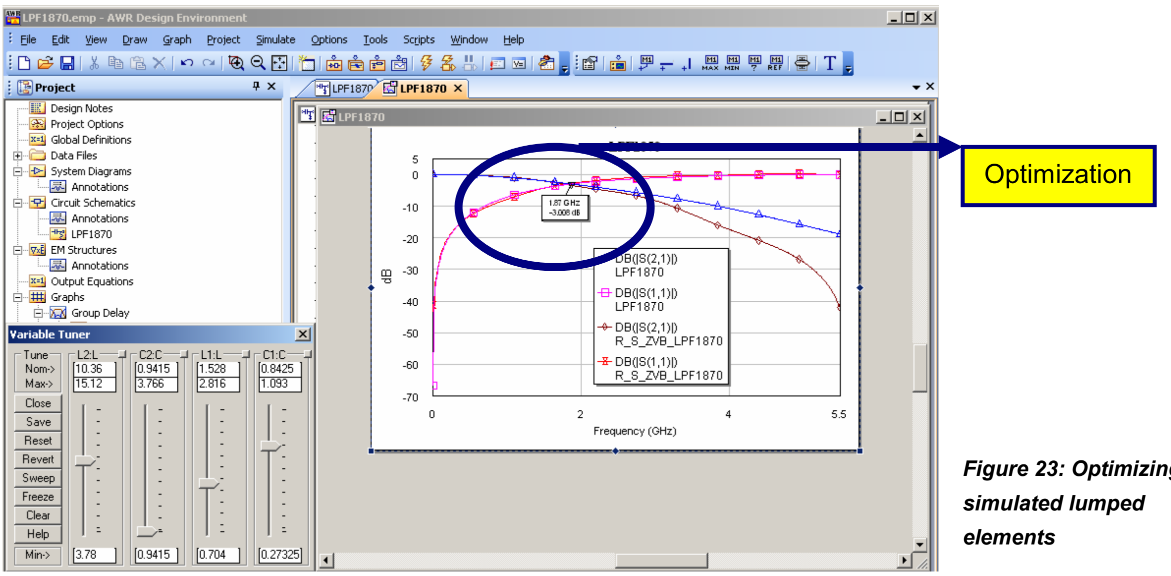


Figure 23: Optimizing simulated lumped elements

Suppose the measured data is a “golden unit” for benchmarking, the simulated data can be optimized for best-fit. Each lumped element that is tuned will automatically change its value in the schematic and the simulation results will be updated in the graph accordingly. The tuning can either be performed manually or with respect to a defined optimization goal, e.g. max deviation of 0.01dB for S21 of measurement and simulation data versus frequency, automatically.

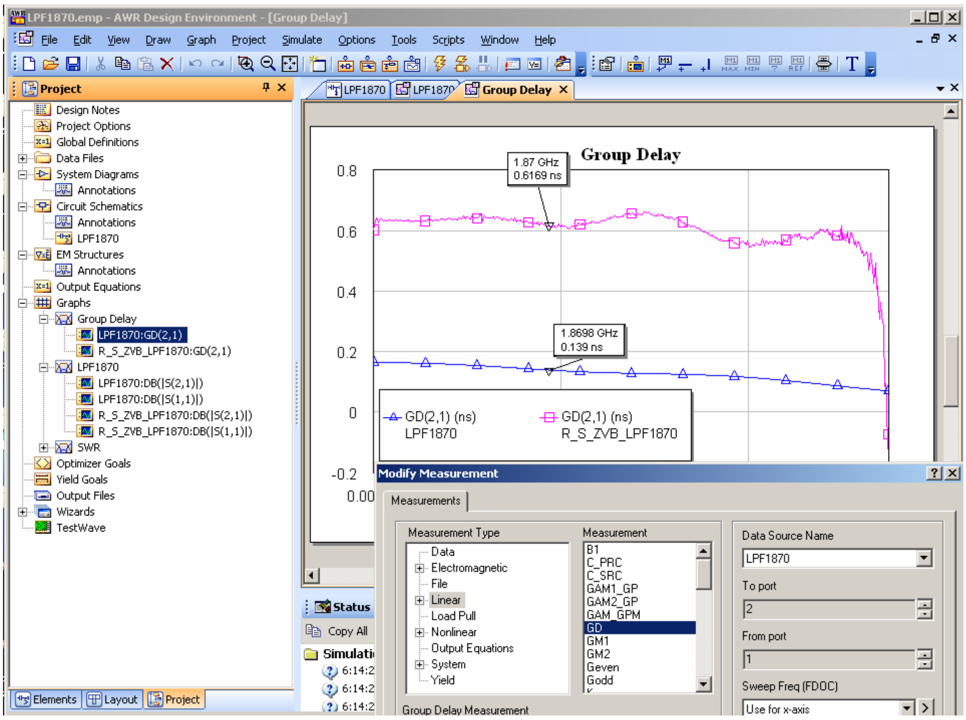


Figure 24: Group Delay Measurement

For group-delay measurement, right-click on graph and select [Linear measurement] followed by the acronym “GD” for group delay.

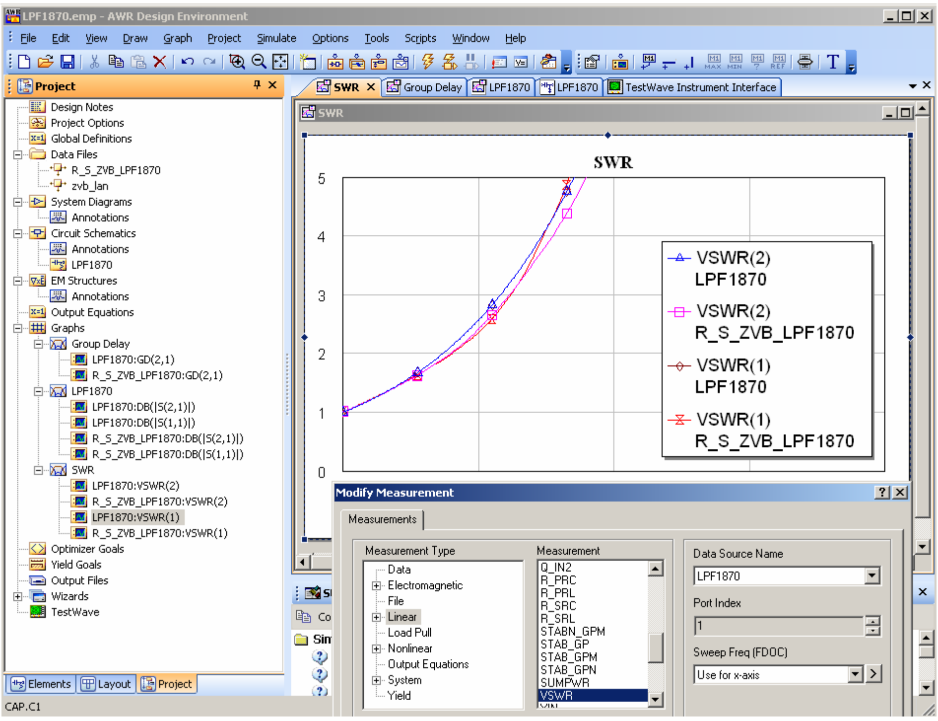


Figure 25: Standing Wave Ratio

For standing wave ratio measurement, right-click on graph and select [Linear measurement] followed by the acronym “VSWR” for standing wave ratio.

4 Conclusion

TestWave™ software integrates Rohde & Schwarz test and measurement (T&M) equipment like the vector network analyzer series ZVA, ZVB and ZVT seamlessly with simulation software for communication systems and radio frequency (RF)/microwave circuits. It brings together circuit and system level simulation with actual measurement data in the same environment.

AWR's TestWave software integrates test and measurement equipment from Rohde & Schwarz with both VSS and Microwave Office simulators over RS-232, GPIB, or LAN. It is tightly integrated into the AWR design environment, including an icon in the project hierarchy. Together with the Microwave Office® and Visual System Simulator™ (VSS) simulation software, TestWave provides wireless system and RF/microwave circuit designers a complete integration of the design process, combining schematic simulation, test signal generation, and test and measurement verification. This capability enables designers to perform computer trade-off studies with "hardware-in-the-loop" simulations. Its user interface allows for a simple, efficient means to import signals and manage data from Rohde & Schwarz test and measurement equipment.

Accessing these two previously disjointed phases of the development process, hardware design and verification, from the same environment saves time and that's why the development time decreases. Further, merging simulation and measurement data in one environment by performing "hardware-in-the-loop" simulations saves design and verification time and increases design accuracy, which leads to a reduced number of design iterations, at the same time. As a matter of fact, joining both development phases speeds up the time to market and provides a competitive edge for RF and microwave designs.

5 Literature

[1] http://web.awrcorp.com/content/Downloads/TestWave-Datasheet.pdf

[2] http://web.awrcorp.com/Usa/Products/Optional-Products/Nuhertz-Technologies-Filter-Synthesis/

[3] Mini-Circuits® filter datasheets, http://www.minicircuits.com/, 2007

[4] Fundamental of Vector Network Analysis, Rohde & Schwarz publication, Michael Hiebel, 2007

6 Ordering Information

Designation	Type	Frequency range	Order No.
Base Unit			
Vector Network Analyzer, 2 Ports, 8 GHz, N	ZVA8	300 kHz to 8 GHz	1145.1110.08
Vector Network Analyzer, 4 Ports, 8 GHz	ZVA8	300 kHz to 8 GHz	1145.1110.10
Vector Network Analyzer, 2 Ports, 24 GHz, 3.5 mm	ZVA24	10 MHz to 24 GHz	1145.1110.24
Vector Network Analyzer, 4 Ports, 24 GHz, 3.5 mm	ZVA24	10 MHz to 24 GHz	1145.1110.26
Vector Network Analyzer, 2 Ports, 40 GHz, 2.4 mm	ZVA40	10 MHz to 40 GHz	1145.1110.43
Vector Network Analyzer, 2 Ports, 40 GHz, 2.92 mm	ZVA40	10 MHz to 40 GHz	1145.1110.40
Vector Network Analyzer, 4 Ports, 40 GHz, 2.4 mm	ZVA40	10 MHz to 40 GHz	1145.1110.45
Vector Network Analyzer, 4 Ports, 40 GHz, 2.92 mm	ZVA40	10 MHz to 40 GHz	1145.1110.42
Vector Network Analyzer, 2 Ports, 50 GHz, 2.4 mm	ZVA50	10 MHz to 50 GHz	1145.1110.50
Vector Network Analyzer, 4 Ports, 50 GHz, 2.4 mm	ZVA50	10 MHz to 50 GHz	1145.1110.52
Vector Network Analyzer, 2 Ports, 67 GHz, 1.85 mm	ZVA67	10 MHz to 67 GHz	1305.7002.02
Options			
Direct Generator/Receiver Access, 2-Port Model, 8 GHz	ZVA8-B16	300 kHz to 8 GHz	1164.0209.08
Direct Generator/Receiver Access, 4-Port Model, 8 GHz	ZVA8-B16	300 kHz to 8 GHz	1164.0209.10
Direct Generator/Receiver Access, 2-Port Model, 24 GHz	ZVA24-B16	10 MHz to 24 GHz	1164.0209.24
Direct Generator/Receiver Access, 4-Port Model, 24 GHz	ZVA24-B16	10 MHz to 24 GHz	1164.0209.26
Direct Generator/Receiver Access, 2-Port Model, 40 GHz	ZVA40-B16	10 MHz to 40 GHz	1164.0209.40
Direct Generator/Receiver Access, 4-Port Model, 40 GHz	ZVA40-B16	10 MHz to 40 GHz	1164.0209.42
Direct Generator/Receiver Access, 2-Port Model, 50 GHz	ZVA50-B16	10 MHz to 50 GHz	1164.0209.50
Direct Generator/Receiver Access, 4-Port Model, 50 GHz	ZVA50-B16	10 MHz to 50 GHz	1164.0209.52
Direct Generator/Receiver Access, 2-Port Model, 67 GHz	ZVA67-B16	10 MHz to 67 GHz	1164.0209.67
Generator Step Attenuator, Port 1, for ZVA8	ZVA8-B21	300 kHz to 8 GHz	1164.0009.02
Generator Step Attenuator, Port 2, for ZVA8	ZVA8-B22	300 kHz to 8 GHz	1164.0015.02
Generator Step Attenuator, Port 3, for ZVA8	ZVA8-B23	300 kHz to 8 GHz	1164.0021.02
Generator Step Attenuator, Port 4, for ZVA8	ZVA8-B24	300 kHz to 8 GHz	1164.0038.02
Generator Step Attenuator, Port 1, for ZVA24	ZVA24-B21	10 MHz to 24 GHz	1164.0109.02
Generator Step Attenuator, Port 2, for ZVA24	ZVA24-B22	10 MHz to 24 GHz	1164.0115.02
Generator Step Attenuator, Port 3, for ZVA24	ZVA24-B23	10 MHz to 24 GHz	1164.0121.02
Generator Step Attenuator, Port 4, for ZVA24	ZVA24-B24	10 MHz to 24 GHz	1164.0138.02
Generator Step Attenuator, Port 1, for ZVA40	ZVA40-B21	10 MHz to 40 GHz	1302.5409.02
Generator Step Attenuator, Port 2, for ZVA40	ZVA40-B22	10 MHz to 40 GHz	1302.5415.02
Generator Step Attenuator, Port 3, for ZVA40	ZVA40-B23	10 MHz to 40 GHz	1302.5421.02
Generator Step Attenuator, Port 4, for ZVA40	ZVA40-B24	10 MHz to 40 GHz	1302.5438.02
Generator Step Attenuator, Port 1, for ZVA50	ZVA50-B21	10 MHz to 50 GHz	1305.5616.02
Generator Step Attenuator, Port 2, for ZVA50	ZVA50-B22	10 MHz to 50 GHz	1305.5622.02
Generator Step Attenuator, Port 3, for ZVA50	ZVA50-B23	10 MHz to 50 GHz	1305.5639.02
Generator Step Attenuator, Port 4, for ZVA50	ZVA50-B24	10 MHz to 50 GHz	1305.5645.02
Generator Step Attenuator, Port 1, for ZVA67	ZVA67-B21	10 MHz to 67 GHz	1305.7077.02
Generator Step Attenuator, Port 2, for ZVA67	ZVA67-B22	10 MHz to 67 GHz	1305.7083.02

Designation	**Type**	**Frequency range**	**Order No.**
Receiver Step Attenuator, Port 1, for ZVA8	ZVA8-B31	300 kHz to 8 GHz	1164.0044.02
Receiver Step Attenuator, Port 2, for ZVA8	ZVA8-B32	300 kHz to 8 GHz	1164.0050.02
Receiver Step Attenuator, Port 3, for ZVA8	ZVA8-B33	300 kHz to 8 GHz	1164.0067.02
Receiver Step Attenuator, Port 4, for ZVA8	ZVA8-B34	300 kHz to 8 GHz	1164.0073.02
Receiver Step Attenuator, Port 1, for ZVA24	ZVA24-B31	10 MHz to 24 GHz	1164.0144.02
Receiver Step Attenuator, Port 2, for ZVA24	ZVA24-B32	10 MHz to 24 GHz	1164.0150.02
Receiver Step Attenuator, Port 3, for ZVA24	ZVA24-B33	10 MHz to 24 GHz	1164.0167.02
Receiver Step Attenuator, Port 4, for ZVA24	ZVA24-B34	10 MHz to 24 GHz	1164.0173.02
Receiver Step Attenuator, Port 1, for ZVA40	ZVA40-B31	10 MHz to 40 GHz	1302.5444.02
Receiver Step Attenuator, Port 2, for ZVA40	ZVA40-B32	10 MHz to 40 GHz	1302.5450.02
Receiver Step Attenuator, Port 3, for ZVA40	ZVA40-B33	10 MHz to 40 GHz	1302.5467.02
Receiver Step Attenuator, Port 4, for ZVA40	ZVA40-B34	10 MHz to 40 GHz	1302.5473.02
Receiver Step Attenuator, Port 1, for ZVA50	ZVA50-B31	10 MHz to 50 GHz	1305.5716.02
Receiver Step Attenuator, Port 2, for ZVA50	ZVA50-B32	10 MHz to 50 GHz	1305.5722.02
Receiver Step Attenuator, Port 3, for ZVA50	ZVA50-B33	10 MHz to 50 GHz	1305.5739.02
Receiver Step Attenuator, Port 4, for ZVA50	ZVA50-B34	10 MHz to 50 GHz	1305.5745.02
Receiver Step Attenuator, Port 1, for ZVA67	ZVA67-B31	10 MHz to 67 GHz	1305.7119.02
Receiver Step Attenuator, Port 2, for ZVA67	ZVA67-B32	10 MHz to 67 GHz	1305.7125.02
Oven Quartz (OCXO)	ZVAB-B4		1164.1757.02
Time Domain (TDR)	ZVAB-K2		1164.1657.02
Frequency Conversion Measurements	ZVA-K4		1164.1863.02
Vector Corrected Mixer Measurements	ZVA-K5		1311.3134.02
True Differential Measurements	ZVA-K6		1164.1540.02
Pulsed Measurements, 3 ms recording time, for all ZVA	ZVA-K7		1164.1511.02
Pulsed Measurements, 25 ms recording time, for all 2-port ZVA	ZVA-B7		1164.1492.02
Pulsed Measurements, 25 ms recording time, for all 4-port ZVA	ZVA-B7		1164.1492.03
Embedded LO Mixer Delay Measurements	ZVA-K9		1311.3128.02
Cable Set for ZVA-K9	ZVA-B9		1311.3134.0x
5 MHz Receiver Bandwidth	ZVA-K17		1164.1070.02
Internal Pulse Generators	ZVA-K27		1164.1892.02
Noise Figure Measurement	ZVA-K30		1164.1828.02
USB-to-IEC/IEEE Adapter	ZVAB-B44		1302.5544.02
Visa I/O Library	VISA I/O BIB		1161.8473.02

About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Regional contact
Europe, Africa, Middle East
+49 1805 12 42 42* or +49 89 4129 137 74
customersupport@rohde-schwarz.com

North America
1-888-TEST-RSA (1-888-837-8772)
customer.support@rsa.rohde-schwarz.com

Latin America
+1-410-910-7988
customersupport.la@rohde-schwarz.com

Asia/Pacific
+65 65 13 04 88
customersupport.asia@rohde-schwarz.com

Certified Quality System
ISO 9001
DQS REG. NO 1954 QM

Certified Environmental System
ISO 14001
DQS REG. NO 1954 UM

Rohde & Schwarz Regional Headquarters Singapore Pte. Ltd.
10 Changi Business Park Central 2
#06-01/08
Singapore 486030

Customersupport.asia@rohde-schwarz.com