4-Port Measurements with Vector Network Analyzer ZVR

Application Note 1EZ25_1E

Subject to change

10 October 1996, Olaf Ostwald

Products:

ZVR

ZVRE

ROHDE&SCHWARZ

1 Hardware Modifications

Three hardware modifications of the option External Measurements ZVR-B25 enable the **bidirectional** network analyzers of the ZVR-family to carry out 4-port measurements. For the measurements, the four ports PORT 1, PORT 2, INPUT b1 and INPUT b2 at the front panel of the ZVR(E) are utilized. The fifth connector, ie OUTPUT a1, is not required for this purpose. As detailed below, the necessary modifications of the test set of the analyzer are described for the model ZVR. Of course, the modifications can be done in a similar way for the model ZVRE as well.

First, the step attenuators for the incident signals a1 and a2, ie ZVR-B21 and ZVR-B22 resp., including their semirigid coaxial connection cables W502, W503, W512 and W513, have to be removed and simply replaced by the original cables W505 and W515. In this way the output signal of the power splitter part of the VSWR bridge is directly connected to the input port of the bridge, as it is in the model without the External Measurements option.

Second, the two (mechanically switchable) step attenuators for the received signals b1 and b2, ie ZVR-B23 and ZVR-B24 resp., are replaced by specially designed electronic step attenuators (Order No. 1045.7000.01). It should be noted that one of the step attenuators, ie ZVR-B23, is mounted in a regular way, while the other (ZVR-B24) is mounted upside down. The described replacement of the original mechanical step attenuators by electronic units is only necessary if the customer needs the high measurement speed which is offered by electronic switching. The mechanical step attenuators of course can also do the job if they do not have to switch too often.

Third, normal SMA-type 10-dB attenuators should be inserted between the rear of the front panel connectors, INPUT b1 and INPUT b2, and the corresponding semirigid cables W508 and W518 respectively. If SMA attenuators are not available, one may use N-type attenuators directly at the front panel instead. Through this measure, the match of the two input ports, which is not required in normal usage and is rather poor when switched to "Internal Mode", is drastically increased while the overall dynamic range of the system is negligibly affected.

2 4-Port Measurements

To perform 4-port measurements, it is recommended to designate the four ports as follows:

Front panel:	PORT 1	PORT 2	INPUT b1	INPUT b2
4-Port:	PORT 1	PORT 2	PORT 3	PORT 4

An arbitrary 4-port is described by 4 x 4 = 16 S-parameters, which can be represented by its scattering matrix (S):

$$(S) = \begin{pmatrix} \boldsymbol{S11} & \boldsymbol{S12} & S13 & S14 \\ \boldsymbol{S21} & \boldsymbol{S22} & S23 & S24 \\ \boldsymbol{S31} & \boldsymbol{S32} & S33 & S34 \\ \boldsymbol{S41} & \boldsymbol{S42} & S43 & S44 \end{pmatrix}$$

As ports 1 and 2 of the network analyzer are bidirectional, which means that they work as driver ports and receiver ports as well, all the four S-parameters ***S11***, ***S21***, ***S12*** and ***S22*** can be measured in the same manner as usual by the analyzer. Additionally, ports 3 and 4, which are just receiver ports, allow the measurement of ***S31*** and ***S41*** in conjunction with Port 1 as driver port, and ***S32*** and ***S42*** in conjunction with Port 2 as driver port. As can be seen, the network analyzer is able to measure directly a total of **eight S-parameters** of an arbitrary 4-port device. These S-parameters are indicated in ***bold type*** in the above scattering matrix.

If one or more of the other (S13 to S44) of the sixteen S-parameters are additionally needed, the device under test has to be reconnected manually. In most practical cases however, a sophisticated assignment of the four ports of the device under test (DUT) to the four ports of the network analyzer will yield a satisfactory solution.

For an **automatic measurement** of the eight S-parameters, IEC-bus control of the analyzer is envisaged. The first four S-parameters, ie ***S11***, ***S21***, ***S12*** and ***S22*** can be measured as usual by the analyzer. This additionally allows calibration of the analyzer and utilization of a full two-port error correction technique, eg TOM, for these parameters.

The other four S-parameters, ie ***S31***, ***S41***, ***S32*** and ***S42***, are measured in the special "4-Port Mode“ of the analyzer. Here, a simple normalization is used for accuracy enhancement. For this TRACE mathematics in all the four display channels, ie CH 1, CH 2, CH 3 and CH 4, of the analyzer are needed. An easy recognition of the S-parameters and the corresponding display channels is possible, if the following assignment is used:

Display channel:	CH 1	CH 2	CH 3	CH 4
Softkey designation in MEAS menu:	S11	S21	S12	S22
Measured S-parameter of the 4-port DUT:	***S31***	***S41***	***S32***	***S42***

For each of the four display channels of the analyzer **normalization** is performed in a similar manner as it is explained in the following for CH 1 and its corresponding S-parameter ***S31*** as an example:

- Connect Port 1 and Port 3 as directly as possible using a through-connection or short cable.
- Use MODE: 4-PORT, CH 1, and MEAS: S11 for measuring ***S31***.
- Press TRACE: DATA TO MEMORY: SHOW MATH with MATH=DATA/MEM.

The normalization for ***S31*** is now finished and should be similarly performed for the three left S-parameters in the other display channels CH 2 to CH 4 by substituting S11 of the above example by the softkey designation of the table above. Connect the ports correspondingly to the measured S-parameter for normalization and use trace mathematics with individual MEM traces in each of the four display channels. After that, the analyzer is **ready for 4-port measurements.**

Finally, connect the 4-port device under test (DUT) and switch off the external inputs using MODE: 4-PORT (softkey becomes grey again) to measure the first four S-parameters ***S11*** to ***S22***. Do not forget to switch off trace mathematics for these measurements, which means only data trace is displayed (SHOW DATA), and to switch off the UNCAL softkey (CAL: UNCAL) for a calibrated measurement of ***S11*** to ***S22***.

After that switch back to the 4-port mode to measure the second four S-parameters ***S31*** to ***S42*** via the display channels CH 1 to CH 4 using trace mathematics DATA/MEM as indicated above.

These operations can, of course, be automatically carried out via a suitable IEC-bus program, which may run on the network analyzer itself, without the need of an additional PC.

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3 Further Application Notes

[1] O. Ostwald: 3-Port Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ26_1E.

[2] H.-G. Krekels: Automatic Calibration of Vector Network Analyzer ZVR, Appl. Note 1EZ30_1E.

[3] O. Ostwald: 4-Port Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ25_1E.

[4] T. Bednorz: Measurement Uncertainties for Vector Network Analysis, Appl. Note 1EZ29_1E.

[5] P. Kraus: Measurements on Frequency-Converting DUTs using Vector Network Analyzer ZVR, Appl. Note 1EZ32_1E.

[6] J. Ganzert: Accessing Measurement Data and Controlling the Vector Network Analyzer via DDE, Appl. Note 1EZ33_1E.

[7] J. Ganzert: File Transfer between Analyzers FSE or ZVR and PC using MS-DOS Interlink, Appl. Note 1EZ34_1E.

[8] O. Ostwald: Group and Phase Delay Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ35_1E.

[9] O. Ostwald: Multiport Measurements using Vector Network Analyzer, Appl. Note 1EZ37_1E.

[10] O. Ostwald: Frequently Asked Questions about Vector Network Analyzer ZVR, Appl. Note 1EZ38_3E.

[11] A. Gleißner: Internal Data Transfer between Windows 3.1 / Excel and Vector Network Analyzer ZVR, Appl. Note 1EZ39_1E.

[12] A. Gleißner: Power Calibration of Vector Network Analyzer ZVR, Appl. Note 1EZ41_2E

[13] O. Ostwald: Pulsed Measurements on GSM Amplifier SMD ICs with Vector Analyzer ZVR, Appl. Note 1EZ42_1E.

[14] O. Ostwald: Zeitbereichsmessungen mit dem Netzwerkanalysator ZVR, Appl. Note 1EZ44_1D.

4 Ordering Information

Order designation	Type	Frequency range	Order No.
Vector Network Analyzers (test sets included) *			
3-channel, unidirectional, 50 Ω, passive	ZVRL	9 kHz to 4 GHz	1043.0009.41
3-channel, bidirectional, 50 Ω, passive	ZVRE	9 kHz to 4 GHz	1043.0009.51
3-channel, bidirectional, 50 Ω, active	ZVRE	300 kHz to 4 GHz	1043.0009.52
4-channel, bidirectional, 50 Ω, passive	ZVR	9 kHz to 4 GHz	1043.0009.61
4-channel, bidirectional, 50 Ω, active	ZVR	300 kHz to 4 GHz	1043.0009.62
3-channel, bidirectional, 50 Ω, active	ZVCE	20 kHz to 8 GHz	1106.9020.50
4-channel, bidirectional, 50 Ω, active	ZVC	20 kHz to 8 GHz	1106.9020.60
Alternative Test Sets *			
75 Ω SWR Bridge for ZVRL (instead of 50 Ω) [1]			
75 Ω, passive	ZVR-A71	9 kHz to 4 GHz	1043.7690.18
75 Ω SWR Bridge Pairs for ZVRE and ZVR (instead of 50 Ω) [1]			
75 Ω, passive	ZVR-A75	9 kHz to 4 GHz	1043.7755.28
75 Ω, active	ZVR-A76	300 kHz to 4 GHz	1043.7755.29
Options			
AutoKal	ZVR-B1	0 to 8 GHz	1044.0625.02
Time Domain	ZVR-B2	same as analyzer	1044.1009.02
Mixer Measurements [2]	ZVR-B4	same as analyzer	1044.1215.02
Reference Channel Ports	ZVR-B6	same as analyzer	1044.1415.02
Power Calibration [3]	ZVR-B7	same as analyzer	1044.1544.02
3-Port Adapter	ZVR-B8	0 to 4 GHz	1086.0000.02
Virtual Embedding Networks [4]	ZVR-K9	same as analyzer	1106.8830.02
4-Port Adapter (2xSPDT)	ZVR-B14	0 to 4 GHz	1106.7510.02
4-Port Adapter (SP3T)	ZVR-B14	0 to 4 GHz	1106.7510.03
Controller (German) [5]	ZVR-B15	-	1044.0290.02
Controller (English) [5]	ZVR-B15	-	1044.0290.03
Ethernet BNC for ZVR-B15	FSE-B16	-	1073.5973.02
Ethernet AUI for ZVR-B15	FSE-B16	-	1073.5973.03
IEC/IEEE-Bus Interface for ZVR-B15	FSE-B17	-	1066.4017.02
Generator Step Attenuator PORT 1	ZVR-B21	same as analyzer	1044.0025.11
Generator Step Attenuator PORT 2 [6]	ZVR-B22	same as analyzer	1044.0025.21
Receiver Step Attenuator PORT 1	ZVR-B23	same as analyzer	1044.0025.12
Receiver Step Attenuator PORT 2	ZVR-B24	same as analyzer	1044.0025.22
External Measurements, 50 Ω [7]	ZVR-B25	10 Hz to 4 GHz (ZVR/E/L) 20 kHz to 8 GHz (ZVC/E)	1044.0460.02

[1] To be ordered together with the analyzer.
[2] Harmonics measurements included.
[3] Power meter and sensor required.
[4] Only for ZVR or ZVC with ZVR-B15.
[5] DOS, Windows 3.11, keyboard and mouse included.
[6] For ZVR or ZVC only.
[7] Step attenuators required.

*** Note:**

Active test sets, in contrast to passive test sets, comprise internal bias networks, eg to supply DUTs.