Multiport Measurements using Vector Network Analyzer ZVR

Application Note 1EZ37_1E
Subject to change
10 October 1997, Olaf Ostwald

Products:

ZVR with option ZVR-B8, ZVR-B14 or ZVR-B26
ZVRE with option ZVR-B8, ZVR-B14 or ZVR-B26
ZVRL with option ZVR-B8
1 Abstract

Using the optional three-port or four-port adapter (ZVR-B8 and ZVR-B14), PORT 1 and PORT 2 of the network analyzers of the ZVR family (ZVRL, ZVRE and ZVR) can be expanded to up to four ports. Thus automatic measurements on three- and four-port DUTs can be easily performed without any reconnection of ports being required. With the electronic switches in the adapters, switchover between the various ports is fast to the extent that the known high measurement and display speed of the analyzers of the ZVR family is fully maintained.

2 Overview

Four different options permit measurements on three- or four-port networks to be performed:

- **ZVR-B8**: Three-Port Adapter
- **ZVR-B14 model 02**: Four-Port Adapter "2 x SPDT"
- **ZVR-B14 model 03**: Four-Port Adapter "SP3T"
- **ZVR-B26**: Extra Inputs, 4-Port

Each option offers different advantages which will be described in the following.

---

**FIG. 1:** Drawing on cover of 3-Port Adapter ZVR-B8

<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ABSTRACT</td>
<td>2</td>
</tr>
<tr>
<td>2 OVERVIEW</td>
<td>2</td>
</tr>
<tr>
<td>3 THREE-PORT MEASUREMENT</td>
<td>3</td>
</tr>
<tr>
<td>3.1 DESCRIPTION OF 3-PORT ADAPTER</td>
<td>3</td>
</tr>
<tr>
<td>3.2 USE</td>
<td>3</td>
</tr>
<tr>
<td>4 FOUR-PORT MEASUREMENTS</td>
<td>5</td>
</tr>
<tr>
<td>4.1 DESCRIPTION OF 4-PORT ADAPTER</td>
<td>6</td>
</tr>
<tr>
<td>4.2 USE</td>
<td>7</td>
</tr>
<tr>
<td>4.2.1 GENERAL</td>
<td>7</td>
</tr>
<tr>
<td>4.2.2 MODEL 02</td>
<td>8</td>
</tr>
<tr>
<td>4.2.3 MODEL 03</td>
<td>9</td>
</tr>
<tr>
<td>4.3 EXTRA INPUTS, 4-PORT</td>
<td>11</td>
</tr>
<tr>
<td>5 SUMMARY</td>
<td>12</td>
</tr>
<tr>
<td>5.1 3-PORT ADAPTER</td>
<td>12</td>
</tr>
<tr>
<td>5.2 4-PORT ADAPTER, MODEL 02</td>
<td>12</td>
</tr>
<tr>
<td>5.3 4-PORT ADAPTER, MODEL 03</td>
<td>12</td>
</tr>
<tr>
<td>5.4 EXTRA INPUTS, 4-PORT</td>
<td>12</td>
</tr>
<tr>
<td>6 FURTHER APPLICATION NOTES</td>
<td>13</td>
</tr>
<tr>
<td>7 ORDERING INFORMATION</td>
<td>13</td>
</tr>
</tbody>
</table>
3 Three-Port Measurements

The 3-port adapter is an optional extra to be used with all Network Analyzers of the ZVR family, ie ZVRL, ZVRE and ZVR. It extends PORT 1 and PORT 2 of the network analyzer to three ports, PORT 1, PORT 2 and PORT 3. It is provided with an electronic switch which connects PORT 1 of the analyzer to PORT 1 or PORT 3 of the 3-port adapter. PORT 2 of the analyzer is directly connected to the PORT 2 of the adapter and is not switched. The 3-port adapter is driven via an optional interface at the rear.

3.1 Description of 3-Port Adapter

Design and function of the 3-port adapter can be seen from the drawing on the adapter cover (see FIG. 1). The adapter comprises an electronic switch (SPDT = single pole double throw) with field-effect transistors permitting signals between 9 kHz and 4 GHz to be switched virtually wattless and without delay. Its insertion loss is typically 1.6 dB at 9 kHz and increases to approx. 4.2 dB at 4 GHz. The deactivated port, eg PORT 3 (with PORT 1 through-connected), is terminated with a low-reflection 50 Ω resistor.

The 3-port adapter is driven with the TTL signal CHNBIT0 via the optional rear-panel MULTIPOWER ADAPTER interface (former name: 3-PORT ADAPTER). In analyzers of the ZVR family, the status of this signal changes synchronously with the active display channel (CH 1 to CH 4) if the decoupled channels mode is selected, ie:

[SWEEP]: COUPLED CHANNELS = OFF.

- For the two odd display channels, ie CH 1 and CH 3, the switch is in position PORT 1.
- For the two even display channels, ie CH 2 and CH 4, the switch is in position PORT 3.

3.2 Use

The 3-port adapter is particularly suitable for measuring special three-port DUTs such as antenna diplexers. In practice, a transmitter signal is applied to the first port of the diplexer. The signal is then routed through the diplexer to the second port which is normally connected to a transmitting/receiving antenna. The received signal is routed through the diplexer to the third port to which a receiver is normally connected.

For measurements on the antenna diplexer, the generator input of the diplexer is connected to PORT 1, the antenna input/output to PORT 2 and the receiver output to PORT 3 of the 3-port adapter. If a bidirectional network analyzer, ie ZVRE or ZVR, is used, the reflection can be measured at all three ports of the diplexer, as well as the transmission between port 1 and port 2 and that between port 2 and port 3 and vice versa. (With the unidirectional Network Analyzer ZVRL only the forward S-parameters S11, S21, S23 and S33 can of course be measured). Direct measurement of transmissions between port 1 and port 3 is not possible because the two ports are connected to the same analyzer port, ie PORT 1, through the switch of the three-port adapter.

Thus the 3-port adapter permits seven of the three times three - ie nine - S-parameters of a three-port DUT to be directly measured without the need to reconnect the DUT. The seven parameters are written in bold in the following general S-parameters matrix of any three-port device.

\[
(S) = \begin{pmatrix}
S_{11} & S_{12} & S_{13} \\
S_{21} & S_{22} & S_{23} \\
S_{31} & S_{32} & S_{33}
\end{pmatrix}
\]

The two remaining S-parameters S13 and S31 may be measured after reconnecting the DUT. However, these parameters need not be known in practical applications. With the aid of the 3-port adapter all key S-parameters of a DUT can be measured quasi simultaneously. Up to four S-parameters can be displayed at the same time on the network analyzer next to or on top of each other.
A typical measurement example is the simultaneous test of the two transmission paths of a diplexer. If, for instance, the transmission coefficient $S_{21}$ from PORT 1 to PORT 2 and $S_{23}$ from PORT 3 to PORT 2 is to be measured, $S_{21}$ can be displayed in channel CH 1 (PORT 1 through-connected) and $S_{23}$ in channel CH 2 (PORT 3 through-connected). Switchover between the two decoupled display channels and therefore between the two measurement paths of the diplexer is performed automatically after each sweep. For example, with 400 test points per channel and a measurement bandwidth of 10 kHz, a switchover is performed every 200 ms. Thus changes in the transmission characteristics of the diplexer can be followed on the analyzer display in real time and the DUT can be adjusted without delay.

**Note:**

Regarding the S-parameter display, the value indicated at the very left in the top line of the analyzer display always refers to test ports PORT 1 and PORT 2 of the analyzer irrespective of whether a 3-port adapter is used or not and of the adapter switch position.

Consequently, $S_{21}$ will always be displayed irrespective of whether $S_{21}$ or $S_{23}$ is measured, as in both cases the forward transmission coefficient from PORT 1 to PORT 2 of the network analyzer is measured.

Additional parameters can be displayed in the other available display channels. For instance, the match $S_{11}$ of the DUT at PORT 1 can be displayed in channel CH 3 (PORT 1 through-connected) and the match $S_{33}$ at PORT 3 in display channel CH 4 (PORT 3 through-connected).

A combination of two 3-port adapters allows also further measurements to be performed. For instance, if the switch input of one 3-port adapter is connected to PORT 1 of the network analyzer, and the second 3-port adapter to PORT 2 of the analyzer, two two-port DUTs can be measured simultaneously. Thus the DUTs can be directly compared and easily adjusted. The two 3-port adapters are driven in parallel from the rear analyzer interface via a simple Y cable.

Other applications are also possible provided the 3-port adapter is not driven with the previously mentioned TTL signal CHNBIT0 but with the alternative TTL signal CHNBIT1 which is also available at the rear analyzer interface. In this case a minor modification has to be made on the control board of the 3-port adapter. The CHNBIT1 signal too changes its state synchronously with the active display channel but it assumes one status for the two lower channels CH 1 and CH 2 and the other for the two higher channels CH 3 and CH 4. This means that the switch is in position PORT 1 when display channel CH 1 or CH 2 is active and in position PORT 3 when display channel CH 3 or CH 4 becomes active.

If two 3-port adapters are used, one driven with a CHNBIT0 and the other with a CHNBIT1 signal, 4-port DUTs can be measured. If, for instance, ports 1 and 2 of the DUT are connected to the first 3-port adapter and ports 3 and 4 to the second, reflection coefficients can be measured at all four ports of the DUT. Eight of the twelve transmission coefficients can be measured as can be seen in TABLE 1 below.

<table>
<thead>
<tr>
<th>Switch position</th>
<th>Display channel</th>
<th>CH 1</th>
<th>CH 2</th>
<th>CH 3</th>
<th>CH 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHN BIT 1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>CHN BIT 0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

5-port S-param.

| 4-port S-param. | S_{31} and S_{13} | S_{32} and S_{23} | S_{41} and S_{14} | S_{42} and S_{24} |

TABLE 1: Four-port measurement using two 3-port adapters

To enhance the measurement accuracy, a commonly used error correction method, e.g., TOM, can be used. It is recommended to perform a separate calibration in each of the decoupled display channels. During operation, an automatic switchover between the associated, independent calibration data sets is performed synchronously with the channel change and the switchover of the 3-port adapter. Switching is fast to the extent that the high measurement speed of the network analyzers of the ZVR family is fully maintained.
4 Four-Port Measurements

The 4-port adapter is used to expand test PORT 1 and test PORT 2 of the network analyzers of the ZVR family to four ports, PORT 1, PORT 2, PORT 3 and PORT 4. The 4-port adapter comes in two models (02 and 03) with different switching functions so the models are suitable for particular types of four-port DUTs.

Model 02 (see FIG. 2) comprises two independent switches (SPDT). The first switches PORT 1 of the analyzer to PORT 1 or PORT 3 of the 4-port adapter. The second switches PORT 2 of the network analyzer to PORT 2 or PORT 4 of the 4-port adapter. This adapter module is particularly suitable for measuring DUTs with two inputs and two outputs such as double-pole switches or directional couplers but also for simultaneous measurements on two two-port DUTs, eg two amplifiers or two filters.

Model 03 (see FIG. 3), by contrast, connects PORT 1 of the network analyzer directly to PORT 1 of the 4-port adapter, while PORT 2 of the analyzer can be connected to any of the three remaining ports of the 4-port adapter, PORT 2, PORT 3 or PORT 4. Thus model 03 is particularly suitable for measuring DUTs with one input and three outputs or vice versa, eg filter banks, where the transmission coefficient is to be measured between one port and the three others.

If a bidirectional network analyzer is used, both models of the 4-port adapter permit simultaneous measurements of the reflection at all four ports of the DUT or measurements of up to four different transmission coefficients or combinations of reflection and transmission measurements. In all cases the complete range of capabilities of the vector network analyzers of the ZVR family, eg a variety of display modes, complex evaluation functions and a wide range of system error calibration methods, can be used independently for any of the four selected parameters.

The 4-port adapter is powered and driven via the optional MULTIPORT ADAPTER interface (former name: 3-PORT ADAPTER) of the network analyzer.
4.1 Description of 4-Port Adapters

As already mentioned, the 4-port adapter comes in two models, model 02 and model 03. Both comprise two electronic switches which are, however, differently wired so that different functions are obtained at their interfaces.

Design and basic functions can be seen from the drawing on the cover of the respective 4-port adapter.

Model 02 (see FIG. 2) comprises two switches (SPDT = single pole double throw). One switches PORT 1 of the analyzer to PORT 1 or PORT 3 of the 4-port adapter (left half of module), the other PORT 2 of the network analyzer to PORT 2 or PORT 4 of the 4-port adapter (right half of module).

Model 03 (see FIG. 3) also comprises two switches. In contrast to model 02, in this model PORT 1 of the analyzer is directly connected to PORT 1 of the 4-port adapter (left section of module) and is not switched. The two electronic switches in the right-hand section of the module are wired such that they act like a 1-to-3 switch (SP3T = single pole triple throw), as seen from the outside. Thus PORT 2 of the network analyzer can be switched to PORT 2, PORT 3 or PORT 4 of the 4-port adapter.

The two electronic switches are made up of FET transistors permitting signals between 9 kHz and 4 GHz to be switched virtually wattless and without delay. The insertion loss in the through-connected path of the electronic switch is typically 1.6 dB at 9 kHz and increases to 4.2 dB at 4 GHz. (With model 03 it should be borne in mind that the insertion loss in the paths to PORT 3 and PORT 4 is twice as high because the switches are series-connected.) The disabled ports of the 4-port adapter, eg PORT 3 and PORT 4 with PORT 1 and PORT 2 through-connected, are terminated with integrated low-reflection 50 Ω resistors.
4.2 Applications

4.2.1 General

The 4-port adapter allows a variety of four-port DUTs to be measured (also two two-ports, a three-port and a one-port or four one-ports). A standard four-port DUT is defined by its scattering matrix (four times four, ie sixteen S-parameters).

\[
(S) = \begin{bmatrix}
S_{11} & S_{12} & S_{13} & S_{14} \\
S_{21} & S_{22} & S_{23} & S_{24} \\
S_{31} & S_{32} & S_{33} & S_{34} \\
S_{41} & S_{42} & S_{43} & S_{44}
\end{bmatrix}
\]

S-parameters measured with model 02

With each model of the 4-port adapter all four reflection coefficients $S_{11}$ to $S_{44}$ can be measured provided a bidirectional network analyzer is used. Six or eight of the twelve transmission coefficients $S_{12}$ to $S_{43}$ can be determined, depending on the selected 4-port adapter model.

Model 02 is able to measure eight transmission coefficients. The measurable S-parameters are written in bold in the matrix above. The four remaining transmission coefficients $S_{13}$, $S_{31}$, $S_{24}$ and $S_{42}$ cannot be determined directly due to the design of model 02 of the 4-port adapter. To measure these parameters, the DUT has to be reconnected or model 03 of the 4-port adapter is to be used.

Model 03 of the 4-port adapter also measures the four reflection coefficients $S_{11}$ to $S_{44}$ of a four-port network. Six of the twelve transmission coefficients $S_{12}$ to $S_{43}$ can be measured, ie the transmissions coefficient from PORT 1 to the other three ports and vice versa. The measurable S-parameters are printed in bold in the following matrix below. Due to the circuit design of model 03 of the 4-port adapter, the remaining six transmission coefficients, ie $S_{23}$, $S_{32}$, $S_{24}$, $S_{42}$, $S_{34}$ and $S_{43}$, cannot be determined directly.

The 4-port adapter is operated via the optional MULTIPORT ADAPTER interface at the rear, which was introduced under the name 3-PORT ADAPTER for the 3-port adapter and has now been renamed.

Control of the two switches in the 4-port adapter is such that in the case of decoupled ZVR display channels ([Sweep]: COUPLED CHANNELS = OFF) different paths of the 4-port adapter are through-connected depending on the activated display channel (channel CH 1, CH 2, CH 3 or CH 4). Models 02 and 03 of the 4-port adapter behave differently:

The exact assignment of active display channel and through-connected ports of model 02 can be seen from the table on the cover of the 4-port adapter (see TABLE 2):

<table>
<thead>
<tr>
<th>CH 1</th>
<th>CH 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>① 〇 〇 ②</td>
<td>① 〇 ④ 〇</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CH 2</th>
<th>CH 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>〇 ③ 〇 ②</td>
<td>〇 ③ ④ 〇</td>
</tr>
</tbody>
</table>

TABLE 2: Channel assignment of model 02

As can be seen, PORT 1 of the 4-port adapter is activated for the two odd display channels (CH 1 and CH 3) and PORT 3 for the two even channels (CH 2 and CH 4). The left-hand switch of the 4-port adapter is actuated each time a switchover is performed between the odd and even display channels. The right-hand switch is in position PORT 2 for the two lower channel numbers (CH 1 and CH 2) and in position PORT 4 for the two higher channel numbers (CH 3 and CH 4). The right-hand switch is therefore actuated each time a switchover is made between the two lower and the two higher channels.
During switchover from CH 1 to CH 4 the four possible port combinations of the 4-port adapter (model 02) are cyclically activated.

Port designation and channel assignment of model 02 of the 4-port adapter are selected so that the CH 1 represents the initial state. In this case PORT 1 and PORT 2 of the network analyzer are directly connected to PORT 1 and PORT 2 of the 4-port adapter. The adapter ports are of the same construction as the two analyzer test ports. Same as in the 3-port adapter, PORT 3 of the 4-port adapter is located next to PORT 1. Thus PORT 1 to PORT 3 of the two adapters are of identical design and function. PORT 1 of the analyzer can be through-connected to PORT 1 or PORT 3 of the 4-port adapter. Symmetrically, PORT 2 of the analyzer is switched to PORT 2 or PORT 4 using the 4-port adapter.

Assignment of the active display channel and through-connected test ports of model 03 can be easily explained: Same as with model 02, port designations and channel assignment in model 03 of the 4-port adapter are such that CH 1 is assumed to be in the initial state. In this case PORT 1 and PORT 2 of the network analyzer are through-connected to PORT 1 and PORT 2 of the 4-port adapter. The remaining three display channels cause the corresponding ports of the 4-port adapter to be through-connected, ie PORT 2 for CH 2, PORT 3 for CH 3 and PORT 4 for CH 4. It can thus be seen that PORT 1 of model 03 is always through-connected (see TABLE 3).

### TABLE 3: Channel assignment of model 03

<table>
<thead>
<tr>
<th>CH 1</th>
<th>CH 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>①〇〇②</td>
<td>①③〇〇</td>
</tr>
<tr>
<td>CH 2</td>
<td>CH 4</td>
</tr>
<tr>
<td>①〇〇②</td>
<td>①〇〇②</td>
</tr>
</tbody>
</table>

4.2.2 Model 02

The following procedure is recommended for measuring four-port S-parameters using model 02 of the 4-port adapter:

1. For the measurement of forward transmission coefficients \(S_{21}, S_{23}, S_{41}, S_{43}\), the S-parameter \(S_{21}\) should be selected as the parameter in all four display channels.
   - [MEAS]: S21
   - [SWEEP]: COUPLED CHANNELS = OFF
   - [DISPLAY]: QUAD CHANNEL QUAD SPLIT

Provided the display channels are decoupled and a quad split display is selected, the S-parameters of the DUT are displayed in the following form:

\[
\begin{array}{cc}
S_{21} & S_{41} \\
S_{23} & S_{43}
\end{array}
\]

2. For the measurement of reverse transmission coefficients \(S_{12}, S_{32}, S_{14}, S_{34}\), \(S_{12}\) should be selected as the parameter in all four display channels. Under the conditions described above the following S-parameters of the DUT are displayed:

\[
\begin{array}{cc}
S_{12} & S_{14} \\
S_{32} & S_{34}
\end{array}
\]

3. For the measurement of reflection coefficients \(S_{11}, S_{22}, S_{33}, S_{44}\), \(S_{11}\) should, for example, be selected as the parameter in display channels CH 1 and CH 4 and \(S_{22}\) in channels CH 2 and CH 3. All four reflection coefficients of the DUT are then displayed in the following form:

\[
\begin{array}{cc}
S_{11} & S_{44} \\
S_{22} & S_{33}
\end{array}
\]

Of course, different combination of forward and reverse transmission and reflection coefficients can be simultaneously displayed. The exact configuration is determined by the S-parameter selected in the different display channels and the predefined assignment of active display channels and through-connected test ports.
A **system error calibration** can be performed as usual prior to the measurement to increase the accuracy. In this case it is recommended to perform a calibration separately for each display channel and to connect the calibration standards to the two through-connected ports of the **4-port adapter** (or to the connected test cable). During operation, up to four system-error correction data sets are automatically switched upon the channel change and synchronously with the switching of the **4-port adapter**. The **measurement and switching speed** is in all cases high enough for the DUT to be adjusted without delay.

**Note:**

Regarding the **S-parameter display** it should be noted that the S-parameter indicated in the respective quadrant at the very left of the top line of the analyzer display always refers to **PORT 1 and PORT 2** of the network analyzer irrespective of whether a 4-port adapter is connected or not or of the switch positions of the adapter.

Consequently, **S21** is always displayed if, for example, **S3** or even **S21** is measured, as in both cases the transmission coefficient from **PORT 1** to **PORT 2** of the network analyzer is measured.

### 4.2.3 Model 03

For measuring **four-port S-parameters** with **model 03** of the **4-port adapter**, the following procedure is recommended:

1. For the measurement of **forward transmission coefficients** (**S21, S31, S41** of the first column in the **scattering matrix** (**S**)), parameter **S21** should be measured first in all four display channels.
   - [MEAS]: S21
   - [SWEEP]: COUPLED CHANNELS = OFF
   - [DISPLAY]: QUAD CHANNEL QUAD SPLIT

   Provided the display channels are **decoupled** and a quad split display is selected, the three measurable forward transmission coefficients of the DUT are displayed in the following form:

   \[
   \begin{array}{c|c}
   S_{21} & S_{31} \\
   \hline
   S_{21} & S_{41} \\
   \end{array}
   \]

2. For the measurement of **reverse transmission coefficients** (**S12, S13, S14** in the top line of the **scattering matrix** (**S**)), **S12** is selected as test parameter in all four display channels. Under the conditions described above, the three measurable reverse transmission coefficients of the DUT are displayed in the following form:

   \[
   \begin{array}{c|c}
   S_{12} & S_{13} \\
   \hline
   S_{12} & S_{14} \\
   \end{array}
   \]

3. For the measurement of **reflection coefficients** (**S11, S22, S33, S44** in the main diagonal of the **scattering matrix** (**S**)), **S11** is selected, for instance, in display channels **CH 1** and **CH 3** and **S22** in display channels **CH 2** and **CH 4**. The four reflection coefficients are then displayed in the following form (see also FIG. 4):

   \[
   \begin{array}{c|c}
   S_{11} & S_{33} \\
   \hline
   S_{22} & S_{44} \\
   \end{array}
   \]

Of course, different combination of forward and reverse transmission and reflection coefficients can be simultaneously displayed. The assignment is determined by the S-parameter selected in the different display channels and the predefined configuration of active display channels and through-connected test ports.
To increase the measurement accuracy, a system error calibration can be performed as usual prior to the measurement. In this case it is recommended to perform a calibration separately for each display channel and to connect the calibration standards to the two through-connected ports of the 4-port adapter (or to the test cable connected). During operation, up to four system-error correction data sets are automatically switched upon the channel change and synchronously with the switching of the 4-port adapter. The measurement and switching speed is in all cases high enough for the DUT to be adjusted without delay.

**Note:**

Regarding the display it should be noted again that the S-parameter indicated in the respective quadrant at the very left of the top line of the analyzer display always refers to PORT 1 and PORT 2 of the network analyzer irrespective of whether a 4-port adapter is connected or not or of the switch positions of the adapter.

Consequently, $S_{11}$ is always displayed if, for example, $S_{11}$ or even $S_{33}$ is measured, as in both cases the reflection coefficient at PORT 1 of the network analyzer is measured.
4.3 **Extra Inputs, 4-Port**

The *Extra Inputs* option ZVR-B26 is a third alternative for measurements on four-port networks. In contrast to the 4-Port Adapter ZVR-B14 described above, no external adapter is connected to PORT 1 and PORT 2 but a modified form of the additional inputs INPUT b1 and INPUT b2 of the *External Measurements* option ZVR-B25 is used as new inputs PORT 3 and PORT 4 for connecting four-port DUTs (see TABLE 4). This option is only available for the bidirectional network analyzers of the ZVR family, i.e. ZVRE and ZVR.

<table>
<thead>
<tr>
<th>Front panel:</th>
<th>PORT 1</th>
<th>PORT 2</th>
<th>INPUT b1</th>
<th>INPUT b2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-port:</td>
<td>PORT 1</td>
<td>PORT 2</td>
<td>PORT 3</td>
<td>PORT 4</td>
</tr>
</tbody>
</table>

**TABLE 4: Front panel for option ZVR-B26**

PORT 1 and PORT 2 are used as usual as bidirectional test ports, i.e. they are able to transmit and receive. The new ports PORT 3 and PORT 4 provided by option ZVR-B26 are receiver ports only; they cannot send. Consequently, with this option too only some of the sixteen S-parameters of a 4-port DUT can be measured. The S-parameters for which ports 3 and 4 would be required to send, i.e. $S_{i3}$ and $S_{i4}$ (i = 1, 2, 3, 4), cannot therefore be directly measured.

In the scattering matrix below the S-parameters that can be measured with the *Extra Inputs* option ZVR-B26 are written in bold.

$$
(S) = \begin{bmatrix}
S_{11} & S_{12} & S_{13} & S_{14} \\
S_{21} & S_{22} & S_{23} & S_{24} \\
S_{31} & S_{32} & S_{33} & S_{34} \\
S_{41} & S_{42} & S_{43} & S_{44}
\end{bmatrix}
$$

The first four parameters $S_{11}$ to $S_{22}$ can be measured as usual with all system error correction methods being available. The remaining four parameters $S_{31}$ to $S_{42}$ are measured in the special 4-port mode of the analyzer. In this case a simple normalization is performed using the trace mathematics. The recommended procedure is illustrated using channel CH 1 and the associated S-parameter $S_{31}$ as an example:

- Connect PORT 1 and PORT 3 directly.
- Press [TRACE]: DATA TO MEMORY: SHOW MATH with MATH = DATA/MEM.

Normalization for this display channel is completed and should be performed analogously for all other display channels. After all four display channels have been normalized, the DUT can be connected and measured. For the *display of the first four S-parameters $S_{11}$ to $S_{22}$*, the 4-PORT mode is switched off again.

- [MODE]: 4-PORT (softkey is grey again)
- [TRACE]: SHOW DATA and
- [CAL]: UNCAL (softkey is grey again)

The 4-PORT mode can now be selected again and the *remaining four S-parameters $S_{31}$ to $S_{42}$* measured in display channels CH 1 to CH 4 using trace mathematics DATA/MEM as described above.

The measured S-parameters of the four-port DUT can be assigned to the respective display channel with the aid of **TABLE 5**:

<table>
<thead>
<tr>
<th>Display channel:</th>
<th>CH 1</th>
<th>CH 2</th>
<th>CH 3</th>
<th>CH 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softkey designation in MEAS menu:</td>
<td>S11</td>
<td>S21</td>
<td>S12</td>
<td>S22</td>
</tr>
<tr>
<td>Measured S-parameter of four-port DUT:</td>
<td>S31</td>
<td>S41</td>
<td>S32</td>
<td>S42</td>
</tr>
</tbody>
</table>

**TABLE 5: Four-port measurement with ZVR-B26**

The described operating steps can of course be performed automatically with the aid of macros or by means of an IEC/IEEE-bus program. If the *Computer Function* option ZVR-B15 is built in, this can be done conveniently on the network analyzer itself without an additional computer being required.

- Press [TRACE]: DATA TO MEMORY: SHOW MATH with MATH = DATA/MEM.

Normalization for this display channel is completed and should be performed analogously for all other display channels. After all four display channels have been normalized, the DUT can be connected and measured. For the *display of the first four S-parameters $S_{11}$ to $S_{22}$*, the 4-PORT mode is switched off again.

- [MODE]: 4-PORT (softkey is grey again)
- [TRACE]: SHOW DATA and
- [CAL]: UNCAL (softkey is grey again)

The 4-PORT mode can now be selected again and the *remaining four S-parameters $S_{31}$ to $S_{42}$* measured in display channels CH 1 to CH 4 using trace mathematics DATA/MEM as described above.

The measured S-parameters of the four-port DUT can be assigned to the respective display channel with the aid of **TABLE 5**:

<table>
<thead>
<tr>
<th>Display channel:</th>
<th>CH 1</th>
<th>CH 2</th>
<th>CH 3</th>
<th>CH 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softkey designation in MEAS menu:</td>
<td>S11</td>
<td>S21</td>
<td>S12</td>
<td>S22</td>
</tr>
<tr>
<td>Measured S-parameter of four-port DUT:</td>
<td>S31</td>
<td>S41</td>
<td>S32</td>
<td>S42</td>
</tr>
</tbody>
</table>

**TABLE 5: Four-port measurement with ZVR-B26**

The described operating steps can of course be performed automatically with the aid of macros or by means of an IEC/IEEE-bus program. If the *Computer Function* option ZVR-B15 is built in, this can be done conveniently on the network analyzer itself without an additional computer being required.
5 Summary

5.1 3-Port Adapter

Three-port DUTs can be measured using the 3-Port Adapter option ZVR-B8 and a Network Analyzer ZVRL (unidirectional only), ZVRE or ZVR. However, due to the construction of the 3-port adapter (SPDT at PORT 1), S-parameters $S_{13}$ and $S_{31}$ cannot be measured.

\[
(S) = \begin{bmatrix}
S_{11} & S_{12} & S_{13} \\
S_{21} & S_{22} & S_{23} \\
S_{31} & S_{32} & S_{33}
\end{bmatrix}
\]

5.2 4-Port Adapter, Model 02

 Twelve of the sixteen S-parameters of any four-port DUT can be measured when a bidirectional Network Analyzer ZVRE or ZVR is used together with model 02 of the 4-Port Adapter option ZVR-B14.

\[
(S) = \begin{bmatrix}
S_{11} & S_{12} & S_{13} & S_{14} \\
S_{21} & S_{22} & S_{23} & S_{24} \\
S_{31} & S_{32} & S_{33} & S_{34} \\
S_{41} & S_{42} & S_{43} & S_{44}
\end{bmatrix}
\]

5.3 4-Port Adapter, Model 03

Model 03 of the 4-Port Adapter option ZVR-B14 is particularly suitable for measurements on four-port DUTs when the transmission coefficient from one port to all other ports is to be measured.

\[
(S) = \begin{bmatrix}
S_{11} & S_{12} & S_{13} & S_{14} \\
S_{21} & S_{22} & S_{23} & S_{24} \\
S_{31} & S_{32} & S_{33} & S_{34} \\
S_{41} & S_{42} & S_{43} & S_{44}
\end{bmatrix}
\]

5.4 Extra Inputs, 4-Port

The Extra Inputs, 4-Port, option ZVR-B26 is the third alternative for measurements on four-port networks.

\[
(S) = \begin{bmatrix}
S_{11} & S_{12} & S_{13} & S_{14} \\
S_{21} & S_{22} & S_{23} & S_{24} \\
S_{31} & S_{32} & S_{33} & S_{34} \\
S_{41} & S_{42} & S_{43} & S_{44}
\end{bmatrix}
\]

In contrast to the other options, no adapter is connected in this case to test ports PORT 1 and PORT 2 of the network analyzer but merely the front panel is extended by two additional test inputs PORT 3 and PORT 4.

Olaf Ostwald, 1ES3
Rohde & Schwarz
10 October 1997
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_1E.
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: Zeitsbereichsmessungen mit dem Netzwerkanalysator ZVR, Appl. Note 1EZ44_1D.

Ordering Information

<table>
<thead>
<tr>
<th>Order designation</th>
<th>Type</th>
<th>Frequency range</th>
<th>Order No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vector Network Analyzers (test sets included)</strong> *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-channel, unidirectional, 50 Ω, passive</td>
<td>ZVRL</td>
<td>9 kHz to 4 GHz</td>
<td>1043.0009.41</td>
</tr>
<tr>
<td>3-channel, bidirectional, 50 Ω, passive</td>
<td>ZVRE</td>
<td>9 kHz to 4 GHz</td>
<td>1043.0009.51</td>
</tr>
<tr>
<td>3-channel, bidirectional, 50 Ω, active</td>
<td>ZVRE</td>
<td>300 kHz to 4 GHz</td>
<td>1043.0009.52</td>
</tr>
<tr>
<td>4-channel, bidirectional, 50 Ω, passive</td>
<td>ZVR</td>
<td>9 kHz to 4 GHz</td>
<td>1043.0009.61</td>
</tr>
<tr>
<td>4-channel, bidirectional, 50 Ω, active</td>
<td>ZVRE</td>
<td>300 kHz to 4 GHz</td>
<td>1043.0009.62</td>
</tr>
<tr>
<td>3-channel, bidirectional, 50 Ω, active</td>
<td>ZVCE</td>
<td>20 kHz to 8 GHz</td>
<td>1106.9020.50</td>
</tr>
<tr>
<td>4-channel, bidirectional, 50 Ω, active</td>
<td>ZVC</td>
<td>20 kHz to 8 GHz</td>
<td>1106.9020.60</td>
</tr>
</tbody>
</table>

| Alternative Test Sets * | | | |
| 75 Ω SWR Bridge for ZVRL (instead of 50 Ω) | ZVR-A71 | 9 kHz to 4 GHz | 1043.7690.18 |
| 75 Ω SWR Bridge Pairs for ZVRE and ZVR (instead of 50 Ω) | ZVR-A75 | 9 kHz to 4 GHz | 1043.7755.28 |
| 75 Ω SWR Bridge Pairs for ZVRE and ZVR (instead of 50 Ω) | 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 | ZVR-B4 | same as analyzer | 1044.1215.02 |
| Reference Channel Ports | ZVR-B6 | same as analyzer | 1044.1415.02 |
| Power Calibration | ZVR-B7 | same as analyzer | 1044.1544.02 |
| 3-Port Adapter | ZVR-B8 | 0 to 4 GHz | 1086.0000.02 |
| Virtual Embedding Networks | 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) | ZVR-B15 | - | 1044.0929.02 |
| Controller (English) | ZVR-B15 | - | 1044.0929.03 |
| 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 | 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 | ZVR-B25 | 10 Hz to 4 GHz (ZVR/E/L) | 1044.0460.02 |

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

* Note: Active test sets, in contrast to passive test sets, comprise internal bias ne tworks, eg to supply DUTs.