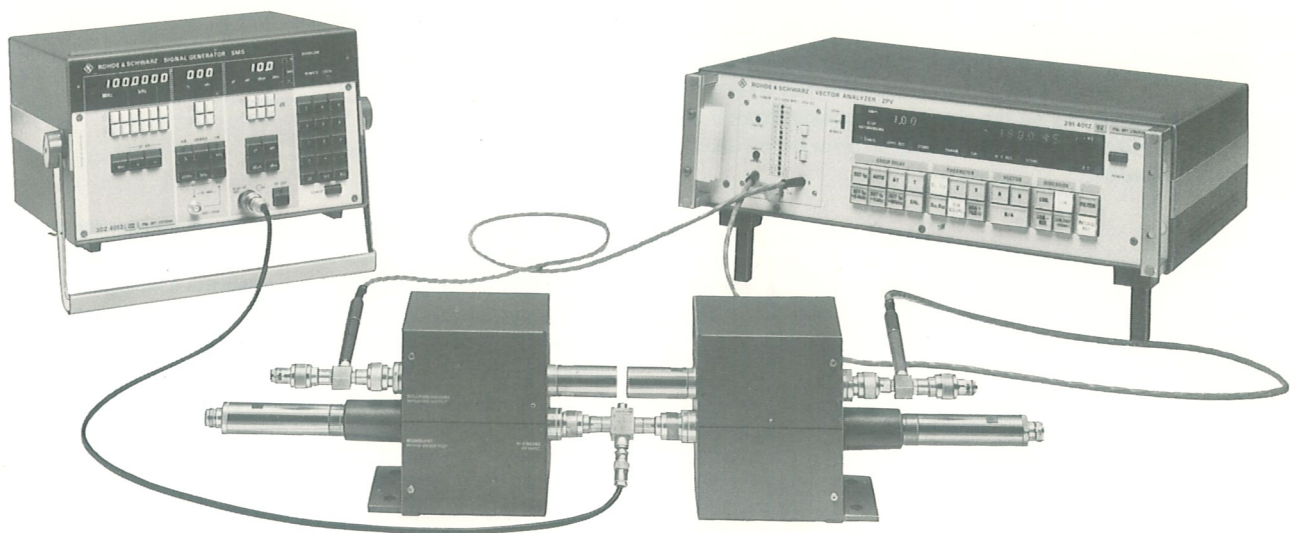# ROHDE & SCHWARZ

DIRECTIONAL COUPLER ZPV-Z3

for measuring s-parameters   1 to 1000 MHz

Reflection measurement (s_{11}, s_{22}) using two Directional Couplers ZPV-Z3, Signal Generator SMS and Vector Analyzer ZPV

Special features

- High precision due to directivity > 45 dB

- Universal application with high and low power levels at test item

- Robust construction

The measurement of current for magnitude and phase (vector measurement) remains a difficult, in some cases even prohibitive, problem in RF engineering. It has therefore become common practice to evaluate derived quantities, i. e. forward wave (a) and reflected wave (b) instead of current and voltage.

Forward wave $a = \dfrac{V}{2\sqrt{Z_L}} + \dfrac{I\sqrt{Z_L}}{2}$

Reflected wave $b = \dfrac{V}{2\sqrt{Z_L}} - \dfrac{I\sqrt{Z_L}}{2}$

Although these defining equations appear quite complicated, the wave quantities can be measured with good accuracy in a relatively simple way.

The instrument used for this purpose is the **directional coupler,** which by definition combines current I and voltage V according to these formulas and delivers at its outputs voltages proportional to a and b.

The directional coupler is mainly characterized by its **directivity,** which expresses in dB the degree to which a clear distinction is possible between forward wave and reflected wave. Directivity depends closely on the mechanical construction; it is > 45 dB for the ZPV-Z3 (Fig. 1), affording an error of < 0.6 % in wave measurements.

When the input and output waves (a_1, b_1; a_2, b_2) are measured instead of currents and voltages at the inputs of a two-port (see Fig. 2), the s-parameters are represented by the following ratios:

$\dfrac{b_1}{a_1} = s_{11}$ **Input reflection coefficient** at port 1 with port 2 match-terminated

$\dfrac{b_1}{a_2} = s_{12}$ **Backward transmission coefficient** from port 2 to port 1 with port 1 match-terminated

$\dfrac{b_2}{a_1} = s_{21}$ **Forward transmission coefficient** from port 1 to port 2 with port 2 match-terminated

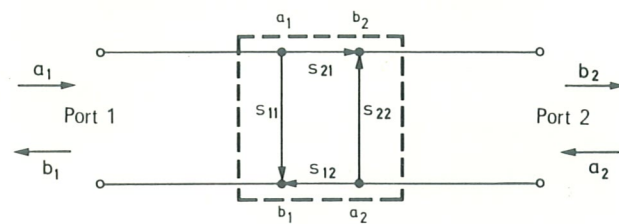$\dfrac{b_2}{a_2} = s_{22}$ **Output reflection coefficient** at port 2 with port 1 match-terminated

Fig. 2   Explanation of s-parameters

For measuring s-parameters one directional coupler for the input quantities a_1, b_1 and another for the output quantities a_2, b_2 are needed. The directional coupler delivers a voltage which is proportional to the wave quantities but is also a function of frequency. To eliminate the frequency dependence in the measured result, the second voltage required to form the ratio (s-parameter) is also derived by means of a directional coupler. This so-called reference directional coupler (DC I in Fig. 4) must show the same frequency dependence as the two test directional couplers. Three directional couplers of equal design are thus required for measuring s-parameters with a ratio meter, e.g. the Vector Analyzer ZPV.
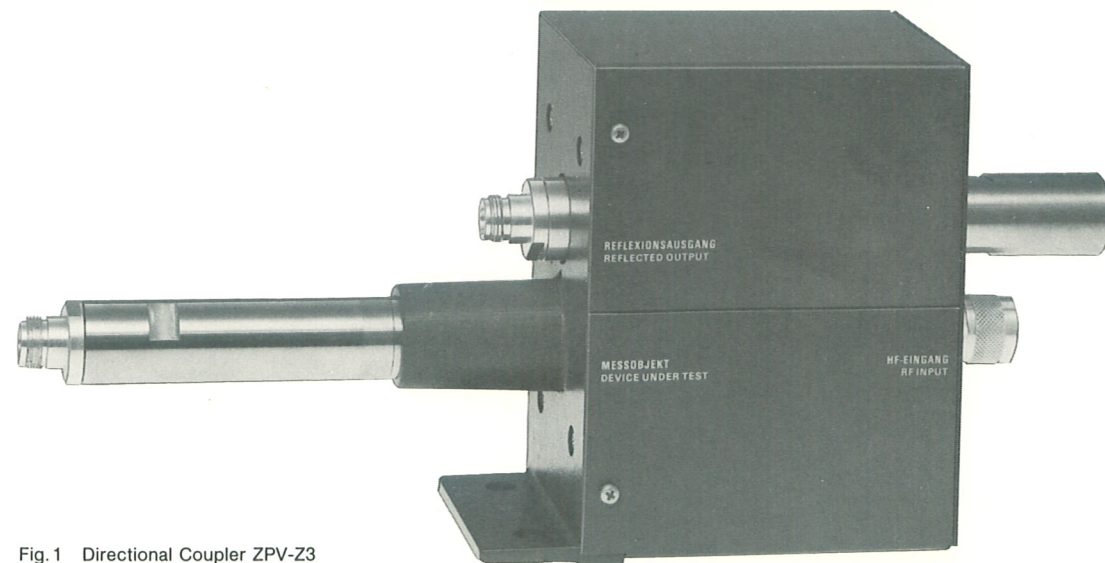
The Directional Couplers ZPV-Z3 constitute triple lines of length L, each consisting of two inner conductors and a common return conductor (case). The capacitances per unit length C_{11}, C_{12} and C_{22} between the conductors (see Fig. 3) are designed to provide optimum directional coupler characteristics with the given characteristic impedance. Coupling between the conductors is of particular importance in this respect.
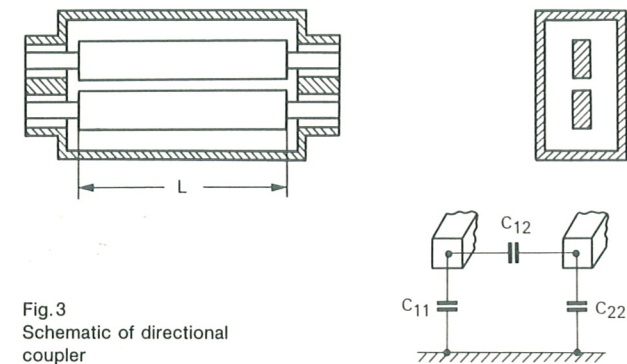

Fig. 3
Schematic of directional coupler

Coupling is $K_{11} = 0.707$ or 3 dB for the Directional Couplers ZPV-Z3. The obtainable measuring accuracy is determined by the directivity of the directional coupler which is > 45 dB for the ZPV-Z3.

The Directional Couplers are of symmetrical design. The test item can therefore be connected either to the primary line or to the auxiliary arm, the only difference being that in the first case a high level is applied to the test item (e.g. power amplifier), in the second case a low level (e.g. for antenna amplifiers [Fig. 4]). This opens up a wide range of applications in RF measurements. One port of the Directional Couplers ZPV-Z3 is permanently match-terminated with a screwed-on resistor.

The lower cutoff frequency, meaning here the frequency at which the directivity decreases appreciably, is about 0.1 MHz for the ZPV-Z3. The voltages delivered at this limit are, however, extremely low. In conjunction with the very sensitive Vector Analyzer ZPV directional-coupler measurements can be made and evaluated only down to 1 MHz.
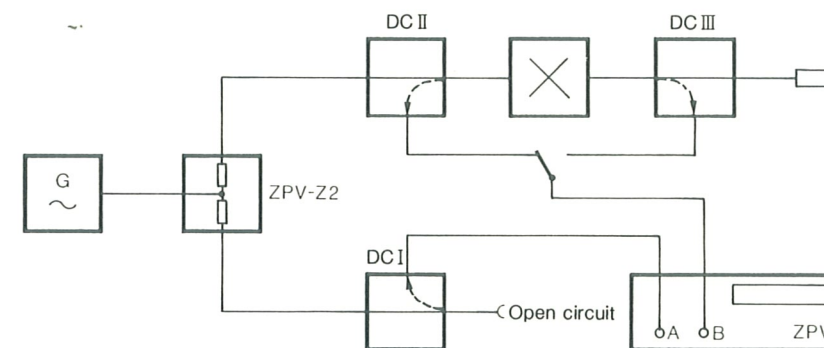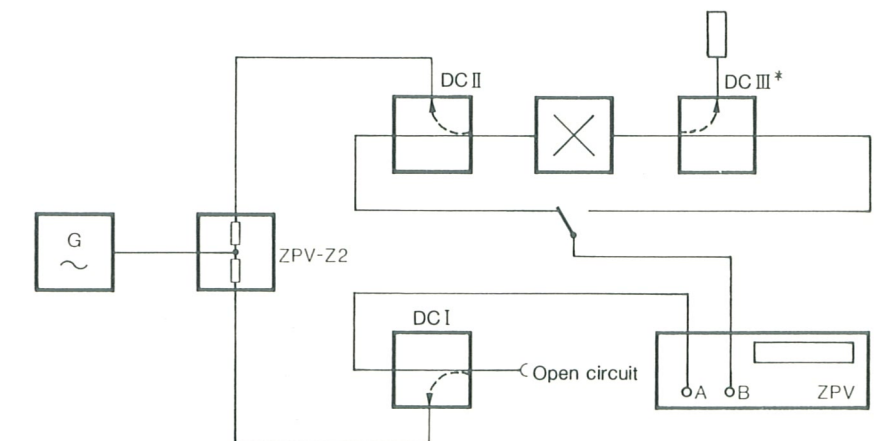

Fig. 4 left:
high level at test item;
below:
low level at test item

Fig. 1   Directional Coupler ZPV-Z3

*) This directional coupler is not essential in this test setup but it helps to realize optimum measurement accuracy.

SPECIFICATIONS

Frequency range	1 to 1000 MHz
Characteristic impedance	50 Ω
Directivity	> 45 dB
Reflection coefficient at test port	< 2 % for f < 500 MHz
	< 4 % for f ≦ 1000 MHz
Measurement error, f < 500 MHz	$0.006 \pm 0.02 \times r^2$
f ≦ 1000 MHz	$0.006 \pm 0.04 \times r^2$
	(r = measured magnitude of reflection coefficient)
Coupling K_{11}	0.707
Coupling length	66 mm
Max. permissible forward power	0.5 W
Connectors: to test item	N female
to generator	N male
Dimensions	360 mm × 150 mm × 100 mm
Weight	2.8 kg

Transmission loss: $K_{11} = 0.707$

	S_{21} [dB]	S_{41} [dB]
1 MHz	57.2	0
3 MHz	47.6	0
10 MHz	37.2	0
30 MHz	27.6	0
100 MHz	17.3	0.08
300 MHz	8.5	0.65
1000 MHz	3.1	2.9

Order designation	▶ Directional Coupler ZPV-Z3
	292.3110.50

Recommended extras

Vector Analyzer ZPV (basic unit)	291.4012.92
Tuner for basic unit ZPV-E2 (0.1 to 1000 MHz)	292.0010.02
Tuner for basic unit ZPV-E3 (0.3 to 2000 MHz)	301.7018.02
Insertion Adapter ZPV-Z1	292.2713.50
Feed Unit ZPV-Z2	292.2913.50
Vector Voltmeter ZPU (0.1 to 1000 MHz)	237.0012.12
Precision Termination RNA (50 Ω, N male connector)	272.4510.50
Termination RNB (50 Ω, N male connector)	272.4910.50
Shortcircuit connector (50 Ω, N male)	017.8080.00
Signal Generator SMS (0.4 to 520/1040 MHz)	302.4012.02