ROHDE & SCHWARZ
MÜNCHEN

TUNER 0.1 - 1000 MHz
ZPV - E2

292.0010.02

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Supplement

to Manual 292.1946 ZV

ZPV-E2 292.0010.02

Complement

Data sheet 292 401 E-1

Under section Magnitude of ratio on page 14 of the Data sheet you should read:

Indication error at fixed frequency with calibration button (linearity) .... ±1.5 % (at f >500 MHz only by U_e <0.3 V)

2. Preparation for Use and Operating Instructions

2.1 Legend for Fig. 2-2

No.	Engraving	Function
1	UNSYNC.	Indication of synchronization; when the lamp lights up, the Tuner is not synchronized.
2		Indication of the selected frequency range; effective only if the autoranging facility on the basic unit is disconnected.
3	↑	Pushbutton for increasing the frequency range step by step (indication on 2) if the autoranging facility is disabled.
4	↓	Pushbutton for decreasing the frequency range step by step (indication on 2) if the autoranging facility is disabled.
5	B	RF input cable for channel B, with probe.
6	↘LOCK.	Knob for locking and unlocking the Tuner inserted in the basic ZPV unit.
7	A	RF input cable for channel A, with probe.
8	SWEEP ON/OFF	Pushbutton for enabling and disabling the sweep mode in which the basic unit functions in purely analog operation without microprocessor; operative only in modes B and B/A with the autoranging facility of the basic unit disabled.
9		Guiding pin for plug-in Tuner.
10		Connector strip ST42 establishing the connection upon insertion of the plug-in into the basic unit.

2.2 Preparation for Use

2.2.1 Adapting the Probes

Depending on the measurement task, the probes can be fitted with the accessories supplied, such as BNC adapters, earth terminals, insulators or 100:1 dividers. For measurements on coaxial systems, the probes can be plugged directly into the Insertion Adapter ZPV - Z1. Since the probe tips are very sensitive to mechanical stress, it is best to provide a protection (e.g. the BNC adapters) even if they are not in use.

Prior to inserting the Tuner, disconnect the ZPV from the power supply. After turning the locking knob 6 to the lefthand stop, the Tuner can be plugged into the basic unit. Next turn knob 6 to the righthand stop and switch the ZPV on. The Tuner is immediately ready for operation. After disabling the autoranging facility on the basic unit, the Tuner can be operated manually and thus checked.

2.3 Operating Instructions

2.3.1 Operation with Autoranging Facility

When using the autoranging facility, the correct frequency subrange is selected on the basic unit so that no controls have to be set on the Tuner. Sweeping is not possible in this mode.

2.3.2 Manual Operation without Autoranging Facility

If the autoranging facility of the basic unit is disabled, the Tuner can be manually operated. The frequency range indication 2 is operative. Buttons 3 and 4 permit the correct range to be selected in accordance with the RF signal applied to 7. If the correct frequency subrange is set and the RF level is $> 150\ \mu V$ at the probe tip of 7, the Tuner is synchronized and delivers, via 10, the IF signal to the basic unit. At the same time lamp 1 goes out. The RF input 5 associated with channel B is ready for receiving an RF signal and, with such a signal applied, delivers an IF signal to the basic unit.

2.3.3 Sweeping

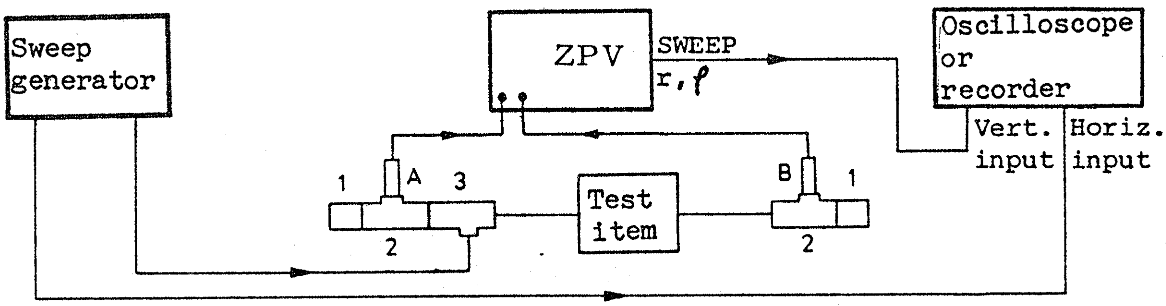
The sweep mode can be switched on and off with 8 if the basic unit is set to mode A or B/A and the autoranging facility is disabled. During sweep operation, purely analog signal processing takes place in the basic unit. The microprocessor monitors only the dynamic range in ratio measurements B/A.

2.4 Measurement Examples

2.4.1 Vector Measurements

2.4.1.1 Filter Measurements

Test setup



1 50-Ω termination
2 Insertion Adapter ZPV - Z1
3 Feed Unit ZPV - Z2

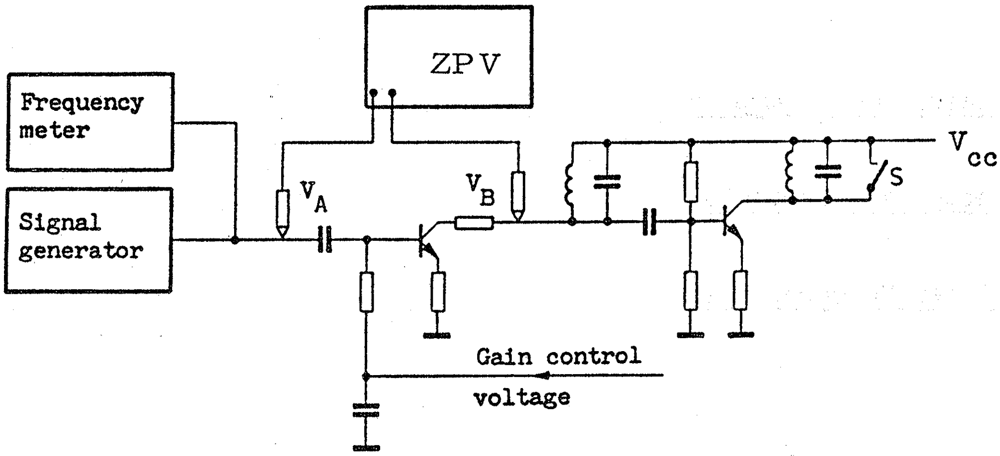
The characteristics of narrowband crystals and filters can be determined with the aid of a sweep generator assembly. For this purpose, the sweep mode is set using 8. Frequency and amplitude autoranging are inhibited on the basic unit, therefore it is necessary to first set the correct ranges. The sweep rate should be max. 30 MHz/s and the sweep width should not exceed 1 MHz so that the synchronization is maintained.

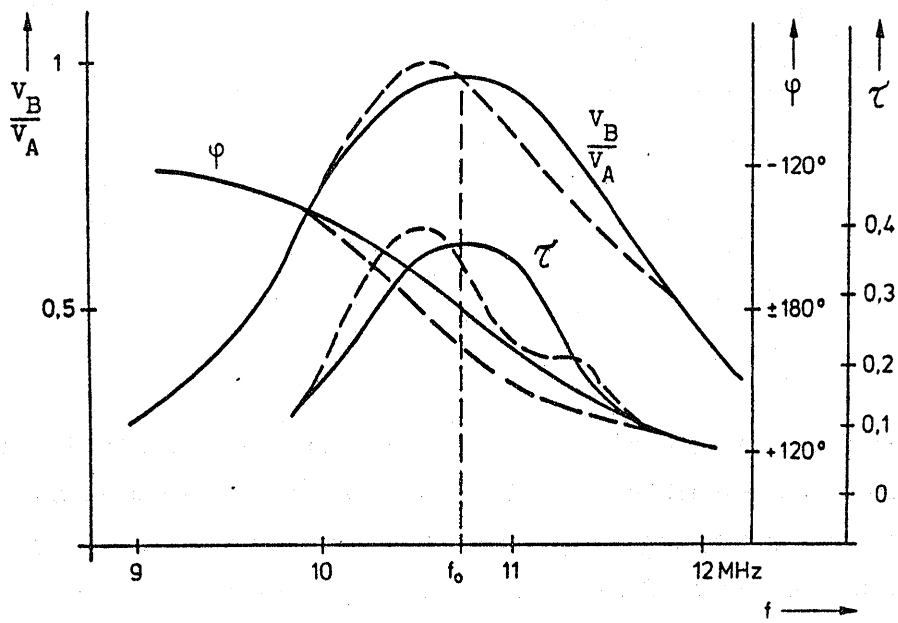
This test assembly permits the passband characteristic and the phase response of a test item to be displayed on an oscilloscope or plotted with a recorder.

2.4.1.2 Measurements on Amplifiers

The voltage gain is here referred to as gain for simplicity.

Test setup





Measurement of gain, phase shift and group delay

Gain, phase shift and group delay are of interest in the development of amplifier circuits. As an example, the gain, phase and group delay of the first stage of a two-stage amplifier are plotted as a function of frequency in the above diagram. The solid-line curves apply to the closed position of switch S, the gain of the second stage being $\leqq 1$ (emitter follower). With the switch open, gain > 1, the dashed curves are obtained. It can be seen how a variation of the input impedance of the second stage affects the gain of the first stage. This reaction is caused by the Miller integration effect of the base-collector capacitance and by the increased gain of the second stage.

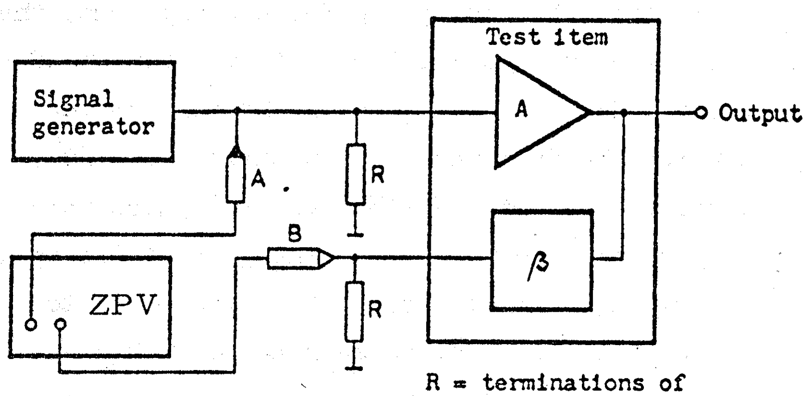
Group delay can be determined from phase variation. The group delay τ is defined as the phase difference $\Delta\varphi$ in a small frequency range Δf

$$\tau = \frac{\Delta\varphi}{360° \cdot \Delta f}$$

The Group-delay Measurement Option ZPV - B3 performs this conversion, the result being indicated on the basic unit (see 2.4.3).

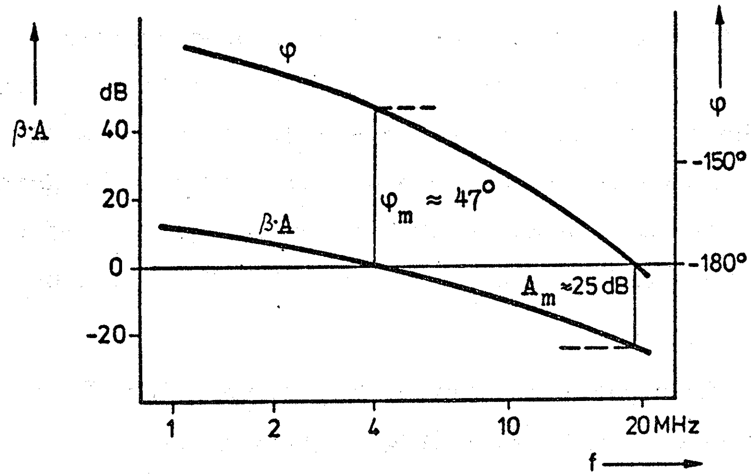
2.4.1.3 Measurement on Open Control Loops

Test setup



R = terminations of closed loop

Result



Measurement of gain and phase of an open control loop versus frequency

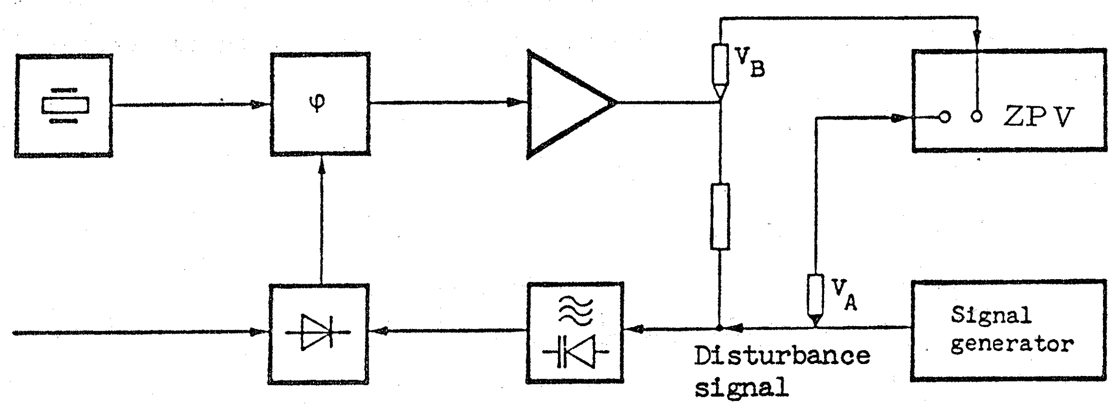
An inverting amplifier with a gain A and feedback factor β has the gain

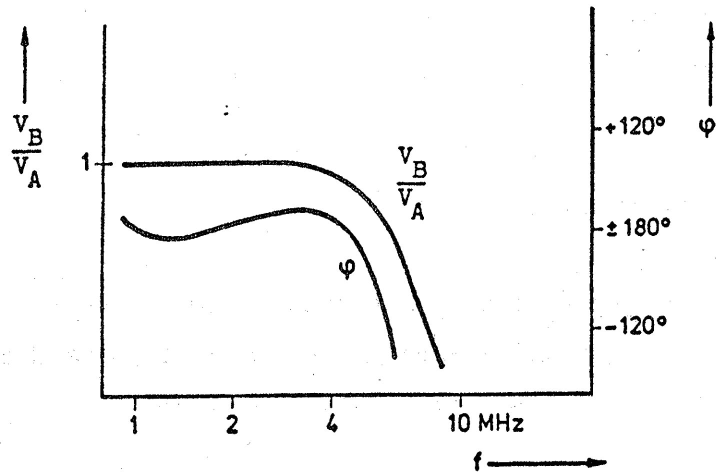
$$A' = \frac{A}{1 - \beta \cdot A}$$

when the feedback loop is closed. $\beta \cdot A$ is the gain of the open loop. If the feedback loop produces a phase rotation of -180°, $\beta \cdot A > 1$ means positive feedback and the amplifier oscillates. When designing feedback systems, the gain margin and phase margin of the open loop are the decisive criteria for the stability of the whole circuit. Gain margin A_m means the gain of the open loop at the frequency at which the feedback phase rotation is -180°; phase margin φ_m is the phase difference between -180° and the phase rotation of the feedback circuit at the frequency at which the gain of the open loop is 0 dB. Typical values providing satisfactory stability are -40 to -10 dB for the gain margin and about 30° for the phase margin. Both quantities can readily be determined by means of the test setup shown above. The results of such a measurement are given in the diagram. The gain and phase as functions of frequency show that the amplifier is stable.

2.4.1.4 Measurement on Closed Control Loops

Control loops with high gain are preferably measured as closed loops. A disturbance signal is fed into the loop and the transmission characteristic measured. An example is shown by the following diagram:



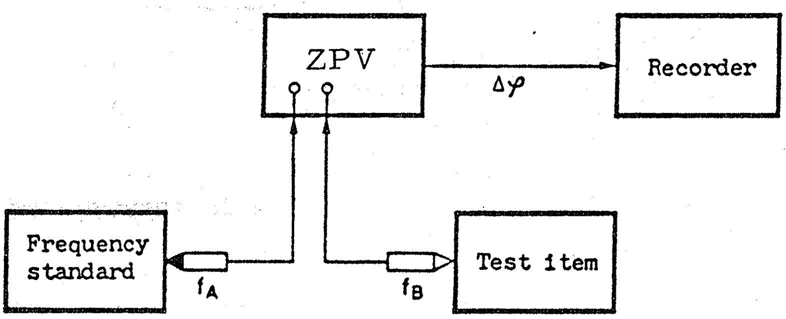


Measurement of the transmission characteristic of a feedback amplifier with closed control loop

2.4.1.5 Frequency Comparison

Many methods employed for the frequency adjustment of precise oscillators or for the measurement of frequency stability yield a result of adequate accuracy only after a relatively long measurement time. Using the Vector Analyzer this time can be cut down considerably. For example, the ZPV permits two frequencies of 1 MHz to be compared within one minute with an accuracy of 3×10^{-10}.

Test setup



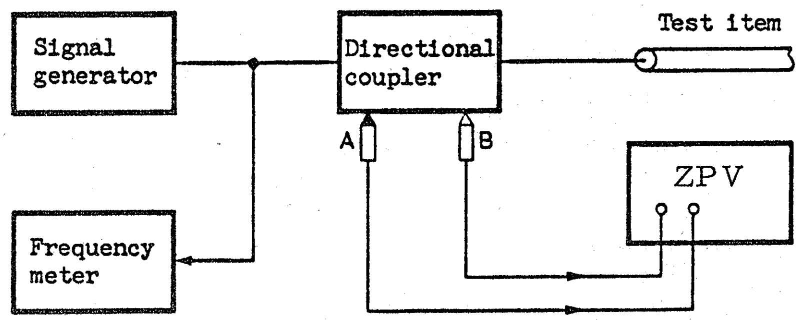
Comparison of two very accurate frequencies

Provided that the two input frequencies f_A and f_B are almost equal, their phase difference varies very slowly. The difference frequency Δf is obtained from the recorded phase difference $\Delta \varphi$ and the measurement time Δt:

$$\Delta f = \frac{\Delta \varphi}{360^\circ \times \Delta t}$$

2.4.1.6 Measuring the Electrical Length of Cables

Test setup



Measuring the electrical length of a cable

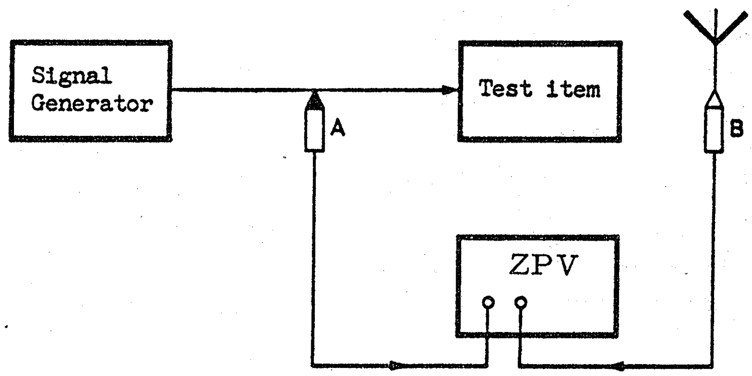
Thanks to its high phase resolution the ZPV can be used for the accurate measurement of the electrical length of cables. The forward and the reflected voltage are derived via a directional coupler and the ZPV measures the phase difference. If the electrical length of the cable is an integral multiple of $\lambda/2$, then the ZPV indicates the phase difference 0°. The test setup is therefore suitable to determine the electrical length of cables differing from multiples of $\lambda/2$. The measuring error decreases proportionally with increasing test frequency.

First set the phase meter to 0° while no cable is connected, i.e. the directional coupler output is open. Then connect the cable and read the phase difference on the ZPV. If, for example, a test frequency of 41.666 MHz is selected, a phase difference of 1° corresponds to 10 mm electrical length of the cable. The number of $\lambda/2$ waves must of course be counted to determine the overall cable length.

To adjust two cables for equal electrical length, the phase difference at the output of the cables can be measured, the two cable inputs being connected in parallel to the signal generator. The indicated phase difference is proportional to the difference in electrical length of the cables.

2.4.1.7 Antenna Measurements

Test setup



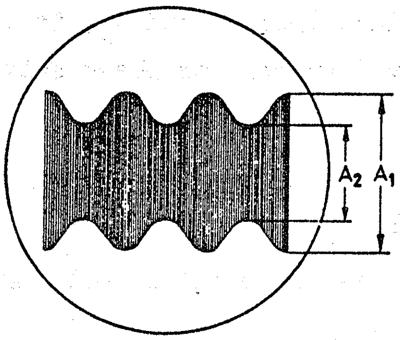
Measuring the radiation pattern of an antenna

Thanks to its uniformly high selectivity in the whole frequency range of 1 to 1000 MHz the Vector Analyzer can be used as a test receiver for the measurement of antenna radiation patterns. The ZPV is synchronized to the test frequency via probe A, while probe B is connected to the antenna. The bandwidth of channel B is 30 Hz in the range < 100 µV and 2 kHz in the other ranges. Other electrical or magnetic fields can be measured in the same way as radiation patterns.

Because of multiple reception due to mixing with harmonics ($f_n = nf_{vco} \pm 20$ kHz), the test system has to be protected from unwanted fields or the useful level has to be selected sufficiently higher than the occurring unwanted levels.

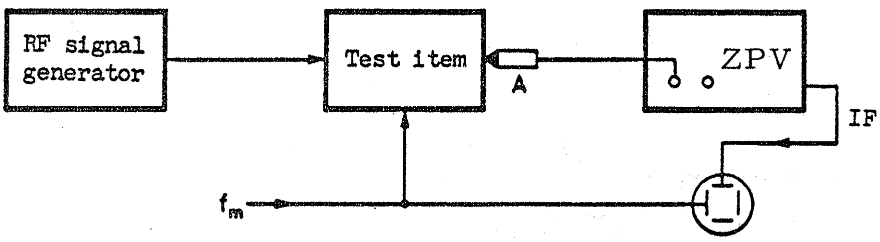
2.4.1.8 Modulation-depth Measurement

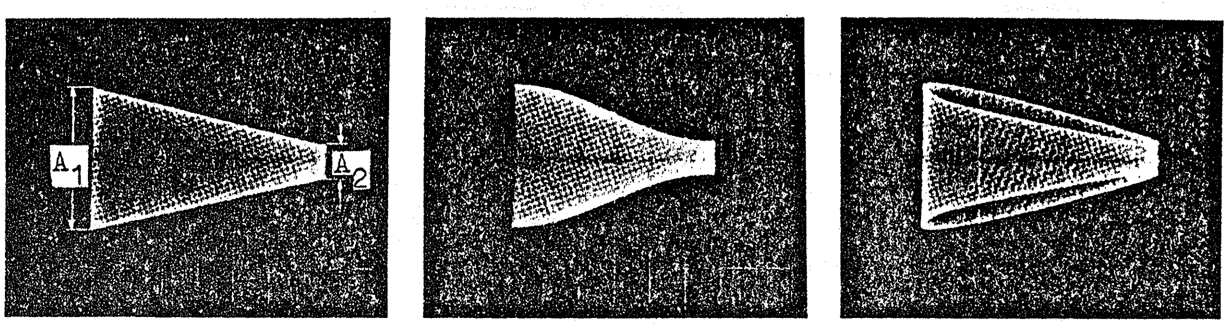
The Vector Analyzer ZPV converts the received RF signal faithfully to IF. Connecting an AF oscilloscope to the IF output one obtains a scanning oscilloscope for RF signals in the range 1 to 1000 MHz. Modulation depth m is calculated from the lengths A_1 and A_2 measured on the screen:



$$m = \frac{A_1 - A_2}{A_1 + A_2} \; 100\%$$

If the modulation signal is available, the nonlinearity and phase shift of the modulator can also be measured. The modulation frequency must in this case be low enough to make sure that the scanning bandwidth and the bandwidth of the IF circuits do not cause an attenuation or phase shift of the modulated signal. The following test setup is used:





Measurement of modulation trapezium

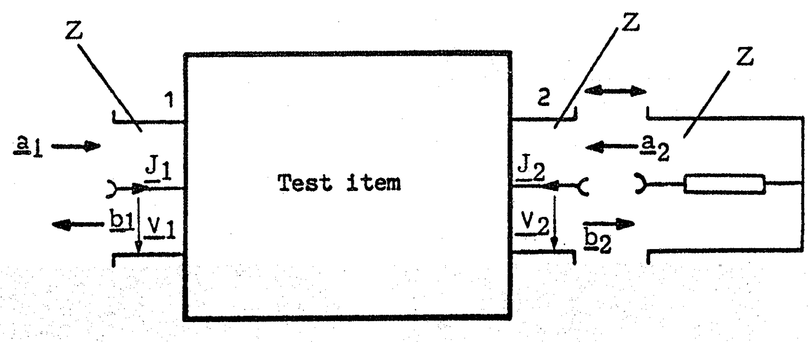
The lefthand oscillogram shows the modulation trapezium of a perfectly modulated signal; the modulation depth can be determined from A_1 and A_2, it is 60%. The other two oscillograms show nonlinearity (centre) and phase shift (right).

2.4.2 Measurement on Four-terminal Networks

The following measurements on four-terminal networks are possible only when using the s-parameter Measurement Option ZPV - B2.

2.4.2.1 General

Accurate measurement of the h, y and z parameters is difficult in the UHF range since a current measurement is hard to perform in this range. The s-parameters can be determined without voltage and current measurements, the wave quantities being obtained by a measurement using directional couplers. Assuming a forward wave at each of the two ports of a four-terminal network, the wave is reflected, absorbed or partly transmitted by the network (see figure).



Test item with complex wave quantities $\underline{a}_1$, $\underline{a}_2$, $\underline{b}_1$, $\underline{b}_2$; match-termination with characteristic impedance Z shown on right

The effect at the ports is described by the reflected waves $\underline{b}$ as functions of the forward waves $\underline{a}$.

$$\underline{b}_1 = \underline{s}_{11}\underline{a}_1 + \underline{s}_{12}\underline{a}_2 \quad (1)$$

$$\underline{b}_2 = \underline{s}_{21}\underline{a}_1 + \underline{s}_{22}\underline{a}_2 \quad (2)$$

The coefficients s_{11}, s_{12}, s_{21} and s_{22} are called the s parameters. The two equations, whose terms are generally complex, fully describe the four-terminal network. If the test item is terminated without reflection at port 2, as shown in the above diagram, the $a_2 = 0$ and equation (1) yields $s_{11} = \frac{b_1}{a_1}$. Thus s_{11} is the input reflection factor at port 1 if port 2 is match-terminated. The equations for the other s-parameters are obtained in the same way:

Meaning of s-parameters

$$s_{11} = \frac{b_1}{a_1} \bigg|_{a_2 = 0}$$

$$s_{22} = \frac{b_2}{a_2} \bigg|_{a_1 = 0}$$

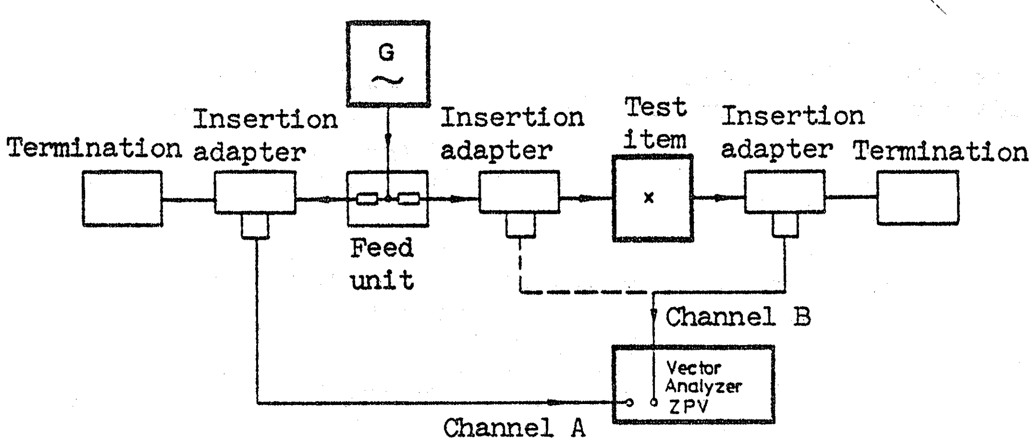
The two quantities are input reflection factors which convey information on input impedance and matching. During measurement the corresponding output must be match-terminated, as indicated by the conditions $a_1 = 0$ and $a_2 = 0$.

$$s_{12} = \frac{b_1}{a_2} \bigg|_{a_1 = 0}$$

$$s_{21} = \frac{b_2}{a_1} \bigg|_{a_2 = 0}$$

S_{21} is the forward transmission factor, s_{12} the backward transmission factor. During measurement the corresponding output must be match-terminated.

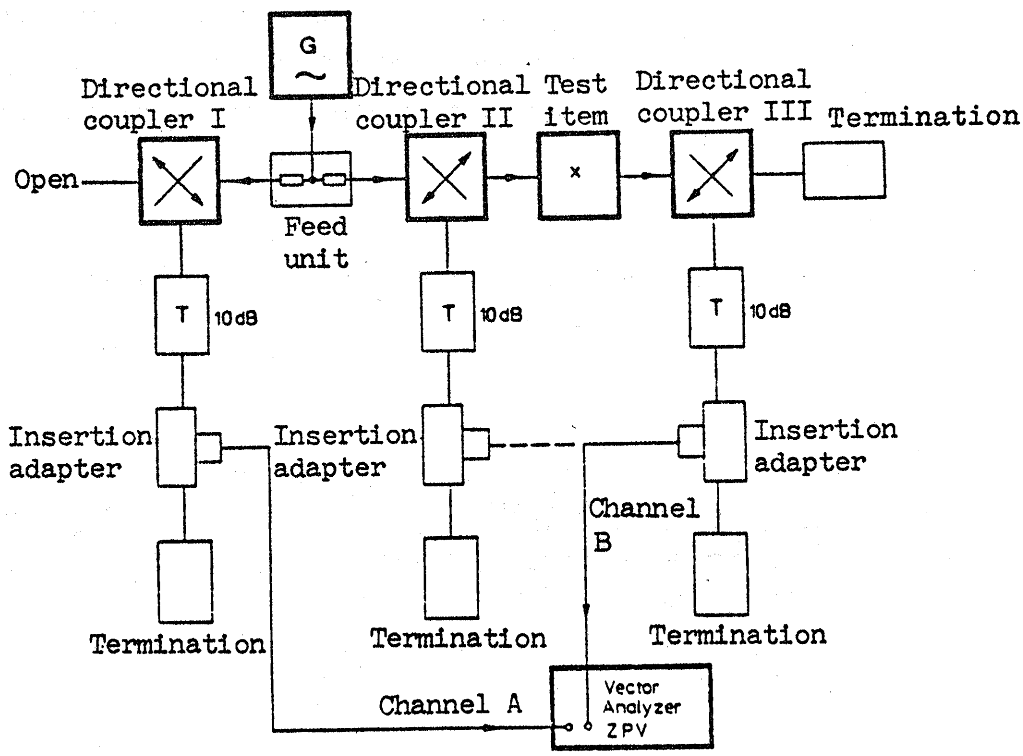
2.4.2.2 Parameter Measurement without Directional Couplers



Test setup for measuring s-parameters without directional couplers

The above method for measuring s-parameters is based on a kind of bridge circuit. It can be used with confidence between 100 kHz and about 100 MHz, but it deteriorates with higher frequencies due to the inherent reflection of the insertion units. Special computing routines in the basic unit take into account the complex relation between measured bridge voltage and s-parameters as well as between input impedance and admittance so that the overall characteristics are directly displayed. When adjusting the test setup for measuring s_{11} and s_{22} the test item is replaced by a virtually reflection-free termination and, in the mode s_{11}, s_{22}, button PARAM. CAL. on the basic unit is pressed. When adjusting the test setup for measuring s_{21} and s_{12}, the units are interconnected without the test item and button PARAM. CAL. on the basic unit is pressed in the mode s_{21}, s_{12}.

2.4.2.3 Parameter Measurement with High Voltage at Test Item using Directional Couplers



Test setup for measuring s-parameters with high voltage at test item

Since the s-parameters, by definition, represent quotients of two waves, the ZPV is used in the ratio meter mode. The measurement range of the transmission factors s_{12} and s_{21} and of the reflection factors s_{11} and s_{22} depends on the quality of the directional couplers. Reflection factors > 1

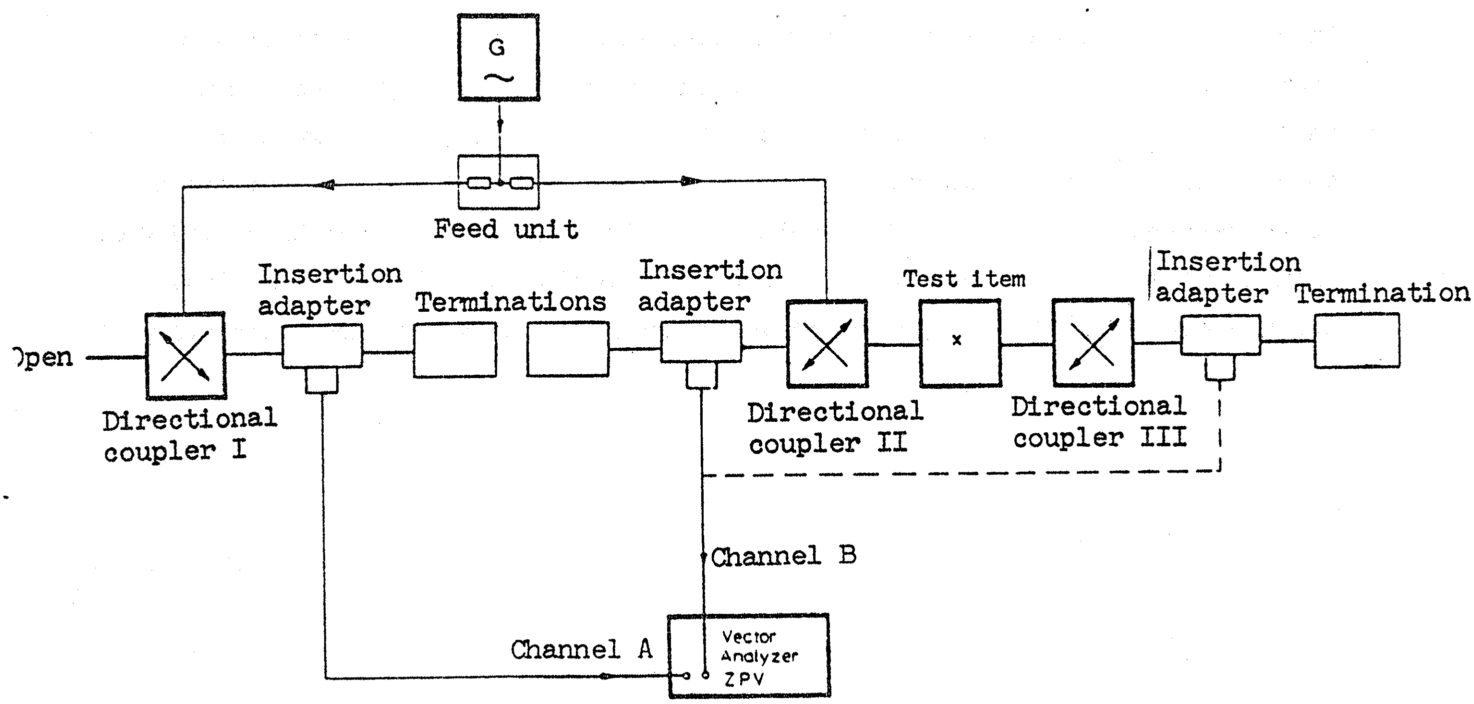
are obtained with test items having a negative incremental resistance, e.g. amplifiers or oscillators using tunnel diodes.

The test setup is shown schematically above. Directional coupler I compensates for the frequency responses of directional couplers II and III. Since the test outputs of the directional couplers must be match-terminated, the two insertion adapters are connected via 10-dB attenuator pads. The ZPV indicates the ratio of the measured wave quantities with respect to magnitude and phase.

When adjusting the test setup for measuring s_{11} and s_{22} the test item is replaced by a short circuit and button PARAM. CAL. on the basic unit is pressed (the s_{11}, s_{22} mode should be selected).

When adjusting the test setup for measuring s_{21} and s_{12}, the units are interconnected without the test item and button PARAM. CAL. on the basic unit is pressed, the s_{21}, s_{12} mode being selected.

2.4.2.4 Parameter Measurement with Low Voltage at Test Item using Directional Couplers



Test setup for measuring s-parameters with low voltage at test item

In the test setup shown in section 2.4.2.3, about half the generator voltage, depending on the input reflection factor s_{11}, is applied to the test item. If the test item tolerates only a low voltage, for instance during measurements on semiconductors and antenna amplifiers, the test setup shown above is used. It differs from the former only in that the feed-in connections are interchanged with the test connections on the directional couplers I and II. With $s_{11} < 0.3$, the voltage across the test item is about the same as that measured in channel B.

Adjustment and performance checking are made in accordance with section 2.4.2.3.

2.4.3 Group Delay Measurements

The constancy of the group delay through a transmission network is a measure of its waveform fidelity. Since the group delay is, by definition, $d\varphi/d\omega$, it can be measured with the aid of the relation $\varphi_2 - \varphi_1/\omega_2 - \omega_1$ if the differences are chosen small enough. The Group Delay Measurement Option ZPV - B3 permits the group delay or the group delay variation - referred to a specified basic group delay - to be indicated directly on the basic unit.

In addition to measurements using a high-impedance probe, measurements on coaxial systems are possible. These measurements can be performed either in the manual mode by pressing two buttons and adjusting the generator accordingly or in the automatic mode which requires a generator permitting DC-voltage-controlled frequency modulation. With automatic operation calibration is made with the aid of the calibrating cable supplied with the Group Delay Measurement Option and by pressing the CAL. button on the basic unit.