ROHDE & SCHWARZ

Manual

POLYSKOP SWOB 5

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1. Characteristics

1.1 Uses

The Polyskop SWOB 5 is a compact two-channel sweep tester. It is as well suited for applications in the laboratory, in test and production departments as for all users who find most of all simple operation an important requirement besides large-screen display for single and high-quantity measurements. Recording may be performed by use uf a recorder or photographic attachment. For the adjustment of the sweep width, there are four possibilities. The total frequency range from 0.1 to 1000 MHz can be swept in a single sweep or the sweep width is continuously adjustable from 5 to 1000 MHz for broad-band measurements. For narrow-band operation, the sweep width can be continuously adjusted from a maximum sweep width of approximately 50 MHz to a minimum sweep width of approximately 300 kHz. It is also possible to cut off sweep operation altogether so that a signal generator is obtained that can be continuously tuned through the range from 0.1 to 1000 MHz (CW operation).

Pulse or line markers provide orientation along the frequency axis, the marker amplitude or intensity being continuously adjustable. A manually adjustable bright-up marker, at which the sweep is stopped for a short time, allows triggering of a frequency counter connected to the RF monitoring output. External markers can be fed in. At the lower screen edge, the individual sweep range selected is indicated by a bright-up bar on a scale. Sweep time can be continuously adjusted from 20 ms to 2 s. The measurement curves are displayed on a long-persistence screen with a diagonal diameter of 28 cm.

The receiver section consists of a measuring head and a deflection amplifier. Termination and insertion units as well as probes are available as measuring heads.

The deflection amplifiers are designed as plug-ins, enabling the user to equip the sweep tester with one or two channels and with linear and/or logarithmic amplifiers to meet all possible requirements.

All three deflection amplifiers are in the position to detect and compensate for spurious signals - such as, for example, appearing with tuners due to the always existing oscillator voltage and which might limit the usable dynamic range - by a measurement performed during the return sweep while the RF is blanked. This is always the case with the logarithmic amplifier plug-ins, while on the linear amplifier this mode can be selected using the input selector switch.

If used together with an RF termination or insertion unit, the two logarithmic amplifiers have a noise limit of 170 µV (typical). This results in a dynamic range of 70 dB for a sweep-generator output voltage of 0.5 V. If the sweep generator, however, is operated at an output voltage of 1 V (selected at the rear panel - see specifications), the dynamic range is 76 dB.

Using the active demodulator 333.8510 ..., the sensitivity can be reduced to approx. 20 µV. Due to the maximum allowable driving level of 50 mV for the active demodulator, a dynamic range of approx. 70 dB is achieved again.

The displayed range on the screen of the logarithmic amplifier plug-in E1 is switchable to 80, 60, 40, 20 and 10 dB and can be shifted over a range of > 70 dB by adjusting a position potentiometer; any part of the displayed curve can thus be spread. A calibrated horizontal line permits accurate level measurement. This line can be shifted by means of a 10-turn potentiometer and its level position can be read in 0.1-dB steps from a dialled knob. The zero position of the level line can be shifted with a control knob which has a detent position equivalent to a reference level of 1 V. Whenever this knob is not in its calibrated detent position, this condition is indicated by a lamp.

The logarithmic amplifier plug-in E3 permits all the SWOB5 RF measuring heads to be connected or the AF signals to be directly applied from the device under test, such as rectifier circuits or IF amplifiers with built-in demodulator. Switchover is possible to handle test voltages of positive or negative polarity. The dynamic range is 76 dB at 1 V input voltage and noise limit of 170 µV when measuring via the AF input. The displayed range on the screen is switchable to 100, 80, 50, 20 and 10 dB and - like with plug-in E1 - can be shifted over a range of >70 dB by means of a position potentiometer. A 10-turn potentiometer is provided for adjustment of the calibrated horizontal line. The level corresponding to the line position is read out on a 3 1/2-digit display. Absolute test result indication in mV or dBV and relative test result indication in dB are possible. During absolute measurements in mV the range is switched over automatically. If a relative measurement is to be made, the reference level (0 dB) is set automatically at the push of a button corresponding to the level of the actual position of the horizontal line. If the amplifier is used with the Active Demodulator SWOB5-Z4 the 20-dB gain of the latter is automatically taken into account in the level indication. Spurious signals at the input, such as occur with tuners due to the inevitable oscillator voltage are compensated for up to a level of about 40 mV when using the Demodulator SWOB5-Z1 or the RF Insertion Unit SWOB5-Z3 and up to about 4 mV when using the Active Demodulator SWOB5-Z4. If these values are exceeded a red LED lights up.

To allow observation of very small signals on the screen, a filter is provided which can be switched on by means of the pull switch which is part of the sweep time switch on the basic unit. A LED lights up when the filter is switched on.

The linear amplifier plug-in E2 has an AF and a measuring-head input. The AF input can be switched for positive and negative input voltages. Deflection factor for the AF input is approx. 0.2 V/cm; via the measuring head it is approx. 1 mV/cm, referred to the RF input voltage. The plug-in is equipped with a compensation circuit for spurious RF signals arising from the device under test; this circuit can be switched to each input as required.

AUTO (forward and return sweep with RF blanked during return), MAN (manual sweep control) and SINGLE (single sweep on manual trigger, recorder operation) can be switch-selected for sweep control.

The rear panel contains the trigger input/output, a connector for remote control, the X, YI and YII outputs, the recorder output and an RF monitoring output. An external X-axis deflection voltage can be fed in through a test socket. The supply voltages (+24 V and +5 or -20 V, optional), a TTL signal with low level during retrace and with high level during the visible forward sweep, and the sweep sawtooth signal are also available at this socket.

The unit can be expanded by fitting the "slow sweep", "external control", "IF markers" and "display-store interface" options into the space left free in the mainframe for this purpose. Interconnection is made by non-reversible plug-and-socket connections in the mainframe.

With the "slow sweep" option, the sweep time is increased to approx. 30 s by connecting two contacts at the recorder output (this is automatically achieved when using the recommended recorder cable). The "external control" option allows generation of an output EMF outside of the basic unit, with levels adjustable from 0.1 to 0.5 V using an insertion head. The RF generator acts as if its source were within the insertion head (at the centre, in parallel with the connection point of the detector diode). The "IF markers" option lends itself to checking the IF of equipment using frequency conversion by means of two markers of crystal accuracy.

The "display-store interface" option permits connection of the Digital Display Store BDS. This option can only be fitted into instruments with serial numbers from 871551 onwards.

1.2 Description

The compact sweep tester SWOB 5 consists of 3 sections:

- The sweep generator with wideband amplifier, ALC, attenuator, marker section and sweep control.
- The deflection amplifiers (linear and/or logarithmic plug-ins) with the AF motherboard.
- The display section with X-axis amplifier, Y-axis generator, comparator, intensity control amplifier, level lines and high-voltage generator.

1.2.1 Sweep Generator

A YIG oscillator has been chosen as variable oscillator which covers the range from 2 to 3 GHz. Its output is converted down to 0.1 MHz to 1 GHz by mixing with a fixed frequency of 2 GHz which is obtained by multiplying a 100-MHz crystal frequency. The mixer is followed by a wideband amplifier which increases the level to 0.5 to 1 V_{rms}. A low-pass filter rejects harmonics above 1.05 GHz. A small portion of the RF power is tapped off for ALC, markers and the second RF output at the rear panel. The attenuator allows attenuation of the output signal by a total of 70 dB in 1-dB and 10-dB steps.

The RF tapped off for ALC is rectified by a diode and fed to an amplifier which regulates the output of the 2 GHz fixed frequency using 2 PIN diodes. The ALC provides for compensating the individual frequency responses of the YIG oscillator, the mixer, the wideband amplifier and the filter which results in a constant, frequency-independent output EMF.

Three frequency spectra are generated by three crystal-stabilized fixed frequencies (1, 10 and 100 MHz) and mixed with the RF tapped off as described above. The AF portion of the signal is filtered out using suitable low-pass filters and is then amplified, limited and rectified. The obtained pulses can be added to the AF signal - pulse marker height is adjustable at the front panel - or fed to the cathode of the CRT through an amplifier, whichever is preferred. A vertical line appears on the screen during on-time of the pulse; the intensity of the line markers is also adjustable. As two marker groups (100 and 10 MHz or 10 and 1 MHz) can be displayed, the pulse height or the intensity of the markers is variable for distinction.

An additional mixer is available for generating beat markers using an external generator.

The YIG oscillator is swept by the sweep control circuit. For this purpose, a sawtooth signal is generated whose DC position and amplitude can be varied to allow sweeping over the total frequency range or only portions thereof, as desired. By switch selection, it is possible to replace the sawtooth signal by a DC voltage which can be varied using a knob on the front panel. This allows manual sweeping over the preset range. A relaxation circuit has been provided which blanks the display and the RF after a complete sweep to enable single sweep display.

To display the variable marker, the sweep is stopped for approx. 12 ms. At the same time, a trigger pulse is supplied which may be used to trigger an external frequency counter. Thus the frequency during on-time of the marker can be measured using the second RF output on the rear panel.

During retrace, the sweep control circuit suppresses the RF. Additionally, this circuit generates the control and X-axis signals which are required for the deflection amplifiers and the display section.

1.2.2 Deflection Amplifiers

1.2.2.1 LOG. AMPLIFIER Plug-ins E1 and E3

The logarithmic amplifier of the LOG. AMPLIFIER plug-ins processes the rectified voltages obtained from RF signals below approx. 20 mV and above approx. 20 mV in two separate receiver sections which are parallelled at the input, to achieve optimal sensitivity and AF bandwidth. After logarithmic conversion, the signal voltages are summed to a display voltage at correct levels.

Signal path I consists of an input amplifier with inherent low noise and low drift, a clamp circuit for RF spurious signal compensation and a precise temperature-stabilized logarithmic amplifier.

Signal path II passes the AF signal through a clamp circuit (spurious signal compensation) to an operational amplifier which is connected in a feedback loop comprising a modulator and a reference detector to linearize the curve-shaped characteristic of the test detector. The output voltage of this amplifier drives a logarithmic amplifier. The outputs of the logarithmic amplifiers of both signal paths are combined in a voltage discriminator stage. If the RF voltage input to the test detector is less than approx. 20 mV, the discriminator output will supply the AF voltage of signal path I. At RF voltages above approx. 20 mV signal path II will be enabled.

The voltage discriminator is followed by a switchable voltage divider with which the range to be displayed on the screen (see specifications) can be selected.

In addition to that, the output signal from the voltage discriminator drives a subassembly on the AF motherboard, which derives a switching criterion from the fast decreasing signal voltage (e.g. appearing when sweeping the falling edge of steep bandpass filters), which is used to slow down the sweep speed automatically. This allows the user to operate at higher sweep speeds without incurring errors due to transients.

The position of the output signal and thus of the display on the screen is adjusted in the last stage. Position adjustment influences the calibrated level line correspondingly so that correct calibration is maintained.

1.2.2.2 LIN. AMPLIFIER Plug-in E2

The AF amplifier of the LIN. AMPLIFIER plug-in has five stages. The amplitude is adjusted by changing the feed-back of the third amplifier stage. This results in a good signal-to-noise ratio also with the level control backed off. The position of the output signal and thus of the displayed curve is adjusted in the last stage of the amplifier.

In the "RF spurious voltage suppression" mode, the second amplifier stage forms a clamp circuit together with an isolating capacitor and a switching FET.

1.2.2.3 AF Motherboard

The AF motherboard interconnects the amplifier plug-ins and the mainframe. It carries two multipoint connectors into which the plug-in boards are inserted.

Each display channel has a low-pass filter. Both filters can simultaneously be switched from WIDE to NARROW by a pull switch at the front panel. The buffer amplifiers following the filters are used to match the AF levels to the comparator inputs of the display section. The supply voltages of the plug-ins are once again stabilized and filtered on the motherboard to provide for good decoupling from the basic unit.

Each logarithmic plug-in has a specific output for driving a differentiating stage. This supplies a switching voltage to slow down the sweep speed during steep slopes of the device under test.

Comparators and CMOS logic are used to generate pulses from the sweep sawtooth signal and a rectangular signal supplied by the sweep control circuit. The pulses serve to gate the clamp circuits for automatic RF spurious signal suppression and for the stabilizing networks of the logarithmic amplifiers. At RF voltages above 20 mV, the test detectors of the logarithmic amplifiers are linearized by applying feed-back through reference detectors with associated modulators. As good carrier suppression is required for the modulators, choppers consisting of two MOS-FETs have been designed for this purpose, which are driven in such a way that both FETs conduct at each switching point. Suitably delayed control voltages are necessary for this; they are generated by an oscillator together with a decimal counter and associated logic on the motherboard. The frequency of this auxiliary signal is approx. 300 kHz.

The trimming potentiometers on the AF motherboard are accessible from the right-hand side of the unit.

1.2.3 Display Section

A CRT with magnetic deflection has been chosen for the display. A DC-coupled amplifier with push-pull output stage is used for X-axis deflection. The input contains a diode/resistor network which distorts the sawtooth signal delivered from the sweep control circuitry to an S-shape and which compensates for non-linearities of the X-axis deflection.

A raster method is used for displaying measured curves, level lines and the intensified bar for range indication. Y-axis deflection is not performed as a function of the curve to be displayed but with constant amplitude and frequency. Amplitude is selected to write on the screen over its full extent; frequency is approx. 50 kHz.

The CRT is dark-traced to make the raster invisible. To display a measured curve, the CRT beam is intensified exactly at points where the raster sinewave of the Y-axis deflection is voltage-coincident with the curve spot to be displayed. The level lines are generated in the same way. It is sufficient, however, to intensify only the spots where the level DC voltage coincides with the rising slope of the raster sinewave. Comparison with the raster sinewave is made in the comparator whose output pulses are amplified by the intensity control amplifier up to a maximum of 60 V and are fed to the control grid of the CRT. A front panel control allows the pulse height and thus the intensity to be varied. During retrace, the comparator is inhibited by a gate signal which provides for retrace blanking.

The intensified bar for range indication is also generated in the comparator and controlled by a separate signal from the sweep control board which is obtained from the tuning voltage.

A post-acceleration voltage of approx. 13 kV is required for good brightness and focusing. A free-running 40-kHz oscillator drives a small ferrite core transformer whose output voltage is increased to the required value by a multiplier cascade.

1.2.4 Mechanical Construction

Both deflection amplifiers are mounted in compartments for better shielding. These are closed by the AF motherboard at the rear end; the AF motherboard also carries the multi-way connector. The right-hand side of the compartment can be detached for repair purposes; at the top of the right-hand side compartment are several drill holes through which the alignments are accessible.

All other subassemblies except power supply, distribution board and control units are housed in three frames which may be swung out by 90°. Cover and bottom are attached by quick-release fasteners. Only the high-voltage section and the Y-axis deflection generator are screw-mounted in a conventional manner to provide for better shielding. All subassemblies are interconnected by pluggable ribbon cables and the distribution board.

RF signals are connected through separate coaxial cables.

The voltage distributor and both divider switches are screw-mounted as a combined mechanical unit for optimal electrical characteristics.

The "external control", "slow sweep", "IF markers" and "display-store interface" options can be retrofitted; attachments and non-reversible connections are provided and accessible after opening the unit.

The "display-store interface" can only be fitted into instruments with serial numbers from 871551 onwards.

1.3. Specifications

Frequency range	0.1 to 1000 MHz (in one band; only centre frequency and sweep width need be adjusted)
Sweep width, four switch positions:	
1000	total frequency range in one sweep
5 - 1000	continuously adjustable from 5 to 1000 MHz
0.3 - 50	continuously adjustable from 0.3 to 50 MHz
0	no sweeping (CW operation)
Spurious sweep width	depending on sweep width (test bandwidth 20 Hz to 30 kHz)
1000	≤ 30 kHz, typ. 20 kHz
5 - 1000	≤ 30 kHz, typ. 20 kHz
0.3 - 50	≤ 5 kHz, typ. 3 kHz
0	≤ 20 kHz, typ. 15 kHz
0, no bright-up bar indication of sweep range	≤ 5 kHz, typ. 3 kHz
Sweep linearity	1:1.01
Indication linearity	better than 1:1.1
Sweep adjustment	Δf and centre frequency (coarse-fine)
external	via remote-control input
Scale error of range indication	±4% of fs
Remote control	via 7-pole female connector on rear panel
Centre-frequency adjustment	3 to 8 V, approx.
Sweep-width adjustment (ext. potentiometer ≈ 5 kΩ)	0 Ω for f_{min}, R_{max} for f_{max}
Sweep time	0 to 5 V for 2 to 0.02 s
RF monitoring output	≈ 50 mV into 50 Ω, BNC female connector on rear panel
Output EMF, models	50 Ω / 75 Ω
(connector: N female)	1 V / 0.7 V (can be increased by 6 dB using rear-panel switch)
Frequency-response flatness of output voltage with match-termination	< ±0.5 dB (typ. ±0.25 dB) for 0.1 to 1000 MHz, < 0.15 dB for 10 MHz sweep
with 6-dB increase	+0.2 dB in addition (5 to 300 MHz, otherwise ≈ ±1 dB)

Output attenuator	0 to 70 dB in 1-dB steps
Total error:	
Coarse adjustment (10-dB steps)	$\leq \pm 0.5$ dB
Fine adjustment (1-dB steps)	$\leq \pm 0.2$ dB
Harmonic suppression (with output EMF = 1 V)	
0.1 to 1 MHz	≥ 30 dB
> 1 to 1000 MHz	≥ 36 dB (typ. 40 dB)
Suppression of non-harmonic spurious signals	≥ 40 dB
Frequency sweep	
AUTO	forward/return sweep with RF blanked during return sweep
MAN	manual sweep adjustment
SINGLE	single sweep triggered by button or external trigger signal
Sweep time: AUTO	forward sweep: 0.02 to 2 s continuously adjustable; return sweep: 0.01 to 0.3 s
SINGLE	≈ 0.02 to 2 s, continuously adjustable
Triggering	in SINGLE mode
Ext. trigger level	≈ +5 V (at rear-panel input)
Frequency markers internal +)	100 MHz; 100/10 MHz; 10/1 MHz; error < $\pm 1 \times 10^{-4}$
external	1 to 1000 MHz, V ≈ 0.2 V (50 Ω)
Marker type	pulse and vertical-line markers
Frequency classification (internal)	height- and intensity-staggered markers
Bright-up marker	manually adjustable in AUTO mode
Trigger signal for counter	TTL H during unblanked period (> 10 ms), female BNC output
Level lines	two; separate adjustment of vertical position; common adjustment of intensity
Useful display area	21 cm x 16 cm; screen type M 28-12 GM
Recorder output	+2.5 V for max. X deflection ±2.5 V for max. Y deflection Z_{out} 5 kΩ
Connector	6-pole female (1 channel) or BNC female (2 channels)

+) At a high output level (rear-panel switch on +6 dB), spurious markers may occur.

External X deflection	±1 V (symmetrical about zero for full display width (rising edge: forward sweep 0.02 to 2 s; falling edge: return sweep 0.01 to 0.3 s)
Connector	7-pole female on rear panel

Amplifier plug-ins

Logarithmic amplifier E1

Input	Measuring head
Connector	7-pole female
Input impedance	matched to the measuring heads SWOB5-Z1, -Z2, -Z3 and -Z4

Measurement using Demodulator SWOB5-Z1 or RF Insertion Unit SWOB-Z3:

Measurement range	10/20/40/60/80 dB
Display adjustment range	> 70 dB
Noise level	typ. 170 µV
Accuracy	better than ±1.5 dB
Max. text voltage at the RF input	1 V

Level line, calibrated in dB:

Reference level	1 V = 0 dB (detent position) shiftable by about -12 dB
Adjustment range	0 dB to -100 dB
Resolution	0.1 dB
Low-pass filter	switch-selectable on basic unit, indicator lamp lights when switched on
3-dB point	about 40 Hz
Compensation for spurious RF signals	20 mV (2 mV if the Active Demodulator SWOB5-Z4 is used)

Linear amplifier E2

Inputs	AF[1]	Meas. head
Connector	BNC female	7-pole female
Input impedance	≈ 500 kΩ	≈ 500 kΩ
Input selector positions	+/-/+≈/-≈[2]	=/≈[2]

1) Connector for probe or test item containing a demodulator.

2) ≈ signifies compensation for spurious RF signals from the device under test.

Deflection factor	0.2 mV/cm	-
Input voltage for full display height with max. sensitivity	< 3 mV	< 15 mV (with SWOB5-Z1 or -Z3)
Max. permissible input voltage	10 V (DC or AC)	5 V (AC or 10 V (DC)

<u>Logarithmic amplifier E3</u>

Input	AF[1]	Measuring head
Connector	BNC female	7-way female
Input impedance	approx. 100 kΩ	matched to the measuring heads SWOB5-Z1, -Z2, -Z3 and -Z4
Measurement using the Demodulator SWOB5-Z1 or RF Insertion Unit SWOB5-Z3		
Measurement range	10/20/50/80/100 dB	
Display adjustment range	> 70 dB	
Noise level	typ. 170 µV	
Accuracy	better than $\pm$1.5 dB	
Max. test voltage at the RF input	1 V	
Measurement via AF input:		
Measurement range	10/20/50/80/100 dB	
Display adjustment range	> 70 dB	
Noise level	typ. 170 µV	
Accuracy	better than $\pm$1 dB	
Max. test voltage	1 V	
Max. permissible input voltage	14 V	
Level line, calibrated in mV, dBV and dB:		
Adjustment range		
Absolute measurement	10 µV to 1 V/-100 dBV to 0 dBV	
Relative measurement	0 dB to 100 dB	
Level readout (Automatic switchover)	on 3 1/2-digit display	
Resolution	10 V 100 V 1000 V	
dBV/dB indicating range	> 100 dB	
Resolution	0.1 dB	
Indicating accuracy	0.1 dB or 2% $\pm$1 digit	

1) Connector for probe or test item containing a demodulator.

Low-pass filter	switch-selectable on basic unit, indicator lamp lights when switched on	
3-dB point	about 40 Hz	
Compensation for spurious signals . .	AF ±6 V	Measuring head 40 mV RF (4 mV if the Active Demodulator SWOB5-Z4 is used)

If the maximum permissible spurious signals are exceeded a red LED lights up.

<u>Recommended extras</u>

VSWR bridge, 50 or 75 Ω, depending on model

Frequency range	10 to 1000 MHz
Test input	N male connector
RF input	N female connector
Detector output	N female connector

Directivity	$\geq$ 40 dB
Insertion loss	approx. 6.5 dB

<u>Overvoltage protection</u> (for RF input or output, 50 Ω only)

Response threshold	approx. 4 V DC or RF
Cut-off time	$\leq$ 3 ms

<u>Options</u> (electrical connections via non-reversible connectors of basic unit)

<u>External control</u>

Switchover	int./ext. via slide switch; lamp lights in ext. mode
Input	7-pole female connector for RF Insertion Unit SWOB5Z3
Voltage adjustment	0.1 to 0.5 V, continuous

<u>Slow sweep</u>

X voltage	±2.5 V for max. deflection
Y voltage	1 V for max. deflection
Sweep time	0.02 to 2 s; about 30 s with recorder cable plugged in
Connectors	6-pole female (1 channel), BNC female (2 channels)

<u>IF markers</u>

Input	frequency-marker input (<u>11</u>, Fig. 2-16)
Frequency range	0.5 to 150 MHz
Input impedance	50 Ω
VSWR	$\leq$ 1.1 (in the range 5 MHz to 150 MHz)
with built-in low-pass filter	$\leq$ 1.3 (in the range 5 MHz to 150 MHz)
Input voltage for satisfactory marker display	10 mV, min.; 1 mV in the range 5 MHz to 150 MHz; 200 mV, max.
Max. permissible input voltage	5 V AC or 10 V DC
Frequency markers	2; produced by plug-in crystal oscillators
Marker frequencies	33.4 MHz; 38.9 MHz
Max. frequency error	2×10^{-5}

General data

Nominal temperature range .... +5 to +40°C

Shelf temperature range .... -25 to +60°C

Power supply .... 110/125/220/235 V +10%,
47 to 63 Hz (180 VĀ)

Dimensions, weight .... 484 mm x 328 mm x 436 mm, 25 kg

Order designation

SWOB 5, without amplifier plug-ins:

50-Ω model 333.0019.52

75-Ω model 333.0019.72

Amplifier plug-ins:

Log Amplifier SWOB5-E1 .... 333.5610.02

Lin Amplifier SWOB5-E2 .... 333.5010.02

Measuring heads:

Demodulator SWOB5-Z1

50-Ω model 333.7513.52

75-Ω model 333.7513.72

RF Insertion Unit SWOB5-Z3

50-Ω model 333.8010.52

75-Ω model 333.8010.72

Log Probe SWOB5-Z2 .... 333.9016.02

Demodulator Probe SWOB3-Z 241.2116.00

Active Demodulator SWOB5-Z4

50-Ω model 333.8510.52

75-Ω model 333.8510.72

Accessories supplied .... power cable

Recommended extras (for data see above)

VSWR Bridge SWOB4-Z

50-Ω model 912.7003.00

75-Ω model 912.7303.00

Overvoltage Protection SWOB5-Z5 ..... 333.9316.52

Recorder Adapter Cable SWOB4-Z 289.5450.02

Options

External Control SWOB5-B1 .... 333.6700.02

Slow Sweep SWOB5-B2 .... 333.9516.02

IF Markers Option

comprising

Basic Unit SWOB5-B3 .... 333.9716.02

with

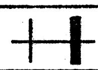
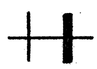
Crystal Oscillators SWOB5-B4 .... 333.9916.02
33.4 MHz and 38.9 MHz

Display-store Interface SWOB5-B6................. 333.5410.02

2. Preparation for Use and Operating Instructions

2.1 Preparation for Use

2.1.1 Legend for Figures 2-16 and 2-17

Pos.No.	Engraving	Function
1	-	Frequency marker
2	-	Variable bright-up marker. Sweep is stopped at the marker for approx. 12 ms. An external frequency counter connected to the RF monitoring output 45 can be triggered from connector 48 to determine the frequency at the marker location. The marker is adjusted by 13.
3	-	Horizontal level line.
4	WIDTH	Width of frequency markers.
5	AMPL. 	Amplitude adjustment of height-staggered pulse frequency markers.
6	INTENSITY 	Basic intensity of frequency markers.
7	FREQ.-MARK. (MHz)	
		Fade-in of height-staggered frequency markers.
		Fade-in of intensity-staggered frequency markers.
	100	100 MHz spacing of frequency markers.
	100 10	10 MHz spacing, 100 MHz marked.
	10 1	1 MHz spacing, 10 MHz marked.
	EXT.	Depressed: Fade-in of frequency markers by external frequencies supplied to connector 11. Released: Fade-in of IF markers with the aid of the IF applied to socket 11 if the option "IF markers" SWOB5-B3 is fitted.
8	GRAT. ILL.	Adjustment of graticule illumination.
9	INTENSITY	Adjustment of beam brightness.
10	POWER	Pushbutton switch (power on/off).

Pos.No.	Engraving	Function
11	0.2 V 50 Ω	Input connector for external frequency to generate frequency markers. Also input socket for the IF if the option "IF markers" SWOB5-B3 is fitted.
12	-	Green indicator, is lit at single sweep (13 SINGLE depressed) after pressing 13 START until end of single sweep.
13		This knob is used to
	⟷ SWEEP	a) shift the beam (spot) across the screen when the 13 MAN. button (manual sweep) is depressed, and
	VAR. MARKER	b) position the variable bright-up marker 2 when the 13 AUTO. button is depressed.
	In the sweep-range positions 1000 MHz, 5 to 1000 MHz and 0.3 to 50 MHz (40)	
	MAN	Manual sweep with the 13 SWEEP knob; external sweep through 52 possible; basic brightness is reduced when the MAN button is depressed.
	AUTO	Automatic sweep.
	SINGLE	Single sweep.
	START	Start of single sweep.
	In the sweep-range position 0 (CW)	
	AUTO SINGLE }	Output signal not swept (CW operation). Frequency adjustment by means of 41 and 42. Frequency indication by means of bright-up bar (48). The deflection amplifiers are inoperative.
	MAN	Same as for AUTO and SINGLE, but no frequency indication (48) and, therefore, reduced spurious sweep width.
	START	No function
14 15	HORIZ. LINES ↕	Positioning both horizontal lines generated by basic unit.
16	INTENSITY	Basic intensity adjustment for horizontal lines and level line (adjustable with 17).
17	HORIZ. LINE - dB	Level line adjustment with dial calibrated in dB; positions reference line in precisely defined relation to zero line
	0 dB ≙ 1 V	(0 dB ≙ 1 V with calibrated zero line).

Pos.No.	Engraving	Function
18	UNCAL.	Red warning light for 0-dB position of level line 17. Warning light is off when 0-dB line is calibrated (0 dB ≙ 1 V).
19	↕ POS. ↕ 0 dB-POS.	Large knob (grey) allows vertical positioning of display (not possible when 20 is set to 80 dB). Small knob (red) allows positioning of zero line; in the clockwise detent position (.CAL, lamp 18 off) zero-line position corresponds to 1 V.
20	OFF 80 60 40 20 10 dB RANGE	Range selector switch, for on/off switching of LOG. AMPLIFIER plug-in E1.
21	PROBE	Connector for probe.
22	⊿	Knob for gain adjustment.
23	↕ POS.	Knob for vertical display positioning.
24		Selects polarity of probe voltage, switches LIN. AMPLIFIER plug-in on/off.
	OFF	LIN. AMPLIFIER plug-in switched off.
	+	Positive input voltage at connector 26 provides upwards deflection.
	-	Positive input voltage at connector 26 provides downwards deflection.
	+ ≈	Same as +, but with RF spurious signal compensation.
	- ≈	Same as -, but with RF spurious signal compensation.
	=	Display of probe voltage (connector 25).
	≈	Same as =, but with RF spurious signal compensation.
25	PROBE	Connector for probe.
26	AF 1 V	AF input (BNC connector).
27	-	Digital display of level line adjusted by means of 29 .

28	dB dBV mV	Selector switch for level indication in dB, dBV or mV.
29	HORIZ.- LINIE	Level line adjustment to shift horizontal level line 3 .
30	OFF 100 80 50 20 10 dB	Range selector and ON/OFF switch for plug-in.
31	↕ POS.	Rotary knob for vertical shifting of display.
32	+ -	Selector switch for AF input socket (positive or negative polarity) or probe input.
33	-	Probe input socket.
34	NF · AF 1 V	AF input (BNC female connector).
35	UNCAL.	Red indicator lamp which lights up if the maximum spurious voltage that can be compensated for is exceeded.
36	0 dB	Pushbutton for automatic setting of reference level (0 dB) corresponding to the level of the actual position of the horizontal line 3 .
37	-	Red indicator lamp; lights up when the noise filter is switched on.

Pos.No	Engraving	Function
38	SWEEP TIME 2s 0.02s FILTER WIDE NARROW	This knob is used to adjust a) sweep time in the AUTO and SINGLE modes (at SINGLE only if "slow sweep" option is not installed), and b) pulse period of RF blanking in MAN mode. This knob is also a pull switch for selecting narrow or wide filter characteristics.
39	Δf	Knob for continuous adjustment of sweep width.
40	 1000 5 - 1000 0.3 - 50 0	Rotary switch for setting sweep width: Total range 0.1 to 1000 MHz in one sweep Continuously adjustable from 5 to 1000 MHz Continuously adjustable from 0.3 to 50 MHz No sweep operation (CW operation).
41	f COARSE	Knob for coarse adjustment of centre frequency.
42	FINE	Knob for fine adjustment of centre frequency.
43	OUTP. VOLTAGE dB	Switch for RF output voltage adjustment in 10 steps of 1 dB each.
44		Switch for RF output voltage adjustment in 6 steps of 10 dB each.
45	1 V (model 333.0019.52 only) 0.7 V (model 333.0019.72 only)	Red indicator lamp; signals increase by 6 dB (switch 54). Labelled according to model.
46	RF 50 Ω 0.5 V (model 333.0019.52 only) 0.35 V (model 333.0019.72 only)	RF output of sweep generator. Additional labelling according to model.
47	EXT. ALC	Red indicator lamp; signals external ALC operational.
48	-	Bright-up bar indication of sweep range. Disabled in the MAN mode.
49	47 - 63 Hz	AC supply connector.
50	220 M1C 235 115 M2E 125 SPARE FUSES INSIDE	AC supply voltage selector with fuse (spare fuses).

<table>
<tr><th>Pos.No.</th><th>Engraving</th><th colspan="2">Function</th></tr>
<tr><td>51</td><td>INT.
EXT.</td><td colspan="2">Internal/external ALC selector.</td></tr>
<tr><td>52</td><td>LEVEL</td><td colspan="2">Adjustment for RF output voltage of approx. 0.1 to 0.5 V at external ALC.</td></tr>
<tr><td>53</td><td>PROBE</td><td colspan="2">Connector for insertion unit. Test detector operates as EMF diode for external ALC.</td></tr>
<tr><td>54</td><td>V_{OUT}</td><td colspan="2">Selector switch for increase of EMF by 6 dB (additional labelling according to model).</td></tr>
<tr><td>55</td><td>RF
ca. 50 mV 50 Ω</td><td colspan="2">RF monitoring output; may be used for connecting a frequency counter with trigger capability.</td></tr>
<tr><td>56</td><td>-</td><td colspan="2">Cover sheets, behind each 2 power transistors 2N3055 (power supplies).</td></tr>
<tr><td>57</td><td>↯</td><td colspan="2">Cover plate, behind it power transformer with soldering-terminal strips.</td></tr>
<tr><td>58</td><td>TRIGGER</td><td colspan="2">Trigger input at SINGLE, trigger output at AUTO mode (13).</td></tr>
<tr><td>59</td><td>REMOTE CONTROL</td><td colspan="2">Input connector for remote control lines; see chapter 2.2.11 for pin assignment.</td></tr>
<tr><td>60</td><td>X</td><td>BNC connector
X-axis output</td><td rowspan="3">If the option "slow sweep" SWOB5-B2 is fitted, these connectors are active only in the modes MAN and SINGLE (START) but not in the mode AUTO.</td></tr>
<tr><td>61</td><td>Y II</td><td>BNC connector
YII output</td></tr>
<tr><td>62</td><td>Y I</td><td>BNC connector
YI output</td></tr>
<tr><td>63</td><td>RECORDER</td><td colspan="2">Recorder connector (6-way).
Pin assignment:
1 X-axis output
2 YI output
3 Ground
4, 6 Pen lift control
5 Identification
(short to ground no. 3 for recorder operation).</td></tr>
</table>

Pos.No.	Engraving	Function
64	TEST	Test output (7-way). Pin assignment: 1 +24 V 2 Sawtooth signal (X-axis deflection) 3 Ground 4 Squarewave: "Low" during retrace, "high" during visible forward sweep 5 -20 V or +5 V (optional) 6 Input for external X-axis deflection (only in MAN. mode). For external X-axis deflection short-circuit from 3 to 7. 7 Identification for external deflection (short to ground No. 3)

2.1.2 Installation

The unit is designed for operation at ambient temperatures from +5 to +40°C. Ventilation holes must not be covered.

2.2 Switching on and Basic Adjustments of Basic Unit

2.2.1 Switching on

The unit is factory-adjusted for a line voltage of 220 V. To adapt it to a different line voltage (115 V, 125 V or 235 V), unscrew the fuse-holder (part of line voltage selector 50, Fig. 2-16) and turn the fuse-holder plate, aligning the marker with the value of available line voltage. Insert a suitable fuse (M1C for 220 V and 135 V, M2E for 115 V and 125 V), then screw cap on fuse-holder. Line frequencies from 47 to 63 Hz are permissible.

Attach power cord 025.2365.00 (supplied as an accessory) to connector 49 and wall outlet. Switch unit on by pushing the button 10. After cathode-heating time for the CRT is elapsed, the intensified bar for frequency range identification 48 appears at the lower screen edge when the unit is ready for operation and if following conditions are met:

9 fully clockwise position

13 AUTO button depressed

40 in the 1000 position.

2.2.2 Brightness Adjustment

Adjust desired basic brightness of CRT beam using 9 (Fig. 2-16) between dark (fully counterclockwise position) and bright (fully clockwise position). Using a screwdriver, the intensity of the frequency markers can be adjusted by means of 6, and the intensity of the horizontal lines by means of 16, to obtain an adequate relation to the intensity of the measured-value display.

In MAN mode 13, basic brightness is automatically reduced to give the same brightness impression to the user as for automatic sweep.

2.2.3 Frequency Markers and Graticule Illumination

Line or pulse markers can be selected using 7 (Fig. 2-16). The amplitude of the height-staggered pulse markers which are superimposed on the sweep curve is adjusted using 5; marker width is adjusted using 4. Pushbuttons 100, 100 10 and 10 1 allow selection of a marker spectrum with 100 MHz, 10 MHz or 1 MHz marker spacing. At 100 10, the 100-MHz markers are identified by greater intensity or amplitude; the 10-MHz markers are enhanced at the 10 1 setting. If the EXT. button is depressed, frequencies fed in through the BNC connector 11 are processed and displayed as markers.

The screen bezel will accommodate cut or engraved graticules which are illuminated from the side. The illuminating brightness can be adjusted using 8.

2.2.4 IF Markers (with Option SWOB5-B3)

The option "IF markers" SWOB5-B3 in conjunction with the option "Crystal oscillators" SWOB5-B4 permits superposition of highly accurate frequency markers when testing equipment using frequency conversion, such as tuners. To this end, the IF must be applied to the BNC connector 11 (Fig. 2-16) and the pushbutton EXT. (7) must be released. At the same time, the RF markers can be added by pressing one of the pushbuttons 100, 100 10, 10 1 (7). For the IF marker display, pulse or line markers may be selected by means of 7. The display is reversible, i.e. line markers are displayed when the pulse marker button is pressed and vice versa, by reversing the polarity of the socket BU303 (section 6.3). In this way, it is easier to distinguish between the IF and RF markers.

2.2.5 Variable Marker

In automatic mode (AUTO button 13 depressed, Fig. 2-16), the variable spot marker 2 can be horizontally positioned using potentiometer 13 VAR. MARKER. The same potentiometer is used for manual sweep control (MAN. button depressed); SWEEP label is valid for this purpose. The frequency of the spot marker corresponds to the frequency point displayed after switching to MAN.

The marker is generated by stopping the sweep for approx. 12 ms at the marker location. At the same time, a TTL pulse is generated which can be used to trigger an external frequency counter connected to the RF monitoring output 55 through the trigger input/output 58 (Fig. 2-17). The frequency counter will then indicate the sweep generator frequency at the location of the variable spot marker (see chapter 2.2.10).

2.2.6 Adjustment of the Horizontal Reference Lines of the Basic Unit

The two horizontal lines can be vertically adjusted using 14 and 15 (Fig. 2-16). The intensity of the horizontal lines and of the level lines is adjusted using 16. Adjustment of horizontal line 3 of the logarithmic amplifier plug-in is described in chapter 2.3.1.

2.2.7 Sweep Operation

2.2.7.1 Sweep Width and Centre Frequency

The sweep width is selected with the rotary switch 40 (Fig. 2-16).

- In position "1000", the entire frequency range is swept. The centre frequency is fixed tuned to 500 MHz. The sweep width control 39 and the centre frequency control 41 are disabled.
- In positions "5 - 1000" and "0.3 - 50", the sweep width can be varied over the specified ranges by means of 39. The centre frequency is adjustable over the entire frequency range by means of 41. Fine centre frequency adjustment by about 3 MHz is possible by means of 42.

  The range 0.3 to 50 MHz is specially intended for narrow-band measurements, the spurious sweep width being reduced to about 3 kHz (typ.).
- In position "0", the RF signal is not swept (section 2.2.8). The selected frequency range is indicated by the bright-up bar 48 at the lower edge of the screen. During manual sweep (MAN mode), there is no such indication.

2.2.7.2 Automatic Sweep (AUTO)

Automatic sweep is selected by pressing button AUTO 13. The RF voltage is blanked during retrace. Sweep time can be adjusted using 38. Forward sweep time can be varied from 0.02 s to 2 s, retrace time will correspondingly vary from 0.01 s to 0.3 s. Potentiometer 13 ◄──► VAR. MARKER is used to adjust a variable marker (see chapter 2.2.5) in automatic sweep mode. Whenever this marker is visible, the forward sweep time increases by approx. 12 ms. Shortest forward sweep time possible is then approx. 0.035 s.

2.2.7.3 Manual Sweep (MAN)

The sweep can be manually controlled by means of the control knob 13 ◄──► SWEEP. For this purpose, the pushbutton 13 MAN must be depressed. Drift-free operation of the Log Amplifier SWOB5-E1 and RF noise signal suppression are ensured by RF and screen display blanking. Since there is no periodic retrace in manual sweep operation, blanking may be visible under certain circumstances. The pulse period corresponds to the sweep time of automatic sweep operation and is thus determined with 38.

Basic brightness is automatically reduced in manual mode to produce a brightness impression similar to that in AUTO mode.

In MAN. mode recorder operation is possible (connections 60 to 63 on the rear panel, section 2.2.12).

External X-axis deflection can be performed using a triangular voltage of approx. ±1 V for full screen coverage. Input for this is connector 64 at the rear panel (pin 6, ground 3); pin 3 is to be connected to pin 7.

2.2.7.4 SINGLE Sweep

A single sweep, consisting of forward and return sweep, is initiated using pushbutton 13 START (Fig. 2-16). The sweep time can be selected with 38 as for AUTO mode (see section 2.2.7.2).

To avoid transients of RF noise signal suppression and frequency drift of the deflection amplifiers, the screen display is blanked but automatic sweeping continues. Upon depression of the pushbutton 13 START, the display signal will be released for the duration of the forward sweep as soon as the sweep generator starts a new forward sweep. The delay between depression of the START button and the display on the screen will in the worst case be 2.3 s.

The green lamp 12 lights immediately after pressing the START button and will go out after the displayed sweep has been completed.

2.2.7.5 Noise Filter

Pulling knob 38 (Fig. 2-16) inserts a 40-Hz low-pass filter into each display channel. The considerably narrower bandwidth reduces the noise and permits evaluation of smallest voltages when using a logarithmic amplifier. It should be borne in mind that errors may occur due to transients with test items presenting sharp slopes and at short sweep times. In this case, the sweep time has to be increased until the sweep curve does not vary any more.
The red lamp 37 lights when the filter is switched in.

2.2.8 CW Operation

If the sweep width selector switch 40 (Fig. 2-16) is set to position "0", an unswept signal is available at the RF output 46 the frequency of which can be adjusted by means of 41 and 42.

For CW operation, RF blanking is disabled. The screen display, with the exception of the frequency indication, is blanked. The control elements 13 ◄—►, AUTO, SINGLE and START are disabled. However, by pressing the push-button MAN, the frequency indication may in addition be blanked, reducing the unwanted sweep width of the output signal to typically 3 kHz.

NOTE: Since the blanking required for drift-free operation of the Log Amplifier SWOB5-E1 and RF noise signal suppression is disabled, the deflection amplifiers are inoperative. Transients may therefore be observed when switching back to sweep operation.

2.2.9 Amplitude at RF Output

The amplitude of the RF signal at output 46 (Fig. 2-16) can be attenuated in ten 1-dB steps using 43 and in six 10-dB steps using 44 The level can be increased by 6 dB over the 5-to-300-MHz frequency range using 54 (at rear panel, Fig. 2-17). This is indicated by the red light 45 (Fig. 2-16).

2.2.10 Trigger Input/Output

The SINGLE mode is to be selected for external sweep triggering. A pulse of approx. +5 V (TTL level) at the BNC connector 58 (Fig. 2-17) will then initiate a single sweep. The effect of the pulse is the same as if the START button were pressed (see chapter 2.2.7.4).

In the AUTO mode 58 serves as the output for pulses which are used to trigger an external frequency counter with which the frequency at the location of the variable dot marker 2 can be determined. For this purpose, the X-axis deflection is stopped for a short while and a TTL pulse (approximately 12 ms high) will be supplied at 58 (see chapter 2.2.5).

2.2.11 Remote Control

Remote control of sweep width, centre frequency and sweep time can be performed through connector 59 (Fig. 2-17). If pin 6 is shorted to ground (pin 5), the internal controls are disabled. For remote control of sweep width, a 5-kΩ potentiometer is connected between pins 1 and 5; the slider is connected to pin 2. Centre frequency can be varied by a DC voltage of +3 to +8 V at pin 3, sweep time by a DC voltage of 0 to +5 V. Both voltages may be obtained from a voltage divider (total resistance approx. 10 kΩ) which is connected to +20 V at pin 4 (Caution: +20 V is not shortcircuit-proof).

2.2.12 Connection of Recorder

2.2.12.1 Connection of Recorder (Without Slow Sweep Option)

For recording purposes, an XY recorder may be connected. This may either be done through BNC connectors 60 (X axis), 61 (YII) and 62 (YI) or the 6-way connector 63 (X axis and YI).

The output voltage for maximum X-axis deflection is +2.5 V and the Y output voltage approximately -2.3 V to +0.7 V (source impedance approximately 5 kΩ).

Connector 63 is wired as follows:

1 X-axis deflection

2 YI output

3 Ground

4, 6 Pen lift

5 Identification (short to ground No. 3 for recorder operation; this is automatically done if the recorder connecting cable 289.5450.02 is being used).

The deflection voltages are permanently present at the outputs in all operational modes (MAN., AUTO and SINGLE). The pen lift contact is only closed during the visible forward sweep in the SINGLE mode. Longest available forward sweep time is 2 s (adjustable with 38).

2.2.12.2 Slow Sweep SWOB 5-B2 (Option)

The "slow sweep" option allows recorder operation at a sweep time of approx. 30 s. For this purpose, pin 5 (identification) is to be shorted to pin 3 (ground) at connector 63 (Fig. 2-17). This is automatically done if the recorder connecting cable 289.5450.02 is being used.

Fitted with the SWOB5-B2 Slow Sweep Option, the deflection voltages (X, Y) of the SWOB 5 are only passed to the output connectors 60 to 63 in the MAN. and SINGLE sweep modes. The recording pen is only activated during the visible forward sweep in the SINGLE mode. The pin assignment of connector 63 is the same as described in chapter 2.2.12.1. The Y output voltage is 0 to 1 V.

2.2.13 TEST Output and Input for External X-axis Deflection

Pinning of the 7-pin TEST connector 64 (Fig. 2-17) is as follows:

1 Supply voltage +24 V

2 Sawtooth signal (X-axis deflection)

3 Ground

4 Rectangular voltage (TTL level) with low level at retrace and high level at visible forward sweep

5 Operating voltage -20 V (+5 optional)

6 Input for external X-axis deflection

7 Identification of external X-axis deflection (short to ground No. 3)

External X-axis deflection is only possible in MAN. sweep mode. For this, a triangular voltage of $V_p \sim \pm 1$ V is required at pin 6 for full screen coverage.

The supply voltage for the Overvoltage Protection is also available at the TEST socket.

2.2.14 RF Monitoring Output

A portion of the generator output power is tapped off before the output voltage divider. Approx. 50 mV across 50 Ω are available at connector 55 (Fig. 2-17). If the level at output 46 (Fig. 2-16) is increased by 6 dB using switch 54 (Fig. 2-17), also the RF monitoring voltage is doubled. If operated with external ALC (see chapter 2.4), this voltage mainly depends on the output level adjusted by 52 (Fig. 2-17) and on the position of switches 43 and 44. Output 55 can be used, for example, to connect an external frequency counter with trigger capability.

2.3 Basic Amplifier Plug-in Adjustments

2.3.1 Basic Adjustments on LOG. AMPLIFIER Plug-in SWOB 5-E1

The logarithmic amplifier E1 receives the rectified voltages from the probe (SWOB 5-Z1, Z2 or Z3) through connector 21 (Fig. 2-16). The plug-in can be switched on or off using 20; this switch is also used to select a display range of 80, 60, 40, 20 or 10 dB for full display height. Vertical position of the displayed curve is adjusted using the larger knob 19 (double rotary knob). The adjustment range is 10 to 80 dB and depends on the position of switch 20.

17 is a 10-turn potentiometer with calibrated dial; it allows precise adjustment of a horizontal line within the range of 0 to -100 dB per 10 turns at a resolution of 0.1 dB. The 0-dB position of this level line can be varied by 12 dB using the smaller knob 19. In the detent position, this horizontal zero line is calibrated to 0 dB ≙ 1 V. An uncalibrated adjustment (small knob 19 not in its detent position) is indicated by the red lamp 18.

Full sensitivity (noise level typical 170 µV) is obtained in connection with Demodulator SWOB 5-Z1 or RF Insertion Unit SWOB 5-Z3 with the noise filter inserted (pull switch 38 on basic unit). (See chapter 2.2.7.5).

2.3.2 Basic Adjustments on LIN. AMPLIFIER Plug-in SWOB 5-E2

Input connector 25 (Fig. 2-16) is used for connecting the probes SWOB 5-Z1, Z2 or Z3. A rectified voltage supplied by the device under test or the AF voltage of the SWOB 3-Z can be applied through BNC connector 26.

Switch 24 allows switching on and off of the plug-in, selection of the input connector and matching to demodulators with positive or negative output. In all switch positions labelled with ≈, the automatic RF spurious signal suppression is operating.

Vertical display position is adjusted using 23, display sensitivity using 22.

2.3.3 Basic Adjustments on LOG. AMPLIFIER Plug-in SWOB 5-E3

The test voltage is applied to the logarithmic amplifier E3 either from the measuring head via socket 33 or directly from the device under test (e.g. IF amplifier with demodulator) via the AF input 34 , depending on the position of the input selector switch 32 .

The plug-in can be switched on or off using the switch 30 which is also used to select a display range of 100, 80, 50, 20 or 10 dB for full display height. The calibrated horizontal line 3 is adjustable by means of the 10-turn potentiometer 29 and the level corresponding to the position of the line is read out on the display 27 in either dB, dBV or mV, depending on the position of the slide switch 28 . When making relative measurements in dB the reference level (0 dB) can be set by pressing button (36) to correspond to the level of the actual position of the horizontal line.

Vertical shifting of the display is accomplished by means of the small rotary knob 31 . The display can be shifted by about 10 to 80 dB, depending on the position of the switch 30 .

A red indicator lamp (35) lights up if the maximum spurious input voltage that can be compensated for is exceeded during the measurement.

Full sensitivity (noise level typical 170 µV) is obtained in conjunction with the Demodulator SWOB5-Z1 or the RF Insertion Unit SWOB5-Z3 and if the noise filter is switched on (pull switch 38 on basic unit). (See chapter 2.2.7.5).

2.4 External Control SWOB 5-B1 (Option)

The "external control" module is housed in a specific compartment within the mainframe and is accessible from the rear. Electrical interconnection is made using a non-reversible plug-and-socket connection.

Using the Insertion Unit SWOB 5-Z3 which generates the level control voltage, the source (EMF) of the RF generator is transferred into the measuring head with this option. This results in supplying constant RF input voltage to the device under test, corresponding to a source impedance tending towards 0.

At higher frequencies, the conductor between voltage source and input of the device under test, which consists of a piece of coaxial tube from the centre of the measuring head to its contact plane and of the connecting line between measuring head and device under test, transforms the source impedance, which then appears complex at the input of the device under test. The connection between measuring head and device under test should therefore be chosen as short as possible.

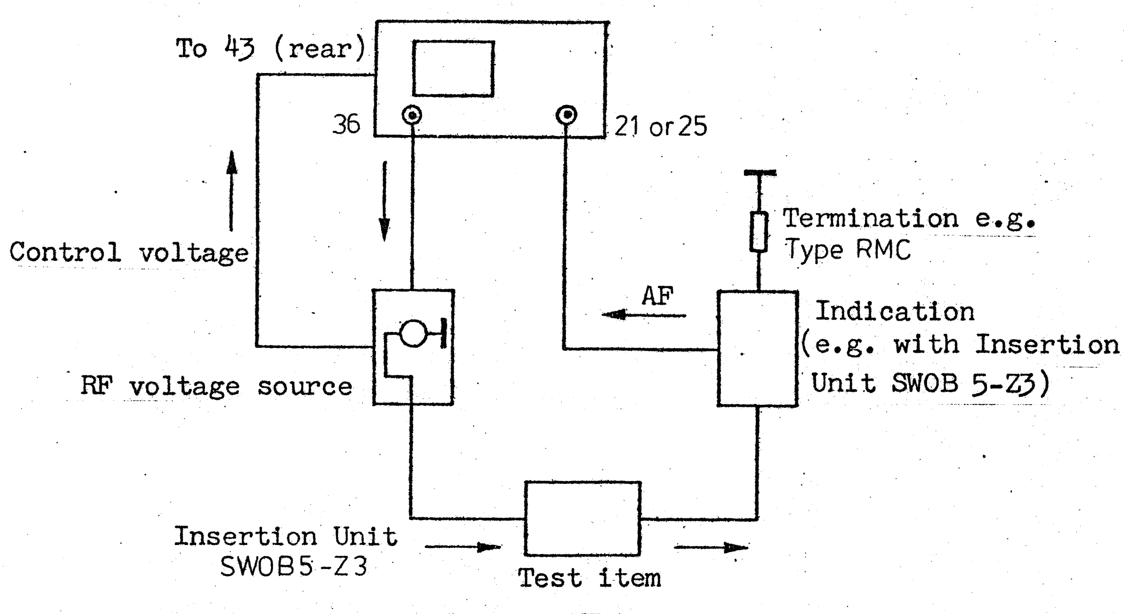


Fig. 2-1 External control

Fig. 2-1 demonstrates the test setup. The AF cable of the measuring head is connected to 53 (rear panel, Fig. 2-17). The RF voltage can be adjusted from approx. 0.1 to 0.5 V using 52. Switch 51 allows selection of internal or external ALC. If the external control is operational, the red lamp 45 (Fig. 2-16) is lit.

Output voltage selector switches 43 and 44 have to be set to

a) enable the sweep generator to supply the desired output voltage without generation of inadmissible harmonics within the frequency range concerned;

b) ensure stable frequency markers;

c) make sure that loop gain of the ALC circuit is not unnecessarily reduced; this would otherwise deteriorate the transient response.

These conditions are met, as a rule, if as much attenuation is introduced using 43 and 44 as corresponds to the RF level referred to 0.5 V. If a level of 0.5 V is adjusted by 52, then 43 and 44 have to be set to their 0 dB positions; at 0.25 V, an attenuation of 6 dB and at 0.1 V of approx. 14 dB is to be inserted.

If the attenuation selected by 43 and 44 is too small, the frequency markers will disappear. At high output voltages, intermediate markers will be caused by generation of harmonics if the inserted attenuation is too high.

2.5 Preparation and Execution of Measurements

2.5.1 Connecting the Device under Test

2.5.1.1 Basic Test Setups

The quantity of paramount interest in radio-frequency engineering is the frequency-dependent magnitude of transmission in forward direction of a two-port network.

For this measurement, the device under test is fed, as a rule, from the RF output 46 (Fig. 2-16) of the SWOB 5 and its output is connected to a measuring head whose detected output drives the display section via a linear or logarithmic amplifier plug-in - according to sensitivity and dynamic-range requirements (Fig. 2-2).

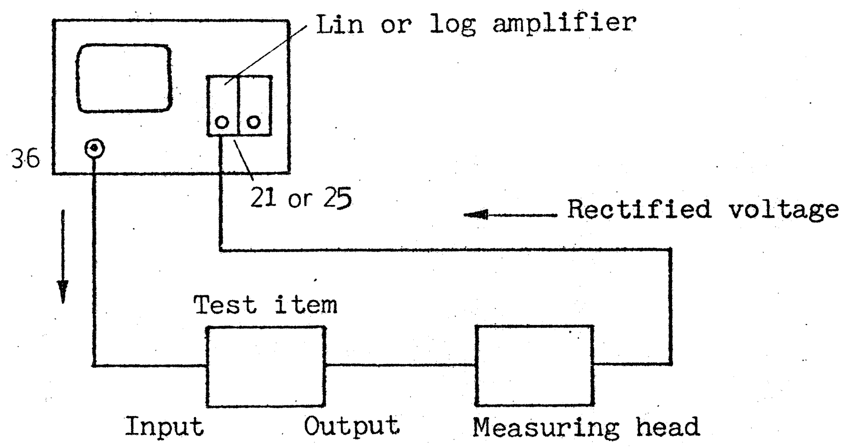


Fig. 2-2 Transmission measurement

Depending on the impedance at the output of the two-port network, an insertion or termination unit or a probe is to be used. This will be explained in more detail together with the corresponding measurement examples.

If the device under test has a built-in demodulator, the output of this can immediately be fed to the AF input 26 of the linear amplifier plug-in or to the AF input 34 of the logarithmic amplifier plug-in E3.

Another important quantity is the return loss at the input of the two-port network as a measure of the magnitude of reflection coefficient and thus of the quality of impedance matching. The reflected RF energy can be fed to the measuring head using a directional coupler or the VSWR bridge SWOB 4-Z. Fig. 2-3 demonstrates the test setup when the bridge is used (the VSWR bridge is described in the appendix of this manual).

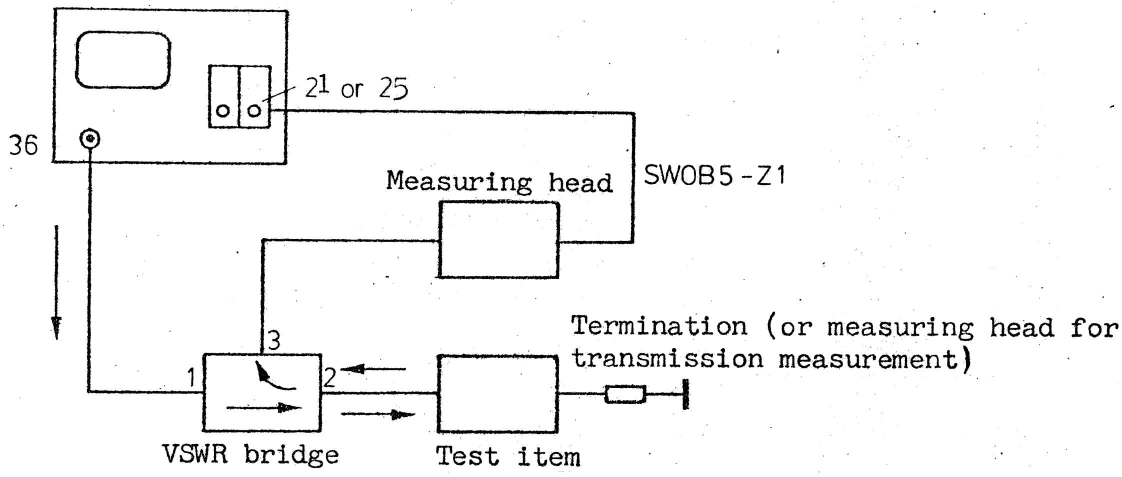


Fig. 2-3 Measurement of return loss for determination of input reflection coefficient

Bridge connections 1 Generator
2 Device under test
3 Measuring head (indicator)

As the SWOB 5 has two display channels, transmission and reflection can be displayed simultaneously on the screen. This offers a special advantage for filter tuning and similar procedures.

For completeness it should be mentioned that the corresponding reverse characteristics of the device under test can also be measured. Doing this, the inputs and outputs of the two-port network have to be reversed in Figs. 2-2 and 2.3.

2.5.1.2 Connection to the Sweep Generator

The test item is connected to 46 (Fig. 2-16). The device under test must not deliver a DC component at its input; if not so, an isolating capacitor or another useful DC decoupling must be inserted. Any DC current flowing into 46 would change the operating point of the RF output level control circuit (EMF control circuit) and might, if high enough, damage the EMF diode or the resistors of voltage dividers 43 and 44 If an RF voltage (e.g. oscillator reradiation of a receiver mixer) appears at the input of the device under test, this may affect the EMF control circuit. Inserting an attenuation of 6 dB or more using 43 and 44 will help in this case.

As a rule, the coaxial cable between 36 and the input of the device under test should be kept as short as possible (short as compared to the wave length of the highest operating frequency), its characteristic impedance should match the source impedance. Mismatch of the device under test will then have only negligible effect.

If the input of the device under test is mismatched and a connecting line of some length cannot be avoided, an attenuator of at least 20 dB should be inserted immediately at the device under test. If this attenuation cannot be tolerated due to level decrease, a suitable parallel resistor may be connected in parallel if the device under test has a high impedance. Harmful reactances can be compensated for if the measurement bandwidth is not too wide.

2.5.1.3 Connection to the Display Channels

2.5.1.3.1 Connection to the Logarithmic Amplifier Plug-in SWOB 5-E1

Connection of the device under test to the logarithmic amplifier plug-in E1 requires the use of a measuring head. According to the task on hand, this may be the Demodulator with terminating resistor SWOB 5-Z1, the Insertion Unit SWOB 5-Z3, the high-impedance Log Probe SWOB 5-Z2 or the Active Demodulator SWOB5-Z4. An RF amplifier (gain 20 dB, frequency range 5 to 1000 MHz) is connected before the latter.

The connecting cables of the measuring heads are equipped with 7-pin connectors which fit into connector 21 at the logarithmic amplifier plug-in E1. Their length of approx. 100 cm allows in practically all cases shortest connection of the measuring head to the device under test.

The measuring heads are in general insensitive to applied DC voltages, as the rectifiers are coupled through isolating capacitors. Care, however, should be taken to avoid overloading of the terminating resistor of the SWOB5-Z1 Demodulator or of the Active Demodulator SWOB5-Z4 or of an external terminating resistor by the sum of DC and RF power. Rated specifications and features of the measuring heads are listed in the appendix of the manual.

RF spurious signals arriving at the test detector (e.g. the oscillator voltage of a receiver mixer) are automatically suppressed in the logarithmic amplifier up to a level of approx. 20 mV (2 mV with Active Demodulator SWOB5-Z4).

Whenever the RF voltage at the SWOB 5-Z1 Demodulator or at the SWOB 5-Z3 Insertion Unit exceeds 1 V, these units are overdriven. This, on the one hand, affects the linearity of the logarithmic circuit and, on the other hand, the circuits incorporated in the units to protect the zero bias detectors from damage by overvoltage limit the rectified voltage. The maximum permissible input voltage to the Active Demodulator SWOB 5-Z4 is 50 mV.

2.5.1.3.2 Connection to the Linear Amplifier Plug-in SWOB 5-E2

The same measuring heads as for the logarithmic amplifier plug-in can be used together with the linear amplifier plug-in E2. The head is connected to connector 25 (Fig. 2-16).

The linear amplifier has an additional AF input (1 V maximum), BNC connector 26 . Switch 24 selects either one of the two inputs. The demodulator signal of an IF amplifier, for example, can be applied to 26 . Switch 24 is used to match the amplifier to demodulators with positive or negative output. The SWOB 3-Z probe (positive output) can also be used with input 26 . The response of the measuring heads to DC voltage input and overdrive conditions is described in chapter 2.5.1.3.1.

Similar to the logarithmic amplifier plug-ins, the linear amplifier plug-in features switch-selectable automatic RF spurious signal suppression. It is effective for both inputs. If the SWOB 5-Z1 Demodulator or the SWOB 5-Z3 Insertion Unit is used, RF spurious voltages of up to 50 mV (5 mV with Active Demodulator SWOB 5-Z4) and DC voltages of up to 100 mV applied to BNC connector 26 can be suppressed.

2.5.1.3.3 Connection to the Logarithmic-Amplifier Plug-in SWOB 5-E3

The logarithmic amplifier plug-in E3 permits all the SWOB 5 RF measuring heads to be connected via socket 33 or the AF signals applied directly from the device under test via BNC socket 34 . The polarity of the AF input can be selected by means of the slide switch 32 to match it to the positive or negative output voltage of a rectifier (e.g. demodulator) in the device under test.

The connecting cables of the measuring heads are fitted with a 7-pole connector which mates with the socket 33 . Their length of about 100 cm allows in practically all cases shortest connections of the measuring head to the device under test.

RF spurious signals arriving at the test detector (e.g. the oscillator voltage of a receiver mixer) are automatically suppressed in the logarithmic amplifier up to a level of about 40 mV (4 mV with the Active Demodulator SWOB 5-Z4). When measuring via the AF input, spurious signals are suppressed up to a level of ±6 V.

The test voltage at the RF input of the measuring head or at the AF input of the plug-in must not exceed 1 V to prevent the logarithmic circuit from being overdriven which would affect the linearity. When using the Active Demodulator SWOB 5-Z4 the overdriving capacity is 50 mV. Otherwise the limit ratings of the measuring heads (see appendix to manual) and the maximum permissible voltage of 10 V at the AF input must be adhered to.

2.5.1.4 RF and Hum Pickup

Special attention should be paid to the ground connection between the device under test and the instrument (especially the probe). A thin, long wire must never be used for grounding at high frequencies. If the cable to the measuring head or another connecting cable or a measuring instrument is moved or touched (body effect), the display is not allowed to change. It is very often required to operate all equipment of the test setup off earth, i.e. from unearthed power lines, and to have only the POLYSKOP connected to safety earth. If the device under test contains a demodulator circuit whose output voltage is to be displayed using the linear amplifier plug-in, measurement results might be invalidated by hum.

2.5.2 Adjustment of Test Voltage

The test voltage is to be selected by means of the calibrated output voltage dividers 43 and 44 so as to avoid overdriving of the device under test and the deflection amplifiers. It is to be assumed that an overdrive condition has occurred whenever the screen display no longer varies proportionally to the change of the test voltage using 43 and 44.

The test result may also be falsified by harmonics of the output signal. Since the harmonic suppression of the SWOB5 is typically 40 dB while the Log. Amplifier SWOB5-E1 covers a dynamic range of 70 dB, a lower stop-band attenuation might be measured with filters (section 2.6.3). The harmonic suppression of active test items may be deteriorated by the output signal. If so, it is advisable to connect a low-pass filter before the test item.

Non-harmonic spurious signals may cause faulty measurements especially when testing very narrow-band filters and resonant circuits, since due to the design of the SWOB 5 the first non-harmonic spurious signal may occur already about 50 kHz from the resonant frequency.

2.5.3 Selecting Centre Frequency and Sweep Width

Centre frequency and sweep width are adjusted according to the frequency response of the device under test and the frequency range of interest (e.g. frequency of passband, recurrence, spurious response, etc.).
The sweep width range is selected using switch 40 according to Table 1:

Table 1
Sweep widths

Switch 40 position	Sweep width 39
1000	Full range sweep, independent of 39 adjustment.
5 - 1000	Sweep width continuously adjustable from 5 MHz to 1000 MHz.
0.3 - 50	Sweep width continuously adjustable from 0.3 MHz to 50 MHz.
0	No sweeping (CW operation)

Centre frequency is adjusted using 31 (coarse) and 32 (fine). The adjusted sweep range is identified by intensified bar 38. Centre frequency and sweep width can be read from the associated scale at the lower screen edge.

2.5.4 Frequency Markers

Pushbuttons 7 (Fig. 2-16) can be used to select a scale of crystal-stabilized frequency markers spaced 1, 10 or 100 MHz apart. They can either be chosen as intensity-staggered line markers or as height-staggered pulse markers which are superimposed on the sweep curve. After depressing the EXT. pushbutton, an arbitrary frequency marker can be generated using an external RF generator which is connected to BNC connector 11 (RF level approximately 200 V into 50 Ω).

In AUTO sweep mode, a variable intensity marker is available. The sweep is stopped for approx. 12 ms at the location of this marker. A pulse supplied to trigger input/output 58 (Fig. 2-17) during this time can be used to trigger an external frequency counter. This permits measuring the frequency of the voltage available at RF monitoring output 55. The gate time of the frequency counter must not exceed 10 ms.

2.5.5 IF Markers Using the Option SWOB5-B3 (SWOB5-B4)

For IF marker display using the option SWOB5-B3, the IF is applied to the input socket 11. Suitable measuring heads are the Insertion Unit SWOB5-Z3, the Active Demodulator SWOB5-Z4 or, if appropriate, the Log Probe SWOB5-Z2. The input socket is terminated with 50 Ω. The input level required

in the frequency range 5 MHz to 50 MHz .... 1 mV to 200 mV,
in the frequency range 0.5 MHz to 150 MHz .... 10 mV to 200 mV.

The pushbutton EXT. (7 in Fig. 2-16) must not be depressed. Simultaneous display of IF and RF markers is possible (pushbutton 100, 100 10, or 10 1 depressed).

In the case of test items with low selectivity at the IF output, the reradiated oscillator signal may reduce the gain of the input amplifier of the option SWOB5-B4 such that the markers are no longer displayed. A low-pass filter (f_{cutoff} = 60 MHz, approx.) is, therefore, supplied with the SWOB5 that can be mounted on the Basic Unit SWOB5-B3 in the place of the connecting link between ST3 and ST4.

Two plug-in crystal oscillators are used for marker synthesis. A trimming potentiometer is provided on the oscillator boards. It is accessible from the top and permits the width of the markers to be reduced. Only the potentiometer located on the oscillator board facing the front panel is operative. Hence, if the Basic Unit is fitted only with one oscillator, this should be inserted in the front retaining clips.

NOTE: The laterally accessible potentiometer on the oscillator boards is factory-adjusted and must not be tampered with.

For IF marker display pulse or line markers can be selected (pushbuttons 7). Distinction between the IF and the RF markers is possible by turning the socket BU303 on the central motherboard by 180° (section 6.3), i.e. the RF markers are displayed as line markers when the IF markers are displayed as pulse markers and vice versa.

An IF of ≦ 300 kHz is directly displayed at a suitable level. Thus a further marker may occur at 0 MHz in addition to the two crystal markers. If overdriven, still other intermediate markers caused by harmonics and non-harmonic spurious signals are displayed.

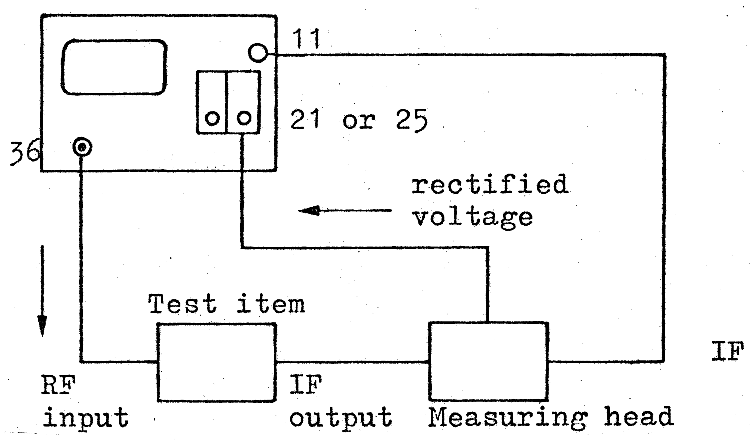


Fig. 2-4 Display of IF markers using the Option SWOB5-B3

2.5.6 Criteria for Selection of Sweep Width and Sweep Time

To obtain an undistorted display of the measurement result on the screen, it is necessary that the frequency of the test voltage is not swept more quickly than the filters connected in the signal path can reach steady state. Frequency change (sweep) speed v_{sw} depends on sweep time t_{sw}, sweep voltage and sweep width $F = f_2 - f_1$ of the swept RF:

$$v_{sw} = \frac{F}{t_{sw}}$$

All two-port networks with energy-storing components (low-pass, high-pass, bandpass and all-pass filters) require a transient time τ for reaching their final output voltage. For example, the transient time of a bandpass with a single tuned circuit (without delay distortions) results is approximately

$$\tau = \frac{1}{B}$$

where B is the 3-dB bandwidth of the filter. Consequently, time t_d (dwell time) during which the signal frequency is smoothly tuned over frequency range B must be equal to or greater than τ. The following relationship is valid:

$$t_d = \frac{K}{B}$$

Factor K depends on the design of the individual bandpass and indicates the ratio of t_d to τ.

If t_d is too short, filter transients result in an erroneous amplitude display on the screen. Due to the delay, the changing values are displayed too small for rising slopes and too high for falling slopes. With narrow-band filters, maximum amplitude is not at all attained. To keep this error as small as possible, sweep time is to be properly selected for a given bandwidth B and desired sweep width F. The relationship of these values is expressed by the following equation:

$$\frac{F}{B} = \frac{t_{sw}}{t_d}$$

For the limit case $t_d = \tau$, the following result is obtained:

$$B_{lim} = \sqrt{\frac{F}{t_{sw}}}$$

When measuring a single tuned circuit with bandwidth B_{lim}, the voltage increases during t_d up to 95% of its final value; thus the error amounts to

5%. If only small errors are tolerable, factor K has to be chosen greater than 1. Multi-circuit filters with the same 3-dB bandwidth as a single tuned circuit, but steeper slopes, require a K factor much greater than unity in order to obtain the same amplitude error.

The dependence of the amplitude error in transient response exists not only for the device under test but also for any selective two-port network inserted into the generator-to-CRT signal path (e.g. noise filter inserted in display channel using 28).

2.5.7 Selecting the Sweep Time

According to the criteria of the previous chapter, sweep time is adjusted using 38 (adjusting range 20 ms to 2 s). Doing this, it is useful to begin with slowest sweep time and to increase sweep speed using 38 until the display changes as compared to the display at slowest speed. Then, 38 is slightly turned counterclockwise towards slower speed until the original shape is just restored.

Sweep curve alterations occur mainly at the transition between steep slopes and nearly horizontal sections as well as at peaks and indentations; special attention should therefore be directed to these.

2.5.8 Measuring the RF Level

2.5.8.1 Level Measurement using LOG. AMPLIFIER Plug-in SWOB 5-E1

The logarithmic amplifier E1 in conjunction with the measuring heads SWOB 5-Z1 and -Z3 permits the display of RF levels from 170 µV to 1 V in one range. The display range can be limited to 80, 60, 40, 20 or 10 dB display height, using switch 20 (Fig. 2-16), which corresponds to a spread Y-axis display. Using the larger one of the double rotary knob 19 (black), the display can be vertically positioned to allow observation of the interesting sections of the sweep curve (e.g. passband of a bandpass filter) on the screen.

The logarithmic amplifier plug-in generates a horizontal line 3 facilitating the determination of the absolute or relative RF level at the input of the measuring head. The vertical position of this line can be adjusted between 0 dB and -100 dB (resolution 0.1 dB) using 10-turn potentiometer 17 which has a calibrated dial. The smaller knob 19 (red) may be used to shift the 0-dB position of the horizontal line from 0 dB ≙ 1 V (0 dB ≙ 100 mV with the Active Demodulator SWOB 5-Z4) to approx. 0 dB ≙ 250 mV (25 mV).

If the smaller (red) knob 19 is set to its CAL. detent position, 0 dB ≙ 1 V (100 mV) is true for the RF input of the measuring head. The red lamp 18 is lit whenever this knob is not in its calibrated detent position.

The level of a particular point on the sweep curve is determined by adjusting the horizontal line, using 17, to intersect the measurement curve at this point. The figure read from the dial on rotary knob 17 indicates the difference in dB between the actual (lower) RF voltage at the measuring head and the (higher) reference value which has been adjusted using 19 (small red knob).

If the reference value is to be calibrated to a different voltage between approx. 250 mV (25 mV) and 1 V (100 mV) using 19 (small knob), the measuring head must be directly connected to RF output 46. The RF voltage is now adjusted to the desired value using output voltage dividers 43 and 44; the screen will display a corresponding horizontal line. The dial knob 17 for the horizontal reference line is now set to 0 dB and the horizontal reference line is positioned to coincide with the display line using 19 (small knob). The new reference value of the level line will now equal the RF voltage adjusted with 43 and 44.

If particular sections of the sweep curve are of interest where the RF test voltage is below approx. 500 µV (approx. 50 µV with the Active Demodulator SWOB5-Z4), it is recommended that the 40-Hz noise filter be switched in using pull switch 38, to improve the signal-to-noise ratio (indicated by red light 37). As the transient time of the overall test setup is to some degree influenced by the noise filter, the sweep speed should be correspondingly decreased (see chapter 2.5.7).

2.5.8.2 Level Measurement using LIN. AMPLIFIER Plug-in SWOB 5-E2

With the linear amplifier used, the display voltage and thus the Y-axis deflection is proportional to the rectified voltage at AF input 25 or 26 (Fig. 2-16). Gain or sensitivity is adjusted using 22; 23 is used to vertically position the display. As all RF demodulators here concerned have a square-law characteristic at RF voltages below approx. 25 mV, a transition range between approx. 25 mV and 500 mV and a linear characteristic only at higher RF levels, it is necessary to calibrate the amplifier for level measurements according to the individual measurement voltage.

This calibration for determination of the relative level will be demonstrated, by way of an example, by the measurement of the 3-dB bandwidth of a selective amplifier (IF amplifier). It is assumed that the display is properly selected using 22 and 23 , and that neither the device under test nor the deflection amplifier (detector) is overdriven. An additional attenuation of 3 dB is inserted using 43 . Horizontal line 3 is adjusted by 14 or 15 to touch the maximum of the sweep curve. 43 is then returned to its original position, i.e. the output voltage is again increased by 3 dB. The horizontal line 3 will now intersect the curve at the 3-dB points. Same procedure applies for all similar measurement problems, two horizontal lines being available.

If the absolute level is to be measured at any point of the sweep curve in the example above, a horizontal line 3 should be positioned to intersect this point. The measuring head is then to be connected directly to RF output 46 . The output voltage should be adjusted using 43 and 44 - also using 44 (Fig. 2-17), if required - until the display line coincides with the horizontal reference line within ± 1 dB, if possible.

The absolute level is determined from the positions of 43 and 44 , taking into account the EMF level which has been switch-selected using 54 . Due to required impedance match, this procedure is only suitable for measuring heads SWOB 5-Z1 and Z3 as well as for the Active Demodulator SWOB 5-Z4 but not for the probes SWOB 5-Z2 and SWOB 3-Z.

2.5.8.3 Level Measurement using LOG. AMPLIFIER Plug-in SWOB 5-E3

The logarithmic amplifier E3 permits the display of levels from 170 µV to 1 V in one range using the measuring heads SWOB 5-Z1 and -Z3 or via the AF input. The display range can be limited to 100, 80, 50, 20 or 10 dB display height by means of switch 30 (Fig.2-16), which corresponds to a spread Y-axis display. Using the rotary knob 31 mounted on the range selector, the display can be vertically positioned to allow observation of the interesting sections of the sweep curve (e.g. passband of a bandpass filter).

The logarithmic amplifier plug-in produces a calibrated horizontal line 3 . The vertical position of this line is adjustable by means of a 10-turn potentiometer (29). The level corresponding to the line position is read out in mV, dBV or dB on a 3 1/2-digit display 27 . In absolute measurements the level of a particular point on the sweep curve is determined by adjusting the horizontal line by means of 29 so as to intersect the measurement curve at this point. The readout obtained is the desired level in mV or dBV at this point.

When operating the SWOB 5-E3 in conjunction with the Active Demodulator SWOB 5-Z4 the 20-dB gain of the latter is automatically taken into consideration in the level indication.

In relative measurements (slide switch 28 in position dB) any desired reference point can be selected by means of pushbutton 36 , the reference level (0 dB) corresponding to the level of the actual position of the horizontal line. If the horizontal line is shifted to another point on the measurement curve using 29 the readout obtained is the difference in dB between the input voltage and the selected reference level.

If particular sections of the sweep curve are of interest where the test voltage is below approximately 500 µV (approximately 50 µV with the Active Demodulator SWOB 5-Z4), it is recommended that the 40-Hz low-pass filter be switched on by means of the pull switch 38 (red LED 37 lights up if ON) to improve the signal-to-noise ratio. Since the settling time of the overall test setup is to some degree influenced by the low-pass filter, the sweep should be correspondingly decreased (see chapter 2.5.7).

2.5.9 Measurement of Transmission Parameters $|S_{21}|$ and $|S_{12}|$

2.5.9.1 Measurement of $|S_{21}|$ and $|S_{12}|$ using the LOG. AMPLIFIER Plug-in SWOB 5-E1

To measure forward transmission, the device under test is to be connected as shown in Fig. 2-2. The test setup will provide the corresponding reverse values if input and output of the two-port network are reversed.

Only the measuring heads SWOB 5-Z1, SWOB 5-Z3 with terminating resistor or the Active Demodulator SWOB 5-Z4 may be used for this measurement, as the device under test must be terminated by Z according to the definition of S_{21} (S_{12}). It should also be ensured that the total configuration is kept free from overdrive (S parameters are small-signal parameters).

The calibrated horizontal line of the logarithmic amplifier plug-in E1 permits determination of the magnitude of S_{21} (S_{12}) in dB at any point of the sweep curve in a simple way: 19 (small knob) is turned clockwise into its CAL. detent position. Using 17 , the horizontal line 3 is positioned to intersect the desired point on the sweep curve. Level p_2 is read in dB referred to 1 V from the dial of 17 .

If the Active Demodulator SWOB 5-Z4 is used for the measurement as described above, 20 dB is to be subtracted from the value of p_2 to take into account the gain before the detector.

The dB values indicated by <u>43</u> and <u>44</u> represent p_1.

If a 75 Ω version of the SWOB 5 (333.0019.72) is used, 3.1 dB has to be subtracted from the p_1 value.

If the EMF selector switch <u>54</u> is set to its V_{OUT} = 0.5 V position (model 333.0019.52) or the V_{OUT} = 0.35 V position (model 333.0019.72), another -6 dB has to be added to the (corrected) value of p_1.

$$S_{21} \text{ dB} = p_2 - p_1$$

where p_1 is obviously the corrected value.

Example: p_1 = -10 dB p_2 = -6 dB

The SWOB 5 (333.0019.52) is used for this measurement together with a demodulator or insertion unit. Switch <u>54</u> is set for an output voltage of 0.5 V.

Due to the setting of <u>54</u> p_1 = -16 dB

S_{21} = -6 dB - (-16 dB) =
= 10 dB

The device under test thus amplifies by 10 dB. The procedure is the same for determination of S_{12} in dB.

2.5.9.2 Measurement of $|S_{21}|$ and $|S_{12}|$ using the LIN. AMPLIFIER Plug-in SWOB 5-E2

The device under test is connected as described in chapter 2.5.9.1. Due to reasons explained in chapter 2.5.8.2, a calibration has to be performed. For this purpose, the measuring head (SWOB 5-Z1 or Z3 with terminating resistor) is immediately connected to RF output <u>46</u> (Fig.2-16). The RF output voltage is selected using <u>43</u> and <u>44</u> so as to avoid overdriving of the device under test. The attenuations of <u>43</u> and <u>44</u> are noted as p_1. A horizontal line <u>3</u> is brought in coincidence with the display line by adjusting either of buttons <u>5</u> and <u>6</u>. Then the device under test is connected between the generator and the measuring head. The output voltage is now to be varied using <u>43</u> and <u>44</u> until the sweep curve intersects the horizontal line at the desired frequency within a tolerance of ±1 dB. The new positions of <u>43</u> and <u>44</u> represent S_{21} or S_{12} in dB.

$$S_{21} \text{ dB} = p_1 - p_2$$

Example:

At calibration p_1 = -10 dB

With device under test p_2 = -20 dB

S_{21} = -10 dB - (-20 dB) = 10 dB

The device under test thus amplifies by 10 dB.

2.5.9.3 Measurement of $|S_{21}|$ and $|S_{12}|$ using the LOG. AMPLIFIER Plug-in SWOB 5-E3

The measurement procedure is the same as described in chapter 2.5.9.1. The slide switch 28 must be set to the dBV position. When using the Active Demodulator SWOB 5-Z4 the 20-dB gain need not be subtracted from the indicated value p_2 as this is automatically considered in the level indication.

2.5.10 Measurement of Impedance Match and Reflection

2.5.10.1 Measurement of Return Loss

The following relationship exists between return loss a_r in dB and the magnitude of reflection coefficient $\bar{r}$:

$$a_r \quad dB = 20 \lg \frac{1}{|\bar{r}|}$$

The return loss can be measured in a simple way using the SWOB 5 together with an impedance-matching bridge or a directional coupler. The reflection coefficient results as:

$$|\bar{r}| = 10^{\frac{-a_r}{20\ dB}}$$

2.5.10.1.1 Measurement of Return Loss using the VSWR Bridge SWOB 4-Z

The test setup for determination of return loss using the VSWR Bridge SWOB 4-Z is shown in Fig. 2-3.

The bridge is available with a characteristic impedance of 50 or 75 Ω. It may be used in the frequency range of 5 to 1000 MHz; its directivity amounts to > 40 dB. A detailed description of the bridge is found in the appendix.

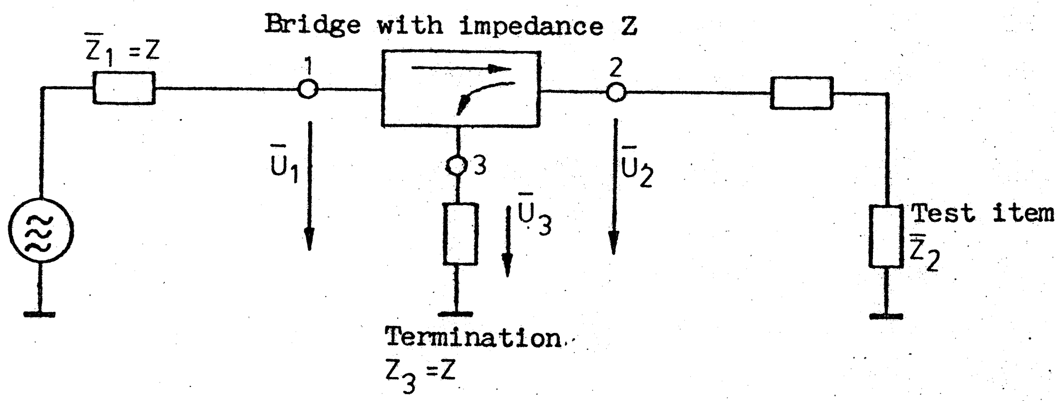


Fig. 2-5 Impedance-match measurement using the bridge

For a better understanding of the test setup of Fig. 2-3, a description of Fig. 2-4 should be given first. The forward wave is attenuated by 6 dB between generator port 1 and device-under-test port 2. If 2 is terminated with an impedance not equal to Z, a reflected wave travels from 2 to 3 which is again attenuated by 6 dB. The magnitude of voltage $\bar{U}_3$ is a measure of the return loss at 2.

In the case of $\bar{r} = 1$ (e.g. short or open circuit at 2), the level at 3 is 12 dB below the level at input 1. This value corresponds to a return loss of 0 dB. With increasing return loss, i.e. improved impedance match at 2, $\bar{U}_3$ decreases proportionally and will theoretically become zero at $\bar{Z}_2 = Z$. In practice, however, no return loss better than the directivity of the bridge can be measured.

For rectifying the voltage $\overline{U}_3$ either the Demodulator SWOB 5-Z1, the Insertion Unit SWOB 5-Z3 with terminating resistor or the Active Demodulator SWOB 5-Z4 can be used. Depending on the requirements for display sensitivity, dynamic range and operating convenience, the linear or a logarithmic amplifier plug-in is to be used to process the rectified voltage.

If a voltage $\overline{U}_2$ = 10 mV is applied to the device under test as is common practice for measurements on input stages of tuners or similar, a dynamic range of approx. 29 dB (noise limit) can be obtained using the logarithmic amplifier plug-in. If the Active Demodulator SWOB 5-Z4 is used in addition to the logarithmic amplifier plug-in, the useful dynamic range is increased to at least 40 dB. The limit is set by the directivity of the bridge.

If the linear amplifier plug-in is used, a display range of approx. 20 dB is obtained at proper settings of sensitivity and display position using 22 and 23 . If the Active Demodulator SWOB 5-Z4 is connected in addition, this dynamic range is maintained up to a voltage $\overline{U}_2$ = 2 mV at the device under test.

A quantitative determination of return loss is on principle a level measurement at terminal 3 of the bridge (see chapter 2.5.8). The reference value of 0 dB is the level at terminal 3 which is also obtained at terminal 2 with short or open circuit. If the logarithmic amplifier plug-in E1 is used as deflection amplifier, its horizontal line 3 is to be brought to coincidence with the display line concerned, by turning 17 . The numerical value read from dial 17 equals the reference level or return loss of 0 dB. If the device under test is then connected to terminal 2, the return loss can be determined in this way at every point of the sweep curve. For this purpose, horizontal line 3 is adjusted by 17 to intersect the curve at the desired point. The corresponding numerical value is to be subtracted from the reference level to yield the return loss a_r in dB.

Example: Reference level: -30 dB
Reading at desired curve point: -50 dB
Reference level - measurement level = -30 dB - (-50 dB) = 20 dB
Return loss is thus 20 dB.

When using the logarithmic amplifier plug-in E3 the return loss is read out directly on the digital display. For this purpose, the slide switch 28 is to be set to the dB position and 29 turned until the horizontal line 3 is positioned such that it coincides with the display line (measuring head at terminal 3 of the VSWR bridge). At the push of button 36 the reference level (0 dB) is set to correspond to the level at this point. If the device under test is now connected to terminal 2 the return loss can be determined at any point of the sweep curve. The horizontal line 3 is adjusted such by means of 29 that it intersects the curve at the desired point. The return loss a_r is read out on the display directly in dB.

If a linear amplifier plug-in serves as the deflection amplifier, calibration has to be performed using output dividers 43 and 44 . To do this, the reference value is first to be determined by applying open or short circuit to terminal 2 of the bridge. The reference value can be identified with a horizontal line 3 of the basic unit, adjusted by 14 or 15 . The output voltage at RF output 46 is now decreased by the amount of the return loss to be measured by means of 43 and 44 , and the obtained position of the display line is identified using a horizontal line. 43 and 44 are now returned to their original positions and the device under test is connected to bridge terminal 2. At the intersection of the sweep curve with the horizontal line, the return loss equals the attenuation increase introduced by 43 and 44 during calibration. As two horizontal lines are provided in the basic unit, two attenuation settings can be identified. As the SWOB 5 has two display channels, return loss and transmission can be displayed simultaneously on the screen; this is of advantage for tuning input circuits of receiver stages or filters. The connecting line between bridge terminal 2 and the device under test should be kept as short as possible to avoid measurement errors by non-ideal RF-cables.

2.5.10.1.2 Measurement of Return Loss using Directional Coupler

A directional coupler (e.g. ZPW) can also be used for reflection measurements, allowing measurement and continuous display of return loss a_r in dB over a wide frequency range. Fig. 2-6 shows the test setup with the directional coupler ZPW.

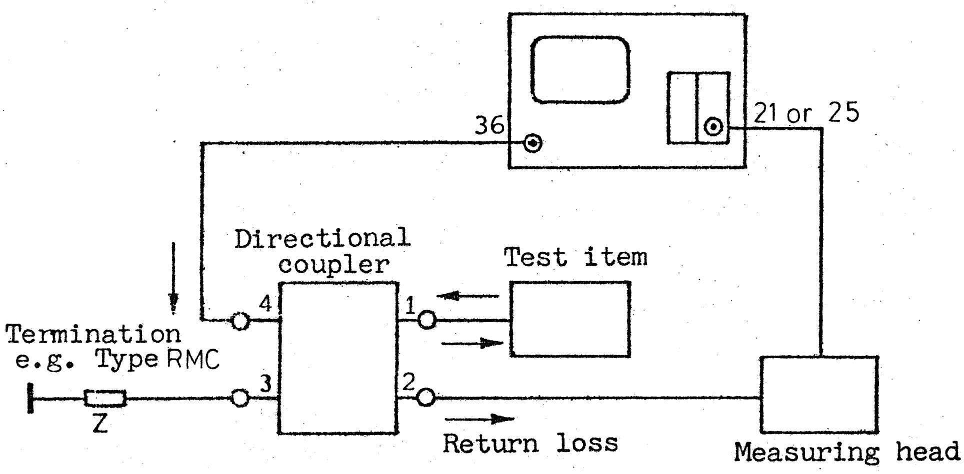


Fig. 2-6 Measurement of Return Loss

The directional coupler consists of two parallel running, coupled conductors which are enclosed by a common outer conductor. At mid-band frequency, the configuration has a length of $\lambda/4$; coupling attenuation is, depending on the characteristic impedance, 3 or 4.5 dB. To achieve the high directivity of 50 dB, terminals 1 to 4 must be connected to the other units as shown in Fig. 2-6. If the generator and the display section match to terminals 4 and 2 (source impedance = Z), the voltage existing at 2 is a measure of return loss. Selection of the appropriate deflection amplifier and its operation are governed by the same considerations as in the measurement using the impedance-match bridge (see chapter 2.5.10.1.1).

The directional coupler covers a narrower frequency band than the bridge but introduces somewhat less attenuation (between 1.5 and 3 dB, depending on characteristic impedance).

2.5.10.2 Reflection Measurement using an Extension Cable

2.5.10.2.1 VSWR Measurement

To check the VSWR, an extension cable (RF cable with very small inhomogeneities) can be connected between RF output 46 (Fig. 2-16) and the device under test. An Insertion Unit SWOB 5-Z3 is inserted into this connection to allow monitoring of the RF output voltage. The linear amplifier plug-in E2 is sufficient for display. As a matter of course, also the logarithmic amplifier plug-ins E1 and E3 may be used for this purpose.

The characteristic impedance of the extension cable must come very close to the nominal impedance of the device under test for good impedance match.

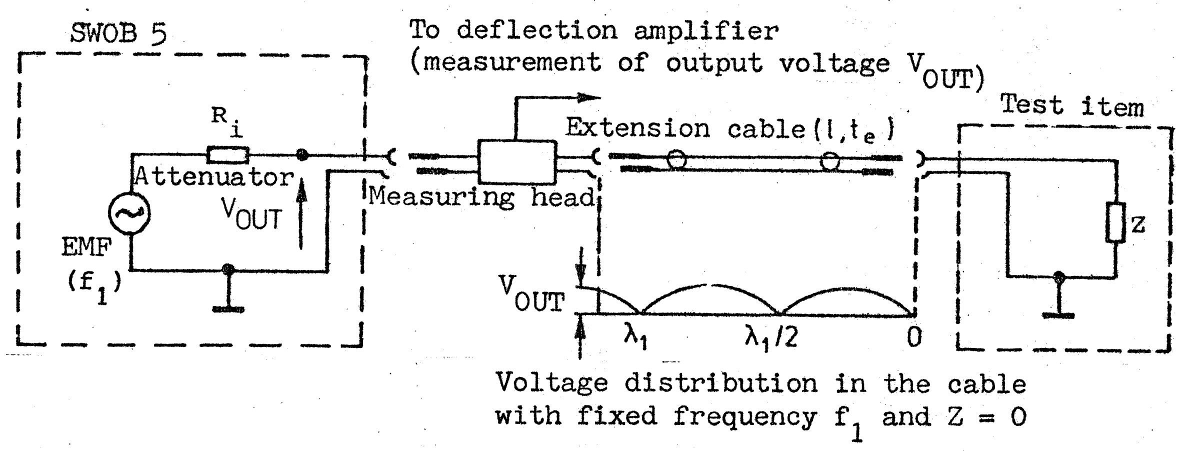


Fig. 2-7 Reflection Measurement using extension cable

The measurement principle is illustrated by Fig. 2-7. The EMF source symbolizes the swept and regulated RF voltage before the output divider, representing the source impedance (50 or 75 Ω). If the output of the extension cable of mechanical length l is short-circuited (Z = 0) and a voltage V_{OUT} with a fixed frequency f_1 is applied to its input, a voltage distribution as shown will occur along the cable. This voltage distribution is caused by total reflection of the forward energy at the cable output, at which always a voltage minimum (maximum for open circuit at cable output) will exist.

More minima (maxima) appear, due to time-dependent phase shift of the forward and reverse waves at distances of λ/2 from the output of the cable. Generally,

$$\lambda = \frac{v_o}{\sqrt{\varepsilon_r} \cdot f}$$

where v_o is the light velocity and ε_r the dielectric constant of the cable. Number N_K of voltage minima (maxima) along the cable depends on f and l and on the echo transmission time t_e (t_e equals twice the cable delay):

$$N_K = \frac{2l \cdot \sqrt{\varepsilon_r}}{v_o} \cdot f = t_e \cdot f$$

Voltage V_{OUT} at the input of the extension cable has a fixed value. If, however, the frequency is swept at a constant EMF, the minima along the cable will constantly change their positions. As a result, the value of V_{OUT} measured at the input and displayed as a function of frequency will also vary.

If, for example, f_1 is increased by F to f_2, only the minimum at the output of the cable will remain unchanged but the other minima will shift towards the cable output until they are mutually spaced $\lambda_2/2$. Voltage V_{OUT} will assume intermediate values between maximum and minimum the frequency changes from f_1 to f_2. The deflection voltage being synchronous with the sweep voltage, a standing display will be seen on the screen (Fig. 2-8).

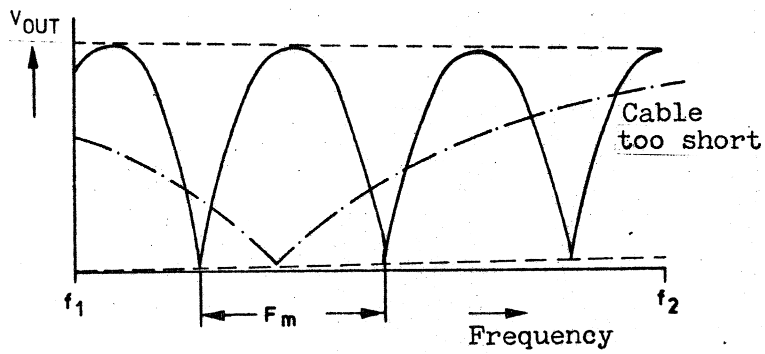


Fig. 2-8 Voltage waveform displayed on screen

Due to the cable losses, the extreme values of V_{OUT} cannot be fully reached at increasing frequency. The distance F_m between two minima (maxima) will remain constant as it depends only on the cable length l or echo transmission time:

$$F_m = \frac{1}{t_e}$$

Number N_B of the voltage maxima occurring at the point of V_{OUT} measurement and displayed on the screen depends on l and $F = f_2 - f_1$:

$$N_B = \frac{2l \cdot \sqrt{\varepsilon_r}}{v_o} \cdot F = t_o \cdot F$$

If the terminating impedance Z of the cable is selected between the extreme values 0 and ∞ , the VSWR of V_{OUT} will decrease until it becomes zero at $Z = Z_o$ (characteristic impedance of the cable). If Z differs from Z_o, the input impedance of the cable as seen from the test point of V_{OUT} will contain reactance components. Due to this fact, the VSWR may vary with frequency.

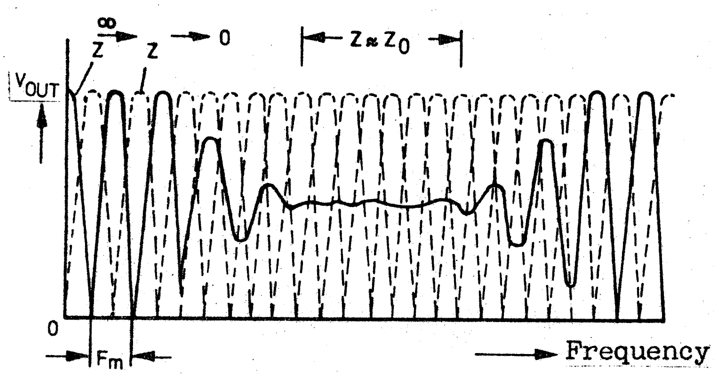


Fig. 2-9 Frequency-dependent VSWR

Fig. 2-9 shows the three possible screen displays, Z being the parameter; losses are neglected.

Measurement procedure:
First of all, the extension cable must be long enough to give a display of at least two voltage maxima or minima, as otherwise evaluation of the VSWR would be impossible (Fig. 2-8). The actual cable length is chosen depending on the desired spacing or number of maxima displayed, using the formulas given above.

Example: The impedance match of a device Z is to be determined in the 530 to 560 MHz frequency range. The maxima are to be spaced 5 MHz; the shortening factor $S = 1/\sqrt{\varepsilon_r}$ of the cable is assumed to be 0.7.

The echo transmission time

$$t_e = \frac{1}{F_m} = \frac{1}{5 \cdot 10^6} = 0.2\ \mu s$$

corresponds to a mechanical cable length

$$l = v_o \cdot S \cdot t_e/2 = 3 \cdot 10^8 \cdot 0.7 \cdot 0.2 \cdot 10^{-6}/2 = 21\ [m]$$

The display will show a number of

$$N_B = t_e \cdot F = 0.2 \cdot 10^{-6} \cdot (560 - 530) \cdot 10^8 = 6$$

maxima (minima).

This shows that the cable must be the longer, the narrower the examined frequency band F is. R&S proposes two extension cables with electrical lengths l/S of 11.6 m and 65 m.

The voltage demodulated at the input of the extension cable by the Insertion Unit SWOB 5-Z3 is fed to the display section through 21 or 25 and displayed on the screen. An attenuation of 6 dB is to be adjusted using output voltage divider 43 for these measurements to avoid reactions on the EMF control at heavy mismatch (> 25% of Z of output 46).

2.5.10.2.2 Measurement of Magnitude and Phase of Reflection Coefficient

a) Determining the Magnitude

The magnitude of the reflection coefficient can be determined by two methods using the extension cable.

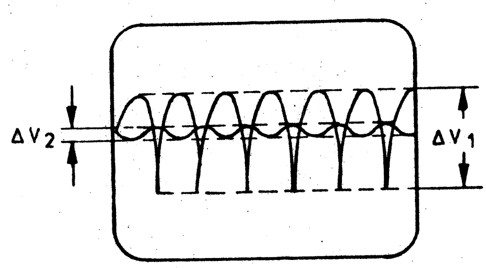


Fig. 2-10 Measurement of reflection coefficient, method 1

By the first method, the amplitude ratio of the output voltage distribution at open-circuit of the cable and with termination by the device under test is evaluated as per Fig. 2-10. The reflection coefficient is

$$|\bar{r}| = \frac{\Delta V_2}{\Delta V_1}$$

Output voltage divider 44 is to be switched to -10 dB for this measurement. The minimum or maximum values which yield the voltage differences ΔV_1 (open-circuit) and ΔV_2 (termination by device under test) are determined according to chapter 2.6.7. The logarithmic amplifier plug-ins E1 or E3 are preferrably used for this application because of their calibrated level reference line.

A second method may be used to determine the magnitude of reflection coefficients $|\bar{r}| < 0.15$; this is also suitable for use of the Linear Amplifier plug-in SWOB 5-E2 (Fig. 2-11).

At the generator output (RF insertion unit), a forward (incident) voltage v_{inc} and a backward (reflected) voltage v_{refl} beat against each other, where v_{refl} is delayed by echo transmission time t_e and the amplitude of v_{refl} decreased by the cable loss. With the attenuation constant α in N/cm and the physical length l of the cable in m

$$v_{inc} = V_o \cdot \sin\omega t,$$

$$v_{refl} = V_o \cdot |\bar{r}| \cdot \exp(-2\alpha l) \cdot \sin\omega(t + t_e).$$

Sum voltage

$$v = V_o \left[(1 + |\bar{r}| \cdot \exp(-2\alpha l) \cdot \cos\omega t_e)\sin\omega t + (|\bar{r}| \cdot \exp(-2\alpha l)\sin\omega t_e) \cos\omega t\right]$$

appears at the test detector.

The cos term may be neglected for $|\bar{r}| < 0.15$. The amplitude of the resulting HF is thus

$$v_H = V_o \, (1 + |\bar{r}| \cdot \exp(-2\alpha l) \cos\omega t_e).$$

The second term of this sum defines the envelope curve of the RF; it reaches a maximum

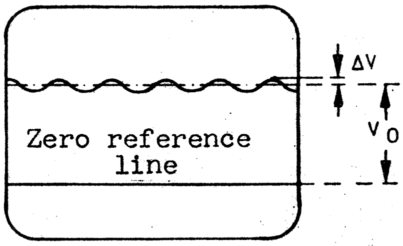
$$V = V_o \cdot |\bar{r}| \cdot \exp(2\alpha l)$$

if $\cos\omega t_e = 1$. The spacing of the maxima is defined by

$$\omega t_e = n \cdot 2\pi \qquad (n = 1, 2, 3 \ldots, i)$$

with $\omega = 2\pi \cdot F_m$

$$F_m = \frac{1}{t_o}$$



To be able to insert the cable loss "a" in dB, the following transformation is introduced:

$$\exp(2\alpha l) = 10^{2a/20}$$

This yields a reflection coefficient of

$$|\bar{r}| = \frac{\Delta V}{V_o} \cdot 10^{2a/20}$$

Fig. 2-11 Measurement of reflection coefficient, method 2

$\Delta V/V_o$ is obtained from level ratio p in dB:

$$p = 20 \lg \frac{\Delta V + V_o}{V_o}$$

$$\frac{\Delta V + V_o}{V_o} = 10^{p/20}$$

$$\frac{\Delta V}{V_o} + 1 = 10^{p/20}$$

$$\frac{\Delta V}{V_o} = 10^{p/20} - 1$$

If the linear amplifier plug-in is used for display, p is determined in dB using output voltage dividers 33 and 34. The non-linearity of the test detector will not cause any errors. If the logarithmic amplifier plug-in is used, p is measured utilizing the calibrated horizontal line.

Example: $\frac{\Delta V + V_o}{V_o}$ has been determined as 0.5 dB

cable loss "a" is assumed to be 3 dB.

From the measurements results $\Delta V/V_o = 0.06$

and, taking the cable loss into account, the reflection coefficient

$$|\bar{r}| = 0.06 \cdot 2 = 0.12$$

b) Determining the Phase Angle

The phase angle of the reflection coefficient can be determined from the shift of the voltage maxima (minima) at different termination conditions of the cable. As described in chapter 2.5.10.2.1, a voltage minimum (maximum) occurs at the output of a short-circuit (open-circuit) cable ($\varphi = \lambda/4$ for maximum). If terminating impedance Z ranges between 0 and ∞, intermediate values of φ will result, causing a corresponding shift of maxima and minima at the test point of V_{OUT} and on the screen.

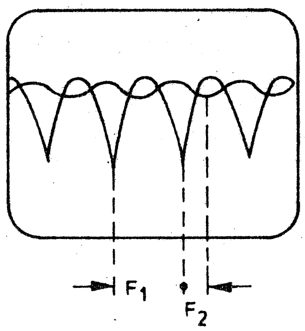


Fig. 2-12 Phase angle of reflection coefficient

For a measurement, the cable is first operated on open circuit and the frequency difference F_1 between two minima is determined using an external marker (Fig. 2-12). When the cable is terminated with the device under test, a minimum is shifted by the amount of F_2 as compared to the value measured before. The phase angle is

$$\varphi = 2\pi \cdot \frac{F_2}{F_1}$$

The sweep width should be reduced for the measurement to keep the error small.

2.5.11 Recorder Operation

2.5.11.1 Recorder Operation Without the Slow Sweep Option

Connectors are available at the rear panel of the unit to operate an XY recorder. The 6-pin socket 63 (Fig. 2-17; pin assignment as per chapter 2.2.12) - to which a suitable plug (018.6646) and a recorder connecting cable (289.5450.02) are available - or BNC connectors 60, 61 and 62 (corresponding to outputs X, YII and YI) can be used. In all sweep modes (MAN., AUTO and SINGLE), the deflection voltages are permanently present at the outputs, causing continuous recorder deflection also in the AUTO mode. The option "slow sweep" (see chapter 2.5.11.2) offers more operational convenience. The pen is only actuated in the SINGLE mode and during forward sweep. Pulse markers are recorded, but not line markers nor horizontal lines. The maximum available sweep time is 2 s. In the MAN. mode, the deflection of the recorder can be calibrated.

2.5.11.2 Recorder Operation with Option "Slow Sweep" SWOB 5-B2

When equipped with the "slow sweep" option, the recorder is also connected to 63 (Fig. 2-17) or to the BNC connectors 60, 61 and 62. Pin assignment remains unchanged.

Sweep time for a single sweep is now approx. 30 s in SINGLE mode. As the deflection amplifiers may drift considerably during this time, a shorter control phase is introduced to stabilize the deflection amplifiers. The resulting blanking intervals are bridged by a sample-and-hold circuit for both Y-axis outputs and for the X-axis output. The pen travel is delayed by 0.3 s against the sweep start to eliminate transient responses. High-speed recorders (e.g. ZSK 2) can proceed within this time from any starting point to the beginning of the test curve and settle.

In MAN. mode, the X-axis and Y-axis outputs are switched in, but the pen is not actuated. This mode allows adjustment of the recorder to suit the test curve as this can be manually swept. When a recorder with longer settling time is used, the settling process can be eliminated by manually moving the recorder pen (MAN. mode) to the starting point of the curve to be recorded. When switching from MAN. to SINGLE mode, the curve point set last (e.g. starting point) is stored in the sample-and-hold circuit.

In AUTO mode, the X-axis and Y-axis outputs are disabled, the pen is not actuated and the sweep time is not changed.

If pulse markers are switched in, these are recorded on the test curves. Level lines and line markers cannot be recorded.

2.6 Measurement Examples

2.6.1 General

In the following paragraphs, several important applications of SWOB 5 are explained using appropriate examples. The operation instructions given in chapter 2.5 should be observed for all measurements.

If the device under test contains limiting or active elements, it should be checked whether an overdrive condition exists. For this purpose, the RF voltage is to be varied using output dividers 43 and 44 (Fig. 2-16); this should then result in a proportional change of the screen display. Otherwise the device under test or the display channel of the SWOB 5 is overdriven and the RF level must be decreased by adjusting 43 and 44.

Sweep time is to be selected as indicated in chapters 2.5.6 and 2.5.7.

2.6.2 Measurement on Amplifier Stages with Parallel Resonant Circuits

An amplifier stage with a parallel resonant circuit at its output is one of the most commonly found basic circuits in RF engineering. Resonance frequency, 3-dB bandwidth and stage gain are the quantities of main interest.

If selectivity requirements are more stringent, the single tuned circuit is combined with others to form a multi-circuit bandpass filter. This requires proper alignment of the individual circuits for tuning to the desired resonance frequency as well as coupling adjustments to obtain the desired frequency response.

The test voltage is applied through a shielded cable which should be as short as possible, according to Fig. 2-13.

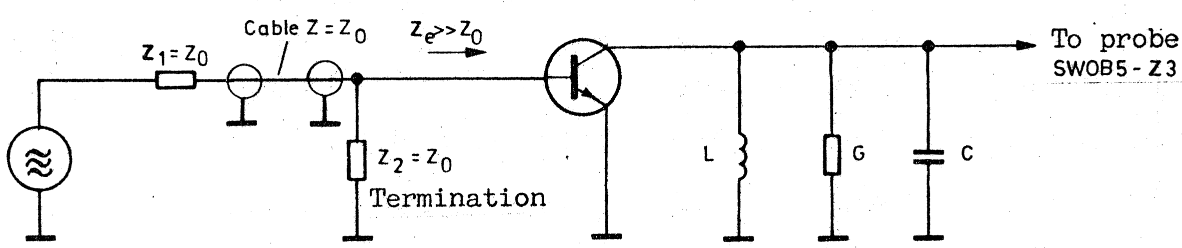


Fig. 2-13 Amplifier with parallel resonant circuit

In general, sufficient decoupling between sweep generator and tuned circuit is achieved. The following should be observed (see chapter 2.5.1.2): If the feeding point carries DC against ground (base bias), an isolating capacitor should be used. If the cable is long and mismatched as much that the fluctuations of the RF voltage at output <u>46</u> (Fig. 2-16) are greater then 20% within the frequency range of interest, the input of the device under test is to be terminated with the characteristic impedance Z_o of the cable (Fig. 2-13). Any existing reactance components must be compensated for by introducing a suitable capacitance or inductance. The input voltage should be selected to avoid overdriving of the device under test and of the display channel. As a rule, a probe (SWOB 3-Z or SWOB 5-Z2) will be connected to the stage output (Fig. 2-13).

Measurement of Resonance Frequency

Coupling of the probe and of the generator to the tuned circuit must be loose enough to avoid detuning and damping of the circuit. If direct coupling to the high side of the circuit is not possible, coupling can be established through a series capacitor of approx. 1 pF. Depending on the level, it might be sufficient to hold the probe close enough to the circuit to be measured to obtain good results.

The resonance frequency can be determined using the internal marker scale, an external RF voltage with variable frequency (external marker) or the variable frequency marker together with a frequency counter with trigger capability (see chapter 2.2.3).

Measurement of 3-dB Bandwidth

If the logarithmic amplifier plug-in E1 is used, the calibrated horizontal line is positioned to the resonance maximum and 17 is read in dB. Now, the level line is decreased by 3 dB. The intersections of the horizontal line with the sweep curve identify the cutoff frequencies.

If the logarithmic amplifier plug-in E3 is used the measurement is still simpler. The calibrated horizontal line is positioned to the resonance maximum (switch 28 in position dB), then the 0-dB button is pressed and the level line is lowered to -3 dB. The intersections of the sweep curve with the horizontal line now identify the cutoff frequencies.

If the linear amplifier plug-in is used, first the attenuation of divider 43 is increased by 3 dB. The resonance maximum is now identified using a horizontal line of the basic unit (14 or 15). Then 43 is again placed to its original setting. The intersections of the resonance curve with the horizontal line give the 3-dB bandwidth. As commonly known, the Q can be calculated from resonance frequency and 3-dB bandwidth.

Measurement of Stage Gain

A reference value must be established to measure stage gain. For this purpose, the probe is to be connected to the amplifier input; the value of the input voltage should be identified using the calibrated horizontal line 3 . The probe is then again connected to the output.

If the logarithmic amplifier plug-in E1 is used, the level can be read off on 17 . This dB-value is noted down. Then the level of the resonance maximum is determined. By subtracting the previously noted value (with correct polarity sign), the voltage gain is obtained in dB. If the output voltage of the device under test is greater than 250 mV, the reference value can be adjusted to 0 dB using the small knob <u>19</u> . The gain can then be determined without performing a subtraction.

If the logarithmic amplifier plug-in E3 is used the stage gain is measured similarly. The input level need not be noted down and subtracted since the reference level (0 dB) can be automatically set at any point. The display reads out the stage gain directly in dB.

Using the linear amplifier plug-in, the gain is measured with an error of less than 1 dB by introducing enough attenuation using 43 and 44 to bring the resonance maximum as close as possible to the identification line. The increase in attenuation adjusted with 43 and 44 equals the voltage gain in dB.

The measurements described above are generally performed in the same way if the amplifier has more than one stage or if mechanical or ceramic filters or crystal filters are in the amplifier path. Proper curve display is not possible any more with devices under test having very narrow bandwidth or steep slopes, because of residual FM of the sweep generator.

2.6.3 Measurement and Alignment of Impedance-matched Filters

Filters (high-pass, low-pass, all-pass, bandpass and band-rejection filters) for higher frequencies are usually impedance-matched at input and output (Fig. 2-14).

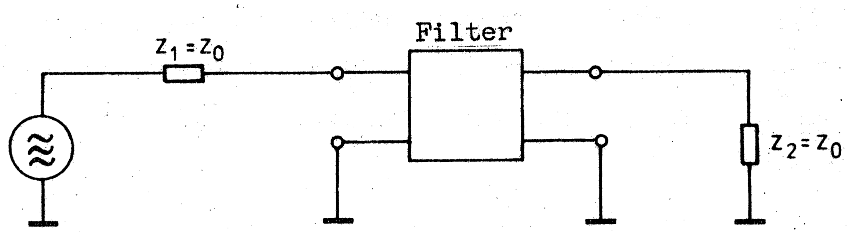


Fig. 2-14 Impedance-matched filter

With tunable configurations, it is mostly attempted to adjust for both optimum transmission behaviour and optimum input reflection. The SWOB 5 is ideal for this kind of adjustments as it allows simultaneous monitoring of both curves (transmission and reflection) through its two display channels. Test setup and procedure for these measurements using the linear or the logarithmic amplifier plug-ins are described in chapters 2.5.9 and 2.5.10 in full detail.

As these filters are impedance-matched, both the Demodulator SWOB 5-Z1 and the Insertion Unit SWOB 5-Z3 with appropriate termination are suitable for rectification of the test voltage. This allows use to be made of the full sensitivity and thus of the full dynamic range of approx. 75 dB (50 Ω version) of the logarithmic amplifier plug-ins E1 or E2 (as opposed to measurements using Probe SWOB 5-Z2) if the EMF is increased by 6 dB using selector switch 45 (rear panel, Fig. 2-17). The logarithmic display is here of particular advantage as far-off selectivity, spurious resonances, attenuation peaks, etc., can also be measured.

With such high sensitivities, harmonics of the sweep generator might under certain conditions cause interference (see chapter Specifications for harmonics attenuation).

Interference caused by harmonics is most easily recognized by sweeping the passband of a bandpass filter. If the passband of the filter goes from f_1 to f_2, the screen will display multiple frequency responses while the sweep generator is tuned through the frequency ranges f_1/n to f_2/n, ... , $f_1/3$ to $f_2/3$, $f_1/2$ to $f_2/2$, f_1 to f_2 (original range). In practice, n = 3 is rarely exceeded. The dB ratio of the curve maximum of the original display to the maximum of the n-th order display equals the corresponding harmonic attenuation.

The influence of the harmonics is less obvious when measuring a band-rejection filter. In this case, no greater attenuation is displayed than that which equals the harmonics attenuation (if at least double the frequency of the attenuation peak is within the passband, which is generally the case for a band-rejection filter.

In the display of a low-pass filter, the effective attenuation seems to decrease from the frequency at which its harmonics fall into the rejection band. This will be demonstrated using the following example: It is assumed that a low-pass filter has the cut-off frequency f_g, that only the 1st and 2nd harmonics are present and that the ratio of 1st to 2nd harmonic amounts to 40 dB. Under these conditions, a down step will be visible at $f_g/2$; below this point, the display is 1% too high. If a high-pass filter is swept under the same conditions as described above, only a maximum rejection-band attenuation of 40 dB can be measured above $f_g/2$. This shows that in practice harmonic interference creates problems only for measurements on band-rejection filters and high-pass filters, where the measured results may be poorer than the actual values.

Similar considerations apply to measurements of return loss using the impedance-matching bridge (see chapter 2.5.10). In this case, bandpass and low-pass filter are the problematical devices. No greater return loss can be measured than the value corresponding to the harmonic attenuation of the sweep generator (assuming an ideal impedance-matching bridge with infinite directivity).

2.6.4 Filter Alignment using a Standard

Due to its two display channels, the SWOB 5 is well suited for the alignment of filters against a standard in batch production testing. The standard and the device under test are connected to RF output 46 (Fig. 2-16) through a T-connector. The device under test is aligned until its test curve coincides with the standard curve. Both display channels are to be equipped with identical amplifier plug-ins and adjusted for equal sensitivity and display position.

2.6.5 Measurements on Wideband Amplifiers

Wideband amplifiers exhibit a frequency response similar to that of band-pass filters and measurements on them are, therefore, made in a similar way. Harmonics may cause the same measurement errors as those described in chapter 2.6.3. If the bandwidth covers more than one octave (video amplifiers, antenna amplifiers), wideband amplifiers can be considered as high-pass filters around their lower cut-off frequency and as low-pass filters around their upper cut-off frequency.

It should be noted that the device under test itself may contribute to deteriorate the harmonics ratio at high input levels.

2.6.6 Measurements on TV Receiver Modules

An important field of application for the SWOB 5 is the measurement and alignment of TV receiver modules such as tuners for bands I to V, picture and sound IF amplifiers, demodulators, chroma and video or luminance amplifiers.

2.6.6.1 Simultaneous Transmission and Reflection Measurement on Tuners

The high sensitivity of the logarithmic amplifier plug-ins permits transmission and reflection measurements on VHF and TV tuners of all frequency bands (I to V) at input levels as low as 5 mV. As the SWOB 5 is equipped with two display channels, the two test curves can be displayed simultaneously on the screen. Fig. 2-15 shows the test setup.

Each display channel is equipped with a Logarithmic Amplifier plug-in SWOB 5-E1. The impedance-matching bridge followed by modulator SWOB 5-Z1 is used for measuring the return loss. The IF output of the tuner is connected to the Active Demodulator SWOB 5-Z4, which increases the transmission channel sensitivity by 20 dB.

This configuration allows return losses greater than 20 dB to be measured (noise limit at approx. 23 dB). Assuming that the tuner has a gain of 20 dB in its passband, resulting in an IF voltage of 50 mV at the active demodulator, image frequency reception (or spurious responses) up to a signal-to-image ratio of approx. 68 dB can be displayed (noise limit below 20 µV). IF voltages greater than 50 mV will overdrive the active demodulator.

Reradiation of the tuner oscillator will be eliminated by the automatic RF spurious signal suppression of the logarithmic amplifiers, as long as it does not exceed 2 mV at the IF output and 40 mV at the tuner input.

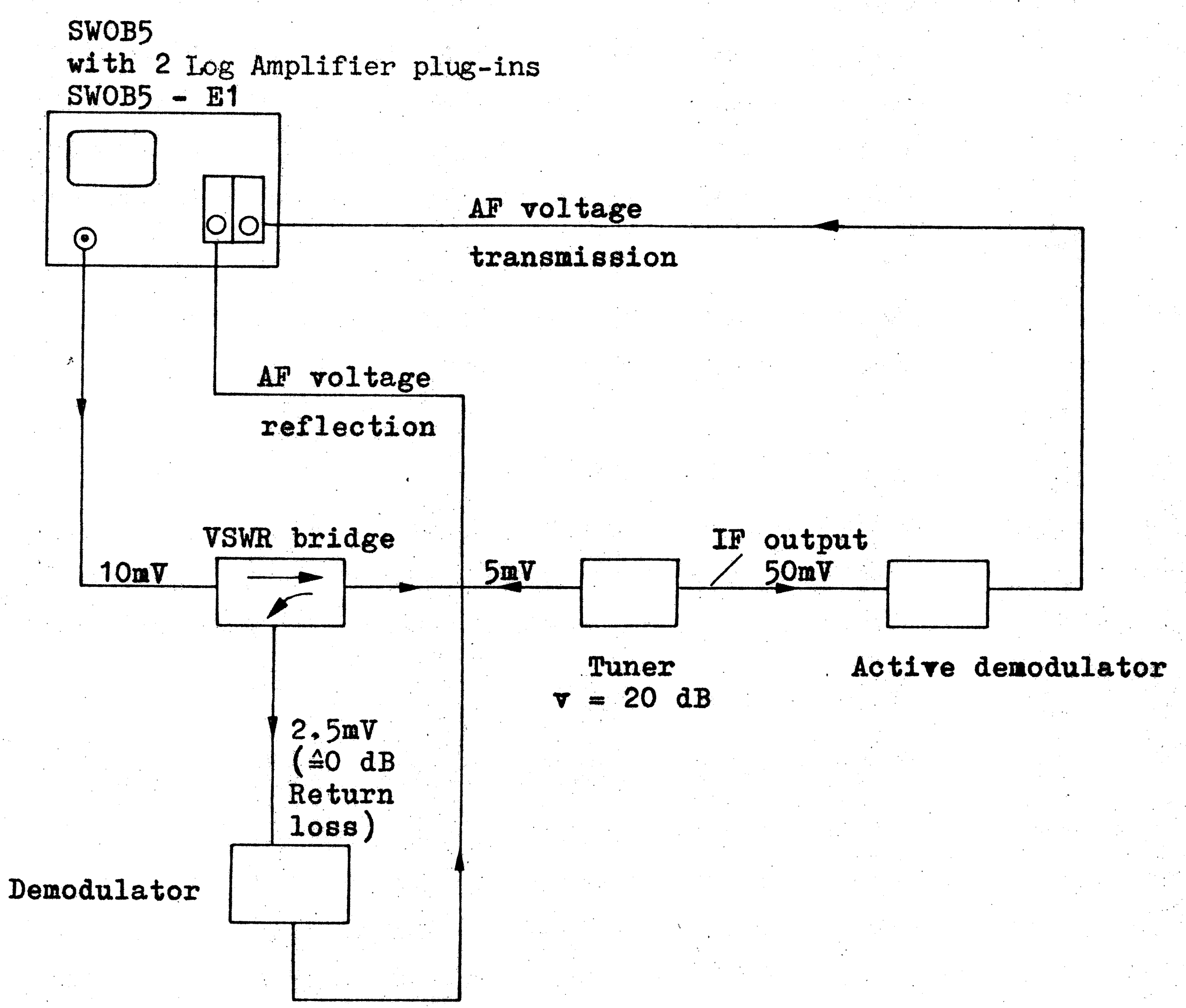


Fig. 2-15 Transmission and reflection measurement on tuners

2.6.6.2 Measuring the IF of TV Tuners with the Aid of the SWOB5-B3 IF Markers Option

The SWOB5-B3 option provides a convenient means of producing two markers of crystal accuracy that indicate the exact IF. Instructions for the connection of the tuners are given in section 2.5.5. Since a reradiated oscillator signal is to be reckoned with at the output of the tuner, in particular in band I, it is recommended that the low-pass filter (f_{cutoff} = 60 MHz, approx.) be inserted in the Basic Unit SWOB5-B3 in the place of the connecting link ST3 ⟶ ST4 (multipoint connector on the left-hand side). As the SWOB5-B3 option features a broadband input of up to 150 MHz which is controlled by PIN diodes, the low-pass filter prevents the control circuit to also respond to the oscillator signal. The clips retain the two crystal oscillators for picture and sound carrier. These can be replaced by oscillators for other frequencies.

If the tuner is, for example, adjusted to band I, the sweep width (39, Fig. 2-16) and the centre frequency (41 and 42) on the SWOB 5 must also be adjusted to band I. The RF markers may be used as an aid for the adjustment. At a sufficiently high tuner output level (section 1.3 Specifications), the two IF markers are superimposed simultaneously. If the tuner is varied, the position of the IF markers varies and so does the passband of the IF filter. Likewise, if the centre frequency (41, 42) on the SWOB 5 is varied, the position of the IF markers and the filter curve also vary. The spacing between RF and IF markers remains, however, constant. Details about the marker display are given in section 2.5.5.

2.6.6.3 Alignment of TV IF Amplifiers

Two logarithmic amplifier plug-ins together with SWOB 5-Z2 Probes are used for aligning TV IF amplifiers.

Band I is used to display the overall transmission characteristic. This is especially useful for observing the positions of attenuation peaks of traps required for IF selectivity. The logarithmic amplifier of the second display channel is switched for a display range of 10 dB. This channel is used to monitor the passband during alignment. The effects of trap alignment can thus immediately be recognized.

A linear amplifier plug-in may also be used to monitor the passband. The output voltage of the video demodulator can then be applied direct to AF input 26 (Fig. 2-16) of the linear amplifier. The overall characteristic including the IF amplifier input (or antenna input at the tuner) and the output of the video (luminance) amplifier can also be displayed.

For determining the frequency, it is possible to employ as usual the pulse and line markers. Furthermore, the bright-up marker 13 may be used to trigger a counter. Finally, the SWOB5-B4 IF Markers Option can be used which permits frequency markers of picture and sound carrier to be superimposed. The input of the SWOB5-B4 is either connected to the output of the item to be tested via an Insertion Unit SWOB5-Z3 (section 2.5.5) or, if the item to be tested has, for example, a high-impedance output, to the RF monitoring output 55 on the rear panel of the SWOB 5.

2.6.6.4 Alignment of Sound IF Section

In the commonly used sound IF configurations with a ceramic filter at the input, an integrated IF amplifier with limiter stages and a coincidence demodulator for FM demodulation, only the phase shifter circuit or a corresponding bandpass filter need be aligned. As integrated IF amplifiers have high gain and as limiting starts at approx. 10 µV, loose coupling to the sweep generator of the SWOB 5 or appropriate attenuation must be provided since the output dividers of the SWOB 5 permit its output voltage to be reduced only to a minimum of approx. 158 µV.

A linear amplifier plug-in is suited for display; the output voltage of the FM demodulator is to be applied to AF input 26 (Fig. 2-16). A coincidence demodulator will normally supply a DC voltage. The sum of signal voltage and DC component, however, must not exceed 1 V as the linear amplifier would otherwise be overdriven. If higher DC components are involved, a suitable isolating capacitor, for example, may help. This, however, will set a limit for the slowest possible sweep speed.

Because of the symmetry of the demodulator curve, the zero line of the display should preferably be positioned in the display centre. The range within which the curve remains unchanged can be determined by varying the RF amplitude using output dividers 43 and 44. This will also cover the function of the limiter stages.

These remarks also pertain to other FM demodulators such as ratio detectors, as well as to measurements on IF amplifiers of VHF radio receivers.

2.6.7 Cable Measurements

2.6.7.1 Determining the Dielectric Constant

A length of some meters of the cable to be measured is connected to RF output 36 (Fig. 2-16) via an insertion unit for the display of V_{OUT}. The other end of the cable remains open. The display of V_{OUT} will be similar to the curve of Fig. 2-7. The first voltage minimum is determined beginning at the lowest frequency range; its frequency should be measured as precisely as possible using an external marker or the bright-up marker after appropriately decreasing the sweep width. Frequency f_1 thus determined and the mechanical cable length l together with light velocity will yield the dielectric constant as follows:

$$\varepsilon = \left(\frac{3 \cdot 10^8}{4 \cdot \frac{f_1}{Hz} \cdot \frac{l}{m}} \right)^2$$

2.6.7.2 Determining Cable Loss

Cable loss increases with rising frequency. To measure cable loss, a piece of cable with a length of more than 10 m is considered as a two-port network whose transmission characteristic is determined according to chapter 2.5.8.

2.6.7.3 Checking Cable Homogeneity

To check the homogeneity of the characteristic impedance of cables, a piece of cable as long as possible is connected via an insertion unit to RF output 46 (Fig. 2-16) and terminated with a coaxial termination of suitable impedance (e.g. RMC). If the cable exhibits appreciable impedance discontinuities, the V_{OUT} display shows greater ripple at particular frequency spacings.

2.6.7.4 Checking the Matching of Cable Termination

Sometimes the quality of termination (impedance-match) of a long cable under operational conditions is of interest in community antenna systems, cable TV networks, or similar. If the cable has low reflection, which is normal, it can be used as the extension cable for the measurement. According to chapter 2.5.10 the cable is connected to RF output 46 (Fig. 2-16) of the SWOB 5 via an insertion unit. The smaller the output voltage ripple, the better is the impedance-match of the termination (Fig. 2-9).

3. Maintenance Instructions

The Polyskop SWOB 5 requires no periodical maintenance; it is, however, recommended that the rated specifications be checked from time to time. Section 3.2 contains detailed information on the test points and the corresponding rated specifications. Small deviations can be corrected by readjustment. The corresponding sub-section of the repair instructions (section 5) is indicated at the end of each sub-section of the maintenance instructions.

Greater deviations indicate a malfunction; adjustment is then no longer possible. A detailed functional description is given in section 4 to help the user carry out the required repair work. This is to be followed by an accurate adjustment of the unit according to the trimming instructions (section 5).

Warning: High Voltage

The post-acceleration voltage of the CRT amounts to approx. 13 kV. When performing checks while the unit is opened, proceed observing the relevant protection-of-labor regulations (e.g. VDE 105, Arbeitsschutz-Markblatt Nr. 57) with extreme care.

Note: The numbers following the designations of knobs, pushbuttons etc. refer to Fig. 2-16 and 2-17.

3.1 Required Test Equipment

Ref. No.	o Unit, required specifications ● Recommended R&S unit	Type	Order No.	Application see section
1	o Power supply 2 x 0 to 20 V/1 A 1 x 0 to 5 V/1 A ● DC Power Supply	NGT 20	117.7133.02	5.14 5.16 5.17 5.21
2	o Digital voltmeter 0 to 1000 V High-voltage probe 15 kV			5.1 5.15 5.2 5.16 5.3 5.20 5.13 5.21 5.14
3	o RF millivoltmeter 10 mV to 1 V 100 kHz to 1 GHz ● Millivoltmeter	URV 4	292.5012...	3.2.1 3.2.2 3.2.3 5.4
4	o Function generator Triangle/sinewave 20 Hz to 1 kHz ● Precision LF Generator	SSN	204.8014.52	3.2.11 5.13 5.18
5	o Oscilloscope Time base 10 ns to 0.5 s, with external X-axis deflection capability Two-channel X-axis input Sensitivity 5 mV/cm to 1 V/cm Differential Y-axis input with internally calibrated compensation voltage Sensitivity 50 mV/cm Compensation voltage ±2.5 V Diff. Y-axis input with selectable upper cutoff freq. 100 Hz to 1 MHz, Sensitivity 50 µV/cm to 1 V/cm Suitable mainframe	e.g. Tektronix 7B80 option 02 e.g. Tektronix 7A24 e.g. Tektronix 7A13 e.g. Tektronix 7A22 e.g. Tektronix 7704		3.2.7 5.3 5.4 5.5 5.12 5.13 5.14 5.15 5.18 5.21
6	o RF spectrum analyzer 100 kHz to 1.2 GHz 2 to 3 GHz			3.2.4 5.4
7	o Modulation meter Frequency range 1 MHz to 200 MHz FM range 1.5 kHz to 30 kHz Test bandwidth > 30 kHz ● Modulation Analyzer	FAM	334.2015...	3.2.5

3.2 Checking the Rated Specifications

Check the rated specifications at nominal line voltage and at an ambient temperature of +25°C.

3.2.1 RF Output Level

Sweep mode 13 in AUTO position.
Sweep range 30 in 0 position.
Adjust centre frequency 31, 32 to 100 MHz.
RF output dividers 34, 33 in 0 dB position (1-dB and 10-dB dividers).
Connect RF millivoltmeter to RF output 36.
The output level is 500 mV or 1 V for the 50-Ω model and 350 mV or 700 mV for the 75-Ω model, depending on switch position 54.

See section 5.4 for adjustment procedures.

3.2.2 RF Output Dividers

Sweep mode 13 in AUTO position.
Sweep range 40 in 0 position.
Adjust centre frequency 41, 42 to 100 MHz.
Connect RF millivoltmeter to RF output 46.
Attenuate the output level in 10-dB and 1-dB steps and check the attenuation using RF millivoltmeter.
The maximum total error must not exceed ±0.5 dB for the 10-dB divider and ±0.2 dB for the 1-dB divider.

Adjustments are not possible.

3.2.3 Frequency Response Measurement

Sweep mode 13 in AUTO position.
Sweep range 40 in 0 position.
RF output dividers 44, 43 in 0 dB position.
Switch 54 in 0.5 V position (or 0.35 V on 75-Ω model).
Connect RF millivoltmeter to RF output 46.
Turn centre-frequency potentiometers 41 and 42 to tune over the 0.1-to-100-MHz range and read the output level from RF millivoltmeter. The frequency response must be flat within ±0.5 dB at impedance-match. In the frequency range < 10 MHz, check the adjusted frequency using a frequency counter.

Adjustments are not possible.

3.2.4 Harmonics Suppression

Sweep mode 13 in AUTO position.

Sweep range 40 in 0 position.

Connect an RF spectrum analyzer to the RF output 46 and adjust appropriate output level.

Vary the output frequency within the 0.1-to-1000-MHz range using centre-frequency potentiometers 41 and 42.

Harmonics are down $\geqq$ 30 dB for the 0.1-to-1-MHz range and $\geqq$ 36 dB for the 1-to-1000-MHz range.

See section 5.4 for adjustment.

3.2.5 Spurious Sweep Width

Sweep mode 13 in AUTO position.

Sweep range 40 in 0 position.

Adjust the potentiometers 41 and 42 for a centre frequency of 100 MHz.

Set appropriate output level by means of the output dividers 44 and 43.

Connect modulation meter to the RF output 46.

The spurious sweep width must not exceed 20 kHz.

Sweep mode 13 in MAN position.

The spurious sweep width must not exceed 5 kHz.

Adjustments are not possible.

3.2.6 Sweep Width, Frequency

Sweep mode 13 in AUTO position.

Sweep time 38 fully clockwise.

Frequency markers 7 in 100 position.

Frequency marker type 7 in line-marker position.

Marker width 4 fully clockwise.

Sweep range 40 in 1000 MHz position.

Adjust 6 and 9 for appropriate marker and display intensity.

The 0-to-1-GHz frequency range must be displayed on the screen; the 500-MHz marker must be positioned at screen centre.

See sections 5.3 and 5.10 for adjustment.

3.2.7 Frequency Scale

Sweep mode 13 in AUTO position.
Sweep time 38 fully clockwise.
Frequency markers 7 in 100 10 position.
Frequency marker type 7 in line-marker position.
Sweep range 40 in 5 - 1000 position.
Sweep width 39 set for 20 MHz.
Adjust appropriate marker width by means of 4.
Adjust centre frequency by means of 41 until the bright-up bar 48 indicates 100 MHz. Determine frequency (at screen centre) with the aid of the superimposed frequency markers. Permissible deviation is ±30 MHz.

Repeat check every 100 MHz up to and including 1000 MHz.

See sections 5.7, 5.9 and 5.10 for adjustment.

3.2.8 Display Margin

Sweep mode 13 in AUTO position.
Sweep time 38 fully clockwise.
Frequency markers 7 in 100 10 position.
Marker width 4 fully clockwise.
Sweep range 40 in 5 - 1000 position.
Adjust sweep width 39 to have the 10-MHz markers spaced approx. 1 cm apart.
Shift centre frequency 41 until the upper or lower display margin becomes visible.
The upper display margin must end within the range of 1020 to 1060 MHz, the lower display margin must end within the range of -20 to -70 MHz.

See sections 5.9 and 5.10 for adjustment.

3.2.9 Sweep Time

Sweep mode 13 in AUTO position.
Manual sweep 13 fully counterclockwise.
Connect oscilloscope to TEST socket, pin 4.
Sweep time 38 fully clockwise, the oscilloscope must display a rectangular TTL signal with a period of 22 to 32 ms.

See section 5.3 for adjustment.

Sweep time 38 fully counterclockwise, the oscilloscope displays a rectangular signal with a period of 1.7 to 2.8 s.

Adjustments are not possible.

3.2.10 Horizontal Lines

Sweep mode 13 in AUTO position.
Sweep time 38 fully clockwise.
Sweep range 40 in 1000 position.
Brightness of display 9 fully clockwise.
Horizontal-line intensity 16 fully clockwise.
Both horizontal lines 14 and 15 must be adjustable across the whole screen along the Y-axis. The lines must be free from noise or spurious frequency components.
It must be possible to reduce the intensity of the horizontal lines and, if provided, of the level lines of the logarithmic amplifier plug-ins to 0, using intensity control 16.

Adjustments are not possible.

3.2.11 Sweep Modes

a) Manual sweep mode
Sweep mode 13 in MAN position.
Horizontal line 14 or 15 in centre position.
Sweep range 40 in 1000 position.
Horizontal-line intensity 16 fully clockwise.
Brightness of display 9 fully clockwise.
It must be possible to write across the whole screen, using manual sweep 13. Blanking intervals may become visible.

Adjustments are not possible.

b) Automatic sweep
This check is the same as the check of sweep time (see section 3.2.9).

c) Single sweep
Sweep mode 13 in SINGLE position.
Sweep time 38 fully counterclockwise.
Horizontal line 14 or 15 in centre position.
Sweep range 40 in 1000 position.
Horizontal-line intensity 16 fully clockwise.

Brightness of display 9 fully clockwise.
After depressing pushbutton SINGLE 13, a single sweep must be visible.
Sweep start may be delayed by 3 s, max. Green lamp 12 must light from the time of depressing pushbutton SINGLE until the end of the displayed sweep.
It must be possible to also initiate a single sweep by a trigger signal (TTL level, positive-going edge) at socket 48.

Adjustments are not possible.

3.2.12 Frequency Markers

Sweep mode 13 in AUTO position.
Sweep time 38 fully clockwise.
Switch 54 in 0.5 V or 0.35 V position (0.35 V for 75-Ω model).
Frequency marker type 7 in line-marker position.
Marker intensity 6 fully clockwise.
Display brightness 9 fully clockwise.
Marker width 4 fully clockwise.
RF output dividers 43 and 44 set to -20 dB.

a) 100-MHz markers
Sweep range 40 in 1000 position.
Frequency markers 7 in 100 position.
All 100-MHz markers within the 100-to-1000-MHz range must appear on the screen without flickering.

b) 100-and 10-MHz markers
Sweep range 40 in 5-1000 position.
Sweep width 39 set for about 500 MHz.
Frequency markers 7 in 100 10 position.
The 100-MHz markers must be somewhat brighter and wider than the 10-MHz markers.
Tune over the total frequency range with centre frequency control 41. The 10-MHz markers must be visible without flickering over the total range.

c) 10- and 1-MHz markers
Sweep range 40 in 5-1000 position.
Sweep width 39 set for about 50 MHz.
Frequency markers 7 in 10 1 position.
The 10-MHz markers must be somewhat brighter and wider than the 1-MHz markers.

Tune over the total frequency range with centre frequency control 41 . The 1-MHz markers must be visible without flickering over the total range. Adjust appropriate marker width by means of 4 .

d) External markers
Sweep range 40 in 1000 position.
Frequency markers 7 in EXT position.
Connect RF generator to socket 11 and adjust RF level to approximately 200 mV into 50 Ω.

A frequency marker must be visible within the frequency range from 1 to 1000 MHz.

e) Marker accuracy
Sweep range 40 in 0.3 - 50 position.
Frequency markers 7 in EXT. position.
Feed 100 MHz (accuracy $> 5 \times 10^{-5}$) to socket 11 .
Position frequency marker at screen centre by means of 41 and 42 .
Sweep width 39 fully counterclockwise.
Adjust appropriate marker width by means of 4 .
Frequency markers 7 in position 100.
The centre position of the frequency marker must not be shifted when switching over (the marker width may possibly undergo a change).

See section 5.5 for adjustment.

3.2.13 Logarithmic Amplifier Plug-in E1

a) Logarithmic amplifier
Sweep mode 13 in AUTO position.
Sweep time 38 fully clockwise.
Sweep range 40 in 0.3 - 50 position.
Sweep width 39 fully counterclockwise.
Centre frequency 41 and 42 set for 100 MHz.
Adjust 9 for appropriate display brightness and 16 for appropriate brightness of the horinzontal lines.
Set 54 to 1 V or 0.7 V position (0.7 V for 75-Ω model)
Range switch 20 in 80-dB position
Connect measuring head to RF output 46 and socket 21 (terminate insertion unit with 50 or 75 Ω).
Turn the position control for level line 19 fully clockwise into its detent position.

50-Ω model

Attenuate the RF signal as desired, using RF output dividers 43 and 44 .

Make level line 17 coincide with the display line.

The level line 17 indication must not differ by more than ±1 dB from the RF output divider setting.

NOTE:

It is recommended that the noise filter 38 be switched on for levels below -50 dB.

75-Ω model

RF output dividers 43 and 44 in 0 dB position.

Level line 17 in 0 dB position.

Adjust the position control for level line 19 until the level line coincides with the display line. Lamp 18 must light. Do not change the adjustment during the following procedure.

Attenuate the RF signal as desired, using RF output dividers 43 and 44 .

Make level line 17 coincide with the display line.

The level line 17 indication must not differ by more than ±1 dB from the RF output divider setting.

NOTE:

It is recommended that the noise filter 38 be switched on for levels below -50 dB.

b) Dynamic characteristics

Sweep mode 13 in AUTO position.

Adjust appropriate brightness of display by means of 9 .

Switch 54 in 0.5 V or 0.35 V position (0.35 V for 75-Ω model).

Range switch 20 in 80 dB position.

Connect a bandpass filter with an attenuation of at least 60 dB.

Connect measuring head.

Adjust sweep range 40 , sweep width 39 and centre frequency 41 and 42 such that the response curve of the bandpass filter is displayed.

The measurement curve must not exhibit discontinuities in the filter slopes.

c) RF spurious signal suppression

Sweep mode 13 in AUTO position.

Sweep time 38 fully clockwise.

Sweep range 40 in 0.3 - 50 position.

Adjust centre frequency of about 100 MHz by means of 41 .
Adjust appropriate display brightness 9 and intensity of horizontal lines 16 . Connect Insertion Unit SWOB 5-Z3 to RF output 46 and to the log amplifier plug-in 21 .
Set the RF output dividers 43 and 44 to -20 dB.
Connect the output of the insertion unit to signal generator with a source impedance of 50 Ω. Adjust the signal generator to about 150 MHz and the output level to < 10 µV or -90 dBm.
Set the range switch 20 to the 10 dB position.
Adjust the display line to screen centre by means of the position control 19 .
Mark the position with horizontal line 18 .
Increase the output level of the signal generator to 20 mV or -11 dBm.
The display line must not deviate from the marker line more than 0.5 dB after a transient period of 0.3 s, max.

d) Drift

Sweep mode 13 in AUTO position.
Adjust appropriate display brightness 9 and intensity of horizontal lines 16 .
Sweep range 40 in 0.3 - 50 position.
Sweep width 39 fully counterclockwise.
Adjust centre frequency of about 100 MHz by means of 41 .
Connect Demodulator SWOB 5-Z1 or SWOB 5-Z3 to RF output 46 and the log amplifier plug-in 21 . (Terminate SWOB 5-Z3 with 50 Ω or 75 Ω).
Set switch 54 to position 0.5 or 0.35 V.
Set the RF output dividers 43 and 44 to 65 dB.
Sweep time 38 fully counterclockwise. Cut in noise filter 38 .
Make the horizontal line 18 coincide with the display line at the left display margin (determine average value of the noisy display line).
The average value of the display line must not differ by more than ±2 mm from the horizontal line at the right display margin.

See chapter 5.20 for adjustment.

3.2.14 Linear Amplifier Plug-in E2

Sweep mode 13 in AUTO position.
Sweep time 38 fully clockwise.
Marker width 4 fully counterclockwise.

Sweep range 40 in 1000 position.
Brightness of display 9 fully clockwise.

a) Deflection sensitivity

Rotary switch 24 in "+" position.
Gain 22 fully clockwise.
Adjust display line to screen centre with position control 23 .
Connect AF generator to 26 (frequency 1 kHz, approx., level 1 mV).
The amplitude displayed must be at least 5 cm.
Adjustments are not possible.

b) Offset

Terminate 26 with low impedance ($\leqq$ 1 kΩ).
Gain 22 fully clockwise.
Rotary switch 24 in "+" position.
Adjust display line to screen centre with position control 23 .
When switching the rotary switch into its "-" position, the display line may differ by a maximum of 5 cm from its adjusted position.

See section 5.19 for adjustment.

c) RF spurious signal suppression

Rotary switch 24 in "+" position.
Sweep time 38 fully clockwise.
Connect LF generator via 10-nF isolating capacitor to socket 26 (frequency 1 kHz, level 20 mV, approx.).

Adjust gain 22 for a visible amplitude of about 5 cm. Adjust the display line to screen centre with position control 23 and mark. Feed additional DC voltage of 100 mV to socket 26 . After 0.3 s the marked position must be reached again.

3.2.15 Logarithmic Amplifier Plug-in E3

a) Logarithmic amplifier

Sweep mode 13 in AUTO position.
Sweep time 38 fully clockwise.
Sweep range 40 in 0.3 - 50 position.
Sweep width 39 fully counterclockwise.
Centre frequency 41 and 42 set for 100 MHz.
Adjust 9 for appropriate display brightness and 16 for appropriate brightness of the horizontal lines.
Set 54 to 1 V or 0.7 V position (0.7 V for 75-Ω model).

Slide switch 28 to the dBV position.
Range selector 30 in 100 dB position.
Slide switch 32 in probe position.
Connect measuring head to RF output 46 and socket 33 (terminate insertion unit with 50 or 75 Ω).

50-Ω model
Attenuate the RF signal as desired using the RF output dividers 43 and 44 .
Make the level line coincide with the display line.
The readout of the level line on 27 must not deviate more than ±1 dB from the setting of the RF output dividers.
NOTE: It is recommended that the noise filter 38 be switched on for levels below -50 dB.

75-Ω model
RF output dividers 43 and 44 in 0 dB position.
Slide switch 28 in dB position.
Make level line coincide with the display line by means of 29 .
Press pushbutton 36 (setting of reference level (0 dB)).
Attenuate the RF signal as desired, using the RF output dividers 43 and 44 .
Make the level line coincide with the display line.

The readout of the level line must not deviate more than ±1 dB from the setting of the RF output dividers.

NOTE: It is recommended that the noise filter 38 be switched on for levels below -50 dB.

b) Dynamic characteristics
Sweep mode 13 in AUTO position.
Adjust appropriate brightness of display by means of 9 .
Switch 54 in 0.5 V or 0.35 V position (0.35 V for 75-Ω model).
Range selector 30 in 100 dB position.
Connect a band-pass filter with an attenuation of at least 60 dB.
Connect measuring head.
Adjust sweep range 40 , sweep width 39 and centre frequency 41 , 42 such that the response curve of the bandpass filter is displayed.
The measurement curve must not exhibit discontinuities in the filter slopes.

c) RF spurious signal suppression
Sweep mode 13 in AUTO position.

Sweep time 38 fully clockwise.
Sweep range 40 in 0.3 - 50 position.
Adjust centre frequency of about 100 MHz by means of 41 .
Adjust appropriate display brightness by means of 9 and appropriate brightness of the horizontal lines by means of 16 .
Connect the RF Insertion Unit SWOB 5-Z3 to the RF output 46 and to the logarithmic amplifier plug-in 33 .
Set the RF output dividers 43 and 44 to -20 dB.
Connect the output of the insertion unit to the signal generator with a source impedance of 50 Ω. Adjust the signal generator to about 150 MHz and the output level to < 10 µ V or -90 dBm.
Set the range selector 30 to the 10 dB position.
Adjust the display line to about screen centre by means of 31 .
Mark the position with horizontal line 3 .

Increase the output level of the signal generator to 40 mV or -15 dBm. The display curve must not deviate from the marker line more than 0.5 dB after a transient period of 0.3 s, max.

If the output level of the signal generator exceeds about 60 mV the red indicator lamp 35 (insufficient spurious voltage suppression) must light up.

d) Drift

Sweep mode 13 in AUTO mode.
Adjust appropriate display brightness by means of 9 and appropriate brightness of the horizontal lines by means of 16 .
Sweep range 40 in 0.3 - 50 position.
Sweep width 39 fully counterclockwise.
Adjust centre frequency of about 100 MHz by means of 41 .
Connect measuring head SWOB 5-Z1 or SWOB 5-Z3 to the RF output 46 and the logarithmic amplifier plug-in 33 (terminate the RF Insertion Unit SWOB 5-Z3 with 50 Ω or 75 Ω).
Switch 54 in 0.5 or 0.35 V position.
Set the RF output dividers 43 and 44 to 65 dB.
Sweep time 38 fully counterclockwise, switch on noise filter 38 .
Make the horizontal line 3 coincide with the display line at the left display margin (determine average value of the noisy display line).
The average value of the display line must not deviate from the horizontal line at the right display margin by more than ±2 mm.

For adjustment see chapter 5.20.

3.3 Cleaning

The unit may be cleaned internally using conventional means (lint-free duster, brush, vacuum cleander, compressed air).

Extreme care should be exercised when handling the high-voltage connection of the CRT. Due to the design of the post-acceleration electrode, the CRT may carry residual charge after being out of operation for a prolonged time. If the anode clip is detached from the CRT, the anode pin must be connected to chassis ground.

When cleaning the deflection unit, be careful to avoid changing the positions of the magnets for geometric correction.

The front panel can be cleaned using alcohol when heavily contaminated. The graticule can be cleaned using available window-cleaning detergents. Never use acetone, trichlorethylene, or similar organic solvents.

4. Circuit Description

(See circuit diagram 333.0019 S Bl. 3)

4.1 Sweep Control

The sweep control circuit generates a saw-tooth voltage which is required for X-axis deflection and the YIG oscillator. This saw-tooth signal is used to derive various clock signals for display, RF and line-marker blanking, the scale pulse, the deflection amplifiers and pen-lift actuation. Sweep width, frequency and sweep time are determined by the sweep control circuit. The variable frequency marker is generated by a sweep stop of 12 ms. The sweep time is extended by a factor of 4 for steep trailing slopes. The automatic sweep can be switched over to single or manual sweep, using the controls of the sweep board. Moreover, the rotary switch S2401 I and II (30; Fig. 2-16) permits selection of swept operation (1000, 5 - 1000, 0.3 - 50) or CW operation (0).

4.1.1 Generation of Saw-tooth Voltage

Module B2401 is the heart of the sweep control circuit. It generates a saw-tooth voltage which is immediately tapped off from integration capacitor C2402. Furthermore, a rectangular signal is available at pin 9 (rising edge = high level, trailing edge = low level). The sweep time is varied by T2409I. T2409II serves as a reference source together with constant-current source T2410. A DC voltage is applied through R2424 and R2435 which controls the sweep time (B2403-B2404-T2409). The gain of B2403 can be adjusted with R2424 to eliminate transconductance spreads of T2409. If the sweep time is to be controlled externally, a DC voltage (0 to +5 V) can be applied to the non-inverting input of B2403 (pin 2); relay RS2401IV is switched.

T2403 switches in the automatic sweep time extension for steep slopes. The gain of B2403 is reduced, thus increasing sweep time by a factor of 4.

To shorten the retrace time, resistor R2421 is connected in parallel with T2409I via FET 2411 during retrace.

In CW operation, T2409I is replaced by resistor R2472. This ensures flicker-free frequency indication independent of the adjusted sweep time.

Recorder operation (option SWOB5-B2) requires a sweep time of approx. 30 s which is generated by direct switchover at the module (T2401, T2402). Furthermore, the saw-tooth sweep can be stopped via T2405/T2406. This is required for the variable frequency marker. In MAN mode, the frequency marker is suppressed by GL2402/R2416. An external sweep signal can be applied through T2408. For this purpose, the module serves as a comparator. The clock signal for the control logic is available at pin 9.

4.1.2 Processing of Saw-tooth Voltage

The saw-tooth signal is tapped off from C2402, B2415 operates as a voltage follower. The amplitude is adjusted with R2447 and the DC offset with R2451. The saw-tooth signal is available at the output of B2402 with an amplitude of ±2.5 V pp (symmetrical), and is used for control in the AF motherboard, as well as for tuning of the YIG oscillator, X-axis deflection, the scale pulse and the display margin through T2416. The saw-tooth signal can be switched off by T2416 in MAN mode and can be replaced by a DC voltage from the sweep board (T2415 conducting).

B2406 inverts the saw-tooth signal and drives the X-axis amplifier. A voltage is tapped off from the sweep-time control circuit and is also applied to the input of B2406 through R2477. This compensates for variations of the display position at different sweep times, caused by propagation delays.

4.1.3 Tuning of YIG Oscillator

The YIG oscillator has two coils which generate a magnetic field. The resultant field of both coils determines the resonant frequency of the oscillator. While the larger coil (DC resistance approx. 33 Ω) can tune the oscillator over its total frequency range, the FM coil (approx. 2 Ω) can only detune the oscillator by a maximum of ±25 MHz. This FM coil is used for narrow-band sweep operation.

a) Tuning over total range from 0.1 to 1000 MHz (1000)
   The saw-tooth signal (the DC voltage in MAN mode) is directly applied to the input of B2408 through rotary switch S2401. R2502 and R2504 define the gain, C2410, C2413 to C2416 and R2483 compensate for frequency response. This measure is necessary to match the frequency response of the YIG-oscillator tuning to that of the X-axis amplifier together with the deflection unit. Errors of these

correction circuits become apparent by shifting of the sweep curve and the frequency markers with varying sweep time, and by distortion of the displayed curves, especially of filter slopes, when the variable frequency marker is used.

The output of B2408 is followed by a bridge circuit consisting of R2507, R2511, R2508 and R2512. A DC voltage is fed into the upper bridge point through R2513. R2509 and R2510 are connected in the diagonal branch. The saw-tooth signal at the tap-off point of the bridge can now be offset by R2513 and varied in amplitude by R2509. These trimming resistors are required to compensate for tolerances of the YIG oscillator. The bridge circuit is dimensioned to avoid variations of the offset level with amplitude adjustments. The resonant frequency of the YIG oscillator is almost proportional to the magnetic field, and the magnetic field is, in turn, proportional to the current which flows through the tuning coil. Therefore, the tuning coil is driven with impressed current. The driver circuit (B2409 and T2424) supplies a driving current which is proportional to the control voltage.

b) Sweep width variable from 5 to 1000 MHz (5 - 1000)
If rotary switch S2401 is in its 5 - 1000 position, the amplitude of the saw-tooth signal can be varied with potentiometer R2470. Since the amplitude of the saw-tooth signal is proportional to the frequency deviation of the YIG oscillator, the sweep width displayed on the screen can be adjusted with this potentiometer. R2471 limits the lowest adjustable sweep width to 5 MHz.

To be able to sweep any desired frequency band, in spite of reduced sweep width, the centre frequency must be adjustable. This is done using 10-turn potentiometer R2475 whose voltage is applied to the input of B2408 through R2503, where it is summed. As the resolution of the 10-turn potentiometer is not sufficient for small sweep widths, which leads to difficulties in adjusting the centre frequency, an additional potentiometer (R2486) has been provided. The voltage from this potentiometer, which is also applied to the input of B2408 through R2484, varies the centre frequency by ± 1.5 MHz. This fine-adjustment potentiometer is operational in all four sweep range positions (1000, 5 - 1000, 0.3 - 50, 0). In the 1000 position, the fine-tuning range is extended (used only for adjustment). The DC voltages from the position potentiometers which are summed at the input of B2408 result in corresponding driving currents from the driver circuit through the tuning coil, thus in a corresponding frequency shift of the YIG oscillator.

c) Sweep width variable from 300 kHz to 50 MHz (0.3 - 50)
If rotary switch S2401 is in its 0.3 - 50 position, the saw-tooth signal is no longer applied to B2408 but to B2407 instead. Together with T2421 and T2422, B2407 forms a driver circuit which converts the input voltage into a driving current. The driving current does, however, not flow through the tuning coil but flows through the FM coil. As a result of circuit dimensioning, a maximum sweep width of 50 MHz is possible. The amplitude of the saw-tooth signal can be varied with potentiometer R2470, thus varying the sweep width. R2471 limits the lowest adjustable sweep width to 300 kHz.

The frequency position is again adjusted with potentiometers R2475 and R2486, and the signal is applied to the tuning coil through B2408-B2409-T2424. Capacitor C2411 is connected to the input of B2409 through the rotary switch to provide for filtering of the DC tuning voltage. This results in a reduction of spurious sweep width. The filter capacitor is charged through R2505 and R2506 to a voltage level which corresponds to the centre frequency of the swept range, if the rotary switch is in its 5 - 1000 or 0.3 - 50 position. This avoids the necessity for charging the filter capacitor through R2514 (33 kΩ) when switching from 5 - 1000 to 0.3 - 50 with S2401, which might lead to visible transients. If the rotary switch is set from 5 - 1000 to 0.3 - 50, the voltage remains unchanged and the capacitor need not be recharged.

d) CW operation (0)
In the 0 position of the rotary switch S2401, the saw-tooth is completely switched off. Only the potentiometers R2475 and R2486 are left connected to B2408, i.e. the YIG oscillator can no longer be swept but still be tuned. To minimize spurious sweep width, C2411 is left connected to the input of B2409.

4.1.4 Blanking of Display Margin

The swept frequency range can be positioned beyond the upper or lower frequency limit at large sweep widths, using the frequency-position potentiometer. As the centre-frequency position is to be maintained when varying the sweep width, it will not be shifted with the sweep width but the screen range above 1050 MHz and below -50 MHz is blanked instead. For this purpose, the control voltage is tapped at the output of B2408 and applied to B2410I and II. Both operational amplifiers are connected to operate as comparators. If the control voltage (saw-tooth plus DC voltage) exceeds or is below the predetermined limit values, the corresponding comparator switches to -15 V. GL2417 and GL2418 operate as an OR circuit; R2528, R2529 and GL2419 limit the output signal to TTL level. The output signal initiates display blanking via the control logic. When operating a recorder (option SWOB5-B2), recording is also disabled.

4.1.5 Generation of Scale Pulse

For indication of the frequency range that is displayed on the screen, an intensified bar is generated at the lower screen edge which helps to identify the swept range on an attached scale.

The frequency information is obtained from the control voltages which drive the YIG oscillator. For this purpose, operational amplifier B2414 receives a saw-tooth signal through R2553 (through R2555 in the sweep range 0.3 to 50 MHz) which is proportional to the sweep width, and the DC voltages through R2552 and R2557 which correspond to the centre frequency. C2428 and C2556 are required to compensate for the frequency response. The signal that is summed by B2414 is passed on to a sample-and-hold circuit (T2435-T2436), which stores the maximum and minimum values in C2423 and C2424. Since module B2401 supplies a rectangular signal whose edges coincide with the peaks of the saw-tooth signal, it triggers two monostables B2411I (rising edge) and B2411II (trailing edge). T2435 is rendered conductive for 300 µs through T2431-T2433 at the beginning of forward sweep. The minimum is stored in C2423. Similarly, T2436 is conductive for 200 µs at the beginning of the retrace, and the maximum value is stored in C2424. B2412 and B2413 operate as comparators. Both receive the saw-tooth signal required for the X-axis amplifier, which allows identification on the attached frequency scale by means of the X-axis deflection (and the CRT). Comparator B2412 now switches from -15 V to +15 V if the saw-tooth signal for X-axis deflection is more positive than the reference voltage across C2423. The switching signal which is translated to TTL level by

R2547-R2549-GL2421, initiates via the control logic the brightening of the luminous bar.
Brightening occurs exactly when the X-axis deflection has reached that point on the scale which corresponds in voltage to the minimum of the control voltage for the tuning of the YIG oscillator, i.e. the lower frequency limit of the swept range. (The minimum of the control voltage has been stored in C2423.) Comparator B2413 stops the brightening via the control logic when the X-axis deflection has reached that point on the scale whose voltage corresponds to the maximum of the control voltage for the tuning of the YIG oscillator (stored in C2424).

The scale pulse may become so narrow for very small sweep widths that a screen display is no longer possible due to the raster method applied. Therefore, an offset is applied to B2412 through R2560 so that the scale pulse cannot become narrower than a predetermined minimum width.

4.1.6 Control Logic

The control logic combines the various operational modes MAN, AUTO and SINGLE, sweep or CW operation as well as external sweep and recorder operation with the sweep functions and controls display, RF and marker blanking, the scale pulse, clamping and pen lift.

4.1.6.1 Sweep Operation (1000; 5 - 1000; 0.3 - 50)

a) SINGLE mode

Failure of the control clock signals must be avoided for trouble-free operation of the deflection amplifiers. Therefore, the function generator continues to operate in SINGLE mode, only the RF, the display, the markers and the scale pulse are blanked. If the sweep circuit (B2433I-B2433II-B2434IV-B2435I) is set by the start pushbutton or the trigger input, the function generator and the clock sequence remain unaffected. Instead, the sweep circuit waits for the beginning of a normal sweep, then enables the RF, the display, the markers and the scale pulse for one cycle, and turns back to its original state after completion of this sequence.

Due to this circuit configuration, the beginning of the sweep curve display may be delayed with reference to the start pulse. If a recorder is connected (without "slow sweep" option), a relay contact on the connection board is closed during the forward sweep to operate the pen lift (SF).

b) AUTO mode

Module B2401 generates the control clock signal that is received by the AF motherboard (LINT) and by B2434II through B2431I and B2434I. Switching pulses for noise-signal suppression and drift compensation are formed together with the saw-tooth signal (output 2406) on the AF motherboard. The output signal from B2434II blanks the RF directly (HFA). After having been delayed by B2437II, combined with the display margin (BR) in B2436II and inverted by B2435III, this same signal switches the line markers (SMA) as well as the noise filters on the AF motherboard. Still further delayed by B2437I in conjunction with B2438III it is available for display blanking (BA). The scale pulse (SKI) is formed from the two comparator signals (B2412 and B2413) and the control clock signal using B2431III and B2436I. In the MAN mode, the scale pulse is suppressed by B2435II to prevent display errors which might be caused by the sampling method applied.

The RF, the display, the line markers and the scale pulse can be blanked simultaneously by B2434II. This is done in the SINGLE mode via B2433IV.

c) MAN Mode

Since the function generator continues to operate, all control functions are maintained as in the AUTO mode. Only the saw-tooth signal for the X-axis deflection and for tuning of the YIG oscillator is replaced by a DC voltage which can be varied with a potentiometer.

For this purpose, B2431II is switched to high level, T2416 is cut off through T2404-T2413-T2414 while T2415 is rendered conductive. C2408 is used for filtering.

If the "slow sweep" option (SWOB5-B2) is fitted, the X-axis and Y-axis signals which have been adjusted last (e.g. the starting point for the recording) are accepted and stored in the hold circuit. To ensure a safe take-over, the X-axis signal (deflection and tuning) and thus also the Y-axis signals are switched over by GL2405 and C2409 with a certain delay as against the switching signal (HP) for the sample and hold circuit. At high sweep speeds, the blanking may be visible as a gap in the displayed curve. The time difference between two blanking intervals depends on the adjusted sweep time and can be varied from 2 s to 20 ms with the SWEEP TIME potentiometer (38; Fig. 2-16).

A switching signal is tapped at the collector of T2413 and used to reduce the brightness. Lower brightness than that used in AUTO mode has proved to be useful in practice.

d) External sweep mode

If set to MAN, the unit can be swept externally. To identify this operational condition, pin 7 at the test socket (MEA) is shorted to ground. B2438I and B2431II combine the switching signal for MAN mode in such a way with the identification that T2408 and T2416 conduct and T2415 is cut off. This results in the external sweep signal being through-connected to C2402, while the manually variable tuning and deflection voltage is disconnected.

e) SINGLE mode with "slow sweep" option

Input pin 10 (S) of B2436III is set to high level for identification. If the sweep circuit (B2432I-B2432II-B2433-B2434IV) is started for a sweep, T2408 conducts through B2436III and T2401, slowing down the sweep to approx. 30 s. During this time, the deflection amplifiers might exhibit excessive drift. Therefore the control clock signal is replaced by the clock generator provided in the option, whose signal is applied through B2433II. This control clock signal is processed by the following logic in exactly the same way as is the internal clock signal in the MAN or AUTO mode. The switching contact for operation of the pen lift remains closed during the whole forward sweep (B2434III) as in the SINGLE mode.

4.1.6.2 CW Operation

a) AUTO and SINGLE modes

In CW operation retrace blanking is disabled. Several gate inputs which are set to low in sweep operation by means of the rotary switch S2401 via the resistor R2473 go high via the resistor R2497.

R2438IV disables RF blanking. B2433II disables the single-sweep circuit. Since the deflection amplifiers are likely to drift without blanking and RF spurious signal suppression is no longer possible the display (display and level lines) is also blanked by means of B2436II and B2438III to prevent faulty test results. The line markers are suppressed to reduce the spurious sweep width.

b) MAN mode

Sweeping by an external deflection signal is disabled in this mode via the gate B2438II.

The spurious sweep width of the YIG oscillator is the sum of the inherent noise of the oscillator, the noise of the driver amplifier and the noise voltages on the supply lines. The latter which are mainly caused by the saw-tooth generator and the control logic are in the µV range and cannot be filtered out. For this reason, no frequency indication is provided in the MAN mode and the saw-tooth generator B2401 is switched off, its input, pin 7-8, being set to low (output B2435VI) via T2405.

NOTE: In normal sweep operation, in particular in the sweep range 0.3 to 50 MHz, these interferences are not apparent since the control logic is inoperative during the forward sweep and the noise voltage caused by the saw-tooth generator adds as additional sweep width to the selected sweep width.

4.1.7 Remote Control

The sweep width, the frequency and the sweep time can be varied and adjusted externally through the "remote control" socket at the rear panel. Pin 6 is taken to ground for identification, which causes relay RS2401 to attract.

The sweep width can be varied with an external potentiometer (5 kΩ) connected to pins 1 and 2. The frequency can be adjusted by a voltage of approx. +3 to +8 V at pin 3. This voltage can be obtained from +20 V at pin 4 by using a simple voltage divider. B2405 is used for DC offset voltage shift, as a voltage of +2.5 to -2.5 V is required for adjusting the frequency. A voltage of 0 to +5 V is required at pin 7 for sweep time control. The relay switches off the internal sweep time control. R2431-R2432-GL2403 protect against overloading and limit the lowest possible sweep time.

4.2 Sweep Board

The sweep board contains the pushbuttons for selecting SINGLE, AUTO or MAN mode, a potentiometer for adjusting the variable marker in AUTO mode or the X-axis deflection in MAN mode, and a light-emitting diode for the indication of the triggered condition in SINGLE mode.

a) SINGLE mode

Pin 6 of plug ST401 is connected to ground, enabling the sweep circuit and the trigger input. The trigger signal is passed through pin 7. The input of B401II is disabled by GL411, thus suppressing the variable marker.

Internal triggering can be initiated by depressing the START pushbutton, discharging C401 and initiating a trigger pulse. An external start pulse can be applied through the trigger connector at the rear panel of the unit. GL406-GL407 limit the pulse, C405 blocks off DC components.

Due to the design of the sweep control circuit, the beginning of the sweep curve display may be delayed by 2.5 s maximum with reference to the start pulse. To recognize the operational condition of the circuit, GL410 is immediately lit after triggering of the sweep circuit and will go out only after the sweep has been completed.

b) AUTO mode

If the AUTO pushbutton is depressed, the variable voltage from R412 is applied to the non-inverting input of B402I. The saw-tooth signal from the sweep control circuit is present at the inverting input, driving also the X-axis deflection through B2406. B402I operates as a comparator which changes state at a certain point during the forward sweep, depending on the voltage adjusted at R412, thus triggering the monostable B401II. The second monostable (B401I) is started after 0.5 ms. The output of B401I is brought out at the TRIGGER output on the rear panel of the SWOB 5 through protective resistor R424 and the switch. This signal can be used to trigger an external frequency counter. At the same time, the sweep is stopped (GL404-GL405-B2435V-T2406). The sweep is, however, stopped already 0.5 ms before the trigger signal to suppress decay transients that are caused by the YIG oscillator and might invalidate the measurement result obtained from the frequency counter.

Comparator B402I exhibits a hysteresis due to R414 and R416. This is necessary to stabilize the switching point, as feedback is applied in this circuit. The comparator stops the function while the sawtooth signal, in turn, is the reference signal for the comparator. C404 and R417 operate as a delay circuit, also stabilizing the comparator action. R417-R418-GL403 match the comparator output to TTL level.

The sweep hold generates an intensity marker on the screen. To stabilize this marker against variations of the sweep time, i.e. ensuring a stable position of the marker with reference to the test curve, a small correction voltage which is generated by GL2407-R2430-R2463 on the Sweep Control board (circuit diagram 333.0019 S Bl. 3) is superimposed on the saw-tooth signal for comparator B402I.

In CW operation, -5 V are applied to the inverting input of B402I by means of the rotary switch S2401 to inhibit the circuit.

c) MAN mode
Pushbutton MAN takes pin 14 of plug ST401 to +5 V. This cuts off T2416 on the sweep control board and makes T2415 conduct. The variable voltage from R412 for the X-axis deflection and the tuning of the YIG oscillator is thereby through-connected.

The variable marker in AUTO mode must coincide with the position of the curve point displayed in MAN mode if the adjustment of R412 has not been changed. Therefore, the loading of the divider R411-R412-R413 is compensated for by R410 and the DC offset by R415 in AUTO mode, as opposed to MAN mode. With external deflection, the signal is matched to the requirements of the sweep control by B402II. R401-R402-R403-GL401-GL402-R404 limit the input signal and protect the circuit from overload. The signal is applied to the function generator through T2408.

4.3 RF Section

4.3.1 RF Generator

The output voltage of the sweep generator is obtained from the RF generator. For this purpose, the YIG oscillator frequency (2 to 3 GHz) is mixed with a fixed frequency of 2 GHz which is obtained by multiplying the 100-MHz voltage from the crystal oscillator (T1801 and crystal Q1801) by a factor of 20. B1801 and T1804 amplify the oscillator voltage to obtain the driving power for step-recovery diode GL1850 which is used for frequency multiplying. The 2-GHz signal is coupled out of the diode multiplier by a cavity resonator with 3 tuned circuits (trimming capacitors C1850-C1851-C1852). The operating points of T1804 and GL1850 are adjusted with R1820 and R1825 for best efficiency.

The operating voltage of the 100-MHz amplifier B1801 is disconnected for RF voltage blanking during the retrace, using transistors T1802 and T1803. The control clock signal for this is supplied by the control logic of the sweep control circuit.

The output voltage from the 2-GHz filter is applied to the RF input of the mixer (consisting of the diode quad GL1953 and transformers TR1951 and TR1952) through a PIN-diode control element (GL1951-GL1952) and the 3-dB attenuator B1951. The oscillator input of the mixer receives its driver voltage (2 to 3 GHz) from the YIG oscillator through the 3-dB attenuator B1952.

The RF voltage (100 kHz to 1 GHz) present at the IF output is amplified by approx. 37 dB in the wide-band amplifier B1901-T1901-T1902-T1903 and filtered by high-pass filter C1921 and L1910 and low-pass filter 289.5415 from interfering spectra.

The operating points of transistors T1901 to T1903 are adjusted with trimming potentiometers R1905, R1915 and R1925 for best harmonics attenuation.

The RF voltage is passed from the low-pass filter to the EMF distributor through coaxial cable K12.

A portion of the RF power is fed from there to RF output BU1 (<u>46</u>) through output dividers 6 x 10 dB (<u>44</u>, Fig. 16) and 10 x 1 dB (<u>43</u>). In addition to that, RF monitor output BU106 (<u>55</u>), marker section connecting cable (K13) and the EMF diode built into the EMF distributor (ALC) are supplied with RF voltage.

4.3.2 ALC

To maintain a constant RF output level, a control voltage is derived from the rectified voltage of the EMF diode by operational amplifier B1751 and acts on the PIN-diode control element GL1951 and GL1952.

The rectified voltage from the EMF diode is passed through filter C1705-L1704-C2005 and applied to the non-inverting input of the ALC amplifier B1751. The output voltage of B1751 causes a control current to flow through PIN diodes GL1951 and GL1952, thus controlling their RF impedance.

B1751 regulates its own output voltage such that the rectified voltage from the EMF diode is equal to the reference voltage at the inverting input. The RF voltage at the distribution point in the EMF distributor is thus maintained at constant level.

The temperature effect on the EMF diode is compensated for by a second identical diode in the reference circuit. The compensation diode is located close to the EMF diode in the EMF distributor to ensure that the two diodes are exposed to the same ambient temperature.

The reference voltage for the RF output level of 0.5 V is adjusted with R1755. If the RF level is switched to 1 V with S103 (44; Fig. 16), T1751 conducts so that R1760 and R1761 are connected in parallel to R1756, which causes the reference voltage to become more negative. This condition is signalled by the red LED GL101. The output level is now adjusted with R1760.

The RF is blanked during retrace. As a result, the rectified voltage of the EMF diode drops to 0 and the ALC amplifier B1751 tries to boost the level by increasing the gain of the PIN diodes. When the RF is switched on again via T1803-T1802-T1801, the ALC amplifier exhibits a certain transient response during which level peaks develop that may be as much as 20 dB depending on the extra gain. The ALC amplifier B1751 is, therefore, fed back via R1781 during retrace, which cuts down its gain to about unity thus avoiding these level peaks. T1752 acts as switch and B1752 as switching amplifier.

4.3.3 "External Control" Option SWOB5-B1

If the "external control" option is inserted into the provided compartment on the rear panel of the SWOB5 and connected to the basic unit through ST110 on the central motherboard, the operation of the ALC circuit described in chapter 4.3.2 remains the same as long as S1 (51; Fig. 2-16) is switched to internal ALC.

For external ALC, the internal control amplifier must be put out of operation. For this purpose, a voltage of -20 V is connected to terminals 3 and 14 of connector ST110 through switch S1 (51; Fig. 2-16). This line feeds the red LED GL102 to signal the "external ALC" mode, and the gate of switching FET T151 (on central motherboard 333.1615) which is now cut off, interrupting the connection between the wiper of R1755 and the compensation diode. This causes the voltage at pin 2 of B1751 to become slightly positive, driving the output into positive saturation. Since the control voltage at pin 11 of control amplifier board 333.2311 is approx. 1.5 V, GL1752 does not conduct, disabling the internal control amplifier.

In "external ALC" mode, the Insertion Unit SWOB5-Z3 replaces the EMF diode. The rectified voltage from its measuring detector is applied to the inverting input of B1 through socket BU1 (53). The auxiliary detector diode of the insertion unit is used for temperature compensation of the reference voltage. This voltage can be varied with R8 (52) to obtain an RF level between 0.1 and 0.5 V.

The output voltage from B1 is applied to the PIN-diode control element through S1, in parallel with the output of the internal control amplifier which has been disconnected by GL1752.

4.4 Spectral Markers

The spectral markers are produced by mixing the sweep frequency with a frequency spectrum in the marker section. The frequency spectrum is derived from a crystal oscillator the frequency of which is taken either direct or after frequency division (10:1 or 100:1) to a multiplier chain where the signal is transformed into very narrow pulses. The harmonic spectrum of these pulses is nearly constant up to 1 GHz.

The AF component is filtered out from the mixer product (sweep frequency ± spectral frequencies) by means of a low-pass filter and amplified (zero beat). The AF bandwidth and along with it the marker width can be varied by the marker processor. Subsequently, after separation of spurious components the AF signal is limited, rectified and supplemented by a monostable so that the signal intervals caused by the zero-axis crossings of the AF signal are filled. Switchover from line markers to pulse markers is performed at the output by means of switching FETs.

Type of markers and marker frequency can be selected by means of switches on the front panel.

4.4.1 Marker Section

The crystal oscillator T1501 is used as a reference for the markers. L1501 tunes the resonant circuit C1503-C1529 required with harmonic-mode crystals to the nominal frequency. T1502 acts as a buffer and T1503 as a driver. If the 100-MHz decade is selected, GL1501 conducts and GL1507 is cut off. T1504 drives the multiplier chain, GL1502 acts as step-recovery diode and L1530 as a storage inductance. The preconduction current for the diode flows through R1520. Positive-going pulses (overshoots) are suppressed by GL1503-GL1504. At the same time, the diode capacitance ensures a broadband multiplier chain.

The step-recovery diode can only make the falling edge of the signal steeper but not the rising edge. Hence, in order to obtain the required narrow pulses a low capacitance (C1517) is used for output coupling which provides for differentiation of the signal.

The resulting frequency spectrum is balanced by means of the transformer TR1531 and taken to the two mixer diodes GL1505I and GL1505II. L1505 serves for return of the DC and corrects the balance of the mixer TR1531-GL1505I-GL1505II towards lower frequencies. The sweep frequency is applied to the mixer TR1531-GL1505I-GL1505II via C1518. The mixer product is coupled out by means of R1523 and amplified in B1501 and B1502. The AF bandwidth is limited by means of C1519-C1522-C1525.

For generation of the 10-MHz and 1-MHz decades, the crystal frequency is branched off by the buffer stage and taken to the 10:1 divider via the driver T1505. The output signal (10 MHz) can be applied via the switching FET T1507 (GL1501 cut off, GL1507 conducting) to the multiplier chain. The broadband multiplier chain T1504-GL1502 and the mixer TR1531-GL1505I-GL1505II are designed for the frequency decades 100 MHz and 10 MHz. Hence, the marker signal for either the 100-MHz or 10-MHz markers is available at the output of the AF branch (B1501-B1502).

Since for easier orientation of the frequency position two groups of spectral markers are to be displayed on the screen distinct from each other (100-MHz and 10-MHz markers or 10-MHz and 1-MHz markers), a second branch is provided with the same function and wiring as the first one. The broadband multiplier chain (T1506-GL1520) and mixer (TR1511-GL1523I-GL1523II) are laid out for the frequency decades 10 MHz and 1 MHz. The AF branch operates with a somewhat lower gain and narrower bandwidth so that the markers will be narrower for easier distinction.

The third branch using TR1521-GL1550-GL1551 as a mixer and B1504-B1505 as an AF amplifier produces a marker with the aid of an external generator. Contrary to the spectral markers, the oscillator input of the mixer is here connected to the sweep frequency. To prevent any interference, the crystal oscillator is switched off by the switching FET T1524 in external marker operation.

The sweep signal is simultaneously applied to the three mixers via a resistance network. C1004 and C1563 make for improved matching. C1564 together with R1605-R1606 forms a low-pass filter. It separates frequencies below 300 kHz which could be processed directly in the AF branch and would effect a 0-MHz marker.

4.4.2 Marker Processing

The marker processing circuit consists of two almost identical branches. The AF signals which are controlled from the marker section are taken to the two channels by means of the switching FETs T1401-T1430-T1460. R101 together with C1401-C1432 form low-pass filters each permitting the marker width to be varied. The two comparators B1401 and B1403 suppress noise and spurious signals. Only the useful signal which exceeds the comparator threshold is further processed. The level of the comparator threshold is determined by R1406-R1403 and R1412-R1413. B1401 processes the positive signal components and B1403 the negative signal components. GL1401 and GL1403 function as an OR element. The following monostable is triggered by the trailing edge. The time constant is fixed such that the gaps between the positive and the negative comparator signal are filled. Both signals are taken to the output amplifier B1410I via the diodes GL1402-GL1419. The marker amplitude is determined by the resistors R1422-R1424.

The second processing branch is designed identically up to the output of B1410II. The output divider is, however, differently dimensioned to permit distinction between the two frequency decades (e.g. 10 MHz and 100 MHz) by the amplitude. The signals of the two branches are combined via the diodes GL1425-GL1446. If T1461 conducts, pulse markers are selected. The line markers are selected via T1462. Since the line markers are unblanked separately by the cathode of the CRT, they cannot be blanked by means of the general display blanking signal. They must, therefore, be separately blanked via T1463 and T1462.

GL1423-R1423 cut off the output amplifier B1410I if a higher decade marker is to be displayed. This prevents the smaller and narrower marker signal from adding up into a staircase.

In the case of very narrow sweep widths, the marker width must be drastically reduced. The time constant of the monostables B1408I/B1408II is then insufficient to fill the gaps between the markers. For this reason, the time constant is switched over via T1402-T1431. The switching point is determined by the potentiometer R101 which to this end functions at the same time as a DC divider (R1431-R101). The DC voltage is applied to the comparator B1412. R1481 and C1481 are AF filter sections. With decreasing marker width, the resistance R101 and consequently the DC value increases until the comparator voltage is exceeded.

Due to the higher time constant, the marker is widened unsymmetrically towards the centre frequency. In general, this shift is negligible. It is, however, possible, if the switchover creates a disturbance, to disable the comparator. To this end, the resistor R1482 - it is mounted on solder terminals - must be removed.

The switch 54 (Fig. 2-16) permits the RF level to be increased by 6 dB. With it, the amplitude of the AF signals at the output of the marker section is increased. To make sure to still reliably separate the useful signal from the spurious signal in the marker processing circuit, the comparator threshold level is also increased by 6 dB by applying -20 V to pin 2 of the plug ST1402. As a result, the negative comparator threshold level directly increases from about -1 V to about -2 V via GL1408-R1407 while the positive threshold is increased by switching over the resistive divider R1412-R1413/R1414 (T1414 conducts).

The power supply for marker generation and marker processing is stabilized via T1530 (approximately +15 V) and T1470 (approximately -15 V).

4.4.3 "IF Markers" Option

Use of the "IF markers" option when testing equipment that operates with frequency conversion (for example, tuners) permits two frequency markers to be produced which represent the IF on the screen. To this end, the IF is applied to a controlled amplifier via a diode switch and the amplified IF signal is applied to the oscillator input of the mixer. The crystal oscillators are connected to the RF input. The low-frequency component (zero beat) is separated from the mixer product using a low-pass filter and subsequently amplified.

Noise and spurious components of the signal are suppressed via a comparator threshold. A monostable fills the gaps of the signal caused by the zero-axis crossings of the AF signal. The output amplifier is followed by two switching FETs which permit selection of line or pulse markers.

In addition, the two pushbutton assemblies for switching over the decade markers and the marker display as well as a potentiometer for varying the marker width are provided on this option which replaces the marker board 289.4931 of the basic unit.

The diode switch GL1-GL2-GL4-GL5 is provided at the input to the circuit (ST305). When the pushbutton EXT. (7; Fig. 2-16) is pressed, the input is connected through to the marker section where it is processed to obtain a marker. If the pushbutton EXT. (7; Fig. 2-16) is disengaged, the input is connected to the amplifier via a plug-in filter. This filter (e.g. a high-pass filter) can blank the oscillator signal of the item under test if it lies in the frequency range of the amplifier, preventing the amplifier control from responding to the spurious signal.

The input impedance is formed by R7-L1 and C1. T10 acts as an impedance transformer. The signal can be attenuated by means of the PIN diodes GL23-GL24-GL22. T20 and T30 boost the IF. T39 acts as an emitter follower. The oscillator input of the mixer is provided in the emitter circuit of the T39. C44 is used for coupling the signal out for level control. This signal is rectified by means of GL45, filtered by means of C45 and applied to the operational amplifier B45. The reference voltage for the mixer level adjustment is determined by means of R26. GL44 compensates for temperature effects on GL45. R34 and R32 are used for the adjustment of the preconduction current through the diodes. The output signal from B45 controls the PIN diodes GL23-GL24-GL22 so that the level at the mixer remains constant. In addition, an offset is produced via the diodes GL26 and GL27 which permits all three PIN diodes to be driven with one voltage.

If an external marker is produced with the aid of an external generator, the gain of the amplifier is reduced to prevent spurious markers from developing at a very high level and adequate frequency through crosstalk. To this end, the reference voltage is shifted appropriately by means of R25 and GL25 if the pushbutton EXT. is pressed.

The two oscillators are connected to the RF input of the mixer via resistors for decoupling purposes. They are of the plug-in type which permits adaptation to the particular IF. The AF component is separated from the mixer product by means of R40-C40 and boosted in B40-B50. The low-pass filter at the output of B50 consists of the potentiometer R125 on the oscillator board and C52. The potentiometer permits the AF bandwidth and consequently the marker width to be reduced.

The following comparator B60 separates the useful signal from noise, harmonics and non-harmonic spurious signals. B60II inverts and processes the negative component and B60I the positive component of the useful signal. The two signal components are combined via GL60 and GL70.

The monostable B75 which is triggered by the trailing edge fills up the signal intervals caused by the zero-axis crossings and comparator thresholds. As a result, the marker signal is smoothed. Only at zero beat is a blanking interval visible.

The marker signal and delayed signal are taken together to the output amplifier B80 via the diodes GL75-GL78. T80 and T90 which are controlled by the pushbuttons 7 (marker type) permit selection of pulse or line markers. On the other hand, they inhibit the marker signal during display blanking (controlled by T95). T70 blanks the bright-up marker. If the SWOB 5 is switched off the +24-V supply collapses more quickly. T70 conducts, shortcircuiting the decaying marker signal. T100 stabilizes the positive switching voltage for the diode switch. This prevents voltage fluctuations from developing at R1 (and R4) and being fed back from the input to the RF Insertion Unit SWOB5-Z3.

The power supply is stabilized via T105 (+15 V) and T110 (-15 V). The monostable supply voltage is stabilized via the Zener diode GL114.

4.5 Deflection Amplifiers

4.5.1 Logarithmic Deflection Amplifier Plug-In SWOB5-E1

Refer to circuit diagram 333.5610 S.

The logarithmic deflection amplifier has to process rectified voltages between approx. 0.3 µV and 1.4 V. To make do with relatively simple logarithmic converter designs in spite of the stringent requirements to be met, two signal paths are employed. The first handles the RF level range from 170 µV to 20 mV, the second one is effective for inputs from 20 mV to 1 V. (Level values apply when using measuring heads SWOB5-Z1 and -Z3.) According to the RF voltage level, either the first or the second path is through-connected to the display section.

Below 20 mV, the rectifying characteristic of the measuring diode is a square-law function, which excludes the necessity for linearizing the input before logarithmic conversion. The output voltage from the logarithmic converter stage appears only multiplied by a factor of 2, compared to the theoretical case that the same logarithmic converter would be driven by a linearly operating detector. To obtain this kind of behaviour, the logarithmic voltage need only be divided by 2, for example, using a voltage divider. In the present case, this factor is taken into account in further processing.

As no constant exponent can be assigned to the diode characteristic between 20 mV and approx. 500 mV - it varies continuously from 2 to 1 - and as linear peak detection is employed above 500 mV, the detector characteristic is linearized by a control amplifier in the second signal path.

4.5.1.1 Signal Path I (for RF Voltages < 20 mV)

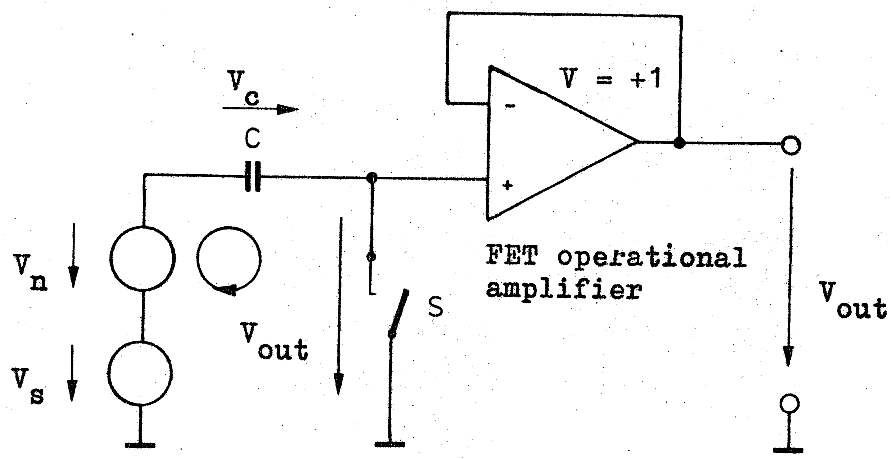
Signal path I leads from terminal 6 of BU701 (test voltage I) to test point MP6 (input I of voltage discriminator).

a) Preamplifier with Clamping Stage

B701 amplifies the test voltage I supplied by the measuring detector through BU701 by a factor of approx. 450. The gain is determined by R700 and R710, as well as by the gain adjustment potentiometer in the measuring head. This potentiometer permits compensation for the spread in diode characteristics. It is adjusted in each measuring head to give 2 V at bridge BR702 for an RF level of 20 mV.

R709 and GL702 limit the output voltage from B701 to 10 V, to protect the following stages B702 and B703 from being driven into saturation. Low-pass filter R712 -R713-C711-C712 limits the bandwidth of the preamplifier stage to approx. 7 kHz. This keeps the logarithmic converter free from interference voltages from the vertical deflection stage (raster sine signal of approx. 50 kHz) and from the high-voltage generator (approx. 40 kHz) of the basic unit.

C708 together with B703 and analog switch B702IV form a clamping stage which is used for automatic RF spurious-signal suppression and to eliminate offset voltage and drift of B701. The basic configuration is shown in Fig. 4-1.



S: open during forward sweep
temporarily closed during retrace

Fig. 4-1 Basic clamping stage design

V_s is assumed to be the signal voltage supplied by the measuring detector and amplified, consequently a representation of the sweep curve. As the RF is blanked during retrace of the sweep generator, V_s is only present during the forward sweep. V_n is the noise voltage, generally resulting from the amplified demodulated voltage of a noise signal (e.g. caused by devices under test with a built-in oscillator, such as receiver mixers, or similar) in combination with the offset voltage of the preamplifier. In contrast to V_s, V_n is also present during the retrace.

During a portion of the retrace time, S is closed. As $V_s = 0$, C is charged to the level of V_n, which yields: $V_C = V_n$. Examining the voltages in Fig. 4-1 during a forward sweep (S opened), results in:

$$-V_n - V_s + V_C + V_{out} = 0$$

$$V_{out} = V_s - V_C + V_n$$

and because $V_C = V_n$

$$V_{out} = V_s - V_n + V_n$$
$$V_{out} = V_s$$

V_n has become ineffective due to the voltage across capacitor C. The following stage must have a very high input resistance to prevent discharge of the capacitor when the switch is opened. Clamping is of course only meaningful as long as V_n does not change much during the forward sweep. If it is assumed that RF noise caused by devices under test has a stable amplitude or is only subject to minor fluctuations, then it is mainly offset voltage drift that may affect this procedure. The slowest forward sweep is, however, only 2 s for the SWOB 5, and the operational amplifier does not virtually change its offset voltage in this time. When operating the "slow sweep" option - the forward sweep is thereby prolonged to approx. 30 s - a clamping period is maintained whose pulse duration is 35/7 ms. Zeroing is performed also in this case at least every 35 ms.

C708 is equivalent to capacitor C, and B702IV assumes the function of switch S in Fig. 4-1. B702IV is closed in the middle of the retrace time, the closing time being 0.3 $t_{retrace}$ (see also the pulse diagram in circuit diagram 333.5610 S). R709-R712-R713 form a series resistor for charging the capacitor C708 during the clamping phase. Due to the large time constant of this RC network, the noise from the preamplifier does not affect the accuracy of the spurious-signal suppression.

Operational amplifier B703 following the clamping capacitor has a FET input stage to keep the charge of C708 unchanged during the forward sweep.

The AF voltage must be limited before the input of the logarithmic converter if the RF voltage is above 20 mV, to initiate the switchover circuit (section 4.5.1.3). The voltage above which limiting occurs (+7.5 V, approx.) is determined by the resistive divider R714-R704-R728-R727.
If the output voltage of B703 exceeds this threshold, the diode GL710 is cut off. The divider R715-R718 provides a second threshold voltage (together with the diode voltage +2 V, approx.). If the RF voltage is increased and consequently the AF voltage, GL711 conducts cutting the divider into circuit which attenuates the AF signal by approximately 2 dB. This ensures a smooth switchover from signal path I to signal path II as the signal level increases.

Since the AF voltage at the output of the clamping stage (BR702) is only 134 µV at an RF level of 170 µV, the offset voltage drift of B703 over the allowable operating temperature range would cause error voltages of the signal's magnitude. This drift is eliminated by means of analog switches B702I to III and C710.

During the clamping phase at retrace (B702IV closed) B702I is opened, while B702II and III are closed. This causes the input of B703 to be at ground level, its output carrying its offset voltage. C710 is charged to this voltage. During forward sweep, only B702I is closed; thus C710 is in series with C708 and the input of B703. Polarity is such that the offset voltage from the voltage-follower is subtracted from the signal voltage.

The control voltages for the analog switches B702I to IV are obtained from the sweep saw-tooth signal and clock signals from the sweep control circuit using comparators and a control logic on the AF motherboard, and are applied to the plug-in board through pins a11 and b11. Their levels and their timing can be seen from the pulse diagram in circuit diagram 333.5610 S.

b) Logarithmic Converter I

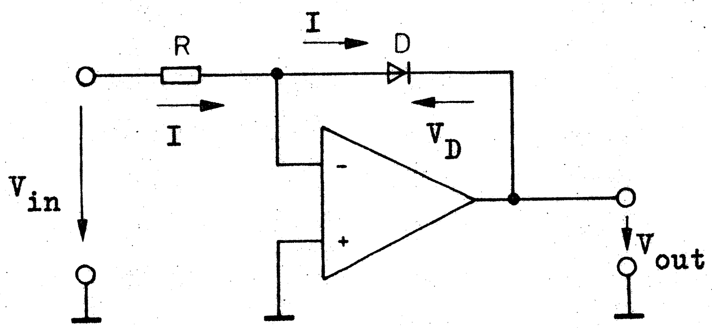


Fig. 4-2 Basic diagram of logarithmic converter

The basic operating principle of the logarithmic converter is shown in Fig. 4-2. Output voltage V_{out} is directly present at diode D. As $V_D = V_{out}$ and I are logarithmically related and I is proportional to input voltage V_{in}, a logarithmic relationship exists also between V_{out} and V_{in}.

The elements of Fig. 4-2 represent R704-R728, T710I (connected to operate as a diode) and operational amplifier B704.

As the dynamic range of the logarithmic converter is approx. 84 dB. the offset voltage drift of operational amplifier B704 and the temperature drift of logarithmic conversion diode T710I have to be eliminated during the retrace period of the sweep generator.

Switching FET T707 separates the logarithmic converter from the signal source during the retrace. During the first half of the retrace (see timing diagram in the circuit diagram for exact times), T706 switches a reference current (adjustable with R735 "linearity I"; see also chapter 5 for adjustment procedures) into the input of B704. The integrator B705 is connected to the output by T709 at the same time. The operating point of the logarithmic converter is adjusted by the integrator voltage (MP3) until the voltage at the inverting input (2) of the integrator becomes zero. The offset voltage of B704 is compensated at proper adjustment of R735 (see adjustment schedule). C715 maintains the control voltage at MP3 during the forward sweep.

During the second half of the retrace, the output level is fixed at the point where switching to signal path II is accomplished. It would otherwise drift due to the temperature effects on T710I.

For this purpose, T705 injects a current into the input of the logarithmic converter which corresponds to the level of the driving signal at an RF level of 20 mV. At the same time, T708 switches a DC voltage to the output of the logarithmic conversion stage (MP4) which corresponds to the value required at an RF level of 20 mV. If the output voltage of B704 differs from that, C717 is charged to this voltage difference level and shifts the potential towards the nominal value. C717 and T708 form a clamping circuit as described in a).

The reference voltage at the source connection of T708 depends on the temperature of a compensation NTC resistor in the measuring head, to compensate for the temperature drift of the measuring diode.

Since the logarithmic converter has a high gain for low levels (the gain increases with decreasing input), the noise voltage would create high positive peaks without GL708. Residual RF voltages, if any (depending on the swept frequency range) are suppressed by R746 and C716.

The clamping circuit C717-T708 requires a subsequent stage with a high input resistance. This condition is met by B706. This operational amplifier amplifies the signal by a factor of approx. 17 and drives B707 (part of the switchover stage).

The switching FETs of the logarithmic conversion stage receive their control voltages (as analog switch B702 of the preamplifier clamping stage) from the AF motherboard. The required signals are applied through a10, b10 and b11.

4.5.1.2 Signal Path II (for RF Voltages > 20 mV)

Signal path II begins at BU701 and ends at MP12.

a) Reference Control Loop

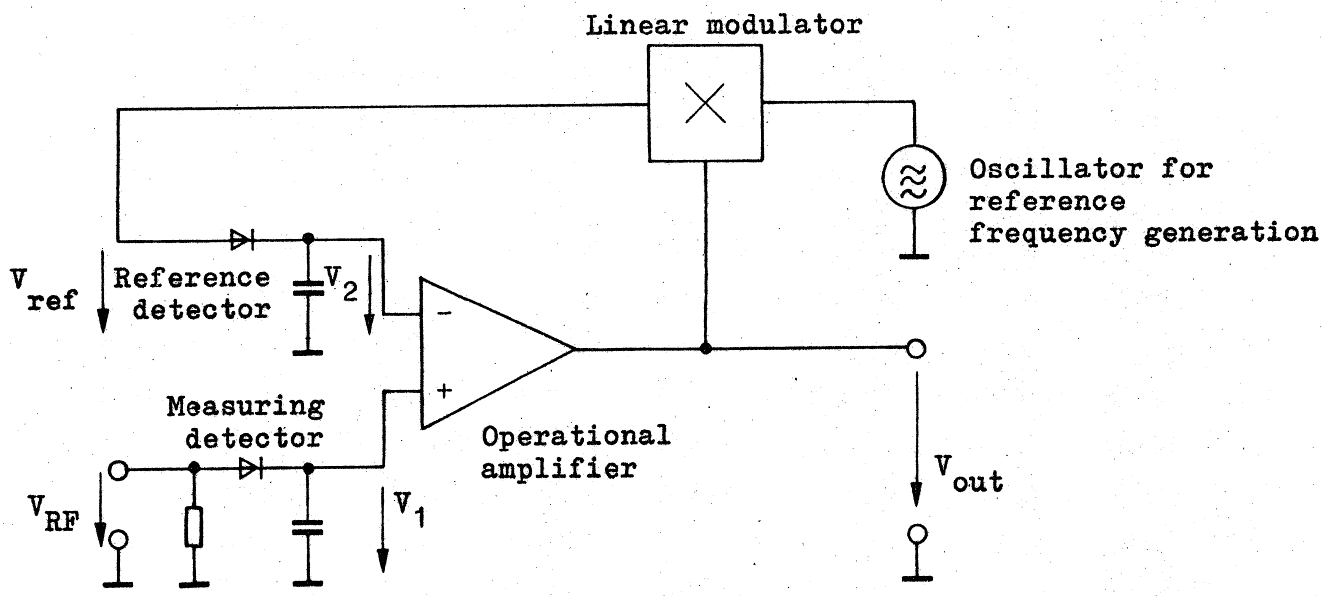


Fig. 4-3 Basic diagram of reference control loop

This control loop establishes a linear relationship between RF voltage V_{RF} and DC voltage V_{out}, thus linearizing the measuring detector.

Fig. 4-3 shows an operational amplifier circuit whose feedback loop is made up of a linearly operating modulator and a demodulator with a rectifying characteristic identical to that of the measuring detector connected in series. The modulator receives an auxiliary signal from an oscillator. This signal is amplitude-modulated by V_{out}, converting V_{out} into a proportional AC voltage. The reference demodulator converts V_{out} back into a DC voltage V_2.

The operational amplifier receives DC voltage V_1 for a given RF voltage V_{RF} at the non-inverting input. It adjusts its output voltage V_{out} until the reference demodulator supplies a rectified voltage V_2 of equal amplitude. As the rectifiers have the same characteristics, V_{RF} is equal to V_{Ref}. Since V_{Ref} is proportional to V_{out}, V_{RF} is also proportional to V_{out}, yielding a linear relationship between V_{RF} and V_{out}. V_{out} can thus be used directly to drive a logarithmic converter.

Measurement voltage II in the circuit diagram is represented by V_1 in Fig. 4-3. It is taken from the measuring demodulator through an adjustable voltage divider in the measuring head. This trimming potentiometer is adjusted for identical rectifying characteristics of the measurement and the reference demodulator (see adjustment schedule in chapter 5).

Measurement voltage II is passed to input stage T711 through BU701/7. This stage has a voltage gain of 1 and isolates the measurement demodulator from clamping stage C720 and T714. The ALC amplifier is B711 which is represented in Fig. 4-3 by the operational amplifier. It is connected in a loop comprised of R758-R763-C723 for compensation of the frequency response. R799 limits the gain. T713 shorts the output during first half of the retrace period to avoid interferences. The voltage at MP8 is represented by voltage V_{out} in Fig. 4-3. It is applied to logarithmic converter II and the feedback path through BR705.

During the second half of the retrace, the offset of B711 is reduced by means of a clamping circuit. Since the RF as well as the 300-kHz reference frequency are blanked the measuring head does not supply a signal voltage, i.e. MP7 is always at the same potential. The reference demodulator voltage (soldering terminal 1) is 0. If an offset voltage is present at B711, it is taken from the output to the input of B712. B712 together with T721 forms a 100% feedback amplifier (G = 1) whose offset is negligible. Spurious voltages caused by B711 are inverted at the emitter of T721. They are tapped off from the divider R2759-R2760 and fed back to the non-inverting input of B711 and the capacitor C720 via T714 which conducts during the second half of the retrace. C720 charges with respect to MP7 until the output voltage of B711 has dropped to the remaining offset (due to the finite gain of B711). If T714 starts to conduct C720 exhibits a voltage which counteracts the offset of B711.

In addition to the circuitry of Fig. 4-3, a polarity limiter is connected before the modulator. The limiter is an active detector consisting of B712-GL751-GL752-T721. The control loop might become unstable without the polarity limiter, as the feedback through the reference demodulator utilizes only the signal magnitude.

A chopper consisting of FETs T722 and T723 serves as modulator. The auxiliary oscillator on the AF motherboard drives the FETs with two rectangular signals of approx. 300 kHz in phase opposition which causes both FETs to be conducting at the switchover point. This measure is used to suppress interfering spike pulses caused by the oscillator signal edges. RC network R2760-R2759-C760 serves the same purpose. Low-pass filter C761-C762-L701 smoothes the chopped DC voltage to form a sine signal. This is amplified by B713 and fed to the reference demodulator in the measuring head via BU701/2. The auxiliary DC voltage obtained there drives the inverting input of B711 (corresponding to V_2 of Fig. 4-3) through BU701/4 and voltage divider R757-R759.

b) Logarithmic Converter II

The principle of operation of logarithmic converter II is the same as that of logarithmic converter I. The elements of Fig. 4-2 represent R766-R768-B714-T710II (the latter used as a diode). At the same time R766-C734 form a low-pass filter which is used for separating signal components obtained from the 300-kHz reference.

As the dynamic range of logarithmic converter II is only approx. 34 dB, an automatic offset zeroing circuit is not required. GL724 limits the positive output voltage. RC network R780-C726 matches the frequency response of the logarithmic converter to that of the control loop.

T716 disconnects the logarithmic converter from the loop during the retrace. The switching point at an RF level of 20 mV is here too defined by a reference current through T717 and the clamping circuit C730-T718. For further details see the description of logarithmic converter I. B716 amplifies the signal that has been logarithmically converted by a factor of approx. 34. The equivalent stage B706 within signal path I has only exactly half the gain. Thus, the square-law function in the lower range of the measurement demodulator's characteristic is taken into account.

4.5.1.3 Switchover Circuit and Output Stage

a) Voltage Discriminator

A voltage discriminator is used for switchover from signal path I to signal path II. The operating principle can be seen from Fig. 4-4.

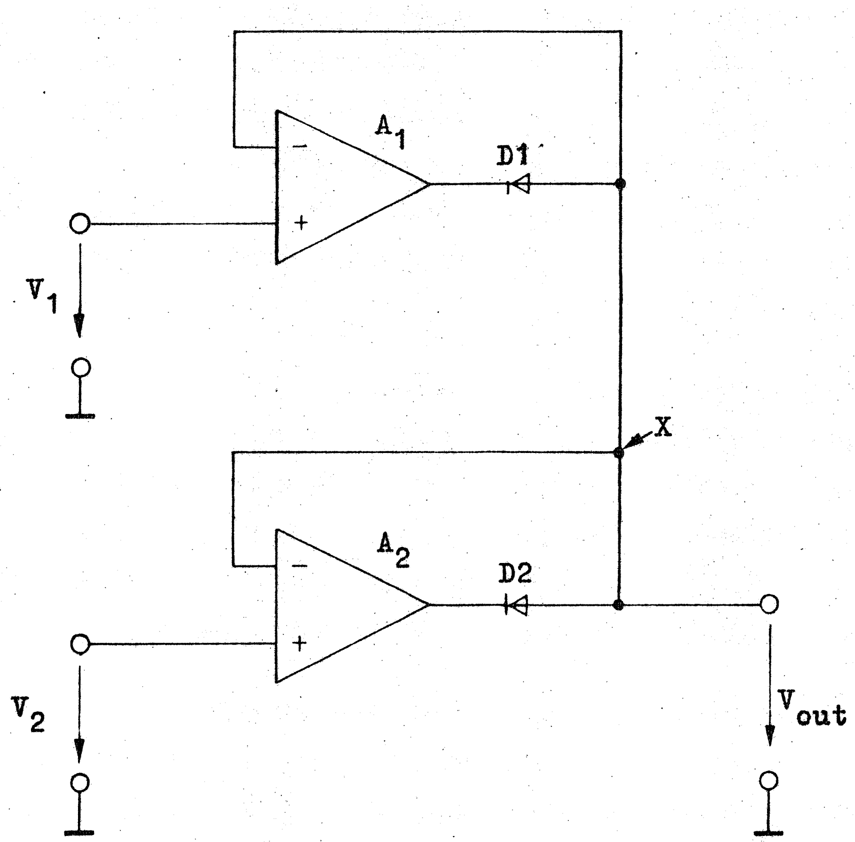


Fig. 4-4 Voltage discriminator

If the stages are disconnected at X, the output voltage will equal the input voltage. It is now assumed that V_1 is more negative than V_2. If the outputs are connected at X, the cathode potential of D2 is more positive than its anode potential; therefore D2 is cut off.

As the voltage at the inverting input of A2 is more negative than the voltage at the non-inverting input, its output is driven into positive saturation, causing D2 to be driven farther into the cutoff region. Only V_1 will thus be present at the common output.

A1 and A2 of Fig. 4-4 represent B707 and B717, D1 and D2 represent GL714 and GL734. GL713 and GL733 prevent the operational amplifiers to be driven into saturation, which would lead to a delay of switchover.

If the level is increased, the signal path I operates exactly logarithmically until it has reached the first limiting threshold. The logarithmic scale is reduced by about 10% between the first and the second limiting threshold, i.e. an edge that is in reality continuous exhibits a break point. The change in the scale indicates a somewhat too low signal voltage. But the signal path II operates exactly in this range. Its output signal is somewhat higher. It is switched over and read out. If the level is again decreased, the signal path II is used until its voltage is lower than that of the signal path I due to non-linearities. The circuitry does not allow the output voltage of the signal path II to be so reduced to always be below the output of the signal path I. For this reason, the comparator B718 has been built in. If the output signal of the signal path I drops below the comparator threshold, the switching FET T719 is cut off through B718. As a result, the output voltage of B716 goes positive and thus is reliably below the signal of the signal path I.

b) Output Amplifier and Horizontal Line

The amplitude of the re-combined AF signal is adjusted with R790. Compensation NTC resistor R793 compensates for the temperature-dependent scaling factors of the logarithmic converters in conjunction with resistor network R794-R796 to R798.

Output amplifier B721 processes the AF signal for driving one display channel of the basic unit. Its gain is varied according to the display range of 10, 20, 40, 60 or 80 dB per vertical display range by selecting feedback resistors R2701 to R2705 with S701III (20). An offset voltage is applied to the inverting input through R2710 for shifting the display position. This offset voltage is adjustable with R702I (19; Fig. 2-16) and its value is chosen with resistors R2711 to R2714, which are in turn selected with S701II, to match the individual display range. If the display range is 80 dB, a position shift is not possible.

The same offset voltage is applied to horizontal-line stage B722 through R2731 as the test signal and the level line must always have the same position relative to one another. The gain is adjusted to fit the display range in the same way as for the AF output stage (resistors R2721 to R2725, switch-selectable with S701I). For matching to the basic unit, an additional offset voltage is applied to B722 through R2730. This offset voltage is adjustable with R2728 (see adjustment schedule of chapter 5).

The 10-turn potentiometer R701 (17) with dial knob allows adjustment of the horizontal line. The alignment of the adjustment range is made using R2736 (see chapter 5).

If potentiometer R702II (19) is turned fully clockwise, the horizontal line is calibrated (0 dB ≙ 1 V). The rotary switch S702 which is mechanically coupled with R702II is then in its CAL position (as shown in circuit diagram 333.5610 S). If R702II is turned left from its detent position, S702 is set to its UNCAL position. This condition is signalled by the LED GL701. The 0-dB position of the level line can now be shifted to smaller values (0 dB ≙ approx. 316 mV) by approx. 12 dB, using R702II.

If the plug-in is switched off with S701 (20), switching FETs T707 and T716 are cut off through GL715. At the same time, the inverting input of B721 is supplied with -15 V through R2706, while the inverting input of B722 receives +15 V through R2720. This causes the output voltages to assume values above the upper or below the lower display margin.

The AF signal which has been logarithmically converted is tapped off through GL730 for automatic sweep control. This lowers the sweep speed in the case of the device under test presenting steep slopes.

4.5.2 Linear Deflection Amplifier Plug-in SWOB5-E2

Refer to circuit diagram 333.5010 S.

The rectified voltage of a measuring head SWOB5-Z1, -Z2 or -Z3 or of active demodulator SWOB5-Z4 is applied to the linear deflection amplifier through BU601 PROBE (25; Fig. 2-16). BNC socket BU602 AF (26) is an AF input for connecting the probe SWOB3-Z or a device under test with built-in detector.

S601 (24) selects the two inputs. The selected operating mode for the individual switch positions and the meaning of the symbols can be seen from the following table:

Symbol	Function
OFF	Linear amplifier plug-in off
+	Positive input voltage at BU602 (26) gives an upwards deflection
-	Positive input voltage at BU602 (26) gives a downwards deflection
+≈	Same as for +, with RF noise-signal suppression
-≈	Same as for -, with RF noise-signal suppression
=	Display of measuring-head voltage (BU601, 25)
≈	Same as for =, with RF noise-signal suppression

Each input operates in conjunction with a separate wafer of switch S601. S601I is used together with BU602, and S601II with BU601. This separation prevents crosstalk between the inputs. S601III connects the desired input to the input stage. To avoid disturbance being caused by ground loops, the reference lines of the measuring inputs are connected to the floating ground of the deflection amplifier via S601IV. RC networks R605-C605 or R606-C606 and R607-C607 establish a connection to the ground of the basic unit. GL606 and GL607 limit any existing potential difference between the ground connection of BU602 and common ground to approx. 0.7 V.

Operational amplifier B601 forms the input stage with a gain of approx. 8. GL601 and GL602 protect its input from overvoltage. The offset voltage of B601 is cancelled out with R613 (section 5).

If S601 is set to a position where RF noise-signal suppression applies (≈, +≈, -≈), S601V applies a negative voltage to the gates of FET switches T601 (n-channel) and T602 (p-channel). Thus T601 is cut off while T602 conducts, passing the AF signal to the second stage through clamping circuit C617-T607 (section 4.4.1.1a). The negative voltage causes also GL609 to become non-conducting, causing the "linear" clock signal from the AF motherboard to drive T606 through R631, closing clamping switch T607 during each retrace.

In operation without RF noise-signal suppression, a positive voltage is applied to the gates of T601 and T602 through S601V, as well as to the anode of GL609. The AF signal by-passes now the clamping circuit and drives the input of the second stage directly, while the conducting diode GL609 causes clamping switch T607 to remain permanently cut off. B602 operates as a voltage-follower with a high input impedance and isolates the clamping circuit from the following amplifier B603. The offset voltages of B602 and B603 are compensated with R644 and R654 (section 5).

The AF gain is adjusted to a maximum of approx. 24 with R650 (22) in the feedback loop of B603. This provides for a good signal-to-noise ratio also when the control is turned back.

If BU601 is selected with S601, or if a positive input voltage applied through BU602 is required to produce an upwards deflection (S601 in its + or +≈ position), the gate of T608 is connected to source potential through R658, causing T608 to conduct. This lets B604I operate as an inverting amplifier with a gain of 1.

In "-" and "-≈" operating modes, a reverse voltage is applied to the gate of T608 through S601IV. The AF voltage is now additionally received by the non-inverting input of B604I, resulting in a non-inverting gain of 2. The total gain, obtained by summing the gains of the inverting and the non-inverting op-amp channels, amounts to -1. B604II which is the output stage of the deflection amplifier, has a voltage gain of 10. It receives a DC voltage through R667 which is adjustable with R601 (23) for vertical positioning of the display.

The diode network GL611 to GL614 within the feedback loop of B604 prevents the following stages of the basic unit from being overdriven.

4.5.3 Logarithmic Amplifier Plug-in SWOB5-E3

Refer to circuit diagram 349.35125 Bl. 1 and 2

The design of the logarithmic amplifier plug-in E3 is based on the logarithmic amplifier plug-in E1 and features, in addition an AF input with polarity switchover, a 3 1/2-digit display for level readout in mV, dBV or dB, automatic reference level setting for relative measurements and an indicator lamp which lights up when the spurious voltage suppression is inadequate.

The plug-in consists of the logarithmic amplifier board, the logic circuit board and the display board. The logarithmic amplifier board is identical to that used in the logarithmic amplifier plug-in E1 with the exception of some electrical and mechanical adjustments so that chapter 4.5.1 basically also applies to the plug-in E3. In the following paragraphs only the newly added logic circuit and display boards are described.

These boards contain the AF input amplifier B2953, the input selector switch S2981, the indication selector switch S2980, automatic reference level setting, the digital voltmeter with LED, the delogarithmization circuit for mV indication, autoranging for mV indication, automatic 20-dB switchover when using the Active Demodulator SWOB5-Z4 and the indicator lamp which lights up in the case of inadequate spurious voltage compensation.

The gain of the AF input amplifier is +0.5 or -0.5 depending on the switching state of the FET T2955, i.e. the signal available at its output can be an inverted one or a non-inverted one. To keep the input impedance in either case at approximately 100 kΩ the resistor R2970 is connected in parallel with the AF input in the case of the non-inverted signal by means of an additional switching contact. The output signal is finally applied to the logarithmic converter I (logarithmic converter II is inoperative when using the AF input) by way of deck I of the switch S2981. Since the signal path amplifies the square-law section of the rectified voltage of the measuring diode when using the probe input, the voltage of the AF input must be "artificially" squared to adapt it accordingly. This is accomplished at the output of the logarithmic converter I through the multiplication by a factor of 2, T2737 operating as switching transistor.

The calibrated level line of the logarithmic amplifier plug-in E3 is produced by means of the 10-turn potentiometer R701 and offset (R2840, B2843) to adapt it to the basic unit. To take the gain of an Active Demodulator SWOB5-Z4, if connected, automatically into account, its supply current of approximately 100 mA is used via R2733 as switching criterion for the comparator B2828 II which, in turn, delivers via T2841 an adequate additional offset voltage to the operational amplifier B2843. For the digital display of the level a digital voltmeter is used. It operates according to the dual-slope principle, has differential inputs, automatic zero adjustment and outputs signals if the range is exceeded or not reached. When using the mV indication, these signals are appropriately processed and used for the automatic triple range selection (B2922, T2930, T2931).

The delogarithmization circuit consisting of B2860, B2865 and T2862 permits the dBV to be converted to mV. This requires an extremely high accuracy, wide dynamic range and low temperature drift. The circuit used offers an accuracy of better then 1% within 60 dB and an overall dynamic range approaching 100 dB. The scale factor is temperature-controlled.

For relative measurements in dB automatic reference level setting is provided permitting any absolute level to be set as reference level (0 dB). The necessary circuit to which this value must be delivered consists of a binary counter (B2810) and a D/A converter (B2811) connected in series. The counter is reset at the push of a button (S2983), counting, after the button has been released, the pulses of a 20-kHz generator (B2806) until it is stopped by the comparator B2818 I. The inputs of the comparator and, as a consequence, also the differential inputs of the digital voltmeter are now at the same potential, i.e. "0 dB" is read out.

The comparator B2818 III which operates in a Schmitt-Trigger circuit is used for the indication of an excessive spurious input voltage that can no longer be compensated for. To determine the magnitude of the spurious voltage without the wanted signal the switching threshold is raised during the forward trace of the sweep signal via diode G2960 so that the comparator will respond only during the return trace during which the RF wanted signal is blanked when the maximum spurious voltage that can be compensated for is exceeded.

4.6 AF Motherboard

Refer to circuit diagram 333.0019 S, Bl. 7.

The AF motherboard carries the multipoint connectors which connect the deflection amplifier plug-ins to the basic unit. Each of the two display channels is equipped with a separate deflection amplifier whose AF bandwidth is switch-selectable. The plug-ins are supplied (±15 V) from the supply voltages for the basic unit, using regulator stages. The switching voltages which are required for the clamping stages and for control of the operating points of the logarithmic converters are obtained from the sweep saw-tooth signal and from clock signals of the sweep control circuit, using comparators and a logic circuit. The AF motherboard furthermore carries the auxiliary oscillator for the reference control loop and the comparators of the automatic sweep control circuit.

4.6.1 Deflection Amplifiers

The deflection amplifiers B501 and B506II match the AF signals of both channels to the comparator inputs (chapter 4.7).

The deflection amplifiers are connected to operate as active AF filters. If T502 or T508 is cut off, the upper cutoff frequency is approximately 7.5 kHz determined by means of R502-R503-R505-R506-C501-C503 or R572-R573-R575-R576-C571-C573. When T502 or T508 conducts, C502 or C772 is connected lowering the cut-off frequency to about 40 Hz. Pull switch S910 of the sweep-time potentiometer R910 (38) is used for switchover to NARROW which is signalled by means of the LED GL910.
When switched to NARROW, the AF filters are automatically set for wide-band during the retrace, to suppress a display of disturbing transients due to RF blanking. This is done using the line-marker blanking pulse SMA generated by the control logic of the sweep control circuit. T502 and T508 receive this signal through B514II and GL556.

A level line comparator is assigned to each AF channel (chapter 4.8). The comparator input is matched to the level-line output of a logarithmic amplifier plug-in with B504 and B505. If no plug-ins are inserted, the output voltage of a deflection amplifier assumes a value corresponding to a line above the upper display margin as R501 or R571 causes the input to go to a corresponding potential. R581 or R591 at the input of a level line amplifier does the same, even when a linear amplifier plug-in is inserted.

4.6.2 Regulation of Supply Voltages

DC voltages of +15 V and -15 V are required to supply the deflection amplifier plug-ins. These voltages are obtained from +24 V and -20 V of the basic unit. As highly stable voltages are required for the plug-ins, operational amplifiers with following power transistors are used.

GL508 stabilizes the reference voltage derived from +24 V. B503I together with T503 regulates the positive, and B503II together with T504 regulates the negative supply voltage. Both voltages are adjusted with R526 (section 5).

4.6.3 Generation of Switching Voltages

a) Generation of pulses for logarithmic amplifier plug-ins
   The control voltages required by the FET and the analog switches of the logarithmic amplifier plug-in for clamping and for stabilizing the logarithmic converters are derived from the sweep saw-tooth signal (LOG. SZ) using the linear clock signal (LINT.) and from the line-marker blanking pulse (SMA). The pulses which occur during the retrace time are generated by three comparators and a logic circuit as shown in Fig. 4-5. The associated output voltages can be seen from Fig. 4-6.

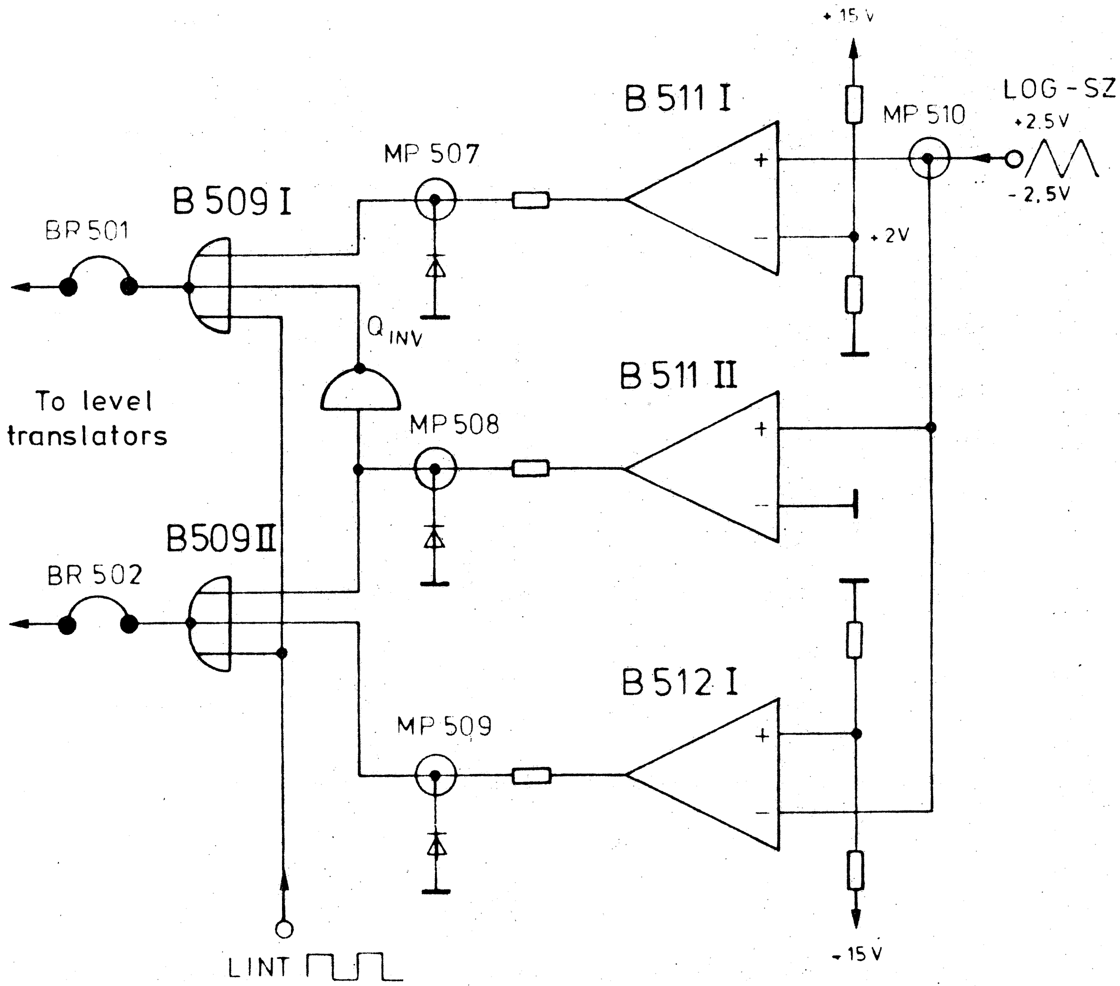


Fig. 4-5 Generation of switching pulses during retrace

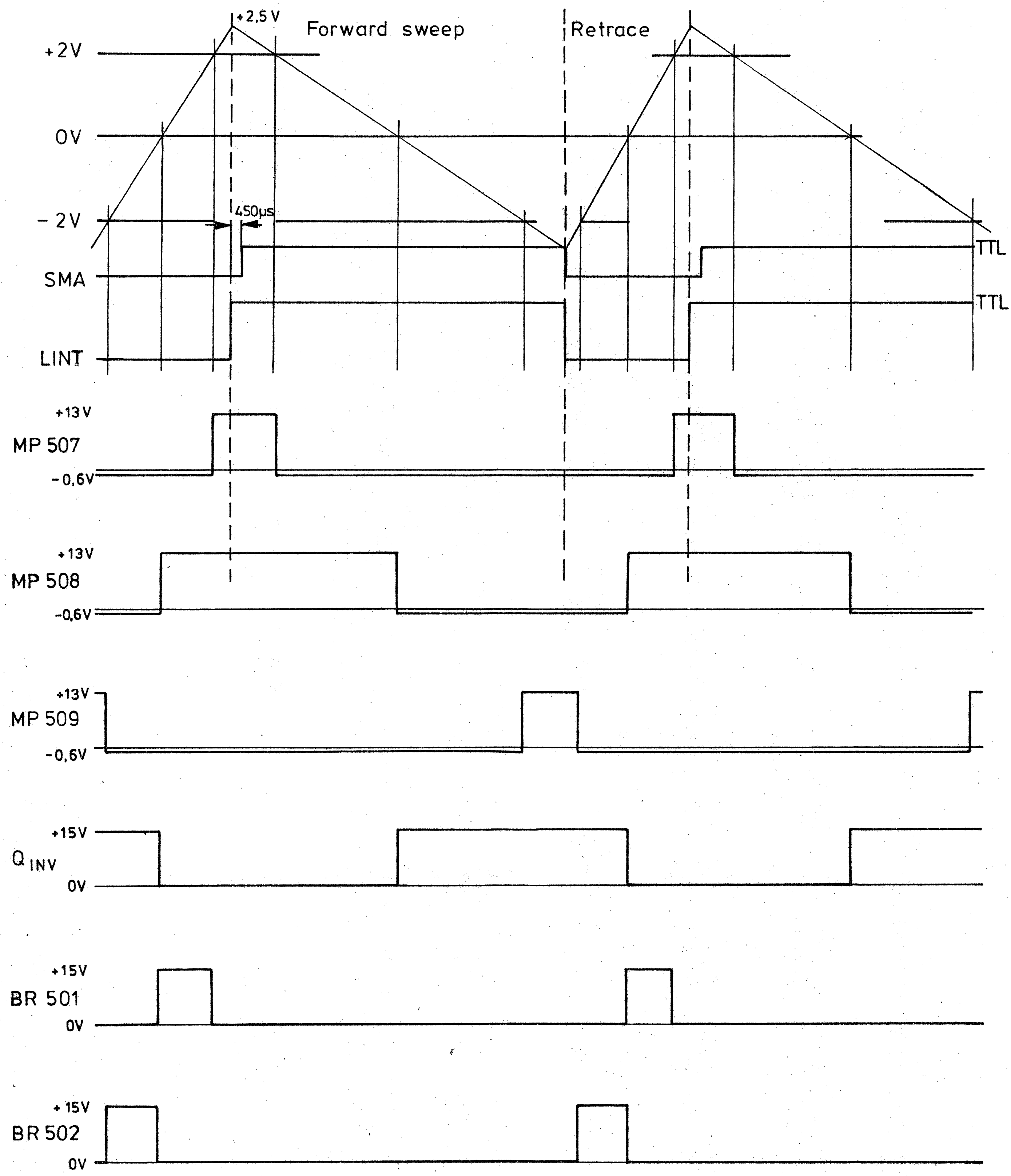


Fig. 4-6 Pulse diagram to Fig. 4-5

B512II, B513I and B513II follow the pulse-generating logic as level translators (from 0 V/15 V to ±13 V). They supply the logarithmic amplifier plug-ins through BU502 and BU503 (at a11, b10 and b11). The SMA pulse is level-translated in B514II from TTL level to ±13 V and applied to BU502/a10 or BU503/a10.

The related pulse diagram (with times and levels indicated) is shown in circuit diagram 333.5610 S for the logarithmic amplifier plug-in.

b) Generation of pulses for the linear amplifier plug-in
The linear amplifier plug-in requires only the linear clock signal LINT. for the clamping stage of the automatic RF noise-signal suppression circuit. The clock signal is level-translated from TTL level to ±13 V by B514I and applied to the linear amplifier plug-ins through BU502/a4 or BU503/a4.

4.6.4 Reference Oscillator

The phase-opposite rectangular signals for driving the chopper FETs T722 and T723 of the reference control loop are generated in the reference oscillator.

T506 generates a signal of approx. 3 MHz together with L501, C542 and C543. T505 adapts the level to the input of CMOS frequency divider B507. Its output signals Q_1 to Q_4 (pins 11 to 14) are combined by diode gates GL512-GL513 as well as GL511-GL514, NOR gate B509III and inverters B508I to B508III to yield a rectangular voltage with a repetition rate of approx. 300 kHz and a duty cycle of 0.6 at the outputs of inverters B508I and B508II (see Fig. 4-7).

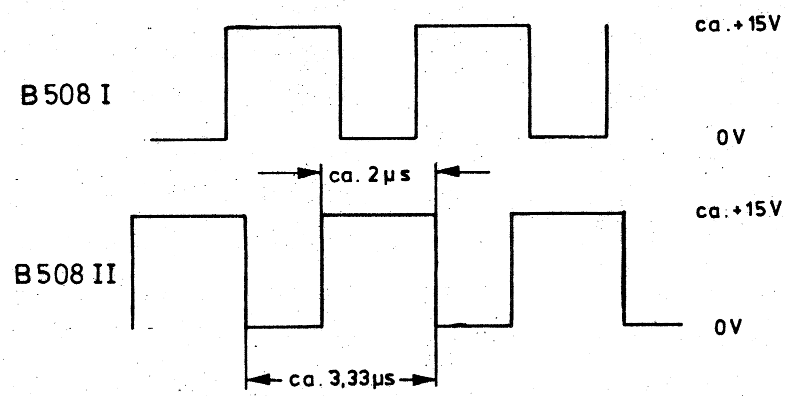


Fig. 4-7 Output voltages from reference oscillator

4.6.5 Automatic Sweep-Time Control

The automatic sweep-time control circuit slows down the sweep speed by a factor of 4, if steep trailing slopes are swept. This sweep-time reduction is only effective in conjunction with the logarithmic amplifier plug-in.

The logarithmically converted AF voltage is coupled out through GL730 (in the logarithmic amplifier plug-in). GL730 is biased negative through R515 and R516 to clip the basic noise. C506 and R519 differentiate the AF signal.

With a steep trailing slope of the measurement curve, which corresponds to a positive slope because the AF signal is inverted, comparator B502I supplies a positive pulse. For stability reasons, this comparator operates with a hysteresis which is defined by R519 and R520.

GL504 and GL505 limit the pulse before it drives the second comparator B502II. This switches T2403 in the sweep control circuit (section 4.1) to increase the sweep time. The switching threshold is varied by sweep-time potentiometer 28 (Fig. 2-16) through GL506 and R523 so that no control pulse is supplied by B502II at long sweep times.

GL549 conducts during the retrace time, disabling the automatic sweep-time control.

4.7 "Slow Sweep" Option

Refer to circuit diagram 333.9516 S.

This option increases the sweep time to approx. 30 s in the SINGLE mode. As the deflection amplifiers might drift considerably during this time, an additional control clock signal is introduced which blanks the RF momentarily and drives the correction circuits of the deflection amplifiers. The control clock signal is generated in B50 (output pin 9), and fed to the control logic of the sweep control circuit (input of B2433II, pin 4) for further processing. A saw-tooth signal is tapped from output B50 pin 3, amplified by B60, inverted and offset symmetrically about zero. This saw-tooth signal replaces the saw-tooth signal for slow sweep (pin 4a) which is required on the AF motherboard for control functions (pin 4b). For this purpose, the switching FET T75 is cut off by the sweep control circuit through switching amplifiers T65, T66 and T62 while T73 is conducting. The switching signal is further passed to the intensity control circuit through pin 3 to reduce the display intensity during slow forward sweep. The amplitude or the DC voltage position of the Y-axis signals of both deflection amplifiers is corrected in B20 or B35. The following sample-and-hold circuit, consisting of T20-C20-B25 or T35-C35-B40 suppresses the blanking pulses.

The FETs T120 and T125 operate as switches which are controlled via B100 I to IV. Only the signal of the actually operating amplifier plug-in is passed on to pin 2 of the recorder socket 53.

If both plug-ins are operating the two FETs are cut off and no signal is supplied to this recorder output.

The control signals are produced in the amplifier plug-ins (amplifier off: V = 0 V; amplifier on: V = -14 to -8 V) and are applied to the FET control logic circuit B100 via pins 8 and 9, respectively.

The X-axis signals are handled the same way by T10-C10-B10, providing several advantages: the retrace is blanked, the X-axis and Y-axis outputs are disabled in AUTO mode. In MAN mode, the test point adjusted last is stored when switching directly from MAN to SINGLE.

For this purpose, three control signals from the sweep control circuit are combined by B1 in an appropriate way, driving the three switching FETs through T5 and T6. The RC networks at the gates of the FETs provide a switch-on delay, suppressing transients. The diodes bypass the resistors at switch-off. The pen-lift is actuated with 300 ms delay with reference to the start of the forward sweep, monostable B45 providing for the required delay time.

4.8 Comparator

Refer to circuit diagram 333.0019 S, Bl. 4

A raster method is applied for the display of test curves and reference lines. The Y-axis deflection is not performed according to the curve to be displayed but using a constant sine signal whose amplitude covers the whole screen height. The raster frequency is 50 kHz. The CRT is unblanked at the points where the raster sine signal for the Y-axis deflection has the same voltage level as the curve point to be displayed. The comparator board contains seven separate comparator modules. The raster frequency is applied to all modules in common through filters (100 Ω - 2 x 330 pF).

The other comparator input is connected to the signal to be displayed. The transistors connected inbetween (B1309I to B1309VII) operate as emitter followers. To compensate for temperature effects, all transistors are arranged in a single array. The raster signal, obtained as a floating signal from a secondary winding in the Y-axis generator, is supplied via the transistor T1300 to the comparators. The amplitude of this signal can be adjusted by means of R1301 and the DC level by means of R1302.

The comparator module consists of the actual comparator followed by a monostable. By external connections of the monostable, it can be chosen whether it should be triggered at every voltage coincidence at the comparator input or only at voltage coincidence accompanied by a specific polarity change. Furthermore, the pulse length can be varied by an external RC network. The monostable can be disabled through input pin 3. This input is used (except B1303) to blank the display during the retrace, at the display margin and after a single sweep, by a suitable signal from the sweep control circuit.

B1301 and B1302 serve to display the measurement curve from both deflection amplifiers. To increase the resolution, the monostable is triggered at every voltage coincidence of the raster signal and the measured signal. The pulse duration is 30 ns.

C1302 and R1303 serve for phase correction between Y-axis deflection and raster signal. Phase errors result in a double appearance of the measurement curve. For alignment, the spots generated at the rising slope of the raster signal.by the measurement curve are made to coincide with the spots created by comparison of the measurement curve with the trailing slope of the raster sine signal.

B1304 and B1305 generate two horizontal lines which can be shifted across the screen by means of the controls 14 and 15 (Fig. 2-16) on the front panel of the basic unit. B1306 and B1310 are associated with the calibrated level lines, which are adjusted with the potentiometer 17 the logarithmic deflection amplifiers. These four comparator modules are connected in such a way that they supply a signal only at the rising slope of the raster signal. The reduced resolution is sufficient for a display of horizontal lines; the intensity of the lines is reduced and adapted to the practical operating conditions. Pulse duration is 30 ns. The output of the four modules are combined through a gate and routed to the intensity control amplifier.

The bright-up bar at the lower display margin is generated by B1303. The pulse duration of the monostable is 0.5 µs, causing the display to be intensified not only for a single spot but for a line with a length of approx. 1 cm along the Y-axis. Lined up, these lines appear as a bright-up bar.

Since the position of the bright-up bar is not changed along the Y-axis, the driving signal is replaced by a DC voltage of 0 V. The outputs of B1301 to B1303 are combined through a gate, driving the second input of the intensity control amplifier.

4.9 Intensity Control Amplifier

Refer to circuit diagram 333.0019 S, Bl. 5.

The intensity control amplifier processes the pulses supplied by the comparator in two parallel branches and unblanks the display through the control grid or cathode. One of the two branches controls the measurement curves and the bright-up frequency bar and the other one the horizontal and the level lines. Thus it is possible to set the intensity of the measurement curves separately from that of the level lines.

The edges of the switching pulses are made steeper at the amplifier input by B1201 and B1202. T1211-T1212, T1215-T1216 and T1220-T1221 operate as push-pull switching amplifiers. Their outputs are combined through GL1251 and GL1252 and brighten up the display via the control grid. The intensity can be varied with the pulse height by simply varying the operating voltage for the switching transistors by T1222-T1224 for the measurement curves, and by T1242-T1244 for the level lines.

The line markers are generated by brightening up the display through T1201. At the same time, the operating voltage for the switching transistors is reduced by T1223 or T1243, reducing the intensity at the intersections of the measurement curves or level lines and the line markers.

GL1253 clips pulse peaks. GL1201 and C1201 blank the display at switch-off.

4.10 Intensity Control Board and Level-line Board

Refer to circuit diagram 333.0019 S, Bl. 5.

The intensity control board carries the controls for adjusting the display brightness, the graticule illumination, the intensity of the line markers and the amplitude of the pulse markers. The level-line board holds the controls for adjusting the sweep time, the horizontal lines and the intensity of the horizontal and the level lines.

The basic display brightness is adjusted with R810. The voltage tapped from R810 is, on the one hand, used to adjust directly the intensity of the measurement curves and the bright-up bar by means of the intensity control amplifier and, on the other hand, to adjust the intensity of the horizontal lines via R915. The intensity of the level lines can be reduced with R915 as against that of the measurement curves. The sweep time is reduced in the case of steep trailing filter slopes, and the display brightness has to be reduced correspondingly by T805 and T810. R801 and C801 introduce an appropriate delay for the switching signal and GL801 suppresses the negative portion of the signal. R805 adapts the control action to the characteristic of the CRT.

The intensity of the line markers is also adjusted with R810 and T815, and can be reduced with R813 as compared to the display brightness. In this case, however, intensity control is not performed through T815 (R817-C817-R818 filter the switching signal out), but through B825 and T825 instead. If T825 conducts, the pulse-marker signal is inverted by B825 and applied to trimming potentiometer R831 through R830. This reduces the signal amplitude appropriately, and adapts the line-marker intensity correspondingly.

Intensity control is also used to reduce the intensity in the MAN mode or in SINGLE mode if the sweep time is 30 s for recorder operation. For this purpose, the switching signals are combined on the central motherboard by GL155-GL156-GL157.

The pulse markers are generated by adding the pulses to the measurement curves. The pulse height is adjusted with R840. B840 serves as a voltage follower. Signal summing is accomplished on the central motherboard through resistors R151-R152 (333.0019 Bl. 4). The graticule illumination is adjusted with R851 and T850.

To position the horizontal lines, a DC voltage of approx. -1 V to +3.5 V is tapped from potentiometer R901 or R905 on the level-line board.
A voltage of 0 to -5 V is generated by R910 for controlling the sweep time. A pull switch combined with R910 can be used to cut in a low-pass

filter on the AF motherboard which reduces the noise of the deflection amplifiers. This condition is signalled by an LED. The filter is switched off via R920 at switchover of the control line from open circuit to -20 V.

4.11 Generator 50 kHz and HT Section 40 kHz

Refer to circuit diagram 333.0019 S, Bl. 2.

The Y generator is used to generate the 50-kHz raster frequency required for the Y-axis deflection of the CRT.

T2001 acts as a free-running oscillator. The resonant circuit consists of C2103-C2104-C2105 and the inductance of the deflection coil; feedback is established through R2104.

The coil current flows through R2105. The comparator receives the voltage which is proportional to the deflection current (raster frequency) through T2101. L2101-C2102 block the operating voltage and R2102 adjusts the amplitude.

The 13-kV anode supply for the CRT is generated by a separate generator with transformer and multiplier cascade.

T2002 operates as a free-running oscillator at approx. 40 kHz. The resonant circuit is formed by the inductance of the secondary winding (HT) of TR2201 and capacitors C2211 and C2212. Feedback is established through a secondary winding of the transformer.

To obtain a constant HT at different beam currents of the CRT, the operating point of the oscillator is regulated through B2201 and T2202. For this purpose, a voltage portion is tapped from the secondary winding for HT, rectified, divided down and applied to B2201. A DC voltage serves as a reference for the inverting input and is used to adjust the HT level with R2210.

The voltage required for focusing (approx. 300 V) is tapped from and adjusted with R2205.

L2201, C2201 and C2202 are used for filtering.

4.12 X-Amplifier

Refer to circuit diagram 333.0019 S, Bl. 3.

The deflection signal is fed to the X-axis amplifier through plug ST1101, pin 8. The amplitude is adjusted with R1101. The tangential error of the deflection is approximately corrected by distorting the saw-tooth signal to an S shape, using network R1106 to R1116-GL1101 to GL1104. R1112 is used to adjust the symmetry. B1101 and transistors T1101 to T1104 form an amplifier with a push-pull output stage. R1133 establishes a feedback loop for the whole amplifier. The output current is thus proportional to the input voltage.

4.13 Power Supply Board

Refer to circuit diagram 333.0019 S, Bl. 3.

The power supply board contains the rectifiers and the regulators for the supply voltages +60 V, +24 V, -20 V, -5 V and +5 V. The power transformer is located at the rear of the SWOB5 and is accessible after removing a cover. The power fuse is also accessible from the rear.

4.13.1 +57.5-V Regulator

This regulator delivers 34 mA at a voltage of 57.5 ±2 V. Fluctuations of line voltage and load current are levelled out. A fold-back loop prevents the components from being overloaded at short circuit.

Bridge-connected rectifier GL281 is connected to input capacitor C281. T282-R282-GL282-GL283 form a constant-current source to supply the collector of the ALC amplifier T283 whose reference voltage at its emitter is stabilized to +5.6 V by Zener diode GL285.

If the output voltage falls slightly below 57.5 V, the current through T283 is reduced and the base potential of the series transistor is raised, reducing the voltage drop across its collector-emitter junction.

As long as the load current flowing through R285 remains below approx. 34 mA, T284 is cut off. At higher load currents, T284 becomes conducting, connecting the base of series transistor T281 to the potential existing at plug ST111.20 (output voltage), thus reducing the current flow through T281.

The value of R285 is selected to provide a steady increase of the voltage drop across R285 with the load resistance decreasing down to short circuit, reducing the current flow through T281 to a limit value far below the threshold value (34 mA) of the foldback circuit.

Overloading of T281 is thus avoided for all values of load resistance between open and short circuit. GL286 prevents negative voltages between ST111.20 and ST111 (9 to 11) which might be applied by error from external sources in case of malfunctioning or during repair work.

4.13.2 +5-V Regulator

This regulated power supply is designed for a nominal output current of 2.4 A. The output voltage (+5.1 ±0.05 V) is largely independent of line voltage and load current fluctuations. The regulator is short-circuit-proof through the use of a foldback circuit.

B251 is a voltage regulator with integrated foldback transistor, especially designed for regulating negative voltages. This regulator type is used to allow T251 (whose collector is directly connected to the transistor case) to be screw-mounted to the heat sink without insulation, thus achieving perfect heat abstraction. T251 is required as a booster because B251 alone cannot supply the required nominal current of approx. 2.4 A.

The base of T251 is driven by the collector of T252 which operates as an inverting amplifier stage. GL255 prevents excessive reverse voltages across the base-emitter junction of T251.

The raw voltage for the circuit is rectified by GL251. C251 is used as the input capacitor. The reference voltage at B251 (2) is generated by R252 and Zener diode GL252. C253 prevents generation of parasitic oscillations. The regulated voltage is applied to the reference input (1) of B251 through R255-R254 from ST111.14. The value of the regulated voltage can be adjusted with R255. C252 is used for additional smoothing of the regulated voltage.

Since the collector of the booster transistor is connected to ground for the above reasons, B251 (8) must also be connected to ground, through ST111.12, at the point where the maximum accuracy of the supply voltage is to be achieved.

The operating current flows back from the load to rectifier GL251 through R260 and T251. If the current flow through R260 exceeds the limit value of approx. 3.5 A, the foldback transistor (included in B251) conducts and the operating current is reduced with decreasing load resistance, reaching 0.6 A at zero load resistance. T253 operates as a constant-current source for the foldback circuit.

4.13.3 +24-V Regulator

The +24-V regulator (tolerance ±0.1 V) consists of rectifier GL201, input capacitor C201 and integrated voltage regulator B201, and operates similarly to the +5-V regulator. Therefore, refer to section 4.13.2 for a detailed functional description. T201 operates as the booster, the inverting amplifier stage is T202. The reference voltage is generated by GL203 and R202. T203 is the constant-current source for the foldback circuit and R210 is the resistor carrying the load current which renders the foldback diode conducting at approx. 3.5 A. The operating current is approx. 0.9 A at zero load resistance.

The 24-V regulator contains a unijunction transistor (T204) to protect the YIG oscillator. T204 conducts even at very short voltage surges which cannot be fully levelled out by the regulator but might destroy the YIG oscillator, and fires SCR GL209, causing Si201 to blow. In this case, GL202 via R201 is lit to signal that the fuse has blown when the unit is opened.

4.13.4 -5-V Regulator

The raw voltage for the -5-V regulator (tolerance ±0.5 V) is generated by rectifier GL241 and input capacitor C241.

T242 operates as an amplifier at the booster output (2) of B241 and drives the booster transistor T241.

The voltage dropping across R250 increases with decreasing load resistance. The nominal operating current is 2.4 A. If the load resistance becomes small enough to result in a current flow of approx. 3.5 A, the voltage drop across R250 is large enough for the foldback transistor T243 to conduct. At zero load resistance, the load current is only 0.7 A. C242 prevents generation of parasitic oscillations. The -5-V voltage is adjusted with R245. GL246 rejects negative reverse inputs. C246 is used as a smoothing capacitor.

4.13.5 -20-V Regulator

This regulator is similar to the -5-V regulator. The rectifier is designated GL221, C221 is the input capacitor. The regulation is performed by B221. T222 operates as an amplifier and drives booster transistor T221. C222 protects the circuit from parasitic oscillations. T223 limits the output current to approx. 0.3 A. R225 is adjusted for an output of -20 V ±0.1 V nominal. C223 prevents parasitic oscillations, C224 and C226 serve as smoothing capacitors.

4.14 Central Motherboard

Refer to circuit diagram 333.0019 S, Bl. 1 to 9.

The central motherboard is vertically plugged onto the power supply board. It carries the connecting lines (except for the RF lines) between the individual subassemblies which are interconnected using non-reversible flat cables and connectors.

The central motherboard contains FET switch T151, which disables the ALC amplifier B1751 if the "external control" option is switched in (see section 4.3).

4.15 "Display-store Interface" Option

The "display-store interface" option is used for connection of the Digital Display Store BDS to the Polyskop SWOB5. It can be fitted (also retrofitted) into instruments bearing serial number 871551 and up. The interface performs the following functions:

a) Switching over the AF and level-line signals (AF, PL) and the sawtooth signal (SZ)

The AF and level-line signals are switched over by means of the FET switches T2 to T6 and T12 to T13. In display-store operation these signals are supplied to the BDS and, in turn, the required signals derived from the display store supplied to the Polyskop. In bypass operation of the BDS or when operating without display storage these signals are returned directly to the SWOB5 by means of the FET switches. The switches are controlled by the level converters B1II, B1III, B2I to B2IV. Under certain circumstances the level lines are not stored in the display store but are displayed directly. In these cases the control is effected via the control lines PSI and PSII (BU13.29 and BU13.30).

b) Switching over the TTL signals

The TTL signals for blanking (BA) (forward-return sweep signal) and the bright-up bar pulse (SKI) are switched over by the TTL chips B3 and B4. Here too, the signals are directly input into the Polyskop if no display store is used (identification BDS).

c) Switching over the marker signals (SM)

T17 serves as a switch. The comparators B5I and B5II act as level converters in display-storage operation as the BDS supplies TTL signals. Networks for matching to the SWOB marker generator (R31-R32-GL31 and R34-R35-GL34) are provided at the output of these comparators. T18 is connected in a common base circuit so as to avoid phosphorous burns when switching off the SWOB5. The vertical-line marker signal (SM) is shorted by T18 after disconnection from the AC supply.

d) Switching over the blanking signals

With steep filter slopes the sweep speed is slowed down when using the logarithmic amplifier plug-in E1 or E3. To counteract the increased beam intensity involved an appropriate signal is supplied to the intensity control amplifier during this time. In display-storage operation, however, the intensity must not be varied since in this case the sweep is constant. The control signal (STB) is, therefore, cut off by means of T1. When the BDS is not used, it is returned to the Polyskop via T1 and B1I. Furthermore, a blanking signal (DSI) is supplied to B1I during recorder operation when using the display store to avoid excessive beam intensity during slow sweep.

5. Repair Instructions

The following test and adjustment schedule allows complete readjustment of the SWOB 5. The required test equipment is listed in section 3.1. The numbers following the designations of knobs and pushbuttons etc. refer to the front- and rear-panel views Figs. 2-16 and 2-17.

Please note that the adjustment work following a repair should cover all the adjustments or checks contained in the section concerned, even if the section is divided into sub-sections and if the repair performed regards only a sub-section. If a cross-reference is made, the corresponding instructions should also be followed.

WARNING: HIGH VOLTAGE

The post-acceleration voltage of the CRT is 13 kV. The CRT may still retain charge and the anode connection may carry voltage even after the SWOB 5 has been switched off.

Allow the unit to warm up over 15 min before beginning adjustments.

Remarks:

a) Technical changes or improvements may necessitate changes in the adjustment or sequence of adjustment. For repair and servicing make, therefore, sure to use the manual pertaining to the particular type and serial number.

b) The tolerances specified for the adjustment are absolute limit values. They must not be exceeded or increased by the tolerances of the measuring instruments used.

5.1 Power Supply

The central motherboard contains test points at its upper edge, where the supply voltages can be measured.

The following table lists:
Voltages with tolerances, load current I_l, short-circuit current I_{sh} and the trimming potentiometers.

The load current depends on the operating condition of the unit. The table indicates the maximum value which is not exceeded.

A tolerance of $\pm 10\%$ is permissible for the AC supply voltage.

V_{out}	I_1	I_{sh}	Adjust
57.5 ±2 V	34 mA	10 mA	-
24 ±0.1 V	2.4 A	0.9 A	R205
5.1 ±0.05 V	2.4 A	0.6 A	R255
-5 ±0.05 V	2 A	0.7 A	R245
-20 ±0.1 V	0.88 A	0.3 A	R225

5.2 HT Section

R2210 (HT section) is adjusted for a high voltage of 13 ±0.1 kV. Detach the anode clip from the CRT and measure directly at the terminal.

R2205 in centre position.

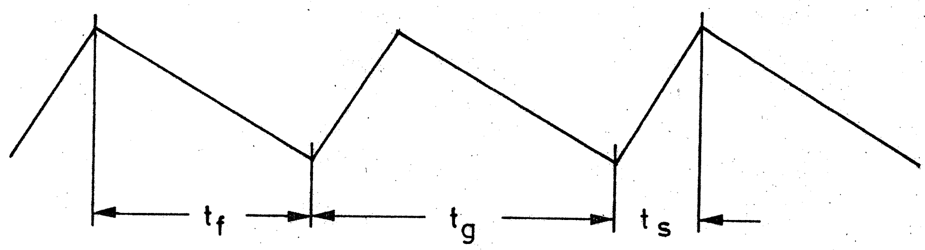
See also chapter 5.19.

5.3 Sweep Control

a) Adjust R2564 for 15 ±0.05 V at MP2408.
Check: -15 ±0.15 V at MP2409
+20 ±0.2 V at MP2410

b) Remove jumpers BR2401 to BR2403.
Plug jumper BR2404 to AB.
Replace jumper BR2405 by a 1.8-kΩ resistor across AC.
Connect the oscilloscope to MP2401.
Adjust R2447 (amplitude) and R2451 (DC voltage position) for a saw-tooth voltage of ±2.5 V_p ±50 mV_p.

c) Remove the 1.8-kΩ resistor, connect jumper BR2405 across AB.
Sweep time (38) fully clockwise.
Connect the oscilloscope to MP2401.



Adjust R2424 for a trailing edge t_f of 17 $\pm$0.2 ms.
Measure rising edge t_s; if t_s < 11 ms, adjust R2424 for
t_s = 11 $\pm$0.2 ms.
Measure period time t_g; if t_g > 32 ms, adjust R2424 for
t_g = 31.5 $\pm$0.5 ms.

NOTE: Make adjustment c) in the sequence indicated above. Do not repeat. Make adjustment at room temperature. Allow warm-up period of at least 15 minutes.

Insert jumpers BR2401 to BR2403. Plug jumper BR2404 on BC. See also section 5.10.

5.4 RF Section

Sweep mode (13) in AUTO position
Sweep range (40) in 0 position
Centre frequency (41) in mid-position
Only for a complete re-alignment acc. to section 5.10 (YIG oscillator):
R2509 fully clockwise.

a) Generation of 2-GHz frequency
Unscrew BU2406 (K15).
Adjust coil L1801 until the 100-MHz oscillator operates. The test point at the input of B1801 can be used to connect an oscilloscope.

Connect RF spectrum analyzer to ST2406 (input to mixer).

Adjust R1820, R1825, C1850, C1851 and C1852 for maximum amplitude at 2 GHz. The signal must be free from non-harmonic spurious waves or noise. The level should be -25 dBm +2 - 0.5 dB. If necessary, correct by means of R1820 (level adjustment) and R1825 (current adjustment for step-recovery diode).

Disconnect RF spectrum analyzer from ST2406.

b) YIG oscillator

Only for a complete re-alignment: R2509 (sweep control) fully clockwise
R2513 (sweep control) in mid-position.

An RF spectrum analyzer is connected to BU2406 for checking the YIG oscillator. Adjust centre frequency (41) to 2.1 GHz ±30 MHz from the YIG oscillator, as displayed by the RF spectrum analyzer. The level at BU2406 should be ≧ 10 dBm.

c) ALC amplifier

Cable K15 is reconnected to ST2002 through BU2406.
Switch RF output dividers (44 and 43) to 0 dB.
Connect RF millivoltmeter to RF output.
Switch (54) in 0.5-V position (or 0.35 V for 75-Ω model).
Adjust R1755 for an RF level of 0.5 ±0.005 V or 0.35 ±0.0035 V.
Switch (54) in 1-V position (or 0.7 V for 75-Ω model).
Adjust R1760 for an RF level of 1 ±0.01 V or 0.7 ±0.007 V.
Set switch (54) to 0.5 V or 0.35 V.

d) Wideband amplifier

Adjust R1905, R1915 and R1925 for maximum harmonics suppression of the wideband amplifier, measured with the RF spectrum analyzer.
The harmonics suppression must be ≧ 30 dB for the 0.1- to 1-MHz frequency range, and ≧ 36 dB for the 1- to 1000-MHz frequency range.
Finally, check step c).

e) RF monitoring output (55).

Check the RF monitoring output by means of an RF millivoltmeter. The output voltage should be 50 mV_{rms} ±10 mV.

5.5 Marker Section

NOTE: When performing adjustments, make sure that the marker section is closed with the cover on the CRT side.

a) Crystal oscillator

Frequency markers (7) in 100 position.
Connect oscilloscope or RF millivoltmeter to MP 15.
Adjust L1501 for maximum amplitude from the crystal oscillator.

Test conditions for test oscillograms are given in the circuit diagram 333.0019 S Bl. 7.1 (appendix).

b) Visual check on the CRT screen
Switch (54) in 0.5-V position (or 0.35 V for 75-Ω model).
Adjust brightness (9) and marker intensity (6) as suitable.
Frequency marker type (7) in line-marker position.
Adjust sweep range (40), sweep width (39) and frequency markers 100, 100, 10, 10 1 (7) to obtain a display of 50 to 60 line markers on the CRT screen. (Only 10 markers can be displayed with the 100-MHz marker spectrum.) Tune the centre frequency (41 and 42) over the total frequency range. No intermediate markers must be displayed in the 1- to 1000-MHz range.
The markers must not flicker.

c) Checking the pulse markers
Position display line at screen centre using the Service Plug-in (position 2) or the Linear Amplifier SWOB5-E2.
Sweep range (40) in 1000 position.
Frequency marker type (7) in pulse-marker position.
Frequency markers (7) in 100 10 position.
Vary the pulse-marker amplitude by means of potentiometer (5). The height of the pulse markers must be staggered.

d) EXT. marker input (11)
Sweep range (40) in 5 - 1000 position.
Frequency-marker type (7) in line-marker position.
Frequency markers (7) in 10 1 position.
Sweep width (39) fully counterclockwise.
Adjust centre frequency (31, 32) for 0 MHz at screen centre.
Apply 1.5-MHz signal (100 mV_{rms} ± 10 mV) to socket EXT. (11).
Frequency markers (7) in EXT. position.
2 line markers (-1.5 MHz and +1.5 MHz) should now be displayed on the screen.

5.6 Y-axis Generator

Sweep range (40) in 1000 position.
Marker width (4) fully clockwise.

Frequency marker type (7) in line-marker position.
Frequency markers (7) in 100 position.
Brightness (9) fully clockwise.
Marker intensity (6) fully clockwise.
Sweep mode (13) in AUTO position.
Sweep time (38) fully clockwise.
Adjust R2102, using the line markers, until the Y-axis amplitude is large enough to exceed the upper or the lower display margin by approx. 10%.

5.7 X-axis Amplifier (Pre-adjustment)

Sweep range (40) in 1000 position.
Manual sweep (13) fully counterclockwise.
Brightness (9) fully clockwise.
Centre frequency (42) fully counterclockwise.
Sweep time (38) fully clockwise.
Sweep mode (13) in AUTO position.
Adjust R1345 on the comparator board for the bright-up bar to coincide on the Y axis with the scale (glued on to the CRT screen (pre-adjustment).
Adjust R1103 for the bright-up bar to extend from approx. 0 MHz to 1000 MHz.
(See also 5.8d and 5.9.)

5.8 Display Geometry

Readjustment of the display geometry is only required after replacing the CRT or the deflection unit.
Frequency marker type (7) in line-marker position.
Frequency markers (7) in 100 position.
Marker width (4) fully clockwise.
Sweep mode (13) in AUTO position.
Brightness (9) fully clockwise.
Marker intensity (6) fully clockwise.
Horizontal-line intensity (16) fully clockwise.
Sweep range (40) in 5 - 1000 position.
Manual sweep (13) fully counterclockwise.

a) Alignment of deflection unit
Adjust horizontal lines (14 and 15) for a suitable display.
Adjust sweep width (29) and centre frequency (41 and 42) for an

appropriate line-marker position on the screen.
Loosen the clamping screw at the CRT neck to free the deflection unit.
Remove the permanent magnets from the deflection unit (only if replacement of the deflection unit is required).
Turn the deflection unit until the departures of the horizontal lines and the line markers from the horizontal and vertical position, respectively, are at a minimum.

b) Magnetic CRT centre adjustment
Pull connector BU113 off while the unit remains switched on.
A dull luminous spot appears independently of the position of the brightness and intensity controls. Adjust the two toroidal magnets at the CRT neck to position the light spot precisely at the centre of the CRT screen.
Plug connector BU113 in after turning the unit off.

c) Pincushion distortions (Fig. 5-1)
Adjust horizontal lines (14 and 15) for a suitable display.
Adjust sweep width (39) and centre frequency (41 and 42) for an appropriate line-marker position on the screen.

Push the magnets on the locking bolts of the deflection unit in a suitable way to minimize the distortions.

The effect of the magnets can be varied by varying their distance to the deflection unit. If the magnets' effect is greater than desired, it is recommended to cut them to the required dimensions using side cutters.

d) Symmetry of X-axis deflection
Adjust sweep width (39) and centre frequency (41 and 42 for an appropriate line-marker position on the screen.
Adjust R112 on the X-axis amplifier board until the line markers are spaced symmetrically around the display centre along the X-axis.

5.9 X-axis Amplifier (Final Adjustment)

Sweep range (40) in 1000 position.
Manual sweep (13) fully counterclockwise.
Brightness (9) fully clockwise.
Sweep time (38) fully clockwise.

Sweep mode (13) in AUTO position.

Adjust R1103 for the bright-up bar to extend from 0 MHz to 1000 MHz.

Shift the bright-up bar using centre frequency (42) as required.

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5.10 YIG Oscillator

Before making any adjustments, check as per 5.3b.

Sweep time (38) fully clockwise.

Sweep mode (13) in AUTO position.

Manual sweep (13) fully counterclockwise.

Marker width (4) fully clockwise.

Frequency marker type (7) in line-marker position.

Frequency markers (7) in 100 position.

Adjust appropriate marker intensity (6) and brightness (9) of display.

a) Preadjustment

Sweep range (40) in 1000 position.

Centre frequency (42) fully counterclockwise.

Adjust R2513 for a frequency of the YIG oscillator such that the 500-MHz line marker coincides exactly with the centre of the CRT screen.

Adjust R2509 for a sweep width of the YIG oscillator that results in a distance of 80 ±2 mm between the 100-MHz or 900-MHz marker and the screen centre (500-MHz marker).

NOTE: The CRT centre is approx. 1 to 2 mm to the right of the 500-MHz line of the glued-on scale

b) Final adjustment

Sweep range (40) in 5-1000 position.

Sweep width (39) fully counterclockwise.

Adjust centre frequency (41 and 42) until the bright-up bar exactly indicates 500 MHz.

Adjust R2513 for a frequency position of the YIG oscillator approximately at CRT centre, reducing the marker width (4) appropriately. Adjust centre frequency (41 and 42) until the bright-up bar exactly indicates 100 MHz.

Adjust R2509 for a sweep width of the YIG oscillator such that the 100-MHz marker is approximately positioned at the CRT centre.

(See also section 5.11.).

5.11 Display Margin

Sweep range (40) in 5-1000 position.

Frequency marker type (7) in line-marker position.

Frequency markers (7) in 100 10 position.

Sweep mode (13) in AUTO position.

Sweep time (38) fully clockwise.

Manual sweep (13) fully counterclockwise.

Marker width (4) fully clockwise.

Adjust appropriate marker intensity (6) and brightness (9) of display.

Adjust sweep width (39) until the 10-MHz markers are spaced approx. 1 cm apart from each other.

Adjust centre frequency (41) until the upper or lower display margin becomes visible. The lower display margin must be within -20 and -70 MHz and the upper display margin within 1020 and 1060 MHz.

5.12 Functional Check of Sweep Modes

Sweep mode (40) in 1000 position.

Horizontal-line intensity (1) fully clockwise.

Brightness (9) fully clockwise.

Adjust horizontal line (14 or 15) until a horizontal line is displayed.

a) Sweep mode (13) in MAN position.
   It must be possible to shift the point displayed by the horizontal line over the total display width using 13.

b) Adjust manual sweep (13) until the point displayed by the horizontal line is approximately at the display centre (X-axis).
   Sweep mode (13) in AUTO position.
   Sweep time (38) fully clockwise.
   A bright-up marker must now be visible on the horizontal line. Its position must be within approx. ±3 mm of that of the horizontal line before switching sweep mode (13) to AUTO (along the X-axis).
   A trigger signal must be present at the TRIGGER socket (58) with the following characteristics: TTL level, duration 13 ±2 ms, repetition rate depending on selected sweep time (38).

c) Sweep mode (13) in SINGLE position.
Sweep time (38) fully counterclockwise.
After depressing the START pushbutton (13), a single sweep must occur. The green indicator light (12) must be lit during the time between depressing the START pushbutton and the end of the sweep. It must also be possible to initiate a single sweep by applying a positive-going TTL signal to the TRIGGER socket (58).

5.13 Functional Check at TEST Socket (64)

a) Measurement of test output signals
Pin 3: ground
Pin 1: +24 $\pm$0.3 V
Pin 5: -20 $\pm$0.3 V
Sweep mode (13) in AUTO position.
Sweep time (38) fully clockwise.
Manual sweep (13) fully counterclockwise.
Pin 2: saw-tooth signal with an amplitude of $\pm 2.5\ V_p$, period 22 to 32 ms
Pin 4: TTL signal, period 22 to 32 ms.

b) Checking the external X-axis deflection
Sweep mode (13) in MAN position.
Frequency marker type (7) in line-marker position.
Frequency markers (7) in 100 position.
Sweep range (40) in 1000 position.
Marker width (4) fully clockwise.
Marker intensity (6) fully clockwise.
Brightness (9) fully clockwise.
Connect pin 7 to ground (pin 3).
Connect a triangle voltage with an amplitude of $\pm 1.2\ V_p \pm 0.2$ V and a frequency of 20 $\pm$5 Hz to pin 6.
The CRT screen must be covered over its total range along the X-axis.
The retrace must be blanked, i.e. the line markers must not appear as pairs.

5.14 Functional Check of REMOTE CONTROL Socket (59)

Pin 5: ground

Pin 4: +20 ±0.3 V

Sweep mode (13) in AUTO position.
Sweep range (40) in 1000 position.
Horizontal-line intensity (16) fully clockwise.
Brightness (9) fully clockwise.
Adjust a horizontal line (14 or 15) to display centre.
Sweep time (38) fully clockwise.
Manual sweep (13) fully counterclockwise.
Apply +5 ±0.3 V to pin 7.
Connect pin 6 to ground (pin 5). The deflection frequency must not change; visual check on the screen is sufficient.
Connect 0 V to pin 7.
The sweep time must be increasing to about 2 s; visual check on the screen is sufficient.

Sweep time (38) fully clockwise.
Sweep width (39) fully counterclockwise.
Centre frequency (41) fully counterclockwise.
Apply +5 ±0.3 V to pin 7.
Apply +6 ±0.3 V to pin 3.
Connect pins 1 and 2.
Connect pin 6 to ground (pin 5).
Frequency marker type (7) in line-marker position.
Frequency markers (7) in 100 position.
Adjust appropriate brightness.
Sweep range (40) in 1000 position.
The total frequency range from 0.1 to 1000 MHz must be displayed on the CRT screen. The 500-MHz marker must not be more than ±200 MHz off the display centre.

5.15 AF Motherboard, Voltage and Clock Signal Check

Adjust R526 for a supply voltage of 15 ±0.01 V at BU503, pin 6.
The multipoint connectors must carry the following voltages and clock signals:

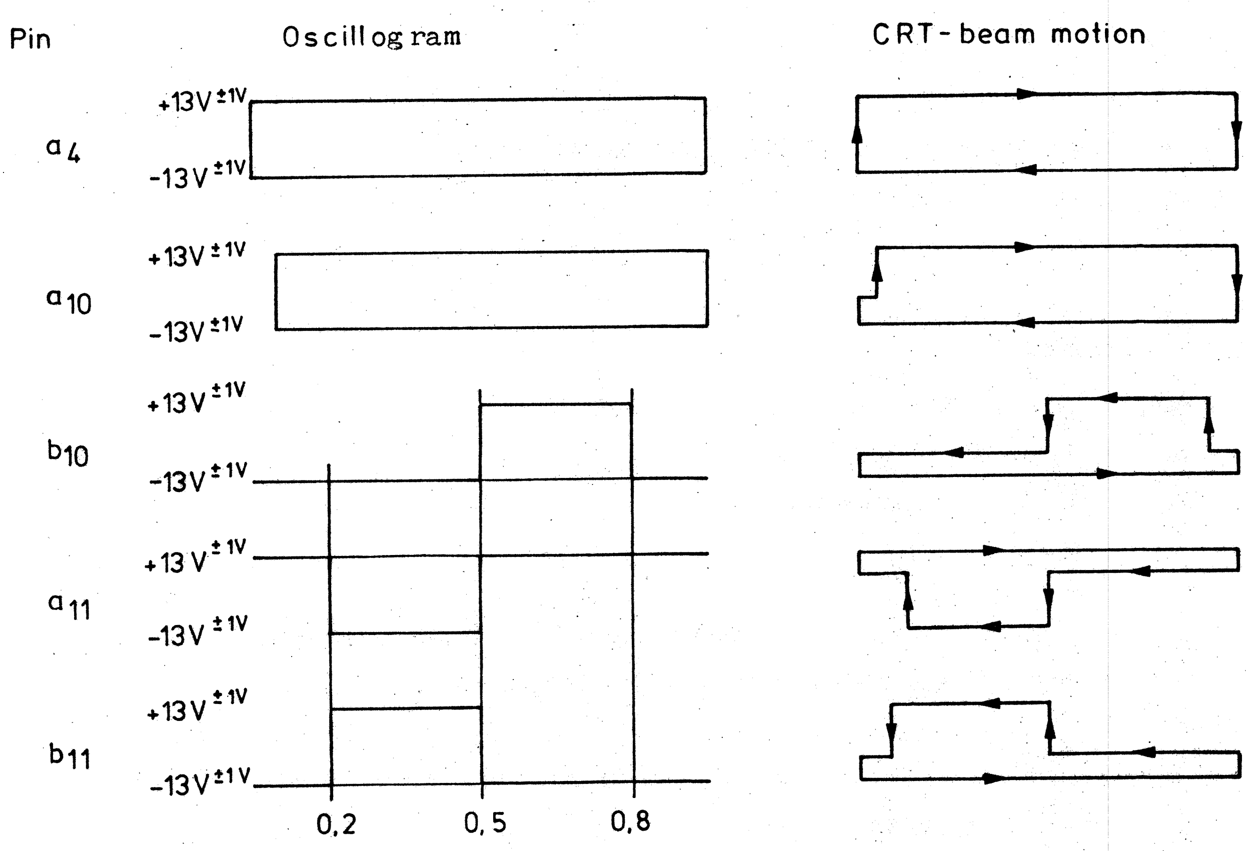
Pin 6a/b: +15 ±0.01 V

Pin 9a/b: -15 ±0.1 V

Pin 12a: +24 ±0.3 V

Sweep range (40) in 1000 position.
Sweep mode (13) in AUTO position.
Sweep time (38) fully clockwise.
Manual sweep (13) fully counterclockwise.
Connect an oscilloscope with external X-axis deflection to TEST socket (64) pin 2 (ground pin 3).

Connect the Y-axis input to the following pins (see the diagram below for the corresponding oscillograms):

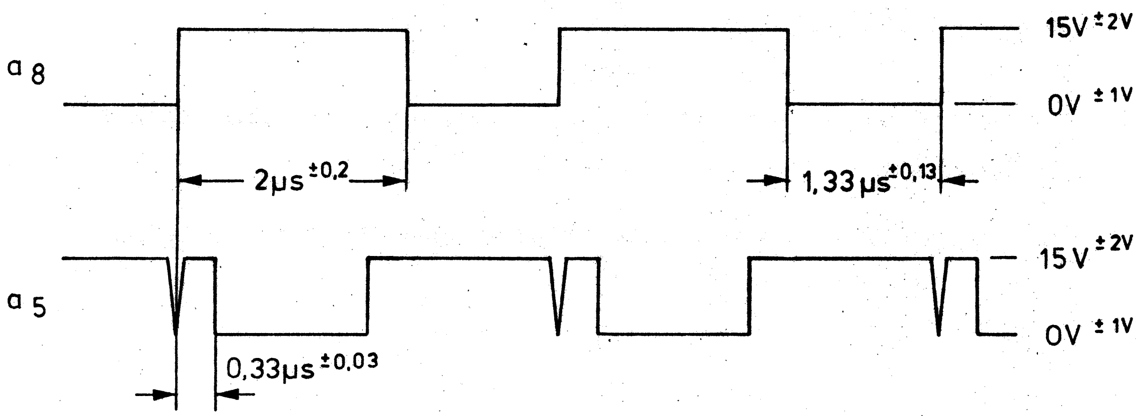


The CRT-beam motion can be made visible by turning sweep time (38) fully counterclockwise.

Sweep mode (13) in AUTO position.

Sweep time (38) fully counterclockwise.

Connect an oscilloscope with two Y-axis inputs to the following pins (see the diagram below for the corresponding oscillograms):



Both signals are either 0 V or +15 V during retrace.

See also section 5.17.

5.16 Comparator

Sweep range (40) in 1000 position.

Sweep mode (13) in AUTO position.

Sweep time (38) fully clockwise.

Adjust appropriate brightness.

a) Apply -1.5 ±0.3 V to BU502 or BU503, pin 7a (AF motherboard).
   Adjust R1303 for coincidence of display line.
   Vary the DC voltage from 0 to -3 V. The coincidence of the display line will deteriorate towards the upper and the lower display margin.
   Adjust R1302 for a compromise.
   Or, insert service unit in compartment I or II.
   Set the rotary switch on the service unit to position 2 (POS.).
   Set the display line to screen centre using the potentiometer POS.
   Adjust R1303 for coincidence of display line.
   Shift display line by means of potentiometer POS.
   The coincidence of the display line will deteriorate towards the upper and the lower display margin. Adjust R1303 for a compromise.

Remove the graticule from the CRT screen.
Sweep time (38) fully clockwise.
Horizontal-line intensity (16) fully clockwise.
Horizontal lines (14 and 15) fully clockwise.
Adjust appropriate brightness.
Filter (38) in WIDE position.

b) Adjustment channel I (BU502).
Apply +2.3 V ±5 mV to pin 2a.
Adjust R539 to position the horizontal line to within 25 ±1 mm from the lower display margin (inner aluminium frame).
Exactly mark this position on the screen.
Apply -0.4 V ±5 mV to pin 2a.
Adjust R1304 to position the horizontal line to within 7 ±4 mm from the upper display margin.
Exactly mark this position on the screen.
Repeat both adjustments.
Alternately apply -0.35V ±5 mV and -3.05 V ±5 mV to pin 7a. Adjust R526 on the AF motherboard, for coincidence of the display line with the position previously marked.

c) Check channel II (BU503) in a similar manner.
Adjust the horizontal line with R542.
Adjust R574 and R571 for coincidence of the display line with the corresponding marks.
Or, using the service unit:
Adjustment channel I
Insert service unit in compartment I.
Set the rotary switch on the service unit to position 3 (level line).

Adjust R1301 and R1302 to position the level line such that the lower section of the rectangular curve is 25 mm ±1 mm away from the lower display margin (inner aluminium frame).

The upper section of the rectangular curve must be 7 mm ±4 mm away from the upper display margin.
Set the rotary switch to position 4 (AF line).

Adjust the rectangle of the AF line (high frequency) to coincide with the rectangle of the level line.

The gain can be varied by means of R501.

The DC voltage level can be varied by means of R504.

Insert service unit in compartment II.

Adjust channel II in the same manner as channel I.

Adjust level line using R542.

The gain of the AF line can be varied by means of R571 and the DC voltage level by means of R574.

5.17 Functional Check of Recorder Outputs (60), (61), (62), (63) (without option)

Sweep mode (13) in AUTO position.

Sweep time (38) fully clockwise.

Manual sweep (13) fully counterclockwise.

Filter (38) in WIDE position.

Recorder output (63), pin 3: ground.

Recorder output (63), pin 1: sawtooth signal with an amplitude of $\pm 2.5\ V_p$ and a period of 22 to 32 ms

X-axis output 60: sawtooth signal with an amplitude of $\pm 2.5\ V_p$ and a period of 22 to 32 ms.

a) Apply a 1 V_{rms}/1 kHz signal to BU502, pin 7a.

Note: The AF generator must have a low-impedance output that provides a DC current sink. If not, connect a 470-Ω resistor in parallel to the AF output.

Recorder output (63), pin 2: 1 kHz; 1 V_{rms}, approx.

YI output (62): 1 kHz

Apply a 1 V_{rms}/1 kHz signal to BU503, pin 7a.

YII output (61): 1 kHz; 1 V_{rms}, approx.

Or, using the service unit:

Insert service unit in compartment I.

Set the rotary switch on the service unit to position 4 (AF line).

Recorder output (63), pin 2 and YI output: squarewave signal 2.5 V_{pp}, approx. blanked during retrace.

Insert service unit in compartment II.

YII output (61) : squarewave signal, 2.5 V_{pp}, approx., blanked during retrace.

b) Sweep range (40) in 1000 position.
Brightness (9) fully clockwise.
Sweep time (38) fully counterclockwise.
Recorder output (63) : connect pin 3 to pin 5.
Recorder output (63): check for continuity between pins 4 and 6.
No continuity in AUTO (13) position.
Continuity during visible forward sweep in SINGLE (13) position (triggered with START).

5.18 Intensity Control Board

a) Sweep time (38) fully clockwise.
Manual sweep (13) fully counterclockwise.
Brightness (9) fully clockwise.
Trimming potentiometer R805 fully counterclockwise.
Insert logarithmic amplifier plug-in SWOB5-E1.
Connect a bandpass or a low-pass filter with a dynamic range of at least 60 dB, and connect a demodulator.

Display the trailing slope of the device under test on the screen.
Adjust sweep width (39) such that the trailing slope is blanked.

Note: Blanking occurs only with steep trailing slopes. The control does not work if the slope is largely expanded due to a small sweep width.

Adjust centre frequency (41) and (42) until the trailing slope is positioned above the bright-up bar. A blanked strip must be clearly visible within the bright-up bar.

Adjustment:

1) Brightness (9) fully clockwise.
   Adjust R805 to compensate for brightness differences.
2) Turn back brightness (9) so far that the display just remains visible.
   Adjust R2205 (HT board) to compensate for brightness differences.

Perform steps 1 and 2 alternately until the brightness differences are also levelled out at different brightness levels.

NOTE: Since the circuitry can only provide a compromise, slight brightness differences will remain at the switchover points.

Or, using the service unit:
Insert service unit in one of the two compartments.
Sweep range (40) in 1000 position.
Set the rotary switch on the service unit to position 5 (intensity control).
Make adjustment as described above.

b) Brightness (9) fully clockwise.
Horizontal-line intensity (16) fully clockwise.
Horizontal lines (14), (15) at screen centre.
Sweep time (38) fully counterclockwise.
Sweep range (40) in 1000 position.
Manual sweep (13) in mid-position.
Sweep mode (13) in AUTO position.
Trace visible on screen.
Sweep mode (13) in MAN position.
The intensity should be noticeably.

5.19 Spurious Sweep Width

Sweep mode (13) in AUTO position.
Sweep time (38) fully clockwise.
Brightness (9) fully clockwise.
Sweep range (40) in 0 position.
Adjust centre frequency (41, 42) for frequency indication of 100 MHz.
Connect modulation meter to the RF output (46).
The spurious FM must be ≦ 20 kHz at a test bandwidth between 20 Hz and 30 kHz.
Sweep mode (13) in MAN position.
The spurious FM must be ≦ 5 kHz at a test bandwidth between 20 Hz and 30 kHz.

5.20 Frequency Response

Sweep mode (13) in AUTO position.
Sweep time (38) fully clockwise.
Manual sweep (13) fully counterclockwise.
Sweep range (40) in 1000 position.

Frequency marker type (7) in line-marker position.

Frequency markers (7) in 100 position.

Adjust appropriate brightness (9) and marker intensity (6).

Connect Demodulator SWOB5-Z1 or Insertion Unit SWOB5-Z3 with termination to the RF output (46).

Connect cable from measuring head to plug-in.

Measure frequency response.

With Log Amplifier SWOB5-E1: for test procedure see section 2.5.7.1.

With Lin Amplifier SWOB5-E2: for test procedure see section 2.5.7.2.

Switch (54) in 0.5 V or 0.35 V position.

The frequency response must not exceed ± 1 dB over the range 0.1 to 1000 MHz.

Switch (54) in 1 V or 0.7 V position.

The frequency response must not exceed ± 1.2 dB over the range 5 to 300 MHz.

Using the service unit:

Rotary switch on the service unit in position 8 (frequency response).

The indicated frequency response must be within the squarewave signal displayed if the RF output attenuator (43, 44) is set to

-28 dB	-34 dB	-25 dB	-31 dB

and the switch (54) is in position

0.5 V	1 V or	0.35 V	0.7 V.

5.21 Logarithmic Amplifier Plug-in E1

Required measuring instruments and auxiliary equipment:

Oscilloscope Tektronix 7000 series with 7A22 plug-in
Digital voltmeter
Power supply
Switchable precision voltage divider with 8 steps of 10 dB each
(inaccuracy < 0.1%, constant output impedance $\leq$ 200 Ω)
Demodulator SWOB5-Z1
Broadband Sweeper Polyskop SWOB 5
Steep-slope bandpass filter as device under test

5.21.1 Control Loop

Disable the amplifier section for the square-law portion of the measurement diode's characteristic by removing BR704.

Make T719 conduct by changing the jumper position of BR706.

Connect oscilloscope to emitter of T721.

Adjust offset by means of R764 so that -200 mV are present at the emitter of T721 during the clamping phase of the retrace.
Remove BR705.
Feed DC voltage to logarithmic converter II.
V_{max} = 2.5 V, reducible in 4 steps of 10 dB each.
Connect oscilloscope to MP12.
Adjust logarithmic converter II by means of R775 for equal steps (accuracy better than 0.2 dB).
Connect BR705 for normal operation.
Feed in RF via measuring head and adjust linearity of the control loop by means of R2752 (0 to -40 dB).
Connect BR706 for normal operation.

5.21.2 Amplifier Section for Square-law Portion of the Measurement Diode's Characteristic

Connect the digital voltmeter to MP1.

Adjust R708 for an offset voltage of < 20 mV of B701.

Remove BR702.

Feed a DC voltage into logarithmic converter I.
Maximum voltage = 2 V, reducible in 8 steps of 10 dB each.

Connect the oscilloscope to MP6.

Adjust logarithmic converter I, using R735, for equal steps (accuracy better than 0.4 dB).

5.21.3 Adjustment of Horizontal Line

Connect the slider of R701 (solder tab 9) to ground.

Turn R702 fully clockwise and set range switch (20) to its 80-dB position.

Connect the digital voltmeter to MP17.

Adjust R2728 for a voltage of 2.65 V at MP17.

Turn R701 (17) fully counterclockwise (0-dB position).

Adjust R2736 for a voltage of -0.17 V at MP17.

Check the zero position shift of the horizontal line by turning R702 (19) fully counterclockwise. Voltage change at MP17 = 370 mV (80-dB position of range switch).

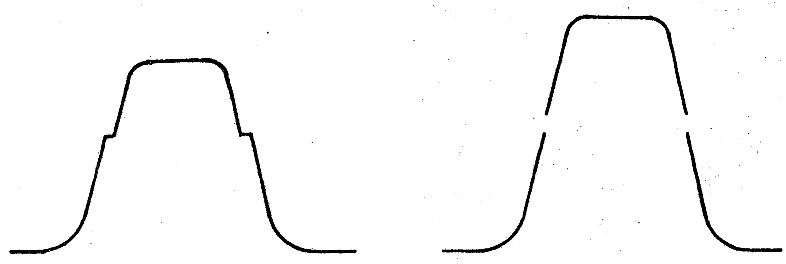
5.21.4 Common Adjustment

Connect BR702, BR704, BR705 and BR707 for normal operation.

Feed RF into the measuring head.
Vary R781 until the 10-dB steps from 10 to 30 dB and from 40 to 60 dB are the same size (measure with level line on screen).

Dynamic check using the device under test (bandpass filter with steep slopes):

Slope discontinuity   Correction



with R778

Feed in RF directly to measuring head.

Adjust R790 for the 10-dB steps of the test and the horizontal line are pretty much the same size (-10 to -60 dB).

Apply RF voltage of 1 V into measuring head.
Adjust horizontal line to 0-dB position.
If necessary, vary R2735 until the test and the horizontal line coincide (if R2735 is varied, R2736 must be readjusted according to 5.21.3.)

Check the overall linearity of the logarithmic amplifier by applying RF voltage to the measuring head.
Maximum voltage = 1 V, reducible in 7 steps of 10 dB each.
Permissible inaccuracy < 1 dB.

5.21.5 Checking the Tracking of the AF and the Horizontal Line

Connect the digital voltmeter to MP15 and MP17.

Adjust a sweep time of 2 s.

Range switch 20 in 40-dB position.
Feed 50-mV RF voltage into measuring head.
Turn R702 (19) from fully counterclockwise to fully clockwise. The voltage measured (2.65 V) must not change by more than 24 mV (measured during forward sweep).

5.22 Adjustment of Linear Amplifier Plug-in E2

Apply +15 V to 6a/b and -15 V to 9a/b of the plug-in or insert the plug-in into the right-hand side compartment of the basic unit SWOB 5.
Allow a warm-up time of 15 min.

Plug BR601 on 1/2.
Connect a digital voltmeter between MP1 and MP3.
Adjust R644 for an offset 1 level of 0 ±0.05 mV.
Connect the digital voltmeter between MP2 and MP3.
Gain (22) fully clockwise.
Adjust R654 for an offset 2 level of 0 ±0.5 mV.

Remove BR601.
Rotary switch (24) in + position (switch position 2).
Terminate input (26) with 50 Ω.
Connect the digital voltmeter between MP2 and MP3.
Adjust R613 for an offset 3 level of 0 ±10 mV.

5.23 Logarithmic Amplifier Plug-in E3

Required measuring instruments and auxiliary equipment:

Oscilloscope Tektronix 7000 series with 7A22 plug-in
Digital voltmeter
Power supply
Switchable precision voltage divider with 8 steps of 10 dB each
(inaccuracy < 0.1%, constant output impedance ≦ 200 Ω)
Demodulator SWOB5-Z1
Broadband Sweeper Polyskop SWOB 5
Steep-slope bandpass filter as device under test

5.23.1 Control Loop

Disable the amplifier section for the square-law portion of the measurement diode's characteristic by removing BR704.

Make T719 conduct by changing the jumper position of BR706.

Connect oscilloscope to emitter of T721.

Adjust offset by means of R764 so that -200 mV are present at the emitter of T721 during the clamping phase of the retrace.
Remove BR705.
Feed DC voltage to logarithmic converter II.
V_{max} = 2.5 V, reducible in 4 steps of 10 dB each.
Connect oscilloscope to MP12.
Adjust logarithmic converter II by means of R775 for equal steps (accuracy better than 0.2 dB).
Connect BR705 for normal operation.
Feed in RF via measuring head and adjust linearity of the control loop by means of R2752 (0 to -40 dB).
Connect BR706 for normal operation.

5.23.2 Amplifier Section for Square-law Portion of the Measurement Diode's Characteristic

Connect the digital voltmeter to MP1.
Adjust R708 for an offset voltage of < 20 mV of B701.
Remove BR702.
Feed a DC voltage into logarithmic converter I.
Maximum voltage = 2 V, reducible in 8 steps of 10 dB each.
Connect the oscilloscope to MP6.
Adjust logarithmic converter I, using R735, for equal steps (accuracy better than 0.4 dB).

5.23.3 Adjustment of Horizontal Line

Set the slide switch 28 to position dBV and the range switch 30 to position 100 dB.
Set R702 (29) to 0 dB position (turn fully clockwise).
Connect the digital voltmeter to MP17.
Adjust R2728 for a voltage of 0.45 at MP17.
Then turn R702 (29) anticlockwise until the voltage at MP17 is 2.64 V.
Adjust R2898 for a level readout of -80.0 on the digital display (R702 must not be varied anymore).

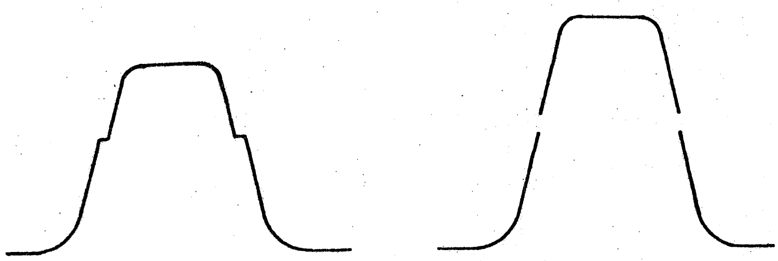
5.23.4 Common Adjustment

Connect BR702, BR704, BR705 and BR707 for normal operation.

Feed RF into the measuring head.
Vary R781 until the 10-dB steps from 10 to 30 dB and from 40 to 60 dB are the same size (measure with level line on screen).

Dynamic check using the device under test (bandpass filter with steep slopes):

Slope discontinuity | Correction



with R778

Feed in RF directly to measuring head.

Adjust R790 for the 10-dB steps of the test and the horizontal line are pretty much the same size (-10 to -60 dB).

Apply RF voltage of 1 V into measuring head.
Adjust horizontal line to 0-dB level.
If necessary, vary R2728 until the test and the horizontal line coincide (if R2738 is varied, R2898 must be readjusted according to section 5.23.3).

Check the overall linearity of the logarithmic amplifier by applying RF voltage to the measuring head.
Maximum voltage = 1 V, reducible in 7 steps of 10 dB each.
Permissible inaccuracy < 1 dB.

5.23.5 Checking the Tracking of the AF and the Horizontal Line

Connect the digital voltmeter to MP15 and MP17.

Adjust a sweep time of 2 s.

Range switch 20 in 50-dB position.
Feed 50-mV RF voltage into measuring head.
Turn R2735 (31) from fully counterclockwise to fully clockwise. The voltage measured (2.65 V) must not change by more than 24 mV (measured during forward sweep).

5.23.6 Delogarithmization Network for mV Indication

Set slide switch 28 to position mV.
Turn R702 (29) fully clockwise.
Vary R2864 until the digital display reads out 1000.
Now set slide switch 28 to position dBV.
Adjust R702 (29) for -40.0 dBV.
Reset slide switch 28 to position mV.
Vary R2866 until the digital display reads out 10.00.
Set slide switch 28 again to position dBV.
Adjust R702 (29) for -80.0 dBV.
Reset slide switch 28 to position mV.
Vary R2923 until the digital display reads out 0.10 and the voltage at MP22 has positive polarity. The settings of R2866 and R2923 affect each other so that it may become necessary to repeat the adjustment process several times at -40 dBV and -80 dBV until no further improvement can be attained (accuracy in the range 0 dB to -80 dB better than 2% ±1 digit).

5.24 "Slow Sweep" Option

a) Connect oscilloscope to MP.

Adjust the position of the sawtooth by means of R55 and the amplitude by means of R54 to $\pm 2.5\ V_{pp} \pm 50\ mV_p$.

Check: rising slope 7 ms ± 2 ms, trailing slope 35 ms ± 10 ms.

b) Sweep time (38) fully counterclockwise.

Sweep range (40) in 1000 position.

Sweep mode (13) in MAN position.

Connect pin 3 of recorder output (63) to pin 5.

Alternately apply +2.3 V ± 5 mV and -0.4 V ± 5 mV to socket BU502, pin 2a

or

insert service unit in compartment I and set rotary switch to position 4.

Connect oscilloscope to YI output (62).

Adjust the amplitude of the signal to 1 $V_{pp} \pm 20\ mV_p$ by means of R16.

Adjust the position of the signal minimum to 0 V $\pm 20\ mV_p$ by means of R19.

Check: connect oscilloscope to recorder output (63), pin 2 where a signal should be present.

NOTE: The signal is blanked every 2 s for about 0.25 s.

Sweep mode (13) in SINGLE position.

Connect oscilloscope to YI output (62) or recorder output (63), pin 2.

The signal must be blanked.

Sweep mode (13) in START position.

The signal must be present during the visible forward sweep. It is periodically unblanked for about 35 ms and blanked for about 7 ms.

c) Sweep time (38) fully counterclockwise.

Sweep range (40) in 1000 position.

Sweep mode (13) in MAN position.

Connect pin 3 of recorder output (63) to pin 5.

Apply alternately +2.3 V ± 5 mV and -0.4 V ± 5 mV to socket BU503, pin 2a or insert service unit into compartment II and set rotary switch to position 4.

Connect oscilloscope to YII output (61).

Adjust the amplitude of the signal to 1 $V_{pp} \pm 20\ mV_s$ by means of R31.

Adjust the position of the signal minimum to 0 V $\pm 20\ mV_p$ by means of R34.

Sweep mode (13) in SINGLE position.

The signal must be blanked.

d) Sweep mode (13) in MAN position.
Manual sweep (13) fully counterclockwise.
Connect pin 3 of recorder output (63) to pin 5.
-2.3 V ±0.2 V must be present at the X-axis output (60) and at the recorder output, pin 1.
Manual sweep (13) fully clockwise.
+2.3 V ±0.2 V must be present at the X-axis output (60).
Sweep mode (13) in SINGLE position.
Vary manual sweep (13).
The voltage at the X-axis output (60) must not change.

e) Sweep mode (13) in SINGLE mode.
Sweep time (38) fully counterclockwise.
Connect pin 3 of recorder output (63) to pin 5.
Connect oscilloscope to MP 510 on the AF motherboard.
Sweep mode (13) in START position.
A sawtooth of ±2.5 V_p ±0.1 V_p and a period of 42 ms ±10 m must be present after 2.5 s, max.

f) Sweep mode (13) in SINGLE position.
Sweep range (40) in 1000 position.
Connect pin 3 of recorder output (63) to pin 5.
Connect pin 1 of TEST socket (64) to pin 4 of recorder output (63).
Connect YI of dual-channel oscilloscope to TEST socket (64), pin 4 and YII to the recorder output (63), pin 6. Trigger YI.
Sweep mode (13) in START position.
YII must go high with a delay of 300 ms ±50 ms as against YI.
Trigger YII. Disconnect YI.
Sweep mode (13) in START position.
The signal YII must go high for 30 s ±15 s.

g) Sweep mode (13) in AUTO position.
Sweep time (38) fully clockwise.
Sweep range (40) in 1000 position.
Brightness (9) fully clockwise.
With lin amplifier or service unit inserted, position display line to about screen centre.
Manual sweep (13) in mid-position.
Connect pin 3 of recorder output (63) to pin 5.

Sweep mode (13) in positions SINGLE and START.
Trace is visible.
Switch sweep mode (13) over between SINGLE and MAN.
The brightness must in both cases be the same.

5.25 "IF Markers" Option

a) Adjustment of crystal oscillator

Insert oscillator in basic unit or
apply +15 V to pin 1, connect pin 2 to ground and pin 3 via 10 kΩ to ground.
Trimming potentiometer R120 fully counterclockwise.
Connect RF millivoltmeter with high-impedance probe to pin 3 (short ground connection to pin 2).
Tune coil L120 to maximum.
Adjust trimming potentiometer R120 for 400 mV_{rms} $\pm$10 mV_{rms}.

b) Adjustment of basic unit

Sweep mode (13) in AUTO POSITION.
Manual sweep (13) fully counterclockwise.
Sweep time (38) fully clockwise.
Sweep range (40) in 5 - 1000 position.
Brightness (9) fully clockwise.
Marker intensity (6) fully clockwise.
Marker width (4) fully clockwise.
Frequency marker type (7) in line-marker position.
Frequency markers (7) in 100 10 position.
Adjust sweep range 0 to 50 MHz by means of sweep width (39) and centre frequency (41, 42).
Connect RF output (46) to IF marker input (11).
Connect Y input of oscilloscope to output B45 and the external X-axis deflection input to TEST socket (64), pin 2.
Adjust RF output voltage (43, 44) to -54 dB with 50-Ω model and to -51 dB with 75-Ω model.
Set R26 so that the output voltage of the operational amplifier is close to the negative saturation voltage (-14 V, approx.), keeping the peaks of the curve on the screen just above the saturation voltage.

6. Retrofitting of Options

6.1 External Control SWOB-B1

Accommodate the External Control SWOB5-B1 in the compartment provided at the rear of the SWOB 5 for this purpose (see Fig. 2-17, Ref. Nos. 51 to 53).

Remove panels on the top of the cabinet and blank panel covering the compartment reserved for accommodation of the SWOB5-B1.

Swing out hinged chassis by 90°.

Insert the External Control and pass the flat cable supplied with the SWOB5-B1 between the chassis of the RF section and the screen to the power supply section. Be sure that none of the coaxial cables in the power supply section runs between the flat cable and the screen.

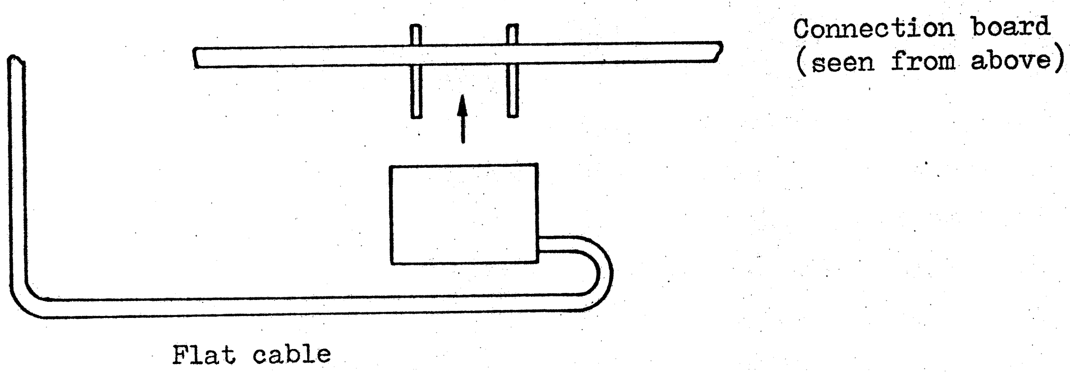


Fig. 6-1 Connection External Control option - connection board.

The External Control can now be put into operation closely observing the instructions given in section 2.4.

For checking use the test setup shown in Fig. 2-1 where a 20-dB attenuator is connected instead of the test item.

6.2 Slow Sweep Option SWOB5-B2

Assembly

Loosen the four screws on the top and the bottom cover of the SWOB5 and remove the two covers.

Unscrew the right side panel with recessed handle (four screws).
Remove the four frequency knobs from the lower chassis.
Loosen the screws on the left and the right angle bracket of the lower chassis such that the chassis can be swung out.

If the option is used in a SWOB5 bearing the Serial No. 871 088, the contact pins 8 and 9 (circuit diagram 333.9616 S) must be pinched off and the transistor TR120 removed.

Remove the multipoint shorting plug from the connection board (at the right-hand corner on the rear wall of the SWOB5).

Connect one end of the supplied flat cable instead. Connect the other end of the cable to the Slow Sweep board (ST119). Make sure that the cable is not twisted.

Insert the seven pins of the Slow Sweep board into the sockets on the connection board and fix the board to the provided snap catches.

Bend the flat cable to the Slow Sweep board such that it is not damaged when the chassis is swung back.

To make sure that the voltages available at the recorder outputs at full display height are exactly 1 V, the Slow Sweep board must be aligned as described below.

Alignment

a) Set SWEEP TIME 38 to the right-hand stop (see Fig. 2-16)

b) Set Δ f (sweep range) 40 to position 1000.

c) Adjust INTENSITY of horizontal lines 9 and 16 as required.

d) Position one horizontal line 14 to the upper display border (about 3 mm below the screen edge).

e) Position the other horizontal line to the lower display margin (about 3 mm above the bright-up bar).

f) Turn the know <--> 13 to about mid-position.

g) Press key MAN. 13 (manual sweep mode). The upper and the lower horizontal display limit lines are reduced to a dot, and so is the level line positioned in-between.

Alignment of the YI amplifier

Connect an oscilloscope to socket Y1 62 (see Fig. 2-17).

If a linear amplifier (Lin. Amplifier SWOB5-E2) is inserted in compartment I:

Set rotary switch 24 to position +.

Turn the gain control 22 counter-clockwise until it will go no further.

Make the dot to which the level line has been reduced coincide with the dot marking the lower display limit (knob 23) and adjust the output signal with R19 (on the Slow Sweep Option SWOB5-B2) to 0 V ±20 mV.

Then make the dot to which the level line has been reduced coincide with the dot marking the upper display limit and adjust the output signal to 1 V.

If a logarithmic amplifier (Log. Amplifier SWOB-E) is inserted in compartment I:

Connect Demodulator SWOB5-Z1 or RF Insertion Unit SWOB5-Z3 to socket 21 .

Connect Demodulator or RF Insertion Unit to RF output 46 .
Match-terminate the RF Insertion Unit.

Set the RF output dividers 44 , 43 , to 0 dB.

Set rotary switch 20 to 60 dB.

Make the dot to which the level line has been reduced coincide with the dot marking the lower display limit (19) and adjust the output signal with R19 to 0 V ±20 mV.

Then make the dot to which the level line has been reduced coincide with the dot marking the upper display limit and adjust the output signal with R16 to 1 V.

Alignment of the YII amplifier

Connect oscilloscope to socket YII 61 .

Make alignment as for YI, but use the potentiometers R34 for coincidence with the lower display limit (0 V ±20 mV) and R31 for coincidence with the upper display limit (1 V).

The control range of the potentiometers permits setting deviations of say -0.5 V/ +0.5 V in order to provide matching to the recorder input, if necessary.

NOTE: Trimmers R54 and R55 have been factory adjusted and must not be changed.

After the alignment the following checks should be made:

a) The output signal must also be present at the recorder output <u>63</u> pin 2 (Fig. 2-17). Check by means of oscilloscope. It should be borne in mind that the signal is blanked for about 10 ms every 20 ms when the SWEEP TIME control <u>38</u> is at the right-hand stop.

b) Connect the oscilloscope to the YI output <u>62</u> or the recorder output <u>63</u> pin 2.

Press the SINGLE key <u>13</u> (single sweep).

The signal must be blanked.

Press the START key <u>13</u> .

The signal must be present during the visible forward sweep.

Disconnect the SWOB5 from the AC supply.

Loosen the four screws on the top and the bottom cover of the SWOB5 and remove the two covers.

Unscrew the right side panel of the SWOB5 (four screws).

Pull out socket BU801 from the intensity control board.

Pull out socket BU301 from the marker board.

Unscrew the knob WIDTH 4 (see Fig. 2-16).

Remove the marker board. To do so, loosen the two screws to the right and left of the pushbutton assembly 7.

Unsolder cable K14 from the input socket for external frequency markers 11 and solder the supplied cable K16 to the input socket instead. Make the earth connection as short as possible. Insert the IF Markers Option, fix in place by means of the two screws on the front panel and replace the knob WIDTH 4.

Insert the supplied angle bracket between the marker board and the upper section of the shielding case for the plug-ins and screw down at the bore holes provided for this purpose. The bore hole on the marker board is close to its rear edge, away from the front panel of the SWOB5.

NOTE: Older SWOB5s do not have the bore hole in the upper section of the shielding case. The bore hole must, therefore, be drilled subsequently or the angle bracket glued in place. If the bore hole is drilled subsequently, first remove the plug-ins and upon completion carefully clean away borings.

Solder cable K14 to the three solder lugs.

Connect cable K16 to pin ST305.

Connect socket BU301 to the marker board.

Connect socket BU801 again to the intensity control board.

Connect socket BU303 to the connection board. The socket BU303 may also be turned by 180° and inserted. Thus it can be determined whether the RF and the IF markers are to be displayed alike (both vertical-line or pulse markers) or differently. Socket not turned corresponds to uniform markers.

Insert oscillators and filter, if desired.

Turn the trimming potentiometer R125 of the oscillators (accessible from the top) clockwise until it will go no further (maximum marker width).

Screw right side panel, bottom and top covers back in place.

6.4 Display-store Interface Option SWOB5-B6

Disconnect the SWOB5 from the AC supply.

Loosen the four screws on the top and the bottom cover of the SWOB5 and remove the two covers.

Unscrew the right-side panel of the SWOB5 (four screws).

Remove the cover panel below the high-voltage symbol on the rear of the SWOB5 (two screws).

Pull out the shorting link from the connector strip on the right-hand side of the connection board.

Insert the female connector strip on the right-hand side of the Display-store Interface into the male connector strip on the connection board until the plastic clips lock in the slots of the connection board (the component side of the Display-store Interface board faces the rear).

Remove the shafts of the four frequency control knobs 29, 30, 31 and 32 (see front view in the SWOB5 manual) from the couplings on the lower chassis by simply pulling the shafts of the knobs 29, 31 and 32 out towards the front. To remove the shaft of the knob 32 first loosen the two screws at its coupling.

Loosen the two screws on the left and the right angle bracket of the lower chassis such that the chassis can be swung out.

Now run the cable harness connected to the Display-store Interface board via two multiway sockets between power supply board and the lower chassis and push the 36-way female connector strip fitted at its end through the square opening from which the cover had been removed before.

Fix the female connector strip in place on the outside by means of two screws M 2,5 (use washers).