RM-5
Radio-Link Measuring Setup

Operating Manual

BN 0916/00.82

Wandel & Goltermann

Electronic Measurement Technology

RM-5
Radio-Link Measuring Setup
35/70/140 MHz

BN 916, series D onwards

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USE OF THE RFZ-1 RETURN LOSS BRIDGE WITH THE RM-5

1. General information

The RFZ-4 and RFZ-14 bridges described in the operating manual as being suitable for use with the RM-5 when making return loss measurements are to be replaced by the 75 ohm version of the new RFZ-1 return loss bridge. This bridge has a frequency range from 75 kHz to 190 MHz, which covers the ranges of both the now obsolete bridges.

2. Operation

The new bridge is operated in a similar manner to that described in section 3.9.7.2 of this operating manual.
A short is provided with the bridge for making shorted measurements.
Further information on the use of the RFZ-1 is found in the operating manual supplied with the bridge.

3. Overall error limits for return loss measurements made using the RM-5 and RFZ-1

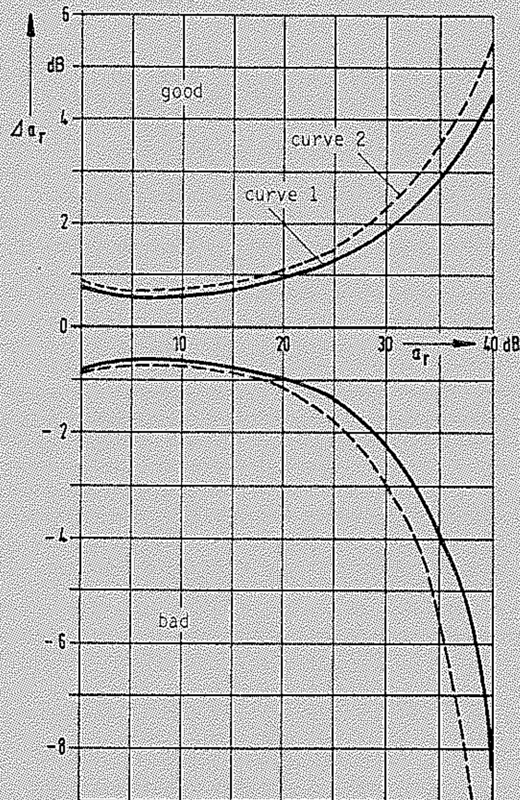
The data below corresponds to that given in sections 1.1.2.7 and 4.5 of this operating manual.

Overall error limits for RFZ-1 with BNC or 1.6/5.6 connectors within the frequency range 25 to 130 MHz, after calibration:

for return loss = 20 dB .... -0.95 / +0.[illegible] dB
for return loss = 30 dB .... -2.2 / +1.[illegible] dB

Overall error limits as a function of the return loss a_r, using RFZ-1 with BNC or 1.6/5.6 connectors:

Frequency range 25 to 130 MHz .... trace 1
Frequency range 130 to 190 MHz .... trace 2



4 Versions and order details

RFZ-1 return loss bridge, 75 ohm version with one of the following options:		BN 2045/10
X connector	IN and OUT connectors	
BNC (m)	BNC (f)[1]	BN 2045/00.10
BNC (f)		BN 2045/00.11
1.6/5.6 (m)	1.6/5.6 (f)[1]	BN 2045/00.12
1.6/5.6 (f)		BN 2045/00.13

1) fitted with basic 75 ohm Versacon® 9 connector. Connector types indicated are standard types; other types suitable for the frequency range (see Versacon® 9 data sheet) can be retrofitted if required.

ΔF MEASUREMENT AT LOW C/N RATIOS

Relatively low C/N ratios (down to 10 dB) are normally encountered when making IF group delay and amplitude/frequency response measurements on satellite transmission systems. In IF 70 MHz mode, the Δf result displayed on the receive side will differ from the value set on the transmit side due to the fact that noise components are also included (wideband measurement). This sometimes makes it impossible to check the transmit side Δf setting from the receive side.

This problem can be solved by using the frequency deviation correction option for satellite system measurements. The option fits in the RME-5 receiver and has the order number BN 917/00.22.

In SAT 70 MHz mode (key [21]) a lowpass filter can be switched in to suppress noise components above 300 kHz, so that these are not included in the frequency deviation evaluation. The Δf result displayed is correct for all test frequencies up to 277.77 kHz.

The frequency deviation correction option can only be used in RM-5 setups not fitted with the 35 MHz option. It only operates in the 70 MHz IF range.

CHARACTERISTICS OF THE FREQUENCY DEVIATION SETTING AT THE OUTPUT OF THE RMS-5

The IF [1] and BB $U_A + U_M$ [17] outputs are fed from the same source, so that a signal is always present at both outputs regardless of the device under test (IF or BB).

There is a frequency modulator between the signal source and the IF output, however. This converts the BB test signal into an IF signal with a certain frequency deviation, Δf. Since the modulator slope characteristic is known, it is possible to set Δf directly in kHz for IF measurements using the RMS-5. The test signal amplitude for BB measurements is therefore set in mV or dBm.

When the RME-5 is used to monitor the Δf setting of the IF output and the setting of the test signal [13] has not been made using the Δf key (in kHz) but using the U_M key (in mV), the RMS-5 exhibits the following characteristic: the Δf display runs through the range 5 kHz to 499 kHz for the test signal setting range from 0.005 mV (-75 dBm) to 4.99 mV (-35.1 dBm) and repeats the range 5 kHz to 500 kHz for the setting range 5 mV (-35 dBm) to 500 mV (+5 dBm). (Note: the range 5 to 15 kHz cannot anyway be displayed by the RME-5).

The following should be noted:

- For purely IF measurements, always use the Δf key (in kHz) for setting the frequency deviation.
- A test object can be connected to the BB and IF outputs at the same time. The Δf and U_M setting ranges specified for the outputs must not be exceeded. The internal modulator slope should be altered accordingly.
- To achieve sensible values for Δf also at very low values of U_M at the IF output, the modulator slope must be altered again.

Figure 3-26:

For range H read range B.

Section 3.10.4.5

RME-5 setting program words

- Add the following program word for setting the horizontal lines:

HL

HL	d	d	d	d	,	HORIZONTAL LINES
	0	F	F			horizontal lines off
	1	5	.	4		line spacing (with decimal point)
						(e.g. 15.4 ns for a $\Delta\tau$ range of 10 ns/div)
	0	F	F			standard setting

The results channel must be switched off to activate the horizontal lines.

- Correct the program word PHxxx (phase setting from IF for U_x):

PH

PH	d	d	d	,	Phase setting in degrees (U_x correction)
	0	0	0		
	.	.	.		
	.	.	.		Setting from 0 to 360° (for U_x from BB)
	.	.	.		
	3	6	0		
	3	5	5		≙ −5°
	3	5	4		≙ −4°
	.	.	.		
	.	.	.		
	0	0	0		≙ 0° Setting from −5 to +5° (for U_x from IF)
	.	.	.		
	.	.	.		
	0	0	4		≙ +4°
	0	0	5		≙ +5°

- Add the following information to program word SR:

  Range of amplitude values Y_i for X_i: ØØØ to 255

Sections 5.1.2.2 and 5.1.2.3

The double-screened 250 mm test cable supplied with the instruments should be used for checking the function of the RM-5 in IF short circuit mode. Place the RME-5 directly on top of the RMS-5 for the measurement.

DETERMINING ABSOLUTE DELAY WHEN SPACE DIVERSITY RECEPTION IS USED (OPTION BN 917/00.20)

1. Introduction

In contrast to analog FM radio-link systems, the effects of dispersive fading caused by multipath propagation give rise to problems in wideband digital radio-link systems using multilevel modulation. This is because the spectrum of digitally modulated signals is much wider than that of an FM signal of the same capacity and not concentrated about the carrier. Space- or frequency diversity reception and adaptive equalisers in the BB and IF band are used to counteract dispersive (frequency selective) fading.

The commonly employed space diversity reception method uses two receiving antennas, mounted a fixed vertical distance apart. The received signals are recombined so as to ensure the correct phase relationship in the RF or IF range. The two receive signal paths must have the same absolute delay so that the phase shift circuits only have to compensate for the phase difference caused by dispersion effects.

As it is not possible to guarantee equal delay times simply by choice of equipment and antenna arrangements, it is essential to compensate for any difference during a fade-free period when the system is being set up. This is done by inserting a line in the shorter receive path.

2. Test setup to determine the absolute delay difference

If, as is usual, the signals are combined at the IF level, the RM-5 can be used to determine the absolute delay difference. To this end, an IF switch which alternately switches the two IF receive paths through to the input of the RME-5 receiver is required. The switching frequency is the same as the sweep frequency used for group delay measurements.

The test setup is shown in fig. 1. Connector [43][1] on the back panel of the RME-5 provides the switching signal and the dc voltage for the switch.

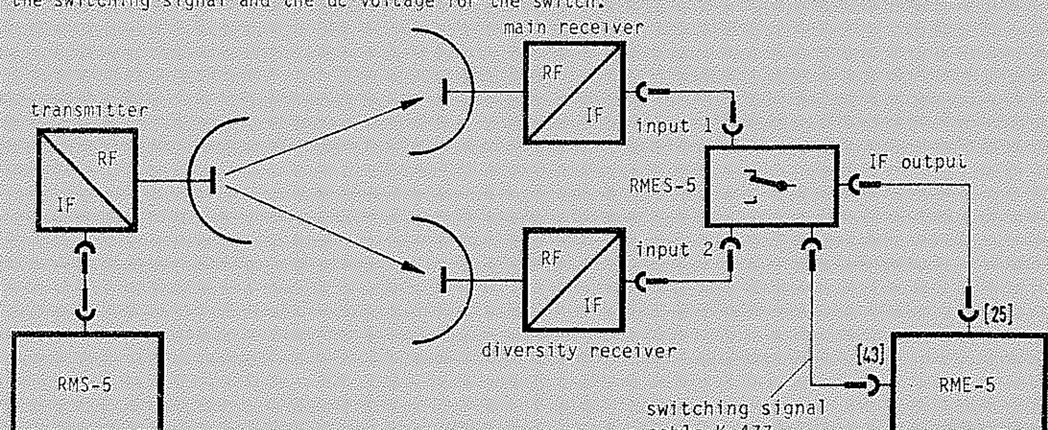


Fig. 1 Test setup for measuring absolute delay differences occurring in space diversity reception

1) The connector is not a standard fitting for series D to K RM-5s, but can be retrofitted.

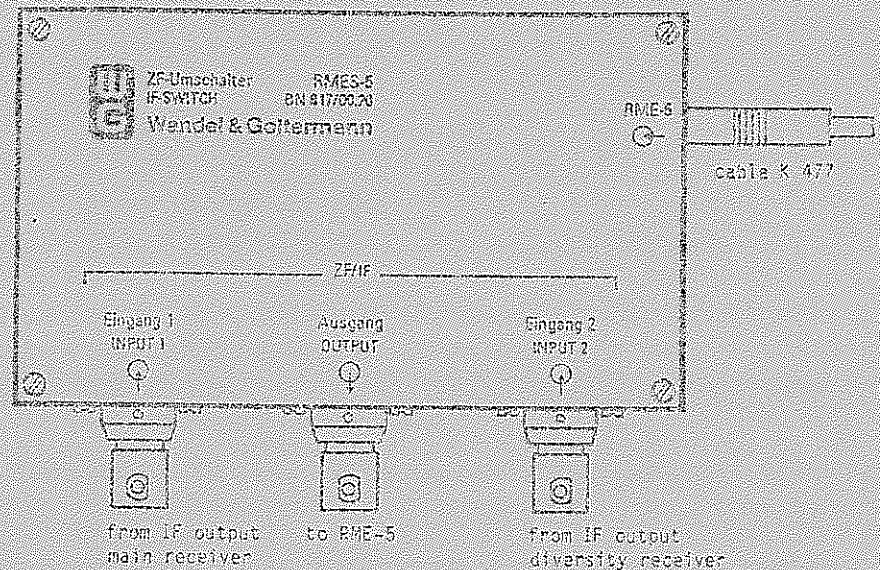


Fig. 2 Front view of the RMES-5 IF switch (1/3 actual size)

In the group delay measurement mode, the RM-5 can be operated in one of three IF ranges.

The second result displayed should be switched off so that group delay results can be read clearly.

Because switching between two receive paths is taking place, two group delays are displayed - there is a jump in value near the centre of the screen. The difference between the results is a direct measure of the absolute delay difference. The length of compensating coaxial cable can be calculated from the absolute delay difference.

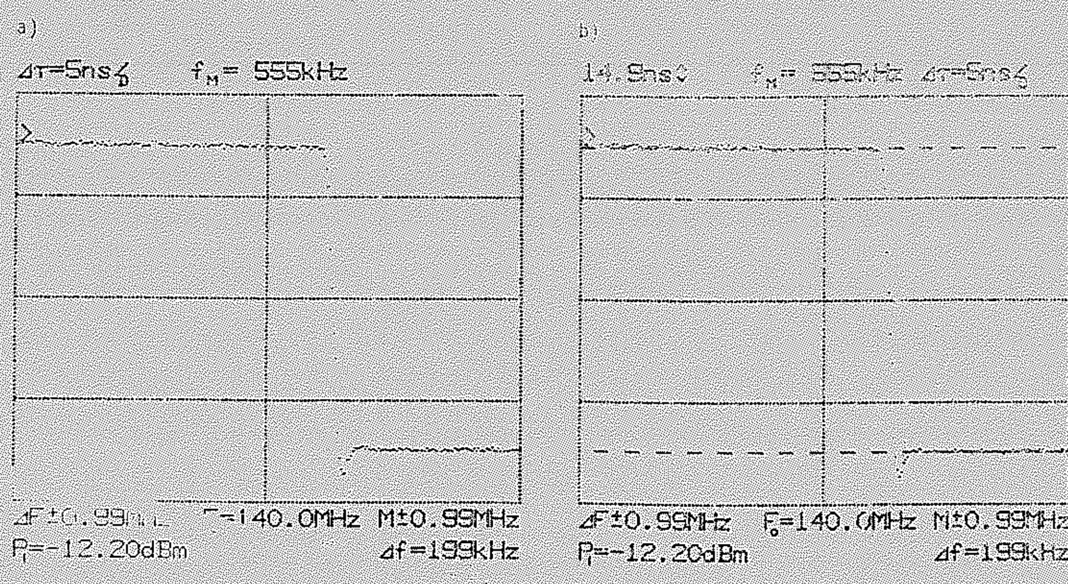


Fig. 3a Display when the IF switch is connected

Fig. 3b reading off the discontinuity using the horizontal cursors.

The difference between the two traces can be determined very accurately at the discontinuity using the horizontal cursors [6] (fig. 3).

As only the difference at the discontinuity is important, not the group delay over the whole transmission band, a low sweep span should be used, e.g. ± 1 MHz.

Note: When there is a level difference at both inputs of the IF switch, the RME-5 might not lock. If this is so, disconnect the coaxial cable between the switch and the IF input of the RME-5,switch off the automatic input level control with key [30] and then reconnect.

If the level in either of the two receive paths is greater than the sensitivity limit of the RME-5, the receiver does not lock. However, to determine the absolute delay difference, an IF amplifier can be connected to the output of the IF switch.

The level displayed on the screen of the RME-5 refers to the level at input 2 of the IF switch.

3. Determining the length of the cable

The length of the cable can be determined by the following formula:

$$L = \frac{\Delta\tau(\updownarrow) \times c_o}{\sqrt{\varepsilon_r}}$$

where $\Delta\tau(\updownarrow)$ is the absolute delay difference in ns

c_o is the speed of light (3×10^8 m/s)

ε_r is the dielectric constant

The formula has been expressed in the form of a diagram. This diagram can be used to determine L , by multiplying this constant with the measured absolute delay difference you obtain the length of coaxial cable required.

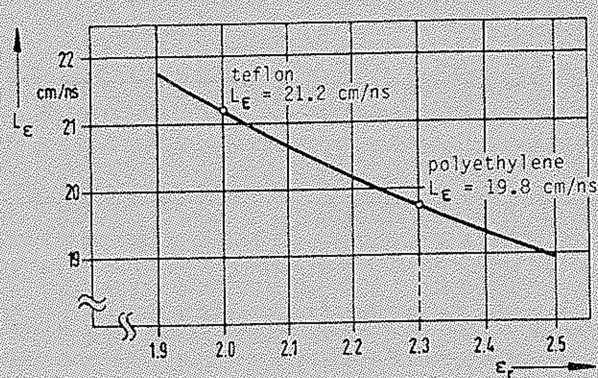


Fig. 4 Determining the constant L as a function of dielectric constant

Example: The absolute delay difference as shown in fig. 3b is 14.9 ns. The dielectric constant ε_r of the cable to be used is 2.3.

Therefore:

L_ε = 19.8 cm/ns and

$L = L_\varepsilon \times \Delta\tau\ (\updownarrow)$ = 19.8 cm/ns × 14.9 ns = 2.95 m

The cable whose length has been determined by the method described should be inserted in the shorter receive path. The results shown by the RME-5 will indicate which path is the shorter:

$\Delta\tau$ result on the left: receive path at input 1 of the IF switch
$\Delta\tau$ result on the right: receive path at input 2 of the IF switch

The shorter path is the one whose display is nearest the bottom of the screen.

4. Technical data of the RMES-5 IF switch

4.1 Inputs and outputs for the IF signals

IFs	35, 70 and 140 MHz
Max. input level	+5 dBm
Impedance	75 ohms
Return loss to 190 MHz	≥ 26 dB
Absolute delay difference between the signal paths	< 100 ps

4.2 Switching characteristics

Insertion loss	6 dB ± 1 dB
Isolation between input and output when switched off	≥ 34 dB
Switching frequency	18 to 70 Hz
Typical switching value	1 µs

4.3 Power supply, switching signal supply

Via special 4-wire cable from the REM-5 (-12 V, switching signal 0 V/5 V, CMOS)

4.4 Dimensions

(w x h x d in mm) without connectors	125 x 75 x 33

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FIGURES

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INTRODUCTION

The most frequently used radio-link IF is 70 MHz, but IFs of 35 MHz and 140 MHz are gaining in popularity. Systems with a small number of channels use 35 MHz; 70 MHz is used by systems having up to 1800 channels. Analog systems with 2700 channels use a 140 MHz IF; in the future this IF will be used by digital radio-links operating at high bit rates, and by satellite links using TDMA. The RM-5 can handle all three frequencies.

The RM-5 comprises a separate generator section, the RMS-5, and a receive section, the RME-5. The RM-5 is the simple way to measure total baseband distortion, the results are clear and easy-to-read. The RM-5 can also be used to measure various kinds of distortion between IF ports, and also modulator, demodulator and IF filter distortion. All these facilities are essential if faults are to be located, and the whole system as well as each system component are to be optimally aligned.

A test modem is essential if basic noise, intermodulation products, or the BB-BB frequency response between IF ports, are to be measured on wideband radio-link systems. The test modem is available as an option.

In many applications the "noise calculation" option can be used instead of the test modem. Using IF-IF differential phase and differential gain results, the option calculates the intermodulation noise in three BB test channels. All relevant system parameters are used for the calculation.

The RM-5 is also ideal for test depts. that are planning to introduce automated testing to cope with a large number of test items, or are looking for a better and more logical way of checking batches containing different items.

All the RM-5's generator and receive functions can be remote-controlled via a standard IEC 625/IEEE 488 interface. This means that the RM-5 can be easily integrated into automated test systems.

Because the RM-5 has very low test frequencies (from 25 kHz), it is possible to test FM or PM systems having a small number of channels.

However, to ensure that all faults can be detected, the RM-5 also has test frequencies up to 5.6 MHz. These frequencies can also be demodulated in the RM-5's receive section. A facility that automatically reduces the sweep witdh prevents incorrect results.

Extreme accuracy, especially at high frequencies, is essential for performing IF-IF distortion measurements. Double modulation of U_M and U_A on the send-side, and tracking demodulation on the receive-side ensure the RM-5 has the required accuracy. The modern design of the RM-5 makes it reliable and easy-to-operate. The generator section and the receive section are operated by buttons. Test parameters can be set very accurately.

The RMS-5 generator displays all the most important transmit parameters by means of a multi-digit 7-segment LED. The parameters can be set by means of up/down keys.

Frequently used setups can be stored and called up when required. An integral battery ensures that memory contents are not lost when the RM-5 is switched off.

Because the generator section is automatically tuned to the test frequency, end-to-end measurements are easy to perform. The sensitivity of the receiver is automatically adjusted to handle a range of signal levels. This facility operates at the IF and BB frequencies.

A new way of displaying results on the RME-5 has been adopted. The display unit can now show curves and alphanumeric results simultaneously in certain areas of the screen. This means sweep traces can be read and understood at a glance, and that any photos or printouts of the results can be fully documented for use at a later date. The RME-5 has a "monitor" output for printing out the results on the screen.

The IF level at the centre frequency and the test deviation are shown on the screen, so that the operator always knows if the test parameters are correct. The IF centre frequency and the sweep width are determined by an integral frequency counter; these parameters are also displayed on the screen.

A further feature which should be mentioned is the facility for displaying two sweep curves on the screen simultaneously. In other words, any pair of results ($\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$[1]), IF-IF frequency response and return loss) can be selected via a pushbutton.

The calibrated ranges for the distortion parameters and the frequency response measurements can be set by means of up/down keys.

The RM-5's display capability and facilities for evaluating sweep traces are greatly enhanced by microprocessor control.

The frequency markers are now a pair of variable line cursors that are symmetrical about the IF centre frequency (i.e. the vertical line through the centre of the screen).

Noisy traces, which often occur when measurements are made via satellite, can be smoothed and made easier to read by means of a noise averaging facility. Five averaging factors are provided to handle signals with various degrees of noise.

To eliminate the intrinsic distortion of the RM-5, or to adjust an item-under-test so that its characteristics follow a given curve, it is possible to store a reference curve and the difference curve obtained by subtracting the test curve from the reference curve.

The RM-5 has special facilities for analysing distortion curves. The linear component and the quadratic (parabolic) component of the curves can be calculated over any frequency interval. In the "Bessel spectrum" operating mode, the receiver displays the frequency-modulated input signal as a spectrum - which means the RM-5 can be used as a spectrum analyser. This mode can also be used to calibrate the test frequency deviation meter in the RM-5, and to set the sensitivity of modulators and demodulators.

To set the IF centre frequency of modulators, you can obtain a display with higher resolution by selecting the frequency counter mode on the RME-5.

Instead of the <IEC 625> interface board for remote controlling the RME-5, it is possible to fit an x-y plotter interface that will only allow you to print out sweep curves.

The RM-5 also has an option for generating all the INTELSAT IF-IF frequency response and IF-IF group delay tolerance masks that are used for lining-up earth stations and satellite communications paths. One keystroke selects the mask you want.

The RM-5 is an up-to-date test set that can handle many complex applications but is nevertheless easy to operate.

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1) See "Terms, symbols and definitions"

Terms, symbols and definitions

Sweep voltage	$\hat{U}_A$	: Also called deflection voltage, peak value of (sinusoidal) sweep voltage.
	U_A	: Instantaneous value of the sweep voltage.
Test voltage	U_M	: RMS value of the (sinusoidal) test voltage.
	$U(U_A)$	: Magnitude of received test voltage as a function of U_A.
	U_o	: Magnitude of the received test voltage at $U_A = 0$.
Non-linear distortion[1)] Differential gain[1)]	$\Delta U/U_o$	$= \frac{U(U_A) - U_o}{U_o} \times 100\%$
Group delay distortion[1)]	$\Delta\tau$	$= \tau - \tau_o$ in ns
	τ, τ_o	= Group delay of test signal at a working point determined by U_A or $U_A = 0$.
Differential phase[1)]	$\Delta\varphi$	$= \varphi - \varphi_o$ in % rad (1% rad = 0,57°; 1° = 1,75% rad)
	φ, φ_o	= Phase angle of test signal at a working point determined by U_A or $U_A = 0$.
IF centre frequency	F_o	: IF carrier frequency, e.g. 70 MHz
Sweep width	$\hat{\Delta F}$	: Peak value of IF sweep width caused by $\hat{U}_A$.
Sweep frequency	f_A	: Frequency of the sweep voltage.
Test deviation	Δf	: RMS value of a frequency deviation caused by U_M or an external sinusoidal signal.
Test frequency	f_M	: Frequency of test voltage.
Reduced sweep width	$\hat{\Delta F}_{RED}$	: Automatic sweep width reduction as the test frequency is increased $\hat{\Delta F}_{RED} = \hat{\Delta F} - f_M$.
Baseband	BB	: Name for wideband signal (telephone multiplex or TV signal) with which the IF carrier of a radio-link or satellite system is modulated. In the RM-5, the designation "BB" is used for both inputs and outputs and subassemblies which process, generate or condition the BB signals or other signals in the same frequency range, such as noise signals or sinusoidal signals.
Intermediate frequency(band)	IF	: In radio-link and satellite systems, the wideband BB signal generally modulates the frequency of an IF carrier signal. The IF carrier or centre frequency is 70 MHz for systems with up to 1800 channels. In the RM-5, the designation "IF" is used for inputs and outputs and for subassemblies which process, generate, or modify the frequency modulated IF signals in the specified IF band.

1) The terms "non-linear distortion" and "group delay distortion" are used up to 1 MHz. Above this frequency these quantities are referred to as "differential gain" and "differential phase" resp..

1 SPECIFICATIONS

1.1 SPECIFICATIONS FOR THE RM-5 SYSTEM

1.1.1 FREQUENCIES AND FREQUENCY RANGES

1.1.1.1 IF ranges

70 MHz range (standard) .... 40 to 100 MHz
35 MHz range (option) .... 25 to 45 MHz
140 MHz range (option) .... 90 to 190 MHz

1.1.1.2 "f_M" frequencies

(series I or series II, f_M < 1 MHz)
Series I .... 27.778, 55.556, 92.593, 277.778, 555.556 kHz
Series II .... 25, 50, 83.3, 250, 500 kHz
High test frequencies (f_M > 1 MHz)[1] .... 2.4 and 5.6 MHz
Either or both frequencies can be replaced
by one of the following options 3.580, 3.579545,
4.430 or 4.433619 MHz

1.1.1.3 "f_A" sweep frequency (sinusoidal)

Two selectable, fixed frequencies .... 18 and 70 Hz
or two frequencies that can be adjusted in 1 Hz steps over the range .... 18 to 70 Hz
One frequency can be synchronised with the mains[2] .... from 47.5 to 63 Hz
External frequency .... 18 to 70 Hz

1.1.2 IF-IF DISTORTION MEASUREMENTS[3]

Unless otherwise stated, the data are valid for input levels, P_I, from -20 to +10 dBm, and for the 70 MHz IF range (standard) and the 140 and 35 MHz ranges (options). The following measurement ranges are valid for a max. screen height of 6 cm. The grid has 4 divisions, the division spacing is 1.5 cm.

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1) Does not apply to the 35 MHz IF range
2) From series F
3) The 18 Hz sweep frequecy must be used when the test frequencies are 25 and 50 kHz or 27.778 and 55.556 kHz

1.1.2.1 "$\Delta\tau$" group delay distortion (f_M < 1 MHz)

Test ranges

f_M = 500 or 555.556 kHz .... 0.8, 2, 4, 8, ..., 80 ns
f_M = 250 or 277.778 kHz .... 1.6, 4, 8, 16, ..., 160 ns
f_M = 83.3 or 92.593 kHz .... 4, 10, 20, 40, ..., 400 ns
f_M = 50 or 55.556 kHz .... 8, 20, 40, 80, ..., 800 ns
f_M = 25 or 27.778 kHz .... 16, 40, 80, 160, ..., 1600 ns

Maximum sensitivity .... 0.2 ns/div.

Intrinsic distortion[1)]

35 MHz[2)]		70 MHz		140 MHz[2)]	
± 5 MHz	± 10 MHz	± 12 MHz	± 25 MHz	± 18 MHz	± 40 MHz
≤ 0.5 ns	≤ 2 ns	≤ 0.4 ns	≤ 1 ns	≤ 0.3 ns	≤ 1 ns

Intrinsic noise[3)] (peak-to-peak) .... ≤ 0.1 ns

1.1.2.2 Non-linear distortion "$\Delta U/U_o$" (f_M < 1 MHz)

Measurement ranges .... 0.4, 1, 2, 4, ..., 40%

Max. sensitivity .... 0.1%/div.

Intrinsic distortion

35 MHz[2)]		70 MHz		140 MHz[2)]	
± 5 MHz	± 10 MHz	± 12 MHz	± 25 MHz	± 18 MHz	± 30 MHz
≤ 0.2%	≤ 0.8%	≤ 0.1%	≤ 0.3%	≤ 0.15%	≤ 0.3%

Intrinsic noise[4)] (peak-to-peak) .... ≤ 0.05%

1.1.2.3 Differential phase "$\Delta\varphi$" (f_M > 1 MHz)

Measurement ranges .... 0.4, 1, 2, 4, ..., 40% rad

Max. sensitivity .... 0.1% rad/div.

---

1) Test frequency 500 or 555.556 kHz; typical value at lower frequencies
2) If option is fitted
3) Averaging factor 32, test deviation $\Delta f \geq$ 200 kHz, test frequency 500 or 555.556 kHz. At lower test frequencies the value increases by a factor of 556 kHz/f_M.
4) Averaging factor 32, test deviation $\Delta f \geq$ 200 kHz

Intrinsic distortion (autom. sweep width reduction on):

70 MHz		140 MHz[1]	
± 12 MHz	± 25 MHz	± 18 MHz	± 30 MHz
≤ 0.5% rad	≤ 1% rad	≤ 0.5% rad	≤ 1% rad

Intrinsic noise[2] (peak-to-peak) .... ≤ 0.05% rad

1.1.2.4 Differential gain "$\Delta U/U_o$" (f_M > 1 MHz)

Test ranges .... 0.4, 1, 2, 4, ..., 40%

Max. sensitivity .... 0.1%/div.

Intrinsic distortion (autom. sweep width reduction on):

70 MHz		140 MHz[1]	
± 12 MHz	± 25 MHz	± 18 MHz	± 30 MHz
≤ 0.2%	≤ 0.4%	≤ 0.2%	≤ 0.4%

Intrinsic noise[2] (peak-to-peak) .... ≤ 0.05%

1.1.2.5 Attenuation/frequency distortion "ΔP_I" (IF-IF frequency response)

Test ranges .... 0.4, 0.8, 1.6, ..., 16 dB

Max. sensitivity .... 0.1 dB/div.

Max. intrinsic frequency response[3]

IF level P_I	35 MHz[1]		70 MHz	140 MHz[1]
	± 5 MHz	± 10 MHz	± 25 MHz	± 50 MHz
+3 dBm	± 0.15 dB	± 0.25 dB	± 0.05 dB	± 0.1 dB
-20 to +10 dBm	± 0.25 dB	± 0.35 dB	± 0.1 dB	± 0.2 dB

Slope correction factor for ΔP_I measurements

Linear errors, caused, for example, by long test cables, can be compensated for by using a slope correction factor. The correction factor can be switched out when required, and does not affect calibration.

1.1.2.6 Attenuation/frequency distortion "ΔP_{II}" (selective)

(Signal has same frequency as IF signal at input P_I)

Level at input P_{II} .... -50 to -10 dBm

1) When option is fitted
2) Averaging factor 32; test frequency deviation Δf = 500 kHz
3) Temperature range +15°C to +30°C

Test ranges .... 8, 16, 40, 80 dB

Max. sensitivity .... 2 dB/div.

Max. intrinsic frequency response

35 MHz ± 10 MHz[1]	70 MHz ± 25 MHz	140 MHz ± 50 MHz[1]
± 0.6 dB		± 0.7 dB

1.1.2.7 IF return loss "ΔP_{II}"

(use the RFZ-4 or the RFZ-14, see 4.5)

Measurement ranges .... 8, 16, 40, 80 dB

Max. sensitivity .... 2 dB/div.

Error limits, using the RFZ-4, with, for example BNC, TNC or 1.6/10 connectors, frequency range 45 to 90 MHz, after calibration

at a_r = 20 dB .... ± 1 dB

at a_r = 30 dB .... -2.1/+1.8 dB

1.1.2.8 "Y_{extern}" (e.g. for rf detector signals)

Measurement ranges .... 8, 20, 40, 80, ..., 800 mV

Max. sensitivity .... 2 mV/div.

Input impedance (dc coupling) .... 10 kΩ

Max. input voltage .... ≤ 7 V

1.1.3 IF TEST PARAMETERS

The test parameters, and the curves showing the results, are both displayed on the screen. The measurement range and the test frequency f_M are shown at the top of the screen. The results for the parameters described in 1.1.3.1 to 1.1.3.4 are shown at the bottom of the screen.

1.1.3.1 Level "P_I"

(at centre frequency F_o)

Test range .... -20 to +10 dBm

Resolution .... 0.01 dB

Error limits (after calibration at a transmission level of 0 dBm) .... ± 0.5 dB

---

1) Option fitted

1.1.3.2 Test frequency deviation "Δf" (rms value)

Measurement range .... 15 to 500 kHz

Resolution .... 1 kHz

Modulation frequency range

in the 35 MHz IF range .... 25 to 555.556 kHz

in the 70 and 140 MHz IF ranges .... 25 kHz to 5.6 MHz

Calibration .... Bessel zero method, f_M = 250 kHz (277.778 kHz)
or f_M = 83.3 kHz (92.593 kHz)

Error limits (after calibration) .... ± 11% of result ± 1% of selected range

1.1.3.3 Sweep width "$\hat{\Delta F}$"

Measurement range .... ± 0.2 to ± 50 MHz

Resolution

0.2 to 9.99 MHz .... 0.01 MHz

10 to 50 MHz .... 0.1 MHz

Error limits .... $\pm 5 \times 10^{-3}$ ± 1 digit

1.1.3.4 Centre frequency "F_o"

(of the swept IF signal at input P_I)

Measurement range .... 25 to 190 MHz

Resolution .... 0.1 MHz

Error limits .... $\pm 5 \times 10^{-3}$ ± 1 digit

1.1.3.5 Frequency markers "M"

(Two adjustable, vertical cursors symmetrical about the centre frequency F_o)

Range .... ± 0.03 to ± 50 MHz

Resolution

0.03 to 9.99 MHz .... 0.01 MHz

10 to 50 MHz .... 0.1 MHz

Error limits .... $\pm 5 \times 10^{-3}$ ± 1 digit

1.1.3.6 Horinzontal cursors "$\Diamond$"

(Two adjustable cursors, symmetrical about the horizontal line through the centre of the screen. The horizontal cursors can be selected instead of one of the test traces.)

Cursor separation shown as .... alphanumeric display on screen
(calculated from the scale)

1.1.4 IF COUNTER

For unswept IF signal at input P_I

Measurement range .... 25 to 190 MHz

Resolution .... 0.01 MHz

Error limits .... $\pm$ 1 x 10^{-4} $\pm$ 2 kHz $\pm$ 1 digit

1.1.5 BESSEL SPECTRUM

To calibrate the RME-5 and to set the sensitivity of modulators and demodulators.

Frequency range of displayed spectrum .... $\pm$ 400 kHz

Test frequencies for calibrating the deviation meter

Frequency series I .... 92.593 and 277.778 kHz

Frequency series II .... 83.3 and 250 kHz

Detectable carrier suppression (Bessel zeroes)

at 92.593 and 83.8 kHz .... $\geq$ 40 dB

at 277.778 and 250 kHz .... $\geq$ 50 dB

Error limits on the frequency deviation

at f_M = 92.593 or 83.3 kHz .... $\pm$ 1.4 kHz

at f_M = 277.778 or 250 kHz .... $\pm$ 1.2 kHz

1.1.6 BB DISTORTION MEASUREMENTS

Unless otherwise stated, the data are valid for the whole BB input-level range from -50 to -10 dBm. The following measurement ranges are given for the full graticule height of 6 cm. There are four divisions with a 1.5 cm spacing.

1.1.6.1 Group delay distortion "$\Delta\tau$" (f_M < 1 MHz)

Measurement ranges

f_M = 500 or 55.556 kHz .... 0.8, 2, 4, 8, ..., 80 ns

f_M = 250 or 277.778 kHz .... 1.6, 4, 8, 16, ..., 160 ns

f_M = 83.3 or 92.593 kHz .... 4, 10, 20, 40, ..., 400 ns

f_M = 50 or 55.556 kHz .... 8, 20, 40, 80, ..., 800 ns

f_M = 25 or 27.778 kHz .... 16, 40, 80, 160, ..., 1600 ns

Max. sensitivity .... 0.2 ns/div.

Intrinsic distortion .... $\leq$ 0.05 ns

Intrinsic noise[1)2)] (peak-to-peak) .... $\leq$ 0.1 ns

---

1) Test frequency 500 or 555.556 kHz. At lower test frequencies the value is increased by a factor 556 kHz/f_M.

2) Averaging factor 32

1.1.6.2 Non-linear distortion "$\Delta U/U_o$ (f_M < 1 MHz)

Measurement ranges .... 0.4, 1, 2, 4, ..., 40%

Max. sensitivity .... 0.1%/div.
Intrinsic distortion .... ≤ 0.02%
Intrinsic noise[1] (peak-to-peak) .... ≤ 0.05%

1.1.6.3 Differential phase "$\Delta\varphi$" (f_M ≥ 1 MHz)

Measurement ranges .... 0.4, 1, 2, 4, ..., 40% rad

Max. sensitivity .... 0.1% rad/div.
Intrinsic distortion .... ≤ 0.05% rad
Intrinsic noise[1] (peak-to-peak) .... ≤ 0.05% rad

1.1.6.4 Differential gain "$\Delta U/U_o$< (f_M ≥ 1 MHz)

Measurement ranges .... 0.4, 1, 2, 4, ..., 40%

Max. sensitivity .... 0.1%/div.
Intrinsic distortion .... ≤ 0.05%
Intrinsic noise[1] (peak-to-peak) .... ≤ 0.05%

1.1.6.5 BB test parameters

Both the parameters to be tested and the traces showing the results appear on the screen simultaneously. The measurement ranges that have been selected are shown at the top of the screen, as is the test frequency f_M.

When BB-BB distortion measurements are being performed, it is also possible to display the IF parameters mentioned in 1.1.3 on the screen when the appropriate IF signal is applied to input P_I, and the deflection signal U_x is obtained from the IF signal.

1.1.6.6 Horinzontal cursors "⇕"

(Two adjustable cursors, symmetrical about the horizontal line through the centre of the screen. The horizontal cursors can be selected instead of one of the test traces.)

Cursor separation shown as .... alphanumeric display on screen (calculated from the scale)

1.1.7 BB LEVEL

For unswept signals from 10 kHz to 12.5 MHz applied to the "BB-level" input.

Measurement range .... -50 to -10 dBm

Resolution .... 0.01 dB
Error limits
for sinusoidal signals .... ± 0.5 dB
for noise signals (white noise) .... ± 0.8 dB

---

1) Averaging factor 32

1.1.7.1 BB return loss

For unswept sinusoidal signals from 100 kHz to 12.5 MHz; measurement performed using the RFZ-14.

Level range at "BB level" input .... -50 to -10 dBm
Resolution .... 0.01 dB

The error limits depend on the directivity of the RFZ-14, the type of connector used, the measured return loss and the error on the BB level measurement.

1.1.8 INTERNAL EVALUATION

1.1.8.1 Weighting bandwidth for distortion measurements

Weighting filter out .... approx. 1 to 4 kHz 1)
Weighting filter in .... 300 Hz

1.1.8.2 Noise averaging

Five averaging factors have been provided so that even very noisy traces can be read easily (e.g. measurements performed via satellite). The shape of the trace is not changed by the averaging process.

Averaging factors 2, 4, 8, 16, 32
Improvement in S/N produced by an averaging factor of 32 .... approx. 18 dB
Time constant, averaging factor of 32 .... approx. 5 s
The time constant is proportional to the averaging factor.

1.1.8.3 Curve difference

To eliminate intrinsic distortion, or to adjust an item-under-test to a specified characteristic, a reference curve "REF" can be stored. This reference curve can then be displayed, or the difference between the reference curve and the measured curve can be shown on the screen.

1.1.8.4 Curve analysis

Can be used for all distortion measurements. The point of intersection of curve with the vertical centre line and the two points of intersection with the two frequency markers are used to perform curve analysis.

"LIN": The difference in the y coordinates of the two points of intersection with the frequency markers.

"PARAB": The difference in the y coordinates of the curve and the secant formed by "LIN" along the x coordinate of the screen centre.

---

1) Depends on the test frequency

1.1.8.5 Noise calculation (option BN 917/00.11)

The intermodulation noise in three BB white noise slots is calculated from the differential phase $\Delta\varphi$ and the differential gain $\Delta U/U_0$ using an approximation method.

System type .... 300, 600, 960, 1260, 1500, 1800, 2100, 2400, 2700 channel systems

Results .... table on screen

Noise analysis

The noise power in pW0p at three channel frequencies is measured at the conventional load, and at overloads of 3 dB and 6 dB.

Distortion analysis

The 1st, 2nd, 3rd and 4th order distortion products for differential gain $\Delta U/U_0$ and differential gain $\Delta\varphi$ are calculated.

Calculation time .... approx. 4 s

1.1.8.6 INTELSAT tolerance masks (option BN 917/00.12)

IF-IF group delay tolerance masks can be displayed in the upper half of the screen; IF-IF frequency response can be displayed in the lower half. All tolerance masks are to SSOG regulations for FDMA and TDMA systems.

1.1.9 <IEC 625>/IEEE 488 INTERFACE BUS (options BN 958/21 and BN 853/21)

Remote controls all the operating functions of the RMS-5 and RME-5 except brightness. All the RME-5's traces and measurement parameters are interrogated. Tolerance masks and alphanumeric characters are shown on the screen. All RMS-5 settings are interrogated.

Interface functions SH1, AH1, T6, L4, SR1, RL1, PP2, DC1, DT1, C0

1.1.10 RESULT DOCUMENTATION

1.1.10.1 Video output

The RM-5's display can be printed out. An external monitor can also be used to display results.

Frame frequency .... 50 Hz

Number of lines (sequential line scan) 312

Amplitude .... 1 V_{p-p}

Impedance .... 75 Ω

1.1.10.2 X-Y plotter interface (option 917/00.01)

Alternative to the <IEC 625> interface. For printing out distortion curves on special graph paper (BN 917/00.79).

Sweep curves [2] and [10] are shown on the left and right of the paper resp.
Dimensions of a graticule area .... 10 x 10 cm
Output sensitivity, switchable .... 0.1 or 0.4 V/cm
Pen-lift .... up/down level can be inverted on interface board

1.1.10.3 Photographing the screen

The screen can be photographed with a hand-held camera (screen dimensions 8.5 cm x 12 cm).

1.2 EXTRA DATA FOR THE RMS-5 GENERATOR SECTION

1.2.1 IF SECTION

1.2.1.1 Main IF output

Centre frequency and sweep width

	35 MHz range 1)	70 MHz range	140 MHz range 1)
Setting range for the centre frequency 2) (in 0.1 MHz steps)	22.5 to 47.5 MHz	40 to 100 MHz	90 to 200 MHz
Centre frequency error limits	± 10 kHz	± 20 kHz	± 40 kHz
Setting range of the sweep width $\hat{\Delta}F$ (in 0.01 or 0.1 MHz steps)	0 to ± 12.5 MHz	0 to ± 30 MHz	0 to ± 50 MHz
Sweep width ($\hat{\Delta}F$) error limits	± 0.03 x $\hat{\Delta}F$ ± 3 kHz		

Centre frequency and sweep width .... set via keyboard in steps or via up/down keys

Display
Centre frequency .... 4-digit LED
Sweep width $\hat{\Delta}F$ .... 3-digit LED

Automatic sweep width reduction

The reduced sweep width can be displayed instead of the sweep width which has been set. The sweep width is reduced by an amount equal to the test frequency so that the limits of the IF range are not exceeded at high test frequencies.

---

1) Option fitted

2) When the 35 MHz or the 140 MHz options, or both, are fitted, the best IF range for the selected centre frequency and sweep width is chosen.

Test frequency deviation Δf (rms)

Setting range .... 5 to 500 kHz
Set via keyboard or up/down keys.
Smallest step .... 0.1 or 1 kHz
Display .... 3-digit LED
Error limits .... 0.08 x Δf

IF level

Level range .... -59.9 to +10 dBm
Set via keyboard or up/down keys.
Smallest step .... 0.1 dB
Display .... 3 1/2-digit LED

Level error-limits

Level	at 35 MHz 1)	at 70 MHz	at 140 MHz 1)
0 dBm	± 0.15 dB		± 0.25 dB
-59.9 to +10 dBm	± 0.5 dB		

Max. frequency response referred to an average value

IF level	30 MHz ± 10 MHz 1)	70 MHz ± 30 MHz	140 MHz -50/+60 MHz 1)
+3 dBm	± 0.05 dB		± 0.1 dB
-59.9 to +10 dBm	± 0.1 dB		± 0.3 dB

Output impedance .... 75 Ω

Return loss

IF level	35 MHz ± 10 MHz 1)	70 MHz ± 30 MHz	140 MHz -50/+60 MHz 1)
≤ 0 dBm	≥ 34 dB		≥ 30 dB
> 0 dBm	≥ 30 dB		≥ 26 dB

Harmonic ratio (2nd and 3rd order) .... ≥ 30 dB

1.2.1.2 Auxiliary IF output

Decoupled from main IF output; signal has same frequency
Level (unregulated) .... approx. -6 dBm
Output impedance .... 75 Ω

---

1) Option fitted

1.2.1.3 "IF_0" output (IF calibration generator option, BN 916/00.20)

Frequency, switchable	35[1], 70 and 140 MHz[1]
Error limits	$\pm$ 5 x 10^{-5}
Level	+5 dBm
Error limits	$\pm$ 0.5 dB
Output impedance	75 Ω
Return loss	$\geq$ 30 dB
Harmonic ratio (2nd and 3rd order)	$\geq$ 30 dB
Noise, to CCIR Recs.[2]	
1800 channels	$\leq$ 1 pWOp
2700 channels	$\leq$ 2 pWOp

1.2.1.4 "U_M extern"

for external test frequencies f_M = 25 kHz to 5.6 MHz

Sensitivity at 250 or 277.778 kHz	10 MHz/V $\pm$ 5%
Test voltage range (rms)	0 to 100 mV
Input impedance	75 Ω
Return loss	$\geq$ 30 dB

1.2.1.5 "$\hat{U}_A$ extern" input

for external sweep frequencies f_A = 18 to 70 Hz

Sensitivity	-10 MHz/V $\pm$ 3%[3]
Sweep voltage (peak)	0 to 5 V
Input impedance	75 Ω
Return loss	$\geq$ 30 dB

---

1) When option fitted

2) In other words

Deemphasis	to CCIR 275
Channel width 140 kHz	to CCIR 404
IF transmission +5.2 dBm	to CCIR 403
Test frequencies	to CCIR 399

3) From series F: +10 MHz/V $\pm$ 3%

1.2.2 BB SECTION

1.2.2.1 "$U_A \pm U_M$" BB output

Output impedance .... 75 Ω
Return loss at test and sweep frequencies used .... ≥ 30 dB

Test frequencies f_M

Series I .... 27.778, 55.556, 92.593, 277.778, 555.556 kHz
or
Series II .... 25, 50, 83.3, 250, 500 kHz
High test frequencies .... 2.4 and 5.6 MHz
or .... 3.580, 4.430, 3.579545, 4.433619 MHz
Error limits .... $\pm 2 \times 10^{-5}$

Setting range for the test voltage U_M

Setting range for voltage .... 0.05 to 500 mV
for level .... -75 to +5.2 dBm
Set via keyboard, or by up/down keys
Smallest step
0.05 to 4.99 mV .... 0.01 mV
5 to 49.9 mV .... 0.1 mV
50 to 500 mV .... 1 mV
Level .... 0.1 dB
Display .... 3 1/2-digit LED
Test-voltage error-limits .... $\pm 0.06 \times U_M$ or ± 0.5 dB
Harmonic ratio (2nd and 3rd order) .... ≥ 30 dB

Sweep frequency f_A .... 18 and 70 Hz
Error limits .... ± 2%
Setting range of sweep voltage $\hat{U}_A$ .... 0 to ± 3 V
Setting via keyboard, or quasi-continuously via up/down keys
Smallest step .... 0.001 V
Display .... 4-digit LED
Error limits .... $\pm 0.03 \times \hat{U}_A \pm 1$ mV
The automatic sweep width reduction facility can be switched off. When the facility is on, it is possible to display either the reduced sweep voltage, or the sweep voltage that has been set.
Entering the appropriate sweep width $\hat{\Delta F}$
in the range .... $\pm f_M$ to $\pm \hat{\Delta F}_{max}$
Harmonic ratio (2nd and 3rd order) .... ≥ 40 dB

1.3 EXTRA DATA FOR THE RME-5 RECEIVE SECTION

1.3.1 IF SECTION

1.3.1.1 IF input "P_I"

Capture range and holding range for the AFC

	35 MHz range[1)]	70 MHz range	140 MHz range[1)]
Capture range	30 to 40 MHz	40 to 100 MHz	90 to 190 MHz
Holding range	25 to 45 MHz		

Min. sweep width, $\hat{\Delta}F$, that gives synchronisation of the x-deflection voltage .... ± 200 kHz

Level range P_I .... -20 to +10 dBm

Automatic range selection (can be switched off).
Out-of-range LED

Input impedance .... 75 Ω
Return loss .... ≥ 26 dB
Max. input voltage (rms) .... 2 V

Test frequency recognition .... automatic

(see 1.3.2.1 for frequencies)
Capture range .... $\pm 2 \times 10^{-5}$
Required test tone deviation Δf .... ≥ 15 kHz

IF-IF distortion measurements

See 1.1.2 for measurement ranges and intrinsic distortion.

Display error limits (not including intrinsic distortion)
for the measurement modes $\Delta\tau$, $\Delta\varphi$, $\Delta U/U_o$ .... ± 10% of result
for the measurement mode ΔP_I .... ± 5% of result

Slope correction for ΔP_I mode (can be switched off) .... approx. ± 0.02 dB/MHz
Correction range "phase U_x" .... ± 6°

1.3.1.2 IF input "P_{II}"

Measurement mode ΔP_{II} (selective)

Frequency range .... see IF input P_I (1.3.1.1)

X-deflection via IF signal with same frequency at input P_I.

---

1) If option is fitted

Level range .... -50 to -10 dBm

Error limits on displayed level difference ΔP_{II}, at the centre frequency f_o,
referred to an input level of -30 dBm .... ± 0.5 dB ± 5% of result

Maximum frequency response referred to an average value

35 MHz ± 10 MHz[1]	70 MHz ± 25 MHz	140 MHz ± 50 MHz[1]
± 0.4 dB		± 0.5 dB

Input impedance .... 75 Ω
Return loss .... ≥ 26 dB
Max. input voltage (rms) .... 2 V

1.3.2 BB SECTION

1.3.2.1 "BB" input ($\hat{U}_A + U_M$)

Input impedance .... 75 Ω
Return loss for test frequencies f_M .... ≥ 26 dB

Test frequencies f_M

Series I .... 27.778, 55.556, 92.593, 277.778, 555.556 kHz
or
Series II .... 25, 50, 83.3, 250, 500 kHz
High test frequencies .... 2.4 and 5.6 MHz
or (option) .... 3.580, 4.430, 3.579545, 4.433619 MHz

Detection of correct test frequency .... automatic

Capture range .... $\pm 2 \times 10^{-5}$

Level ranges for U_M .... -50 to -10 dBm

Range selection .... automatic

LED indicates signal out of range.

Sweep frequency f_A .... sinusoidal

Automatic synchronisation from 18 Hz to 70 Hz

Sweep voltage $\hat{U}_A$ .... ± 50 mV to ± 5 V

Setting range "phase U_x" .... 0° to 360°

BB-distortion

See 1.1.6 for measurement ranges and intrinsic distortion.
Display error limits (not including intrinsic distortion)
for the measurement modes $\Delta T, \Delta\varphi, \Delta U/U_o$ .... ± 10% of result

---

1) Option fitted

1.3.2.2 "BB-level" input

See section 1.1.7 for frequency and test ranges.

Input impedance .... 75 Ω

Return loss .... ≥ 26 dB

1.3.2.3 "Y_{extern}" input (on back panel)

Input for rf detector signals for example.

See section 1.1.2.8 for data.

1.3.2.4 Demodulator output (back panel)

Output for the demodulated test signal U_M

Demodulator sensitivity

in the nominal range of use for ambient temperature .... 60 mV/MHz ± 10%

Output impedance .... 75 Ω

1.3.3 RESULT FORMAT

It is possible to show all results and parameters, in graphic and alphanumeric form, on the screen.

1.3.3.1 Graphic display

The graticule and two test curves can be shown simultaneously. Any combination of the measurement modes

$\Delta\tau$, $\Delta\varphi$, $\Delta U/U_o$, ΔP_I, ΔP_{II} and Y_{ext}.

Both curves can be shifted independently in the y-direction over the whole graticule.

Size of graticule .... 5.6 cm x 8.4 cm

or .... 205 lines x 256 pixels

Graticule format

Horizontal .... 5 lines

Vertical .... 3 lines

plus two variable frequency markers

Either one of the two test curves can be replaced by two variable horizontal cursors which are symmetric about the centre line.

If the results of two distortion measurements are shown simultaneously, arrows indicate the appropriate measurement mode.

In the spectrum mode, only the graticule reference lines are shown.

1.3.3.2 Alphanumeric format

There are a total of three lines above and below the graticule for displaying the test parameters. These are: measurement ranges, test frequency, sweep width, centre frequency, marker separation, IF level and test tone deviation.

Other parameters that are concerned with curve evaluation may also be shown within the graticule; e.g. the results of LIN and PARAB.

1.4 WIDEBAND DEVICES FOR THE RM-5 (70 AND 140 MHz)

1.4.1 WIDEBAND MODULATOR, OPTION BN 916/00.31

Fitted in the generator section, RMS-5

1.4.1.1 BB input

Modulator sensitivity at 277.778 or 250 kHz .... 10 MHz/V ± 5%
Modulator frequency range, IF 70 MHz .... 50 Hz to 12.5 MHz
IF 150 MHz .... 50 Hz to 13.6 MHz
Max. wideband level for noise signals corresponding to (1800) 2700 channels
at 6 dB overload .... (-2.2) -0.4 dBm
Max. level for sinusoidal signals .... -10 dBm
Input impedance .... 75 Ω
Return loss .... ≥ 30 dB
Max. input level (permanent damage) .... +20 dBm
Max. dc voltage .... ± 5 V

1.4.1.2 IF output

For data and error limits, except frequency response, see 1.2.1.1

1.4.1.3 Basic noise

When operated at (70 MHz/1800 channels) 140 MHz/2700 channels under CCIR conditions[1],
between +15°C and +30°C .... ≤ (15) 20 pW0p

1.4.2 RMED-5 WIDEBAND DEMODULATOR, BN 2018/01

Separate unit with 19" format (2 U)

1.4.2.1 IF input

Centre frequency .... 70 MHz ± 50 kHz
can be switched to .... 140 MHz ± 100 kHz
Level range .... -4 to +6 dBm
Input impedance .... 75 Ω
Return loss at 70 ± 12 MHz or 140 ± 18 MHz .... ≥ 30 dB
Max. input voltage (rms) .... 2 V

---

1) CCIR conditions:

Use of pre-emphasis and de-emphasis	to CCIR 275
Channel width 140 kHz	to CCIR 404
Conventional load +17.5 dBm0 (70 MHz), +19.3 dBm0 (140 MHz)	to CCIR 399
IF transmission level, +5.2 dBm	to CCIR 403
IF receive level, 0 dBm	to CCIR 403
Test frequencies	to CCIR 399

1.4.2.2 BB output

Demodulator sensitivity .... 50 mV/MHz ± 10%
Demodulator frequency range at 70 MHz IF .... 50 Hz to 12.5 MHz
at 140 MHz IF .... 50 Hz to 13.6 MHz
Output level for 140 kHz sweep width (rms) .... -32 dBm ± 1 dB
Output impedance .... 75 Ω
Return loss, 6 kHz to 13.6 MHz .... ≥ 30 dB

1.4.2.3 Basic noise

When operating at (70 MHz/1800 channels) 140 MHz/2700 channels under CCIR conditions[1],
from +15°C to +30°C .... ≤ (7.5) 12.5 pWOp

1.4.3 CHARACTERISTICS OF THE MODEM LOOP

The data apply to an ex-works modem pair, comprising the RMS-5, the wideband modulator option and the RMED-5 wideband demodulator. This data should be considered to be typical for any RMS-5/RMED-5 setup.

1.4.3.1 Basic and intermodulation noise

When operating at (70 MHz/1800 channels) 140 MHz/2700 channels under CCIR conditions[1],
from +15°C to +30°C.
Basic noise .... ≤ (20) 35 pWOp
at conventional load .... ≤ (40) 50 pWOp
at 3 dB overload .... ≤ (60) 80 pWOp
at 6 dB overload .... typ. (100) 120 pWOp

1.4.3.2 BB frequency response

from 50 Hz to 12.5 MHz, referred to 1 MHz (at 70 MHz IF) .... ± 0.5 dB
from 50 Hz to 13.6 MHz, referred to 1 MHz (at 140 MHz IF) .... ± 0.5 dB

1.4.3.3 TV transmission

Droop, 50 Hz squarewave modulation .... ≤ 1%

---

1) CCIR conditions:

Use of pre-emphasis and de-emphasis	to CCIR 275
Channel width 140 kHz	to CCIR 404
Conventional load +17.5 dBm0 (70 MHz), +19.3 dBm0 (140 MHz)	to CCIR 399
IF transmission level, +5.2 dBm	to CCIR 403
IF receive level, 0 dBm	to CCIR 403
Test frequencies	to CCIR 399

1.5 O P T I O N S

Unless otherwise stated, options are charged extra and fitted ex-works.

1.5.1 WIDEBAND MODULATOR

Fitted in the RMS-5 generator section, cf 1.4.

1.5.2 35 MHz OR 140 MHz EXTENSION

Fitted in the generator section and the receive section, cf Ordering Information 1.8.

1.5.3 IF CALIBRATION GENERATOR (QUIET TONE)

Fitted in the generator section: 35/70 MHz or 35/70/140 MHz, cf 1.2.1.3.

1.5.4 <IEC 625> INTERFACE BOARD WITH IEEE 488 CONNECTOR

cf 1.1.9
Either the <IEC 625> interface bus or the XY plotter interface can be accommodated in the receive section.

1.5.5 XY PLOTTER INTERFACE

Fitted in the receive section (instead of <IEC 625> interface), cf 1.1.10.2.

1.5.6 COLOUR SUBCARRIER FREQUENCIES

Fitted in the generator section and the receive section, cf 1.8.
Either or both test frequencies can be replaced by ... 3.580 (M/NTSC)[1], 3.579545 MHz (M/NTSC)[1]
4.430 (B, G, H, I/PAL)[1] or 4.433619 MHz (B, G, H, I/PAL)[1]

1.5.7 NOISE CALCULATION

Fitted in the receive section (back panel)
Alternative to the "INTELSAT tolerance mask" option
cf 1.1.8.5

1.5.8 INTELSAT TOLERANCE MASKS

Fitted in the receive section (back panel)
Alternative to the "noise measurement" option
cf 1.1.8.6

---

1) The letter before "NTSC" and "PAL" designates the system type. The system designation for each country is given in Annex 1, CCIR Report 624 (Geneva 1974).

1.6 A C C E S S O R I E S

charged extra

1.6.1 RFZ-4 RETURN LOSS COEFFICIENT MEASUREMENT BRIDGE

cf 1.1.2.7

Frequency range .... 10 MHz to 200 MHz
Characteristic impedance .... 75 Ω
Insertion loss .... 6.5 dB nominal
Max. measurement error .... $0.003 \pm 0.12\ r^2$
Connectors .... Versacon® 9 with BNC insert

1.6.2 RFZ-14 RETURN LOSS COEFFICIENT MEASUREMENT BRIDGE

Frequency range .... 100 kHz to 100 MHz
Characteristic impedance .... 75 Ω
Insertion loss, open Z_x connector .... max. 8 dB
Max. error .... $0.015 \pm 0.13 \times r^2$
Connectors .... Versacon® 9 with BNC insert

1.6.3 RFZ-12 RETURN LOSS MEASURING ATTACHMENT

Frequency range .... 200 Hz to 4.5 MHz
Operating mode .... balanced and unbalanced
Standard impedances
switchable .... 75, 124, 135, 150, 600 Ω
Return loss (unbalanced) .... $\geq$ 46 dB
Max. measurement error (unbalanced) .... $\pm 0.003 \pm 0.2\ r$
Connectors
for item-under-test .... 3-pole CF connector
for generator and receiver .... Versacon® 9 with BNC insert

1.6.4 RMSF-5 FREQUENCY SPLITTER

Frequency range for sweep voltage $\hat{U}_A$ .... 18 Hz to 100 Hz
Frequency range for test voltage U_M .... 25 kHz to 12.4 MHz
Characteristic impedance .... 75 Ω
Return loss in the frequency ranges for $\hat{U}_A$ and U_M .... $\geq$ 30 dB
Connectors .... Versacon® 9 with BNC insert
Intrinsic distortion (peak to peak) .... $\leq$ 10% of the smallest range

	Frequency range	Insertion loss
Low-pass branch ($\hat{U}_A + U_M$ input to $\hat{U}_A$ output)	$\leq$ 100 Hz 25 kHz to 12.4 MHz	$\leq$ 0.3 dB $\geq$ 46 dB
High-pass branch ($\hat{U}_A + U_M$ input to U_M output)	< 100 Hz 25 kHz to 12.4 MHz	$\geq$ 46 dB $\leq$ 0.25 dB

1.6.5 PRE- AND DE-EMPHASIS NETWORKS

Nominal value of input and output impedances .... 75 Ω

Max. input level .... +10 dBm

Networks for television transmissions via FM radio-links (CCIR 405-1)

TV system No. of lines	f_c kHz	f_n kHz	a_{EP} at f_n dB	a_{ED} at f_n dB	Order numbers Pre-emphasis	De-emphasis
405[1)]	3000	853	2	12	BN 445/01	BN 446/01
525	4000	761.6	3.4	10	BN 445/02	BN 446/02
625	5000	1512	3	11	BN 445/03	BN 446/03
819	10000	1402	7	7	BN 445/04	BN 446/04

f_c : Highest videoband transmission frequency
f_n : Neutral frequency
a_{EP} : Insertion loss of the pre-emphasis network at the neutral frequency f_n
a_{ED} : Insertion loss of the de-emphasis network at the neutral frequency f_n

Error limits of the insertion loss as a function of frequency .... $\pm$ (0.1 + 0.05 f/f_c) dB

Networks for telephone transmissions via FM radio-links (CCIR 275-3)

No. of channels	f_{max} kHz	f_n kHz	Order numbers Pre-emphasis	De-emphasis
24	108	66.2	BN 445/05	BN 446/05
60	300	184.0	BN 445/06	BN 446/06
120	552	338.5	BN 445/07	BN 446/07
300	1300	797.1	BN 445/08	BN 446/08
600	2660	1631	BN 445/09	BN 446/09
960	4188	2568	BN 445/10	BN 446/10
1260	5636	3456	BN 445/11	BN 446/11
1800	8204	5031	BN 445/12	BN 446/12
2400	11067	6787	BN 445/32	BN 446/32
2700	12388	7596	BN 445/13	BN 446/13

1) to CCIR Rec. 405, Oslo 1966

Networks for telephone transmission via FM satellite links (CCIR 464-1)

Number of channels	f_{max} kHz	f_n kHz	Order numbers Pre-emphasis	De-emphasis
12	60	36.8	BN 445/15	BN 446/15
24	108	66.2	BN 445/05	BN 446/05
36	156	95.7	BN 445/16	BN 446/16
48	204	125.1	BN 445/17	BN 446/17
60	252	154.5	BN 445/18	BN 446/18
72	300	184.0	BN 445/19	BN 446/19
96	408	250.2	BN 445/20	BN 446/20
132	552	338.5	BN 445/21	BN 446/21
192	804	493.0	BN 445/22	BN 446/22
252	1052	645.1	BN 445/23	BN 446/23
312	1300	797.2	BN 445/24	BN 446/24
372	1548	949.2	BN 445/33	BN 446/33
432	1796	1101	BN 445/25	BN 446/25
492	2044	1253	BN 445/34	BN 446/34
552	2292	1405	BN 445/35	BN 446/35
612	2540	1558	BN 445/26	BN 446/26
792	3284	2014	BN 445/27	BN 446/27
972	4028	2470	BN 445/28	BN 446/28
1092	4892	3000	BN 445/29	BN 446/29
1332	5884	3608	BN 445/30	BN 446/30
1872	8120	4979	BN 445/31	BN 446/31

f_{max} : The upper frequency of the transmission band for telephone channels.

f_n : 0.6132 x f_{max}; neutral frequency, i.e. the frequency at which the frequency deviation of the system is the same whether or not a pre-emphasis network is fitted. The insertion loss, a_{EP}, is compensated for at f_n.

Insertion loss at neutral frequency f_n:

Pre-emphasis a_{EP} = 5.0 dB ± 0.13 dB

De-emphasis a_{ED} = 3.98 dB ± 0.13 dB

Error limits of insertion loss as a function of frequency .... ± (0.1 + 0.05 f/f_{max}) dB

1.7 GENERAL SPECIFICATIONS

1.7.1 ENVIRONMENTAL CONDITIONS

Ambient temperature

Nominal range of use (= limits range of use)

Altitude of operation — without cooling fan

up to 1000 m above sea-level .... 0 to +40°C
up to 3000 m above sea-level .... 0 to +30°C

with cooling fan

up to 1000 m above sea level .... 0 to +50°C
up to 3000 m above sea level .... 0 to +40°C

Storage and transit .... -40 to +70°C

Warm-up time .... ≤ 30 min

1.7.2 POWER SUPPLY

Mains voltage range .... 96.5 to 261 V
Mains frequency range .... 47.5 to 63 Hz
Safety class to IEC 348 and VDE 0411 .... class I
EMI/RFI suppression to regulation 1046/1984 of the Federal German Postal Authority (DBP).

Power consumption
RMS-5, generator .... approx. 80 VA
RME-5, receiver .... 90 VA[1)]
RMED-5, wideband demodulator .... approx. 20 VA

1.7.3 DIMENSIONS in mm

RMS-5 generator

Bench model
Width with handles 477
Overall height 155
Depth with handles 434

1) Series D ... F: approx. 60 W, I_{rms} at 220 V: approx. 1.3 A (switching mode power supply)

19" rack mounting (DIN 41 494)

Width 443
Height (3 U) 131
Depth 379

19" conversion kit .... BN 700/00.03

RME-5 receiver

Bench model

Width with handles 477
Total height 288
Depth with handles 434

19" rack mounting

Width 443
Height (6 U) 264
Depth 379

19" conversion kit .... BN 700/00.06

RMED-5 wideband demodulator

Bench model

Width with handles 477
Total height 110
Depth with handles 434

19" rack mounting

Width 443
Height (2 U) 86
Depth 379

19" conversion kit .... BN 700/00.02

1.7.4 WEIGHT

RMS-5 generator .... approx. 13 kg

RME-5 receiver .... approx. 19.5 kg
  with cooling fan .... approx. 20.5 kg

RMED-5 wideband demodulator .... approx. 8 kg

1.8 ORDERING INFORMATION

RM-5[1], 70 MHz version, sweep frequencies 18 Hz and 70 Hz

Comprising the RMS-5* generator section — BN 916/..

RME-5* receive section — BN 917/..

Test frequencies						Order numbers
Series I: 27.778 kHz 55.556 kHz 92.593 kHz 277.778 kHz and 555.556 kHz	Series II: 25 kHz 50 kHz 83.3 kHz 250 kHz and 500 kHz	2.4 MHz	3.580 MHz or 3.579545 MHz	4.430 MHz or 4.433619 MHz	5.6 MHz	
A		A	B	B	A	BN 916/11[2] BN 917/11
	A	A	B	B	A	BN 916/12 BN 917/12

A Standard

B Colour sub-carrier, instead of 2.4 or 5.6 MHz test frequencies; see options

Wideband modulator/demodulator for the RM-5

Wideband modulator (option, fitted in RMS-5) — BN 916/00.31

Wideband demodulator RMED-5 — BN 2018/01

Permanently fitted options:

Unless otherwise stated, the option is fitted before the instrument leaves the factory. An extra charge will be made.

	For the RMS-5	For the RME-5
35 MHz extension	BN 916/00.03	BN 917/00.03
140 MHz extension	BN 916/00.30	BN 917/00.30
IF calibration generator		
35/70 MHz*	BN 916/00.02	---
35/70/140 MHz*	BN 916/00.20	---
<IEC 625> interface board[3] with IEEE 488 connector	BN 958/21	BN 853/21
XY plotter interface[3]	---	BN 917/00.01

---

* Fitted with the 75 Ω version of Versacon®9; BNC insert provided. If you require a connector other than a BNC connector, please specify when you order the instrument. See 5.2.

1) 35 MHz and/or 140 MHz extension: see options

2) Has the 55.556 kHz, 92.539 kHz and 277.778 kHz test frequencies recommended by INTELSAT.

3) Either the <IEC 625> interface or the XY plotter interface can be used.

	For the RMS-5	For the RME-5
Colour sub-carriers		
M/NTSC 3.580 MHz[1)]	BN 916/00.06	BN 917/00.06
M/NTSC 3.579545 MHz[1)]	BN 916/00.04	BN 917/00.04
B, G, H, I/PAL 4.430 MHz[2)]	BN 916/00.07	BN 917/00.07
B, G, H, I/PAL 4.433619 MHz[2)]	BN 916/00.05	BN 917/00.05
Noise calculation[3)]	---	BN 917/00.11
INTELSAT tolerance masks[3)]	---	BN 917/00.12

<u>Accessories (at extra cost)</u>

Ventilator for the RME-5	BN 917/00.10
Return loss measurement bridges[4)]	
RFZ-4* (IF test bridge, 100 to 200 MHz)	BN 697/00.04
RFZ-14* (BB/IF test bridge, 100 kHz to 100 MHz)	BN 830/00.01
RFZ-12* (BB test bridge, 200 Hz to 4.5 MHz)	BN 810/01
Frequency splitter $\hat{U}_A$, U_M; RMSF-5	BN 916/00.10
Pre-emphasis and de-emphasis networks*	see 1.6.5
IEEE 488/IEC 625 adaptor (m-m) for the <IEC 625> interface board	S 832
Plotter forms, 50 sheets, English/German	BN 917/00.79
Transportation cases	
TPK-3 for the RMS-5 generator	BN 626/09
TPK-6 for the RME-5 receiver	BN 626/12
Protective transportation covers (1 set, for the front and back of the instrument)	
SD-3 for the RMS-5 generator	BN 700/00.23
SD-6 for the RME-5[5)] receiver	BN 700/00.26
SD-2 for the RMED-5 wideband demodulator	BN 700/00.22
19" rack frame conversion kit	
for the RMS-5 generator	BN 700/00.03
for the RME-5 receiver	BN 700/00.06
for the RMED-5 wideband demodulator	BN 700/00.02

---

* Fitted with the 75 Ω version of Versacon® 9; BNC insert provided. If you require a connector other than a BNC connector, please specify when you order the instrument. See 5.2.

1) 3.580 or 3.579545 MHz are available instead of the 2.4 or 5.6 MHz test frequencies

2) 4.430 or 4.433619 MHz are available instead of the 2.4 or 5.6 MHz test frequencies

3) Either the noise calculation facility <u>or</u> the INTELSAT tolerance masks are available

4) See measuring accessory spec. sheet for more technical information and ordering information

5) The back cover for the RME-5 cannot be used when the ventilator is fitted

2 TECHNICAL DESCRIPTION

This chapter explains, using simplified block diagrams, how the RM-5 works, so making it easier to understand the test procedures used. First of all the technique used to measure distortion will be explained. We will then procede to a description of the generator and receiver hardware.

2.1 DISTORTION MEASUREMENTS

Figure 2-1 shows how intermodulation is used to determine amplitude and phase distortion on an IF-(RF-)-IF transmission path.

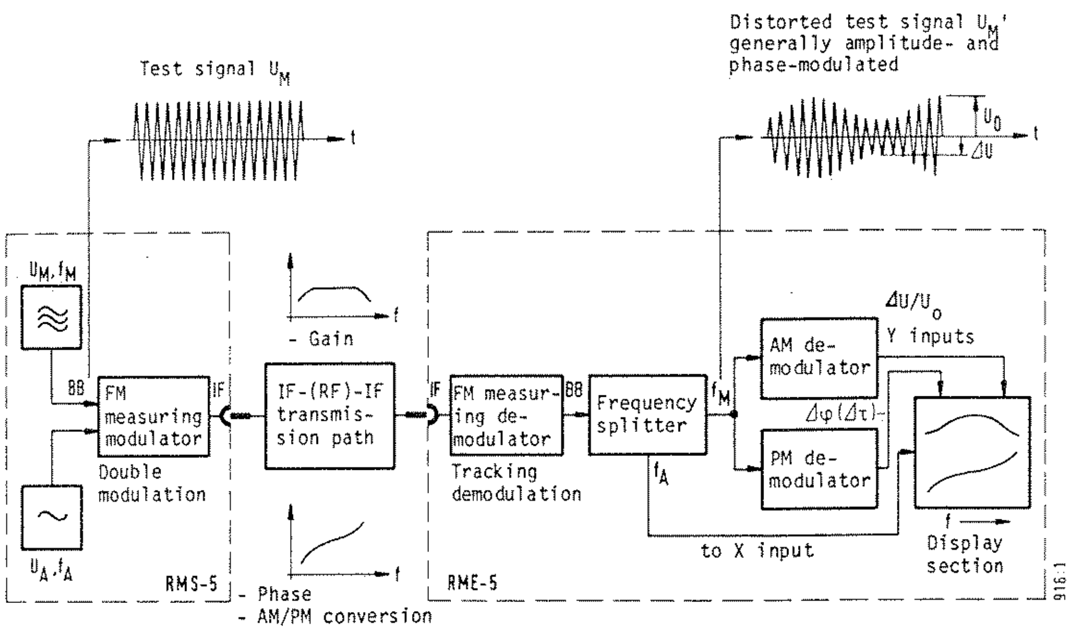


Figure 2-1 Method of determining amplitude distortion $\Delta U/U_0$ and phase distortion $\Delta\varphi$

In the generator section, the low-frequency sweep voltage U_A (f_A = 18 Hz to 70 Hz) and the high frequency test voltage, which simulates a BB signal from an FM radio link, are fed to the test modulator. The amplitude of the sweep voltage is very much greater than the amplitude of the test voltage.

The output of the FM demodulator delivers a carrier, which is frequency-modulated by the test voltage and whose centre frequency F_0 sweeps slowly over the whole bandwidth of the IF-(RF-)-IF link at a rate determined by the frequency f_A (see Figure 2-2a). The modulation index η is - at least at the higher test frequencies - considerably less than 1 due to the low amplitude of the test voltage U_M. The frequency spectrum (Bessel spectrum) at the modulator output then consists only of the carrier U_T and the first sidebands U_{M1}, U_{M2}. This frequency triplet scans the IF-(RF-)-IF bandwidth. A vector diagram of the frequency triplet is shown in Figure 2-2b.

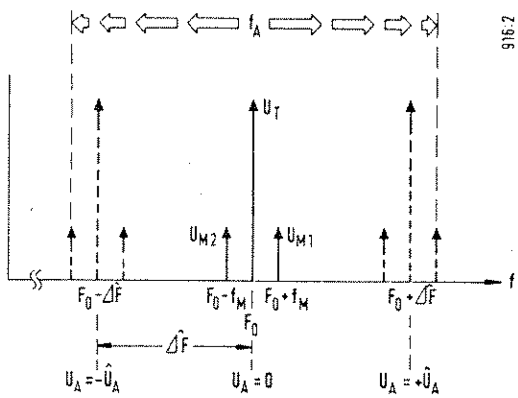


Figure 2-2a Swept frequency triplet of the FM signal

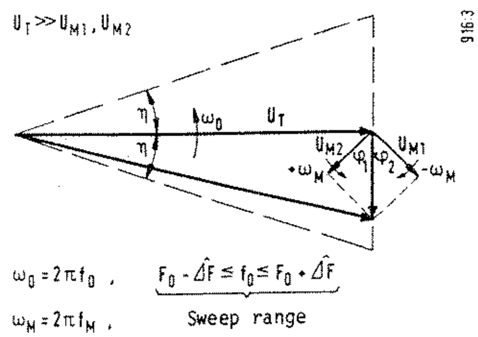


Figure 2-2b Vector diagram of the frequency triplet ($\eta \ll 1$, not shown to scale)

If the attenuation of the IF-IF link depends on frequency, the length of vectors U_T, T_{M1}, U_{M2} is a function of the frequency ω_o. The quantities shown by the vector diagram change periodically with the sweep frequency. It can be shown that, under these circumstances, the test signal U_M (t) is amplitude modulated, even if subsequent limiting is ideal.

The output signal from the FM test demodulator has the sweep signal and the distorted test signal superimposed on it. The sweep signal is connected to the X-input of the video section, while the test signal is connected to the amplitude demodulator, whose output voltage is proportional to the amplitude variation ΔU. ΔU referred to the value U_o is displayed via the Y-input of the video section (see Figure 2-1, test signal U_M' (t)). U_o is the value of U_M at $\Delta\hat{F} = 0$ or $\hat{U}_A = 0$.

If the phase of the signal varies with the frequency, the vectors U_{M1}, U_{M2} no longer rotate at the constant angular velocity ω_M when the phase curve is sampled. As a result of this, a signal phase modulated with the frequency f_A appears at the output of the test demodulator. The distorted test signal is compared in a phase demodulator with a constant phase sinusoidal voltage. The output voltage, which is proportional to the phase difference ($\Delta\varphi$) between the test signal and the reference signal, is fed to the 2nd Y-input and displayed.

The measured parameters $\Delta U/U_o$ and $\Delta\varphi$ are called differential gain and differential phase respectively. They can be displayed simultaneously on the screen over a frequency interval $\pm\,\Delta\hat{F}$, selected by the user ($\Delta\hat{F}$: sweep width).

If a low test frequency ($f_M < 1$ MHz) is selected, the width of the frequency triplet 2 f_M is so narrow that the section of the phase curve from $f_o - f_M$ to $f_o + f_M$ can be regarded as linear. $\Delta\varphi$ is therefore a measure of the slope of the phase curve, and so a measure of the difference in group delay.

Amplitude variations at low frequencies are referred to as non-linear distortion $\Delta U/U_o$.

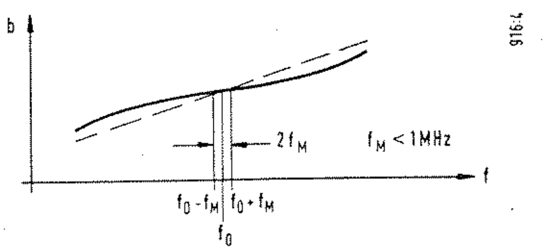


Figure 2-3 Phase curve of the IF-IF link

An advantage of this method is, that in addition to detecting frequency-dependent attenuation and group delays, it also detects interference caused by AM/PM conversion. The cause of the interference can be determined from the shape of the result and its dependency on the test frequency f_M 1) (see also 4.1.2).

2.2 HOW THE RMS-5 GENERATOR SECTION OPERATES

Figure 2-4 is a simplified block diagram of the generator. It shows the microprocessor, and the most important subassemblies for BB and IF signal generation. Double modulation is explained in detail. This method is superior to others because of its very low intrinsic distortion.

2.2.1 BB SIGNAL GENERATION

Test signal (U_M) branch

The RMS-5 generates 7 different frequencies, 5 below 1 MHz and 2 above. The test frequencies are produced by dividing the outputs of a 10 MHz crystal oscillator and two adjustable oscillators. In the U_M control circuit, the squarewave signal is limited, and a variable current to adjust the amplitude is generated. A switchable 20 dB attenuator follows.

The test signal passes through a selective amplifier that suppresses the harmonics of the squarewave signal. From the amplifier the signal is fed into a branching filter. It is then processed further depending on the operating mode (BB, IF). There is a choice of two test-frequency series.

Deflection voltage ($\hat{U}_A$) branch

The deflection or sweep voltage is a very pure sinusoidal signal with a stable amplitude. The signal path branches at the output of the U_A generator; one branch goes to the BB output, the other branch is processed further to produce an internal sweep voltage for the frequency regulator. The signal for sweep widths up to 10 MHz or up to 50 MHz is obtained by means of a divider.

Automatic sweep reduction is carried out by a special program using appropriate D/A converters.

2.2.2 AUTOMATIC SWEEP REDUCTION

When this facility is on, and a high test frequency is selected, the sweep voltage is automatically reduced to a point where the IF sidebands do not leave the selected sampling range. The sweep signal is switched off if the test frequency selected is greater than the sweep width $\hat{\Delta F}$.

2.2.3 IF SIGNAL GENERATION, DOUBLE MODULATION

The test signal and the sweep signal are applied in parallel to the frequency modulator. As shown in Figure 2-4, the IF carrier signal is produced in the RMS-5 by mixing two high frequencies. The following frequencies can be obtained from oscillators I and II:

795 MHz - 760 MHz = 35 MHz (option)
830 MHz - 760 MHz = 70 MHz (standard)
900 MHz - 760 MHz = 140 MHz (option)

This process is called double modulation because both oscillators are modulated (even though the frequencies used are different). The sinusoidal test voltage U_M (25 kHz to 5.6 MHz) produces frequency modulation in oscillator I. Because the test voltage is relatively small, a small frequency deviation Δf is obtained, so that the operating point on the voltage/frequency characteristic is far from the overdrive point. This means that the signal from oscillator I is practically undistorted.

Depending on the IF selected, the low-frequency sweep voltage (18/70 Hz) causes the frequency of oscillator II to vary in the range 830 ± 30 MHz (or 900 ± 50 MHz, 795 ± 12.5 MHz[1)]). When both oscillator signals are mixed, the result is a frequency modulated, swept IF signal that has low non-linear distortion.

In spite of the large drive range, the sweep width $\hat{\Delta F}$ is always proportional to the sweep voltage U_A. In the frequency regulation circuit, a linear frequency discriminator compares the target value with the instantaneous voltage of the sweep signal. A voltage which is proportional to the difference between the nominal value and the actual value is used to correct the frequency of oscillator II.

The IF centre frequency F_0 is automatically calibrated by a comparator circuit. By altering the centre frequency of oscillator II, the centre frequency F_0 can be offset by ± 30 MHz (± 50 MHz or 12.5 MHz)[1)] if a non-standard frequency is entered via the keyboard.

IF output signal

The low-pass filter following the mixer suppresses unwanted mixing products which result from conversion of the two oscillator signals. There are two IF outputs. At one IF output, the level can be adjusted continuously between -50 and +10 dBm, while the second IF output delivers a fixed level of -6 dBm.

IF calibration generator (option)

The IF calibration generator provides a highly accurate 70, 35 or 140 MHz signal at output ZF_0. The signal has a high S/N ratio and a low harmonic content and so is ideal for quiet tone measurements. The output level is +5 dBm.

---

1) 35 MHz or 140 MHz IF options

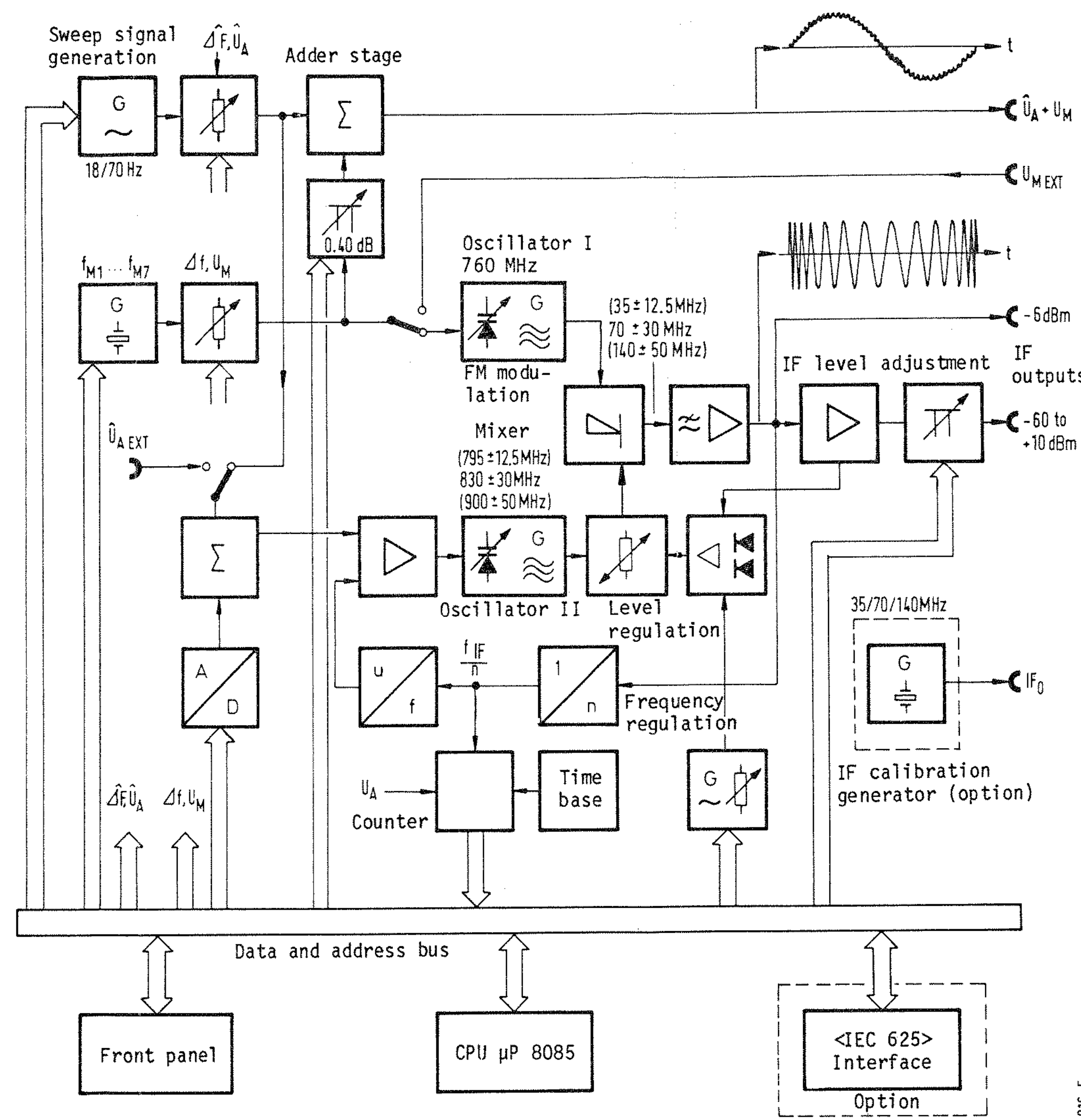


Figure 2-4 Simplified block diagram of the RMS-5 generator section

2.2.4 DIGITAL SECTION

The digital section comprises the CPU board with an 8085 microprocessor, the RAM and ROM areas, the front panel and controls, and the control and regulation board.

The dialog between the user and the instrument is performed via the keypad on the front panel.

The control signals for the input gates and output gates of the keypad are decoded by the front panel board. A request for service entered via the front panel is indicated to the CPU by means of an interrupt. The CPU board communicates with the analog section of the RMS-5 via the control and regulation board. All input and output gates and the D/A converters are on the control and regulation board. The control signals are decoded on the board.

A trigger signal for regulating the centre frequency is derived from $\hat{U}_A$. The trigger signal is then fed to the CPU subassembly.

The standard <IEC 625> bus subassembly is used with the IEC bus interface option. The gate control signals are decoded on the board. An interrupt tells the CPU that a request for service has been made via the IEC interface.

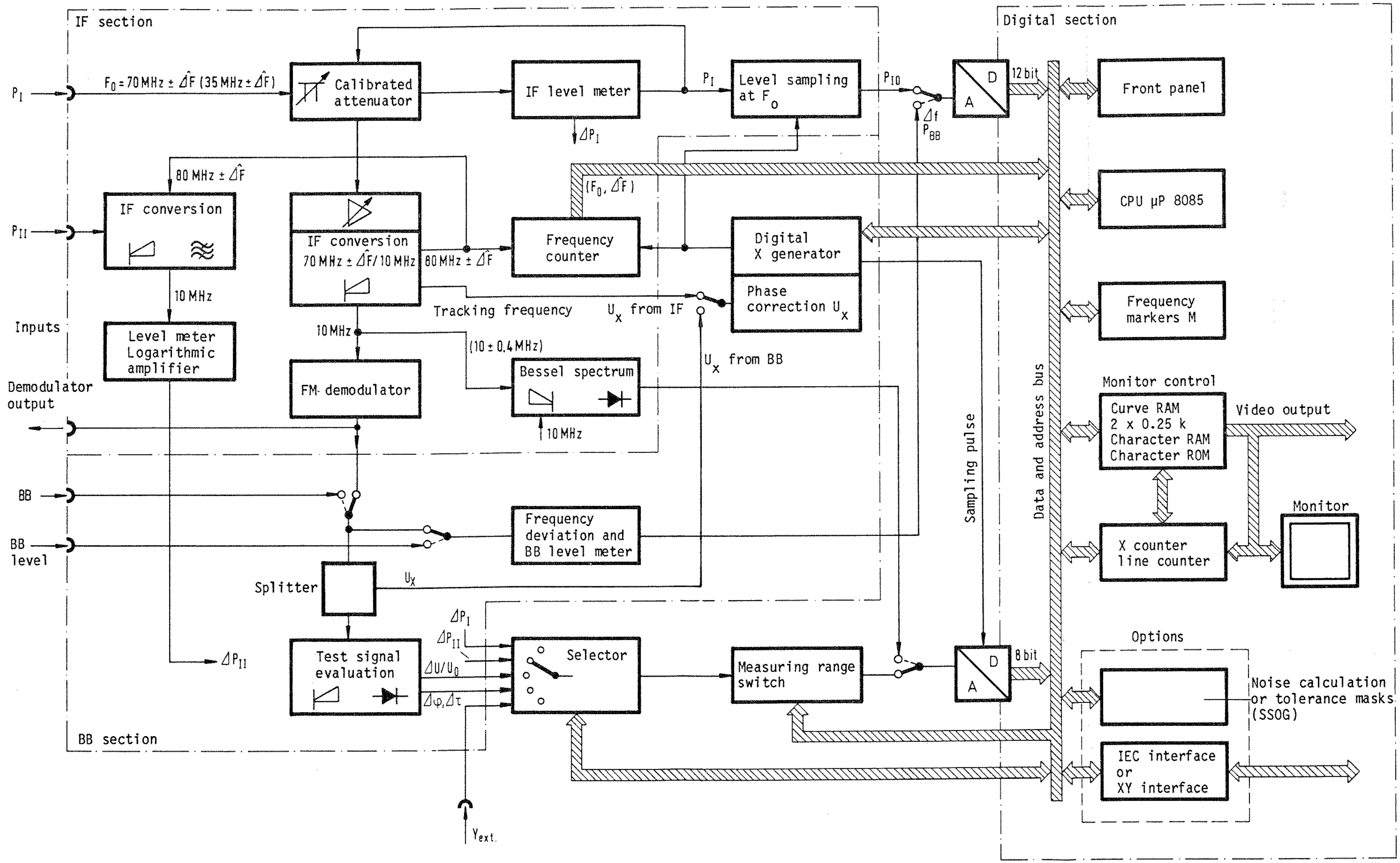


Figure 2-5 Simplified block diagram of the RME-5 receive section

2.3 HOW THE RME-5 RECEIVE SECTION OPERATES

2.3.1 BLOCK DIAGRAM OF THE RME-5

Figure 2-5 shows the block diagram of the receiver and its three main constituent subassemblies:

- IF section,
- BB section with "Digital X-Generator",
- Digital section with microprocessor and screen control.

The function of each subassembly and how they interwork is described in the following sections.

2.3.2 IF SECTION

2.3.2.1 IF level meter

Absolute level P_I (F_o)

The swept IF signal passes via the automatic input attenuator to the IF level meter where the signal is detected.

The IF level, whose magnitude over the sweep range depends on the frequency response of the IF link, is fed to the 12 bit A/D converter in the sampling circuit whenever its frequency is equal to F_o. The digital x-generator controls this process, i.e. selects the correct instant for sampling.

The large range of the 12-bit A/D converter, which converts the static results P_{Io}, Δf, P_{BF}, gives a high level resolution.

IF distortion measurement ΔP_I

The frequency response of the IF link can be displayed in the operating mode ΔP_I.

$\Delta P_I = \Delta P_I\ (f)$, where $F_o - \hat{\Delta F} \leq f \leq f_o + \hat{\Delta F}$ (sweep range).

The signal ΔP_I coming from the IF level meter is connected via the selector to the 8 bit A/D converter which converts the dynamic results.

2.3.2.2 IF distortion measurements (selective) ΔP_{II}

Using input P_{II} on the RME-5, it is possible to measure IF frequency responses that have large variations in attenuation selectivity. $\Delta P_{II} = \Delta P_{II}\ (f)$, (f = sweep range). Return loss measurements can also be made. The main components of the circuit are the mixer at input P_{II}, the logarithmic amplifier and the detector. The carrier signal for the mixer is provided by the tracking oscillator, see Figure 2-6. A swept IF signal with a constant level must be present at input P_I. In most cases, the -6 dBm output of the RMS-5 can be connected to receiver input P_I. Alternatively, a decoupled IF-system test port can be used.

2.3.2.3 Tracking demodulation

The test demodulator in the RME-5 operates on the "tracking principle" (Figure 2-6), which guarantees low distortion demodulation of the frequency-modulated IF signal. With the aid of a frequency control circuit (which is described later), the IF carrier frequency at the FM demodulator input is kept constant. In this manner, the demodulation characteristic is used only around the centre frequency, which means that "frequency demodulation" is carried out in a strictly linear range.

The principle of operation of the frequency control circuit is as follows: First (as shown in figure 2-6), the swept and frequency-modulated input signal - whose centre frequency can be 70 MHz or 35 MHz - is converted in the mixer to a constant difference frequency
$f_D = f_F - f_o = 10$ MHz.

For this purpose, the mixer receives a signal with the frequency f_F from the tracking oscillator. For a 70 MHz input signal, f_F = 80 MHz, and this frequency can vary by up to ± 30 MHz (depending on the sweep width $\hat{\Delta F}$ of the input signal). For the 35 MHz IF, f_F = 45 ± 10 MHz (150 ± 50 MHz).

The ± $\hat{\Delta F}$ frequency variation in the tracking oscillator is provided by a control circuit. For this purpose, the difference frequency f_D = 10 MHz is connected via the frequency divider to the frequency discriminator and the actual value of the output voltage is compared with the constant setpoint. This results in a low frequency, sinusoidal control voltage, which corresponds to the sweep voltage and which modifies the tracking frequency f_F such that the difference frequency remains constant at f_D = 10 MHz. The low frequency control voltage also supplies the deflection voltage U_x for the display section.

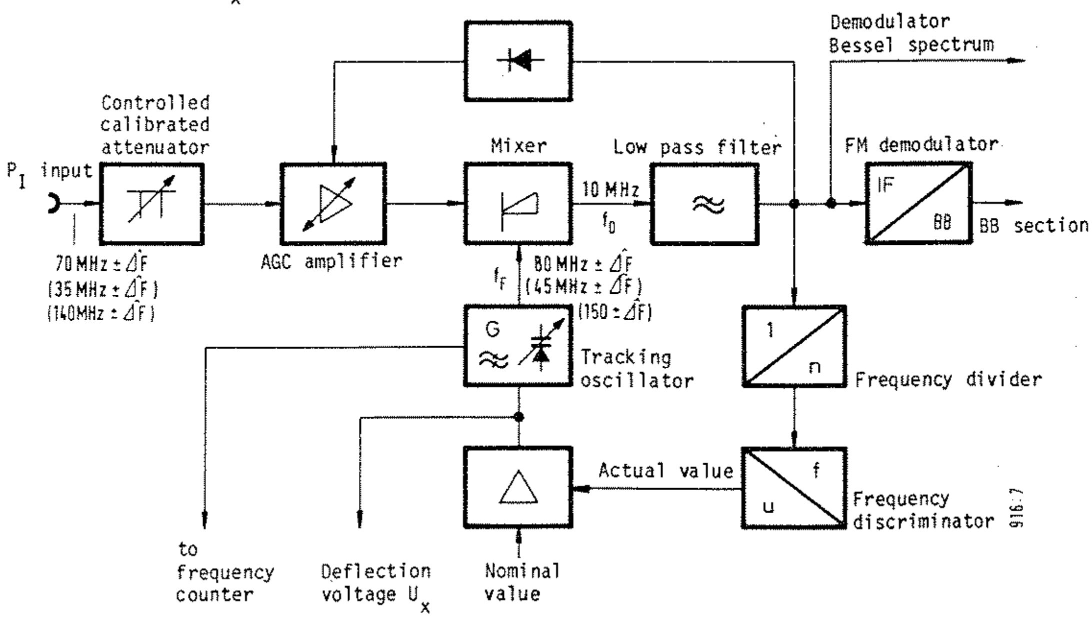


Figure 2-6 Tracking demodulation, RME-5

2.3.2.4 Bessel spectrum

To display the FM spectrum, the tracking oscillator (see figure 2-6) is swept so that the 10 MHz intermediate frequency, and thus the converted FM spectrum, varies by ± 0.4 MHz. This intermediate frequency is connected to the mixer of the evaluation circuit, which simultaneously receives a constant 10 MHz signal as the carrier frequency. In this operating mode, the RME-5 acts as a spectrum analyser.

2.3.2.5 Frequency counter $F_o, \hat{\Delta F}$

The frequency counter first determines the sweep limits of the tracking frequency (80 MHz $\pm \hat{\Delta F}$) from the signal of the tracking oscillator. At the instant where the sweep voltage reaches its extreme values ($-U_A$ and $+U_A$), the frequency counter receives an interrogation pulse from the X-generator via the gate control. The two counter values are evaluated in the digital section, i.e. the parameter F_o is calculated from $F_o \pm \hat{\Delta F}$.

2.3.3 BB SECTION

2.3.3.1 Test signal evaluation

The frequency-demodulated signal which is present at the BB input (see figure 2-7) consists of the sweep voltage and the superimposed test voltage, which is generally amplitude- and phase-modulated.

The test frequency detection circuit automatically determines the test frequency being used. Selection of the correct test frequency is carried out with the aid of band-pass filters.

Non-linear distortion or differential gain

Before the actual measurement, the test signal is kept constant by an AGC circuit. The amplitude modulation is not suppressed, as the AGC process is very slow. The resulting constant voltage U_o (U_M at $U_A = 0$) acts as a reference parameter. The variation ΔU of the envelope is a measure of non-linear distortion or differential gain.

Group delay or differential phase

Group delay distortion ΔT and the differential phase $\Delta\varphi$ are determined by the phase demodulator. As a phase measurement has to be performed to determine group delay distortion, only the phase shift that arises when the signal is swept need be measured.

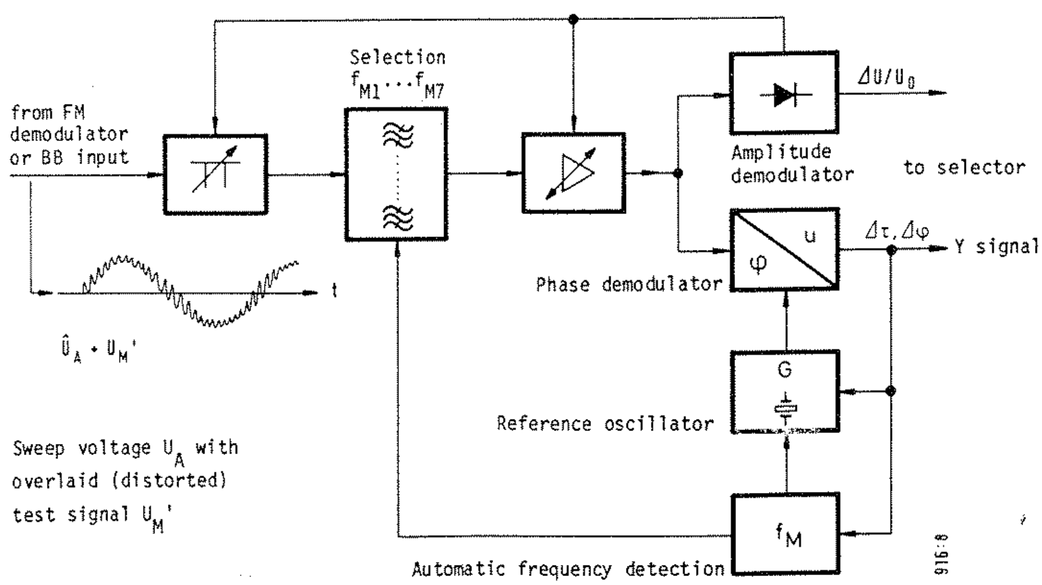


Figure 2-7 Deriving the distortions $U/U_o, \Delta T, \Delta\varphi$ from the BB signal $U_A + U_M'$; simplified block diagram

The phase is measured by comparing the signal with a reference signal whose phase is constant. The reference signal is supplied by a crystal-controlled oscillator.

The output voltage of the phase meter is proportional to the phase change which has the same timing as the sweep.

2.3.3.2 Test frequency deviation meter and BB level meter

The rms value of the test frequency deviation Δf is determined in the deviation measurement detector by the level of the demodulated IF signal, i.e. by U_M. The 12 bit A/D converter determines the level of the test signal very precisely, and displays this level. Alternatively, the sensitivity of the FM demodulator is used to derive the test frequency deviation.

2.3.4 DIGITAL SECTION

The microprocessor circuit consists of the central processing unit (CPU) - a microprocessor type 8085 - the monitor control with the memories for the two sweep curves and alphanumeric characters, the frequency marker generation circuit, and the input and output ports.

The controls on the front panel are connected to the microprocessor via control lines. The microprocessor accepts commands from the keyboard and sends them to the appropriate subassemblies. The microprocessor stores the distortion measurement results and displays them on the monitor.

As well as performing control functions, the microprocessor also calculates parameters such as the sweep limits, or processes the distortion curves (e.g. curve difference).

The <IEC 625> bus board option can perform all keyboard functions, which means that the RME-5 and the RMS-5 can be integrated into modern computer controlled test systems.

2.3.5 SWEEP CURVE DIGITISATION

The resolution of the analog results, i.e. ΔT, $\Delta\varphi$, $\Delta U/U_0$, ΔP_I, ΔP_{II}, Y_{EXT} (y direction), and the deflection voltage U_x are determined by the 8-bit A/D converter. An 8-bit converter has 256 (2^8) discrete output levels, but only 205 are shown on the screen. The space that would have been occupied by these levels, is used for various kinds of alphanumeric displays above or below the graphic display.

During half a sweep-period ($F_0 - \hat{\Delta F}$ to $F_0 + \hat{\Delta F}$), the "digital x-generator" converts the sweep voltage U_x into 256 voltage values to digitise the frequency axis. Each discrete frequency value is assigned an x address (0 to 255). The digital sweep is performed by cyclically calling up each address in the range 0 to 255 with the x counter in the monitor control circuit.

The y-signal is digitised by driving the x generator with the microprocessor. When the x addresses are the same, A/D conversion is initiated by the microprocessor. The correct assignment of the frequency values x_n (n = 0, 1, ..., 255) to the y_m values (m = 0, 1, 2, ..., 255) on the sweep curve is thus obtained.

256 pixels are required to draw a sweep curve - 256 memory locations, each of 8 bits, form the whole curve.

Using this form of curve storage, one can easily access x-values (e.g. frequency markers) or y-values (horizontal cursors). It is also possible to store whole curves for internal processing, e.g. noise averaging or curve difference modes. External evaluation via the <IEC 625> bus is also possible.

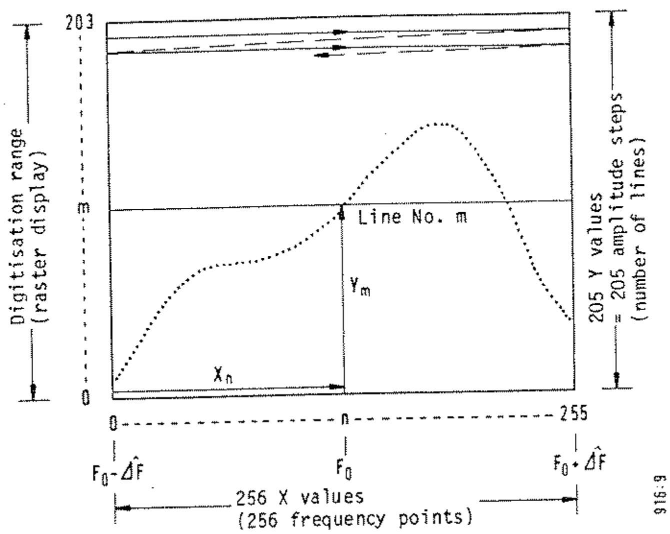


Figure 2-8 Displaying distortion curves on the integral screen (graticule, no text lines)

2.4 <IEC 625> I N T E R F A C E B U S

The <IEC 625> interface bus is used to operate microprocessor controlled devices.

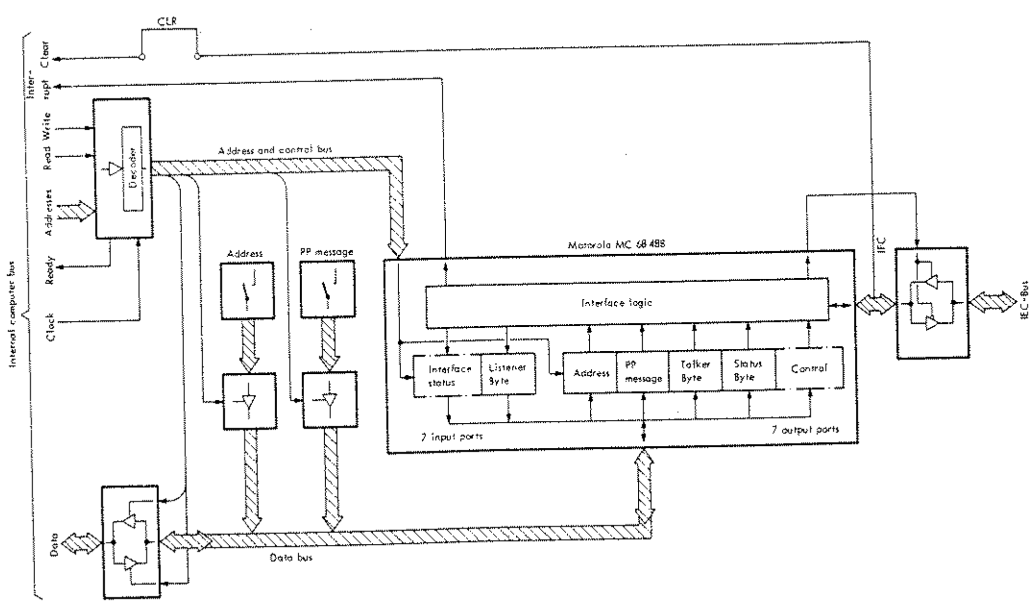


Figure 2-9 Block diagram of the <IEC 625> interface bus option

Figure 2-9 shows the simplified block diagram of the <IEC 625> Interface Bus board.

The interface to the IEC bus with the necessary driver and receiver circuits is shown on the right-hand side of the figure.

The comb connector to the input/output bus of the internal microprocessor is shown on the other side of the figure.

For the microprocessor, the IEC Bus Interface is nothing more than a collection of input ports and output ports. The exchange of data between the IEC Bus and the instrument is executed via these ports.

The exchange of data between the IEC Bus and the instrument is controlled by the IEC Bus program. The PROMs in which this program is stored are not located on the IEC Bus interface board, but within the instrument.

The actual interface logic is located in one IC, the IEC bus interface module MC 68 488 made by Motorola. This interface logic handles the major part of the interface tasks independently, i.e. without use of the internal microprocessor; for example, it automatically handles the IEC Bus handshake cycle and decodes all messages which are transferred on the IEC Bus. The interface states assumed as the result of these messages are written into the corresponding input ports. A further input port is used as a transfer register for listener bytes. Listener bytes are data which are transferred from the IEC Bus to the instrument as long as the instrument is addressed as the listener; for example, when setting parameters for the instruments are being transferred.

In addition to the input ports, the module contains output ports which are used for:

- Reception of control commands with which the microprocessor can modify the behavior of the interface logic (for example, as one of many possibilities, it can stop the handshake cycle or transmit a service request SRQ via the IEC Bus).
- As transfer registers for bytes which must be transferred from the instrument to the IEC Bus, for example talker bytes and status byte.

Talker bytes are data which are transmitted from the instrument to the IEC bus as long as the instrument is operating as the talker, for example when it is transmitting results of measurement.

The status byte is the response of the instrument to a serial poll and contains the current instrument status.

The instrument address can be set on the address switch.

With the aid of the "PP switch", it is possible to determine the data line of the IEC bus on which the device is to send its status bit SRQ if the controller executes a status interrogation by means of parallel poll.

Important Safety Instructions

A.C. power line voltage

The operating voltage of the instrument should be the same as the a.c. line voltage, so check whether or not the two voltages are equal.

Safety Class

This instrument is categorized as Safety Class I according to VDE 0411 or IEC Publ. 348. The power cord delivered with the equipment has a protective ground conductor. The a.c. power plug must be plugged into an a.c. power receptacle that has a third wire to ground, except in rooms that are particularly certified otherwise. Any disconnection of the protective ground conductor either inside or outside of the instrument is not permitted.

Connection to measuring circuits presenting hazards to personnel

Before the connection is made to a hazardous circuit, a protective ground connection, for protection against the measurement circuit, ought to be connected to the enclosure. In case the protective ground conductor of the a.c. power line can also assume this protective function, the a.c. power connection should be established first of all. If the measuring circuit has an inherent protective ground conductor, then this conductor must be connected to the enclosure before a connection is made to the measuring circuit.

Defects and Exceptional Conditions

When it can be assumed that safe operation is no longer possible, the equipment should be taken out of service and inadvertent operation should be prevented.
This occurs when
- the equipment shows external signs of damage
- the equipment no longer operates
- after being overstressed in any way (e.g. storage, transport) so that the tolerable limits are exceeded.

Fuses

Only specified fuses are permitted for use.

Opening the Instrument

After the covers have been removed or when components are removed with tools, certain components that operate with applied voltage could be exposed. And also connection points might be carrying a voltage.
Therefore, before the instrument is opened for inspection, all voltage sources should be disconnected.
But sometimes calibration, maintenance or repairs require that the instrument be open and operating with applied voltage. So only experienced craftspersons who understand the dangers associated with working on instruments that have exposed voltage points should undertake the job.
Capacitors can retain a voltage charge even after the instrument has been disconnected from voltage sources. Thus, the circuit diagrams should be observed.

Repairs, Replacement of Components

Repairs must be done according to correct technical practice. With that, particular attention must be paid to the characteristics of construction. None of the safety precautions should be changed, especially for leakage paths and air gaps, and separation by insulation must not be reduced.
Only original replacement parts ought to be used. Other replacement parts are only permitted if the safety and protection against human injury are not degraded through the use of non-original components.

Safety Testing after Repair and Maintenance

Testing of the protective ground conductor in the power cord for the instrument:

The resistance of the protective ground conductor shall be measured. It should be $<0.5\,\Omega$. The power cord should be bent and kinked during the measurement so as to reveal any intermittent connection. This gives evidence of a defective power cord.

Testing the insulation of the a.c. power circuit:

The insulation resistance is measured at 500 V between the a.c. power connection and the protective ground conductor connection. For this measurement, the instrument's power switch should be ON.
The insulation resistance ought to be $>2\,M\Omega$.

3 COMMISSIONING AND OPERATION

3.1 PREPARATION FOR USE

3.1.1 UNPACKING THE INSTRUMENTS

The generator section and the receive section are shipped in special packaging.

The instruments should be removed carefully from the packing which should be kept, should it be necessary to ship the instruments at a later date. If the packing material has been thrown away, see 3.1.1.1.

3.1.1.1 Notes on shipping

The RMS-5 and the RME-5 should only be shipped in appropriate packing materials. If the original materials have been lost the instruments should be packed as shown in Figure 3-1.

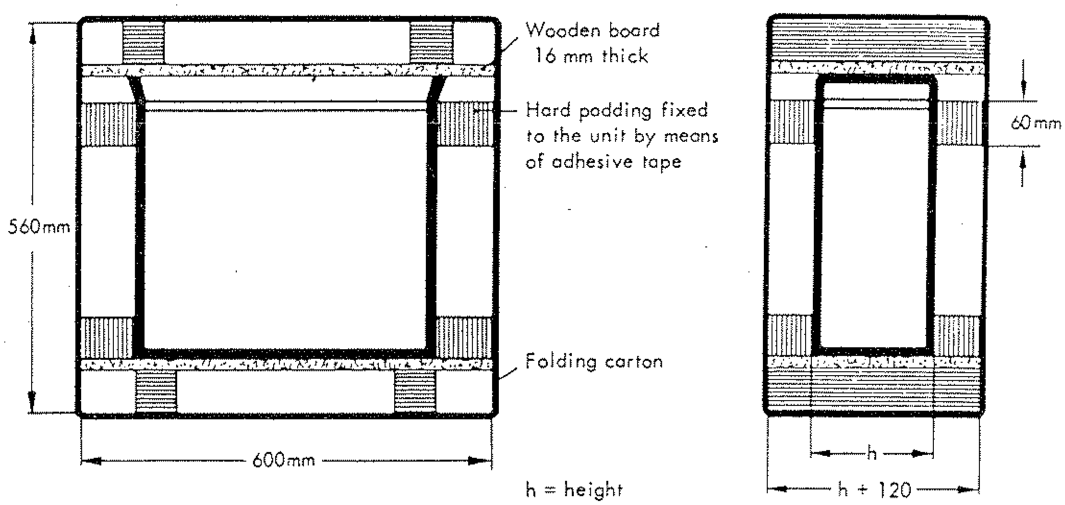


Figure 3-1 Packing the instruments

3.1.2 SETTING UP THE INSTRUMENTS

3.1.2.1 Use as a bench-top instrument

The RMS-5 and RME-5 bench-top models can be used in a horizontal position or tilted on a fold-out support. If the RMS-5 and the RME-5 are to be stacked, the RMS-5 must be the instrument at the bottom of the stack.

The specifications in chapter 1 for the RM-5 are only valid for the nominal ranges of use defined in that section.

If the RM-5 is to be used in locations where the ambient temperature is very high, a ventilator fan can be fitted to the back of the RME-5. The fan is easy to fit and take off if you want to ship the RM-5 (TPK-3 and TPK-6 Transportation Cases, see 5.6).

The nominal operating temperatures are:

	RME-5 without fan	RME-5 with fan
up to 1000 m above sea level:	0 to +40°C	0 to +50°C
up to 3000 m above sea level:	0 to +30°C	0 to +40°C

3.1.2.2 Use in 19" racks

The RMS-5's and the RME-5's case dimensions comply with DIN 41 494 and the American standard ASA C 83.9 "Racks and front panels".

The instrument can therefore be installed in a 19" rack if the front panel is widened by means of two mounting brackets (see figure 3-2).

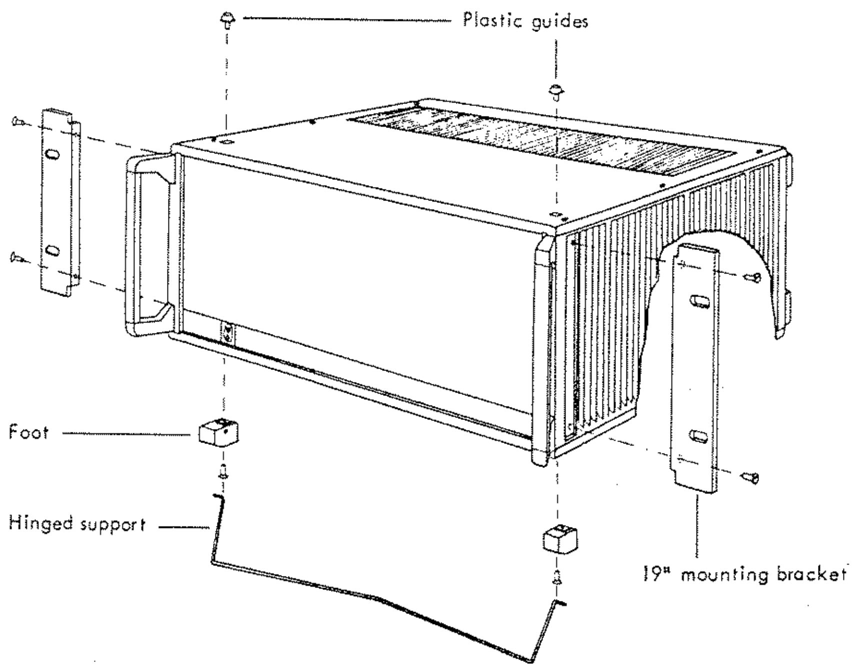


Figure 3-2 Converting the bench model for rack installation

The order numbers for the complete conversion kit (including screws) are given below:

BN 700/00.03 (RMS-5 Generator Section)
BN 700/00.06 (RME-5 Receive Section)

The feet on the bottom of the instruments and the locating studs on the tops of the instruments must be removed before installation (cf. figure 3-2).

Caution: If you want to install the instruments in cabinets, make sure that the nominal range of use for ambient temperature is not exceeded (see 3.1.2.1). Generally, a gap of 1 U (44.4 mm) must be left between the instruments. It may be necessary to fit fans to dissipate the heat generated in the cabinet. Filters should be used to stop dust collecting.

3.2 MAINS CONNECTION

3.2.1 POWER SUPPLY

Each instrument can be operated from a mains supply having a frequency between 47 and 63 Hz.

N.B.
Before connecting the instruments, check that the mains voltage selector is set to the correct value and that the correct fuses have been fitted.

Instrument	Mains voltage	Fuse
RMS-5 Generator Section	220, 227, 235 V 110, 117, 127 V	T 0.63 B (0.63 A slow-blow) T 1.25 B (1.25 A slow-blow)
RME-5 Receive Section (series D to F)	96 to 261 V	T 3.15 B (3.15 A slow-blow)
RME-5 Receive Section (from series G)	220 V (193 to 261 V) 110 V (96 to 140 V)	T 0.8 B (0.8 A slow-blow) T 1.6 B (1.6 A slow-blow)
RMED-5 Wideband Demodulator	220, 227, 235 V 110, 117, 127 V	T 0.25 B (0.25 A slow-blow) T 0.5 B (0.5 A slow-blow)

When the instruments are delivered they are set to 220 V, unless another setting was specified when the set was ordered. The mains voltage selector at the back of the instrument can be set to 110, 117, 127, 227 or 235 V. (All RME-5s to series F are powered by a switching mode supply, and so it is not necessary to set the mains voltage; the RME-5 can be operated from any ac supply with a voltage between 96 and 261 V).

The protective conductor of the mains connector of both the RMS-5 and the RME-5 is connected to the instrument case so that the latter is at earth potential when the instruments are connected to the mains. Both instruments are therefore safety class I instruments as defined in VDE 0411 or IEC 348.

3.2.2 REPLACING FUSES

Figures 3-3b and 3-4b show where the fuses are.

Remove the fuse-cap to replace the fuse. The table in 3.2.1 indicates what type of fuse must be used.

Spare fuses are in the compartments at the back of the instruments.

3.3 SWITCHING ON THE INSTRUMENTS

After the mains switch has been pressed (on position indicated by red panel), the RM-5 carries out a short test routine and is then ready for operation. The RM-5 reaches full accuracy after a warm-up period of about 30 mins.

To check the functions of the RM-5, connect the RMS-5 and the RME-5 back-to-back, and use the test in 5.1.2.

3.3.1 WHAT HAPPENS WHEN THE RMS-5 IS SWITCHED ON

When the RMS-5 is switched on it performs a self-test. The setting that was valid the last time the instrument was switched off is recalled from memory.

- Front panel test (approx. 2 s)
  All indicators are activated. The 7 segment digits in the four display fields are all set to "8".
- CPU board self-test
  If there is a fault, a 4-digit error message appears in display field B (see figure 3-3a).
  The codes have the following meanings:
  ROM error: 01.0i; i = 0 to 6 = ROM Ø to ROM 6
  RAM error: (no change in contents)
  02.ji; i = 0 to 3 = RAM Ø to RAM 3
  j = 0: cell error
  j = 1: address error (AØ to A10)
  j = 2: address error (A11, A12)
  I/O error: 03.00
  IEC 625 interface error: 06.00 (only if interface board is fitted)
  The instrument halts if there is an error message.
- If the self-test does not find any errors, the instrument shows the instrument address (standard address: 12) in display field D, provided that the instrument is fitted with the IEC 625/IEEE 488 interface, cf figures 3-3a,b.
- If the instrument is not fitted with the interface, the setting that was valid before the instrument was last switched off is shown after the self-test.
  (Series D and E RMS-5s show address 30 in display field D if no IEC 625/IEEE 448 interface has been fitted).
- If the RMS-5 has not been used for a long time and its battery has discharged, it will go into a standard setting (see 3.3.3) when it is switched on. Front panel setups stored by means of the MEM function are lost.

3.3.2 WHAT HAPPENS WHEN THE RME-5 IS SWITCHED ON

- If the instrument is fitted with the IEC 625/IEEE 488 interface, the instrument address (standard address: 13) appears on the screen for about 10 s when the instrument is switched on.
- The RME-5 then restores the last front panel setup. If no signal has been applied to the inputs and a distortion measurement was selected in the last setup, the message "SWEEP SIGNAL TOO LOW" appears on the screen. The LEDs (⇩) which indicate that the input level is too low come on.
- When a sweep signal with the correct level is applied to the appropriate input, the LEDs (⇩) go out, and the trace appears on the screen.

  The "SWEEP SIGNAL TOO LOW" message also appears if the applied signal goes outside the nominal range for more than 10 s. The deflection voltage U_X for displaying the sweep trace is not generated or synchronised.
- If the RME-5 has not been used for a long time and its battery has discharged, the message "BATTERY LOW" appears on the screen for about 10 s when the instrument is switched on (this does not apply to series D instruments). The RME-5 then selects the standard setup, see 3.3.3.

3.3.3 STANDARD SETUP

All the front panel setups for the RME-5 and the RMS-5 are stored in RAMs which are powered by battery when the instruments are switched off. Front panel setups that are stored by the RMS-5's MEM function and the normaliser trace stored by the RME-5 are therefore not lost when the RM-5 is switched off.

If the RM-5 is not used for some time (> 30 days), the batteries will discharge and the parameters will be lost. If this is the case, a standard setup is selected when the RM-5 is switched on.

RMS-5:

Transmission parameter	Value	Front panel key
IF centre frequency F_o (IF_{CENT})	70 MHz	[9]
IF level P_{IF}	0 dBm	[8]
Sweep voltage $\hat{U}_A$	1 V	[10]
Sweep width $\Delta\hat{F}$	0.5 MHz	[10]
Automatic sweep reduction	off	[5]
Frequency deviation Δf	100 kHz	[13]
Test voltage U_M	100 mV (-8.7 dBm)	[13]
Sweep frequency f_A	18 Hz	[14]
Test frequency f_M	500 or 555.55 kHz 1)	[4]
$U_{A\ EXT}$	off	[11]
$U_{M\ EXT}$	off	[12]
Gap	off	[6]
Facility for switching off sweep signal	off	[10]
Wideband function (only if option fitted)	off	[18]

RME-5:

Receiver functions	State	Front panel key
Operating mode	IF measurement	[22]
IF centre frequency	70 MHz	[21]
Phase U_x (IF)	on	[18]
ALC	on	[30]
Distortion result 1	on	[2]
Distortion result 2	on	[10]
Measurement mode $\Delta\tau$, $\Delta\varphi$	(depends on f_M)	[2]
Measurement mode ΔP_I	0.4 dB/DIV	[10]
Frequency response correction ΔP_I	off	[19]
Noise averaging	factor of 4	[5]

All other key functions are disabled.

1) Test frequency series I or II

3.3.4 REINITIALISATION

Under certain circumstances (e.g. batteries partially flat), it may not be possible to operate the RMS-5 or the RME-5 via the front panel as the instrument is disabled.

Counter measure: "Reinitialisation"

* Switch off
* Hold down LOCAL [19] (RMS-5) or [24] (RME-5) and switch on instrument simultaneously
* Press down LOCAL for about 5 s.

The instrument is now in the standard setting as described in 3.3.3. Front panel setups that have been stored (MEM function) and reference curves (NORMALISER) are lost.

3.4 CONTROLS AND INDICATORS

The standard RM-5 has a 70 MHz IF. The versions with 35 MHz or 140 MHz or both are marked with G (RMS-5) and E (RME-5).

It should also be noted that two different test frequency series (f_M < 1 MHz) can be selected when the internal test frequencies are used. For this reason, two values for the test frequencies are often stated.

The lettering on the test frequency selection keys [4] on the RMS-5 will tell you if the test frequency facility has been fitted or not. A plate marked F on the front panel of the RME-5 also indicates that the test frequency series option has been fitted (frequency in kHz).

All the controls, indicators, inputs and outputs that you will normally use are located on the front panels of the RME-5 and RMS-5.

The mains connector, the mains voltage selector and the instrument fuse are at the back of the instrument, this also applies to the connectors for the <IEC 625> interface bus, the XY plotter and the video printer for listing the results.

Tables 3-1 and 3-2 describe the controls and indicators. The codes used in figures 3-3 and 3-4 are also used here. The numbers in the square brackets on the front and back panels of the instrument which are used to mark controls etc., are also used in the tables and text.

The symbols used to designate the controls etc. in the circuit diagram are shown in the right-hand columns of the tables.

> When a key (or keys) on the RMS-5 or RME-5 is pressed, the function may not be carried out immediately; continue pressing the key until the function is activated.

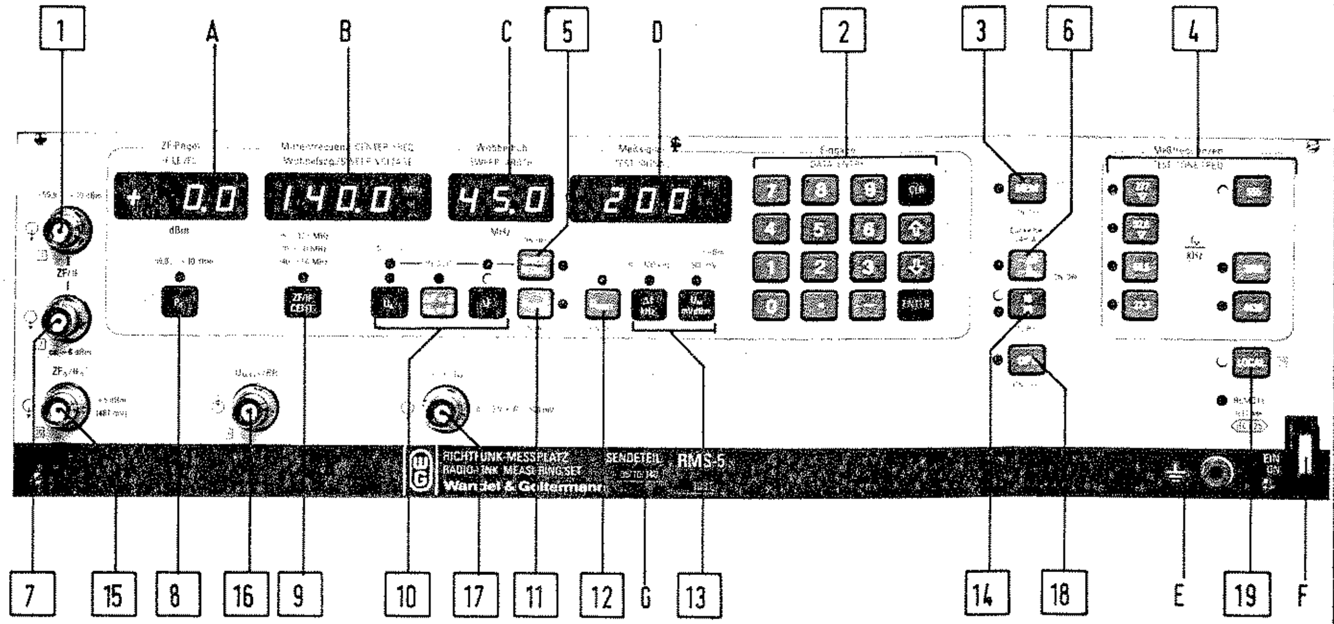


Figure 3-3a   Front view of the RMS-5

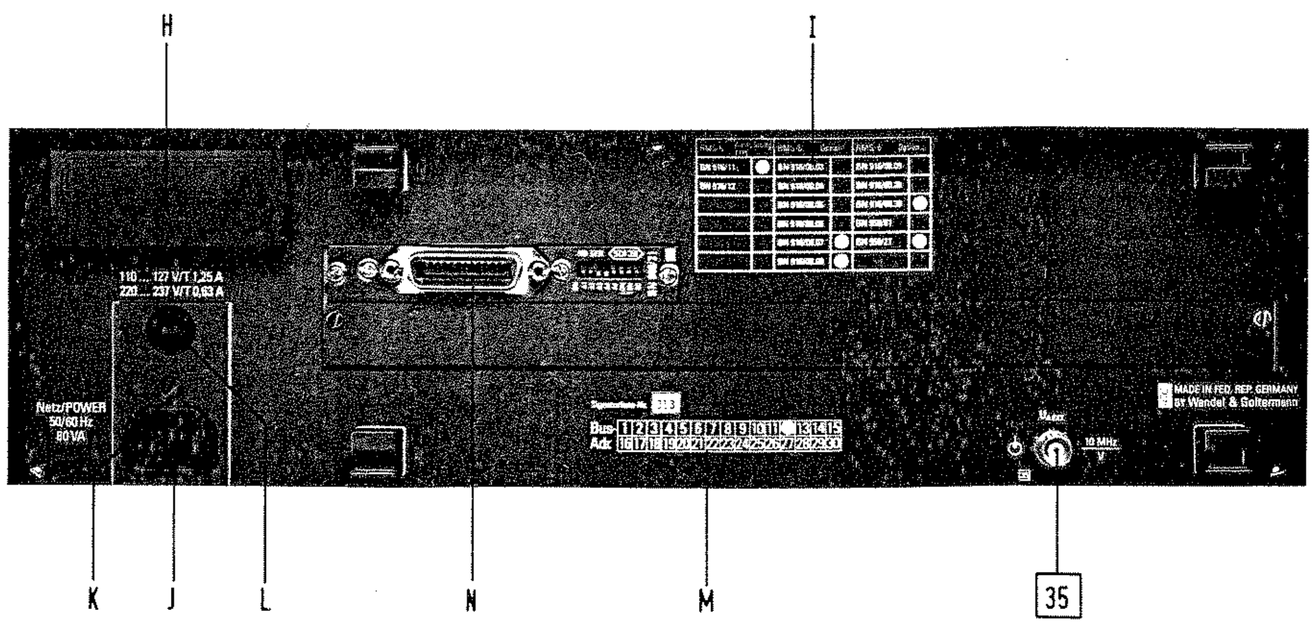


Figure 3-3b   Rear view of the RMS-5

3.4.1 THE RMS-5's CONTROLS AND CONNECTORS

Code	Key symbol	Function	Circuit diagram code
[1]		Main IF output: Z_{out} = 75 Ω, level range -59.9 to +10 dBm Types of IF signal: - frequency modulated, swept signal (distortion measurements $\Delta\tau$, $\Delta\varphi$, $\Delta U/U_o$) - unmodulated carrier, swept (frequency response measurements ΔP_I, ΔP_{II}) - frequency modulated signal, not swept (Bessel spectrum)	6 Bu 4
		DATA ENTRY (see 3.5.2.1)	
[2]	9 … 0	Numerical keypad - for entering parameter values directly P_{IF}, IF_{CENT} (F_o), $\hat{U}_A$, $\hat{\Delta F}$, Δf, U_M Select the parameter type using the dark-grey buttons below displays A, B, C, D - for entering setup addresses (front panel setups)	7 S 11 ... S 26
[2]	CLR	Clear key for erasing incorrect numerical entries, but not complete parameter entries	
[2]	ENTER	Key for terminating parameter entries (numerical keyboard)	
[2]	⇧ ⇩	Up/down keys (dual function) - step or quasi-analog setting for the values of P_{IF}, IF_{CENT} (F_o), $\hat{U}_A$, $\hat{\Delta F}$, Δf, U_M Select the parameter type using the appropriate key (dark-grey keys below displays A, B, C, D) - for use with the memory function (key [3] on) STO: stores front panel setups RCL: recalls front panel setups	
[3]	MEM	Memory key for storing and recalling a maximum of 20 different front panel setups; see 3.5.3	7 S 27
[4]	5600 … 27,7	Keys for setting the test frequency f_M - 1 from 7 direct selection (appropriate LED on) - interlocked keys	7 S 31 ... 37

Code	Key symbol	Function	Circuit diagram code
[5]	SWEEP REDUC.	Automatic sweep reduction (on/off) see 3.5.2.3 $\hat{\Delta F}_{RED} = \hat{\Delta F} - f_M$! ($\hat{\Delta F}$ is not erased) $\hat{U}_{A\ RED} = \hat{U}_A\ (1 - f_M/\hat{\Delta F})$	7 S 6
[6]	$-\hat{\Delta F}$ $-\hat{U}_A$	Key for injecting a gap pulse ($\Delta U/U_0$ curve) - Removes uncertainty of 180°	7 S 28
[7]		Aux. IF output, fixed level -6 dBm (Z_{out} = 75 Ω) - Signal shape same as that from output [1] - as auxiliary signal for ΔP_{II} frequency response measurements (connection to P_I output of the RME-5)	8 Bu 3
[8]	P_{IF}	IF-level entry key (P_{IF}) When the key is pressed (LED on) the parameter setting is made via keyboard [2] (display A) IF level range: -59.9 to +10.0 dBm	7 S 1
[9]	ZF/IF CENT.	IF frequency input key (F_0) When the key is pressed (LED on), F_0 can be set via keypad [2] (display B) F_0: - 22.5 to 47.5 MHz (35 MHz IF option) - 40.0 to 100.0 MHz - 90.0 to 200.0 MHz (140 MHz IF option)	7 S 2
[10]	$\hat{U}_A$	Sweep voltage entry ($\hat{U}_A$) Press the key (LED on) and set $\hat{U}_A$ via the keypad [2] (display B) $\hat{U}_A$ range: 0 to 3 V	7 S 3
	$\hat{\Delta F} = 0$ $\hat{U}_A = 0$	Sweep width key, $\hat{\Delta F}$ = 0, sweep voltage $\hat{U}_A$ = 0 - On/off function with red LED (cf display B or C) - The original setting is restored after switch off.	7 S 4
	$\hat{\Delta F}$	Sweep width key ($\hat{\Delta F}$) When the button is pressed (LED on), the $\hat{\Delta F}$ setting is made via keypad [2], (display C) $\hat{\Delta F}$ range: - 0 to 12.5 MHz (35 MHz IF option) - 0 to 30.0 MHz - 0 to 50.0 MHz (140 MHz IF option)	7 S 5

Code	Key symbol	Function	Circuit diagram code
[11]	$U_{A\,EXT}$	Key for switching in an external test signal (via the back panel connector [35], display C off)	7 S 7
[12]	$U_{M\,EXT.}$	Key for switching in an external test signal (via connector [16], display D off)	7 S 8
[13]	Δf kHz	Test tone deviation key ($\Delta f \cong$ rms value) Press the key (LED on) and enter Δf via keypad [2], display D - Δf: 0 to 500 kHz	7 S 9
	U_M mV dBm	Test voltage entry key ($U_M \cong$ rms value) Press the key (LED on) and enter U_M via keypad [2]; entry in mV or dBm (see display D) Press "U_M" again to select mV or dBm. - U_M: 0.05 to 500 mV or -75 to +5.2 dBm	7 S 10
[14]	18 70	Sweep frequency selector key (f_A) f_A setting is shown by appropriate LED	7 S 29
[15]		IF_o output (option) quartz accurate signal 35/70/140 MHz Frequency at the output depends on the IF centre frequency setting [9]	18 Bu 1
[16]		Input for external test signal U_{MEXT}/BF - Sweep mode: sinusoidal signal, frequency 25 kHz to 5.6 MHz - Wideband mode (option): wideband baseband signal, e.g. white noise	16 Bu 6
[17]		$\hat{U}_A + U_M$ output: test signal for BB mode (Z_{out} = 75 Ω)	16 Bu 5
[18]	OPT.	"Option" key for switching over to wideband mode (internal wideband demodulator in operation) - $\hat{\Delta F}$ and Δf displays are off	7 S 30
[19]	LOCAL	Key for selecting manual mode (green LED on), if the RMS-5 is remote controlled via the IEC 625/ IEEE 488 bus	7 S 38

Code	Key symbol	Function	Circuit diagram code
		Digital displays (red LEDs)	
A		- 3 digit display plus sign for IF level (dBm)	7 IC 1, 5, 6, 7
		- 4 digit display for centre frequency F_o (MHz) or sweep voltage $\hat{U}_A$ (V)	
C		- 3 digit display for sweep width ΔF (MHz)	7 IC 12 ... 14
D		- 3 digit display plus sign for test tone deviation Δf (kHz) or test voltage U_M (mV, dBm)	7 IC 2, 4, 15 ... 17
E		Earth connector	1 Bu 3
F		Mains switch	1 S 1
G		IF ranges fitted	

Table 3-1a Controls, indicators and connectors on the front panel of the RMS-5 (see figure 3-3a)

Code	Function	Circuit diagram code
[35]	Input for external, sinusoidal sweep signal (f_A = 18 to 70 Hz).	9 Bu 1
H	Compartment for spare fuses, Versacon® 9 keys, allen keys and board extractors	
I	Table showing incorporated options (BNs)	
J	Mains connector	1 St 1
K	Mains voltage selector	
L	Mains fuse	
M	Number of signature list for address bus	
N	Slot for the IEC 625/IEEE 488 interface (option BN 958/21)	

Table 3-1b Connectors etc. on the back panel of the RMS-5 (see figure 3-3b)

3.4.2 CONTROLS, INDICATORS AND CONNECTORS ON THE RME-5

Code	Key symbol	Function	Circuit diagram code
[1]	⇧	Keys for shifting the sweep trace vertically [2]	27 S 49, 50
[2]	⇩	Key pad, each key calls up a measurement mode, cf 3.6.2	27 S 35 ... 38 27 Gl 21 24
	ΔP_{II}	"IF frequency response" (selective), test signal at input P_{II} [26] with IF reference signal at input P_I, [25]; IF return loss measurement	
	ΔP_I	"IF frequency response" (wideband) test signal applied to input P_I, [25].	
	$\Delta\tau, \Delta\varphi$	"Group delay distortion/differential phase" test signal applied to IF input P_I [25] or BB input [27]	
	Y_{EXT}	"$Y_{ext.}$" external sweep result applied to input [41]	
	⇧ ⇩	Up/down keys for selecting the measurement range	27 S 29, 30
	START STOP	Key for activating the plot function (xy plotter interface) or to freeze the video display	27 S 28 27 Gl 36
	ON OFF	Key for switching off the current measurement mode [2]	27 S 43
[3]		Key for selecting the BESSEL SPECTRUM mode - IF signal spectrum	27 S 41 27 Gl 15
[4]		Frequency counter function key - for measuring unswept IF signals	27 S 40 27 Gl 14
[5]	⇧ ⇩	Up/down keys for setting the noise averaging factor (see appropriate LED display)	27 S 23, 27 27 Gl 37 ... 41
[6]		Press this key for horizontal lines on screen	27 S 12
	⇧⇩ ⇩⇧	Arrowed keys for adjusting the distance between the horizontal lines	27 S 10, 11 27 Gl 51
[7]		Selects a bandwidth of 300 Hz to weight the sweep signal	27 S 19 27 Gl 31
[8]		Potentiometer for calibrating the IF level meter (see 3.6.7.1)	10 P 34
[9]	⇧	Keys for shifting the selected sweep trace vertically [10]	27 S 47, 48
[10]	⇩	Key pad for calling up the second sweep trace; Except for non-linear distortion/differential distortion, the measurement modes are the same as those on keypad [2], see 3.6.2	27 S 31 ... 34 27 Gl 17 ... 20 27 S 25, 26
	$\Delta U/U_0$		27 S 24, 27 Gl 35, 27 S 42

Code	Key symbol	Function	Circuit diagram code
[11]		Potentiometer for calibrating the frequency deviation meter for the BESSEL SPECTRUM mode (see 3.6.7.2)	18 P 103
[12]		Keypad for forming the trace difference (NORMALISER), see 3.7.3	27 S 6 ... 8 27 Gl 42 ... 44
	STORE REF.	Storing the reference curve	
	DISPL.	Calling up the difference curve or reference curve	
	OFF	Displaying the current sweep trace	
[13]		Keypad for operating the noise calculation and the INTELSAT tolerance mask options (cannot both be fitted, see 3.7.5 and 3.7.6)	21 S 1 ... 5 27 Gl 46, 47
[14]		Potentiometer for altering the brightness of the display	29 P 1
[16]	⇦⇨	Pair of keys for shifting the frequency markers "M" (vertical lines)	19 S 1, 2
[17]	⇨⇦	Key for showing outward and return sweeps	27 S 17
[18]		Key pad for performing phase corrections on the deflection mode U_x (see 3.6.2.3)	27 S 13, 14, 53, 54 27 Gl 26, 27
	U_x(IF)	The deflection voltage is derived from the IF signal.	
	⇦ ⇨	Pair of keys for adjusting the phase of U_x: U_x (IF): ± 6°, U_x (BB): ± 180°	
	U_x(BB)	Deflection voltage from the BB signal.	
[19]		Key for linear frequency response corrections ΔP_I via the appropriate potentiometer	27 S 20 27 Gl 32, 10 P 33
[20]	LIN. PARAB	Key for evaluating the sweep curves: LIN and PARAB, the results are shown on the curve	27 S 9 27 Gl 45
[21]	IF/MHz	IF range: 35, 70 and 140 MHz (depends on option fitted)	27 S 45 27 Gl 9, 10, 53
[22]	IF	Key for IF mode, activation of inputs P_I and P_{II}	27 S 16 27 Gl 28
[23]	BB	Key for BB mode (ΔT, $\Delta \varphi$ and $\Delta U/U_o$), Input [27] enabled	27 S 15 27 Gl 27
[24]	LOCAL	Key for switching from manual to remote mode	27 S 44 27 Gl 16

Code	Key symbol	Function	Circuit diagram code
[25]		IF input P_I, Z_{in} = 75 Ω, for the following signals: - frequency modulated and swept signals ($\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$) - unmodulated, swept carriers (ΔP_I measurements) - frequency modulated, unswept signals	2 Bu 1
[26]		IF input P_{II}, Z_{in} = 75 Ω, for frequency response measurements (P_{II}) where there are large variations in attenuation, also return loss measurements, IF reference signal applied to input P_I	8 Bu 1
[27]		BB input, Z_{in} = 75 Ω, test signal is $\hat{U}_A + U_M$ from the item-under-test; input is enabled when key [23] is on.	5 Bu 2
[28]		BB level meter key for enabling input [29]	27 S 39 27 Gl 50
[29]		BB level input, Z_{in} = 75 Ω, for measuring the level of unswept signals from 10 kHz to 12.5 MHz	18 Bu 1
[30]		Switches off the automatic IF-level matching facility (LED on); wait until AFC capture occurs before pressing this key	27 S 46 27 Gl 52
A		Screen for displaying all types of results: - Sweep traces and cursors. The relevant parameters are shown above and below the graticule. - IF signal spectrum (section of frequency range) - Monitor mode "frequency counter function" and "BB level-meter function".	
B		AFC indicator lamp is on, when the input frequency is within the capture and holding range	27 Gl 13
C		LED on if the IF input level is outside the nominal range	27 Gl 11, 12
D		Indicates when the BB input level (distortion measurements) at connector [27] is outside the nominal range	27 Gl 48, 49
E		Indicates what IF ranges have been fitted	
F		Indicates what test frequency series have been fitted (series I or series II, or colour subcarrier)	
G		Earth connector	
H		Mains switch	1 S 1

Table 3-2a Controls, indicators and connectors on the front panel of the RME-5 (see figure 3-4a)

Code	Function	Circuit diagram code
[40]	Demodulator output that allows the test signal U_M to be processed externally.	5 Bu 6
[41]	Input for the low-frequency signal "Y_{EXT}" for evaluation in the RME-5, Z_{in} = 10 kΩ, measurement range 8 to 800 mV.	10 Bu 2
[42]	Video-signal output for results (video printer, monitor)	19 Bu 7
I	Table showing options that have been fitted (BN)	
J	Battery compartment for the NiCads used to buffer the memory contents when the instrument is switched off.	
K	Mains connector	1 St 1
L	Mains fuse	
M	Compartment for spare fuses, Versacon® 9 keys, allen keys and a board extractor	
N	Number of signature list for address bus	
O	Slot for the noise calculation option (BN 917/00.11) or INTELSAT tolerance mask option (BN 917/00.12)	
P	Slot for the IEC 625/IEEE 488 interface option (BN 853/21) or the xy plotter interface option (BN 917/00.01)	

Table 3-2b Connectors etc. on the back panel of the RME-5 (see figure 3-4b)

3.5 OPERATING THE RMS-5

3.5.1 USE OF INTERNAL OR EXTERNAL TEST AND SWEEP SIGNALS

When the RM-5 is in its standard operating mode using internal test and sweep signals, the keys $U_{A\ EXT}$ [11] and $U_{M\ EXT}$ [12] are disabled. The appropriate LEDs are off (cf figure 3-3a).

External test signals (input [16]) and external sweep signals (input [35]) in the appropriate frequency ranges can be used when keys [11] and [12] are pressed; the appropriate LED indicators come on.

The modulator sensitivity at both outputs is 10 MHz/V.

When $U_{A\ EXT}$ [11] is pressed, the sweep width display disappears, as if the IF sweep width is determined by the external sweep voltage and the sensitivity of the modulator in the RMS-5.

$\hat{\Delta F} = S_{Mod.} \times \hat{U}_{A\ EXT}$; $S_{Mod} = 10$ MHz/V

NOTE: A minimum voltage must be applied to input $U_{A\ EXT}$: This voltage depends on the IF range that has been selected. The following minimum values (typical values) are necessary to ensure that the IF centre frequency regulator works properly.

IF range	Minimum voltage $\hat{U}_{A\ EXT}$	$\hat{\Delta F}_{min}$
35 MHz	2.5 mV	25 kHz
70 MHz	5 mV	50 kHz
140 MHz	10 mV	100 kHz

When $U_{M\ EXT}$ [12] is pressed, the frequency deviation display disappears as the frequency deviation is now determined by the voltage of the external test signal and the sensitivity of the modulator (see above).

It is also possible to use an internal test signal with an external sweep signal or vice versa.

3.5.2 SETTING THE RMS-5'S TRANSMISSION PARAMETERS

The transmission parameters described in table 3-3 are set by first of all selecting the parameter type with the dark grey keys and then entering the numerical value using numerical keypad [2] (DATA ENTRY). The parameter values are shown numerically in display panels above the keys, where appropriate the unit is indicated.

Mode	Transmission parameter	Key	Display	Display format	Unit	Range	Resolution
IF mode	● IF level (P_{IF})	[8]	A	Sign 10^1 10^0 . 10^{-1}	dBm	-59.9 to +10.0 dBm	0.1 dB
IF mode	● IF centre frequency F_{CENT} (F_o)	[9]	B	10^2 10^1 10^0 . 10^{-1}	MHz	a) 22.5 to 47.5 MHz b) 40.0 to 100.0 MHz[1] c) 90.0 to 200.0 MHz[2]	0.1 MHz
IF mode	● Sweep width ($\hat{\Delta F}$)	[10]	C	10^0 . 10^{-1} 10^{-2} 10^1 10^0 . 10^{-1}	MHz MHz	a) 0 to 9.99 MHz 10.0 to 12.5 MHz b) 0 to 9.99 MHz 10.0 to 30.0 MHz c) 0 to 9.99 MHz 10.0 to 50.0 MHz	0.01 MHz 0.1 MHz 0.01 MHz 0.1 MHz 0.01 MHz 0.1 MHz
IF mode	● Test tone deviation (Δf) (Δf, rms)	[13]	D	10^1 10^0 . 10^{-1} 10^2 10^1 10^0	kHz kHz	0 to 49.9 kHz 50 to 500 kHz	0.1 kHz 1 kHz
BB mode	● Sweep voltage ($\hat{U}_A$)	[10]	B	10^0 . 10^{-1} 10^{-2} 10^{-3}	V	0 to 3.000 V	0.001 V
BB mode	● Test signal (U_M)	[13]	D	10^0 . 10^{-1} 10^{-2} 10^1 10^0 . 10^{-1} 10^2 10^1 10^0 Sign 10^1 10^0 . 10^{-1}	mV mV mV dBm	0.05 to 4.99 mV 5.0 to 49.9 mV 50 to 500 mV -75 to +5.2 dBm	0.01 mV 0.1 mV 1 mV 0.1 dB

Table 3-3 Transmission parameters that can be set via keypad [2]

- Test frequency (f_M): Selection is made directly via keypad [4]; the selected test frequency is shown by the LED above the key. The frequency (in kHz) printed on the key refers to frequency series I and is an approximate value. Test frequencies that are used to calibrate the frequency deviation meter are marked with a "▽".

- Sweep frequency (f_A): Key [14] "18/70" is used to select the sweep frequency. Each time the key is pressed the other frequency is selected.
  Upper LED on: 18 Hz
  Lower LED on: 70 Hz

---

1) If 35 MHz IF option is fitted
2) If 140 MHz IF option is fitted

3.5.2.1 Numerical entries

The parameter values are entered using numerical keypad [2]. (The LED above the blue MEM key must be off). The RMS-5 is only set to the new value when the ENTER key is pressed.

Example: The IF level is to be set to -3.5 dBm.

* Press "P_{IF}" [8]	● appropriate LED on
* Press "-" "3" "." "5"	- the old display is erased - the sign and digits enter the display from the left - LED flashes while the digits are being entered
Press "ENTER"	● LED stops flashing and remains on ● a transmission level of -3.5 dBm is output at [1]

If you make an incorrect numerical entry, use "CLR" to erase this entry, and enter the value again. The LED for the appropriate parameter key will flash until the entry is terminated with "ENTER".

If you enter a value which is out-of-range (see table 3-3), an alarm tone is output when the entry is terminated. The RMS-5 always takes the maximum or minimum value in such cases.

3.5.2.2 Quasi-analog settings

Quasi-analog adjustment of the selected parameter over a certain range can be carried out using the arrowed keys in keypad [2], i.e. by holding down the key; (the LED above the blue MEM key must be off). While you adjust the parameter, the current value is always shown in the appropriate display, this value is set immediately by the RMS-5.

By observing the results on the screen of the RME-5, and by pressing the keys "⇧" and "⇩" alternately, the setting you want can be obtained (e.g. carrier vanishes at the Bessel zero = Δf).

"⇧":	- Key held down:	"Continuous" increase in parameter until the upper limit is reached
	- Key pressed for a short time (< 2 s):	Parameter increased in steps, the step width is equal to the smallest increment that can be set (cf table 3-3)
"⇩":	- Key held down:	"Continuous" decrease in parameter until lower limit is reached
	- Key pressed for a short time (< 2 s):	Parameter decreased in steps, the step width is equal to the smallest decrement that can be set (cf resolution, table 5-3)

An alarm tone is output when a range limit is reached.

3.5.2.3 Setting the IF centre frequency and the sweep width

The RM-5 can be fitted with a max. of 3 IF ranges, including the standard 70 MHz range. Table 3-3 gives the IF frequencies and their limits.

Within these frequency ranges, any IF centre frequency F_0 and any IF sweep width $\hat{\Delta F}$ can be chosen provided that $F_0 \pm \hat{\Delta F}$ does not exceed the given limits.

Example: 70 MHz range: 40 to 100 MHz

at F_0 = 70 MHz ⇨ $\hat{\Delta F} = \pm$ 30 MHz at most

at F_0 = 84 MHz ⇨ $\hat{\Delta F} = \pm$ 16 MHz at most

If $F_0 \pm \hat{\Delta F}$ is outside the limits, the sweep width is set to its max. value, the centre frequency is not altered.

If you enter a IF centre frequency which is outside the IF range, the IF frequency is set to the appropriate range limit and the sweep width is set to zero.

An alarm tome is output whenever the sweep width or centre frequency are out of range.

When the RM-5 is fitted with several IF ranges, there is some range overlap. The RMS-5 will always select the range that gives the greatest sweep width.

3.5.2.4 Automatic sweep reduction

The automatic sweep reduction facility prevents the sidebands furthest from the swept IF carrier from going outside the IF range of the object under test, when a new test frequency is selected. The sweep reduction facility does this by setting the sweep voltage to an appropriate value. To understand how the circuit functions, we must examine what happens when the test signal $\hat{U}_A + U_M$ is fed into the modulator (see figure 3-5). The carrier frequency of the frequency modulated signal is swept over the range $\pm \hat{\Delta F}$ which depends on the modulator sensitivity and the sweep voltage $\hat{U}_A$. The first pair of sidebands, f_M from the swept carrier, is caused by the test voltage U_M. If the sweep voltage has been selected so that the IF carrier touches the edges of the IF transmission band, the upper and lower sidebands will be outside the IF transmission band $F_0 - \hat{\Delta F}$ to $F_0 + \hat{\Delta F}$ at IF carrier $\pm \hat{\Delta F}$. At lower test frequencies this is not of major importance because the sidebands are very close to the IF carrier (figure 3-5a). However, assuming the same sweep voltage, a pair of sidebands will be outside the bandwidth being examined if higher test frequencies are used. These sidebands undergo certain changes and may falsify the results (figure 3-5b).

If the test frequency f_M is set to a higher value, a circuit in the generator section sets the sweep voltage to a value that will prevent sidebands being shifted outside the bandwidth that was to be investigated, i.e. the selected bandwidth, see figure 3-5c.

When the automatic sweep reduction facility has been switched on by means of "SWEEP REDUC" [5], it works for all test frequencies, no matter whether IF or BB measurements are being made.

> It has no value to use sweep reduction for measurement modes other than ΔT, $\Delta\varphi$ and $\Delta U/U_0$, as these modes use a swept, frequency-modulated signal.

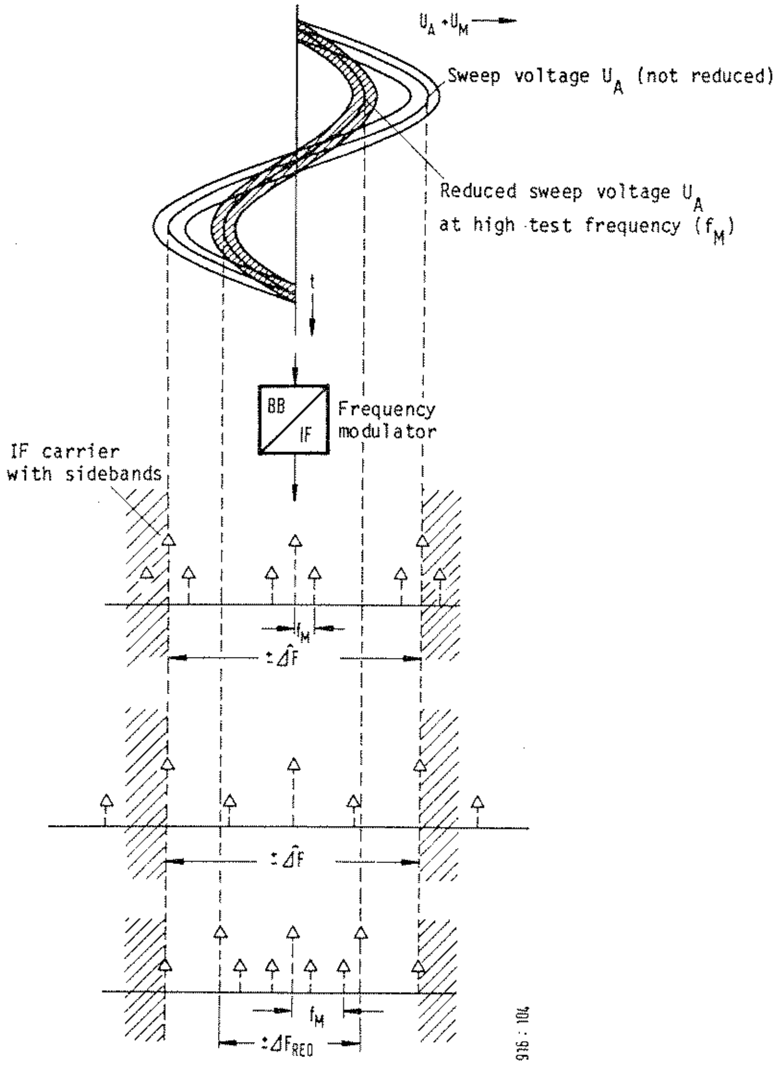


Figure 3-5 Automatic sweep reduction

a) Sweeping the IF range with a low test frequency (automatic sweep reduction off)
b) Sweeping the IF range with a high test frequency (automatic sweep reduction off)
c) Sweeping the IF range with a high test frequency (automatic sweep reduction on)

- Sweep reduction $\hat{\Delta F}_{RED}$ (IF distortion measurements)

The IF centre frequency and the IF sweep width have already been entered:

* "$\hat{\Delta F}$" on (lower LED on) Display C: ● $\hat{\Delta F}$
* Select sweep width reduction by pressing "SWEEP REDUC." [5] (red LED on) Display C: ● $\hat{\Delta F}$
* Press "$\hat{\Delta F}$" (upper LED on) Display C: ● $\hat{\Delta F}_{RED}$

The actual sweep width is:

$$\hat{\Delta F}_{RED} = \hat{\Delta F} - f_M$$

f_M = current test frequency [4]

* Select higher test frequnecy using the numerical keypad [4] Display C: ● $\hat{\Delta F}_{RED}$

The sweep width $\hat{\Delta F}_{RED}$ decreases, while the sweep range (cf figure 3-5) remains the same.

If you enter a test frequency f_M which is larger than the sweep width $\hat{\Delta F}$, the internally generated sweep signal is disabled (display C = 0, acoustic alarm).

If a value for $\hat{\Delta F}_{RED}$ is displayed (upper LED above the "$\hat{\Delta F}$" key on) and an entry is made via the numerical keypad [2], the entry is interpreted as a normal sweep width entry, i.e. not reduced. The display shows $\hat{\Delta F}$ instead of $\hat{\Delta F}_{RED}$ (lower LED above the "$\hat{\Delta F}$" key on).

- Sweep width reduction $\hat{U}_{ARED}$ (BB distortion measurements)

When the test signal $\hat{U}_A + U_M$ is applied to an external modulator, the IF output range of the modulator can be kept constant at different test frequencies, if automatic sweep reduction is on. The modulator sensitivity S_{ext} must be taken into account when the sweep voltage $\hat{U}_A$ is set. The following equations apply:

$$\hat{U}_A = \frac{\hat{\Delta F}}{S_{ext}} \quad \text{or}$$

$\hat{U}_{ARED}$ can be calculated from the following formula:

$$\hat{U}_{ARED} = \frac{\hat{\Delta F} - f_M}{S_{ext}} = \hat{U}_A \left(1 - \frac{f_M}{\hat{\Delta F}}\right)$$

$\hat{\Delta F}$ = half the IF output range

Example: Sensitivity of external modulator: 12 MHz/V, IF range $\pm\ \hat{\Delta F} = \pm$ 10 MHz

$\hat{U}_A = \hat{\Delta F}/S_{ext}$ = 10 MHz/12 MHz/V = 0.833 V

$$\hat{U}_{ARED} = 0.833\ \text{V} \left(1 - \frac{f_M}{10\ \text{MHz}}\right)$$

f_{M1} = 500 kHz: $\hat{U}_{ARED}$ = 0.791 V

f_{M2} = 2.4 MHz: $\hat{U}_{ARED}$ = 0.633 V

RMS-5 settings:

* Test signal U_M, f_{M1} = 500 kHz
* Sweep voltage $\hat{U}_A$
  - Press "$\hat{U}_A$" [10] (lower LED on)
  - Enter 0.833 V via numerical keypad [2] — Display B: ● 0.833 V ($\hat{U}_A$)
* IF range $\pm\ \hat{\Delta F}$
  - Press "$\hat{\Delta F}$" [10] (lower LED on)
  Enter "10 MHz" via numerical keypad [2] — Display B: ● 10.0 MHz ($\hat{\Delta F}$)
* Reduced sweep voltage $\hat{U}_{ARED}$
  - Press "SWEEP REDUC." [5] (red LED on)
  - Press "$\hat{U}_A$" (upper LED on) — Display B: ● 0.791 V ($\hat{U}_{ARED}$)
* Set test frequency f_{M2} to 2.4 MHz — Display B: ● 0.633 V ($\hat{U}_{ARED}$)

The swept FM signal whose upper and lower sidebands coincide with the IF range limits $F_0 \pm$ 10 MHz when the carrier is at its maximum and minimum frequencies ($\pm\ \hat{\Delta F}_{RED}$), is output by the modulator.

If a test frequency f_M, which is greater than the selected IF transmission range (with "$\hat{\Delta F}$"), is set, the internal sweep signal is switched off (displays B and C are 0, and an alarm sounds).

If an entry is made via the numerical keypad [2], when $\hat{U}_{ARED}$ is displayed (upper LED above key "$\hat{U}_A$" on), the entry is not taken to be a reduced value. The display then shows $\hat{U}_A$ (lower LED above key "$\hat{U}_A$" on).

3.5.3 STORING AND CALLING UP COMPLETE FRONT PANEL SETUPS (MEMORY FUNCTION)

Using the blue "MEM" key, it is possible to store and recall a total of 20 complete RMS-5 front panel setups. This facility makes it easy to perform measurements that have to be carried out regularly as all the settings are immediately ready for use. When the RMS-5 is switched off, or there is a power failure, an integral battery will power the memory for about 30 days.

3.5.3.1 Storing setups (STORE)

* Enter parameter type and value
* Press "MEM" [3] — ● MEM LED on
* Select memory location XX via numerical keypad [2], e.g. 01 (address range XX = 01 to 20) — ● MEM LED flashes ● Number of memory location shown in display D
* Press "STO" (⇧) — ● all displays show the last parameter setting
* Enter the next front panel setup (e.g. use address "02").

If you are not sure what is stored at a particular address, and do not want to overwrite a useful setup, the VIEW functions (see 3.5.3.3) will allow you to check the contents of each address. If an address no. ≤ 0 or > 20 is entered, the error message 010 (out-of-range) appears in display B and a warning tone sounds.

3.5.3.2 Recalling setups (RECALL)

* Press "MEM" [3] — ● MEM LED on
* Select the memory location you want (XX) via the numerical keypad [2] (address range XX = 01 to 20) — ● MEM LED flashes Memory location number in display D
* Press "RCL" (⇩) — ● MEM LED off ● all displays show setup parameter values

If an address ≤ 0 or > 20 is entered the error message 010 is shown in display B and an acoustic alarm is given. If memory locations with no contents are called up, the error message 001 (no contents) is shown in display B and an acoustic alarm is output.

If the instrument is not used for a long time (batteries go flat), of if a reinitialisation is performed, stored setups may be lost. When the address is called up, the error message 001 appears in display B and an alarm sounds.

Note: The standard setup is stored at address 0, as described in 3.3.3.
If "LOCAL" and the mains on button are pressed simultaneously to perform reinitialisation (approx. 5 s), all the setups are erased, however these are not lost when address 0 is called up.

3.5.3.3 Displaying setup parameters (VIEW)

You want to find out what setup is stored at address XX (the RMS-5 stays in its present operating mode).

* Press "MEM" [3] (LED on)	● MEM LED on ● MEM LED flashes
* Enter address XX via the numerical keypad (address range XX = 01 to 20)	● Address no. shown in display D
* Press "VIEW" (ENTER)[1]	● The setup (XX) is displayed without being set on the instrument as long as "VIEW" is held down.

If nothing is stored at address XX, the RMS-5 displays the following:
Display B: 001 (≙ no contents) and
Display D: address XX

If you want to set the instrument to the setup displayed in VIEW mode, simply press "RCL" (⇩).

To look at another address in view mode, erase the address display with "CLR" and enter a new address.

3.5.3.4 Erasing setups

Erasing a single setup

* Press "MEM" [3]	● MEM LED on
* Enter address XX via the numerical keypad	● MEM-LED flashes Address no. shown in display D
* Press "VIEW" (ENTER)[1] and "CLR" simultaneously	● Display B = 001 (not used) ● Display D = address XX and acoustic alarm
* Press "MEM" [3]	● MEM LED off

Erasing all setups (XX: 01 to 20)

* Press "MEM" [3]	● MEM LED on
* Enter "100" via the numerical keypad	● MEM LED flashes "100" shown in display field D
* Press "VIEW" (ENTER)[1] and "CLR" simultaneously	● Display B: 001 Display D: 100 and acoustic alarm
* Press "MEM" [3]	● MEM LED off

1) Series D and E: The ENTER key does not have the additional "VIEW" marking

3.6 O P E R A T I N G T H E RME-5

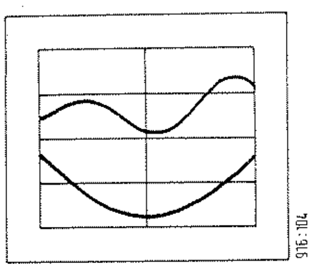
3.6.1 MEASUREMENT MODE OVERVIEW (OPERATING SEQUENCE)

3.6.1.1 IF measurements

* Press "IF" [22] (LED on)
* Select the IF range you want with "IF/MHz" [21]; if several IF options are fitted, e.g. 35 MHz or 140 MHz, press key [21] until the display indicates the frequency you want (LED on).

● Distortion measurements (input [25] (or [26]) used)

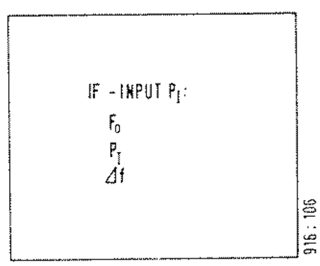
* Measurement mode $\Delta\tau$, $\Delta\varphi$, $\Delta U/U_0$, ΔP_I or ΔP_{II} is selected via keypad [2] or [10] (appropriate LED on)



* Shift the curve to the required position using the arrowed keys [1] or [9]
* Set the sensitivity using the arrowed keys marked RANGE
* Use the keypad [17], [18] to shift the outward and return sweeps of the distortion curve so that they coincide (cf 3.6.2.3)
* Evaluation of the result curve using keypad [5], [12], [13], [20]

● Frequency counter (input [25] used)

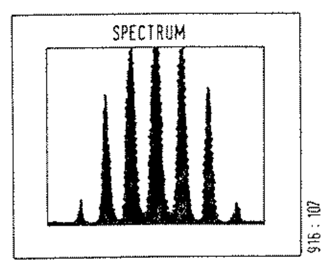
* Press [4] (LED on)



cf 3.6.4

● Bessel spectrum (input [25] used)

* Press [3] (LED on)

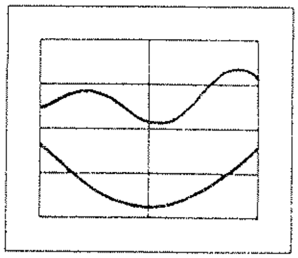


cf 3.6.3

3.6.1.2 BB measurements

BB-BB distortion measurements, use input [27]

* Press "BB" [23] (LED on)
* Measurement mode $\Delta\tau$, $\Delta\varphi$ or $\Delta U/U_o$ is selected via keyboard [2] or [10] (appropriate LED on)

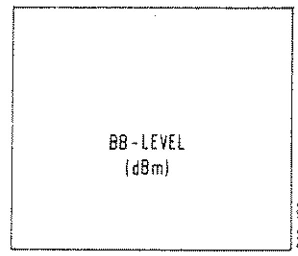


916:104

* Shift the curve to the required position using the arrowed keys [1] or [9]
* Set the sensitivity with the arrowed keys marked "RANGE"
* Adjust the outward and return sweeps of the distortion curve (keypads [17], [18]) until they coincide (cf 3.6.2.3)
  180° phase uncertainty
  (gap injection with RMS-5)
* Keypads [5], [12], [13], [20] are used to evaluate the result curves

BB-BB level measurements, use input [29]

* Press [28] (LED on)



916:108

cf 3.6.5

3.6.2 DISTORTION MEASUREMENTS

Some of the distortion measurements (sweep method) that can be shown on the graticule are listed below:

- "$\Delta\tau$" group delay distortion or "$\Delta\varphi$" differential phase
- "$\Delta U/U_o$" non-linearity distortion or differential gain
- "ΔP_I" attenuation/distortion (IF-IF frequency response)
- "ΔP_{II}" attenuation/frequency distortion (IF to IF frequency response) selective measurement of large level differences
  IF return loss measurements (a_r)
- "Y_{EXT}" Displays the detected rf signals that are associated with the sweep signal of the RM-5

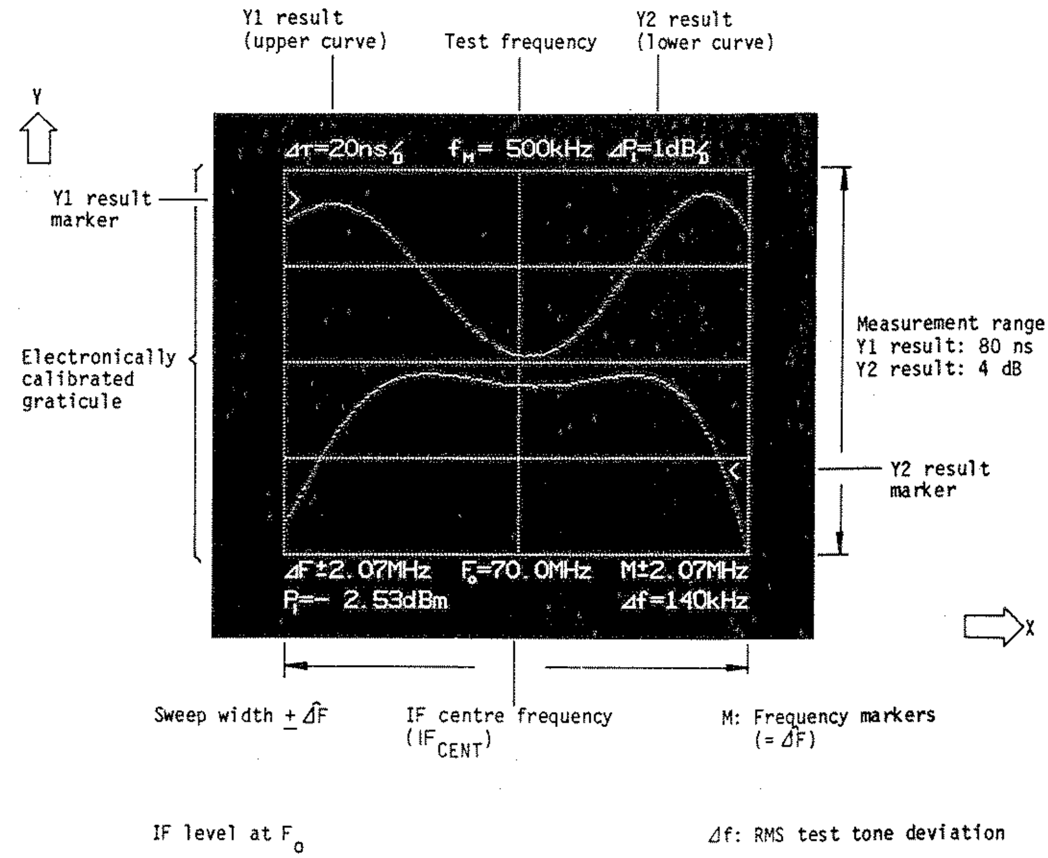


Figure 3-6 IF measurement illustrating the display of distortion measurement results (The lines at the bottom of the screen are not present for BB measurements, input [27] is used).

With the keys in rows [2] and [10] you can display (call up) two sweep curves, Y1 and Y2, simultaneously. Each row of keys is used to select a measurement mode - see figure 3-4a - the selected measurement mode is indicated as the current measurement mode by the appropriate LED (on). The arrangement of both rows of keys is the same, the only difference being that of the measurement mode, i.e. "$\Delta T, \Delta\varphi$" or "$\Delta U/U_0$". As the keys "P_{II}", "P_I" and "Y_{EXT}" are contained in both rows, combinations such as "$\Delta T, \Delta\varphi$" with P_{II} or P_I and Y_{EXT} can be displayed simultaneously. The same is true for "$\Delta U/U_0$" at [10] with the measurement mode combinations in row [2]. The ease with which various modes can be displayed simultaneously is very useful in practice.

If the test frequency $f_M < 1$ MHz, the result of the distortion measurement "$\Delta T, \Delta\varphi$" is automatically displayed as a group delay measurement (ΔT): if $f_M > 1$ MHz a differential phase measurement ($\Delta\varphi$) is performed.

The sweep curve can be shifted vertically with the arrowed keys marked POSITION [1] (or [9]). The position of the other curve is not altered.

NOTE: The markers ">" and "<" show that the results cannot be displayed on the graticule with the current settings. They indicate where the results have gone off the screen. They also indicate whether a listing has been made with a videoprinter or a camera.

If you only want ONE sweep curve displayed on the screen, e.g. Y1, the Y2 trace can be switched off with the appropriate ON/OFF key. The appropriate measurement mode LED goes off.

The range for the selected measurement mode can be adjusted in steps using the arrowed keys marked RANGE.

Press "⇧": the measurement range is increased by one step
Press "⇩": the measurement range is decreased by one step

The current range per division (DIV) is always shown on the screen for all appropriate measurement modes. The measurement mode is shown in the top line of the screen. Measurement mode Y1 is on the left of this line, measurement Y2 is on the right, see figure 3-6. The possible measurement modes are shown in table 3-4.

Sweep curve	Measurement mode	Measurement ranges (≅ 4 DIV.)							Unit
	● $\Delta\varphi$	0.4	1	2	4	10	20	40	% rad
Y1	● ΔT 1) 2$\bar{7}$.7/25 kHz	16	40	80	160	400	800	1600	ns
	55.$\bar{5}$/50 kHz	8	20	40	80	200	400	800	ns
	92.6/83.$\bar{3}$ kHz	4	10	20	40	100	200	400	ns
	277.$\bar{7}$/250 kHz	1.6	4	8	16	40	80	160	ns
	555.$\bar{5}$/500 kHz	0.8	2	4	8	20	40	80	ns
Y2	● $\Delta U/U_0$	0.4	1	2	4	10	20	40	%
Y1, Y2	● ΔP_I	-	0.4	0.8	1.6	4	8	16	dB
Y1, Y2	● ΔP_{II}	-	-	8	16	40	80	-	dB
Y1, Y2	● Y_{ext}	8	20	40	80	200	400	800	mV
	Max. voltage	± 40	± 100	± 200	± 400	± 800	± 800	± 800	mV

Table 3-4 Variable measurement ranges for the RME-5 (scale range = 4 DIV)

When making distortion measurements, it is best to choose 18 Hz as the sweep frequency. At this frequency, the two lowest test frequencies < 60 kHz can be used without any restrictions. Also, no problems will be caused by using bandwidth reduction for noise averaging (cf 3.7.1.1). The 18 Hz sweep frequency does not cause any flicker on the RME-5's screen.

When you are using an IF in the 35 MHz range, the highest test frequencies that can be used are 500 or 555.56 kHz. If a higher test frequency is selected, the error message "f_M > 1 MHz" appears instead of the frequency display. The display showing the results of the distortion measurement is, however, not disabled, because, depending on the item under test, it is still possible to make measurements (because of the small IF range, however, the results are, in most cases, of little value).

1) The measurement ranges for ΔT depend on the test frequency, f_M, selected.

3.6.2.1 Frequency markers [16]

When IF input [25] is used, the x-axis of the graticule can be further subdivided by a pair of vertical cursors to read off the results for $\Delta T, \Delta\varphi$ $\Delta U/U_o$, ΔP_I, ΔP_{II} and Y_{EXT}. The cursor pair (dashed lines) is symmetrical about the centre frequency f_o. A quasi-analog adjustment of the separation is possible over the sweep width. The frequency marker range is ~ $0.1\,\Delta F \leq M \leq \Delta F$. The keys marked FREQ. MARK have the following effects:

" ⇨ ⇦ " reduces separation
" ⇦ ⇨ " increases separation

The parameter value indicated by the frequency marker is shown in the line below the graticule, see figure 3-7.

You should note that the frequency markers cannot be set in 0.1 MHz or 0.01 MHz steps (depends on sweep width), as may be suggested by display on the screen. The maximum resolution is determined by the measured sweep width and the number of pixels along the x-axis (256).

When the instrument is switched on, the frequency markers are at the sweep limits ($M = \Delta F$), and therefore cannot be seen. To bring the markers onto the screen, the cursor pair must be moved to the appropriate position in the sweep range using the " ⇨ ⇦ " key. The longer the key is held down, the faster the movement of the cursors becomes. Fine adjustment of the markers can be made by quickly pressing the keys " ⇨ ⇦ " " ⇦ ⇨ " to shift the vertical cursors to the required position on the screen.

In some frequency marker positions, the marker lines may flicker. The reason for this is the variation in the last digit of the sweep width display. It is still possible to detect frequency marker flicker if a large sweep width has been selected (display resolution is reduced to 100 kHz and the sweep width display flickers less). This is because the frequency counter that determines the sweep width still operates at a resolution of 10 kHz.

3.6.2.2 Horizontal cursors [6]

Adjustable horizontal cursors (dotted) can be used to read off values on the y-axis. The cursor pair is symmetrical about the centre line, see figure 3-7. In this way, it is possible to set a tolerance band for <u>one</u> sweep result or to determine the extreme values of the trace. The separation of the horizontal cursors " ⇕ " is shown numerically above the screen graticule (left).

When the horizontal cursors are used, it is only possible to display either Y1 or Y2. If two sweep curves are displayed and the horizontal cursors are switched on, the Y2 curve disappears (keypad [10]). Sweep trace Y1 has precedence (keypad [2]). Switchover from Y1 to Y2 is possible.

The horizontal cursors are switched on using the ON/OFF button [6] (LED on). The separation is adjusted using the arrowed key below [6]:

" ⇧⇩ " increases separation; limits are the upper and lower graticule lines

" ⇩⇧ " reduces separation

As long as one of the arrowed keys is held down the separation of the cursors will be increased or decreased in a quasi-analog manner. Fine adjustments can be made by pressing the keys quickly.

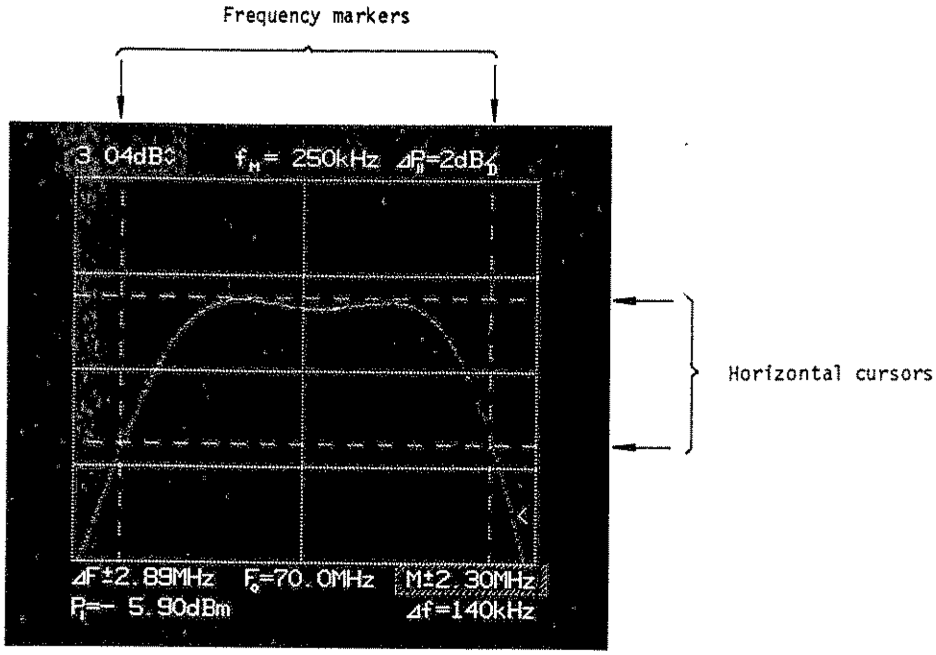


Figure 3-7 Sweep with frequency markers "M" and horizontal cursors "⇕" switched on

It should be noted that the resolution with which the separation of the horizontal cursors is displayed depends on the measurement range selected and the number of pixels along the y-axis (i.e. 205).

3.6.2.3 Phase correction for the deflection voltage U_x

- BB distortion measurements

When displaying BB distortion measurements, the phase of the deflection voltage for the display unit should always be checked (note above BB key [23]: phase U_x). If the outgoing and return sweep are not the same, this means that the phase is not correct. The return sweep must be displayed using key [17]. If two curves are displayed simultaneously the result selected via keypad [10] disappears. Switchover from row [2] to row [10] is possible.

* Display return sweep on screen: press key [17] (LED on), cf figure 3-8.
* Shift the outward and return curves with keys "⇦" or "⇨", until the curves coincide.
* Remove the return trace from the screen by pressing key [17] (LED off).
  The 180° phase shift that occurs can be eliminated using the blanking gap described in the following section.

There are some FM demodulators which behave like high-pass filters and block the low-frequency sweep signal. If this is the case, it is not possible to obtain the deflection voltage from the BB signal. Instead, one can feed an IF signal from a test port before the demodulator input into the P_I input on the RME-5 (press "U_x(IF)").

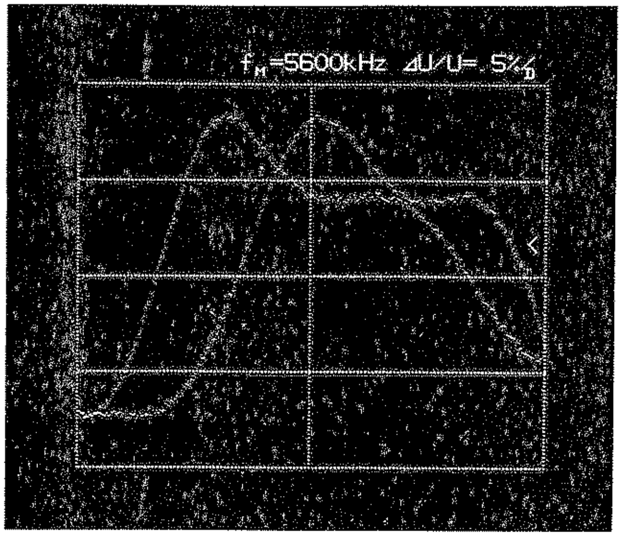


Figure 3-8   Phase shift between the outward and return sweep during a BB measurement

- IF distortion measurements

In the IF mode, the deflection voltage obtained has the correct phase. However it may be necessary to carry out fine adjustments on the phase of U_x, if the instrument is operated under extreme ambient temperatures, component ageing has taken place or a new sweep frequency has been selected. Carry out the correction as described in the section on BB distortion measurements. The correction range is at most ± 6°.

- Gap pulse

As the deflection signal is sinusoidal, there is always a 180° uncertainty on the phase of the result.

This can be removed by inserting a blanking gap in the test trace by pressing key [5] (LED on) on the RMS-5. The gap is displayed most clearly on the screen in the $\Delta U/U_0$ mode, and should - assuming positive modulation - be moved to the lefthand edge of the screen with the arrowed keys [18] on the RME-5, see figure 3-9.

The gap only gives you a rough guide when you adjust the phase of the deflection voltage, fine adjustments should be made with key [17] and the arrowed keys [18] until the outward and return traces coincide.

The polarity of modulators and demodulators can be determined using the blanking gap (not if the phase shift of the BB output signal is too large). If the gap is on the left of the screen this means positive polarity, on the right negative.

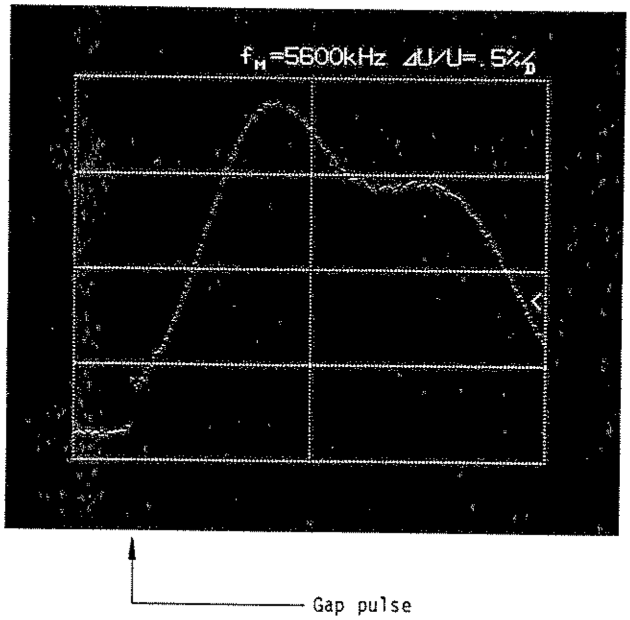


Figure 3-9 Using the blanking gap to eliminate the 180° phase uncertainty

3.6.3 BESSEL SPECTRUM MEASUREMENT MODE [3]

In the "BESSEL SPECT.▽" mode (key [3] on the RME-5), the spectrum of the IF signal applied to P_I input [25] is shown. The RME-5 therefore functions as a spectrum analyser, see also 4.2.

The frequency range that can be displayed is about 800 kHz. This is sufficient to show the 1st sidebands if a test frequency f_M = 250 kHz (or 277.8 kHz) is selected. This mode has been supplied to make the calibration of the frequency meter (see 3.6.7.2) and the adjustment of modulators and demodulators (sensitivity) possible.

In the FM spectrum monitor mode, the lower line on the screen contains the test frequency f_M, the rms frequency deviation of the test signal at the first bessel zero (η = 2.405) "Δf_o", and the currently set rms deviation "Δf"; see figure 3-10.

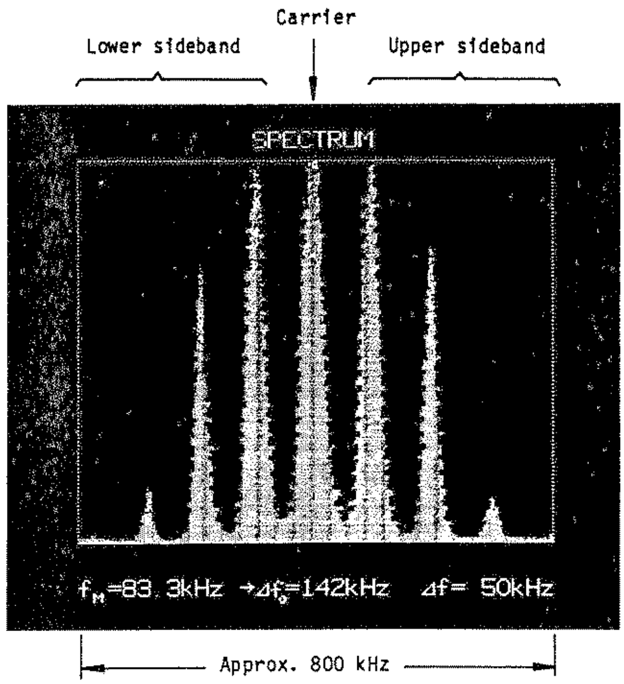


Figure 3-10 "BESSEL SPECT.▽" monitor mode, key [3]

3.6.4 "IF COUNTER" MEASUREMENT MODE [4]

The frequency counter in the RME-5 can be used to measure the frequency of unswept IF signals (range 25 to 190 MHz). The test signal which is applied to input P_I [25] is displayed digitally with a resolution of 0.01 MHz. Key [4] controls the display. Ensure that the signal level is in range. The frequency F_0 below the line "IF INPUT P_I" should be read off as shown in figure 3-11. As well as the frequency, the IF level P_I is also shown. If the test signal is FM (e.g. from the RMS-5) the rms test deviation Δf is also shown.

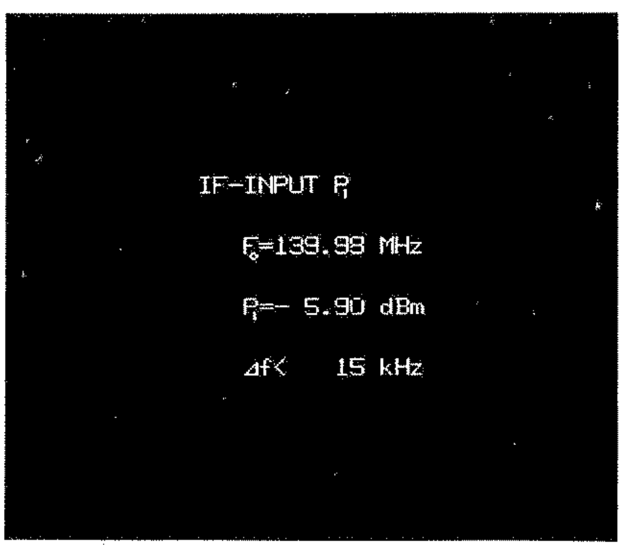


Figure 3-11 IF COUNTER results, key [4]

3.6.5 "BB LEVEL METER" MODE [28]

The frequency range of the BB level meter is 10 kHz to 12.5 MHz; the level range is -50 to -10 dBm.

The BB level meter is calibrated automatically.

The signal to be measured is applied to the "BB level" input connector [29] and is switched in by pressing key [28] (ON/OFF), the appropriate LED comes on.

As shown in figure 3-12, the power level is shown as a 4-digit number, the resolution is 0.01 dB. The error message "> -10 dBm" or "< -50 dBm" appears if the signal is out-of-range.

The BB level meter can be used in the following applications which are described in 3.9.

3.9.4.2 Adjusting modulator sensitivity
3.9.5.1 Adjusting demodulator sensitivity

If these measurements are carried out to check systems that have already been installed, you should ensure that no other signals (e.g. pilots) are applied to BB level input [29] in addition to the test signal, as the wideband level meter in the RME would show the total level. Signals with frequencies ≤ 100 Hz are an exception (e.g. the sweep signal $\hat{U}_A$) as they are not registered by the level meter.

Total wideband signals can also be measured if quasi rms calibration is used for the BB level meter. This is useful for measuring system loading at a decoupled BB test port, or for measuring total noise level.

Press key [28] to switch off the BB level meter (LED off). The last used input is still enabled - even during BB level measurements (key function [28]).

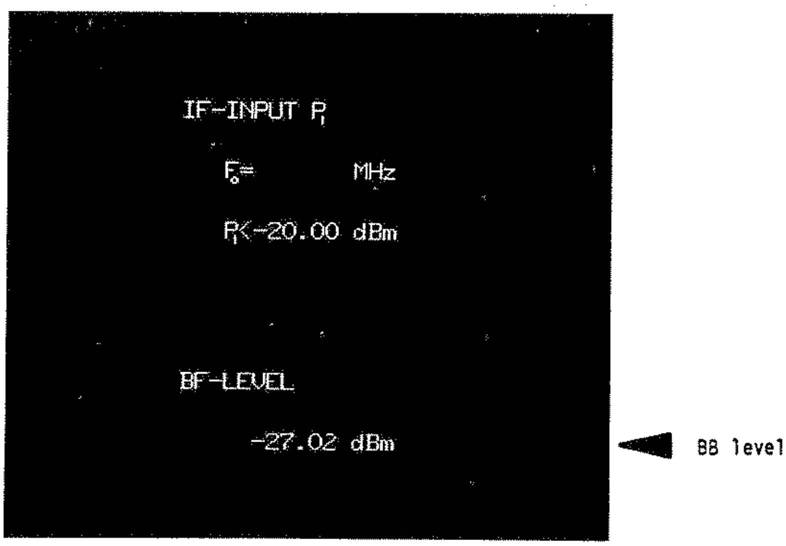


Figure 3-12 "BB LEVEL METER" results, key [28]

3.6.6 SIMULTANEOUS MEASUREMENT OF BB DISTORTION AND BB LEVEL

It is not possible to adjust demodulators unless BB distortion (ΔT, $\Delta U/U_0$) and BB level can be measured simultaneously, as demodulator sensitivity depends on the BB level.

As there are separate inputs for BB distortion measurements and BB level measurements a T-branch is required to split the signal.

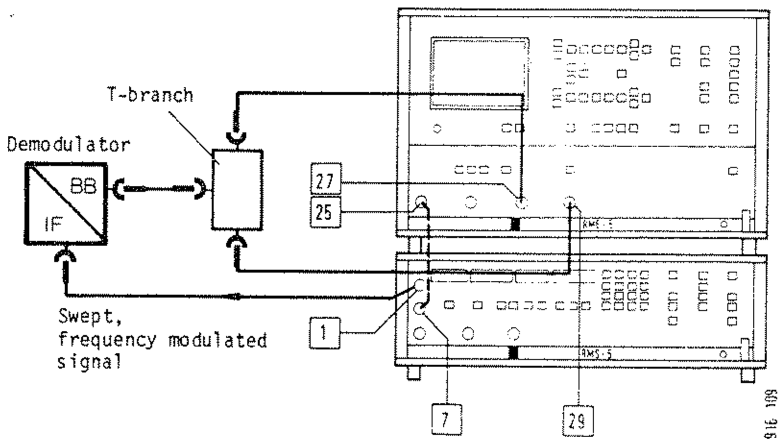


Figure 3-13 Measuring the BB distortion introduced by a demodulator while at the same time measuring the BB level

The results of the distortion measurement and the level measurement can be displayed simultaneously by switching over from BB distorton mode ("BB" key [23] on) to BB level mode. Key [28] must be held down for longer than 3 s. The result format is shown in figure 3-14.

The BB level meter only measures the level at the output of the T-branch.

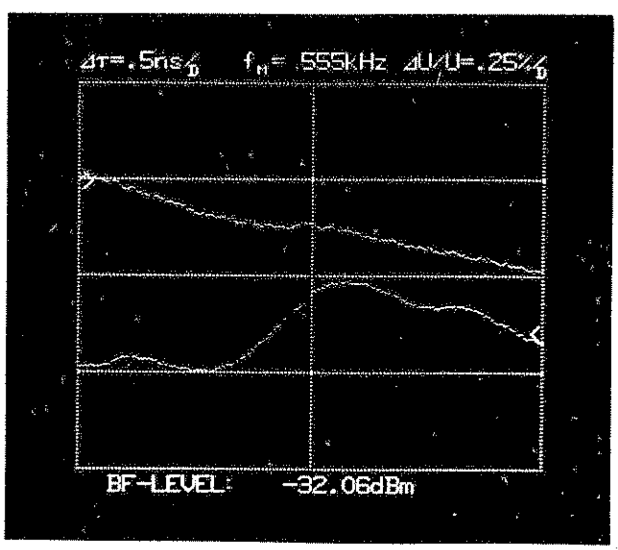


Figure 3-14 Result format for simultaneous BB distortion and level measurements

3.6.7 CALIBRATING THE IF LEVEL METER AND THE FREQUENCY DEVIATION METER

Accurate IF level and frequency deviation measurements can only be made after the IF level meter and the frequency deviation meter have been calibrated. The RME-5 and the RMS-5 must be operated in back-to-back mode by connecting connector [1] (RMS-5) to connector [25] (RME-5).

The IF level meter is calibrated at the approximate centre frequency F_o (IF_{CENT}) using an IF level of 0 dBm, the frequency deviation meter is calibrated using the Bessel method at the test frequencies f_M = 250 kHz (or 277.8 kHz) or 83.3 kHz (or 92.593 kHz), cf 3.6.3.

3.6.7.1 Calibrating the IF level meter (P_I calibration)

RMS-5 settings

* Enter IF level "P_{IF} = 0 dBm ([8], [2])
* Enter IF centre frequency "IF_{CENT}" ([9], [2])
* Enter sweep width "$\hat{\Delta F}$" = 0 MHz (press "$\Delta F/U_A$ = 0", LED on)

RME-5 settings

* IF measurements: press "IF" [22] (LED on)
* Select IF range: appropriate setting with "IF/MHz" [21]
* IF counter measurement mode: Press [4] (LED on)
  - Compare displayed level P_I with 0 dBm transmission level
  - If the two values are not equal, adjust pot. [8] "CAL. P_I" so that the level displayed is 0.00 dBm.

3.6.7.2 Calibrating the IF frequency deviation meter

Basic settings as above, i.e. 3.6.7.1.

Other RMS-5 settings

* Set test frequency f_M = 250 kHz (or 277.8 kHz): press appropriate key [4] (LED on)
* Select "frequency deviation Δf": by pressing "Δf/kHz" (LED on)
* Set a sufficiently small frequency deviation, e.g. 25 kHz

Other RME-5 settings

* Select SPECTRUM display: press "BESSEL-SPECT.▽" [3] (LED on)

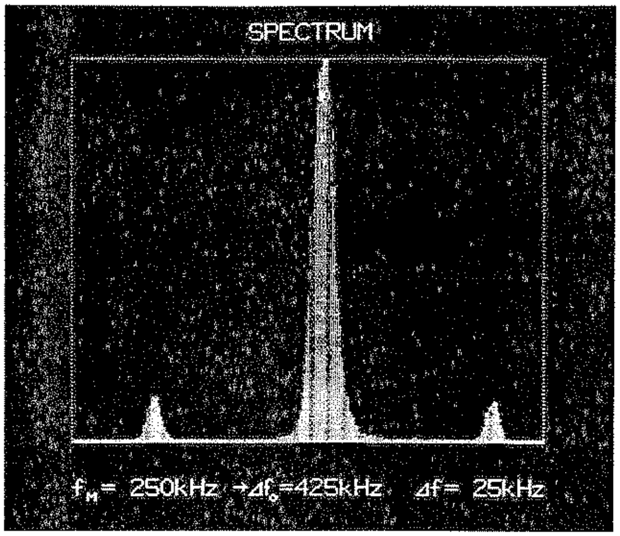


Figure 3-15a Weakly modulated IF carrier

According to the Δf-setting on the RMS-5, the Bessel spectrum is shown on the screen of the RME-5 (in the example illustrated in figure 3-15a for Δf = 25 kHz, the weakly modulated carrier is shown). For calibration, a Δf-value of exactly 425 kHz is required (→ Δf_o).

- The rms test deviation on the RMS-5 should be set (e.g. via the up/down keys [2]) so that the carrier disappears, see figure 3-15b.
- If the displayed Δf-value (in the example 421 kHz) is not equal to the theoretical value f_o = 425 kHz, adjust pot. [11] "▽ CAL. Δf" so that the displayed value is equal to 425 kHz.
  (Note: After calibration, it may be possible that the Δf-display on the RMS-5 indicates a value which is not the same as the theoretical value: cf 1.2.1.1 error limits on settings).
- If required, calibration can be carried out at f_M = 83.3 kHz (or 92.593 kHz).

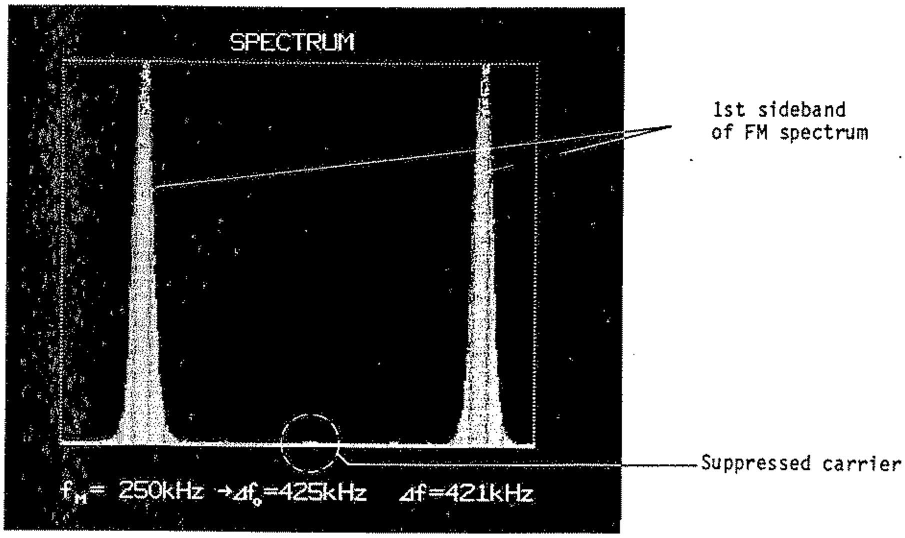


Figure 3-15b Suppressed IF carrier, phase deviation η = 2.405 (1st Bessel zero) before calibrating the frequency deviation meter ($\Delta f \neq \Delta f_0$)

3.7 SPECIAL WAYS OF DISPLAYING SWEEP TRACES ON THE RME-5

3.7.1 NOISE AVERAGING

3.7.1.1 Reducing bandwidth [7]

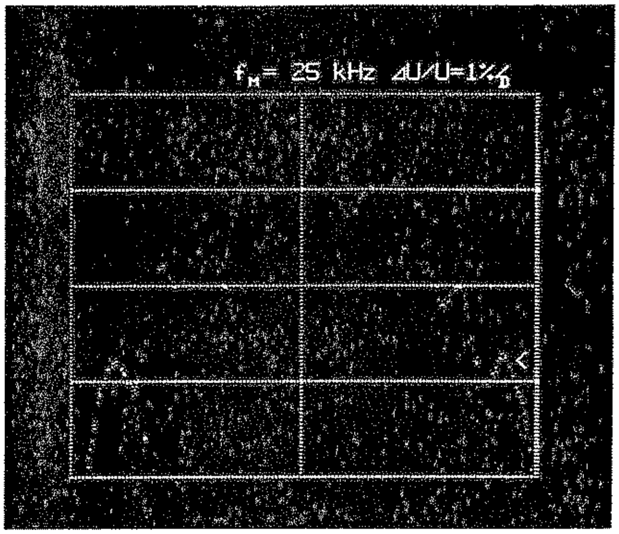
One way of reducing the effects of noise on the results is to reduce the bandwidth used. However, it should be noted that under certain circumstances, high-frequency signal components may be lost, so falsifying the results.

Instead of the usual bandwidth (1 to 4 kHz, depends on test frequency), a bandwidth of 300 Hz can be selected by pressing [7].

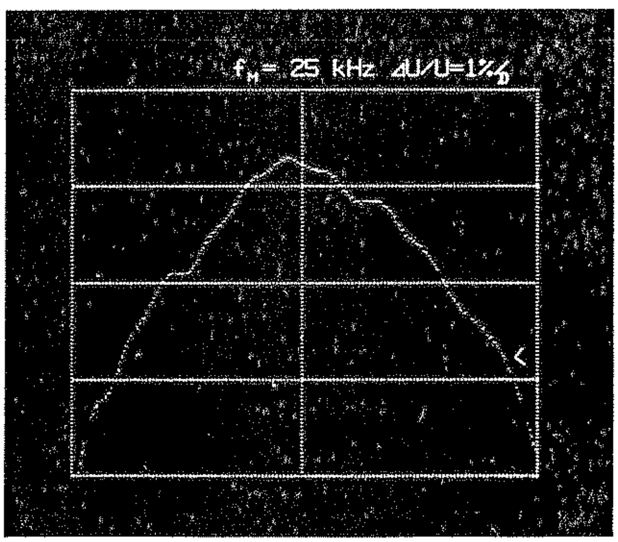
When performing sweep measurements (18 or 70 Hz) you should check the correctness of the results by switching from a wide to a narrow bandwidth. Figure 3-16 shows what happens to the results if the bandwidth which has been selected is too narrow.

Note: When the 300 Hz bandwidth has been selected you should, as a rule, always use the 18 Hz sweep frequency to prevent incorrect results. This is because at this frequency the ratio bandwidth/sweep frequency is still sufficiently large. The RM-5's display does not flicker when a sweep frequency of 18 Hz is selected.

The 300 Hz filter can also be used in conjunction with the digital noise averaging facility (see 3.7.1.2) to achieve an optimal result.



a) 300 Hz bandwidth not selected



b) 300 Hz bandwidth selected

Figure 3-16 Effect of the 300 Hz filter on a sweep curve with ripple, sweep frequency f_A = 70 Hz

3.7.1.2 Digital noise averaging [5]

Unlike reducing the bandwidth, (cf 3.7.1.1) digital noise averaging (arrowed keys [5]) does not remove ripple components from sweep curves.

The average is calculated using a current value $\bar{Y}_{i+1}$ and a value Y_i that was stored when the last sweep was made. The following averaging factors can be selected N = 2, 4, 8, 16, and 32. The new average value $\bar{Y}_{i+1}$ is displayed on the screen. To form a trace, a total of 256 averages are calculated per sweep, see 4.3.

The averaging facility is switched on by pressing "⇧" below [5]: N = 2 is the standard averaging factor (appropriate LED on). Each time "⇧" is pressed the averaging factor is doubled, the appropriate value is indicated by an LED. Maximum noise averaging is obtained for N = 32. Figures 3-17a to 3-17c show the effect of the various averaging factors - the larger the factor the less noisy the curve is. Two sweep curves showing the results of "ΔT" and $\Delta U/U_o$ distortion measurements are displayed simultaneously.

The averaging factor is reduced by pressing "⇩" [5]. If a factor of 2 has been selected and this key is pressed, the averaging facility is switched off. All the LEDs are off.

Note: Before switching on the noise averaging facility [5], the sweep curve should be shifted (vertical shift, measurement range) so that the noise peaks fall within the digitisation range (graticule), otherwise the results will be incorrect.

When the noise averaging facility is switched on, there will be some delay between pressing the keys ([1] or [9]) to vertically shift the curve and the curve being shifted (especially if N = 32). The adjustments, therefore, have to be made gradually. If necessary, reduce the noise averaging factor, or switch off the facility.

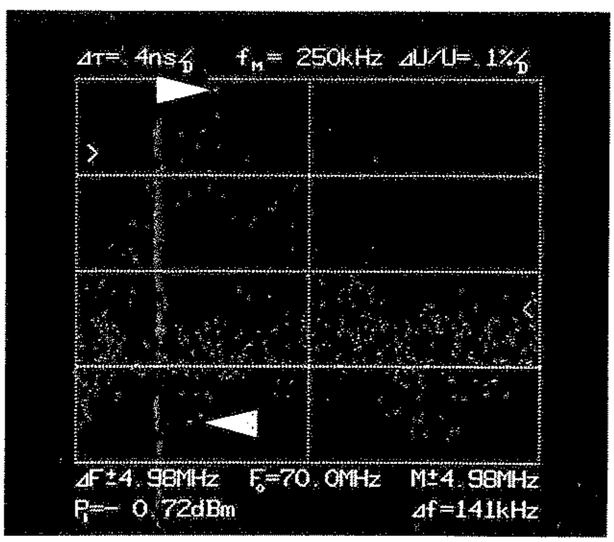


Figure 3-17a Noisy sweep curves for ΔT and $\Delta U/U_o$; noise peaks: ▶

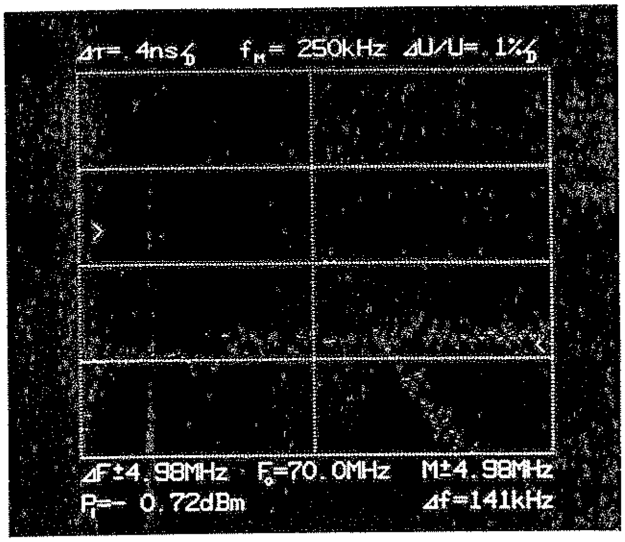


Figure 3-17b Sweep measurements as a), averaging factor N = 2

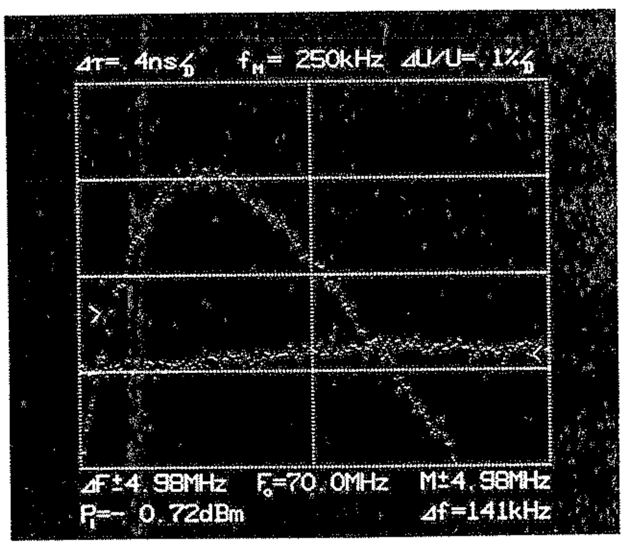


Figure 3-17c Sweep measurements as a), averaging factor N = 8

3.7.2 IF FREQUENCY RESPONSE CORRECTION ΔP_I [19]

When ΔP_I measurements are being made, it is possible to eliminate the spurious linear frequency responses caused by long test cables; see figure 3-18.

The first step in the procedure is to make a back-to-back measurement with the RMS-5 and the RME-5 using the cables that are to be used but without the item-under-test. If the most sensitive range is used (0.01 dB/DIV) the frequency response of the cables is displayed as an oblique line on the screen.

Then press key "P_I frequency response correction" - the red LED lights. The potentiometer on the right of key [19] should then be adjusted until the oblique line displayed on the screen is horizontal.

The P_I measurement is then performed with the frequency response correction facility on. The frequency response displayed is now solely that of the item-under-test.

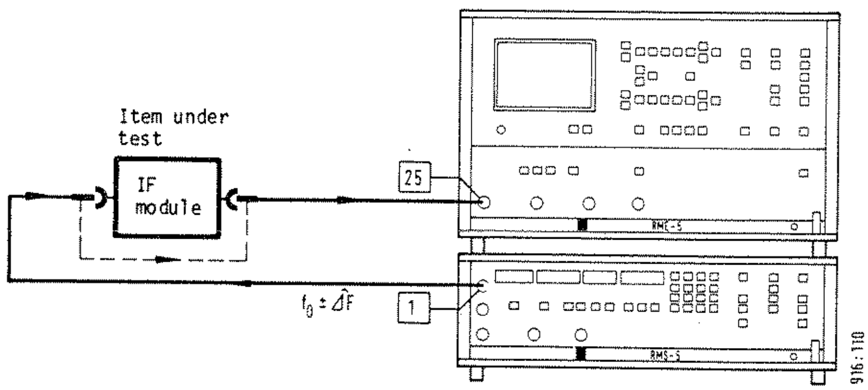


Figure 3-18 Eliminating the effects of test cables on the ΔP_I frequency response

3.7.3 CURVE DIFFERENCE (NORMALISER [12])

To eliminate intrinsic distortion from the results, or to align an item-under-test to a particular curve, a reference curve REF can be stored using the normaliser function using keypad [12]. In the latter case, the item-under-test is connected up and the stored curve can be subtracted from the measured curve A: DIFF = A - REF.

The reference curve is stored by pressing "STORE/REF", see example after figure 3-19a. When the REF curve has been transferred to the memory, the LED above "STORE/REF" flashes for a short period.

After the item-under-test has been connected to the test setup, the current curve A appears on the screen (see example after figure 3-19b). When the key "DISPL" is pressed (LED "DIFF" on), the difference curve appears on the screen and the text "DIFF" appears on the bottom line of the screen, see figure 3-19c. As the item-under-test is adjusted the variations in the parameter being measured are shown in the difference curve. This is very useful for alignment work.

When the reference curve is shown on the screen, the only front panel key functions to be enabled are [6] for the horizontal cursors and [5] noise averaging. The parameters that are valid for the reference curve are also transferred (measurement mode, measurement range). This prevents incorrect measurements.

The reference curve can be called up by pressing "DISPL" once more. "REF" appears in the bottom line of the screen. In this way, the three curves can be distinguished when they are listed - serial print out (video-printer).

When "OFF" is pressed, the current curve reappears on the screen.

The difference curve can also be formed for two sweep curves which are displayed simultaneously, if two reference curves are stored.

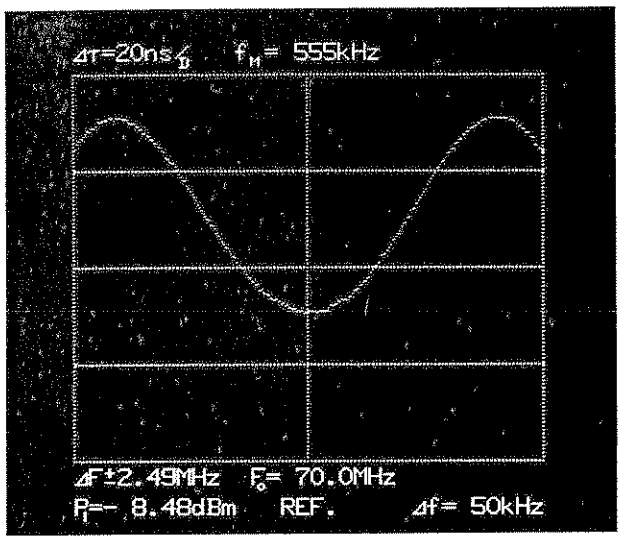


Figure 3-19a Stored reference curve REF (e.g. item under test 1)

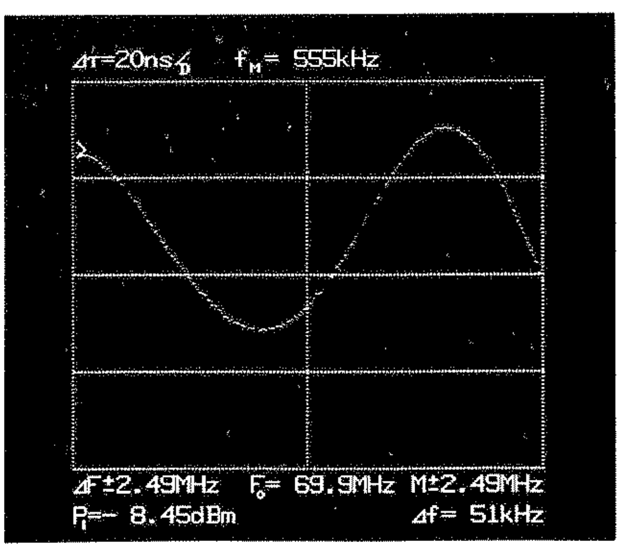
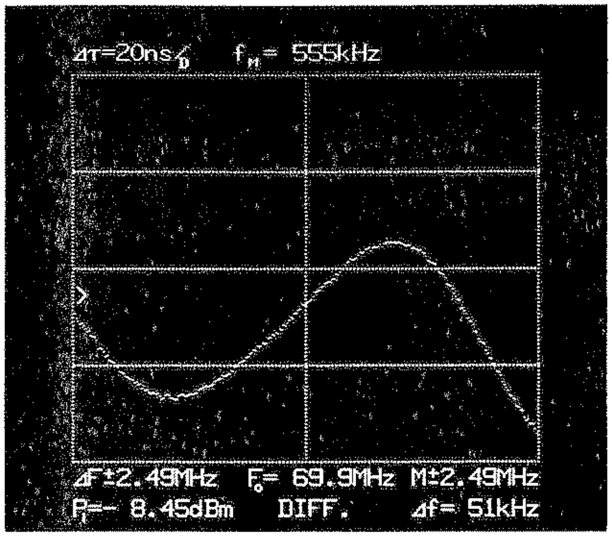


Figure 3-19b Current test curve A (e.g. item under test 2)



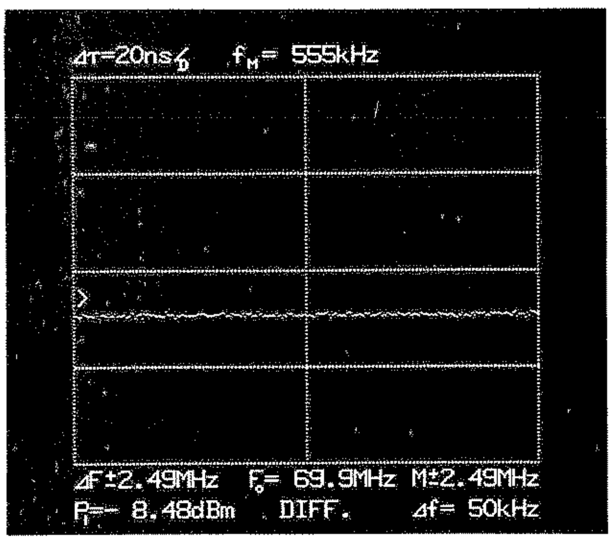


Figure 3-19c Difference curve "DIFF" (≅ "REF"-"A")
- Top: before alignment
- Bottom: after alignment (zero line coincides with the lowest point on the reference curve)

The following should be borne in mind when using the normaliser function:
- The digitisation range for the RME-5 comprises 256 amplitude steps in the y direction, of which only 205 are shown on the screen.
  To ensure that the difference curve will not go off the screen when the normaliser function is switched on, the most negative point of the reference curve should be moved as far as possible into the display range, before the reference curve is stored.
- The measurement range should be selected to leave as much room as possible above and below the curve in the digitisation range.
- The difference curve can be shifted with keys [1] or [9], this also means that the current curve is shifted. If the test curve goes outside the digitisation range, the difference curve will be absent at the appropriate points.

3.7.4 CURVE ANALYSIS "LIN"/"PARAB" [20]

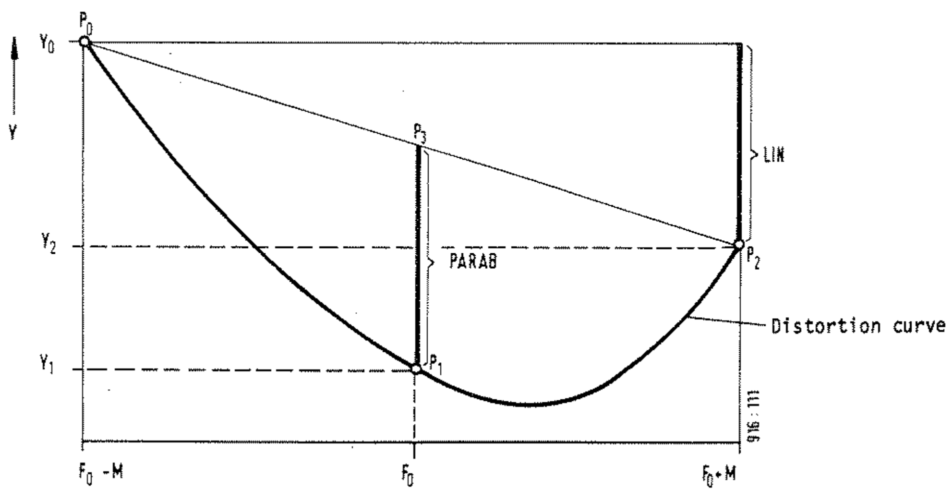
Important information is given by the separation of the maximum and minimum values on the sweep curve and also by the shape of the curve itself. The latter can be analysed fully by determining its frequency components, however this requires extensive calculations (see 3.7.5). A simplified method, which uses linear and parabolic components, is useful for alignment work; this method is described below.

INTELSAT uses this simplified method to adjust group delay pre-equalisers and it is described in SSOG (Satellite Systems Operating Guide).

The microprocessor analyses the curve by calculating the difference in the y-coordinates of the two end points (P_0, P_2) of the curve between the frequency markers M, see figure 3-20. This value is displayed as "L" on the screen. The μP also calculates the parab. component, i.e. the difference between the y coordinates (at F_0) of the chord joining the end points of the curve and the y coordinate of the curve at F_0. The parabolic component "P" is shown with the correct sign and correct scale on the screen, see figure 3-21. As the calculation is performed continuously, the values can be used to align equalisers.

To display "L" or "P": Press [20] "LIN/PARAB", LED on.

When key [20] has been pressed, the result you do not require can be erased from the screen using keypad [10], as curve analysis can only be performed on one sweep trace. It is possible to switch from keypad [2] to keypad [10].



$$LIN = Y_2 - Y_0 \quad \begin{cases} \text{positive if } Y_2 > Y_0 \\ \text{negative if } Y_2 < Y_0 \end{cases}$$

$$PARAB = \frac{Y_0 + Y_2}{2} - Y_1 \quad \begin{cases} \text{positive if parabola is concave} \\ \text{negative if parabola is convex} \end{cases}$$

Figure 3-20 Definition of LIN and PARAB components

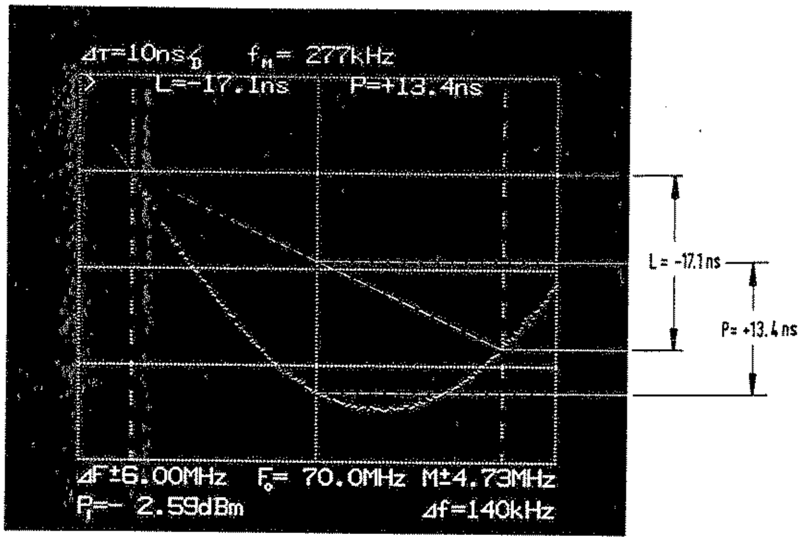


Figure 3-21 Numerical display showing the L and P components determined during a group delay measurement

3.7.5 NOISE CALCULATION (OPTION BN 917/00.11)

3.7.5.1 General remarks

Using the noise calculation option, it is possible to determine the components of intermodulation noise at the baseband of all common radio-link systems (see table 3-5), provided the intermodulation noise is caused on the transmission path between the IF ports. The calculation uses the results of $\Delta\varphi$ and $\Delta U/U_0$ measurements. Section 4.7 deals more fully with the basic theory and the limitations of this method.

The intermodulation noise is determined using three white noise test channels (CCIR 399) for conventional load, 3 dB overload and 6 dB overload. Noise is displayed in pWOp.

The RME-5 can be retrofitted with the noise calculation option. Refer to 5.5 for more information.

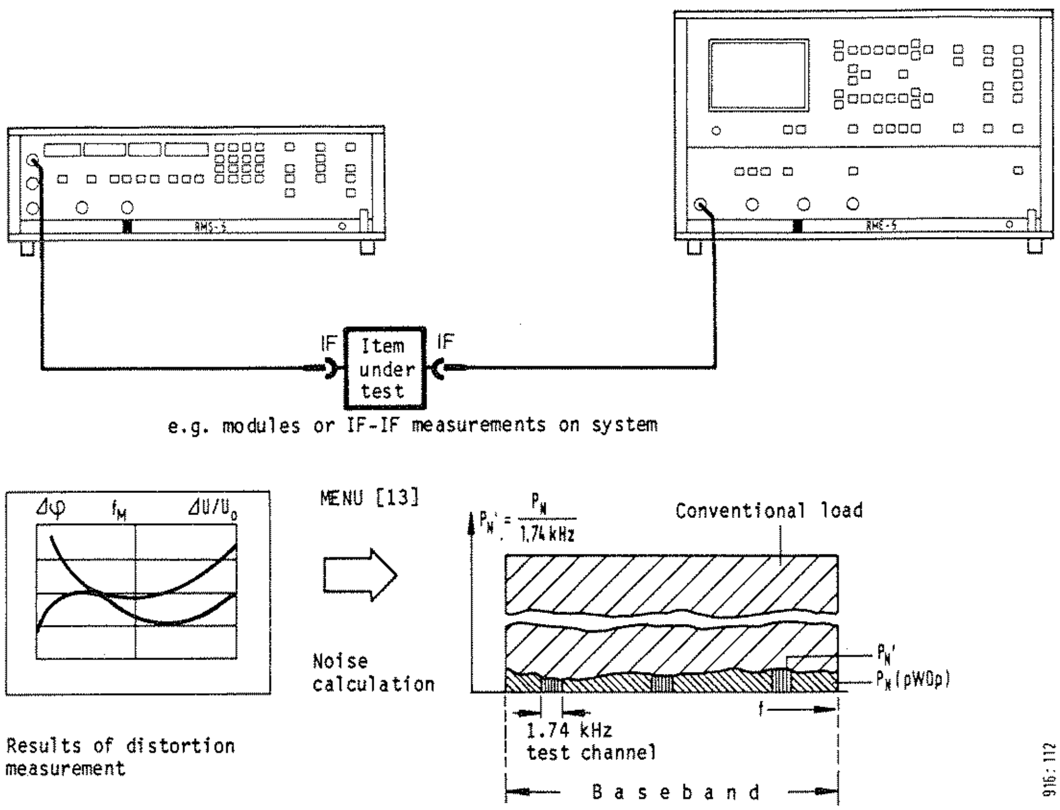


Figure 3-22 Calculating noise from the results of distortion measurements

3.7.5.2 List showing what radio-link systems can be tested with the RM-5 and the appropriate parameters

System		RMS-5 setting		RME-5:		Calculated noise for 3 baseband test channels		
No.[3]	No. of channels	sweep width $\hat{\Delta F}$[2] autom. sweep reduction on	Test frequency f_M[4]	Measurement mode: distortion	Nominal value of displayed sweep width $\hat{\Delta F}$[4]	f_1/kHz	f_2/kHz	f_3/kHz
1	300	± 4 MHz	2400 kHz 3580 kHz	differential phase $\Delta\varphi$ and differential gain $\Delta U/U_0$	± 1.6 MHz ± 0.4 MHz	270	534	1248
2	600	± 6 MHz	2400 kHz 3580 kHz		± 3.6 MHz ± 2.4 MHz	270	534	1248
3	960	± 9 MHz	2400 kHz 3580 kHz		± 6.6 MHz ± 5.4 MHz	534	1248	3886
4	1260	± 10 MHz	2400 kHz 3580 kHz		± 7.6 MHz ± 6.4 MHz	534	2438	5340
5	1500[1]	± 12 MHz	2400 kHz 3580 kHz		± 9.6 MHz ± 8.4 MHz	534	2438	5340
6	1800	± 13 MHz	2400 kHz 3580 kHz		± 10.6 MHz ± 9.4 MHz	534	3886	7600
7	2100[1]	± 15 MHz	5600 kHz 4430 kHz		± 9.4 MHz ± 10.6 MHz	534	3886	7600
8	2400[1]	± 17 MHz	5600 kHz 4430 kHz		± 11.4 MHz ± 12.6 MHz	534	3886	7600
9	2700	± 18 MHz	5600 kHz 4430 kHz		± 12.4 MHz ± 13.6 MHz	534	5340	11700

1) US systems, all other systems to CCIR 399-3
2) The given sweep width is the setting value for ± $\hat{\Delta F}$, which equals the range scanned.
3) The digit is used to identify the system, when noise calculation is remote-controlled via the IEC bus.
4) If the RM-5 has the high test frequencies.
Software is available for the following test frequency combinations:
- Standard version: 2.4 MHz and 5.6 MHz
- Special version 1: 2.4 MHz and 4.43 MHz (TV)
- Special version 2: 3.58 MHz (TV) and 5.6 MHz
- Special version 3: 3.58 MHz (TV) and 4.43 MHz (TV)

Table 3-5 Radio-link systems on which tests can be performed

3.7.5.3 Menu operation (RME-5)

The noise calculation option is operated by means of a menu which is displayed on the screen. The menu is called up with keypad [13]. The 1st page of the menu is a list containing all the types of radio-link system on which tests can be made, as well as instructions on setting the RME-5 and the RMS-5. The following page contains the results of the noise calculation and the components (1st to 4th order) obtained from an analysis of the sweep curve. This page also lists the appropriate setting parameter so that all the relevant parameters can be checked at a glance (listing).

Before starting the noise calculation procedure, make sure that the results for the $\Delta\varphi$ and $\Delta U/U_0$ measurements are displayed properly on the screen (in the digitisation range). If necessary, use keys [1] or [9] to shift the curve vertically, or change the measurement range, cf figure 3-23a.

Example shown in figure 3-23a:

* Press MENU (LED on) — ● Menu as shown in figure 3-23b appears on the screen

* Select required system with CURSOR keys "⇧" or "⇩": corresponds to marking ■ — ● 1800 channel system

* RMS-5 settings
  - f_M
  - $\hat{\Delta F} = (\hat{\Delta F}_{RED} + f_M)$
  - Automatic sweep width reduction on

  ● f_M = 2.4 MHz
  $\hat{\Delta F}$ = 10.6 + 2.4 MHz = 13 MHz!
  These parameters must be used for selected system.

* Start noise calculation
  Press RUN/STOP (LED on)

  ● The following appears on the screen:
  - NOISE CALCULATION RESULTS
  - BUSY (approx. 3 s)
  - Results, see figure 3-23c

The intermodulation noise in the three slots is shown for the appropriate loadings (range 0 to 99999 pWOp).

* Return to normal display
  Press RUN/STOP (LED off)

* If RUN/STOP is pressed again, you can branch directly via the menu into the noise calculation routine. This makes alignment easy (distortion alignment ⟶ subsequent noise check).

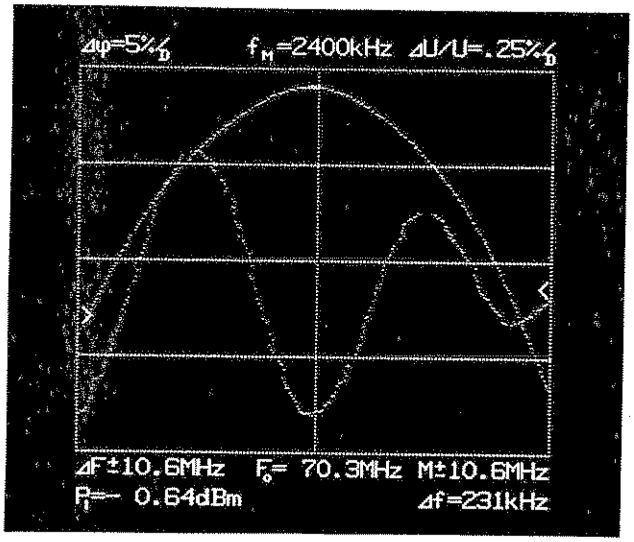


Figure 3-23a Example showing the results from an IF distortion measurement

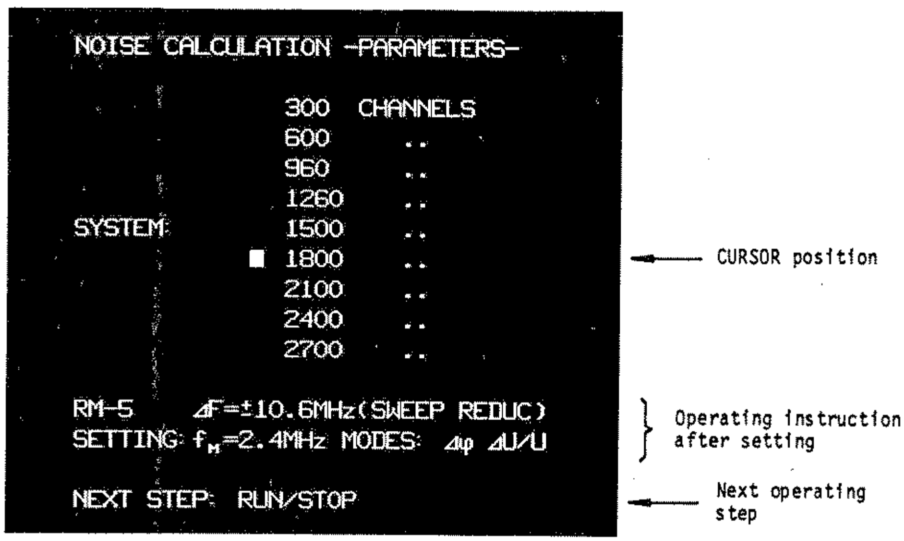


Figure 3-23b Menu: list of systems on which tests may be made (no. channels)

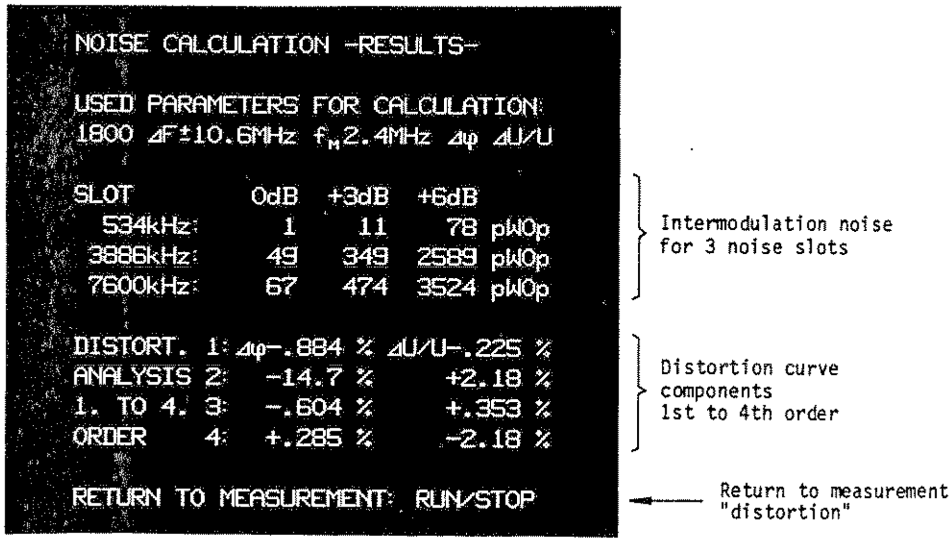


Figure 3-23c Results of noise calculation (derived from distortion curve in figure 3-23a)

N.B.: - If the settings on the RMS-5 (f_M, $\hat{\Delta F}_{RED}$) or on the RME-5 ($\Delta\varphi$, $\Delta U/U_o$) are wrong, the error message "WARNING IMPROPER PARAM. SETTING" is displayed on the screen (the incorrect parameter flashes). The results for the noise calculation are not displayed. Check the settings and make suitable corrections by leaving the noise routine and returning to the normal display. Press RUN/STOP (LED off).
After the correction has been made, you can restart the noise calculation routine directly by pressing RUN/STOP (LED on).

- On the other hand, the results of a distortion measurement are shown whether or not the appropriate parameters have been entered. It is therefore possible to perform curve analysis at any sweep width, provided it is not larger than the test frequency. This means that the RM-5 can be used on digital radio-link systems where the calculation of intermodulation noise is not important.

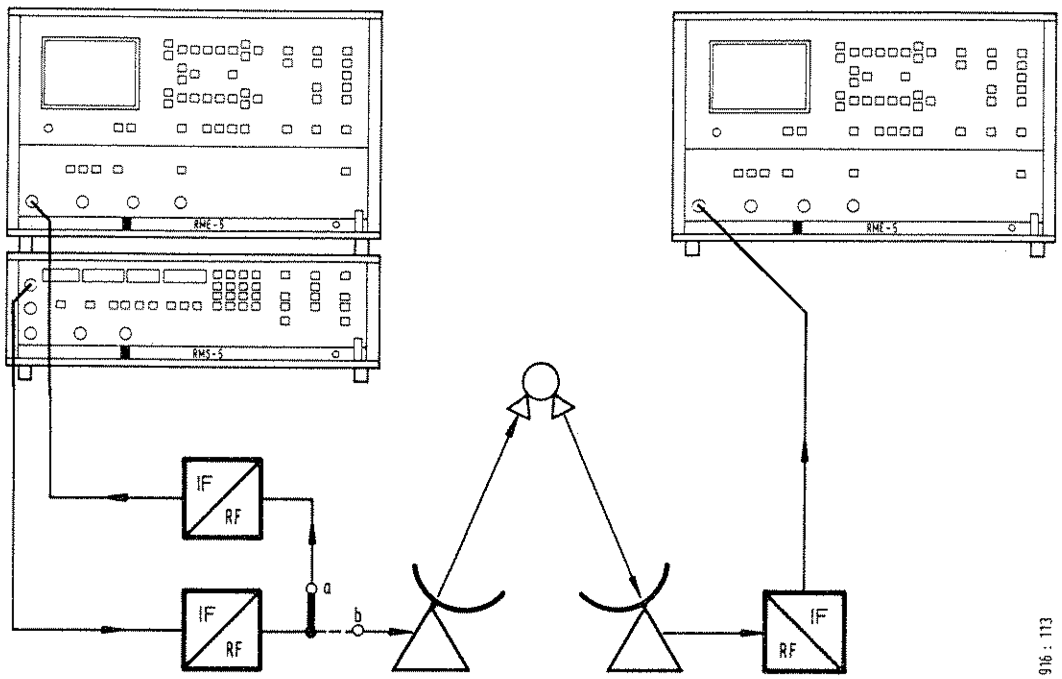
3.7.6 INTELSAT TOLERANCE MASKS (OPTION BN 917/00.12)

3.7.6.1 General comments

The limits for distortion occuring in satellite systems are laid down in SSOG (Satellite Systems Operation Guide). When systems of this kind are lined up, IF-IF group delay (ΔT) and IF-IF frequency response (ΔP_I) i.a. must be measured for the various carrier sizes.

The RME-5 has a facility (option BN 917/00.12) for displaying tolerance masks and the results of the distortion measurements simultaneously. This means that when alignment work is being done the effect that varying ΔT has on ΔP_I can be seen at a glance. Tolerance masks for all carrier bandwidths[1] from 1.25 MHz (12 channels) to 36 MHz (1872 channels) and for two TV systems with carrier bandwidths of 17.5 MHz and 30 MHz are available. It is also possible to call up tolerance masks for TDMA operation (earth station response limits, SSOG vol. 3). As well as selecting the system, the type of signal path must also be specified, i.e. end-to-end measurement or an in-station-measurement, see figure 3-24. Instructions on setting the RM-5 and how to proceed during the measurement appear on the screen of the RM-5.

The INTELSAT tolerance mask option (board to be plugged into the back panel of the RME-5) can be fitted instead of the noise calculation option. See 5.5 for more information.



Signal path a: TRANSMIT FREQUENCY RESPONSE (in-station-measurement)
Signal path b: IF-IF-FREQUENCY RESPONSE (end-to-end measurement via satellite)

Figure 3-24 Line-up signal paths

1) The carrier bandwidth is equal to the bandwidth of the IF filter. The sweep width ΔF is smaller than the BW.

3.7.6.2 Tolerance mask types

The following figures show the general format of the INTELSAT tolerance masks. The appropriate dB, ns and MHz values are given in table 3-6 for the carrier bandwidth BW. There are two sets of values, one for transmit mode and one for IF-IF mode.

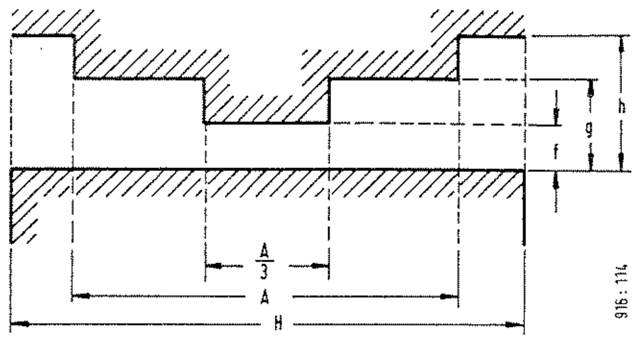


Figure 3-25 IF-IF group delay tolerance mask (ΔT)

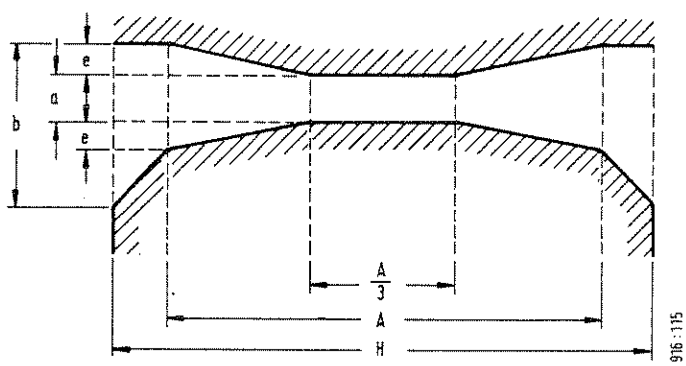


Figure 3-26 IF-IF frequency response (ΔP_I)

No.[1]	Tolerance mask Carrier size MHz	Type[3]	B[4] MHz	$\Delta\hat{F}$[5] MHz	H MHz	A MHz	A/3 MHz	Group delay ΔT f ns	g ns	h ns	Meas. range ns/D	Amplitude ΔP_I a dB	e dB	b dB	Meas. range dB/D	Test frequency
01 21	1.25	TR IF	1.13	± 0.57	1.13	0.9	0.3	24 48	24 48	30 60	20 50	0.7 1.4	0 0	1.5 3.0	1 2	f_M = 55.5 kHz
02 22	2.5	TR IF	2.25	± 1.13	2.1	1.8	0.6	16 32	16 32	20 40	25 50	0.7 1.4	0 0	1.5 3.0	1 2	f_M = 93 kHz
03 23	5.0	TR IF	4.50	± 2.25	4.1	3.6	1.2	12 24	12 24	20 40	10 20	0.5 1.0	0 0	2.0 4.0	1 2	
04 24	7.5	TR IF	6.75	± 3.38	6.2	5.4	1.8	12 24	12 24	20 40	10 20	0.4 0.8	0 0	2.5 5.0	1 2[2]	
05 25	10.0	TR IF	9.00	± 4.50	8.3	7.2	2.4	9 18	9 18	18 36	10 20	0.3 0.6	0.1 0.2	2.5 5.0	1 2[2]	
06 26	15.0	TR IF	13.50	± 6.75	12.4	10.8	3.6	6 12	6 12	15 30	10 20	0.3 0.6	0.1 0.2	2.5 5.0	1 2[2]	
07 27	17.5	TR IF	15.75	± 7.88	14.2	12.6	4.2	6 12	6 12	15 30	10 20	0.3 0.6	0.1 0.2	2.5 5.0	1 2[2]	
08 28	20.0	TR IF	18.00	± 9.00	16.6	14.4	4.8	4 8	5 10	15 30	10 20	0.3 0.6	0.1 0.2	2.5 5.0	1 2[2]	f_M = 277.7 kHz
09 29	25.0	TR IF	22.50	± 11.3	20.7	18.0	6.0	3 6	5 10	15 30	10 20	0.3 0.6	0.2 0.4	2.5 5.0	1 2[2]	
10 30	36.0 +	TR IF	32.4	± 16.2	29.9	25.9	8.63	3 6	5 10	15 30	10 20	0.6 1.2	0.3 0.6	2.5 5.0	1 2[2]	
11 31	36.0 ++	TR IF	36.00	± 18.0	33.1	28.8	9.6	3 6	5 10	15 30	10 20	0.6 1.2	0.3 0.6	2.5 5.0	1 2[2]	
12 32	Video *	TR IF	15.75	± 7.88	14.2	12.6	4.2	6 8.4	6 8.4	15 21	10 20	0.3 0.6	0.1 0.2	2.5 5.0	1 2[2]	
13 33	Video **	TR IF	30.00	± 15.0	30.0	24.0	8.0	5 7	5 7	15 21	10 20	0.5 0.7	0.3 0.4	2.5 3.5	1 2[2]	
14	80	TDMA	-	± 36.0	-	-	-	-	3 to ± 30 MHz	8 to ± 36 MHz	4	0.5 to ± 24 MHz	-	1.0 to ± 36 MHz	1	

1) This digit indicates the carrier size when the INTELSAT tolerance mask is remote-controlled via the IEC bus.
2) The tolerance mask has been altered to obtain the appropriate resolution (2 dB instead of 2.5 dB, 4 dB instead of 5 dB).
3) TR: Transmit frequency response (in-station test), IF: IF-IF frequency response
4) B: Bandwidth of the wanted IF signal
5) $\Delta\hat{F}$: RMS-5 sweep width

Table 3-6 INTELSAT tolerance masks to SSOG

3.7.6.3 Using the menu (RME-5)

The tolerance masks are selected using a special menu, which is called up by means of keypad [13].

* Press MENU (LED on)
  - ● The menu, as shown in figure 3-27a, appears on the screen.
* Select the appropriate carrier bandwidth with CURSOR keys "⇧" or "⇩", corresponds to marking ■
  - ● In example: 2.5 MHz
* Press ENTER[1)]
  - ● The menu, as shown in figure 3-27b, is displayed on the screen
* Select transmit mode or IF-IF mode using the CURSOR keys "⇧" or "⇩"; corresponds to marking ■
* Set RMS-5 to the appropriate values: f_M, ΔF
  - ● In the example: f_M = 92.6 kHz, ΔF = ± 1.13 MHz
* Press RUN/STOP (LED on)
  - ● Tolerance masks are displayed as shown in figure 3-27c
* Shift the $\Delta\tau$ curve using the keys marked with [1] until it lies in the upper part of the tolerance mask

  Shift the ΔP_I curve using the keys marked [9] until it lies in the lower part of the tolerance mask

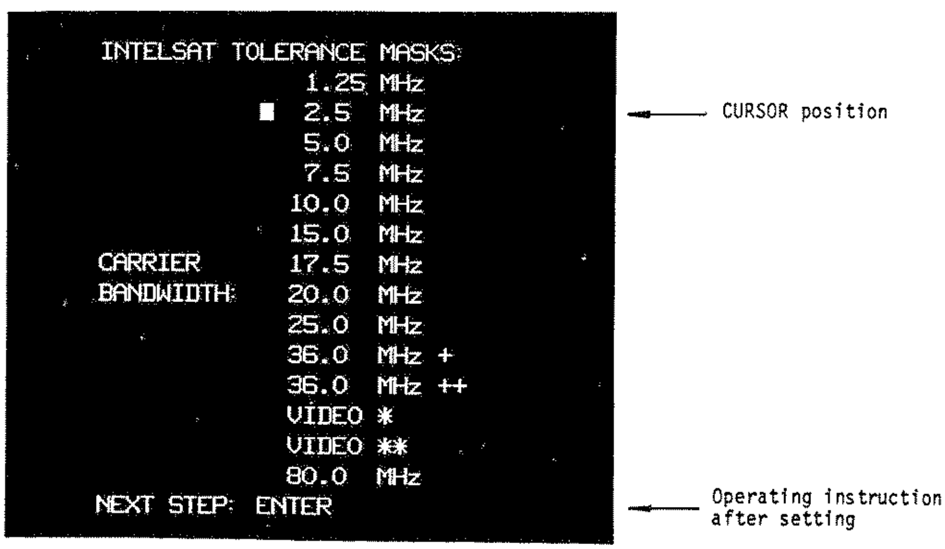


Figure 3-27a Menu: list of carrier bandwidths

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1) If a bandwidth of 80 MHz has been selected (TDMA), the operator is not prompted to press the enter key after the appearance of the 1st menu, because it is not possible to make a choice between TR mode and IF-IF mode. The parameters to be set on the RMS-5 (f_M and ΔF) are shown on the tolerance mask; the measurement ranges on the RME-5 are selected automatically.

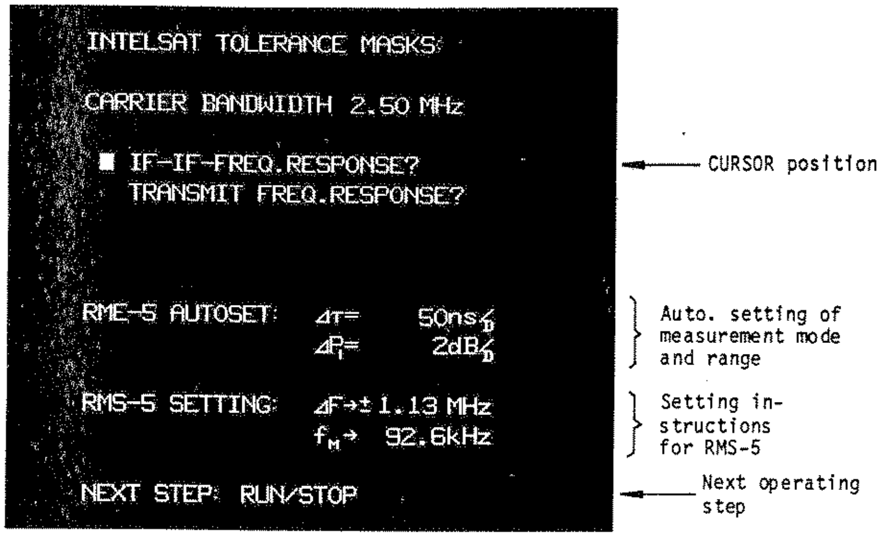


Figure 3-27b Menu: setting list

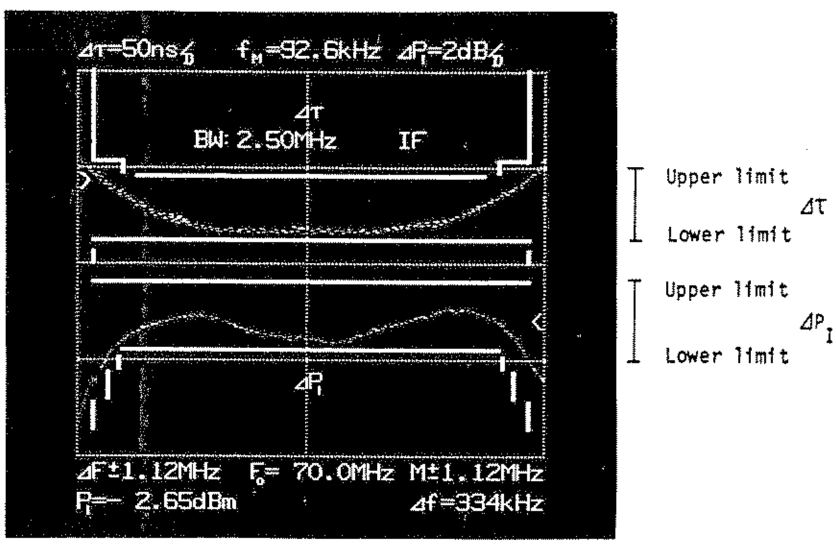


Figure 3-27c INTELSAT tolerance masks for a carrier bandwidth of 2.5 MHz

3.8 LISTING THE RESULTS

3.8.1 VIDEO PRINTOUT/MONITOR DISPLAY

The RME-5 monitor, which operates on the video principle, allows you to obtain a display with a larger format via the video-output [42] and also allows you to print out the information displayed on the screen on a video-plotter. The printout, which contains all essential parameters, is an accurate and easy-to-read result protocol.

The video printer or the external monitor is connected by means of a coaxial cable with BNC connectors to [42] on the back panel of the RME-5. The printer can be operated at considerable distances from the RME-5. The video-signal is always present at the output; the print procedure is started using the printer controls.

When the screen contents are being printed out, the display must not change. The RME-5 should not be adjusted. It is a good idea to freeze the screen contents during printout by using the START/STOP key function [2] (or [10] on the RME-5).

Video-output

For connecting a video-printer or an external monitor

Connector	:	BNC
Output impedance	:	75 Ω
Output signal	:	Video/positive/625 lines
Output voltage at $Z_{out} = Z_{in}$	:	V_{p-p} (BAS) = 1 V

3.8.2 XY PLOTTER (OPTION BN 917/00.01)

Instead of printing out everything on the screen, it is also possible to print out the sweep traces on their own using an XY plotter. Any standard XY plotter can be connected via the XY plotter interface. The RME-5 can be retrofitted with the plotter interface at any time. See 5.5 for more information.

Before fitting the XY plotter interface into the back of the RME-5 (see 3-4b), the sensitivity of the outputs should be adjusted so that they are the same as those of the plotter. Two values can be set using switch S 1 - see figure 3-28 for settings.

S 1/1 and S 1/2 open:	0.4 V/cm
S 1/1 and S 1/2 closed:	0.1 V/cm

There is also the possibility of inverting the polarity of the pen lift function by means of the pen-lift link. When the plotter board leaves the factory, link b-c is fitted, see figure 3-28.

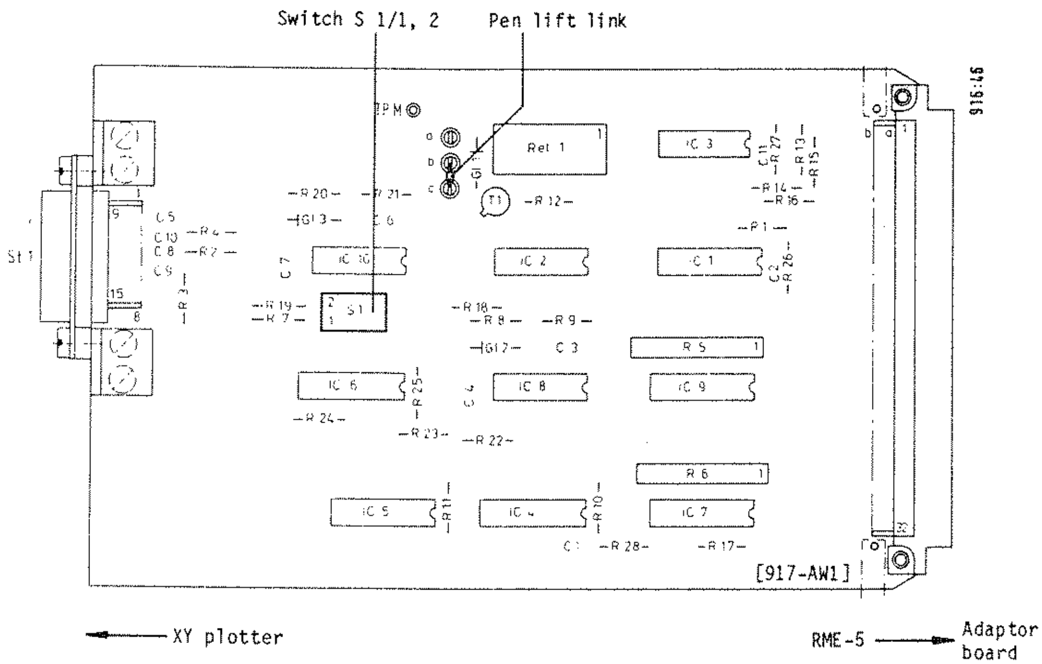
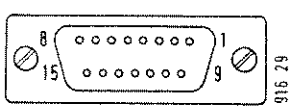


Figure 3-28 XY plotter board with switch S 1/1, 2, and pen lift link

The supplied cable K 379 should be connected to the XY plotter interface connector. The other end of the cable should be connected to the remote control connector of the plotter - see table 3-7.



View onto pins

XY plotter interface connector pins for cable K 379

Connector pins	Function	Cable colours	Connection point at the plotter[1]
1	Ground	Screen	
2	Output "+X"	Grey	....
3	Output "-X"	White	....
4	Output "+Y"	Green	....
5	Output "-Y"	Yellow	....
6	Pen-lift	Brown	....
7	Pen-lift	Red	....
8	Ground	Screen	
9	Ground	Screen	
10 ⋮ 15	Not used		

Table 3-7 Pin assignments for the plotter interface output

1) To be entered by customer

Special forms are available for recording sweep results. There is room at the top of the form for all important parameters; plotter protocol BN 917/00.79.

The x and y sensitivity of the plotter must be set. The pen should be placed on the zero point on the form; see figure 3-29.

Sweeps Y1 or Y2 are recorded by pressing the START/STOP key (LED on) in the appropriate row. If there are two traces on the screen and START/STOP [2] is pressed (LED on) the curve (including cursors etc., see figure 3-30) is drawn on the left of the form. After 20 s, the time taken to draw the curve etc., the pen returns to the zero point.

When START/STOP [10] is pressed (LED on) the second trace is drawn on the right of the form.

It is, of course, possible to reverse the position of the traces on the form.

The plot can be interrupted at any time by pressing the appropriate START/STOP key (LED off), the pen returns to the zero point.

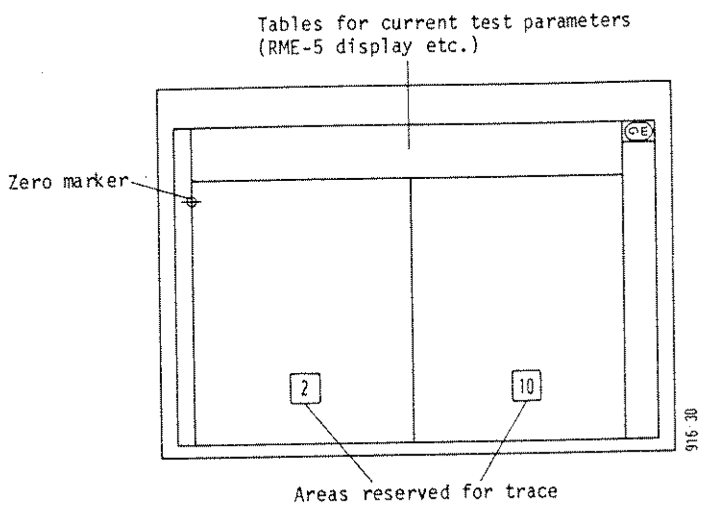
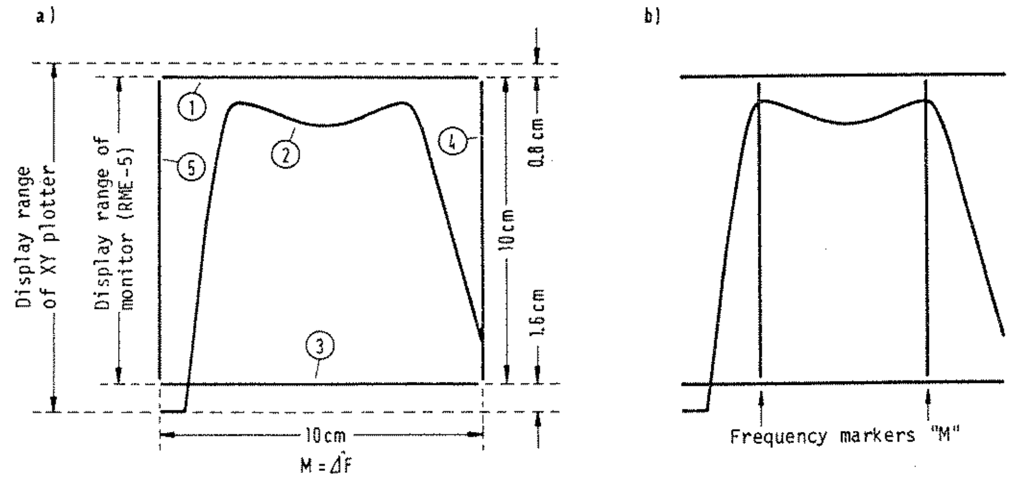


Figure 3-29 Result form (DIN A4) with two areas for traces, BN 917/00.79

The speed of the plotter can be increased by up to x 4 by using up/down key "⇧" [5]. The appropriate speed should be chosen to match the ripple on the trace. The speed should be chosen to match the ripple on the trace. The speed can be reduced by pressing "⇩" [5].

Figure 3-30 shows a trace displayed by the RME-5 and the cursors etc. that can be displayed with the plotter interface.



① to ⑤ Recording sequence

Figure 3-30 a) XY plotter printout; dimensions, format
b) Listing after a) with frequency markers

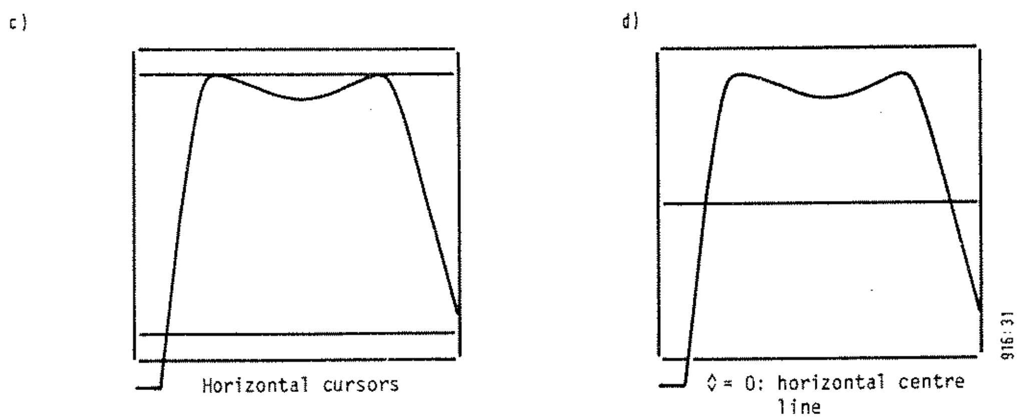


Figure 3-30 c) Listing after a) with cursors (M = ΔF)
d) Listing after c) with " ◊ = 0"

3.9 APPLICATIONS FOR THE RM-5

The type of item to be tested is used as a basis for describing the various measurement modes, so giving the description a practical value. This may mean that some measurement modes are referred to more than once, however details will only be given when the measurement mode is described for the first time. Later only new aspects are mentioned and a reference to the detailled description is given.

There are three basic applications for the RM-5:

- In-service measurements on radio-links performed by system manufacturers or system operators at installation or for maintenance purposes.
- Testing radio-link or satellite system modules in the lab or test dept.
- Satellite system measurements.

BB-BB, IF-IF and BB-IF, IF-BB measurements can be made. The IF of the item-under-test can be 35, 70 or 140 MHz[1)]; other values are also possible, see 3.5.2.3.

3.9.1 END-TO-END MEASUREMENTS ON RADIO-LINKS (BB-BB)

Terminal stations of radio-links are the ends of a modulation section, which consists of several radio-links and relay stations. The baseband (BB) signal supplied by the FDM multiplex device is converted in the radio-link terminal station into a frequency modulated IF signal. For transmission via a radio-link antenna, further conversion to the radio-frequency (RF) level is necessary. At the opposite end, the signal is converted back to the BB level.

The most important measurements which are carried out between radio-link terminal stations are:

- Measurement of group delay and linear distortion ΔT and $\Delta U/U_0$ (measurement frequencies $f_M < 1$ MHz),
- Measurement of differential phase and gain $\Delta\varphi$ and $\Delta U/U_0$ (measurement frequencies ≥ 1 MHz).
- Measuring the variation of attentuation of BB signals.
- Measuring the basic and intermodulation noise.

The RM-5 is ideal for the first two measurements, however to perform the last two measurements with the RM-5 you require the wideband option, and a sweep test setup (e.g. RK-50 or RK-25 from W&G).

1) IFs of 35 MHz and 140 MHz as option

3.9.1.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$, and $\Delta U/U_0$

Test setup:

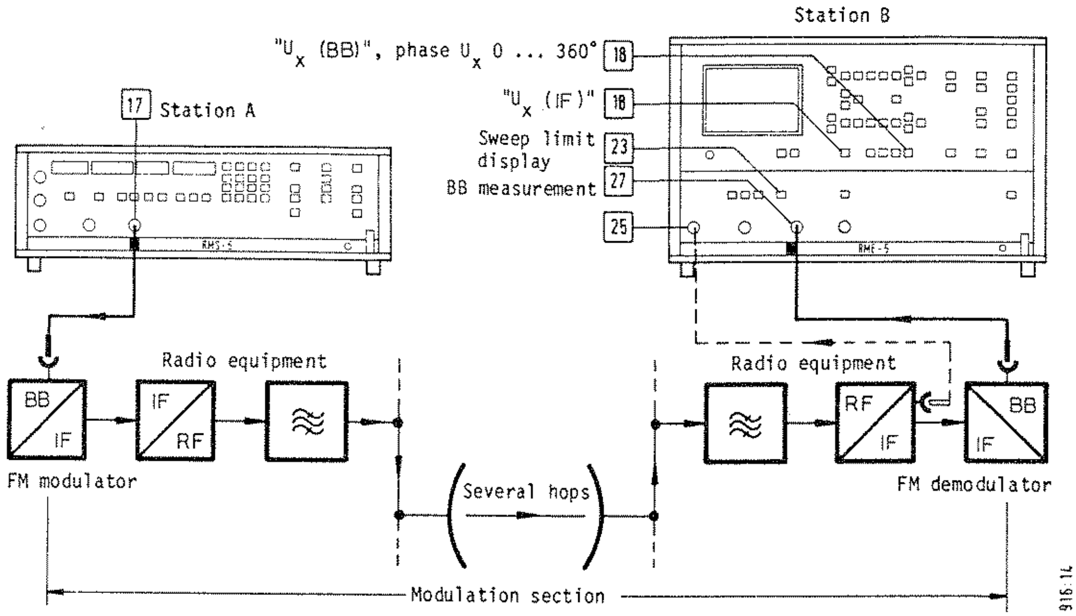


Figure 3-31 Distortion measurements between radio link terminal stations (BB-BB)

Set the test voltage (key U_M [13]) and the sweep voltage (key $\hat{U}_A$ [10]) on the RMS-5 generator section in station A using the numerical keypad [2].

As a rule, the procedures and settings for testing radio-link systems are prescribed by various organisations so that results are comparable.

If there is no appropriate test procedure, there are two ways of proceeding:

- The receive section of the RME-5 is in station A and is connected to the IF test-port at the system modulator output so that the sweep width can be displayed on the screen. At the lowest test frequency or when the automatic sweep width reduction facility is switched off, set the sweep width as shown in table 3-8 by varying the sweep voltage output by the RMS-5.
- There is no RME-5 in station A; see figure 3-31 for test setup. The sweep voltage to be set, $\hat{U}_A$, can be calculated from the following formula:

  $$\hat{U}_A = \frac{\Delta\hat{F}}{\Delta f_n} \times 274 \text{ mV} \times 10^{(p_Q' + a_p)/20}$$

  Where:

  $\Delta\hat{F}$ = Peak value of IF sweep width (= IF transmisson band).

  Δf_n = rms value channel frequency deviation at neutral frequency f_n.

  p_Q' = Power level at modulator input Q', which causes an rms channel frequency deviation Δf_n; in an 1800 channel system, for example, a level of -40 dBm at point Q' with the relative level -40 dBr results in an rms deviation Δf_n of 140 kHz at the neutral frequency f_n = 4988 kHz.

  a_p = Preemphasis attenuation at sweep frequency f_A; in the case of preemphasis networks for voice grade channels, a_p = 4 dB.

Table 3-8 shows values for $\hat{U}_A$ that are likely to occur in practice.

The magnitude of the test voltage depends generally on the rms channel frequency deviation Δf. A satisfactory result is achieved if - starting at a small value - the test voltage is increased until the result no longer appears noisy. If the test voltage is too large, the fine structure of the result will be lost.

Radio-link system	Relative level at point Q'	P_Q'	Δf_n	$\hat{\Delta F}$	$\hat{U}_A$
960 channels	-48 dBr	-48 dBm	200 kHz	± 12 MHz	0.104 V
1800 channels	-40 dBr	-40 dBm	140 kHz	± 12 MHz	0.372 V
2700 channels	-40 dBr	-40 dBm	140 kHz	± 18 MHz	0.558 V

Table 3-8 Values for determining the sweep voltage $\hat{U}_A$ for three standard radio-link systems

Evaluation of the results at station B is carried out either on the monitor of the RME-5 (simultaneous display of $\Delta U/U_0$ and $\Delta \tau$ or $\Delta \varphi$!) or externally by a computer (IEC Bus). The results can be logged with the aid of a video plotter.
If you make a connection between the decoupled IF test port before the demodulator input in station B and the P_I input [25] on the RME-5, as shown by the dotted line in figure 3-31, the sweep width $\hat{\Delta F}$, the IF-level P_I and the frequency markers can be shown on the screen if U_x(IF) [18] has been pressed. The LED above the BB key [23] is on and shows that a BB measurement is being made.

Another case where the auxiliary IF signal has to be connected is where the system demodulator blocks the sweep frequency required for recovery of the deflection voltage U_x. In this case, press pushbutton "U_x (IF)" [18] (LED on) and correct the phase of the deflection signal - the RMS-5 to remove the 180° phase uncertainty (see section 3.6.2.3).

3.9.2 END-TO-END MEASUREMENTS BETWEEN REPEATER STATIONS (IF-IF)

To detect faults, BB-BB measurements over a modulation section must be made as a series of separate measurements. Relay station to relay station measurements via a radio-link are very important.

As a rule only the IF ports are accessible in relay-stations, i.e. the test signal passes from the IF input of the transmitter to the IF output of the receiver in the next station.

The RMS-5 outputs a swept, FM IF signal (test signal) which is received and processed by the RME-5. The various types of measurement are described in the following sections.

3.9.2.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

Test setup:

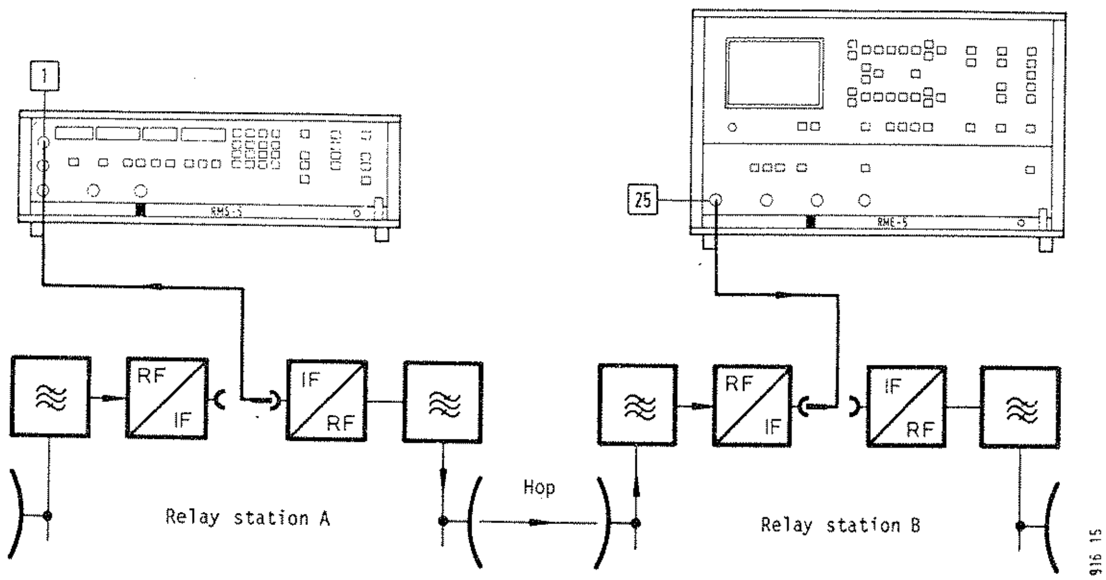


Figure 3-32 Repeater to repeater distortion measurements (IF-IF)

RMS-5 settings (entry via [2]):

[8] "P_{IF}" : Nominal system value for U_{IF} = 300 mV ≅ 0.8 dBm
[9] "IF_{CENT}" : IF centre frequency
[5] "SWEEP REDUC" : Automatic sweep reduction on (at f_M > 1 MHz)
[13] "Δf" : Test tone deviation is the same as the rms channel or set frequency deviation to such a high value that result displayed on the RME-5 no longer appears to be noisy (limit: when the fine structure of the result is lost).
[10] "$\hat{\Delta F}$" : Sweep width $\hat{\Delta F}$, set to value appropriate for the system
[4] "f_M" : Test frequency as laid lown in the test procedure
[14] "f_A" : Sweep frequency as laid down in the test procedure

System	IF_{CENT}	RMS channel frequency deviation Δf	Sweep width $\hat{\Delta F}$
960 channels	70 MHz	200 kHz	± 12 MHz
1800 channels	70 MHz	140 kHz	± 12 MHz
2700 channels	140 MHz	140 kHz	± 18 MHz

Table 3-9 Values for common systems

RME-5 key functions

[22] : IF measurement
[21] : IF same as RMS-5

The results are shown on the screen of the RME-5 (simultaneous display of $\Delta U/U_0$ and $\Delta\tau$ or $\Delta\varphi$!) or the results can be sent to a computer via an IEC bus for further processing.

N.B.: The results of the distortion measurements can be sent back to the transmit-side relay station (cf 3.9.3).

3.9.2.2 IF-IF frequency response ΔP_I

The IF-IF frequency response of the swept IF carrier can be measured using the setup shown in figure 3-32, assuming that there are no limiters in the system which would flatten the frequency response.

So that the sweep signal $\hat{U}_A$ covers the whole IF range either switch off the automatic sweep reduction facility, or at least use a low test frequency (the latter possibility lets you display the results for $\Delta\tau$ and ΔP_I measurements simultaneously). Except for P_I below [2] or [10] all the other settings are the same as those given for the distortion measurement in 3.9.2.1. See the frequency response correction facility described in 3.7.2.

3.9.2.3 White noise measurements using the RM-5's wideband device

As an alternative to calculating the noise from the results for $\Delta\varphi$ and $\Delta U/U_o$ (distortion measurements) using the RM-5 and the noise calculation option (cf 3.7.5), it is also possible to measure noise using a white noise measuring setup as shown in figure 3-33. The wideband device is essential for this measurement. On the transmit-side it comprises the RMS-5 and wideband modulator, on the receive-side there is the separate RMED-5 wideband demodulator.

Before the noise signal reaches the modulator input [16] of the RMS-5 - OPT. [18] must be on - it is passed through a preemphasis network so that the S/N ratio will be approx. constant over the whole frequency range of the wideband signal after demodulation. After demodulation in the RMED-5, the signal should be passed through a deemphasis network[1].

RME-5 settings (keypad entry via [2]):

[8] "P_{IF}"	: Nominal system value for U_{IF} = 300 mV ≙ +0.8 dBm
[9] "IF_{CENT}"	: IF centre frequency
[18] "OPT."	: Wideband modulator on (sweep mode is off; sweep width and test tone deviation display are disabled)

RMED-5 settings:

[2] : Centre frequency 70 MHz (key up) or 140 MHz (key down)

See figure 3-52 (table 3-12) for a description of the RMED-5's controls and displays.
Figure 3-34 gives the settings for the white noise measuring setup.

The values in figure 3-29 are based on the following considerations:

To obtain a certain rms channel frequency deviation of Δf_n at the neutral frequency f_n, and assuming that the sensitivity of the modulator is known, a voltage V_{rms} must be applied at the input of the modulator.

$$V_{rms} = \frac{\Delta f_n}{S_{Mod}}$$, this corresponds to a power level into 75 Ω

$$p = 20 \log \frac{V_{rms}}{274\ mV}.$$

The resulting power level is the same as the relative level at the modulator input $p = p_r$.

1) Preemphasis and deemphasis networks for all common CF and TV systems can be delivered as test accessories.

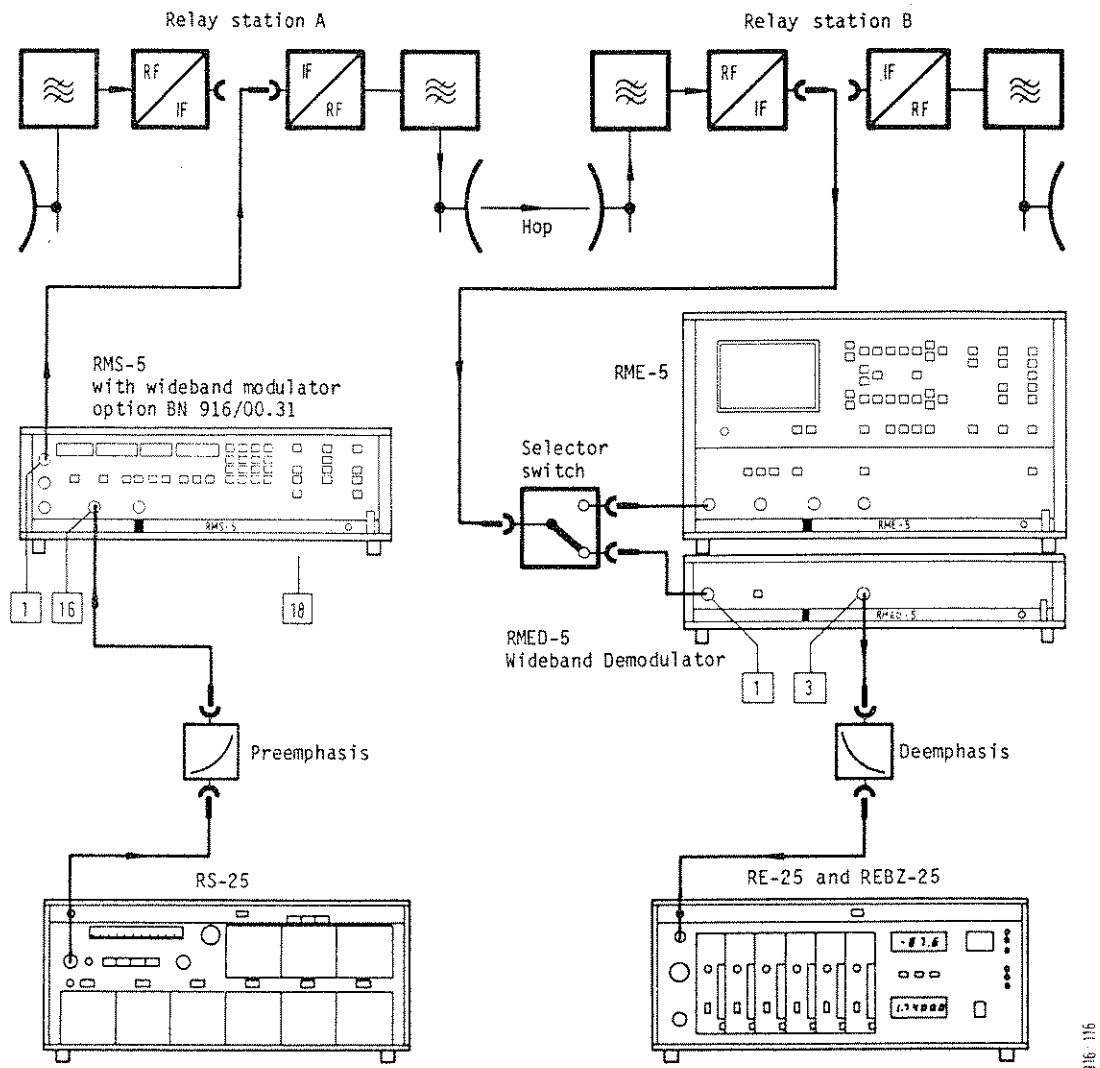
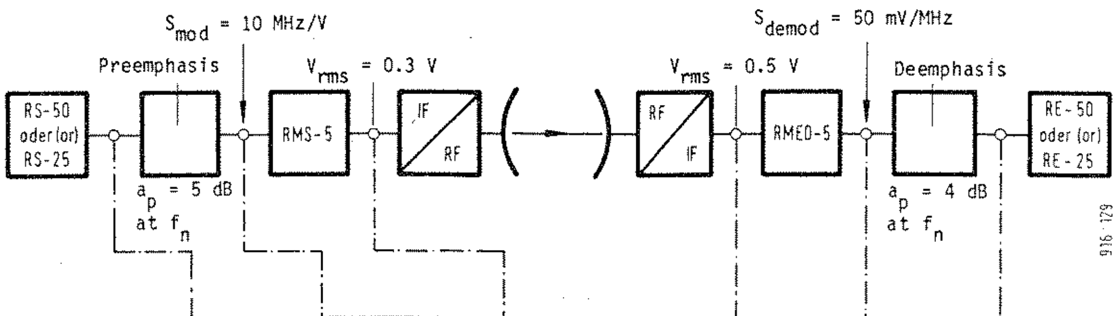


Figure 3-33 Test setup for white noise measurements between relay stations (IF-IF) using the RK-25 by W&G



System	Relative level p_r'	Relative level p_r	RMS channel freq. deviation Δf_n at neutral frequency f_n	Relative level p_r	Relative level p_r'
960 channels	-17.7 dBr	-22.7 dBr	200 kHz	-28.7 dBr	-32.7 dBr
1800 channels	-20.8 dBr	-25.8 dBr	140 kHz	-31.8 dBr	-35.8 dBr
2700 channels	-20.8 dBr	-25.8 dBr	140 kHz	-31.8 dBr	-35.8 dBr
					RE-50, RE-25 settings

System	Norm. conventional load $p^*_{\Sigma,c}$	Conventional load total level at input	Total rms deviation $\Delta f_\Sigma = 10^{p^*_{\Sigma,c}/20} \times \Delta f_n$	Conventional load total level at output
960 channels	+14.8 dBm0	-2.9 dBm	1.099 MHz	-17.9 dBm
1800 channels	+17.6 dBm0	-3.2 dBm	1.062 MHz	-18.2 dBm
2700 channels	+19.3 dBm0	-1.5 dBm	1.292 MHz	-16.5 dBm
		Set on RS-50, RS-25		Measure with REBZ-25

Figure 3-34 Settings for white noise measurements between relay stations (IF-IF)

At the neutral frequency, the preemphasis network attenuates the signal by a_p. Therefore the relative level which has to be taken into account when the noise level is set is

$$p_r' = p_r + a_p$$

As the noise signal must simulate both the telephone channel loading and the average loading of the system as a whole, the conventional load total level $p^*_{\Sigma,c}$ is greater than the relative level p_r' by a value equal to $p^*_{\Sigma,c}$ the normalised conventional load

$$p_{\Sigma,c} = p^*_{\Sigma,c} + p_r'.$$

The normalised conventional load $p^*_{\Sigma,c}$ for various systems is given by the formulae below.

$$p^*_{\Sigma,c} = \begin{cases} 4 \log n - 1 \text{ dBm0} & \text{for systems with less than 240 channels} \\ 10 \log n - 15 \text{ dBm0} & \text{for systems with 240 or more channels} \end{cases}$$

Similar considerations apply to the receive side. The noise produced by the modem loop can be determined in back-to-back mode and eliminated from the result.

The test setup shown in figure 3-33 allows you to measure noise and distortion alternately by switching over from wideband to sweep mode on the RMS-5 and by making the appropriate switch-over on the receive side. Effects produced by adjustments to reduce distortion can be checked immediately using a white noise measuring setup.

3.9.2.4 Modulation frequency response measurements using the RM-5's wideband option

Modulation frequency response (frequency dependent attenuation distortion in the baseband) is a measure of the non-linearity voltage and frequency deviation as a function of the modulation frequency.

It is usually measured between BB ports using a CF sweep setup. However when performing such measurements it is important to determine each type of error contributing to the total error as well as the total error itself.

Each contribution to the total error arising between the IF ports of radio-link transmitters and receivers can be measured using the RM-5 and the wideband option (wideband modulator in the RMS-5 and the RMED-5 wideband demodulator).

The only difference between the test setup for modulation frequency response measurements and that for white noise measurements is that the white noise measuring setup is replaced by a CF sweep setup (e.g. the PS-19 on the transmit side and the SPM-19 and SG-4 by W&G on the receive side). The preemphasis and deemphasis networks are not required.

RMS-5 settings (keypad entry via [2])

[8] "P_{IF}" : Nominal system value for U_{IF} = 300 mV ≅ +0.8 dBm
[9] "IF_{CENT}" : Enter IF centre frequency
[18] "OPT." : Wideband modulator on (sweep mode off; sweep width and test tone deviation displays disabled)

RMED-5 settings:

[2] : Centre frequency 70 MHz (key up) or 140 MHz (key down)

The settings for the sweep setup (e.g. sweep limits, transmission level etc.) depend on the system under test.

The error introduced by the modem loop can be eliminated by making a measurement in back-to-back mode which is used to adjust the final result.

3.9.3 RETURNING DISTORTION MEASUREMENT RESULTS TO THE TRANSMITTING STATION DURING END TO END MEASUREMENTS (IF-IF)

3.9.3.1 Results in analog form (IF signal)

If end-to-end measurements are carried out at the IF level, it is possible to return the distortion measurement results $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$ from the receiving station (B) to the transmitting station (A). A complete measuring setup must be installed at both stations. The configuration is shown in Figure 3-35.

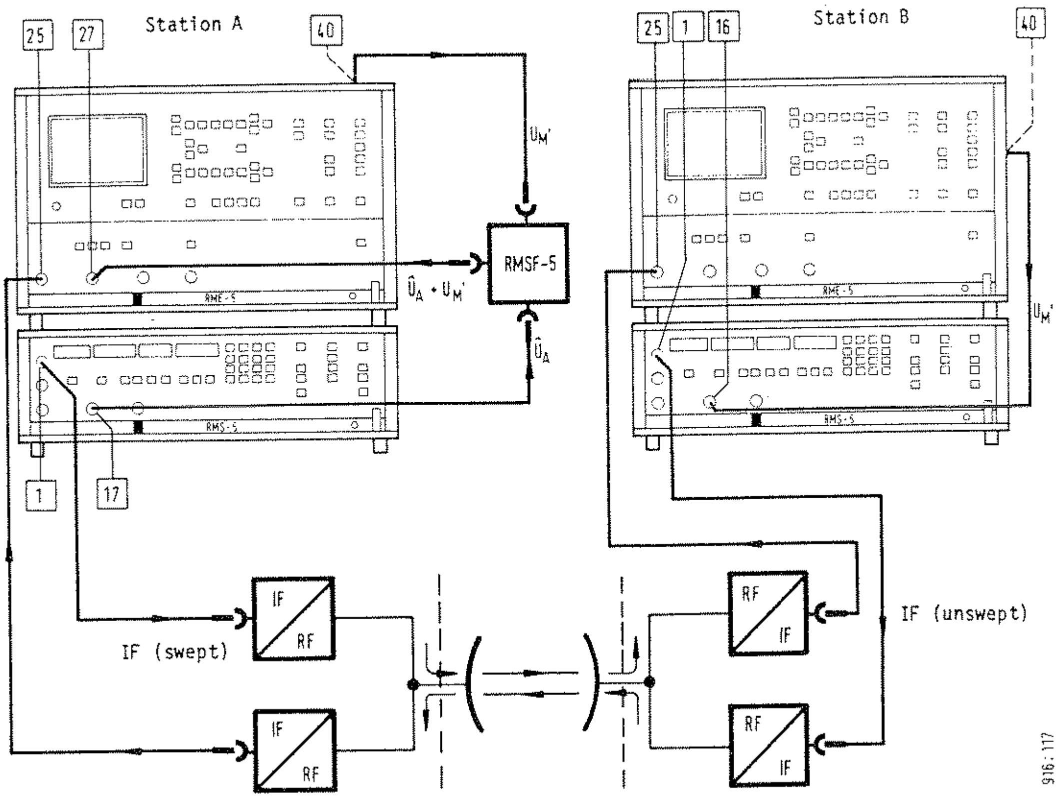


Figure 3-35 Transmitting distortion measurement results from station B to station A

The RME-5 at station B after demodulation, passes the received IF signal, via the demodulator output [40] (the distorted test signal U_M') to input [16] (U_{MEXT}) of the RMS-5 in the same station. The test signal U_M' is frequency-modulated in the RMS-5 but not swept (ΔF = 0 [10]). The unswept IF signal is transmitted back to station A and connected to the IF input [25] (P_I) of the RME-5. The test signal U_M' available at the demodulator output [40], which was not distorted further during transmission (ΔF = 0), is connected together with the sweep voltage $\hat{U}_A$ derived from the RMS-5 (station A) to the BB input [27] of the RME-5, which operates in BB mode - pushbutton [23] down.

3.9.3.2 Results in digital form (RME-5 with IEC bus interface)

The results of distortion measurements can be returned to the RMS-5 via a data channel using the RME-5's IEC bus interface. Figure 3-36 shows the system. The parallel IEC bus signal from the RME-5 is converted to a serial data signal (V.24) and transferred via a modem to station A, where after being demodulated it is processed further by the computer (IEC bus extender).

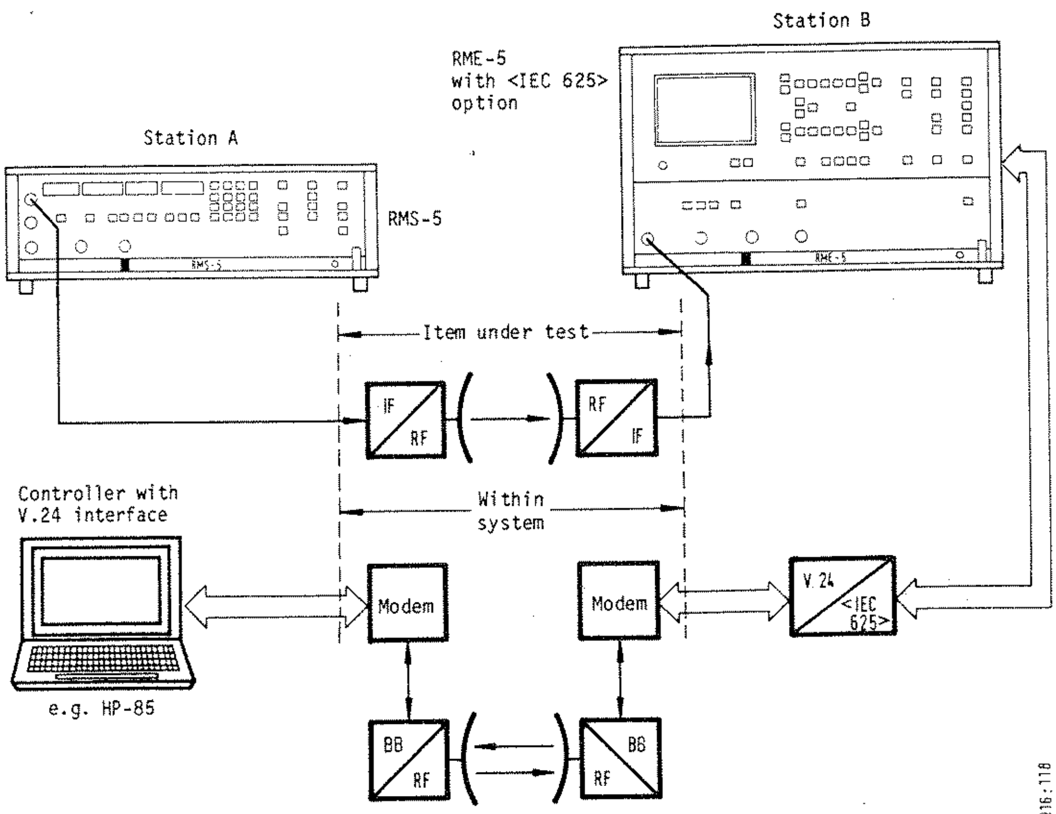


Figure 3-36 Using a data channel to return the results of a distortion measurement to the transmit station

3.9.4 MODULATOR MEASUREMENTS (BB-IF)

It is necessary to carry out tests on modulators and demodulators separately to eliminate any non-linear characteristics which would have to be compensated for later.

3.9.4.1 Setting the IF centre frequency

To set the IF centre frequency of modulators, the RME-5 is used as an "IF counter" - pushbutton [4] pressed, with resolution of 0.01 MHz for the value "F_o". Figure 3-37 shows the test setup.

RME-5 settings:

[22] : IF measurement
[21] : IF centre frequency
[4] : IF counter

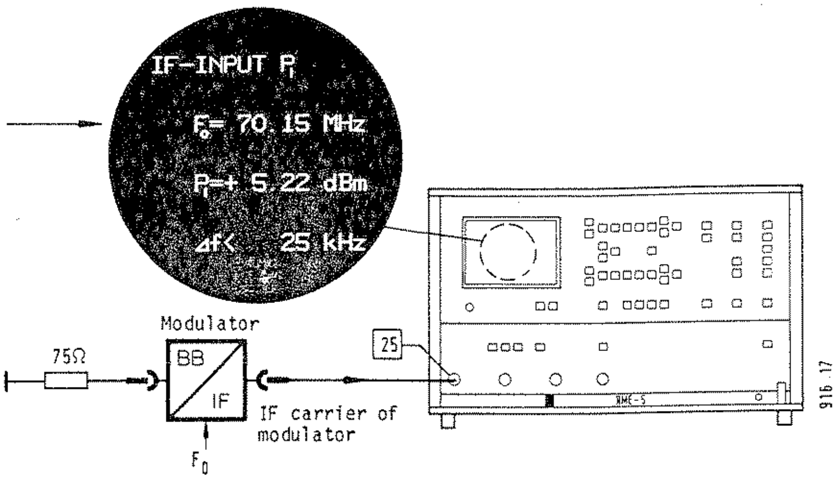


Figure 3-37 Setting the modulator centre frequency "F_o"

The required F_o value is set by making appropriate adjustments on the item-under-test.

3.9.4.2 Adjusting the modulator slope "S_{Mod}"

The slope S_{Mod} of a modulator is defined as

$$S_{Mod} = \Delta f/U_M$$

where Δf is the rms value frequency deviation and U_M is the RMS value of the modulation voltage, i.e. RMS value of the test voltage.

In the case of frequency modulation with <u>one</u> sinusoidal signal, the IF carrier disappears from the spectrum of the frequency-modulated signal at a modulation index η = 2.405 (first zero of the Bessel function). As the modulation index η is

$$\eta = \hat{\Delta f}/f_M$$

with peak deviation $\hat{\Delta f}$ and modulation frequency f_M (or test frequency), the rms value deviation at the modulation index η = 2.405 is

$$\Delta f = \frac{2.405}{\sqrt{2}} \times f_M$$

As a specific slope is required for the modulator and as the modulation frequency f_M can be set on the RMS-5, the modulation voltage U_M which is necessary for generation of the first Bessel null position can be calculated:

$$\boxed{U_M = \frac{2.405 \times f_M}{\sqrt{2} \times S_{Mod}}}$$

Example: The slope of a modulator is to be 10 MHz/V; f_M = 277.$\bar{7}$ kHz

$$U_M = U_{Mod} = \frac{2.405}{\sqrt{2}} \times \frac{0.278\ \text{MHz}}{10\ \text{MHz/V}} = 47.28\ \text{mV} \cong -15.26\ \text{dBm}$$

Set the calculated level value on the RMS-5: Press U_M [13] (LED on) so that dBm is shown as the unit (if necessary press U_M twice). Enter the level with keypad [2].

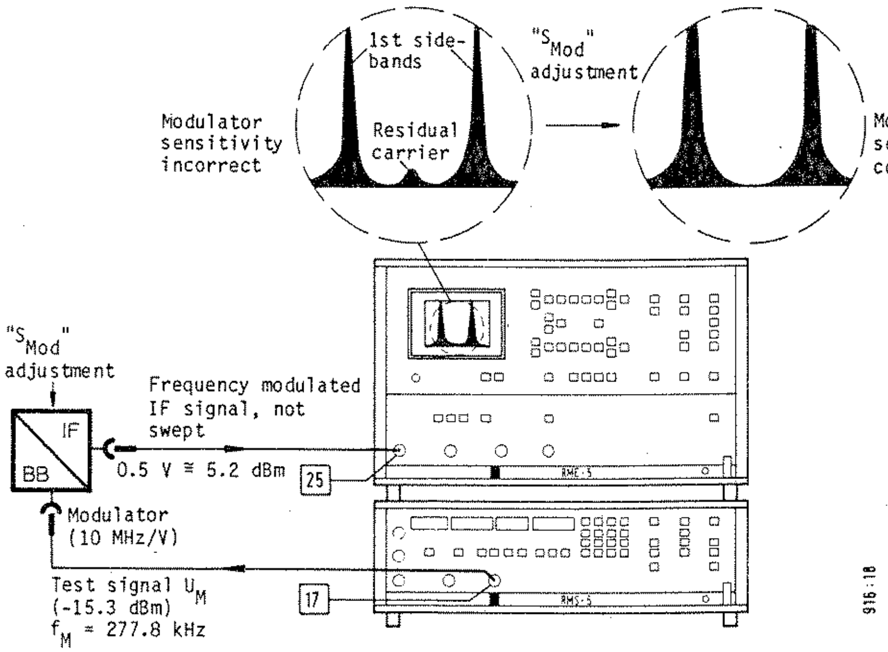


Figure 3-38 Setting modulator slope with the Bessel method

After this, use test setup shown in Figure 3-38. The RME-5, which acts as a spectrum analyser, displays only the sidebands of the IF signal on the monitor; if the slope S_{MOD} of the unit being tested is correct.

If the IF carrier appears in the frequency spectrum, which means that $S_{Mod} \neq 10$ MHz/V, then the unit being tested should be adjusted until the modulator slope is correct.

If a preemphasis network is connected to the modulator input, which is in the case with modulators used in radio-link systems, the above considerations are true only if the attenuation of the preemphasis network at f_M is taken into account. The modulation voltage must be increased by an amount equal to this.

RMS-5 settings: (keypad entry via [2]):

[13] "U_M"	: U_M calculated in accordance with the above formula and with the aid of a precise level meter at output [14]
[10]	: $\hat{U}_A$ = 0 (red LED on)
[4]	: Pushbutton function "277▽" or "92.6▽" (or "250▽" or "83.3▽")

RME-5 settings:

[22]	: IF measurement
[21]	: Appropriate IF for unit being tested
[3]	: "BESSEL SPECT.▽"

Note: There is no reason why the modulator slope should not be adjusted at other test frequencies of the RMS-5 and depends only on whether the maximum possible modulation voltage U_M of the RMS-5 is sufficient to generate the first Bessel zero for a given modulator slope.

Instead of the RMS-5, a level generator can be used, its output signal being connected directly to the BB input of the modulator being tested. This makes it possible to use test frequencies which are not available in the test frequency series of the RMS-5 (e.g. neutral frequency).

In both cases, care must be taken that the peak deviations at a given test frequency do not become larger than the IF transmission band of the modulator.

3.9.4.3 Distortion measurements ΔT, $\Delta\varphi$ and $\Delta U/U_0$

For distortion measurements on modulators, the RMS-5 generator supplies a composite signal consisting of the sweep voltage and test voltage. The sweep voltage $\hat{U}_A$ determines the sweep width of the IF signal measured at the output of the unit being tested.

RME-5 settings:

[22] : IF
[21] : IF corresponding to IF of unit being tested
[2], [10] : Measured parameters ΔT, $\Delta\varphi$ and $\Delta U/U_0$

The sweep width $\hat{\Delta F}$ for exploring the IF transmission band is set up with the aid of the $\hat{\Delta F}$ value displayed on the RME-5, with "automatic sweep width reduction" switched off and at the lowest test frequency. The appropriate settings must be chosen for item under test.

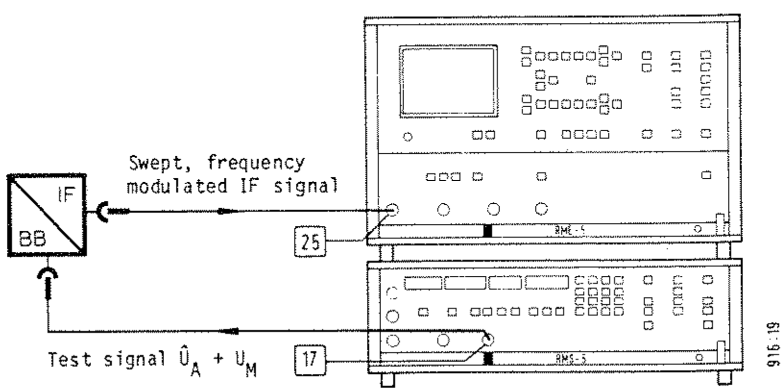


Figure 3-39 Distortion measurements on a modulator

The test voltage U_M must be set so that the displayed result is as free of noise as possible, without losing the fine structure of the result (approx. value = 1 ... 2 x channel frequency deviation).

The evaluation of the results is carried out on the screen of the RME-5 or externally by a computer connected via the IEC bus.

3.9.4.4 Measuring the variation of the IF centre frequency with temperature for modulators

A measurement that is frequently of interest in development labs and test depts. is the variation of the IF centre frequency with frequency. This measurement can be performed easily using the frequency counter facility of the RME-5 (key [4] down). The test setup is shown in figure 3-39. $\Delta F/U_A$ = 0 [10] should also be pressed (red LED on). The unswept FM spectrum is applied to the input of the frequency counter: If the centre frequency varies by more than 10 kHz, this fact is recorded or the current absolute value F_0 is shown numerically on the screen (monitor display IF-INPUT P_I). It is therefore possible to determine the variation of the centre frequency with temperature by observing F_0 at suitable intervals.

To return the original distortion measurement results to the screen press $\Delta F/U_A$ = 0 (RMS-5) again, (LED off), the RME-5 IF counter facility must also be switched off. The sweep width has the value that was previoulsy set.

3.9.4.5 IF frequency response ΔP_I

The test setup is shown in figure 3-39.
See 3.9.2.2 for test procedure and result evaluation.

3.9.5 DEMODULATOR MEASUREMENTS

3.9.5.1 Adjusting demodulator sensitivity

The sensitivity, S, of a demodulator is defined as:

$$S_{Demod} = U/\Delta f$$

With $\Delta f = 2.405 \times f_M/\sqrt{2}$ (η = 2.405: 1. first Bessel null position, see also 3.9.4.2), the voltage at the output of the demodulator becomes

$$\boxed{U_{Demod} = \frac{2.405 \times f_M}{\sqrt{2}} \times S_{Demod}}$$

If the sensitivity of the demodulator and the test frequency f_M are known (selected on the RMS-5), the voltage U_{demod} is output by the demodulator, this voltage can be measured with BB level meter.

RMS-5 settings:

[8], [2]	: +0.8 dBm (≅ demodulator IF-input level)
[9], [2]	: Appropriate centre frequency for the item-under-test
[13] "U_M"	: U_M = 0 V (Press "0", "ENTER" on the numerical keyboard)
[10] "$\Delta F/U_A$ = 0"	: red LED on
[4]	: Key function "277▽" (or "250▽")

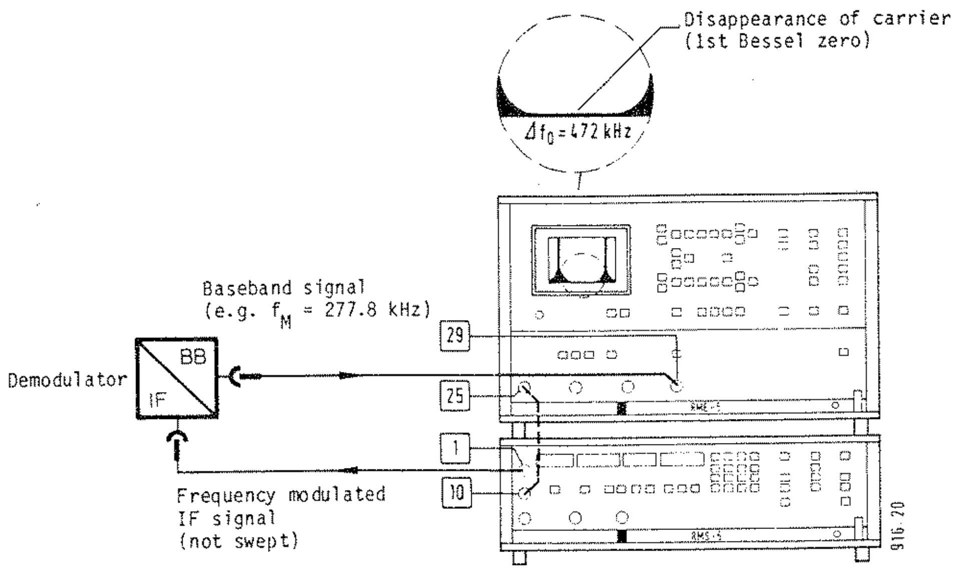


Figure 3-40 Demodulator sensitivity adjustments

RME-5 key functions:

[22] : IF

[21] : IF range appropriate for item under test

The demodulator sensitivity is adjusted in two steps: use the test setup in figure 3-40.

1st step: Select the BESSEL SPECTRUM measurement mode on the RME-5 by pressing [3].
Increase the test voltage output by the RMS-5 using the arrowed key ⇧ until the 1st Bessel zero is reached (carrier suppression)

2nd step: Select the BB LEVEL MEASUREMENT mode on the RME-5.
Press [28] (LED on).

The voltage U_{demod} can be expressed in terms of a power level:

$$P_{demod} = 10 \log \left[\frac{U^2_{demod}/75\ \Omega}{1\ mW} \right]$$

U_{demod} is given by the formula in 3.9.5.1.

If the measured value is not the same as the theoretical value, adjust the sensitivity of the demodulator.

If a deemphasis network is connected to the demodulator output, its attenuation should be taken into account when the test frequency is set.

3.9.5.2 Distortion measurements ΔT, $\Delta\varphi$ and $\Delta U/U_0$

The RMS-5 generates a frequency modulated, swept IF signal which is applied to the input of the demodulator, see figure 3-41. The demodulated signal is applied to the BB input [27] of the RME-5.

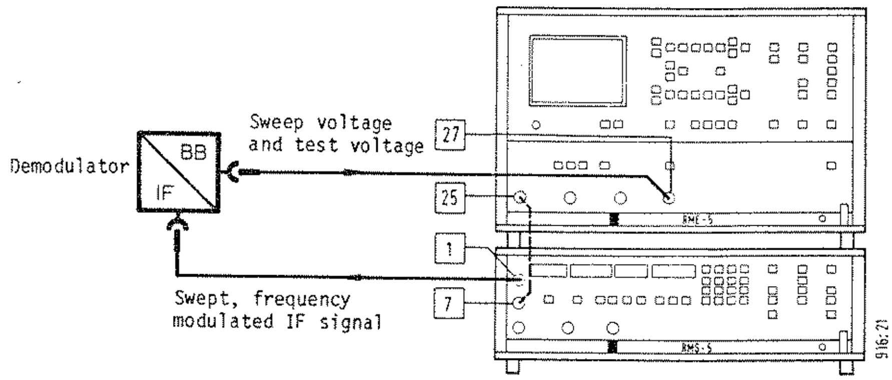


Figure 3-41 Distortion measurements on a demodulator

RMS-5 settings:

[8], [2] : Nominal value for U_{IF} = 300 mV ≘ +0.8 dBm
[9], [2] : Appropriate IF centre frequency for the item under test
[10] "$\hat{\Delta F}$", [2] : Sweep width $\hat{\Delta F}$ depends on system
[4] : Test frequency as laid down by test procedure
[14] : Sweep frequency as laid down by test procedure
[13] "Δf", [2] : Test tone deviation Δf the same as the rms channel frequency deviation, depends on the item under test. To reduce noise the test tone deviation can be increased until the point where the fine structure of the sweep is just about to be lost.

RME-5 key functions:

[23] : BB measurement ⟶ "U_x (BB)" [18]
[2], [10] : Appropriate distortion parameters
[17] : Set the phase for $\Delta U/U_0$ using the blanking gap; cf 3.6.2.3

Evaluation of the results is carried out on the screen of the RME-5 (simultaneous display of $\Delta U/U_0$ and ΔT or $\Delta\varphi$!), with the internal evaluation facilities described in 3.7, or on an external computer connected via the IEC bus.

The auxiliary connection between output [7] (RMS-5) and input [25] (RME-5) permits insertion of frequency markers in the BB distortion results. This is absolutely necessary if the demodulator being tested suppresses the sweep signal. Press pushbutton "U_x (IF)"; LED on. Phase correction - pushbutton [17] pressed - with the arrow pushbuttons under [18] is also necessary.

3.9.5.3 Measuring return loss at demodulator inputs

See 3.9.7.2

3.9.5.4 Measuring demodulator idle noise

For this measurement, a noise-free sinusoidal signal with minimum harmonic content ("quiet tone") for the appropriate IF is provided by the RMS-5 at output [15] if the RMS-5 is equipped with the optional feature "IF calibration generator".

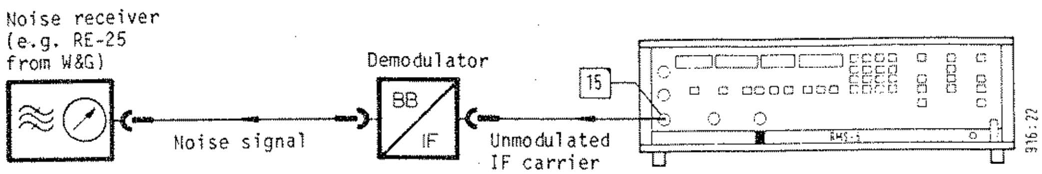


Figure 3-42 Measuring demodulator idle noise

Select the required IF, i.e. 35 MHz, 70 MHz or 140 MHz (depending on the option fitted) using [9] and [2]. No further settings are required as the signal is transmitted at a fixed level of +5 dBm.

The intrinsic noise power generated in the demodulator is measured at the baseband frequency with a white noise receiver or selective level meter. If the RE-25 White Noise Receiver from W&G is used, the relative level can be set directly and the noise can be read off directly in pW0p.

3.9.6 MEASUREMENTS ON MODEM LOOPS (BB-BB)

Measurements are frequently carried out on modem loops, i.e. modulators and demodulators connected in series. As these measurements are performed between BB ports, only distortion measurements are relevant in this context.

3.9.6.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

RMS-5 settings:

[4] : Test frequencies as laid down in test procedure

[14] : Sweep frequencies as laid down in test procedure

[10] "$\hat{U}_A$", [2] : Sweep voltage $\hat{U}_A = \hat{\Delta F}/S_{mod}$; $\hat{\Delta F}$ as per test procedure (depends on item under test, it is assumed that S_{mod} is known)

[13] "U_M", [2] : Increase the test voltage until the sweep curve is free of noise.

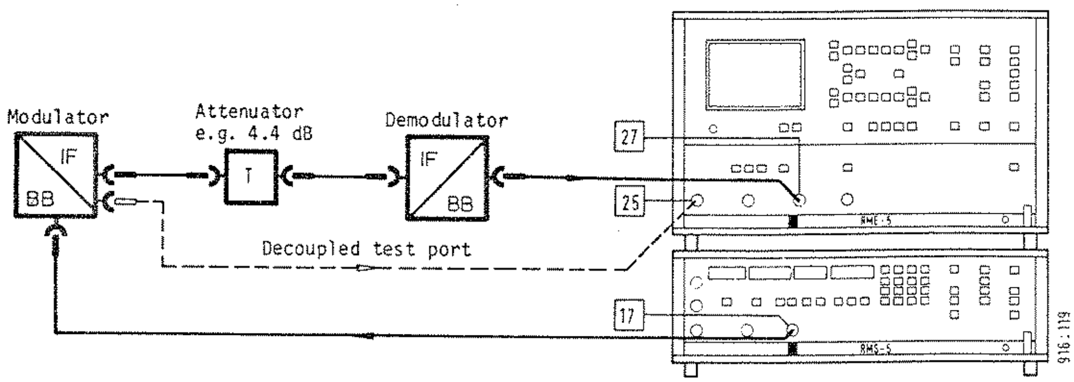


Figure 3-43 Distortion measurements on a modem loop

RME-5 keyfunctions:

[23] : BB measurement ——► "U_x (BB)" [18]
[2], [10] : Select relevant distortion parameters
[17] : Correct the phase of U_x (see 3.6.2.3), then switch off key function [17]
[18] : "U_x (IF)" when IF reference signal is input, (see figure 3-43): connection marked as a dotted line, correct the phase of U_x

To match the levels, a 4.4 dB attenuator should be connected between the modulator output and the demodulator input.

The connection to input [25] (shown as a dotted line in figure 3-43) allows you to calibrate the x-axis of the screen grid - press U_x (IF) [18] - with the sweep limits $F_o \pm \Delta F$ and the frequency markers. This is useful for interpreting the sweep traces.

This means that the sweep width $\hat{\Delta F}$ ($\hat{U}_A$ setting by means of [10], [2]) can be checked directly on the screen of the RME-5. The sweep width (or $\hat{U}_A$) should be set to a low test frequency (keypad [4]) when the automatic sweep width reduction facility is off.

The resulting test tone deviation Δf (U_M setting) can be checked using the RME-5's frequency deviation meter - Δf on screen - when the IF signal is applied (e.g. test tone deviation Δf to equal the rms channel frequency deviation for the system in question).

The results can be evaluated internally as described in 3.7 or externally by computer via the IEC bus.

3.9.7 TESTING IF MODULES (IF-IF)

Unlike IF measurements on installed radio link systems with standardised IF levels, the signals used to align IF modules (amplifiers, filters etc.) may not lie within the level range of the P_I input. If this is the case, the RME-5 cannot lock onto the signal, and because of the method used to recover the deflection voltage, it may take several seconds for the display to return when the input level returns to the correct range. Section 4.6 describes a test setup that can be used in cases such as these.

3.9.7.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

The measurements are basically the same as those described in 3.9.2.1. The values for the IF level, test tone deviation and sweep width depend on application.

Note: By pressing ΔP_I in keypad [2] or [10] on the RME-5 (LED on), the frequency response P_I can be displayed simultaneously with the $\Delta\tau$, $\Delta\varphi$ sweep or with the $\Delta U/U_0$ sweep (see 3.9.2.2).

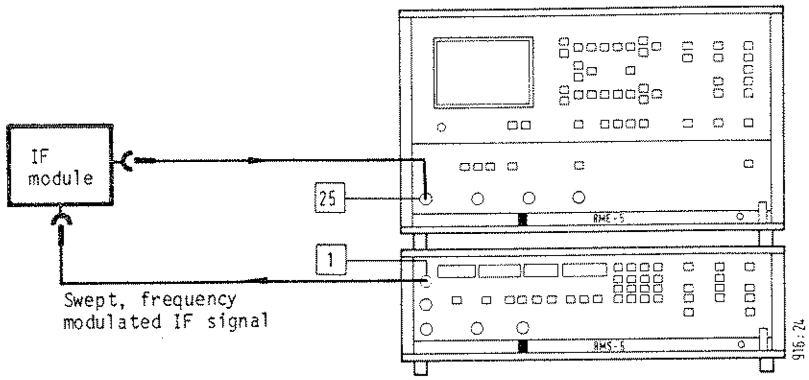


Figure 3-44 Distortion measurements on IF modules

3.9.7.2 IF return loss a_r and group delay $\Delta\tau$

The RFZ-4 or RFZ-14 Return Loss Measuring Bridge, which are available as accessories, are essential for IF return loss measurements.

When the RME-5 is in measurement mode ΔP_{II}, the measurement range (full screen height) is adjustable between 8 and 80 dB, cf table 3-4.

The bridge connector to the item under test is fitted with an insert from W&G's Versacon® 9 Universal Connector System. This means that the bridge can always be connected to the item under test without any other adaptors or connectors. In this way, errors introduced by connectors are minimised.

Use the test setup shown in figure 3-45 for a_r measurements.

The advantage of this test setup is that it allows you to display the a_r result (ΔP_{II} key function) simultaneously with a distortion sweep or the IF frequency response ΔP_I, see figure 3-46a.

In practice, it is important to be able to display group delay $\Delta\tau$ and return loss simultaneously to observe the effects of the adjustment of one on the other. When setting the RME-5 and the RMS-5, it is assumed that return loss a_r and group delay will both be measured. It is also assumed that a test frequency < 1 MHz will be selected, as the automatic sweep reduction facility limits the sweep width at higher test frequencies and this would mean that the IF range for the measured return loss a_r would be reduced.

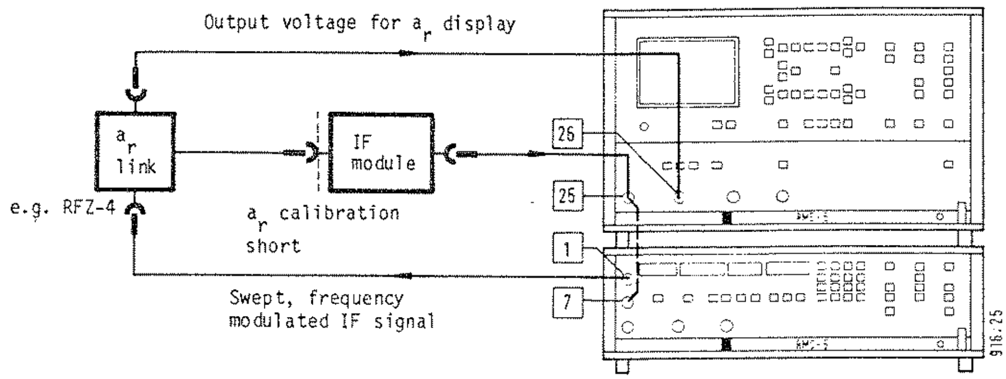


Figure 3-45 Return loss measurements on IF modules

RMS-5 settings:

[8], [2]	: Set IF level. To compensate for the bridge loss set the IF level 6 dB higher than the requirement for the item-under-test.
[9], [2]	: IF centre frequency 35/70/140 MHz
[10] "$\hat{\Delta F}$", [2]	: Sweep width $\hat{\Delta F}$ as laid down in test procedure (depends on item under test)
[4]	: Test frequency as required, $f_M < 1$ MHz!
[14]	: Sweep frequency as required
[13] "Δf", [2]	: Set the test tone deviation (rms channel frequency deviation) to the system value or to a value so large that the noise on the sweep disappears but the fine structure is not lost. Using "noise averaging" on the RME-5 (cf 3.7.1) remove the noise from $\Delta\tau$ results.

RME-5 key functions:

[22]	: IF measurement
[21]	: IF range appropriate to item under test
[2]	: "$\Delta\tau$" measurement, if result noisy: [5] "averaging" (see 3.7.1)
[10]	: "ΔP_{II}"

First of all obtain an optimal result by adjusting the test tone deviation Δf (key [13] and up/down keys [2]). Only when this has been done can the RME-5 be calibrated.

Calibrating the RM-5 for a_r measurements: item under test disconnected:

Method 1: The RM-5 is calibrated with the test output of the bridge short-circuited (r = -1).

The short-circuit should be made with the short (order no. S 818) provided with the RM-5.

To calibrate the RM-5 make the following alterations in the test setup: Remove the connection from the output of the item under test to the P_I input [25] on the RME-5 and connect output [7] on the RMS-5 with input P_I on the RME-5 (dotted line in figure 3-45). The connection is essential for the tracking control of output P_{II} [26] on the RME-5.

When total reflection occurs ($r = +1$ or $r = -1$) the return loss is 0 dB. This then serves as a reference for the a_r measurement. The 0 dB line on the screen should be shifted to the upper edge of the screen with [9] and adjusted until it is on the upper grid line. To display an a_r range of 40 dB, the sensitivity of P_{II} should be set to 10 dB/DIV.

Method 2: To eliminate the intrinsic errors of the test setup, the transmission level can be reduced during the calibration procedure so that a reference line which lies close to the expected value can be chosen.

Example:	Expected value a_r	= 34 dB
	Reference line at a_r	= 30 dB
	Transmission level set on the RMS-5	= 30 dB less than the transmission level of the following measurement

The 30 dB reference line can be shifted to a suitable position with [9] (e.g. centre of the screen). In method 1, a resolution of 10 dB (or 20 dB) must be selected; in method 2, a resolution up to 2 dB/DIV can be selected using the measurement range keys below [10].

The short on the bridge connection to the item-under-test should be left in place while calibration is being performed.

Method 3: Standard mismatch

If a standard mismatch is available (e.g. 20, 25 and 30 dB mismatches are contained in our Versacomp® 75 range), the advantages of method 1 (same transmission level for calibration and measurement) and method 2 (better resolution) can both be obtained. Instead of the short, the standard mismatch should be connected to the bridge connection of the item-under-test.

The reference line corresponding to the standard mismatch appears on the screen. Using the POSITION keys it can be made to coincide with any line on the grid.

a_r measurements with item-under-test connected:

After calibrating the test setup, connect the item-under-test to the bridge. If method 2 was used to perform the calibration, raise the transmission level to the required value.

When reading off the results, the horizontal cursors (keys marked [6]) can be used to increase the resolution given by the measurement range that has been selected. One of the cursors is placed on the point of interest, then using the cursor separation displayed at the top of the screen and the scale factor, it is possible to read off the return loss at the point with a resolution < 0.5 dB.

N.B.: The following calibraton procedure for a_r measurements is only valid if the test tone deviation Δf, and the test frequency f_m, which were set for the ΔT measurement before calibration, are not changed. This is because any alteration would change the energy distribution between the IF carrier and the sidebands as the level at the P_{II} input [26] is measured selectively.

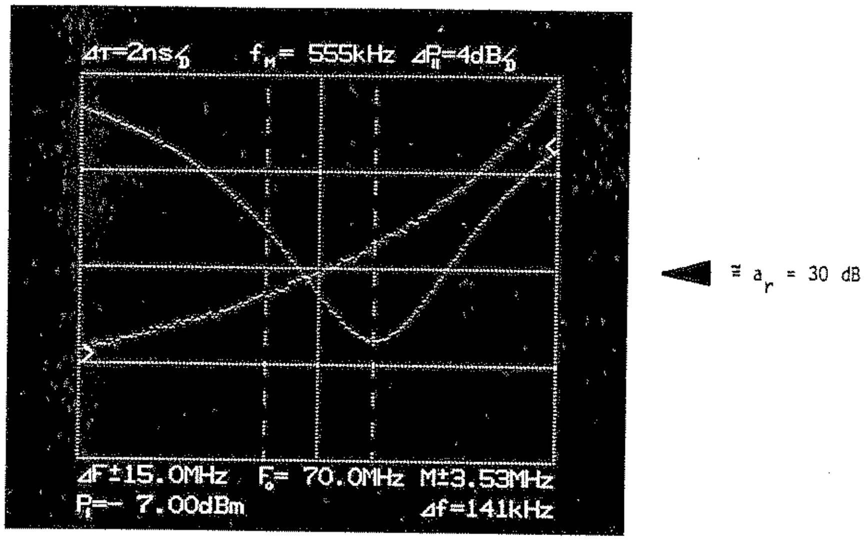


Figure 3-46a IF return loss a_r (and group delay ΔT) after calibration to the horizontal central line

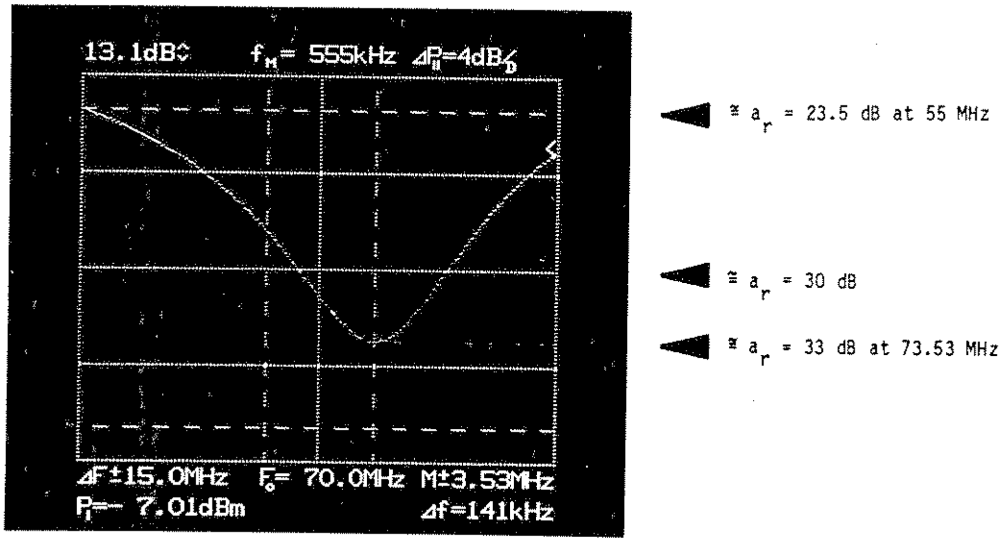


Figure 3-46b Using horizontal cursor for high resolution read-off of a_r results

If you do not intend displaying another result simultaneously with the a_r result, the following changes should be made in the test setup shown in figure 3-45: there is no connection between the output of the item under test and the P_I output [25] on the RME-5, this is shown by a dotted line. The output of the item-under-test is terminated with a 75 Ω impedance (BN 922). On the RMS-5 switch off the automatic sweep width reduction facility and the test tone deviation.

3.9.7.3 IF frequency response ΔP_{II}

The ΔP_{II} IF frequency response is the selective measurement of variations in attenuation using a large dynamic range. The linear level display range covers 40 dB, the max. measurement range (ΔP_{II} = 20 dB/DIV) on the screen of the RME-5 is however 80 dB.

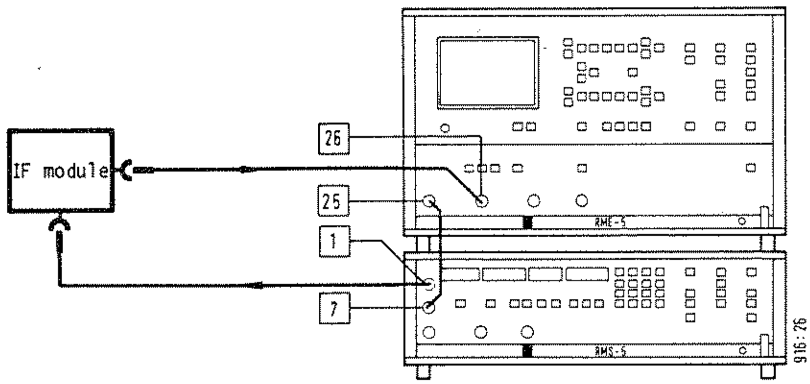


Figure 3-47 Selective measurement of the variation in attenuation of an IF module

RMS-5 settings:

[8], [2] : as required, but the level at input [26] of the RME-5 must be $\leq$ -10 dBm
[9], [2] : IF frequency same as IF of item under test
[13] "Δf", [2] : Δf = 0
[10] "$\hat{\Delta F}$", [2] : $\hat{\Delta F}$ as required
[14] : Sweep frequency as laid down in test procedure

RME-5 key functions:

[22] : IF measurement
[21] : IF range appropriate to that of item under test
[2], [10] : "ΔP_{II}"

The connection between connector [7] (RMS-5) and connector [25] (RME-5) is required for the tracking control of input [26] and to obtain the deflection voltage U_x.

The frequency markers [16] and the horizontal cursors [6] can be used to read off the attenuation curve values for the item-under-test (e.g. an IF filter). This makes it easy to determine pole attenuation and the 3 dB limits.

Figure 3-48 shows the attenuation curve of a 70 MHz bandpass with a pole attenuation of 76.8 dB at 92.2 MHz. In figure 3-49, the 3 dB limits are determined. The only measurement mode that cannot be used for this purpose is measurement mode ΔP_{II} via input P_{II} [26]. Measurement mode ΔP_I via input P_I [25] can however be used. The advantage of measurement ΔP_I is the higher resolution (1 dB/DIV) and the possibility of measuring group delay distortion and displaying the trace simultaneously without having to reconnect any cables.

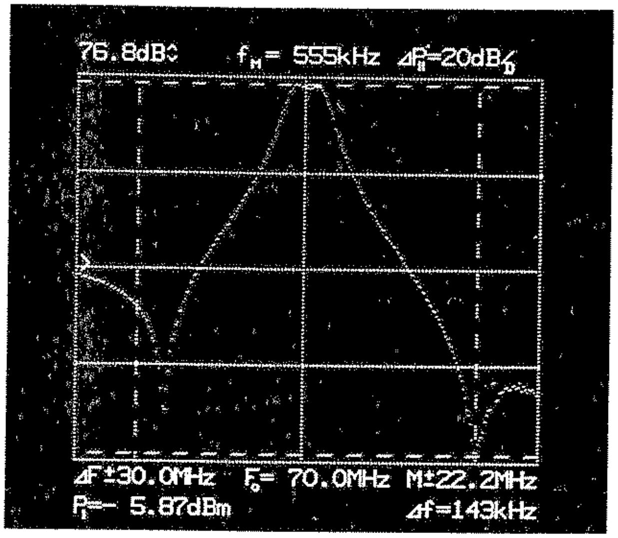


Figure 3-48 Variation in attenuation of a 70 MHz bandpass in measurement mode ΔP_{II}

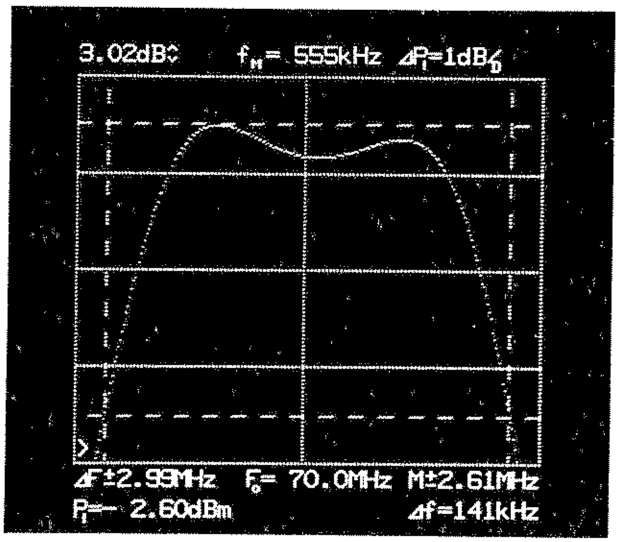


Figure 3-49 3 dB limits of a 70 MHz bandpass filter in measurement mode ΔP_I

3.9.7.4 White noise measurements

The measurements are basically the same as those described in 3.9.2.3. The settings on the RM-5 (or RMED-5) and the white noise measuring setup are determined by the user.

3.9.8 MEASUREMENTS ON SATELLITE SYSTEMS

The same equipment and techniques used to test radio-link systems can also be used without any problems to test FM satellite systems.

However, a sinusoidal sweep frequency of 18 Hz is laid down for end-to-end satellite measurements and a sweep frequency of 70 Hz is used for radio-link testing. The reason for using a lower sweep frequency for testing satellite systems is the large amount of noise associated with the transmitted signal which necessitates measurements with as small a bandwidth as possible. On the other hand, to obtain valid results, the bandwidth to sweep frequency ratio must be as high as possible.

The obligatory test frequencies are 55.556 kHz (12 channels), 92.593 kHz (for systems with 60 or more channels) and colour carrier frequencies of 3.58 or 4.43 MHz for TV transmissions.

The following measurements which are prescribed by INTELSAT can be performed by the RM-5.

- IF-IF frequency response ΔP_I,
- IF-IF group delay distortion ΔT,
- BB-BB non-linearity distortion $\Delta U/U_o$.

The test setups and test procedures are given in 3.9.1 and 3.9.2. Measuring the group delay distortion of the modulation equipment in the earth station, before making tests via satellite is also recommended.

Another important test is checking the IF filters with respect to frequency response ΔP_I and group delay distortion ΔT. The IF filters are accommodated in the earth station and are used for the transmit and receive side selection of the various IF transmission bands; these filters have therefore to meet stringent requirements. The bandwidth of the filters varies between 1.25 and 36 MHz depending on the number of telephone channels carried. To adjust these filters the prescribed tolerance masks can be displayed on the screen when the INTELSAT tolerance mask option if fitted in the RME-5 (BN 917/00.12), cf 3.7.6.

RF measurements using the RM-5 and sweepers or down-converters are also possible. More information is given in 3.9.9.

At present, only BB-BB white noise measurements are laid down for satellite systems. IF-IF white noise measurements would however be useful for fault localisation purposes. The RM-5, fitted with the wideband option, can be used to perform measurements of this kind. The preemphasis and deemphasis networks required are available from W&G, cf 1.6.5.

Like the values given in figure 3-34, 3.9.2.3, the values for white noise measurements are listed in tables 3-10 and 3-11. Using the obligatory values for the rms channel frequency deviation and the sensitivity of the wideband modulator in the RMS-5 and the wideband demodulator in the RME-5, the relative level at the BB ports is calculated.

The facility for calculating noise from the results of the $\Delta\varphi$ and $\Delta U/U_o$ distortion measurements is an alternative to the classical procedure, see 3.7.4 for more details.

Number of telephone channels	Appropriate IF bandwidth (MHz)	Relative level p'_r at input of preemphasis network (dBr)	Relative level p_r at the BB input of the RMS-5 (dBr)	RMS channel frequency deviation Δf_n at the neutral frequency f_n (kHz)	Relative level p_r at the BB output of the RMED-5 (dBr)	Relative level p'_r at the output of the deemphasis network (dBr)
12	1.25	-23.0	-28.0	109	-34.0	-38.0
24		-19.5	-24.5	164	-30.5	-34.5
36		-19.2	-24.2	168	-30.2	-34.2
48	2.5	-20.2	-25.2	151	-31.2	-35.2
60		-21.1	-26.1	136	-32.1	-36.1
72		-21.8	-26.8	125	-32.8	-36.8
60		-15.1	-20.1	270	-26.1	-30.1
72		-14.4	-19.4	294	-25.4	-29.4
96	5.0	-15.4	-20.4	263	-26.4	-30.4
132		-16.8	-21.8	223	-27.8	-31.8
192		-18.6	-23.6	180	-29.6	-33.6
96		-12.6	-17.6	360	-23.6	-27.6
132		-12.3	-17.3	376	-23.3	-27.3
192	7.5	-14.3	-19.3	297	-25.3	-29.3
252		-15.5	-20.5	260	-26.5	-30.5
132		-11.1	-16.1	430	-22.1	-26.1
192		-10.6	-15.6	457	-21.6	-25.6
252	10.0	-12.7	-17.7	358	-23.7	-27.7
312		-13.7	-18.7	320	-24.7	-28.7
252		-8.5	-13.5	577	-19.5	-23.5
312	15.0	-9.0	-14.0	546	-20.0	-24.0
372		-10.1	-15.1	480	-21.1	-25.1
432		-11.7	-16.7	401	-22.7	-26.7
492		-12.2	-17.2	377	-23.2	-28.2
432	17.5	-9.5	-14.5	517	-20.5	-24.5
432		-8.0	-13.0	616	-19.0	-23.0
492		-13.8	-13.8	558	-19.8	-23.8
552		-9.6	-14.6	508	-20.6	-24.6
612	20.0	-10.6	-15.6	454	-21.6	-25.6
792		-12.7	-17.7	356	-23.7	-27.7
432		-6.5	-11.5	729	-17.5	-21.5
492		-6.4	-11.4	738	-17.4	-21.4
552		-7.1	-12.1	678	-18.1	-22.1
612		-7.8	-12.8	626	-18.8	-22.8
792	25.0	-9.8	-14.8	499	-20.8	-24.8
972		-11.5	-16.5	410	-22.5	-26.5
792		-5.5	-10.5	816	-16.5	-20.5
972		-6.9	-11.9	694	-17.9	-21.9
972		-5.7	-10.7	802	-16.7	-20.7
1092		-6.8	-11.8	701	-17.8	-21.8
1332	36.0	-8.3	-13.3	591	-19.3	-23.3
1872		-11.3	-16.3	419	-22.3	-26.3

Table 3-10 Determining the relative levels at the BB ports of the wideband facility of the RM-5 for IF-IF white noise meaurements on INTELSAT satellite systems

No. of tele-phone channels	Appro-priate IF band-width (MHz)	Reduced conventional load $p^*_{\Sigma,c}$ (dBm0)	Conventional load - total level at input (dBm)	Total rms deviation $\Delta f = 10^{\frac{p^*_{\Sigma,c}}{20}} \Delta f_n$ (MHz)	Conventional load - total level at output (dBm)	Relative level p'_r at the out-put of the deemphasis network (dBr)
12	1.25	+3.3	-19.7	0.159	-34.6	-38.0
24 36 48 60 72	2.5	+4.5 +5.2 +5.7 +6.1 +6.4	-15.0 -14.0 -14.5 -15.0 -15.4	0.275 0.306 0.291 0.275 0.261	-29.9 -28.9 -29.4 -29.9 -30.3	-34.5 -34.2 -35.2 -36.1 -36.8
60 72 96 132 192	5.0	+6.1 +6.4 +6.9 +7.5 +8.1	-9.0 -8.0 -8.5 -9.3 -10.5	0.545 0.614 0.582 0.529 0.457	-23.9 -22.9 -23.4 -24.2 -25.4	-30.1 -29.4 -30.4 -31.8 -33.6
96 132 192 252	7.5	+6.9 +7.5 +8.1 +9.1	-5.7 -4.8 -6.2 -6.4	0.797 0.892 0.755 0.741	-20.6 -22.4 -21.1 -21.3	-27.6 -27.3 -29.3 -30.5
132 192 252 312	10.0	+7.5 +8.1 +9.1 +9.9	-3.6 -2.5 -3.6 -3.8	1.02 1.16 1.02 1.00	-18.5 -17.4 -18.5 -18.7	-26.1 -25.6 -27.7 -28.7
252 312 372 432 492	15.0	+9.1 +9.9 +10.7 +11.4 +11.9	+0.6 +0.9 +0.6 -0.3 -0.3	1.65 1.707 1.65 1.49 1.48	-14.3 -14.0 -14.4 -15.2 -16.3	-23.5 -24.0 -25.1 -26.7 -28.2
432	17.5	+11.4	+1.9	1.92	-13.0	-24.5
432 492 552 612 792	20.0	+11.4 +11.9 +12.4 +12.9 +14.0	+3.4 -1.9 +2.8 +2.3 +1.3	2.29 2.20 2.12 2.00 1.78	-11.5 -11.9 -12.2 -12.6 -13.6	-23.0 -23.8 -24.6 -25.6 -27.7
432 492 552 612 792 972	25.0	+11.4 +11.9 +12.4 +12.9 +14.0 +14.9	+4.9 +5.5 +5.3 +5.1 +4.2 +3.4	2.71 2.90 2.83 2.76 2.50 2.28	-10.0 -9.5 -9.7 -9.9 -10.7 -11.5	-21.5 -21.4 -22.1 -22.8 -24.8 -26.5
792 972 972 1092 1332 1872	36.0	+14.0 +14.9 +14.9 +15.4 +16.2 +17.7	+8.5 +8.0 +9.2 +8.6 +7.9 +6.4	4.09 3.86 4.46 4.13 3.82 3.22	-6.5 -7.0 -5.7 -6.3 -7.0 -8.5	-20.5 -21.9 -20.7 -21.8 -23.3 -26.3
			RS-50, RS-25 settings		To be measured with REBZ-25	RE-50, RE-25 settings

Table 3-11 Noise measurement setup settings for IF-IF noise measurements on INTELSAT satellite systems using the RM-5's wideband device

3.9.9 RF MEASUREMENTS

To perform rf measurements, the RM-5 must be used in conjunction with other test sets. As these test sets are all commercially available (e.g. Scientific Atlanta, Hewlett Packard), only the principle of two measurements will be outlined.

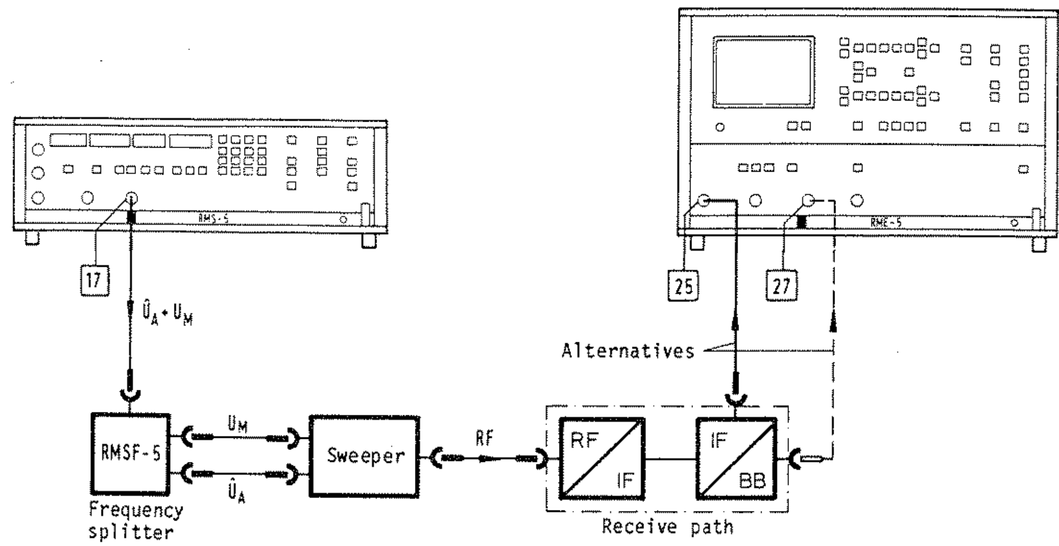


Figure 3-50 RF measurements using the RM-5 and a sweeper

A swept, frequency modulated rf signal with low distortion is required for performing measurements on the receive path of radio-link or satellite systems. A sweeper which is driven by U_M and $\hat{U}_A$ produces the required rf signal directly. The RMSF-5 splitter is used to divide the composite signal $\hat{U}_A + U_M$ at output [17] of the RMS-5 into its components $\hat{U}_A$ and U_M. The RMSF-5 is an accessory that can be ordered[1]. The measurements can be performed at the IF or BB ports.

Measurements can also be made on the transmit path. The transmission signal is generated by the RMS-5. The rf signal at the output port of the transmission path is then down-converted and applied to input P_I of the RME-5, see figure 3-51.

1) Order no. BN 916/00.10

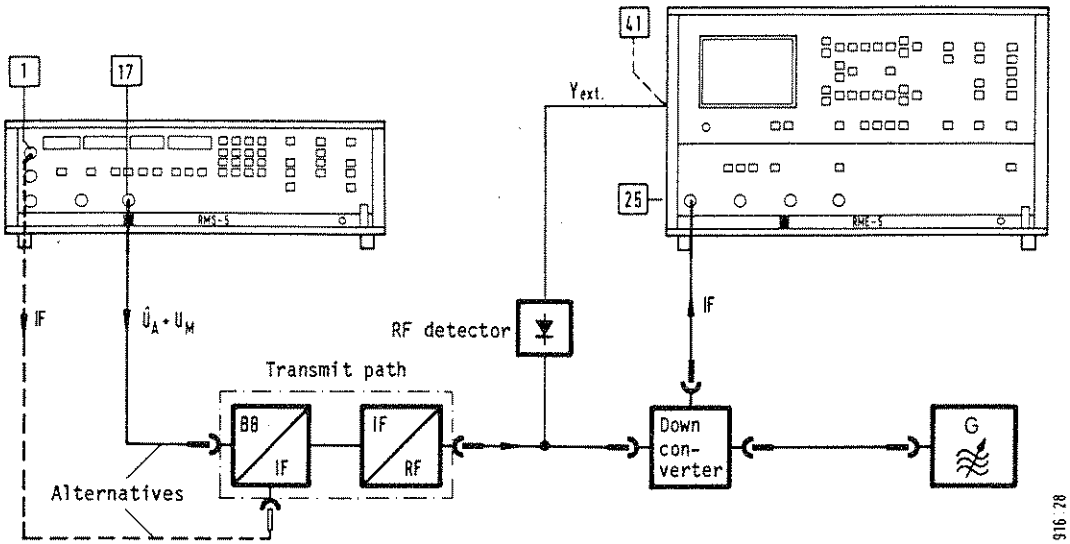


Figure 3-51 RF measurements using the RM-5 and a down converter

Using an rf detector it is possible to display the rf frequency response on the screen of the RME-5. The output signal from the detector is applied to the $Y_{ext.}$ input [41] on the back panel of the RME-5. The key Y_{ext} in keypad [2] or [10] is then pressed (LED on). The measurement range (8 to 800 mV) can be selected in several steps to give the largest possible display.

The sweep trace can then be recorded as indicated in 3.8.

Using the RM-5, the sweeper and the down converter, it is also possible to make rf-rf end-to-end measurements (e.g. transponder measurements on satellite systems), or to test rf modules.

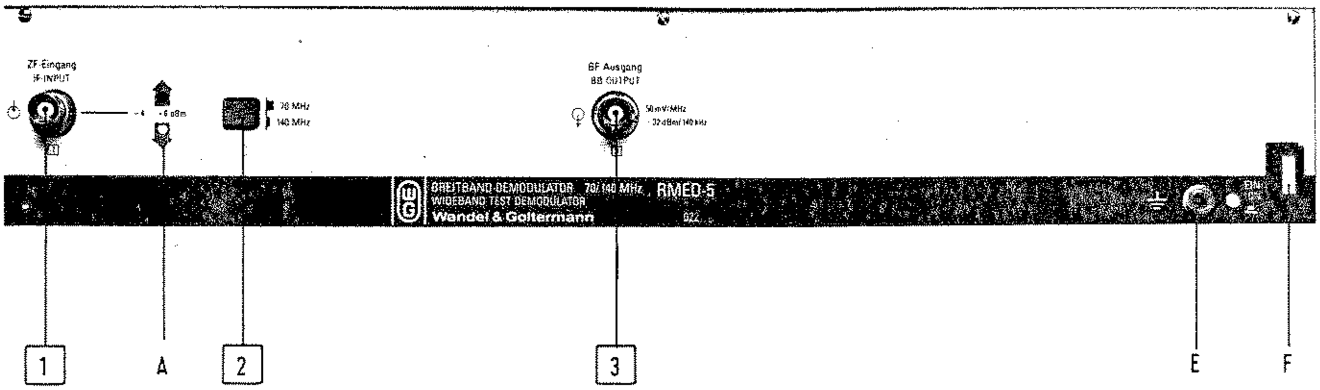


Figure 3-52 Front view of the RMED-5 Wideband Demodulator

Code	Function	Abbreviation in the circuit diagrams
[1]	Input for a wideband, frequency modulated IF signal IF centre frequency 70 or 140 MHz Level range -4 to +6 dBm	2 Bu 1
[2]	Key for selecting a centre frequency of 70 MHz or 140 MHz	3 S 1
[3]	Output for demodulated wideband BB signal	4 Bu 2
A	Input level out-of-range indicators	2 Gl 51, 52
E	Earth connector	1 Bu 1
F	Mains switch	1 S 1
Back panel:	Mains connector, mains-voltage selector, mains fuse	

Table 3-12 Controls and connectors on the RMED-5

3.10 R E M O T E   C O N T R O L   (<IEC 625> BUS)

3.10.1 PRELIMINARY REMARKS

The RMS-5 Generator Section and the RME-5 Receive Section are microprocessor controlled instruments whose functions can be controlled manually or via a desktop or process computer. If the latter mode of operation is required the instruments can be fitted with a remote control board to IEC 625 which requires a byte serial bit parallel interface system for programmable test equipment. The IEEE 488/78 or the HP-IB interface which is encountered in may computers and test instruments are electrically compatible with the IEC 625 interface. Using this interface, a computer and up to 14 test instruments (not necessarily from the same manufacturer) can be connected together to form a flexible, efficient system. Any difficulties caused by different connectors (e.g. 25-pin Canon connectors or 254-pin Amphenol connectors) can be circumvented using appropriate adaptors.

All compatible instruments are connected in parallel to the IEC bus, this means that they can access all bus lines. All the instruments connected to the IEC bus can transmit measurement or status data (TALKER) or receive programming data (LISTENER) according to their type. There must however only be one controller in the system, and one TALKER may transmit data at any one time. When selecting a controller various criteria should be borne in mind, e.g. what IEC bus functions have been implemented, speed, controller programming, memory capacity and so on, if a powerful and efficient test system is to be set up. All bus messages use ISO 7 bit code (ASCII code).

Programming is made much easier if you know how to operate the instruments manually (see previous chapter) and are acquainted with the general characteristics of the IEC bus (see Wandel & Goltermann brochure "IEC 625 Interface Bus" order No. 6390/00.39).

If required, Wandel & Goltermann will provide you with complete, ready-to-use systems. The advantage being that the user does not need to bother about the electrical, mechanical, functional and programming problems that may arise.

3.10.2 INSTRUMENT CONFIGURATION/INTERFACE FUNCTIONS

Figure 3-53 shows the setup of an automatic test system with an <IEC 625> interface. This is the smallest possible configuration comprising the controller and the RM-5.

Before connecting the various instruments together, fit the interface boards in the instrument and controller and set the device addresses. This procedure will be described in the following sections.

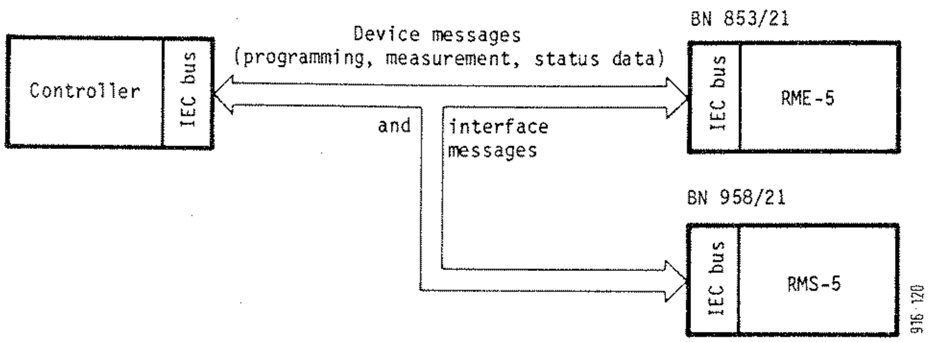


Figure 3-53 RM-5 controlled by computer via IEC bus

3.10.2.1 Interface boards for the IEC bus (IEC bus board)

The test instruments must be fitted with an IEC bus board (BN 958/21 or BN 853/21) if they are to be used in an IEC bus system, see Figure 3-53. They may be easily retrofitted by removing the dummy panels on the back panel of the instrument and inserting the boards in the appropriate slots. Before fitting, check that the wire-links are as shown in figure 3-54 or 3-55 and that the address switch (see 3.10.2.2) and the parallel poll switch (see 3.10.2.3) are set correctly.

Notes on the CLEAR (CLR) wire link

If the IEC bus command IFC (INTERFACE CLEAR) is intended for the instrument as well as the interface, the wire link CLR must be fitted on the interface board (BN 853/21) or the CLR switch set to ON. In this case, the IFC command initiates a DCL (DEVICE CLEAR) and a GTL (GO TO LOCAL) command. Re-initialising the instrument produces the same result, i.e. the instruments are reset to their standard settings, stored front panel setups (RMS-5) and stored reference curves (RME-5) are lost.

After fitting the CLR wire-link in the RME-5 it is a good idea to repeat the IFC several times over a period t $\geq$ 25 ms using a suitable program loop to ensure that these functions are implemented.

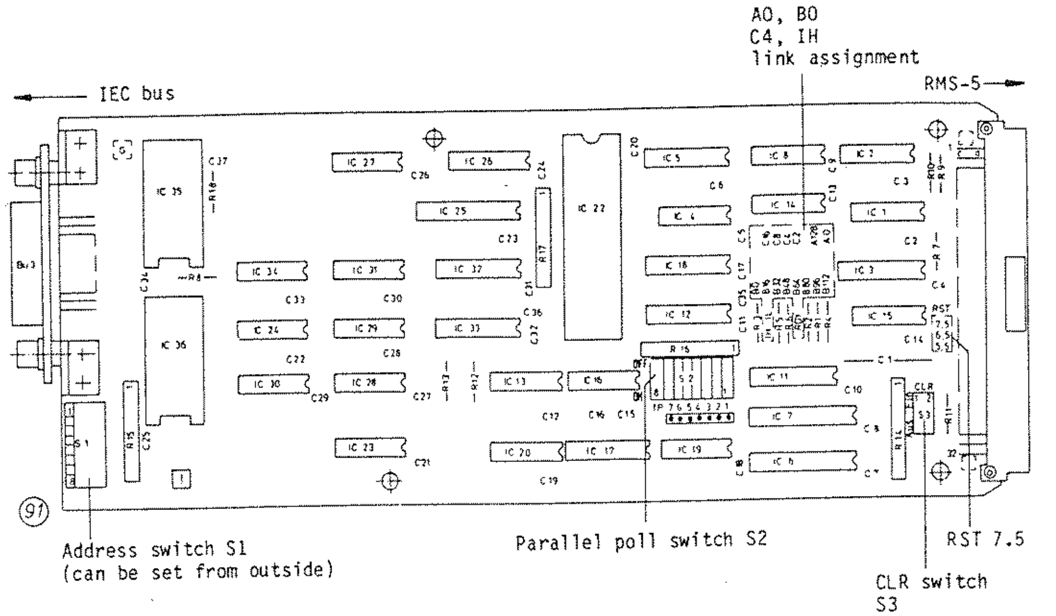


Figure 3-54 <IEC 625> interface board (BN 958/21) with address switch and parallel poll switch (RMS-5)

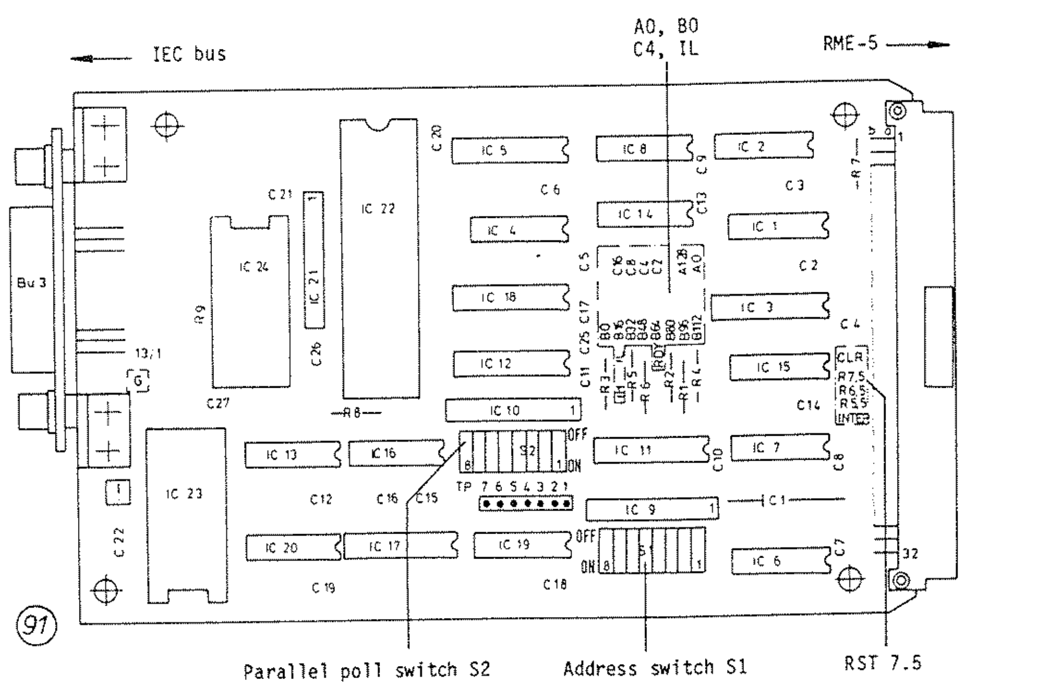
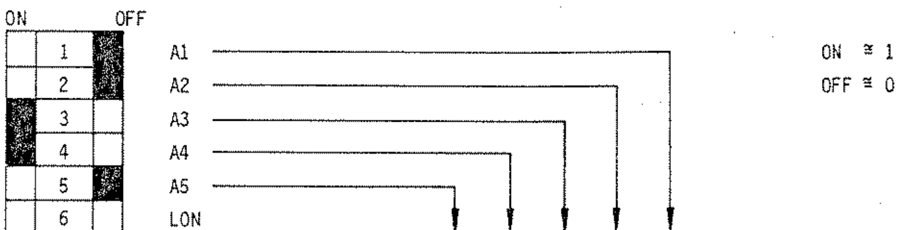


Figure 3-55 <IEC 625> interface board (BN 853/21) with address switch and parallel poll switch (RME-5)

3.10.2.2 Instrument addresses

Each instrument in the system must have a unique address so that the controller can call up the instrument in question. To set the addresses for the RMS-5 and RME-5, switch off and set the address switch S1 on the interface board using binary switches A1 to A5. The RME-5's interface board must be taken out, the address for the RMS-5 can be set from the back panel, see figures 3-54 and 3-55. When the RMS-5 leaves the factory its address is set to 12, the RME-5's address is set to 13.

Example: Setting the device address to 12 : 01100 (binary)



Switch	A5	A4	A3	A2	A1
Setting	0	1	1	0	0
Value	16	8	4	2	1

Figure 3-56 Example showing how to set the instrument address

Special care should be taken to ensure that instrument addresses are not duplicated (the address of the controller too, e.g. 21 for some hp controllers). There is a maximum of 31 address numbers available (0 to 30).

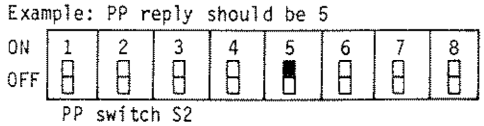
3.10.2.3 Setting parallel poll

The parallel poll interface function which has been implemented on the IEC bus boards BN 958/21 and BN 853/21 allows the the appropriately addressed device to output one status bit on one of the data lines DIO 1 to DIO 8 without being previously addressed as a talker when the controller initiates a parallel poll.

In this way, one can determine very quickly and clearly which instruments (max. 8) have sent a service request to the controller.

The data line which the instrument uses to reply to the parallel poll, must be specified using parallel poll switch S2 (see figure 3-54 and 3-55) on the IEC bus board. The instrument must be switched off.

Example: PP reply should be 5



S5 is on
≅ reply on data line DIO 5 (read into a controller variable as $2^{5-1} = 16$)

Figure 3-57 Example showing how to set parallel poll mode
(e.g. data line DIO 5 for the RMS-5 and data line DIO 6 for the RME-5)

3.10.2.4 Bus connections

The IEC bus boards are fitted with a 24-pole Amphenol connector. The pin assignment is shown in figure 3-58 (on the right). IEC bus cables of various lengths are available to connect the test instruments to other equipment or to a controller. Instrument to instrument connections must not exceed 4 m.

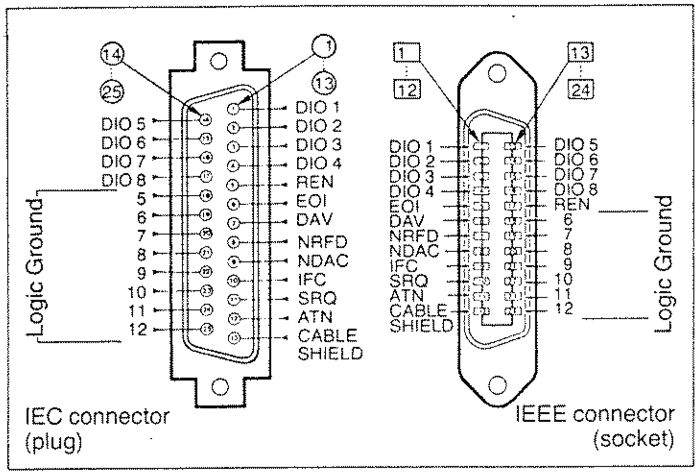


Figure 3-58 Bus connection assignment on the instrument

A maximum of 15 instruments can be connected together by the interface. The total length of the bus must not exceed 20 m (see DIN standard <IEC 625>, part 1, section 31.1 p.66 and section 39, p.71).

The length can be increased by using interface couplers (2-wire or 4-wire) or modems.

3.10.2.5 Interface functions

The following table is an overview of the interface functions realised on the RMS-5 and the RME-5 in accordance with the IEC standard. The abbreviations for each function are described in detail in the brochure "<IEC 625> interface bus" (order No. 6390/00.39). The necessary controller interface functions are also given so that the functions provided by the RME-5 and the RMS-5 can be fully exploited. The hp computer which we recommend ensures fast and straightforward programming of our remote-controllable instruments. Other computers with an IEC interface bus can also be used for this control function. The user must however be sure that the computer he chooses has all the necessary controller functions. Information of this kind will be found in the manual or can be obtained directly from the manufacturer. We can say nothing about the performance of our instruments when they are used with controllers which do not fulfil the minimum requirements (see DIN IEC 625, part 1).

Function		Description	RMS-5	RME-5	Controller
SH 1	Source handshake	Source handshake, full implementation	x	x	x
AH 1	Acceptor handshake	Acceptor handshake, full implementation	x	x	x
T 6	Talker	Talker, all functions	x	x	x
L 4	Listener	Listener, all functions	x	x	x
SR 1	Service request	Service request, full implementation	x	x	x
RL 1	Remote/local	Remote/local switchover, full implementation (disables manual operation with IEC bus command LLO)	x	x	
PP2	Parallel poll	Parallel poll activated via switch	x	x	
DC1	Device clear	Device clear, full implementation	x	x	x
DT 1	Device trigger	Device trigger, full implementation	x	x	x
C0	Controller functions	not a control function	x	x	
C1		System control			x
C2		Transmit IFC			x
C3		Transmit REN			x
C4		React to SRQ			x
C5		Take over control transfer take over synchronously request return of control, parallel poll Transmit interface message			x
C7		like C5 but no parallel poll			(x) Instead of C5
C9		like C5 but no "request return of control"			(x) Instead of C5
C11		like C5 but no request return of control and no parallel poll			(x) Instead of C5

Table 3-13 Implemented control functions on the RMS-5 and RME-5 plus essential controller functions

3.10.3. PROGRAMMING

In the following examples programming on the RM-5 is carried out with the hp 85 as the controller. It has been fitted with the 82937 A IEC bus interface and the I/O ROM. The statements used for the IEC bus are contained in the I/O manual of the computer. Section 3.10.4 contains the programming words that are used to form the programming data which can be called up by the RME-5. Depending on the statement used, the controller automatically sets the test instruments to talker mode to output test data, or to listener mode to accept programming data.

3.10.3.1 Preparations

Before programming data can be transferred to the instruments, they must be switched over from manual to remote control mode. The remote control mode (REN) is enabled with the hp 85 statement

ABORTIO 7
or REMOTE 7,

"7" is the select code of the controller interface.

If ABORTIO 7 is used, the interface functions will be cleared (IFC) to ensure a definite initial status on the bus. If the CLR wire-link has already been connected on the interface board (see 3.10.2.1), the instruments will also be returned (DCL) to their standard settings (see 3.10.4.2). Any front panel setups (MEM) or reference curves that have been stored will be lost.

If the wire-link has not been fitted, the IEC bus command SDC can be used to bring the addressed instrument to a specific status. The purpose of this procedure is to prevent any setting that would interfere with the test run. The hp 85 controller performs this function with

CLEAR 712.

By calling up the address of the instrument (12 in the case of the RMS-5), the instrument in question is set to the listener mode. All the keys on the front panel with the exception of the local key are disabled.

In the remote control mode, the instrument can also be set by remote control by transmitting the REN IEC bus command and addressing it as a listener, e.g. by using the instruction

REMOTE 712

It is possible to prevent the instruments from being switched over from remote to manual mode when the local key is pressed for any reason if the command LLO follows the IEC bus command REN. This is achieved with the statement

LOCAL LOCKOUT 7.

To cancel the LLO command and to select manual mode (see IEC bus brochure), the IEC bus command GTL can be used, which is executed in conjunction with the statement

LOCAL 712

3.10.3.2 Using programming data to set the instruments

After the appropriate preparations have been made, e.g. resetting the interface functions, setting the instruments to their standard settings and enabling the remote control mode, programming data (instrument input data) can be transferred from the controller to the instrument with the statement

```
                                          4Ø OUTPUT 712; programming word
                                           |    |     |          |
line number--------------------------------+    |     |          |
Output command----------------------------------+     |          |
Select code (7) and device address (e.g. 12)----------+          |
Programming word/words (PW, see 3.10.4)--------------------------+
```

The programming word comprises the header, a decimal number and a comma. The word is assigned to a specific device function. Tables 3-14 and 3-15 show the logical form of the headers, each programming word is described in 3.10.4.3 to 3.10.4.6 (alphabetical order, separate for RMS-5 and RME-5).

To set the RMS-5 or the RME-5, several programming words, separated by a comma, can be concatenated to form the device input data string. The RME-5 could be set in the following way:

```
CLEAR 713
OUTPUT 713; "IBF , DP , R13 , Y2Ø , AV3 ,"
             |     |    |     |     |
             |     |    |     |     └── Noise averaging factor of 8
             |     |    |     └──────── Show Y2 result on screen
             |     |    └────────────── Measurement range R13
             |     └─────────────────── Measurement mode ΔT, Δφ
             └───────────────────────── BB mode
```

The programming words are processed from left to right.

NOTE: Each programming word must be terminated with a comma, i.e. also the last entry in a string.

3.10.3.3 Trigger

From the first programming example for the RME-5 in 3.10.3.2, one can see that the RME-5 is immediately set to the new parameters after the program line has been entered and the "END LINE" key has been pressed. Afterwards the instrument behaves as if it were in manual mode, provided the RMS-5 provides an appropriate input signal. It performs measurements continuously as if in the operating mode "continuous trigger", which is part of the standard setting (3.10.4.2) or can be set with programming word "TØ" (trigger mode TØ).

If you want the controller to call up the results in remote control mode, a single measurement must be triggered. The programming word "T1" (trigger mode T1) is used to set the device to the single trigger operating mode, the controller then sends the BASIC statement

```
TRIGGER 713
```

the GET (GROUP EXECUTE TRIGGER) command to the device in question (in this case the address is 13).

When the trigger command is received, single trigger interrupts the current device function and a new measurement is performed.

3.10.3.4 Statusbyte, service request

In general, a waiting time to allow for setting, settling, calibration, and the measurement time must be allowed between triggering the measurement and calling up the results (RME-5). For this reason, the statement ENTER ... must not follow the statement TRIGGER, as the result obtained will be incorrect.

In the case of distortion measurements, the waiting time is mainly determined by the synchronisation of the deflection voltage U_x when parameters are changed and by the time it takes to form the sweep trace.

Waiting times have also to be set for the RMS-5, as incorrect transmission parameters would also give incorrect results.

Delay times are easy to program with the hp 85, simply use the WAIT statement with the waiting time specified in ms (e.g. WAIT 2000); delay times can be obtained with FOR NEXT loop on other types of controller.

The waiting times for the RMS-5 and RME-5 are given in the following:

Settling time when a parameter is altered (time after trigger command):

RMS-5:

Parameter change	Settled after
- Centre frequency	$6 \times 1/f_A$ or status bit for $\Delta f_{CENT} < \pm$ 100 kHz
- Sweep width	70 ms
- $\Delta \hat{F} = 0/\hat{U}_A = 0$	40 ms
- IF level	140 ms
- Test signal Δf, U_M	50 ms + T 1)
- Test frequency	90 ms
- $U_{M\ EXT}$	30 ms
- $U_{A\ EXT}$	250 ms $+ 6 \times 1/f_A$
- Wideband demodulator (option)	20 s
- Store front panel setup (MEM, RCL)	250 ms $+ 6 \times 1/f_A$ (or 20 s in wideband mode)
- Store front panel setup (IEC bus, IN ...) ...	250 ms $+ 6 \times 1/f_A$ (or 20 s in wideband mode)
- Sweep frequency	1.5 s
- Gap	30 ms

RME-5:

A sweep result can be interrogated after

- Averaging factor 0	200 ms
- Averaging factor 2	approx. 3 s
- Averaging factor 4	approx. 3 s
- Averaging factor 8	approx. 6 s
- Averaging factor 16	approx. 11 s
- Averaging factor 32	approx. 11 s

The test result is only called up in the shortest possible time, if the end of the measurement is recognised automatically. This can be done by checking certain bits in the status byte, or by continually interrogating the SRQ line, or by using the SRQ interrupt.

In the case of serial polls, the device that has been addressed outputs its status byte (status data; see 3.10.4.4 (RMS-5) or 3.10.4.6 (RME-5)). The controller only evaluates the "busy bit", in this case bit 5 with a value of $2^4 = 16$. An SRQ is not required.

---

1) T = 50 ms = time constant of 1st order

After	Test signal has settled to
T	63.2%
2 T	86.4%
3 T	95%
4 T	98.2%
5 T	99.3%

The hp 85 uses the following statements:

```
23Ø  S = SPOLL (713)     !serial poll of device with address 13
24Ø  IF  BIT (S,4) THEN 23Ø
```

The controller executes this loop until the busy bit which has been set by TRIGGER ... (true = 1) is set to 0 at the end of the measurement; the controller therefore waits until the results are ready.

Other bits in the status byte, e.g. those used for error messages or for incorrect evaluation, whose coding and meaning are described in 3.10.4.4 (RMS-5) or 3.10.4.6 (RME-5) may also be true.

Another way of determining the end of the measurement, if continuous data exchange is not taking place on the bus, is to poll the IEC-bus control lines, i.e. the interface control line SRQ in the controller interface.

```
23Ø  STATUS 7, 2; Q              !polling the IEC bus control lines
24Ø  IF NOT BIT (Q,5) THEN 23Ø    !SRQ bit evaluation without renewed SRQ poll
```

So that the instrument can transmit the service request message on the SRQ line, "SRQ on end of test" should be programmed using the programming word "XX...," when the instrument is set. The loops (lines 23Ø, 24Ø) are executed until the "SRQ bit" of status register 2 (IEC-bus control lines) is true.

As well as continually polling the IEC bus control lines in the controller interface, several types of controller have statements such as ON INTERRUPT ... or ON SRQ GOSUB .... This allows the computer to do calculations, for example, while it is waiting for an SRQ. After the SRQ, the program branches to a line number where it can access the test data.

If several instruments have been connected to the IEC bus, each of which could have sent an SRQ in the time period in question, a serial poll of all the instruments must be carried out and the results evaluated to determine from which instrument the SRQ came. Only those instruments which have their RQS bits set (bit 7 = 1) and the busy bit = false (bit 5 = 0), have sent SRQ after the end of the test.

Using a parallel poll, instead of the serial poll described above, it is possible to determine somewhat more quickly which instrument (max. of 8) has sent a request for service.

The hp 85 parallel poll statement is:

```
A = PPOLL (7)
```

The sum of the values for each bit for lines DIO 1 to DIO 8 is assigned to variable A. For example, if the status bits for DIO 1 and DIO 3 are set, A is assigned the value 5 ($2^0 + 2^2$). A serial poll is then carried out on the instruments that have been so identified, to determine from the status byte what the reason for the request for service was.

3.10.3.5 Control word

The control word is a further way of determining the instantaneous status of the RME-5. As a reply to the programming word "CO", the RME-5 transfers a 16 digit control word to the computer (2 ASCII characters from the extended character set). Only bits B_0 to B_7 are used to perform the evaluation. Only those bits that are relevant to a particular operating mode are evaluated, other bits have no significance.

CONTROL WORD	C	0	,

Format: | B_7 | B_6 | B_5 | B_4 | B_3 | B_2 | B_1 | B_0 |

Bit	Signal	Bit status Ø	1
B_7	AFC	Not captured	Captured
B_6	U_x synchronisation	Not in sync.	In sync.
B_5	IF level indicators: too high/too low	Out-of-range	Level OK
B_4	U_M level indicators: too high/too low	Out-of-range	Level OK
B_3	IF level P_I	Out-of-range	In range
B_2	Test tone deviation Δf	Out-of-range	In range
B_1	BB level (signal at [29])	Out-of-range	In range
B_0	Test frequency f_M	Not detected	Detected

The following example shows how the control word is displayed on the screen of the computer.

```
10 DIM A$[16],B$[16]            ---- Prepare memory
20 OUTPUT 713 USING "K";"C0,"   ---- Request control word
30 ENTER 713 USING "%,W";A      ---- Transfer to memory A
40 A$=DTB$(A)                   ---- Convert to binary word
50 B$=A$[9,16]                  ---- Mask bits B7 to B0
60 DISP B$
70 END
11111111                        ---- Displayed control word
```

If the previous control word were used to poll an RME-5 operating at IF frequencies, there would be no point in evaluating B_1.

3.10.3.6 Interrogating results; functions that have been set and operating states

The controller can obtain test data from the RME-5 or setting data from the RMS-5 and process them further, provided the instrument has been addressed as a talker. The hp 85 uses the following statement to obtain test data or setting data.

ENTER 713 USING "%, % K"; A$

ENTER 713 is used to address the instrument as a talker (in this case its address is 13). The format specification "%, % K" (see the hp 85 I/O programming guide) means that the controller uses EOI and LF as terminators.

The type of transferred data that can be stored in a string variable (in the example A$) or that can be printed out after, for example, "PRINT A$", or that can be displayed on the screen after "DISP A$", depend on the measurement that has been programmed before these data are transferred.

The units, e.g. dBm, kHz, MHz, ns etc. are not transferred by the RME-5, but can be deduced from the data output mode (cf 3.10.4.4 or 3.10.4.6) or from the programming mode.

If the test data is assigned to a numeric variable, this value can be used immediately for further calculations, but the information in the first two alphanumeric characters is lost.

Interrogating the distortion curves (dynamic results)

When the computer scans the points on the trace, it takes the 51 amplitude steps outside the grid as well as the y values inside the grid into account (RME-5, 205 values). Figure 3-59 shows the internal range of the grid and the y values.

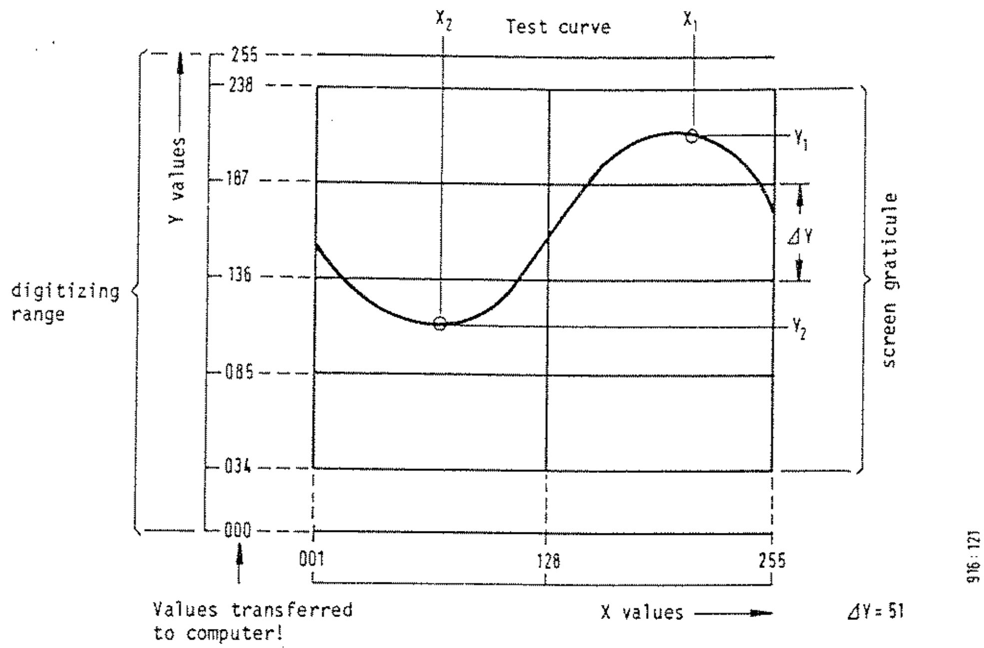


Figure 3-59 X and Y range of screen (digitisation)
$001 < x \leq 255$; $000 < y \leq 255$

Using appropriate programming words with the format "RE ..." (cf 3.10.6.4) it is possible to interrogate any point on a sweep trace (y values) or the whole trace.

When a single point is interrogated transfer to the controller takes place in the form of a 3 digit decimal number in ISO 7-bit code (ASCII code), i.e. the y values corresponding to a particular x value.

When the whole trace is interrogated, the y values are expressed in terms of binary coded decimals (EBCDIC code) to save time. Transfer of this kind is 3 times faster than the transfer of single points. The hp 85 uses the NUM statement to convert the ASCII characters.

If the y values of two points on the trace are known, the difference of the distortion values can be calculated from the following equn.

Trace difference: $\frac{Y_1 - Y_2}{Y}$ x sensitivity/DIV; Y = 51

For example, the points could be the maximum (Y_1 value in figure 3-59) and the minimum (Y_2 value). When both these points are known, the maximum distortion can be determined.

The extreme values of a distortion measurement can be found for both curves using the programming words "REØA," and "REØB,".

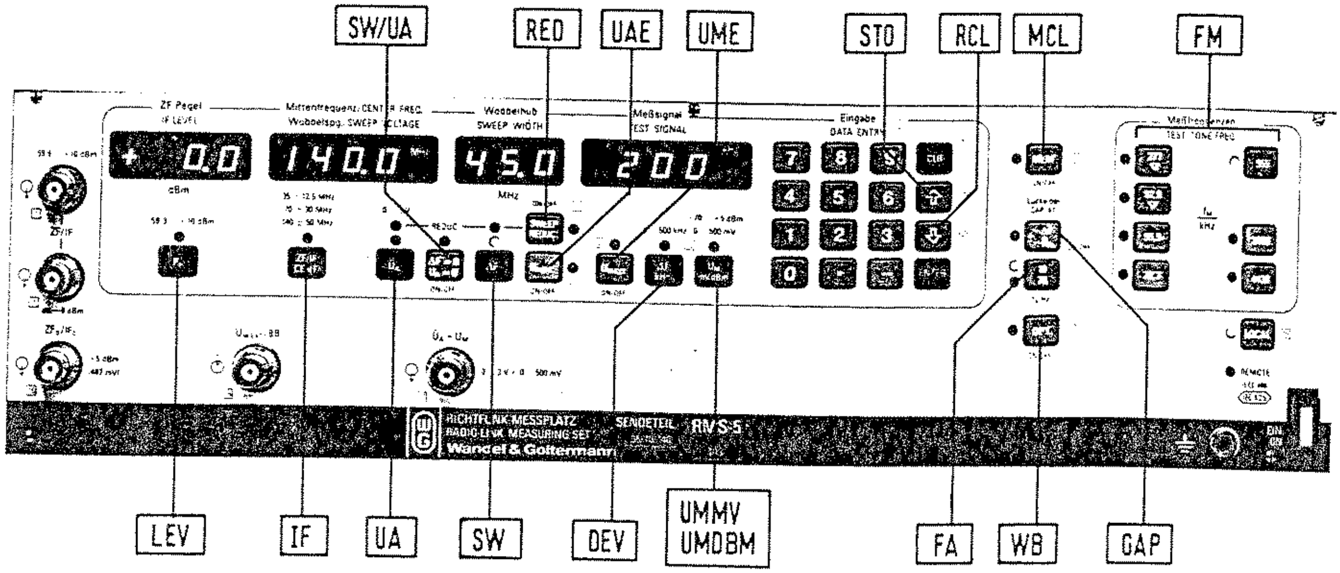


Figure 3-60   Programming words and associated controls on the RMS-5

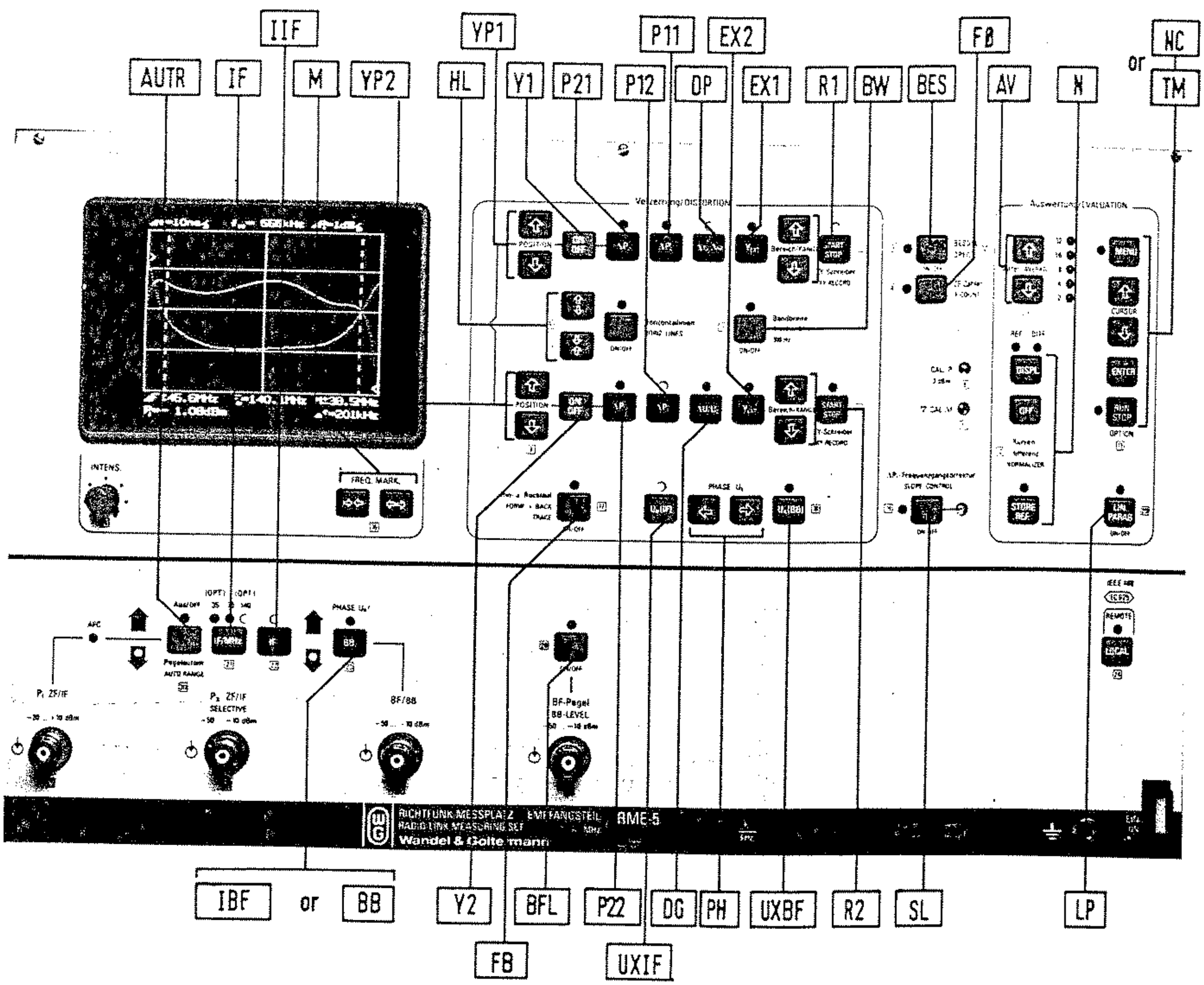


Figure 3-61   Programming words and associated controls on the RME-5

3.10.4 DEVICE MESSAGES

3.10.4.1 Overview of programming data for setting the RMS-5 and RME-5

Tables 3-14 and 3-15 show the programming data formats (instrument input data) for the RMS-5 and RME-5, ordered according to function. Programming data may comprise one or more programming words. Each programming word (PW) comprises a header, a decimal number and a + or - sign and a comma.

The header has a max. of 5 letters (e.g. UMDBM: test voltage with unit dBm).

After the header for the required function has been found, the programming word is easy to find, as they are listed alphabetically in 3.10.4.4.

The syntax given in the tables for the programming words must always be observed. Numerical entries for the RMS-5 are an exception however and leading or trailing zeros may be ignored.

It is never possible to enter a unit, similarly data that the test set sends to the controller does not contain units.

Figures 3-60 and 3-61 show the front panel; each function on the front panel is assigned a code which will help you find the appropriate programming word in the following section.

RMS-5		
Device function (controller → RMS-5)	HEADER	BODY AND TERMINATOR
Complete front panel setup		
- Standard setting (cf table 3-16)	IN	d ,
- Store device setup	STO	2d ,
- Load device setup	RCL	2d ,
- Erase device setups	MCL	2d ,
Frequencies		
- IF centre frequency	IF	5d ,
- Sweep width $\hat{\Delta F}$	SW	4d ,
- Test frequency f_M	FM	d ,
- Test tone deviation Δf	DEV	4d ,
- Sweep frequency f_A	FA	d ,
Level and voltages		
- IF level P_{IF}	LEV	5d ,
- Sweep voltage $\hat{U}_A$ (V)	UA	5d ,
- Sweep voltage "external" $U_{A\ EXT}$	UAE	d ,
- Test signal U_M (mV)	UMMV	4d ,
- Test signal U_M (dBm)	UMDBM	5d ,
- Test signal $U_{M\ EXT}$	UME	d ,

d = Number of characters, the max. number is always given

Table 3-14 RMS-5 function/programming word assignment

RMS-5		
Device function (controller ⟶ RMS-5)	HEADER	BODY AND TERMINATOR
Additional functions		
- Sweep width reduction	RED	d ,
- Gap (for $\Delta U/U_0$ results)	GAP	d ,
- Wideband mode	WB	d ,
Data traffic		
- Interface mode	XX	4d ,
- Trigger mode	T	d ,
- Data output (setting parameters)	E	5d ,

d = Number of characters, the max. number is always given

Table 3-14 RMS-5 function/programming word assignment (continued)

RME-5		
Device function (controller ⟶ RME-5)	HEADER	BODY AND TERMIMATOR
Standard setting (cf tables 3-17, 3-18)	IN	d ,
IF range	IF	3d ,
Signal inputs		
- Activate BB-IF inputs	I	2d ,
Measurement modes		
- Group delay, diff. phase $\Delta T, \Delta\varphi$	DP	,
- Non. lin, distortion, diff. gain $\Delta U/U_0$	DG	,
- Attenuation distortion ΔP_I, ΔP_{II}	P	2d ,
- External sweep signal Y_{EXT}	EX	d ,
- Switch on/switch off distortion results Y1, Y2	Y	2d ,
- Frequency counter	FØ	d ,
- Bessel spectrum	BES	d ,
- BB level meter	BFL	d ,
- BB mode and BB level display	BB	d ,
Measurement range		
- for distortion measurements Y1, Y2	R	2d ,
Phase correction		
- U_x from BB or IF	UX	2d ,
- Phase setting	PH	3d ,
- Display outward and return sweep	FB	d ,

d = Number of characters, the max. number is always given

Table 3-15 RME-5 function/programming word assignment

RME-5		
Device function (controller → RME-5)	HEADER	BODY AND TERMINATOR
<u>Evaluation of distortion results</u>		
- 300 Hz filter	BW	d ,
- Digital noise averaging	AV	d ,
- Curve difference	N	3d ,
- Curve analysis	LP	d ,
ΔP_I frequency response correction	SL	d ,
Vertical displacement of Y1, Y2	YP	6d ,
Auto. level control	AUTR	d ,
Frequency markers	M	5d ,
Horizontal cursors	HL	3d ,
<u>Screen displays</u>		
- Text entry (in lines)	L	$,
- Erase character field	ER	,
- Reference curve	SR	$,
- Tolerance masks (general)	TO	$,
<u>Additional functions</u>		
- Noise calculation (option)	NC	2d ,
- Tolerance masks to SSOG (option)	TM	2d ,
- Control word (RME-5 status, cf 3.10.3.6)	CO	,
<u>Data traffic</u>		
- Interface mode	XX	5d ,
- Trigger mode	T	d ,
- Result, measurement mode and measurement range interrogation	RE	4d ,

d = Maximum number of characters

$ = String whose number of characters depend on the programming word; cf relevant programming words in 3.10.4.5

Table 3-15 RME-5 function/programming word assignment (cont.)

3.10.4.2 Standard settings on the RMS-5 and RME-5

The instruments are set to a well-defined initial state (standard setting), when the DCL or DCE IEC bus commands are received. If the battery that supplies current to the CMOS memory is flat, the RMS-5 or RME-5 will be set to these standard settings when they are switched on.

The standard settings for the RMS-5 and the RME-5 correspond to the programming words given in tables 3-16 or 3-17, see 3.3.3.

The standard settings for the RMS-5 and the RME-5, can also be called up with the programming word "IN1", when the instruments are in program mode.

RMS-5 "IN1,"	
IFØ7Ø.Ø,	IF centre frequency IF = 70 MHz
LEV+Ø.ØØ	IF level P_I = 0 dBm
UA1.ØØØ,	Sweep voltage $\hat{U}_A$ = 1 V
SWØ.5Ø,	Sweep width $\hat{\Delta F}$ = 0.5 MHz
DEV1ØØ,	Frequency deviation Δf = 100 kHz
UMMV1ØØ,	Test voltage U_M = 100 mV
UMDBM-8.7Ø,	Test voltage U_M = -8.7 dBm
FA1,	Sweep frequency f_A = 18 Hz
FM5,	Test frequency f_M = 500 or 555.55 kHz
TØ,	Continuous trigger mode
XXØ1ØØ	Interface mode
- All other functions are inoperative - Entry preparation: IF level entry is selected - Data output mode to "EIF," (≡ IF centre frequeny); see 3.10.4.4 - Device setups cannot be called up (except RCLØ)	

Table 3-16 Standard setting for the RMS-5

RME-5 "IN1,"	
IF7Ø,	IF range 70 MHz
IIF,	IF signal inputs [25] and [26] active
UXIF,	Phase U_x from IF
AUTR1,	ALC on
Y11,	Y1 result on
Y21,	Y2 result on
DP,	Measurement mode ΔT, $\Delta\varphi$
P12,	Measurement mode ΔP_I
R14,	Measurement range for Y1 result, depends on f_M
R24,	Measurement range for Y2 result = 0.4 dB/D
AV2,	Noise averaging factor 4
TØ,	Continuous trigger mode
XXØ1ØØØ,	Interface mode
- All other functions are inoperative	

Table 3-17 Standard setting for the RME-5 in "IF mode" (reinitialisation)

It is only possible to call up a standard setting for the BB mode in remote control mode. The appropriate programming word is "IN2,".

RME-5 "IN2,"	
IF7Ø,	IF range 70 MHz
IBF,	BB signal input, connector [27] active
UXBF,	Phase U_x from BB
AUTR1,	ALC on
Y11,	Y1 result on
Y21,	Y2 result on
DP,	Measurement mode $\Delta\tau$, $\Delta\varphi$
DG,	Measurement mode $\Delta U/U_o$
R14,	Measurement range for Y1 result, depends on f_M
R24,	Measurement range for Y2 result: 1%/DIV
AV2,	Noise averaging factor 4
TØ,	Continuous trigger mode
XXØ1ØØØ,	Interface mode
- All other functions are inoperative	

Table 3-18 Standard setting for the RME-5 "BB mode"

3.10.4.3 Programming words for setting the RMS-5 (in alphabetical order)

DEV

DEV	d	d	d	d	,	Test tone deviation Δf (kHz) (DEVIATION)
						Max. of 4 characters including decimal point; cf table 3-3
	1	Ø	Ø			Standard setting: 100 kHz

FA

FA	d	,	Sweep frequency f_A (Hz)
	1		18 Hz
	2		70 Hz
	1		Standard setting

FM

FM	d	,	Test frequency f_M
	1		Lowest test frequency: 27.778 kHz or 25 kHz
	⋮		⋮
	7		Highest test frequency: 5.6 MHz (for standard version)
	5		Standard setting: 555.556 kHz or 500 kHz

GAP

GAP	d	,	Gap in distortion results
	Ø		Gap off
	1		Gap on
	Ø		Standard setting

IF

IF	d	d	d	d	d	,	IF centre frequency F_0 (MHz)
							Max. of 5 characters including decimal point; cf table 3-3
	Ø	7	Ø	.	Ø		Standard setting: 70 MHz

IN

IN	1	,	Standard setting (INITIALIZATION)

The standard setting for the RMS-5 as shown in table 3.16 can be called up by the controller with this programming word.

LEV

LEV	d	d	d	d	d	,	IF level P_{IF} (dBm) (IF-LEVEL)
							Max. of 5 characters including the decimal point and sign; cf table 3-3
	+	Ø	.	Ø	Ø		Standard setting: 0 dBm

MCL

MCL	d	d	,	Erase front panel setups (MEMORY CLEAR)
	Ø	1		Erase setup at address 1
	⋮	⋮		⋮
	2	Ø		Erase setup at address 20

RCL

RCL	d	d	,	Call up setups
	Ø	1		Call up setup at address 1
	⋮	⋮		⋮
	2	Ø		Call up setup at address 20
	Ø	Ø		Standard setting ≙ "INI,"

RED

RED	d	,	Sweep width reduction
	Ø		Off
	1		On
	Ø		Standard setting

STO

STO	d	d	,	Store setups
	Ø	1		Store setup at address 1
	⋮	⋮		⋮
	2	Ø		Store setup at address 20

SW

SW	d d d d ,	Sweep width $\hat{\Delta F}$ (MHz)
		Max. of 4 characters including decimal point
	Ø . 5 Ø	Standard setting: 0.5 MHz

SW/UA

SW/UA	d ,	Sweep signal on/off
	Ø	Off
	1	On: $\hat{\Delta F}$ = 0 MHz or $\hat{U}_A$ = 0 V
	Ø	Standard setting

T

T	d ,	Trigger mode
	Ø	Free run (continuous)
	1	Trigger type (single)
	Ø	Standard setting

UA

UA	d d d d d ,	Sweep voltage $\hat{U}_A$ (V)
		Max. of 5 characters including decimal point, cf table 3-3
	1 . Ø Ø Ø	Standard setting: 1 V

UAE

UAE	d ,	Sweep voltage "external" $U_{A\ EXT}$
	Ø	Off
	1	On
	Ø	Standard setting

UMDBM

UMDBM	d d d d d ,	Test signal U_M (dBm)
		Max. of 5 characters including decimal point and sign, cf table 3-3
	- 8 . 7 Ø	Standard setting: -8.7 dBm

UME

UME	d ,	Test signal "external" $U_{M\ EXT}$
	Ø	Off
	1	On
	Ø	Standard setting

UMMV

UMMV	d d d d ,	Test signal U_M (mV)
		Max. of 4 characters including decimal point, cf table 3-3
	1 Ø Ø .	Standard setting: 100 mV

WB

WB	d ,	Wide Band Mode[1)]
	Ø	Off
	1	On
	Ø	Standard setting

1) with wideband modulator option

XX

XX	d	d	d	d ,	Interface mode	
	Ø 1				SERVICE REQUEST after "mains on"	NO YES
		Ø 1			SERVICE REQUEST after execution of the trigger function	NO YES
			Ø 1 2		PARITY BIT: (i.e. with ISO 7-bit code)	no parity odd parity even parity
				Ø 1 2 3	TERMINATOR (i.e. with ISO 7-bit code)	no terminator END & DATA BYTE END & ETX ETX
	Ø	1	Ø	Ø	Standard setting	

The character @ can be selected instead XX.

3.10.4.4 Programming words for the RMS-5 data output mode, status byte

E

Controller → RMS-5							RMS-5 → Controller
E						Transmission parameters	Format
	L	E	V	,		IF level P_{IF} (dBm)	Sn _ _ . _
	I	F	,			IF centre frequency F_0 (MHz)	_ _ _ . _
	S	W	,			Sweep width $\Delta\hat{F}$ (MHz)	_ _ . _ _
	S	W	/	U	A ,	Sweep signal $\Delta\hat{F}/\hat{U}_A = 0$	Ø Ø off; Ø 1 on
	U	A	,			Sweep voltage $\hat{U}_A$ (V)	_ . _ _ _
	U	A	E	,		External sweep voltage	Ø Ø off; Ø 1 on
	D	E	V	,		Frequency deviation Δf (kHz)	_ _ _ . _
	U	M	M	V	,	Test signal U_M (mV)	_ _ _ . _ _
	U	M	D	B	M ,	Test signal U_M (dBm)	Sn _ _ . _
	U	M	E	,		Test signal U_M "external"	Ø Ø off; Ø 1 on
	F	A	,			Sweep frequency f_A (Hz)	_ _
	R	E	D	,		Sweep width reduction	Ø Ø off; Ø 1 on
	F	M	,			Test frequency f_M (kHz)	_ _ _ _
	G	A	P	,		Gap	Ø Ø off; Ø 1 on
	W	B	,			Wideband mode (option)	Ø Ø off; Ø 1 on

Sn ≅ sign

SPOLL	8	7	6	5	4	3	2	1	Status byte (RMS-5 → Controller)
	Ø 1								Remote Local
		Ø 1							NO YES RQS
				Ø 1					Trigger function ended Trigger function still operative
								Ø 1	ΔIF < 100 kHz centre frequency ΔIF > 100 kHz offset

Data lines (bits 8 to 1)

The command "SPOLL" is only used to interrogate the status of the instrument. It is not a programming word.

3.10.4.5 Programming words for setting the RME-5 (in alphabetical order)

AUTR

AUTR	d	,	Automatic level control (AUTO RANGE)
	Ø		Off
	1		On
	1		Standard setting

AV

AV	d	,	Digital noise averaging (AVERAGING)
	Ø		Averaging off
	1		Averaging factor "2" – Averaging on
	2		Averaging factor "4" – Averaging on
	3		Averaging factor "8" – Averaging on
	4		Averaging factor "16" – Averaging on
	5		Averaging factor "32" – Averaging on
	2		Standard setting: averaging factor "4"

BB

BB	d	,	BB mode with BB level display (BASE BAND)
	Ø		Special function off
	1		Special function on
	Ø		Standard setting

BES

BES	d	,	Bessel operating mode
	Ø		Off
	1		On
	Ø		Standard setting

BFL

BFL	d	,	BB level meter (BASE BAND FREQUENCY LEVEL)
	Ø		Off
	1		On
	Ø		Standard setting

BW

BW	d	,	300 Hz weighting filter (300 Hz BANDWIDTH)
	Ø		Off
	1		On
	Ø		Standard setting

CO

CO	,	Control word (status RME-5, cf 3.10.3.6)

DG

DG	,	Differential gain $\Delta U/U_0$ (DIFFERENTIAL GAIN)
		Standard setting: not selected

DP

DP	,	Group delay/differential phase $\Delta T/\Delta \varphi$ (DIFFERENTIAL PHASE)
		Standard setting: measurement mode selected

ER

ER	,	Erase whole character field (text) (ERASE)

EX

EX	d	,	External sweep result Y_{EXT}
	1		As Y1 result
	2		As Y2 result
			Standard setting: not selected

FØ

FØ	d	,	IF counter operating mode
	Ø		Operating mode off
	1		Operating mode on
	Ø		Standard setting

FB

FB	d	,	Outward and return sweep (FORWARD/BACK TRACE)
	Ø		Only outward trace (standard)
	1		Outward and return trace
	Ø		Standard setting

I

I	d	d	,	Signal inputs (INPUTS)
	B	F		BB input [27] active
	I	F		IF inputs [25], [26] active
	I	F		Standard setting

IF

IF	d	d	d	,	IF input frequency (INTERMEDIATE FREQUENCY)
	3	5			35 MHz IF range (option fitted)
	7	Ø			70 MHz IF range
	1	4	Ø		140 MHz IF range (option fitted)
	7	Ø			Standard setting: 70 MHz IF range

IN

IN	d	,	Standard setting (INITIALISATION)
	1		IF mode; see table 3-17; same as setting when reinitialised
	2		BB mode, see table 3-18
	1		Standard setting

L

L	d	d	$	,	Text displayed inside screen grid (LINES)
	Ø	1			Line 1 (line at top of grid)
	⋮	⋮			⋮
	1	3			Line 13 (line at bottom of grid)

The string $ comprises a max. of 30 characters; the character field a maximum of 5 lines per screen. The lines can be numbered in any way (5 from 13).

L	d	d	,	Erase single lines
	Ø	1		Erase line No. 1
	⋮	⋮		⋮
	1	3		Erase line No. 13

See the programming word "ER,". (Lines that have been set can be overwritten).

LP

LP	d	,	Trace analysis (LIN/PARAB)	
	Ø		Off	
	1		On	LIN and PARAB values shown
	Ø		Standard setting	

The programming word "REØ9," can be used to interrogate the LIN/PARAB values.

M

M	d	d	.	d	d	,	Enter frequency marker deviation (FREQUENCY MARKERS)
	Ø	1	.	5	3		Example M = 1.53 MHz
	9	9	.	9	9		Standard setting: frequency markers outside the sweep range
	MHz			kHz			

- If the marker deviation is greater than the sweep width $\hat{\Delta F}$, limiting to $\hat{\Delta F}$ takes place.
- The programming word "REØ5," can be used to interrogate the M value

NC

NC	d	d	,	Noise calculation option, BN 917/00.11 (NOISE CALCULATION)	
	Ø	Ø		Off	
	Ø	1		Select system No. 1 (300 channels)	cf 3.7.5.2, table 3-5
	⋮	⋮		⋮	
	Ø	9		Select system No. 9 (2700 channels)	
	Ø	Ø		Standard setting	

- The RMS-5 must be set to the required parameters f_M and $\hat{\Delta F}$.
- The results for the $\Delta\varphi$ and $\Delta U/U_0$ distortion measurements must be selected. The traces must lie within the digitisation range.
- The results can be interrogated by means of the programming words "REØE," and "REØF,".

N

N	d	d	d	,	Formation of trace difference (NORMALISING)
	0	F	F		Function off (current trace A displayed)
	D	I	F		Difference trace "DIF" displayed
	R	E	F		Reference trace "REF" displayed
	S	T	O		Store reference trace
	0	F	F		Standard setting

P

P	d	d	,	Attenuation/frequency distortion
	1	1		ΔP_I result (key row [2], Y1 result)
	1	2		ΔP_I result (key row [10], Y2 result)
	2	1		ΔP_{II} result (key row [2], Y1 result)
	2	2		ΔP_{II} result (key row [10], Y2 result)
	1	2		Standard setting

PH

PH	d	d	d	,	Phase setting (correction of U_x) in degrees
	0 : 3	0 : 6	0 : 0		Setting 0 to 360° (U_x from BB)
	- : +	Ø : Ø	5 : 5		Setting -5 to +5° (U_x from IF)

- The functions "UXBF," or "UXIF," and "FB1," must be programmed beforehand.

R

R	d	d	,	RANGE								
				$\Delta\tau$ (ns/D)					$\Delta\varphi$ (% rad/D)	ΔP_I (dB/D)	ΔP_{II} (dB/D)	Y_{EXT} (mV/D)
				f_{M1}	f_{M2}	f_{M3}	f_{M4}	f_{M5}	f_{M6}, f_{M7}			
Y1	1	1		4	2	1	0.4	0.2	0.1	-	-	2
Y1	1	2		10	5	2.5	1	0.5	0.25	0.1	-	5
Y1	1	3		20	10	5	2	1	0.5	0.2	2	10
Y1	1	4		40	20	10	4	2	1	0.4	4	20
Y1	1	5		100	50	25	10	5	2.5	1	10	50
Y1	1	6		200	100	50	20	10	5	2	20	100
Y1	1	7		400	200	100	40	20	10	4	-	200
				$\Delta U/U_0$ (%/D)						ΔP_I (dB/D)	ΔP_{II} (dB/D)	Y_{EXT} (mV/D)
Y2	2	1		0.1						-	-	2
Y2	2	2		0.25						0.1	-	5
Y2	2	3		0.5						0.2	2	10
Y2	2	4		1						0.4	4	20
Y2	2	5		2.5						1	10	50
Y2	2	6		5						2	20	100
Y2	2	7		10						4	-	200
Y1	1	4		Standard setting: selected measurement range depends on f_M								
Y2	2	4		Standard setting: 0.4 dB/D (ΔP_I result)								

- f_{M1} to f_{M5} ≅ low test frequencies (< 1 MHz)
- f_{M6}, f_{M7} ≅ high test frequencies (> 1 MHz)

SL

SL	d	,	ΔP_I Frequency response correction (SLOPE CONTROL)
	Ø		Off
	1		On
	Ø		Standard setting

SR

SR	d	X_1	Y_1	X_2	Y_2	…	X_{255}	Y_{255}	,	Store reference curve
		Ø Ø 1		Ø Ø 2			2 5 5			
	1									Store reference curve in Y1 memory
	2									Store reference curve in Y2 memory

A reference curve is a curve that is defined by the user (≅ a string with 2 x 3 x 255 characters), e.g. a previous result that has been stored in the controller. The reference curve is used to form the trace difference in the normaliser mode.

T

T	d	,	Trigger mode
	Ø		Free run mode (continuous)
	1		Trigger request (single)

TM

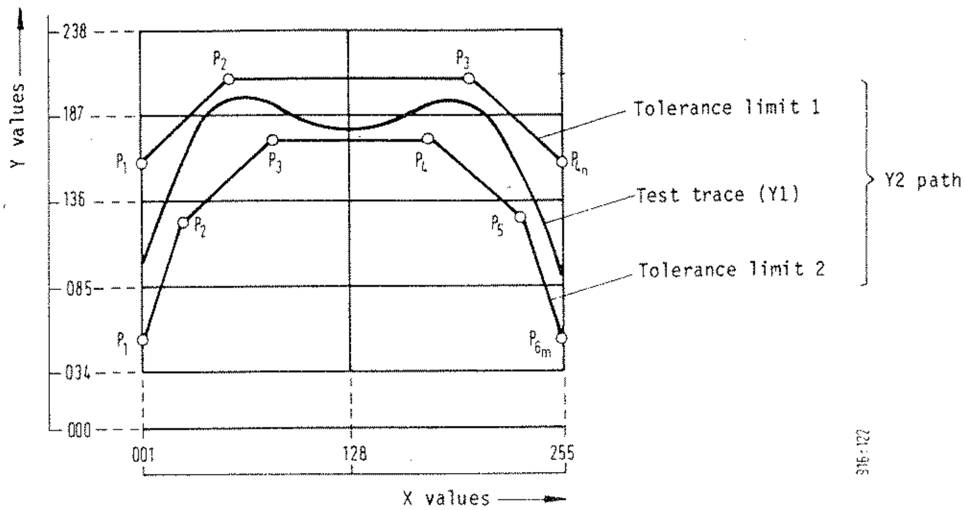
TM	d	d	,	INTELSAT tolerance masks (TOLERANCE MASKS), option BN 917/00.12	
	Ø	Ø		Off	TR measurement cf 3.7.6.2, table 3-6
	Ø	1		Tolerance mask (carrier bandwidth 1.25 MHz)	
	⋮	⋮		⋮	
	1	3		Tolerance mask for VIDEO**	
	1	4		Tolerance mask für TDMA	
	2	1		Tolerance mask (carrier bandwidth 1.25 MHz)	IF-IF-measurement, cf 3.7.6.2, table 3-6
	⋮	⋮		⋮	
	3	3		Tolerance mask for VIDEO**	

TO

P_1 = (X_1, Y_1), P_2 = (X_2, Y_2) … $P_{n,m}$ = ($X_{n,m}$, $Y_{n,m}$)

TO	d	X_1	Y_1	X_2	Y_2	…	$X_{n,m}$	$Y_{n,m}$	,	Tolerance mask programming
		Ø Ø 1					2 5 5			
	1									Set tolerance mask 1 (string with 2 x 3 x m characters)
	2									Set tolerance mask 2 (string with 2 x 3 x m characters)
	Ø	,								Switch off tolerance mask (≅ standard setting)

- To define a tolerance limit at least 2 points must be defined, a maximum of 16 may be used (range for n and m)
- If the 1st x value > ØØ1 and/or the last x value is < 255, no tolerance mask lines will be displayed in the range from ØØ1 to X_1 or $X_{n,m}$ to 255.



- To enter a tolerance mask, the test channel in which the tolerance mask is to be displayed must be switched off (programming word "Y ...,"). In the previous figure this would be the Y2 channel; the result is determined in the Y2 channel, which is provided for the tolerance mask, the format of the instrument input data string is: OUTPUT 713; "Y2Ø, T01 ..., T02 ...,"

UX

UX	d	d	,	Derivation of deflection voltage U_x
	B	F		Deflection voltage U_x from BB signal
	I	F		Deflection voltage U_x from IF signal
	I	F		Standard setting

XX

XX	d	d	d	d	d	,	Interface mode		
	Ø						SERVICE REQUEST after "power on"		NO
	1								YES
		Ø					SERVICE REQUEST after execution of		NO
		1					trigger function		YES
			Ø				PARITY BIT:	no parity bit	
			1				(ISO-7-bit code)	odd parity bit	
			2					even parity bit	
				Ø			TERMINATOR:	no terminator	
				1			(ISO-7-bit code)	END & DATA BYTE	
				2				END & ETX	
				3				ETX	
					Ø		TERMINATOR:	no terminator	
					1		(ISO-7-bit-code)	END & DATA BYTE	
					2			END & ETX	
	Ø	1	Ø	Ø	Ø		Standard setting		

The character @ can be used instead of XX.

Y

Y	d	d	,	Test channels Y1, Y2 for the distortion measurement modes
	1	Ø		Channel 1 off } Equivalent to ON/OFF button [2]
	1	1		Channel 1 on
	2	Ø		Channel 2 off } Equivalent to ON/OFF button [10]
	2	1		Channel 2 on
	1	1	}	Standard setting
	2	1		

YP

YP	d	d	d	d	d	d	,	Vertical shift for Y results (Y POSITION)
	1	+						Y1 results shifted upwards
	1	-						Y1 results shifted downwards
	2	+						Y2 results shifted upwards
	2	-						Y2 results shifted downwards

Shift values: Ø to 9999, there is an internal correction for the max. shift value.

3.10.4.6 Programming words for interrogating the RME-5's results, status byte

Controller ⟶ RME-5   RME-5 ⟶ Controller

RE

RE	d	d	,	Result (static) (RESULT)	Test data format (variable)	Unit[1)]	Output for incorrect operation
	Ø	Ø		Test frequency f_M	☐☐.☐ at f_{M1}, f_{M2}, ☐☐☐☐ f_{M3}, f_{M4}, ☐☐☐☐ f_{M5}, f_{M6}, f_{M7}	kHz kHz kHz	ØØØØ f_M not detected
	Ø	1		Frequency deviation Δf	☐☐☐	kHz	ØØØ[3)] 999
	Ø	2		IF level P_I	Sn☐☐.☐☐	dBm	± 99.99[3)]
	Ø	3		IF centre frequency F_o (resolution 0.1 MHz)	☐☐☐.☐	MHz	ØØØ.Ø[4)]
	Ø	4		Sweep width $\hat{\Delta F}$	☐.☐☐ $\hat{\Delta F}$ < 10 MHz ☐☐.☐ $\hat{\Delta F}$ ≥ 10 MHz	MHz MHz	ØØØØ[4)5)]
	Ø	5		Frequency markers M	☐.☐☐ M < 10 MHz ☐☐.☐ M ≥ 10 MHz	MHz MHz	ØØØØ[4)5)]
	Ø	6		IF centre frequency F_o[2)] (resolution 0.01 MHz)	☐☐☐.☐☐	MHz	when AFC is not captured, do not evaluate output word
	Ø	7		BB level	Sn☐☐.☐☐	dBm	-ØØ.ØØ[3)] -99.99
	Ø	8		Horizontal cursor separation	.☐☐☐ ☐.☐☐ ☐☐.☐ ☐☐☐☐	depends on measurement mode	If the AFC is not captured and U_x is not synchronised, do not evaluate output word
	Ø	9		LIN/PARAB component	Sn☐☐☐☐ Sn☐☐☐☐ LIN value PARAB value	depends on measurement mode	As for horizontal cursor separation
	Ø	A		Extreme values trace Y1	☐☐☐ ☐☐☐ ☐☐☐ ☐☐☐ X_{Min} Y_{Min} X_{Max} Y_{Max}	depends on measurement mode	12 x Ø[4)5)]
	Ø	B		Extreme values trace Y2			

Example: Determine the extreme values of the Y1 trace

Controller ⟶ RME-5: "REØA,"

RME-5 ⟶ Controller: | 0 6 4 | 1 1 2 | 2 2 1 | 2 1 0 |

	X_{min}	Y_{min}	X_{max}	Y_{max}
Cf figure 3-59:	X_2	Y_2	X_1	Y_1

---

1) Cannot be taken into account with output statements (PRINT, DISP); (form output string)

2) IF counter mode

3) Out-of-range

4) AFC not in captured state

5) U_x not synchronised

RE

Controller → RME-5 | RME-5 → Controller

RE	d	d	,	Result	Test data (strings)		Dimension
	Ø	C		Measurement range for Y1 result	P 1 x P 2 x D P x E X x	x = 1 ... 7	Follows from the table for programming word "R...,"
					Ø Ø Ø	Y1 result off	
	Ø	D		Measurement range for Y2 result	P 1 x P 2 x D G x E X x	x = 1 ... 7	
					Ø Ø Ø	Y2 result off	

P1: ΔP_I; P2: ΔP_{II}; DP: ΔT or $\Delta\varphi$; DG: $\Delta U/U_0$; EX: Y_{EXT}

Example: The measurement range for the Y1 result is to be determined.

Controller → RME-5: "REØC,"

RME-5 → Controller: P25

Measurement mode ΔP_{II} — Measurement range R15

Follows from the table for programming word "R...,": 10 dB/D

RE	d	d	,	Measured results for noise calculation	Test data (string)	Dimension
	Ø	E		Intermodulation noise	f_1 f_2 f_3: 0 3 6 0 3 6 0 3 6 → Load in dB - Output words (9) each comprising 5 characters (incl. decimal point) - Separator: comma Terminating line corresponds to interface mode	pWOp (not transferred)
	Ø	F		Distortion components 1st to 4th order	$\Delta\varphi$: 1st 2nd 3rd 4th; $\Delta U/U_0$: 1st 2nd 3rd 4th order → - Output words (8) each comprising 5 characters (incl. decimal point) - Separator: comma Terminating line corresponds to interface mode	% (not transferred)

See figure 3-23c

RE

Controller ——► RME-5 | RME-5 ——► Controller

RE	d	d	d	d	,	Result Distortion trace	Format
	1					Interrogation of each point (Y1)	Y value: [| |] 10^2 10^1 10^0
	2					Interrogation of each point (Y2)	
		10^2	10^1	10^0			The transfer is performed using a three digit decimal having a value between ØØØ and 255
		See figure 3-59 for x value Range of definition (ØØ1 to 255)					
	1	Ø	Ø	Ø		Interrogate whole curve Y1	String with 255 characters (each point on the curve is expressed as a binary coded decimal in EBCDIC code[1])
	2	Ø	Ø	Ø		Interrogate whole curve Y2	Y_1 Y_2 ... Y_{254} Y_{255} (x=1 x=2 ... x=254 x=255)

SPOLL	8	7	6	5	4	3	2	1	Status byte (RME-5 ——► Controller)
	Ø								Remote
	1								Local
		Ø							No RQS
		1							YES
				Ø					Measurement[2] Ready
				1					Busy
					Ø				No Return of mains voltage
					1				Yes

Data lines (bits 8 to 1)

The SPOLL command is used exclusively to determine the status of the device. It is not a programming word.

1) The hp 85 uses the NUM. statement to convert the transferred characters into decimals between ØØØ and 255.

2) SRQ is possible, see programming word "XX...,"

4 MEASURING NOTES

4.1 OCCURENCE OF DISTORTION IN FM RADIO-LINK SYSTEMS AND INTERPRETATION OF THE RESULTS ΔT; $\Delta\varphi$ AND $\Delta U/U_0$

The intermodulation noise measured at the BB output of a radio-link system with a white noise measuring setup increases as the power level in the system is raised. This increase is caused by the linear and non-linear distortions within the assemblies. The most important of these are:

- non-linear relationship between voltage and frequency in modulators and demodulators;
- amplitude frequency response within the transmission band for the FM signal;
- non-linear phase response within the transmission band for the FM signal;
- AM/PM conversion in IF limiters and travelling wave tubes;
- long, incorrectly matched transmission lines for the FM signal;
- distortion in the baseband amplifiers.

A disadvantage of the white noise measuring method is that the result provides little information on which of the distortions has caused the noise. Generally, several sources are responsible for the resulting noise. Precise analysis of distortion is possible only with a distortion measuring setup such as the RM-5. The measuring method used is the intermodulation method which is used generally in radio-link measuring technology, and whose principle is described in Section 2.1.

The following questions are important for interpreting the distortion measurement results displayed on the screen of the measuring setup:

- Is this an amplitude or phase result?
- At which measuring frequency, in operating mode "automatic sweep width reduction", are the distortions maximum?
- Is there a relationship between the measuring frequency and the result?
- What is the shape of the result?

If these four questions can be answered clearly, then there are only a few possible causes of the interference. In order to permit the user of the RM-5 to answer the questions, the following sections deal with the various causes of interference and effects on the measured results. In order to simplify comprehension of these sections, the origins of most of the formulas used have been omitted. For further information, see the W&G special brochure written by
R. Dick: "Detection of faults in the transmission path of FM signals with the aid of modern distortion measuring equipment", Order No. 5022.

4.1.1 DISTORTIONS RESULTING FROM NON-LINEARITIES IN MODULATORS AND DEMODULATORS

If the characteristic curve of a frequency modulator or demodulator is not straight, i.e. has variations in the slope, then the signal at the receiving end will be amplitude modulated by the deflection frequency. Display of the demodulated signal on an oscilloscope will lead to various results for the non-linear distortion $\Delta U/U_0$, depending on the shape of the characteristic curve.

A square law characteristic ($\Delta f = au + bu^2$) leads to a tilted straight line on the screen of the receiver, while a cube law characteristic ($\Delta f = au + cu^3$) will result in a parabolic curve. If square law and cube law distortions occur simultaneously, the components can be displayed separately on the screen:

One component "LIN" describes the linear component of the curve, and a second component "PARAB" indicates the parabolic component of the curve (see Section 3.7.3).

The relationship between the shape of the characteristic curve and the shape of the curve on the screen is shown in Figure 4-1.

As modulator and demodulator characteristic curves are generally independent of frequency, the displayed non-linear distortions $\Delta U/U_0$ are also independent of the test frequency used. It is therefore sufficient to measure with only one test frequency $f_M < 1$ MHz for measurements on modulators and demodulators.

4.1.2 DISTORTION IN THE TRANSMISSION PATH OF THE FM SIGNAL

In the transmission of the FM signal (IF or RF level), distortion is caused both by amplitude and group delay frequency responses and by AM/PM conversion.

The cause of the distortion can be determined from the type ($\Delta\tau$ or $\Delta\varphi$ or $\Delta U/U_0$), shape, and variation with test frequency of the results displayed on the screen of the RM-5.

The transfer function of a transmission path in practice (in this case: path of the FM signal) $H(\Omega) = A(\Omega) \cdot e^{jb(\Omega)}$ can be approximated by a series expansion:

$$H(\Omega) = [1 + g_1 (\Omega - \Omega_0) + g_2 (\Omega - \Omega_0)^2 + g_3 (\Omega - \Omega_0)^3 + g_4 (\Omega - \Omega_0)^4 + \ldots] \\ \exp. j [b_2 (\Omega - \Omega_0)^2 + b_3 (\Omega - \Omega_0)^3 + b_4 (\Omega - \Omega_0)^4 + \ldots] \quad (1)$$

In the development of this series, the linear element b_1 was ignored, as this indicates only a group delay and causes no distortion.

The transmission two port network is supplied with an angular modulated signal, whose amplitude is normalised to the carrier voltage to make a valid simplification:

$$u_e (t) = \cos [\Omega_0 t + \Phi (t)] \quad (2)$$

Ω_0 is the carrier frequency and $\Phi(t)$ is the phase angle; taken together as containing the information.

After the signal has passed through the transmission two port network, there is generally an additional amplitude modulation $P(t)$ and a phase modulation $Q(t)$, which means that the signal can now be represented as:

$$u_a (t) = [1 + P(t)] \cos [\Omega_0 t + \Phi (t) + Q(t)] \quad (3)$$

Limiters in the FM signal path are generally designed to suppress frequency-dependent interference AM $P(t)$. This requirement can be fulfilled only with difficulty, as both the travelling wave tube limiter and the limiter preceding the FM demodulator convert a part of the amplitude modulation into additional interference PM $Q_z (t)$. The relationship is given by the AM/PM conversion factor θ:

$$Q_z(t) = \theta P(t) \quad (4)$$

θ is normally also frequency dependent and can be described approximately by a series expansion:

$$\theta (\Omega) = \theta_0 + \theta_1 (\Omega - \Omega_0) + \theta_2 (\Omega - \Omega_0)^2 + \ldots \quad (5)$$

The additional spurious PM $Q_z(t)$ is then

$$Q_z(t) = \theta_0 P(t) + \theta_1 P(t)\Phi'(t) + \theta_2 P(t)\Phi'^2(t) \quad (6)$$

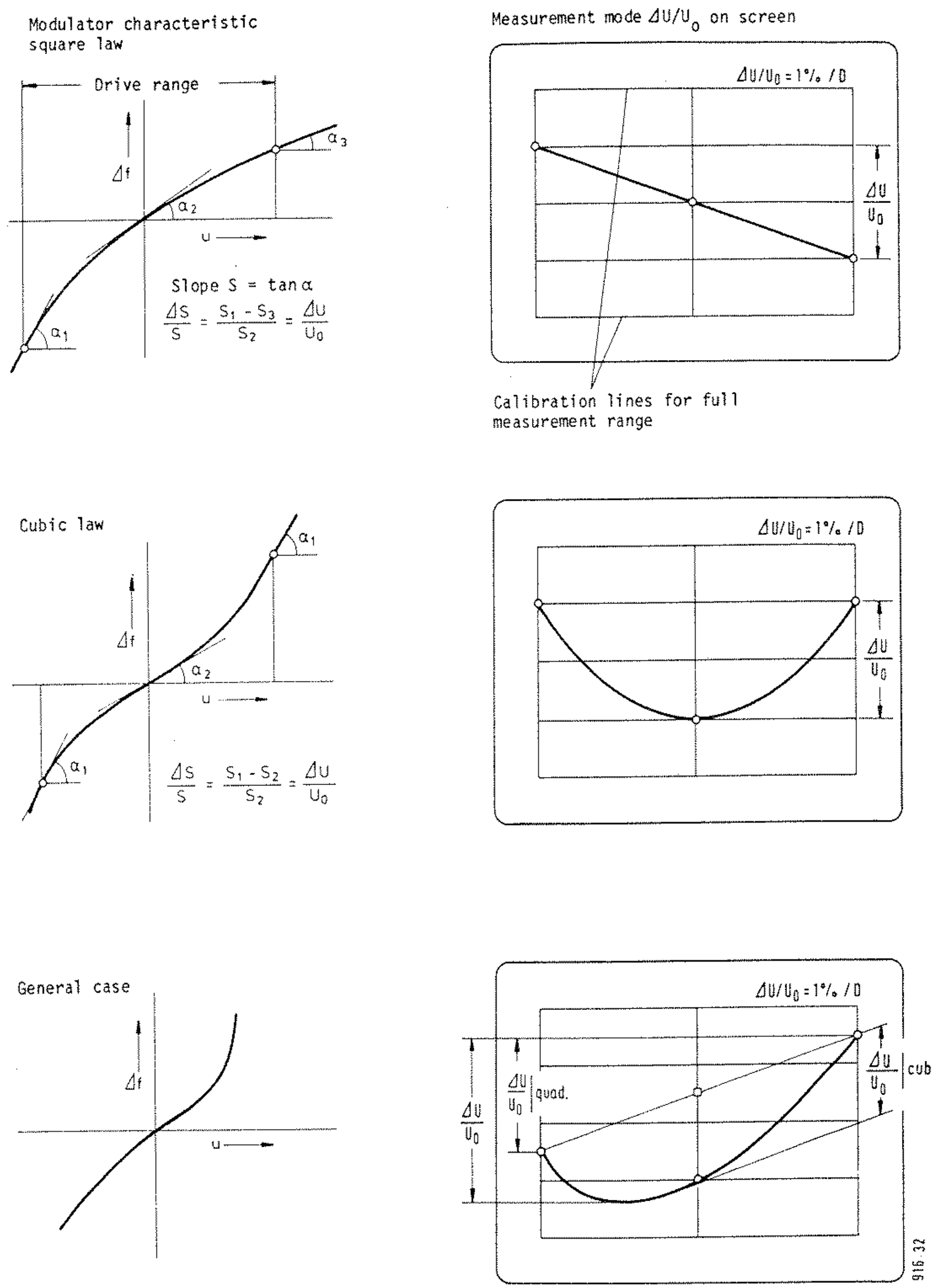
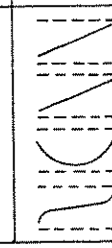


Figure 4-1 Non-linear distortion $\Delta U/U_0$ on the screen as a function of the modulator characteristic

The signal has the following shape before passing through the FM demodulator if the AM/PM conversion is included:

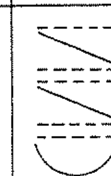
$$u_a(t) = \cos\,[\Omega_0 t + \Phi(t) + Q(t) + Q_z(t)] \tag{7}$$

Tables 4-1 and 4-2 show the distortion measurement results for the important causes of impairments with respect to resulting intermodulation noise. In the calculation, the results of coefficients g_1, g_2, g_3, g_4 and b_2, b_3, b_4 were included. The effects of AM/PM conversion were assumed to be both frequency independent (Θ_0) and varying linearly with frequency (Θ_1').

Cause of impairment		Phase results $\Delta\varphi$: General $\Delta\varphi$	With constant sweep range $\pm\Delta\Omega_A$: $\omega_{M\,opt}$	With constant sweep range $\pm\Delta\Omega_A$: $\Delta\varphi_{max}$	Form
Parabolic phase	b_2	$4b_2\,\Delta\Omega\,\omega_M$	$1/2\ \Delta\Omega_A$	$b_2\Delta\Omega_A^2$	
Cubic phase	b_3	$3b_3\,\Delta\Omega^2\,\omega_M$	$1/3\ \Delta\Omega_A$	$4/9\ b_3\Delta\Omega_A^3$	
Quadratic phase	b_4	$8b_4\ (\Delta\Omega\,\omega_M^3+\Delta\Omega^3\omega_M)$	$1/2\ \Delta\Omega_A$	$b_4\Delta\Omega_A^4$	
AM/PM conversion	$g_1\Theta_1$	$4g_1\Theta_1\,\Delta\Omega\,\omega_M$	$1/2\ \Delta\Omega_A$	$g_1\Theta_1\Delta\Omega_A^2$	
	$g_2\Theta_0$	$4g_2\Theta_0\,\Delta\Omega\,\omega_M$	$1/2\ \Delta\Omega_A$	$g_2\Theta_0\Delta\Omega_A^2$	
	$g_3\Theta_0$	$3g_3\Theta_0\,\Delta\Omega^2\,\omega_M$	$1/3\ \Delta\Omega_A$	$4/9\ g_3\Theta_0\Delta\Omega_A^3$	
	$g_4\Theta_0$	$8g_4\Theta_0\ (\Delta\Omega\,\omega_M^3+\Delta\Omega^3\omega_M)$	$1/2\ \Delta\Omega_A$	$g_4\Theta_0\Delta\Omega_A^4$	

916 48

Table 4-1 Phase measurement results as a function of cause impairments

Cause of impairment		Amplitude results $\frac{\Delta U}{U_0}$: General $\frac{\Delta U}{U_0}$	With constant sweep range $\pm\Delta\Omega_A$: $\omega_{M\,opt}$	With constant sweep range $\pm\Delta\Omega_A$: $(\frac{\Delta U}{U_0})_{max}$	Form
Parabolic gain	g_2	$g_2^2\,\Delta\Omega^2\,\omega_M^2$	$1/2\ \Delta\Omega_A$	$\frac{g_2^2}{16}\ \Delta\Omega_A^2$	
Cubic gain	g_3	$6g_3\,\Delta\Omega\,\omega_M^2$	$2/3\ \Delta\Omega_A$	$8/9\ g_3\Delta\Omega_A^3$	
Quadratic gain	g_4	$6g_4\,\Delta\Omega^2\,\omega_M^2$	$1/2\ \Delta\Omega_A$	$3/8\ g_4\Delta\Omega_A^4$	
AM/PM conversion	$b_2\Theta_1$	$2b_2\Theta_1\,\Delta\Omega\,\omega_M^2$	$2/3\ \Delta\Omega_A$	$8/27\ b_2\Theta_1\Delta\Omega_A^3$	
	$b_3\Theta_0$	$6b_3\Theta_0\,\Delta\Omega\,\omega_M^2$	$2/3\ \Delta\Omega_A$	$8/9\ b_3\Theta_0\Delta\Omega_A^3$	
	$b_4\Theta_0$	$6b_4\Theta_0\,\Delta\Omega^2\,\omega_M^2$	$1/2\ \Delta\Omega_A$	$3/8\ b_4\Theta_0\Delta\Omega_A^4$	

916 49

Table 4-2 Amplitude results as a function of cause of impairments

The form of the results depends on the cause of impairment. These are sketched in tables 4-1 and 4-2, in each case for positive g_n, b_n and Θ.

The type of measured result which occurs - phase or amplitude - is a further indication of the cause of the impairment.

The measured results shown in the general case also depend on the test frequency selected ω_M.

For example, the amplitude result increases as a square of the test frequency for coefficient g_3. Due to the finite bandwidth of the transmission path, however, limits exist.

If the operating mode "automatic sweep width reduction" is used, i.e. if fixed sweep limits of $(\Delta\Omega_A = \Delta\Omega + \omega_M)$[1] are specified, then $\Delta\Omega$ in the general form of the results can be replaced by $(\Delta\Omega_A - \omega_M)$. It is now obvious that small results must be expected for low test frequencies and that the result becomes 0 when $\omega_M = \Delta\Omega_A$.

The optimum test frequency lies between these values. It is found by differentiating the general form of the measured result, with $(\Delta\Omega_A - \omega_M)$ instead of $\Delta\Omega$, the equation is then solved for ω_m.

For example, Table 4-2 shows that the optimum test frequency $\omega_{M,opt} = 2/3\ \Delta\Omega_A$ for the cubic gain g_3.

In a further step, the maximum result can be calculated if the optimum test frequency is inserted in the general form of the result for ω_M. In the selected example with g_3, the maximum amplitude measurement results $\Delta U/U_0 = 8/9\ g_3\ \Delta\Omega_A^3$.

The values for the optimum test frequencies in the operating mode "automatic sweep width reduction" (constant exploring width) show that many causes of impairments can be detected only if high test frequencies are used.

For a system with 2700 channels this means a test frequency of about 12 MHz. More generally one can say that test frequencies that are approx. equal to the highest baseband frequencies of the various multichannel radio-link systems, i.e. 5.6 MHz, 8.2 MHz and 12.39 MHz, must be available.

If one looks at the characteristic sensitivity curves as a function of test frequency referred sweep range (figure 4-2), one sees that a test frequency of 5.6 MHz the results are sufficiently sensitive for systems with 1800 and 2700 channels. As an example we will take the case where an optimal test frequency of 2/3 of the sweep range is required to find the cause of impairment. For a 2700 channel system the IF transmission bandwidth is equal to sweep range $\pm$ 18 MHz. The optimal test must therefore be 2/3 x 18 MHz = 12 MHz to obtain an optimal result. At the highest test frequency of 5.6 MHz, with x = 5.6/18 = 0.31 the sensitivity, y, is still equal to 0.46. This example is however the most unfavourable case that can occur. For other impairments the sensitivity is very much better.

For in-service measurements one usual only performs distortion measurements at 500 or 555.55 kHz or less, or at the TV colour carrier frequencies of 3.58 or 4.43 MHz. One also measures the group delay distortion of radio-links and satellite systems using TDMA at IF frequencies.

For this reason, there are no test frequencies > 5.6 MHz provided by the RM-5, instead you will find the test frequencies for systems with a small channel number.

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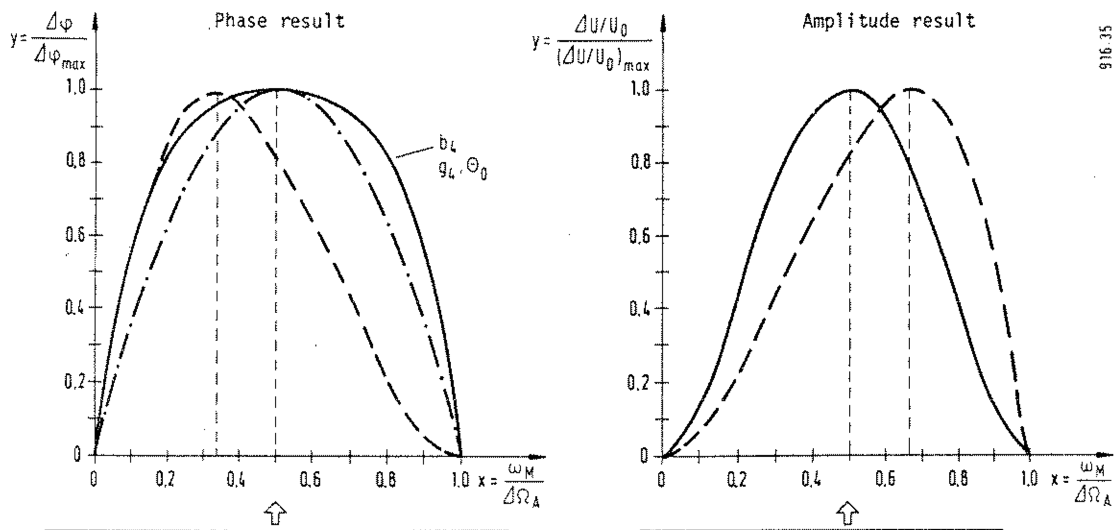
1) $\Delta\Omega_A = \Delta\Omega + \omega_M$ means $\hat{\Delta F} = \hat{\Delta F}_{RED} + f_M$



Cause of interference with resulting shape:			
x_{opt}	Straight	Parabolic Quadr.	Parabolic Cubic
1/3		b_3 $g_3 \cdot \theta_0$	
1/2	b_2 $g_1 \cdot \theta_1$ $g_2 \cdot \theta_0$		b_4 $g_4 \cdot \theta_0$

Cause of interference with resulting shape:		
x_{opt}	Straight	Parabolic
1/2	g_2	g_4 $b_4 \cdot \theta_0$
2/3	g_3 $b_2 \cdot \theta_1$ $b_3 \cdot \theta_0$	

Figure 4-2 Relative measuring sensitivity as a function of the test frequency referred to the exploring range ($x = \omega_M/\Delta\Omega_A$, $y = \Delta U/U_0/(\Delta U/U_0)_{max}$ or $y = \Delta\varphi/\Delta\varphi_{max}$).
In the tables: corresponding causes of impairments

For evaluation, the measured results ΔT or $\Delta\varphi$ and $\Delta U/U_0$ are first measured at all available test frequencies and the curve is recorded. After this, the causes of impairments are determined with the aid of Table 4-1 and 4-2, this is explained using the following example:

In practical applications, the results shown in Tables 4-1 and 4-2 will generally not appear in such a pure form. However, interpretation is possible in most cases.

If a $\Delta U/U_0$ result with $\omega_{M,opt.} = 2/3\,\Delta\Omega_A$ occurs, and if the shape is a straight line, then the cause of the impairment can, on the basis of Table 4-2, be g_3, $b_2 \cdot \theta_1$ or $b_3 \cdot \theta_0$.
If AM/PM conversion also occurs, then this can be detected clearly on the basis of the characteristic results for b_2 or b_3. If none of the expected $\Delta\varphi$ results occur, then the cause of the impairment must be g_3.

4.2 Bessel spectrum

So that you will be better able to understand how the RM-5 operates (in particular the bessel spectrum mode), the following sections will give a short overview of the fundamentals of frequency modulation.

4.2.1 Frequency modulation

Radio-relay systems generally use frequency modulation, which is a special form of angle modulation. The general formula for an angle-modulated signal is

$$u(t) = \hat{U}\sin\psi(t).$$

For angle modulation, the argument $\psi(t)$ is varied in the rhythm of the modulation signal, which means that the above equation can be rewritten, with the carrier frequency Ω_T and varying phase $\Phi(t)$, as

$$u(t) = \hat{U}\sin\psi(t) = \hat{U}\sin[\Omega_T t - \Phi(t)] \qquad (1)$$

where the information is "hidden" in $\Phi(t)$.

If a sinusoidal modulation signal

$$u_1(t) = \hat{U}_1\cos(\omega_1 t + \varphi_1)$$

is used, then $\Phi(t) = \eta\cos(\omega_1 t + \varphi_1)$. The variation of the angle with time is then

$$\psi(t) = \Omega_T t - \eta\cos(\omega_1 t + \varphi_1). \qquad (2)$$

A measure for the magnitude of the phase variation is the phase deviation η, also called the *modulation index*. As a variation of the angle ψ with time naturally causes a frequency change, then the instantaneous frequency is

$$\frac{d\psi(t)}{dt} = \Omega_T + \eta\omega_1\sin(\omega_1 t + \varphi_1) = \Omega_T + 2\pi\hat{\Delta f}\sin(\omega_1 t + \varphi_1).$$

The frequency deviation $\hat{\Delta f}$ is a measure for the frequency deviation. This can be calculated, from $\eta\omega_1 = 2\pi\hat{\Delta f}$, as

$$\hat{\Delta f} = \eta \cdot f_1.$$

The phase deviation or modulation index is thus

$$\eta = \frac{\hat{\Delta f}}{f_1}.$$

These relationships apply to frequency and phase modulation. The only differences between the two types of modulation are the following:

- If the frequency deviation $\hat{\Delta f}$ is proportional to the amplitude of the modulating signal, then the process is called frequency modulation (FM). The phase deviation η then varies, as shown by equation (3) in inverse proportion to the modulating frequency f_1.
- If the phase deviation η varies proportionally with the amplitude of the modulating signal, then the process is called phase modulation (PM).

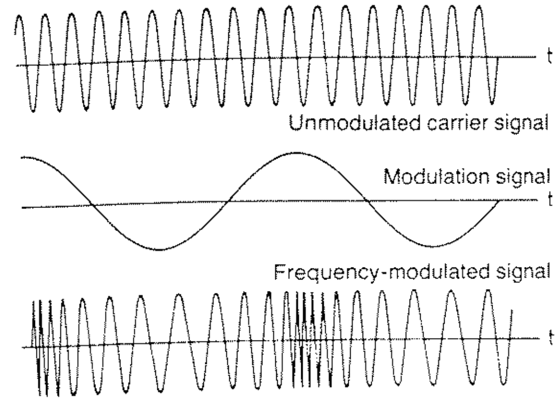


Figure 4-3 Frequency-modulated signal

Figure 4-3 shows the signal curve of a frequency-modulated signal.
The frequency spectrum of such a frequency-modulated signal with sinusoidal modulation is calculated below. First, it is necessary to obtain the exponential representation of the signal. For the general relationship

$$e^{jx} = \cos x + j\sin x$$

it is possible to write the imaginary part as

$$Jm\left\{e^{jx}\right\} = \sin x.$$

For the angle modulated signal in equation (1), the relationship is thus

$$u(t) = Jm\left\{U_T\, e^{j\psi(t)}\right\}.$$

If equation (2) is inserted in this equation, then

$$u(t) = Jm\left\{U_T e^{j[\Omega_T t - \eta\cos(\omega_1 t + \varphi_1)]}\right\}. \qquad (5)$$

The Bessel functions with the order 0, 1, 2, 3, ... apply to the expression $e^{-j\eta\cos(\omega_1 t + \varphi_1)}$, which means that it can be represented as follows.

$$\begin{aligned} e^{-j\eta\cos(\omega_1 t + \varphi_1)} = J_0(\eta) &- 2jJ_1(\eta)\cos(\omega_1 t + \varphi_1) + \\ &+ 2j^2J_2(\eta)\cos(2\omega_1 t + 2\varphi_1) - \\ &- + 2j^3J_3(\eta)\cos(3\omega_1 t + 3\varphi_1) + \\ &+ \ldots\ldots \\ &- \ldots\ldots \end{aligned}$$

If this expression is then introduced into equation (5), the result is

$$\begin{aligned} u(t) = Jm\{U_T(\cos\Omega_T t + j\sin\Omega_T)[J_0(\eta) \\ - 2jJ_1(\eta)\cos(2\omega_1 t + \varphi_1) + \\ + 2j^2J_2(\eta)\cos(2\omega_1 t + 2\varphi_1) - \\ - 2j^3J_3(\eta)\cos(3\omega_1 t + 3\varphi_1) + \\ + \ldots\ldots]\}. \end{aligned}$$

As only the imaginary parts must be considered, then

$$u(t) = U_T \{J_0(\eta)\sin \Omega_T t - 2J_1(\eta)\cos\Omega_T t \cdot \cos(\omega_1 t + \varphi_1) - 2J_2(\eta)\sin \Omega_T t \cdot \cos(2\omega_1 t + 2\varphi_1) - 2J_3(\eta)\cos \Omega_T t \cdot \cos(3\omega_1 t + 3\varphi_1) - \ldots\}. \quad (6)$$

With the aid of the general trigonometrical relationships

$$\cos\alpha \cdot \cos\beta = \frac{1}{2}[\cos(\alpha - \beta) + \cos(\alpha + \beta)]$$

$$\sin\alpha \cdot \cos\beta = \frac{1}{2}[\sin(\alpha - \beta) + \sin(\alpha + \beta)]$$

and

$$-\cos x = \sin\left(x - \frac{\pi}{2}\right)$$

$$-\sin x = \sin(x - \pi)$$

$$\cos x = \sin\left(x - \frac{3\pi}{2}\right)$$

it is possible to obtain the spectral composition of the frequency-modulated signal when modulated with the sinusoidal signal $\hat{U}_1\cos(\omega_1 t + \varphi_1)$.
The following is true for the FM signal

$$\begin{aligned} u(t) = {} & U_T J_0(\eta)\sin\Omega_T t + \\ & + U_T J_1(\eta)\left\{\sin\left[(\Omega_T + \omega_1)t + \varphi_1 - \frac{\pi}{2}\right] + \right. \\ & \left. + \sin\left[(\Omega_T - \omega_1)t - \varphi_1 - \frac{\pi}{2}\right]\right\} + \\ & + U_T J_2(\eta)\left\{\sin\left[(\Omega_T + 2\omega_1)t + 2\varphi_1 - \pi\right] + \right. \\ & \left. + \sin\left[(\Omega_T - 2\omega_1)t - 2\varphi_1 - \pi\right]\right\} + \\ & + U_T J_3(\eta)\left\{\sin\left[(\Omega_T + 3\omega_1)t + 3\varphi_1 - \frac{3\pi}{2}\right] + \right. \\ & \left. + \sin\left[(\Omega_T - 3\omega_1)t - 3\varphi_1 - \frac{3\pi}{2}\right]\right\} + \\ & + \ldots \end{aligned} \quad (7)$$

The curve of the Bessel function $J_0(\eta)$, $J_1(\eta)$... for the amplitude of the carrier and of the sidebands is shown in Figure 4-4.

With the aid of the formulas for the frequency-modulated signal [equation (7)], it is possible to derive the vector diagram for a frequency-modulated signal (Figure 4-5). The vector diagram for four different instants in time with a phase deviation $\eta = 1 \triangleq 57.3°$ is shown in Figure 4-6. In Figures 4-5 and 4-6, the vectors of the carrier signal and of the sideband signals of the 1st and 2nd order are shown. The geometrical addition of these vectors results in a total vector (resultant vector) which moves over an arc of ±57.3°. The generation of this arc is understandable because the amplitude of an undistorted FM signal, as shown by Figure 4-3, is constant. The radius of the arc is equal to the amplitude of the unmodulated carrier signal.

In contrast to amplitude modulation, the amplitude of the carrier varies in the case of frequency modulation. The carrier amplitude is 0 when the Bessel function $J_0(\eta) = 0$; this is the case (as can be seen from Figure 4-4) at the phase deviations η = 2.405, 5.520, 8.654.

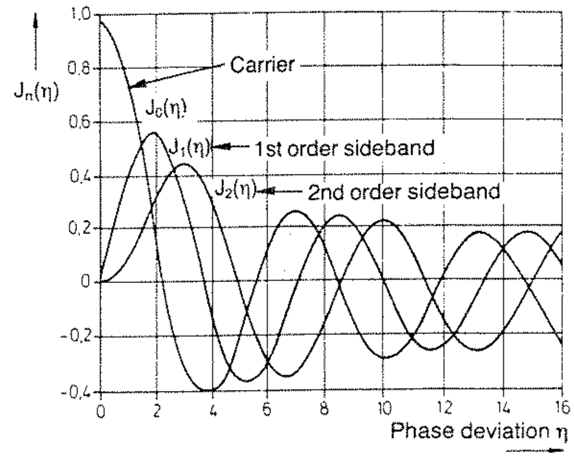


Figure 4-4 Bessel functions as a function of the phase deviation η

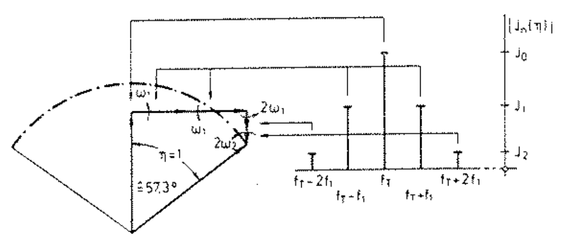


Figure 4-5 Frequency spectrum and vector diagram of the frequency-modulated signal for $\eta = 1 \triangleq 57.3°$ with a sinusoidal modulation signal of $f_1 = \omega_1/2\pi$

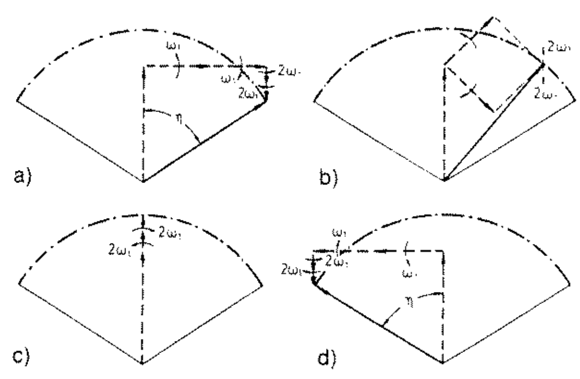


Figure 4-6 Vector diagrams a, b, c, d at four different instants for a frequency modulated signal with a phase deviation $\eta = 1 \triangleq 57.3°$ with a sinusoidal modulation signal

4.2.2 BESSEL SPECTRUM AS A FUNCTION OF THE TEST FREQUENCY AND RMS VALUE TEST FREQUENCY DEVIATION

The frequency spectra which result from equation (4) for various phase deviations ($\eta \sim \Delta f \sim U_M$) are shown for three different test frequencies in Figure 4-7. It can be seen that the frequency spectrum becomes wider due to augmentation of higher order sidebands as the phase deviation increases.

In the operating mode "distortion measurement", where the complete FM spectrum is swept with the sweep frequency within the IF range (depending on the sweep width $\hat{\Delta F}$), the phase deviation η is always less than one, as only the carrier and the first sidelines are required.

For calibration of the rms value deviation meter, and for setting the slopes of modem units in the operating mode "Bessel spectrum", a phase deviation $\eta = 2.405$ (first Bessel null position) is set up:

$$\Delta f = 2.405 \times f_M = \Delta \hat{f}_0; \quad (\Delta \hat{f} = 2\sqrt{\Delta f})$$

Disappearance of the carrier - "Bessel" - on the screen of the RME-5 is best seen at the test frequencies f_M = 83.3 kHz (or 92.6 kHz) and 250 kHz (or 277.8 kHz); see Figure 4-7.

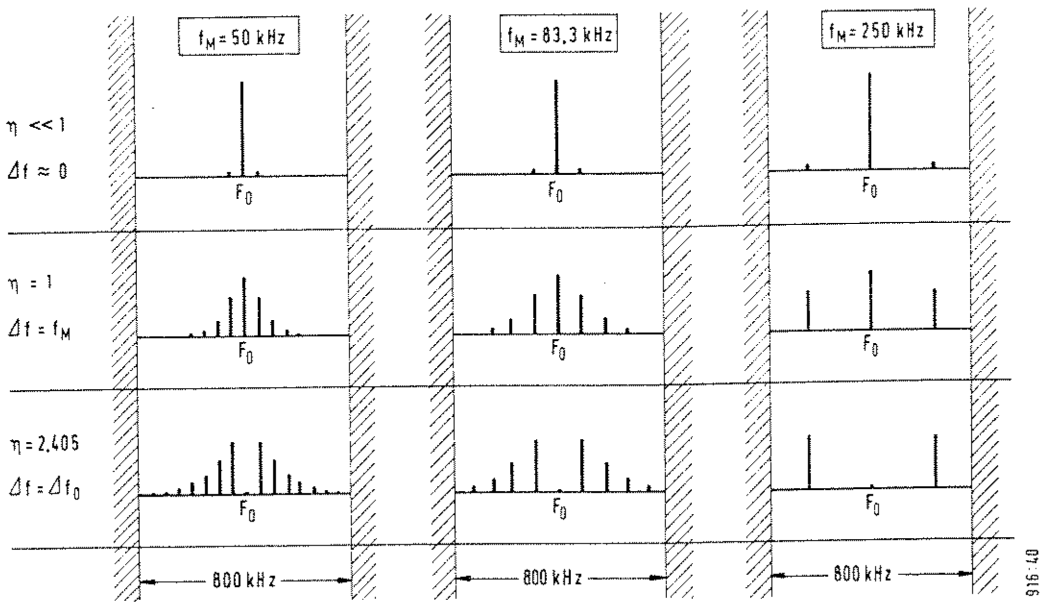


Figure 4-7 "Bessel spectra" as a function of the rms test deviation Δf (or U_M) at three test frequencies; the frequency range displayed on the screen of the RME-5 is approximately 800 kHz.

4.3 USE OF LOW TEST FREQUENCIES

The RM-5 has the low test frequencies of 25 kHz (27.778 kHz) and 50 kHz (55.556 kHz). The importance of these low test frequencies in conjunction with a low phase deviation ($\eta < 1$) is shown with the aid of two examples.

4.3.1 MEASUREMENTS ON NARROWBAND SYSTEMS

Figure 4-8a shows the group delay T(f) of a test object (narrowband system) with bandwidth B, together with the frequency triplet of the sampling FM spectra with the

<u>high</u> test frequency f_{M2} in Figure 4-8b and
<u>low</u> test frequency f_{M1} in Figure 4-8c.

From the ratio of the bandwidth B and sweep deviation ΔF, it can be seen that sufficient exploration is not possible at the high test frequency f_{M2}. The group delay behavior of the system can be displayed with sufficient accuracy only at the smallest test frequency; $\Delta F \sim B/2$.

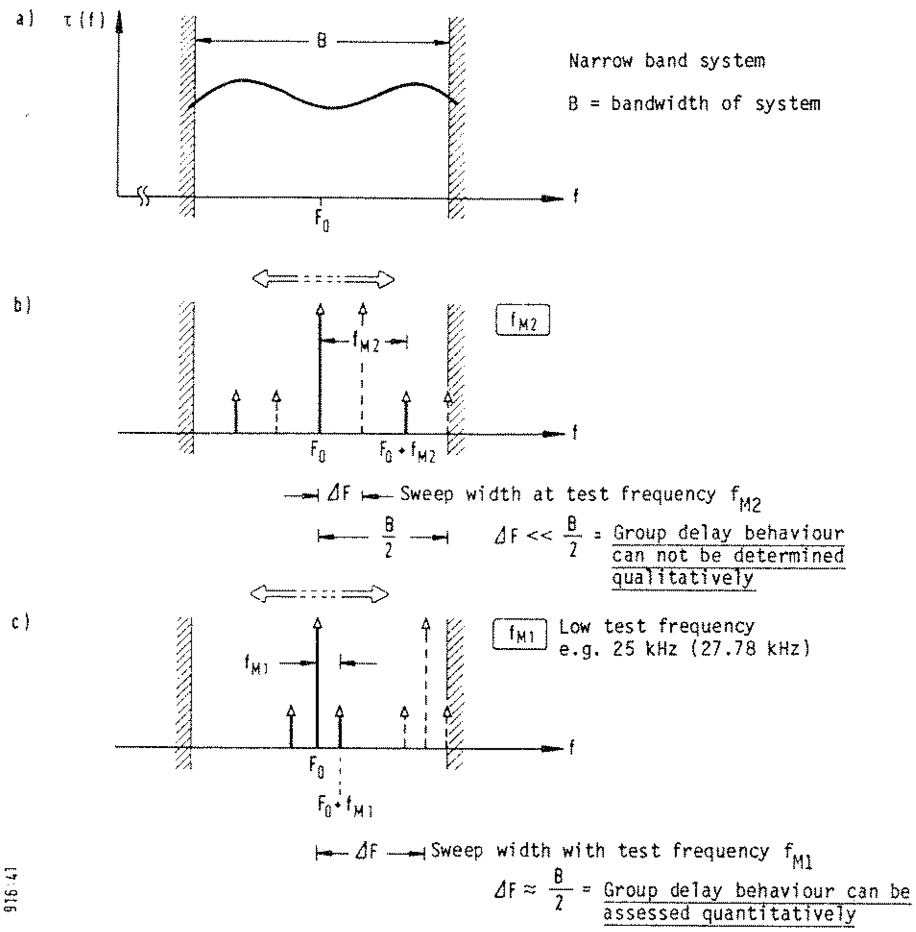


Figure 4-8 Sweeping of a narrowband system with "automatic sweep width reduction" on
a) Group delay $\tau(f)$
b) With high test frequency f_{M2}
c) With low test frequency f_{M1} ($<< f_{M2}$)

4.3.2 MEASUREMENTS ON SYSTEMS WITH RIPPLE-SHAPED TRANSFER FUNCTIONS

Figure 4-9 shows the conditions during exploring of a group delay curve $\tau(f)$ with a ripple shape - e.g. SAW filter - with two different test frequencies f_{M1} and f_{M2} ($f_{M1} < f_{M2}$).

Figures 4-9a, b show the explored frequency triplets of the FM spectrum at a given point of the sweep range (B). If the values for the various spectral lines are considered - particularly the upper and lower sidebands - different values for the difference $\Delta\tau_1$, $\Delta\tau_2$ at test frequencies f_{M1} and f_{M2} are obvious. The slope "$\Delta\tau/2f_M$" is a measure of the resolution. The steeper the slope, the better the resolution.

From this example, it is clear that the fine ripple structure in the group delay curve can be resolved only with a very low test frequency (f_{M1}) and a small phase deviation ($\eta < 1$). A test frequency which is too high (f_{M2}) would flatten the curve.

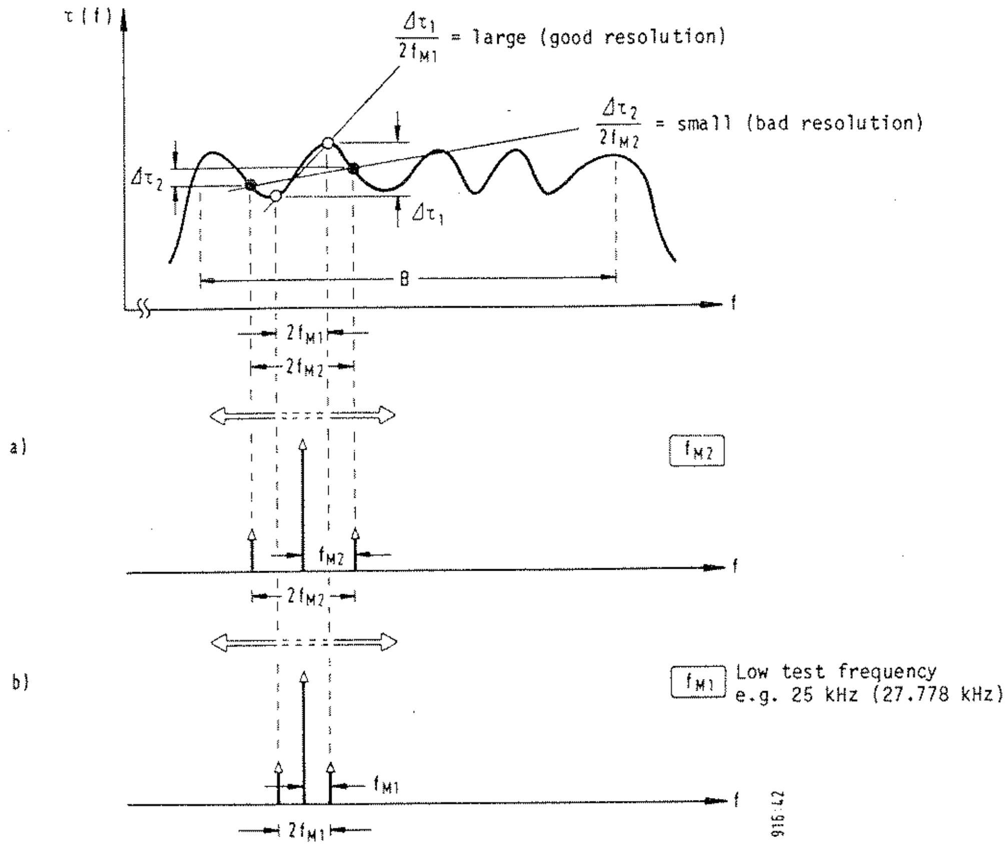


Figure 4-9 Sweeping a ripple shaped group delay curve $\tau(f)$ (wideband system)
a) with high test frequency f_{M2}
b) with low test frequency f_{M1}

4.4 SUPPRESSION OF NOISE BY AVERAGING

If the Y signals of two consecutive sweeps (Y_i and Y_{i+1}) are averaged, effective noise suppression can be achieved, and is an economical solution as far as memory is concerned. For a specific frequency point x_n, averaging is carried out using the following relationship:

$$\overline{Y}_{i+1} = \overline{Y}_i + \frac{Y_{i+1} - \overline{Y}_i}{N}$$

N : selectable averaging factor 2, 4, 8, 16, 32

$\overline{Y}_i$: average value of preceding sweep (shown on screen)

Y_{i+1} : current signal value (not displayed on screen)

The new average value $\overline{Y}_{i+1}$ is calculated from the current signal value Y_{i+1} and the preceding average value $\overline{Y}_i$. $\overline{Y}_{i+1}$ (or the complete curve) is then displayed on the screen. The average value $\overline{Y}_i$ determined in the preceding sweep cycle and used for calculation in turn depends on the preceding cycle (i-1) (etc.); see Figure 4-10.

Noise averaging can be increased further by increasing the value of N (> 2), as the difference $Y_{i+1} - \bar{Y}_i$ approaches zero; the average values of two consecutive sweeps passes become equal and the distortion curve becomes smoother.

This method of noise averaging has the advantage that recording occurs after each sweep cycle and the result can be shifted vertically on the screen at any time.

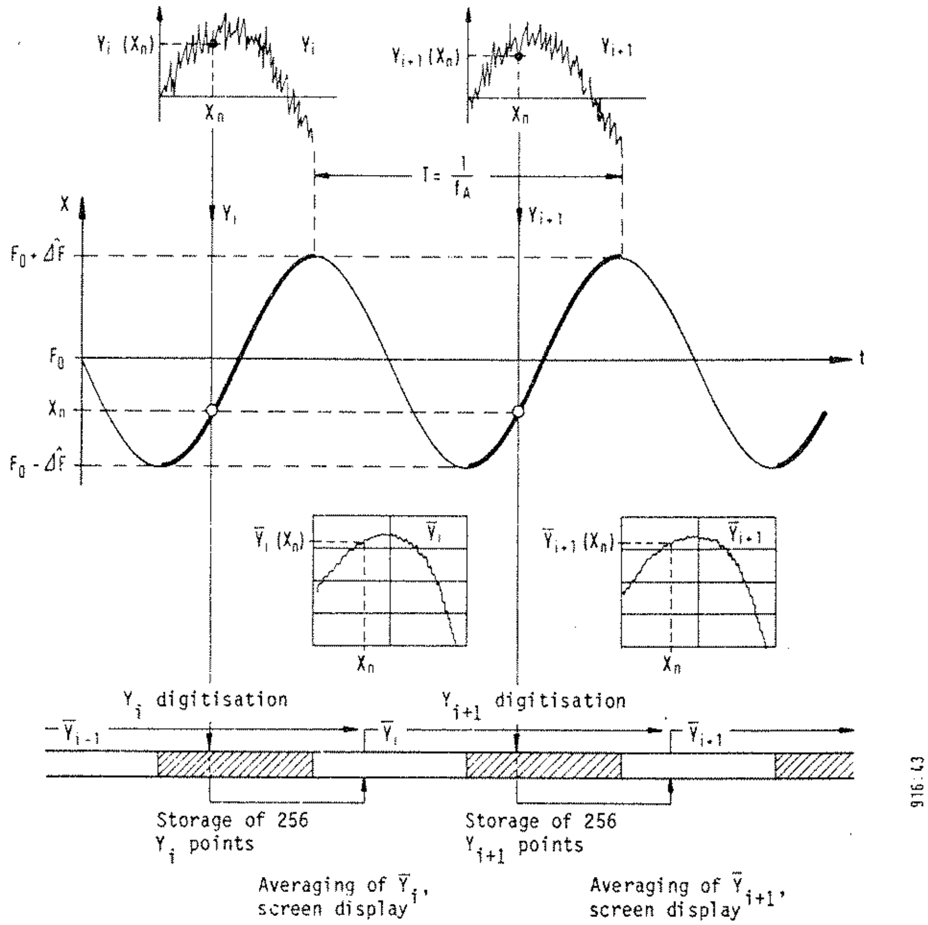


Figure 4-10 Basic timing plan for noise averaging

4.5 USE OF THE RFZ-4 RETURN LOSS MEASURING BRIDGE

See also TECHNICAL DATA 1.1.2.7 "IF return loss measurement"

With the aid of the RFZ-4 Return Loss Measuring Bridge (BN 697/00.04), the return loss of coaxial test objects can be measured or swept in the frequency range 10 MHz to 200 MHz. The reference impedance (characteristic impedance) is 75 Ω. With the aid of the RM-5 Radio-Link Measuring Set-up, return loss measurements can be carried out in the IF ranges 22.5 to 47.5 MHz or 40 to 100 MHz. Matching to all common connector types is ensured by the conversion system Versacon® 9.

4.5.1 ERROR LIMITS

The error limits are a function of the directivity ratio D of the bridge and of the measured value a_r. The value D depends on the plug type and the frequency as shown in Figure 4-11.

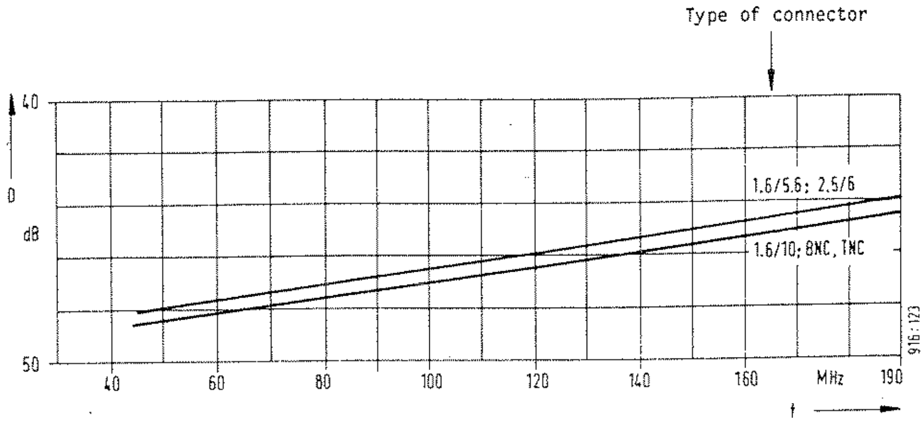


Figure 4-11 Directivity ratio D(f) of the a_r bridge "RFZ-4"
Parameter: type of plug screwed into Versacon connector

The error limits of the a_r measurement (function of a_r and D) are shown in Figure 4-12. A prerequisite for this is calibration of the Measuring Setup for a_r measurements with a short circuit (r = -1) at the measuring output of the bridge and in the required sweep range. See also Section 3.9.7.2.

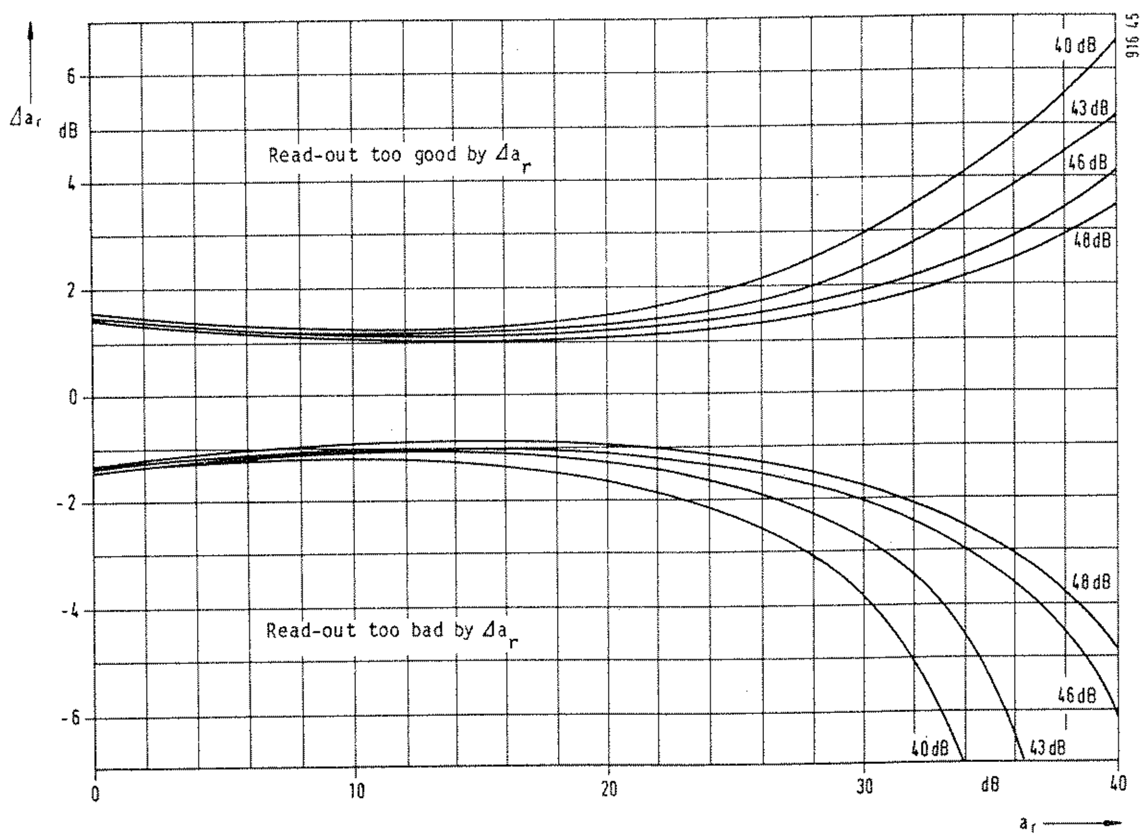


Figure 4-12 Error limits of a_r measurement with the RM-5 after calibration
Parameter: D as shown in Figure 4-11

4.6 ADJUSTING IF MODULES DURING PRODUCTION OR IN TEST DEPTS.

If the IF level at the IF output of the RME-5 varies too much when IF modules are being adjusted synchronisation will be lost. Several seconds may go by before sync. is restored and the X deflection voltage is recovered. If a frequency splitter is used this difficulty can be avoided. The test setup shown "converts" the IF measurement into a BB measurement by using the demodulator output at the back of the RME-5. The sweep signal is input from the generator via the frequency splitter. The sweep voltage can be any value greater than zero.

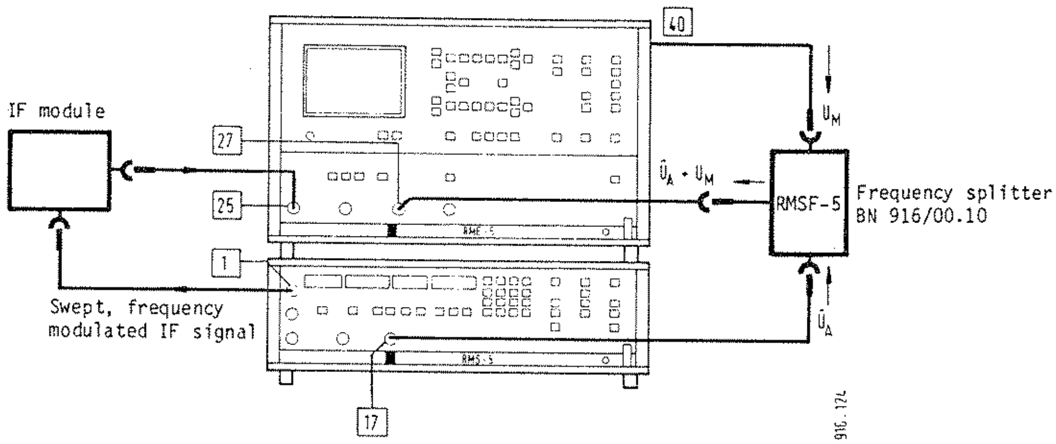


Figure 4-13 Test setup for adjusting IF modules

Set the RME-5 to BB mode ([23]). The deflection signal U_x must also be recovered from the BB signal ([18] U_x (BB)). Ensure that the phase of the deflection is correct.

Figure 4-14a and 4-14b show the results, a pure IF measurement is used and also when the previous test setup is employed.

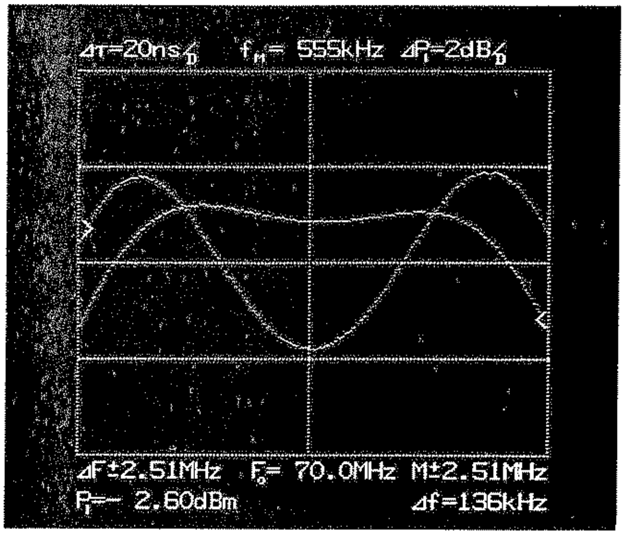


Figure 4-14a   IF results

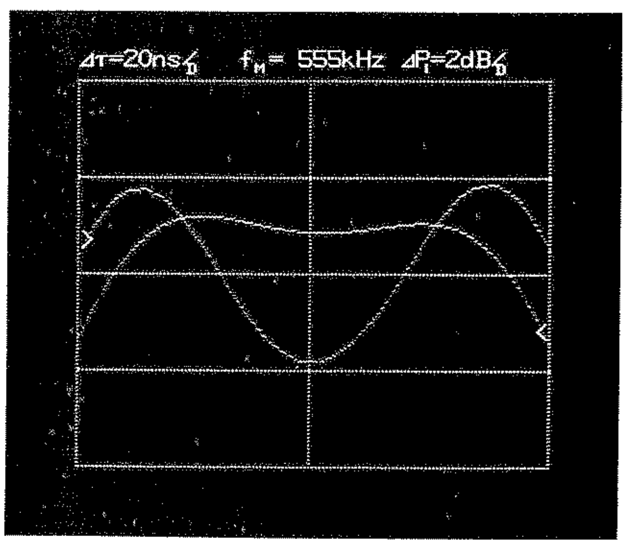


Figure 4-14b   Results for the same item under test, but using the setup shown in figure 4-13

Unlike the upper display, no IF parameters and no frequency markers are shown in the lower display.

The great advantage of the test setup described previously is that when the signal returns to the IF input level range, the RME-5 is synchronised.

4.7 INTERMODULATION NOISE CALCULATION

Two test methods are of special importance for FM radio-link systems:

- White noise techniques allow one to directly determine the quality of a transmission path. The disadvantage of this method is the limited scope for determining the sources of noise. Only limited improvements can be made in the noise behaviour of the system by using this method to perform adjustments.
- Distortion measurements using the RM-5 can be used to analyse the causes of noise and to align systems and modules to give optimal distortion.

By optimising unavoidable distortion we mean, reducing the intermodulation noise power in the maximum number of channels possible to at least the permitted values. An extra noise measurement is therefore necessary to check the alignment.

As there is a close relationship between distortion and intermodulation noise, it would be a good idea to try to calculate intermodulation noise from distortion.

The RM-5 has all the prerequisites to make calculations of this kind: Digitised distortion curves and a µP.

The algorithm for calculating the noise must be so designed that the µP will give a result in a time acceptable to the user.

The following sections will give the user the theory of the method and describe its limitations in practice, so that he can apply the method in the best way possible.

4.7.1 RELATIONSHIP BETWEEN DISTORTION AND NOISE

The basis of the method is knowing the transfer characteristics of the system. Figure 4-15 shows the essential elements of an FM transmission system.

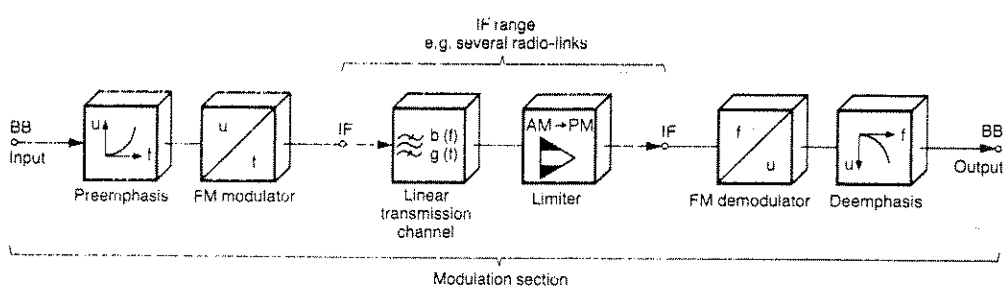


Figure 4-15 Block diagram of a FM transmission system

The intermodulation distortion at the baseband output is due to linear distortion i.e. deviations from flat amplitude and group delay responses in the IF range, non-linear distortions introduced by amplifiers in the BB also contribute to intermodulation noise but will not be considered further here.

The effects of AM/PM conversion in the limiter amplifiers and the travelling wave tubes also play a role. Modulator and demodulator non-linearity also contributes to intermodulation noise but can usually be neglected if the modulation section between the BB ports is treated as a whole. No modem is present anyway if the IF sections are being investigated. Therefore in the system model the modem is assumed to be ideal.

4.7.2 DETERMINING THE TRANSFER FUNCTION

The transfer function (phase and magnitude) could be determined by using the RM-5 to measure the frequency response (ΔP_I) and the group delay distortion (ΔT) directly.

However the sensitivity of group delay measurements is not sufficient and the presence of amplitude limiting circuits makes it impossible to obtain useful results from frequency response measurements. Also it is not possible to precisely determine the effects of AM/PM conversion.

It is therefore best to perform distortion measurements on FM systems using differential phase ($\Delta\varphi$) and differential gain ($\Delta U/U_0$). This is particularly true of wideband, multi-channel systems. Systems of this kind to prone to intermodulation and so to intermodulation noise even if distortion is minimal.

The results of differential phase ($\Delta\varphi$) and differential gain $\Delta U/U_0$ measurements, are determined by the frequency response and the group delay frequency response of the linear network, and the effects arising from the combined effects of linear distortion and non-linear AM/PM conversion. The first problem to be solved is deriving the transfer function from the $\Delta\varphi$ and $\Delta U/U_0$ curves. A formula expressing the relationship between the transfer function and $\Delta\varphi$ or $\Delta U/U_0$ can be obtained after some manipulation and by neglecting terms that are insignificant. Figure 4-16 gives an overview of this procedure.

4.7.3 THE ACTUAL NOISE CALCULATION PROCEDURE

Using the expression for the transfer function and a system model like the one in figure 4-15, the noise power components of the 2nd and 3rd order can be calculated. The calculations are very complex and so could only be made using a mainframe computer.

However, if certain test parameters such as sweep width and the test frequency can be taken as constant, and the standardised system parameters like channel no. etc. are used, coefficient tables for each type of system can be calculated on a mainframe computer and stored in ROM which can be accessed by the RME-5's microprocessor. The noise calculation is then relatively simple, only involving the distortion coefficients and the values in the table. The calculation time is therefore reduced to an acceptable length (figure 4-16).

4.7.4 EXPRESSING THE RESULTS OF DISTORTION MEASUREMENTS AS A MATHEMATICAL FUNCTION

As has been mentioned previously, an alegraic expression that gives the best possible description of the results is required, e.g. a polynomial of the 4th degree.

Each term in this expression corresponds to the linear, quadratic, cubic and quartic components of the distortion curve.

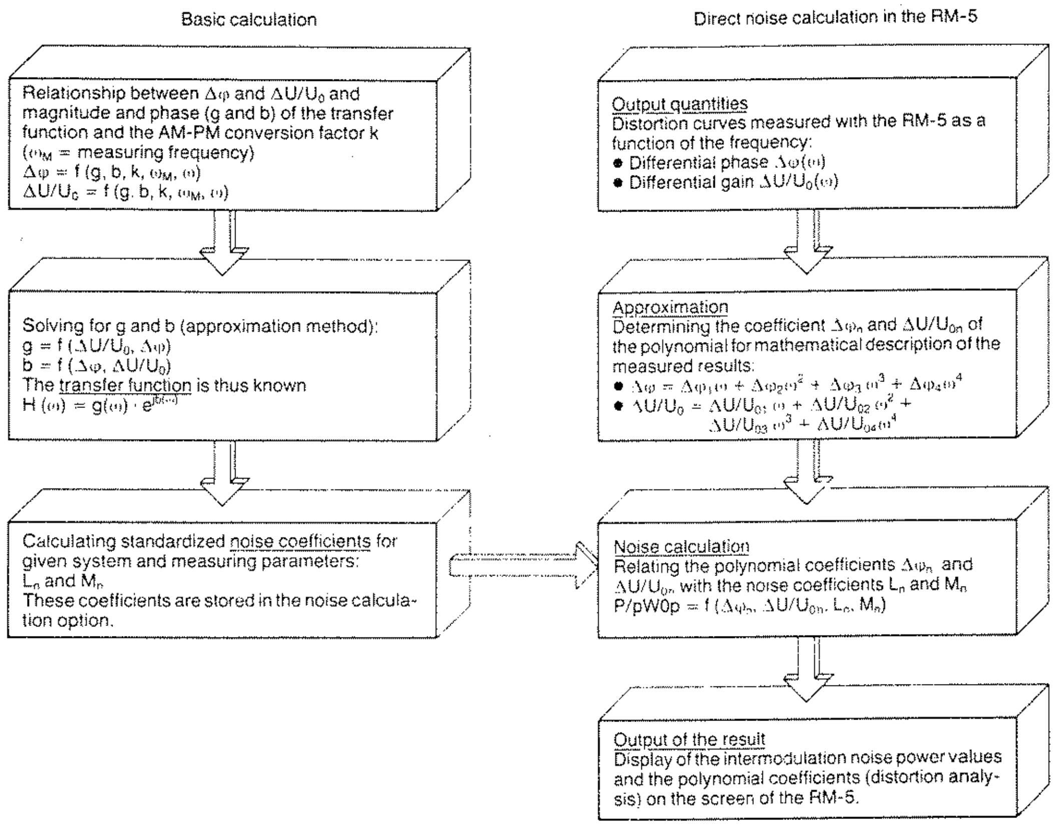


Figure 4-16 Diagram showing the steps in the noise calculation procedure

The method of least squares is used to determine the polynominal. Tests have shown that this method is suitable for curves with some noise and ripple. However, it should be borne in mind that a polynomial of the 4th degree will not give a very good approximation to curves that are very irregular. However in practice reservations of this kind may safely be ignored.

Figure 4-17 shows the measured curve and the graph of the polynomial that is used to approximate it. Increasing the degree of the polynomial to obtain a better approximation would not be useful as the terms of higher degree could not be used to calculate the intermodulation noise.

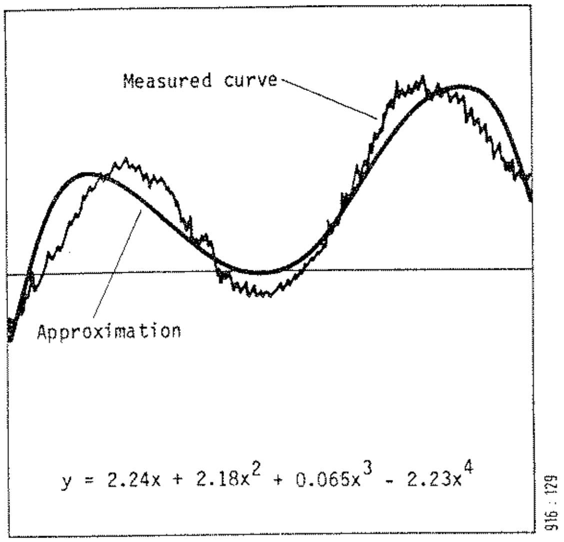


Figure 4-17 Measured distortion curve approximated (least squares) by polynomial of 4th degree

4.7.5 COMPARISON BETWEEN CALCULATED AND MEASURED NOISE

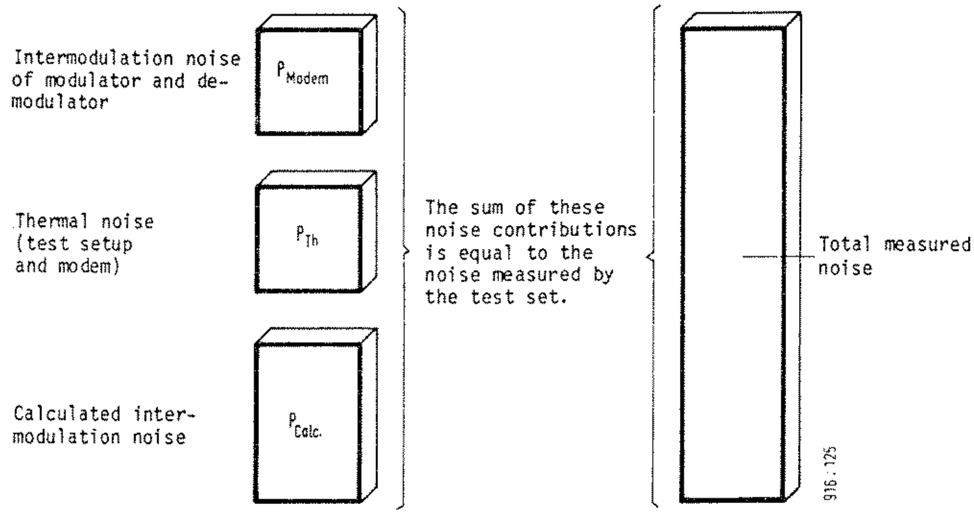
If noise calculation is to be of use, the results must be comparable with the results of white noise measurements.

When comparing intermodulation noise calculated from the results, the following extra noise contributions should also be taken into account.

- Thermal noise from item-under-test and modulator/demodulator
- Modem intermodulation noise

Both noise contributions can be determined with the white noise measuring setup and modem that were used for the reference measurement, see figure 4-19.

A further contribution to the measured noise may arise from the AM/PM conversion of the demodulator. This depends on the type of distortion introduced by the item under test and its magnitude, as well as the PM/AM conversion factor of the demodulator. The latter is generally small.



$$P_{Calc.} + P_{Th} + P_{Mod.} \; (+ P_{AM/PM}) \Leftrightarrow P_{Meas.}$$

Figure 4-18 Comparison of calculated noise and measured noise

When making a comparison, the errors introduced by the test set (approx. 10%) and the inaccurate setting of the relative level on the test set (frequency response of relative level) must also be taken into account.

If there is not a good fit between the measured curve and the approximate curve, one can, as a rule, expect that the calculated noise will be too low (see 4.7.4).

The following example will show in details how the comparison is made, figure 4-20 and table 4-3.

There is a very good agreement between the results. This is shown very clearly by the noise diagram, figure 4-21.

Noise calculation is particularly useful when adjustments on separate modules are made. Usually when measurements of this type are made with a white noise test setup, the noise from the wideband modem, which can be circumvented, swamps the noise from the item under test. Noise calculation is the only way of obtaining a good estimate for the intermodulation noise introduced by the IF module while adjusting distortion. There are no effects introduced by the modem. Other valuable information is obtained from the results of the distortion analysis which are displayed on the screen with the noise results. The 1st to 4th order distortion components are shown. This means that the noise calculation option need not just be used for intermodulation noise but has other applications, e.g. on digital radio-links.

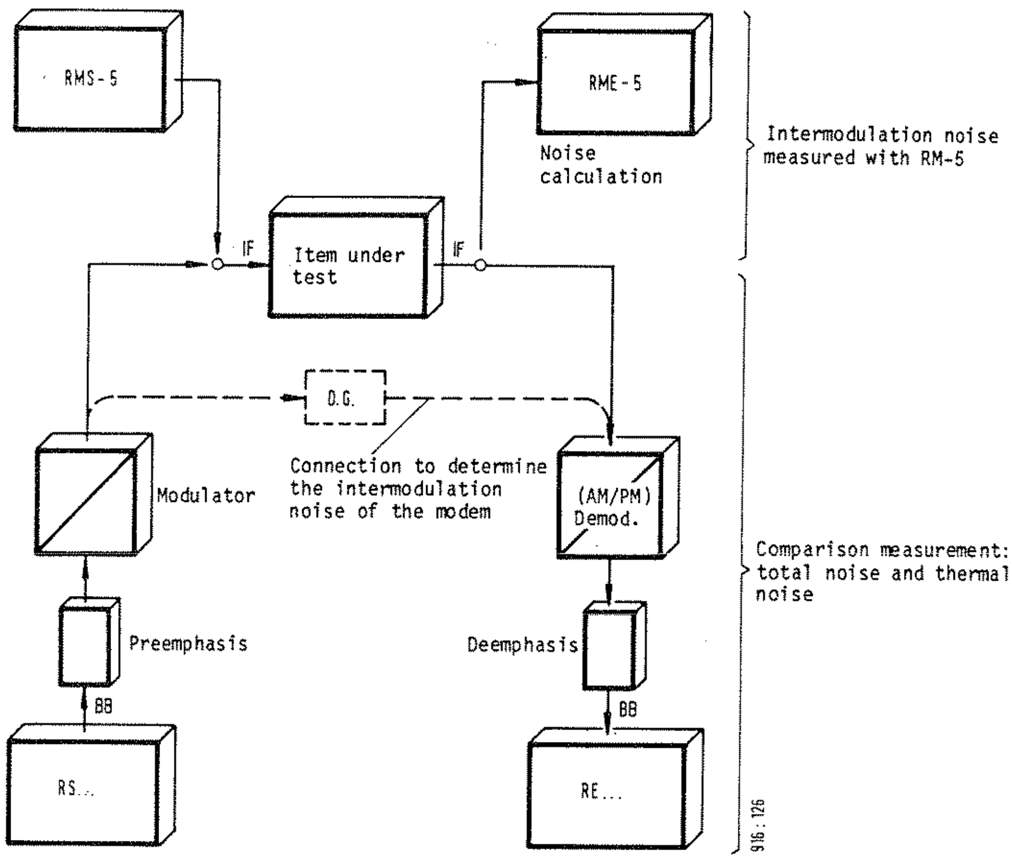


Figure 4-19 Test setup for comparing calculated noise with measured noise

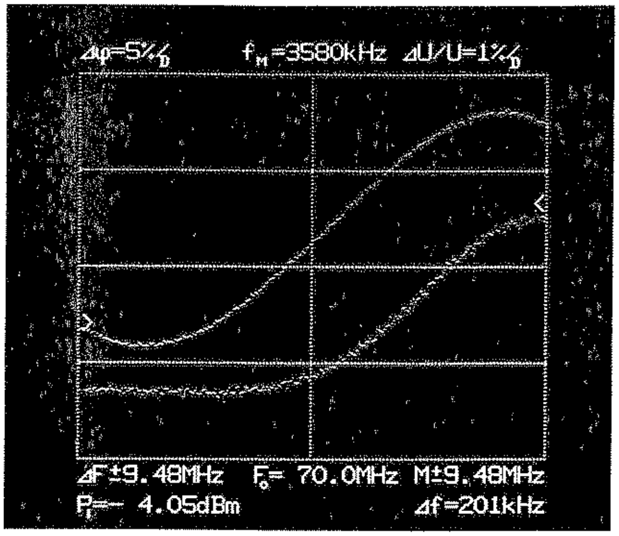


Figure 4-20a Results of an IF distortion measurement

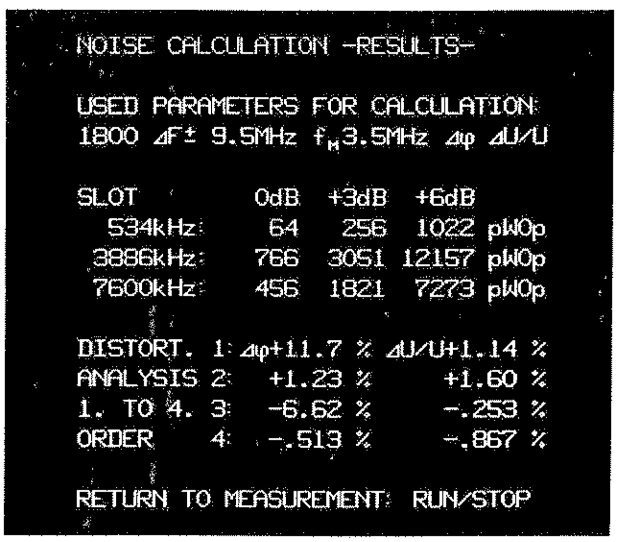


Figure 4-20b Noise calculated from the results in figure 4-20a

		Convent. load 0 dB		+ 3 dB		+6 dB	
		Calculated	Measured	Calculated	Measured	Calculated	Measured
534 kHz	$P_{Cal.}$	64		256		1022	
	P_{Th} P_{Mod}	30		79		240	
	P_{Σ}	94	102	335	355	1262	1230
		-8% ≅ -0.4 dB		-6% ≅ -0.3 dB		+3% ≅ 0.1 dB	
3886 kHz	$P_{Cal.}$	766		3051		12157	
	P_{Th} P_{Mod}	16		26		51	
	P_{Σ}	782	813	3077	3090	12208	11000
		-4% ≅ -0.2 dB		-0,4% ≅ -0.02 dB		+11% ≅ 0.5 dB	
7600 kHz	$P_{Cal.}$	456		1821		7273	
	P_{Th} P_{Mod}	11		17		42	
	P_{Σ}	467	417	1838	1620	7315	5890
		+12% ≅ 0.5 dB		+13% ≅ 0.5 dB		+24% ≅ 0.9 dB	

(P in pWOp)

Table 4-3 Comparison between calculated noise and measured noise

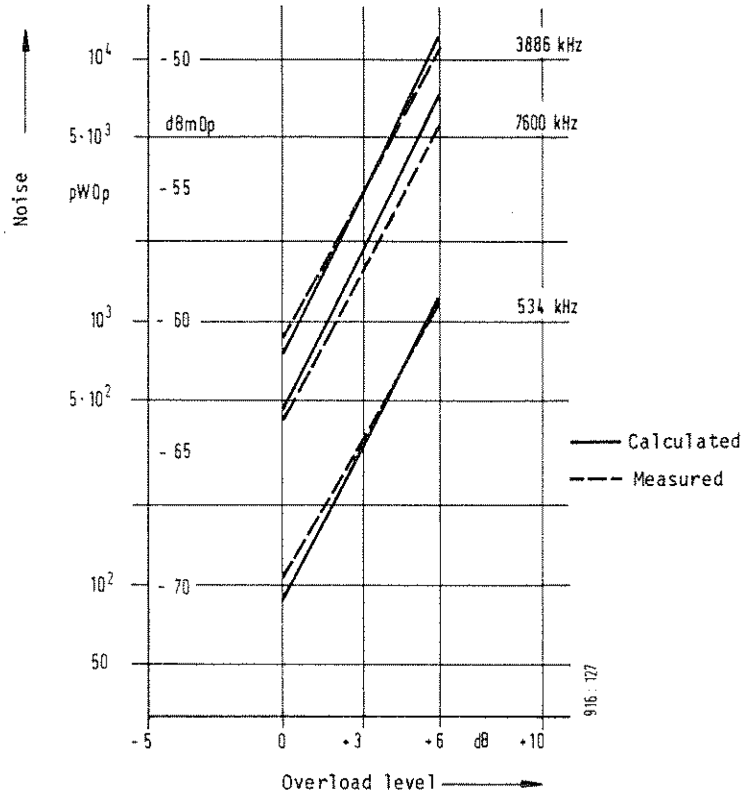


Figure 4-21 Graphic comparison of calculated noise and measured noise

4.8 DETERMINING THE AM/PM CONVERSION FACTOR USING THE RM-5

Digital radio-link systems often use modulation procedures where a part of the information to be transmitted is coded in terms of discrete amplitude setps, e.g. 16 QAM. This means that signal degradation could be caused by compression and AM/PM conversion. Non-linear effects of this kind are encountered in power amplifiers, limiters and mixers.

Limiters are, of course, only used in sytems with pure phase modulation, e.g. 4-PSK. However linéar distortion in the transmission band always means that amplitude modulation is present. When amplitude modulation is converted to phase modulation, this means that the phase of the modulation steps is incorrect.

This means that AM/PM conversion and compression must be measured. The following describes a way of measuring AM/PM conversion using the RM-5.

The noise calculation option for the RM-5 is essential because of its distortion analysis facility. A network with a parabolic group delay with frequency response and a flat attenuation with frequency response in the IF range must also be included in the test setup.

The AM/PM conversion coefficient, Θ in rad/%, is defined by the following equation:

$$\Theta = \frac{\Delta \emptyset_o}{\Delta V_i} \qquad (1)$$

$\Delta \emptyset_o$ is the phase deviation in rad at output of the item under test and ΔV_i is the relative amplitude in % at the input of the item under test. Sometimes the conversion factor K_p will be used instead of the coefficient Θ.

The approx. relationship between the factor and the coefficient is given by the following formula:

$$K_p = 6.6 \cdot \Theta \text{ [grad/dB]} \qquad (2)$$

AM/PM conversion measurements can be performed with the test setup given in figure 4-22, using an IF module as the item under test. It is, of course, possible to use the same method for IF-BB modules, i.e. FM demodulators. In the latter case, the BB output of the item under test is connected to the BB input of the RM-5.

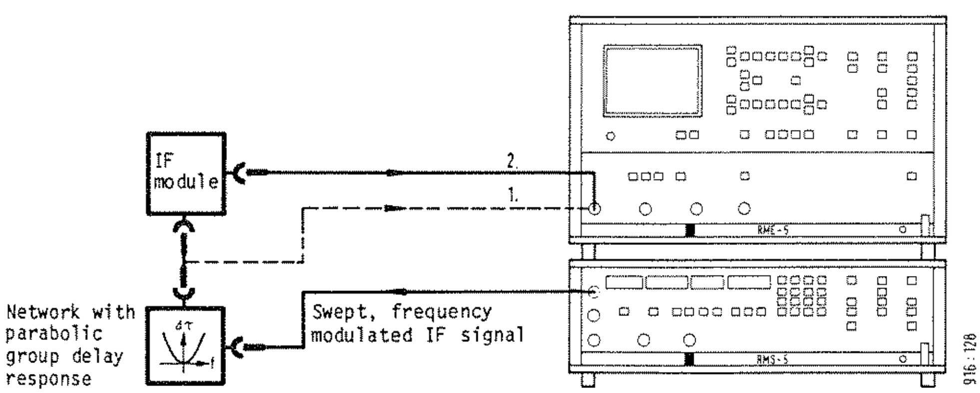


Figure 4-22 AM/PM conversion measurements using an IF module as the item under test

A network with a known group delay/frequency response (parabolic) τ_2 the units are ns/MHz^2 is connected between the output of the generator and the input of the object under test. The amplitude/frequency response of the network must be flat over the bandwidth swept.

A test frequency in the MHz range, f_M, is selected on the generator, e.g. 5.6 MHz and a sweep width appropriate to the bandwidth of the system in question. If AM/PM conversion is present, the differential gain $\Delta U/U_o$ in %/MHz is displayed as a slanting straight line. The AM/PM conversion factor can be calculated from τ_2 and ΔDG.

$$K_p = 10.504 \frac{\Delta DG}{\tau_2 f_M^2} \qquad (3)$$

Where

ΔDG	is in %/MHz
τ_2	is in $ns/(MHz)^2$
f_M	is in MHz
K_p	is in grad/dB

It is also possible to convert K_p to rad using equation (2), in both cases it should be noted that this approximate formula is only valid for small values of K_p (< 5°/dB).

$$\Theta = \frac{K_p}{6.6} \qquad (4)$$

The test method used is described in IEC 487 and 510 and will also be contained in the new publications on systems with digital modulation.

The following steps must be made:

- Connect the RMS-5 with the input of the τ_2 network and set the sweep with to $\pm$ B/2 and select a low test frequency of 83.3 or 92.59 kHz. The test tone deviation Δf should be approx. 100 kHz. Check if the IF frequency response is within $\pm$ 0.05 dB and calculate τ_2 in the following way (step 1, figure 4-22).

  $\tau_2 = \Delta\tau / \Delta\hat{F}^2$

- Switch on the automatic sweep width reduction facility ([5] SWEEP REDUC.) and select a test frequency f_M in the MHz range (about 1/2 to 1/3 of B/2) and determine the linear component of differential gain as described below.

  To eliminate the intrinsic error of the test setup, two different reference measurements should be made, depending on the frequency range of the item under test (IF or BB).

  Item under test with a IF output:
  The linear components of the differential gain $(\Delta U/U_o)_1$ are determined using the noise calculation option's distortion curve analysis facility. The item under test is disconnected but the group delay network is in place (step 1, figure 4-22).

  Item under test with a BB output:
  Determine the linear components of the differential gain $(\Delta U/U_o)^1$ using the noise calculation's options distortion curve analysis facility. The item under test (FM demodulator) is connected, no group delay network.

- Determine the linear components of the linear gain as above but this time with the item under test and the group delay network connected in tandem (step 2, figure 4-22).

- Calculate the difference between the two components

  $\Delta U/U_o = (\Delta U/U_o)_2 - (\Delta U/U_o)_1$

- Calculate the linear component of the $\Delta U/U_o$ result in the following way:

  $\Delta DG = \Delta U/U_o/B - 2f_M$ [%/MHz]

- Calculate the AM/PM conversion factor in grad/dB:

  $$K_p = 10.51 \frac{\Delta DG}{T_2 f_M^2}$$

Example:

The AM/PM conversion factor of an IF module is to be measured. Figure 4-22 shows the test setup.

- As figure 4-23 shows, the amplitude frequency response is within ± 0.05 dB. The T_2 value of the group delay network is calculated using figure 4-24 and is equal to 12.8 ns/ 12 MHz)^2 = 0.089 ns/MHz^2.
- Without the item under test but with the group delay network connected, determine the linear component of differential gain $\Delta U/U_o)_1$ (f_M = 4.43 MHz and $\hat{\Delta F}$ = ± 7.6 MHz when the auto sweep reduction facility is on). Figure 4-25a shows the results for differential gain and figure 4-25d the linear component with

  $(\Delta U/U_o)_1$ = +0.689%

- With the item under test connected $(\Delta U/U_o)_2$ is determined (figures 4-25c and 4-25d):

  $(\Delta U/U_o)_2$ = -0.546%

- The difference is

  $|(\Delta U/U_o)| = |(-0.564\% - 0.689\%)| = 1.253\%$

- The linear component is therefore

  ΔDG = 1.253%/(24 - 2 x 4.43) = 0.083%/MHz.

- The AM/PM conversion factor is therefore:

  $$K_p = 10.51 \times \frac{0.083}{0.089 \times 4.43^2} = 0.5°/dB$$

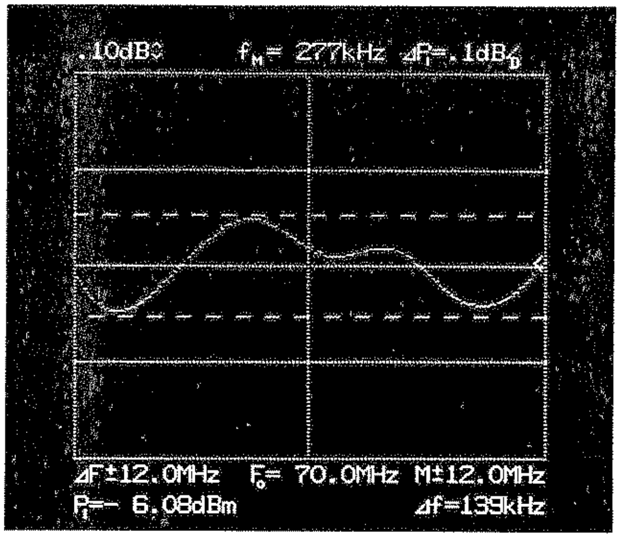


Figure 4-23 Frequency response of the group delay network

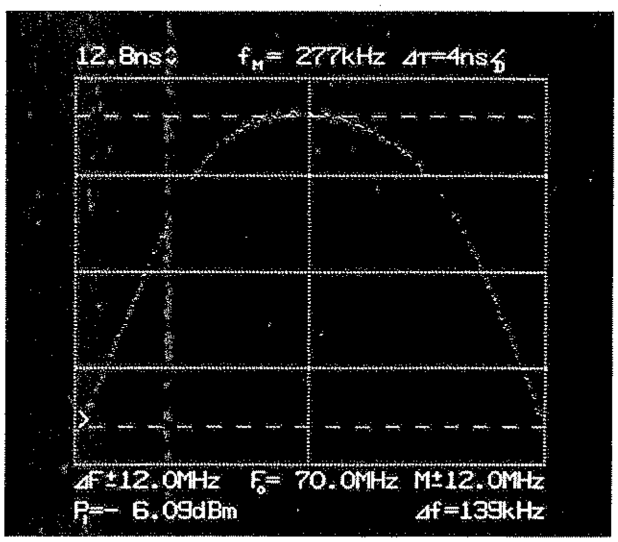


Figure 4-24 Group delay frequency for group delay network

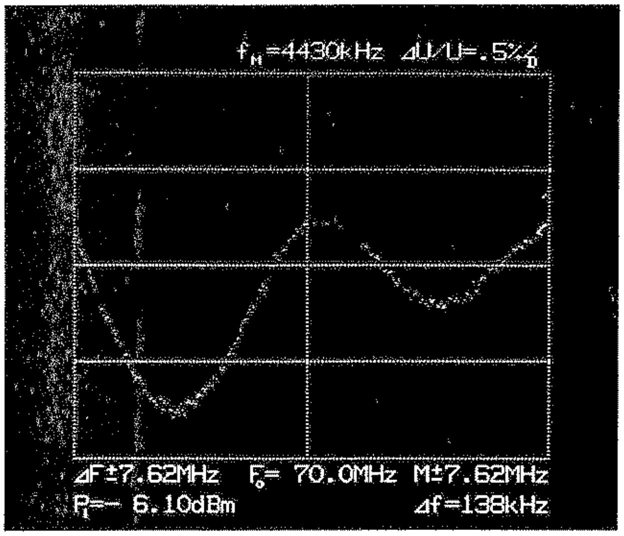


Figure 4-25a Differential gain of test setup without item under test

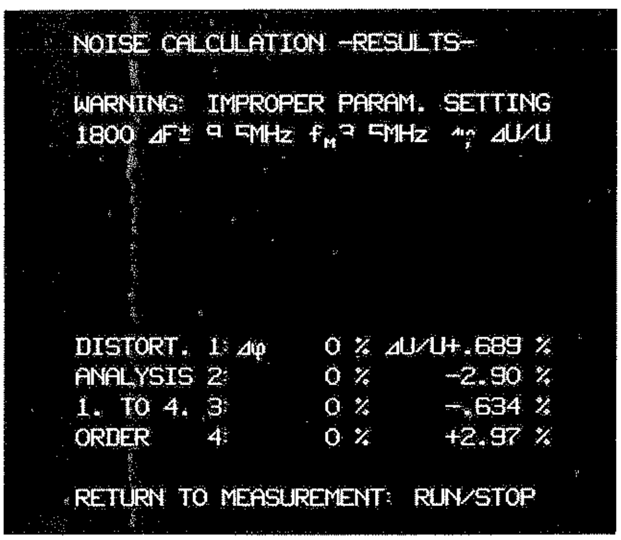


Figure 4-25b Distortion analysis of results from figure 4-25a

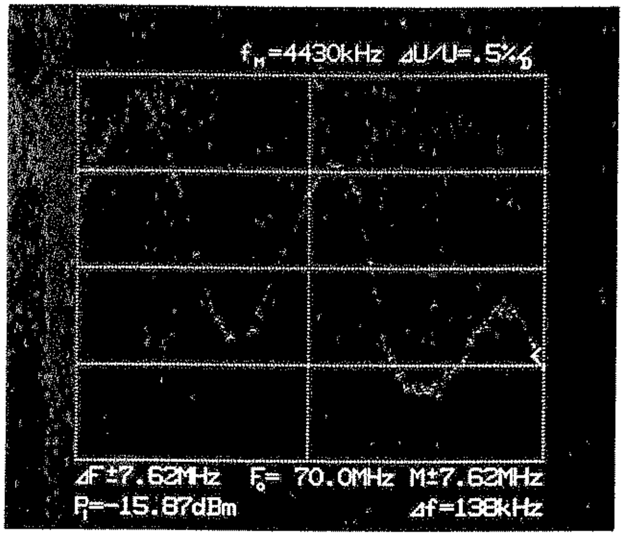


Figure 4-25c Differential gain when item under test is connected

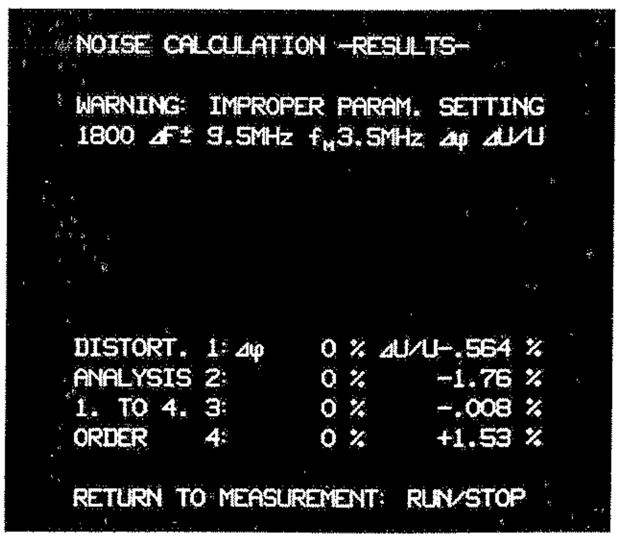


Figure 4-25d Distortion analysis of results from figure 4-25c

5 FUNCTIONAL TEST, MAINTENANCE, ETC.

5.1 FUNCTIONAL TEST

The functions of the RM-5 that are relevant for its main applications are tested with the generator section and the receive section in back-to-back mode (5.1.2). A functional test determines whether the instrument is performing to the specifications given in the data sheet and whether the error limits are OK. The instrument settings given in each section may not necessarily correspond to the worst case. The short, double-screened 75 Ω cable, delivered with the RM-5 should be used to perform the measurements.

If the RME-5 is fitted with the xy plotter interface or a video printer is available, it is a good idea to list the test results.

So that one can determine which instrument is responsible for a fault, the most important characteristics of the generator section should be tested with a calibrated attenuator and a frequency meter. These measurements preceed the back-to-back measurements (5.1.1).

N.B. The measurement should be carried out after a warm up time of 30 min. The function test uses test and sweep frequencies that are generated internally.

5.1.1 CHECKING THE GENERATOR SECTION OF THE RMS-5

5.1.1.1 IF output level

Required test equipment: Calibrated level meter (e.g. EPM-1 with TK-10 test probe from W&G)

RMS-5 settings:

[8], [2] : 0 dBm
[9], [2] : 70 MHz (35 MHz, 140 MHz with appropriate option)
[13], [2]: U_M = 0 mV
[10] : ΔF = 0
[4], [14]: any

- Calibrate the calibrated level meter at 0 dBm, Z_{in} = 75 Ω
- Connect the calibrated level meter to connector [1]
- Required reading on level meter: $\leq \pm$ 0.15 dB ($\pm$ 0.15 dB at 35 MHz, $\pm$ 0.25 dB at 140 MHz)

5.1.1.2 BB output level

Test voltage U_M

Required equipment: calibrated level meter (e.g. EPM-1 with TK-10 test probe from W&G)

RMS-5 settings:

[13], [2] : U_M = 0 dBm (≡ 274 mV)
[10] : $\hat{U}_A$ = 0 V
[4] : f_M = 92.6 or 83.3 kHz

- Set the calibrated level meter to 0 dBm at U_{in} = 75 Ω
- Connect the calibrated level meter to connector [17]
- The level meter must indicate 0 dBm ± 0.5 dB
- Call up test frequencies under [4]
- In each case the reading must be: 0 dBm ± 0.5 dB

Sweep voltage U_A

Required test equipment: Calibrated level meter (e.g. EPM-1 with TK-10 test probe from W&G)

RMS-5 settings:

[13] [2] : U_M = -75 dBm (approx. 0 mV)
[10], [2] : $\hat{U}_A$ = 0 V

- Set calibrated level meter to 0 dBm at Z_{in} = 75 Ω
- Connect a 9.03 dB attenuator (accessory) to connector [17]
- Using the arrow key ⇧ [2] increase the sweep voltage $\hat{U}_A$ until the level meter indicates 0 dBm
- The $\hat{U}_A$ display (B) must lie within the range 1.100 V ± 0.035 V.

5.1.1.3 IF centre frequency (standard frequency, whole IF range)

Required test equipment: frequency counter to 200 MHz, error < 10^{-6} of displayed value.

RMS-5 settings:

[9], [2]: 70 MHz (35 MHz or 140 MHz option fitted)
[10] : ΔF = 0 MHz
[13] : Δf = 0 kHz
[8], [2]: P_{IF} = 0 dBm

- Connect the input of the frequency counter to connector [1] of the RMS-5.
- Use the settings in the following table to perform the appropriate measurements:

	35 MHz range (option)	70 MHz range	140 MHz range (option)
Frequency settings [2], [9]	22.5, 25, 30, 35, 40, 45, 47.5 MHz	40, 45, 58, 70, 82, 95, 100 MHz	90, 110, 122, 140, 158, 170, 190, 200 MHz
Error limits	± 10 kHz	± 20 kHz	± 40 kHz

5.1.1.4 Test and sweep frequencies

Required test equipment: frequency counter (see 5.1.1.3)

T e s t f r e q u e n c i e s

RMS-5 settings:

[13], [2] : U_M = 0 dBm
[10] : $\hat{U}_A$ = 0 V
[12] : U_{MEXT} = OFF

- Connect frequency counter to connector [17]
- Call up all test frequencies under key pad [4], see table:

Key down (LED on)		Display on frequency meter (in kHz)	
f_M (series I)	f_M (series II)	f_M (series I)	f_M (series II)
"27.7"	"25"	27.778 ± 0.0006	25 ± 0.0005
"55.5"	"50"	55.556 ± 0.0011	50 ± 0.0010
"92.6"	"83.3"	92.593 ± 0.00185	83.3 ± 0.00167
"277"	"250"	277.778 ± 0.00556	250 ± 0.00500
"555"	"500"	555.55 ± 0.01200	500 ± 0.01000
"2400"		2400 ± 0.048	
"5600"		5600 ± 0.112	

S w e e p f r e q u e n c i e s

Switch frequency counter to average period display mode.

RMS-5 settings:

[13], [2] : U_M = -75 dBm (approx. 0 mV)
[10], [2] : $\hat{U}_A$ = 1 V
[14] : 18 Hz, frequency counter displays average period = 55.556 ± 1.111 ms
[14] : 70 Hz, frequency counter displays average period = 14.286 ± 0.286 ms

5.1.2 CHECKING THE RM-5 (RMS-5 AND RME-5 IN BACK-TO-BACK MODE)

5.1.2.1 BB-BB distortion measurements

- Connect connector [17] (RMS-5) with connector [27] (RME-5)

I n t r i n s i c d i s t o r t i o n

Settings

RMS-5

[13], [2] : U_M = -10 dBm
[10], [2] : $\hat{U}_A$ = 1 V
[4] : f_M = 555.5 kHz (500 kHz)
[14] : 70 Hz

RME-5

[23]: BB mode
[2] : $\Delta\tau$, $\Delta\varphi$ measurement, measurement range 0.2 ns/D
[10]: $\Delta U/U_0$ measurement, measurement range 0.1%/D
[5] : averaging factor 4

- $\Delta\tau$- and $\Delta U/U_0$ result shifted in the display area (POSITION [1], [9])
- Evaluate result and select each test frequency in return

Intrinsic distortion limits

$\Delta\tau$: $\leq$ 0.05 ns; $\Delta\varphi$: $\leq$ 0.05% rad; $\Delta U/U_0$: $\leq$ 0.02%
(only for f_M > 1 MHz)

I n t r i n s i c   n o i s e

Settings

RMS-5

[13], [2] : U_M = -30 dBm

RME-5

[5] : averaging factor 32

Intrinsic noise limits (peak-to-peak)

$\Delta\tau$(at 555 kHz or 500 kHz): $\leq$ 0.1 ns $\Delta U/U_0$, $\Delta\varphi$/rad: $\leq$ 0.05%

When selecting the test frequencies with the RMS-5's key pad [4], check the frequency values shown in the upper line of the RME-5's screen.

5.1.2.2 IF-IF distortion measurements

Settings

RMS-5

[8], [2] : 0 dBm (IF level)
[9], [2] : 70 MHz (35 MHz, 140 MHz, when option is fitted)
[10], [2] : $\hat{\Delta F}$ = 12 MHz (sweep width)
[13], [2] : Δf = 500 kHz
[14] : 70 Hz
[4] : f_M = 555.5 or 500 kHz

RME-5

[22]: IF mode
[21]: 70 MHz (35 MHz, 140 MHz, when option is fitted)
[2] : $\Delta\tau$, $\Delta\varphi$ measurement
measurement range 0.2 ns/D
[10]: $\Delta U/U_0$ measurement
Measurement range 0.1%/D
[5] : averaging factor 32

- Connect connector [1] (RMS-5) with connector [25] (RME-5)
- Position $\Delta\tau$- and $\Delta U/U_0$ result on the screen (POSITION [1], [9])

The measurements should be made for two sweep ranges, see table.

Intrinsic distortion limits:

IF	$\hat{\Delta F}$	f_M < 1 MHz		f_M > 1 MHz 2)	
		$\Delta\tau$ 1)	$\Delta U/U_0$	$\Delta\varphi$	$\Delta U/U_0$
35 MHz	± 5 MHz	≤ 0.5 ns	≤ 0.2%	-	-
	± 10 MHz	≤ 2.0 ns	≤ 0.8%	-	-
70 MHz	± 12 MHz	≤ 0.4 ns	≤ 0.1%	≤ 0.5% rad	≤ 0.2%
	± 25 MHz	≤ 1.0 ns	≤ 0.3%	≤ 1.0% rad	≤ 0.4%
140 MHz	± 18 MHz	≤ 0.3 ns	≤ 0.15%	≤ 0.5% rad	≤ 0.2%
	± 30 MHz	-	≤ 0.3%	≤ 1.0% rad	≤ 0.4%
	± 40 MHz	≤ 1.0 ns			

1) at 555.5 or 500 kHz

2) Automatic sweep width reduction

Intrinsic noise (peak-to-peak), averaging factor 32, sweep width 0.2 MHz
at f_M = 555.5 or 500 kHz: $\Delta\tau \leq 0.1$ ns; $\Delta U/U_o \leq 0.05\%$
at f_M > 1 MHz and Δf = 500 kHz: $\Delta\varphi \leq 0.05\%$ rad; $\Delta U/U_o \leq 0.05\%$

5.1.2.3 IF frequency response measurement ΔP_I and ΔP_{II}

I F - f r e q u e n c y   r e s p o n s e ΔP_I (frequency response correction [19] off)

Settings

RMS-5

[8], [2] : -10 dBm (IF level P_I)
[9], [2] : 70 MHz (35 MHz, 140 MHz with options fitted)
[10], [2]: $\hat{\Delta F}$ = 25 MHz (10 MHz at 35 MHz IF, 50 MHz at 140 MHz IF)
[13], [2]: U_M = -75 dBm (approx. 0 mV)

RME-5

[22]: IF mode
[21]: 70 MHz (35 MHz, 140 MHz with options fitted)
[2] : ΔP_I measurement, measurement range 0.1 dB/D

- Connect connector [1] (RMS-5) to connector [25] (RME-5), use a short cable
- Position the ΔP_I result on the screen using the arrow keys and note result, cf in the following table.

Frequency response ΔP_I limits:

IF	$\hat{\Delta F}$	ΔP_I
35 MHz	± 5 MHz	± 0.25 dB
	± 10 MHz	± 0.25 dB
70 MHz	± 25 MHz	± 0.1 dB
140 MHz	± 50 MHz	± 0.2 dB

- Set the IF level on the RMS-5 to -20 dBm and note the ΔP_I result, cf table.

I F   f r e q u e n c y   r e s p o n s e ΔP_{II} (selective)

- Settings as for ΔP_I measurement, but select ΔP_{II} result on the RME-5 (e.g. under [2]), measurement range 2 dB/D
- Connect connector [1] (RMS-5) to connector [26] (RME-5).
- Connect connector [7] (RMS-5) to connector [25] (RME-5).
- Position ΔP_{II} result with arrowed keys [1] on the screen and note result, cf following table.

IF	ΔF	ΔP_{II}
35 MHz	± 10 MHz	± 0.6 dB
70 MHz	± 25 MHz	± 0.6 dB
140 MHz	± 50 MHz	± 0.7 dB

5.1.2.4 IF level and frequency deviation measurement, including calibration

- Carry out calibration as described in 3.6.7.

Check the IF level display:

- Set the IF level on the RMS-5 to -10 dBm ([8], [2])
- Select the IF counter function on the RME-5 [4]: the displayed level value must not lie outside the range -10 to ± 0.5 dBm.

5.2 VERSACON®9 UNIVERSAL CONNECTOR SYSTEM

The coaxial signal inputs and outputs are fitted with the Versacon®9 Universal Connector System by Wandel & Goltermann (figure 5-1). This means any one of the connector types shown below can be used without the need for soldering. The appropriate connector insert can be fitted to the universal connector (fixed to instrument) with a special key (in accessory compartment at back of instrument).

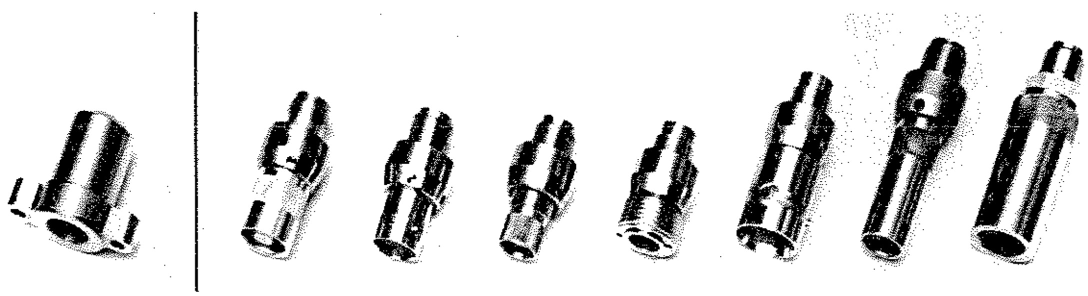


Figure 5-1 The Versacon®9 connector with some of the available inserts

5.3 MAINTENANCE ETC.

The RM-5 does not need any special maintenance, as long as it is treated carefully. The closed housing protects the circuits even when the RM-5 is in transit. In this case, it is a good idea to use the SD-3 (RMS-5) and the SD-6 (RME-5) covers to protect the instrument.

If the RM-5 is to be shipped over long distances or under severe conditions the TPK-3 (RMS-5) and the TPK-6 (RME-5) transportation cases should be used.

5.4 MECHANICAL CONSTRUCTION

⚠ Caution: Disconnect from mains before opening the instrument! The instrument must be switched off when fitting or removing subassemblies or other devices.

The dimensions of the housing comply with DIN 41 494 and the American standard ASA C 83.9. The instrument can therefore be fitted in a 19" rack (see 3.1.2.2). The cover, the floor and the sides of the instrument are made from robust aluminium castings. Six Allen head screws are used to hold these components together.

The Allen key supplied with the instrument can be used to undo the screws. The key is in the accessory compartment at the back of the instrument.

The subassemblies of the RMS-5 are arranged in three levels, the upper and lower subassemblies are accessible when the top or bottom of the instrument are removed. The middle subassembly can be removed from the back of the instrument when the covering plate is removed.

When the top of the RME-5 is removed, the complete chassis including the front panel and the back wall can be lifted out.

It should be noted that the chassis is connected by several cables to the power supply which is fixed to the righthand side panel of the instrument.

As all important subassemblies in the analog and digital sections (plug-in-boards) are arranged vertically as seen from the back panel (see figure 5-2), it is a good idea to leave the chassis in the housing when replacing any boards and simply remove the back panel. It is then simple to extract the board.

A detailed description can be found in the Service Manual.

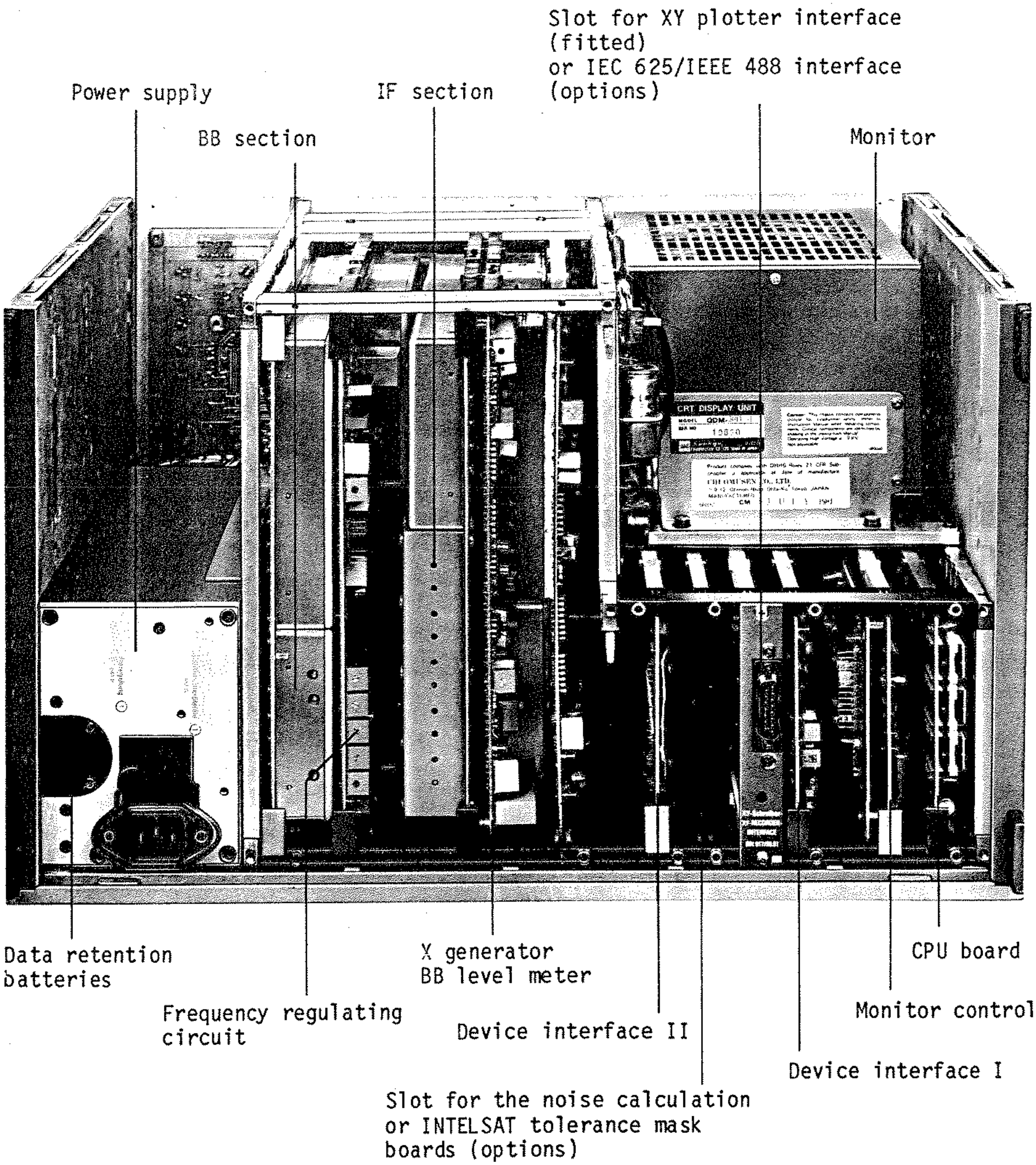


Figure 5-2 Arrangement of subassemblies in the RME-5 (back panel removed)

5.5 RETROFITTING OPTION BOARDS

The following option boards can be easily retrofitted from the back of the instrument:

RMS-5:	<IEC 625> interface board, BN 958/21	Position N, see figure 3-3b
RME-5:	<IEC 625> interface board, BN 853/21 XY plotter interface, BN 917/00.01	Position P, see figure 3-4b
	Noise calculation board, BN 917/00.11 INTELSAT tolerance masks, BN 917/00.12	Position O see figure 3-4b

N.B.: In the case of the RME-5 only the IEC 625/IEEE 488 interface and the XY interface or the noise calculation board and the INTELSAT tolerance mask board may be inserted in the two available slots. If you want to fit the noise calculation and INTELSAT tolrance mask options to series 0 instruments the software must also be replaced.

To insert the option board first remove the dummy panels, insert, and fix with two screws.

A somewhat different procedure has to be used to fit the XY plotter interface or the IEC 625/IEEE 488 interface. The board [917-AW1] is fixed to the dummy panel by means of a plate. The board can be released by removing two screws, the board is then attached to the interface board. Using the two wire attachments that are supplied with the instrument, a stable mechanical connection can be made between the boards. Both boards can then be inserted into the instrument.

5.6 RETROFITTING THE RME-5 WITH A FAN

When the RME-5 is used in environments with a high ambient temperature (e.g. 19" racks) it is advisable to fit the instrument with a fan. The retrofitting procedure is very simple and can be carried out by the user himself.

- Remove the plate from the RME-5 (see 5.4).
- Remove the upper part of the back panel covering plate (5 screws).
- Remove the two dummy panels (marked BN 917-16.1).
- Fit a plate with screw threads above and below each of the fan openings that have been exposed (4 plates each with 8 M3x8 screws).
- Fix the tube behind the righthand fan opening with 4 M3x6 screws.
- Fix the fan (4 captive screws).
- Replace plate.

5.7 Removal of NiCd batteries when scrapping the RME-5/RMS-5

Instructions are given below for removal of the NiCd batteries used in the RME-5 and RMS-5. Please heed the safety precautions found in the section entitled "Opening the instrument" (p. 2-5).

RME-5

The batteries are located in a compartment on the back panel of the instrument (see figure 5-2, page 5-8). Remove both Phillips screws and pull out the holder. Remove the batteries from the holder and dispose of them as described in the section on environmental protection.

RMS-5

1. Set the instrument on its left side panel.
2. Loosen the screws between the right side panel and the cover or bottom.
3. Return the instrument to its normal position and remove the cover completely.
4. Disconnect the cable between the power supply and housing module.
5. Lift out the housing module so that the right side panel with the power supply can be removed on the side.
6. Remove the NiCds from the holder on board 916-BT of the power supply.
7. Dispose of the batteries as described in section on environmental protection.

Help to protect our environment

The batteries contain heavy metals which may represent an environmental hazard when they are disposed of at the end of their useful life or when the instrument is scrapped.
Dispose of the batteries by returning them to the appropriate collection point for used batteries, or to a company specializing in the recycling of such items, or to the place where new batteries are purchased. Batteries purchased from Wandel & Goltermann can be returned to your nearest W&G service center.