2006

INSTRUCTIONS AND APPLICATIONS

Heterodyne Voltmeter Type 2006

A selective voltmeter covering the frequency range: 100 kHz—230 MHz. Sensitivity: 50 μV—50 V full scale deflection. Direct reading AM and FM modulation. Fully transistorized battery or mains operated.

BRÜEL & KJÆR

NÆRUM, DENMARK. Teleph.: 80 05 00. Cable: BRUKJA. Telex: 5316. COPENHAGEN

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Heterodyne Voltmeter

Type 2006

March 1969

Contents

1. Description

General.

The Heterodyne Voltmeter Type 2006 is a transistorized, selective voltmeter for measuring RF voltages in the frequency range from 100 kHz to 230 MHz. It is provided with a meter circuit having a maximum sensitivity of 50 μV for full scale deflection when switched for measuring RF voltages. When switched for modulation measurements, there will be a full scale deflection for 80 % amplitude modulation (AM) or for a frequency swing of $\pm$ 80 kHz frequency modulation respectively.

The input probe has an impedance of 3 MΩ in parallel with 6 pF, or may be terminated by a 50 Ω resistor.

It is a light weight, portable instrument, which can be operated from the mains or from a built-in nickel-cadmium storage battery. A unit for recharging the battery is contained in the instrument.

It is especially useful for measurements on:

Antenna amplifiers and distribution systems for AM, FM and TV Receivers
Transmitters
Transceivers
R.F. circuits
I.F. circuits

The Heterodyne Voltmeter Type 2006 is particularly designed for measuring the amplitude of high frequency signals and determining the frequency as well as the percentage modulation. The measured frequency is indicated on a scale. A meter indicates the amplitude of the measured RF voltage and the modulation. A loudspeaker provides an audible signal check.

Input Probe.

The miniaturized Input Probe (Fig. 1.1) contains an FET stage and features the advantages of a high input impedance and easy handling due to its small outside dimensions. The input impedance at 1 MHz is greater than 3 Megohm parallel to 6 pF. At higher frequencies the input impedance decreases. At 100 MHz it is about 20 kΩ and at 200 MHz it is about 5 kΩ. When using the Attenuator described below the input impedance is greater than 10 kΩ at all frequencies up to 200 MHz (C_{in} = 2 pF).

A Capacitive Voltage Divider is provided in order to extend the voltage range of the voltmeter. The attenuation of the Voltage Divider is 60 dB and the input capacity is as low as 2 pF. The Voltage Divider is made as a mechanical

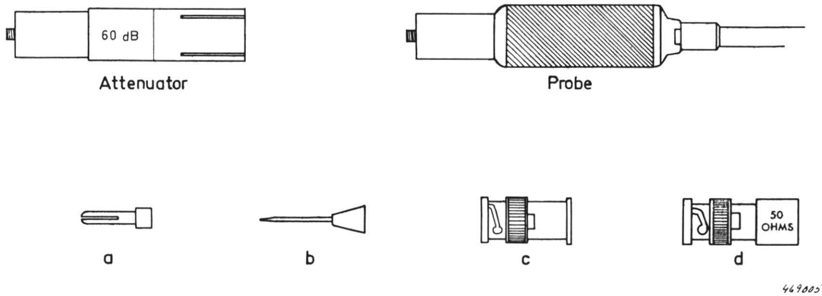

Fig. 1.1. Input Probe and 60 dB Attenuator a, b and c: Adaptors.

extension of the input probe (see Fig. 1.1). The connection from the input probe to the Voltmeter consists of a multicore cable, which also supplies the necessary voltage for the probe. At the terminating end, the cable is supplied with a BNC-connector. The signal pin of the Probe itself can be unscrewed and replaced with a BNC conversion plug, for instance for calibration purposes or with a 50 Ω termination, see OPERATION, p. 14.

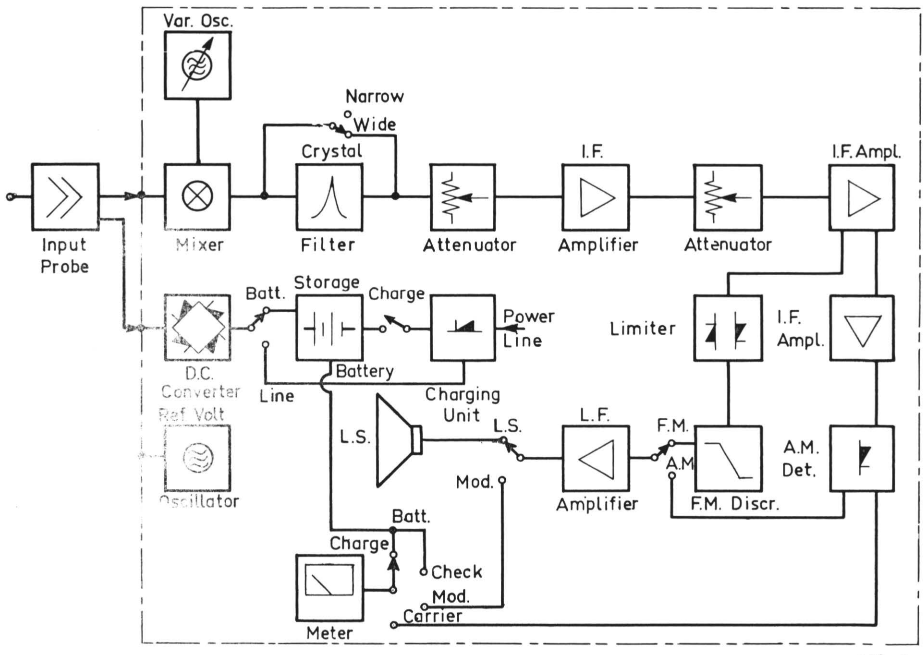

Fig. 1.2. Heterodyne Voltmeter Type 2006. Block diagram.

Main Unit of Type 2006.

A block diagram of Type 2006 is shown in Fig. 1.2. The input stage of the Heterodyne Voltmeter consists of an untuned mixer stage containing a PNP-transistor in "grounded emitter" configuration. The signal from a variable oscillator is supplied to the emitter while the collector circuit is tuned to the IF-frequency, which has been chosen to be 11.3 MHz.

By careful amplitude stabilization of the variable oscillator the conversion transconductance of the mixer is kept independent of frequency. To furthermore ensure frequency stability the oscillator is temperature compensated and different oscillator components are used for different frequency ranges. Following the mixer stage is a crystal filter with a bandwidth of 2.5 kHz. This filter is shorted when the BANDWIDTH switch is set to "Wide".

From the filter the IF-signal is fed into a 3-stage IF-amplifier via an emitter follower and a stepped attenuator stage. The IF-amplifier itself is stabilized by means of current feedback. The first stage of IF-amplification contains a special diode-attenuator which is operated from the sensitivity controls marked CARRIER ADJ. and LS AND MOD. ADJ., on the instrument front panel, respectively. The diode voltage divider avoids different damping levels influencing the tuned stage. Actually the potentiometers marked CARRIER ADJ. and LS AND MOD. ADJ. only determine the working points of the diodes. Having passed the first two stages in the IF-amplifier the signal is

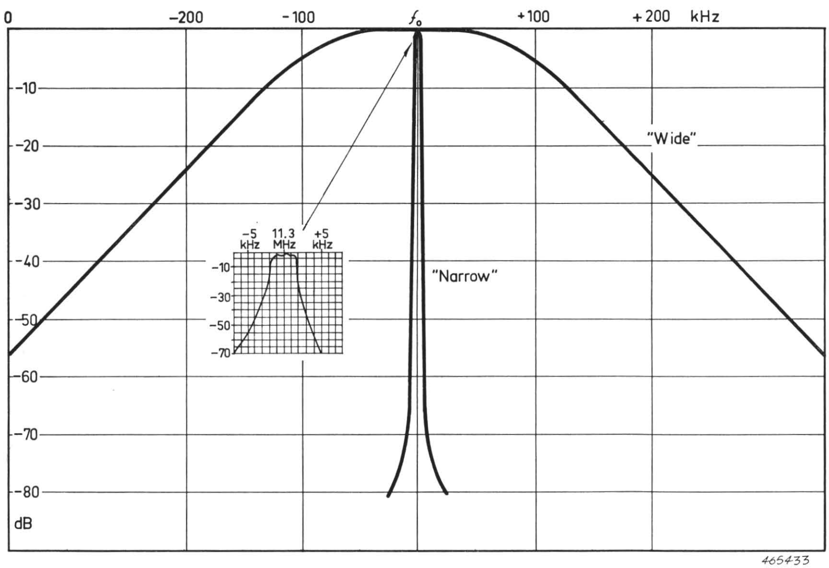

Fig. 1.3. Bandwidth of the Heterodyne Voltmeter in BANDWIDTH switch position "Wide" and "Narrow".

"split" so that it is fed both to a Foster-Seeley type FM-detector, and to the third IF-stage for further amplification after which it is applied to a conventional AM-detector and peak indicating RF-meter.
The demodulated signal is then selected for further amplification in a low frequency amplifier. Finally the signal is fed to a rectifier for meter detection, or to a loudspeaker for aural detection. The absolute sensitivity of the Heterodyne Voltmeter Type 2006 can be checked by means of a built-in reference oscillator which supplies a highly stabilized voltage to the terminal marked REF. VOLTAGE on the front plate. Possible sensitivity adjustment

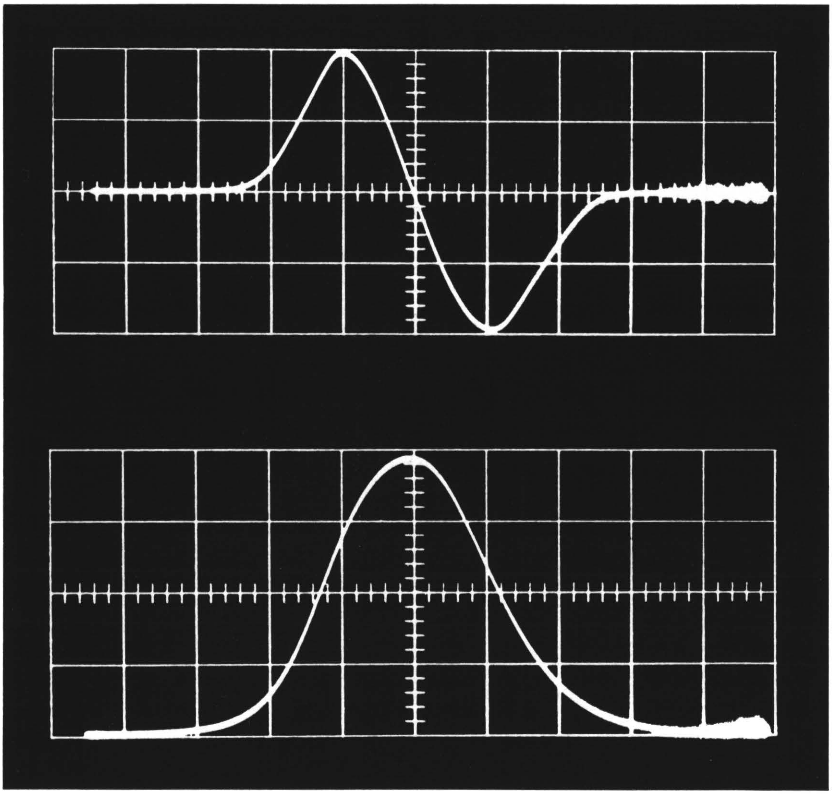

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Fig. 1.4. FM-Discriminator and IF-Frequency Response (Wide) Characteristics
Oscilloscope setting:
x: 130 kHz/cm.
y: Discriminator curve: 100 mV/cm.
IF-Frequency Response: 10 mV/cm.

can be made as described under "Operation", p. 14. To allow the reference voltage to be independent of whether the oscillator is loaded by 50 Ω or by the high impedance of the Input Probe, the output impedance at the REF. VOLTAGE terminal is less than 1 Ω. The reference voltage will change by less than 2 % for a 0—50° C temperature variation.
An overall accuracy of the RF-meter of $\pm$ 0.5 dB is to be expected in ranges 1, 2, 3, and 4. Better than $\pm$ 1 dB in ranges 5 and 6 and better than $\pm$ 1.5 dB in range 7. At the higher frequencies the attenuator must be employed if capacitive loading is not acceptable.
However, this accuracy is achieved only for voltages well above the level of

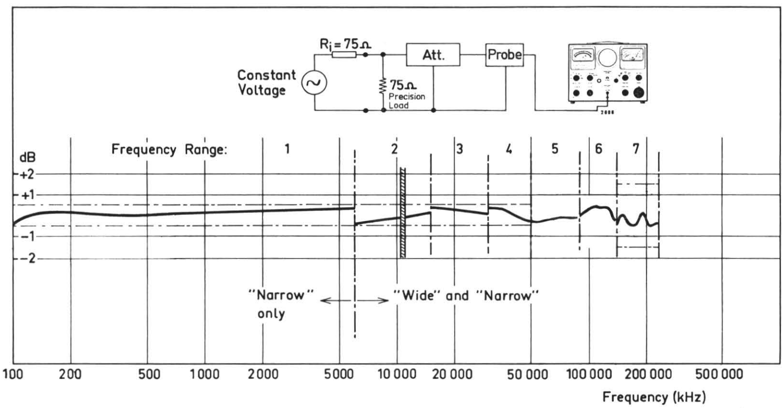

Fig. 1.5. Sensitivity of the Heterodyne Voltmeter Type 2006.

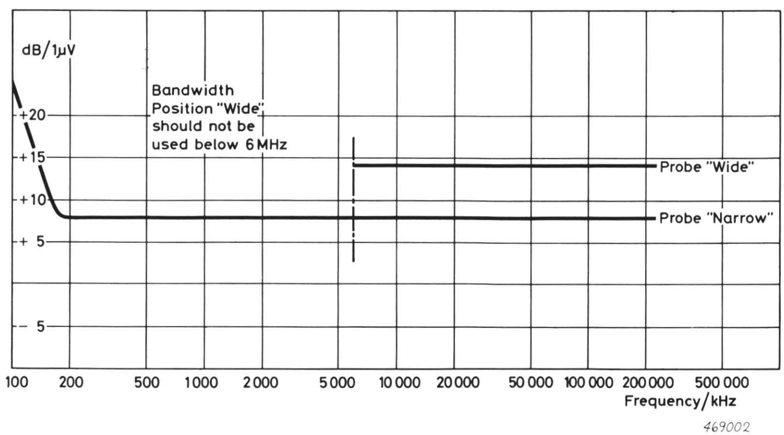

Fig. 1.6. Inherent Noise of the Heterodyne Voltmeter Type 2006 (50 μV range)

inherent noise in the Heterodyne Voltmeter. In Fig. 1.5 is shown typical curves of sensitivity and Fig. 1.6 shows the inherent noise for the Heterodyne Voltmeter.

Input voltages around the noise level can be measured by comparison with a reliable standard signal generator.

A limitation of the measuring range will occur at the lower frequencies of the input signal for which the corresponding oscillator frequency approaches the IF and tends to block the IF-amplifier. Consequently, the higher the frequency is, the lower the level of the measurable input voltage. As indicated in Fig. 1.5 this limitation is small compared with the frequency range of the instrument.

Measuring at the IF-Frequency, 11.3 MHz.

The sensitivity of the Heterodyne Voltmeter Type 2006 will change at frequencies just around 11.3 MHz, which is the center frequency of the IF-amplifier. Depending on the setting of the BANDWIDTH switch it will increase (Wide) or decrease (Narrow) as shown in Fig. 1.7a. At f = 11.3 MHz it is thus only possible to make measurements if the FREQUENCY RANGE switch is set out of position (between 7 and 1). The oscillator is then disconnected, and the frequency response of the Heterodyne Voltmeter will be as shown in Fig. 1.7b when the BANDWIDTH switch is set in position "Wide". As the sensitivity under these circumstances depends on the current amplification factor of the Mixer transistor, the Heterodyne Voltmeter must in this case be calibrated specially with a known signal voltage at 10.7 MHz.

Rear Connection Jack.

On the rear plate is a 6-pinned jack to which the following internal connections are made: Fig. 1.8).

External Battery.

The built-in battery is connected directly to the jack, pins 1 and 5. Therefore *the internal battery should be removed if an external battery is connected to teh terminals.* The external battery must have the positive terminal connected to pin 5.

LF-Output.

The output for external loudspeaker connected directly across the LF-output should not be loaded with more than 60 Ω, and in this case the frequency response is $\pm$ 1 dB from 20 Hz to 20ooo Hz. The LF output is found at pins 2 and 4.

Meter Circuit.

The terminals 3 and 4 can be used for connecting an external meter or amplifier. Pin 4 is connected to the chassis ("ground") and pin 3 is connected to the meter circuit in series with a 63 kΩ resistance.

The Power Supply.

The Heterodyne Voltmeter Type 2006 is designed for battery-operation. The battery is contained in the instrument and is of the nickel-cadmium storage

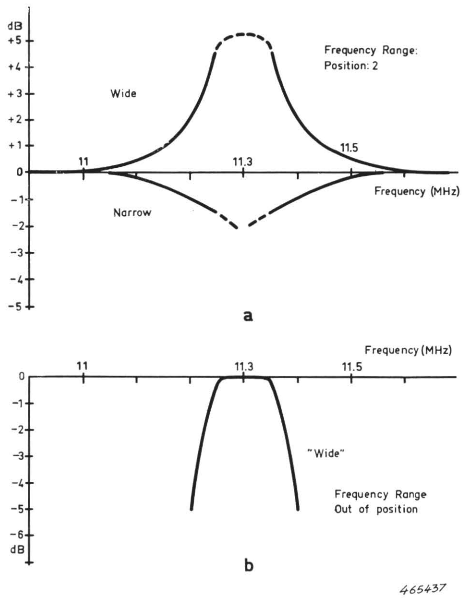

Fig. 1.7. Sensitivity of the Heterodyne Voltmeter Type 2006 (typical curves) around the IF-Frequency

a. BANDWIDTH switch in position "Wide" and "Narrow" respectively. FREQUENCY RANGE switch in position 2.

b. BANDWIDTH switch in position "Wide". FREQUENCY RANGE switch out of position.

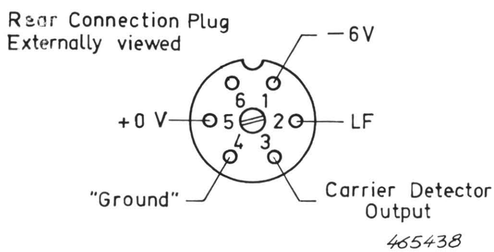

Fig. 1.8. Rear Connection Plug.

Pin 1: Battery voltage negative pole. A 6 volts external battery can be connected here.
Pin 2: Output for external loudspeaker.
Pin 3: An external meter can be connected here.
Pin 4: "Ground" for loudspeaker and meter circuit.
Pin 5: Battery. Positive pole. Connected to chassis.

type. It can be re-charged from a charging unit which is also contained in the instrument.
However, the instrument can also be driven from power lines carrying 100 — 115 — 127 — 150 — 220 — 240 volts AC, 50—400 Hz. Power consumption is about 15 watt. Adjustment for the various mains voltage is carried out at the back plate of the instrument cover. A disc indicates to which mains voltage the instrument is adjusted. The instrument is protected by a fuse which is inserted in the primary side of the power transformer. The fuse can be replaced from the back of the apparatus
The battery has a charge of 3.5 Ampere-hours which corresponds to 8 hours of continuous operation of the unit. The power supply for the transistors is stabilized and the internal impedance is only a fraction of an ohm. A transistorized DC converter and voltage-doubling circuit is used to obtain the power mentioned above. The converter frequency is approximately 20 kHz.
It has been found convenient to give some sort of easy, visual indication of whether the instrument is switched for battery or mains voltage operation so that an unnecessary use of the battery is avoided. This is made by means of a neon-lamp. When the instrument is operated from the battery the light comes on at certain regular intervals, while during mains voltage operation the light is continuous. When recharging, only the meter lights are on.
When it is desired to re-charge the battery the instrument is connected to the mains voltage and the POWER SWITCH set to position "Charge" (or "Line").

2. Control Knobs and Terminals

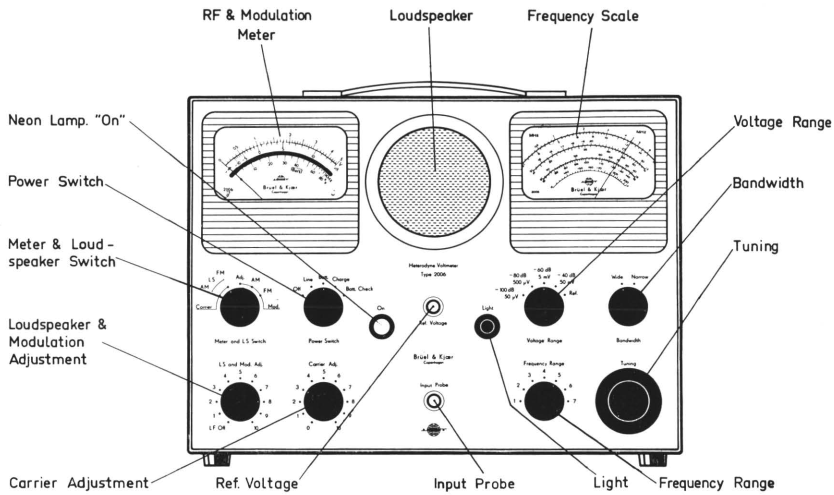

Fig. 2.1. Control Knobs and Terminals of the Heterodyne Voltmeter Type 2006.

METER AND LS SWITCH: This Switch is a function selector switch. It has five positions. An AM (amplitude modulation) and an FM (frequency modulation) position for carrier frequency measurements. One position for adjustment ("Adj.") at modulation measurements, and finally an AM and an FM position for measuring AM and FM modulation respectively. The loudspeaker (LS) is only switched on when the selector switch is in one of the two "Carrier" positions.

LS AND MOD. ADJ.: Loudspeaker and Modulation Adjustment Switch. When the METER AND LS SWITCH is in the "Carrier" positions the LS AND MOD. ADJ. knob controls the volume of the loudspeaker. With the METER AND LS SWITCH in the "Adj." position

the modulation meter is calibrated by means of the LS AND MOD. ADJ.
If the LS AND MOD. ADJ. is turned fully anti-clockwise the low frequency amplifier is switched off.

POWER SWITCH: This switch has five positions:

"Off": The instrument is disconnected.

"Line": The instrument is powered from the mains. According to the mains voltage the proper voltage must be selected by the switch-fuse combination situated at the rear of the instrument. During the use of the instrument the built-in battery is recharged automatically.

"Batt.": In this position of the POWER SWITCH the instrument is supplied from the battery.

"Charge": In this position of the switch the instrument itself is disconnected but the battery is recharged. For instance the instrument can be left in this position over night and by the next morning the battery will be fully charged and the instrument is ready for a full days work "in the field" .(Recharge time: 16 hours approx.).

"Batt. Check": With the POWER SWITCH in this position the meter pointer should deflect to within the green area of the scale. If not, recharge the battery.

CARRIER ADJ.: This is a potentiometer used for calibrating the instrument as described under "Operation", p. 14.

ON: A neon-lamp which gives a visual indication of whether the instrument is switched to battery or mains voltage operation. When operated from the battery the light comes on at certain regular intervals, while during mains voltage operation the light is continuous.

PROBE INPUT: BNC connector for connection of input probe.

REF. VOLTAGE: BNC connector for the reference voltage. Stabilized to better than 2 % from 0—50 °C. Output impedance less than 1 Ω.

LIGHT: A push-button for scale-illumination when the instrument is supplied from the battery.

VOLTAGE RANGE: Attenuator selecting the full scale meter pointer deflection to 50 μV, 500 μV, 5 mV or 50 mV. With the 60 dB Attenuator the voltage ranges will be: 50 mV, 500 mV, 5 V and 50 V. If the amplitude of the input signal is unknown start from the 50 V full deflection and then increase the sensitivity until a suitable deflection is obtained on the meter. The position "Ref." of the VOLTAGE RANGE switch is for calibration of the instrument.

FREQUENCY RANGE: The figures engraved around this knob refer to the different frequency meter scales and cover the following frequency ranges:

1\. 0.1 MHz— 6.0 MHz
1\. 5.6 MHz— 15.0 MHz
3\. 14.5 MHz— 30 MHz
4\. 29 MHz— 52 MHz
5\. 48 MHz— 86 MHz
6\. 82 MHz—140 MHz
7\. 132 MHz—230 MHz

BANDWIDTH:

"Wide": In the position "Wide" the 3 dB bandwidth is ± 100 kHz. *This bandwidth should only be used for measurements at frequencies higher than 6 MHz.*

"Narrow": When set to this position a crystal filter with a bandwidth of ± 1.25 kHz (3 dB) is switched in.

TUNING: This knob is used for frequency tuning and the frequency is indicated by the pointer of the frequency meter. The scale in use is indicated by the FREQUENCY RANGE switch.

3. Operation

General.

Check that the instrument is adjusted to the appropriate power supply voltage or if an external battery is used that the battery voltage is correct. It should be 6.3 volts ± 0.5 volt. If the instrument is not adjusted to the appropriate mains voltage the necessary adjustment can be carried out by means of a screwdriver operated switch at the rear of the apparatus. The battery voltage is checked by switching the POWER SWITCH to position "Batt. Check", whereby the instrument meter pointer should deflect to within the green area on the scale.

When the POWER SWITCH is set to one of its positions "Line" or "Batt." the neon lamp (ON) will come on. In the position "Line" it will be on continuously but in the "Batt." position it will come on with certain regular intervals. Also, when the switch is in position "Line" the instrument scales will automatically be illuminated. In position "Batt.", on the other hand, it is necessary to press the push-button marked LIGHT on the front panel if scale illumination is desired.

Reference Adjustments.

Before the measurements are started the reference level should be adjusted as follows:

1. Set POWER SWITCH to "Line" or "Batt." as described above.
2. Set FREQUENCY RANGE to position "4".
3. Set VOLTAGE RANGE to "Ref".
4. Set BANDWIDTH to "Narrow" or "Wide" as desired.
5. Set METER AND LS SWITCH to "Carrier" (AM or FM).
6. Connect the Input Probe to the REF. VOLTAGE terminal. The center pin of the Probe should be unscrewed and replaced by the special BNC-connector fitting the REF. VOLTAGE socket.
7. Set the CARRIER ADJ. knob to around position 6.
8. Adjust the TUNING knob to a frequency around 30 MHz for maximum meter pointer deflection. (Marked with a red area on the frequency scale).
9. Adjust the CARRIER ADJ. knob until the meter pointer deflects to "2.5" (mV) on the upper meter scale. This point is marked by a red line on the scale, indicating correct adjustment.
10. Disconnect the Input Probe from the REF. VOLTAGE socket. The instru-

ment is now adjusted to the correct reference, and RF measurements can be carried out.

RF Voltage Measurements.

1. Set the VOLTAGE RANGE switch to its "50 mV" position.
   Note: If the RF Voltage to be measured is considered higher than 50 mV the attenuator should be applied to the Input Probe.
2. Select BANDWIDTH, Wide or Narrow. In the FREQUENCY RANGE I (o.1—6 MHz) use only "Narrow" for precise measurements.
3. Set the FREQUENCY RANGE switch to the desired range, and with the TUNING knob tune to the signal frequency. If no signal, then;
4. Turn the VOLTAGE RANGE switch anticlockwise until a suitable deflection is obtained on the RF-meter.
5. Fine adjust the frequency TUNING knob for maximum deflection on the meter. The LS AND MOD. ADJ. knob should be turned up when tuning is carried out to aid the identification of the signal. The RF voltage can now be read off the meter in conjunction with the VOLTAGE RANGE switch.

Due to the untuned input circuit, a signal applied to the Heterodyne Voltmeter will give a deflection on the meter for two different settings on the frequency scale. The freqeuncy difference between the two settings will be

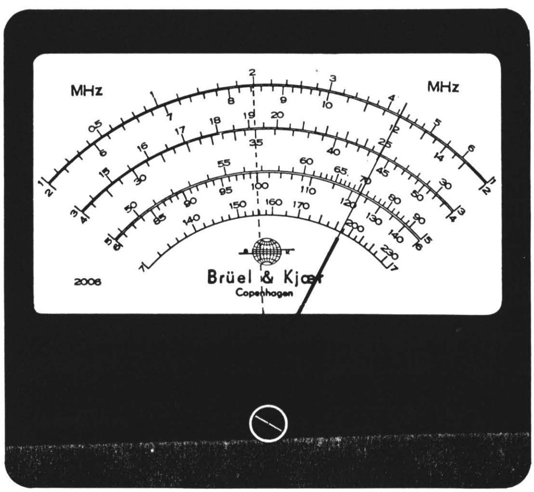

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Fig. 3.1. Determination of an unknown frequency.
Equal RF-voltage readings at 122.6 MHz and 100 MHz
e.g. Signal frequency: 122.6 MHz.

twice the IF, i.e. 22.6 MHz. This condition is valid for signals with frequencies between 22.6 MHz and 230 MHz. The frequency scale of the instrument is calibrated such as to be correct at the higher mode, i.e. the higher of the two readings on the frequency scale is the correct one. For the measurement or analysis of unknown frequencies the operation procedure should thus be continued as follows:

6. Note the reading of the meter, when tuned in.
7. Adjust the frequency scale pointer to a frequency which is 22.6 MHz above (or below) the frequency first found. Tune for maximum deflection and note this value.

This is to ensure that it is the right signal which is found. The two readings must be of equal value and the distance between them 22.6 MHz. As mentioned before it is now the higher mode which is the correct one (see Fig. 3.1).
Note: The loudspeaker may often be of great help for the proper identification of the signals obtained under items 6 and 7.

Modulation Measurements.
When it is desired to measure the degree of modulation of a signal the carrier signal should be tuned in as described above.
Then proceed:

1. Set the METER AND LS SWITCH to position "Adj.".
2. Adjust the LS AND MOD. ADJ. knob for full scale deflection on the meter. (If full scale deflection cannot be obtained by means of the LS AND MOD. ADJ. knob, turn the VOLTAGE RANGE switch to a more sensitive range).
3. Set the METER AND LS SWITCH to AM or FM depending upon the type of modulation to be measured.

The reading on the meter is now, in the case of AM signals, directly the percentage of amplitude modulation, while in the case of FM-signals it is the frequency swing in kHz.
When measuring AM modulation at modulation frequencies higher than 1 kHz the BANDWIDTH switch should be set to "Wide". When measuring FM modulation the BANDWIDTH switch should always be set to "Wide".

4. Applications

General.

The Heterodyne Voltmeter Type 2006 has been designed for selective measurements with a high degree of accuracy and sensitivity. This makes it a useful instrument in numerous applications.

Furthermore the Heterodyne Voltmeter Type 2006 under special circumstances can be used as a frequency analyzer and, when fitted with a calibrated antenna (not manufactured by Brüel & Kjær) it can be used as a field strength meter as well.

The latter two applications are a little more involved and must be carried out with great care, as the input circuit of the 2006 is untuned, and therefore sensitive to image frequency signals, signals of intermediate frequency, harmonics of the intermediate frequency generated by the detector, and also harmonics of the incoming signal generated in the converter transistor.

Because the input is untuned, however, the mixer circuit could be designed to have a flat frequency response, making it possible to calibrate the instrument at one single frequency. With a tuned input, which will always have a different "Q" value at different frequencies, voltage calibration would have been required at every single frequency, and thus have made voltage measurements much more difficult and time consuming.

Antenna Distribution System.

Antenna Distribution Systems for receiving AM, FM as well as TV signals are very easily checked by means of the Heterodyne Voltmeter Type 2006.

To ensure that the quality of the system is good enough it must meet certain demands. Among others can be mentioned:

1. The system must give an adequate and, within certain limits, constant signal.
2. The cross talk from one connection plug to another must be high.
3. It must have a response to the incoming signal which satisfies the demand of quality.
4. It must shield from local fields of noise.

Re 1. Fig. 4.1 shows the Heterodyne Voltmeter used to check a signal voltage. The antenna is removed and a signal generator is connected to the input of the antenna amplifier. The signal generator is now tuned to a frequency in the range of the antenna system, whereby the signal output voltage at every connection plug of the system can very easily be

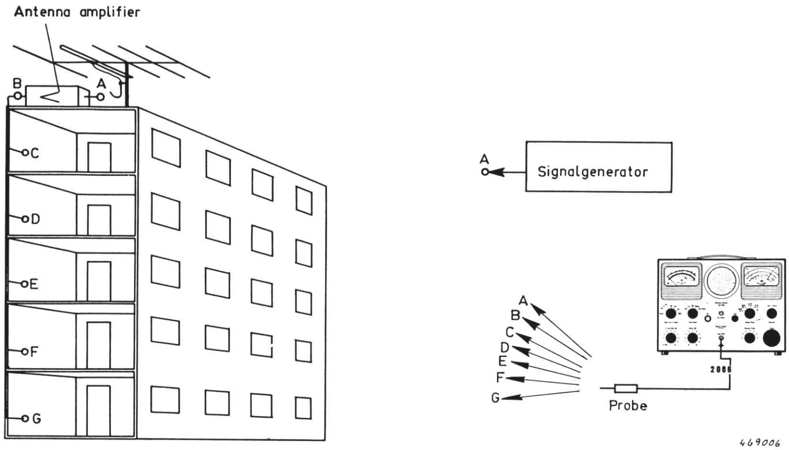


Fig. 4.1. Measurements on Antenna Distribution Systems.

checked. To determine the amplification of the amplifier, the signal voltage can be measured first at the input and then at the output of the amplifier.

The output of the antenna system must be loaded by its matching impedance. This is achieved most easily by connecting the probe in parallel to the receiver connected to the system, assuming that the receiver matches the system. Otherwise the measurement will not be correct due to loss and standing waves in the cables.

Re 2. The cross talk can be measured when the signal generator is connected to one connection plug and the 2006 to another.

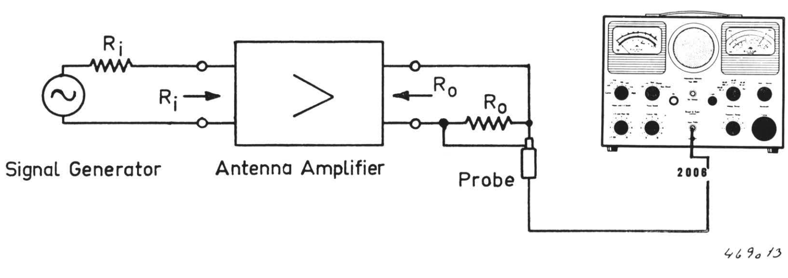


Fig. 4.2. Frequency Response of antenna amplifier.

From this measurement cross talk attenuation is found:

$$A = -20 \log \frac{\text{signal voltage}}{\text{cross talk voltage}} \text{ dB}$$

Re 3. The intermodulation of the Amplifier in an Antenna distribution system can be measured with a set-up as shown in Fig. 4.3. Input and output must be loaded as prescribed by the supplier of the amplifier. The level of the input signal should not exceed that which corresponds to maximum intermodulation-free output voltage. Using the probe the output voltage from the amplifier is measured with the Heterodyne Voltmeter Type 2006 across a load corresponding to the input impedance of the transmission lines. Maximum output voltage is the maximum voltage that the amplifier can deliver when the intermodulation between two signals of different frequencies inside the pass band should not exceed 1 percent The measurement is carried out at frequencies where overloading is most probable. Attention should also be paid to the distortion in the 2006 (see specification) which under extreme conditions could influence measurements. An input voltage as low as possible wil reduce the distortion caused by inter- and cross modulation in the input of the 2006.

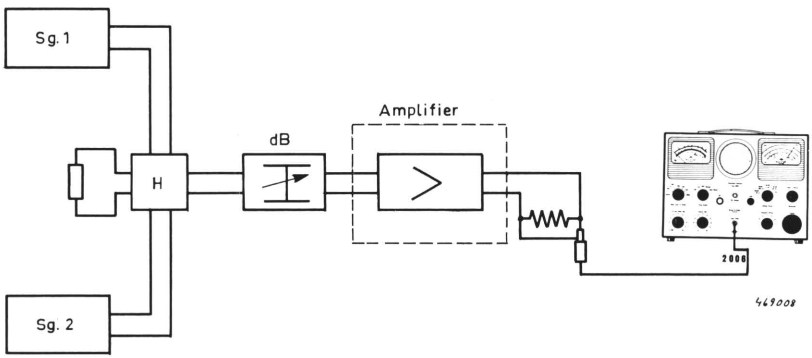


Fig. 4.3. Set-up for measuring intermodulation in antenna amplifier.

In Fig. 4.3 the two signal generators Sg 1 and Sg 2 have their outputs connected in parallel via a hybrid transformer (H) and an attenuating network (dB) to the antenna amplifier. The Heterodyne Voltmeter is connected to the output of the amplifier as described above.

Sg 1 and Sg 2 are tuned to two frequencies which are both inside the passband of the amplifier but such a distance apart that the 2006 can separate the two signals (see Fig. 2.3). The BANDWIDTH should be set to "Narrow" and a Microphone Amplifier should be connected to the 2006 to increase the accuracy of the measurement (see Fig. 4.15). The Attenuator (dB) is adjusted so that crossmodulation does not occur. Sg 1 and Sg 2 are set to the same peak voltage by means of the 2006. Sg 1 is set to square wave modulation while Sg 2 is unmodulated.

The Heterodyne Voltmeter Type 2006 is then tuned to the signal of the unmodulated signal generator Sg 2 and switched to modulation measurements (see section 4: Operation).

The amplitude of the total signal is increased (dB) until 3 % modulation is measured arising from the crossmodulation with the signal from Sg 1.

Re 4. Sensitivity to noise through the mains can be measured with a set-up as shown in Fig. 4.4.

The Heterodyne Voltmeter Type 2006 is connected alternately to the measuring points A and B. The set-up shown in Fig. 4.4 is used to check that a noise voltage from the mains is attenuated 40 dB at the output

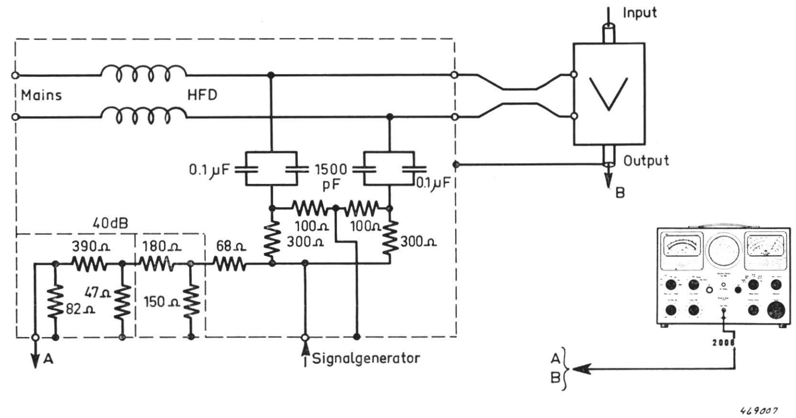


Fig. 4.4. Measurement of sensitivity to noise through the mains.

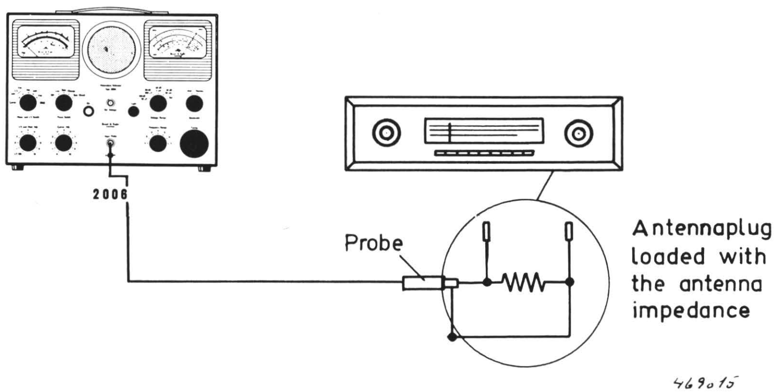


Fig. 4.5. Set-up for measuring oscillator voltage on the antenna terminals of a radio receiver.

of the amplifier. If the voltage B is smaller than the voltage A this requirement is fulfilled.

In Fig. 4.5 is shown a set-up for measuring the oscillator voltage on the antenna terminals.

Automatic Recording of RF Voltages.

At the rear connection plug pins 3 and 4 (4 is grounded) the DC voltage to

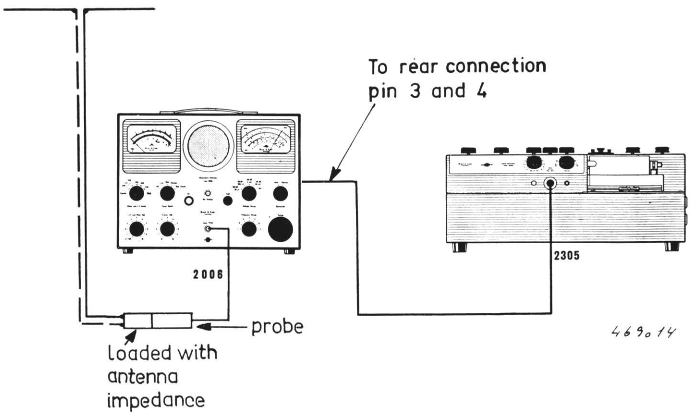


Fig. 4.6. Relative fieldstrength as a function of time. Set-up.

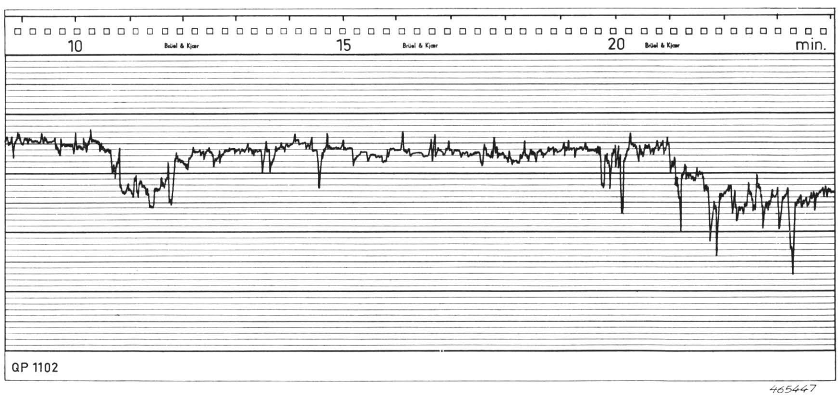


Fig. 4.7. Recording of relative fieldstrength as a function of time. Measured indoor with a Room antenna.
f = 97 MHz
Paper Speed: 0.3 mm/sec.
Writing Speed: 250 mm/sec.
Low. Lim. Freq.: 50 Hz
Rectifier Res.: DC
Potentiometer: 25 dB

the meter of the 2006 is available (in series with a 63 kΩ resistance). With the METER AND LS SWITCH in "Carrier" positions it is therefore possible to have the RF voltage recorded when the meter output mentioned above is connected for instance to the Level Recorder Type 2305. As the input resistance of the Level Recorder is about 18 kΩ in the DC position of the RECTIFIER RESPONSE switch, and the output of the 2006 for full deflection of the meter pointer is about 3 volts in series with 63 kΩ it means that there will be about 700 mV available at the Level Recorder input.

In Fig. 4.6 is shown a set-up for measurement of the relative field strength as a function of time. The corresponding recording is shown in Fig. 4.7. A 25 dB range potentiometer was used on the level recorder as the relatively small dynamic range of the detector does not allow greater variations than

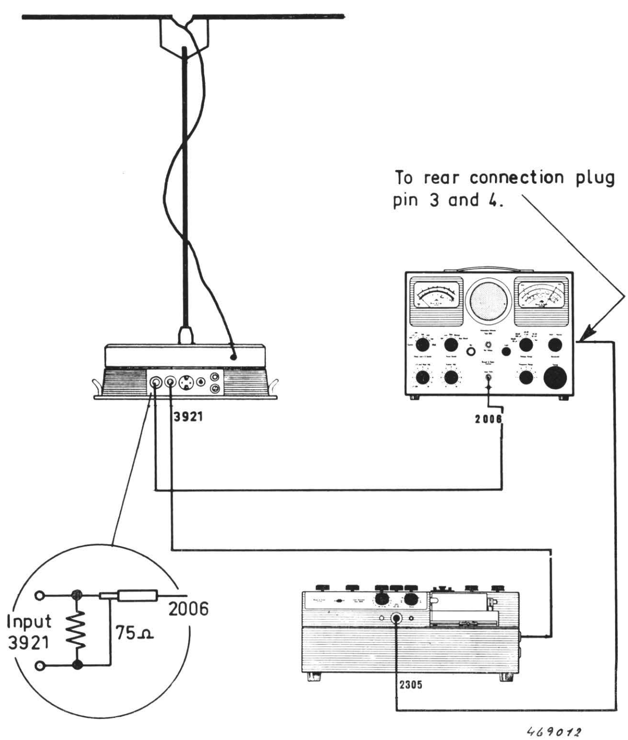


Fig. 4.8. Set-up for measuring directional characteristics of antenna.

25 dB to be recorded. To have the fieldstrength in V/m the antenna must be calibrated.

Directional Characteristics of Antennas.

With a set-up as shown in Fig. 4.8 the directional characteristics of antennas can be measured. For this type of measurement polar diagram charts QP 5102 should be used on the Level Recorder. The antenna is mounted on the turntable Type 3921, which is synchronized with the Recorder (see the instruction manual for the Level Recorder). Fig. 4.9 shows the directional characteristic of a simple dipole. Here too the antenna must be calibrated if the fieldstrength is desired in V/m.

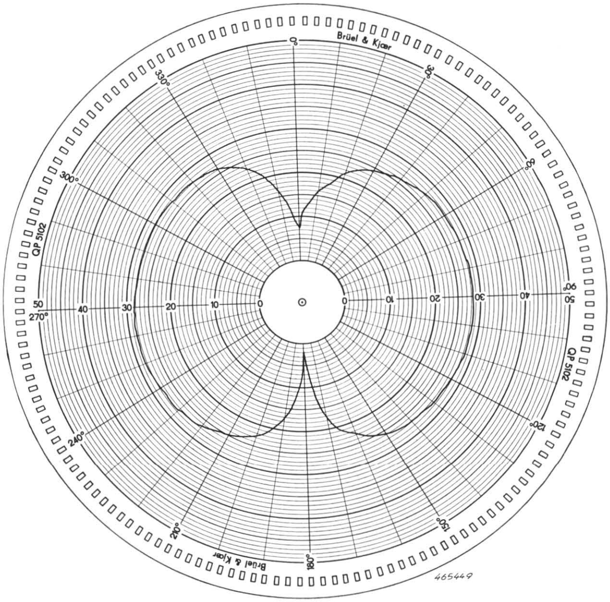


Fig. 4.9. Directional characteristic of antenna.

Control of Signal Generator.
Correction Curve.

The high accuracy of the Heterodyne Voltmeter makes it possible to use it to check the output voltage of a signal Generator as shown in Fig. 4.10.
However, it is very important that the matching impedance is correct and the signal Generator must be loaded with its matching impedance.

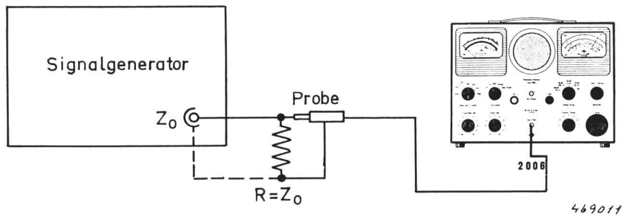


Fig. 4.10. Checking the output of a signal generator.

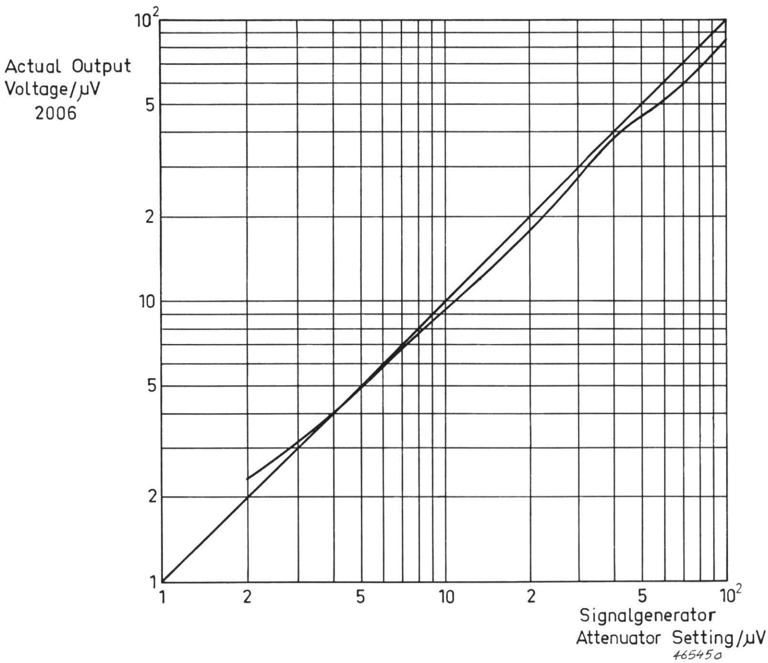
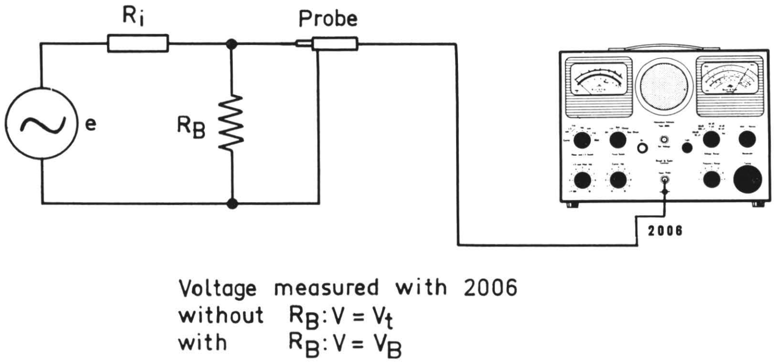


Fig. 4.11. Correction curve.

As can be seen from the passage below the output voltage of a Signal Generator depends on the load, and this must be considered when making a calibration curve. Fig. 4.11 shows a calibration curve made for a Signal Generator with a 75 Ω output impedance. It was measured with the 2006 using a 75 Ω termination, and the output voltage should thus agree with the attenuator setting if the attenuator had been exact over the whole range. **Note:** The Heterodyne Voltmeter Type 2006 is as mentioned before a selective voltmeter and therefore it will not give the same deflection as a diode voltmeter for the same signal if the signal is anything but a pure sinewave. This is because the diode voltmeter includes the harmonics of the signal.

Output Impedance.
If the output impedance of the signal generator is unknown it can be calculated in the following way (see Fig. 4.8).



469.76

Fig. 4.12. Determination of output impedance.

The unloaded voltage (V_t) can be measured with the Probe. However, at frequencies higher than about 150 MHz the Attenuator should be used due to the loading effect of the Probe input impedance. Connecting a load (R_B) across the output of the signal generator will change the reading on the 2006 to V_B. Now it is found that:

$$V_B = \frac{R_B}{R_i + R_B} \times V_t \text{ volts}$$

which leads to:

$$R_i = R_B \left(\frac{V_t}{V_B} - 1\right)$$

Nonlinear Distortion Conversion Scales

$$\text{Nonlinear distortion: } d = \frac{\sqrt{a_2^2 + a_3^2 + a_4^2 + \dots a_n^2}}{\sqrt{a_1^2 + a_2^2 + a_3^2 + \dots a_n^2}} \times 100\,\% = \frac{\sqrt{a_2^2 + a_3^2 + a_4^2 + \dots a_n^2}}{\text{RMS value of complete signal}} \times 100\,\%$$

The harmonic distortion d in percent for sine-waves can be calculated from the number of dB the individual harmonics lie below the r.m.s. value of the complete signal containing the fundamental and all harmonics.

Example: The harmonics of a signal are found to lie the following number of dB below the r.m.s. value of the complete signal.

2. harmonic $a_2 = -68$ dB
3. harmonic $a_3 = -62$ dB
4. harmonic $a_4 = -76$ dB

From scale A: the value X for the individual harmonics is found to,

2. harmonic $X_1 = 0.0016$
3. harmonic $X_2 = 0.0064$
4. harmonic $X_3 = 0.00025$

$\Sigma X = 0.00825$

From scale B it is now found that for $\Sigma X = 0.00825$ the distortion d in % will be,
$d = 0.09\,\%$

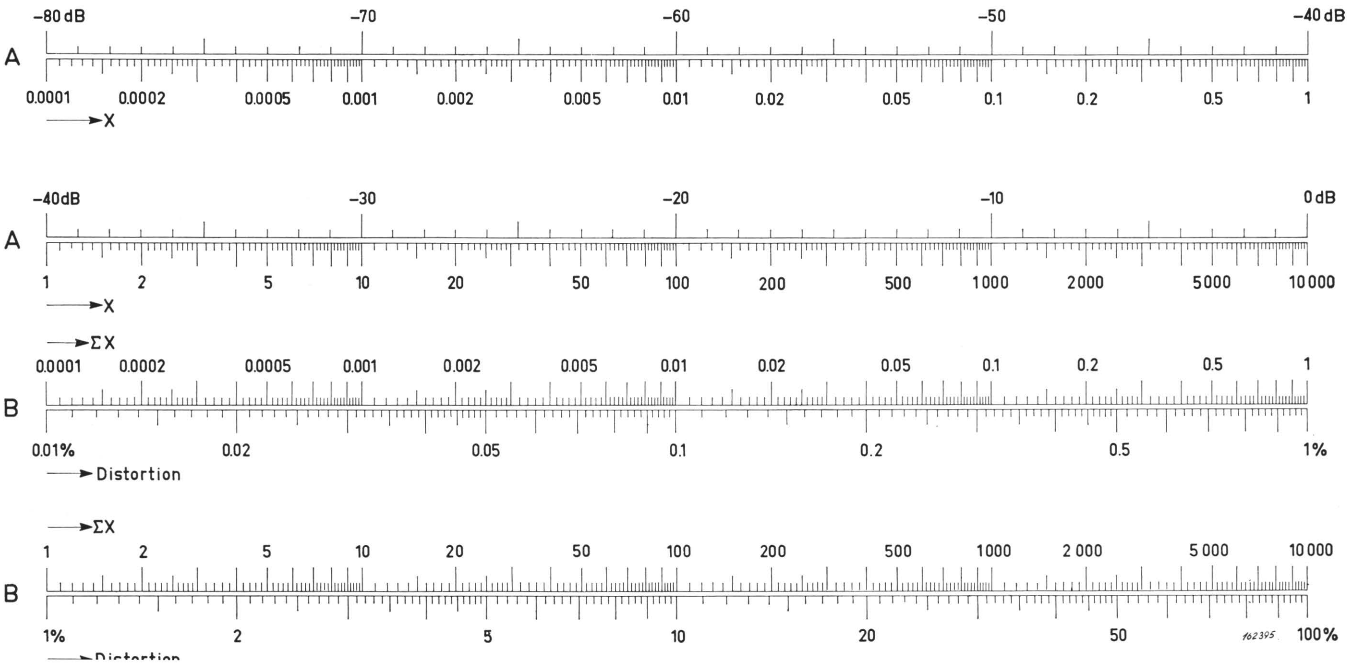


Fig. 4.13. Conversion scales for determinating the Distortion.

Distortion and Harmonics.
The selectivity of the 2006 makes it possible to measure the distortion of a signal. The amplitude of the fundamental frequency and the amplitudes of the harmonics are then measured separately with the 2006, and the distortion can be calculated from the conversion scales given in Fig. 4.13.
When measuring distortion at frequencies lower than 6 MHz the BANDWIDTH must be set to "Narrow" in order to make sure that the attenuation of the first harmonic is adequate.
Furthermore, it is important that the fundamental of the signal does not exceed 50 mV thus overloading the input transistor. Fig. 4.14 shows the harmonics of a 12 MHz signal.
As mentioned before, the distortion of the signal due to inter- and cross modulation in the input could influence the measurements of high input signals (see specifications).

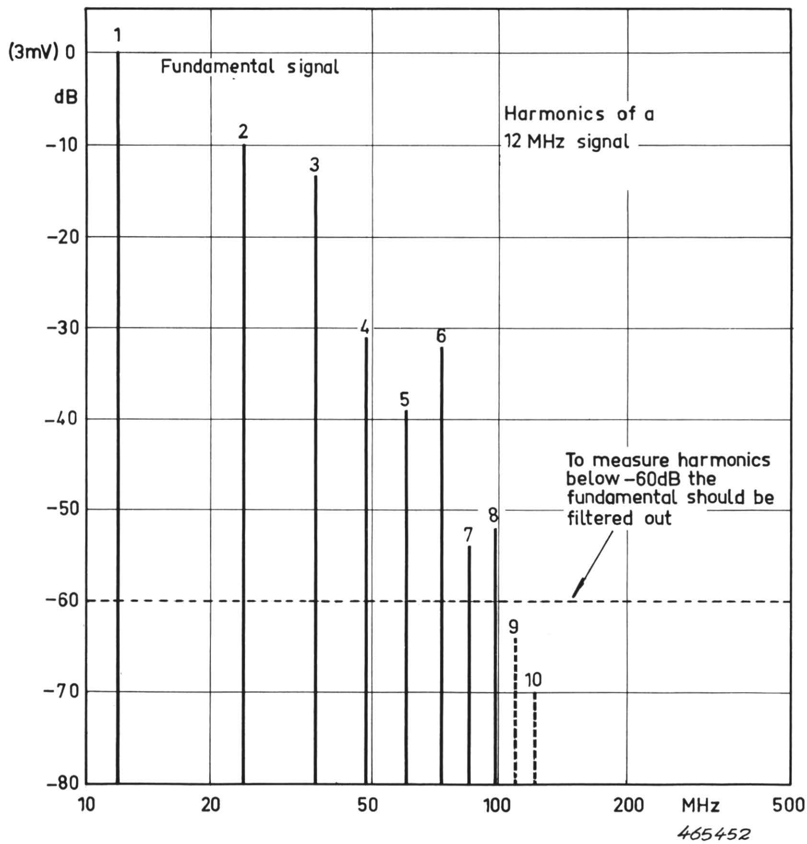


Fig. 4.14. Harmonics of a 12 MHz signal.

Modulation down to 3 % (kHz).

Fig. 4.15 shows how to measure modulations down to 3 %. As described in a previous section (3. Operation) the Heterodyne Voltmeter Type 2006 is calibrated for measuring modulation (AM or FM). If the degree of modulation is low the accuracy of the measurement can be improved by connecting a Microphone Amplifier Type 2603 to the rear connection plug (pin 2 and 4. 4 being ground).

The Microphone Amplifier is calibrated as described in the instruction book delivered with the instrument, and the knob setting should be:

INPUT SWITCH is set to "Input Potentiometer".

RANGE MULTIPLIER: 0 dB.

METER RANGE: 1 volt full deflection.

With a signal with a relatively high degree of modulation (30—40 % (kHz)) the INPUT POTENTIOMETER of the 2603 should be adjusted, so that the meter reading (in volts) at the 2603 corresponds to the meter reading of the 2006 (in %/kHz).

Turning the METER RANGE switch on the 2603 one step anticlockwive (100 mV full deflection) the degree of modulation can now be read from the meter of the 2603 directly. Full deflection corresponds to a modulation of 10 % (kHz).

If desired the sensitivity of the 2603 can be increased further. It should, however, not be increased by more than 10 dB (RANGE MULTIPLIER) as the noise of the amplifiers themselves will then influence the measurements.

Using the Audio Frequency Spectrometer Type 2112 instead of Type 2603 the noise can be reduced by measuring selectively.

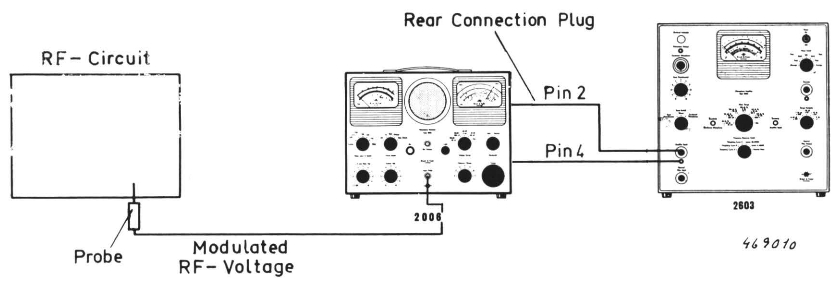


Fig. 4.15. Set-up for modulation measurements.

Automatic Recording of Modulation.

When desired the degree of modulation can be recorded automatically. Connect the RECORDER output of the Microphone Amplifier Type 2603 to the Level Recorder Type 2305 fitted with a linear potentiometer (ZR 0002: 10—110 mV).

The output voltage from the Heterodyne Voltmeter is taken from the rear connection plug via pins 2 and 4 (pin 4 is grounded).

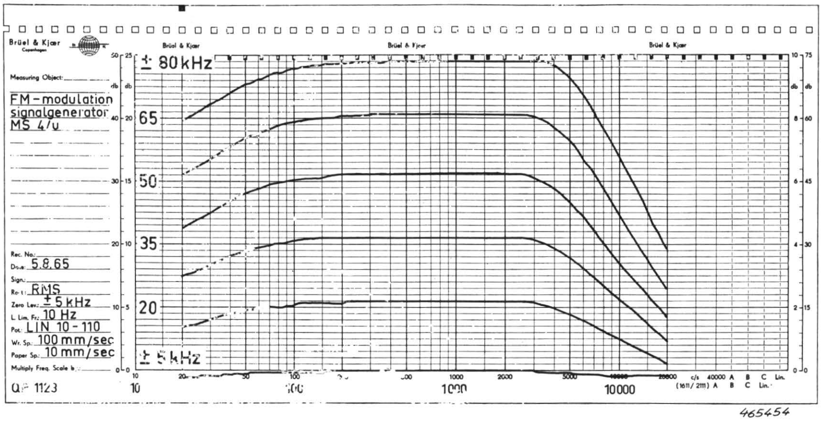


Fig. 4.16. Modulation frequency response of a signal generator.

The Microphone Amplifier Type 2603 is calibrated as described previously. Using the lined paper (QP 1102, QP 0102 or QP 0402) the Level Recorder can now be calibrated to indicate modulations from 5 to 80 % (kHz) with the METER RANGE switch in position "1 volt" full deflection. This is done with the INPUT ATTENUATOR SWITCH and the INPUT POTENTIOMETER of the Level Recorder.

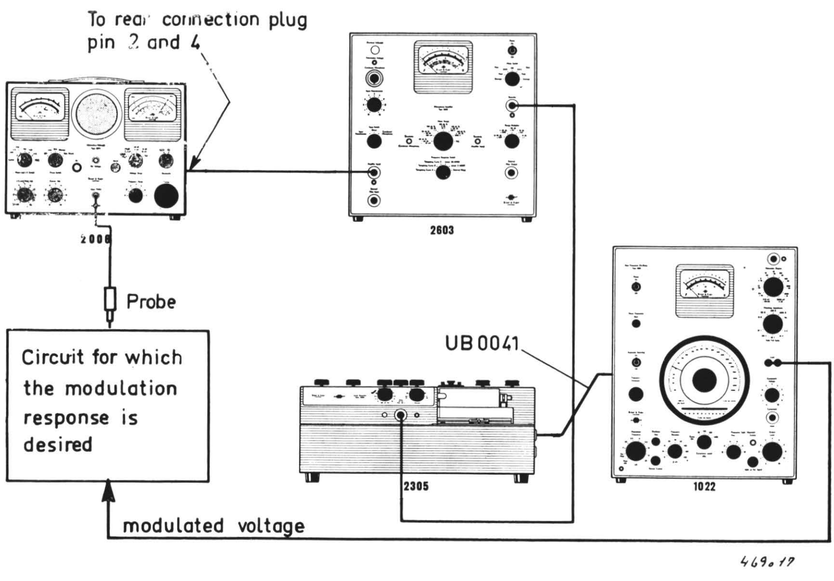


Fig. 4.17. Set-up for automatic recording of modulation .

It should be noted that for a high degree of modulation (70—80 % (kHz)) the Recorder will record a modulation degree 2—5 % (kHz) too low owing to the nonlinearity of the meter detector. This has been compensated for in the meter circuit of the Heterodyne Voltmeter so that the meter indicates the correct degree of modulation.

Fig. 4.16 shows the modulation frequency response of a signal generator modulated with a Beat Frequency Oscillator Type 1022. By connecting the BFO mechanically to the Level Recorder via a flexible shaft (UB 0041) and using frequency calibrated paper (QP 1123, QP 0123, QP 0423) it can be recorded automatically. Fig. 4.17 shows the measuring arrangement.

With regard to synchronizing the recording paper with the BFO reference should be made to the instruction book of the BFO Type 1022 or of the Level Recorder Type 2305.

Radiation from AM, FM and TV-Receivers.

The Heterodyne Voltmeter Type 2006 can also be used for measuring the radiation from broadcast radio and television receivers. If more than just a relative measurement is desired it is recommended, however, to follow the methods of measurement described in Publication 106 (1959) from the International Electrotechnical Commission (I.E.C.).

The Heterodyne Voltmeter Type 2006 Used as a Field-Strength Meter.

The Heterodyne Voltmeter Type 2006 may be used as a field-strength meter if it is calibrated with an antenna in a known electrical field and the frequency of the field to be measured is known. A frame antenna should be used for the lower frequencies and although it may also be used for the higher frequencies, i.e. for frequencies higher than about 50 MHz, it is just as convenient then to use a dipole-antenna. When calibrating the antenna should be placed about four metres above ground.

If calibration is not possible a dipole antenna made of two telescopic antennas mounted together can be used for the frequency range from about 50 MHz to 230 MHz, and should be adjusted to be $\frac{\lambda}{2}$ long (Fig. 4.18). Connect the antenna to the Heterodyne Voltmeter Type 2006 after having calibrated the instrument as described in section 3.

The connection should be made by connecting a resistor of 75 Ω across the end of the antenna cable (matched) and then measure the voltage across this resistor by means of the probe. Tune to the signal frequency with FREQUENCY RANGE switch and TUNING knob. Turn antenna to maximum response.

Find the correction factor, K(f), corresponding to the measuring frequency (Fig. 4.18). The electrical field-strength is then found from:

$$E = K(f) \times V \text{ volt/meter.}$$

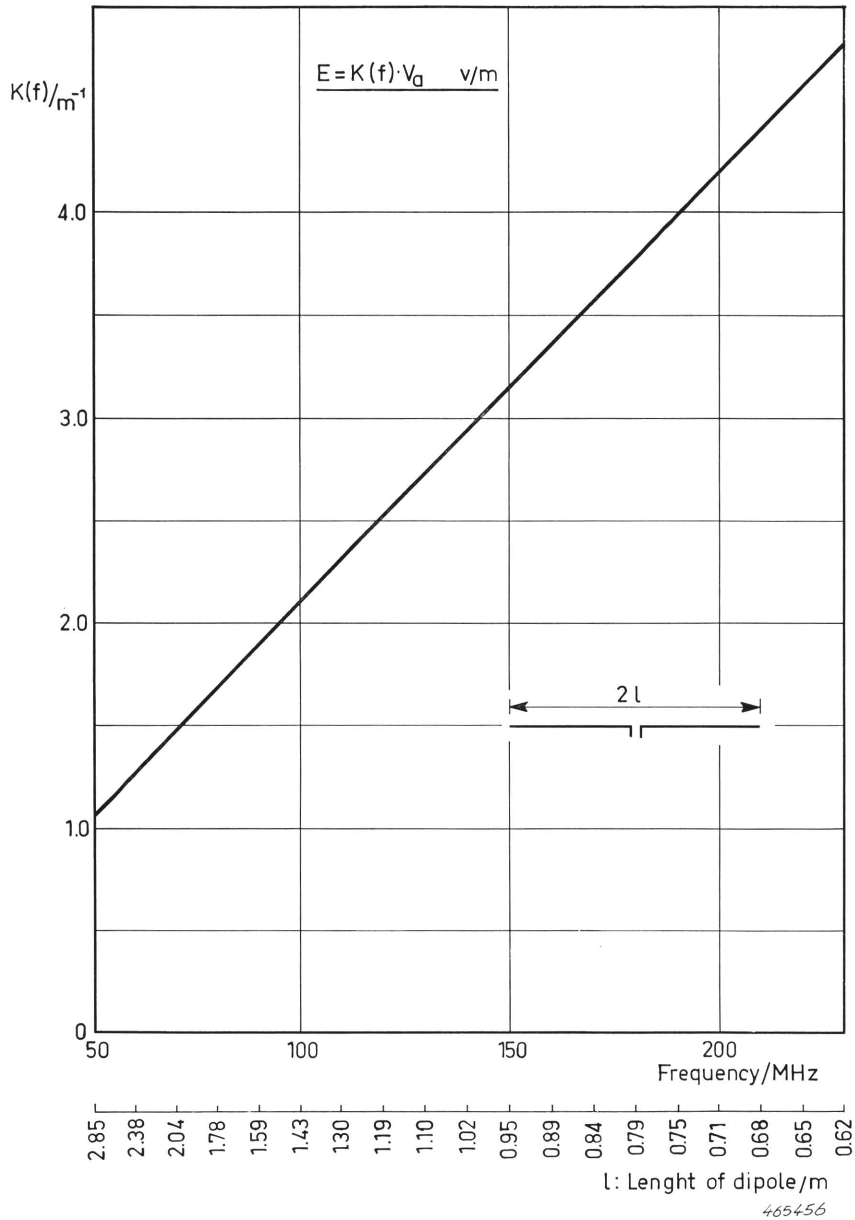


Fig. 4.18. Correction factor, K(f) for tuned $\frac{\lambda}{2}$ dipole.

Note: This measuring result is reached on the assumption that the electrical field is homogeneous and that the antenna is ideal. Therefore, an absolute accuracy higher than ± 3 dB should not be expected. However, as this accuracy will be sufficient in most cases, the method proves to be quick and simple as the 2006 needs only one calibration covering the whole frequency range. So when changing frequency only the antenna need to be adjusted.
A dipole antenna becomes inpractical for measurements at frequencies lower than about 50 MHz because of the length that would be required. For these lower frequencies therefore, it will be found to be much more convenient to construct a frame antenna and calibrate it in a known field. It should be mentioned here that should a higher accuracy than ± 3 dB be required then the method of calibrating the antenna in a known field, whether it be frame or dipole, should be adopted. Furthermore it should be noticed that the Heterodyne Voltmeter Type 2006 can only be used as a fieldstrength meter when the fieldstrength of the measured signal is strong compared to the other signals at the measuring position. This is to be sure that noise and false signals from image—and cross modulation do not interfere with the measurement.

5. Specifications

Frequency Range:	100 kHz—230 MHz in 7 ranges.
Voltmeter Range:	With probe and without input attenuator full meter pointer deflection for 50 μV, 500 μV, 5 mV and 50 mV. With 60 dB attenuator: 50 mV, 500 mV, 5 V and 50 V.
Input Impedance:	3 MΩ at 1 MHz 4 kΩ at 200 MHz With attenuator $>$ 10 kΩ all frequencies.
Input Capacitance:	6 pF. With attenuator 2 pF.
50 Termination:	Standing Wave Ratio $<$ 1 : 1.2.
Intermediate Frequency:	11.3 MHz.
Bandwidths:	"Wide", ±100 kHz (—3 dB points). *This bandwidth should only be used during measurements at frequencies higher than 6 MHz.* "Narrow", ± 1.25 kHz (—3 dB points).
Frequency Accuracy:	2 % ± 20 kHz.
Voltage Accuracy:	Ranges 1, 2, 3, and 4: ± 0.5 dB Ranges 5 and 6: ± 1.0 dB Range 7: ± 1.5 dB See Fig. 1.5. For ranges 6 and 7 use 60 dB attenuator to reduce input capacity if necessary.
Modulation Accuracy:	2 % of full scale deflection (1000 Hz). ±0.5 dB { 30 Hz — 8 kHz, 40 % AM Modulation; 30 Hz — 40 kHz, ±40 kHz FM Modulation
Meter:	Mirrored scales for accurate reading. Scale calibrated from —10 to 14 dB and 0—5 volts. Modulation scales: 0—80 % AM, 0—80 kHz FM. The meter can be illuminated when desired.

Audible Control:	Built-in loudspeaker to be used for both AM and FM.
Reference Voltage:	2.5 mV (±o.5 dB), 30 MHz from built-in oscillator. The reference voltage is stabilized to better than 2 % from 0—50° C. Better than 1 % for ± 10 % change in mains voltage.
Inherent Noise:	Less than 2.5 μV when using Probe and bandwidth "Narrow" (see Fig. 1.6).
Distortion:	Typical 1 % at 31.5 mV input o.1 % at 4.0 mV input
Power Supply:	Built-in storage battery and charging unit. The instrument can be operated from this batery or directly from the mains. Mains voltages of 100—115—127—150—200 or 240 volts AC, 50—400 Hz can be connected. The instrument can be operated from an external battery (6.3 volts) connected to the rear connection jack, pins 1 and 5 (5 is the + pole). Power consumption (AC) $<$ 15 W. Scale-illumination: 3 W approx., recharging unit 5 W approx. Charging time for totally discharged batteries is about 16 hours.
Dimensions:	
2006 A:	Height: 28 cm (11″), Width: 38 cm (15″), Depth: 15 cm (6″). The instrument can also be supplied in a mahogany case as Type 2006 B.
Weight:	2006 A: 9 kg (20 lbs). 2006 B: 12 kg (26 lbs).

Accessories Included:

1 Input Probe	ZC 0008
1 Attenuator (—60 dB)	ZF 0003
1 50 Ω termination	RZ 0006
2 Adaptors	JL 0029
1 Testpin	UA 0124
1 BNC connector	JP 0029
Fuses and Lamps.	

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