Causes of pickup from strong LF and HF sources in the recording studio, measuring methods and protective measures in connection with capacitor microphones *)

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Summary

In recording studios, strong HF fields and interference pulses from radio and television transmitters, radar stations, fluorescent tubes and thyristor-controlled light switching systems frequently give trouble. The field strength in the studio may be more or less evenly distributed or standing waves may be produced with field strength maxima and minima. In addition to metal screening, studio microphones usually incorporate such design features as HF chokes, by-pass capacitors, ferrite beads, static protective windings in the transformer or some special configuration of the amplifier components to fend off HF or prevent any HF which might have intruded from being demodulated and appearing in the form of background.

Apart from the microphone, the cable and cable couplings in use are of great significance in keeping HF away from the equipment in operation. This applies also to strong LF fields, which have an inductive effect on the cable and/or microphone. Moreover, multiple grounding (microphone, stand, cable coupling) can be the cause of large equalizing currents in the cable screening, even with very low potential differences, and these can likewise lead to interference with inadequately protected microphones.

Whereas the measurement of magnetic scatter is provided for in DIN 45 591, "Microphone Test Methods", there are othwerwise no specific test specifications for microphones for simulating, measuring and evaluating the types of interference described.

A number of examination methods are therefore presented and measured results obtained in connection with various types of microphone cables, connectors and circuits are discussed.

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Today's professional capacitor or condenser microphones have such excellendt acoustical and electrical properties that they rank as a strong link - indeed, frequently the strongest link - in the recording chain, even when used with state-of-the art recording techniques.

Nevertheless, interference may still be occasionally experienced in the course of everyday recording routines; examples encountered in our own experience have been compiled, and are examined in the following.

Interference can be caused by low-frequency alternating fields or currents, which exercise an inductive or galvanic effect on the microphone cable or the microphone itself; interference may also be brought about - and it is almost more frequently the case - by strong high-frequency fields and pulses which find their way into the cable, the cable connectors or straight into the microphone itself and thus become audible, either directly or after demodulation of the signal.

On the one hand it is proposed to discuss protective measures incorporated in the design of the microphone (i.e. by the manufacturer); on the other, such which might be considered by the user, and in which the microphone cable and the cable connectors play a leading role.

Whereas the measurement of stray magnetic fields is provided for in DIN 45 591, "Microphone Test Methods" /1/, there are otherwise no special test specifications for microphones which enable the types of interference indicated above to be stimulated, measured and evaluated in the laboratory.

In the Standard Specifications 3/5 of the ARD /2/, there are a number of provisions, some of which can be applied analogously to condenser microphones - analogously because, as far as cable-related interference is concerned, the microphone input and output are identical, in contrast to other items of studio equipment.

Power systems

Before a studio microphone is ready for operation, it must have an electrical power supply. We are not concerned here as to whether any necessary capsule polarizing voltage is derived direct from the supply source or from a built-in dc-dc converter, for it goes without saying that the onus is on the manufacturer to ensure that any high frequencies generated in such a converter cannot penetrate the modulation (audio) leads or cause interference in the microphone itself. This he can accomplish by means of shielding plates or chambers or with blocking capacitors or HF chokes.

The power supply which has found the widest acceptance in all parts of the world is the 48 V phantom powering system introduced by Neumann in 1966. Its dominance is explained by its numerous advantages in comparison with conventional A-B or audio-conductor powering systems. In the present context, special attention is drawn only to the very effectived electrical de-coupling of the modulation from the supply dc made possible by its high common mode rejection. It thus tolerates a hum voltage in the millivolt range imposed on the dc (A-B powering: uV range, see Fig. 1).

In order to achieve good balancing and ensure at the same time that no detrimental dc voltage appears across the audio conductors, the input resistors of the phantom powering circuit R 1 and R 2 (Fig. 1) must be precisely matched within 0.4% (their absolute value may be by ±20% from nominal).

Interference by LF cable currents

In order to obtain effective protection against high frequencies, it is important, as will be shown later, always to connect the cable shield with the appropriate pin of the cable connector at both ends of the cable and with the case. One side of the shield is frequently left open for fear of multiple loops resulting in hum.

It is possible, indeed, for a voltage drop to occur between the "grond" of the current supply and a chassis connection of the microphone suspension.

Such transients can then cause interference in a microphone if one pole of the capsule is connected to the case/chassis and the noise and capsule voltages are superimposed on each other, as is the case with the section of conductor marked with an asterisk in Fig. 2.

For this reason, some of our miniature microphones are provided with a 10-ohm resistor (R 13 in Fig. 2) in the ground lead, the purpose of this may not be immediately apparent when first considering the circuit diagram, as it is by-passed by a properly grounded plug connector.

However, if the path of the capsule (useful) current (shown dashed in Fig. 2) and that of the interference current (thick, continuous line) are followed, it becomes clear that most of the noise voltage is dropped across the 10-ohm protective resistor, and the microphone is rendered more resistant to interference by 30 dB (see Fig. 4, examples 5 and 6).

In addition, it is usual for a passive or active filter section (R, C in Fig. 1) behind the dc decoupling circuit in phantom powered microphones to ensure that no ac interference reaches the microphone amplifier, and that only a minute fraction of it is dropped across the input restistors.

Fig. 3 shows a test set-up used by us for determining the susceptibility of microphones to hum voltages in the cable shield. The resuls of measurements as per Figs. 2 and 3 are shown in Fig. 4, the ordinate showing which alternating voltage applied to the cable shield worsened the inherent unweighted signal-to-noise ratio of the microphone by 3 dB. This voltage level is just barely audible as "hum".

<u>Interference by induced LF fields</u>

The lines of strong magnetic fields generated, for instance, by transformers or power leads parallel with the microphone cables are liable to produce hum or noise in the microphone leads or in the kmicrophone itself. In order to avoid this as far as possible, the individual conductors of the cables are twisted together. Conductors in connectors, portable power units and plug receptacles should be as short as possible and likewise twisted together.

Notwithstanding such precautions, plug connectors in the vicinity of a strong LF field should be avoided as far as possible. When situated close to a power transformer, a plug connector, for instance, was found to lower the s/n ratio of a microphone by 9 dB, whereas an uninterrupted lead at the same point remained unaffected.

To protect the microphone itself, the onus is mainly on the manufacturer to ensure low susceptibility to interference by means of a high common mode rejection.

The measurement of common mode attenuation is described in DIN 45 404 /3/ and in Annex 4 of the above-mentioned Standard Specifications (Fig. 4).

For professional purposes, an attenuation ratio of at least 60 dB is required. Neumann microphones of the Series fet 80 attain with their output transformers at least 80 dB, that is to say any interference which penetrates the modulation conductors and finds it way into the microphone is attenuated to this extent.

Furthermore, the output transformers of our microphones all have separate primary and secondary windings, the halves of which are divided between the opposite sides of an E-I core section, as shown in Fig. 6. Any interference field thus induces an antiphase voltage in each half of the winding, with the result that it is largely self-cancelling.

In the case of a multi-conductor cable as used, for example, to connect our SM 69 fet stereo microphone, the eleven conductors are very carefully assigned to the various dc voltages and to the modulation carriers in accordance with the diversely selected twist of the leads, so that the same conditions for both systems are obtained at every point along the cable, together with the best possible channel separation (Fig. 7).

Interference by strong HF fields

High-frequency fields can be present in evenly distributed form, appear at intervals, i.e. in pulses, for instance from a rotating radar aerial, or produce maxima and minima in a room in the form of standing waves.

It is thus possible for a studio to have areas where interference is strong and others where there is no interference at all.

We have also ovserved that a studio suffered no interference from a nearby transmitter, as the latter's horizontally polarized waves passed over the top of it, whereas a television station some kilometres away caused interference.

The picture frequency (vertical frequency) of TV transmitters (50 Hz in Europe) is easy to confuse with mains hum, a circumstance which can lead to long and fruitless fault-finding work. HF interference can be identified, however, by reason of its spatial characteristics, as exemplified above.

A properly designed microphone can be affected only by high frequencies which penetrate the cable and arrive in its amplifier/impedance transformer, where it is demodulated. We have recorded experience only of interference by amplitude-modulated transmitters, that is by mediumwave and television stations. Fig 8a demonstrates how HF which has penetrated a cable connector finds its way to the microphone input stage, where it is demodulated and culminates in audible AF interference. Fig. 8b illustrates possible protective measures.

Conductive objects, which may also include the human body when we are considering high field strengths, can have the effect of secondary emitters in the vicinity of a microphone, thus lending added power to the interference.

In the event of high-frequency interference, the cable material and the plug connectors should be checked:

As indicated in the foregoing, the metal bodies of plug connectors must have a highly conductive connection with the cable shield, whereby preference should be given to a soldered joint over any kind of clamp (e.g. under the cable end strap).

The body of the plug connector at the microphone end is always in contact with the grounded microphone case, of course, thus providing a good connection as measured with an ohmeter, but as far as high frequencies are concerned, it may constitute a high-value transfer resistance if there is no additional shield connection in the plug.

Cable shielding may take any of the following forms:
- Copper braiding - may also be tinned,
- sheaves of flat, parallel copper wires laid helically around the conductor (spiral braiding)
- conductive plastic sheathing.

An imporatant criterion for the HF resistance of copper shielding is its surface coverage, although in the context of cable shielding this must be considered in conjunction with the length of lay, the braid angle and the diameter of the copper wire used /4/. A high-coverage braided cable (80...90% is usual) may thus be less effective than one with a lower coverage standard, depending on whether the other parameters are properly observed.

The cables we use have double, counter-rotating spiral braiding of very high coverag standard (95%). This type of cable shield is not easily damaged by bending, and makes for a very flexible cable (see also Fig. 7). In our experience, this method of spiral braiding offers the most effective high-frequency shield.

In order to examin the resistance of a microphone to HF, we employ several different methods:

A "natural" interference field is given by the company's particular situation, for there are 13 radio 8 TV stations in Berlin, and the East Berlin Television Tower and also the rotating radar system at Tempelhof Airport are all quite near to us and in line of sight.

This means that microphones and cables installed on our flat roof can be subjected to direct examination of their HF resistance. A point to consider here is that the beam of the radar system definitely causes more interference in dry weather than when it is humid or rainy (absorption and diffusion of water droplets).

A much more powerful source of interference /5/ is a sparplug, which generates a noise signal over a very broad bandwidth with the aid of a multivibrator and transistorized ignition.

This type of generator is shown in Fig. 9. It is installed in an unshielded, non-conductive housing, which has a cable fitting to accomodate a microphone cable at a defined distance from the sparkplug.

Fig. 10 illustrates the effect of various HF-protective measures on a microphone. The ordinate represents the weighted interference voltage level (noise level) caused by the wideband noise generator shown in Fig. 9.

In a further test set-up, an amplitude-modulated HF voltage is fed directly into a cable shield (see Fig. 11). The carrier frequency is varied over a range from 100 kHz to 30 MHz, whereby the modulation frequency f_m = 1 kHz and the modulation depth m = 70% (adopted from DIN 45 410 /6/ and ARD Standard Specification 3/5, Annex 8).

This arrangement enables selective examination to be carried out as to whether a microphone is susceptible to interference at specific frequencies. This can also be the case if unsuitable filters with resonance points in the interference band are used.

To summarize, it can be said that a well-designed condenser microphone is capable of functioning with complete satisfaction even in strongly interference-prone situations if properly shielded plug connectors and a suitable microphone cable are used.

References

/1/ DIN 45 591, 2.74, Mikrophon-Prüfverfahren; Meßbedingungen und Meßverfahren für Typprüfung (Microphone Test Methods; Measuring Rules and Methods for Type Testing)

/2/ Technische Pflichtenhefte der öffentlich-rechtlichen Rundfunkanstalten in der Bundesrepublik Deutschland Nr. 3/5, Januar 1977 (Technical Specifications of the ARD No. 3/5, January 1977)

/3/ DIN 45 404, 8.74 Messung der Unsymmetrie elektroakustischer Geräte; Erdunsymmetrie (Measurement of Unbalance in Electroacoustic Equipment; Unbalance to Ground

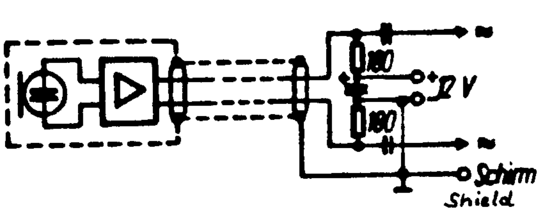
/4/ Geschirmte Kabel mit optimalem Geflechtsschirm Erich Homann Nachrichtentechnische Zeitung Heft 3, 1968 (Shielded Cables with Optimum Braided Screening)

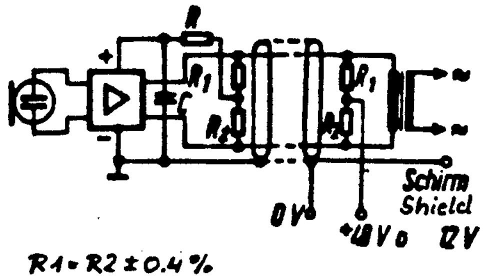
/5/ Nach einer Prüfanordnung des Instituts für Rundfunktechnik Hamburg, Rundfunktechnische Mitteilungen, Heft 1, 1962 (Adapted from a Test Set-up of the Institute for Broadcasting Technology, Technical Bulletins (Radio), Issue 1, 1962

/6/ DIN 45 410, 5.76, Störfestigkeit von elektroakustischen Geräten; Meßverfahren und Meßgrößen (Resistance of Electroacoustical Equipment to Interference; Measuring Methods and Parameters.

	A-B POWERING	PHANTOM POWERING

Basic circuit

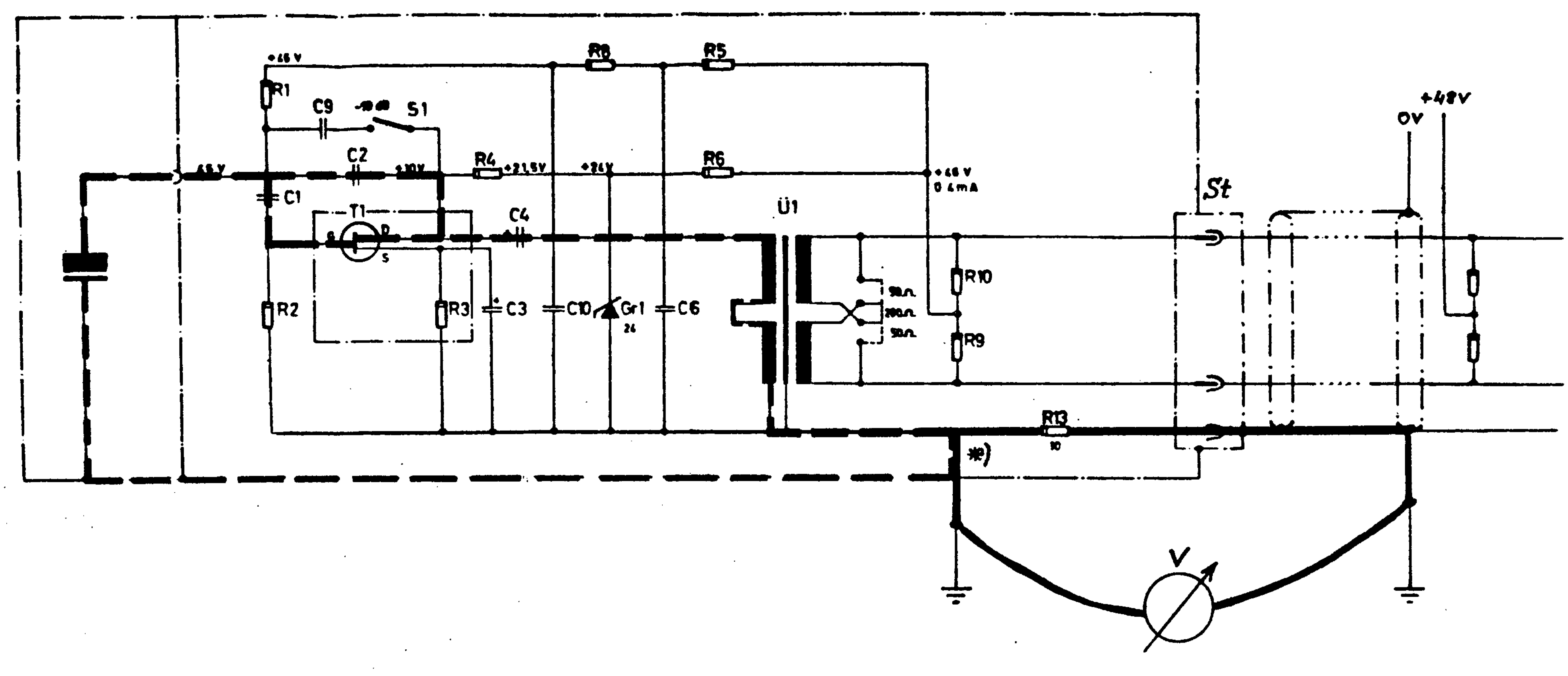




	A-B POWERING	PHANTOM POWERING
Principle	One conductor is connected to the plus pole and the other to the minus pole of the voltage source via R-C networks. The input resistors are simultaneously the working resistance of the last microphone amplifier stage, which, in terms of DC, is in series with the remaining voltage.	DC is fed to the two conductors in the same sense via 2 large resistors, derived from the "electrical midpoint" and filtered in the microphone. The return path is the cable shield or a third conductor.
Characteristics Powering with:	7.5...13 V; 5...10 mA	e.g. 48 V +/- 4 V; 0.4...10 mA
Supply voltage and LF output voltage	are parallel to each other	are decoupled from each other
Permissible hum voltage	≤ 0.004 mV	approx. 10 mV
Power units require	elaborate filtering	elementary filtering
Feeder bus requires	mutual decoupling of all supply leads	no decoupling network
Each supply branch contains	4 resistors and 3 large electrostatic capacitors	2 miniature resistors
Pole reversal of terminals	not permissible	permissible
Other microphones	can be connected after switching off the supply and disconnecting the input resistors (2 x 180 ohms)	can be connected without any switching
Standardized as per	DIN 45595, IEC 268-15A	DIN 45 596, IEC 268-15A

Fig. 1

Supply systems for transistorized condenser microphones



F i g. 2

Path of capsule (useful) current and shield (noise) current
in a condenser microphone

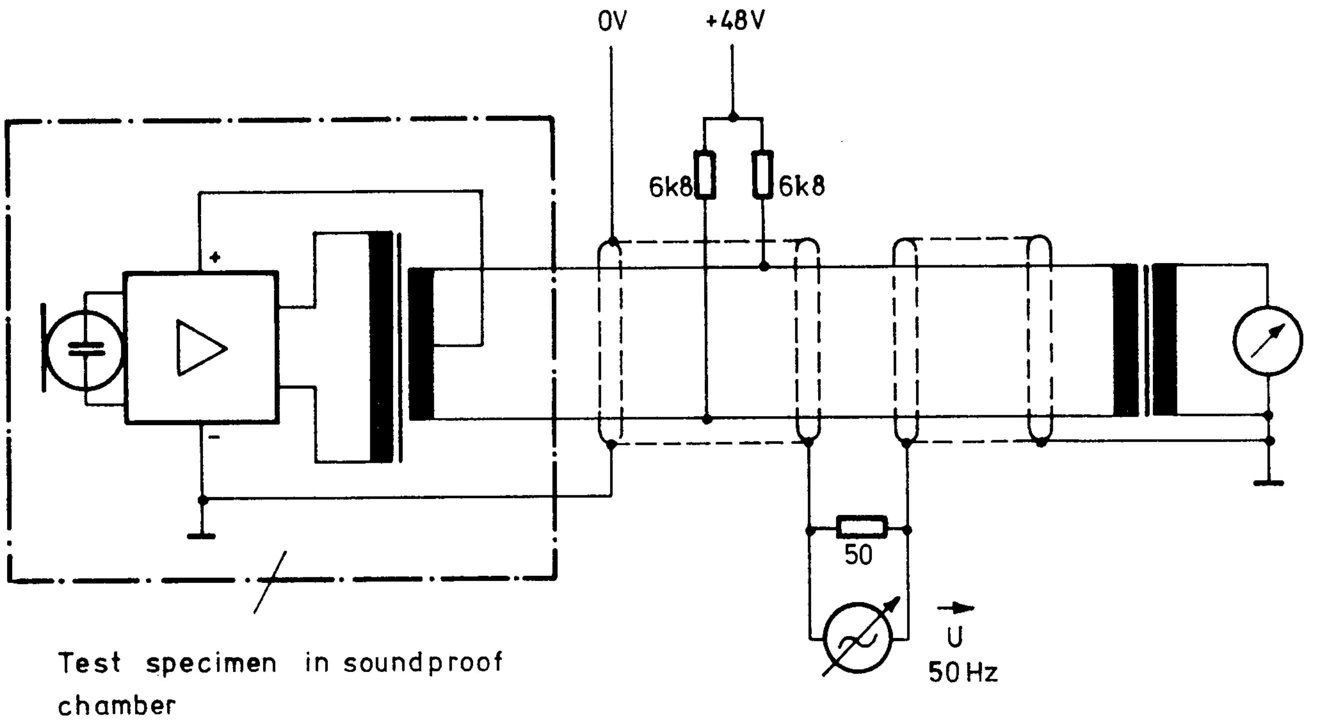
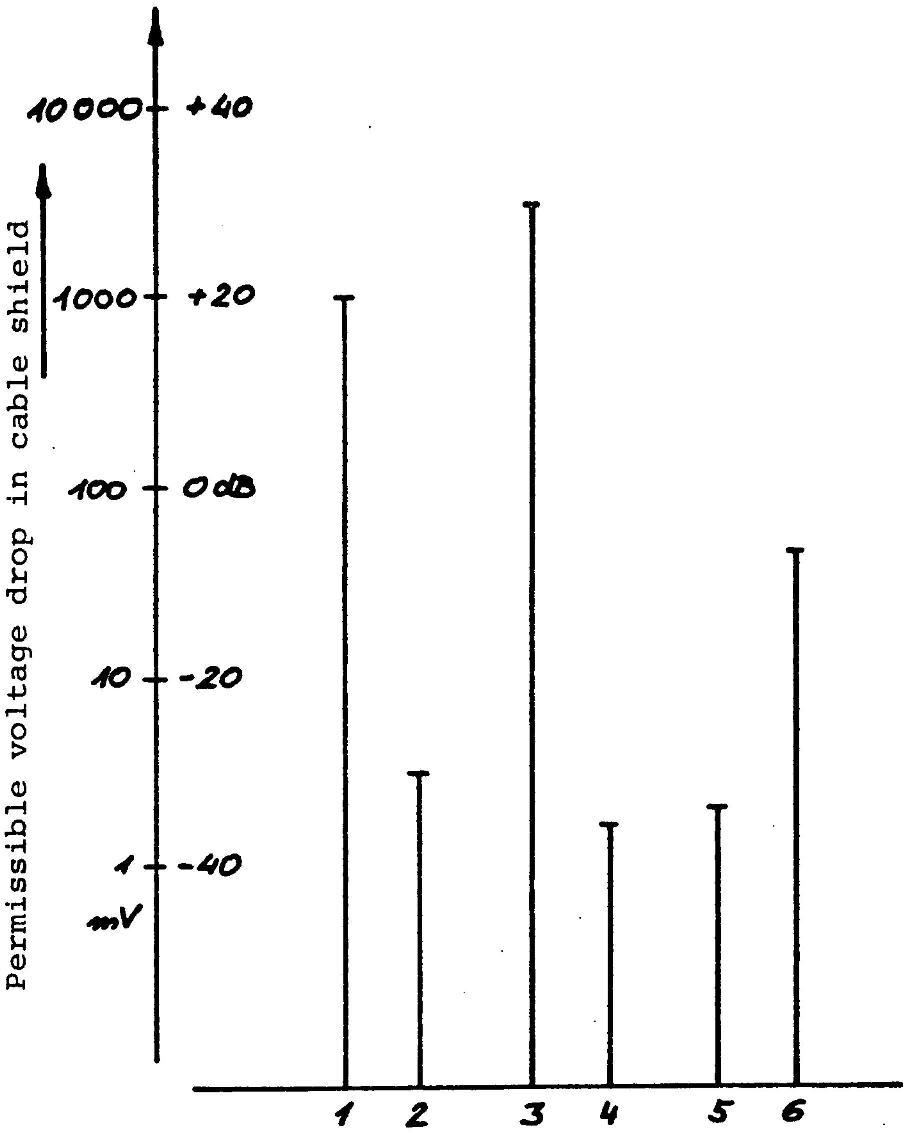


Fig. 3

Measurement of microphone susceptibility to cable-induced currents



Measurements as per Fig. 3:

1 Phantom-powered microphone, input resistors identical

2 Phantom-powered microphone, input resistors varying by 1 %

For comparison:

3 Dynamic microphone

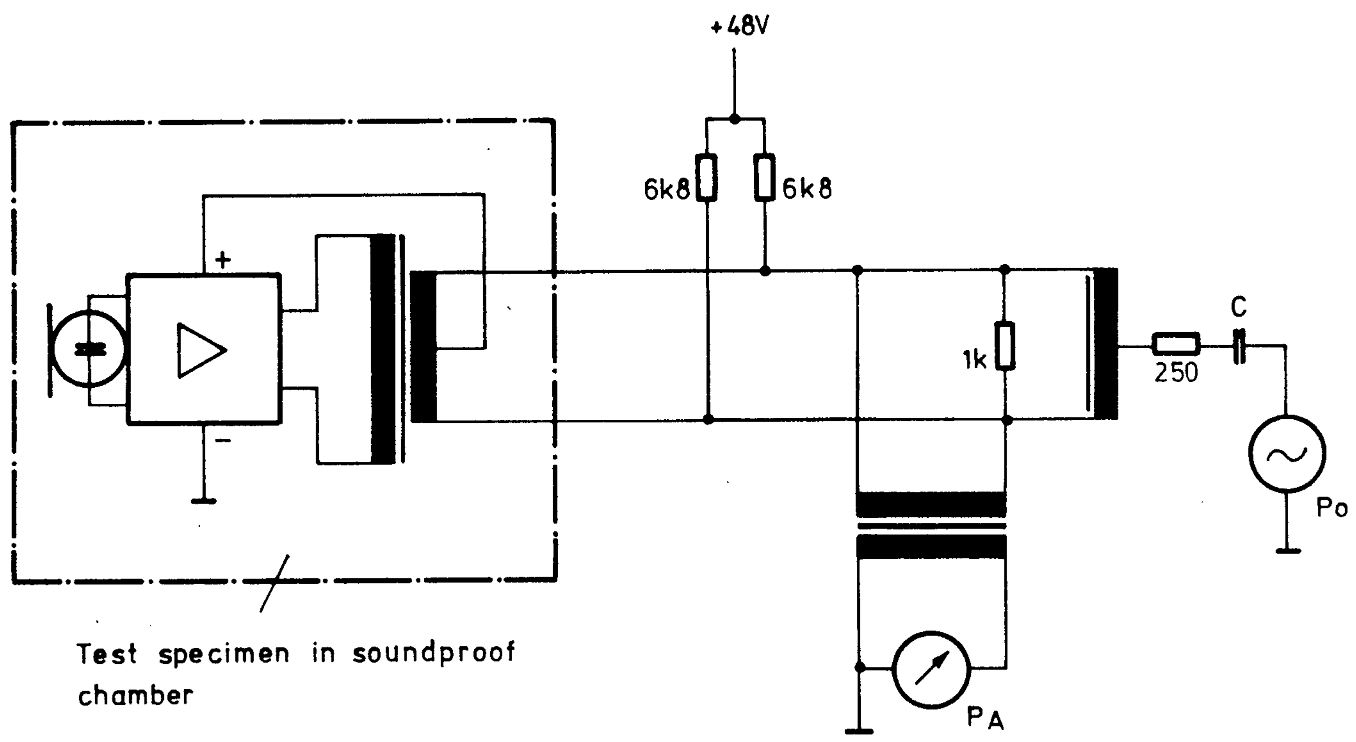
4 A-B powered microphone

Effect of protective resistor:
(R13, 10 ohms, see text)

5 Microphone as in Fig. 2, without R13

6 Microphone as in Fig. 2, with R13, approx. 30 dB improvement

Fig. 4
Permissible voltage drop in cable shield which worsens the inherent noise of the test specimen by 3 dB



Common mode rejection $a_u = P_o - P_A$ [dB]; C = DC blocking

Fig.5

Measurement of common mode rejection of a condenser microphone

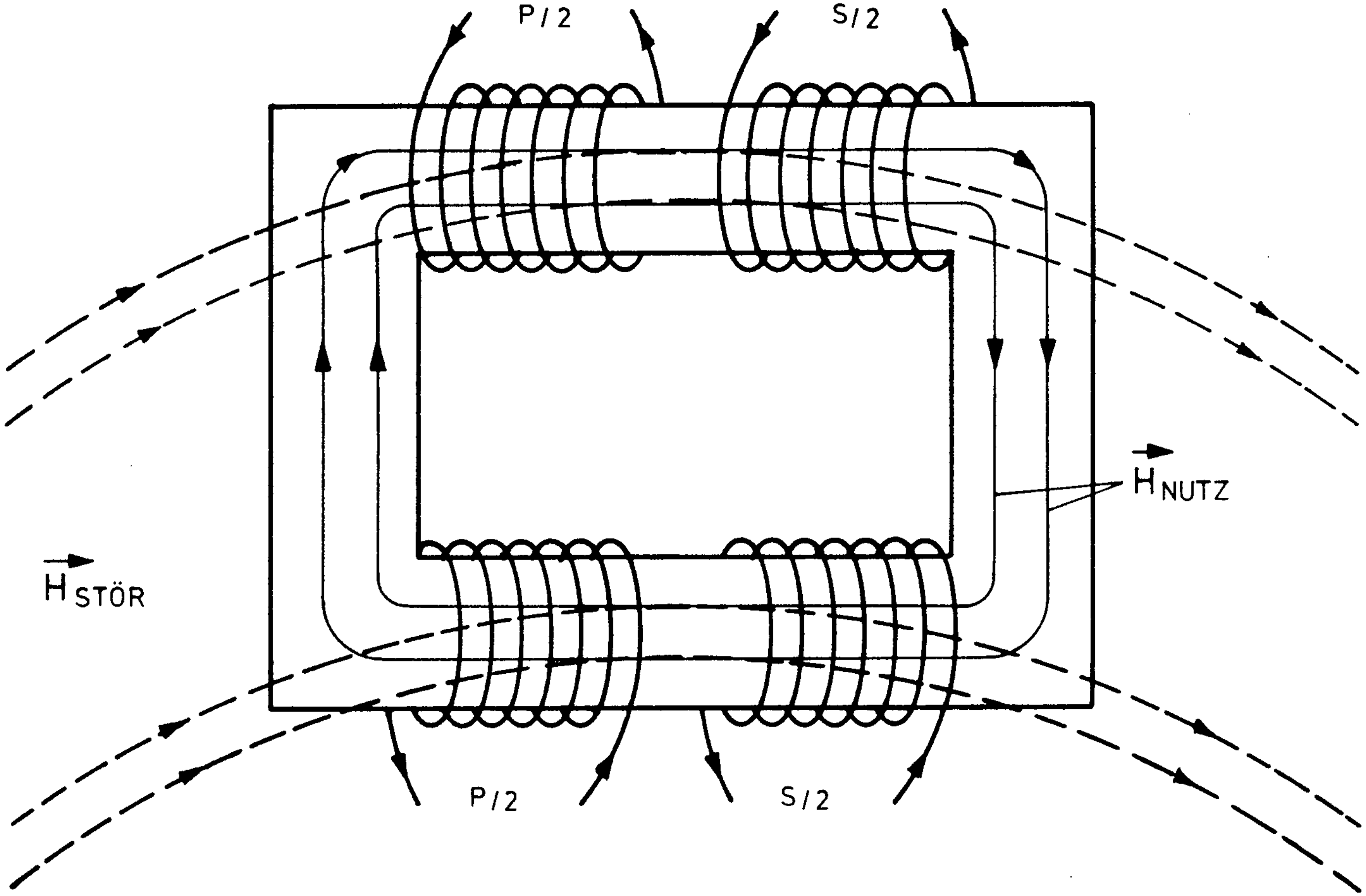


Fig.6

Division of the windings of a microphone transformer

P = primary , S = secondary winding

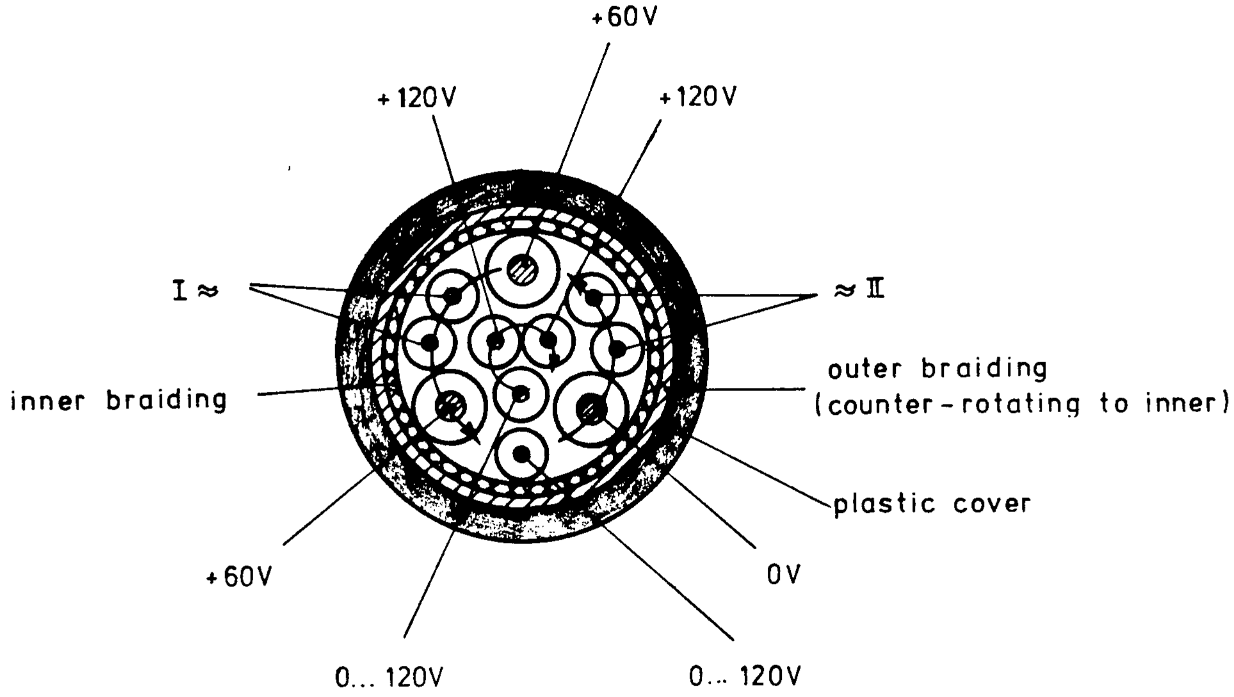
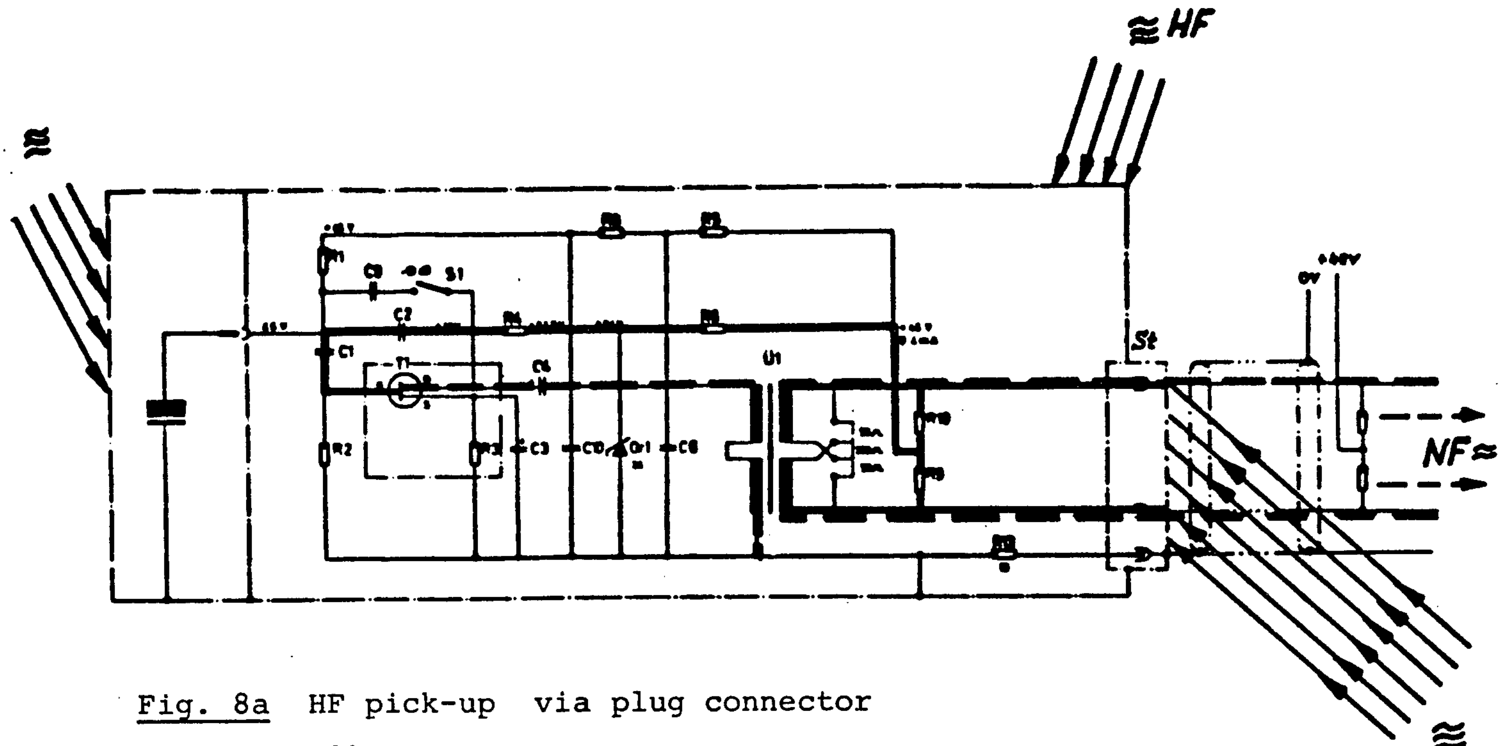
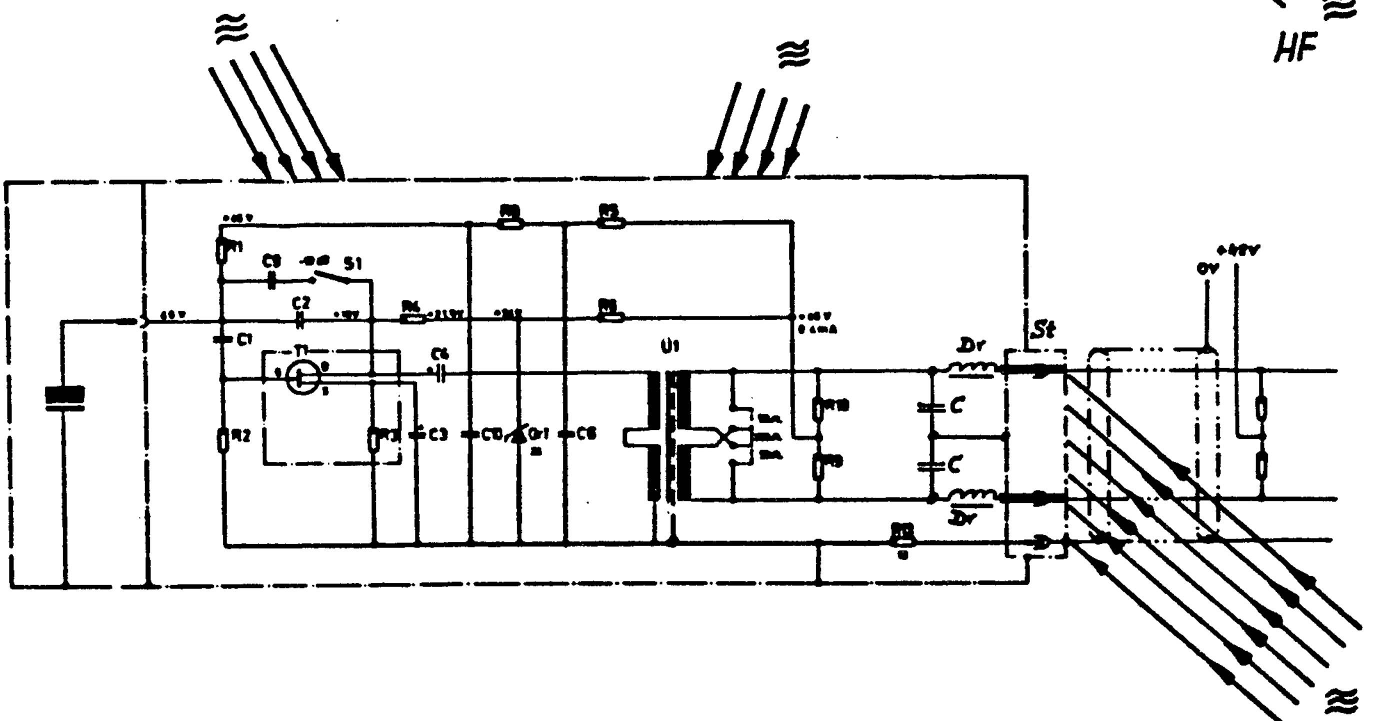


Fig.7

11-core cable for stereo microphone



<u>Fig. 8a</u> HF pick-up via plug connector



<u>Fig. 8b</u>: HF protection by the installation of a static protective winding in Ü1 (Tr 1) and an HF filter (Dr (choke) C) in the connector

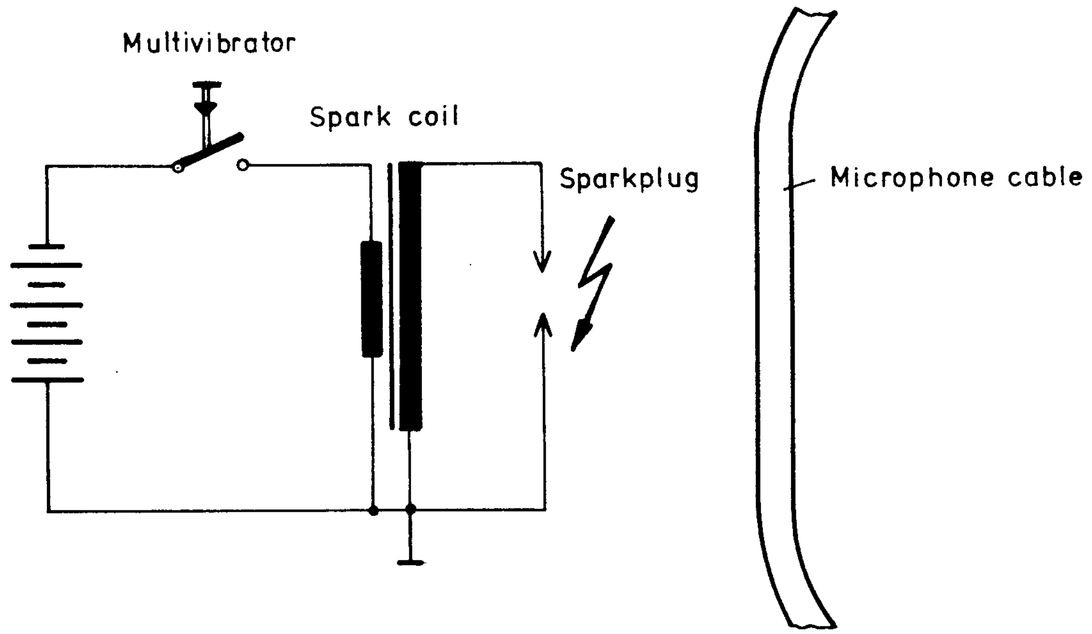
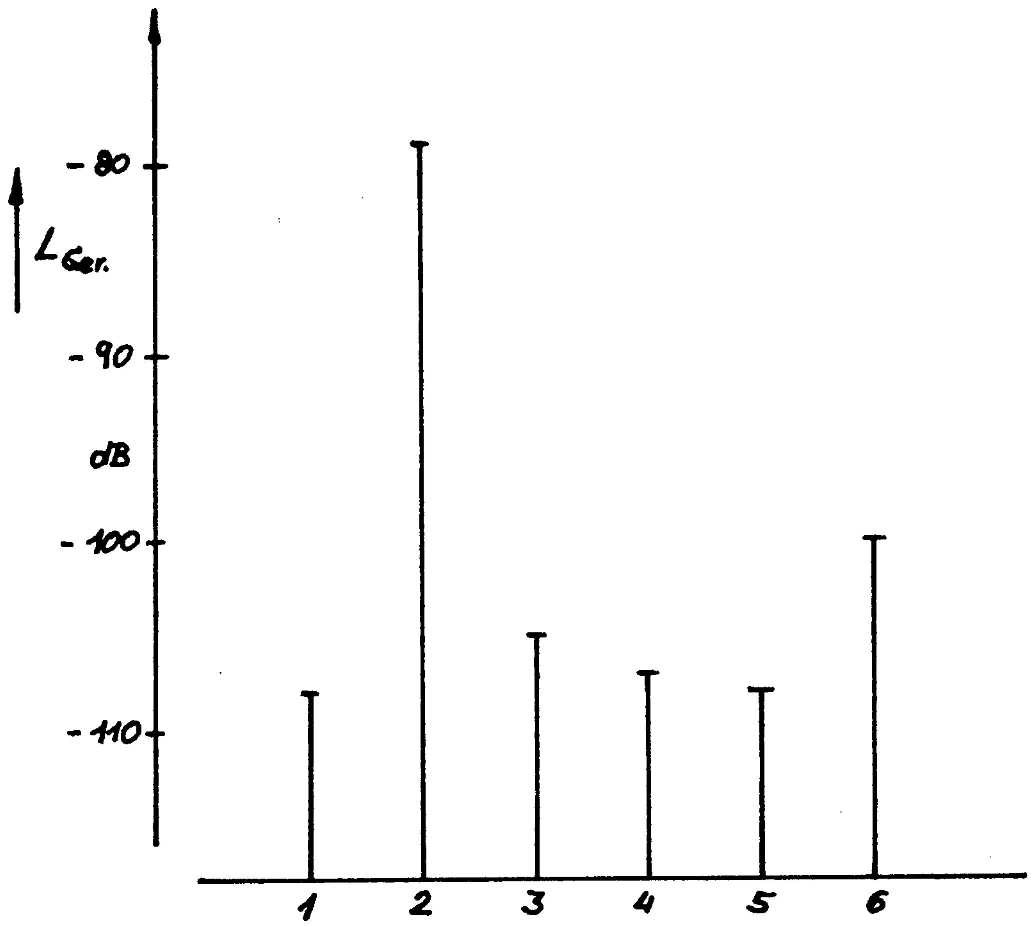


Fig. 9

Ignition spark generator with specimen



Noise level of a microphone (cp. Fig. 8):

1 without HF interference
2 with HF interference, without electrical protection
3 with HF interference, with 2 HF chokes
4 with HF interference, with 2 HF chokes and 2 blocking capacitors
5 with HF interference, as 4 + static protective winding
6 as 5, but with poorly shielded cable connection

$$L_{Ger} = 20 \lg \frac{U}{0.775 \text{ V}} \text{ dB (CCIR 468-1)}$$

Fig. 10

Noise level of a microphone caused by ignition spark generator as per Fig. 9

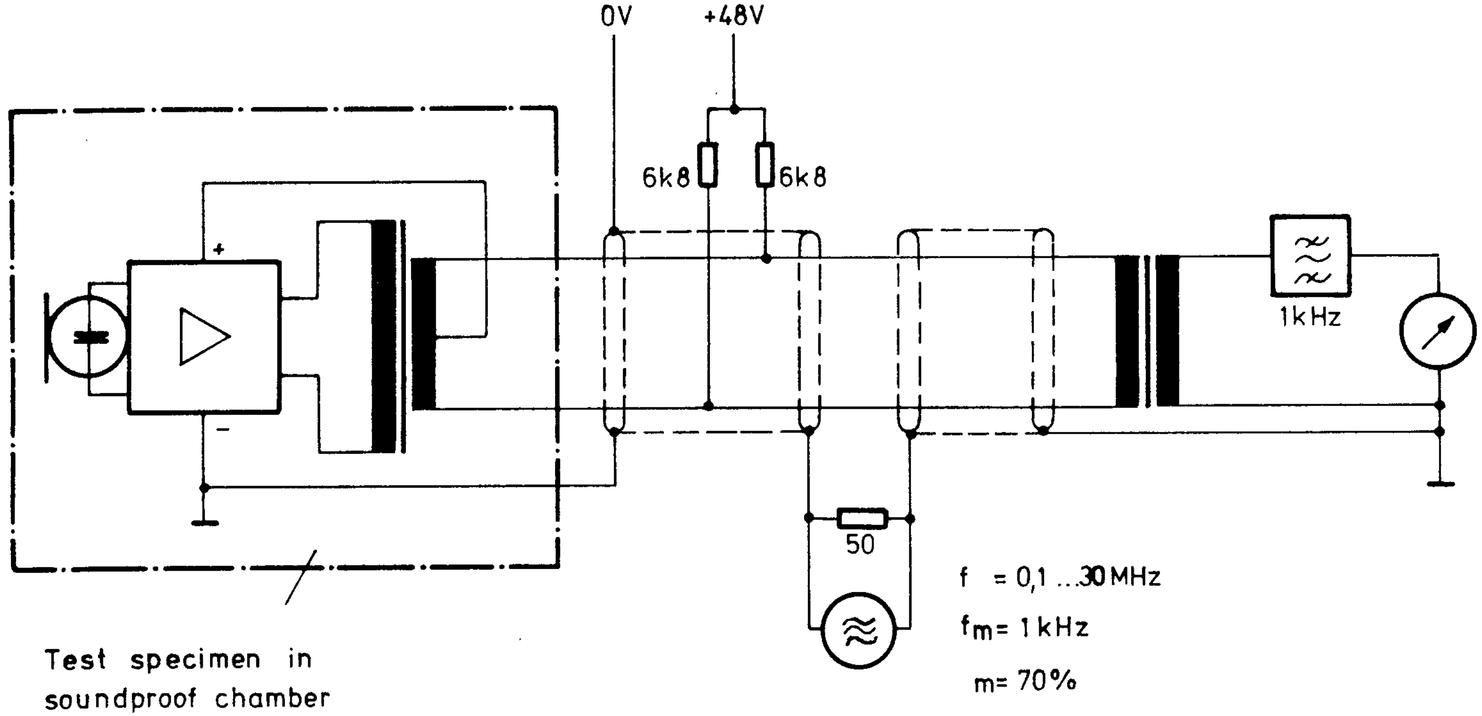


Fig. 11

High- frequency pick-up by the cable shield of a microphone