B&K Instruments, Inc.
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application notes

Telephonometry

Symposium in Scandinavia 1974

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General Introduction

On the 12th and 13th November 1974 a special Telephonometry Symposium was held in Copenhagen. Hosts for the symposium were KTAS (Copenhagen Telephone Company) and JTAS (Jutland Telephone Company), and initiative for the meeting was mainly due to the efforts of Mr. P. V. Arlev and S. A. Jäger of JTAS.

The symposium consisted of lectures and discussions related to developments in the field of telephonometry, and participants from England, Denmark, Finland, Norway and Sweden contributed to the success of the meeting.

Of the papers presented, two summaries and six full texts were later printed in the B & K Technical Review No. 1, 1975, copies of which are available on demand from B & K. This Application Note prints a further five papers plus an extra paper which although not presented at the symposium received some discussion there.

Papers printed in Technical Review No. 1, 1975:

Problems in Telephone Measurements, by Norman Gleiss

Proposals for the Measurement of Loudness Ratings of Operators' Headsets, by R. B. Archbold

Comparison of Results obtained by Subjective Measuring Methods, by Ib Gilberg

Repeatabilities in Electro-Acoustic Measurements on Telephone Capsules, by R. E. Walford

Stable Subset Measurements with the 73D, by K. Damsgaard

Vibration Testing of Telephone Equipment, by R. Fluhr

Measuring methods and experiences with the objective measurement of reference equivalents in Norway

by *Trond Ulset,* Sectional Engineer.

Norwegian Telecommunications Administration, Central Laboratory Acoustics Group.

Summary

Information on the use of objective measuring of reference equivalents in Norway. Description of measuring methods and adjustment procedure for the measurement of telephone sets equipped with linear microphone and amplifier. Description of future adjustments and improvements. Description of additional measurements made in connection with the telephone transmission measuring set. Experiences with the use of objective reference equivalents.

1. Introduction

The purpose of this paper is to give some information on the measuring methods for objective telephone measurements used by the Norwegian Telecommunications Administration.

Our first objective electro-acoustic telephone transmission measuring set was purchased in 1959. It was a laboratory version of the Siemens Objektiver Bezugdämpfungsmeßplatz (OBDM). The system was used for equivalent measuring of telephone sets. Later on we became interested in measurements of objective reference equivalents for special equipment, automatic answering machines in particular, to ensure that this equipment had a transmission efficiency comparable with that of telephones.

In 1971, we decided to procure a Brüel & Kjær Electroacoustic Telephone Transmission Measuring Set Type 3352. Our work itself had not been considerably changed, but the amount had increased. Relatively soon we were using only the new measuring set.

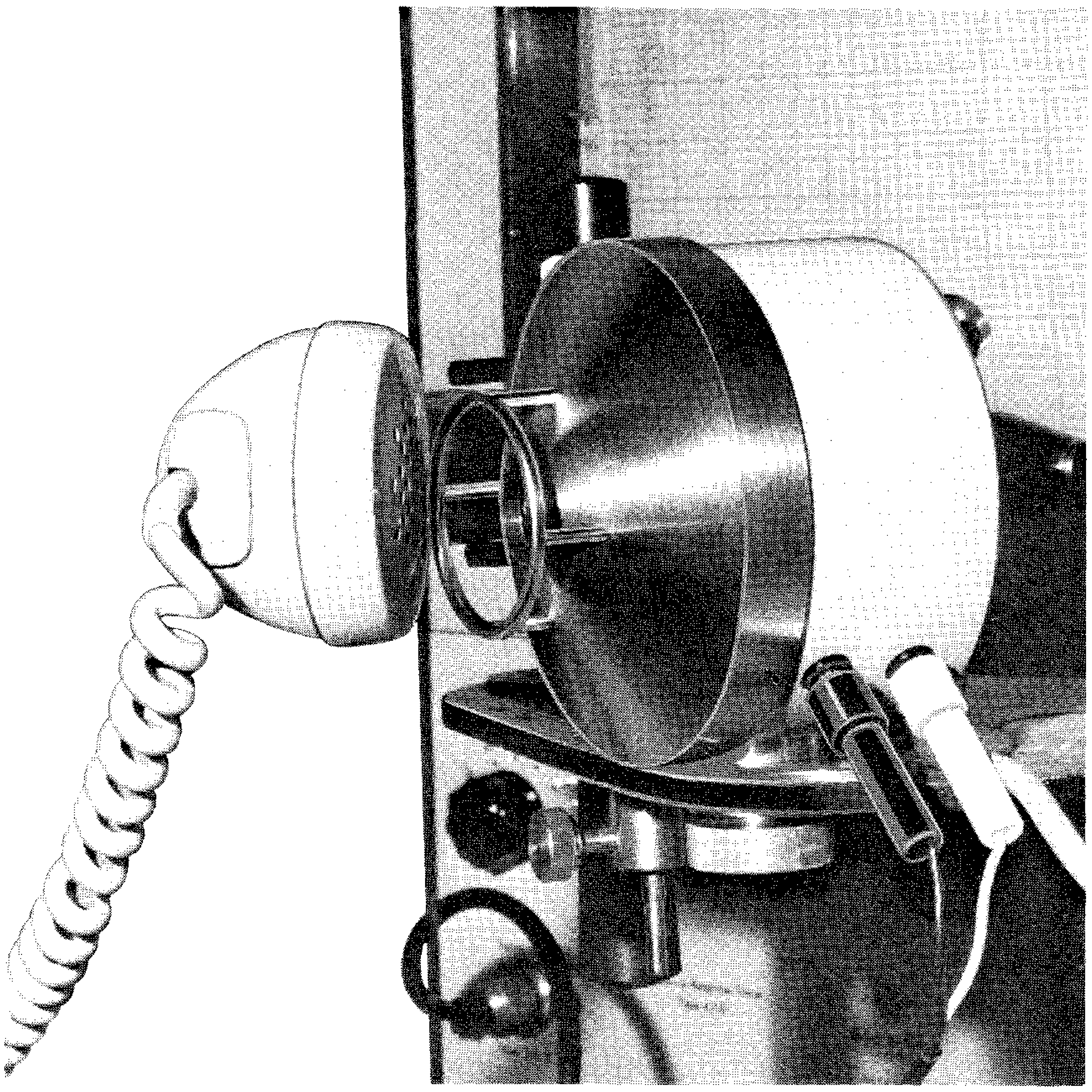
As from 1st January, 1974, a new unit has been established at our Central Laboratory. One of the main tasks of the new unit is to study measuring methods for subjective and objective telephonometry and to participate in international cooperation. In the light of the constantly increasing amount of objective measurements and the preparation of improved measuring methods, the Central Laboratory has purchased another measuring set Type 3352.

2. Measuring Requirements

In 1967, the Norwegian Telecommunications Administration introduced a new telephone set. This set was equipped with an electrodynamic microphone and a two-step microphone amplifier. All special sets provided by the Norwegian Telecommunications Administration today are also equipped with linear microphone and amplifier. This means that by far the majority of the objective measurements of reference equivalents are conducted with sets without carbon microphone. In the preparation of standard measuring methods it is consequently not necessary to consider factors such as non-linearity and packing. In the examination and control of carbon microphone sets we follow the prescriptions corresponding to OREM C, described in the Instruction Manual for the Type 3352.

In Norway the objective reference

equivalents are presented as a function of inserted line length. Because of the linearity of the microphone 2 or 3 measurements are sufficient to describe the variation of the transmission/reception equivalent as a function of inserted line length. Sidetone equivalents must be measured for several lengths of inserted line in order to describe the variation.



The feeding system of most new types of telephone exchanges in Norway is 48 V, 2 × 250 Ω, and this has usually been used during measurements. The artificial line equivalent generally used has been 0,4 mm, 280 Ω/km, 45 nF/km.

Objective telephone measurements are conducted for the following purposes:

— Type control of special sets
— Type control of headsets
— Type control of privately owned equipment
— Production control of telephone sets and handsets
— Production control of microphones and earphone capsules
— In connection with minor changes on old models

3. Measuring Methods

3.1. OREM A (N)

Usually we measure the properties of a complete telephone set; not just the microphone and earphone capsules. That was the reason for originally selecting the OREM A procedure. This procedure prescribes an artificial mouth in the REF-position. This led to a mechanical contact between the labial ring and the mouthpiece. We therefore had to use the AEN position. We also chose to use the new IEC audiometric coupler instead of the NBS 9A coupler. The sound pressure was adjusted with a SFERT-baffle to 93,6 dB re 2 × 10^{-5} N/m^2 (—0,4 dB re 1 Pa). The receiving reference level was also set at 93,6 dB re 2 × 10^{-5} N/m^2. The meter damping was OBDM. The rest of the procedure is identical with OREM A described in the Instruction Manual for Type 3352. We also chose to read the left deflection on the reference equivalent meter because we thought that this was simpler and safer.

3.2. Orem C (N)

In the beginning of 1973 we changed the measuring procedure.

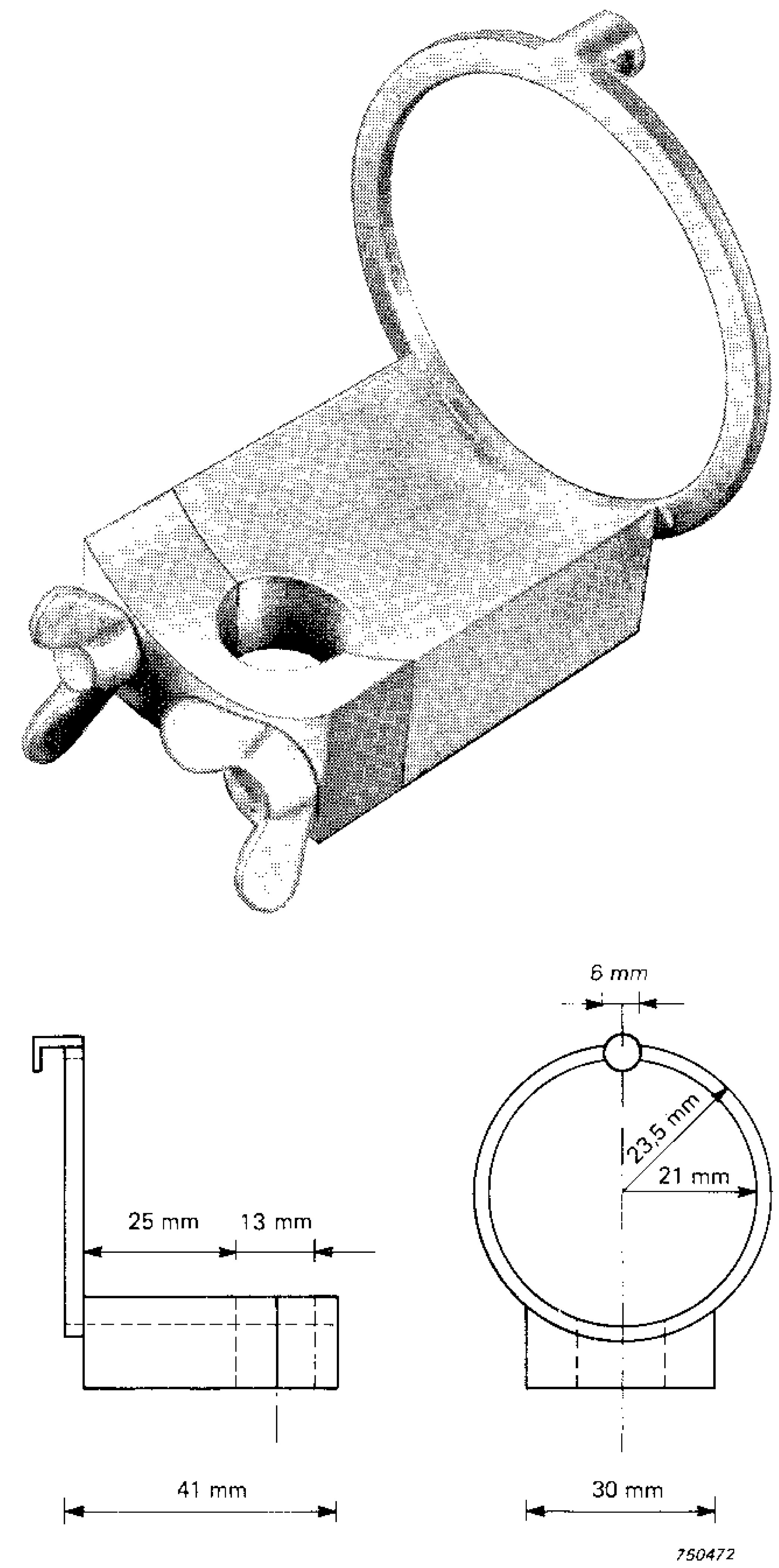


Fig.1. Voice pressure measuring jig used in OREM C (N)

The main reason for the change was that we wished to use an unweighted sound pressure from the artificial mouth. This meant that the SFERT-baffle for adjusting the sound pressure could no longer be used for calibration, so we designed a support for a 1/2" microphone (Fig.1).

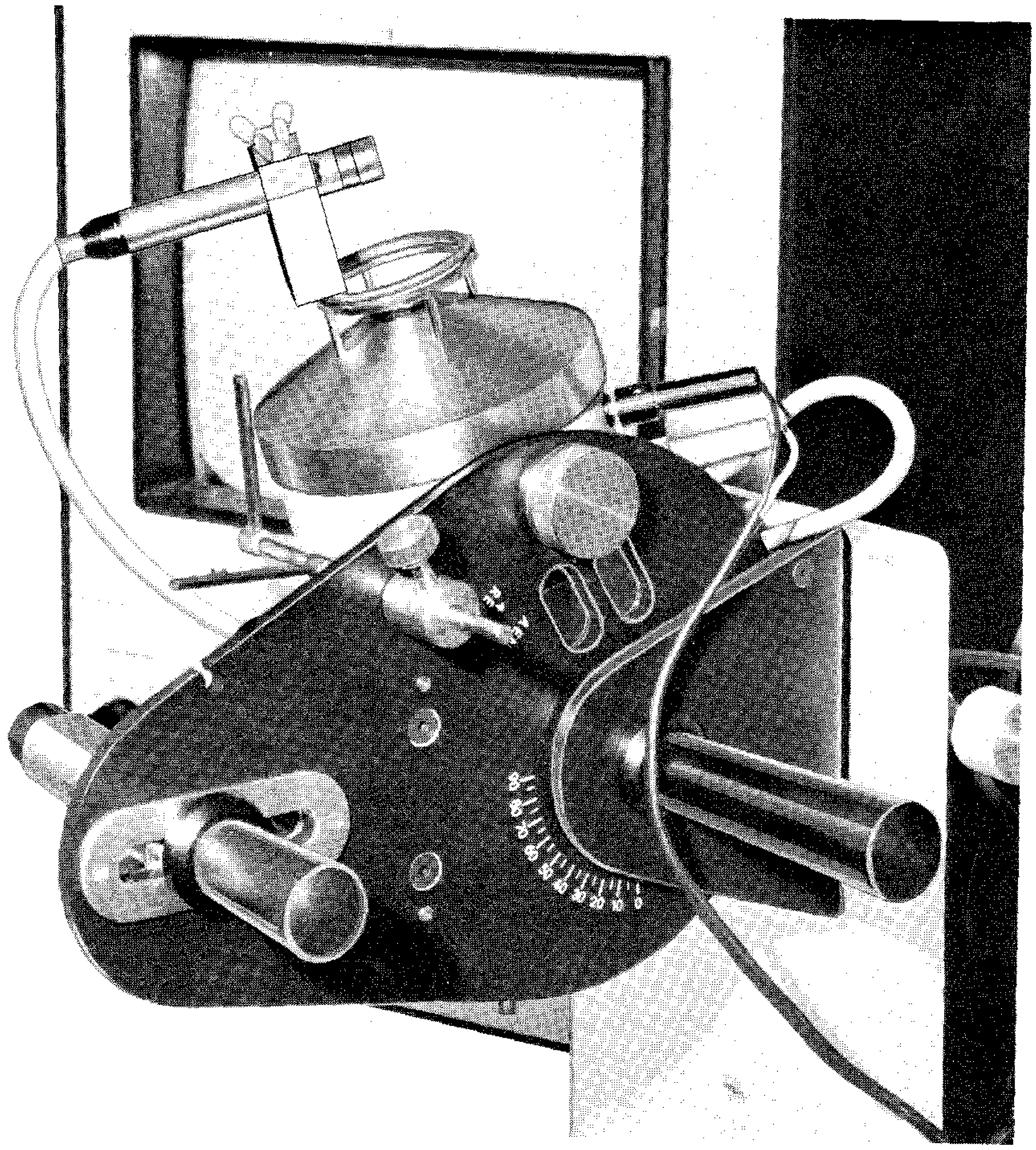
We chose a reference sound pressure of 94 dB re 2 × 10^{-5} N/m^2 (1 Pa). This sound pressure from the artificial mouth was measured 25 mm in front of the labial ring.

The following parameters describe the measuring procedure:

— Artificial ear: IEC Audiometric
— Artificial mouth: AEN position
— Sweep: 0,2 — 4,0 kHz
— Meter scale: $y = k\,x^{0,6}$ dB
— Meter damping: OBDM
— Weighting network: Off

Reading of the left deflection of the objective reference equivalent meter.

Modern lightweight headsets are loaded with 2 cm^3 artificial ear dur-



ing measuring of receiving and sidetone equivalents.

3.3. Modifications of the existing measuring method

The purpose of further preparation of objective measuring method is to

— Describe the qualities of the telephone set in the most appropriate way with as few basic errors as possible
— Achieve the best possible correspondence between the subjective and the objective measuring results.

Because it is not possible to carry out subjective tests in the Norwegian Telecommunications Administration today, we have concentrated our effort on the preparation of the most suitable objective measuring procedures.

For sets with linear microphone and amplifier a sound pressure of 94 dB re 2×10^{-5} N/m^2 (1 Pa) is too high for measurements of transmission and sidetone equivalents. When the conditions are unfavourable peak limiting may occur in the amplifier. Apart from this, such a high pressure will not be necessary. Experience has shown that a sound pressure of 84 dB re 2×10^{-5} N/m^2, adjusted according to procedure OREM C (N), results in an objective transmission equivalent deviating relatively little from subjective transmission equivalents rel. NOSFER.

We also re-considered the choice of sweep width and decided that a sweep of 300 — 3300 Hz corresponds more to the bandwidth of a telephony channel.

The meter function and the meter attenuation for the objective reference equivalent meter also have to be considered. A meter function of $y = kx^{0,5}$ dB corresponds more to the presented results. The question of using the Slow meter needle damping or whether it would be more correct to use the so-called OBDM damping, i. e. a damping corresponding to that of the meter needle in the Siemens OBDM, is also something to consider.

The practical execution of objective reference equivalent measurements is important and is given much consideration. In the preparation of measuring procedures for telephone sets with linear microphone and amplifier, we may disregard phenomena like packing. The measuring procedure itself will accordingly be simpler, quicker and safer than a procedure for measuring carbon microphones. It is necessary to check that the handset is appropriately attached and that acoustic connection between the earphone and the coupler is good. The acoustic coupling is most simply checked by means of a Frequency Response Tracer.

We must take due account of the conditions under which the measurements are carried out. The essential factors are those influencing the amplifier of the telephone set, the line current and the sound pressure. Too high a line current may cause part or complete destruction of elements in the amplifier; unfavourable combinations of line current and sound pressure may cause peak limiting of the amplifier.

For the subscribers' protection most modern telephone sets are equipped with a limiter in the earphone to prevent aural damage caused by acoustic shock. In measurements of reception equivalents we must take this into consideration when we decide the pressure level.

Finally, we must consider the surroundings. As far as possible reflections must be avoided during measurements of transmission and sidetone, and noise must be prevented from disturbing the measurements.

3.4. Additional measurements

In addition to the objective reference equivalent measurements we carry out the following measurements on the measured set:

(a) — Characteristics of current/voltage
(b) — Harmonic distortion
(c) — Adjustment attenuation (impedance)

(a) The characteristics of current/voltage, i. e. voltage drop over the telephone set as a function of the line current, are found by varying the voltage of the power-supply and reading off the line current and the voltage over the set connectors.

(The switch of the voltmeter is in position Line 2).

(b) We have considered different methods for the measurement of harmonic distortion:

- Measuring of harmonic components by means of a spectrometer.
- Measuring of harmonic distortion by means of a slave filter.
- Measuring of harmonic distortion and products of intermodulation by means of sweep and highpass filter.

The first two methods give information on harmonic distortion as a function of the frequency. The result may be written out in curves. The last method gives information on a mean value of the sweep area.

We are usually interested in information on the total harmonic distortion, not the harmonic components, and find that the use of a spectrometer is not appropriate. In the opposite case, however, it is used.

The use of a slave filter requires a room with a good noise insulation, usually special rooms like anechoic chambers. It is possible that a combination of a slave filter and a frequency analyzer Type 2020 or 2021 may prove useful.

The use of sweep and high pass filter gives an expression of mean generation of harmonic distortion and intermodulation over the frequency range of the sweep. This is a fast measurement, and we have found it gives adequate information. Today we use two measuring techniques:

- Sweep 200 — 4000 Hz, 1 sweep per/s, filter with limit frequency 5000 Hz, sound pressure 84 dB re 2×10^{-5} N/m^2, (—10 dB re 1 Pa) 25 mm in front of the lip ring of the artificial mouth.
- Sweep 300 — 800, 2,5 sweep per/s, filter with limit frequency 900 Hz, sound pressure 94 dB re 2×10^{-5} N/m^2, (1 Pa) 25 mm in front of the lip ring.

(c) The return loss is expressed by the ratio between the impedance of the equipment and a reference impedance given in the equation.

$$a = \frac{Z + Z_R}{Z - Z_R}$$

Z = equipment impedance.
Z_R = reference line impedance

The measuring schematic is shown in Fig.2.

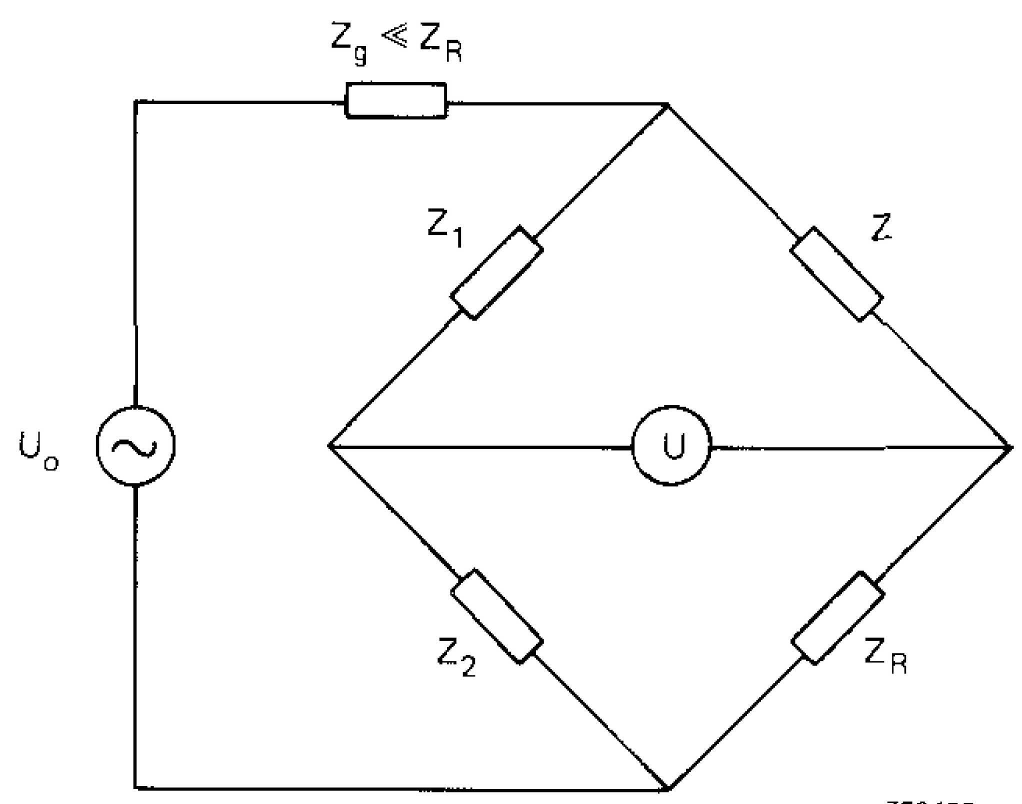


Fig.2. Arrangement for return loss measurement

The ratio between impressed and measured voltage when $Z_1 = Z_2$ is

$$\frac{U_O}{U} = 2\frac{Z + Z_R}{Z - Z_R}$$

and the result may be read off the frequency response tracer or the level recorder.

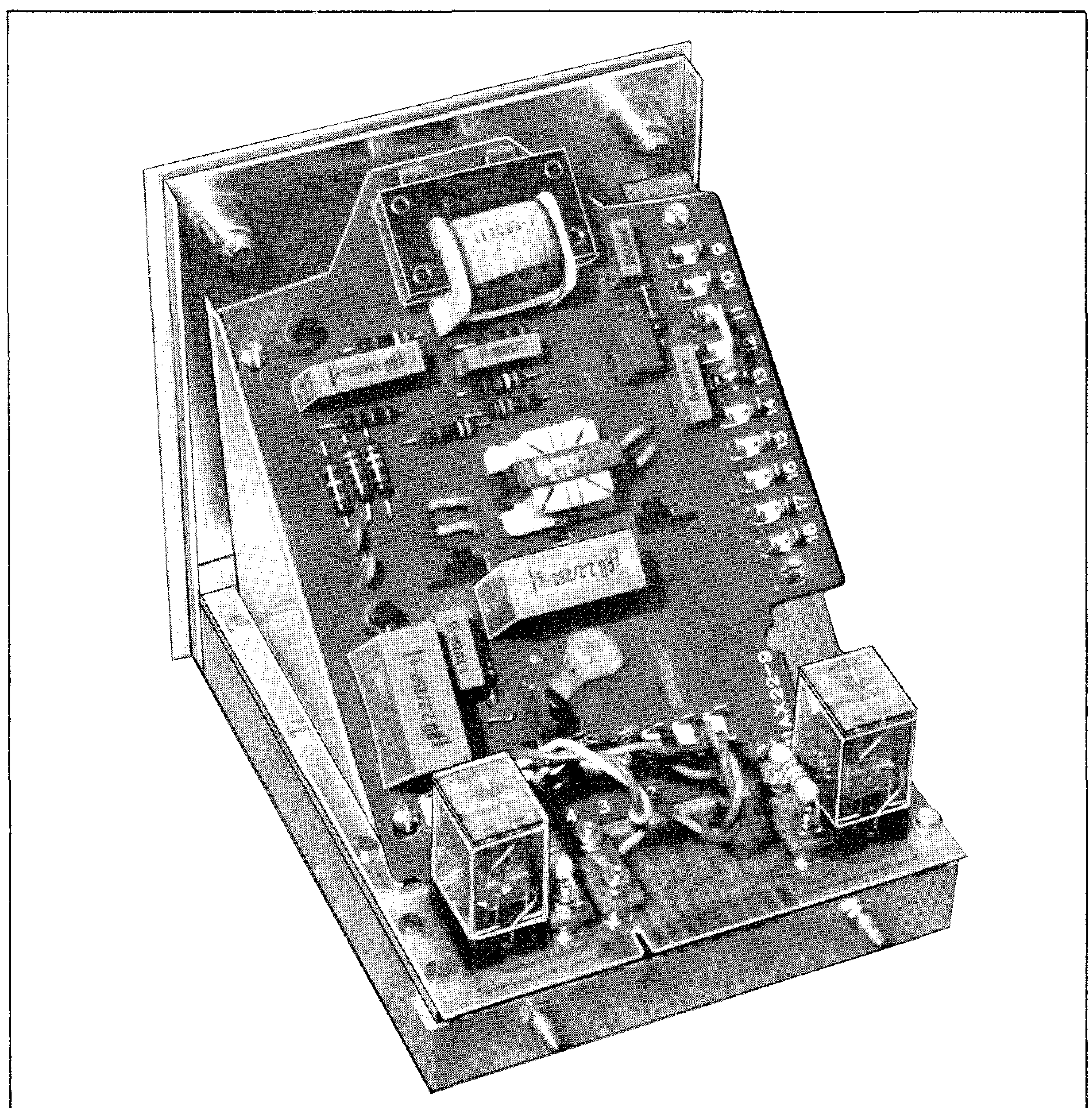
3.5. Use of plug-in units

For use in the examination of capsules and as a reference, we have constructed two plug-in units. We have used two ordinary telephone sets, one of each of the most common models in the Norwegian Telecommunications system.

In order to increase the benefit of the use of plug-in units we are constructing a special reference set. From a transmission technical point of view, it will be a perfect telephone set built with particularly strict tolerances in components and stability. Such a reference set constructed as a plug-in unit has great advantages when used in type controls and environment tests of capsules as well as of telephone sets.

4. Experiences

Our experiences from the use of objective measuring of reference equivalents of telephone equipment in the Norwegian Telecommunications Administration have been very satisfactory. An objective telephone transmission measuring set is indispensable in the production control of larger quantities. We have also



found that objective measurements of reference equivalents give us reliable information on the transmission qualities of the equipment. *The transmission qualities of a telephone set may be described in a simple and well defined measurement presentation.* The measurement precision seems to be satisfactory.

The determination of reference *equivalents rel. NOSFER based on* OREM measurements seems for the present to be somewhat insecure. It is therefore with great interest that we are watching the work carried out by CCITT SG XII in this field because an improved conformity between the OREM and NOSFER *measurements will make the bene*fits of the objective measurements of reference equivalents even greater.

Review of current telephonometric measurements in Finland

by *I. Jäntti* and *T. Tuisku* *

Equipment used in reference equivalent measurements

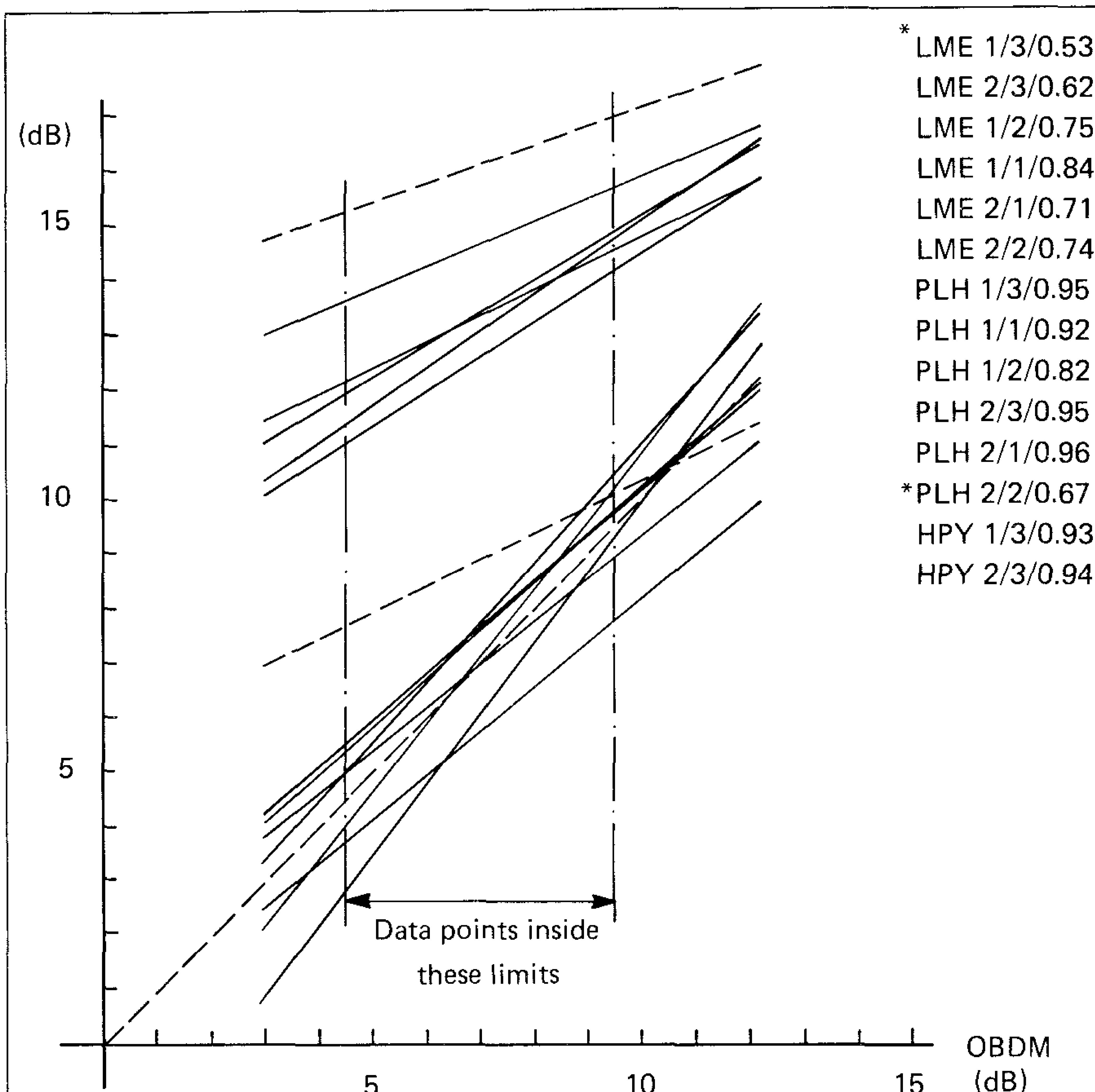
As a national standard for measuring objective reference equivalents a Siemens OBDM is used. It was supplied to Telephone Laboratory of General Direction of Posts and Telegraphs (PLH) in 1960.

Measurements with OBDM are *made as instructed by the manufac*turer. Following points may, however, make an exception to the common practice:

- *the shape of the lip ring of the ar*tificial mouth has been slightly modified in order to allow measurements of sets with modern short handsets.
- when reading the OBDM meter the average position of the needle is observed.
- carbon microphones are conditioned in principle according to IEEE standard 269-1971, but technicians show a tendency to have individual features in the method.

In addition to Telephone Laboratory of PLH objective reference equivalent measurements are made by following institutions:

- Helsinki Telephone Company (HPY), research and on-receipt inspection.
- OY L.M. Ericsson AB (LME), production control.
- PLH/Division for Supply (HO), on-receipt inspection.



Telephones with carbon microphones, linear relations for sending

LME 1,2 : 2/LTM 357500

HPY 1,2
PLH 1,2 equipments based on OBDM

eg LME 1/2/.95 : LME 1, test 2, correlation coefficient .95

* Correlation coefficient deviates significantly from other coefficients calculated to the same equipment

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Fig.1.

* General Direction of Posts and Telegraphs Telephone Laboratory, Helsinki.

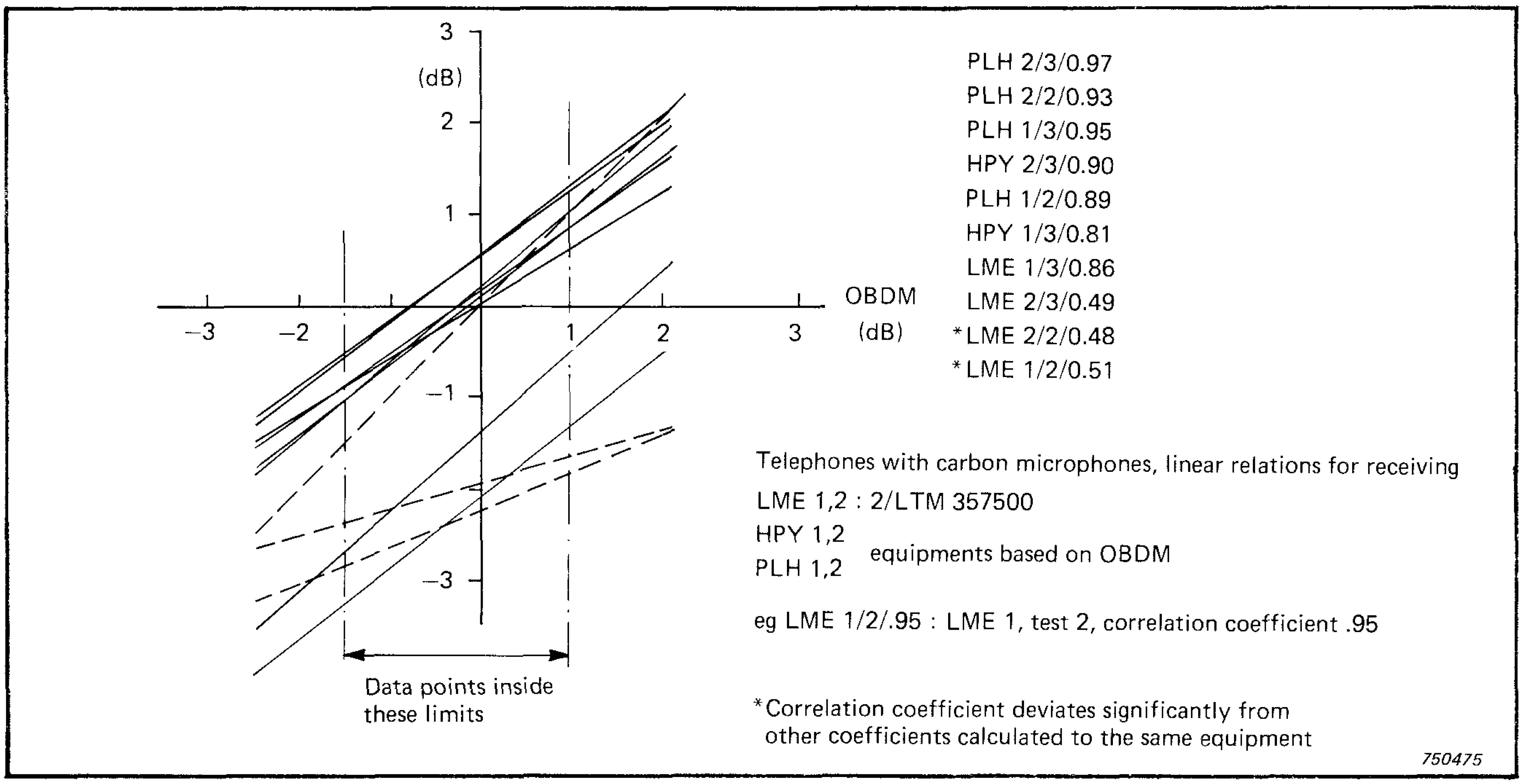
3
(dB)
2
1
−1
−3
−3
−2
1
2
3
OBDM
(dB)
PLH 2/3/0.97
PLH 2/2/0.93
PLH 1/3/0.95
HPY 2/3/0.90
PLH 1/2/0.89
HPY 1/3/0.81
LME 1/3/0.86
LME 2/3/0.49
*LME 2/2/0.48
*LME 1/2/0.51
Telephones with carbon microphones, linear relations for receiving
LME 1,2 : 2/LTM 357500
HPY 1,2
PLH 1,2
equipments based on OBDM
eg LME 1/2/.95 : LME 1, test 2, correlation coefficient .95
Data points inside
these limits
*Correlation coefficient deviates significantly from
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Fig. 2.

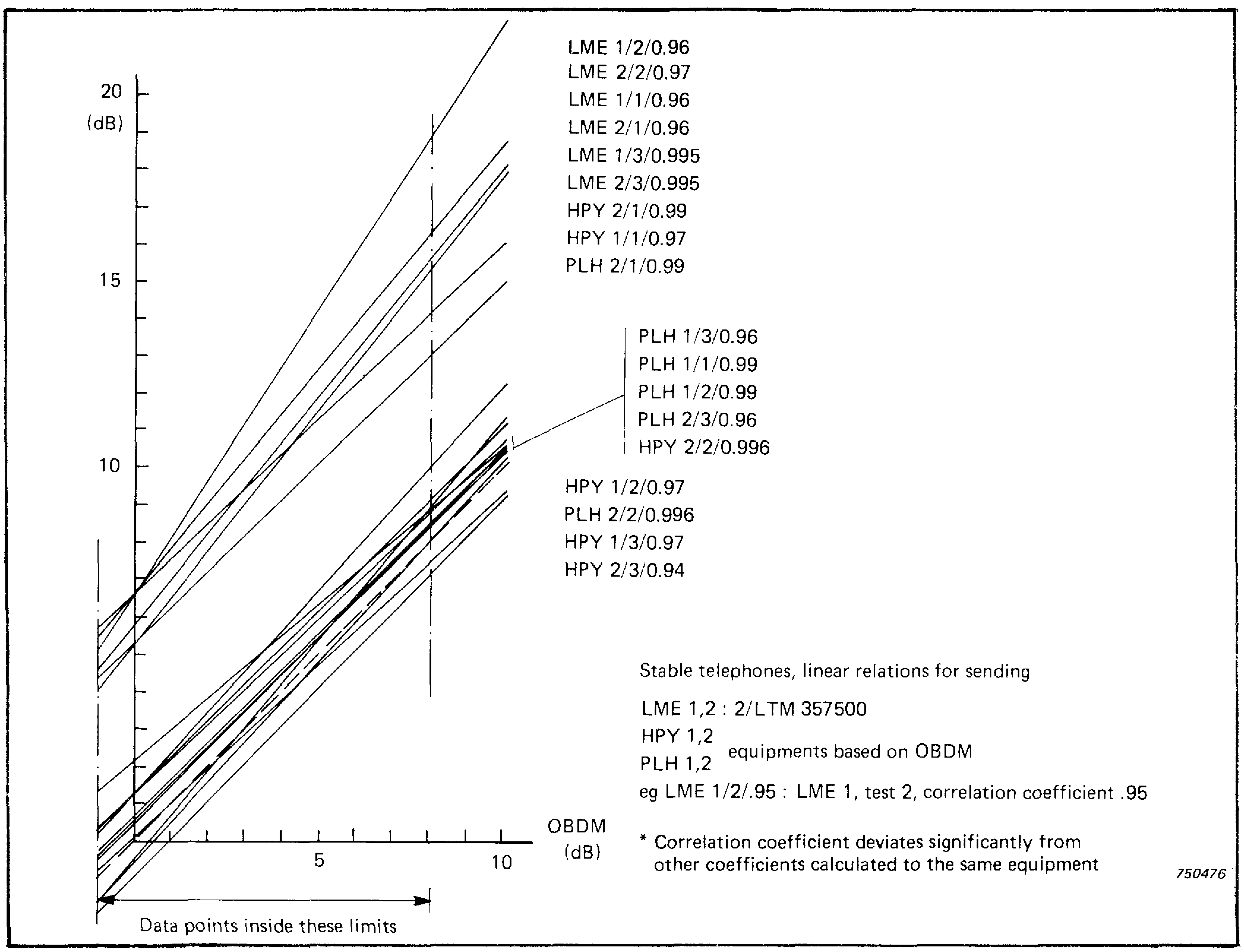
20
(dB)
15
10
5
10
OBDM
(dB)
LME 1/2/0.96
LME 2/2/0.97
LME 1/1/0.96
LME 2/1/0.96
LME 1/3/0.995
LME 2/3/0.995
HPY 2/1/0.99
HPY 1/1/0.97
PLH 2/1/0.99
PLH 1/3/0.96
PLH 1/1/0.99
PLH 1/2/0.99
PLH 2/3/0.96
HPY 2/2/0.996
HPY 1/2/0.97
PLH 2/2/0.996
HPY 1/3/0.97
HPY 2/3/0.94
Stable telephones, linear relations for sending
LME 1,2 : 2/LTM 357500
HPY 1,2
PLH 1,2
equipments based on OBDM
eg LME 1/2/.95 : LME 1, test 2, correlation coefficient .95
* Correlation coefficient deviates significantly from
other coefficients calculated to the same equipment
Data points inside these limits
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Fig. 3.

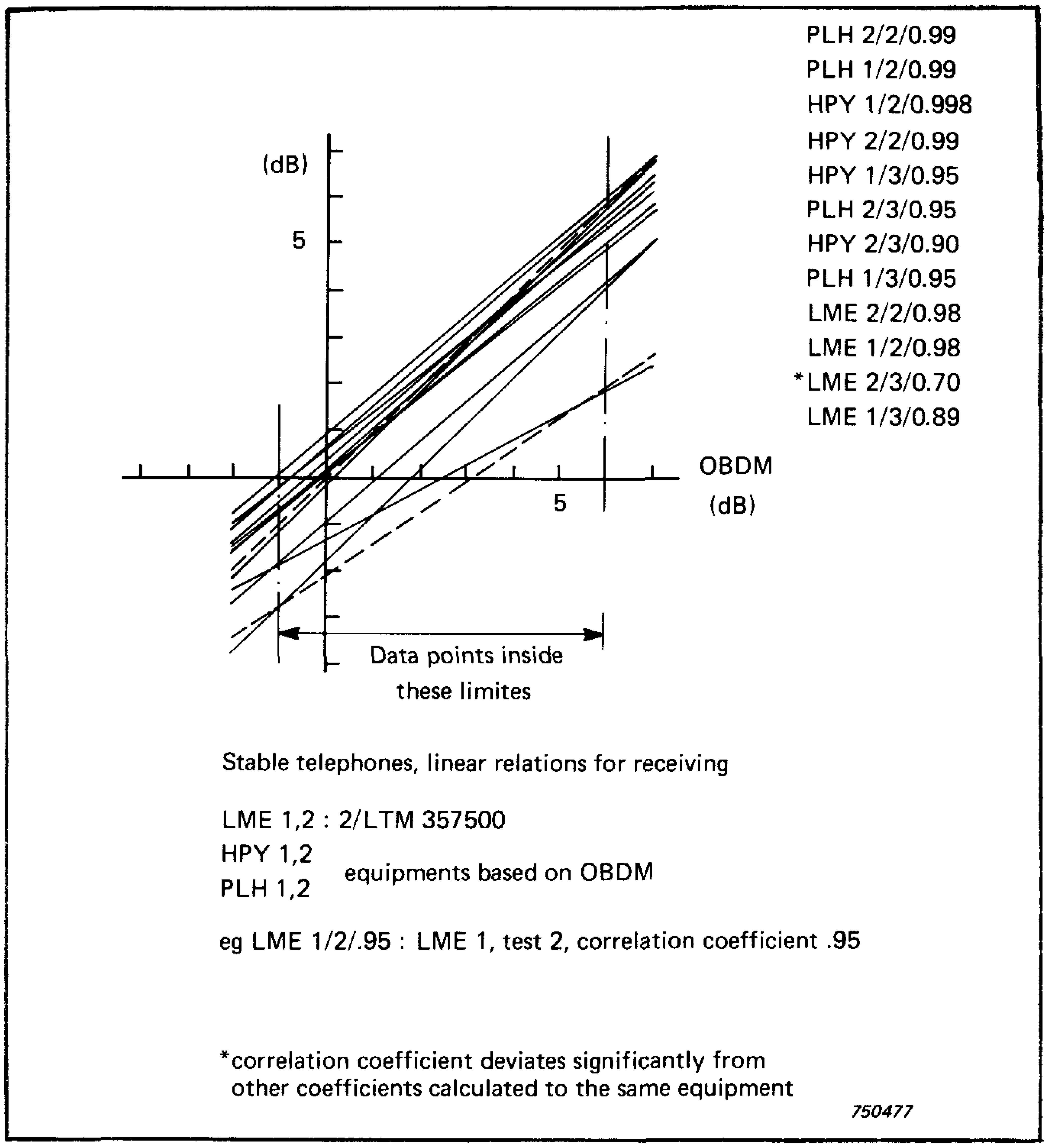


Fig.4.

LME use their own design of transmission test equipment 2/LTM 357500. The equipments used by HPY and PLH/HO are manufactured by HPY Research Institute. They are based on the principle developed by Dr. Braun and are calibrated against OBDM by means of stable telephone sets. Though the purpose has been to make these equipment essentially identical with OBDM, there are small differences in the frequency sweep, artificial mouths and time constants of the meters.

HPY also has a SRE working standard for subjective tests, but it has not been very much used recently.

An Electroacoustic Telephone Transmission Measuring System B & K 3352 has been ordered by the Telephone Laboratory of PLH, and was delivered in November 1974.

Comparison measurements of reference equivalents

During the last three years, objective reference equivalent values obtained with OBDM and other equipments have been compared. Measurements have been made on both stable and carbon microphone sets, which have been circulated between all the institutions mentioned above. The main reason why these measurements were started, was the use of completely different objective R.E. measuring equipment at manufacturers production control and buyers' on-receipt inspections. In addition to that, correlation with the national standard was needed.

Some results of these comparisons are shown in figures 1 and 2 (17 sets with carbon microphones) and 3 and 4 (3 stable sets). These results do not encourage one to think that the difference between values could be predicted, even though always same types of sets are measured.

A review of the network

The telephone network of Finland has been planned in accordance with recommendations of CCITT. The reference equivalent figures used in planning agree with those in P. 21, but the reference equivalents have to be measured with OBDM.

The publication "Puhelinverkkojen rakennemääräykset" (Regulations for building telephone networks) essentially states:

> "As reference equivalent values those values shall be used, which have been obtained by loudness comparison to an internationally accepted standard speech circuit (NOSFER).
> Until further notice an objective equipment for measuring reference equivalents (OBDM), which is located in Telephone Laboratory of PLH, shall be used as a national standard".

The regulations do not say anything about the difference in values obtained with subjective and objective methods, and the practice has been to use only values measured with OBDM. This means that instead of the target value (mean value of SRE's of several sets SRE = 4, 5, ... 7 dB at 0 Ω line) the telephones have 6 . . . 7 dB higher SRE's.

Measurements of speech voltages were started in October this year in our network. The first results make us believe that the send reference equivalents really are somewhat high. The speech volume at the line terminals of the set has a mean value —27,6 vu and a standard deviation 4,1 vu at local calls.

An immediate question is, what, if anything, we should do to correct the send reference equivalents of the local telephone circuits. At present we feel, that it would not be wise to hurry, but to wait until the work on Question 15/XII is ready. After that we perhaps will have a better view of the situation.

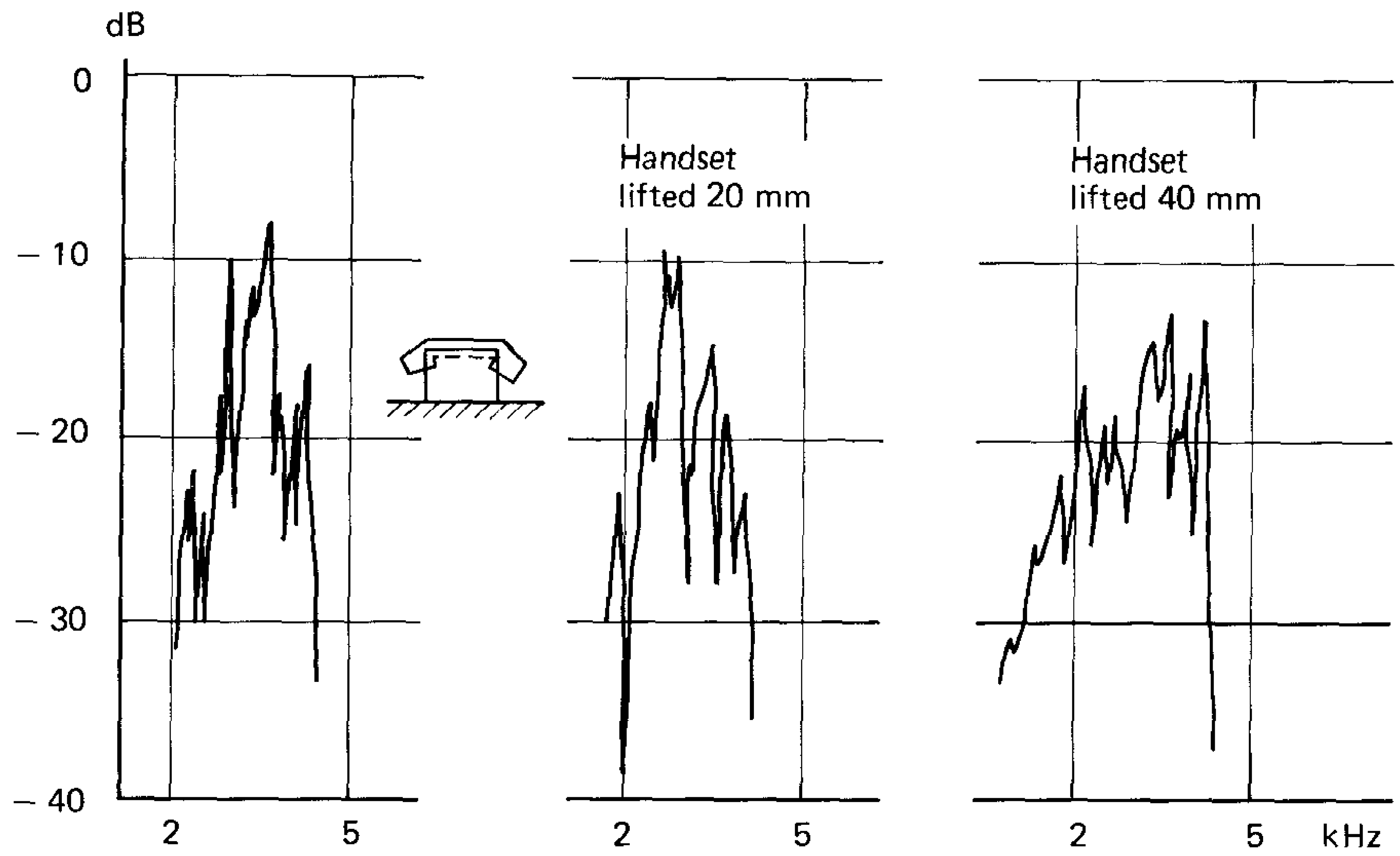


Fig.4. **Ratio of receiver drive signal and microphone pick-up signal for various heights of handset above subset**

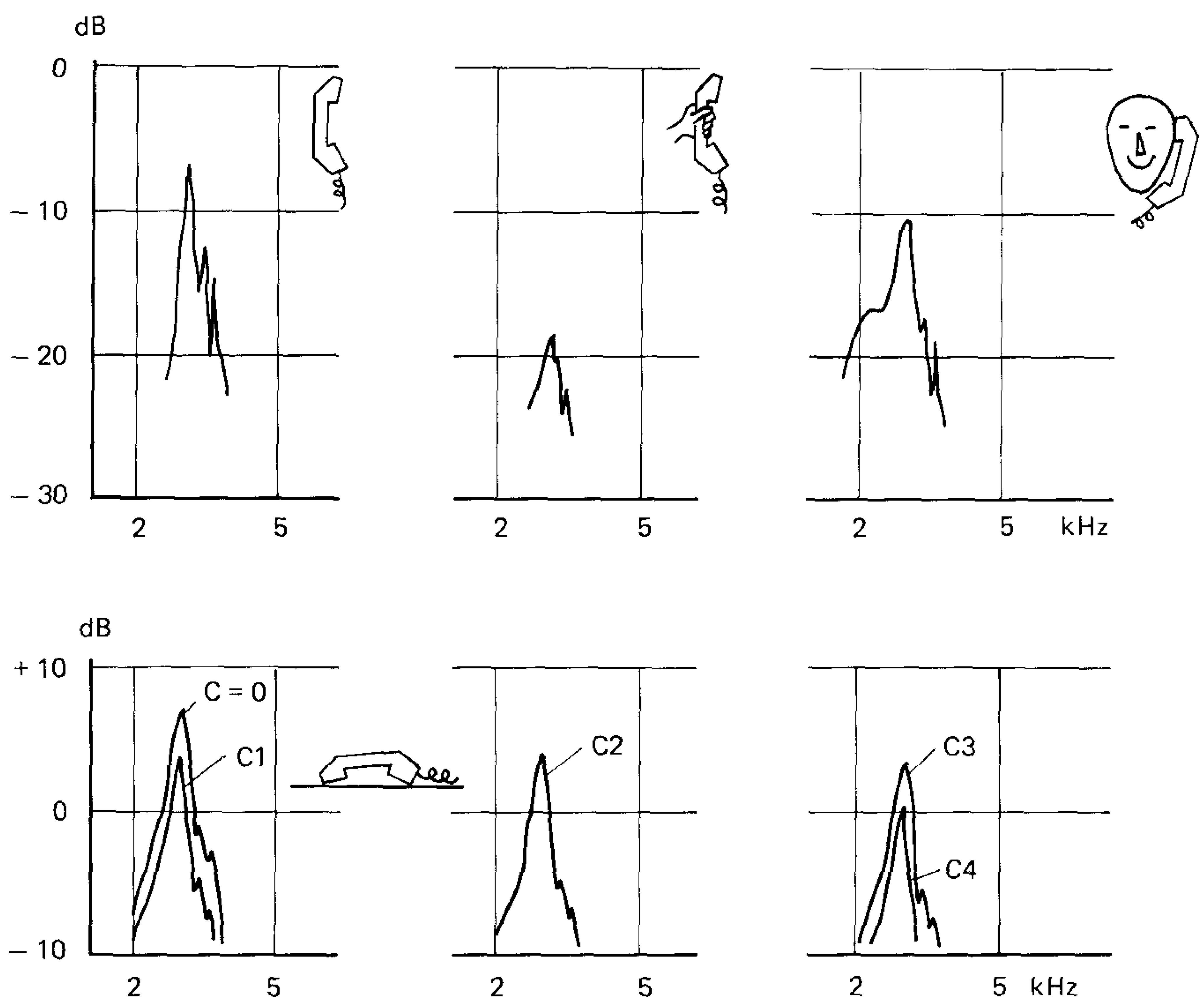


Fig.5. **Upper: ratio between receiver drive signal and microphone pick-up signal as the handset approaches a user**
Lower: Effect of a capacitance C on a frequency-dependent feedback path

difference varies according to frequency when the handset is kept in different positions: in free field, in normal positions on the telephone set, on table with holes parallel to table and on table with holes down.

The last mentioned position will give howling at about 3 kHz, at zero degrees phase difference.

In all examples shown, the set terminal is open and without any line length, if not particularly mentioned.

The telephone sets are chosen to illustrate the different measuring methods, and they are not typical for the Norwegian sets produced today by A/S Elektrisk Bureau.

If the handset is put on the telephone set in its normal position and then gradually lifted, we can see the peaks in the stability responses get lower and the resonances move to other frequencies (Fig.4).

We found that the phase difference between supplied and measured voltage change about three times 360 degrees during the first couple of cm the handset is lifted from the telephone set. The signal are in phase three times, and if the loop gain is sufficient, unstable conditions can occur.

Handset position

In the upper part of Fig.5 is demonstrated how the handset position influences the degree of stability: in free field, vertical in hand and held against the ear.

The lower part indicates the influence of a frequency dependent feedback in the microphone amplifier (a capacitor), C = 0 and C1 to C4 (increasing capacity). The handset is here placed on a table with holes down.

Free field

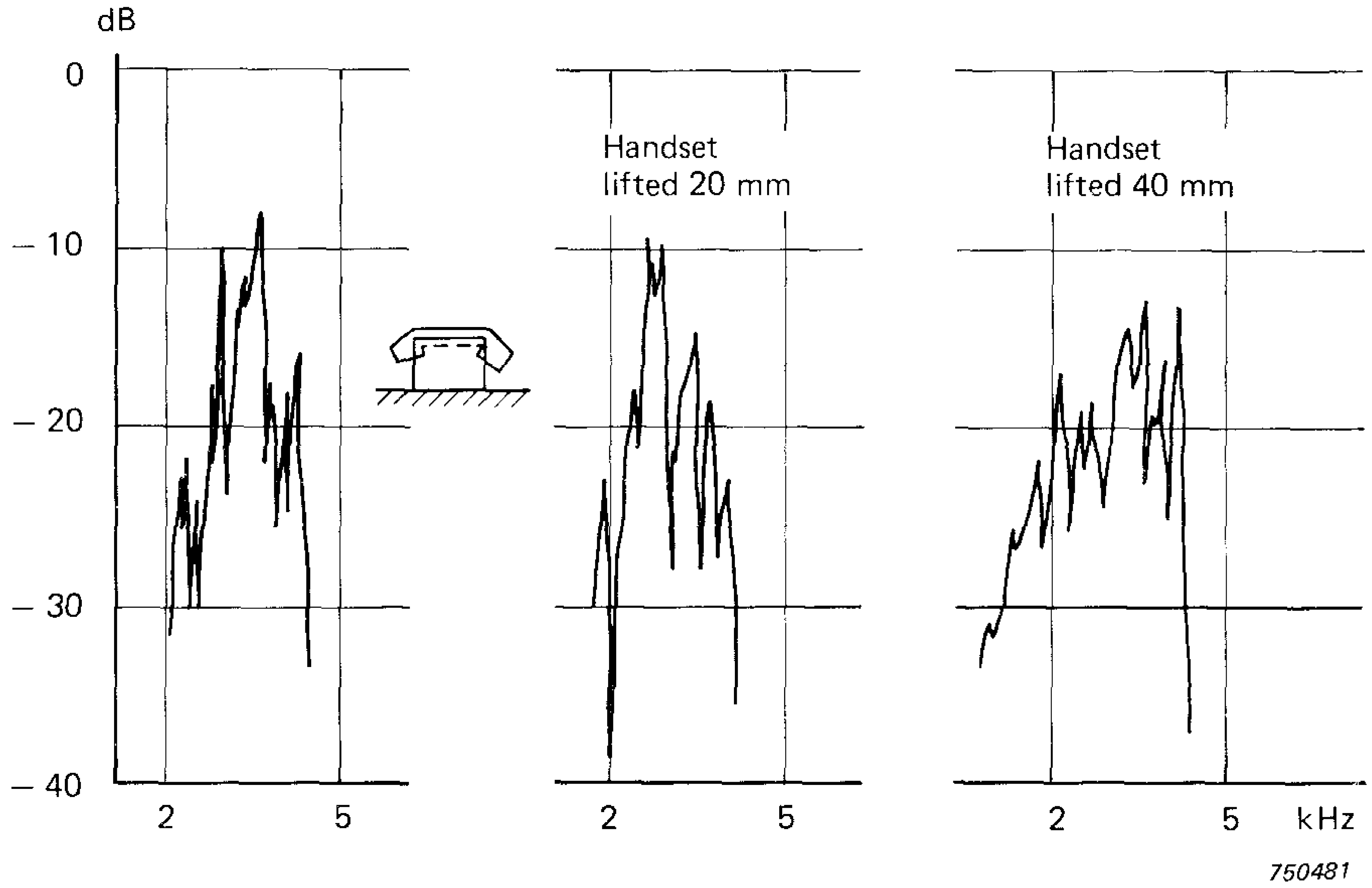
We have also kept the handset position constant, in free field, and varied other factors.

On the upper left in Fig.6 is shown the result of two different types of capsules with the same sensitivity but different frequency responses. The middle curves show the effect of the capacitor in the feedback of the amplifier, and on the right we have two different cord capacities (corresponding to the feedback capacitor).

In the middle response row, the left curves indicate how important the line matching (sidetone) is, here demonstrated with open line and terminated with 600 Ω. The two responses on the right show two different line lengths, zero and one km (open line).

On the lower left, the caps are fastened with different tightness, and on the right, the microphone cap holes are varied.

Studying the mechanical feedback will clarify the need for elastic suspension of the capsules.



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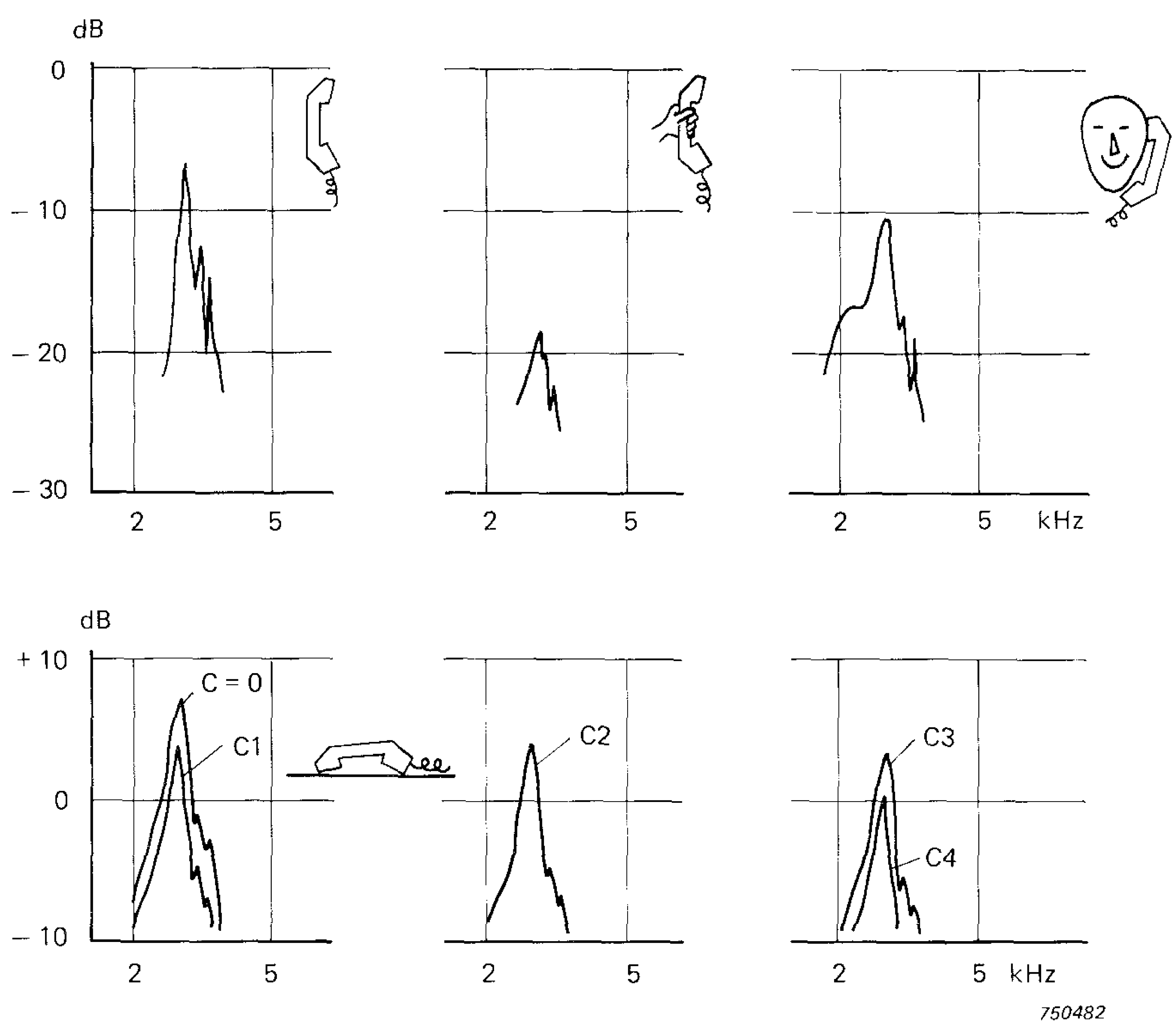

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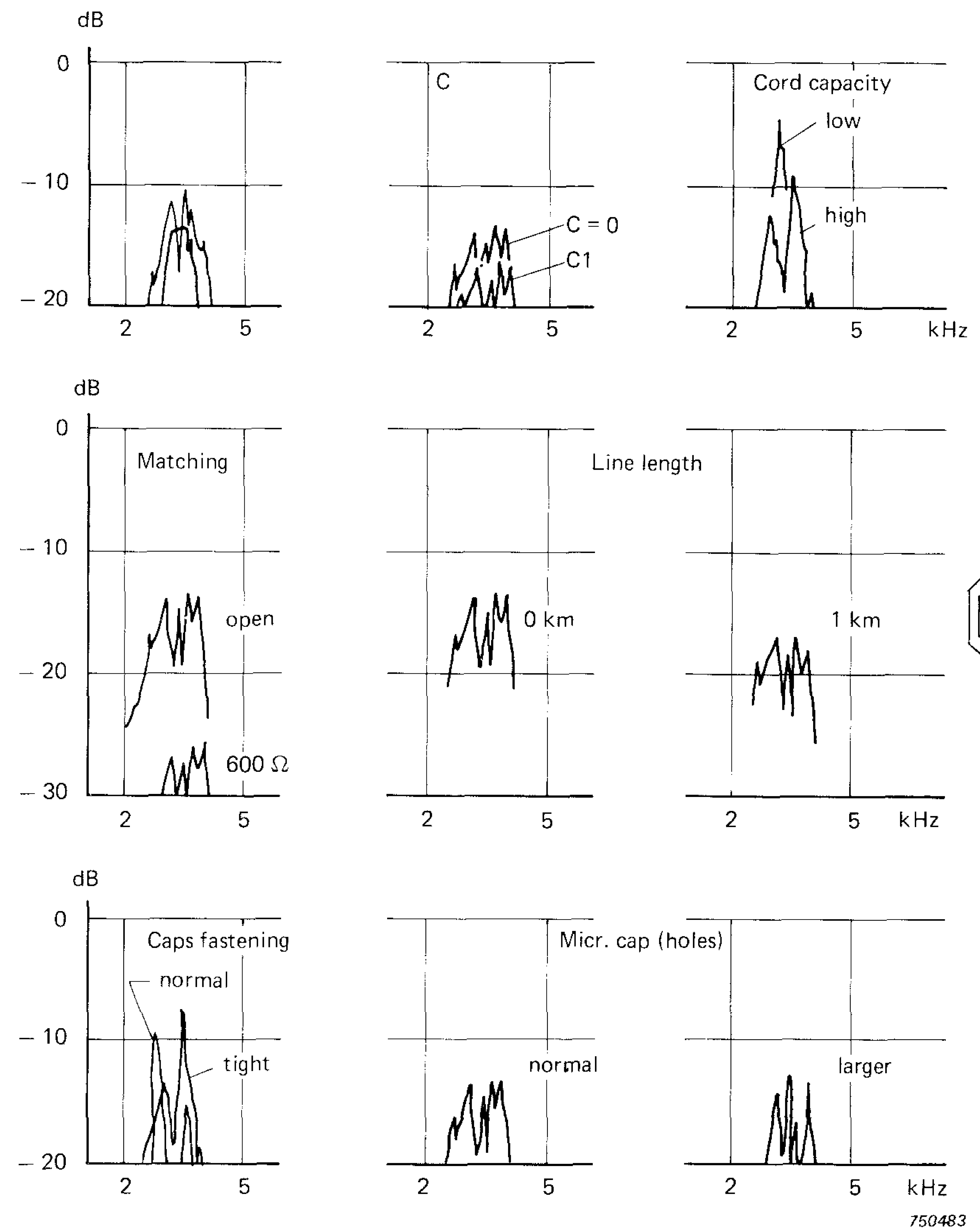


Fig.6. Effects of various parameters on howlback response

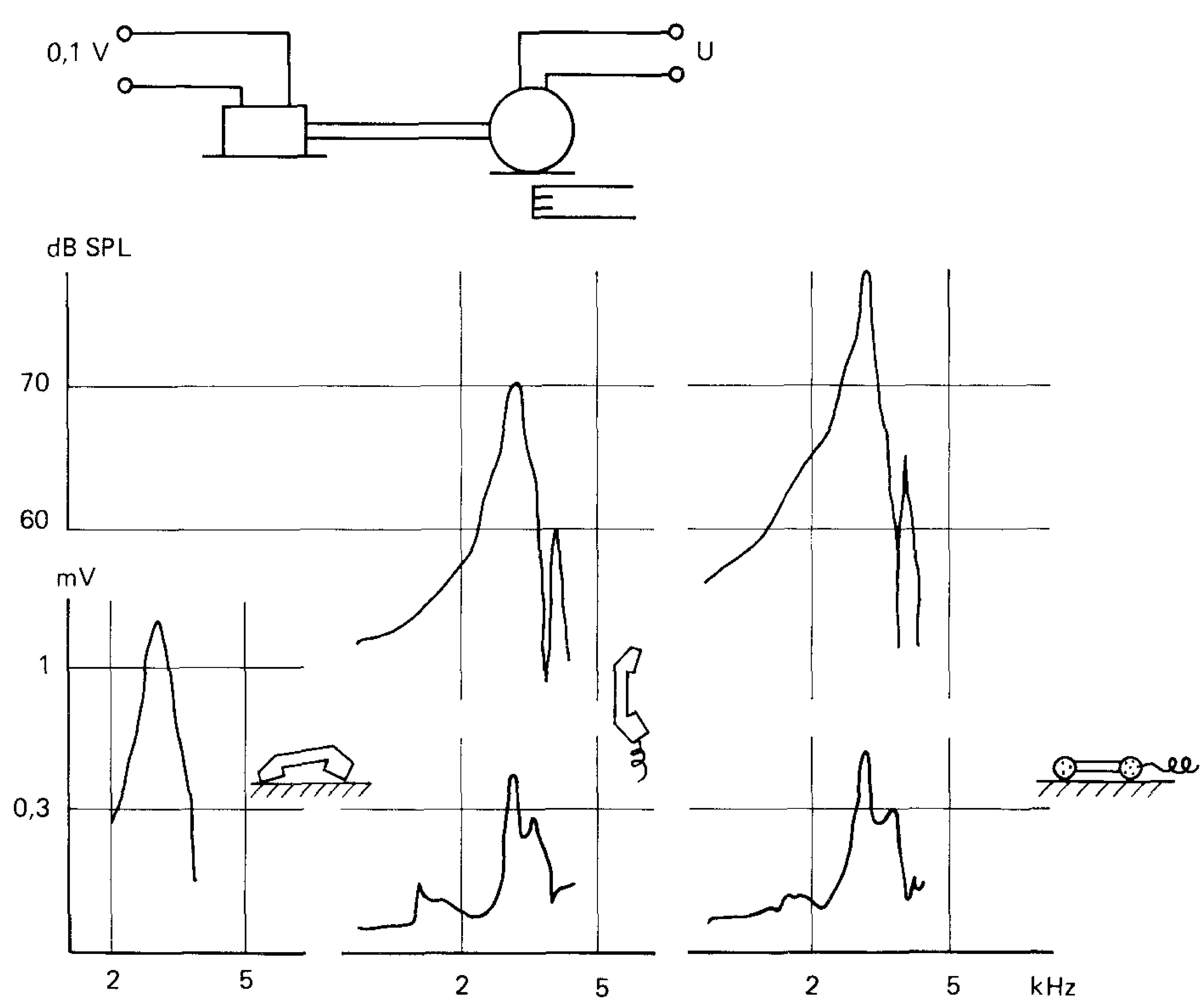


Fig.7. Direct measurement of voltage induced in a microphone output connection when a receiver is driven by a fixed amplitude signal

Measuring method 2

We can directly measure the induced voltage in the microphone when the receiver is driven by a signal (Fig.7). This method does not tell us if there is any chance of howling in the system, but for relative measurements it can be of great interest to use such a simple method. Critical frequencies can be studied in this way. We can also measure the frequency response of the receiver at the microphone entrance.

Below are shown examples of such measurements. On the left, the induced microphone voltage is measured when the handset is placed on a table with holes down. In the middle, the microphone voltage and receiver (loudspeaker) responses are shown when the handset is in free field, and on the right we have the same responses when the handset is placed on a table with holes parallel to the table.

Measuring method 3

A very simple method that can be used e. g. in production control is shown in Fig.8. Varying the line

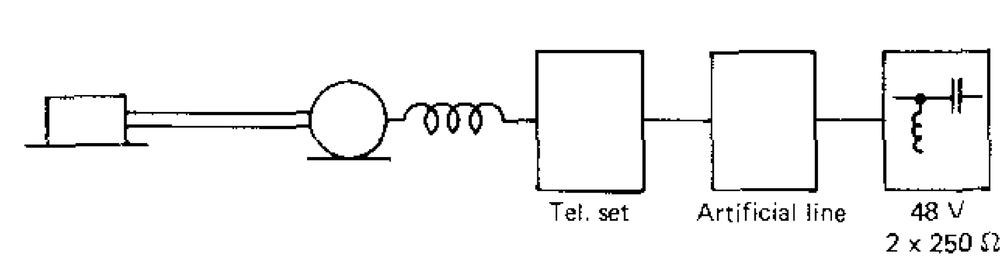


Fig.8. Adjustment of line length to find minimum required to give a howlback-free system

length, this measurement tells us the minimum length that is necessary to give a stable system when the handset is lifted off the telephone set, when it is placed on a table in different positions or held in other ways.

Factors determining the reproducibility and accuracy requirements of telephonometry measurements. Review of some practical experiences

by *I. Salama*

1. Introduction

The intention of this presentation is to discuss the factors, which from the telephone company's point of view determine the accuracy and reproducibility requirements of the reference equivalent measurements.

Let me start by putting a simple question. Why do we have to measure telephone sets? Two answers can be given: we have to check the fulfilment of the transmission plan and we have to check the quality of the telephone sets.

To discuss how these factors determine the accuracy requirements of the measuring equipment, I have to say a few words about the transmission plan of the Finnish telephone network, and the quality control methods used in the Helsinki Telephone Company.

2. The transmission plan

In 1970 a new transmission plan was adopted in Finland. It is based on the CCITT plan a), Recommendation G 121 (p. 21). In this plan the maximum value of the nominal sending reference equivalent of the subscriber system of the local exchange is 9,6 dB (1,1 Np) and the corresponding receiving reference equivalent is 0,9 dB (0,1 Np).

Based on these values there has been a tendency to draw up the reference equivalent requirements of the telephone set, so that less than 3% of the incoming and outgoing calls in a local exchange area will exceed the given values. There is further a desire to limit the lowest reference equivalent of the local connection to a mean value of 2,6 dB (0,2 Np). Based on these facts the reference equivalent requirements for the telephone set as seen in Figure 1 are derived.

The transmission characteristics of a set are determined by connecting the set to a subscriber cable of 0,5 mm and 37 nF/km, and to a feeding-bridge of 60 V and 2 × 500 Ω in such a way that the mean value of a suitably large sample of a consignment must fulfil the specifications in Figure 1. The length of the cable is 0 to 5 km. The standard deviation shall not exceed at any length the value 1,3 dB (1,5 dNp) on sending and the value 0,9 dB (1 dNp) on receiving. The measurements are made with an objective reference equivalent measuring equipment (OBDM).

These requirements imply that telephone sets with automatic level control have to be used. On the receiving side the cable attenuation must be compensated completely, whereas on the sending side feeding loss and only a part of the cable attenuation must be compensated.

The experience has shown that the combined reference equivalent of the telephone set and the local line is approaching the allowed maximum value mainly on long subscriber lines. If the main objective is that only 3% of the calls of the entire exchange area will exceed the limits 9,6 and 0,9 dB, a bigger exceeding percent value for subscribers far from the exchange may be allowed.

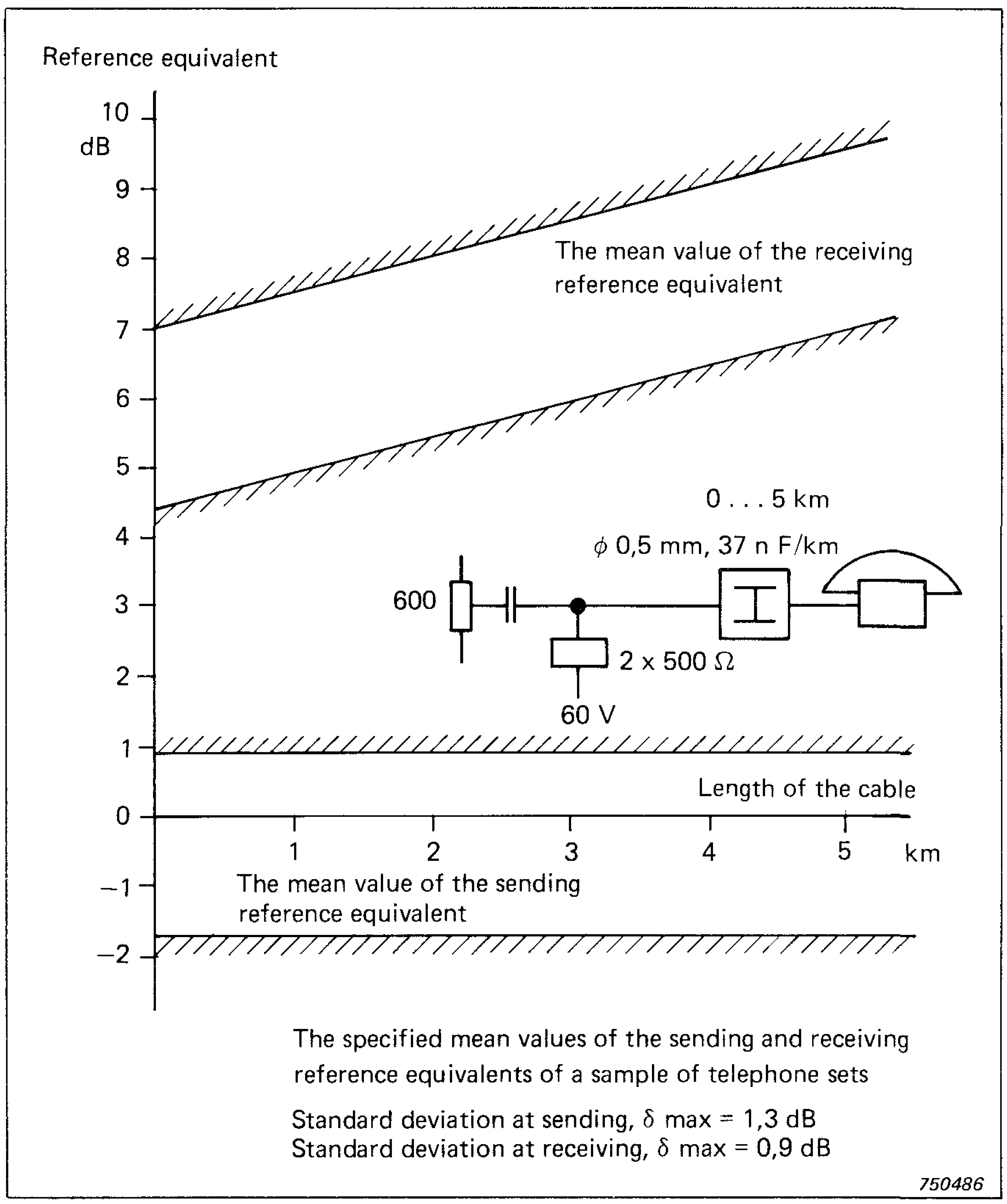


Fig. 1.

In Figure 2 a typical mean value curve of a telephone set is shown. It is supposed that the mean value at a distance of 5 km is exactly 9,6 dB. It is further supposed that the standard deviation is exactly the allowed 1,3 dB. The upper end of the curve has been substituted by steps of 1 km. Over both steps there are three numbers. The numbers shown come from a large investigation made in Finland some years ago. The lowest number indicates the percentage of subscribers in the corresponding 1 km region.

The middle number indicates percentage of telephone sets exceeding 9,6 dB (assuming normal distribution). The uppermost number indicates the percentage of the subscribers exceeding the allowed limit 9,6 dB. When adding the last two numbers it is found that the limit of 9,6 dB is exceeded by about 3,8% of the subscribers.

In reality the situation is, however, not so simple. The mean value curve and standard deviation are varying from one manufacturing lot to the other. However, with this method we can roughly estimate the percentage of the subscribers who will exceed the allowed limit.

3. Quality control

Helsinki Telephone Company buys about 50 000 telephone sets per year. The telephone sets are delivered in lots of about 800 pieces. Our Quality Control performs a sampling inspection of the telephone sets, where the most important functions of the telephone sets are tested and the reference equivalents are measured objectively with measuring equipment designed according to K. Braun's principle. The method of inspection is mainly the inspection by attributes whereas the reference equivalent is tested "by variables". The reference equivalents are measured with cable lengths of zero, 2 and 5 km (diameter 0,5 mm). Mean value and standard deviation is calculated for each line length. However, in addition to this, if an individual reference equivalent differs more than 4 dB on sending and more than 3 dB on receiving from the mean value requirement, the telephone set is considered defective and the inspection by attributes is applied. These values are excluded in calculations of mean value and standard deviation.

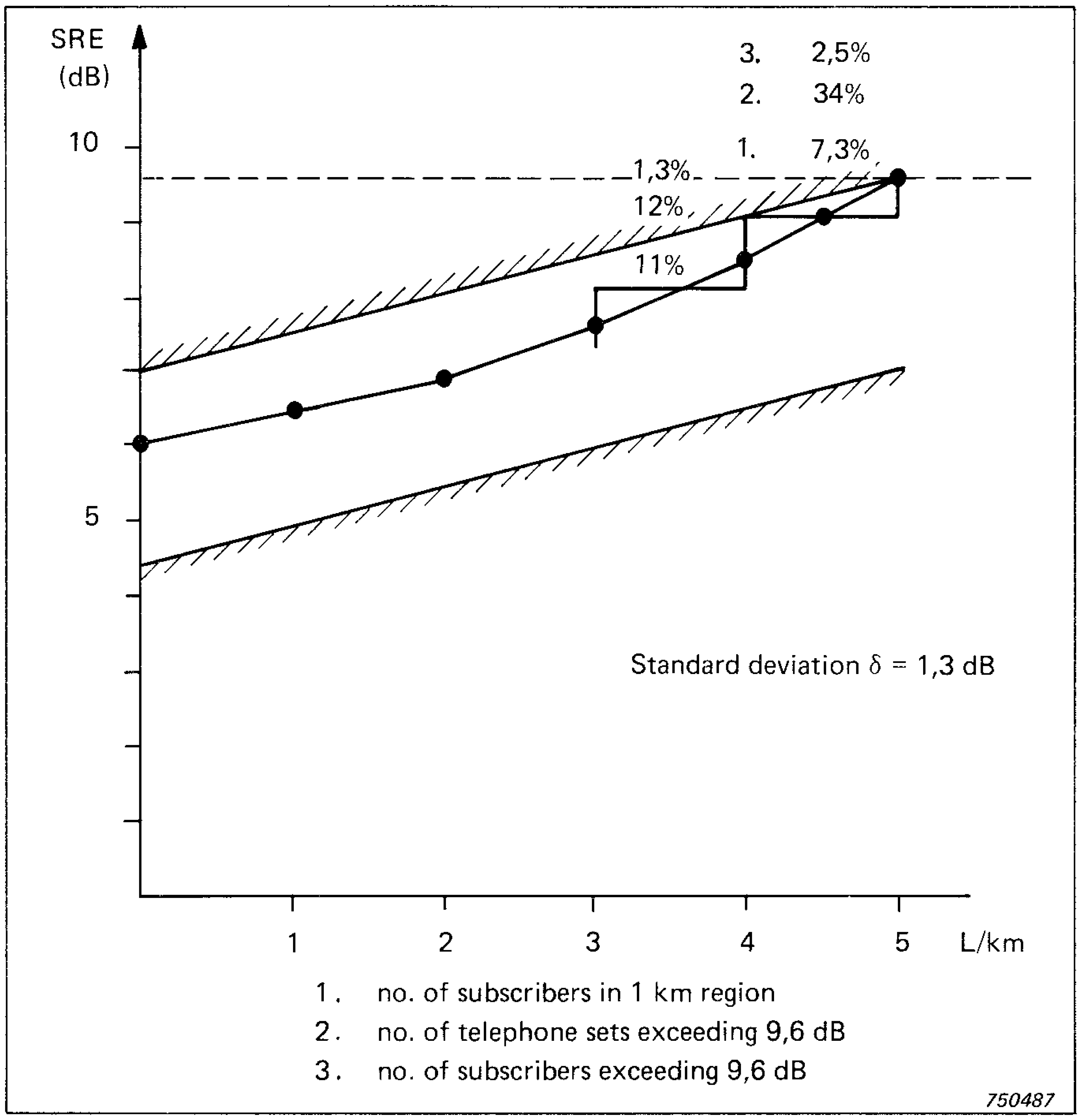


Fig.2.

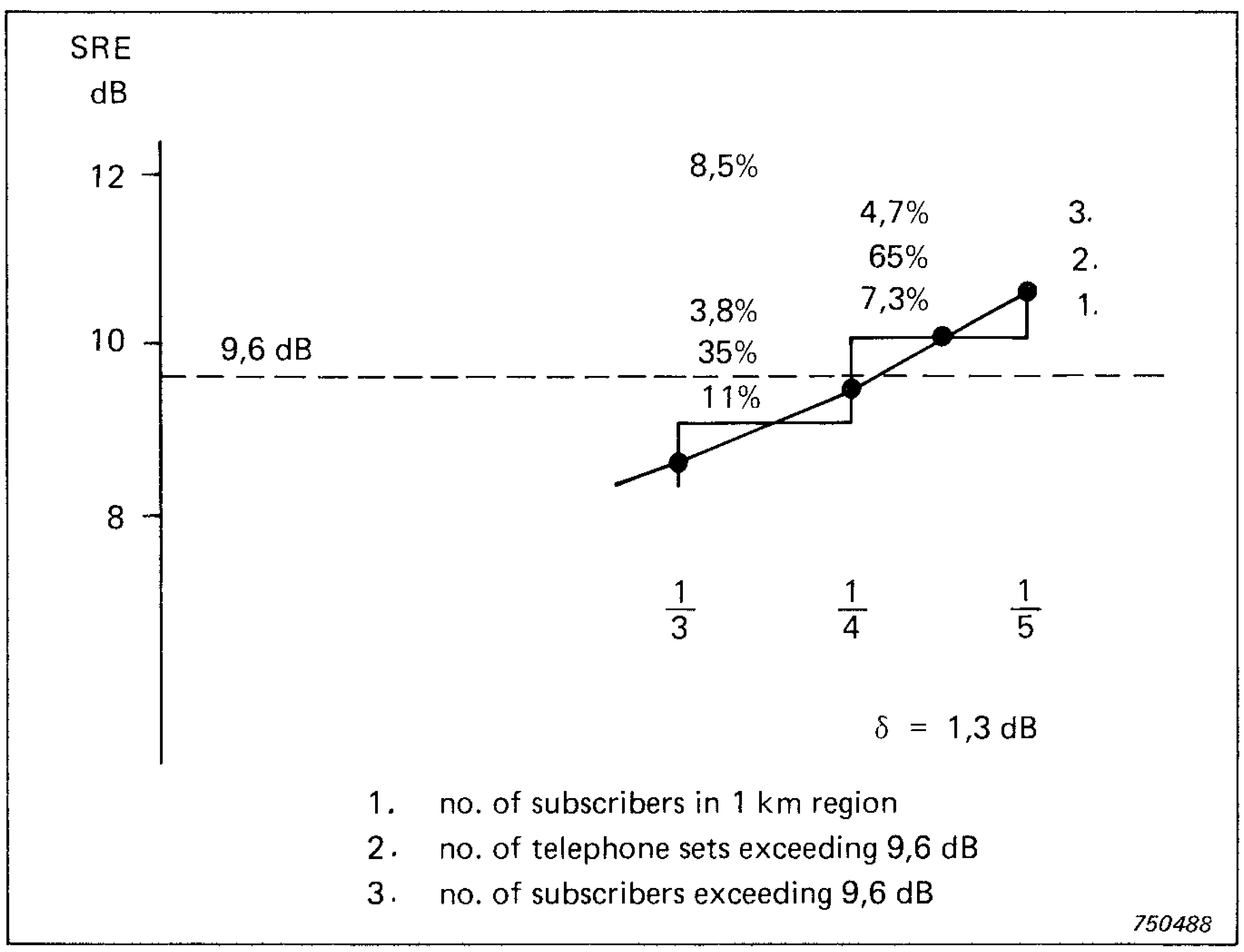


Fig.3.

4. The accuracy requirement of a measuring equipment

The influence of the accuracy of a measuring equipment can be examined according to the same method as above.

Let us assume that the measuring equipment reads incorrectly 1 dB in the direction that the real reference equivalent is 1 dB higher than the measured value. In Figure 3 the same situation as in

Figure 2 is shown, but now 1 dB higher. Again, it is easy to calculate from the reference equivalents and subscribers distribution given in Figure 3 that the percentage of the subscribers exceeding 9,6 dB is now 4,7 + 3,8 = 8,5%. If we further assume that the error of the measuring equipment is 2 dB, an exceeding percentage of 14% is obtained. In addition to this the subscribers located nearer than 3 km must now be taken into account.

In practice the mean value of the incoming telephone sets is varying between the allowed limits from one lot to another. However, at 5 km, the mean value is more often approaching the upper than lower-limit. It can thus be estimated that the exceeding percentage will be moderate, if the inaccuracy is about 1 dB. An inaccuracy of 2 dB begins to be critical from the standpoint of fulfilment of the transmission plan.

Let's compare the result with the measuring accuracy of the other parts of telephone connection. The attenuation is usually measured using level meters and signal generators. Nowadays, very accurate level meters and stable generators are available, but very often the accuracy of the measuring equipment in use is only about 0,5 dB. In addition to this we must notice other varying factors, for example on carrier frequency connections about 1 dB must be reserved for variation with time of the loss. Thus we can conclude that the other parts of the telephone connection cannot either be determined with greater accuracy than 1 dB.

5. Other factors affecting the accuracy of the measured results — the reproducibility of the results

As mentioned above, the mean value and standard deviation of the incoming lots of telephone sets are varying. This is partly caused by component parameters and productional deviation. Total deviation is also increased by variations of environmental factors, especially temperature and humidity.

To enable the comparison of the results of the different lots with each other, the reproducibility should be as good as possible. To investigate the reproducibility of the reference equivalent values measured objectively, we made the following test. 10 telephone sets equipped with carbon microphone and 5 telephone sets equipped with linear microphone were chosen. The sending reference equivalent of them was measured on 20 successive days and the mean value was calculated every day. The results can be seen in Figures 4 and 5. From these figures it is immediately noticed that the mean values for carbon microphones may vary widely.

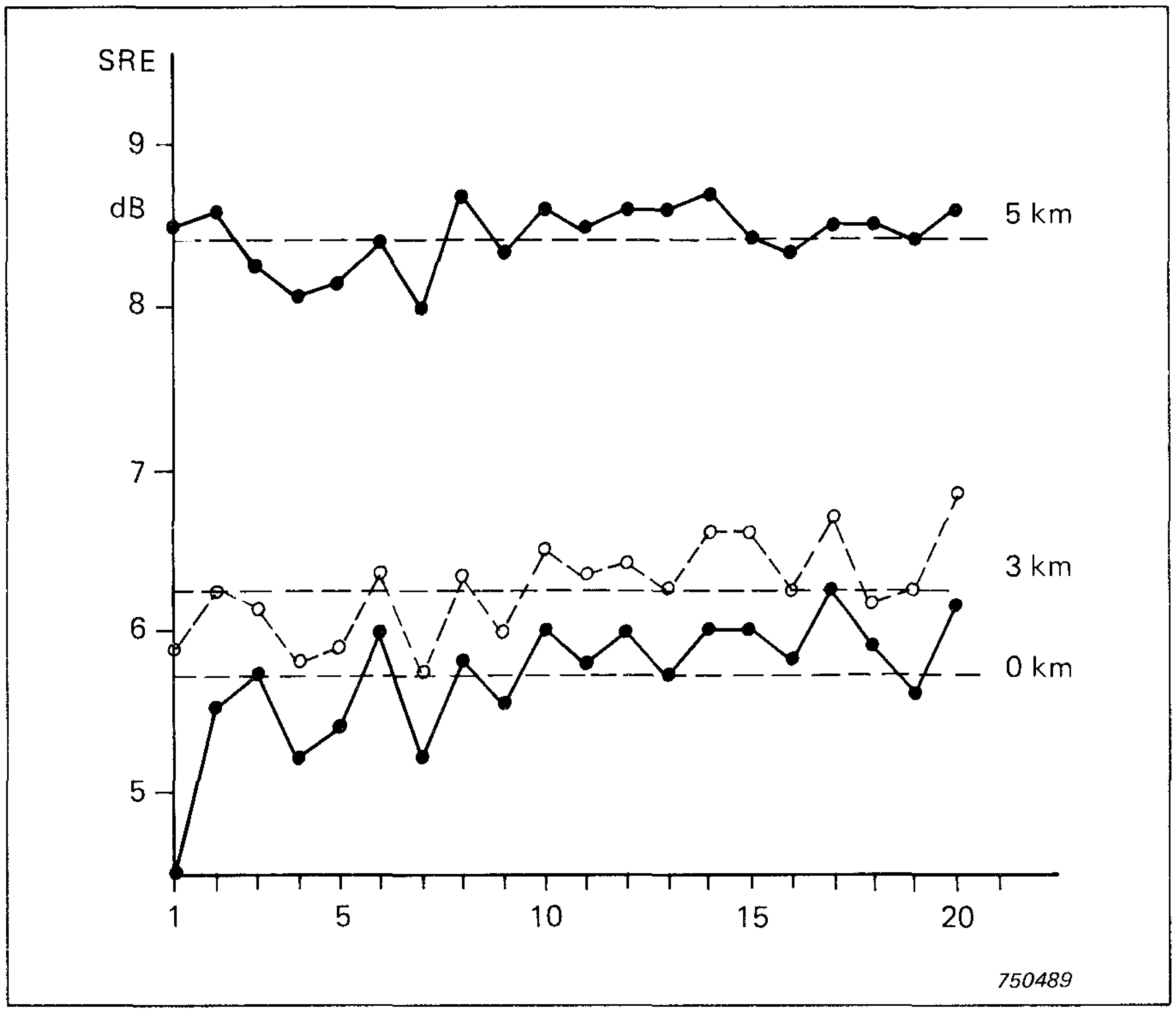


Fig. 4.

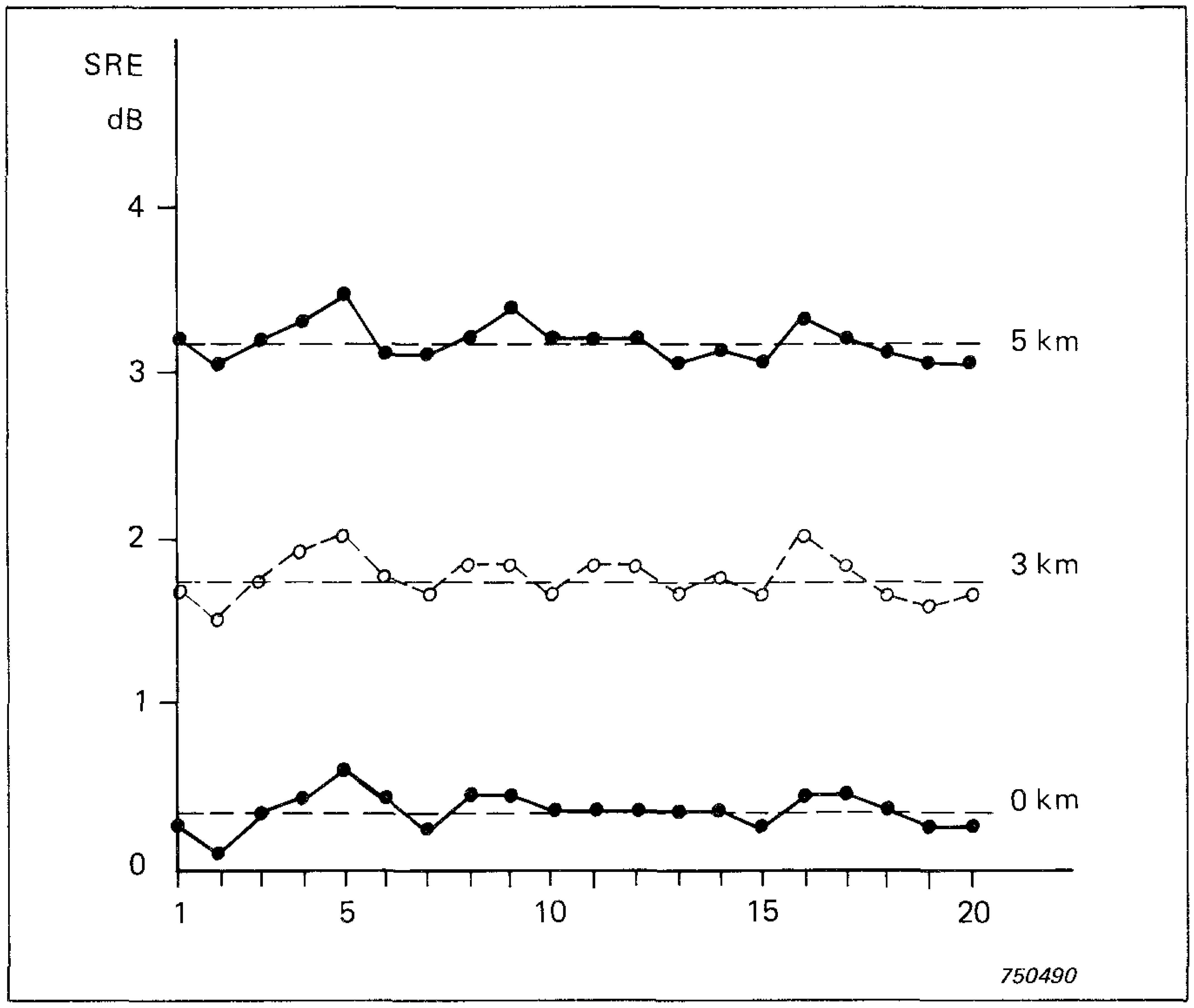


Fig. 5.

Telephone sets equipped with linear microphones vary considerably less. It is difficult to say, how this variation should be divided between telephone sets and measuring equipment. However, it is evident that for stable telephone sets the reproducibility of the results is acceptable if the deviation is of the magnitude 0,5 dB.

It should be possible to achieve the same reproducibility with different measuring equipment. Our experience has shown that if the difference between the mean values obtained by the manufacturer and the customer is more than 1 dB, it will be difficult to decide who has got the correct value. Without any further examination it can be concluded that results obtained using different measuring equipment must be within the accuracy limits.

6. Practical quality control

As we know that reproducibility of the results of the carbon microphone telephone sets is bad, we cannot immediately return a lot of telephone sets, if the mean value slightly exceeds the permitted limit. Our Quality Control logs continuously the mean value and standard deviation of the incoming lots in the manner seen in Figures 6 and 7. Steps are taken against the supplier, if the mean value remains continuously outside the limit or if the mean value deviates considerably (1 dB) from the allowed limit.

The standard deviations (maximum 1,3 dB on sending and 0,9 dB on receiving) are also very good quality criteria. If the standard deviation suddenly increases, it is usually a sign of some production error, usually when assembling the carbon microphone or receiver.

It happens, however, sometimes that we have to discard the lot because of our inspection. Our inspection system enables us to prove to the manufacturer that the returning is justified.

7. Conclusions

I have tried to describe the accuracy requirements of the objective reference equivalent measuring equipment implied by transmission plan and quality control. The conclusion is that the accuracy ought to be about 1 dB (maximum 1,5 dB) regardless of the principle of the measuring equipment. A different subscriber distribution and different requirements for reference equivalents might lead to a different accuracy requirement, but I think that our final result is quite realistic as it is based on both examination above and practical experiences.

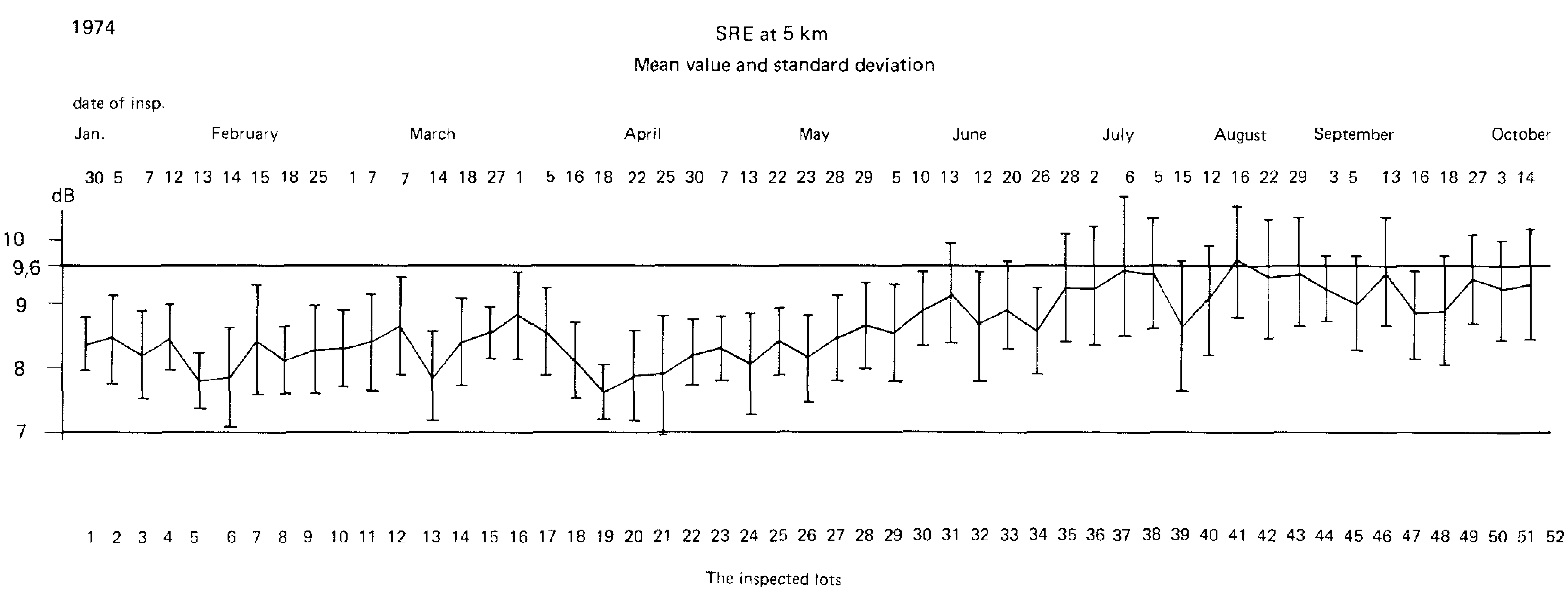


Fig.6.

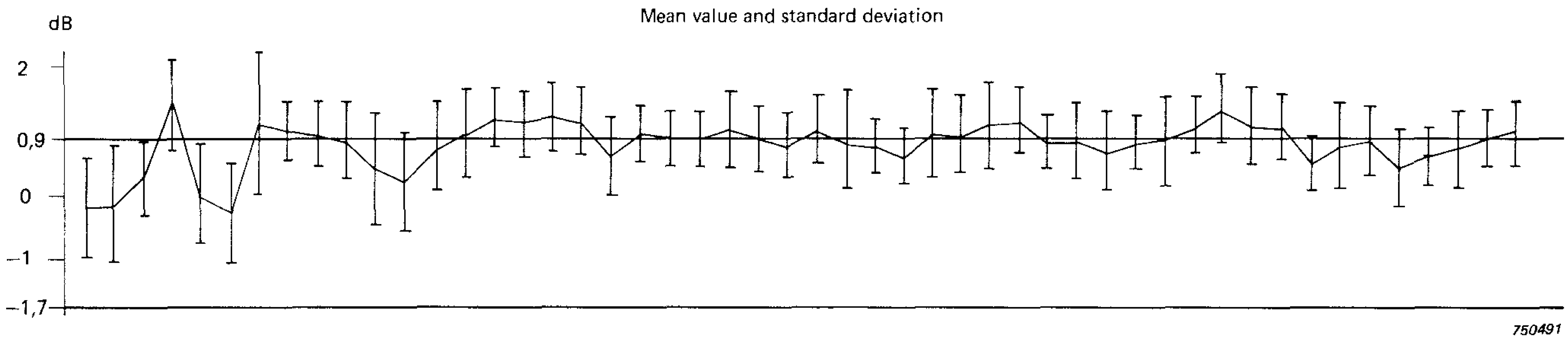


Fig.7.

Frequency response measurement on the telephone sets 73D, F68 and 47E connected via a telephone line

by *S. A. Jäger and P. Schnack,*
Jydsk Telefon A/S.

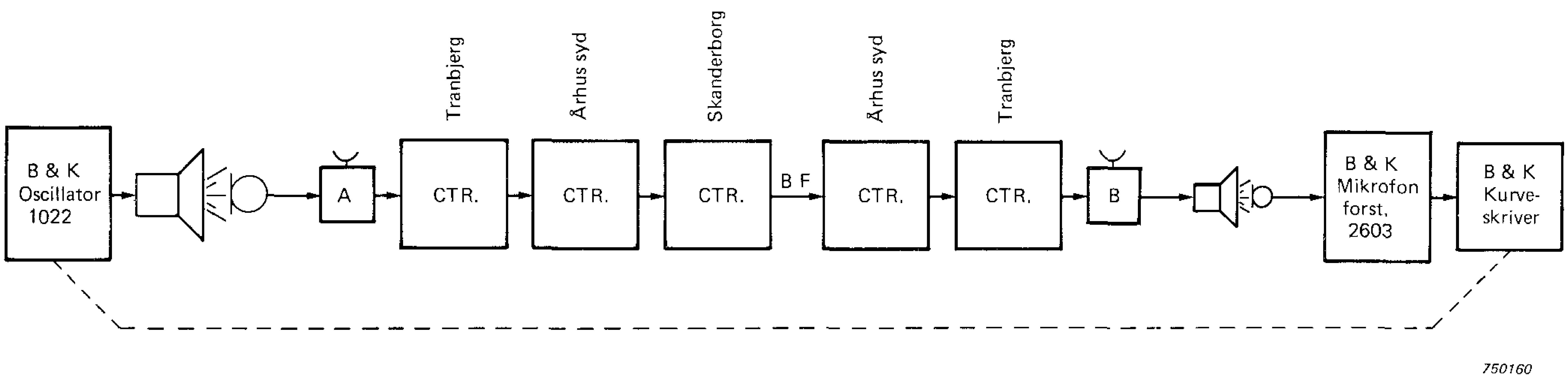


Fig. 1. The measured chain

Introduction

From the State Audiology Centre in Århus, Denmark, the Danish telephone company J.T.A.S. received a request regarding the frequency response and sound pressure levels to be expected from normal telephone connections in Denmark. To answer this question experiments were made with commonly used telephone sets and an arbitrarily chosen trunk connection.

The Measuring Arrangement

The trunk connection was set-up over Tranebjerg — Århus South — Skanderborg — Århus South and *back to Tranebjerg, involving five* telephone exchanges. Measurements were made with the B & K equipment shown in Fig. 1.

Various separate calls were made using three different types of telephone set, and for each call frequency response curves were recorded. A comparison of the results shows that the connection itself was almost identical in response from call to call. The curves shown in this report may therefore be regarded as typical for the particular trunk connection chosen for the experiments.

Important Note

At frequencies below 200 Hz the response shown on the diagrams are not correct due to excessive distortion from the Artificial Voice signal.

Transmission Line Measurements

Fig. 2 shows the frequency response of the "pure" telephone-connection Tranebjerg — Århus South — Skanderborg — Århus South — Tranebjerg, loaded by a 600 Ω resistance in each end. As the connection between Skanderborg and Århus South is of the carrier frequency type bandwidth limitations are present. These can be clearly seen from Figure 2 (bandwidth: 250 Hz — 3400 Hz). The peaks and valleys occuring in the 1000 Hz to 3400 Hz region indicate artificial (Pupin) loading of the line.

Measurements with Different Telephone Sets

In the following figures, various frequency responses are shown, including sender (A) set and receiver (B) set connected via the above described line connection, see also Fig. 1. A brief outline of the characteristics of the telephone sets used in the experiments is given in Appendix A.

Typical response using the telephone set 73D as transmitter (A) as well as receiver (B) i. e. **A: 73D — B: 73D** is shown in Fig. 3.

Note that over the complete frequency range 300 Hz — 3400 Hz the received sound pressure level is of the order of 80 dB, which, according to several investigations is the *preferred mean sound pressure* level for normal connections.

Typical response using the telephone set F68 as transmitter (A)

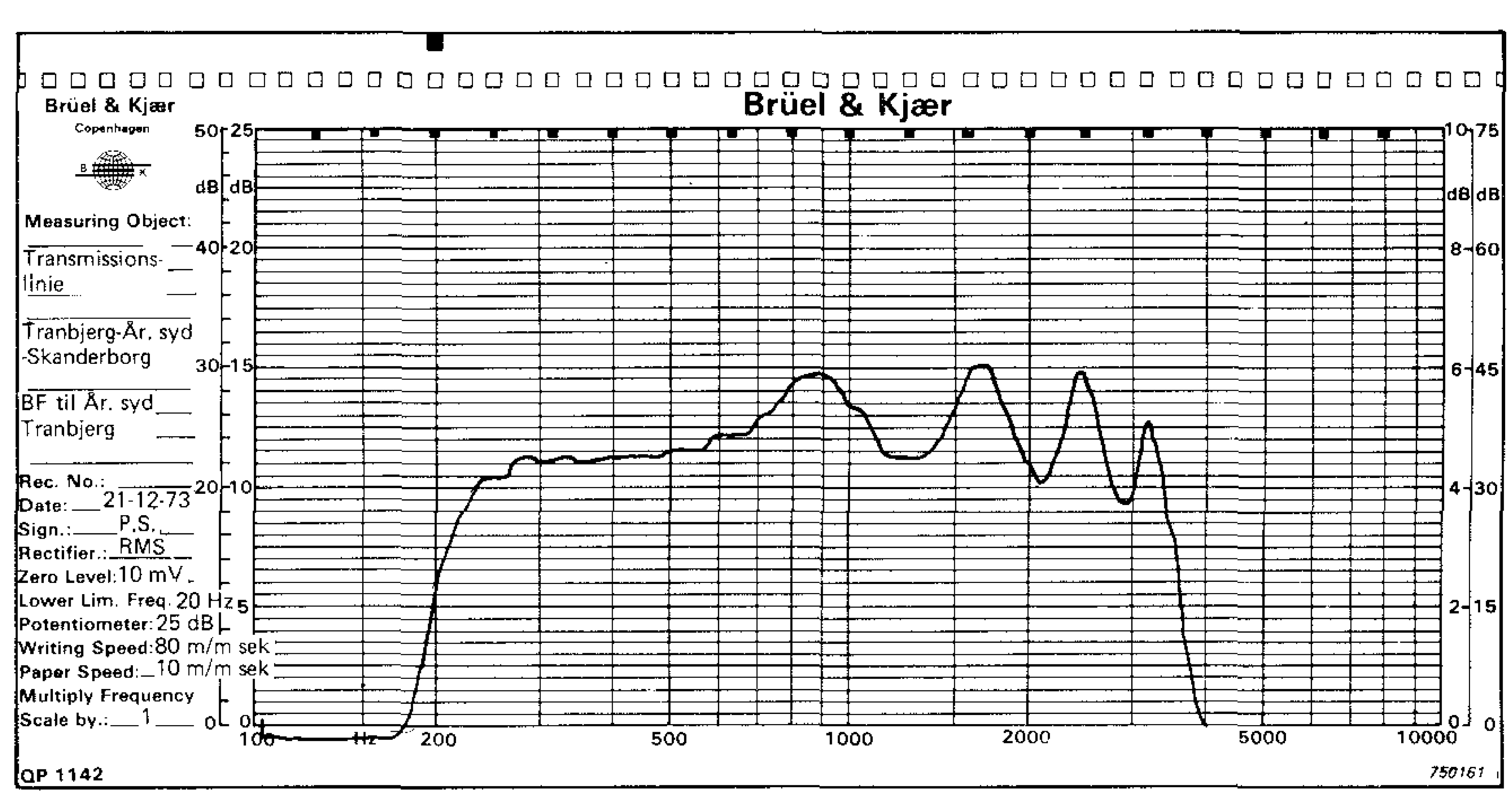


Fig. 2. Characteristic frequency response of the plain transmission line

and the set 73D as receiver (B), i. e. **A: F68 — B: 73D** is shown in Fig.4.

Here again, the received sound pressure level is of the order of 80 dB over the complete frequency range 300 Hz — 3400 Hz. The average pressure level is, however, somewhat lower than that shown in Fig.3. This is because the telephone set F68 has a "weaker" transmitter than the 73D set.

Typical response using the telephone set 47E as transmitter (A) and the set 73D as receiver (B), i. e. **A: 47E — B: 73D** is shown in Fig.5.

The received sound pressure level is somewhat lower than 80 dB over the complete frequency range 300 Hz — 3400 Hz, as the transmitter in the telephone set 47E is "weaker" than that in the 73D set, Fig.3.

Typical response using the telephone set 47E as transmitter (A) and the set F68 as receiver (B), i. e. **A: 47E — B: F68** is shown in Fig.6.

It is seen that in the frequency range 300 Hz — 1000 Hz, the received sound pressure level is of the order of 75 dB, while in the range 1000 Hz to 3400 Hz a received sound pressure level of some 82 dB is obtained. This is due to the combination of the somewhat "weak" transmitter in the 47E set and the considerable frequency nonlinearity of the receiver in the F68 set.

Typical response using the telephone set F68 as transmitter (A) as well as receiver (B), i. e. **A: F68 — B: F68** is shown in Fig.7.

Here the received sound pressure level is somewhat below 80 dB in the frequency range 300 Hz to 1000 Hz. However, again the received sound pressure level in frequency range 1000 Hz to 3400 Hz is in the region of 82 dB.

From this and foregoing figure it may thus be concluded that the telephone set F68 contains a relatively good transmitter, and that it receives low frequency signals poorly.

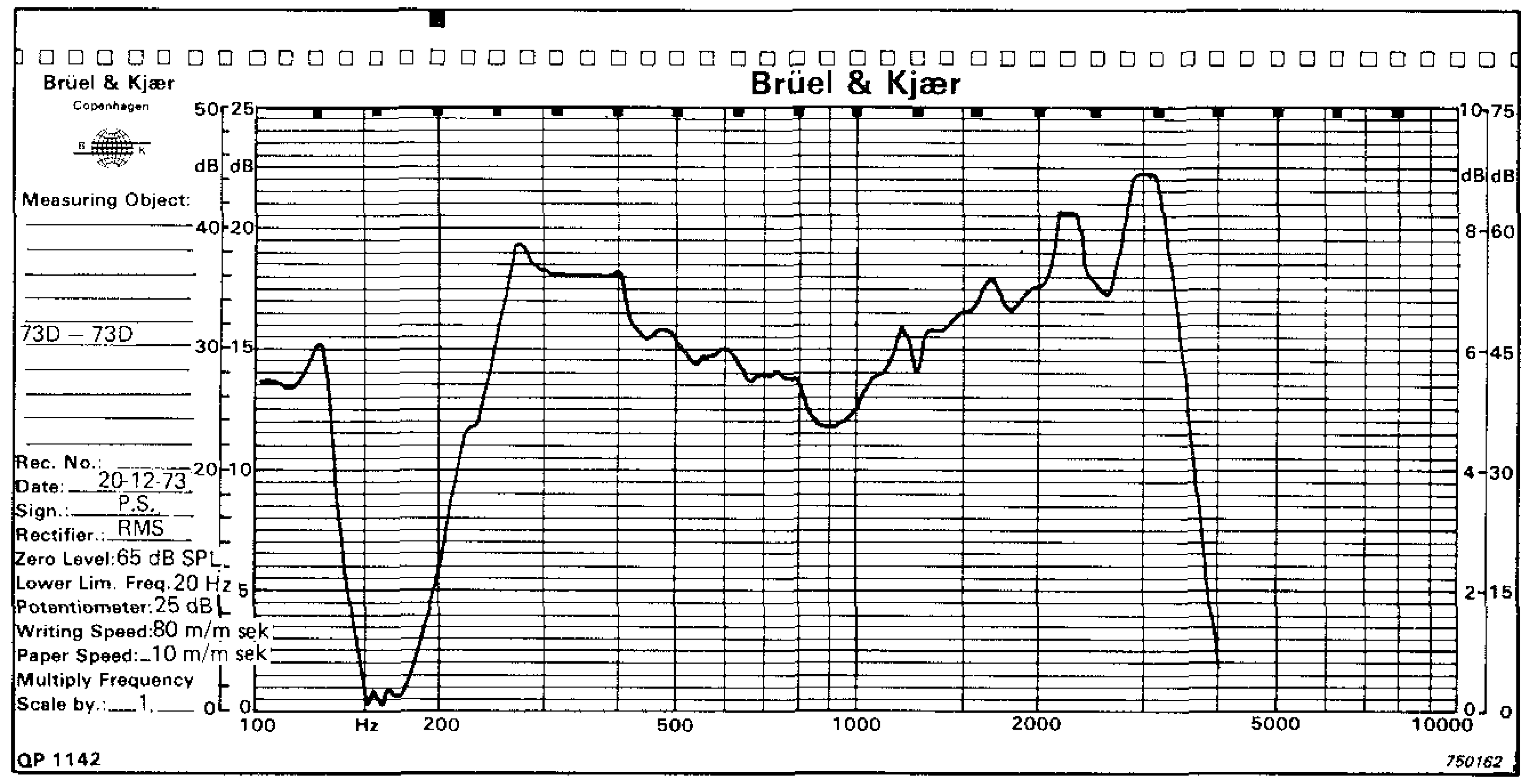


Fig.3. Telephone 73D transmitting to 73D

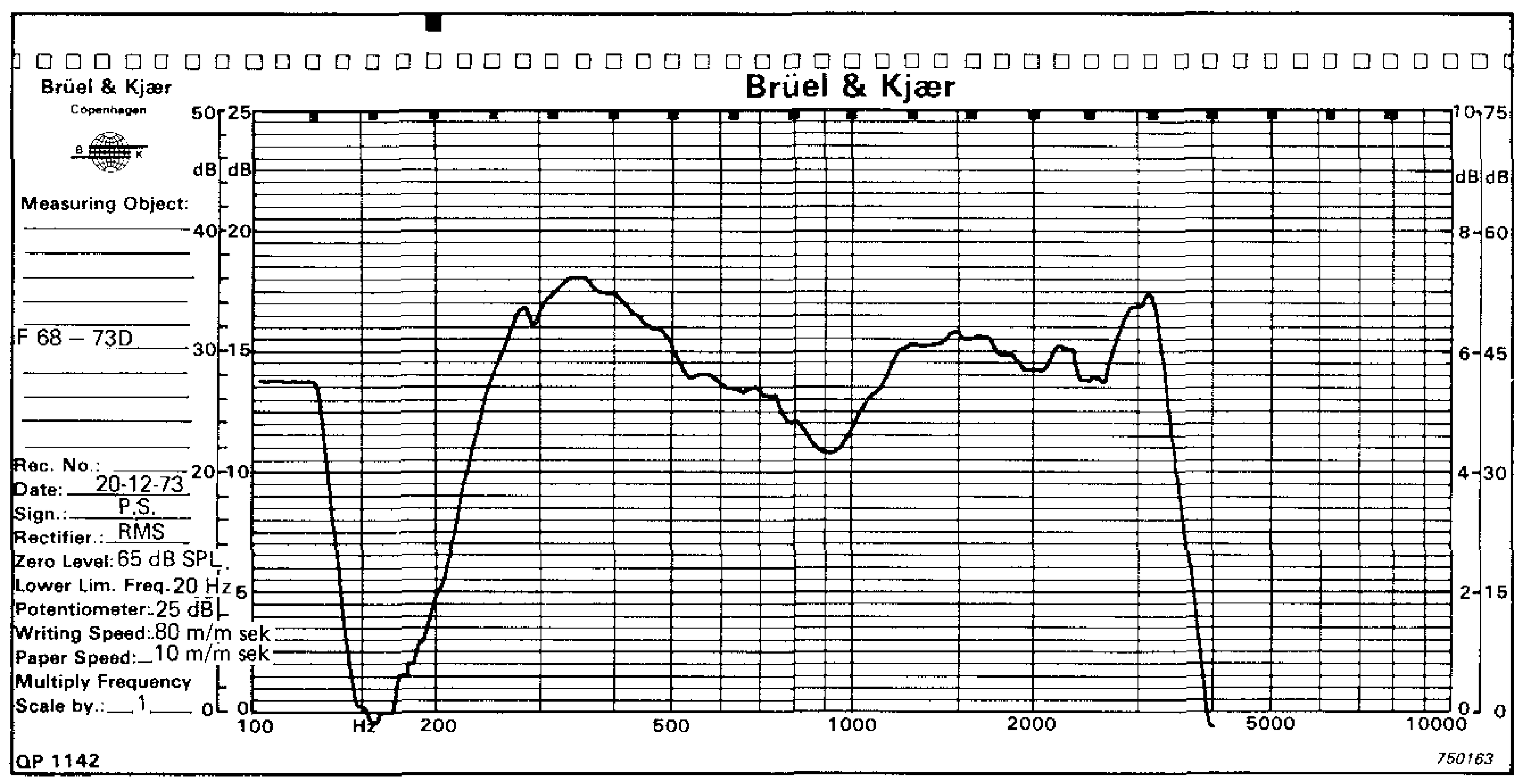


Fig.4. F68 to 73D

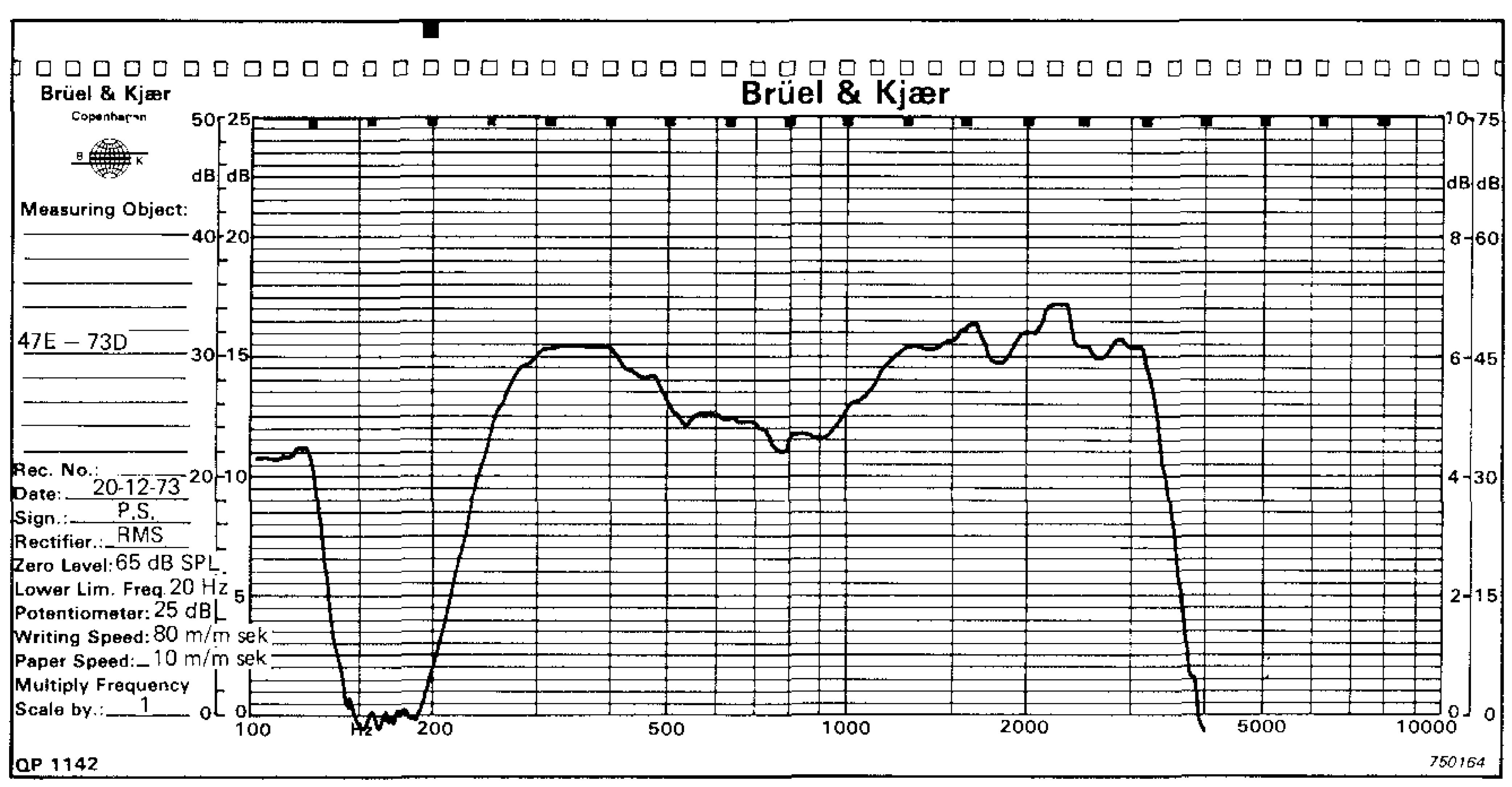


Fig.5. 47E to 73D

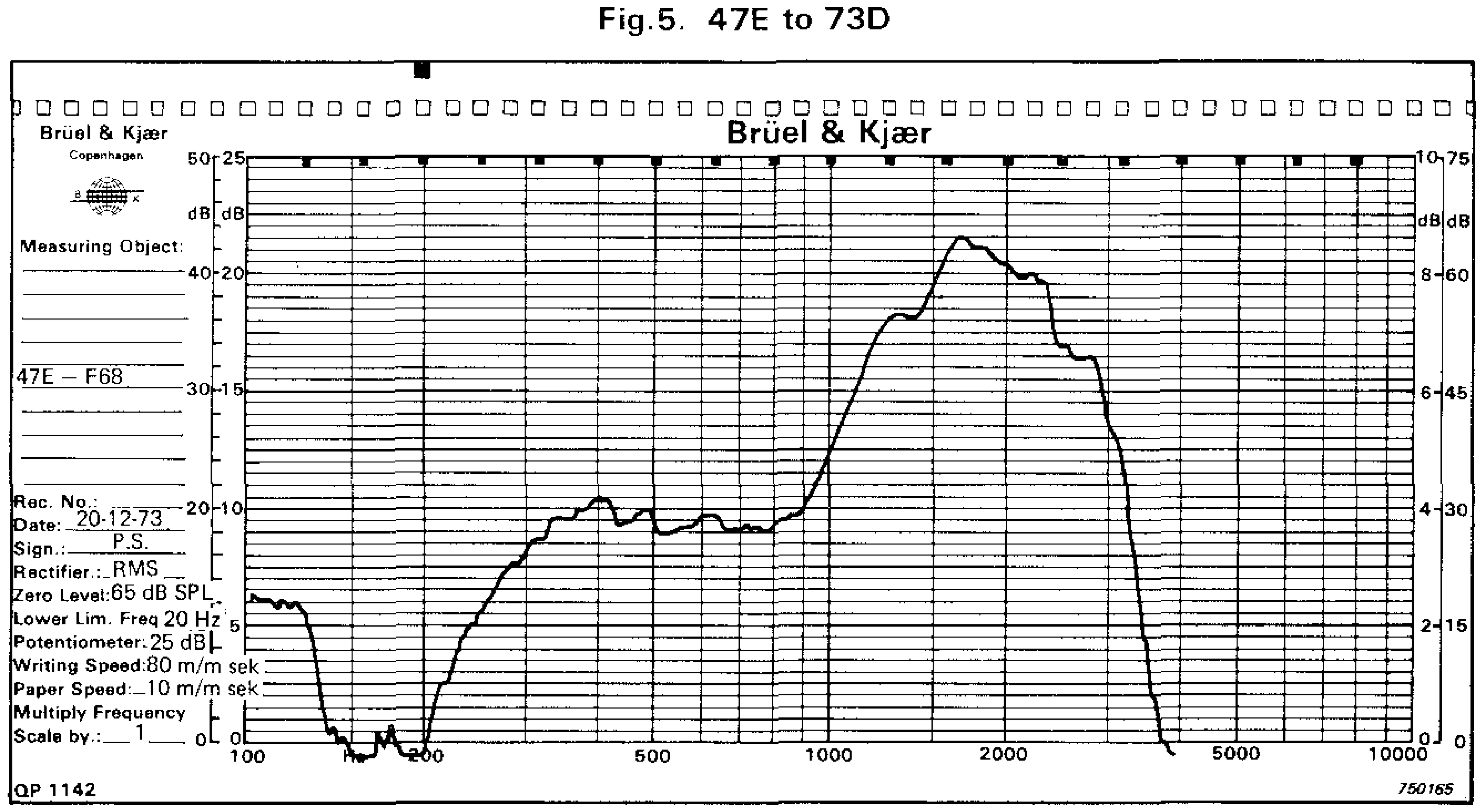


Fig.6. 47E to F68

Typical response using the telephone set 73D as transmitter (A) and the set F68 as receiver (B), i. e. **A: 73 D — B: F68** is shown in Fig.8.

Once again, the poor receive characteristics of the F68 apparatus results in a response with a relatively large frequency nonlinearity. In the region 300 Hz — 1000 Hz the received sound pressure level is of the order of 77 dB, while in region 1000 Hz to 3400 Hz it is approximately 84 dB. The overall received sound pressure level is, however, somewhat larger than that indicated in Figs.6 and 7 due to the fact that the transmitter in the 73D set is stronger than those used in the 47E as well as in the F68 sets.

Typical response using the telephone set 73D as transmitter (A) and the set 47E as receiver (B), i. e. **A: 73D — B: 47E** is shown in Fig.9.

The received sound pressure level is here somewhat above 80 dB over the complete frequency range 300 Hz to 3400 Hz, as the set 73D contains a relatively strong transmitter, and the 47E set receives well. The receiver in the 47E apparatus does, although not too pronounced, show reception properties better in the frequency range above 1000 Hz than below 1000 Hz.

Typical response using the telephone set F68 as transmitter (A) and the set 47E as receiver (B), i. e. **A: F68 — B: 47E** is shown in Fig.10.

It is seen that the received sound pressure level is around 80 dB over the complete frequency range 300 Hz to 3400 Hz, although considerable frequency nonlinearity is present.

Typical response using the telephone set 47E as transmitter (A) as well as receiver (B), i. e. **A: 47E — B: 47E** is shown in Fig.11.

Here the received sound pressure level in the frequency range 300 Hz — 1000 Hz is approximately 76 dB, while in the frequency range

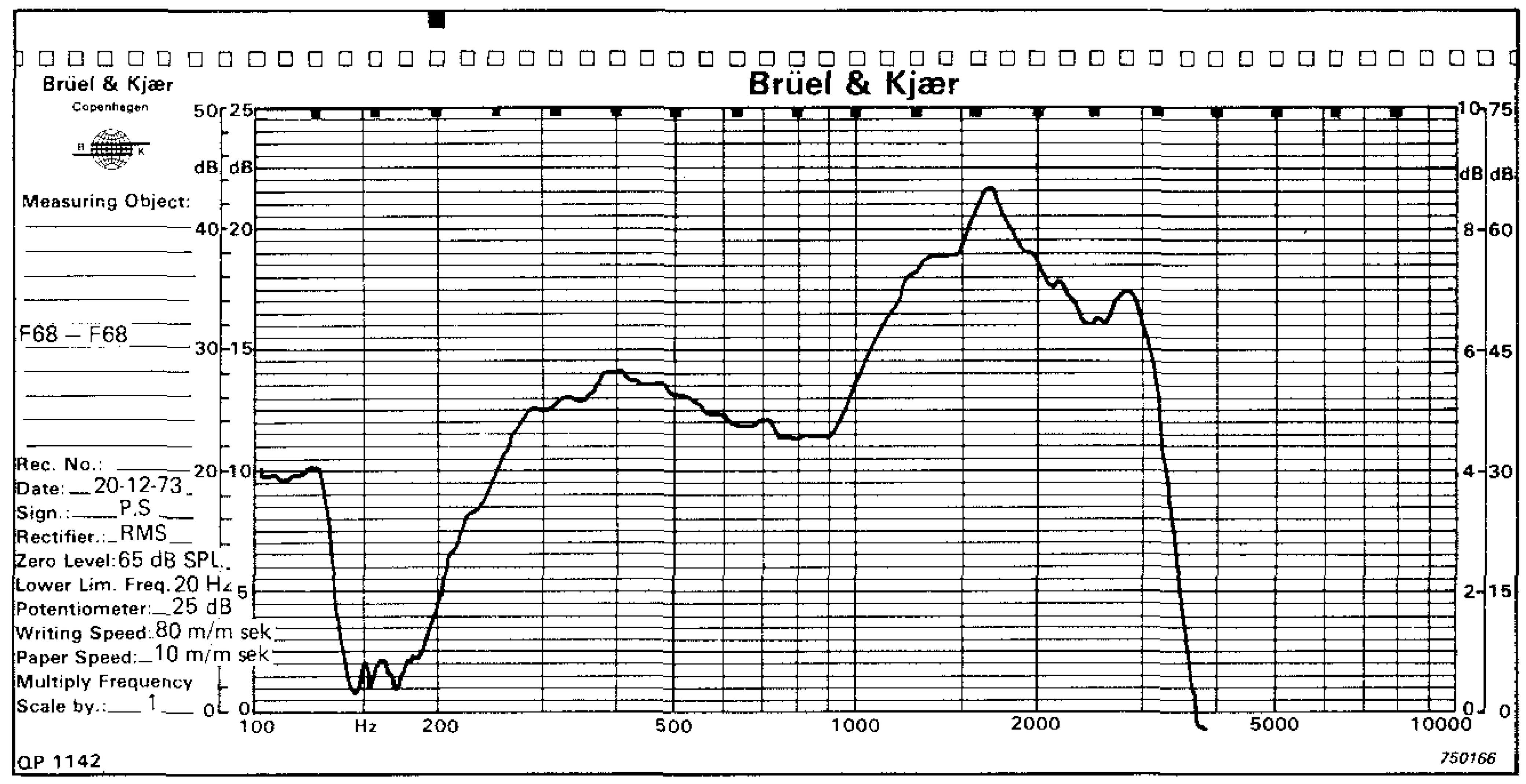


Fig.7. F68 to F68

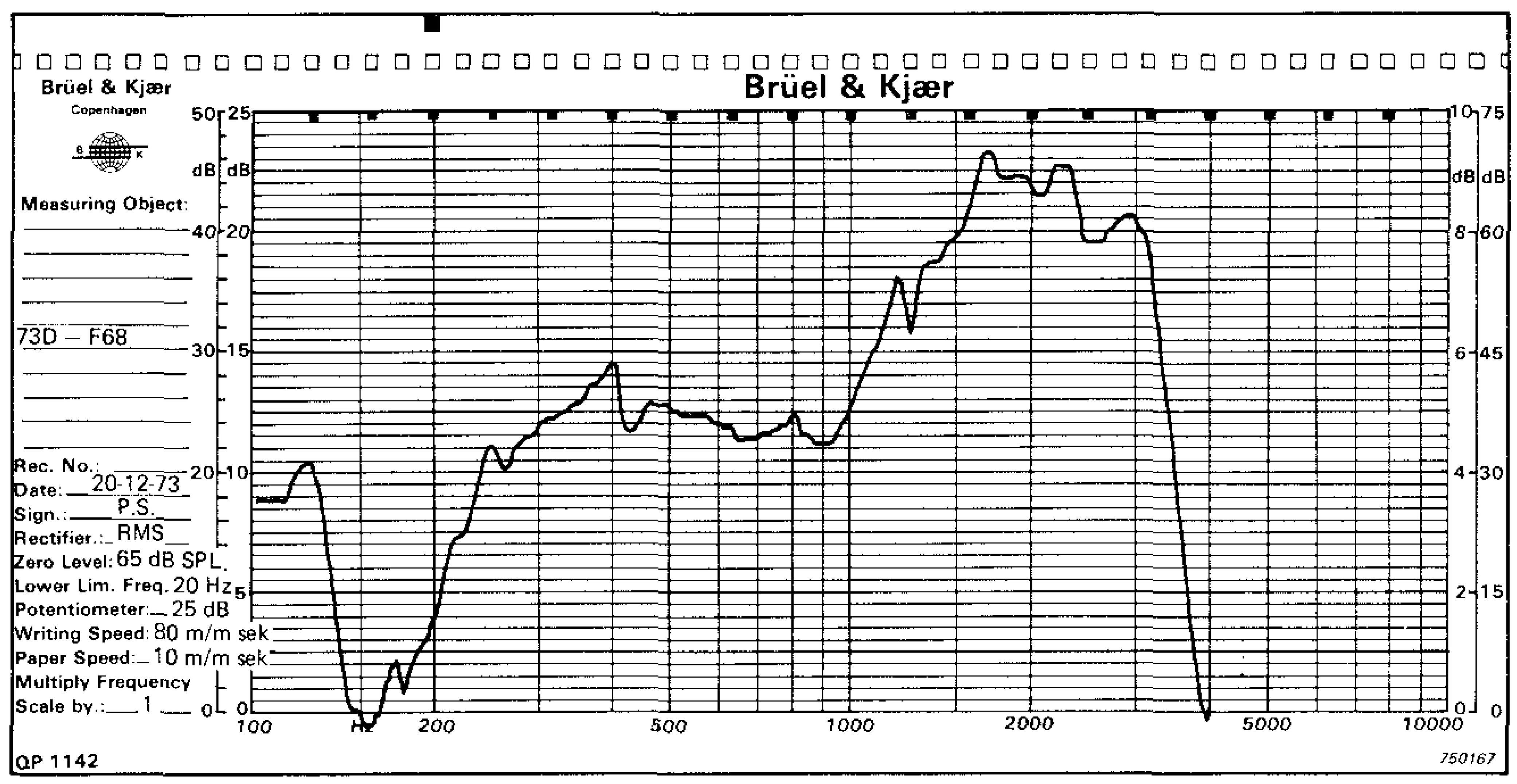


Fig.8. 73D to F68

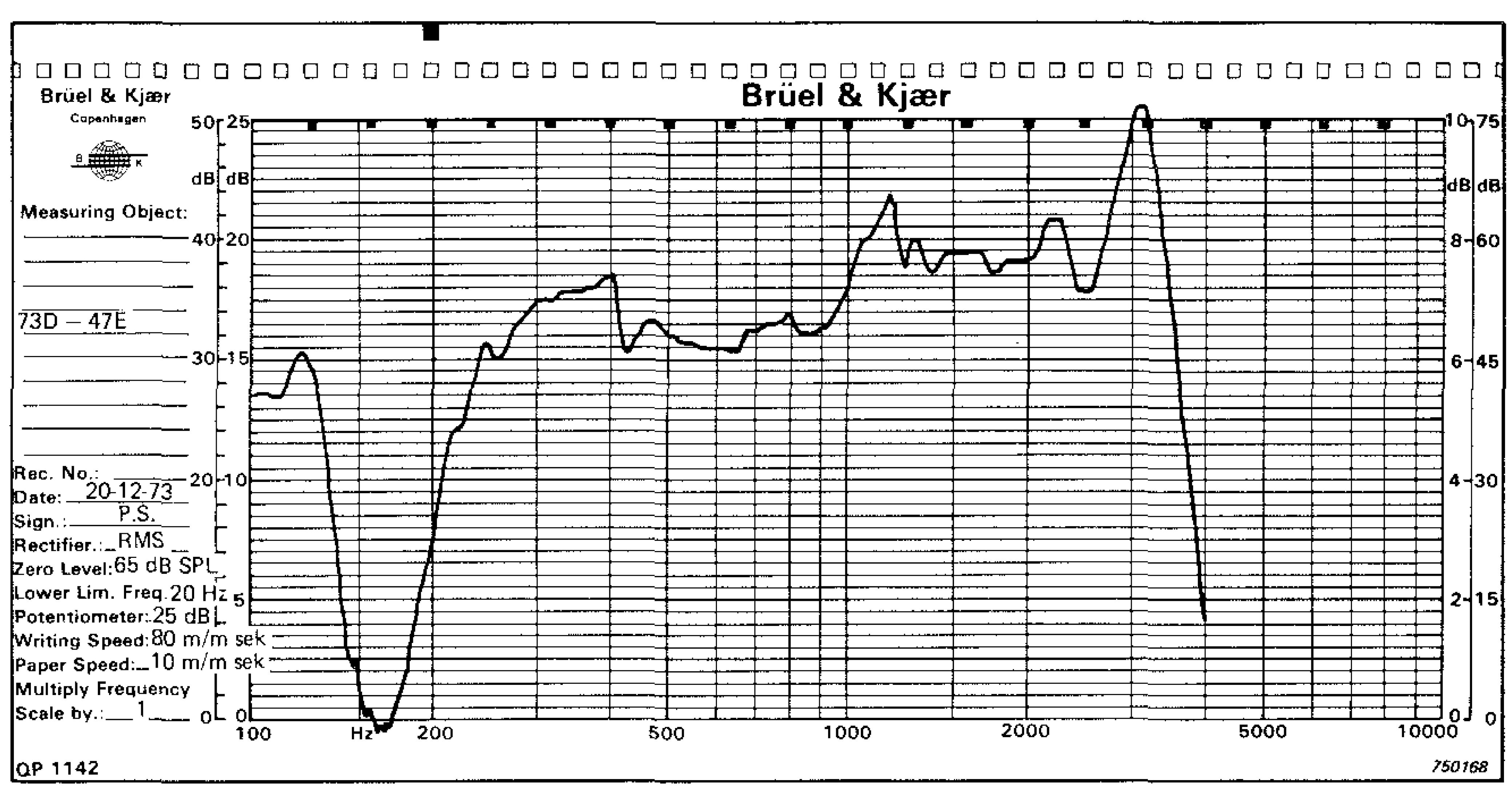


Fig.9. 73D to 47E

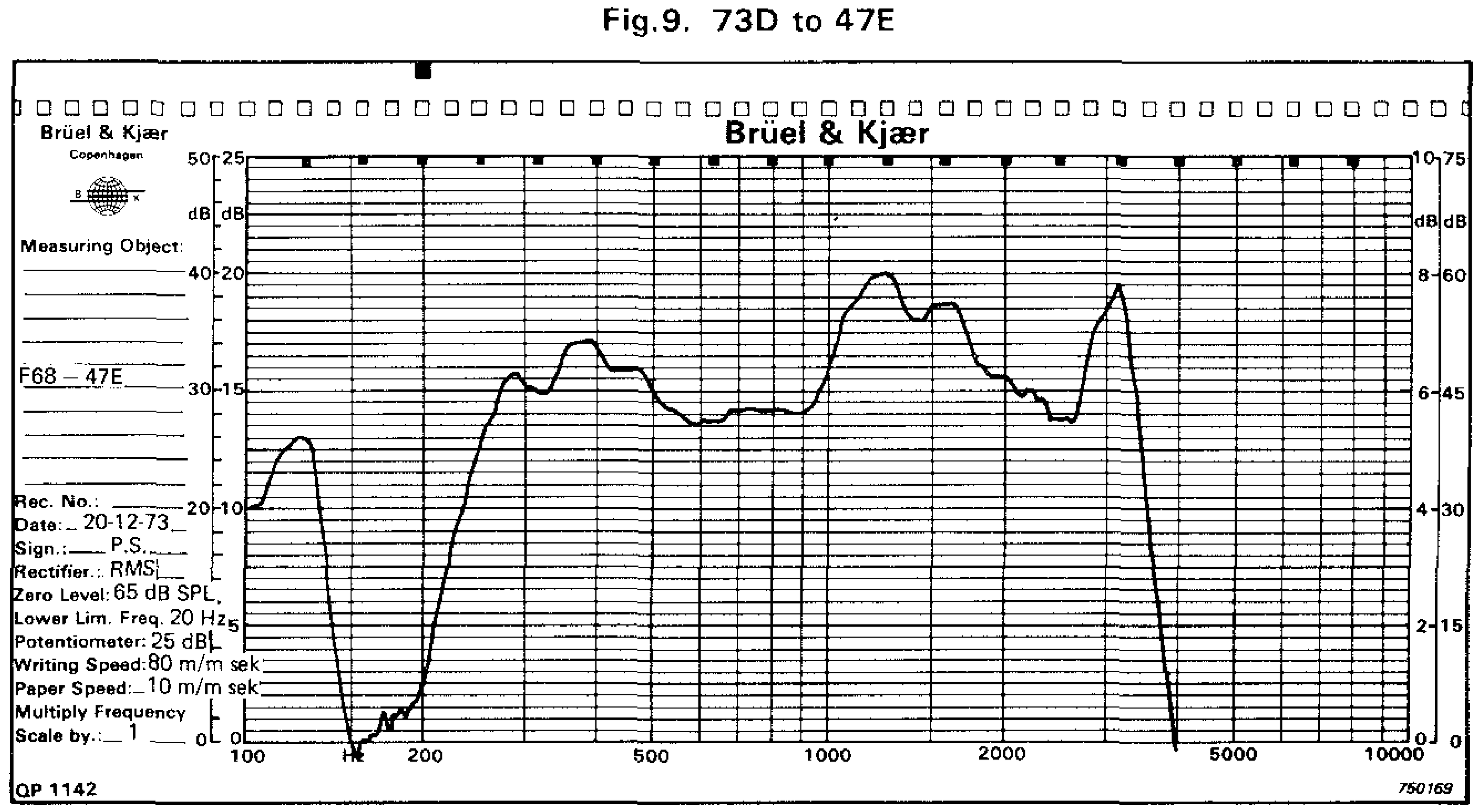


Fig.10. F68 to 47E

1000 Hz to 3400 Hz it is in the region of 82 dB. This is due to a combination of the 47E sets relatively weak transmitter and the tendency in its receiver to receive low frequencies insufficiently.

The major results of the described experiments are summarized in the table.

Conclusion

By looking at the figures 3 to 11, as well as the summarizing table, it seems that the best and most pleasant sound picture, with highintelligibility, is obtained when the telephone set 73D is used both as transmitter (A) and receiver (B).

Furthermore, in all combinations where the set 73D is used as receiver (B), good results are achieved, and the sound pressure level vs. frequency characteristics is reasonably constant around the preferred mean sound pressure level of 80 dB.

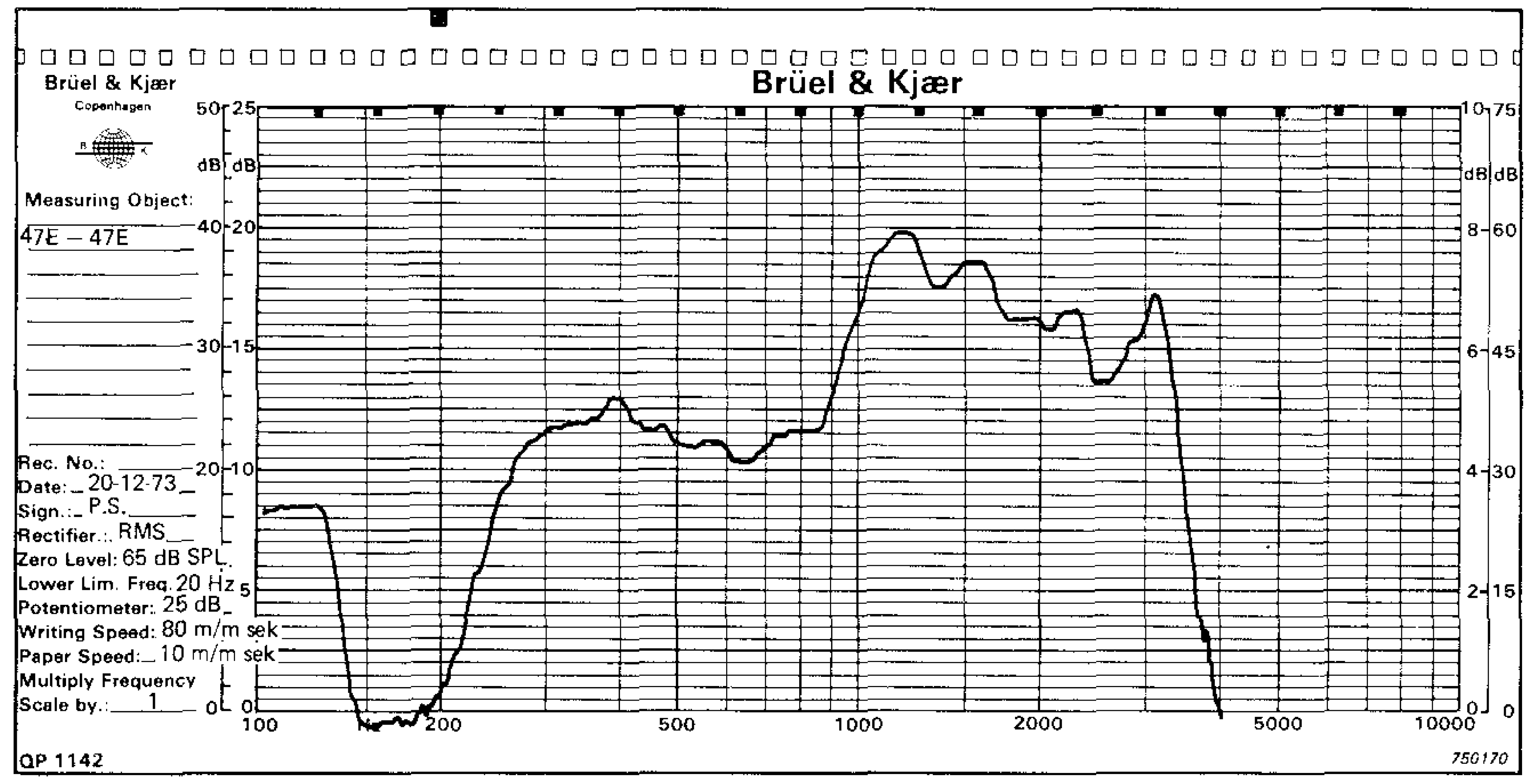


Fig.11. 47E to 47E

Transmitt. (A)	Receiver (B)	Receiver Sound Pressure Level 300 Hz — 1000 Hz	1000 Hz — 3400 Hz	Remarks
73D	73D	81 dB SPL	81 dB SPL	Fig.3 Both high frequency and low frequency ends of the passband are somewhat pronounced, resulting in a pleasant and highly intelligible sound picture.
F68	73D	80 dB SPL	80 dB SPL	Fig.4. As Fig.3 but with a somewhat lower overall level.
47E	73D	78,5 dB SPL	78,5 dB SPL	Fig.5. As Fig.3. The overall level is, however, still lower than that obtained in Fig.4.
47E	F68	74,5 dB SPL	82 dB SPL	Fig.6. Fairly high attenuation in the low frequency region. This gives a sort of "metallic" sound picture which is less pleasant for the listener.
F68	F68	77,5 dB SPL	82 dB SPL	Fig.7. As Fig.6. The attenuation in the low frequency region is less than in Fig.6, which results in a slightly more pleasant sound picture.
73D	F68	77,5 dB SPL	84 dB SPL	Fig.8. As Fig.6, but with a higher average sound pressure level, resulting in a better intelligibility.
73D	47E	81,5 dB SPL	85 dB SPL	Fig.9. Fairly high overall sound pressure level and only slight attenuation in the low frequency region resulting in a pleasant sound picture and good intelligibility.
F68	47E	80 dB SPL	85 dB SPL	Fig.10. As Fig.9, the overall received sound pressure level is, however, slightly lower.
47E	47E	76,5 dB SPL	81,5 dB SPL	Fig.11. As Fig.6, with less pronounced attenuation in the low frequency region.

Appendix A

Brief Classification of the Telephone Sets used in the Experiments

The **Telephone Set 47E** is a conventional set containing a carbon microphone and an electromagnetic receiver cartridge. It was introduced into J.T.A.S. in 1947.

The **Telephone Set F68** is again a conventional set with carbon microphone and electromagnetic receiver. It is, however, supplied with a varistor in the microphone circuit to compensate for differences in feed-currents between different lengths of lines. This should allow for relatively constant sending (transmitting) level. The classification No. F68 referes to the year of introduction into Denmark, 1968.

The **Telephone Set 73D** is a set containing an all-electronic transmission system, and electrodynamic microphone and receiver cartridges. The apparatus was ready for production in 1973.

What should be required of a telephone measuring equipment? production control experiences

by *O. Larsson*

1. Introduction

Normally we require that telephone transmission measuring equipments both for laboratory testing and production control shall measure characteristics close to true Reference Equivalents (RE). By the definition true RE's can only be measured subjectively (Recommendation P72 CCITT Green Book Vol. V). However, as loudness (in this case represented by RE's) is a main factor contributing to the transmission quality, we want to make a measurement that brings us as close as possible to the true RE's.

Other important transmission characteristics are for instance frequency responses, impedance and distortion. At manufacturing it is both unpractical and uneconomic to measure all characteristics at the final testing and we have to keep to the most important ones.

2. Measuring Equipment for Different Purposes

The requirements on laboratory equipment for objective measurements do not necessarily have to be the same as those for manufacturing control. In our opinion the differences can be described by table 1.

Requirement	Purpose	
	Laboratory	Manufacturing
Accuracy ± 0,5 dB	x	x
Easy to calibrate		x
Easy to handle		x
Fast measurements		x
Insensitive to low frequency room noise		x

Table 1

The specific requirements for manufacturing control caused us to develop a special transmission tester, 2/LTM 357500, which is used in all LME factories with telephone instrument production. Sending, Receiving and Sidetone with and without local cable are tested.

In the laboratory we use both Brüel & Kjær 3350-52 and 2/LTM 357500.

When the microphones and receivers are manufactured as components, they are tested regarding level and frequency response. Together with the final control of sending, receiving and sidetone on all telephone instruments we think we have a good check of the transmission quality. (Other characteristics are checked by random sample tests).

3. Transmission Testing Equipment 2/LTM 357500 (comparison with B & K 3352 and NOSFER)

The 2/LTM 357500 Transmission Testing Equipment is described in LME/G 1551-998 Ue (submitted to the participants in the meeting). In principle it works with white noise, speech weighting network, artificial ear, artificial mouth, VU meter, amplifiers and attenuators.

As mentioned under 2 above we use both B & K 3352 and 2/LTM 357500 in our laboratory work. The theoretics for loudness are not so well simulated in 2/LTM 357500 as in B & K 3352 but some confusing results have been obtained and are compared and commented below.

In table 2 are listed sending measuring results at 0 Ω line for two types of telephones with carbon microphones.

As can be seen 2/LTM 357500 gives a good estimation of the true SRE's for both sets while the OREM-A equipment shows a difference of 2,2 dB for set A and 5,6 dB for set B showing that a correlation figure must be related to the specific telephone sets concerned.

Another example of sending measurements is shown in table 3.

Method	Measurements of Sending Reference Equivalents	
	Tel set A	Tel set B
Estimation by 2/LTM 357500	+ 4,4	+ 4,5
Subjective tests rel NOSFER	+ 4,0 (95% ± 0,5)	+ 4,6 (95% cont. int. ± 0,4)
	Diff —2,2	Diff —5,6
Estimation by OREM-A	+ 1,8	—1,0

Table 2

Method	Measurements of Sending Reference Equivalents Tel set B	
	0 km	3 km 0,4 mm line
Estimation by 2/LTM 357500	+ 4,5	+ 12,1
	Diff —0,1	Diff —1,1
Subjective measurements rel NOSFER	+ 4,6	+ 13,2
	Diff —5,6	Diff —4,1
Estimation by OREM-A	—1,0	+ 9,1

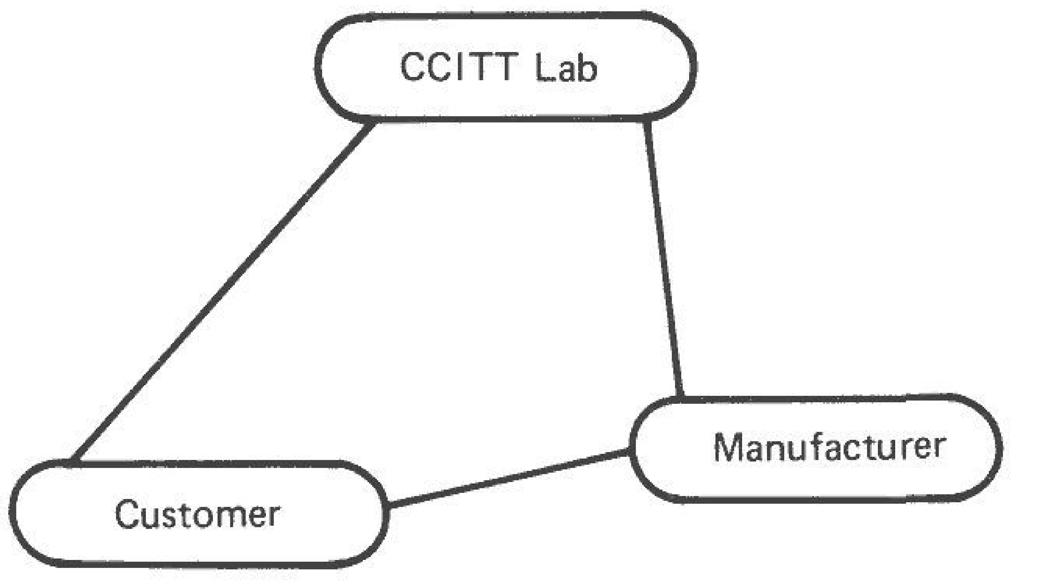
Table 3

Here we can see that the difference between objective and subjective measurements is not the same for 3 km local line as a 0 km. Again 2/LTM 357500 is closer than B & K 3352. This is confusing because the more accurate realisation of the loudness theory should in theory make the B & K 3352 show more accurate values (except for a calibration constant). However, the time variation of the noise signal is closer to that of speech than the sinoidal, so we have a feeling that this can be an explanation. There might also be others.

The discussion above does **not** prove that 2/LTM 357500 is a better laboratory equipment than B & K 3352. In fact we at LME use both. On the contrary it may happen that telephone instruments can be found, for which B & K 3352 gives the closest correlation to true SRE's. But the results imply that the importance of simulating the time-amplitude characteristics of normal speech should be included in the study to make a good equipment for loudness rating measurements.

4. The Customer — CCITT LAB — The Manufacturer

Very often the customer (the administration) requires tolerances of SRE and RRE of about ± 3 dB.



In the CCITT documentation is shown that differences between laboratories for subjective measurements can be expected to be ± 3 dB. If we then add a transfer factor from subjective to objective values, we may land in a very bad accuracy. Therefore, when an agreement is reached on the acceptance of a certain type of telephone instrument (of course based on true reference equivalents) there must also follow an agreement of objectively measured values related to a specific measuring equipment. Otherwise it will be almost impossible to keep the tolerances within the ± 3 dB wanted by the acceptance control. Thus the acceptance control and the manufacturer shall preferably use the same type of testing equipment to minimize the measuring problems. It is not said that the best laboratory equipment is the best one for this purpose too. On the contrary the requirements for manufacturing is likely to agree with those for acceptance control for instance for economical reasons.

The following example shows the practical arrangements used by L. M. Ericsson and the Swedish Administration (Tvt). In the laboratory LME and Tvt use subjective measurements to determine loudness ratings and other transmission characteristics. The laboratories are also equipped with OBDM and 2/LTM 357500 for supplementary measurements. At manufacturing and for acceptance control Transmission Tester 2/LTM 357500 is used both at LME and Tvt.

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