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On cover: Automatic telephone switchboards being tested in the laboratory of the telephone section at LM Ericsson's.

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Rational Charging Methods for Automatic Telephone Traffic

C BERGLUND, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

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In automatic traffic the running costs are governed by the duration of conversation and not by the number of calls. The charges should therefore be based on the total time of conversation. This article shows how recording of duration of conversation for local calls can be introduced with advantage.

The charges per 3-minute period begun, as used in manual traffic, are without justification in automatised toll traffic and should be replaced by charges for the actual time of conversation. By means of suitable numbering and distribution of rates it is possible to arrive at effective time zone meters, if the charges are permitted to deviate slightly from what would correspond to the exact geographical distance between the calling and called exchanges.

Automatisation of the telephone operation alters the costs on which telephone rates should be based and provides possibilities for introducing more rational methods of charging calls. Nevertheless it is quite ususal to apply in automatic operation rates that have been drawn up when taking account of manual operation and its more limited possibilities. This would seem chiefly to be due to the reluctance of telephone administrations to depart from rates that have been found to give satisfactory financial yield and which subscribers have become accustomed to and have accepted. Nothing is more likely to rouse criticism among subscribers than changes in rates and these if ill-considered may have catastrophic financial results. It is hardly surprising, therefore, that reforms connected with methods of charging meet with particularly strong opposition and that conceptions from long experience with manual telephone operation are disposed to persist, though they lack all justification after change over to automatic operation.

Nevertheless these circumstances should not be allowed to prevent the introduction of more rational charging methods and it is therefore extremely important that the proper shaping of rates for automatic operation should be investigated objectively and information about them widely disseminated. In this way it should be possible to combat incorrect conceptions and prepare the ground for reforms which are motivated in high degree.

An attempt will be made in this article to consider without prejudice the demands that should be made on rational rates for automatic telephone traffic and to indicate the possibilities of introducing them which present technical practice allows.

Among those who have already dealt with this question is Mr. S A Karlsson of Helsingfors Telephone Society in an address to the Northern Countries Electrotechnicians meeting 1937. Though the author of this present article recommends technical solutions which depart partially from those given by Mr. Karlsson, he shares the latter's opinions on the main question and permits himself to make use of them as points of departure for further reflexions.

Mr. Karlsson puts forward the following demands on an appropriate telephone tariff:

1. It shall promote development of the telephone traffic.
2. The various charges shall correspond to the costs involved.

3. The various charges should not be dependent on one another.
4. The tariff shall be such that it can remain in force for an appreciable length of time.
5. The tariff shall involve small recording and encashment expenses.

There can hardly be any difference of opinion regarding the desirability of the above conditions being fulfilled. It might be possible to supplement them by further requirements which, however, are more of a social or psychological nature and so scarcely of general application.

Local Calls

The old method of charging a fixed rate, independent of the traffic (flat rate) meets point *5* particularly well, but is in such sharp conflict with *1*, *2* and *4* that it cannot be regarded as rational.

The tariff form now customary with a fixed rate plus a charge per call meets point *2* fairly well in manual operation, as in manual systems the running costs are chiefly costs of attendance which are fairly proportional to the number of calls attended to.

In automatic operation, however, almost all running costs are governed by the time of conversation and not by the number of calls. It is therefore undoubtedly more correct that in automatic operation the tariff should comprise a fixed rate plus a variable charge proportional to the duration of conversation. For the subscriber, too, it must appear more fair that he should pay less for a short conversation, *e. g.*, where he only gets word that the person desired is not at home, than for a lengthy conversation. Mr. Karlsson is therefore right in declaring that the promotion of the telephone traffic's expansion should not consist only in recruiting a large number of telephone subscribers but above all in getting the telephone plants to deal with as large a number of useful conversation hours as possible.

In Austria there was introduced a considerable time ago such a tariff, but the charging there was done for the time of occupation both for the subscriber's outward and his incoming calls. It can hardly be considered right that a subscriber should have to pay for calls which he does not initiate. It should be taken as the fair principle that a subscriber should be able to calculate more or less in advance his telephone expenses and by his own efforts keep them within fixed limits. He should therefore be charged only with those calls he himself initiates.

Mr. Karlsson proposes that the time of occupation should only be recorded for the calling subscriber from the moment the first figure is received at the exchange and that for recording of time there should be employed a common impulse machine, which transmits at regular intervals a recording impulse to the calling subscriber's call meter. By means of this recording method simpler devices are obtained at the exchange than are required to send a single impulse to the meter at the close of each effective call. With a certain amount of justice it is declared that the time recording should be begun immediately the exchange is occupied since it is this occupation that for the most part gives rise to the running costs.

However, well-founded opposition against this may be expected from subscribers. These, of course, have no means of estimating the ineffective occupation time's length, as such occupation arises when the called subscriber does not answer or is busy, when delays occur through the number of connecting devices being insufficient and other circumstances over which the individual subscriber has no control. He must therefore consider it unfair that such extra occupation should be charged to him, just because he had the misfortune to be caught by these unavoidable circumstances, disagreeable in themselves. Mr. Karlsson therefore has proposed measures for time recording of effective conversation time only. The supplementary equipment required to avoid recording of ineffective occupation is not expensive and in the opinion of the author, should in any case not be absent from in a modern automatic telephone exchange. Such an exchange should, to provide for rational recording of toll calls, be so constructed that the facility exists of sending impulses at any moment during the call to the call meter of the calling subscriber. An automatic telephone system equipped in this manner can easily be altered from recording per call to time recording. The supplementary equipment consists only of time impulse devices common to several connecting circuits, which are inexpensive and ought to be there to some extent for the time recording of toll calls.

By employing common time impulse devices the first time impulse will come at no fixed time during the call and the time registration therefore for a single call will be inexact. It is, however, the sum of the time for many calls that is of interest and errors in the individual recordings balance each other so that a satisfactory recording accuracy is ensured. This question is dealt with in the next article »Registering of duration of conversation» in this number of Ericsson Review.

As it is easy to vary the length of the impulse interval it is possible to apply with time charging a higher rate during periods of heavy traffic, thus maybe ensuring more even loading and consequently better utilisation of the exchange connecting devices.

Toll Calls

A manually served toll call involves costs both for setting up and charging the call and for the occupation of the lines and the exchange equipment. The former are dependent on the number of calls, the latter on the conversation time. It would then appear natural that toll charges should consist of a charge depending on the number of calls plus a charge dependent on the total duration of conversation.

With manual recording however such charges, would involve considerable work of computation and there would also arise trouble in getting the subscribers to understand and accept such a complicated tariff. As moreover with manual operation it is not always possible to determine the exact moment when calls terminate, and the operators should not be burdened with or permitted to break in frequently on the connection to check whether conversation is proceeding, the calls are usually charged at a rate per 3-minute period begun. In point of fact such a rate to a certain extent takes into account that the costs are dependent both on the number of calls and the time of conversation, seeing that on the one hand for each call, irrespective of its length, a certain minimum charge equivalent to a 3 minute conversation is obtained and on the other hand a higher charge is obtained when the call exceeds 3 minutes in length. Nevertheless such a tariff is not ideal, as for instance a call of 3 minutes is obtained for the same price as a call of 1 minute, despite the fact that the former, especially with long distance calls, involves appreciably higher costs. It is equally obvious that the first 3-minute period involves higher costs than the subsequent ones and that consequently long calls are charged considerably higher than can be considered just. However, it is hardly possible for practical reasons to find a more suitable form of tariff with manual operation.

On the automatisation of the toll traffic practically the whole cost for a call will be dependent on the occupation time and moreover it is nearly proportional to it. This very simple relation makes it possible to arrive at a really simple and rational tariff, namely one by which the subscriber is charged a rate which is directly proportional to the occupation time. Neither would it then be right to charge according to periods started of certain duration, as in the manual system. As the costs are directly proportional to the occupation time the subscriber should be debited according to the real call duration, so that the cost for a call of 5 minutes will cost exactly 5 times as much as a call of 1 minute.

Charging of toll calls according to actual duration of conversation is most simply arranged in manner similar to that described above for local calls but, in order that the rate may be varied according to the distance between the subscribers talking, the time recording must be multiplied by a zone factor. This is done by the interval between the impulses of the subscriber's call meter being made correspondingly shorter.

Mr. Karlsson has recommended that each line section over which the call is carried be equipped with simple impulse devices which transmit, at impulse intervals adapted to the length of the line section, time impulses to the subscribers call meter. The time impulses from the line sections comprised in the call connection are then added up by the subscriber's call meter and a recording is obtained which corresponds to the total length of line over which the call is carried. Automatised networks, however, are usually built up radially from a network group centre. Thus, for example, the distance between two terminal exchanges may then often be fairly short though the call is routed the long stretch by way of the network group centre. It cannot be right that the subscriber should, for a call between two such terminal exchanges, be charged a high rate because the call is actually carried over a long detour because this, taking account of the collected traffic of the network group, involves less expense to the telephone administration. Later Mr. Karlsson worked out a modified proposal which provides for the application of a single time tariff for traffic within one network group and for recording of traffic to other network groups being done by means of time zone meters located at the network group centre.

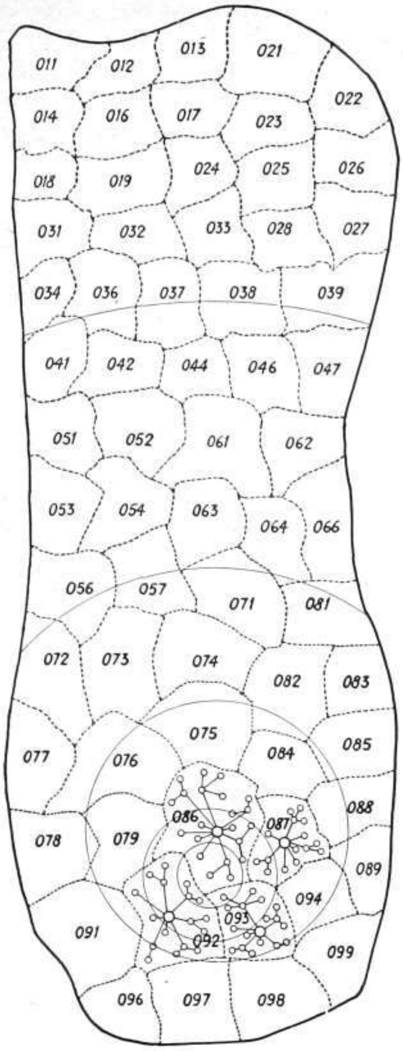


Fig. 1 X 4305
Area divided up into network groups

Time Zone Meters

Distance rates should be based on the crow-flight distance between the departure and receiving exchanges. The apparatus which transmit a number of impulses corresponding to the fixed distance rates to the subscriber meters are time zone meters. These would be very complicated if in an extensive rural automatisation network the charging was to be adapted exactly to the geographical distance between the exchanges. They can, however, be made quite simple if certain approximations are permitted. If an area, the traffic in which is to be automatised at some future date, is divided into network groups, see Fig. 1 there will be obtained for the calls over long distances an accuracy that is satisfactory in determining rates if only the distance between network group centres is taken into account.

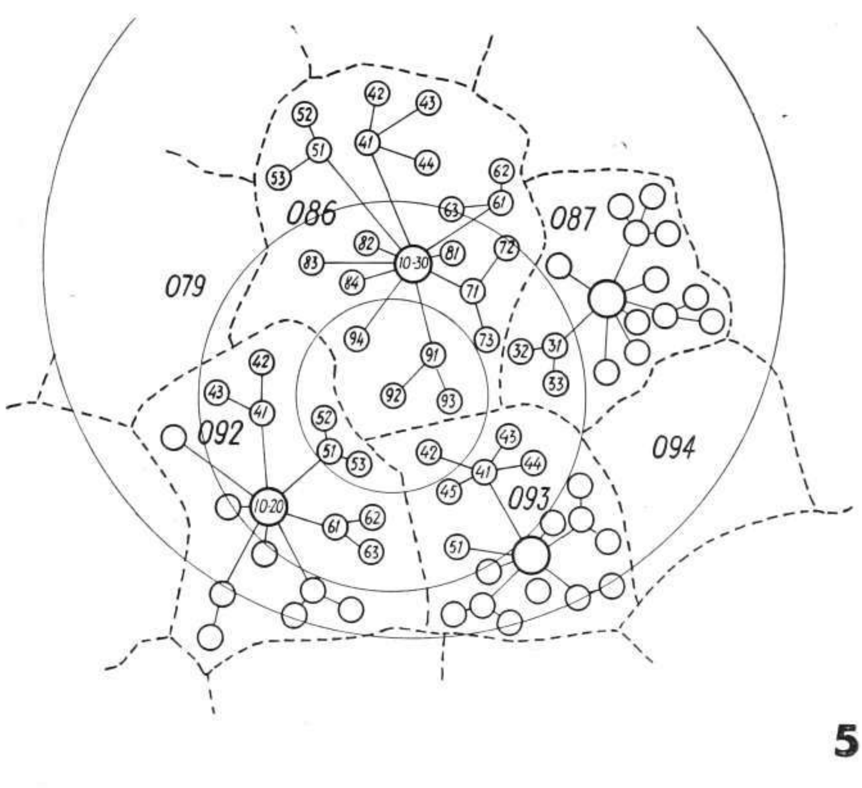


Fig. 2 X 6043
Network group 086 and adjoining network groups

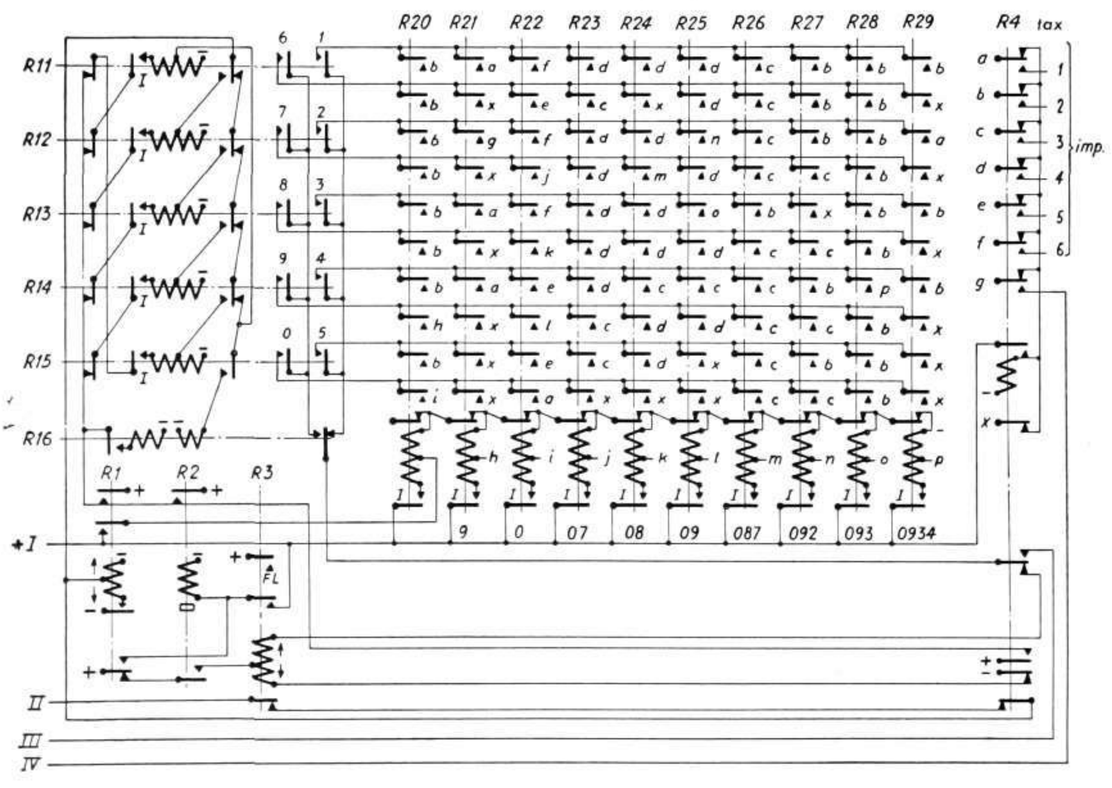
For calls between exchanges in adjoining network groups, see Fig. 2, however, such an approximation would not be satisfactory. The distance between exchange *92* in network group *086* and exchange *52* in network group *092* constitutes, for instance, merely a fraction of the distance between the respective network group centres. Similarly it can hardly be considered right to apply, as is at present usual, the same rate for all calls between intermediary places within a network group. Thus it cannot be regarded as fair that calls within the network group *086* between exchanges *91* and *93* should be charged equally as high as calls between exchanges *92* and *42*. An acceptable approximation is arrived at, however, if the cheapest distance rate is fixed exactly in conformity with the crowflight distance between exchanges — for exchange *92* to other exchanges within the innermost circle in Fig. 2 — while the next cheapest rate is applied to all other exchanges in the same network group and to other exchanges in other network groups which lie at a fixed distance from the calling exchange — in the area between the two innermost circles. If these approximations are accepted and it is decided that calls to other exchanges in the whole area are to be charged according to the distance between the network group centres, then possibilities have been created of arriving at simple time zone meters.

Fig. 3 shows a form of construction for a time zone meter which, for exchange *92* in network group *086*, fulfils these rate conditions for the area as per Fig. 1. It is assumed that for traffic within a single network group there is dialled only the subscriber number and that the two first digits in that number determine the exchange. For traffic between the network groups there is dialled before the subscriber number the routing number for the network group, this consisting of *0* plus two digits.

The dial impulses come in on wire *II*, see Fig. 3, over a relay set in the outgoing end of the intermediate exchange line. The number dialled is registered by the relay chain *R 11—R 16*. These relays, like relays *R 20—R 29*, operate in such a manner that when + V. C. is connected to the centre point only contact *I* is made, the remaining contacts being actuated only when + V. C. disappears and the short-circuiting of one of the windings ceases. When the first impulse series ceases *R 20* actuates all contacts and during the delayed release time for *R 2* there is closed a circuit to one of the contacts on *R 20*, which are connected to the contacts on *R 4*, or to other relays in the relay

Fig. 3
Time zone meter principle in diagram

X 7372



chain *R 21—R 29*. All contact points designated by the same letter are linked to each other.

From Fig. 2 it will be seen that all exchanges within the network group *086*, with the exception of those having subscriber numbers beginning with *9*, should be charged the next to lowest rate, rate 2. Thus, if the first figure *4* is received by the time zone meter a circuit is closed over the *b*-contact on the rate relay *R 4* to its coil. *R 4* is energised and connects in impulses, at a speed corresponding to rate *2*, to outgoing wire *III* from the time zone meter. When the conversation begins these impulses are connected in to the subscriber's call meter. If the first figure *9* is dialled relay *R 21* is energised over contact *h* on *R 20*. Before the next impulse series is received the relay chain *R 11—R 16* is restored so that it can register the next figure. According to Fig. *2*, calls to exchanges *91, 93* and *94* are to charged as per rate *1*. After the second figure has been registered *R 4* is energised over its contact *a* and connects impulses for rate *1*. If on the other hand the second figure were 2, *i. e.*, the number dialled is for subscriber's own exchange *92*, then *R 4* will be energised over its contact *g*. In this case no rate impulses will be connected in but a circuit will be made between the outgoing wires *III* and *IV*. By means of a relay not shown in Fig. 3 the routing of the connection for internal traffic is directed.

If another network group is to be called, the figure *0* is first dialled, this causing energising of *R 22*. From Fig. 1 it can be seen that for more than one network group the rate can be directly fixed by the next succeeding figure. For traffic to the network groups *011—019*, for example, the rate *6* will always be applicable. If *01* is registered *R 4* is energised over contact *f* and it connects in impulses for rate *6*. Nevertheless in many cases the rate cannot be determined by the second figure. For example, if the call is for exchange *42* in network group *093* the rate can only be fixed after the fifth figure has been received. The connecting process will then be such that when the second figure is dialled *R 25* is energised, when the third figure is received *R 28*, when the fourth figure comes *R 29* and finally when the fifth figure is registered *R 4* is actuated and connects in the corresponding rate impulses.

In principle this form of construction for time zone meters allows an unlimited number of rates to be employed and permits the figure combinations which determine the rate to contain any number of figures. However, if the conditions in this respect are very complicated there is required a large number of relays having the same function as *R 21—R 29*. By suitable numbering of the network groups and exchanges and by limiting of the number of rates, which is also desirable from other points of view, it should in most cases be possible to have time zone meters which do not require appreciably more of such relays than indicated on Fig. 3.

Time zone meters constructed on these principles will be so simple that they can with advantage be installed even at small terminal exchanges. If the time zone meters are centralised to junction exchanges extra expenses arise to determine whence the call comes and to transmit impulses over the junction circuits. It is then customary to have discriminating selectors at the terminal exchanges, among their functions being to re-route for internal traffic. These discriminating selectors must contain a large part of the equipment which is comprised in time zone meters.

As regards intermediate exchange calls the charging method proposed will certainly have a stimulating influence, as it makes available to the subscriber a new kind of telephone call, *viz:* intermediate exchange calls of short duration for a low charge. In Ericsson Review No. 2/1943 it was demonstrated with some specimen computations that it is the expensive manual charging method that is chiefly responsible for short duration intermediate exchange calls being disproportionately expensive, and that nevertheless this traffic is frequently rather poor business for the telephone administration. This disadvantage can best be remedied by automatisation, but only by introducing the charging here recommended based on actual duration of conversation would it be possible to attain really effective popularising and good yield from this traffic.

Registering of Duration of Conversation

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U.D.C. 621.395.663.2:654.155.4

In registering the duration of calls by impulses to the call meters of subscribers from common time impulse units the times recorded for each individual call will contain errors. Nevertheles such errors compensate each other over a charging period, so that satisfactory accuracy of measurement is attained. This article indicates the magnitude of the deviations and the excess recordings that arise.

In automatic telephone operation the running costs are not governed by the number of calls executed but by their total duration. It is therefore right that with local calls it should be the total duration of calls and not the number of calls which constitutes the basis for charging.

It should be possible to employ a small electricity meter for each subscriber to measure the duration of the calls, thus giving the possibility of noting the exact time for each individual call. Such a recording device would, however, be more expensive and take up more space than the customary impulse driven call meters, which can advantageously be used for time registration as well, by arranging so that during the course of the call they receive, at fixed intervals, impulses from a common time impulse unit. The first impulse to the call meter then comes at some indefinite moment during the call and the time recording for a single call is thus not always exact. If the conversation terminates before the first impulse arrives the call meter will not record the call at all. But as during a charging period a large number of time recordings will occur for each subscriber the errors in the individual recordings balance each other, and with proper selection of impulse interval a satisfactory accuracy will be achieved. Doctor C Palm has published a mathematic investigation of the subject, from which the particulars below are derived.[1]

[1] Tekniska Meddelanden från Kungl. Telegrafstyrelsen 1941, No. 7—9.

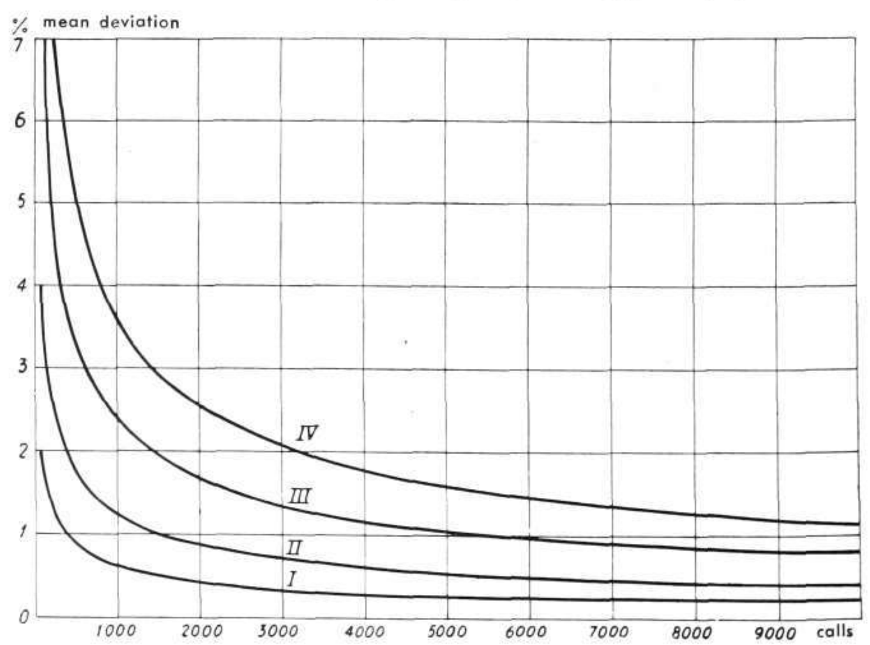


Fig. 1 X 6040

Meter readings' mean deviations in % as function of number of calls read

Curve I impulse interval/mean call duration=½
„ II „ „ / „ „ „ =1
„ III „ „ / „ „ „ =2
„ IV „ „ / „ „ „ =3

Accuracy of measurement is dependent both on the ratio between the length of the impulse interval and the mean duration of calls and on the number of calls during the period of time for which measurement accuracy is to be calculated. The estimated *mean deviation* for different values for these magnitudes may be read in Fig. 1. It is assumed that the mean deviation for one year is to be computed for subscribers with an average of 2000 calls of 2 minutes per year. If the impulse interval is put at 6 minutes, the impulse interval/mean call duration = 3 and there is read from curve IV for 2000 calls a mean deviation of 2.6 %. If the impulse interval is shortened to, *e. g.*, 1 minute considerably greater measurement accuracy is obtained. From curve I the mean deviation of 0.5 % may be read for this case.

However, it is not the mean deviation alone that is of interest but, above all, the excess recordings for which the subscriber is charged. Doctor Palm has therefore computed the probability of excess recordings of various magnitudes in relation to the mean deviation occurring, see Table I.

With the aid of the curves in Fig. 1 and Table I it is possible to compute the probability of a given excess recording being exceeded. Thus if there is sought an excess recording value which may only be exceeded in one case per 1000 (i. e., with the probability 0.001) there is obtained by interpoliation in Table I a value of $z = 3.1$. In the above examples with mean deviation 2.6 % or 0.5 % there is then obtained in one case per 1000 excess recordings of $3.1 \times 2.6 = 8.06$ % or $3.1 \times 0.5 = 1.55$ %.

Generally a subscriber is required to bind himself for one year for a telephone subscription and it is therefore the error recording during one year's time that is particularly important. Usually however a subscriber retains the telephone subscription for many years, so that the over and under recordings for these years will compensate each other, and therefore in the long run the amounts charged will agree still more with what the subscriber ought by rights to have paid.

Charges are usually paid by quarter. There is therefore a certain importance that correct charges should be debited each quarter, as the subscriber might possibly observe variations in amounts debited from quarter to quarter. The error recording for such a shorter period would naturally be relatively greater than for a whole year. In the above example there is obtained a traffic of 500 calls per quarter. The mean deviation is then read from the curves IV and I in Fig. 1 to 5.2 % and 0.95 % respectively. In one case per 1000 the excess recording is exceeded by $3.1 \times 5.2 = 16.1$ % and $3.1 \times 0.95 = 2.9$ %.

The probability of excess recordings of such order of magnitude that will be noticed by the subscriber should be kept small and it may therefore be convenient to fix the excess recording value at not more than one case per 10000, *i. e.*, with the probability 0.0001. In this case there is obtained from Table I $z = 3.9$, which gives 28 % higher excess recording value than if excess could occur in one case per 1000.

The above method for time charging can be used with advantage also for trunk calls with time zone charging, in which case the length of impulse interval varies according to the zone. As the impulse intervals will be shorter and the average call duration be longer with trunk calls than with local calls the percentage of deviation per call will be appreciably lower for trunk calls than for local calls. It should also be observed that as the impulses to the call meters for trunk calls are added to the impulses for local calls, the total percentage of error falls.

Account should also be taken of the fact that the telephone charge should consist of a fixed charge together with the variable charge which is governed by the duration of call. The percentage of error on the variable charge debited represents therefore a smaller percentage of error on the total charge debited. The smaller the traffic a subscriber has the larger will be the percentage of error on his call meter. As, however, with a subscriber having small traffic the fixed charge constitutes proportionately a larger part of the total charge, the error in proportion to the total charge will usually not be greater for such subscribers than for subscribers with heavy traffic and the total error debited will be relatively independent of the subscriber's traffic.

When introducing the above described system of debiting according to duration of calls there should first be decided the accuracy of measurement that is considered necessary. The impulse interval is then selected to ensure the measurement accuracy decided upon. Nevertheless the impulse interval should not be made too short, as this strains the call meters unduly. The impulse interval should not be so short that there is risk with some subscribers that the figure drums of the call meter during the period of reading go beyond the positions they had at the beginning of the period. Call meters are generally made with four drums allowing of 9999 impulses being received during a reading period. If such call meters are employed and these are read once a quarter it would for this reason not be advisable to make the impulse interval for local calls shorter than 1 minute. Moreover a completely satisfactory accuracy of measurement is obtained if the impulse interval is made longer. If greater measurement accuracy is required, necessitating the introduction of shorter interval, meter reading may be done for subscribers with heavy traffic more than once per quarter or call meters with five figure drums may be installed.

When charging according to number of calls established, no matter what the duration of call, there occurs a certain uncertainty in the recording, as calls that never lead to real conversation, *e. g.*, calls to P. B. X., are recorded as established calls. To allow for this there is sometimes made a deduction of a certain percentage, *e. g.*, 5 % of the number of recordings, when calculating the charges for debiting.

If, in conclusion, it is considered essential that even small excess recordings shall only occur to small extent, it is possible even with debiting according to duration of calls to introduce a deduction. For example, if the impulse interval has been fixed so that a subscriber with normal traffic in one case per 10000 gets excess recording greater than 5 % and a deduction of 5 % is made, this means that for such subscribers excess recording in general only occurs in one case per 10000. In reality it is obviously rather immaterial whether the deduction is made, as in that case the charge per unit should be put 5 % higher than if no deduction were to be made.

Table I. Probability S for an excess recording greater than z times mean deviation

z	S	z	S
0.0	0.50	3.0	0.0014
0.2	0.42	3.2	0.00069
0.4	0.34	3.4	0.00034
0.6	0.27	3.6	0.00016
0.8	0.21	3.8	0.000073
1.0	0.16	4.0	0.000032
1.2	0.12	4.2	0.000013
1.4	0.081	4.4	0.0000054
1.6	0.055	4.6	0.0000021
1.8	0.036	4.8	0.00000080
2.0	0.023	5.0	0.00000029
2.2	0.014	5.2	0.00000010
2.4	0.0082	5.4	0.000000034
2.6	0.0047	5.6	0.000000011
2.8	0.0026	5.8	0.000000004
		6.0	0.000000001

8-Channel Carrier Systems for Unloaded Cables

S JANSON, ROYAL BOARD OF TELEGRAPH, & R STÅLEMARK, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

U.D.C . 621.395.44

Older, loaded cables can after unloading be made available for carrier operation with frequencies up to 60000 to 65000 c/s.

Methods and apparatus for re-splicing the cable and for balancing the far-end crosstalk is treated, and a description of characteristics and design of the carrier equipment is given in this article, which will be continued in the coming number of this periodical.

General Principles

When the developing work of modern multi-channel carrier systems for non-loaded cables was started in earnest, the interest was concentrated on so-called U-systems. These systems were designed for transmitting the same frequency band in both directions but on different cables, hereby getting around the difficulties with the near-end crosstalk. The number of channels was mostly 12 or 16 and the frequency range 12—60 kc/s. These systems have and will most certainly for a considerable length of time play an important part in the construction of the long distance network in different countries. The communication circuits obtained in this way are of high quality, and thanks to the short and practically constant propagation time within the frequency range of a channel, circuits with a length of 10000—20000 km can be connected without the propagation time being more than 50—100 ms.

The interest of later years, perhaps especially in Sweden, has turned to a new field of application for carrier systems of similar types. Sweden has a large network of loaded cables which have been used for two-wire circuits on long distances. Some of these cables were installed in the early 1920's. The cut off frequency was low, 2300 c/s, and the loading interval large, 2700 m. These circuits were thus in modern meaning of poor quality regarding transmission properties and improvements sooner or later were unavoidable. As at the same time the traffic on the state cables showed a tendency to increase steadily and this at a quicker rate than what was expected, all reserves were soon exhausted and one faced the problem of quickly bringing forth new circuits.

It was then necessary to investigate, if these cables after unloading could be used for carrier systems and in such a case to choose a suitable system. Also abroad, in U. S. A. and Germany, one had got on to the same line of thought, but the lines of development have to a certain extent gone different ways on account of local conditions. In Sweden there is usually only one cable along the same route. One can therefore not use the usual U-system like in the U. S. A., as it requires two separate cables. On several routes, as for example Stockholm—Gothenburg, there are, however, two cables but they follow *different* routes, and the number of repeater stations would then have to be doubled, which was not considered suitably neither in economical nor technical point of view.

After the measurements of one unloaded test-section of the old state cable Stockholm—Gothenburg had shown, that this cable was very well suited for carrier operation after resplicing and balancing were made over again according to methods which are described elsewhere in this paper, a carrier system was designed to work on one cable, the so-called 8-channel system. In this system the two directions of transmission are devided into two frequency ranges, one 8.4—33.6 kc/s and one 38.4—63.6 kc/s. In each group 8 channels are transmitted. By dividing into groups the two directions of transmission can be separated by means of filters instead of using two cables.

At a light study it may seem, as if this method of arranging the carrier systems for non-loaded cables, always ought to be economically more favourable than the U-system, but this is not the case. On one side stands the cost of one cable against on the other side the cost of the filter equipment and the fact that the amplifying unit is not fully employed. In comparison with a 16-channel system for instance each unit amplifies only half as many speach channels. For news projects when also the cable is to be laid, this solution has shown, at a closer investigation, not to be economically justified, as the two-cable system comes far lower in cost.

In the present case, where the cable already is installed, and where the unloading, re-splicing and balancing are the only charges on the cable account, the 8-channel system is, however, superior. In a border-line case the 8-channel system can probably compete with the U-system even on new installations such as sea-cables and special deep-sea cables with pressure protection.

Finally, it must be pointed out the great importance at the present time with the shortages of raw material, that a large network of 8-channel systems can be manufactured within the country without drawing on the stocks of copper and lead. The project of extension for new facilities based on this carrier system which the Royal Swedish Telegraph Administration now has started and plans to continue, would be impossible to realize under present conditions if it assumed laying new cables, loaded or of carrier-type.

Choice of Frequencies and Levels

The usual U-system, 12- as well as 16-channel systems, works as mentioned within the frequency range 12—60 kc/s. Between the two groups, one for each direction, a certain frequency band must be left unused between the two groups, so that the filters without mobilizing too many elements can give the required attenuation. The larger this band is the lower the cost of the filters. At the same time, however, the useful transmission frequency range becomes smaller, *i e.* a less number of circuits can be operated. For several reasons it is not good practice to use higher frequencies than 60 to 65 kc/s. The circuit loss will be so great that more than two unattended repeater stations must be placed between those for the loaded circuits existing repeaters, and this one wants to avoid when considering station supervision. Furthermore the difficulties to reduce the far-end crosstalk in the cable by balancing increases at higher frequencies. The lower frequency limit can without inconvenience be fixed lower than 12 kc/s but on account of the risk of interference to any low frequency radio program circuits, it ought not to be set much lower. Furthermore the phase velocity decreases at lower frequencies.

Based on the above the aproximate frequency range was fixed at 8—64 kc/s.

When choosing between the much discussed 3000 or 4000 c/s-band one stands between Scylle and Charybdis. The 4000 c/s interval recommended by C. C. I. F., 1938, for international circuits, would only allow six channels to be placed within the given frequency band.

With the 3000-interval the number of channels will be eight, but then there is no possibility of transmitting the cable-circuit band recommended by C. C. I. F. which would be a disadvantage even if the majority of all circuits are national. From an economical stand point the difference between six and eight circuits is of decisive importance.

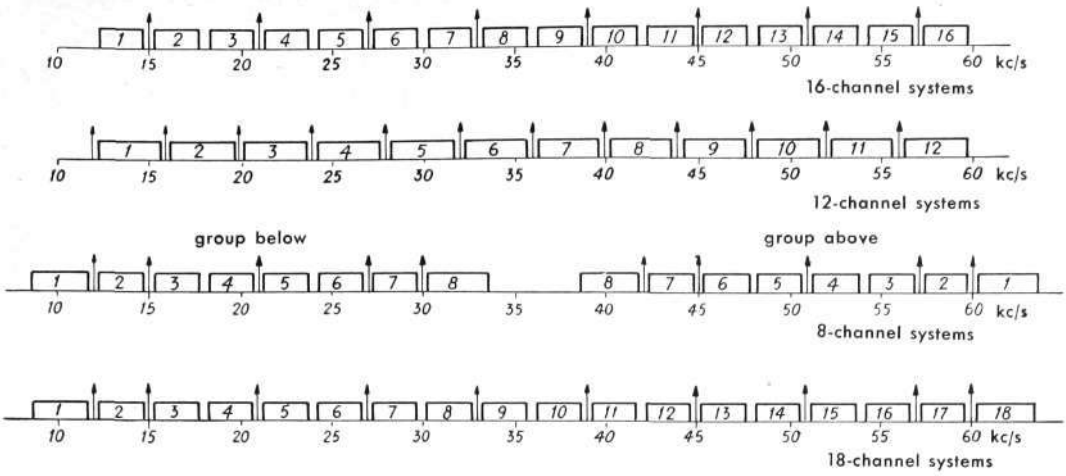


Fig. 1
Frequency allocation of 16-, 12-, 8- and 18-channel systems

X 7378

The final solution means a compromize, as six of the circuits are arranged with 3000 c/s-interval while two have the band of 4000 c/s recommended by C. C. I. F. and consequently can be used for international circuits.

The 8-channel system frequency allocation is shown in Fig. 1, which for the sake of completeness also shows the frequency allocation of all the carrier systems that L M Ericsson at present manufactures for non-loaded cables. In this diagram it is shown, that the 8-channel system is arranged in such a way that 12 of its 16 frequency bands coincide with corresponding frequency bands in the 16- and 18-channel systems. Those filters, modulators and demodulators in the terminal equipment which handle the same frequency bands in the different systems, are identical as level conditions, and loss and gain requirements etc. have been kept alike.

As the number of channels is less one ought to be able to transmit with higher levels than in the 12-, 16- and 18-channel systems, without risk for intermodulation in the common amplifiers, but several reasons go against this. The high frequency output level has been chosen alike for all systems, being + 0.5 neper (272 mW) for each channel when the input level is equalled to zero level (1 mW). The high frequency amplifiers, which are of the same type for all these systems, become therefore over-dimensioned as employed in the 8-channel system as regards the output power. This condition has, however, been taken as a pretext to work the amplifiers in the unattended repeater stations with a lower anode voltage, 85 V, instead of the usual voltage of 130 V. Hereby are essential advantages gained. The new power supply equipment for these stations can be made more simple, the anode current drain is 60 % of normal and the life of the valves which is of greatest importance for the dependable operation of the unattended repeater stations, will increase considerably. The length of the repeater section has been chosen so that the circuit loss amounts to not more than 7 nepers at 64 kc/s, which corresponds to an input level to the amplifiers of — 6.5 nepers.

Direct Crosstalk

In a carrier system of this type the transmission circuits must meet certain requirements as regards freedom from crosstalk and from interference. In this case special care must be taken to improve the crosstalk on account of the cable lines from the beginning not being intended for carrier transmission. In the following, different kinds of crosstalk that can occur, and methods for improving it, will be described, primarily with reference to the conditions of the old trunk-cable Stockholm—Gothenburg. On this cable 10 quads were arranged for carrier operation. As all quads in the cable were loaded, the loading coils of the selected quads had to be removed to allow transmission of the rather high frequencies of the 8-channel system. It was also found suitable to improve the crosstalk between the cable pairs affected by the

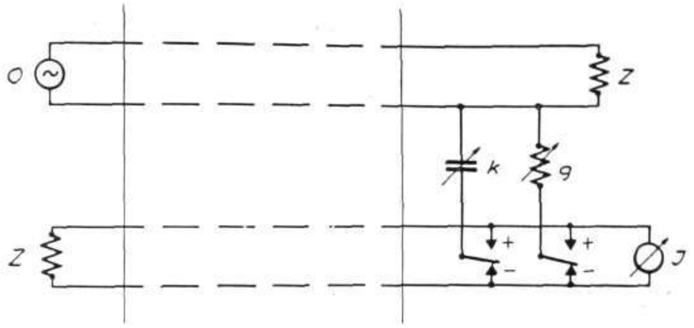


Fig. 2 X 6050
Schematic of far-end crosstalk compensation
0 oscillator
1 indicator instrument
2 terminating impedance
k, g variable elements of unbalance

removal of the loading coils. As different frequency bands were chosen for each direction of transmission only the direct far-end crosstalk was of importance. Near-end crosstalk may however be of importance for indirect crosstalk.

Direct crosstalk between two circuits arises through inductive and capacitive unbalance conditions. The terms for the relation of the crosstalk to respective unbalance conditions are as known

$$\begin{cases} v_M = \dfrac{j\,\omega\,M}{2\,Z} \cdot V \\ v_k = \dfrac{j\,\omega k Z}{8} \cdot V \end{cases}$$

In these terms, M and k stand for inductive and capacitive unbalance respectively, while Z is the characteristic impedance of the circuit. V stands for the voltage in the disturbing circuit, and v_M and v respectively denote crosstalk voltages in the disturbed circuit.

Through comparison between these terms it is evident that the crosstalk voltages increase in straight proportion to the frequency, whether they are caused by capacitive or inductive unbalance. On the other hand the impedance characteristics differ according to the terms above. This is the reason why the inductive unbalance has a greater effect than the capacitive unbalance in non-loaded cable circuits, while the condition is the opposite for loaded circuits. Estimatively $Z = 130$ ohms for nonloaded cable circuits, while for loaded circuits of the type in question this figure was about 1300 ohms for the side-circuits. When removing the loading coils the impedance characteristics fall in proportion 10 : 1, by which the relation between the inductive and the capacitive crosstalk voltages rises in proportion 100 : 1.

In connection with the removal of the loading coils the unbalances were measured on the loaded sections. The measuring arrangement for this is shown in Fig. 2. As seen in this figure the far-end crosstalk is compensated on the measured section between the two pairs by means of connecting variable

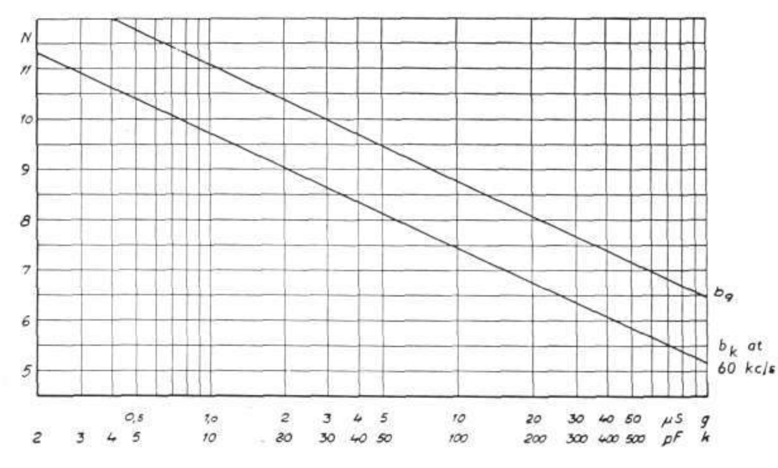


Fig. 3 X 6051
Relation between crosstalk attenuation (b_k, b_g respectively) and unbalance figures (k, g respectively) in nonloaded cable pairs

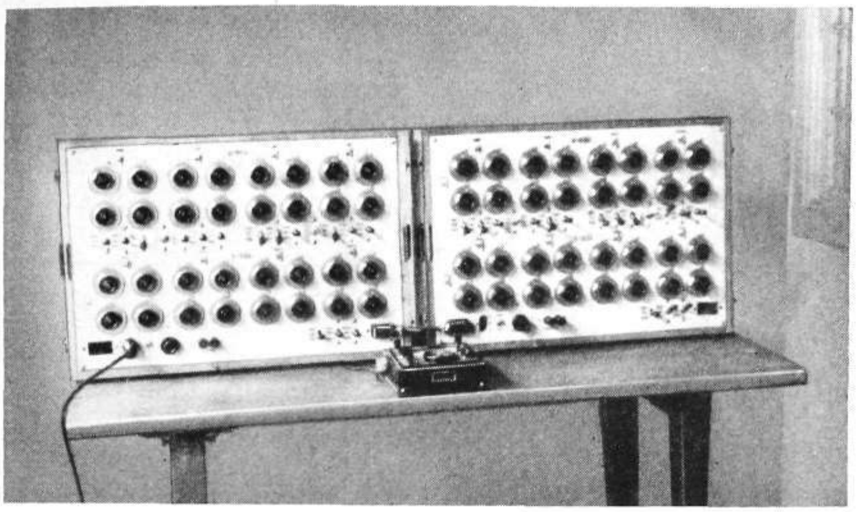


Fig. 4 X 6052
Instruments for splicing calculations

leakage resistance and capacitive unbalance. These measurements were as a rule made with 60 kc/s. When the far-end crosstalk between the two circuits, usually caused by inductive unbalance, becomes compensated with a capacitive unbalance, k, usually also a real unbalance is required, g, owing to the fact that z is imaginary.

When measuring unbalance with 60 kc/s on the loaded sections, sometimes very high figures of unbalance were obtained, within-quad as well as between different quads. The highest obtained figure of unbalance on one loaded section (2700 m) thus reached some over 300 pF, being equivalent to a crosstalk attenuation of about 6.3 nepers as shown in Fig. 3. The purpose was to arrange special end-balancing of the far-end crosstalk by connecting compensating elements of unbalance on all repeater stations. It was, however, for several reasons desirable to try to improve the unbalances also on the cable sections in connection with the splicing at the loading points, so that the unbalances in the different sections as far as possible would compensate each other. The grounds for doing so will be given in the section about indirect crosstalk.

At the usual capacitive balancing only the capacitive unbalances *within* the quads will be lowered. For a group of 10 quads the number of unbalances to be considered are 30 on each side of the splice. When balancing side-side within and between quads the number of unbalances are $190\left(=\frac{20 \cdot 19}{2}\right)$ on each side of the splice. The number of splicing possibilities for 10 quads, if the quads are not split, are given partly by $\lfloor\!\underline{10}$ possiblities in selecting quads on both sides and partly by 8 possible splicing plans for each quad. The total number of splicing possibilities are thus

$$\lfloor\!\underline{10} \cdot 8^{10} \simeq 2^{52}$$

This means that e. g. sign could be chosen arbitrarly for 52 combinations. When balancing, the 30 unbalance figures within the quads, in addition a certain amount of liberty is given for combining, the unbalancing figures from both sides of suitable values. When balancing the 190 unbalances within and between the quads apparently not even the sign for more than a fraction of the combinations can be free of choice. It is easily understood that it is more difficult to systemise the splicing calculations in this latter case. At the crosstalk measurements in question the unbalance figure could then not be brought down to zero in the same way as at the usual capacitive balancing, and a final end-balancing of the repeater section was therefore required. By doing the balancing in connection with the splicing, the far-end crosstalk was improved on the average by about 1 neper, at which the minimum figures were improved considerably.

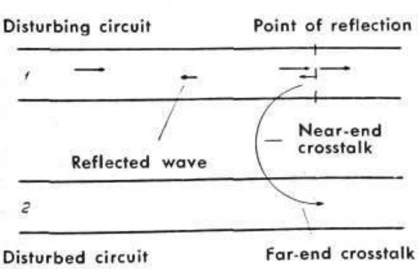


Fig. 5 X 4309
Arise of reflected near-end crosstalk

The new repeater sections covered on the average 11 loading sections. These loading sections were spliced in succession into two half-sections while the measured direct far-end crosstalk at 60 kc/s was taken into consideration. At

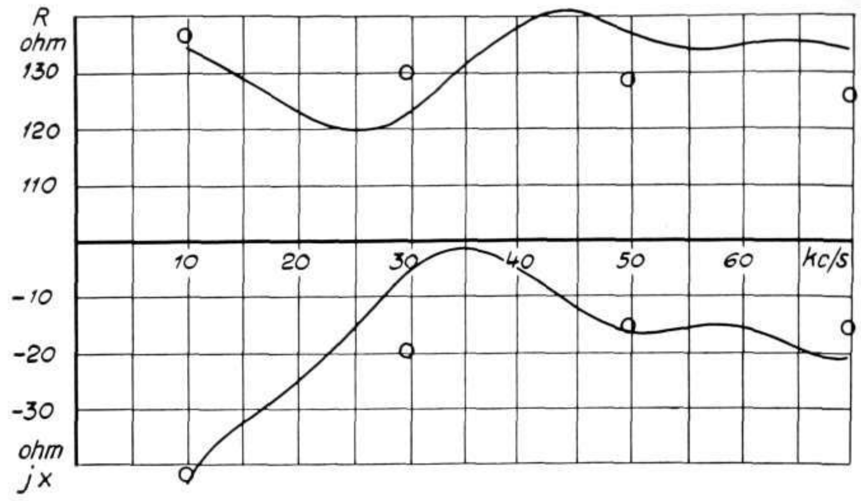


Fig. 6 X 6053
Typical impedance characteristics for nonloaded, 1.3 mm side circuit in trunk cable Stockholm—Gothenburg
O mean value of total circuits

the mid-point splice of the repeater section more extensive measurements were performed, and when making this splice the indirect couplings were chiefly taken into account, about which more comes in the following.

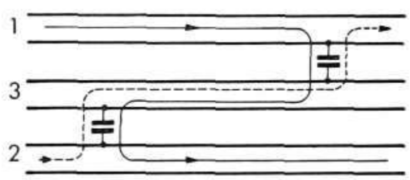
In order to simlify the splicing calculations a special calculating machine was made, see Fig. 4. This machine contains a number of potentiometers on which respective unbalance figures can be set, and keys for testing the different splicing plans. The readings on the attached instrument give that splicing plan which gives the best R. M. S. value of the resulting unbalances. Despite the possibilities of adding and subtracting related unbalance figures by the splicing procedure, it has been shown that the criterian of the best splicing plan in the above mentioned respect is derived from the product of the related unbalances. The calculating machine is therefore designed in such a way that the meter deflection according to the above is a measure of the sum of these products for the different unbalances, at which signs are depending on the splicing plans.

Indirect Crosstalk

The direct crosstalk is, according to above, dependent on the frequency in a simple relation, and furthermore, the direct crosstalk which is caused by an unbalance, can be completely compensated with a reversed unbalance at a point free of choice on the circuit on the assumption that the two circuits have identical transmission properties. This, however, is not the case with the direct far-end crosstalk, which among other things is dependent on its frequency characteristics being comparatively complicated.

Indirect far-end crosstalk between two circuits can be caused by reflected near-end crosstalk, by double crosstalk over other circuits and by differing transmission properties of the two circuits.

How reflected near-end crosstalk arises is shown in Fig. 5. The direct wave in circuit 1 (disturbing) gives at the point of reflection the rise to a reflected wave which in its turn through near-end crosstalk to circuit 2 (disturbed) causes indirect far-end crosstalk, in the latter.



—►— = crosstalk from 1 to 2
--►-- = » » 2 » 1

Fig. 7 X 4324
Indirect far-end crosstalk over third circuit

Each splicing point can become a point for reflection, when the near-by pairs in respective splicing sections have comparatively different impedance characteristics. This condition is shown with the measured impedance curves of already spliced circuits, of which Fig. 6 gives an exemple. Very large differences can evidently occur between separate pairs. Points of reflection are furthermore found at the repeaters, when their input and output impedances do not entirely correspond with the differing impedances of the circuits. These points of

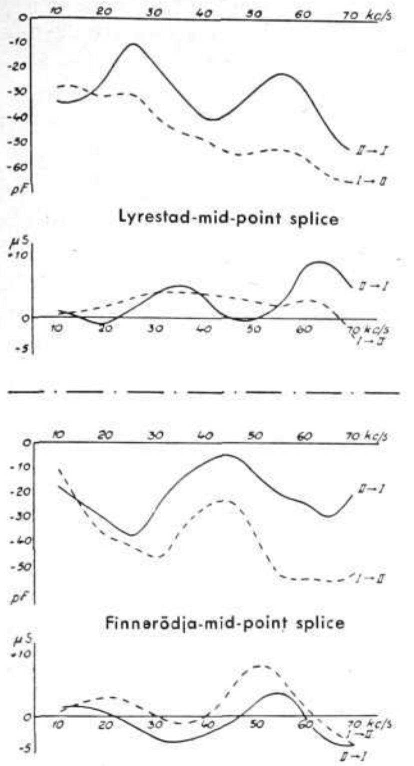


Fig. 8 X 4310
Far-end crosstalk coupling within-quad (frequency characteristics of parts sections)

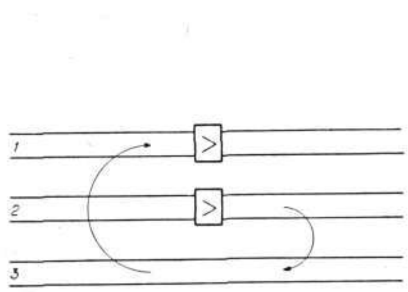


Fig. 9 X 4311
Far-end crosstalk over third circuit at intermediate repeater (feed-back)

reflection are of special importance, when the near-end crosstalk its deteriorated at these points by connecting extra elements of unbalance at the end-balancing. This fact is one of the reasons why crosstalk balancing is done on the line. In this way the size of the extra elements for unbalance is brought down.

As is shown in Fig. 7 indirect far-end crosstalk can also occur between two circuits, 1 and 2, through double crosstalk over a third circuit.

Then the crosstalk current from circuit *1* to circuit *2* will pass a considerably longer way than corresponding currents from circuit *2* to circuit *1*. Corresponding crosstalk attenuations can therefore also be quite different. When measuring the unbalances on a longer section with the measuring arrangement as in Fig. 2, different figures can as a rule be obtained if the sending pair is interchanged with the receiving pair. The difference between these unbalances, the so-called coupling-difference, is a measure of the direct couplings. It is obvious that coupling differences are also caused by other indirect couplings, for instance through reflected near-end crosstalk.

According to the foregoing a direct coupling between two circuits can be entirely compensated by an equally great reversed coupling at some other point of the circuits, provided they have identical transmission properties between the coupling points. If this condition is not fullfilled, but the two circuits then have different attenuation or different propogation time, full compensation cannot be obtained. To make improvements in this respect with given properties of the circuits it is evidently necessary to keep the line sections between the splicing points, with each other compensated unbalances, as short as possible, *i e.* the unbalances have to be brought down as far as possible when splicing the repeater sections.
In addition to this reason for making the crosstalk balancing out on the section, the risk of making the near-end crosstalk to high if only end-balancing is used has previously been pointed out. Futhermore the following reason can be given; if the balancing is made only at the end-points, the balancing elements as an average become bigger, and the risk for variations in them on account of the temperature etc. thereby also becomes greater. It can furthermore be expected that unbalances on a cable section in general can be better compensated all over the frequency range with unbalances on another cable section than with condensers and resistances.

As mentioned previously the different sections of a repeater section were spliced in succession into two half-sections taking the measured direct unbalances at 60 kc/s into consideration. These half-sections were then spliced at the mid-splice of respective repeater sections after more extensive measurements of unbalance at different frequencies and chiefly considering the indirect couplings. These couplings can, as a matter of fact, even to a certain degree be reduced when splicing, despite they sometimes go under the name »couplings not possible to balance». The indirect unbalances according to the above give rise to coupling difference and cause, furthermore, rather complicated frequency characteristics for the far-end crosstalk. If therefore the resulting unbalances between two pairs are measured at different frequencies with the measuring arrangement as in Fig. 2 coupling figures varying with the frequency are obtained, which furthermore are different for the two measuring combinations (crosstalk from circuit *1* to *2* and from *2* to *1* respectively). In Fig. 8 a typical example is shown of this which is taken from measurement on the section Lyrestad—Finnerödja. The frequency variations and the coupling differencies were so great, especially for the combinations within the quads, that relatively poor final results would have been obtained for the far-end crosstalk after end-balancing, if nothing had been done to improve these conditions. Trials were therefore made with good results to match the quads on respective half-sections, see Fig. 8, so that after the splicing both the frequency variations and the coupling differences were decreased if possible.

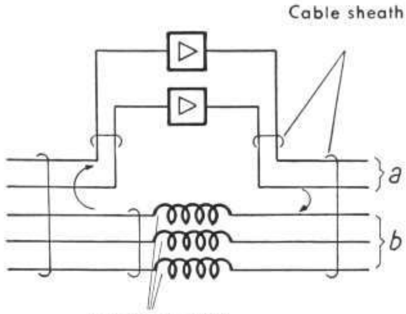


Fig. 10 X 4325

Arrangements at intermediate repeater station for suppressing feed-back

a carrier circuits

b loaded circuits

In addition to the above described types of couplings there is still another possibility for indirect crosstalk, and that is interacting crosstalk over a third circuit at the intermediate repeaters. The conditions in this case are shown in Fig. 9. This type of indirect crosstalk is evidently a very serious matter as on this account a very strong crosstalk can occur owing to the difference in level between the points of coupling (from the high level side of circuit *2* to the low level side of circuit *1*). This difference in level can be as high as 7 nepers equivalent to the highest loss for the transmitted band. As about 9 nepers is desired as an average of the effective crosstalk attenuation between the different circuits, the measured crosstalk between outgoing and incoming pairs in a repeater station, the so-called feed-back, must evidently come up to about 16 nepers. Special steps must be taken to meet these rigorous requirements. A crosstalk attenuation of 16 nepers is at 60 kc/s equivalent to a capacitive unbalance of only 0.02 pF. To begin with, incoming and outgoing pairs therefore had to be laid in two separate cables. When laying the pairs in the same cable hardly higher figures than about 9 nepers would have been obtained. According to Fig. 10 these precautions, however, are not enough, but special arrangements must also be made for preventing the crosstalk currents to be induced from the outgoing to the incoming carrier pairs over the passing loaded circuits. In Fig. 10 these arrangements have been shown as inductance coils in the passing circuits, which coils therewith suppress the crosstalk currents of higher frequencies. In reality the new intermediate repeater stations have been placed at loading points and the two cables to the intermediate station were spliced on each side of the loading point. The loading coils prevent hereby the crosstalk currents from getting through over the passing, loaded side- and phantom circuits. This is, however, not sufficient, as also by-passing phantom circuits of a higher order may allow interacting crosstalk. According to the measurements the crosstalk attenuation came up about 12 nepers at 60 kc/s without extra coils. From performed measurements its seems as if twisted circuits cause this crosstalk. One branch of this twisted circuit is formed of one quad (the four conductors in parallel) and the other branch is the lead sheathe (or earth). Such a circuit is ony loaded with the mutual inductance of the loading coils which is in the order of 1 mH.

In order to improve the feed-back attenuation it was necessary to insert extra inductance coils in the twisted circuits. At each intermediate repeater station a so-called suppressing coil box therefore was inserted which contains coils with four-wired windings which were spliced into the loaded quads. The coils introduce an inductance of about 30 mH in the twisted circuits and they are tuned to parallel resonance right below 60 kc/s. These coils have a very slight effect on the v. f. side- and phantom circuits. After insertion of these coils an improvement of the feed-back attenuation with about 5 nepers at 60 kc/s was obtained which was quite acceptable. The measured feed-back attenuation (R. M. S. values) after the insertion and the required amplification at different frequencies are given in the table below.

f kc/s	10	30	60	64
Feed-back attenuation nepers	15.9	15.2	17.4	16.4
Amplification = max. cable loss nepers	3.4	4.7	6.7	7.0
Difference neper	12.5	10.5	10.7	9.4

The difference given in the table is equivalent to the effective crosstalk that is caused by the feed-back and apparently these figures are sufficient.

Modern Radio Loudspeakers

E LINDSTRÖM, SVENSKA RADIOAKTIEBOLAGET, STOCKHOLM

U.D.C. 621.396.623.7

Svenska Radioaktiebolaget took up the manufacture of electro-magnetic loudspeakers in 1928 and has continued with it since then, applying and improving the principles introduced with the dynamic loudspeaker. The following article gives an account of a number of problems connected with the manufacture of loudspeakers and in addition gives a short description of the design and manufacture of Svenska Radioaktiebolaget's latest types of radio loudspeakers.

Right up to 1928 horn loudspeakers had been predominant in the domain of loudspeakers. The sound system in these funnel loudspeakers consisted of an enlarged telephone receiver of electro-magnetic type. Unfortunately the self-resonance for the vibrating device lay right between the speech and music registers to the disadvantage of high and low frequencies. Coupled to the sound system was a horn of sheet-metal or wood, often shaped for its appearance, which directed and strengthened the sound. The valves of old battery receiving sets could not deliver any distortion-free capacity and the music reproduction was therefore cracked and not enjoyable.

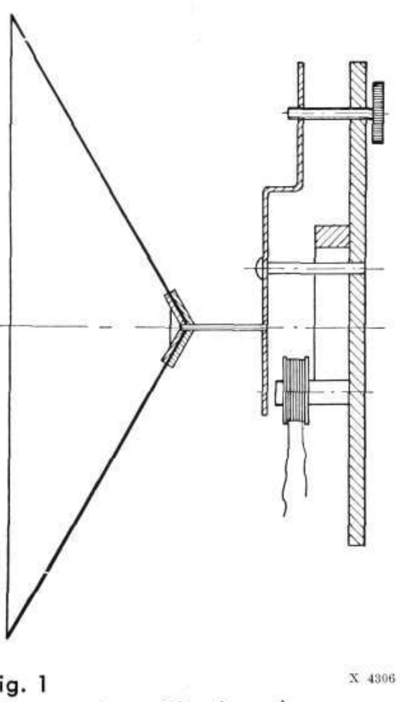
In conjunction with the design of new types of valves and the construction of receiving sets for connection to the lighting mains, the amplification and the output capacity could be increased. In addition the cone loudspeaker quickly made its appearance. By replacing the circular sheet-metal diaphragm by a soft iron tongue, to which was attached a cone of cardboard, see Fig. 1, it was possible, while building the whole system into a wooden case, to lower the self-resonance of the system. As regards music the quality was acceptable, but as the self-resonance coincided with the lower voice frequencies 200—300 c/s the intelligibility of the speech was difficult, especially as frequencies over 2000 c/s were entirely lacking.

In 1928 Svenska Radioaktiebolaget, after prolonged experiment, were ready with their first loudspeaker design. The magnet system was of simple construction with adjustable tongue and the material for the cone consisted of drawing-paper, stamped out, pasted over forms and sprayed with cellulose laquer. Instead of having the cone edges gummed in the case, wich had been the practice hitherto, it was allowed to swing freely being attached only by four fabric strips. This arrangement, together with the small depth of the loudspeaker case, served to reduce considerably »boom-boom» resonance.

By fitting the radio receiving set itself in the loudspeaker case there was then introduced the »all-in-one» principle, and in this way the wireless receiver obtanied its modern shape.

If it is a question of transmitting large capacity, the electro-magnetic loudspeaker will be too small with poor acoustic efficiency and doubtful reproduction. In order that the music shall be enjoyable, the loudspeaker should have a fairly straight frequency curve between 100 and 4000 c/s. The dominant downwards causes »boom» in speech and makes a violin seem like a cello. Peaks in the upper register make the music thin and without acoustic space. Should these peaks lie between 1500 and 2500 c/s moreover they coincide with highest range of sensitivity of the ear and have an irritating effect.

In America Rice-Kellog and others succeeded in designing the type of loudspeaker which ever since then has been practically the only one: the dynamic loudspeaker.



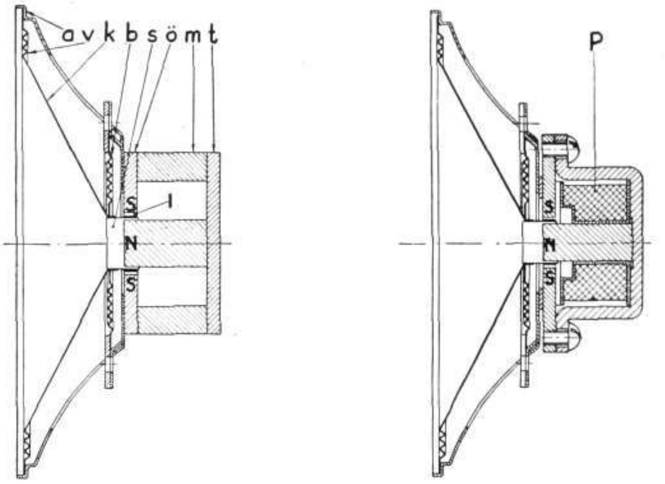
X 4306

Fig. 1
Cross-section of loudspeaker

Fig. 2 X 6044

Cross-section of dynamic loudspeaker

left, with permanent magnet
right, with magnetising coil
a basket edge
b spreader
k cone
l air-gap
m magnet
p magnetising coil
s cylindrical coil
t core with under-piece
v folds
ö upper piece



The principle of this will be seen from Fig. 2. The cone, *k*, is fitted towards the apex with a cylindrical coil, *s*, which lies in the circular air-gap, *l*. At the base the cone is enlarged and provided with folds, *v*, and pasted to the basket edge, *a*. To ensure that the cone moves perfectly parallel with its axis, it has at the apex a guide, the spreader *b*. The air-gap, *l*, is traversed by a magnetic field generated by a permanent magnet, *m*, or by a magnetising coil, *p*, see Fig. 2 right. The polarity will be, *e. g.*, *N* at the core *t* and *S* at the edge of the hole in the upper piece *ö*. If the cone coil receives an alternating tension it will move to and fro in the air-gap in time to the A.C. tension. In these movements the cone accompanies its coil and, with sufficiently high frequency, generates a tone.

Design

Before designing a loudspeaker one should be clear regarding its range of employment. The aim is not always to produce a »good» loudspeaker, *i. e.*, a loudspeaker which reproduces all audible frequencies with the same intensity. A good loudspeaker should have fairly straight frequency curve, 40—5000 c/s. When great demands regarding reproduction are imposed, such as with sound films, a number of different loudspeakers are used, each one covering its allotted part of the register.

For a battery receiver, *e. g.*, a portable radio, it is necessary before designing the loudspeaker system to investigate what output capacity and what degree of distortion the apparatus has. Distortion is a deformation of the curve originally sinus shape, which gives rise to overtones that have an irritating effect on the ear. A portable radio should be made as light as possible and should be cheap in operation. The valves and batteries must be as small as possible and the sound quality suffers. Nevertheless, if the loudspeaker is suitably designed the sound can still be surprisingly good. For example, the cone paper may be fitted with resonance folds, causing the loudspeaker to lose its ability to reproduce high frequencies and the undesirable overtones arising in the apparatus are not heard. In order that the register shall be well balanced, such a loudspeaker should not reproduce too much base and the cone will thus be small and rigidly suspended.

In a mains wireless receiving set of ordinary size there often arise case resonances. These should not be amplified by the loudspeaker, but the aim should be to make a »hole» in the register for the resonance frequencies in question.

How large shall the loudspeaker be for a given receiver case? The lower cut-off frequency is the deciding factor.

If a loudspeaker system is placed on the table and allowed to play, no base whatever will be heard in spite of the cone giving large amplitudes. The sound waves radiated from back and front of the cone have a mutual phase shift

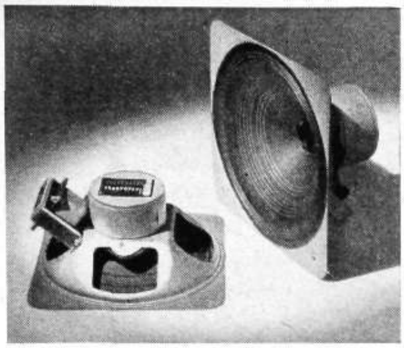


Fig. 3 X 4308
Loudspeakers HPU—918 and HPU 1021 F

of 180° and therefore cancel out each other. If the loudspeaker system is fitted in the hole of a sound screen, about 1 m square, there will at once arise a full sound, the contrabase is heard clear and soft and the loudspeaker attains its full efficiency. The length of the screen side should theoretically be equal to half the longest wave length to be heard, *i.e.*, the lowest frequency. If the loudspeaker is to reproduce clearly 100 c/s, the side length should be 1.5 m. In practice, however, considerations of space require one to be satisfied with much more modest dimensions. Moreover it has been found that the ear is generally satisfied with the first overtones of the basic tone.

The measure of a loudspeaker's base reproduction is what is known as suspension resonance. This is governed by the rigidity of the cone and the spreader, *i. e.*, the mobility of the whole cone system. The moulding of the cone is then made with the edge thinner than the remainder of the cone material. The spreader is corrugated in circles and must not be allowed to lose its springiness with temporary overload.

A large cone reproduces a given amplitude of base frequencies better than a small one, on account of the larger volume of air it sets in motion. If the smaller cone were to reproduce the same frequency with the same strength the amplitudes would be so great that there would be risk of the cone coil jumping out of the air-gap or causing distortion. It is therefore bad economy to fit a large and certainly more expensive loudspeaker in a small case with poor screening, with resultant inferior base reproduction.

Frequencies from 1000 c/s upwards have a marked direction effect. If one is at the side of the apparatus the S-sound, for example, will be heard much worse than right in front.

The magnetic field in the air-gap is generated either by a permanent magnet or by a small D.C. fed magnetising coil. The permanent magnets are circular and consist of an alloy of iron, nickel and aluminium. The intensity of a magnet system is expressed in the number of lines of force per cm^2 that flow through the air-gap. The measurement unit is called Gauss. The greater field intensity the magnet has the greater distortionless acoustic effect and the straighter the frequency curve it is possible to get from the loudspeaker. But as the price per kilo of the magnet steel is high and the weight rises with the square of the field intensity, the aim should be to be economical with lines of force. The upper piece, the under piece and especially the core must have small remanence and are made of soft iron. The air-gap is made as small as it can conveniently be. The cone coil in Svenska Radioaktiebolaget's loudspeaker has 0.20 mm air at each side.

In apparatus for alternating current, field-fed loudspeakers are most often used. The magnetising coil may be used as screen choke for the rectified A.C. The tension field over the coil is sufficient to ensure a large enough field in the air-gap. The unscreened A.C., which is superimposed on the magnetising current would, were there no compensating, induce tensions in the cone coil, which are heard as noise in the loudspeaker. On account of this there is laid over the magnetising coil a winding, connected in series with the cone coil and so wound that the induced tensions in it and the cone coil counter balance each other.

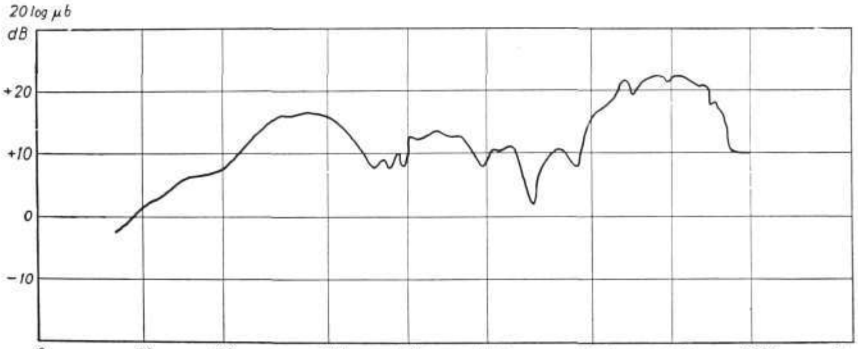


Fig. 4 X 6045
Sound pressure delivered at 75 cm distance from loudspeaker HPU 1021 F
inserted in 100×100 cm baffle and with 1 V tension over the voice coil

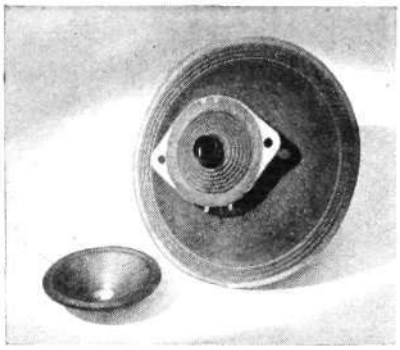


Fig. 5
Loudspeaker cones X 4307

Manufacture

The raw material for the making of the cones consists of paper pulp, supplied in semi-dry-form. The pulp is soaked in water and stirred until the fibres are separated and then put in a semi-automatic moulding machine. The moulded cone is subjected to centrifugal force to remove as much water as possible, after which it is pressed in strong heat in a hydraulic press. The speed and pressure of the press are varied according to whether the cone is to be hard or soft, thick or thin. The cone apex (neck) and resonance folds if any are pressed in special forms, after which the cone is weighed for checking and examined.

The spreader is made of rather longer fibred pulp than the cone and in the same way. Depending on the suspension resonance desired and the loudspeaker size, the spreaders are made in four qualities. As great demands are imposed on the spreader it must be subjected to particularly careful inspection. Each spreader is examined through light to ascertain if the fibres are properly felted together and that there are no spots or clots.

The cone and spreader are impregnated to protect them against damp. Exacting demands are placed on the impregnating material, as a finished cone should be capable of being immersed in water without being deformed when dry. Two different impregnating materials are used, one for soft and one for hard cones. The former should not affect the consistency of the paper itself, while the latter, which consists of a resin solution with a fixed viscosity, stiffens the paper when it dries.

The cone coils are wound on a hard short-fibre frame about 0.03 mm thick for the smaller loudspeakers. For the larger loudspeakers there is used a material like presspahn, 0.1 mm thick. The low impedance coils, 2—8 ohm, are wound with two layers of enamelled copper wire, the 20 ohm coils are wound with four layers. Each layer is copiously coated with paste which dries hard and tough. In order that they shall not lose their circular form the coils must dry on their mandrels for 24 hours.

The joining of cone paper, spreader and cone coil is done on templets, a rapid drying paste being used. After drying in an oven the cones are ready for fitting in the loudspeaker chassis. They are pasted to the basket edge and centred, after which the finished loudspeaker is ready for testing.

Loudspeaker Types

Svenska Radioaktiebolaget's loudspeakers are made in three constructions as per Fig. 7. Technical data for these will be found in the table below.

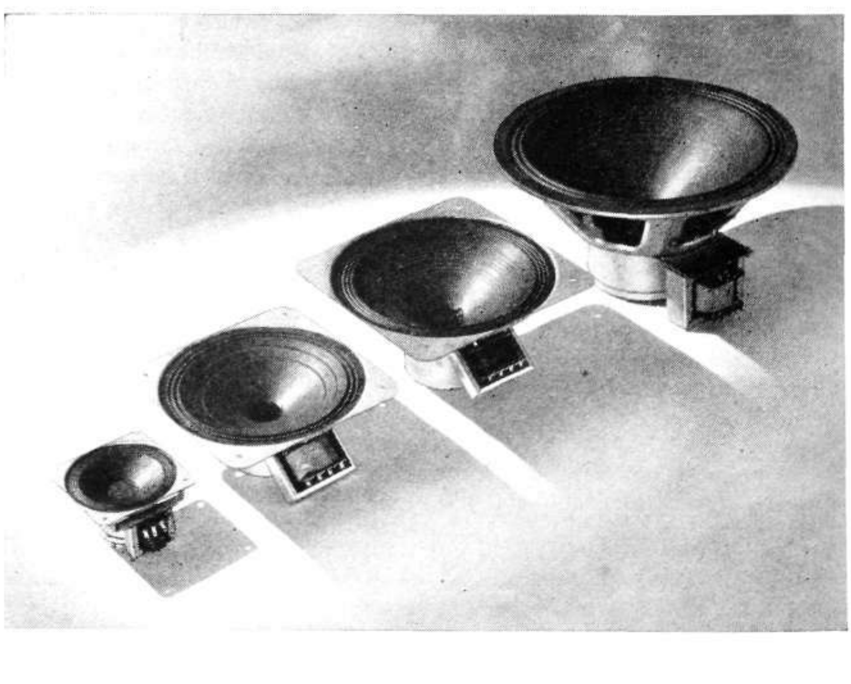
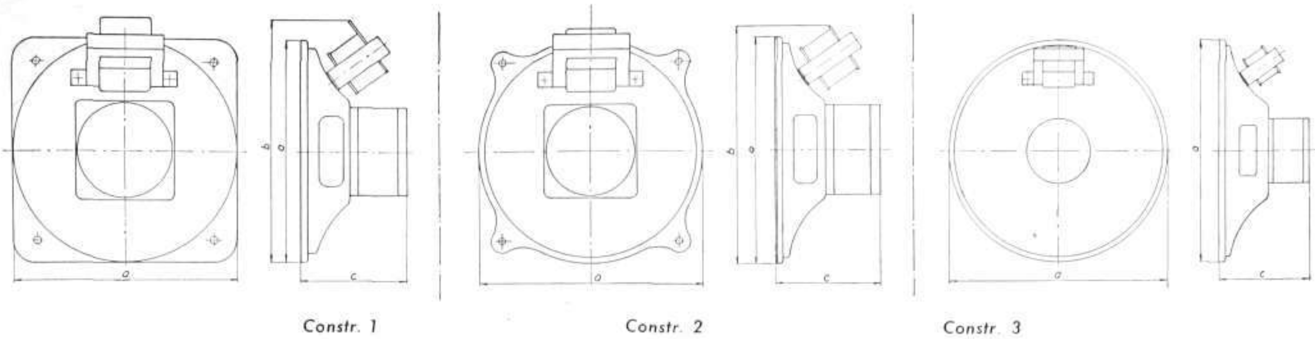


Fig. 6
Loudspeakers X 6048



X 7373

Fig. 7
Dimension sketches of Svenska Radio-aktiebolaget's loudspeaker types

Table I
Technical data of Svenska Radioaktiebolaget's loudspeaker types

Type[1])	Construction[2])	Dimension a	Dimension b	Dimension c	Field intensity in air-gap	Magnetising capacity	Cone suspension resonance	Max. load	Loudspeaker transformer's nonreflexion resistance
		mm	mm	mm	Gauss	W	c/s	W[3])	ohm
HP—710	1	97	—	55	7000	—	170	0.5—1	—
HPU—710	1	97	108	55	7000	—	170	0.5—1	20, 1000, 3000, 7000
HP—713	1	125	—	60	7000	—	170	1—2	—
HPU—713	1	125	145	60	7000		170	1—2	20, 1000, 3000, 7000
HF—613	1	125	—	70	6000	3	170	1—2	—
HP—716	2	162	—	67	7000		120	3—4	—
HP—916	2	162	—	73	9000		120	4—5	—
HPU—916	2	162	181	73	9000		120	4—5	20, 100, 500, 1000, 2500, 3000, 3500, 4000, 6500, 7500
HF—616	2	162	—	77	6000	3	120	4—5	
HP—718	1	186	—	76	7000		90	4—5	
HP—918	1	186	—	82	9000		60—90	5—6	
HPU—918	1	186	190	82	9000		90	5—7	20, 100, 500, 1000, 2500, 3000, 3500, 4000, 6500, 7500
HF—618	1	186	—	86	6000	4—5	60—90	5—6	
HP—921	1	213	—	108	9000		70	6—8	
HP—1021	1	213	—	108	10000		70	7—9	
HPU—921	1	213	—	108	9000		70	6—8	20, 100, 500, 1000, 2500, 3000, 3500, 4000, 6500, 7500
HPU—1021	1	213	—	108	10000		70	7—9	
HP—924	3	237	—	99	9000		65	7—9	
HP—1024	3	237	—	102	10000		65	8—10	
HPU—924	3	237	—	99	9000		65	7—9	20, 100, 500, 1000, 2500, 3000, 3500, 4000, 6500, 7500
HPU—1024	3	237	—	102	10000		65	8—10	
HP—1330	3	305	—	160	13000		60	12—15	
HPU—1330	3	305	—	160	13000		60	12—15	20, 115, 150, 500, 750, 1000, 1500, 2000, 2500, 3000

1) HP designates loudspeakers with permanent magnets.
HF » » » magnetising coils.

2) Construction refers to basket, no matter whether the loudspeaker is of P-type or F-type.

3) Lower figure applies if loudspeaker connected to amplifier with full register.
Higher » » » » » » » » cut-down base register.

New L M Ericsson Exchanges 1939—1944

During 1939—1944 the following exchanges and switchboards on the LM Ericsson system with 500-line selectors were put into service:

town	exchange	number of lines	year of opening
Argentine			
Godoy Cruz	(extension)	500	1940
Mendoza	(extension)	1000	
Santiago del Estero	(extension)	500	
Tucumán	(extension)	1000	
Santa Fé	(extension)	1500	1941
Mendoza	(extension)	1000	1942
San Juan		2500	
Tucumán	(extension)	2000	
Salta		3000	1943
Santiago del Estero	(extension)	500	
San Rafael	(extension)	300	1944
Bolivia			
La Paz		2500	1941
Cochabamba		1000	1944
Brazil			
Blumenau		500	1939
Juiz de Fora	(extension)	500	1940
Manáos	(extension)	500	1942
Natal		500	1943
Natal	(extension)	500	1944
Colombia			
Medellin		10000	1940
Dutch West Indies			
Curacao		1500	1939
Rotterdam		2000	1940
Rotterdam	(extension)	3700	
Rotterdam		5000	1941
Rotterdam		5000	1942
Rotterdam	(extension)	5000	1944
Esthonia			
Tartu		2500	1939
Finland			
Ekenäs	(extension)	100	1940
Helsingfors	PABX	250	

town	exchange	number of lines	year of opening
Jyväskylä	(extension)	500	1941
Tammerfors	(extension)	1000	
Mariehamn		1000	1942
Åbo		7000	
Forssa		700	1943
Rauma	(extension)	500	
Åbo	(extension)	1000	
Vasa	(extension)	1000	
Kuopio		3000	1944
Tammerfors	(extension)	500	
Italy			
Milan	PABX	260	1939
Venice	(extension)	500	
Sondalo	PABX	400	
Treviso		1500	
Napoli	PABX	120	1940
Torino	PABX	160	
Bologna	PABX	100	1941
Brescia	(extension)	500	
Venezia	PABX	300	
Vercelli	(extension)	500	
Libia			
Tripolis	(extension)	500	1940
Morocco			
Tanger	(extension)	1000	1944
Mexico			
México D. F.	(extension)	4500	1939
Guadalajara	(extension)	1000	
Puebla		1000	
León	(extension)	500	1940
México D. F.	(extension)	1000	
México D. F.		2000	
Puebla	(extension)	1000	
Toluca	(extension)	500	
México D. F.	(extension)	4500	1941
Puebla	(extension)	2000	
Guadalajara	(extension)	500	1942
México D. F.	(extension)	7500	
Merida	(extension)	500	1943
México D. F.	(extension)	2500	
New Zealand			
Wangarei	(extension)	400	1940
Norway			
Fredrikstad	(extension)	500	1939
Halden		1200	
Kristiansand	(extension)	500	
Oslo	PABX	600	
Arendal	(extension)	500	1940
Halden	(extension)	300	
Hamar	(extension)	300	
Stavanger		6000	

town	exchange	number of lines	year of opening
Haugesund	(extension)	500	1941
Larvik	(extension)	500	1943
Trondheim		9000	
Fredrikstad	(extension)	500	1944
Halden	(extension)	300	
Kristiansand	(extension)	200	
Poland			
Bydgoszcz	(extension)	500	1939
Lublin	(extension)	500	
Warsaw	(extension)	4000	
Slovakia			
Nitra	(extension)	580	1943
Spain			
San Sebastián	(extension)	1500	1942
Sweden			
Barkarby	PABX	50	1939
Fagersta	PABX	260	
Göteborg	PABX	570	
Göteborg	PABX (extension)	120	
Hälsingborg	PABX	120	
Kinna		700	
Norrköping	PABX	670	
Skelleftehamn	PABX	180	
Stockholm		11700	
Stockholm	(extension)	3160	
Trälleborg	PABX (extension)	20	
Uddevalla	PABX	3500	
Viggbyholm	PABX	50	
Västerås	PABX	320	
Örebro	PABX	120	
Bollnäs		1500	1940
Djursholm		5000	
Hälsingborg		11000	
Södertälje		4000	
Various places	39 exchanges PABX	4510	1940
Various places	8 exchanges PABX (extension)	420	1940
Borås		2000	1941
Göteborg		5000	
Göteborg	(extension)	5500	
Karlstad		6500	
Norrköping		2000	
Skellefteå		2500	
Stockholm		5000	
Stockholm	(extension)	12000	
Västerås		7000	
Örebro	(extension)	2000	
Various places	21 exchanges PABX	2110	1941
Various places	13 exchanges PABX (extension)	570	1941
Göteborg		3500	1942
Göteborg	(extension)	2000	
Karlskoga		3500	
Kristinehamn		3000	

town	exchange	number of lines	year of opening
Lidingö	(extension)	500	1942
Mölndal		2500	
Stockholm		11660	
Sölvesborg		800	
Various places	PABX	4690	1942
Various places	PABX (extension)	1080	1942
Eskilstuna	(extension)	7600	1943
Göteborg		5300	
Stockholm		5500	
Stockholm	(extension)	26000	
Uddevalla	(extension)	500	
Various places	45 exchanges PABX	5140	1943
Various places	28 exchanges PABX	926	1943
Göteborg	(extension)	8000	1944
Hälsingborg	(extension)	1000	
Karlstad	(extension)	1200	
Lund		7500	
Stockholm		2000	
Stockholm	(extension)	14000	
Södertälje	(extension)	2500	
Sölvesborg	(extension)	200	
Upsala		12000	
Västerås		1000	
Various places	35 exchanges PABX	5400	
Various places	22 exchanges PABX (extension)	1120	1944
Union of South Africa			
Moddersfontein		190	1939
Cape Town	PABX	130	1940
Turkey			
Ankara		2000	1939
Istanbul		2000	
Ankara	PABX (extension)	100	1941
Ankara	(extension)	2000	1943
Istanbul	(extension)	3000	

During 1939—1944 the following exchanges and switchboards with 100, 25 and 12 line selectors have been delivered. Extensions to existing plants are not included in the figures.

	number	number of lines
Exchanges with 100 line selectors	43	6170
Switchboards with 100 line selectors, system AHD	75	7003
Switchboards with 25 and 12 line sectors, system OL	1338	30912

Concerning the exchanges on British Post Office system opened during 1939—1944 by Ericsson Telephones Ltd., London-Beeston, and the exchanges on the Rotary system put into operation by Société des Téléphones Ericsson, Colombes, no information is available.

Ericsson Technics No 6, 1939

T Laurent: Transformation fréquentielle des réseaux d'impédances correcteurs d'affaiblissement

In Ericsson Technics No 3, 1937, it was shown how it is possible mathematically to treat attenuation correcting impedance networks by frequency transformations. The present article constitutes a complement to that work with regard to the continued development of the frequency transformations. To begin with it is shown how all correction attenuations may be determined with frequency transformations by a single universal original attenuation curve. There are then presented new graphic methods for direct transformation according to the summation method, which has proved to be of great significance for attenuation correction networks. Moreover the graphic treatment of properties is supplemented by a successive direct transformation with inclined construction rays, through which the procedure becomes just as general as the summation method. It is then demonstrated how it is possible to transform direct with indirect functions, which in certain frequency ranges makes the phase shift of the correction network equal to zero. Finally it is shown that the complicated frequency transformations are only justified in exceptional cases for correction attenuation and that it is then possible to treat the attenuation graphically if the original attenuation is allowed to vary with frequency.

From this work it should be clear that frequency transformations with a small number of frequency functions enable the attenuation correcting impedance networks to be mathematically controlled in a simple and clear manner, as has previously been shown to be the case with electrical filters, circuits etc.

Ericsson Technics No 43

Håkan Sterky: Übertragungsverhältnisse auf bespulten und wahlrufbetriebenen Fernsprechleitungen

Selective calling telephone lines present much of interest, not only because of their properties enabling telephone traffic peculiar to railways, but also from purely technical points of view. At the request of a special committee appointed by the Royal Board of Railways the author has carried out certain computations and measurements with the object of making clear the general transmission properties of selective calling telephone lines. The results of these computations are noteworthy from a number of standpoints.

On loading selective calling telephone lines shunted by telephone instruments there is obtained in certain cases, contrary to expectations, a rise instead of a fall in the attenuation constant. In the paper the explanation of this is given, both by application of the band pass filter theory and by reference to general formulae. The transmission properties of the selective calling telephone line may be compared with those of the Pupin-Thomson line. The computations have been confirmed by extensive measurements on various types of line and with different selective calling telephone instruments. The agreement between theory and practice is good, though the telephone posts in practice are not distributed along the line so regularly as must be assumed for mathematical treatment.

In addition there is dealt with the question of the most advantageous instrument impedance in order to arrive at a suitable compromise between low attenuation constant and best transmitter and receiver reference equivalents. An account is also given of intelligibility tests carried out with a proposed new type of selective calling telephone instrument. The paper concludes with general directions for the planning of sectional telephone circuits for various types of aerial and cable lines, with or without coil loading.

U.D.C. 621.395.663.2:654.155.4.032.16

Berglund, Cornelius: *Rational Charging Methods for Automatic Telephone Traffic*. Ericsson Rev. *22* (1945) No 1 p. 2—7.

In automatic traffic the running costs are governed by the duration of conversation and not by the number of calls. The charges should therefore be based on the total time of conversation. This article shows how recording of duration of conversation for local calls can be introduced with advantage.
The charges per 3-minute period begun, as used in manual traffic, are without justification in automatised toll traffic and should be replaced by charges for the actual time of conversation. By means of suitable numbering and distribution of rates it is possible to arrive at effective time zone meters, if the charges are permitted to deviate slightly from what would correspond to the exact geographical distance between the calling and called exchanges.

U.D.C. 621.395.663.2:654.155.4

Berglund Cornelius: *Registering of Duration of Conversation*. Ericsson Rev. *22* (1945) No 1 p. 8—10.

In registering the duration of calls by impulses to the call meters of subscribers from common time impulse units the times recorded for each individual call will contain errors. Nevertheless such errors compensate each other over a charging period, so that satisfactory accuracy of measurement is attained. This article indicates the magnitude of the deviations and the excess recordings that arise.

U.D.C. 621.395.44

Jansson, Stig & Stålemark, Ragnar: *8-Channel Carrier Systems for Unloaded Cables*. Ericsson Rev. *22* (1945) No 1 p. 11—18.

Older, loaded cables can after unloading be made available for carrier operation with frequencies up to 60000 to 65000 c/s. Methods and apparatus for re-splicing the cable and for balancing the far-end crosstalk is treated, and a description of the characteristics and design of the carrier equipment is given in the article, which will be continued in Ericsson Rev. *22* (1945) p. 30.

U.D.C. 621.396.623.7

Lindström, Erik: *Modern Radio Loudspeakers*. Ericsson Rev. *22* (1945) No 1 p. 19—23.

Svenska Radioaktiebolaget took up the manufacture of electro-magnetic loudspeakers in 1928 and has continued with it since then, applying and improving the principles introduced with the dynamic loudspeaker. The following article gives an account of a number of problems connected with the manufacture of loudspeakers and in addition gives a short description of the design and manufacture of Svenska Radioaktiebolaget's latest types of radio loudspeakers.

Ericsson LM