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A new service: a country-wide radio code paging system

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Summary *The author describes the new selective radio code paging system which will be put into operation by the Netherlands Postal and Telecommunications Services in 1963. This system will enable subscribers connected to the automatic exchanges of the public telephone system to call a subscriber possessing a radio code paging receiver and to pass on a message to him in code form, irrespective of where he is in the Netherlands. Observations on a trial network were used to determine the requirements to be satisfied by the national network and enabled an estimate to be made of the number of subscribers for which the network should be designed. The system operates by transmitting VF pulses in the 80 Mc/s band. Three transmitters and two frequency channels are needed to give complete coverage of the country. The receiver, not being equipped with a frequency control, operates on one channel only. A short description of the calling system and the receiver is given. The radio code paging system can also be used for alarm purposes.*

Introduction

If a large number of stations in a mobile radio network have to use a single RF channel in common, long waiting times result because at any particular moment the probability that another station has seized the channel is great. Waiting times can be reduced by making more channels available, but to this there is the objection that the number of suitable RF channels is very limited, while the possibility of interfering signals from sufficiently powerful transmitters belonging to a remote network is not excluded.

This article will describe the considerations which led the Netherlands Postal and Communications Services to develop a national paging network which will go into operation officially in 1963.

Requirements to be satisfied

For anyone wishing to make a call over the Dutch national Mobilophone (radio-telephone) network from a motor-car, ship or other vehicle it is a great convenience to be able to choose a free channel from a number of channels. The difficulty in this case lies in the fact that the fixed station does not know in which channel to call the mobile station in order to establish the connection. Moreover, it is also possible that if channels are distributed on a geographical basis the mobile station may be tuned to a channel for which the local fixed transmitter has not the necessary facilities.

It follows that a system whereby, in any given hour, a large number of mobile stations have to be called which may be anywhere inside a large area, must satisfy the following requirements:

1. Calls to a particular mobile station must always be transmitted on the same channel, irrespective of the position of the station at that moment.
2. The probability of calls being unsuccessful must be very small.
3. If the area to be covered is too big for a single transmitter, a number of transmitters must be arranged in such a way that reliable reception throughout the area is ensured.
4. The mobile stations must be so light that it is possible for the subscriber to take his set with him when he leaves his means of transport.
5. Mobile stations must not have channel selector switches since the public do not know the operational areas of the transmitters.
6. If a mobile station enters the operational area of a foreign network, it should not receive that network's signals.

As a large number of subscribers need nothing more than facilities for being called by radio, after which they can use local telephone facilities for the required telephone conversation, it is obviously not desirable to build the radio code paging equipment into the same container as the equipment concerned with the Mobilophone network. With regard to the types of communication facilities they desire, subscribers can be divided into four categories, as shown in Table I.

It will be seen from the table that all needs can be met with two separate sets, viz. a multichannel Mobilophone without selective calling and a radio code paging receiver with selective calling – a very attractive situation from both the operational and manufacturing point of view.

TABLE I. *Categories of communication facilities required by mobile subscribers*

Facilities	from	to	by
Call + conversation	mobile subscr.	telephone subscr.	Mobilophone
Call + conversation	telephone subscr.	mobile subscr. in limited area	Mobilophone
Call + conversation	telephone subscr.	mobile subscr. in extensive area	Mobilophone + radio code paging rec.
Call + code inform.	telephone subscr.	mobile subscr.	Radio code paging rec.

Experimental network

To acquire the necessary experience of the radio code paging system the Netherlands Postal and Communications Services set up a small experimental network in The Hague as long ago as 1955. At the same time an insight was gained into the public's need for a system of this kind. It was deduced that the resultant saving in time and money by users would cause a snowballing demand for the equipment and that a very large number of subscribers could be expected, the great majority of whom would need only the radio code paging receiver and not the Mobilophone. The total number of subscribers to the radio code paging system is in fact expected to be many times greater than the number who belong to the national Mobilophone network. This means that the radio code paging system will have to handle a large number of calls. This volume of traffic eliminates the possibility of using the calling channel for conversation. It is essential to keep the radio code paging network and the Mobilophone network distinct from each other. In the former of these two systems calling will take the form of voice-frequency signals. Inquiries also revealed a desire for the facility referred to in item 4 above: that the subscriber should be able to take the receiver with him when he leaves his means of transport. This in turn gives rise to fresh requirements:

1 When the set is used indoors or in narrow streets, it must be possible to check whether the field strength is sufficiently great to ensure reliable reception.

2 When the set is removed from the vehicle, it should switch automatically from car battery supply to dry battery supply.

These requirements are met by the radio code paging receiver type ESC (8MO 520) shown in Fig. 1. This receiver has been developed and tested by the mobile-radio experts of the Netherlands Postal and Telecommunications Services and N.V. Philips' Telecommunicatie Industrie.

Operation of network

Not only were the requirements of the receiver determined, but the operation of the network was also closely studied.

In the trial network operation was in the hands of a telephonist who could be reached via a special telephone number. The calling party would then give the operator his number and the number of the wanted radio code paging receiver, and then the operator would call the latter number. The person called then had to report (by telephone) to the operator to find out the contents of the message, for only actual calling was possible in this experimental network.

Answering telephone subscribers and persons connected to the radio code paging system takes up so much time, however, that the calling channel can only be effectively used by a fraction of the total time. The recruitment of additional operators would allow better use to be made of the calling channel, but would also result in deterioration of the service offered to radio code paging system subscribers, who would first have to enquire which operator was dealing with their call.

It follows from the above that manual operation is only possible in areas where little traffic can be expected, which is not the case in the Netherlands. Only complete automation can handle the situation here. Under this arrangement the facility for passing on messages by word of mouth will have to be omitted as it takes too much time and existing channels can be used for the purpose (national telephone network and national Mobilophone network).

Nevertheless, facilities for conveying not only calls but also a few items of information to the called party have been successfully incorporated in the radio code

Fig.1. The radio code paging receiver as fitted under the dashboard of a car.

paging system. To keep the equipment simple this message is transmitted in coded form. Three small lamps on the receiver enable six different coded items of information to be conveyed. Subscibers to the new service have to arrange with those who are liable to call them what the meaning of these codes will be. A telephone subscriber wishing to get a message through to a radio code paging subscriber obtains access to the system by dialling the appropriate combination of numbers. Once he is connected to the central control equipment, he dials the number of the receiver and finally the digit representing the desired message code.
As an example of this message code we will assume that a radio code paging system subscriber has arranged that code 1 will be transmitted if he has to call up his home, and code 2 if he has to ring his office. This still leaves four codes available and he can decide for himself how these are to be used. He may, for instance, arrange with a business friend that the latter will use code 3 on a particular day to indicate that he wishes to speak to the subscriber on the telephone. On the same day he may allocate code 4 to a message he is expecting, to the effect, for instance, that an appointment has been cancelled, so that he need not be home early. And so on.
An advantage of this system is that no directory of subscribers need be compiled. For a stranger who does not know that the person concerned is away from home will ring this office or home first; if necessary, the subscriber can then be contacted from there via the radio code paging network. Moreover, the stranger will not be familiar with the pre-arranged code.

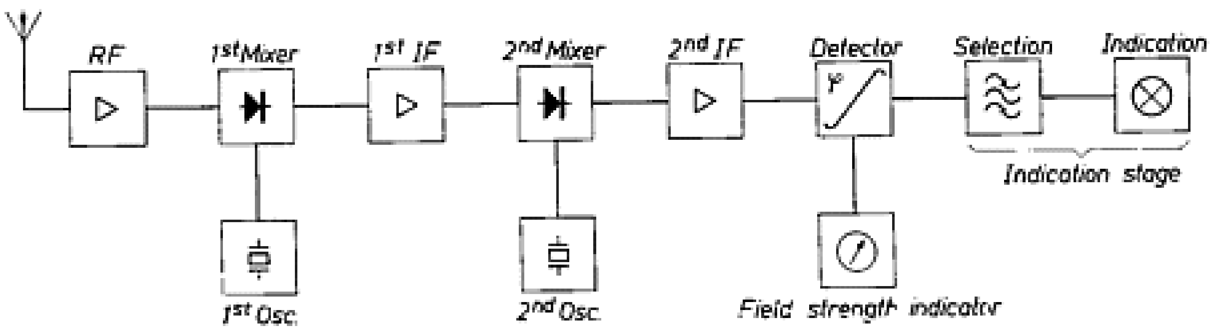

Fig.2. Block diagram of the radio code paging receiver.

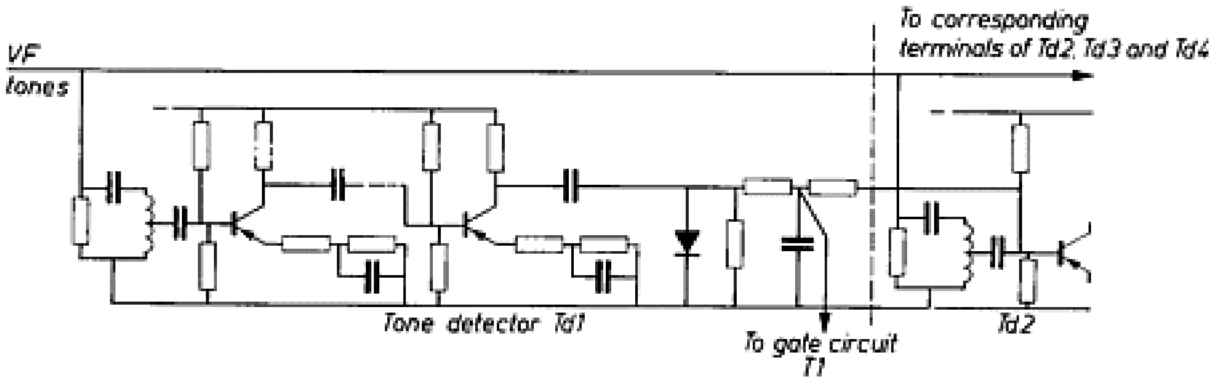

Fig.3. Circuit diagram of a tone detector.

The receiver

As the number of radio code paging receivers will be large and the central control equipment occurs only once per network, the receiver design has been kept as simple as possible.

Fig.2 shows a block diagram of the receiver. To keep the network, which operates in the 80 Mc/s band, as free as possible from interference, phase-modulation is employed. The receiver is designed as a double superheterodyne to give great sensitivity, a high degree of image frequency rejection and high selectivity. The mixing oscillators are both crystal-controlled. The sensitivity is 0.5 µV. The user can check whether the field strength is sufficient by pressing a button; if it is, a lamp should light up.

Tone detectors are used for selective calling and for passing the message code on. The transmitter sends out six successive tones which are chosen so as to correspond with the tuning of VF circuits in the relevant receiver. The choice of the tone system will be dealt with in greater detail below. To keep the receivers simple, no attempt has been made to transmit two or more tones simultaneously. Because of the need to have a sufficient number of tones in a limited frequency band, the tone circuits are very selective. Each circuit (see Fig.3) is followed by a two-stage amplifier incorporating a detector. The rectified VF voltage from the first tone detector will, if sufficiently strong, switch the second one on. The time constants of the circuit as a whole are chosen so that the second detector remains switched on long enough after the end of the first tone to respond to the second tone. The second detector (see Fig.4) switches the third on in the same way as

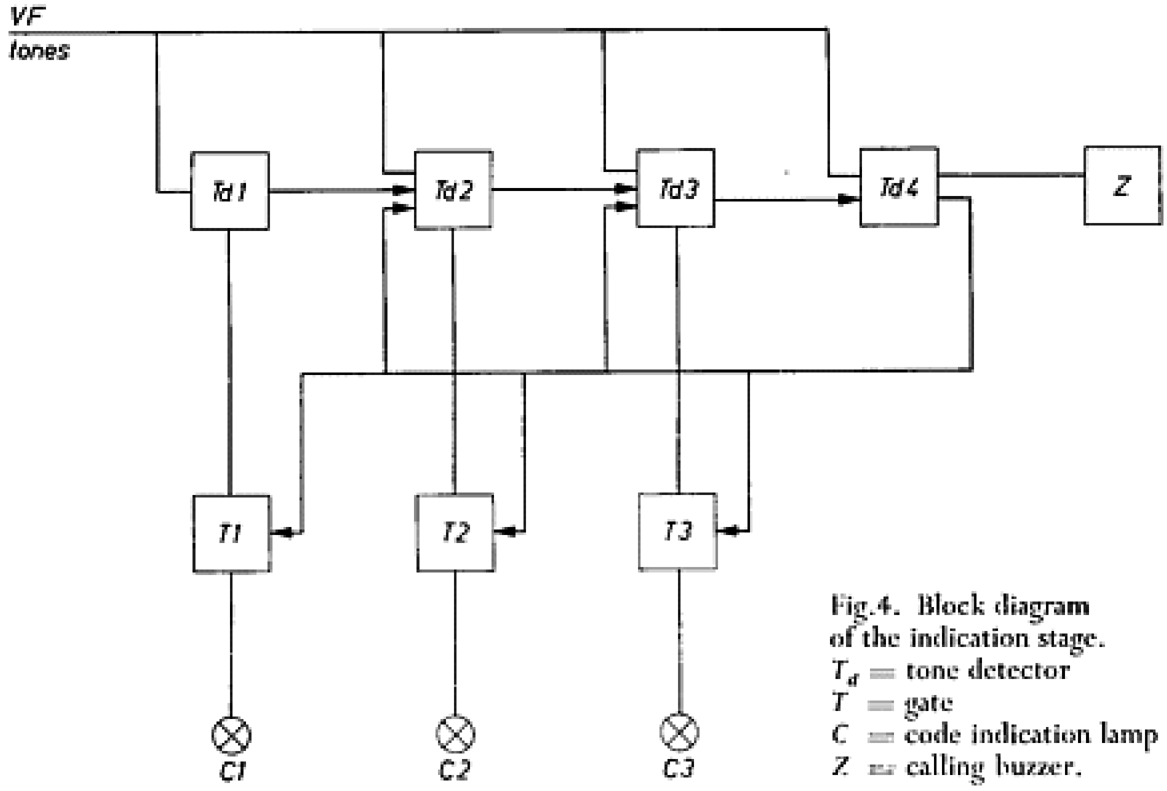

Fig.4. Block diagram
of the indication stage.
T_d = tone detector
T = gate
C = code indication lamp
Z = calling buzzer.

before. These three 'selection' tones are followed by the fourth tone, which is known as the separation tone. This tone is the same for all receivers in a particular network but differs from one network to another. The separation tone prevents spurious calls such as might result if, under anomalous propagation conditions, a call for a similarly tuned receiver (same RF and three AF frequencies) were received from an adjacent network. This might happen if a neighbouring country introduced a similar system.

The output signal from the fourth tone detector now switches the first three detectors on, a holding circuit being used in this process. This signal also has the effect of opening gates $T1$, $T2$ and $T3$. The transmitter will now pass on the message code by repeating one or two of the tones previously used for selection, thus causing one or two of lamps $C1$, $C2$ and $C3$ to light up, while an audible signal will also be given by a buzzer. In this way 6 codes can be transmitted ($C1$, $C2$, $C3$, $C1 + C2$, $C1 + C3$ and $C2 + C3$). To simplify the reading of codes, the digits 1, 2 and 4 are placed beside the lamps. The latter continue to burn until put out by pressure on the extinguishing button.

Choice of tone system

In choosing the tone system, the number of tones which can be sent in succession to the receiver deserves closer consideration. If the introduction of stable selective VF circuits gives a choice of a larger number of different receiving tones, a reduction can be made in the number of successive tones to be transmitted towards the receiver. Selection from an increased number of tones, however, calls for either more selective, and consequently more expensive, VF circuits or a wider frequency band. The transmission of a small number of tones per call reduces the duration of each call.

To simplify tone detection, different frequencies are always used for two successive tones. Table II shows the maximum number of subscribers that can be catered for by a system giving a choice of 3 or 4 out of a larger number of tones.

Fig.5. The radio code paging receiver ready for carrying.

A 3-out-of-30 system has been decided upon for the Dutch network. By using two RF channels and connecting a half of the total number of subscribers to each of them, as many as $2 \times 25{,}230 = 50{,}460$ subscribers can be catered for.

Fig.5 is an illustration of the radio code paging receiver. On the far edge, to the left, is a switch with three positions: off – intermediate position – on. When it occupies the intermediate position, the four lamps will light up if they and the

TABLE II

Tone code used	Max. number of subscr.
3 out of 20	7,220
3 out of 25	14,400
3 out of 30	25,230
3 out of 35	40,460
4 out of 10	7,290
4 out of 12	15,972
4 out of 15	41,160
4 out of 20	137,180

dry battery are in working order. In the centre of the far edge are the lamp and push-button for checking the field strength. On the right, also at the back, is a telescopic aerial. Of the two knobs on the front edge, that on the left is for extinguishing the three code lamps in the middle of the same edge, and that on the right is a paper clip for holding a note of the pre-arranged codes, which are thus immediately available if a message arrives.

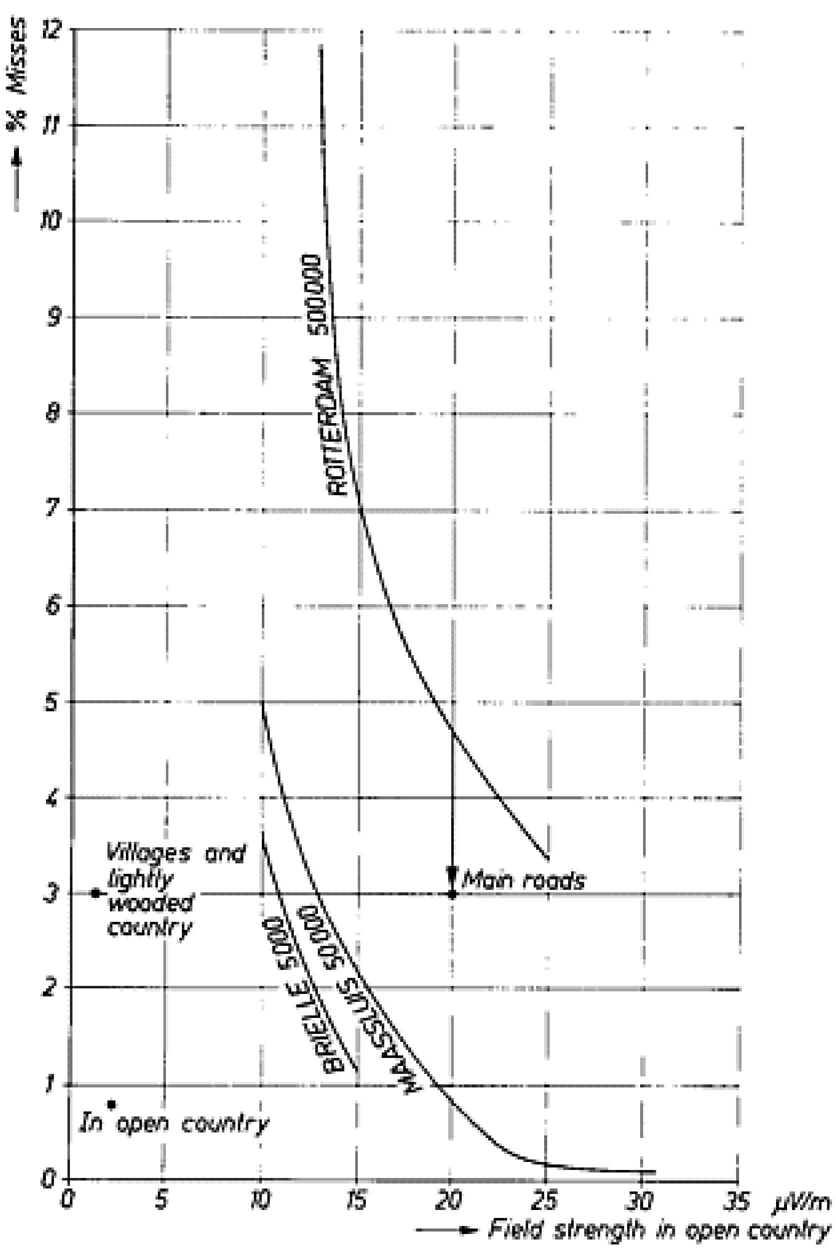

Fig.6. Graph of minimum field strength versus minimum chance of interference. The test transmitter was on the TV tower at Roosendaal.

Transmitter network

The sites and power of the transmitters have been determined on the basis of a large number of observations. Some code calls were transmitted continuously from a transmitter set up on the TV tower at Roosendaal. A receiver calibrated in field strength was used to determine the contour line of 2 µV/m field strength. An automatic system of counting at the receiver found the number of wrongly received codes, circuit or code failures and correctly received codes. With the tone detectors properly adjusted the following 'scores' were returned at 2µV/m: 0.5% wrong, 1.2% misses and 98.3% correct. To obtain values of 0%, 0% and 100% a field strength of 10 µV/m over flat ground proved adequate.
The local level of interference is higher in towns. 20 µV/m is generally sufficient for towns with populations of 5,000 — 50,000, while in large cities over 100 µV/m is necessary to ensure reliable working in narrow streets. Fig.6 shows the relation between field strength and chance of interference (misses) as measured in several towns.

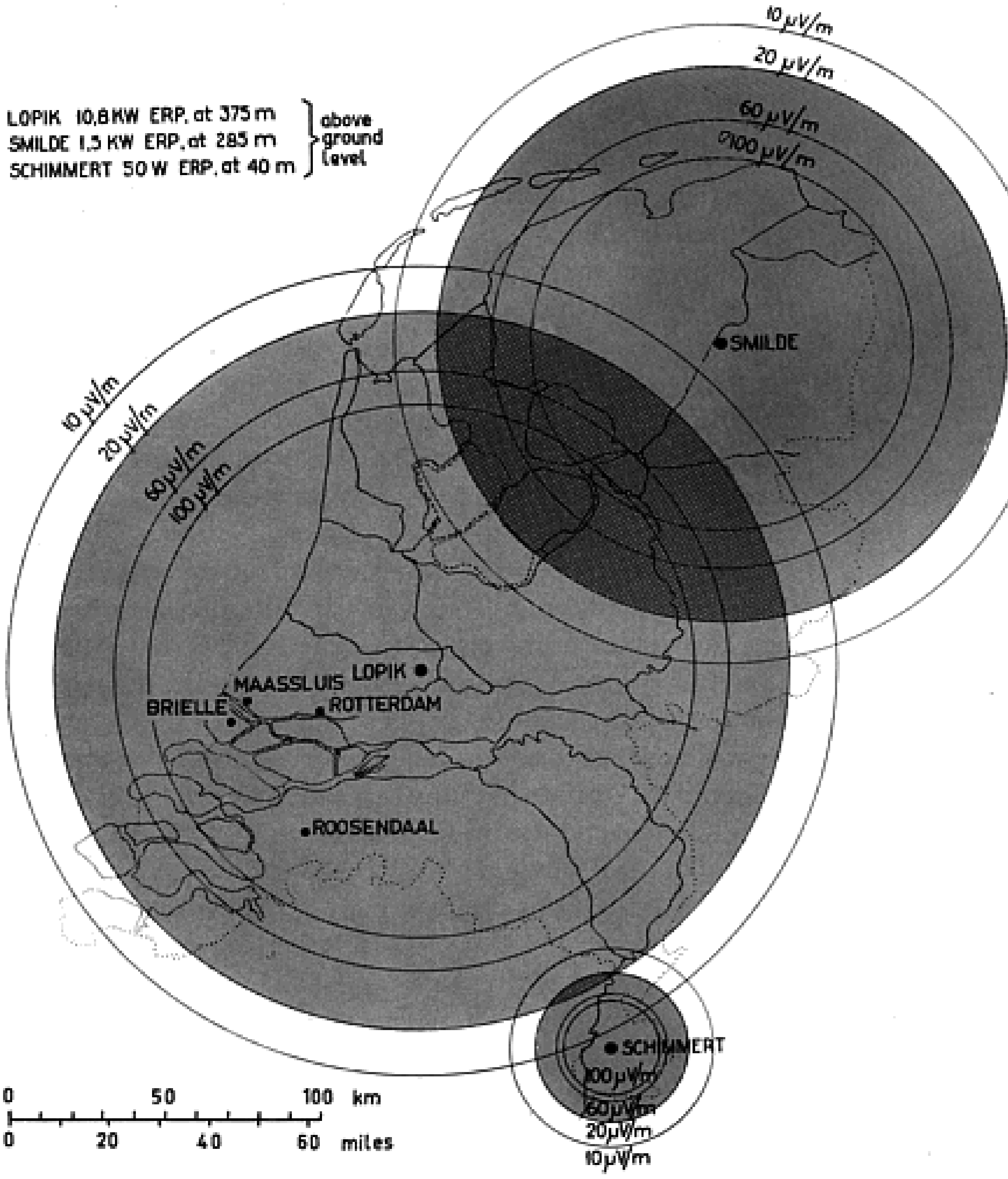

Fig.7. Transmitter plan for the national radio code paging system showing the field strength expected.

Another danger is that the signal will come through too weakly when the vehicle is passing under bridges or viaducts. As the tone detectors will not respond in such cases, the call will be lost. To overcome this difficulty it is necessary to transmit each call twice with an interval of, say, 15 seconds.
A 10.8 kW ERP transmitter sited at the highest point of the TV transmitting mast at Lopik (aerial height 375 m or 1230 ft.) gives the field strengths shown in Fig.7. Although a large part of the country is effectively covered, the field strength in some remote areas is too low. The most economical solution was to set up two small auxiliary transmitters in addition to the main transmitter. The sites chosen were Smilde, where it was possible to set up a 1.5 kW ERP transmitter with an aerial height of 285 m (940 ft.) on the existing TV mast, and Schimmert, where a transmitter of only about 50 W ERP was necessary.
To prevent interference between the Lopik transmitter and the auxiliary transmitters, the main transmitter is silenced while calls are repeated by the auxiliary

transmitters on the Lopik frequency. But the main transmitter is silenced only on its first channel, and while calls are being repeated by the auxiliary stations, it can transmit calls on the second RF channel to which one half of the subscribers are tuned (see Fig.8).

The main transmitter now reverts to its first channel while the auxiliary stations are repeating on the second channel the calls it has already broadcast on the second channel. This arrangement ensures that a receiver suitable for only one channel can receive calls whether it is in the area of the main transmitter or in those of the auxiliary transmitters. The latter are so far apart that they can safely work on the same frequency without risk of mutual interference. An interval of 50 kc/s between the two RF channels means that the frequency change-over of the transmitters is easily effected.

To prevent the service from being interrupted by transmitter failure, all transmitters are duplicated. They work at half power, each into its own aerial. This increases the life of the power tubes and adds 3 dB to the received field strength. If one transmitter or aerial develops a failure, the power of the other transmitter is automatically doubled.

We will now examine how much time is available for the transmission of one call. Observations in the trial network and American literature on the subject show that allowance must be made for an average of 0.5 call per subscriber per day. We also assume that 10% of all calls on any given day must be handled in the busy hour. It follows from this that with 25,000 subscribers in the service a total of 25,000 × 0.5 × 0.1 = 1,250 calls can be expected during the busy hour. A maximum time of 3600 : 1250 = 2.88 sec is therefore available per call. As each call has to be transmitted twice by the main transmitter and twice by the auxiliary transmitters, 0.7 sec is available per channel per message. Since two channels are available, the network capacity is 50,000 subscribers. The tone system chosen can cope with this rate.

Link with the public telephone network

To reach one of the radio code paging receivers from a telephone connected to the public telephone network, the first step is to call the radio code paging service This is done by dialling a group of exchange codes which are not used in the numbering scheme compiled for automatic trunk traffic in the Netherlands. To keep within reasonable limits the total number of digits to be dialled by callers to the new service, the eventual 50,000 or so subscribers to the service are divided into six groups of 9,999. A different 'exchange code' is allocated to each of these groups. On receiving the second dialling tone, which indicates he has reached the central control equipment, the caller has to dial only four digits to identify the desired subscriber in the 9999-group. He then dials a fifth digit to indicate the code message to be transmitted to the receiver.

An electronic system comprising a storage unit, registers and code translators operating on the scanning principle handles incoming calls (see Fig.9). Calls are recorded in a central register and tested for relevance. If the number exists, the calling party receives acknowledgement from a talking machine that his call has been accepted; he may then hang up. The register ensures that the transmitters are appropriately modulated. If the number does not exist, the caller receives 'number unobtainable' tone. If a number of calls arrive simultaneously at the radio code page system, they are held in a storage circuit until the register can deal

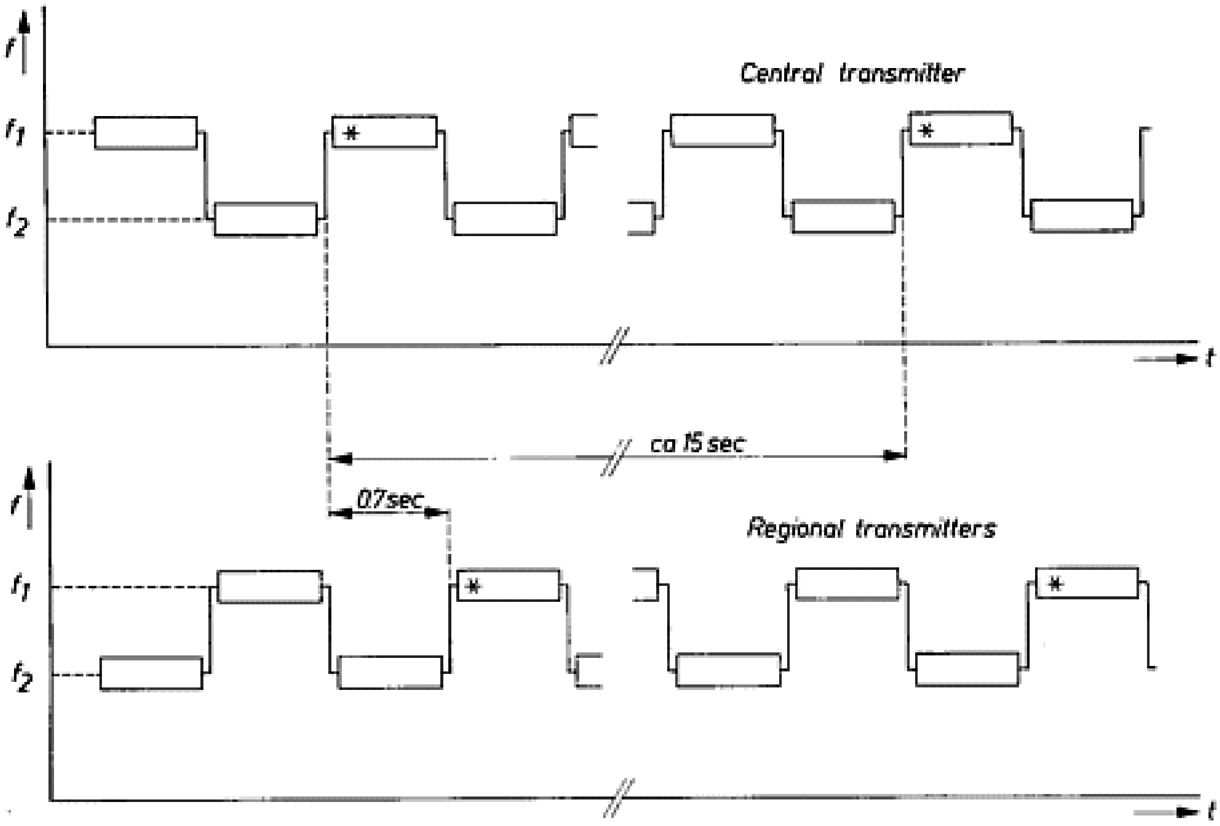

Fig.8. Each message code is transmitted first by the central transmitter and then by the regional transmitters; about 15 sec later each message is repeated once. The periodic change-over of the transmitting frequency ensures that a message (marked *) intended for a particular receiver is always transmitted on the same frequency.

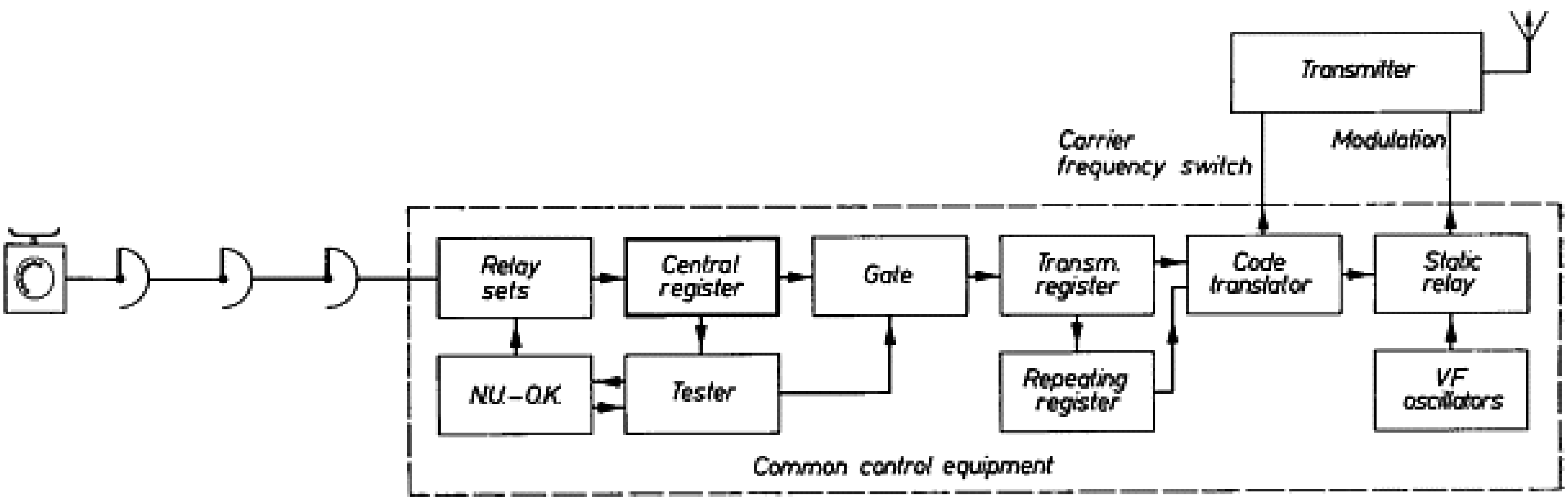

Fig.9. The central control equipment for the radio code paging network. *N.U. – O.K.* = number unobtainable – number accepted.

with them. The 'engaged' signal is thus practically limited to cases where a failure has occurred in the system.

It follows from what has been said above that anyone on the fully automatic public telephone network can convey a message to a subscriber on the radio code paging service without the aid of an operator, wherever the latter subscriber happens to be in the Netherlands, provided he has his receiver with him and on.

Use as alarm or for remote control

An important application of the radio code paging system is as an alarm system for alerting firemen, rescue teams, etc. Hitherto the practice has been to use a cable network linking the homes of the firemen, etc., with the alarm exchange and operating buzzers or the like to indicate an alarm.

If no direct answering facilities are required, the radio code paging system has the following advantages to offer:

1 The members of the crew are not confined to their homes.

2 When one member goes off stand-by duty, the radio code paging receiver can be transferred to or taken over by his relief.

3 No extra cost is incurred by removals. The crew member can be contacted at all times. In the case of a cable network, it takes days to lift and lay cable and make the necessary connections.

4 The code facility can be used to give information, e.g. where to report, extent of the fire, etc.

5 If receivers are all tuned to the same tones, alarm can be signalled simultaneously to a number of people anywhere in the Netherlands.

To remove all possibility of a false alarm resulting from faulty dialling of the alarm number, a special version of the radio code paging receiver has been developed. Instead of dry batteries, this receiver incorporates a rectifier and six relays which are circuited in such a way that two successive calls each containing a different message code, are necessary before alarm can be given. The first call makes the receiver receptive for the second call; only upon receipt of the second call will the alarm operate. To accelerate matters an automatic pulse transmitter can be used which carries out the entire procedure after an alarm button has been pressed.

This double dialling arrangement also makes it possible to distinguish a larger number of codes (30).

If a relay box is incorporated, the receiver can be used as a remote switching device.

Note

1 The Netherlands Postal and Telecommunications Services call this radio code paging system the 'Simofoon' system. The word Simofoon is made up from a phrase used to describe the set's function, viz. to *si*gnal to a *mo*bile user that he is wanted on the 'tele*foon*' (telephone).

2 The original article, which has been adapted and translated for this Journal, was published in Dutch by the author in the weekly "*De Ingenieur*", Vol. 73, No.52, of 29th December, 1961, pp. E105–E115, under the title of: Een nieuwe dienstverlening van PTT: de Simofoon (A new service of the Netherlands Postal and Telecommunications Services: the Simofoon). We acknowledge our gratitude to the Editor of "*De Ingenieur*" for permission to publish it here.