NATEL, the swiss car telephone network

Autor(en): **Wey, Emil**

Objekttyp: **Article**

Zeitschrift: **Technische Mitteilungen / Schweizerische Post-, Telefon- und Telegrafenbetriebe = Bulletin technique / Entreprise des postes, téléphones et télégraphes suisses = Bollettino tecnico / Azienda delle poste, dei telefoni e dei telegrafi svizzeri**

Band (Jahr): **58 (1980)**

Heft 7

PDF erstellt am: **17.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-875884

NATEL, the Swiss Car Telephone Network[1]

Emil WEY, Berne

621.395 (494):621.396.931 (494):654.165.3 (494)

1 Introduction

The national car telephone network (Natel) is interconnected with the public telephone network and covers the entire country. Depending on traffic and on the degree of extension, 5000 to 10 000 mobile subscribers can be connected. These subscribers are offered virtually the same facilities as ordinary telephone customers. By means of conventional number dialling, they can call both each other and normal stationary telephone customers at home and abroad.

The system was developed by the Research and Development Division of the PTT, paying particular attention to operational considerations, bandwidth economy and cost effectiveness [1]. The Natel radio equipment and switching installations are produced in Switzerland.

2 Fixed radio network

21 Radio service areas

A national car telephone network requires a radio service which covers the whole country or at least the most important parts thereof. In this case, the network cannot be served by a single fixed radio station. An economical solution can best be achieved by means of a network of widely spaced radio stations, particularly if the PTT's existing mountain radio stations are used for this purpose. The corresponding radio service areas which form the basis of the national car telephone network are indicated by thick boundary lines in *Figure 1.* These are contours on which the mean field strength per kilometer of path length amounts to 10 μV/m. These lines result if a transmitter output of 10 W is radiated from the various transmitter locations via a 160 MHz dipole antenna system. At field strength of 10 μV/m, the transmission quality of trunk telephone calls is still acceptable if the external noise level at the receive end is not excessive. An acceptable transmission quality for telephone calls in urban areas can in general be guaranteed only for field strength values of 30 μV/m and above [2].

The car telephone system operates with separate radio calling and speech networks. The same stations are used for the two basic networks. The only difference is that the radio speech equipment is replaced by radio calling transmitters. Thus, the broad contours of Figure 1 also illustrate the radio calling network, the assumed call sensitivity being 10 μV/m.

The national car telephone network extends over regions consisting of large areas with a small number of vehicles and of cities with dense traffic. Therefore, the number of transmission channels required is not the same everywhere.

In the present case, it is advantageous from the point of view of equipment and bandwidth economy if the widely spaced basic service network is equipped with only a small number of channels, e.g. with two channels. If one channel is occupied, there is always a spare channel available. At points of high traffic density, short-range local stations with a larger number of channels are added so that the number of channels available is proportional to the traffic density everywhere. One may assume that traffic density is proportional to population density. On the basis of these considerations, a population density map was used to determine those zones which had to be equipped with supplementary stations. They were not located on mountains so that the service areas could be limited to the high traffic regions in question. Otherwise the interference ranges of the individual stations would have become so large that the same channels could have been reused only at a great distance. Thus, the installation would have been uneconomical from the point of view of bandwidth. In Figure 1, the local service areas are designated by the 30 μV/m field strength contours. The regions which, according to this projection, are not served can be covered subsequently by further supplementary stations if required. The maintenance of radio connections inside long road tunnels presents a particularly difficult problem. It is well known that radio connections are interrupted shortly after the vehicle enters a tunnel. Therefore, it is intended to equip the most important tunnels with a radiating cable, where the radio calling transmitter and one radio speech transmitter being connected at one end and a radio speech receiver at the other end of the cable. If the tunnel ducts are longer than 1 km, the cable loss is compensated by incorporating wideband amplifiers [3]. Thus, the tunnel acts as a separate, stationary radio calling und speech service area.

The radio stations are equipped with radio calling transmitters and transceiver devices for speech transmission. For this purpose, ordinary 160 MHz radiophone equipments with phase modulation for a channel spacing of 25 kHz are used [4]. For modulation transmission between the radio stations and the exchanges, phase-locked two-wire lines are required for calling transmission and four-wire lines of any kind are required for speech transmission.

---

[1] Die deutsche Originalfassung ist in den Techn. Mitt. PTT Nr. 7/1979, S. 236...246 erschienen.
La version française est parue dans le Bull. techn. PTT No 7/1979, p. 236...246.

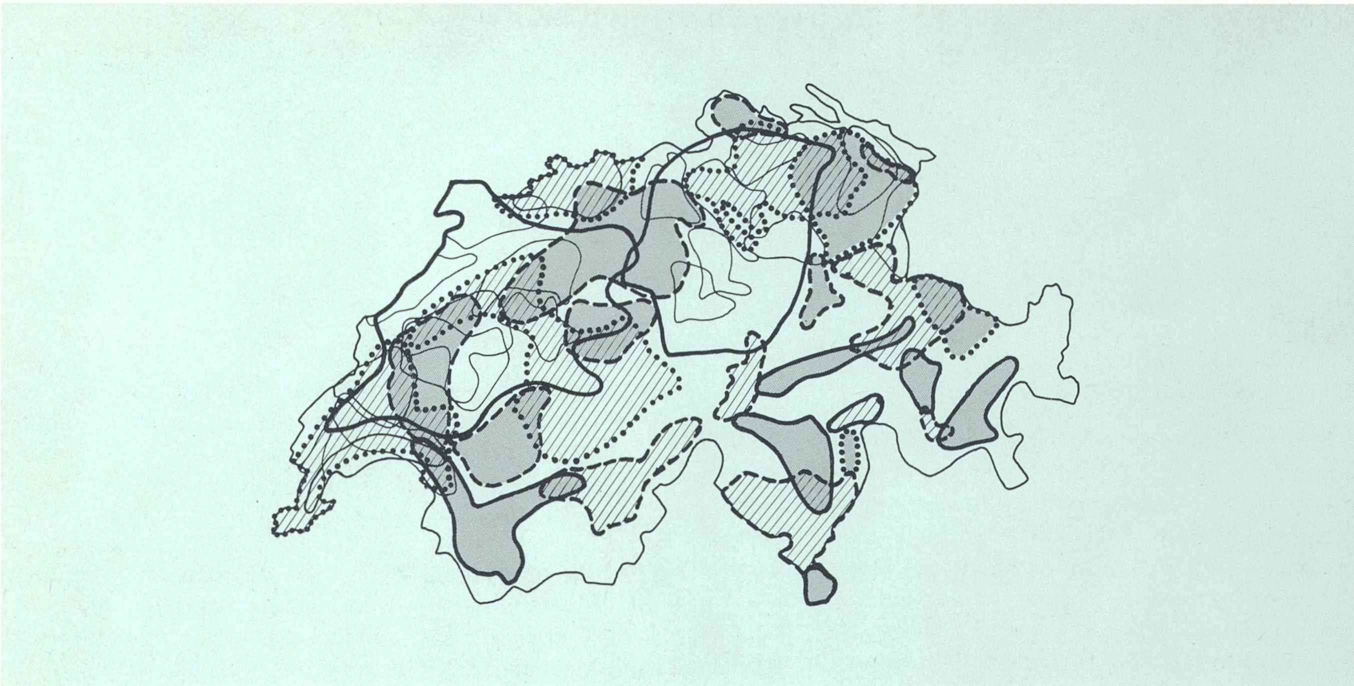


Fig. 1
Stationary radio network for the national car telephone network (radio calling and radio speech networks)

▒ ——	Basic regions ≥10 µV/m	—— Local regions ≥30 µV/m Transmitter output: 10 W
▨ – – –		
☐ ·····		

22 Network structure and radio channel distribution

The Swiss car telephone network is subdivided into five radio network areas for economic reasons. The network structure is shown in *Figure 2.* To serve the entire network, 28 station locations are required for the basic network and 17 station locations for the supplementary zones. The locations of the supplementary stations have been allocated to a larger or a smaller number of radio

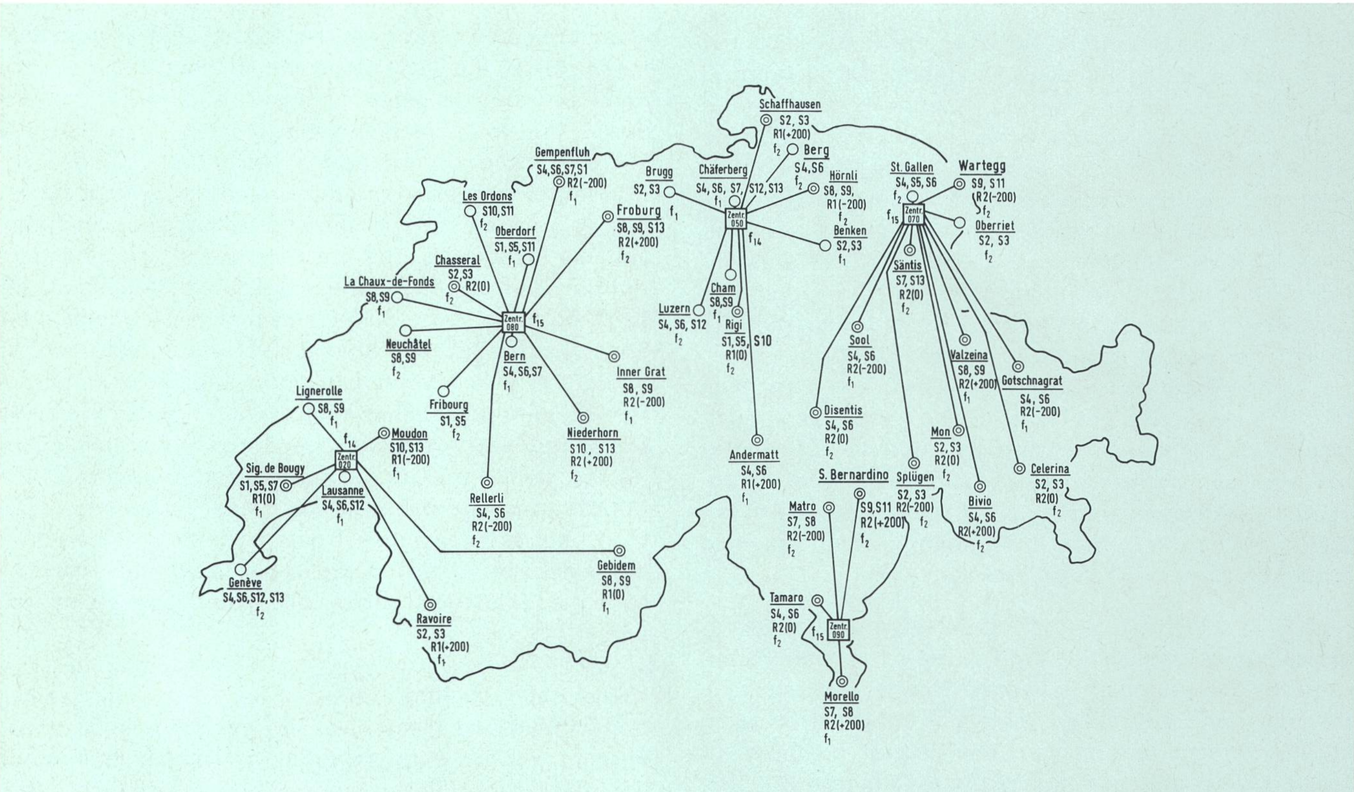


Fig. 2
Network area plan and radio channel distribution for the national car telephone network

R_1, R_2, (−200), (0), (+200)	Calling channels with frequency offset in Hz	f_1, f_2	Monitoring signals
		f_{14}, f_{15}	Idle signals
S_1...S_{13}	Speech channels		

channels, depending on the population of the service area. These radio channels must not be subject to mutual interference. They must therefore be free of intermodulation interference. It is also necessary to require that the radio calling channel and the basic network channels in whose area the supplementary station is located be free of intermodulation interference. In the case of Zurich, for example, the channels in question are those of the Rigi. The channel allocations of each radio station, which have been determined on the basis of these considerations, are represented in Figure 2. A total of 105 radio speech devices and 28 radio calling transmitters are required for the 45 radio station locations.

The frequencies allocated to the channels can be seen from *Figure 3.* There are 13 frequency pairs; 12 of these are used for speech transmission and one for radio calling transmission. All the radio calling transmitters of a network group use single channel operation with a carrier offset of ±200 Hz.

3 System and planning aspects

31 Subscriber capacity and extendability

Each radio network area has its own exchange over which it is connected to the public telephone network. A total of approximately 10 000 mobile subscribers can be connected to the fully extended network. In the Zurich and Berne network areas, this will necessitate a parallel transceiver network with 13 further radio channels in order to deal with the telephone traffic load. This parallel network is used to accommodate those subscribers who do not belong to any other network area. Experience shows that the busy hour traffic value amounts to approximately 0.01 erlangs per subscriber and the mean duration of occupancy is 55 s. 1.75 times more calls are made from «mobile to fixed» locations than in the opposite direction, and only about 40 % of the calls made to mobile subscribers are answered. 60 % of the traffic is chargeable; the remainder is dialling, setting up of calls and unproductive channel holding time.

In order to avoid traffic overloading, the number of subscribers which may be connected per service area with n channels is as shown in *Table I.* In this case there

Table I. Permissible number of subscribers depending on the number of channels in a service area

Number of channels n	2	3	4	5
Maximum number of subscribers	140	250	350	450

is a probability of 90...95 % of finding a free channel within 30 s during peak traffic periods.

32 Calling reliability and speech quality

During travel in the 10 μV/m marginal zones of the respective service areas, calling reliability is about 99.5 % and sound articulation approximately 80 %. The same values can be achieved in the stationary state at a field strength of about 2.5 μV/m. Calling impairment occurs in the form of calling failures while the loss of articulation is caused by the increase in noise resulting from ground reflection and ignition interference. External interference due to other mobile radio services causes a

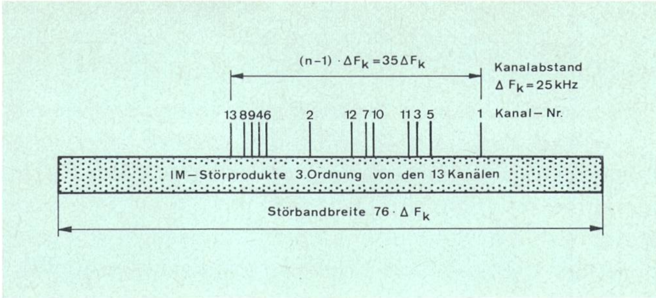


Fig. 3
Radio channel distribution and intermodulation interference band
Kanalabstand — Channel spacing
Kanal-Nr. — Channel number
IM-Störprodukte 3. Ordnung von den 13 Kanälen — Third order intermodulation interference products from the 13 channels
Störbandbreite — Interference bandwidth

changeover to a different channel and occurs only in the immediate vicinity of the transmitters in question; because the intermodulation loss und adjacent channel selectivity of the Natel receivers is greater than 80 dB.

Observation of the system in operation has shown that a further 2 % of wrongly set-up calls has to be expected, the majority of these being attributable to op-

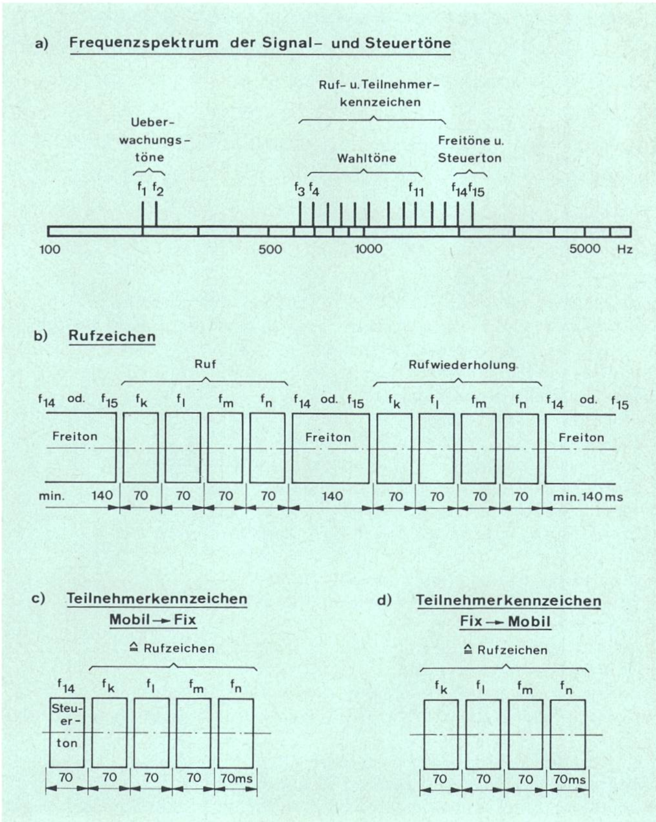


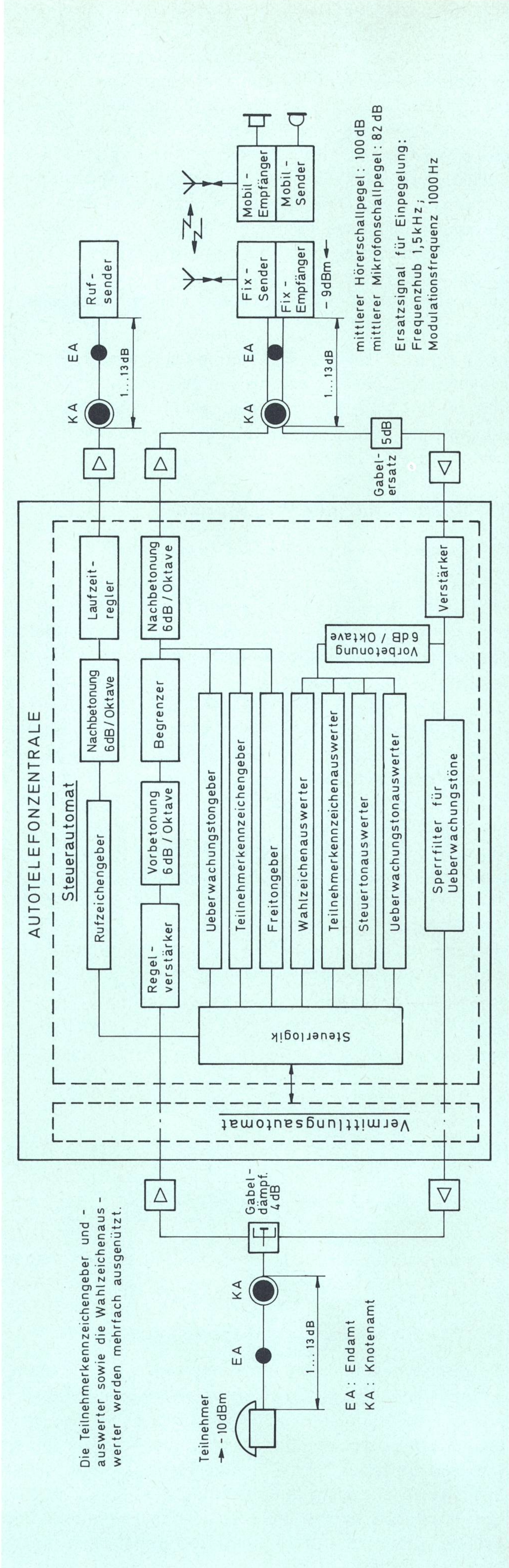
Fig. 4
Frequencies and codes for signalling and control
Frequenzspektrum der Signal- und Steuertöne — Frequency spectrum of the signalling and control tones
Überwachungstöne — Monitoring tones
Ruf- und Teilnehmerkennzeichen — Calling and subscriber identification codes
Wahltöne — Dialling signals
Freitöne und Steuerton — Idle signals and control signal
Rufzeichen — Calling signal
Ruf — Calling
Rufwiederholung — Calling repetition
Freiton — Idle signal
Teilnehmerkennzeichen «Mobil → Fix» — Subscriber identification code mobile → fixed
Teilnehmerkennzeichen «Fix → Mobil» — Subscriber identification code fixed → mobile
Steuerton — Control signal

erating errors on the part of the subscribers, which are common in the public telephone network, and to switching errors.

Within the region of the level plan, the speech quality of Natel connections is equivalent to that of conventional telephone connections. Volume and sidetone attenuation are slightly greater than in ordinary telephone stations so that the higher ambient noise level in the vehicle has a less adverse effect on transmission quality.

33 Signalling and control

All stationary transmitters are constantly radiating their carrier frequency. Whenever they are not occupied by a calling process or by a conversation, they are modulated with an idle signal. The occupied speech channels are constantly monitored by an out-of-band pilot signal from the fixed station to the vehicle station and back to the fixed station. Two calling channels are needed so that adjacent network areas can operate without influencing each other. As can be seen from Figure 2, they alternate between network areas. In addition, two different idle signals are used; these change from one network area to the next in correspondence with the two calling channels. In order to reduce the danger of interference between adjacent common channel transmitters, the monitoring signals in the appropriate service areas are alternated in analogous fashion. In *Figure 4,* these frequencies are graphically represented together with the remaining signalling and control frequencies. *Figures 5* and *6* additionally provide an indica-



▶
Fig. 5
Schematic diagram of the NATEL exchange and connection
Die Teilnehmerkennzeichengeber und -auswerter sowie die Wahlzeichenauswerter werden mehrfach ausgenützt — The subscriber identification signal generators and decoders and also the dialling signal decoders are multiplexed
Teilnehmer — Subscriber
Gabeldämpfung — Hybrid circuit attenuation
Autotelefonzentrale — Automobile telephone exchange
Steuerautomat — Automatic control equipment
Rufzeichengeber — Calling signal generator
Nachbetonung 6 dB/Oktave — Post-emphasis 6 dB/octave
Laufzeitregler — Delay control unit
Regelverstärker — Variable gain amplifier
Vorbetonung 6 dB/Oktave — Pre-emphasis 6 dB/octave
Begrenzer — Limiter
Vermittlungsautomat — Automatic switching equipment
Steuerlogik — Control logic
Überwachungstongeber — Monitoring signal generator
Teilnehmerkennzeichengeber — Subscriber identification signal generator
Freitongeber — Idle signal generator
Wahlzeichenauswerter — Dialling signal decoder
Teilnehmerkennzeichenauswertung — Subscriber identification signal decoder
Steuertonauswerter — Control signal decoder
Überwachungstonauswerter — Monitoring signal decoder
Sperrfilter für Überwachungstöne — Suppression filter for monitoring signals
Verstärker — Amplifier
Gabelersatz — Dummy hybrid
Rufsender — Calling transmitter
Fixsender — Fixed transmitter
Fixempfänger — Fixed receiver
Mobilsender — Mobile transmitter
Mobilempfänger — Mobile receiver
Mittlerer Hörerschallpegel — Mean handset receiver sound level
Mittlerer Mikrofonschallpegel — Mean microphone sound level
Ersatzsignal für Einpegelung — Dummy signal for level line-up
Frequenzhub — Frequency deviation
Modulationsfrequenz — Modulation frequency
Endamt — Local exchange
Knotenamt — Group switching centre

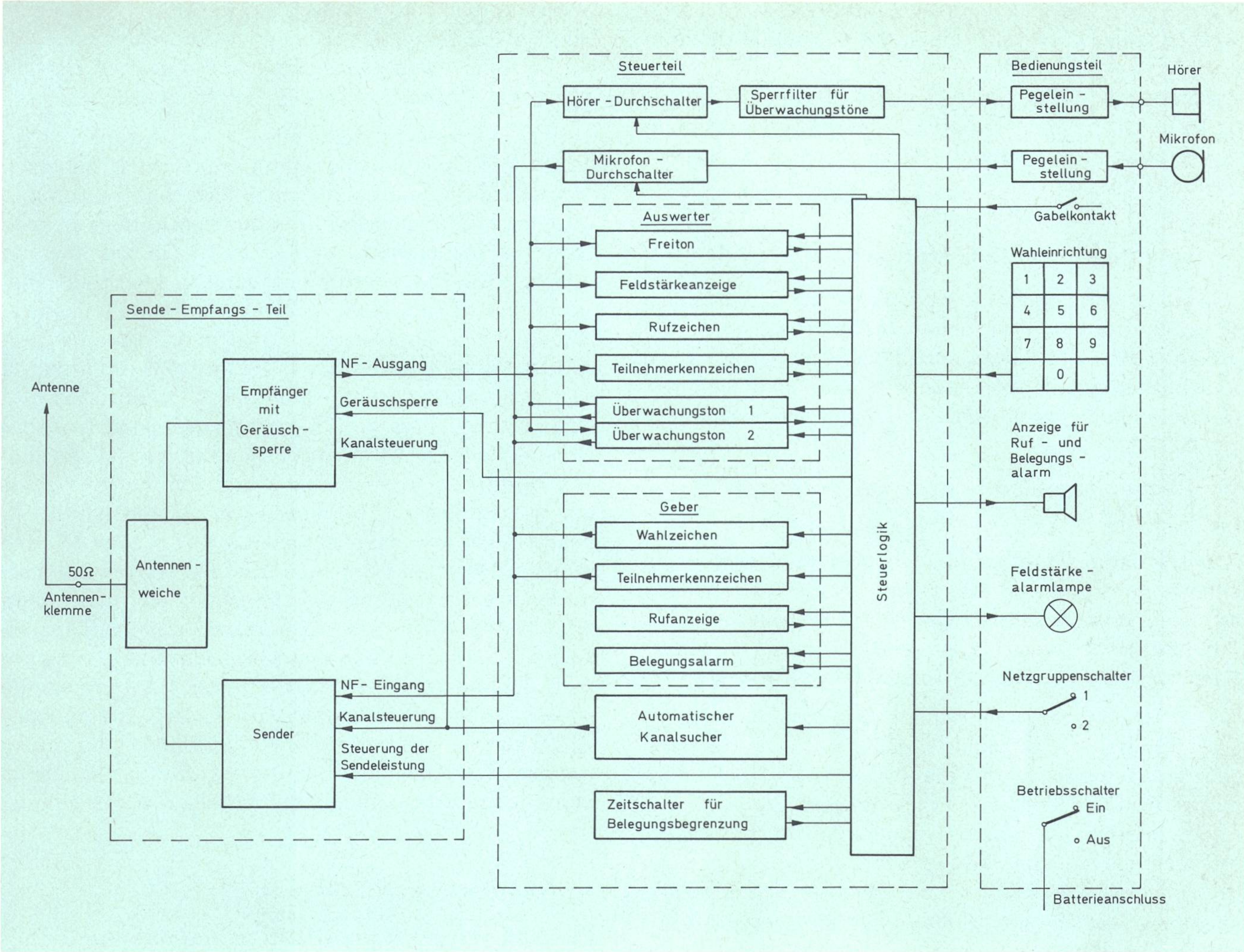


Fig. 6
Schematic diagram of the mobile NATEL station
Steuerteil — Control section
Hörer-Durchschalter — Handset receiver through-connection
Sperrfilter für Überwachungstöne — Suppression filter for monitoring signals
Mikrofon-Durchschalter — Microphone through-connection
Auswerter — Decoder
Freiton — Idle signal
Feldstärkeanzeige — Field strength indication
Rufzeichen — Calling signal
Teilnehmerkennzeichen — Subscriber identification signal
Überwachungston — Monitoring signal
Geber — Generator
Wahlzeichen — Dialling signal
Rufanzeige — Calling indication
Belegungsalarm — Seizure alarm
Automatischer Kanalsucher — Automatic channel finder
Zeitschalter für Belegungsbegrenzung — Time switch for seizure limitation
Steuerlogik — Control logic
Sende-Empfangs-Teil — Transmit-receive section
Antennenklemme — Antenna terminal
Antennenweiche — Antenna diplexer
Empfänger mit Geräuschsperre — Receiver with noise suppressor
NF-Ausgang — Low frequency output
Geräuschsperre — Noise suppressor
Kanalsteuerung — Channel control
Sender — Transmitter
NF-Eingang — Low frequency input
Steuerung der Sendeleistung — Control of transmitter output
Batterieanschluss — Battery connection
Betriebsschalter «Ein/Aus» — Operating switch «On/Off»
Netzgruppenschalter — Network group switch
Feldstärkealarmlampe — Field strength warning lamp
Anzeige für Ruf- und Belegungsalarm — Indication for calling and seizure alarm
Wahleinrichtung — Dialling equipment
Gabelkontakt — Cradle-switch contact
Pegeleinstellung — Level control
Bedienungsteil — Operating section
Hörer — Handset receiver
Mikrofon — Microphone

tion of the interaction of the tone generators and decoders required for this purpose.

The trunk prefixes of *Table II* are used to select the five radio network areas.

Table II. Long distance prefixes of the various radio network areas

Radio network area	1	2	3	4	5
Long distance prefix	020	080	050	070	090

The car telephone subscriber numbers have six digits; these are 2, 2, k, i, m, n, the last four digits being characteristic of the respective numbers. These four digits are converted into a frequency code fk, fl, fm, fn for radio transmission in the exchange. Four frequencies from the set of available frequencies $f_3 \ldots f_{12}$ are used for this purpose. If a number contains the same digit twice in succession, the second of these is replaced by the repeat frequency f_{13}. The same frequency code is used in the speech channel as a subscriber identification for call requests, as a seizure acknowledgement or as a call termination signal. In the direction from the mobile to the fixed station («mobile→ fixed»), the identification code is supplemented by a control tone signal f_{14}. This signal ensures that an identification signal decoder is connected in the exchange.

The internationally standardized CCITT two-tone method is used for transmitting the dialling information from «mobile to fixed». Each digit is formed by two simultaneous tones from the set of available frequencies $f_4...f_{11}$ when the MFC keypad is operated. The maximum pulse duration is limited to 90 ms in order to prevent double counting.

34 Locating the mobile stations

In many car telephone systems, locating the mobile subscribers presents a problem. In the Swiss system the calling signal is radiated simultaneously via all calling transmitters of a network area in a single channel. Thus, vehicle stations can be located without any problem.

35 Radio channel utilization and automatic channel finder

In the interests of bandwidth economy, each radio channel must be utilized as well as possible. This is achieved, if the occupancy duration is virtually limited to the duration of the calling process and of the conversation, and if the intervals between the calls are very short.

The Natel system meets these requirements in an almost optimal way. A calling process occupies the radio calling channel for approximately 1 s. The speech channels remain unoccupied until the conversation is begun. Approximately 1 s after the connection is terminated, the channels are again available for further use. The use of a call store enables the occupancies of the calling channel to succeed each other without a gap. Unfortunately, the conversations cannot be stored and joined together as desired. It is usual in telephone networks to compensate for this to a certain extent by making available several lines for automatic selection. This principle is being applied in the case of the Swiss car telephone system. In all areas, several radio channels are available which can be selected at the vehicle station by means of an automatic channel finder. This is one of the most important elements of the Swiss car telephone system. It steps from one channel to another in a predetermined order, using a switching cycle of 70 ms. Each mobile station is provided with all 12 radio speech channels. If a carrier modulated by the idle tone arrives at a channel, the call finder stops, switches on the mobile transmitter and modulates the latter's carrier with its recognition code. This is passed via the fixed station in question to the exchange, causing the modulation of the fixed transmitter to be changed from the idle tone to a monitoring tone. Depending on whether or not the incoming recognition code in the exchange has already been marked, a line is switched through to the calling subscriber who has effected the marking or, alternatively, the connection of the dialling device in the public telephone exchange is initiated.

The automatic channel finder not only allows a substantial improvement in traffic handling and in the utilization of frequency bands compared to the usual systems; it also allows the vehicle to move from one fixed station to another within the same network area during a conversation without the connection being interrupted. The finder is started every time the handset is lifted regardless of whether the subscriber has been called or wishes to dial another subscriber himself. It is also activated if the required minimum transmission quality is not being achieved, for example in the case of low field strength or if interference signals are received.

Even in a well planned network there is inevitably a certain probability of the useful signal being subject to interference by external signals. This may be common channel interference from remote transmitters or interference from neighbouring transmitters outside the useful channel. They occur if selectivity, intermodulation resistance or subsidiary receive station attenuation are inadequate or, alternatively, if the modulation and noise spectra of the interfering transmitters are too broad. In all these cases, the interference can be obviated by a change of channel. In the system described here, the channel finder performs this task automatically. As soon as interference is present or arises, the monitoring signal is suppressed. This causes the channel finder to change over to a channel which is not subject to interference. When this happens, the call is in most cases routed via the new channel almost without interruption. The channel which has been cleared is immediately released; i.e. it is made available to subscribers within the service area not subject to interference. Interference is usually limited to small local areas. Also, the channels which suffer interference are not the same in the various regions. One may, therefore, say that traffic and channel utilization in almost unaffected by selective interference.

4 Call setting and clearing

41 Call setting from «fixed to mobile» stations

A telephone customer wishes to make a call to a mobile subscriber from a public network subscriber station. He lifts the handset and dials a 9-digit number as for a trunk call. The first three digits select the car telephone network area via which the call will be made (see 33). The subscriber number is converted into a calling code in the selected exchange. This calling code is transmitted simultaneously via all calling transmitters of the network area in question. In order to increase calling reliability, the calling process is repeated once. Immediately after the number has been entered in a call register, the subscriber who has dialled the number is marked in the exchange for the mobile called subscriber. In order to convey the impression of an ordinary telephone call, the subscriber line is simultaneously occupied by the normal telephone ringing tone. This condition is maintained until the loop is closed by the mobile subscriber. If this does not occur within about 2 minutes, the connection is cleared and the waiting subscriber receives the engaged signal.

On the mobile side, the following process takes place: All stations which are not currently engaged in a call are set to the receive state in the calling channel of the network area in question. Each station is equipped with a calling signal decoder which responds to the code allocated to it. If this code is received, acoustic and optical signals are given. The subscriber now lifts his handset, thus releasing the automatic channel finder. The latter searches for the next free speech channel which is characterized by the idle tone modulation. Reception of the idle tone causes the mobile transmitter automatically to send its identification signal back to the fixed station via the appropriate transmitter channel. This identification code is passed from the transceiver selected via the modulation line to the calling exchange. There, the code evaluation arrangement swithces over from the idle signal generator to the monitoring signal generator. In order to avoid double occupation, the identification signal is simultaneously transmitted back to the mobile station and a check is made as to whether a call is marked for the subscriber concerned. If it is, the connection with the waiting subscriber at the public network is made.

As is usual, the closing of the loop effected in this way initiates charging. The call duration is limited to 3 minutes.

42 Call setting from «mobile to fixed» stations

A mobile subscriber wishes to make a call to a public network subscriber or to another mobile subscriber. He lifts his handset, thus causing the automatic channel finder to operate. Up to the transmission of identification signals in both directions, the process is the same as in the case of calls from «fixed to mobile» stations. However, this time no call is marked in the exchange. As a result, the mobile subscriber receives the dialling tone from the public telephone exchange to indicate that he can start dialling. The setting up process continues in the same way as in the normal telephone network. When the loop has been closed, charge raccording on magnetic tape starts. It remains to be pointed out that a call limit of three minutes has been fixed in this direction also.

43 Call clearing

As is usual in telephony, the clearing down of a call and the termination of metering are initiated by the interruption of the loop in the following cases:

- When the mobile subscriber replaces his handset or the result of a three-minute call limit. To mark the end of the connection, the identification code is transmitted to the exchange as a clearing signal and the mobile transmitter is switched off. In the exchange, the transmitter modulation is changed from the monitoring tone to the idle tone.
- If the vehicle remains in zones of inadequate field strength for more than 30 s.

In case the mobile subscriber should forget to replace his handset, the mobile transmitter is automatically switched off four minutes after the beginning of the call.

44 Entering a different network area

When entering a different network area, the driver must switch over the calling channel and the idle tone decoder simultaneously. When he leaves a calling region or, to be more precise, when the field strength of the calling region falls short of a minimum value, the driver is alerted by an alarm indication:«Please switch over; you have entered a different network group!» This alarm initiation appears if the mean field strength is approximately 1.5 μV/m.

The Natel system described has been in service for more than two years.

Bibliography

[1] *Wey E.* Das schweizerische Autotelefonsystem. Bern, Techn. Mitt. PTT 48 (1970) 9, S. 367...380.

[2] *Wey E.* Der mobile Ruf- und Sprechfunk. Bern/Stuttgart, Hallwag-Verlag (1972), Blaue TR-Reihe, Heft Nr. 107.

[3] *Grüssi O.* and *König P.* Radio Links for Highway Tunnels. Bern, Techn. Mitt. PTT 56 (1977) 7, pp 285...293.

[4] Pflichtenhefte für das nationale Autotelefonnetz PTT 839.24 und PTT 839.25, IV. 1976 (NATEL).