REPORT 499-5

RADIO-PAGING SYSTEMS

(Question 12/8)

(1970-1974-1978-1982-1986-1990)

Introduction

This report describes the technical characteristics of radio-paging systems. It includes two parts, A and B and one annex.

Part A focuses more particularly on the transmission aspects, as seen in existing systems.

Part B focuses more particularly on the services and network aspects as presented in more recent studies carried out by several European countries. It considers in more detail the general approach to international roaming and its implications. Alternative solutions to those of Recommendation 539-2 are also presented.

Annex I gives an overview of a particular implementation of the new concepts introduced in Part B: the system studied for pan-European usage.

PART A

TRANSMISSION CHARACTERISTICS OF RADIO-PAGING SYSTEMS

1. Introduction

1.1 The radio-paging systems referred to in this part are described as one-way selective signalling systems without speech facilities and designed as extensions of the telephone network.

1.2 Some principle modes of operation are:

1.2.1 Dialled call to a common terminal, where a telephone number dialled into the telephone network is routed to a common terminal for processing into a radio-paging call;

1.2.2 Dialled call, with audio-frequency secondary end-to-end signalling, to a common terminal, where the common terminal accepts directly dialled digits and then accepts second stage audio-frequency digits to complete the information for processing into a radio-paging call;

1.2.3 Operator-handled calls.

1.2.4 Other modes are presented in Part B of this report;

1.3 False calls and messages should be eliminated so far as practicable, e.g. not more than one incident per user per year.

In the case of multiple-area paging systems, the user should be able to choose the area or areas within which he desires to be paged (see Part B).

The radio signal strength should be as uniform as practicable within the service area but restricted outside it. Special system considerations may be necessary to operate an aircraft paging receiver.

Radio paging could also be used to enhance other mobile services, e.g. paging aircraft in the ground-to-air direction.

2. Control terminal design concepts

For a high-capacity system, the use of a stored programme device seems to be desirable to perform the storing and forwarding functions of the paging calls.

It would be desirable for the control terminal to make a validity check of all calls entering the system.

The control terminal should return the necessary supervisory signals to the telephone switching network.

The control terminal should generate directly or indirectly the transmitter modulating signals.

The number of control terminals needs to be limited to ease the telephone access and switching problems. For access to the control terminal, the dialling codes used over the public telephone network should conform to agreed national and international standards.

As the control terminal will be an integral part of the switched telephone network it should conform to the normal requirements for equipment in that network. The capacity of each control terminal should therefore be either 1000 or 10 000 or 100 000 paging addresses, i.e. discrete subscriber dialling codes. The last-mentioned capacity of 100 000 is considered to be optimum between all the requirements for the majority of applications and leads to an economic design. To obtain greater user capacity in any system, a number of such terminals could be used.

3. Radio-frequency considerations

3.1 The following factors need to be taken into account in the choice of a suitable radio frequency channel(s):

- economics of the system for a given area;
- availability of frequencies;
- propagation considerations and operational requirements;
- environmental noise levels;
- practical limits of receiver sensitivity;
- permitted limits of emitted power levels and antenna heights according to local regulations;
- levels of paging traffic.

3.2 *Possible frequency bands*

All three ITU Regions have some or all of the following frequency bands allocated to mobile services:

26.1 to 50 MHz
68 to 88 MHz
146 to 174 MHz
450 to 470 MHz
806 to 960 MHz

In the future, it is possible that higher frequencies may be allocated to the mobile service in all three Regions and consequently be available for radio paging, but the utility of such frequencies is not yet proved.

In addition, documents submitted by Sweden illustrate the possible use of the VHF-FM sound broadcasting transmitter network in the frequency band 87.5 to 104 MHz for a wide-area paging system over the coverage area of the broadcast transmission [CCIR, 1978-82].

3.3 *The cost of coverage*

The costs and ease of providing base station antenna gain at 150 MHz and 450 MHz, to overcome increased propagation losses at these frequencies, compared with the lower bands such as 26.1 to 50 MHz (in North America) and 68 to 88 MHz (in Europe), are of the same order as those for the basic unity gain antenna systems for the lower frequencies.

3.4 *Effect of man-made noise*

For receivers with identical gain, which is the current situation with paging receivers designed to operate in the various frequency bands, the receiver noise factor increases with frequency.

The level of man-made noise, which is particularly high in inner city areas and on busy highways, where paging systems find most of their subscribers, is inversely proportional to frequency.

In the category of man-made noise we can also include on-frequency interference. 150 and 450 MHz (the latter being the highest frequency for which any practical paging system has been designed) provide relative freedom from long-distance transmission and thus from interference, which is a major disadvantage of the bands around 50 MHz and below.

3.5 *Radio propagation into buildings*

Measurements results submitted by a number of administrations have indicated that frequencies in the range of 80 to 460 MHz are suitable for personal radio paging in urban areas with high building densities. It is possible that frequencies in the bands allocated around 900 MHz may also be suitable but that higher frequencies are less suitable.

From measurements made in Japan, the following median values of the propagation loss suffered by signals in penetrating buildings (building penetration loss) have been derived. These are shown the Table I below:

TABLE I

Frequency	150 MHz	250 MHz	400 MHz	800 MHz
Building penetration loss (see note)	22 dB	18 dB	18 dB	17 dB (1)

(1) Somewhat less accurate than the other results.

Note. – The loss is given as the ratio between the median value of the field strengths measured over the lower floors of buildings and the median value of the field strengths measured on the street outside.

Similar measurements made in other countries confirm the general trend but the values of building penetration loss vary about those shown. For instance, measurements made in the United Kingdom indicate that building penetration loss at 160 MHz is about 14 dB and about 12 dB at 460 MHz.

Frequencies of about 80 MHz suffer losses similar to those at 150 MHz, but still lower frequencies e.g., 35 MHz, 26 MHz have been shown [Mino *et al.*, 1965; Rice, 1959] to be less suitable for use in urban areas but have some slight advantage over higher frequencies in suburban fringe areas.

For radio-paging systems which are intended to cover large areas with little urban development, the frequency bands around 80 MHz and 160 MHz seem to be most suitable.

3.6 *Techniques applicable to multiple transmitter zones*

To cover a service area effectively, it will usually be necessary to use a number of transmitters. When the coverage from a single transmitter is small, a single radio-frequency channel should be used so as to avoid the need for multi-channel receivers. In these circumstances, the separate transmitters may operate sequentially or simultaneously. In the latter case, the technique of off-setting carrier frequencies, by an amount appropriate to the coding system employed, is often used. It is also necessary to compensate for the differences in delay to the modulating signals arising from the characteristics of the individual land-lines to the transmitters. One way to do this is to carry out the synchronization of the code bits via the radio paging channel. Information is required about the bit rates which this synchronization method would permit.

It is preferable that the frequency off-set of the transmitter carrier frequencies in a binary digital radio-paging system be at least twice the signal fundamental frequency.

It is also preferable that delay differences between the modulations of the transmitters in a binary digital paging system should be less than a quarter of the duration of a bit if direct FSK, non-return to zero modulation is used. For sub-carrier systems the corresponding limit should be less than 1/8 of a cycle of sub-carrier frequency.

Studies are required to determine optimum methods for the transmission of signals over land lines and for simultaneous operation of a number of transmitters.

3.7 *Receiver design*

Built-in antennas can be designed for 150 MHz with reasonable efficiency. A typical radio-paging receiver antenna using a small ferrite rod exhibits a loss factor of about 16 dB relative to a half-wave dipole.

The feasibility of large scale integration of circuits (LSI) seems now to be realized. Component costs for a receiver using these techniques are low.

The majority of wide-area systems which have been established have employed some form of angle modulation.

Repeated transmission of calls can be used to improve the paging success rate of tone alert pagers. If p is the probability of receiving a single call, then $1 - (1 - p)^n$ is the probability of receiving a call transmitted n times, provided the calls are uncorrelated. Correlation under Rayleigh fading conditions can be largely removed by spacing the call more than 1 s apart. Longer delays between subsequent transmission (≈ 20 s) are required to improve the success rate under shadowing conditions.

Receivers with numeric or alpha-numeric message display can only take advantage of call repetitions if the supplementary messages are used to detect and correct errors.

4. Signalling format

The signalling format should be standardized. The choice of the appropriate coding techniques should take into account the required capacity of code combinations, speed of transmission, call success rate, and lowest practicable false calling rate. The code should be designed to allow for transmission of various types of messages. Recommendation 584 provides details of a recommended code and format.

Cyclic block codes such as the Bose-Chaudhuri-Hoquenghem (BCH) codes, permit the reliability of signalling to be improved and the probability of false calling to be much reduced, because of their distance and their inherent error detection and correction capability.

It is desirable that the standardized code can easily share a channel with other codes.

Message repetition is one possible way of increasing the successful call probability.

For the measurement of the signalling reliability of equipment, it is understood that the IEC is working on this subject. Results from field tests are also desirable.

5. System capacity

The number of users to be catered for still has to be determined.

In a document submitted by France, it was estimated that the available overall capacity at a national level should be at least 20 per 1000 inhabitants.

The capacity of any system is affected by at least the following:

- the number and the characteristics of the radio channels used;
- the number of times each channel is re-used within the system;
- the actual paging location requirements of the individual users;
- the peak information (address and message) requirement in any location(s);
- tolerable paging delay;
- data transmission rate;
- code efficiency;
- method of using the total code capacity throughout the system (this may also affect the system's capabilities for "roaming");
- any inefficiency introduced by battery saving provisions.

In addition to the above, there may also be telephone system input restrictions.

6. Compatibility between international and national radio-paging systems

It was recognized that a high degree of compatibility would be necessary between the national and international radio-paging systems. However, this does not preclude the establishment of radio-paging systems in factories, buildings, etc., using different standards.

On an international basis, between systems that are technically compatible, the international user should be able to move to another country, and the service provided in his home service area be extended to him in remote service areas of another nation.

One method of providing service between systems which are technically incompatible, would be to exchange the subscriber's paging receiver, and to use an agreed method to transfer the access data between national telephone systems.

7. Conclusion

In respect of codes and formats needs have been largely satisfied by Recommendation 584. The various existing domestic and international systems may soon be followed by new systems. Some administrations have an urgent need for a standard for their future systems and have made new studies in order to permit easy implementation of cross-border systems, sharing of users between various system providers, and to give good guidance to providers of paging services. The studies necessary to define the requirements for international radio-paging systems are not complete and should be continued. Results obtained to date are presented in Part B, and Annex I provides an example of a particular system design.

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PART B

TECHNICAL AND OPERATIONAL CHARACTERISTICS OF PAGING SYSTEMS SUITABLE FOR INTERNATIONAL ROAMING

1. Introduction

Part B describes the technical characteristics of radio-paging systems on which international agreement is desirable, including consideration of harmonization if more than one solution (for example, to cater for a range of transmission rates) is needed. The most important of these are the capability to carry text and data, and the possibility to use a single receiver in all locations allowing for roaming within the total coverage area.

Annex I provides an alternative configuration to those described in Recommendation 539 and Report 900 which do not address system concepts. Thus, this Annex does not comply fully with Recommendation 539 which lists generic features suitable for international paging, e.g. multiple transmitter zones, rate and type of data modulation, selectivity, signalling code and format.

2. Architecture

Any wide area or local paging system must have at least two well defined interfaces:

- the radio interface between the base station transmitter and the paging receivers;

- the interface between the paging system controller and the access networks.

In addition other internal interfaces may also be defined.

3. Services and facilities

Since in many cases wide area paging systems will be introduced when other national systems are already in operation, they should be able to support efficiently the main services characteristics of the existing systems such as tone only, numerical and alphanumerical pagings. In addition to these basic services a number of supplementary services may be provided, however, the networks should be capable of supporting a minimum set of services to ensure full compatibility with the basic version receiver.

The main services and facilities can be summarized as follows:

- international roaming;

- choice of call destination;

- temporary barring of incoming traffic;

- constitution of closed users' groups (the possibility of mobile and fixed subscribers to establish a group with only internal communication possibility; the mobile or fixed subscribers can be members of more than one closed users' group);

- protection against messages lost;
- establishment of priority levels;
- diversion of traffic to other receivers;
- security facilities;
- charging facilities;
- out of range indication;
- deferred delivery.

Regarding the paging categories, they can be summarized as follows:

- tone only;
- numeric;
- alphanumeric.

The type of message will be:

- individual calls;
- group calls (using common or multiple radio identity code).

4. Radio coverage

As far as the radio coverage is concerned, the system should have the possibility to guarantee the continuous coverage of a given territory (e.g. a whole country).

A paging area is defined as the area served by a single transmitter or set of transmitters which send the same information. It is possible to foresee that the system area may be divided into several paging areas, overlapping or not. Messages may be transmitted in a limited number of paging areas and a dedicated procedure will enable roaming subscribers to temporarily reroute the calls to one or more alternative areas where appropriate.

5. Radio network structure

The radio network structure needs to be defined in such a way as to permit maximum flexibility for national implementation and efficient spectrum utilization (specifically in border areas), whilst retaining essential common characteristics.

6. Network aspects

The main principle of a wide area system is to keep the access to the system as easy as possible. Access to the system could be given through telephone or data networks, either private or public.

ANNEX I

TECHNICAL AND OPERATIONAL CHARACTERISTICS OF ERMES

1. Introduction

A number of European countries are developing a new pan-European radio paging system named ERMES (European Radio MEssage System) capable of offering service both to national subscribers and to those roaming outside their home country, in the whole CEPT area.

The complete draft standard, according to the present working programme will be ready in June 1990 and the introduction of ERMES is foreseen in early 1993.

This annex contains a general description of ERMES.

2. General description

ERMES architecture is shown in Figure 1. In this figure the following main interfaces are shown:

- I1: Radio interface, based on the following characteristics:
  - frequency band: 169.4 - 169.8 MHz;
  - 25 kHz channel bandwith;
  - modulation method: 4PAM/FM;
  - symbol rate: 3.125 kbaud (6.25 kbit/s bit rate);
  - transmission protocol as described in Figure 2;
  - frequency agile receiver (16 channels).
- I2: Interface between the Paging Area Controller (PAC) and the base station;
- I3: Interface between the PAC and Paging Network Controller (PNC);
- I4: Interface between different PNCs, that ensures the roaming between countries and/or operators;
- I5: Interface between the PNC and access networks;
- I6: User access interface.

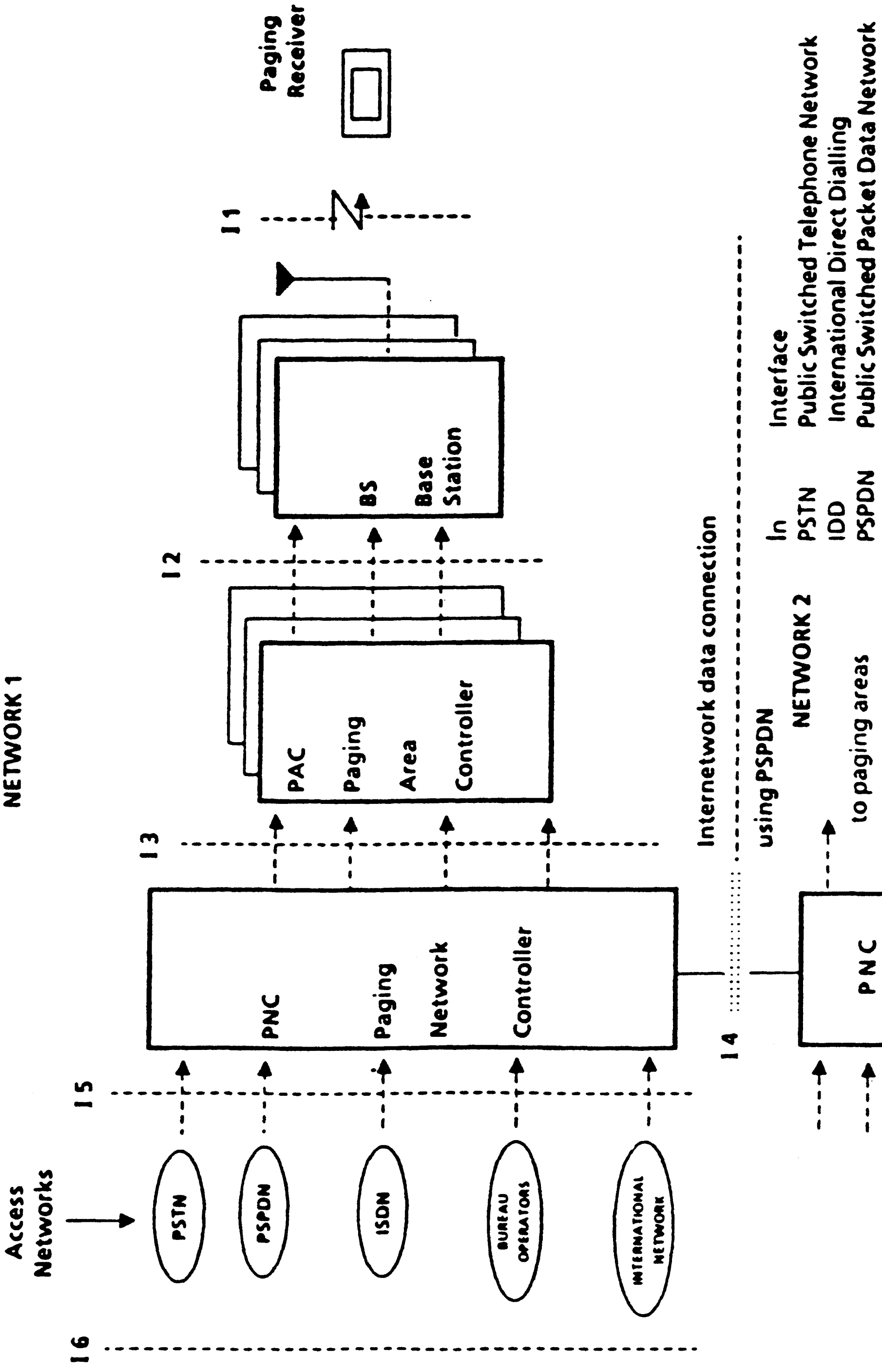
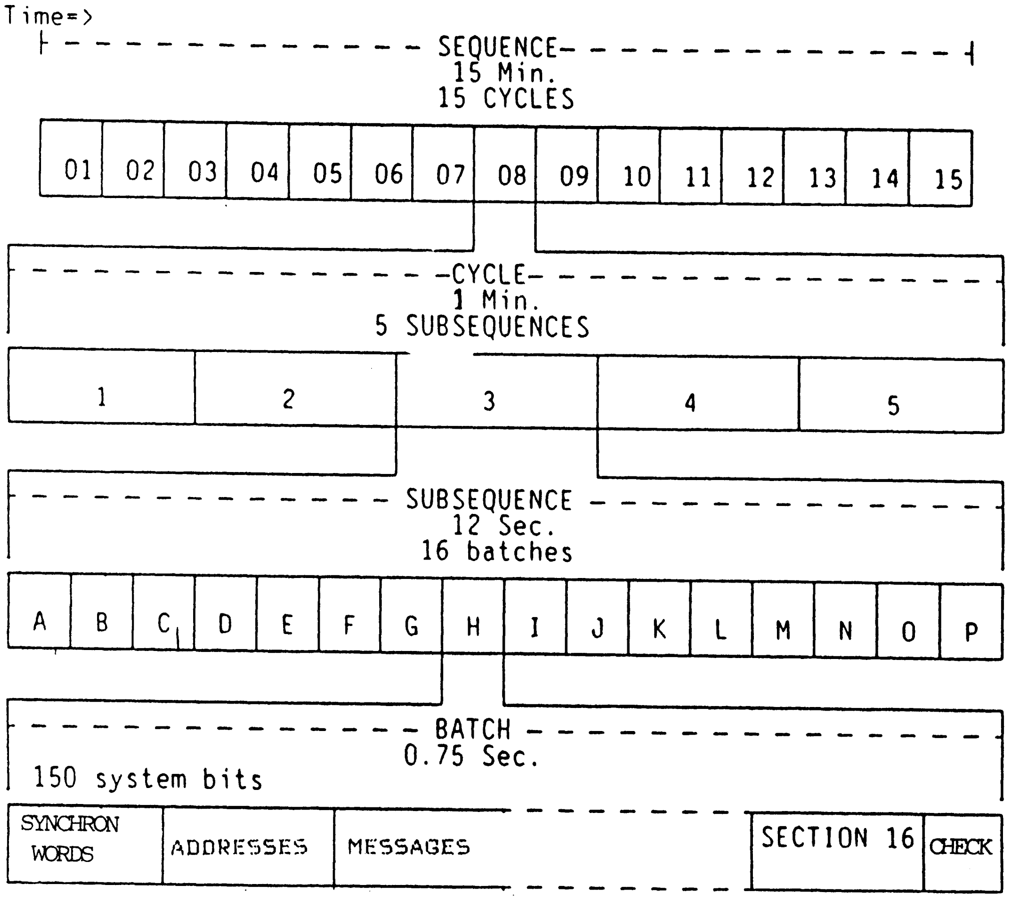
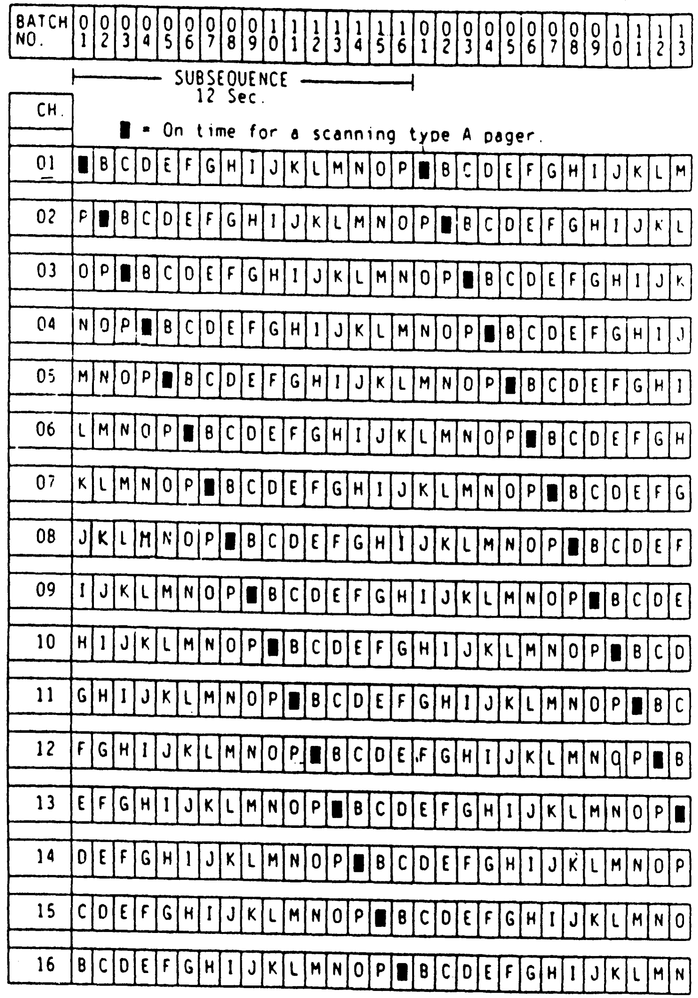


Fig. 1 ERMES architecture



Structure in the radio protocol on one frequency



Synchronization between channels

Fig. 2 ERMES transmission protocol

3. Services and facilities

ERMES provides the basic services as follows:

- tone only (8 different alerts possible per radio identity code) (RIC);
- numeric (20 characters);
- alphanumeric (400 characters);
- transparent data (in the form of an arbitrary bit data stream) for several applications such as graphics, telecommands, coded voice, etc.

In addition to these basic services a great number of supplementary services will be provided, some of which might be offered by individual countries, such as:

- international roaming;
- choice of call destination (under control of the mobile subscriber or of the calling party);
- temporary barring of incoming traffic;
- constitution of closed user groups (the possibility of mobile and fixed subscribers to establish a group with only internal communication possibility; the mobile or fixed subscribers can be members of more than one closed user group);
- protection against messages loss (repetition, numbering, storing and retrieval, etc.);
- establishment of priority levels (urgent calls, normal calls, non-critical time-related calls);
- diversion of traffic to other receivers;
- security facilities (encryption, legitimization code, verification for access);
- charging facilities (standard rate, reverse charge, charging information);
- out-of-range indication;
- deferred delivery.

Regarding the paging categories they can be summarized as follows:

The types of messages will be:

- individual calls;
- group calls (using common or multiple RIC);
- radiodistribution, understood as the possibility of a calling party to broadcast information for a selective group of receivers.

4. Radio network structure

The ERMES radio network structure is based on time divided and/or frequency divided network operation and it is up to network operators in each country to decide the mode of operation. Figure 3 shows the three modes of operation viable in the system.

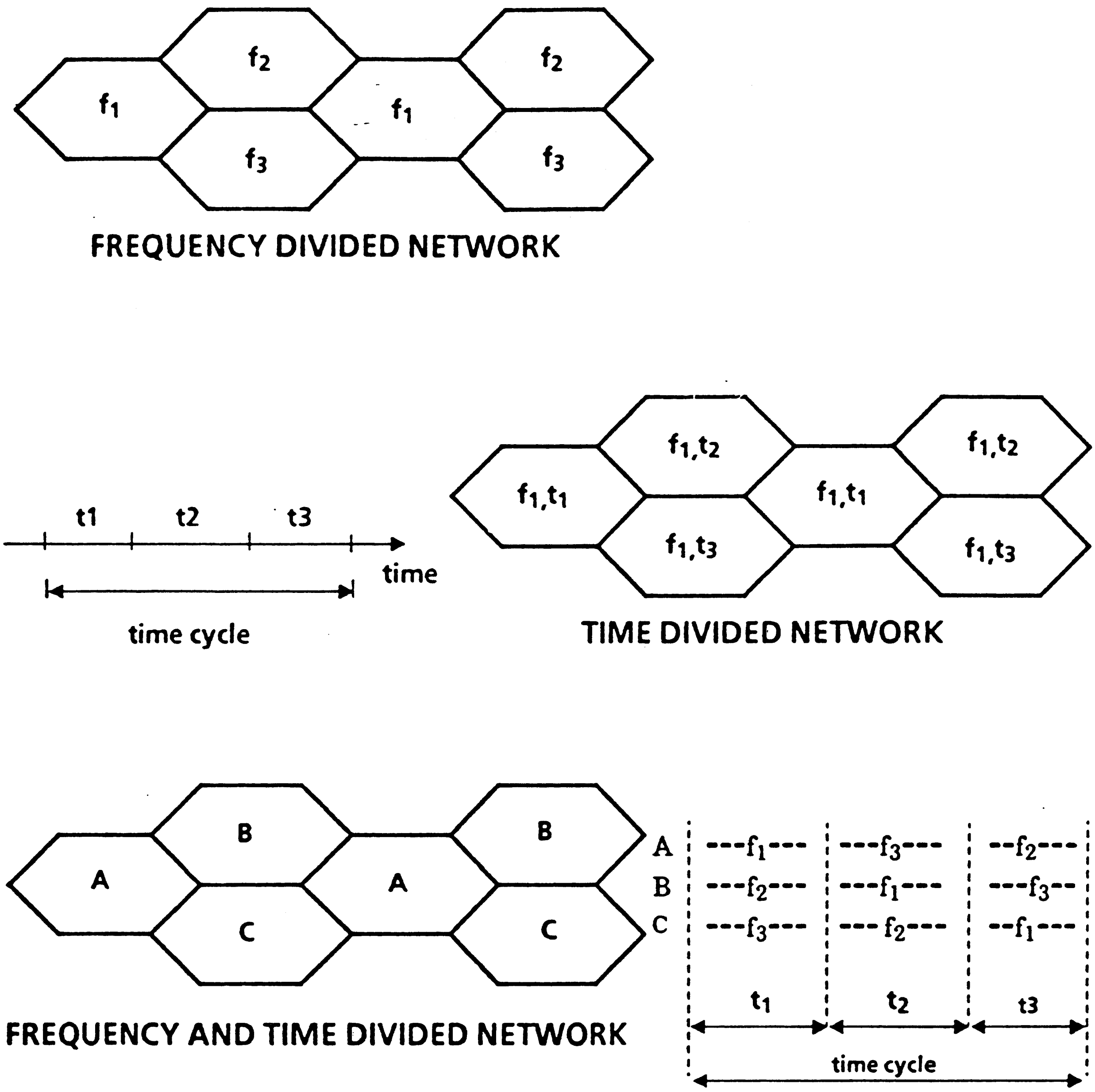


Fig. 3 Possible configurations of ERMES radio structure

5. Network aspects

The main principle of ERMES is to keep access to the system as easy as possible. Since access to the system should be through telephone or data networks, the following methods are possible:

- Direct: which consist of two main phases: first, input the address code (ADC); second, input the message;

- End to End: access with three main phases: input the service number, input the ADC, input the message.

Direct access applies only to the access via telephone network.

ADC is used for identification of the mobile subscriber and it consists of three parts:

- Country number: having the same meaning of that used in the PSTN;

- Network identification: which identifies the network operator within the country;

- Subscriber identification.

Regarding the different phases of call processing, the PNC has three functional entities:

- PNC-I for the input of the ADC messages;

- PNC-H checking the validity of input (ADC);

- PNC-T sending the message to the appropriate paging area controller.

In any case the responsibility of the overall call processing is ensured by PNC-H.

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