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Foreword

This ETSI Technical Report (ETR) describes the concepts of the European Radio Message System (ERMES), as specified in European Telecommunication Standard (ETS) 300 133, Parts 3 and 4. The concepts are described, with examples in order to clarify the method of implementation of the ERMES system.

Computer simulation results showing expected performance for a number of different situations are given in Annex A.

A cross-reference index for both the ERMES ETS and this ETR is also provided, to help the reader to find specific information from these documents.

ETSI Technical Reports (ETRs) are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status. An ETR may be used to publish material which is either of an informative nature relating to the use or application of ETSs or I-ETSs, or which is immature and not yet suitable for formal adoption as an ETS or an I-ETS.

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1 Scope

This ETSI Technical Report (ETR) contains explanations of concepts that are considered to be new or to require further clarification. These concepts include aspects of the radio interface I1 (ETS 300 133-4 [3]) and techniques used in the network design (ETS 300 133-3 [2]). Descriptions are included together with examples demonstrating possible uses of the concepts. The examples given are only suggestions and do not necessarily form part of any conformance requirement for equipment that is to be used on a European Radio Message System (ERMES) network.

An informative clause which pertains to several aspects of the I1 interface is included as a planning guide to radio network design. Computer aided simulations which have been used to determine the performance of an idealised radio receiver under various propagation conditions is included in Annex A. Queueing functions and network performance parameters are described in Annex B.

A cross referenced index is provided which has been compiled from ETS 300 133 parts 2, 3, 4, 5, 6 and 7 (1992).

2 References

The following references are used within this document.

[1]   ETS 300 133-2: "Paging Systems (PS); European Radio Message System (ERMES) Part 2: Service aspects".

[2]   ETS 300 133-3: "Paging Systems (PS); European Radio Message System (ERMES) Part 3: Network aspects".

[3]   ETS 300 133-4: "Paging Systems (PS); European Radio Message System (ERMES) Part 4: Air interface specification".

[4]   ETS 300 133-5: "Paging Systems (PS); European Radio Message System (ERMES) Part 5: Receiver conformance specification".

[5]   ETS 300 133-6: "Paging Systems (PS); European Radio Message System (ERMES) Part 6: Base station specification".

[6]   ETS 300 133-7: "Paging Systems (PS); European Radio Message System (ERMES) Part 7: Operation and maintenance aspects".

[7]   CEPT Recommendation T/R 25-07 (Lecce 1989 (CR)). Frequency coordination for the European Radio Message System (ERMES) Edition Jan 1990.

[8]   IBRAHIM M.F. and PARSONS. J.D. "Signal strength predictions in built-up areas Part 1." Proc IEE 1983 130 Part F (8) p377.

[9]   YARWOOD A HOLMES W.H. and GIDLOW A.C. "European radio paging" British Telecom Tech J 1990 8 Jan p1.

[10]   ALLSEBROOK K and PARSONS J.D. "Mobile Radio Propagation in British Cities at frequencies in the VHF and UHF bands" Proc IEE Vol 124 No.2 pp95-102. Feb 1977.

[11]   CSELT. Performance of the ERMES Radio Chain in Simulcast Environment. ETSI/PS2(91)35 Nov 1991.

[12]   ISO 646 (1990): "Information processing - ISO 7-bit coded character set for information interchange".

3 Definitions

For the purposes of this ETR, the following definitions apply.

Codeblock: nine codewords interleaved as a unit as used in the batch message partition.

Codeword: the standard information unit of 30 bits length.

Empty batch: a batch which has K=I=0 (Where K= number of codeblocks in the messages partition, I=number of initial addresses). In other words the batch has minimum data. It does not contain initial addresses or messages for any receiver.

Full batch: a batch which has data to be transmitted during all the batch time. The transmission of its last bit is followed directly by the beginning of the next batch without any time in between.

Incomplete batch: a batch which has data to be transmitted during the batch time, but this data transmission time does not occupy the whole batch time.

4 Abbreviations

ACK	Positive Acknowledgement
ACSE	Association Control Service Element
AIF	Additional Information Field
AIN	Additional Information Number
AP	Address Partition
APT	Address Partition Terminator
ASN.1	Abstract Syntax Notation one
AWGN	Additive White Gaussian Noise
BAI	Border Area Indicator
BER	Bit Error Ratio
BSF	Battery Saving Factor
BSR	Battery Saving Ratio
CFEK	Carrier Frequency Exchange Keying
CTA	Common Temporary Address
CW	Code Word
ECC	Error Correction Code (as defined in ETS 300 133-4 [3], Clause 7)
ENL	Number of LSBs to be compared when operating outside home network
ERMES	European Radio Message System
ETI	External Traffic Indicator
FSI	Frequency Subset Indicator
FSN	Frequency Subset Number
GA	Geographical Area
HNL	Number of LSBs to be compared when operating within home network
IA	Initial Address
LSB	Least Significant Bit
MD	Message Delimiter
MESP	Message Partition
OMC	Operation and Maintenance Centre
O&M	Operation and Maintenance
OPID	Operator Identity
OS	Operation System
PAC	Paging Area Controller
PAC-OS	The part of the PAC dealing with the O&M process
PNC	Paging Network Controller
POCSAG	Post Office Code Standardisation Advisory Group
PR	Preamble
PRE	Preamble word
PSPDN	Packet Switched Public Data Network
QOS	Quality of Service
RIC	Radio Identity Code
ROM	Read Only Memory
ROSE	Remote Operation Service Element

SI	System Information
SIP	System Information Partition
SMSS	Skip Mode Scan Sequence
SP	Synchronisation Partition
SSI	Supplementary System Information
SW	Synchronisation Word
SYNCP	Synchronisation Partition
TLC	Telecommunication
TMN	Telecommunications Management Network
UTC	Universal Time Co-ordinated

5 General description of the ETR

This ETR contains explanations of concepts that are considered to be new or to require further clarification.

5.1 Concepts from ETS 300 133-4

The aspects of part 4 of the ERMES standard which appears to cause the most difficulty for those who did not participate in the development of the standard stems from the codeword structure, how particular bits should be used and the message handling procedures.

The special codewords which have been chosen as the preamble word, synchronisation word, address partition terminator and message delimiter are discussed and criteria for their choice explained.

Use of the border area indicator is explained and how the frequency subset number / frequency subset indicator are intended to operate are described.

Some of the more complex message procedures (group call and long message) are described and typical examples given.

A description of time divided and frequency divided network operation is given.

An extensive discussion of battery saving techniques incorporated in ERMES is provided and a detailed comparison made with equivalent Post Office Code Standardisation Advisory Group (POCSAG) receiver performance.

5.2 Concepts from ETS 300 133-3

A wide range of system concepts are detailed in Clause 7. An underlying common feature with Clause 6 is to further explain the air interface batch structure from the network viewpoint.

5.3 General planning guidelines for an ERMES network

The radio network planning guide given in Clause 8 summarises the special considerations that must be taken into account when designing an ERMES transmitter network.

5.4 Cross referenced index

A cross referenced index of key words from Parts 3, 4 and 5 of the ERMES standard is given in Clause 9.

6 Clarification of concepts from ETS 300 133-4

6.1 Border area indicator

In the transmission protocol between the base station and the receiver the System Information (SI) part of the radio transmissions informs receivers about the network, paging area, external traffic, etc. In the system information there is also the Border Area Indicator (BAI) bit, which is intended to help receivers to receive a call in adjacent paging areas which belong to different networks.

There can be various locking and non-locking receivers in the ERMES system. Examples of the operation of non-locking and locking receivers are given respectively in ETS 300 133-4 [3], subclauses 10.5.1 and 10.5.2. The BAI is relevant only to locking receivers. Furthermore the BAI is relevant only in the receiver's home network. Consequently it is understood that the BAI overrides the FSI/FSN combination.

The BAI must be the same throughout a paging area. Setting the BAI=1 is not very useful for operators with large paging areas, since it forces all locking receivers to act as non-locking receivers and they lose the advantage of battery economy. By setting the BAI=0 an operator can inform receivers which are able to utilise the information, that they can lock to that channel, if other conditions in ETS 300 133-4 [3], subclause 10.5.2 are met.

A call could be lost when a paging receiver is travelling between networks, e.g. from one in the Netherlands to one in Germany. The customer has for example subscribed originally to a network of the Dutch operator and roamed to a network in Germany. A locking receiver could remain locked to a poor quality channel of the Dutch operator when the receiver is in Germany. While the receiver is locked to the Dutch channel, there could be a call addressed to that receiver sent on the channel of the German operator. To prevent the receiver losing this call, an operator can set the BAI=1 in the paging area adjacent to the paging area of another network. The locking receiver should start scanning after receiving system information with the BAI=1. Thus the receiver should successfully receive its call from the German operator on his channel.

If the operator chooses not to use the BAI, then he could transmit all roaming calls also in the receiver's home network. Consequently receivers travelling between networks will receive their calls from their home network when the quality of the reception is sufficient on that channel (although signal quality from a local operator may be better). When the quality of reception becomes insufficient, then the locking receiver acts like a non-locking receiver and starts scanning. Therefore it will find the channel of the roamed operator and will receive its message there.

An operator may also choose to introduce roaming (for home receivers) between different paging areas inside his network. If different frequencies are used in those paging areas, the BAI can be used in the way described above. In this case the procedure where roaming calls are transmitted both in home and roamed areas gives the operator a more flexible way to plan the size and number of paging areas.

6.2 Frequency subset indicator and frequency subset number

In single frequency networks the paging receiver knows on which channel to expect its message. The same applies for multifrequency networks and a locked paging receiver. In both cases the paging receiver behaves like a "single channel" pager.

One can think of various reasons why a paging system uses more than one radio channel. For example, for large operators one channel is most of the time not sufficient to offer an acceptable service (long delivery times).

In such multifrequency networks each paging receiver belongs, in principle, to one of those channels. In that respect the pager still behaves like a "single channel" receiver.

However, there are many reasons why this relation between pager and channel should be as flexible as possible:

- one channel can be taken out of service for maintenance;

- the loading of different channels is out of balance;

- during busy hours more channels are in operation than normally;

- there is no direct relation between the (virtual) channel number and the actual frequency of that channel (channel 12 can change from, say, 169,500 MHz to 169,800 MHz).

In order to make it possible to have a dynamic number of channels in use a so called FSI/FSN arrangement has been designed.

The Frequency Subset Indicator (FSI) is part of the transmitted system information partition which is transmitted to all receivers. The Frequency Subset Number (FSN) is permanently stored in the receiver.

Each paging receiver is informed on which channel to expect its messages by a combination of the transmitted FSI and the stored FSN.

From the receiver point of view:

All receivers have assigned a FSN between 0 and 15. Each FSN defines a unique subset of 5 FSIs. Only channels which transmit one of these FSIs can contain messages for this particular pager.

EXAMPLE 1:   If the FSN = 12 the pager should only look for messages on channels transmitting FSI values of 12, 22, 27, 29 or 30.

From the system point of view:

Each FSI defines a unique subset of FSNs (i.e. pagers) to which the message may be directed.

EXAMPLE 2:   With FSI = 30 all the pagers (with FSN from 0 to 15) may be called, with FSI = 13 only messages for pagers with FSN = 13 are allowed to be transmitted.

For a complete overview of all the possible combinations see figure 1 below.
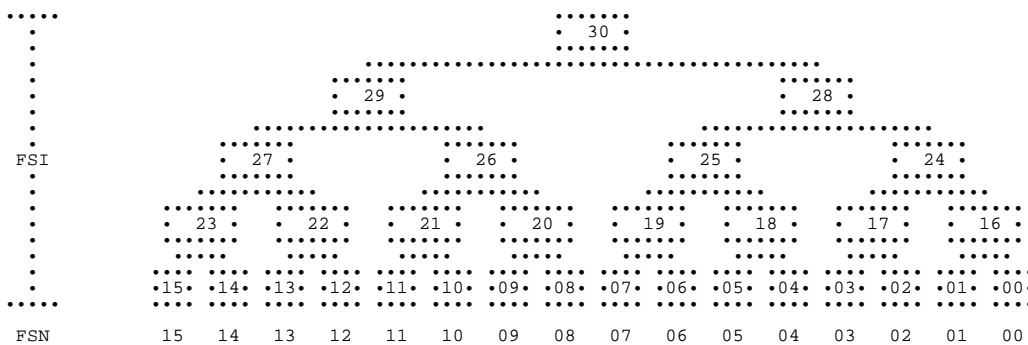
Figure 1: Illustration of FSI subsets

In a single channel network the (transmitted) FSI will always be 30. In that case all the pagers will be capable of receiving messages.

In a network with two channels operating during busy hours and one channel during the rest of the day, the pager population may be split as follows:

```
...............................................
•        Active FSN        á<FSI>         •
...............................................
•Period of the day     •   Channel 1    •   Channel 2    •
...............................................
•Normal hours:         •   allá<30>     •   none         •
•Busy hours:           •   00 – 07á<28> •   08 15á<29>   •
...............................................
```

Traffic may be split into 5 channels as follows:

```
...............................................
•       • Channel 1 • Channel 2 • Channel 3 • Channel 4 • Channel 5•
...............................................
•FSI:•    24      •    25     •    26     •    22     •    23     •
•FSN:•  00 – 03   •  04 – 07  •  08 – 11  •  12 & 13  •  14 & 15  •
...............................................
```

In order to force a paging receiver to change channels (i.e. change frequency) it has to be unlocked. This normally happens when the transmitted FSI no longer matches the FSN (or by simply closing down the channel).

In the case of splitting the pager population with FSN = 12, 13, 14 and 15 into two groups, 12 + 13 and 14 + 15, this can easily be achieved by:

a)   changing the FSI from 27 into 22. This forces the pagers with FSN equal 14 and 15 to unlock and to start scanning;

b)   starting a channel with FSI = 23. The scanning pagers from this group will find this channel and lock to it.

With the above described method each network operator is able to optimise his system continuously without interrupting the service or exchanging pagers.

6.3   Special "Codewords" or code words that are not codewords

All data transmitted over the radio path is coded as described in the ERMES standard ETS 300 133-4 [3], Clause 7. Beyond the codewords belonging to the code, four special words are defined. The four words are 30 bit words like a real codeword, but they are invalid according to the code. The four words are used to synchronise and separate the batch data, and because they are invalid according to the code, there is little risk that they will get confused with data.

The four special codeword are:

the Preamble word (PRE):
00 10 00 10 00 10 00 10 00 10 00 10 00 10 00

the Synchronisation Word (SW):
10 00 10 10 00 10 00 00 10 10 00 00 10 10 10

the Address Partition Terminator (APT):
10 01 00 11 10 00 01 10 00 10 00 11 10 01 00

and the Message Delimiter (MD):
11 01 01 01 11 10 01 11 11 10 11 10 11 10 11

The preamble word (PRE) may be used to obtain bit synchronisation. It is characterised by only consisting of the two outer modulation symbols**(1)**, and that there is a regular shift between these two symbols.

The synchronisation word may be used to obtain word synchronisation. Like PRE it is characterised by only consisting of the outer modulation symbols. Furthermore it is characterised by a low correlation with PRE, and together with PRE it has an almost equal distribution of the two outer symbols (a low DC-level).

There exist one codeword with a Hamming distance of 3, and 68 codewords with a Hamming distance of less than 6 to PRE, the corresponding values for SW is 2 and 87. In principle this means that the error correcting possibility of the code is reduced, but because PRE and SW are only used to obtain synchronisation it is of little importance.

The Address Partition Terminator (APT) is used to separate the address partition from the message partition. It is an invalid codeword with a Hamming distance greater than 5 to every real codeword and to the other three invalid codewords. Furthermore it has a low DC-level and good detection qualities.

The Message Delimiter (MD) is used to separate messages and as a fill word at the end of the message partition. Like APT it is an invalid codeword with a Hamming distance greater than 5 to every real or invalid codeword. The message delimiter will always be interleaved, and it is chosen to have a low DC-level and good detection qualities when multiple message delimiters appear in an interleaved block.

6.4 Battery saving features of the ERMES protocol

6.4.1 Background

The ERMES paging system supports a versatile multi-channel, multi-service provider compatible paging receiver that has built into it a variety of battery saving features. This section of the ETR elaborates on the wide variety of operating methods that can be used to allow optimum battery saving operation for receivers on the ERMES system.

Readers of this section are expected to understand that battery saving opportunities occur by cycling the power supplied to selected circuits within the receiver during the period when the receiver is turned-on and waiting for messaging. The ERMES system sends synchronous channel transmissions to the receiver. The majority of time no information is expected by the receiver and these instances are determined by decoding codewords contained in the system information and addressing sections of the transmissions. As a result of determining that no message is to be sent for the receiver at this time, the receiver may go into a battery saving mode with the expectation of not missing messages. Similarly, the receiver's specific time for active searching of the channel information is controlled by its assignment within the system's sequence, cycle, subsequence and batch structure. These elements of the ERMES system transmission protocol and their influence on the battery saving capabilities of the receiver will be expanded in the following sections.

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(1) The outer modulation symbols are the two symbols 10 and 00 which are mapped to the outermost frequencies (carrier + 4687,5 Hz and carrier - 4678,5 Hz). See ETS 300 133-4 [3], subclause 9.3.1.

6.4.2 General description of the air interface protocol

The structure of the basic transmission protocol on a single channel is shown in figure 2. A receiver can be assigned to operate on the ERMES System in a number of different structured ways. We will discuss several protocol features that can be used to give favourable battery saving operation of the receiver.

```
.......................... SEQUENCE ..........................
                60 minutes   60 Cycles
.............................................  ...............
• 00• 01• 02• 03• 04• 05• 06• 07• 08• 09• 10•...• 57• 58• 59•
..........................................   .................
                              •   •
..........................   .................................
•                             CYCLE                          •
                1 Minute   5 Subsequences
.............................................................
•      0      •     1     •     2     •     3     •     4     •
.............................................................
                    •   •           •   •
        .................           .................
•                          SUBSEQUENCE                       •
                12 seconds   16 Batches
        .............................................
•A •B •C •D •E •F •G •H •I •J •K •L •M •N •O •P  •
        .............................................
                        •   •
..........................   .................................
•                             BATCH                          •
.............................................................
•Synchronisation • System Inform.•  Address    •  Message    •
• partition      •  partition    •  partition  •  partition  •
.............................................................
```
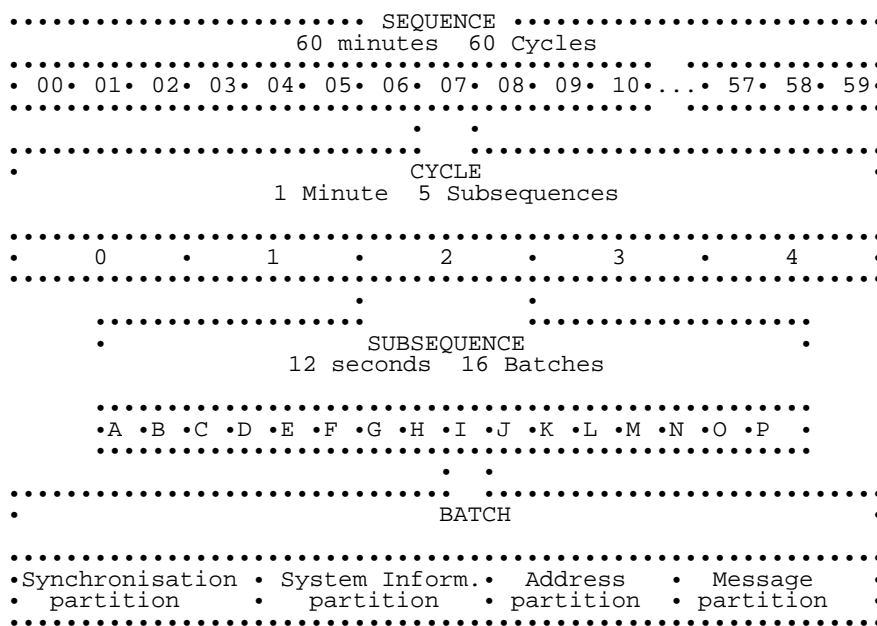
Figure 2: Structure of the radio protocol on channel one

The paging service provider, depending on the level of expected calls per user hour identified by the subscriber, can give each subscriber a message priority level (latency assignment) suitable to the tariff rate they will accept. The latency assignment can be used to determine how often their receiver will look for a potential message on the system. From the transmission protocol the following latency factors can be identified and the resulting Battery Saving Ratio (BSR) calculated.

6.4.3 Home network operation

(a) Sequence assignment

A sequence consists of 60 identified cycles in a 1 hour time period (see figure 2). If a user would accept a latency assignment that would only deliver paging events in a single time period each hour, the receiver would only need to come out of the battery saving mode for 1 cycle out of the 60 cycle sequence. It would require a very stable timing oscillator within the receiver to allow this degree of sleep-mode to active-mode control and still remain in synchronisation with the ERMES system. Although this can result in a 60:1 battery saving factor it is highly unlikely that a caller to the subscriber would be willing to have a worst case turn-around time of 1 hour to answer their enquiry. Similarly, the subscriber expecting an urgent message would be very unhappy with this length of queued reaction time.

The active cycles within a 60 cycle sequence can be determined by comparing the Least Significant Bits (LSBs) of the cycle number to the LSBs of the receiver's initial address (see ETS 300 133-4, [3] Clause 12). If they match then the cycle may carry initial addresses for the receiver. The number of LSBs to be compared (in the range 0 to 5) shall be defined by two 3 bit numbers; HNL for operation within the home network, and ENL for operation outside the home network. A value HNL=0 shall cause the receiver to be active in all cycles whilst HNL=1 shall cause the receiver to be active in every second cycle. For HNL=5 receivers with initial addresses ending in 00000 to 011011 shall be active in two out of sixty cycles whilst receivers with initial addresses ending in 11100 to 11111 shall be active in only one of sixty cycles. This is summarised in the table 1:

Table 1

Number of LSBs to be compared	Value of HNL or ENL	Receiver active (per Sequence)
0	000	all cycles
1	001	every second cycle
2	010	every 4th cycle
3	011	every 8th cycle
4	100	every 16th cycle
5	101	every 32nd cycle

HNL and ENL shall be set to default values of 000 and 010 respectively.

It is assumed that for all practical purposes a single cycle assignment per the hour long sequence will not be recommended to an ERMES subscriber because it is not consistent with the ETS 300 133-2 [1] priority level constraints.

(b)   Cycle assignment

The cycle is a one minute portion of the ERMES protocol which is divided into 5 equal duration subsequences. This structure allows the subscriber a 5:1 battery saving factor since the receiver need only become active during 1 of these 5 subsequence intervals. The latency assignment associated with the queued reaction time of receiving active messaging once per minute could be considered a reasonably acceptable service level for some portion of the ERMES subscribers. The active subsequences for a particular receiver is set by the Subsequence Mask (SM) (5 bits) stored in the receiver (see ETS 300 133-4 [3], Clause 12). If any of the bits is set to 1, signals should be expected on the corresponding subsequence. The MSB of SM corresponds to subsequence number 4, the LSB to subsequence 0. The default value of SM stored in the receiver shall be 11111.

However, from a practical stand-point, a subscriber could be sent a level 1 priority message, which should be handled by having the receiver look at every subsequence, if it is to satisfy the quality of service criterion.

(c)   Subsequence assignment

The subsequence portion of the cycle is 12 seconds in duration. The subsequence is further subdivided into 16 portions called batches. The initial 15 batches are of equal duration while the 16th batch position is purposely longer to facilitate completion of messages within the same subsequence. Since an ERMES receiver is assigned to only one batch per subsequence, the battery saving factor available due to the subsequence structure is a 16:1 multiplier. With the existence of 5 subsequences per cycle, the opportunity to have an additional battery saving factor of 5:1 is possible as discussed previously. From a practical stand-point, a preferred ERMES receiver latency assignment will have it actively searching for messages during every subsequence instead of having it assigned to 1 of the 5 subsequences per cycle.

The ERMES system is targeted particularly at alphanumeric receiver users so the possibility of long messages occupying major portions of each batch requires optimised messaging queue management. Further, ETS 300 133-2 [1], Clause 5, on priority assignments, requires that all priority 1 messages of less than 400 characters be sent within 1 minute of the page accepted acknowledgement having been sent, thus it is desirable to have the receiver operate during **every** subsequence of each cycle.

(d)   Batch assignment

The heart of the basic transmission protocol is in the batch. Here the receiver determines from the address partition (see figure 3) if an actual paging message for the receiver will be sent during the subsequence. The receiver can determine if it should stay active for the balance of its subsequence (note that messages can be extended into the following batch(es) and subsequence and a receiver should remain active for a period of 12 seconds if its initial address is found in the address partition of its assigned batch).

```
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
•PRE•SW •SI •SI •SSI•   I*IA   •   J*APT   •    K*CODEBLOCKS        •
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• SYNCH • SYSTEM INF•      ADDRESS      •        MESSAGE        •
• PART  • PARTITION •      PARTITION    •        PARTITION      •
```
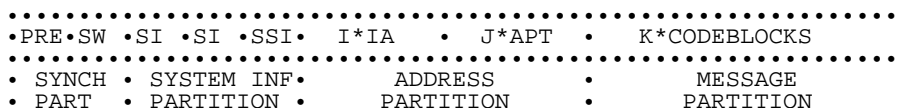
PRE	-	Preamble word.
SW	-	Synchronisation Word.
SI	-	System Information.
SSI	-	Supplementary System Information.
IA	-	Initial Address.
APT	-	Address Partition Terminator.
CODEBLOCK	-	interleaved messages .
I	-	number of initial addresses $0 \leq I \leq 139$.
J	-	number of address partition terminators: $J = 9 - MOD\{(4+I),9)\}$ where $MOD \{M,N\} = M - N*INT(M/N)$ and INT returns the integer part of the number.
K	-	number of codeblocks in the message partition: $K \leq (149 - I - J)/9$ first 15 batches of a subsequence $K \leq (185 - I - J)/9$ last batch of a subsequence

Typical values of parameters for   Typical values of parameters for
the first 15 batches are: the last batch are:

I=0	J=5	K=16 ⌉ maximum number		I=0	J=5	K=20 ⌉	maximum number	
I=4	J=1	K=16 ⌋ of messages		I=4	J=1	K=20 ⌋	of messages	
I=5	J=9	K=15		I=22	J=1	K=18		
I=139	J=1	K=1 -	maximum number of initial addresses	I=139	J=1	K=5 -	maximumnumber of initial addresses	

Figure 3: Composition of a batch

Since the receiver will be operating most efficiently using its batch assignment within the ERMES protocol, we need to expand on how a typical receiver will decode typical transmissions. We assume that the designated batch will be actively searched in every subsequence in the following scenario.

6.4.3.1 Messages all alphanumeric

- Expected number of calls per day is defined to be 3 for each subscriber.

- Typical message length = 55 characters.

- Required Code Words (CW) to satisfy the 55 character messaging are:

    (2*Address CWs + 22*Messaging CWs + 1 Message Delimiter) = 25 CWs.

- Typical batch loading will fully contain 5 paging events of the 55 character messaging duration.

- Address partition would typically contain 5 Initial Addresses (IAs) + 9 Address Partition Terminators (APTs).

- Receiver warm-up (settling) time ⌣ 10 milliseconds from a battery saving mode; this is effectively equal to 2 codewords:

    (6 250 bit/s * 0,01 seconds) = 62,5 bits -> ⌣ 2 CWs

    Therefore, a receiver would initialise its turn-on sequence prior to the expected synchronisation partition by this time period. This adds to the actual active-mode of the receiver.

- Each receiver after completing its turn-on sequence will always remain on for the full duration of the Synchronisation Partition (SP), the System Information Partition (SIP) and a meaningful portion of the Address Partition (AP) of its batch assignment. The typical number of equivalent codewords the receiver will be active during the search for its initial address (remember that they are in descending order) will be:

    2*Warmup + 5*SP/SIP + 3*IA   = 10*CWs
        (Midway Radio Identity Code (RIC))

    2*Warmup + 5*SP/SIP + 5*IA   = 12*CWs
        (Lowest RIC)

    Since the initial addresses (the 18 most significant bits of the local address) are always sent in descending order the receiver needs to remain looking only until the next initial address is lower than its initial address. Therefore, if a particular receiver has a high initial address relative to another, it will have a higher Battery Saving Factor (BSF) because of the normally short SP / SIP / AP portion of the batch. Conversely, a low initial address receiver will be subject to a lower battery saving factor.

- A receiver will remain in the active-mode once their correct initial address is found. The duration of each of these events can be as long as 12 seconds.

- Total available codewords in a typical Batch assignment is equal to 154 CWs:

    5*SP/SIP + 149*AP/MP = 154 CWs

- The overall number of available codewords sent per 24 hour day in the designated 7 200 batches for the receiver is:

$$\frac{154 \text{ CW/batch} * 86\,400 \text{ sec./24 hr day}}{12 \text{ sec/batch sequence}} = 62,4{:}1 \text{ BSR}$$

Results:

A 24 hour day Battery Saving Factor (BSF) analysis.

- For the 3 calls that will be received per day over a 24 hour time period, it will be assumed that on the average these messages will be in the middle of its assigned batch (i.e. after 6 interleaved blocks of 9 codewords) and not within the following batch(es). Taking all codeword commitments into account this results in:

$$3(2*warmup + 5*SP/SIP + 5*IA + 9*APT + 54*CWs + 27*Add/Mess/MD) = 306 \text{ CWs}$$
$$\ldots \ldots \text{Interleaved CWs} \ldots \ldots \text{->}$$

The BSF resulting from within the batch:

$$\frac{1\,108\,800 \text{ CWs}}{\underbrace{7\,197 * 10}_{\text{(non-IA batches)}} + \underbrace{306}_{\text{(true pages)}}} = 15,3:1 \text{ Midway RIC BSF for a 24 hour day}$$

6.4.3.2 Messages a combination of tone, numeric and alphanumeric

If we consider various mixed system operations where alphanumeric messaging is not the only service being provided, the main difference in the receivers active-mode lies in the number of initial addresses processed due to the increase number of potential system subscribers. Two RIC influenced batch multipliers are presented to show the impact of having a midway RIC number assigned to the receiver as well as having the lowest number assignment for a given batch which will require the receivers initial address search to remain through the entire initial address partition. We present without the calculations being shown these resulting battery saving factors for the batch activity portion of the BSR:

Subscriber Composition	Non-IA RIC batch multiplier		24 hour day batch activity battery saving factors	
	Midway	Lowest	Midway	Lowest
50% T, 30 % Num, 20 % Alpha	16	24	9,6:1	6,4:1
10% T, 60 % Num, 30 % Alpha	13	18	11,8:1	9:1
33,3% T, 33,3 % Num, 33,3 % Alpha	12	17	12,8:1	8,5:1
10% T, 20 % Num, 70 % Alpha	11	14	14:1	11:1

The call rates assumed per day are: Tone - 1,5 calls per day, Numeric - 2,5 calls per day and Alphanumeric - 3,0 calls per day.

6.4.4 Battery saving factor calculation - home network operation

In the preceding section many battery saving factors were discussed. If we take all of these into account the following BSR can exist for ERMES receivers.

Protocol element	Battery saving factors		
	All alphanumeric Typical	Mixed system Typical	Maximum multiplier
Cycle	1:1	1:1	60:1
Subsequence	1:1	1:1	5:1
Batch	16:1	16:1	16:1
Batch activity: Midway RIC	15,3:1	9,6:1 - 14:1	18:1 (no addresses present)
Lowest RIC		6,4:1 - 11:1	

All alphanumeric typical battery saving ratio estimate:

> 1:1 x 1:1 x 16:1 x 15,3:1 = 245:1 Midway RIC

Some typical mixed system battery saving ratio estimates:

> 1:1 x 1:1 x 16:1 x 14:1 = 224:1 Midway RIC, high % alphanumeric

> 1:1 x 1:1 x 16:1 x 6.4:1 = 102:1 Lowest RIC, low % alphanumeric

A BSR for a fully dedicated alphanumeric ERMES receiver is typically above 200:1 for an average subscriber who is always in his home network. With a truly mixed system operation a BSR performance above 100:1 would be expected for subscribers within their home network.

The impact when the subscriber roams throughout the ERMES system will be covered in the next section.

6.4.5 The impact of subscriber location - roaming operation

In the preceding BSR calculation for a subscriber in their home network it was considered that the ERMES receiver was operating in a manner where the networks system coverage was always adequate to obtain a consistent signal and the battery saving capabilities operated without interruption. The receiver's own batch assignment within the transmission protocol was correctly handled and on the occasion when a page was received the message was located, stored and subsequently read by the subscriber. This scenario considers the user as residing in their home network. The receiver is not exercising its channel scanning capability of receiving its messages on other than its own assigned channel out of the 16 possible channels built into the ERMES system. Although this may be true for a large portion of the ERMES subscribers, the intent of the ERMES system is to provide full European Community coverage for its users.

The preceding analysis must be expanded into a roaming scenario to demonstrate how the full European Community coverage capability of the ERMES receiver is realised. The ERMES receivers entry into the roaming mode directly impacts the previously predicted 100:1 BSR. When the ERMES receiver is not located in its home network the channel scanning capability of the receiver is activated. Figure 4 shows the system information partition details leading the receiver to begin the scanning sequence. The ERMES scanning receiver enters the scanning procedure when the channel conditions, system information or receiver preferences are not satisfied:

- no ERMES transmissions are recognised on the channel;

- the quality of reception on the channel is insufficient;

- the prior presence of the Home network no longer exists due to lack of the programmed information matching:

    e.g.
    - country code of the transmitting network;
    - operator code of the network operator;
    - paging area code;

- the BAI (Border Area Indicator) is set to 1;

- the FSI (Frequency Subset Indicator) changes;

- the receiver is a "non-locking" receiver.

For the receiver to operate under the constraints listed above as well as to the total requirements of the ERMES system specifications it must have a dynamic operating system to direct its message handling procedures. These procedures are best handled by a microprocessor based receiver design. The attributes of this selection for operating system management will be discussed in the following sections.

System Information Word 1
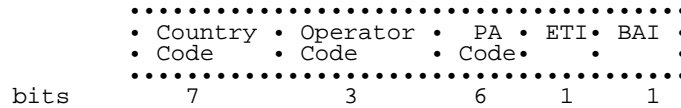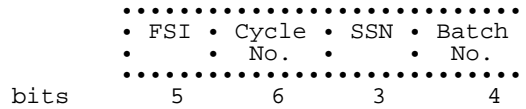
```
••••••••••••••••••••••••••••••••••••
• Country • Operator •  PA  • ETI• BAI •
• Code    • Code     • Code•    •     •
••••••••••••••••••••••••••••••••••••
bits      7          3        6     1     1
```

System Information Word 2

```
••••••••••••••••••••••••••••
• FSI • Cycle • SSN • Batch •
•     • No.   •     • No.   •
••••••••••••••••••••••••••••
bits   5      6       3      4
```

Supplementary System Information Word

```
••••••••••••••••
• SSIT • SSIF •
•      •      •
••••••••••••••••
bits    4      14
```
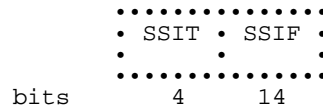
Country Code	-	of the transmitting network.
Operator Code	-	code of the network operator.
PA Code	-	paging area code.
ETI	-	External Traffic Indicator
		0 indicates that roaming traffic does not exist in this batch.
		1 indicates that roaming traffic exists in this batch.
BAI	-	Border Area Indicator.
		0 indicates non border area
		1 indicates border area.
FSI	-	Frequency Subset Indicator (0-15)
Cycle No.	-	0 to 59 covers exactly 1 hour.
SSN	-	Subsequence Number (0-4)
Batch No.	-	A-P (0-15)
SSIT	-	Supplementary System Information Type.
		0000 zone / hour / date / RSVD (3, 5, 5 bits)
		0001 day / month / year (3, 4, 7 bits)
		others reserved for future.
SSIF	-	Supplementary System Information Field.

Figure 4

6.4.6   Battery saving features of microprocessor controlled receivers.

The sophistication required to receive, decode and ultimately display received messages in ERMES receivers dictates that operations within the receiver are controlled by a microprocessor. This allows the receiver to orchestrate its performance based on the operating system instructions programmed into the Read Only Memory (ROM) linked to the microprocessor. Operational control of the receiver's many circuits depends on what decoded information is obtained during the assigned channel monitoring time(s). As described previously, the majority of time the receiver will not be receiving a page and as a result should exercise the most effective battery saving operations to conserve the energy provided by the single cell power source. The following diagrams indicate typical battery saving techniques that will operate in ERMES receivers.

The on-mode and fully powered active-mode of the receiver is indicated in figure 5. All functional circuits required to maintain synchronisation with the assigned batch time slot are powered during the on-mode. The active-mode requires that all circuits are turned on to full readiness to allow the receiver to decode their received batch time protocol transmissions. If the decoded information indicates further active-mode operation should continue then the active-mode will be extended until the completion of the received messaging event as shown in figure 6.

```
                                          •  •  Receiver warm-up and
                                     ->•  •_ duration of SP / SIP / AP
                                          •  •
        Active-Mode Current Drain ••••••••
                                          •  •
                                          •  •
          On-Mode Current Drain ••••• ••••••••••
                                     ->•1 Batch time•
                                        •            •
```
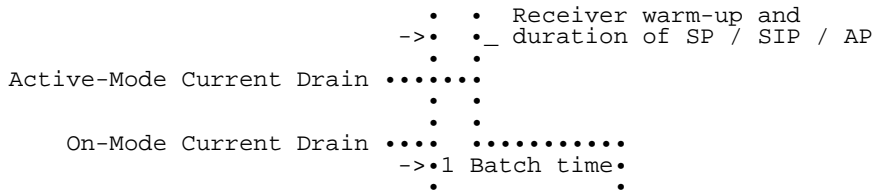
Figure 5

Figure 5 indicates a typical Active-Mode duration with no receiver messaging present for this RIC. As stated previously, the 5:1 battery saving factor is realised over this time period.

```
        ->•                                 •  The pager is in the
          •                                 •  Active-Mode for 3
    ••• •••••••••••••••••••••••••••••••••••  SP / SIP / AP batch
        •••Message       ••Message    •• •  periods and the
        •••Partition     ••Partition  •• •  necessary message
    ••••                               ••  partitions to
        •Batch time 1 •  Batch time 2•     receive the full
        •                •            •    paging event.
```
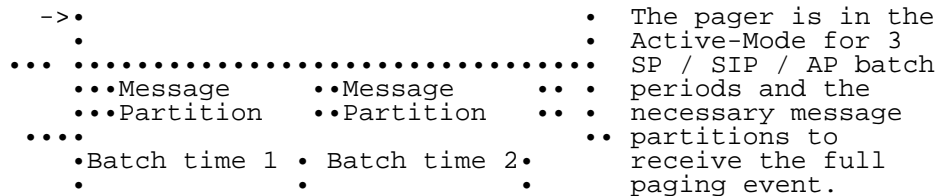
Figure 6

Figure 6 shows the extended active-mode that the receiver needs to receive the total messaging event (assuming that the message data occurs in the next but one batch or was continued into that batch).

The active-mode to on-mode relationship must change to cover the roaming scenario. Within the ERMES receiver's microprocessor ROM programming the opportunity exists to have several channel scanning procedures outlined for the receiver to follow depending on the knowledge gained during the preceding scanning activity. Each of these procedures will allow an improvement in the BSR because the length of time the receiver is in the active-mode is diminished. Let us consider the following roaming examples as the most desirable scanning instructions for improved BSR operation.

6.4.6.1   Scan sequence with sleep-mode time period.

Assumptions:

-    HNL set to 000; ENL set to 000;

-    majority of receivers in service are alphanumeric.

When the receiver enters the roaming mode and for whatever reason is unable to find any ERMES transmission on each channel after "X" successive times stepping through all 16 ERMES channels the receiver will remain in a long duration on-mode (sleep-mode). The value of "X" could be 2 or perhaps 5 (or more) which would have the receiver initiating expanded searching for ERMES transmission protocol over a time period of 24 or 60 seconds (or more). It would be desirable to have the sleep-mode be on the order of 1 to 2 minutes to allow a reasonable battery saving factor to be achieved during these extended non-signal times. After leaving the sleep-mode the receiver again begins to search all 16 channels for expected ERMES transmissions. If no changes in ERMES channel recognition have occurred, the receiver would again return to the long duration sleep-mode after the "X" long sequence.

It is assumed that the ERMES receiver was initially in synchronisation with the ERMES system and that the value of HNL and ENI were both set to the 000 value; all cycles active. It is also assumed when the receiver begins to search the first channel its active-mode search length is equal to 5 codewords (Synch Partition + 1 additional codeword time). With no channel activity found the receiver will return to the on-mode powered level until the next channel is selected and the receiver then returns to the active-mode for this 5 codeword (CW) time duration. If no ERMES channel activity has been found after all 16 channels have been examined, 1 codeword time will be added during each subsequent scan sequence for the duration of the "X" sequences. This additional codeword time is necessary since the receiver clock can be expected to drift with respect to system time, one method of compensating is to lengthen each scan sequence cycle by an appropriate time, possibly one codeword time. This adds up to an active-mode time duration equal to 48 codewords in the initial 16 channel scan sequence.

Over this initial 16 channel search a total of 2 500 codeword time could be sent. The apparent BSR is:

$$\frac{2\ 500\ \text{CW}}{80\ \text{CW}} = 31 : 1\ \text{BSR}$$

If the value of "X" totals 2 full 16 channels searches then the resultant BSR under the continuing rule of 1 added codeword time per each 16 channel scan search sequence yields:

$$\frac{5\ 000\ \text{CW}}{(80 + 96)\ \text{CW}} = 28 : 1\ \text{BSR}$$

If this "X" scan length to sleep-mode sequence is not followed then the receiver would eventually remain in the active-mode until a suitable ERMES system channel is located. No BSR would be achieved under this situation.

The illustrations in figures 7 and 8 reflect this proposed programming. The receivers frequency synthesiser follows the instructions of the microprocessor based operating system as defined in the ETSI specification channel scanning sequence shown in figure 9.

```
                            ••     Receiver warm-up and
                        ->••<-  duration of synch partition search
Active-Mode       ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••
                  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••  ••
   On-Mode     ·················································································
                 01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02
```
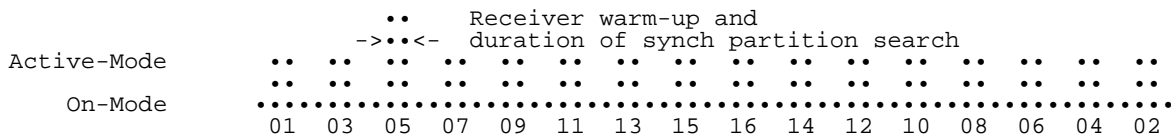
Figure 7: Frequency synthesiser scanning synch partition search sequence

The battery saving performance of the microprocessor controlled receiver as shown in figure 7 can be further enhanced by having the instructions recognise the lack of channel activity and having the receiver enter a sleep mode.

```
                                 ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
Scan sequence 1                  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
     .                           ......................................................................
     .                           01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02
     .
                                 ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
Scan sequence "X"                ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
                                 ......................................................................
                                 01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02

Sleep-mode time period
          On-Mode               ......................................................................
     .
     .
     .
                                 ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
Scan sequence 1;                 ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
full 16 channel scan             ......................................................................
begins again                     01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02
```
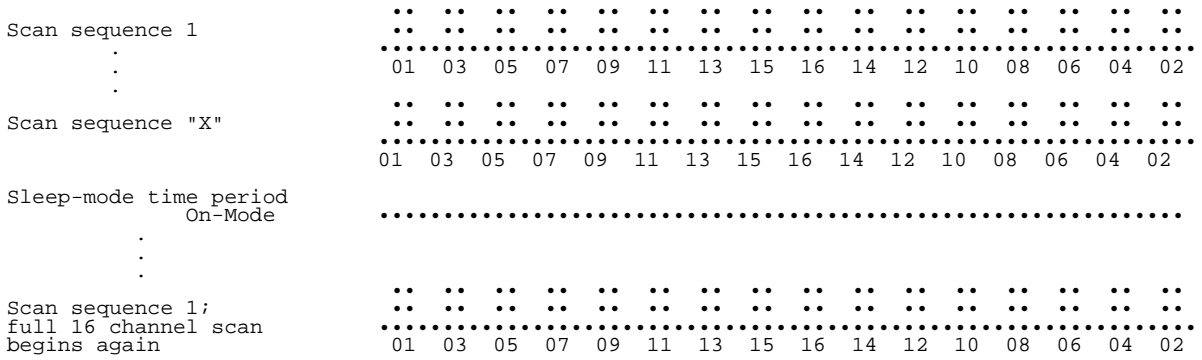
Figure 8: Receivers microprocessor controlled scan and sleep-mode sequence

The "X" duration scanning sequence and the predetermined sleep-mode is shown in the multiframe portrayal of Figure 8. The ERMES receiver can be programmed to follow this style of battery saving enhancement when no active ERMES channels are found.

If we let "X" = 5 and the sleep-mode be equal to 1 minute (5 subsequences) these battery saving results are obtained:

$$\frac{\text{Scan Sequence} \quad \text{Sleep-mode}}{400 \text{ CW}}$$

$$\frac{(5 * 2\ 420 \text{ CW } + 5 * 2\ 420 \text{ CW})}{400 \text{ CW}} = 60,5 \text{ BSR}$$

```
••••••
•CHAN•<••••••••• 12 secs ••••••••••>•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 01 •••B•C•D•E•F•G•H•I•J•K•L•M•N•O•P •••B•C•D•E•F•G•H•I•J•K•L•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 03 •P•••B•C•D•E•F•G•H•I•J•K•L•M•N•O •P•••B•C•D•E•F•G•H•I•J•K•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 05 •O•P•••B•C•D•E•F•G•H•I•J•K•L•M•N •O•P•••B•C•D•E•F•G•H•I•J•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 07 •N•O•P•••B•C•D•E•F•G•H•I•J•K•L•M •N•O•P•••B•C•D•E•F•G•H•I•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 09 •M•N•O•P•••B•C•D•E•F•G•H•I•J•K•L •M•N•O•P•••B•C•D•E•F•G•H•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 11 •L•M•N•O•P•••B•C•D•E•F•G•H•I•J•K •L•M•N•O•P•••B•C•D•E•F•G•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 13 •K•L•M•N•O•P•••B•C•D•E•F•G•H•I•J •K•L•M•N•O•P•••B•C•D•E•F•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 15 •J•K•L•M•N•O•P•••B•C•D•E•F•G•H•I •J•K•L•M•N•O•P•••B•C•D•E•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 16 •I•J•K•L•M•N•O•P•••B•C•D•E•F•G•H •I•J•K•L•M•N•O•P•••B•C•D•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 14 •H•I•J•K•L•M•N•O•P•••B•C•D•E•F•G •H•I•J•K•L•M•N•O•P•••B•C•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 12 •G•H•I•J•K•L•M•N•O•P•••B•C•D•E•F •G•H•I•J•K•L•M•N•O•P•••B•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 10 •F•G•H•I•J•K•L•M•N•O•P•••B•C•D•E •F•G•H•I•J•K•L•M•N•O•P•••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 08 •E•F•G•H•I•J•K•L•M•N•O•P•••B•C•D •E•F•G•H•I•J•K•L•M•N•O•P•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 06 •D•E•F•G•H•I•J•K•L•M•N•O•P•••B•C •D•E•F•G•H•I•J•K•L•M•N•O•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 04 •C•D•E•F•G•H•I•J•K•L•M•N•O•P•••B •C•D•E•F•G•H•I•J•K•L•M•N•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• 02 •B•C•D•E•F•G•H•I•J•K•L•M•N•O•P•• •B•C•D•E•F•G•H•I•J•K•L•M•
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
```

•   = Active batch for a batch type A receiver.

Figure 9: Channel synchronisation and the scanning procedure

6.4.6.2   Scan sequence with HNL set to 000 and ENL set to 010 (the default conditions)

Assumptions:

-    receiver skips 3 out of every 4 sequences (roaming ENL default);

-    majority of receivers in service are alphanumeric;

-    external traffic indicator is present in every batch;

-    all or some of the ERMES channels are available.

Here the roaming sequence scenario changes because the receiver will only be looking for messages on every 4th cycle. When it is not in the active-mode the receiver will remain in the on-mode. Here is the summary of available codewords:

Off-time available codewords: $\dfrac{3 * 60 \text{ Seconds} * 6\,250 \text{ bit/s}}{30 \text{ bits/CW}}$ = 37 500 CWs

Active-mode available codewords: $\dfrac{60 \text{ Seconds} * 6\,250 \text{ bit/s}}{30 \text{ bits/CW}}$ = 12 500 CWs

For a 10 hour day there are 150 of these cycle events which will result in 7 500 000 codewords being potentially available for transmission. We will assume the number of expected calls to be received each day will remain at 3 for the roaming subscriber.

For all 16 channels present over a 10 hour day:

$$\dfrac{7\,500\,000 \text{ CWs}}{\underset{\text{(true pages)} \quad \text{(non-IA batches)}}{306 \text{ CW} \;+\; 11\,997 \,(10 \text{ CW})}} \qquad = 62{,}4{:}1 \text{ BSR}$$

For 3 active channels present over a 10 hour day:

$$\dfrac{7\,500\,000 \text{ CWs}}{\underset{\text{(true pages)} \quad \text{(non-IA batches)} \quad \text{(no channels)}}{306 \text{ CW} \;+\; 2\,247 \,(10 \text{ CW}) \;+\; 9\,750 \,(5 \text{ CW})}} \qquad = 105{:}1 \text{ BSR}$$

For 1 active channel present over a 10 hour day:

$$\dfrac{7\,500\,000 \text{ CWs}}{\underset{\text{(true pages)} \quad \text{(non-IA batches)} \quad \text{(no channels)}}{306 \text{ CW} \;+\; 747 \,(10 \text{ CW}) \;+\; 11\,247 \,(5 \text{ CW})}} \qquad = 117{:}1 \text{ BSR}$$

As can be seen neither of these roaming approaches achieve the BSR expectations available when the subscriber is in their own home network locations.

6.4.6.3   Skip-mode scan sequence

During those situations when the ERMES receiver is in the roaming sequence and active ERMES transmissions are found only on a select number of the 16 channels, it is possible to have battery saving enhancements as mentioned previously. The microprocessor memory management can recognise which of the channels over a given time period ("Y") are active. The receiver's operating system instructions can then skip those channels that are not presenting ERMES system transmission over several scanning sequences. A fixed time later the full 16 channel scanning sequence will be made and the microprocessor memory management process repeated. This series of decisions is represented in figure 10.

    NOTE: Active channels are shown as double line enclosures.

```
                          ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··
Scan Sequence 1           ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··
      .                  ................................................................
      .                   01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02
      .
                          ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··
Scan Sequence "Y"         ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··
                         ................................................................
                          01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02

Skip-Mode Scan            ··          ··          ··                  ··          ··                  ··
Sequence - only 6         ··          ··          ··                  ··          ··                  ··
active channels are      ................................................................
given Active-Mode         01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02
status for a fixed
time period.
      .
      .
      .
                          ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··
Scan Sequence 1;          ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··  ··
full 16 channel          ................................................................
scan begins again.        01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02
```
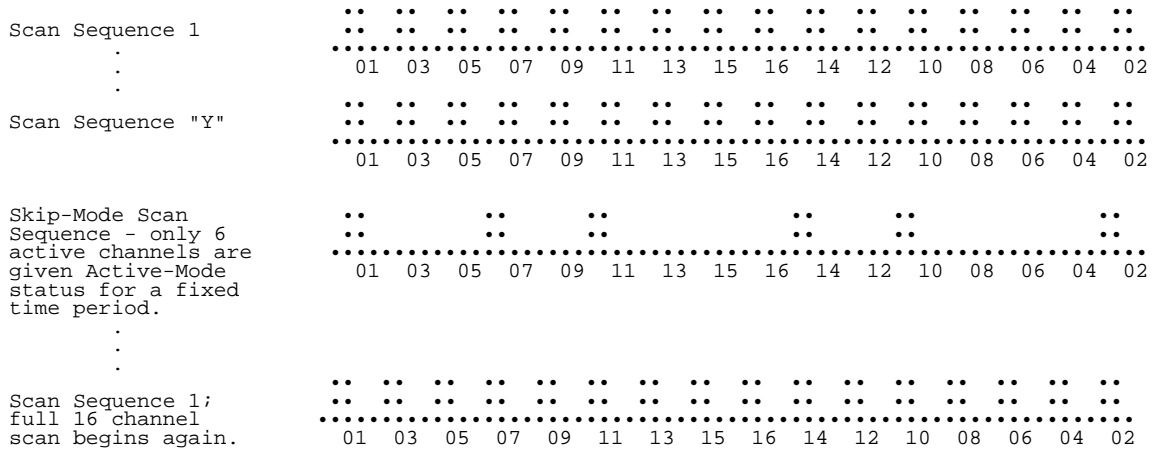
Figure 10

This battery enhancement technique results in 6 active channels with at best a BSR = 15:1. The remaining 10 channels will follow the 5 CW long active-mode for the first channel scan sequence which is 50 CW.

Scan sequence 1: $\dfrac{2\,500\ CW}{(60+50)\ CW} = 22{,}7{:}1$ BSR $\qquad$ Scan Sequence 2: $\dfrac{2\,500\ CW}{(60+60)\ CW} = 20{,}8{:}1$ BSR

Skip-Mode Scan Sequence: $\dfrac{2\,500\ CW}{60\ CW} = 41{,}7{:}1$ BSR

If we let "Y" equal to 5 (1 cycle of 5 scan sequences) and the Skip Mode Scan Sequence (SMSS) equal to 15 (3 Cycles Long) the 6 active channels allow the following BSR performance to be obtained for a 10 hour day:

$$\frac{7\,500\,000\ CWs}{\underset{\text{(true pages)}}{306\ CW}\ +\ \underset{\text{(scan sequences)}}{749\ (130\ Ave.\ CW)}\ +\ \underset{\text{(SMSC channels)}}{2\,248\ (60\ CW)}} = 32{,}2{:}1\ BSR$$

6.4.6.4   Channel scan programming for a selected coverage area plan

Another example of battery saving enhancement under full roaming conditions would be similar to the prior discussion of the skip-mode scanning sequence. The network operator would determine from the subscribers requested coverage area plan that not all 16 channels need to be actively scanned for ERMES messaging. The receiver would be programmed to respond to only those selected channels know to be encountered during the subscribers expected travels. The network operator has activated channels 01, 07, 11, 14, 10 and 02 in the subscribers receiver as noted in figure 11. This yields a skip-mode scanning sequence BSR = 41,7 : 1

```
6 channel selections      ··          ··          ··                  ··          ··                  ··
per the subscribers       ··          ··          ··                  ··          ··                  ··
coverage plan:           ................................................................
                          01  03  05  07  09  11  13  15  16  14  12  10  08  06  04  02
```

Figure 11

6.4.6.5 Non-locking receiver operation

In those instances where the ERMES subscriber has identified the need for a non-locking receiver, the network operator can program the receiver to look only for the channels that would be available over the subscriber's specified coverage area. If this assortment of channels were represented by the choices in figure 11 then this roaming scenario would yield as stated before a BSR = 41,7 : 1.

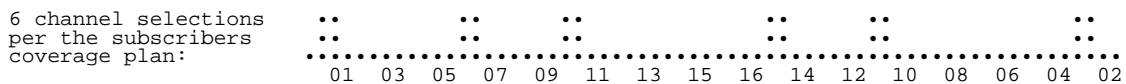It should be obvious to the reader that if a subscriber is outside of his home network and all 16 channels of the ERMES system are present each having the External Traffic Indicator (ETI) active the resultant BSR will typically be operating at $\leq$ 15:1 when no actual messaging is indicated by the lack of initial addresses. For those occasions when the proper initial addresses are decoded there will typically be no battery saving capability over the length of these batches for a fully loaded system as only the previously described SP / SIP / AP saving remains. Even this highly unlikely case compares well with the basic POCSAG BSR of 5,7:1.

6.4.7 Summary of battery saving features

This subclause has considered a wide range of battery saving features of the ERMES transmission protocol. A receiver operating in its home network can expect to obtain a BSR of 100:1. The same receiver whilst roaming, in an unlikely case where all channels are in service, could shrink this BSR to a level of 62:1. It is possible to enhance the low BSR roaming cases as described in the various microprocessor controlled scenarios. All of these cases are considered as easily attainable and highly desirable. They are but a small sample of many possible alternatives that the paging receiver manufacturer may incorporate in the design of the ERMES receiver and the network operators could require in their system specifications.

From an infrastructure stand-point, there must be reasonable management of the messaging queues for each forthcoming batch and subsequence. It must be remembered that the ERMES receiver must remain in the active-mode until its message is found after it finds its initial address in the address partition. This active-mode search time can last as long as 12 seconds. The loading of each batch / subsequence event with active messaging should be done with as much balance as possible so not to overburden the receivers as they search for their initial address and messages. The selection of HNL, ENL and SM for the receiver should closely follow the expectations obtained from the subscriber profile when they signed up for the ERMES service. The expectation of a high messaging rate for the subscriber will mean a higher than average battery drain for the receiver. This effectively leads to a low BSR for the receiver which can be balanced by the network operator assigning a high RIC to these subscribers.

A further means to provide battery saving enhancement for receivers that entered a scanning sequence is provided by the use of the Frequency Subset Indicator (FSI) which is part of the SIP and the receivers' assigned Frequency Subset Number (FSN). For multifrequency networks of a single operator or in those situations where a group of separate operators co-operate in using the FSI subset structure a means is provided to optimise the channel scanning behaviour of ERMES receivers.

The FSN assigned to the receiver defines a unique subset of five FSIs it will be looking for on a channel. If the prescribed FSI is not presented in the channel's SIP the receiver will be able to power down from the active-mode. With the utilisation of the FSI / FSN relationship the receiver can have the opportunity for additional battery saving when it enters a roaming / home network channel scanning scenarios.

The readers of this battery saving feature section can submit alternative scenarios to the ETSI secretariat for consideration. Those suggestions accepted may be included in reissued versions of this ETR.

6.5 Time divided and frequency divided networks - some examples

6.5.1 General

The ERMES transmission protocol has sufficient flexibility, so that networks may be operated with different schemes for time and frequency division.

After a basic description of time division and frequency division operation some examples are presented for combination of these two methods.

6.5.2 Time division between paging areas

For each frequency the five subsequences from the same cycle are distributed to adjacent paging areas.

Time division provides flexibility for traffic adjustment, because the elementary resource unit is one subsequence that is 1/5 of a full channel.

Transmission on the same frequency for each batch type occurs at least once every minute in time division areas.

To avoid problems of synchronisation between networks of different operators, time division is not used in paging areas adjacent to network boundary (border areas).

6.5.3 Frequency division between adjacent paging areas

Each available frequency of the network is allocated to one of the adjacent paging areas, so that transmission use different frequencies in these areas. The complete cycle, with five subsequences is available on each frequency.

6.5.4 Time division/frequency division combination

A network may be operated with a combination of time division and frequency division. Inside a country time division may be used to adapt system capacity to traffic requirements, with the restriction of using frequency division for paging areas adjacent to network boundary.

Near boundary, border areas may be used by each network to provide the physical separation necessary to prevent interference between networks. Channels are distributed to border areas according to traffic requirements. These channels are used in frequency division.

6.5.4.1 Inside a network

Figure 12 gives an example with four paging areas inside the same network.

Adjacent paging areas are using time division on each frequency (Fa-Fp), and may use frequency division.

Non adjacent paging areas have sufficient physical separation to prevent interference, and use the same time slots (T1) on each frequency.

6.5.4.2 Urban centres away from border

Figure 13 gives an example with borders between three networks or countries.

Whole border areas use frequencies Fa to Ff in frequency division. Paging areas adjacent to border areas cannot use the frequencies allocated to border areas.

On figure 13, the network below the boundary uses frequencies Fa to Fb for border area, and Fc to Fp for areas adjacent to border areas. These last channels are shared in time division between three adjacent areas (T1 to T3). Inside the network, urban centres have more or less frequencies available, according to their geographical position. time division allows all frequency channels to be used inside the network.

6.5.4.3 Urban centres on border

Figure 14 gives an example with a border between two independent networks, and urban centres requiring large resources on this border.

Whole non urban border areas use frequencies Fa to Fd, and urban centres on borders use frequencies Fe to Fp.

The network below the boundary uses frequencies Fa to Fb for border areas, and the remaining Fc to Fp for areas adjacent to border areas. Urban centres on the boundary have to share remaining frequencies in frequency division between the two networks.

Time division allows all frequency channels to be used inside the network.

6.5.4.4   Urban centres on border

Figure 15 gives an example with borders between three different networks or countries, and urban centres on borders.

In this case, if frequency resource becomes insufficient, network synchronisation is a possible solution. This is illustrated by figure 15.

Synchronisation of networks allows to suppress some border areas required to separate the networks. An optimum time division is possible for urban centres on the border. Whole border areas uses frequencies Fa to Ff, and the remaining frequencies Fg to Fp are shared by urban centres in time division. Border areas provide sufficient separation, so that areas inside the network can reuse available frequencies, for example Fc to Fp, in time division.

——————————————   Paging area limit

$1 \leq a < b$ .... $0 < p \leq 16$

T1 + T2 + T3 = 1 minute (cycle)
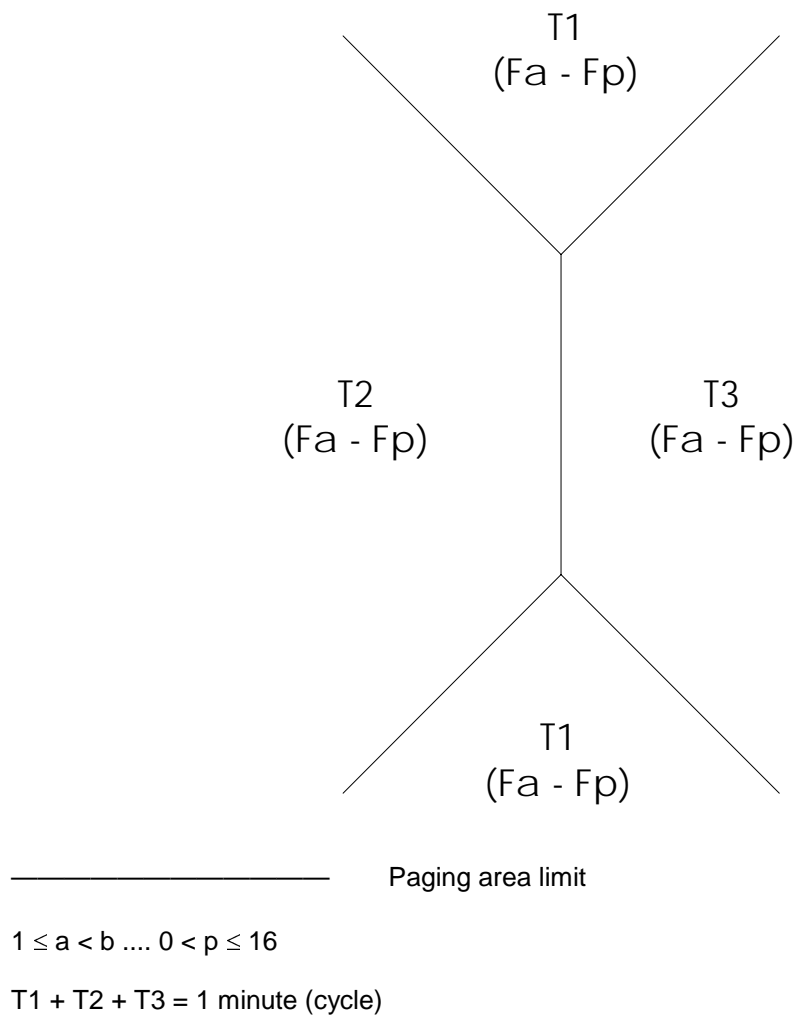
Figure 12: Inside a network

```
              .        ..         .
              .        ..         .
              .        ..         .
...................... ..         .........................
       Fc - Fd*        ..               Fe - Ff*
                       ..
                       ..
                       ..
                       ..
..............................................................
..............................................................
                        Fa - Fb*

.............................................................
    .              .                            .
    .     T1       .                            .
    .  (Fc - Fp)   .                            .
    ..............                              .
          .                                     .
          .                                     .
     T3   .      T2                   .............
  (Fc - Fp) .  (Fc - Fp)             .            .
          .                          .    T1      .     T3
          .                          . (Fa - Fp)  .  (Fc - Fp)
          .                          ..............
    ..............                              .
    .              .                            .
    .     T1       .                            .
    .  (Fa - Fp)   ..............................
    .              .
    ..............
          .
      T2  .              T3
   (Fa - Fp)          (Fc - Fp)
          .
```

```
                                    ..............
                                    .            .
..............                      .            .   great urban centre.
..............   Border.            .            .
                                    ..............

............   Paging area limit.    *  means BAI = 1.
```
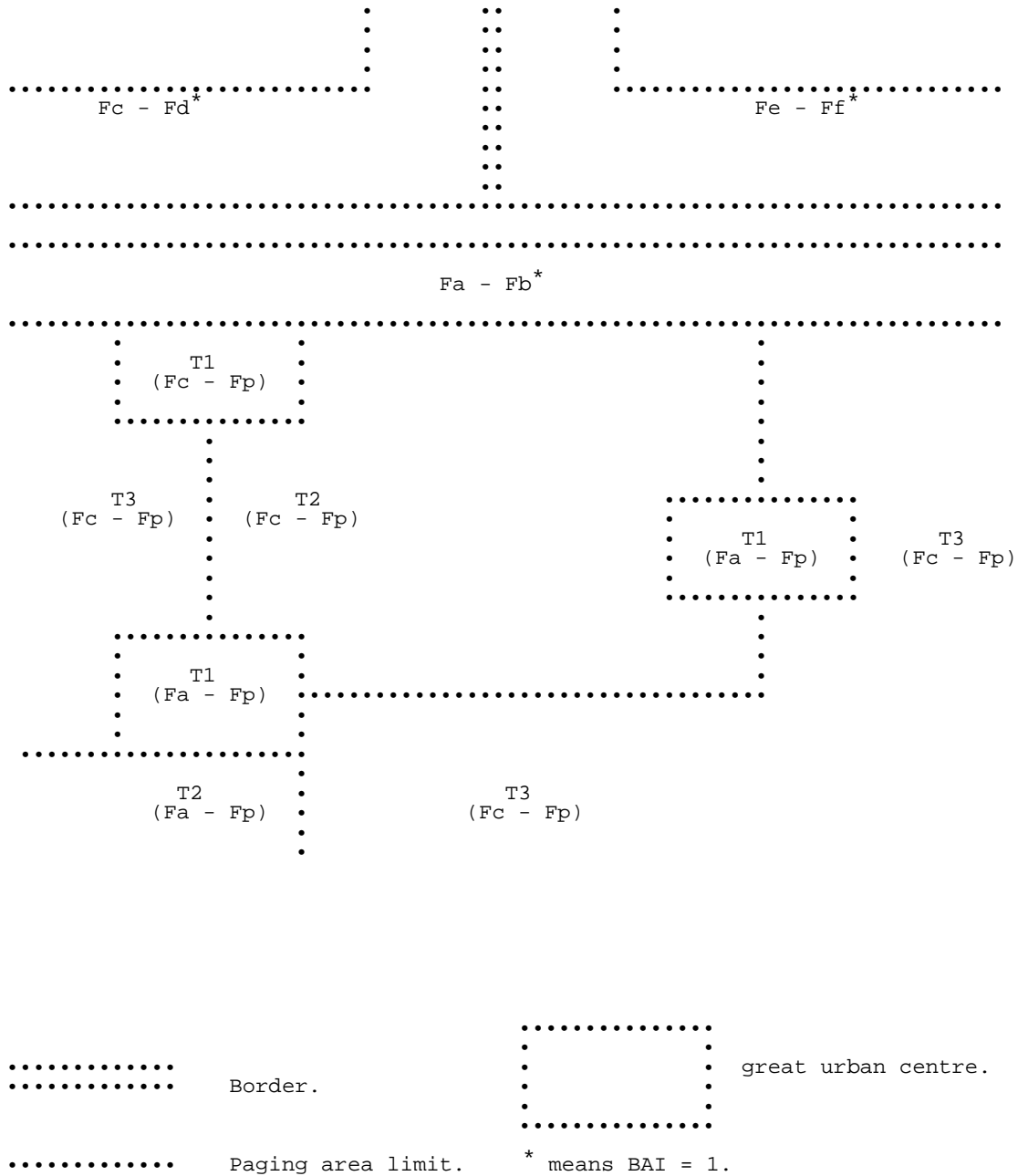
$1 \le a < b \ldots 0 < p \le 16$

T1 + T2 + T3 = 1 minute (cycle)

Figure 13: Urban centres away from border

```
                                         •
                                         •
         T'3                             •                    T'2
   (Fa - Fb ; Fe - Fp)                   •              (Fa - Fb ; Fe - Fp)
                                •••••••••••••••••••••
 ••••••••••••••••••••••••••••   •                   •   ••••••••••••••••••••••••••
                                •        T'1        •
         Fc - Fd*               •     (Fh - Fp)*    •         Fc - Fd*
                                •                   •
                                •                   •
 •••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
 •••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
                                •                   •
         Fa - Fb*               •        T1         •         Fa - Fb*
                                •     (Fe - Fg)     •
 ••••••••••••••••••••••••••••   •                   •   ••••••••••••••••••••••••••
                                •••••••••••••••••••••
                                         •
         T3                              •                    T2
     (Fc - Fp)                           •                (Fc - Fp)
                                         •
                                •••••••••••••••••••••
                                •                   •
                                •        T1         •
                                •     (Fa - Fp)     •
                                •                   •
                                •••••••••••••••••••••
                                         •
                                         •
                                         •
                                         •
```
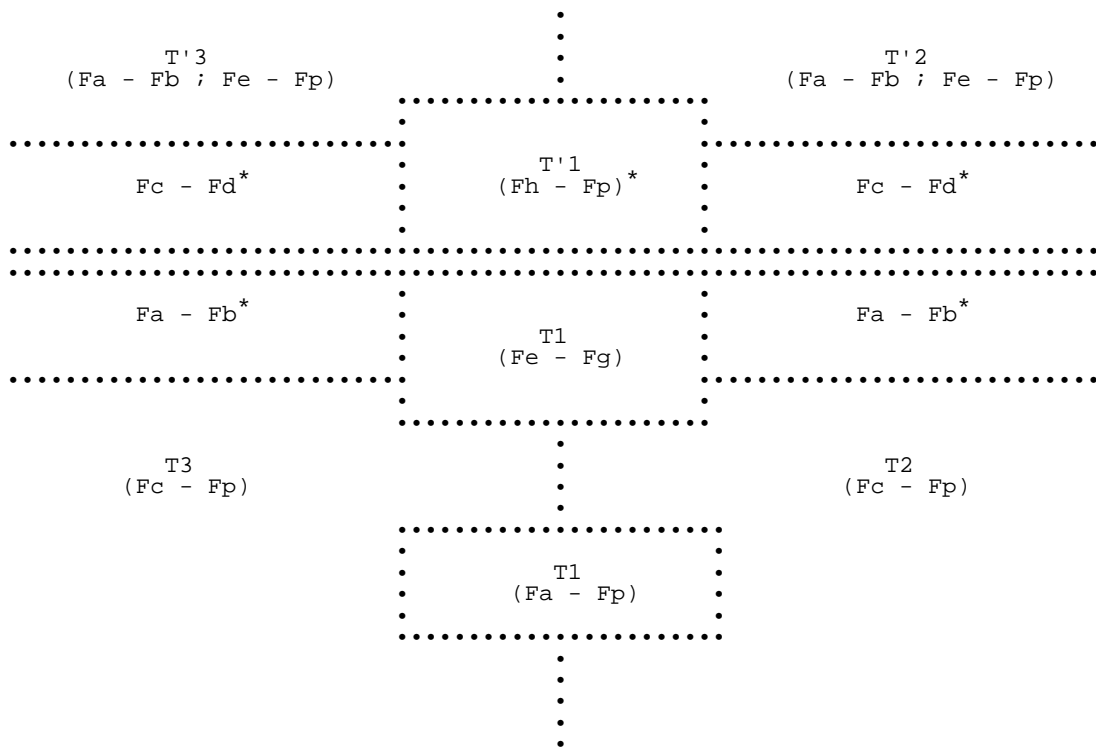
```
                                    •••••••••••••••
                                    •            •
 •••••••••••••                      •            •   great urban centre.
 •••••••••••••    Border.           •            •
                                    •••••••••••••••

 •••••••••••••    Paging area limit.     * means BAI = 1.
```

$1 \leq a < b \ldots 0 < p \leq 16$

T1 + T2 + T3 = 1 minute (cycle)

T'1 + T'2 + T'3 = 1 minute (cycle)

Figure 14: Urban centres on border

```
         •              • •              •
         •              • •              •
 (Fc - Fp)    •    Fa - Fb*  • •   Fc - Fd*    •
••••••••••••••••••••••••    • •              ••••••••••••••••••••••••
         •              • •
         •              • •
         •              • •
         •              • •
         •              • •
         ••••••••••••••••• • •
         •    T1       • •      T2       •
         •  (Fg - Fg)* • •   (Fg - Fp)*  •
         •              • •              •
•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                               •
         •            T3                  •
         •         (Fg - Fp)*             •
         •                               •
         ••••••••••••••••••••••••••••••••
                  Fe - Ff*


•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
```

```
                                  ••••••••••••••
                                  •            •
 ••••••••••••                     •            •   great urban centre.
 ••••••••••••    Border.          •            •
                                  ••••••••••••••
 ••••••••••••    Paging area limit.    *  means BAI = 1.
```
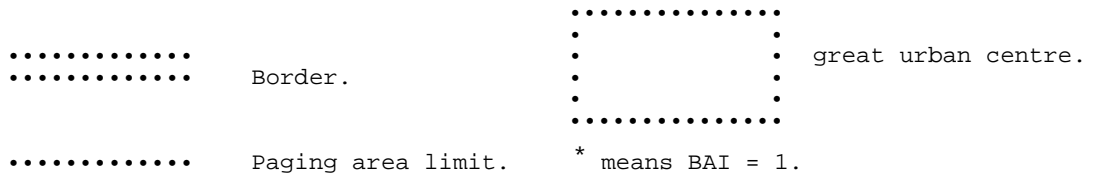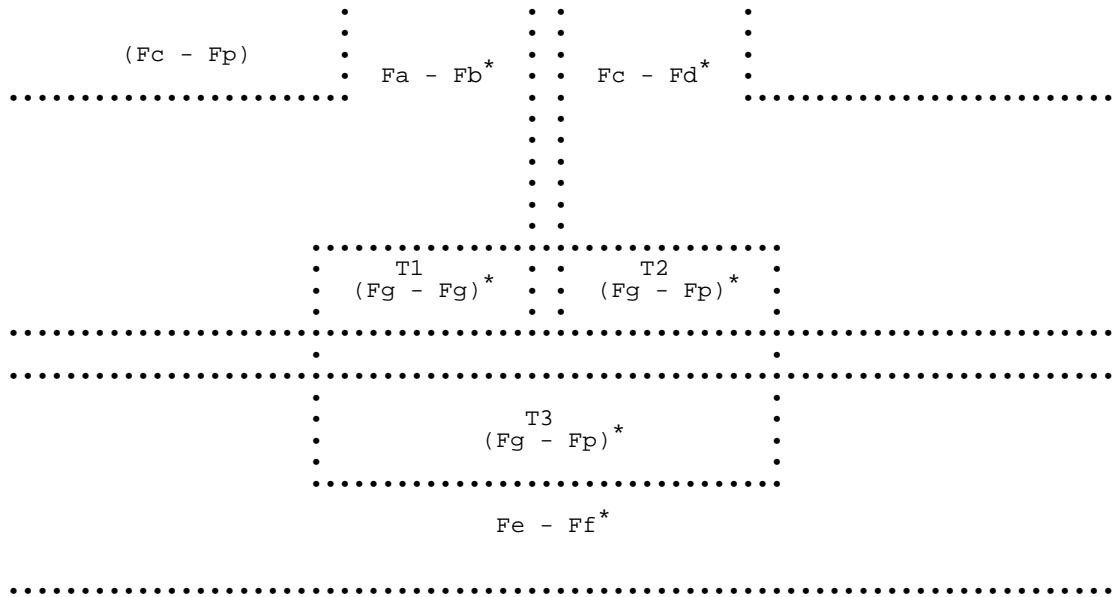
$1 \le a < b \ldots\ 0 < p \le 16$

T1 + T2 + T3 = 1 minute (cycle)

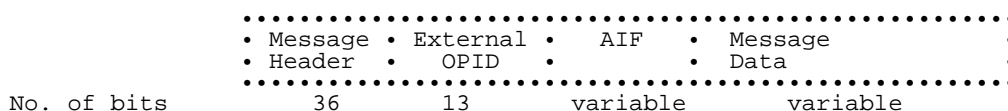**Figure 15: Urban centres on border**

6.6 Message procedures

6.6.1 General description of message format

Each batch is divided into four partitions, namely the synchronisation, system information, address, and message partitions.

The synchronisation partition and system information partition are of fixed length. The boundary between the address and message partitions can be altered depending on traffic type and density. The requirement for codeword interleaving in the message partition imposes detailed constraints on the position of the boundary. Messages are assembled and transmitted in blocks of 9 codewords and the address partition / message partition boundary positioned accordingly.

The message partition consists of messages separated by message delimiters. The message delimiters are not considered part of an individual message. Each individual message consists of a fixed length message header (essential) followed by the optional items - external operator identity, the Additional Information Field (AIF) and the message data as appropriate.

```
                 ••••••••••••••••••••••••••••••••••••••••••••••••••
                 • Message • External •   AIF   •  Message         •
                 • Header  •  OPID    •         •  Data            •
                 ••••••••••••••••••••••••••••••••••••••••••••••••••
     No. of bits      36       13        variable       variable
```

OPID = Operator Identity

The precise definition of each field is given in ETS 300 133-4 [3], subclause 6.5 and the reader is recommended to read the following text in conjunction with that reference.

During design of the air interface protocol the decision was made to minimize control data transfer and hence if any of the three optional items is not required then an empty field is not transferred. The appropriate information to achieve this is sent in the message header. The message thus has the complication of irregular bit positioning depending on which of the optional items are present. This inevitably leads to a slight increase in data manipulation.

However it was arranged that the most common extended message procedure (the second stage of a group call within home network) could be transacted by transfer of a single 36 bit message header with no extensions (see subclause 6.6.3)).

The message data format will be illustrated with the following examples:

a)   individual call to home and external receivers;
b)   group call to home and external receivers;
c)   long message to home and external receivers;

6.6.2 Individual call procedure

6.6.2.1 Calls to home receiver

The procedure to set up individual calls to mobile subscribers is described in detail in ETS 300 133-4 [3] subclause 11.2. The description will be extended by showing the precise data format for transfer of an urgent numeric message of type 4 alert[2].

In this case the following parameters apply:

EB = 0   AII = 0   Paging category = 01   UMI = 1   ALERT = 100

Neither the external OPID nor AIF are present and the numeric message data immediately follows the message header.

---

[2]   The different alert types also offer the facility to have eight sub-addresses for each RIC.

6.6.2.2   Calls to external receiver

Similar values to subclause 6.6.2.1 will be chosen except this is now an external receiver. Thus the parameters will be as follows:

EB = 1   AII = 0   Paging category = 01   UMI = 1   ALERT = 100

Consequently the external OPID will be present but the AIF absent. The message header will be followed by the external OPID and then by the message data.

6.6.3   Group message to home and visiting mobile subscribers

The exact stages in setting up a group call are defined in ETS 300 133-4 [3], subclause 11.3. That description will be supplemented here by an example showing the precise parameters and message format for a non urgent alphanumeric message of alert type 2[2] sent to a group of home and visiting receivers.

> NOTE 1:   It is assumed that only one group message will be sent to a particular receiver at any one time.

> NOTE 2:   Groups are not necessarily predefined and as the example shows, groups can include receivers from different batch types.

Group calls to mobile subscribers using individual RICs are handled using the principle of the Common Temporary Address (CTA). This allows an individual message header to be sent to every receiver of the group and then the actual message (which may be much longer) need only be sent once to a common temporary address of which the receivers have already been individually informed. The procedure is performed in the following three stages:

1)   during the first stage each receiver of the group is initially addressed in its own batch and should start searching for its local address in subsequent batches. Message format for home and visiting receivers are identical at this stage;

2)   during the second stage each receiver of the group is sent an individual message to its local address or full RIC if outside of its home area. This takes the following form:

Receiver in its home area

```
            ••••••••••••••••••••••••••••••••••••••••••••••••••••••
Second  •Individual•Individual• External •        •        • AIN •
 stage  •  Local   • Message   •   Bit    •  AII   •  AIT  •(ctap•
        • Address   • Number    •   (0)    •  (1)   •(111)• no.)•
            ••••••••••••••••••••••••••••••••••••••••••••••••••••••
No of bits    22         5          1          1       3      4
```

> NOTE 3:   Although AII = 1 the fact that AIT = 111 (corresponding to a group call) informs the receiver that the AIF is empty and that the message data field is empty. AIN corresponds to one of the sixteen common temporary address pointers (for instance AIN=0011) and is allocated and re-used by the system as appropriate (see ETS 300 133-4 [3], subclause 16.6.8.2 regarding time-out criteria for group calls).

---

[2]   The different alert types also offer the facility to have eight sub-addresses for each RIC.

Receiver outside its home area

```
         ..................................................................
Second  •Individual•Individual• External •         •        • AIN  •
 stage  • Local    • Message  •   Bit    •   AII   •  AIT   •(ctap•
        • Address  • Number   •   (1)    •   (1)   •(111)•  no.)•
         ..................................................................
No of bits   22          5         1          1        3        4
```

The message header shown above must have the external OPID appended to provide the complete RIC. The codeword is then completed with trailing binary zeros as defined in ETS 300 133-4 [3], subclause 6.5.2. The individual message numbers contained in the individually addressed message headers depend on the ongoing message count for each receiver.

Each receiver of the group appends the four bits of the AIN to its internally stored or generated group initial address (comprising eighteen ones) to form the Common Temporary Address (CTA).

The CTA is used by the receivers only for a single group call and all receivers of a group receive the same CTA. After the initial individual addressing there is no distinction between home and visiting members of a group.

3)   At the third stage the actual message is sent only once using the CTA and a dummy message number 00000 in the message header. All other parameters of the message have the form of an individual message. In fact having reached this stage there is no distinction between individual and group message procedures. Thus long messages can also be sent to groups and group receiver parameters remotely reprogrammed.

The form of the group message header at the third stage is as follows.

```
         ..................................................................
Third   •  Common   • Message  • External •        •         •        •
 stage  •Temporary  • Number   •   Bit    •  AII   •   VIF   •
        • Address   • (00000)  •   (0)    •(0 or 1)•
         ..................................................................
No of bits   22          5          1         1         7
```

Receivers allocate to the message the appropriate message number transferred in the second stage of the procedure. At the third stage of the group message procedure always EB = 0 since individual addressing was achieved at the previous stage. Nevertheless the values of AII and VIF are characteristic of the type of message being transferred. For the chosen example of a non urgent alphanumeric message of alert type 2, AII = 0 and the VIF takes the following form:

```
          ..............................................................
         • RSVD • Paging      •   UMI  •  ALERT  •
         •      •Category(10)•   (0)   •  (010)  •
          ..............................................................
No. of bits   1         2          1         3
```

The alphanumeric data follows straight after the group message header.

A dynamic example for two receivers belonging to the same group but of different batch types further illustrates the time related aspects of the procedure. Suppose that receiver No. 1 is an A batch receiver and receiver No. 2 is a B batch receiver. A typical transmission sequence could be as shown in figure 16.
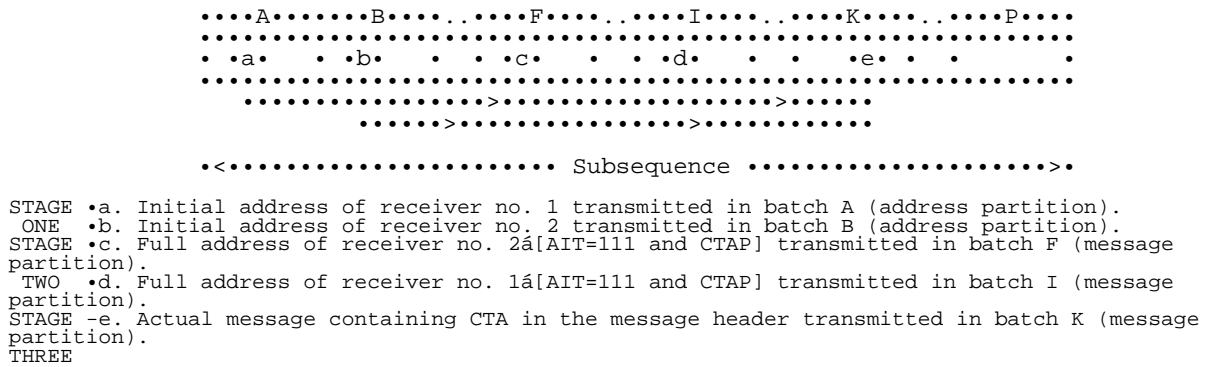
Batches

```
•••••A••••••••B••••..••••F••••..••••I••••..••••K••••..••••P••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
• •a•   • •b•  •  • •c•  •  • • •d•  •  •   •e• • •  •     •
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
   ••••••••••••••••••••>••••••••••••••••••••>••••••
        ••••••>••••••••••••••••••>••••••••••••
•<•••••••••••••••••••••• Subsequence ••••••••••••••••••••••>•
```

STAGE •a. Initial address of receiver no. 1 transmitted in batch A (address partition).
 ONE •b. Initial address of receiver no. 2 transmitted in batch B (address partition).
STAGE •c. Full address of receiver no. 2á[AIT=111 and CTAP] transmitted in batch F (message
partition).
 TWO •d. Full address of receiver no. 1á[AIT=111 and CTAP] transmitted in batch I (message
partition).
STAGE -e. Actual message containing CTA in the message header transmitted in batch K (message
partition).
THREE

Figure 16: Typical on-air calling sequence for a group call on channel one

6.6.4 Long message to home and external receivers

The procedure for sending long messages is defined in ETS 300 133-4 [3], subclause 11.4. That description will be supplemented here with the details of the format of the message headers for the data transfers.

To start with, the called receiver is initially addressed in its own batch and starts searching for its local address in the current and subsequent batches just as for a normal call. Let us, for the sake of this example, take the case of a receiver outside its home area. Thus each part of the long message (i.e. each submessage) will have the external bit set to 1 (EB=1), the external OPID will be present, as will AIF, followed by the message data. For long messages AIF is of length 18 bits and contains the paging category of the message followed by 16 bits indicating the number of bits of the message that remain to be transmitted.

> NOTE: The following example is undergoing revision to incorporate a diagram to clarify form of each submessage. Each submessage needs an EOM plus filler bits which are not counted as part of the message.

The overall length of the alphanumeric message is 10 000 bits. This comprises 1 428 seven bit alpha characters (the last one at least must be EOM) plus 4 bits partial EOM filler bits. In this example the 10 000 bit message will be sent as three submessages. The message header will be the same for each submessage (including same message number) and take the following form:

```
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
        •Individual•Individual• External •   •     •    •    •
        • Local    • Message  •   Bit    • AII • AIT • AIN  •
        • Address  • Number   •   (0)    • (1) •(001)•(1100)•
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
No of bits    22        5          1        1     3      4
```
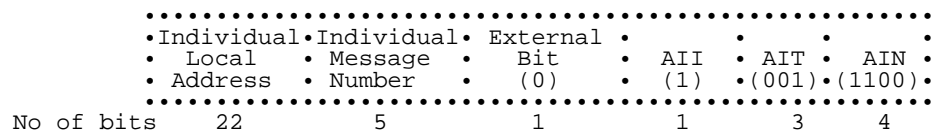
Each submessage will comprise the four items described in subclause 6.6.1 (message header, external OPID, AIF, message data). The AIF and message data will be different for each submessage. The value of AIF for the submessages is as follows:

First submessage: 10 000 bits to be sent hence AIF = 10 00 10 01 11 00 01 00 00. 2 000 bits actually sent.

Second submessage: 8 000 bits to be sent hence AIF = 10 00 01 11 11 01 00 00 00. 5 000 bits actually sent.

Third submessage: 3 000 bits to be sent hence AIF = 10 00 00 10 11 10 11 10 00. 3 000 bits actually sent.

7 Clarification of network related aspects

7.1 System architecture and functional units

7.1.1 General

The system architecture described in ETS 300 133-3 [2], Clause 5, is a functional description of the system.

Each operator network is split into two main parts, the telecommunication part and the operation and maintenance part.

For the telecommunication part, the central processing unit is the Paging Network Controller (PNC) and for the operation and maintenance part, the Operation and Maintenance Centre (OMC).

In an operator network only one functional entity PNC exists. This functional entity can consist of one or more physical PNC units.

Normally only one I4 interface and one IOMC interface exist between each operator with each other.

It is up to each operator to decide how the physical PNC unit should be configured as well as how the internal addressing between the different PNC parts should be done if required, assuming that it complies with the requirements of the ETS 300 133.

In this subclause different configurations for the organisation of operator networks are proposed with a description of alternatives for implementing PNC and OMC functions. Some elements concerning the interworking between networks which have different organisations are considered. Additionally the various possibilities for distribution network organisation compatible with all implementations of the PNC units is considered. Other solutions may be possible, but are not described.

7.1.2 Operator network architecture: PNC/OMC unit organisation

7.1.2.1 One unit

In this case, the two functionalities PNC and OMC are implemented in one unit.
The call processing PNC functionalities (PNC-I, PNC-H, PNC-T) are implemented in the same unit.

```
  ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●
  ●                                                               ●
  ●     ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●       ●
  ●     ●E●              PNC                    ●       ●
  ●     ●Q●----------------------------●       ●
  ●     ●1●              OMC                    ●       ●
  ●     ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●       ●
  ●Network                                                ●
  ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●
```
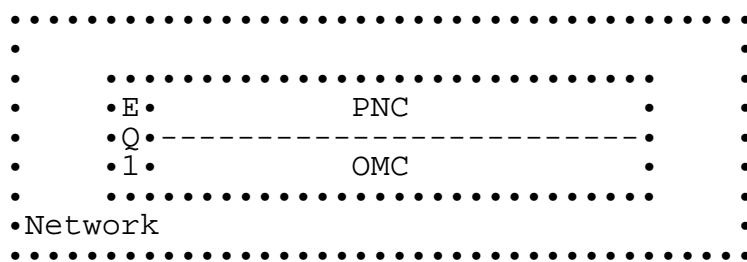
7.1.2.2 Two units

- In this case, one unit deals with the PNC entities and one unit deals with the OMC entities.

- The PNC call processing functionalities (PNC-I, PNC-H, PNC-T) are implemented in the same unit.

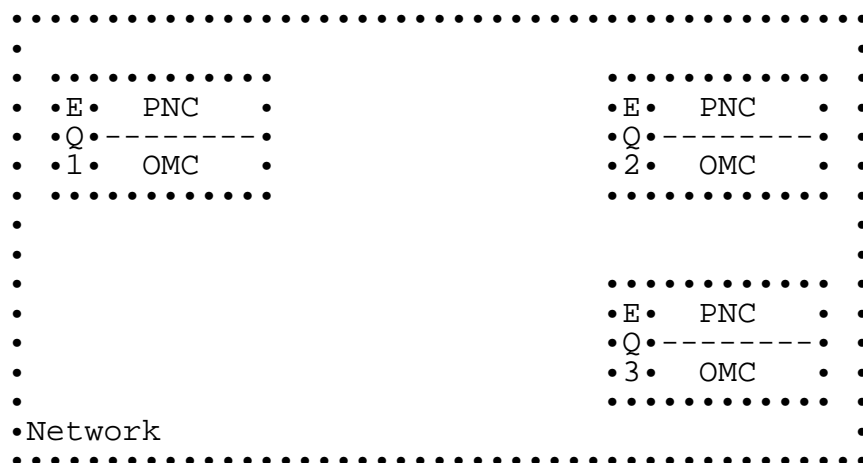- This implementation includes a unit for telecom function management.

```
•••••••••••••••••••••••••••••••••••••••••••
•                                          •
•   •••••••••••           •••••••••••       •
•   •E•         •         •E•         •     •
•   •Q•  PNC    •         •Q•  OMC    •     •
•   •1•         •         •2•         •     •
•   •••••••••••           •••••••••••       •
•Network                                    •
•••••••••••••••••••••••••••••••••••••••••••
```
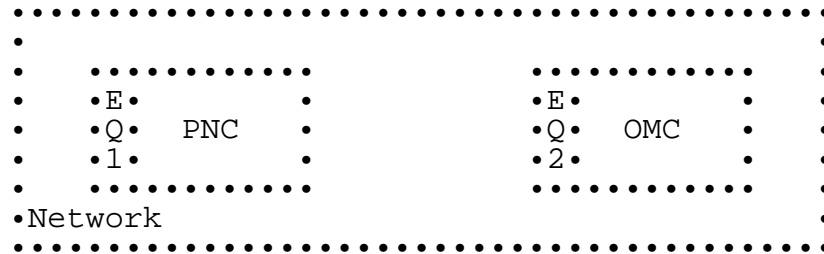
7.1.2.3 Several PNC/OMC units

- In this case the PNC call processing functionalities could be implemented on different units according to different choices: all the functionalities PNC-I, PNC-H and PNC-T are implemented on all the units; or each unit could be dedicated to a specific functionality (PNC-I unit, PNC-H unit, PNC-T unit) according to the operator choice.

   These types of organisation could be chosen for a network with either a large number of subscribers or a large network covering a large country. In these cases the functionalities could be implemented in different units and the I4 protocols could be used for the exchanges between these units.

7.1.2.3.1 Each unit supports PNC and OMC functionalities

This case is similar to the case of subclause 7.1.2.1.

Operator network can be divided into sub-networks and each sub-network could be considered as a network and the same rules could be applied.

```
••••••••••••••••••••••••••••••••••••••••••••••
•                                            •
• •••••••••••              •••••••••••        •
• •E•  PNC    •            •E•  PNC    • •    •
• •Q•--------•             •Q•--------• •    •
• •1•  OMC    •            •2•  OMC    • •    •
• •••••••••••              •••••••••••        •
•                                            •
•                                            •
•                         •••••••••••        •
•                         •E•  PNC    • •    •
•                         •Q•--------• •    •
•                         •3•  OMC    • •    •
•                         •••••••••••        •
•Network                                      •
••••••••••••••••••••••••••••••••••••••••••••••
```

7.1.2.3.2 Several PNC units, one OMC unit

This case is similar to the case of subclause 7.1.2.2 with several units supporting the PNC functionalities and one unit supporting the OMC functions.

```
·············································
·                                          ·
· ··············          ··············   ·
· ·E·                     ·E·          · ·
· ·Q·   PNC      ·        ·Q·   PNC    · ·
· ·1·            ·        ·2·          · ·
· ··············          ··············   ·
·                                          ·
·                                          ·
· ··············          ··············   ·
· ·E·            ·        ·E·          · ·
· ·Q·   OMC      ·        ·Q·   PNC    · ·
· ·3·            ·        ·4·          · ·
· ··············          ··············   ·
·Network                                   ·
·············································
```
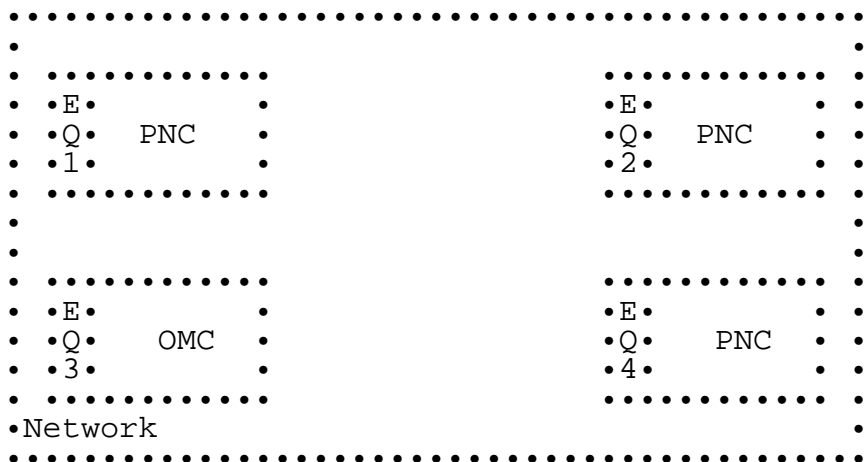
7.1.2.3.3 Several PNC/OMC units, one OMC unit

-    In this case several units support PNC functionalities and some OMC functions, one unit supports all the other OMC functions.

-    The OMC functions implemented in the PNC units are those which are specific for the management of this type of unit and used for the local operation.

-    The OMC unit supports the centralised functions such as the IOMC management or statistic storage and calculation for example.

```
·············································
·                                          ·
· ··············          ··············   ·
· ·E· PNC       ·         ·E· PNC      · ·
· ·Q·--------   ·         ·Q·-------- · ·
· ·1· OMC       ·         ·2· OMC     · ·
· ··············          ··············   ·
·                                          ·
·                                          ·
· ··············          ··············   ·
· ·E·           ·         ·E· PNC      · ·
· ·Q·  OMC      ·         ·Q·-------- · ·
· ·4·           ·         ·3· OMC     · ·
· ··············          ··············   ·
·Network                                   ·
·············································
```
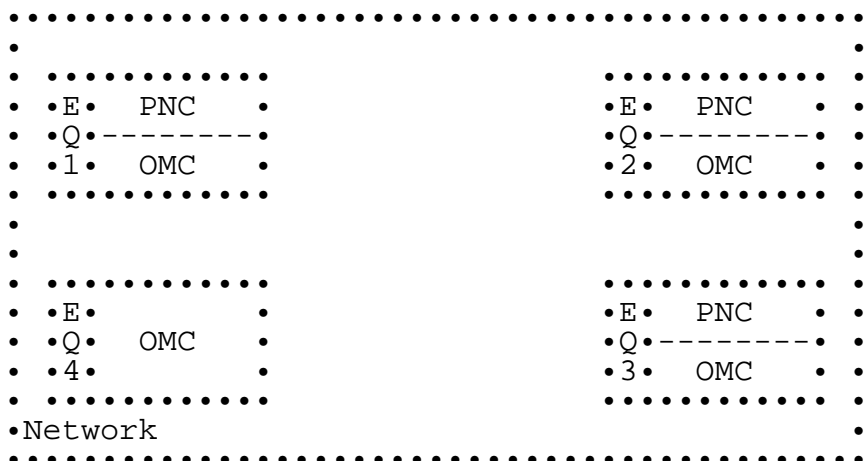
7.1.3 Internetwork interworking

Different networks could have different types of implementation according to the PNC/OMC organisation. With the capabilities of I4 and IOMC protocols using X.25, some examples of interworking capabilities are given. Each case can be connected to each other.

If an operator chooses to configure his network with several PNC units including a gateway, one equipment is dedicated to the gateway to the other operator networks. Then there is only one PNC address to be used by each operators to access this network.

7.1.3.1 Networks with one PNC/OMC unit

```
         ERMES network
                                  • •
         • • • • • • • • • • •           •
         • E •   PNC    • • •            •
         • Q • − − − − − − − •  • • • • • • •     X.25
         • 1 •   OMC    • • •           •   network
         • • • • • • • • • • •          •
                                  • •
```
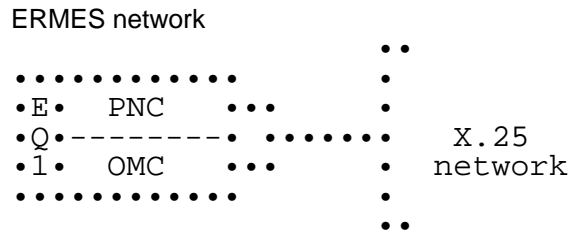
The same X.25 access shares the traffic for I4 and IOMC.

Nevertheless, whatever the implementation, one or several X.25 accesses can be used.

7.1.3.2 One network with two units, one for OMC and one for PNC

```
         ERMES network

         • • • • • • • • • •
         • E •           •
         • Q •   PNC   • • • • • • •       • • •
         • 1 •          •         • I4 •
         • • • • • • • • • •       • • • • • •
                                         •     X.25
                                         •   network
         • • • • • • • • • •       • • • • • •
         • E •          •      • IOMC •
         • Q •   OMC   • • • • • • •       • • •
         • 2 •          •
         • • • • • • • • • •
```
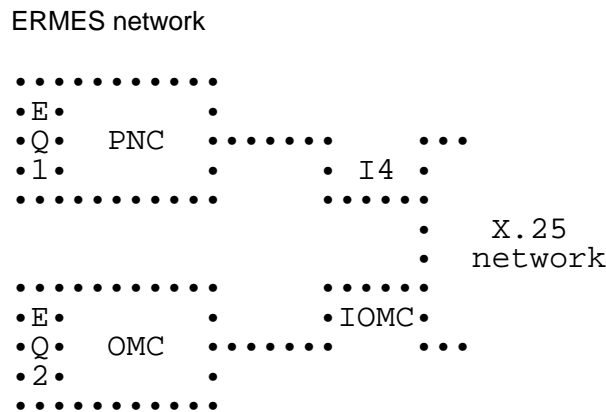
Normally there are two X.25 accesses, one which bears the I4 PDUs and one which bears the IOMC PDUs. However it would be possible also to have only one X.25 access using the interface between OMC and PNC to exchange Operation and Maintenance (O&M) data.

7.1.3.3 Network with several PNC/OMC units and one OMC unit

ERMES network

```
•••••••••        •••••••••        ••••
•E• PNC  •        • PNC  •E•            •
•Q•------•        •------•Q•            •
•1• OMC  •        • OMC  •2•            •
•••••••••        •••••••••            •
      •                •              •
      •                •              •
      •••••••••••••••••••            •
      •          •------------•  X.25
      •  Gateway  ••••••••••••••  network
      ••••••••••••••••••            •
      •                •              •
•••••••••        •••••••••            •
•E•       •        • PNC  •E•            •
•Q• OMC  •        •------•Q•            •
•3•       •        • OMC  •4•            •
•••••••••        •••••••••        ••••
```
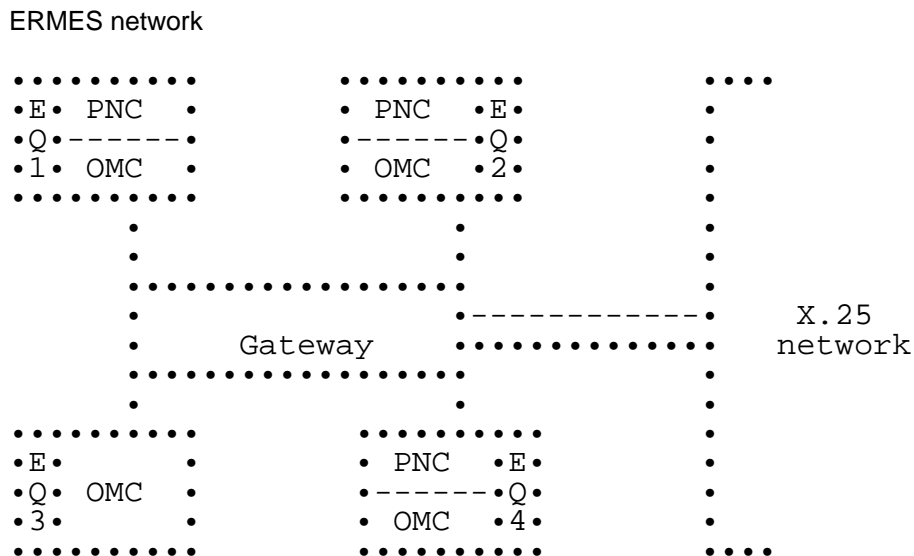
The same X.25 access shares the traffic for I4 and IOMC or there are two X.25 accesses, one which bears the I4 PDUs and one (corresponding to the dotted line in the drawing) which bears the IOMC PDUs.

The gateway is used for managing the unit addressing and routing.

7.1.4 Distribution network organisation

In this part some examples of possible unit organisations are given according to the implementation or not of the optional internal interfaces (I2, I3).

Several types of interfaces could be used for I2 and I3. In the schemes below only the standardised I2 (dedicated lines given as an example in ETS 300 133) is represented.

7.1.4.1 Three types of unit

```
        I2              I3
         ↓               ↓
•••••   ••••••
•BS1•••  •    •
••••• ••••PAC1•••••••
••••• ••••   •      •
•BS2•••  •••••    •        ••••••••
•••••         •••••••••        •
•••••   ••••••           •      •
•BS1••••••PAC2•••••••••••••  PNC  •
•••••   ••••••           •      •
•••••   ••••••  •••••••••        •
•BS1••••••  •       •    •••••••••
••••••••••PAC3•••••••
•••••• •••    •
•BS2•• • ••••••
••••• •
••••• •
•BS3••••
•••••
```

7.1.4.2   Two types of unit

```
            I2

      •••••
      •BS1•••••••
      •••••       •
                  •           •••••••••••••
      •••••      •••••••••••   •           •
      •BS2•••••••       •PAC1•        •
      •••••      •••••••••••   •           •
                          •••••••   •
      •••••           •   •           •
      •BS1•••••••••••••••••••••PAC2• PNC  •
      •••••           •   •   •           •
      •••••           •••••••   •
      •BS1•••••••••••••••••   •           •
      •••••        •••••••PAC3•           •
      •••••       •   •••   •   •••••••••••
      •BS2•••••••••••   •   •••••••••••••
      •••••           •   unit
      •••••           •
      •BS3•••••••••••••••••
      •••••
```
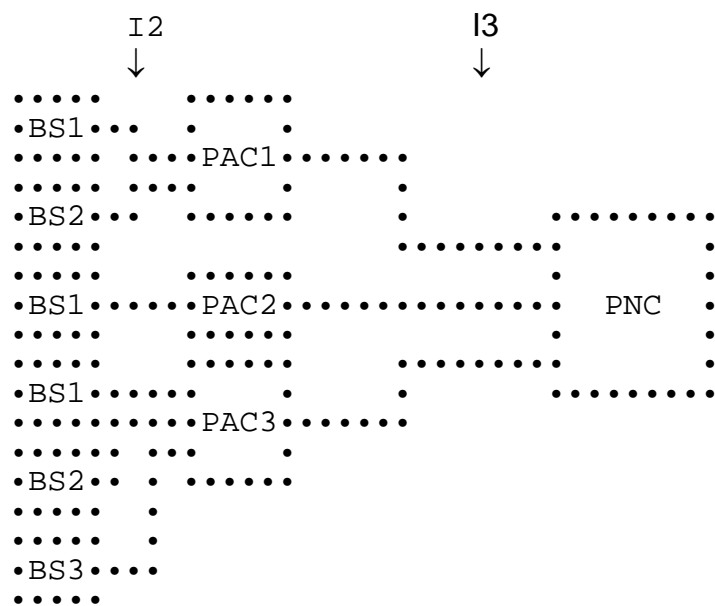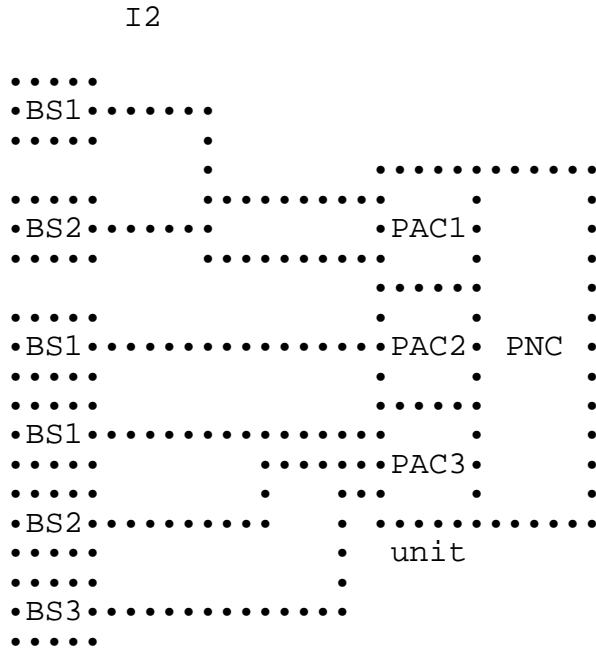
7.2   Call processing in a general paging call

7.2.1   General

This subclause contains an example of a page call. It constitutes the frame of the call processing part of the ETR. Its purpose is to recapitulate the general call process and to show the relation between the different specific processes, described in this part of the ETR. The call is presented as dialogues in an ERMES network, which are illustrated with sequential diagrams with explanations. The subclause is structured into three chapters corresponding to the start sequence, input of supplementary service sequence and input of message sequence of the calling party dialogue.

7.2.2   Example call

In this example it is assumed that a calling party accesses an ERMES network by telephone to send a tone-only, a numerical or an alphanumeric message to a mobile subscriber. The access type is two stage selection. It is assumed that the I, H and T functions are in different operator networks, i.e. the calling party accesses one network, the mobile subscriber is registered to another and has activated roaming in a third network. See figure 17.

```
                                                      •••••
                                                      •     •
      •••••           •••••                           •  P  •
      •  A  •           •     •                         •  N  •
      •  C  •           •  P  •                •••••••••  C  •
      •  C  •           •  N  •                •       •     •
   I6 •  E  • I5  •  C ••••••••••       •••••    •       •  T  •
      •  S  •           •     •           •     •   I4    •••••
      •  S  •           •  I  •    I4    •  P  •   •
      •••••           •••••         •     •  N  •   •
                              •••••••••  C ••••••••••
                                      •     •
                                      •  H  •
                                      •••••
```
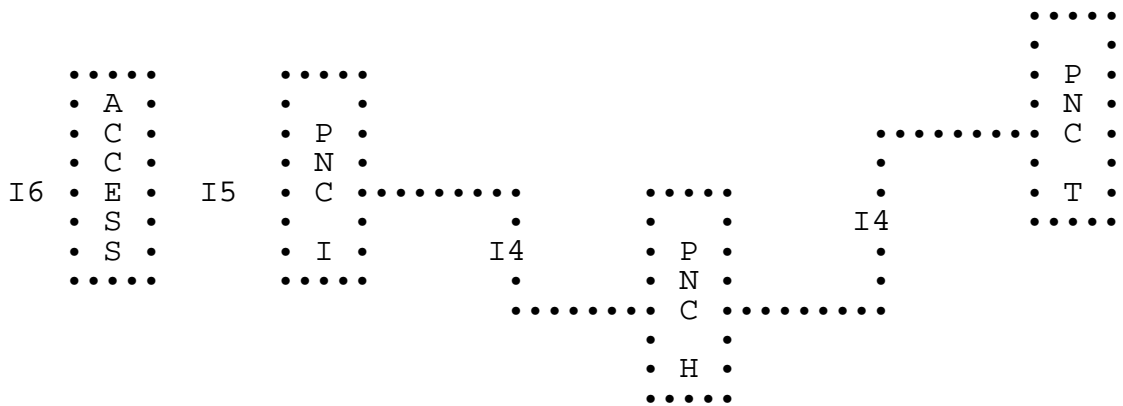
Figure 17: The message flow

Referring to figure 17, the dialogues will be described between:

- a calling party and the PNC access method;

- the access method and its corresponding PNC-I;

- the PNC-I and the PNC-H of the mobile subscriber; and

- the PNC-H and one of the PNC-Ts of the area of transmission.

The PNC access method is a function of the PNC, described in ETS 300 133-3 [2], figure 6 and Clause 7, that handles the dialogue with the calling party, according to the access methods defined in ETS 300 133-3 [2], Clause 8.

7.2.3 The start sequence

The call sequence starts when the ERMES network is called with a service number (1). See figure 18 below. The service number specifies that the calling party wants to make a call input and use related supplementary services.

```
Calling party              I6         Access method
             SN 1#  ---- 1 ---->

                    <---- 2 ----      Greeting

                    <---- 3 ----      AdC request

             AdC#   ---- 4 ---->
```
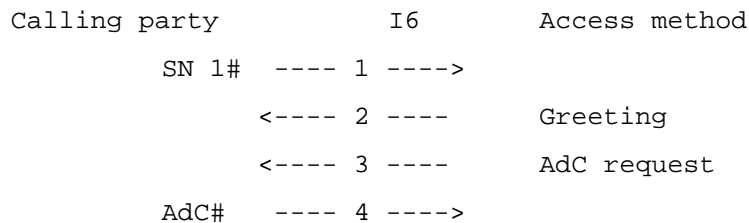
Figure 18: Calling party dialogue, start sequence

The calling party establishes a connection with the access method of the PNC using the service number (1). The ERMES network greets the calling party (2) and asks for the mobile subscriber address code, AdC (3). Calling party dials the address code (4). The calling party signifies with a #, that the input is completed.

Let us leave the calling party dialogue for a moment, to see what happens, with the data input so far, in the PNC and what kind of I4 traffic the start sequence generates. See figure 19.

```
Access method           I5          PNC-I                      I4          PNC-H

Page request          --- a --->

                                    Pager info.            --- b --->
                                    demand

                                                           <--- c ---    Pager info
                                                                         response

                      <--- d ---   Page response
```
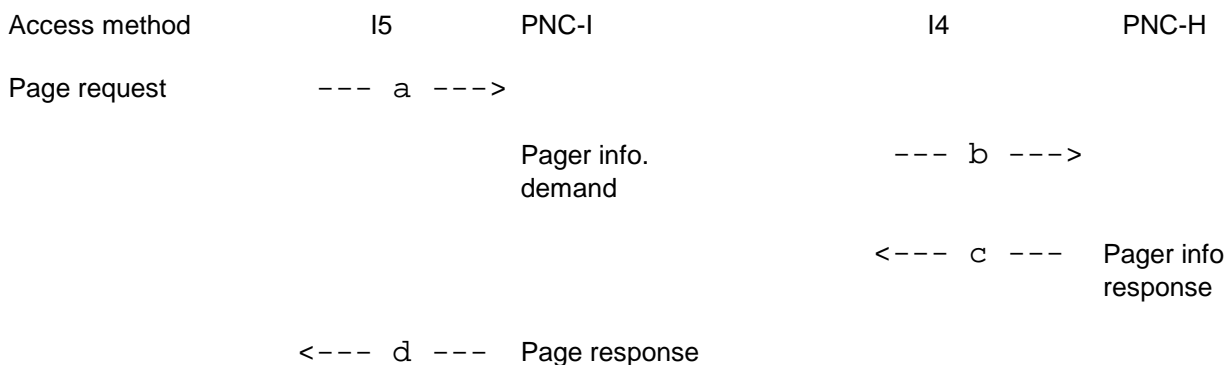
Figure 19: PNC dialogue, page request sequence

When the access method has received the mobile subscriber address code, it checks its syntax. If the syntax is correct, it sends a page request to the PNC-I, with the input address code included (a), since the input service number indicates a page call. The PNC-I sends a pager information demand, over I4, to the mobile subscriber PNC-H. The identity of the correct PNC is given by the mobile subscriber address code. See also ETS 300 133-3 [2], subclause 6.2.1.1.2 "Two stage selection".

The PNC-H will analyse if it is possible to send the page message. First it checks whether the address code corresponds to an address code of a registered mobile subscriber. Second, if the address exists, it evaluates the call acceptance. See ETS 300 133-3 [2], subclause 13.6 call acceptance principals and calculations and subclause 7.7 of this ETR, call acceptance mechanism. If the call is accepted, the calling party may continue with the call dialogue. The access method is notified of this, with a positive page response (d), through a positive pager information response from the PNC-H to the PNC-I (c). See subclause 7.4. If any of the checks, in the PNC-I or the PNC-H, give a negative result, the PNC units send a negative response back to the access method.

The pager information response (c) also contains information on the active supplementary services of the mobile subscriber. This information will be needed when the supplementary services, input by the calling party, are to be verified.

7.2.4 Input of supplementary services

We now return to the dialogue between the calling party and the access method of PNC-I. See figure 20.

```
Calling party                    I6              Access method

                        <---- 5 ----            Call acc

                        <---- 6 ----            Message request

*S.S code#               ---- 7 ---->

                        <---- 8 ----            S.S Ackn
```
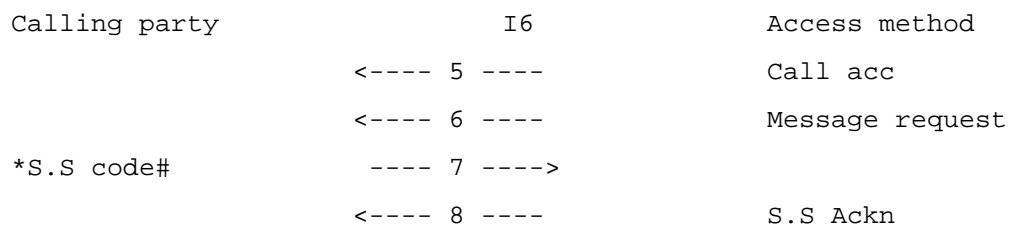
Figure 20: Calling party dialogue, input of supplementary services

After the access method has received the positive page response, the calling party is informed that the call has been accepted (5). On a negative page response from the PNC-I, the access method sends a call not accepted to the calling party. The response may contain information on the cause of the error, depending on operator choice. The access method prompts the calling party to input more information (6). Calling party can choose to enter either a supplementary service code or the actual page message.

Let us see what happens in the PNC, if a supplementary service code is entered (7), see figure 21.

The dialogue may differ from the described dialogue, depending on which service the calling party requests and on operator choice; e.g. it is possible that not all services require legitimisation. In this example the calling party chooses a service that does.

```
Calling party              I6        Access method          I5            PNC-I

*S.S code#             ---- 7 ---->

                      <----7.1----   Legitimisation
                                     request

Legitimisation        ----7.2---->
Code

                                     S.S request        -----e--->

                                                        <----f----  S.S
                                                                    response

                      <---- 8 ----   S.S ackn.
```

Figure 21: PNC dialogue; input of supplementary services

After having received the service code and checked its syntax, the access unit prompts the calling party to enter the required legitimisation code (7.1). When the code is entered, the access method sends a supplementary service request to the PNC-I (e). The PNC-I checks, with the mobile subscriber data, if the service entered by the calling party is in conflict with any of the services activated through the mobile subscriber subscription and if the legitimisation code is correct. If there is no conflict, the PNC-I gives a positive S.S response to the access method (f), which, in turn, acknowledges the receipt of the requested service to the calling party (8). With the acknowledgement, the calling party knows that the service will be performed on the page message, after the page input is completed. If the result of any of the analyses is negative, the calling party will receive a supplementary service not accepted from the system. As in the case with call not accepted, the response may contain information on the cause of the error, depending on operator choice.

7.2.5   Input of the message

When the calling party has requested all the supplementary services he wants, he is again prompted for information (9) and enters the actual message (10). (See figure 22).

```
              Calling party                       I6        Access method

                                              <----- 9 ----   Message request

              Message #                        ---- 10 ---->

                                              <---- 11 ----   Page acc/not acc
```

Figure 22: Calling party dialogue; input of message

The access method checks the syntax of the message and, if nothing is wrong, gives an acknowledgement that the message is received and will be transmitted according to the requested supplementary services (11). The page is on its way and the calling party dialogue is ended.

The message will now be moved through the ERMES system, by gradual demands (g, i, k) and responses (h, k, l), towards the area of transmission, in this case the roaming area. The supplementary services requested by the calling party or activated through the mobile subscriber subscription, will be a carried out on the way. See also ETS 300 133-3 [2], roaming and Clause 7.

Access Method	I5	PNC-I	I4	PNC-H	I4	PNC-T

Message   ---g--->

        <---h---   Message response

                Page demand   ---i--->

                      <---j---   Page response

                          Transmit demand   ---k--->

                                <--l---   Transmit response
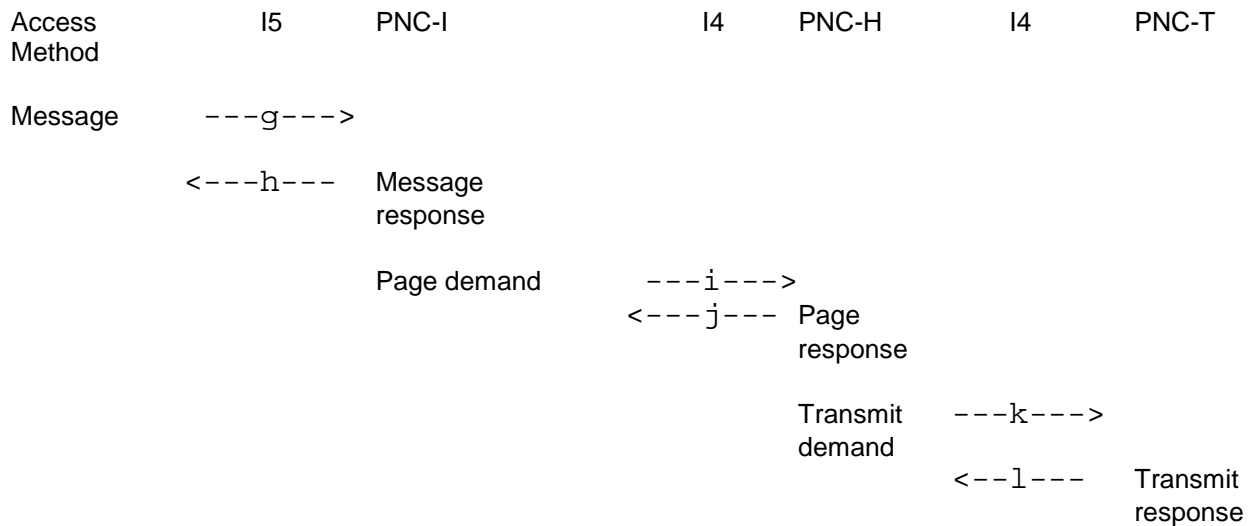
Figure 23: PNC dialogue, transmission of message

From the PNC-T, the message will be distributed to the PACs and their base stations where it will be transmitted. Finally, it will reach the ERMES receivers and be decoded by the intended mobile subscriber.

7.3   Roaming, geographical areas and paging areas

7.3.1   General

Roaming enables a mobile subscriber to change the area where his message will be transmitted to an area outside his normal service area. This subclause explains how geographical area and paging area concepts are used in connection with roaming.

7.3.2   Area concepts

To start with, it is useful to explain some of the area concepts used in ETS 300 133: paging area, geographical area, service area and roaming area. A paging area is the area controlled by a Paging Area Controller (PAC) and it is the smallest area to which a mobile subscriber can subscribe. The paging area address is used as a message address when a page message is distributed to the mobile subscriber service area. When a message is sent to the roaming area, it is addressed to geographical areas.

A geographical area is a set of paging areas used with roaming or choice of destination. Geographical areas can be defined within the home network, by the home network operator, or in external networks. Which paging areas a geographical area defined in an external network consists of, is a result of a mutual agreement between network operators. An operator can, but does not have to, offer the same sets of paging areas to all operators.

The service area, of a mobile subscriber, is the set of paging areas he wants to have his messages sent to when no services of redirecting are active. It may consist of paging areas controlled by his own operator network and/or geographical areas from other operator networks. The service area is an abstract area in so far as it does not have a physical address. It only represents a set of paging areas, with separate addresses.

The roaming area, of a mobile subscriber, is abstract in the same sense as the service area. It represents the set of geographical areas the subscriber wants his messages to be sent to when the roaming service is active. As mentioned in the opening, roaming normally changes the distribution area of a message. However, if the roaming area is adjacent to or overlaps the service area the messages must be transmitted in both areas. If he wants to, the operator may choose to transmit the message in both areas, even if they are well separated.

As opposed to service areas and roaming areas, geographical areas have specific identities. These are specified by the operator that wants to be able to address them. This means that an operator may have to recognise different names for his Geographical Areas (GAs) depending on the network from which they are addressed. e.g. GA 1 in a network in Sweden may be called GA 2 in England and GA 5 in Italy. Thus a geographical area identity is only unambiguous in connection with the identity of the network sending it.

7.3.3 GA data

Information on geographical areas is kept both in networks which address them, referred to as addressing networks, and in networks which control them, called controlling networks. Addressing networks need to know which areas they have access to and the identity of the networks that control them. With these geographical areas, a mobile subscriber can define his roaming area, which will be updated in the mobile subscriber database in the PNC-H of the mobile subscriber network.

Addressing networks also need to know the status of the geographical areas offered to them, to be able to do the network status calculations in the call acceptance analysis. See also subclause 7.7 of this ETR, call acceptance mechanism. Geographical area status information is distributed between networks over the IOMC interface, specified in ETS 300 133-7 [6]. See also subclause 7.4 of this ETR.

Controlling networks need to know which paging areas the geographical areas consist of, as well as the identities of the geographical areas in the addressing networks. They also have to measure the status of their paging areas, to be able to calculate the status of both geographical areas, offered to other networks, and mobile subscriber service areas. See also subclause 7.7 of this ETR, call acceptance mechanism.

7.3.4 Roaming example

We conclude with an example of a roaming page. In the example, a calling party accesses network one, to send a page message to a mobile subscriber with a subscription to the same network. The mobile subscriber has activated roaming, in geographical area one in network two and area three and six in network three. Some of the geographical areas of the roaming area borders the service area, explaining why the message is transmitted in both areas. Figure 24 below shows the data of the roaming area and service area records of the mobile subscriber database.

Network 1, PNC-H

Roaming area	Service area
PNC 2, GA 1 to PNC(2) for tx	PA 1 for tx
PNC 3, GA 3 to PNC(3) for tx	PA 2 for tx
PNC 3, GA 6 to PNC(3) for tx	PA 3 for tx

tx = transmission

Figure 24: Mobile subscriber data, roaming area and service area specifications

After the status of the area of transmission has been checked and the page has been accepted (see subclause 7.7 of this ETR, call acceptance mechanism), the message will be transmitted. It is addressed to the geographical areas of the roaming area and the paging areas of the service area, for transmission. The PNC of network two and three receives the message and translates the geographical area identities into paging area addresses. The linkage is stored in geographical area data records, as illustrated in figure 25.

Network 2, PNC	Network 3, PNC
GA - PA linkage	**GA - PA linkage**
PNC 1, GA 1 = PA 1, PA 2, etc.	PNC 1, GA 3 = PA 1, PA 2, etc.
PNC 3, GA 1 = PA 3, PA 4, etc.	PNC 1, GA 6 = PA 5, PA 6, etc.
PNC...	PNC...

Figure 25: Linkage between geographical areas and paging areas

With the paging area addresses, the message is distributed to the proper PACs and their base stations. From there it is transmitted to the ERMES receiver of the mobile subscriber.

7.4 Use and presentation of I4 parameters

7.4.1 General

The I4 internetwork interface is described in ETS 300 133-3 [2], Clause 10. The protocol uses a standard protocol stack with a minimum of functionality given for all the layers according to the CCITT recommendations.

At the application layer the protocol uses two sub-layers Association Control Service Element (ACSE) and Remote Operation Service Element (ROSE) and the specific part for the I4 application.

In ETS 300 133-3 [2], Annex E, all the I4 ROSE operations are described and in ETS 300 133-3 [2], Annex F this description is written according to Abstract Syntax Notation one (ASN.1) notation.

In this subclause some indications about the use and the presentation of some of the I4 ROSE operations parameters are given in order to have a common understanding.

In ETS 300 133-3 [2], Annex E there are eleven I4 ROSE operations and the first table indicates the correspondence between the name of the operation, the name given in the ASN.1 description and the name of the operation ACK (corresponding to the positive result).

In ETS 300 133-3 [2], Annex E, for each operation there are three sections. The first section is a table with all the parameters of the operation, indicating if the presence of this parameter is mandatory or not and if more information are requested with this parameter.

The second section includes the positive result of each operation which is a kind of "positive response". This result includes also parameters and corresponds to the operation ACK of the ASN.1 description.

The third section corresponds to the negative result description and corresponds to the errors described in an ASN.1 table and coded from 1 to 17.

Except when it is specifically described, the parameters with the octet string type are coded in the following way: 1 octet corresponds to the code of the character according to the table described in ISO 646 [12].

If an optional parameter is not present in the operation fields the associated facility is not activated or possible.

7.4.2 Description of parameters

7.4.2.1 Pager information operation

Parameter:

AdC. Only the third part, subscriber identification is present (see ETS 300 133-3 [2], subclause 6.2). AdC could be a GAdC.

Positive result:

PT (Pager Type) is coded 1 for tone , 2 for numeric, 3 for alphanumeric and 4 for transparent data.

In case of GAdC, the pager type corresponds to the value of the "Class of subscribed basic service" included in the group database for group calls (ETS 300 133-3 [2], subclause 13.2.4).

STS (used for the three state status concept) is coded TRUE in case of status higher than the upper threshold and FALSE in case of status between the upper threshold and the lower threshold (in case of status below the lower threshold this corresponds to the low network status and a negative result is sent). In case of GAdC STS is coded TRUE.

CL is coded TRUE if legitimisation is required (the value FALSE is not relevant).

CD is not relevant (this parameter is optional in fact it will not be used).

PR1: the diagram in figure 26 summarises the behaviour of PNC when receiving a pager information operation:

- the value TRUE means that the mobile subscriber has asked for this facility (included in his database) and that the given status is calculated according to this priority 1 level;

- the value FALSE means that the mobile subscriber has not asked for priority 1 and that (according to calculation made in the PNC-H) the priority 1 is allowed for the calling party (the given status is calculated according to the priority 1 level);

- not present means that the mobile subscriber has not asked for priority 1 and that (according to calculation made in the PNC-H) the priority 1 is not allowed for the calling party (the given status is calculated according to the priority 2 level).

PR3:

- the value TRUE means that the mobile subscriber has asked for the priority 3 (included in his database), that the status is given according to this level of priority and according to calculation the parameter PR1 is coded FALSE to indicate that priority 1 is allowed for the calling party;

- the value FALSE means that the mobile subscriber has asked for the priority 3 (the given status is according to the priority 3 level) and that according to calculation the priority 1 is not allowed for the calling party;

- not present means that the mobile subscriber has not asked for priority 3 the status is given according to the priority 2 level except if the parameter PR1 is present.

UR is coded TRUE if urgent message indicator is included in the mobile subscriber database (the value FALSE is not relevant).

DD is coded TRUE if the PNC-H of the mobile (or the mobile itself) foresees a limit for the activation of the service and the linked DDT parameter corresponds to this limit (the value FALSE is not relevant).

MDD is coded TRUE if the mobile subscriber has activated deferred delivery service, the linked parameter DDM corresponds to the date given by the mobile subscriber (the value FALSE is not relevant).

ST is coded TRUE if it is possible for the calling party to access standard text provided by the PNC-H (the value FALSE is not relevant). The linked parameter MST indicates the maximum number of these standard texts.

RP is coded TRUE if the repetition service is requested by the mobile subscriber with a legitimisation code. RP is coded FALSE if the repetition is requested without legitimisation code.

RC is coded TRUE if reverse charging facility is subscribed to by the mobile subscriber with a legitimisation code and is coded FALSE if reverse charging facility is given without any legitimisation code.

GAdC is coded TRUE if the requested AdC is a GAdC (the value FALSE is not relevant). In this case the STS parameter is not relevant.

Negative result:

"**AdC not valid**" corresponds to the case where the AdC included in the pager information operation is not recognised by the PNC-H.

"**AdC out of service**" corresponds to the case where the AdC is known by the PNC-H but is not activated (subscription failure, etc.).

"**Low network status**" corresponds to the case where the network status is below the lower threshold.

7.4.2.2 Choice of Destination Operation

Parameter:

GAs correspond to the geographical areas defined according to the operator agreement taking in account the calling party demand.

Positive result:

ST (used for the three state status concept) is coded TRUE in case of status higher than the upper threshold and FALSE in case of status between the upper threshold and the lower threshold (in case of status below the lower threshold this corresponds to the low network status and a negative result is sent).

Negative result:

"**AdC not valid**" corresponds to the case where the AdC included in the pager information operation is not recognised by the PNC-H.

"**AdC out of service**" corresponds to the case where the AdC is known by the PNC-H but is not activated (subscription failure, etc.).

"**GAs not valid**" is returned if at least one of the GAs is not valid.

"**Low network status**" corresponds to the case where the availability is below the lower threshold taking in account the GAs requested by the calling party and the service area of the mobile.
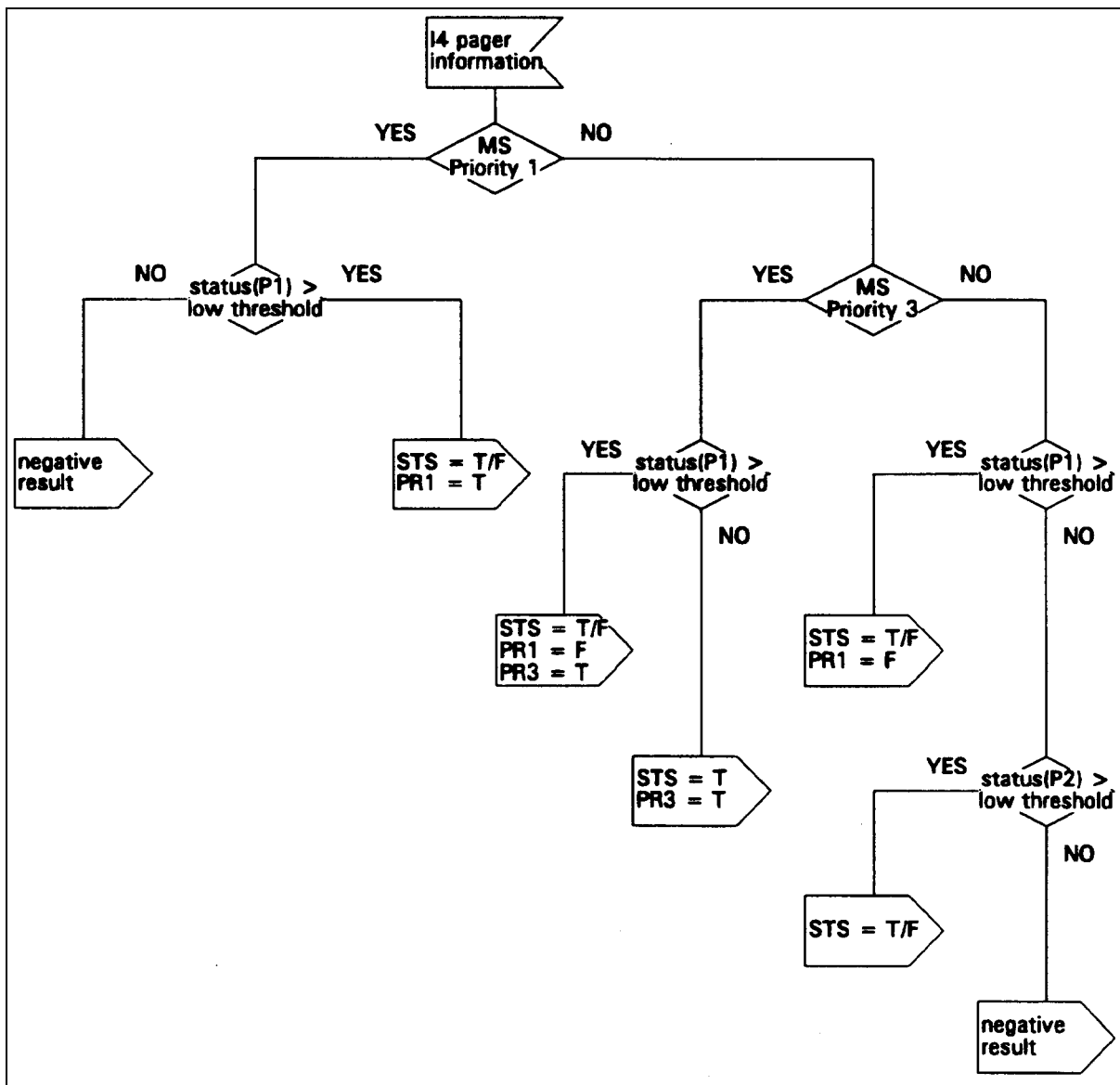
Figure 26: PNC-H behaviour (status and priority parameter) when receiving a pager information operation

7.4.2.3 Page request operation

Parameter:

AdC1 and **AdCn**: Only the field Subscriber Identification is present (see ETS 300 133-3 [2], subclause 6.2) AdC1 and AdCn could be a GAdC.

PT is coded 1,2,3 or 4 according to the **message type** (1 corresponds to a tone only message, 2 corresponds to a numeric message, 3 corresponds to an alphanumeric message and 4 corresponds to a transparent data message).

TO is coded TRUE if the message type is a Tone Only message (the value FALSE is not relevant) in this case there is no message part.

ST indicates that standard text is required and the value of the parameter corresponds to the number of this standard text.

PM corresponds to the message sent by the calling party, this message is either a numeric message or an alphanumeric message or a transparent data message:

- if the message is a numeric message each numeric character is coded in ISO 646 [12] (and corresponds to the ERMES character);

- if the message is an alphanumeric message, each character is an ERMES character coded according to the table described in ETS 300 133-2 [1], Annex B;

- if the message is a transparent data message, data will be grouped into octets. The end of the message follows the procedure described in ETS 300 133-4 [3], subclause 6.5.3, Message data.

PR is coded 1 if the priority 1 is activated with the message, PR is coded 3 if the priority 3 is activated with the message.

UR is coded TRUE if urgent message indicator is activated (the value FALSE is not relevant).

DD indicates that deferred delivery is requested and the value of the parameter corresponds to the requested date and time of the transmission of the message.

RP is coded TRUE if repetition is requested (the value FALSE is not relevant).

RC is coded TRUE if reverse charging is requested (the value FALSE is not relevant).

Positive result:

If there is no error the Boolean "general-result" of the corresponding ASN.1 description is coded TRUE, otherwise this Boolean is coded FALSE and is followed by one AdC or a list of AdCs (in case of group call) combined with an error code (called "unit-error" in the ASN.1 description) according to the following list:

0   AdC not valid
1   AdC out of service
2   Low network status
3   inconsistency between AdC and the request operation parameters

Negative result:

"**All AdCs not valid**" corresponds to the case where there is no AdC at all which is valid.

7.4.2.4   Transmit operation

Parameter:

AF1,AFn are coded from 0 to 7.

MN1,MNn are coded from 1 to 31.

MSI1,MSIn are coded TRUE if the correspondent facility is one of the characteristics of the receiver. This type of parameter is used by the transmitting network for the transmission of the long messages according to the specific procedure described in ETS 300 133-4 [3], subclause 11.4.

PR1 (and PRn) is coded 1 if the priority 1 is requested, PR1 (and PRn) is coded 3 if the priority 3 is requested and these priorities will be activated only if they are agreements between operators.

UMI1 (and UMIn) is coded TRUE if urgent message indicator is requested.

ECN this parameter corresponds to the number of the ERMES version of coding on I1 used by the operator (initial value is coded 1).

PT is coded 1,2,3 or 4 according to the **message type** (1 corresponds to a tone only message, 2 corresponds to a numeric message, 3 corresponds to an alphanumeric message and 4 corresponds to a transparent data message).

TO is coded TRUE if the message is a tone only message (the value FALSE is not relevant).

AT is coded TRUE if the transmit message corresponds to the transmission of the latest message number, in this case there is no message part (the value FALSE is not relevant).

PM corresponds to the message sent by the calling party, this message is either a numeric message or an alphanumeric message or a transparent data message.

-        if the message is a numeric message each numeric character is coded in ISO 646 [12] (and corresponds to the ERMES character);

-        if the message is an alphanumeric message, each character is an ERMES character coded according to the table described in ETS 300 133-2 [1], Annex B;

-        if the message is a transparent data message, data will be grouped into octet. The end of the message follows the procedure described in ETS 300 133-4 [3], subclause 6.5.3, Message data.

Positive result

if there are no error at all the Boolean "general-result" of the corresponding ASN.1 description is coded TRUE, otherwise this Boolean is coded FALSE and is followed by one RIC or a list of RICs (in case of group call) combined with an error code (called "unit-error" in the ASN.1 description) according to the following list:

0   RIC not valid
1   RIC out of service
2   Low network status
3   inconsistency between RIC and the request operation parameters

Negative result

"**All RICs not valid**" corresponds to the case where there is no RIC at all valid.

7.4.2.5 Roaming validation operation

Parameter:

AdC is not a GAdC**(3)**.

Negative result:

"**AdC out of service**", it includes the case where temporary barring is activated for the corresponding AdC.

7.4.2.6 Roaming Reset Operation

Parameter:

AdC is not a GAdC**(3)**.

7.4.2.7 Roaming information operation

Parameter:

AdC is not a GAdC**(3)**.

7.4.2.8 Change Roaming Operation

Parameter:

AdC is not a GAdC**(3)**.

A/D is coded TRUE for add and FALSE for delete.

Negative result:

"**AdC not valid**" it includes the case where the change roaming is not possible due to incompatible services (for instance deferred delivery already activated).

7.4.2.9 Confirm Change Roaming Operation

Parameter:

AdC is not a GAdC**(3)**.

A/D is coded TRUE for add and FALSE for delete.

Negative result:

"**AdC not valid**" it includes the case where the proposed AdC is a GAdC.

7.4.2.10 Call Diversion Start Operation

Negative result:

If both the two errors exit, only one is sent.

---

(3)   GAdC is not compatible with the roaming facility even though this is not explicitly stated in ETS 300 133 Parts 2 or 3.

7.4.2.11 Call diversion Stop Operation

Negative result:

If both the two errors exit, only one is sent.

7.4.3 Internetwork long message operation

The ERMES standard allows the maximum message capability of a called receiver to be passed over the I4 interface to a visited PNC. There are however other optional features of the receiver or the operator's PNC that may affect the transmission of long messages to a receiver in a visited network.

For the receiver these include:

a)   the ability to handle submessages in accordance to the optional long message procedure (see ETS 300 133-5 [4], subclause 9.1);

b)   if the receiver can handle sub messages, what is the maximum length of each submessage?

For the visited paging network:

c)   the maximum length of message offered as a service to the paging customers in the network.

These parameters may affect the possibility of paging reception in visited networks if such a network has been programmed with different data to that held by the home network (PNC-H):

-       because of a) and b) above it is recommended that paging calls to visiting pagers do not use the long message procedure as defined in ETS 300 133-4 [3], subclause 11.4;

-       to ensure visiting paging call acceptance it is also recommended that the PNC-H holds data on c) above for all networks to be visited.

7.5 Fixed Subscriber in ERMES

7.5.1 Services

Beside the basic services (tone-only, numeric, alphanumeric or transparent data) there are two other categories of services in the ERMES system:

-       services related to the input of information in conjunction with a page call from a calling party i.e. call input related supplementary services;

-       services related to the mobile or the fixed subscriber on a subscription basis or on a registration basis.

Some services belong to both categories.

7.5.2 Users

There are three types of users within the ERMES system: calling party; mobile subscriber; and fixed subscriber. In addition an operator is needed to handle the operation and maintenance of the system.

The calling party sends page message to the mobile subscriber. The messages can be entered with or without call input related supplementary services. The use of some of the services may be restricted by the mobile subscriber or by the network operator.

The mobile subscriber can, in addition to receiving messages from the calling party, access the system and change some of his subscriber features. This requires authentication e.g. by use of password. A subscription to a service, however, has to be registered by the network operator.

7.5.3 Fixed subscriber

A fixed subscriber is a calling party that is registered in an operator network. He can only send messages, not receive them.

The fixed subscriber has been introduced into the ERMES system:

a)   to enable traffic related charging of calling party;

b)   to support the management of groups for group call using individual RICs, standard texts and closed user groups.

The fixed subscriber will thus preferentially access the system with some kind of alphanumeric terminal.

Groups, for group calls using individual RICs, are intended to be administered primarily by fixed subscribers. It should however be possible for a mobile subscriber to handle such groups with operator assistance.

Standard texts can be handled both by the operator and the fixed subscribers. The intention is that the main part of the standard texts should be defined by and available through the fixed subscriber.

Closed user group require fixed subscribers since only fixed subscribers are allowed to send messages to mobile subscribers within such a group.

7.5.3.1 Fixed subscriber services

Listed below are the services that a fixed subscriber may use:

-    authentication code management;

-    legitimisation code management;

-    priority;

-    standard text management;

-    management of groups for group calls using individual RICs;

-    management lists for closed user groups;

-    charge information for fixed subscribers.

Authentication code management enables the fixed subscriber to change the authentication code he uses to identify himself when he accesses the system as a fixed subscriber.

Legitimisation code management enables the fixed subscriber to restrict the use of some of his services for other calling parties. For example he may require that only calling parties entering a certain legitimisation code are allowed to use his standards texts.

Priority enables the fixed subscriber to set the priority of his page messages regardless of the priority subscribed to by the mobile subscribers.

On subscribing the standard text service the fixed subscriber is given access to memory for storing and tools for handling standard text messages.

On subscription to group management, the fixed subscriber is given memory for group lists. As a closed user group manager the fixed subscriber is only entitled to administer the member list of his own group.

As a manager of a group for group calls using individual RICs the fixed subscriber manages the member list of the group as well as the features of the subscribed services of the group.

Charging information for fixed subscribers is only available to fixed subscribers. It enables him to monitor his accumulated charges.

A fixed subscriber who wants to send a message should be able to do so without log-off before entering the message. This may depend on the access network capability.

7.6   O&M aspects of the network

7.6.1   General

A powerful management service is important for the successful and efficient utilisation of a modern telecommunication network. In ERMES this has been considered so important that a separate part of the standard (part 7) has been dedicated to the subject.

The ERMES network consists of computer systems, transmission systems and radio base stations. It is essential that the system managers are always able to supervise and control every element in the network.

The central element of the network is the Operation and Maintenance Centre (OMC) which contains continuously updated information on all the network elements. The OMC also includes a database containing the status of all subscribers in the network. The OMC arranges a regular update of the PNC's subscriber database. Moreover it collects the quality of service and the availability data.

Operationally, information is gathered in the OMC to control all the O&M functions in the network and exchange data with other OMCs via the IOMC interface. For practical reasons a Mediation Device (MD) may be utilised to reduce the direct engagement of the OMC (see figure 27, which is taken from ETS 300 133-7 [6], figure 1).
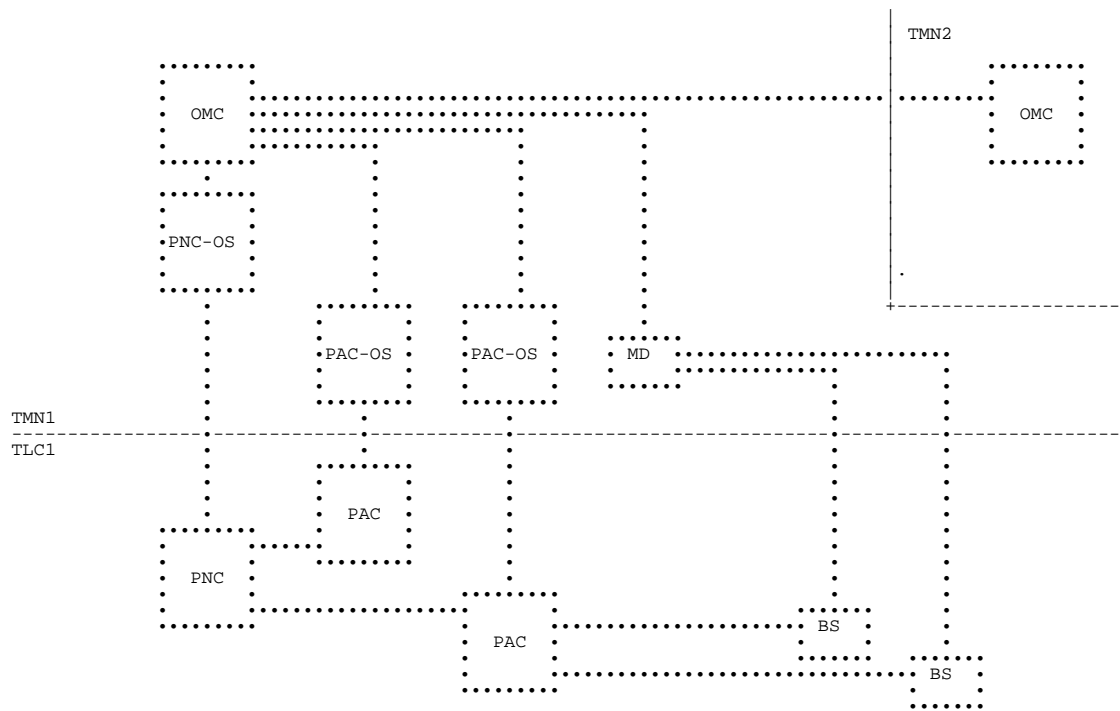
TLC = Telecommunication

Figure 27: ERMES functional architecture

7.6.2 IOMC operations

The IOMC interface was not conceived in order to allow control of another operator's network. The interface can only be used to exchange information required in connection with some cooperation functions. Roaming requires that some data are exchanged between the different operator's OMCs and this is performed via the IOMC interfaces.

The IOMC interface has a port in the international Packet Switched Public Data Network (PSPDN) as does the I4 interface. If appropriate it should therefore be possible to utilise the same physical data-ports. In this case data will be exchanged via the PNC-OMC interface (the interface between the OMC and its PNC).

The OMC is mainly engaged in connection with the roaming call procedure.

Call acceptance depends on an investigation that checks the network condition, the quality of service and the availability. The condition of the home network is known by the "home" OMC. The exchange of network conditions are not tied to a call. It is impractical and expensive to make individual requests in connection with every call.

Three methods are proposed for exchanging information through the IOMC.

First option: Periodic network status reporting

> The status of each network could automatically be reported at constant intervals defined by agreement between the operators. The network status is reported if a change occurs in the network during the time interval. This information is stored in the OMC and used when a call for a roaming user arises or choice of destination is requested by the calling party.

This option is good for networks which exchange information on a more or less regular basis. When low amounts of information are exchanged or long time gaps without exchange of information exist the second alternative can be used.

Second option: Change based reporting

> Initially no calls for roaming users occur and no choice of destination is requested by the calling party regarding the other network and so no status information need be transferred between the networks. The first time one of these situations occurs a status request is sent via the IOMC to the relevant OMC and the response stored together with any other requests for that area. The other network only reports its status when it changes. Moreover the time is checked to avoid information obsolescence. If the information is too old, a new request has to be sent via the IOMC to the OMCs concerned.

Third option : Combination of options one and two

> Networks can use any combination of the above options. For example, during rush hours or during the day the first option is used, and during the night the second is used.

Information exchange in connection with roaming is the most frequently used activity over the IOMC interface. In addition the interface is also used for exchanging configuration data between operators, e.g. when there is a change of network name and password or when a new Geographical Area (GA) is defined. Sometimes the interface may also be used for exchange of specific traffic data.

7.6.3   Functional requirements

The contents of ETS 300 133-7 [6] are based on CCITT Recommendation M.30, where the principles and the architectural requirements for a Telecommunications Management Network (TMN) are defined.

There are, however, some differences:

-        ETS 300 133-7 [6] does not include the Qx interfaces;

-        some of the ERMES interfaces bear both Telecommunication (TLC) and O&M data;

-        a common management of several different ERMES networks has not been defined in ETS 300 133-7 [6], and has been left for agreement between operators;

-        the administrative aspects are outside the scope of ETS 300 133-7 [6].

O&M functions generally have a high dependence on hardware implementation. For this reason, ETS 300 133-7 [6] covers general aspects instead of being more detailed, as in the TLC part for the I1 and the I4 interfaces. All the mandatory definitions involved in ETS 300 133-7 [6] relate to the management of the mandatory TLC requirements defined in other parts of the ERMES specification ETS 300 133.

The TMN entities include some basic functions belonging to the O&M areas which are considered to be mandatory.

The operations functions are:

- configuration management;

- issuing and handling of reports;

- database management.

The maintenance functions are:

- failure detection;

- fault localisation;

- fault correlation and filtering;

- failure isolation for system protection.

Moreover there is an additional function, located in the OMC, PNC-OS and PAC-OS that is Quality of Service (QOS) monitoring.

7.6.4 Formal description of IOMC interface

ETS 300 133-7 [6], Annex A (normative) describes the IOMC interface in terms of operations, arguments and results. The form used is fully compliant with the ROSE (Remote Operations Service Element) operations as defined for OSI stack, layer 7.

The following mandatory operations together with the necessary parameters have been specified:

- network status request/report;

- change of network name and password;

- definition of a new GA configuration;

- modification of GAs;

- report fo traffic data.

ETS 300 133-7 [6], Annex A, Clause A.2 is devoted to the formal ASN.1 description of the IOMC information model. ASN.1 (Abstract Syntax Notation One) is a formal language standardised by CCITT, specifically tailored to handling complex data structures, such as protocol applications.

The ASN.1 description of IOMC ROSE includes operations imported from the ROSE-ISO standard and operations which are peculiar to ETS 300 133-7 [6]. Mandatory and optional parameters are defined for each operation.

7.7 Call acceptance mechanism

7.7.1 Call acceptance criterion - availability and delay

An innovative concept in the radio paging environment is the "call acceptance mechanism" introduced in the ERMES system. This technique conditions the delivery of any valid incoming call to the availability and delay status of the required destination area. To implement such a rule, every PNC must know both the availability and the expected delay for transmission existing in the controlled PAs. At the same time each PNC must also know the equivalent figures for any GA available to its subscribers roaming in another network.

The network availability concept applies to any single call. It is defined as the probability that the message (in case of transmission) will reach the destination receiver regardless of its status (switched on/off).

The transmission delay concept also applies to individual calls. It is defined as the rate between the 90% percentile of the delay distribution and the threshold for the message delivery time as defined in ETS 300 133-2 [1], subclause 7.2.7.

The reference to the individual call for both parameters has to be viewed in the sense that the network applies (explicitly or implicitly) the relevant calculation to any single delivery requirement as a function of its destination attributes.

Both availability and transmission delay are calculated as percentages. Afterwards, to improve the efficiency of the data exchange among PNCs, the two figures are converted in integer numbers according to the following tables 2 and 3:

Table 2: Determination of availability status

PERCENTAGE AVAILABILITY	>15	≥15 <25	≥25 <35	≥35 <45	≥45 <55	≥55 <65	≥65 <75	≥75 <85	≥85 <95	≥95
NETWORK AVAILABILITY STATUS	0	1	2	3	4	5	6	7	8	9

Table 3: Determination of delay status

PERCENTAGE 100 DELAY	>300	≤300 >275	≤275 >250	≤250 >225	≤225 >200	≤200 >175	≤175 >150	≤150 >125	≤125 >100	≤100
NETWORK DELAY STATUS	0	1	2	3	4	5	6	7	8	9

NOTE: The "k·th GA user visibility" $\bullet_{n,k}$ and the "mean 90 % delay time" $\mu_{n,k}$ introduced in ETS 300 133-7 [6], subclauses 8.1.4.1 and 8.1.4.2, respectively, are calculated as fractional probabilities (positive numbers less than or equal to 1). However, they are quoted as percentages in ETS 300 133-3 [2] and in tables 2 and 3 above.

Availability and delay are evaluated by using the simple calculation procedures described in subclauses 7.7.2 and 7.7.3.

The acceptance procedure for delivery of a call leads to one of the following situations:

– if the availability and the delay status of the message delivery area (call service area) are both above an upper threshold, then the call is unconditionally accepted and it proceeds in the normal way. The calling party is notified accordingly;

– if the lowest figure between availability and delay lies between the upper threshold and a lower one, then the PNC-I is informed about this degraded status. Possibly, according to the operator policy, PNC-I may inform the calling party who will choose whether to send or cancel the call. This conditional acceptance criterion can be avoided if upper and lower thresholds are set to the same value;

– if the availability or the delay status are below the lower threshold, then the call shall be rejected. The calling party is notified accordingly.

The upper and lower thresholds are chosen by the operator for both local and international service.

Availability and delay are calculated by each PNC in its PNC-H role. The calculation takes place by combining two kinds of attributes:

–   those related to the specific call bearing the acceptance mechanism (destination service area, priority);

–   those related to the network(s) status within the required service area (availability and delay status).

The first attribute belongs entirely to the telecommunication environment while the second one is evaluated and updated through the management network (TMN network).

For these reasons both I4 and IOMC interfaces consider the information exchange needed for the call acceptance mechanism.

Nevertheless, in order to reduce the message complexity within the above interfaces, one case does not obey the call acceptance rules described in ETS 300 133, i.e. the call for a Closed User Group (identified with a Group AdC). In this case the call is unconditionally accepted, regardless of the network status.

The two following sections clarify concepts and functions to be used for calculation.

7.7.2   Availability

For the TMN role, each OMC, say the n-th OMC (OMC_n) associated with the n-th PNC, is continuously updated about the paging area portion $C^*_{n,l}$ (controlled by its l-th PAC) which can be reached for message transmission. $C^*_{n,l}$ is a part of the area $C_{n,l}$ globally controlled by PAC_l.

Moreover OMC_n knows the equivalent pager densities $D^*_{n,l}$ and $D_{n,l}$ characterising respectively the available and the global area under the PAC_l control.

These data are sufficient to characterise each call with the availability figure needed for the call acceptance mechanism. They are used in two ways:

–   directly for local calls, i.e those regarding any set of paging areas belonging to the n-th network;

–   as basic elements for calculating the availability status of each GA belonging to the n-th network, as defined through inter-operator agreement.

The latter mechanism, described in ETS 300 133-7 [6], subclause 8.1.4.1, leads to the calculation of the GA percentage availability, simply given by the rate between the equivalent number of reachable pagers within the GA and the equivalent number of pagers belonging to it. The percentage availability is then transmitted to the interested OMCs (operators) in terms of network availability status for that GA (see table 2). In ETS 300 133-7 [6], subclause 8.1.4.1, the work availability status of the k-th GA belonging to the n-th network is named $AS_{n,k}$.

The concepts recalled so far refer strictly to the network status and do not imply any call-related attribute. Such attributes, dealing with two cases (the local call and the call for a roaming user), are now introduced.

The network availability for a local call is calculated in ETS 300 133-3 [2] subclause 13.6.4.1. Formula (1) follows the same concept described for the calculation of the percentage availability for GA, with the only (significant) difference that now PAs addressed by the call are considered.

Formula (1) can also be written as:

$$S(c) = \underset{l \,\in\, A_n^*(c)}{S} \frac{C_{n,l}^* \cdot D_{n,l}^*}{C_{n,l} \cdot D_{n,l}} \cdot \underset{i \,\in\, A_n(c)}{S} \frac{C_{n,l} \cdot D_{n,i}}{C_{n,i} \cdot D_{n,i}}$$

where the first factor represents the probability that the pager is reached in the l-th PA, given that it is there, and the second factor represents the conditioning probability.

The network availability for a call directed to a roaming user is calculated in ETS 300 133-3 [2] subclause 13.6.4.2. It is simply the average network availability status taken over the destination GAs, specified by the entering call.

In both cases the call-related calculation is performed by the PNC, playing its H-role.

7.7.3 Delay

For the TMN role, the n-th OMC is continuously updated about the 90 % delay time $F_{n,l}$, characterising its l-th PAC. $F_{n,l}$ can be evaluated by applying the method described in ETS 300 133-7 [6] subclause 6.4.3.1.

These data are sufficient to characterise each call with the delay figure needed for the call acceptance mechanism. Similar to availability, they are used both directly for local calls and as basic elements for calculating the delay status of each GA belonging to the n-th network.

The GA delay status is simply evaluated as the mean 90 % delay time taken over the PACs involved in that GA (see ETS 300 133-7 [6], subclause 8.1.4.2). The mean 90 % delay time is then used by OMC_n to calculate the network delay status, according to table 3. The Network Delay Status is exchanged between the OMCs of the ERMES system.

The above concepts refer to the network status. They are not affected by call-related attributes.

We will now consider the call-related attributes. As for the delay evaluation, local calls and calls for roaming users are handled in a similar way. In both cases, the network delay for the call is simply an average delay. In the first case the average is taken over the PACs involved in the call, in the second case it is taken over the destination GAs addressed by the call itself (see ETS 300 133-3 [2], subclauses 13.6.4.4 and 13.6.4.5 respectively).

It has to be underlined that the 90 % delay time calculation concerns also the flow control scheme applied by the OMC to the PACs. Such a mechanism may block any message potentially loading a PAC whose 90 % delay time exceeds a given flow-control threshold. In that case, in addition to managing the flow-control status in the PNC, the OMC declares unavailable the overloaded PAC. Hence the delay status can also affect the network availability configuration.

7.8 Transmission protocol

7.8.1 Transmission in one paging area

7.8.1.1 General

The transmissions in one paging area are controlled by the Paging Area Controller (PAC) which ensures that the same information is sent at the same time all over the paging area.

The transmission mode depends on the network organisation defined by the operator (time divided or frequency divided or time and frequency divided modes of operation).

The transmission protocol is divided into time units related to the Universal Time Co-ordinated (UTC). Each unit has a fixed time duration (the only factor that is variable is the time of transmission). Data is not

necessarily transmitted in every time unit and the data transmission may be less than the duration of the whole batch time.

The time units are defined as follows: (see ETS 300 133-4 [3], Clause 5)

- **batches** of type "A" to "P". The batch time durations are:
    - 739,2 msec (154 codewords) for the first 15 batches of a subsequence;
    - 912 msec (190 codewords) for the last batch of a subsequence;

- **subsequences** of 12 sec (2 500 codewords) each[4]. Each subsequence includes 16 batches. The first fifteen batches each have a fixed duration of 739,2 msec (regardless of batch type). The last batch has a fixed time duration of 912 msec (regardless of batch type);

- **cycles** of 1 minute each. Each cycle includes 5 subsequences numbered 0 to 4;

- **sequences** of 60 minutes each. Each sequence includes 60 cycles numbered 0 to 59.

Each frequency channel has it own non varying batch type order in a subsequence (see ETS 300 133-4 [3], Clause 5, figure 2). The batch types in each channel follow sequentially the letters "A" to "P" in a cyclic order starting at each subsequence time. The only difference between frequency channels is the batch type at the beginning of a subsequence.

EXAMPLE: Channel 1 starts it's subsequences with a batch type "A" followed by batches "B,C,D,E,F,G,H,I,J,K,L,M,N,O,P". Channel 15 starts its subsequences with a batch type "J" followed by batches "K,L,M,N,O,P,A,B,C,D,E,F,G,H,I" (see figures 28 to 30).

7.8.1.2 Transmission in time division mode

Time division mode means that the same frequency channel is used during different subsequences (periods of a time cycle) in adjacent paging areas to convey paging messages.

Figure 28 shows an example of two adjacent paging areas using time division mode. Frequencies F1, F2 and F5 are transmitted in paging area 1. Paging area 2 transmits on the frequencies F1, F2 and F16. They share the time for frequencies F1 and F2 (e.g. frequency F1 is transmitting during subsequence 0 in paging area 1 and during subsequences 1, 2 and 3 in paging area 2).

For each subsequence in each channel the letters of the two first and two last batch types are noted (batch types "A" to "P").

7.8.1.3 Transmission in frequency division mode

Frequency division mode means that different frequencies are simultaneously used in adjacent paging areas to convey paging messages.

Figure 29 shows an example of two adjacent paging areas using frequency division mode. Each area uses different frequencies. Transmission in paging area 1 is of frequencies F3, F8 and paging area 2 transmits in the frequencies F11 and F4.

For each subsequence in each channel the letters of the two first and two last batch types are noted.

---

[4] The subsequence transmission length can be reduced in units of a codeblock (i.e. 9 codewords or 43,2 msec). The transmission length can be reduced for any batch or batches of a subsequence. Reducing the subsequence transmission length means that no data is transmitted in that time. The subsequence time duration is fixed and is always 12 sec.

7.8.1.4   Transmission in frequency and time division modes

Figure 30 shows an example of two adjacent paging areas transmitting in frequency and time division mode.

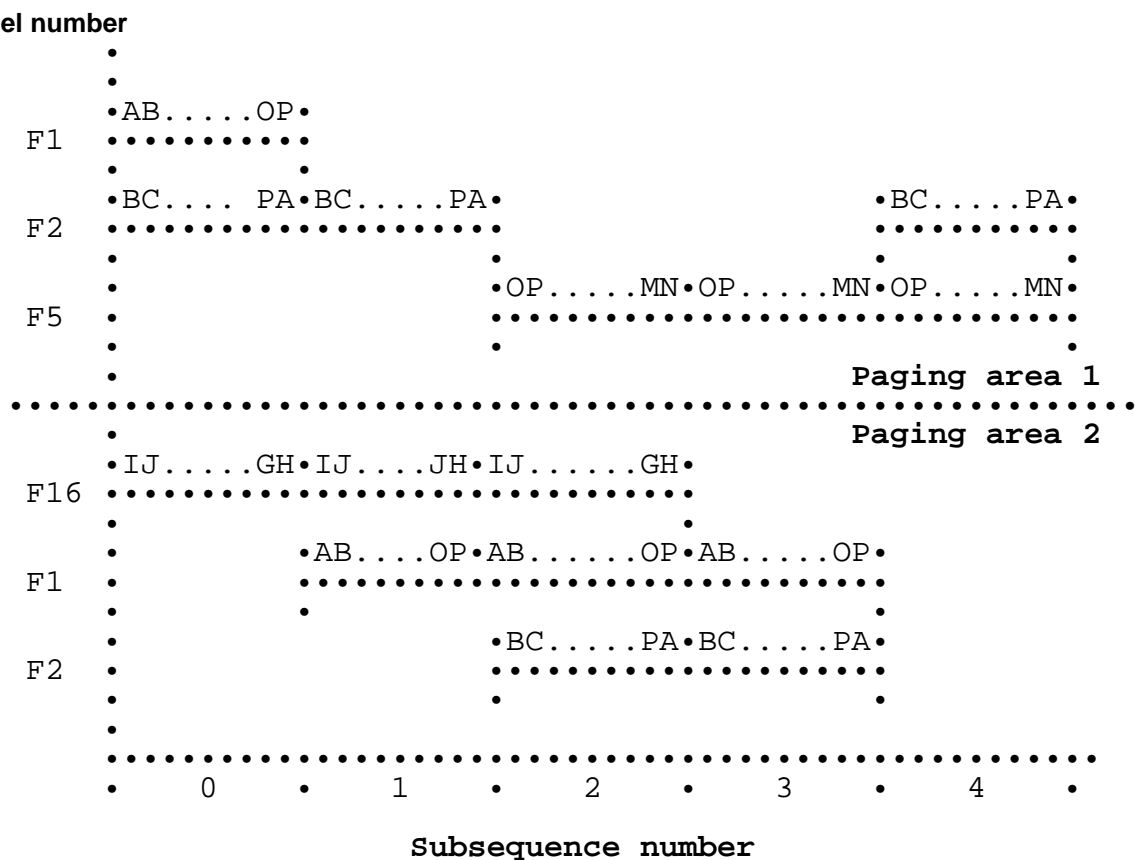For each subsequence in each channel the letters of the two first and two last batch types are noted.

Channel number

```
              •
              •
              •AB.....OP•
      F1      •••••••••••
              •             •
              •BC.... PA•BC.....PA•                          •BC.....PA•
      F2      •••••••••••••••••••••                          •••••••••••
              •                   •           •         •         •
              •                   •OP.....MN•OP.....MN•OP.....MN•
      F5      •                   •••••••••••••••••••••••••••••••••••
              •                   •           •                   •
              •                                        Paging area 1
      •••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
              •                                        Paging area 2
              •IJ.....GH•IJ....JH•IJ......GH•
      F16     •••••••••••••••••••••••••••••••
              •                             •
              •           •AB....OP•AB......OP•AB.....OP•
      F1      •           •••••••••••••••••••••••••••••••••
              •           •                             •
              •           •BC.....PA•BC.....PA•
      F2      •           ••••••••••••••••••••••
              •           •                   •
              •
              •••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
              •     0     •     1     •     2     •     3     •     4     •
```

Subsequence number

Figure 28: Example of time division mode

Channel number

```
         •
         •
        •PA.....NO•PA.....NO•PA.....NO•PA.....NO•PA.....NO•
F3      ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                              •
        •EF.....CD•EF.....CD•EF.....CD•EF.....CD•EF.....EF•
F8      ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                              •
         •                                       Paging area 1
•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                       Paging area 2
        •LM.....JK•LM.....JK•LM.....JK•LM.....JK•LM.....JK•
F11     ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                              •
        •CD.....AB•CD.....AB•CD.....AB•CD.....AB•CD.....AB•
F4      ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                              •
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •    0     •    1     •    2     •    3     •    4     •
```

Subsequence number
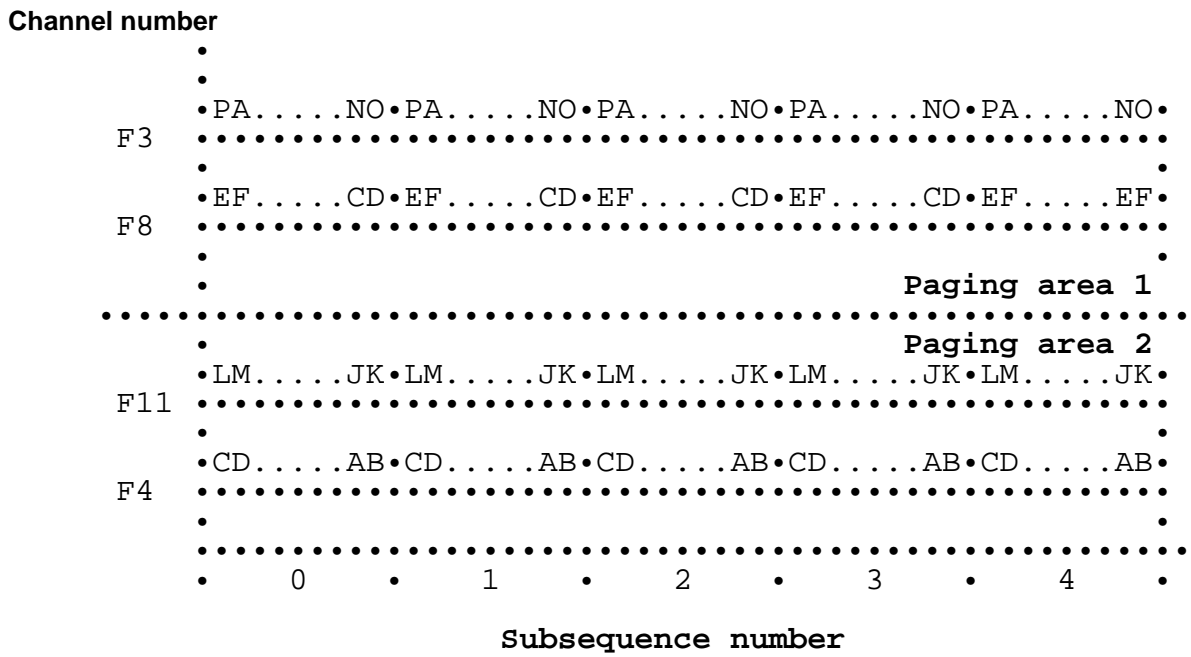
Figure 29: Example of frequency division mode

Channel number

```
         •
         •
        •DE.....BC•DE.....BC•DE.....BC•DE.....BC•DE.....BC•
F6      ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                              •
        •HI.....FG•HI.....FG•HI.....FG•
F14     ••••••••••••••••••••••••••••••
         •                         •
         •                •GH.....EF•GH.....EF•GH.....EF•
F12      •                ••••••••••••••••••••••••••••••••
         •                •                            •
         •                                       Paging area 1
•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                       Paging area 2
         •                •HI.....FG•HI.....FG•
F14      •                ••••••••••••••••••••••
         •                                 •
        •NO.....LM•NO.....LM•NO.....LM•NO.....LM•
F7      ••••••••••••••••••••••••••••••••••••••••
         •                                 •
        •KL.....IJ•KL.....IJ•KL.....IJ•KL.....IJ•KL.....IJ•
F13     ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •                                              •
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
         •    0     •    1     •    2     •    3     •    4     •
```

Subsequence number
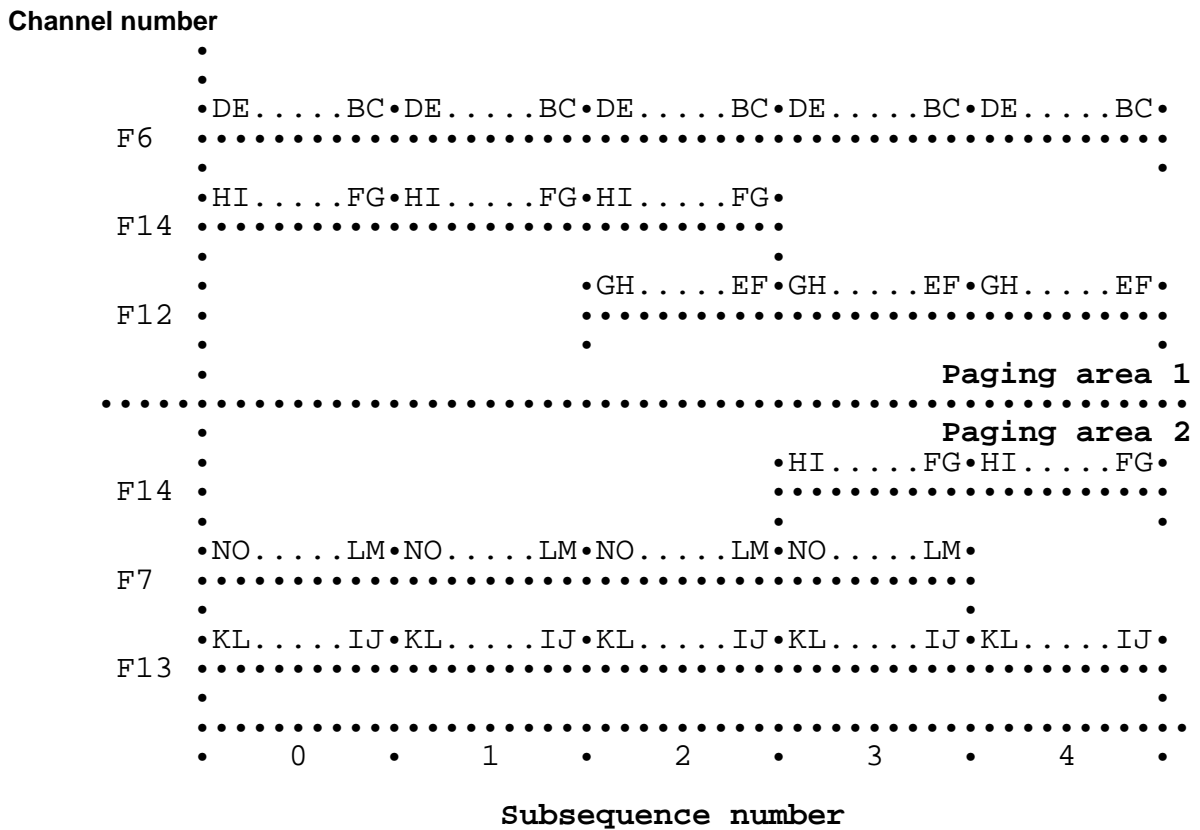
Figure 30: Example of time and frequency division modes

7.8.2 Transmission during batch time

The smallest duration transmission unit for both time division and frequency division modes is a batch time period. Thus it is convenient to explain the transmission in a PA by illustrating the transmission forms of a batch. For more details and additional constraints concerning other transmission units see ETS 300 133-4 [3].

The transmission during a batch time in a paging area can take the following forms:

1)   no transmission during the whole batch time[5];

2)   transmission of a "full batch" (see subclause 5.2);

3)   transmission of an "empty batch" followed by:

   3a)   no transmission until the next batch; or
   3b)   completing the batch with Message Delimiters (MDs) up to the end of the batch; or
   3c)   filling an integer number of codeblocks with MDs. The number of codeblocks filled is not important since it does not exceed the maximum codeblock in a batch, i.e. it is not necessary to complete the whole batch (see subclause 5.3);

4)   transmission of "incomplete batch" followed by:

   same as 3a, or 3b, or 3c with the exception that in each case at least the codeblock of the last message of the batch is completed with MDs (see subclause 5.4).

Completion of an integer number of codeblocks relating only to the message part is done after the last message.

When the message part exists and needs to be completed it is recommended only to use MDs for the completion. If no completion is done, then the transmission should be stopped.

The minimum transmission time in a batch (excluding zero time) is the time taken to send an "empty batch" (10 codewords).

The minimum switch off time in a batch (excluding zero time) is one codeblock transmission time (43,2 msec).

7.8.3 Batch structure

Each batch is further subdivided into four partitions (see ETS 300 133-4 [3], subclauses 5.1 and 6.2 to 6.5)

-       Synchronisation partition;
-       System information partition;
-       Address partition;
-       Message partition.

7.8.3.1 Synchronisation and system information partitions

The synchronisation partition and the system information partition are of fixed length and are present at the beginning of each batch transmission. Overall they are five codewords (150 bits) long.

---

[5]   Transmission on the same frequency for each batch type occurs at least once every minute (to enable receivers to retain synchronisation). A channel which has not transmitted on a particular batch type for more than 1 minute is considered by the receiver (belonging to this type) as a closed (unused) channel. Therefore to avoid this situation and keep the receiver holding on this channel, it is necessary to transmit a minimum of one "empty batch" for each batch type at least once a minute. For example if there is no data to be sent during one minute for receivers of batch type B on channel 2, an "empty batch" should be transmitted during batch B in one of the following five subsequences.
      This restriction dictates the maximum time limit without any system information.

7.8.3.1.1 Synchronisation partition

This partition includes 2 words of 30 bits each (See subclause 6.3).

PRE = Preamble word (30 bits as defined in ETS 300 133-4 [3], subclause 6.2). No ECC shall be performed on that word (i.e. no check bits are added to this word).

SW = Synchronisation word (30 bits as defined in ETS 300 133-4 [3], subclause 6.2). No ECC shall be performed on that word.

7.8.3.1.2 System information partition

The system information partition is divided into two parts. The first part is system information (two codewords) and the second part is supplementary system information (one codeword).

In ETS 300 133-4 [3], subclause 5.4, the first part of the system information partition is defined as two SI(s). It is clearer to view them as two different codewords named SI-1 and SI-2 because they have different information. The bit description for both SIs is given in ETS 300 133-4 [3], subclause 6.3.1. The bit description in that subclause describes both SI-1 and SI-2, 18 bits for each. Each 18 bit SI is translated by the ECC process to a 30 bit codeword.

SI-1 includes: country code, operator code PA code, ETI and BAI.
SI-2 includes: FSI, cycle number, SSN, and batch number.
(See also subclause 6.4.5).

The second part of the system information is the Supplementary System Information (SSI). The 18 information bits are described in ETS 300 133-4 [3], subclause 6.3.2. These 18 bits are translated by the ECC process to a 30 bit codeword.

```
        ...................................................
        •  PRE    •  SW     •   SI-1  •  SI-2   •   SSI    •
        ...................................................
  bits  •  30        30     •  18->30    18->30    18->30  •
        ...................................................
        Synchronisation     •   System information
        partition           •   partition
```
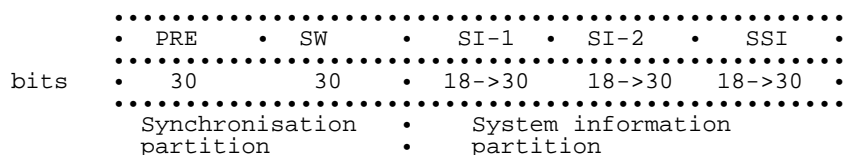
Figure 31: Synchronisation and system information partitions

7.8.3.2 Address partition

The address partition is of variable length and appears in every batch transmission ("Full", "Empty" or "Incomplete" batches). It contains either Initial Addresses (IAs) followed by Address Partition Terminators (APTs) or only APTs. There is one case of the address partition comprising only APTs, this is when there are no initial addresses and the address partition contains 5 APTs.

The minimum length of an address partition is 5 codewords (150 bits) that can include:

0   IA with 5 APTs; or
1   IA with 4 APTs; or
2   IAs with 3 APTs; or
3   IAs with 2 APTs; or
4   IAs with 1 APT.

The maximum length of the address partition is 140 codewords (4 200 bits) that can include one of the following:

Number of IAs	Number of APTs
131	9
132	8
133	7
134	6
135	5
136	4
137	3
138	2
139	1

See ETS 300 133-4 [3], subclauses 5.4, 6.4 and 11.6.

At least one APT must be present in an address partition. The maximum number of APTs in an address partition is 9 APTs.

Each IA is 18 bits long, converted by ECC to a 30 bit codeword.

APT is already a 30 bit codeword and no ECC should performed (see subclause 6.3).

The receiver's IA shall be transmitted during the address partition of the batch type corresponding to the receiver[6]. The associated message can be sent in the same batch or in following batches, due attention being paid to the time out criteria (see ETS 300 133-4 [3], subclause 11.8).

An address partition can be of two kinds. The first is address partition without IAs and the second is address partition including IAs.

Option 1: Address partition without initial addresses.

When there is no initial address to be sent, the address partition has a fixed length of 5 APTs. The common use of this example is in an "empty batch".

```
      ..............................................
      •   APT   •   APT   •   APT   •   APT   •   APT   •
      •         •         •         •         •         •
      ..............................................
bits:      30        30        30        30        30
```
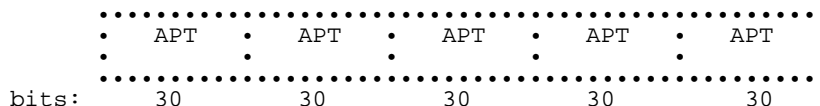
Figure 32: Example of address partition with no address information

Option 2: Address partition with some initial addresses present.

When there are initial addresses to be sent the length of the address partition is variable.

For 0 to 4 IAs the address partition length is 5 codewords. For more than 4 IAs the length of the address partition is 5 plus an integer number of codeblocks (the last codeblocks being completed with APTs).

The relationship between IA and APT is according to the formula given in figure 3, subclause 6.4.3 (calculation of J, the number of APTs). The address partition length can be calculated as: (I+J)*30 where I is the number of IAs (0•I•139) and J is the number of APTs (1•J•9).

---

[6]   To gain most advantage from the ERMES battery economy schemes (see subclause 6.4) it is recommended that the IAs associated with a specific receiver are all of the same batch type.

```
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
        •   IA    •   IA    •   IA    •  APT    •  APT     •
        •        •        •        •        •        •
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
Bits:      18->30    18->30    18->30     30        30
```
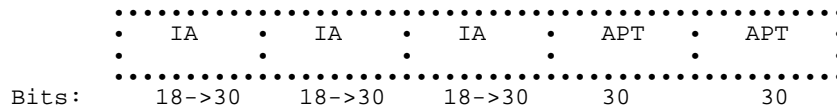
Figure 33: Example of address partition with 3 initial addresses (5 codewords)

7.8.3.3 Message partition

The message partition is of variable length and is optional in each batch transmission.

7.8.3.3.1 Message delimiters and continuation in a further batch or subsequence

The content of the message partition (if it exists) may include:

1)   message delimiters only;

2)   complete messages each followed by an MD;

3)   one incomplete message:

   3a)   up to the end of the message partition. In this case the message is not followed by a MD and continues in the next batch (see option 3 below); and/or

   3b)   starting at the beginning of the message partition. This message is the continuation of the incomplete message from the previous batch (as described above). The message information thus starts at the beginning of the message part without an MD before (see option 4).

The message partition normally starts with an MD (being aware of the case 3b mentioned above). The message part length is an integer number of codeblocks completed by MD(s) if necessary. The message partition length depends on the address partition length. For the maximum occupation length of the batch and the quantities of messages see ETS 300 133-4 [3] subclauses 5.4 and 6.5.

The message partition is organised so that the messages follow one after another with a single MD separating them. An MD at the beginning or at the end of the message part can exist or not depending on the first and the last message forms.

The message part does not necessarily contain MDs (e.g. see option 6 below).

The length of each message is variable. Each message must be terminated as defined in ETS 300 133-4 [3], subclause 6.5.3. After the MD of the last message in a batch the length of the whole message part is completed by MDs to an integer number of codeblocks.

The maximum length of a message that can be delivered from the calling party is 65 535 bits (64 kbits). If this maximum length message is encountered it should be completed to 65 538 bits with binary zeros before conversion to 109 230 bits by ECC (excluding its MD).

The minimum message length is 36 bits (i.e. tone only message) converted to two codewords (60 bits) by ECC (excluding its MD).

The following examples illustrate the possible message partition forms.

Option 1: message partition includes only MDs.

```
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
        •MD  •MD  •MD  •MD  •MD.............MD  •MD  •MD  •MD  •MD  •
        ••••••••••••••••••••••••••••••••••••••••••••••••••••
```
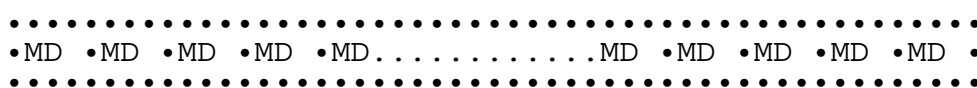
Option 2: message partition includes complete messages.

```
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
•MD •  MESSAGE  •MD •    MESSAGE        •MD •MESSAGE•MD •
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
```

Option 3: message partition includes complete messages and one incomplete message (the first part of a continued message).

```
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
•MD •  MESSAGE•MD •MESSAGE•MD •      MESSAGE            •
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
```

Option 4: message partition includes complete messages and one incomplete message (the last part of a continued message).

```
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
•  MESSAGE      •MD •   MESSAGE      •MD •MESSAGE•MD •
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
```

Option 5: message partition includes complete messages and two incomplete messages (one with the last part of a message and the other with the first part of another message).

```
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
•MESSAGE•MD •MESSAGE•MD •MESSAGE •MD •   MESSAGE   •
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
```

Option 6: message partition includes one incomplete message (the middle part of a continued message).

```
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
•                         MESSAGE                    •
• • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •
```

The message partition of options 3, 5 and 6 arrive at the end of the batch. In options 1, 2 and 4 a message delimiter terminates the message partition but the end of the message partition does not necessarily coincide with the end of the batch.

The number of messages in options 2 to 5 can be:

from 1 to a maximum of 48 messages (16*9/3=48 When the message partition total length is of 16 codeblocks if the batch is of 739,2 msec), or

from 1 to a maximum of 60 messages (20*9/3= 60) When the message partition total length is of 20 codeblocks if the batch is of 912 msec)

NOTE: The maximum number of complete messages was calculated by assuming the minimum message length (i.e. 3 codewords for each message, that includes 2 codewords of the message header and 1 codeword for the MD, as in the tone only message).

7.8.3.3.2   Multiple messages

More than one message may be sent to a receiver in the same batch or in the same subsequence. In this case the receiver's initial address IA must be transmitted in the address partition the same number of times as there are messages. Each associated message will be treated independently.

7.8.3.3.3 Long messages

A "long message" is defined as a message divided into submessages (see ETS 300 133-4 [3], subclause 11.4). "Long messages" can be of any length up to the maximum dictated by the link counter (i.e. 65 535 bits). Long messages can in fact be quite short (a message with length two codewords by definition becomes a long message if the system chooses to divide it in two and send it using the long message procedure). Use of the long message procedure is an operator option dictated by traffic loading and reliability of delivery.

Submessages are sent in order when transmitted on the radio path i.e. in the correct message sequence. The submessages all have the same message number when transmitted on the radio path. So far as message delimiters and continuation in further batches/subsequences is concerned each submessage is treated in exactly the same way as a message. An IA is sent for each submessage.

7.8.3.3.4 Unconstrained messages

The air interface protocol is in fact capable of supporting the transmission of messages with unconstrained length using the "messages continued in further batches and subsequences" procedures defined in ETS 300 133-4 [3], subclauses 11.5 and 11.6.

Note   If there is a gap in the transmission equal to or greater than a subsequence then the long message procedure must be used.

7.8.4 Transmission sequences during a batch

This subclause gives examples of transmission sequences during a batch. Table 4 gives the possible options of address partition and message partition described in figures 34 to 40.

Table 4: Address partition and message partition options for figures 34 to 40

Figure number	Address partition option number	Message partition option number
34	1 or 2 The usual option is No. 2	any option
35	1 or 2 The usual option is No. 2	1 or 2 or 4
36	1	1
37	1	No message partition
38	1	1
39	1 or 2 The usual option is No. 2	1 or 2 or 4
40	1 o 2 The usual option is No. 2	1 or 2 or 4

7.8.4.1   No transmission

Nothing transmitted during the whole batch time. The transmitters are switched off.

7.8.4.2   "Full batch" transmission

A Full batch is a batch which has data to be transmitted during all the batch time. The transmission of it's last bit is followed directly by the beginning of the next batch without any time between.

```
   UTC batch x                              UTC batch (x+1)
        •                                        •
        •                                        •
   ..........................................................
   •SYNCP•  SIP •     AP        •       MESP      •
   ..........................................................
        •                                        •
        •                                        •
   ..........................................................
        •              Batch    time             •
```
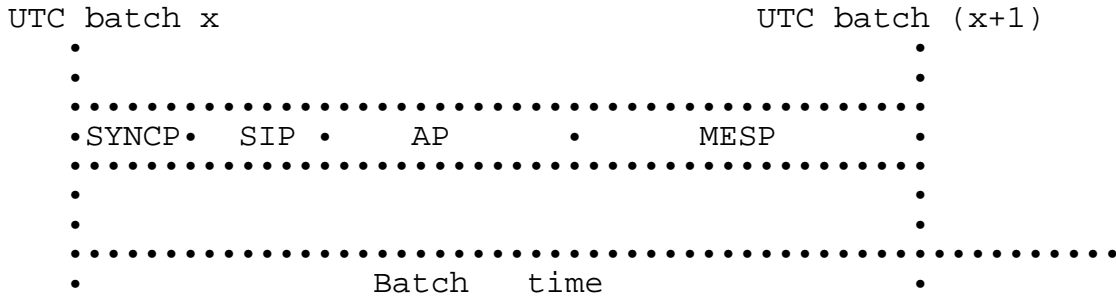
Figure 34: Example 1 of "Full batch" transmission: The batch data occupies all the batch time

```
   UTC batch x                              UTC batch (x+1)
        •                                        •
        •                                        •
   ...................................... ...........
   •SYNCP•  SIP •  AP        •MESP•  •MD •MD •MD •
   ...................................... ...........
        •                                        •
        •                                        •
   ..........................................................
        •              Batch    time             •
```
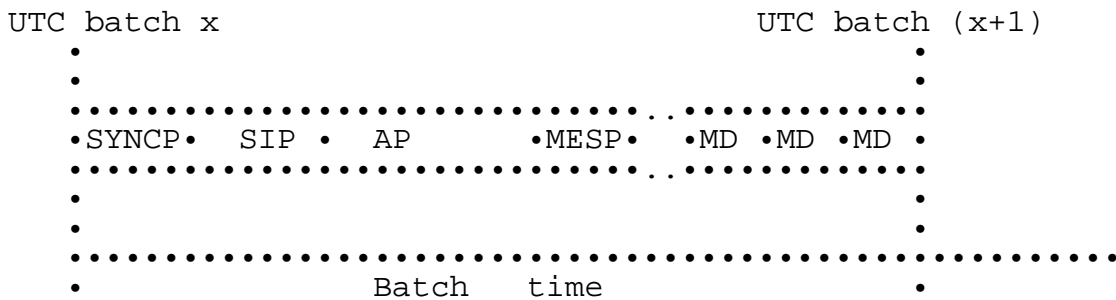
Figure 35: Example 2 of "Full batch" transmission

The "Full batch" in figure 35 is comprised of an "incomplete batch" followed by MDs until the end of the batch time.

```
   UTC batch x                              UTC batch (x+1)
        •                                        •
        •                                        •
   ........................................ .........
   •SYNCP•  SIP •APT•APT•APT•APT•APT•    •MD •MD •
   ........................................ .........
        •                                        •
        •                                        •
   ..........................................................
        •              Batch    time             •
```
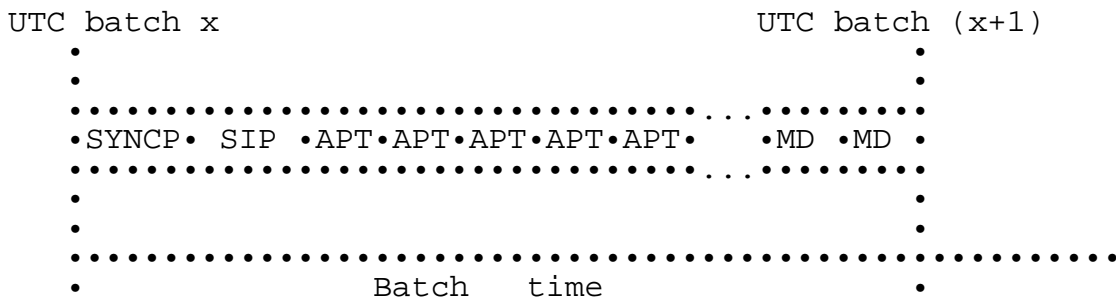
Figure 36: Example 3 of "Full batch" transmission

The "full batch" in figure 36 is comprised of an "empty batch" followed by MDs until the end of the batch time.

7.8.4.3   **"Empty batch" transmission**

An empty batch is a batch which has K=I=zero (K= number of codeblocks, I=number of initial addresses). In other words it has minimum data. It does not contain initial addresses nor messages for receivers. The structure of this batch is: Preamble word, synch word, 2 SI words, 1 SSI word, 5 APT words (total 300 bits). Completion of the batch data with MDs is optional.

```
   UTC batch x                                    UTC batch (x+1)
      •                                                •
      •                                                •
   ••••••••••••••••••••••••••••••••••••               •
   •SYNCP•  SIP •APT•APT•APT•APT•APT•                 •
   ••••••••••••••••••••••••••••••••••••               •
      •                                                •
      •                                                •
   ••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
   •                    Batch   time                  •
```
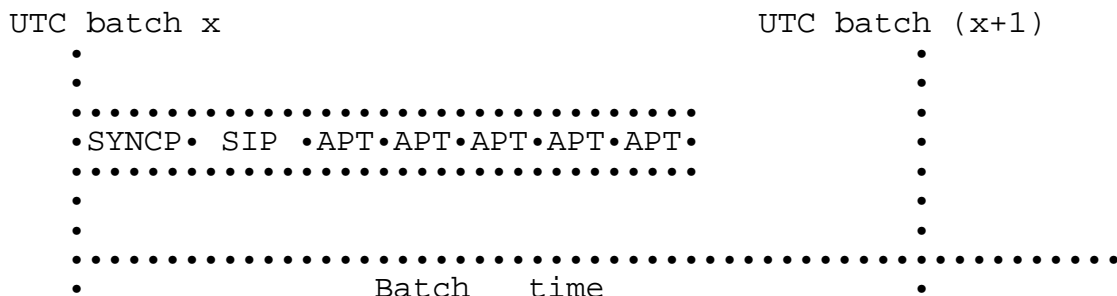
Figure 37: Example 1 of "empty batch" transmission: "empty batch" followed by no transmission until the next batch (see subclause 7.8.2, point 3a)

```
UTC batch x                                                 UTC batch (x+1)
•                                                                      •
•                                                                      •
••••••••••••••••••••••••••••••....•••••••••••••••••••••••••••••••       •
•SYNCP• SIP • 5 APTs•         •MD•MD•MD•MD•MD•MD•MD•MD•MD•              •
••••••••••••••••••••••••••••••....•••••••••••••••••••••••••••••••       •
•                                                                      •
•                                                                      •
•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
•                    Batch   time
```
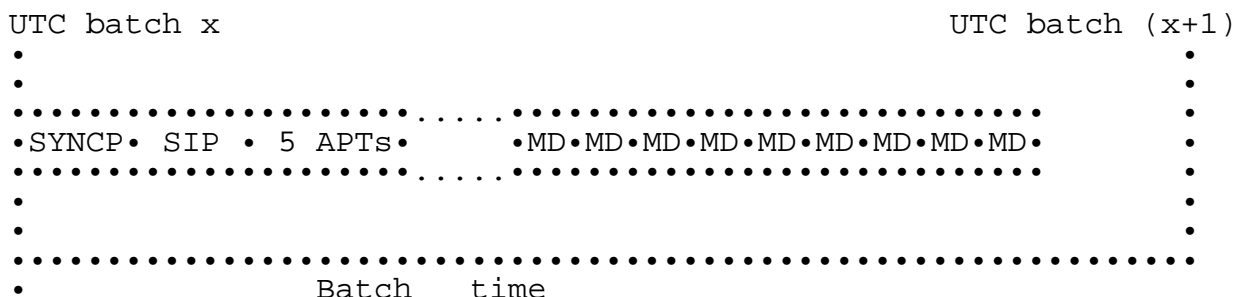
Figure 38: Example 2 of "empty batch" transmission: "empty batch" followed by an integer number of MD's codeblocks. (see subclause 7.8.2, point 3c)

Another example given in figure 36 of an "empty batch" followed by MDs until the end of the batch time (see Clause 3).

7.8.4.4   **"Incomplete batch" transmission**

An incomplete batch is a batch which has data to be transmitted during the batch time, but this data transmission time does not occupy the whole batch time. (see subclause 7.8.2, point 4)

```
   UTC batch x                                    UTC batch (x+1)
      •                                                •
      •                                                •
   •••••••••••••••••••••••••••••••••••                •
   •SYNCP•  SIP •  AP  •  MESP  •MD •                 •
   •••••••••••••••••••••••••••••••••••                •
      •                                                •
      •                                                •
   ••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
   •                    Batch   time                  •
```
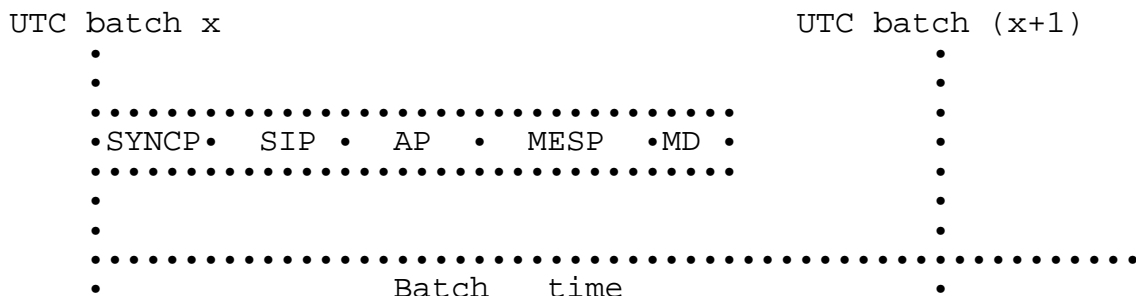
Figure 39: Example 1 of an "incomplete batch" followed by no transmission until the next batch

The number of MDs after the last message can be from 1 to 9 depending on the MESP length.

```
UTC batch x                                     UTC batch (x+1)
         •                                              •
         •                                              •
         ...........................................•..........•
         •SYNCP•  SIP •  AP  •  MESP  •  •MD •MD •       •
         ..........................................•..........•
         •                                              •
         •                                              •
         ...................................................•..........•....
         •                   Batch    time                  •
```
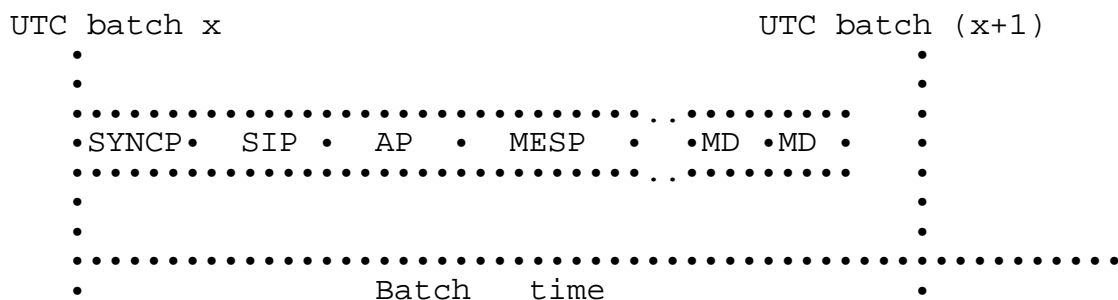
Figure 40: Example 2 of an "incomplete batch" followed by MDs

The requisite number of MDs includes the MDs necessary for completion of the message partition to the length of codeblocks, followed by an additional integer number of codeblocks made up of MDs.

8 Radio network planning guide

8.1 General

The European Radio Message Service (ERMES) is a international terrestrial paging service for the 1990's. ERMES has met its objectives to provide an agreed standard for:

a)   a common network across all the countries of Europe to allow European wide roaming;

b)   a common air interface that allows very high capacity text traffic to be handled efficiently in a narrow radio channel;

c)   a common European paging receiver specification that allows conformance testing for European wide performance compatibility.

Together with these fundamental characteristics ERMES offers to the system operators the capability of giving their customers the pager users a wide choice of facilities and features. Some are features that form part of the Paging Network Control (PNC) architecture and some are features the paging receivers are able to utilise to give unique user facilities. These include:

-    text messages of 9 000 alpha numeric characters;
-    transparent data (up to 64 kbits per message);
-    message numbering;
-    multi levels of message delivery time priority (<1 minute; <2,5 minutes; <24 hours);
-    flexible user grouping;
-    remote radio path RIC programming;
-    flexible use of frequencies to optimise network investment;
-    flexible roaming between different operators systems;
-    extended battery life;
-    call success rate within and at the boundary of a coverage area of >95 %;
-    false call rate < one false call per pager per year;
-    message calling rates for a single area system - tone = 47,41 calls/sec;
     15 digit Numeric   = 23,08 calls/sec;
     30 character Alpha = 9,50 calls/sec;
     80 character Alpha = 5,33 calls/sec;
     transparent data   = 3 504 bits/sec.

These represent improvement factors over current POCSAG systems of 1,35; 2,64; 3,26; 4,44 and 5,01 respectively.

The key to achieving all these advantages for ERMES is a well designed radio network. To obtain the success rates specified which match the best POCSAG systems while achieving an improvement of over five times in message throughput within the same channel bandwidth requires special attention to the radio propagation considerations of the network. The price to be paid for these big advantages is the level of the design tolerances, control and maintenance of the ERMES network.

8.2   The base station

The specification of the transmitter is found in ETS 300 133-6 [5]. The key to achieving the message calling rate and success rate in a multi transmitter network, within a narrow 25 kHz channel allocation, is the modulation specified for the transmitter.

4-PAM/FM - 4 frequencies will convey 2 bits per symbol.

The data rate is 6 250 bits/sec.

The symbol rate is 3,125 kbaud.

The four signalling frequencies are:

> f00 = fc - 3fb/2   an offset = - 4687,5 Hz
> f10 = fc - fb/2   an offset = - 1562,5 Hz
> f11 = fc + fb/2   an offset = + 1562,5 Hz
> f01 = fc + 3fb/2   an offset = + 4687,5 Hz
>
> where fb = baud rate.

The arrangement is a four level equivalent of Carrier Frequency Exchange Keying (CFEK) and has, when switching between adjacent levels, a modulation index m = 1,0.

The data is shaped using a 10th order Bessel filter with a 3 dB point at 4 kHz so that the carrier oscillator can move smoothly from one signalling frequency to the next within the symbol period. (i.e. 1/3,125 kbaud i 320 µsec as sketched in figure 41). (see reference [9])
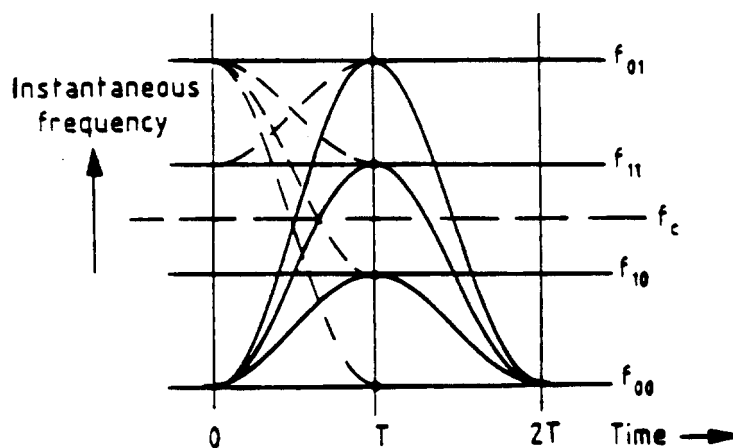
Figure 41

To give the paging receiver the best opportunity to achieve optimum sensitivity and synchronisation performance, especially when receiving two or more signals of similar levels from different transmitters, the specified tolerances, on the symbol frequencies, symbol transition shaping and symbol rate must be satisfied:

- the difference between any two adjacent symbol frequencies shall be 3,125 kHz +/- 15 Hz (see ETS 300 133-6 [5], subclause 6.3);

- the rise (or fall) time for the frequency transition between two successive symbols shall be 88 µsecs +/- 2 µsecs. (see ETS 300 133-6 [5], subclause 6.2.1);

- the short term symbol rate shall be 3,125 kbaud +/- 1 ppm over periods of up to one second. (see ETS 300 133-6 [5], subclause 6.4);

- the nominal frequency of the transmissions shall be within 200 Hz of the centre frequency. (see ETS 300 133-6 [5], subclause 6.3);

- transmitters shall be capable of being configured so that relative offsets of less than 10 Hz are avoided in areas where overlapping radio coverage occurs. (see ETS 300 133-6 [5], subclause 6.3).

8.3 Wide area coverage strategy

Because the ERMES paging receivers have a 16 channel frequency scanning characteristic the designer of an ERMES network has many options available. A time division or a frequency division structure can be employed. Large areas or small cells can be used.

A small cell multiple frequency network rather similar to a cellular architecture with frequency reuse is theoretically possible if one operator has access to many channels. This would allow single transmitters to be used without the requirement for delay equalisation synchronisation. The advantage would be a simple signal distribution requirement and maximum channel utilisation (traffic capacity), if a micro cell structure for a large city was installed. The disadvantages are seven or more channels per operator from the initial outset, many transmitter sites and, because the pagers are continuously scanning, less than optimum battery life.

The use of quasi synchronous transmission techniques to allow large area coverage with initially only one or two channels per operator is the expected mode of operation for a typical ERMES system. The network operators can define a paging area size from one to cover and entire country to many localised areas divided on a combination of time and frequency. The traffic dynamics and the distribution of subscriber population on a geographic basis will determine area dimensions and allocation of time to each area.

It must be remembered that the ERMES common air interface specification defines 5 subsequences in one cycle of one minute duration. It is these subsequences that can be allocated on a time divided area basis. This means that any area allocated just one subsequence will have only one fifth the traffic handling capacity, (e.g. 1,9 eighty character calls per second instead of 5,33 calls per second for a complete cycle).

In any time divided paging network at least one area will have only one fifth the capacity of a frequency divided area. It is thus important to plan the traffic distribution requirements and tariffing policies well in advance to get the right balance between regional and local area customer requirements. Dynamic subsequence allocation on a paging area and traffic queuing basis is possible to satisfy grade of service requirements.

8.4 Channel frequency allocation

The ERMES system has been specified to operate within 16 defined radio frequency channels. Within one geographical area (e.g. country) these radio channels will be allocated on an operator basis. It is possible for one operator to be assigned any number of channels from one to sixteen. However, it is not possible for two operators to share the same radio frequency channel in the same geographical area. A country without any border area could in the limit support 16 operators. The System Information (SI) part has assigned two possible codes per country and eight operator codes.

Countries with border areas must use frequency divided paging areas at the borders and as a result if each operator wishes to cover the whole country only eight operators can be supported with one radio

frequency channel within the country and one radio frequency channel in the border area. Border area frequencies must be agreed with border countries. Countries which have borders with two or more countries may have to restrict the number of paging operators to less than eight. With less than eight operators it is possible for one operator to use two or more internal channels for every border channel. This will depend on population and the traffic in the border areas.

It will also be important to ensure that border paging areas are large enough to avoid interference with border paging areas in the adjacent country (see CEPT Recommendation T/R 25-07 [7]).

An operator within one country allocated more than one channel for internal use (not border use) may choose to use a single base station (transmitter) per site in a quasi synchronous network in low traffic paging areas. In these low traffic areas the transmitters could operate on only one of the assigned frequencies, or be switched on a time divided basis between the two radio frequencies. If only one radio frequency is used the pagers must move out of lock (if locked to obtain maximum battery life) in accordance with an agreed algorithm as they move from a two channel to a single channel area or vice versa. The use of FSI's will assist this process.

8.5 Quasi synchronous transmission networks

As has been explained, a successful quasi synchronous transmission network is key to satisfying the ERMES standard.

The essential requirements are that each of the multiple radio signals received by the pager are each within the limits specified for:

- the difference between any two adjacent symbol frequencies;
- the short term symbol rate.

Also the differences between the multiple signals shall, if they are within a level of < 6 dB, be within the limits specified for:

- the difference between the radio frequency of any two received signals;
- the difference in time of reception of any two received signals.

8.6 Transmitter frequency stability

In any network of ERMES base stations the nominal frequency of the transmissions shall be within 200 Hz of the centre frequency. This will result in a difference offset (or frequency) between two transmitters of between 0 Hz and 400 Hz. The standard however ensures that the transmitters are capable of being configured so that minimum difference is 10 Hz.

The difference frequency in many POCSAG systems has been set to the bit rate in Hz. This is based on the cancellation period being less than the bit period and from laboratory tests has shown superior results over other offset strategies. Systems with lower offset strategies have been apparently working well, and this may be explained by the effects of Rayleigh and log normal fading in the real world environment. Such a high offset frequency strategy for an ERMES network is not possible because the symbol rate is 3,125 kbaud.

Computer simulations (see reference [11], appendix X) of the ERMES system with various offset frequency strategies have shown best performance with very low offset frequencies in terms of Bit Error Ratio (BER).

These results do not simulate distribution of bit errors and it is possible at the 1 Hz differences many long bursts may be observed beyond the ERMES bit interleaving capability. The results do show however that difference frequencies about 200 Hz would be best avoided.

8.7 Synchronisation between base stations

Field results of POCSAG paging networks has shown that difference in times of reception of identical signals at a paging receiver has a very marked effect on the paging call success rate. The practical limit for POCSAG systems has been found to be 25 % of the bit period.

The ERMES standard specifies that "The maximum difference in times of reception of identical signals from different transmitters shall not exceed 50 µsec." (see ETS 300 133-4 [3], subclause 13.3)

The difference in the time of reception consists of three parts:

a)   difference in delay in base stations.

The base station conformance specification does not define the tolerance on delay within the base station. A +/- 2 µsec limit on the rise time for the frequency transition between two successive symbols is given;

b)   accuracy of synchronisation between base stations.

Synchronisation between base stations has not been defined in the standard. Manufacturers and operators are able to define their own preferred method. This could be to use an off air time standard for clocking of synchronous data stored in each base station or to transmit by satellite the ERMES signals direct to each base station. Systems are available that allow synchronisation accuracy to within 20 µsecs. This is considered to be the absolute maximum allowable limit for a) and b);

c)   difference in propagation times to the receiver.

Propagation delay difference is thus limited to a maximum of 30 µsecs. This is discussed in subclause 8.8.

The computer simulations (see reference [11], appendix X) produced results for various delay differences from 20 µsec to 80 µsec. These results suggest that there was little degradation up to 80 µsec. The results of this simulation are thus very encouraging. It would be wise however to hold to the ERMES standard requirements because the receiver simulated by the computer was ideal and perfect bit synchronisation was assumed at all times.

The ERMES paging receiver conformance specification defines a 30 Hz offset frequency and 50 µsec differential delay performance (see ETS 300 133-5 [4], subclause 6.2, point k).

8.8 Radio frequency propagation delay

The required limits on the difference in propagation times to the ERMES paging receiver of two signals is 30 µsecs. This means that the maximum path length difference of two radio signals arriving at the paging receiver with amplitudes within 6 dB is 9 kilometres. (A radio signal travels 1 kilometre in 3,3 µsecs.)

The key factors to be considered in the design of an ERMES transmitter network to ensure that these requirements are satisfied are best understood in the light of radio propagation theory.

The ERMES paging receiver has a specified eight position average body worn sensitivity of 25 dBµV/m. (see ETS 300 133-5 [4], subclause 6.1).

The power received by the paging receiver antenna P_r in terms of field strength E in dBµV/m is given by:

$$P_r(dBm) = 10 \log G_r \; . \; \frac{\lambda^2}{4 \pi^2 120} \; - \; 90 \log 10 + E(dB\mu V/m).$$

If the paging receiver had an antenna gain G_r equal to that of a short dipole (G_r=1,5) then the power received by the antenna in a 168 MHz signal field strength of 25 dBµV/m would be

$$P_r(dBm) = -30 - 90 + 25 = -95 \; dBm$$

A typical ERMES paging receiver may require an input power of - 119 dBm to achieve the specified paging success rate.

Therefore the effective gain of a typical paging receiver antenna is - 119 + 95 = - 24 dB.

This gain is not the same in all directions and will often typically vary from = - 18 dB to - 30 dB.

The classical propagation model for radio transmission over a typical paging area considers not only free space, but:

a)   ground specular reflection;

b)   surface roughness;

c)   line of sight obstacles;

d)   buildings and trees;

e)   through structure/ building loss.

Research over recent years have resulted in the development of empirical models that fit extensive field measurements.

One proposed by Ibrahim and Parsons could be used for a typical ERMES system (see references [8] & [10]).

$$P_r \; (dBm) = 10 \log Pt + 30 \log 10 + Gt + GR + 20 \log HtHr - 40 \log d - B$$

Where:

> Pt = transmitter power (Watts).
> Gt = transmitter antenna gain (dB).
> G_r = paging receiver antenna gain (dB).
> Ht = effective height of transmitter (metres).
> Hr = effective height of receiver (metres).
> d = range transmitter to receiver distance (metres).
> B = (K + S) (dB) structure.
> S = through (building) loss factor (dB).
> K = loss factor due to urbanisation characteristics (dB).

K is a function of:

> U = degree of city urbanisation area covered by building of four or more floors.
> H = relative spot height of average terrain in the pager location.
> F = frequency.
> L = land usages area occupied by buildings.

For a paging area the path loss from one transmitter will vary with direction thus the radio signal coverage from one transmitter will not be circular. The path loss in any direction will be determined by the receiver antennas gain G_r, the relative height of the receiver, the degree of urbanisation and the structural objects encountered.

These variations are typically G_r +/- 6 dB,   K +/- 10 dB, S +/- 6 dB

It is thus probable that differences in both loss to many locations in a paging area from two or more transmitters covering the area will be in the order of 20 dB.

The effects of a 20 dB and 0 dB path loss difference between two transmitters separated by 15 km and 25 km are shown in figures 42 and 43. Different nominal values of K were used in figures 42 and 43 to allow for two levels of general urbanisation.

It can be seen that in figure 43 the equal signal level location is 19 km from one transmitter and 6 km from the other. This 13 km path would lead to a 43 µsec signal delay differential which is in excess of the 30 µsec allowed, if the best synchronisation difference achievable is 20 µsec. Even with 15 km separation in figure 42, a 3 dB signal level difference gives a 30 µsec delay differential from a 9,1 km path difference.
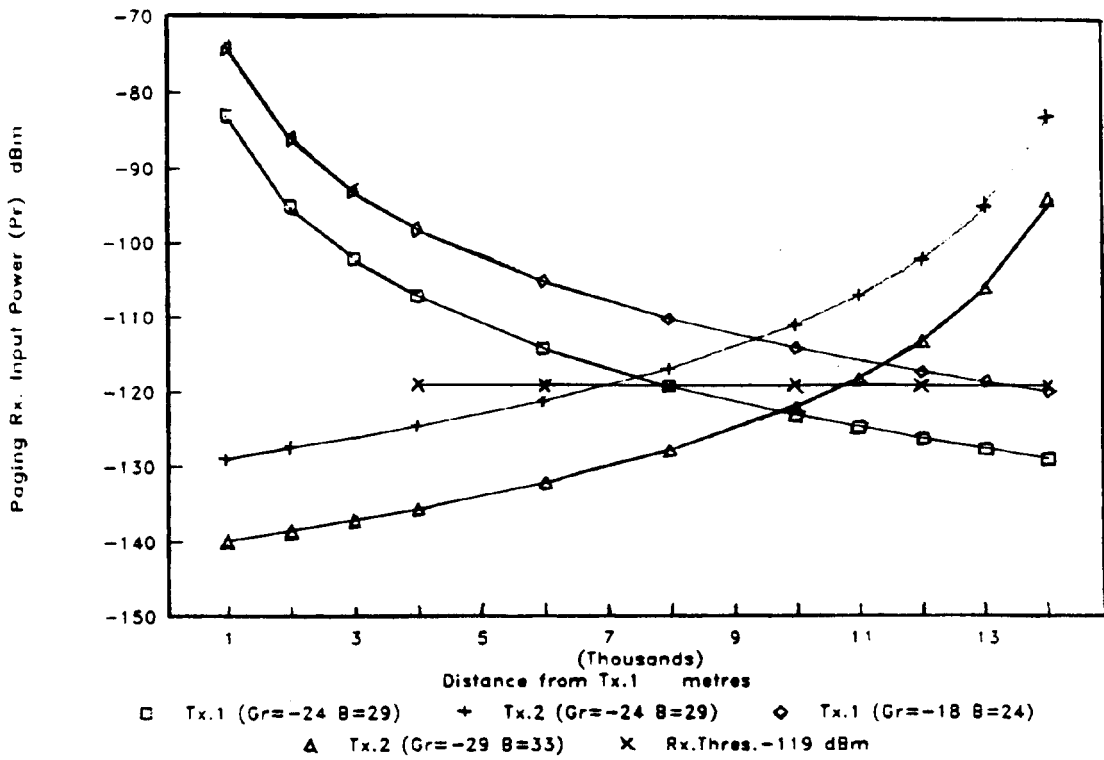
Figure 42: An ERMES propagation model (two transmitters (100 Watt) 15 km apart, 60 m antenna)
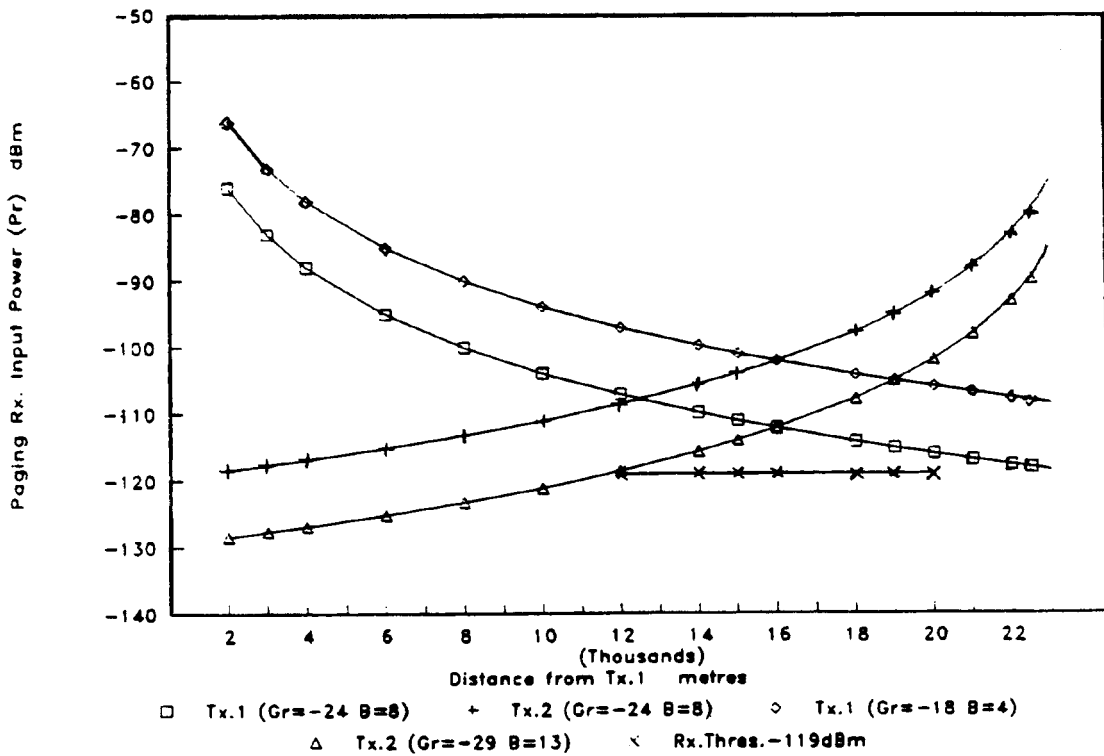
Figure 43: An ERMES propagation model (two transmitters (100 Watt) 25 km apart, 60 m antenna)

8.9 Conclusions

The following factors should be given special consideration in an ERMES radio transmitter network:

- transmitter separation. This should ideally be less than 25 km;

- transmitter effective antenna heights. These should all ideally be the same (a 20 m difference about a nominal 60 m effective height will give a 3 dB variation in path loss);

- transmitter antenna gain. These should be the same for all transmitters and the same in all directions;

- transmitter synchronisation accuracy. The synchronisation differential delay difference should be less than 20 µsec as this has a direct relationship to the permissible transmitter separation;

- transmitter sites should be positioned to give the same levels of urbanisation in the transmission paths from each base station;

- transmitters should be maintained to satisfy the limits and tolerances specified in the ERMES standard, ETS 300-133.

9 Cross referenced index

This Clause gives a cross referenced index for ETS 300 133, Parts 2, 3, 4, 5, 6 and 7.

The part numbers are given in parentheses, followed by the page numbers.

Home PNC	(2)	10, 16, 17, 34, 47
	(3)	18, 21, 30
	(7)	19
I1 interface	(3)	23, 24, 150, 151
	(4)	8
	(6)	7
I2 interface	(3)	23, 24, 145, 146, 147, 148, 150, 179, 181, 188
	(4)	8
	(6)	7, 8
	(7)	44, 80, 81
Initial address	(3)	20, 21, 185, 186, 187, 189, 190
	(4)	8, 10, 14, 17, 20, 28, 29, 30, 31, 32, 33, 34
	(5)	9, 10, 12, 13, 16, 17, 18, 19
Input PNC	(2)	10, 43
	(3)	18, 21, 30
	(7)	19
Internal interface	(3)	18, 23, 24
	(7)	25
Legitimisation code	(2)	30, 32, 33, 35, 36, 37
	(3)	18, 32, 38, 39, 40, 42, 43, 51, 61, 66, 71, 77, 81, 82, 120, 122, 123, 126, 127, 133, 263
Local address	(4)	8, 18, 29, 30, 32
	(5)	9, 10, 19
Long message	(3)	186, 187
	(4)	8, 9, 19, 29, 32
	(5)	15, 24
Operator code	(3)	31, 187, 190
	(4)	8, 15
	(5)	9, 10, 19
	(7)	78
Operator identity	(3)	21
	(4)	8, 9, 17, 21
	(5)	9, 10
Paging area	(2)	44
	(3)	13, 18, 21, 22, 179, 180
	(4)	8, 9, 15, 19, 20, 27, 33, 34, 35
	(5)	10
	(6)	7, 8
	(7)	10, 11, 12, 22, 23, 24, 78, 79
Paging message	(3)	19, 23, 29, 32, 46, 95, 144, 145, 175, 178
	(4)	8, 9, 13, 29, 32
	(5)	9, 10, 11
Paging signal	(2)	41
	(4)	8
	(5)	10, 11, 25, 26, 29

Annex A: Results of simulation

Performance of the ERMES radio chain in simulcast environment

A.1 Introduction

This annex contains the computer analysis carried out for performance of the ERMES radio chain in a simulcast environment. In particular the performance has been evaluated in terms of Bit Error Ratio (BER) both in Additive White Gaussian Noise (AWGN) channel and in Rayleigh fading channel (for a speed of the mobile receiver equal to 3 km/h) as a function of the typical parameters characterising the quasi-synchronous simulcast environment (in the case of two received signals), such as time delay, frequency shift, phase shift and amplitude imbalance.

A.2 Simulated radio chain

In figure A.1 the simplified block diagram of the simulated transmission radio chain in the case of simulcast environment (2 transmitters) is depicted.

As indicated in the ERMES standard ETS 300 133, the modulation is the 4-PAM/FM with modulation index (defined as the radio of the steady-state frequency deviation corresponding to the highest modulation level at the level generator output, to the bit rate of the input signal) of 0,75 and with a bit rate of 6,25 kbit/s; the pre-modulation filter is a 10th order Bessel filter with 3 dB bandwidth of 3,9 kHz.

The simulcast environment has been simulated considering two signals arriving at the receiver with the same digital information but with constant frequency offset (Δf) between the carriers, different initial phase (whose difference is indicated with $\Delta\emptyset$), constant time delay (Δt) and different values of the carrier amplitude (whose difference is referred to as ΔA with respect to the strongest one).

As far as the receiver is concerned the pre-discrimination filter has 3 dB bandwidth of 11 kHz, whilst the post-discrimination filter has 3 dB bandwidth of 3 kHz.

A.3 Performance results and conclusions

The sensitivity of the performance to the parameter $\Delta\emptyset$ has been investigated. In particular, it has been verified that for values of Δf greater than about 25 Hz the influence of this parameter on the BER performance is negligible. For values of frequency offset lower than about 25 Hz, the simulations have been carried out with a random $\Delta\emptyset$ (phase shift, with an uniform distribution between 0 to 360 degrees) changing values every transmitted symbol. This situation, in accordance with the view of PS2 expressed during the previous meeting, seems to be the most realistic with respect to other possible assumptions.

Figures A.2 to A.4 report the performance, in terms of BER, in AWGN channel for three values of time delay Δt, i.e. 20, 50, 80 µs, respectively. Each figure illustrates, other than the reference performance in the case of single transmitter, three sets of curves obtained for values of amplitude imbalance ΔA equal to 0, -3 and -6 dB. Furthermore, for each value of ΔA, simulations have been carried out for different values of frequency shift Δf, in the range between 0 and 600 Hz.

From the comparison of figures A.2 to A.4 it can be seen that the time delay Δt, for values up to 80 µs, does not have remarkable impact on the performance. The decision instant used in the simulations has been fixed equal to $\Delta t/2$. According to some PS2 delegates, laboratory tests have shown greater sensitivity to time delay values above 50 µs (see previous meeting reports); this impairment could perhaps be explained by a stronger sensitivity of the implemented clock recovery circuit to values of parameter Δt above a certain threshold, with respect to the simulated device. Beside, still from the comparison of figures A.2 to A.4, it can be seen that the performance is sensitive to the amplitude imbalance; in fact, the greater ΔA the closer the performance with one transmitter, while if the signals show comparable amplitudes ($\Delta A = 0$ dB) the performance presents asymptotic behaviour. Another not negligible influence is the one of frequency shift Δf, which becomes more and more noticeable for decreasing values of ΔA; in particular, if $\Delta A = -6$ dB values of Δf up to 600 Hz causes about 2,5 dB degradation of the Eb/No ratio at BER = 1 %, and if $\Delta A = 0$ dB a Δf of 200 Hz makes the performance asymptotic above BER = 1 %.

Figures A.5 to A.7 show the simulation results , with the same values of parameters Δt, ΔA and Δf as before, in the presence of Rayleigh fading and a mobile receiver speed of 3 km/h. In this case it is still true

that values of Δt up to 80 µs do not influence the performance in a noticeable way, but also the effect of parameter ΔA (in the simulated range between 0 and -6 dB) seems to be negligible in comparison to that of Δf. In fact, the irreducible BER's highlighted in figures A.5 to A.7 appear to be more influenced by Δf than by any other parameter. The asymptotic BER is around 1 % for Δf on the order of 600 Hz, whilst it is lower than 0,1 % only if Δf is smaller than 200 Hz.
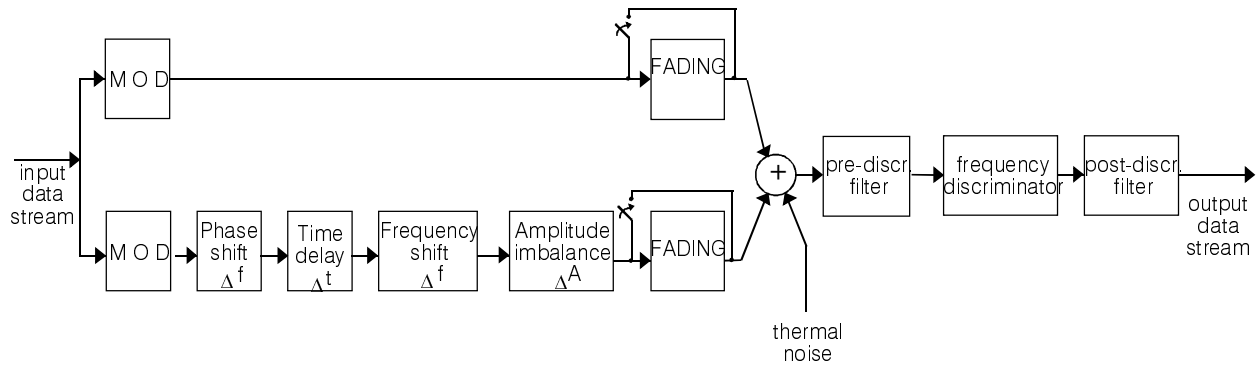
Figure A.1: Simplified block diagram of the simulated transmission radio chain in the case of simulcast environment (2 transmitters)

Parameters of the curves are the amplitude imbalance and the frequency shift between the carriers.

Modulation: 4-level PAM/FM (modulation index = 0,75).
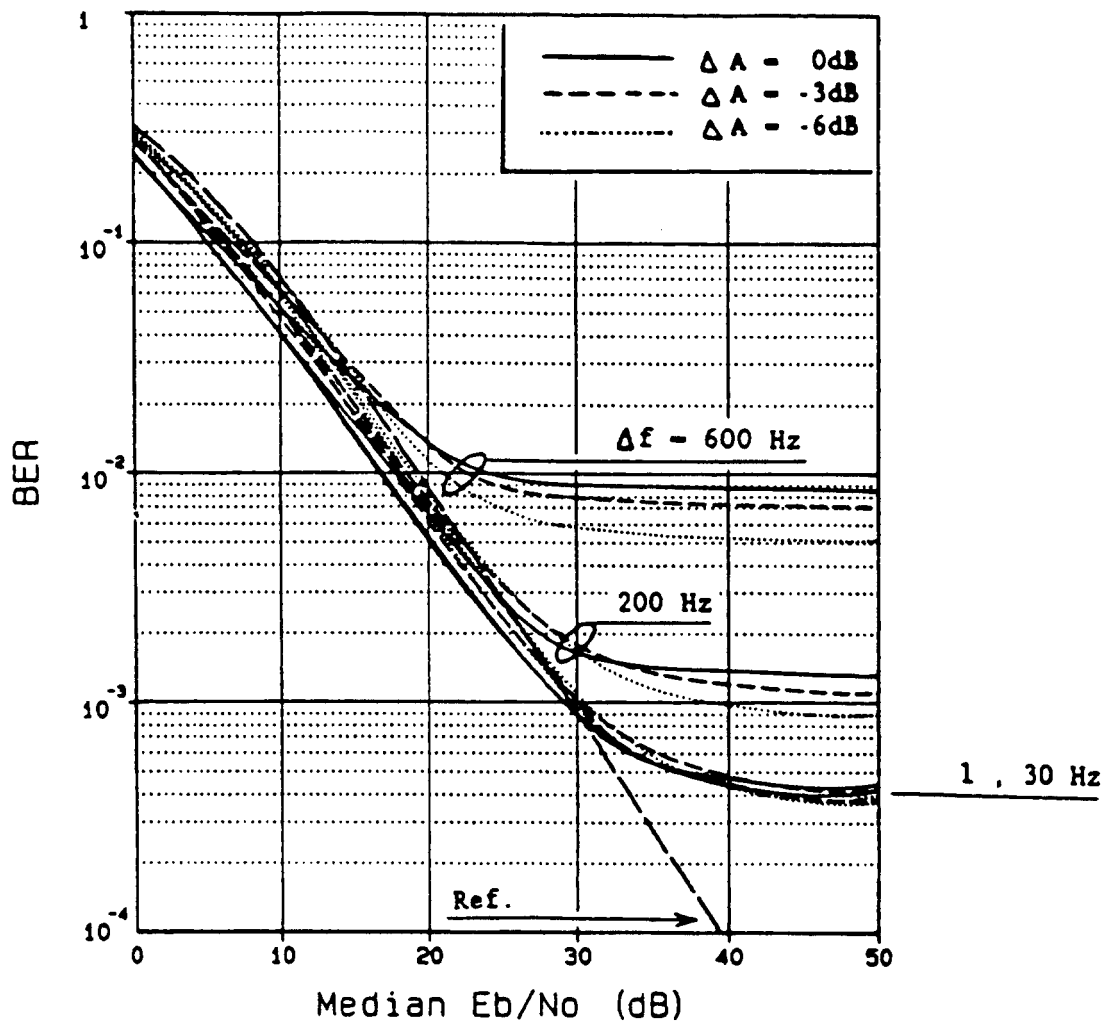
Bit rate: 6,25 kbit/s.

No. of transmitters: 2.

Time delay between the signals: 20 μsec.

The abscissa represents the ratio of the energy per transmitted bit to the noise spectral density pertaining to the strongest received signal.

The reference curve is relevant to the performance with a single transmitter.

Figure A.2: Performance in AWGN.
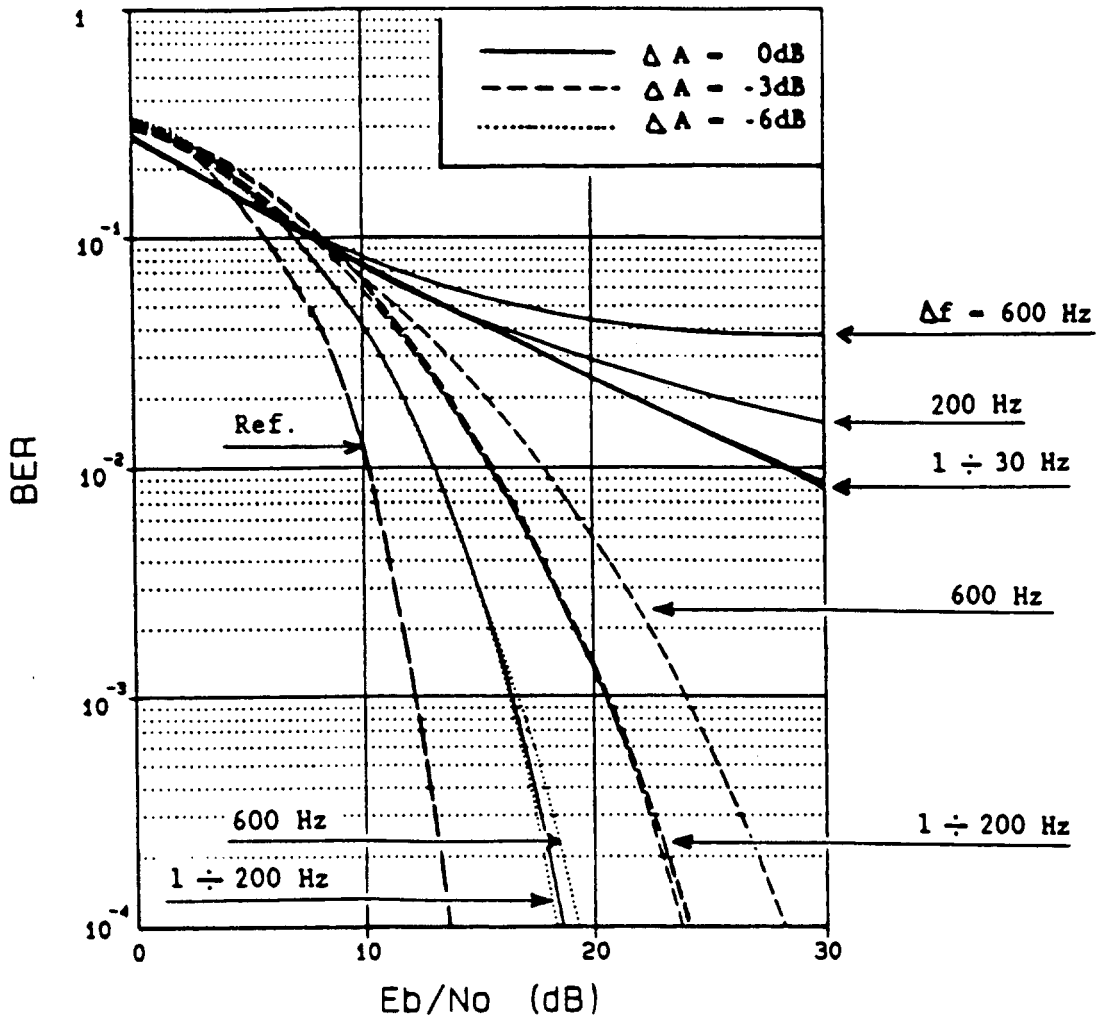
Parameters of the curves are the amplitude imbalance and the frequency shift between the carriers.

Modulation: 4-level PAM/FM (modulation index = 0,75).
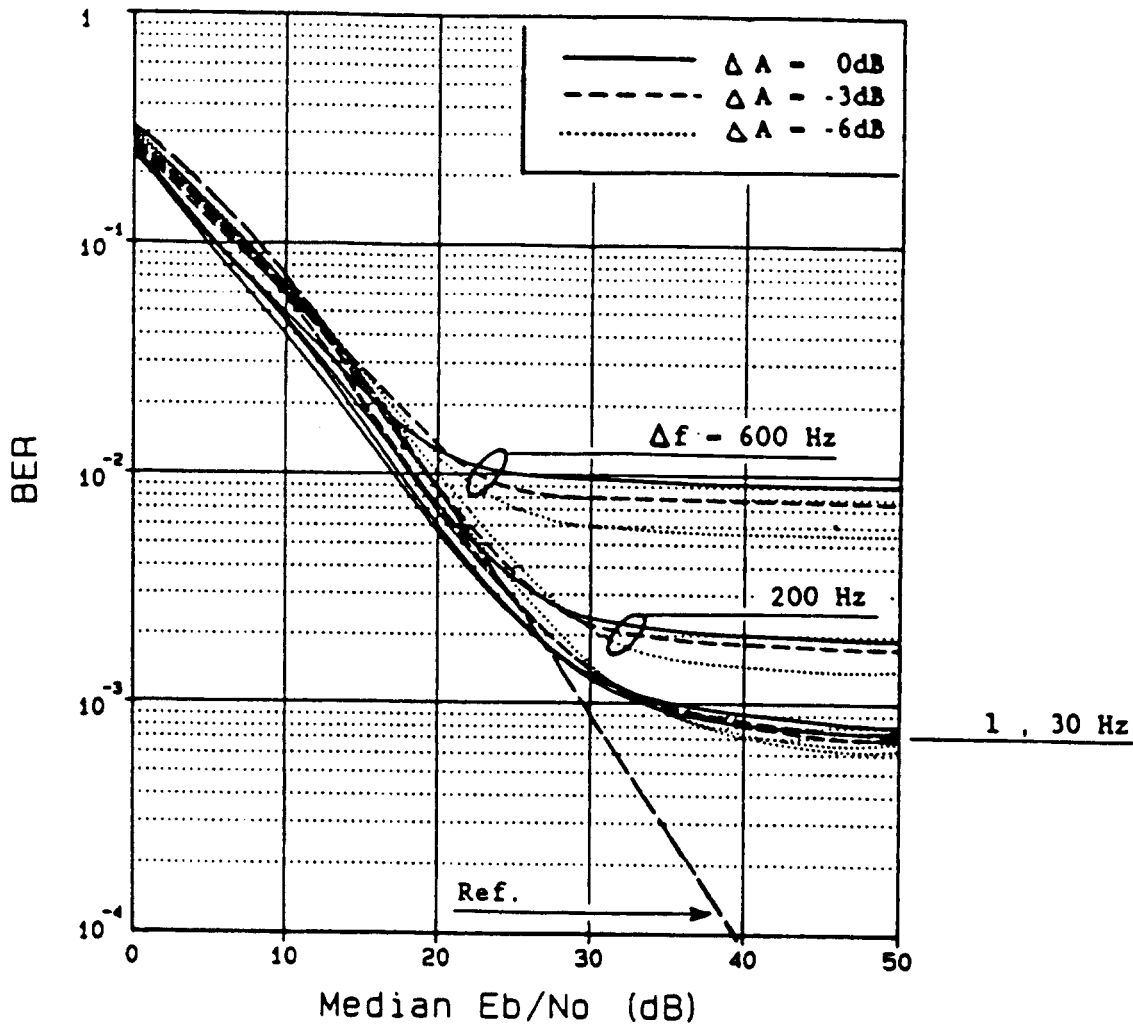
Bit rate: 6,25 kbit/s.

No. of transmitters: 2.

Time delay between the signals: 50 μsec.

The abscissa represents the ratio of the energy per transmitted bit to the noise spectral density pertaining to the strongest received signal.

The reference curve is relevant to the performance with a single transmitter.

Figure A.3: Performance in AWGN.
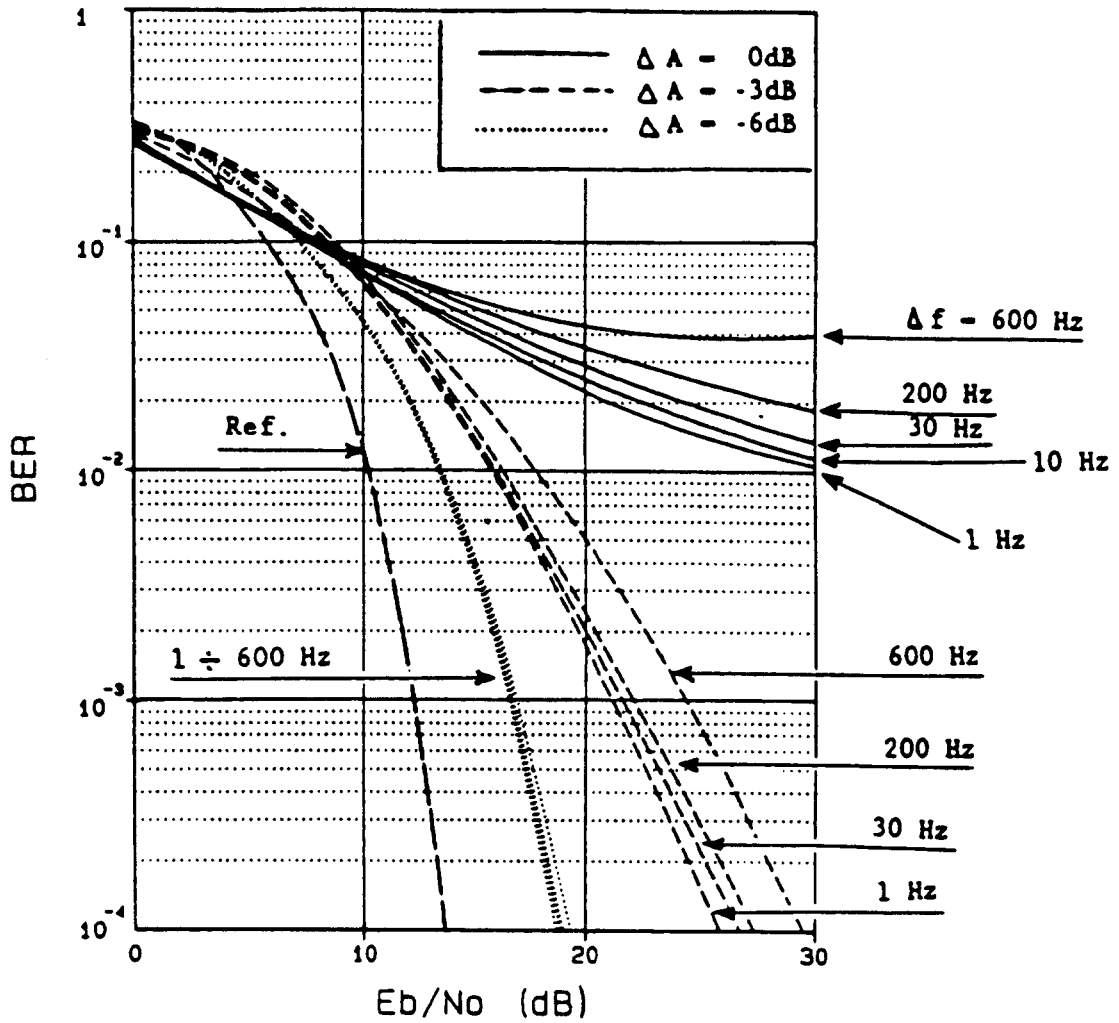
Parameters of the curves are the amplitude imbalance and the frequency shift between the carriers.

Modulation: 4-level PAM/FM (modulation index = 0,75).

Bit rate: 6,25 kbit/s.

No. of transmitters: 2.

Time delay between the signals: 80 μsec.

The abscissa represents the ratio of the energy per transmitted bit to the noise spectral density pertaining to the strongest received signal.

Figure A.4: Performance in AWGN.
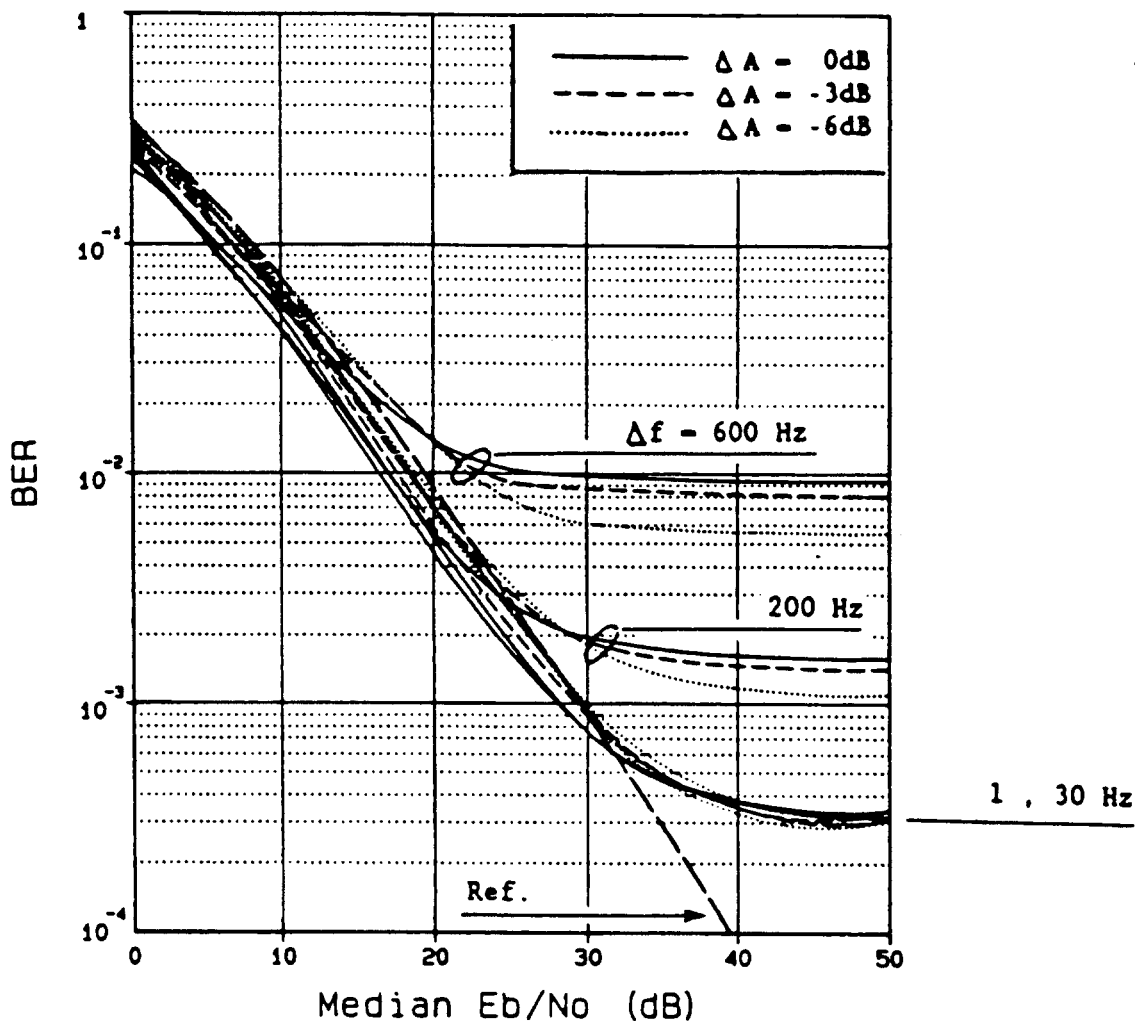
Parameters of the curves are the amplitude imbalance and the frequency shift between the carriers.

Modulation: 4-level PAM/FM (modulation index = 0,75).

Bit rate: 6,25 kbit/s.

No. of transmitters: 2.

Time delay between the signals: 20 μsec.

The abscissa represents the median ratio of the energy per transmitted bit to the noise spectral density pertaining to the strongest received signal.

The reference curve is relevant to the performance with a single transmitter.

Figure A.5: Performance in Rayleigh fading channel with a mobile receiver speed of 3 km/h.

Parameters of the curves are the amplitude imbalance and the frequency shift between the carriers.

Modulation: 4-level PAM/FM (modulation index = 0,75).

Bit rate: 6,25 kbit/s.

No. of transmitters: 2.

Time delay between the signals: 50 μsec.

The abscissa represents the median ratio of the energy per transmitted bit to the noise spectral density pertaining to the strongest received signal.

The reference curve is relevant to the performance with a single transmitter.

Figure A.6: Performance in Rayleigh fading channel with a mobile receiver speed of 3 km/h

Parameters of the curves are the amplitude imbalance and the frequency shift between the carriers.

Modulation: 4-level PAM/FM (modulation index = 0,75).

Bit rate: 6,25 kbit/s.

No. of transmitters: 2.

Time delay between the signals: 80 μsec.

The abscissa represents the median ratio of the energy per transmitted bit to the noise spectral density pertaining to the strongest received signal.

The reference curve is relevant to the performance with a single transmitter.

Figure A.7: Performance in Raleigh fading channel with a mobile receiver speed of 3 km/h

Annex B: Queueing functions

B.1 Queues, QOS and network performance parameters

For its basic service, i.e. message delivery, the ERMES system behaves as a store and forward network whose nodes are represented by the PNCs in their different roles (I, H, T) and the PACs, in charge of allocating the message in accordance with the air interface structure. The message delivery time which is the basic QOS parameter is determined by the delay undergone by the message through the store and forward nodes involved in its routing across the network.

It has to be stressed that the transfer and the broadcasting of the message is preceded by an interactive phase where the network generates system responses towards the calling party. Also this phase is then characterised by network delays which determine, by turn, other QOS features. Particularly the system response delay, the call accepted acknowledgment delay and the page accepted acknowledgment delay defined in ETS 300 133-2 [1], subclause 7.2 are generated by the processing and transmission times experienced inside the PNC and during the PNC to PNC transmission of user related data.

A similar delay mechanism operates when the network is acting as "service provider" entity, able to provide a service profile definition for any ERMES user. The subscriber feature acknowledgment delay represents the performance of such a delay mechanism. Major elements affecting this QOS parameter are again PNC processing and transmission times.

In general, the value of each parameter depends on a number of delay times experienced in different queues, established whenever a random service requirement flow loads a limited-capacity server (examples are the mentioned processing and transmission queues, concerning: the former, a CPU capacity; the latter, a bit rate capacity of a transmission line).

In any case PNC and PAC are the devices where the queueing processes take place. Figure B.1 shows a possible scheme for such queue arrangement.

A particular problem arising in the ERMES system derives from the storage feature needed for those services which are booked for activation or execution in a subsequent time. Examples are the roaming service and a number of supplementary services, such as temporary barring, traffic diversion and deferred delivery. Accordingly the PNC must be able to prepare in a suitable database, a list of activation or execution events to be visited with a frequency connected to the time granularity assigned to those services. Any how this storage function cannot be viewed as belonging to a standard queueing context.

Hence, the delay mechanisms inside the ERMES system are so complex that a queueing network model should be used, in principle, to represent their behaviour. Nevertheless the network portion having by far the greatest impact on the delay operation is the PAC-BS region. In fact, firstly, the PAC represents the functional entity where the messages are allocated according to the particular ERMES air interface characteristics (cycles, subsequences, batches). In this sense, PAC functions are relevant to the true bottleneck of the network in terms of both capacity and time organisation for message transmission. Moreover, PAC is also dealing with the priority management and any suitable solution for improving the air interface efficiency and the load distribution among the channels. PAC is also the device where flow control situations are activated according to a detected overload status on the radio channels.

For these reasons, Clause B.2 is completely devoted to showing the meaning and the role of some PAC working parameters, introduced in ETS 300 133-3 [2], Clause 14.
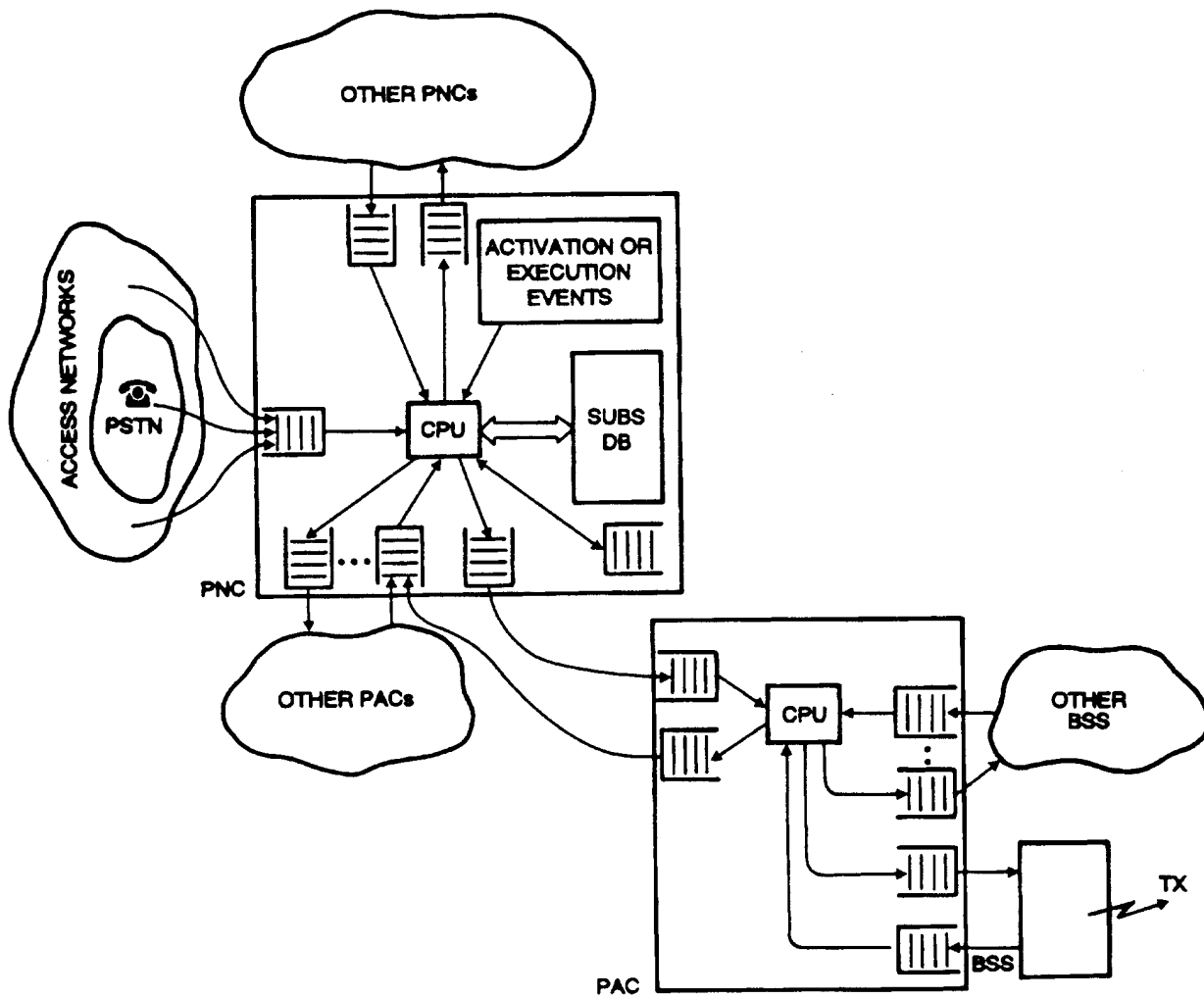
Figure B.1

B.2   Queues in the PAC

The PAC deals with the traffic control process, mainly handling queueing functions. These queues are affected by the data flows from I3 and towards I2 interfaces. The PAC carries the messages to be transmitted as soon as possible, depending on its status. The messages are carried mainly according to:

-        priority;

-        batch type;

-        channel number;

-        length;

-        time limits.

As stated in ETS 300 133-3 [2], Clause 14, the control section of the PAC manages three kind of processes:

-        the input process, which enter the messages from the input section (I3 interface), allocates the messages according to the proper channel queue (FSN, FSI mechanism) and priority;

-        the output process which organise the data (system data, messages, addresses) according to the I2 interface format, sends the data to the output section, receives results from the output section stating if the page request operation has been correctly received by the BSs;

-        the allocation process, which assumes any decision about the message allocation inside the batches; such decisions are taken aiming at a high channel efficiency together with a low message delivery delay and by respecting at the same time the batch organisation and the other system constraints.

The most critical element affecting the message delivery delay is the allocation process. In ETS 300 133-3 [2], subclause 14.5.5, two working parameters are introduced: n_d, the decision interval; and **TA**, the anticipation interval. Even though the use of such parameters is not normative, some comments on them can help to clarify the message allocation alternatives present in the PAC.

The anticipation interval represents the time anticipation the control section must obey to in order to allow a transmission (to I2 interface) of the assembled batches in due time with respect to the true batch sequence so as it goes on in the air. TA is defined as the time elapsing between the instant the control section hands the batch over to the output section (I2 interface) and the instant the batch must be present in BS before its transmission in the proper time window on the air interface.

In line with the definition, TA depends on four factors:

-        the processing time spent by the output section to arrange the batch in the transmission form;

-        the grouping of batches in the page request operation on the I2 interface; if more than one batch per operation is transmitted towards the BS, then the reference batch to determine TA is the first batch in the batch sequence belonging to the operation;

-        the operation transmission time on the PAC-BS line;

-        the processing time in BS.

The value of TA in a real device implicitly defines a sequence of "interrupts", each one arising exactly when the control section must stop the allocation algorithm for a given batch by freezing the relevant content and sending the batch itself to the output section for transmission on the I2 interface. Hence TA establishes the start-stop sequence for the allocation algorithm according to the batch/subsequence time constraints to be fulfilled on the air.

As for the decision interval n_d, it embodies a useful mechanism to adapt the message allocation scheme to the traffic characteristics during the day, or in different load environment situations. In particular it represents a way for sharing the radio resources among different batch-flows. For n_d=1 each batch acts as a separate resource completely devoted to the load (addresses and message information part) related to the batch itself. If n_d is given, for instance, the value 4, then the load is offered to 4 batches shares (for only the message information part) a capacity (bit/s) equivalent to 4 times the capacity assured by a single batch.

This sharing mechanism affects the system behaviour in both balanced and unbalanced traffic situations among the batches.

A balanced situation arises whenever the batch-offered traffic is the same for all batches (only statistical fluctuations around the same mean value). Unbalance is present when the batch-offered traffic differs from batch to batch; it may depend on long-term statistical trends.

To evaluate the effects of such control parameter, a single area simulation has been developed. It implements both the queueing mechanism within the PAC (as described by ETS 300 133-3 [2]) and the air interface framing (batches, sequences) without taking into account any battery saving techniques. The traffic profile along a generic day is shown in figure B.2. The ordinate of each hour corresponds to the percentage of the daily amount of calls offered to the batch during that hour.

In the traffic profile of figure B.2, the message flow has been assumed to be formed by three kinds of service i.e. tone only numeric and alphanumeric[B1]. The message length for numeric and alphanumeric is 20 digits and 80 characters respectively. Three priorities are introduced according to the portions shown in figure B.2. They apply to each service.

It has been assumed that the arrival process of the messages to be transmitted on the air interface is a Poisson process; the mean rate arrival rates, expressed in calls/batch/hour are shown in figures B.3 to B.6.

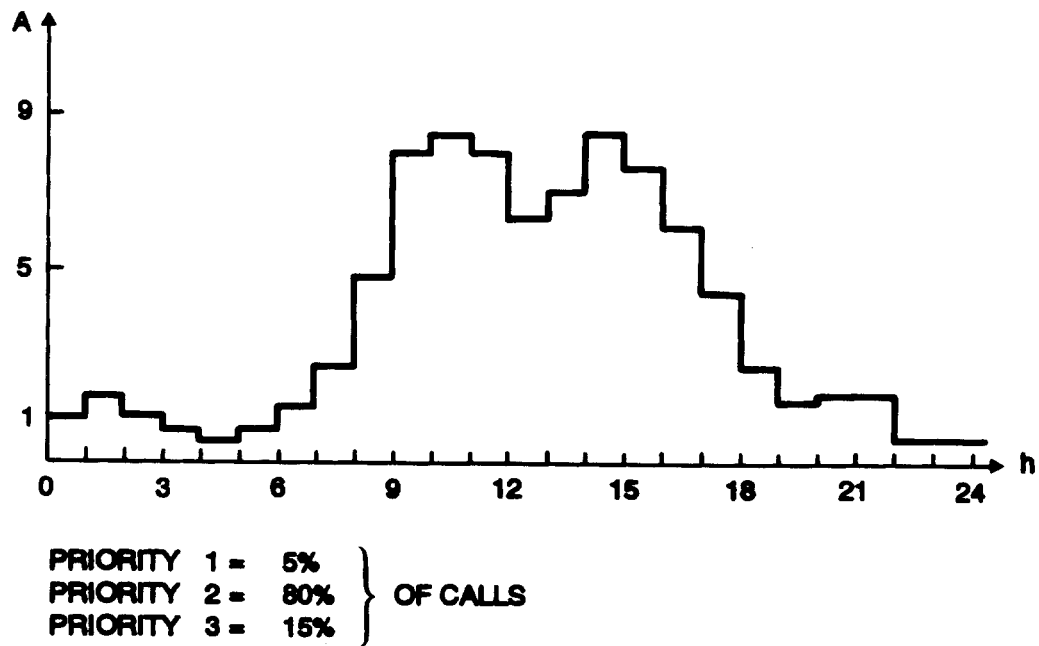[B1] no long messages have been simulated.

Figure B.2

The simulation evaluates:

- the average message delivery time and the 95 % delay D due to PAC and air interface delay;

- the batch efficiency E;

- the average battery consumption Bc undergone by the receiver for "capturing" the message addressing the receiver itself.

Another case is shown in figure B.6. It represents the delay for priority 2 service in case of traffic unbalance (abscissa) on one batch out of 4.

In this situation, the value of n_d much more heavily affects the system performance[B2]: a figure of $n_d=4$ is sufficient to recover an acceptable message delivery delay even for high traffic unbalance.

The simulation has been used to verify the system performance in the "rush hour" situation which can be deduced from the traffic model of figure B.2. Figures B.3, B.4 and B.5 show the delay evaluated for priority 1, 2 and 3 services. If the nominal "rush hour" situation arises, the performance figures are below the thresholds set by ETS 300 133-2 [1]. This happens even with $n_d=1$. Nevertheless, the same figures show that, with increasing traffic, the performance thresholds are soon passed. A way to improve such behaviour is to utilise a greater value of the control parameter n_d. In the same figures the influence of n_d is pointed out. In fact the impact, from the delay point of view, of having $n_d=16$ is depicted with a dashed curve demonstrating the capability of the system in supporting an increase of traffic.

Another case is shown in figure B.6, where an unbalance situation has been assumed: one batch out of 4 is characterised by an offered message rate greater than the nominal one (rush hour value), of the rate shown in abscissa. In this situation the value n_d affects the system performance even more. A value of $n_d=4$ keeps the delivery delay below the threshold even for unbalances of 40 % with $n_d=1$.

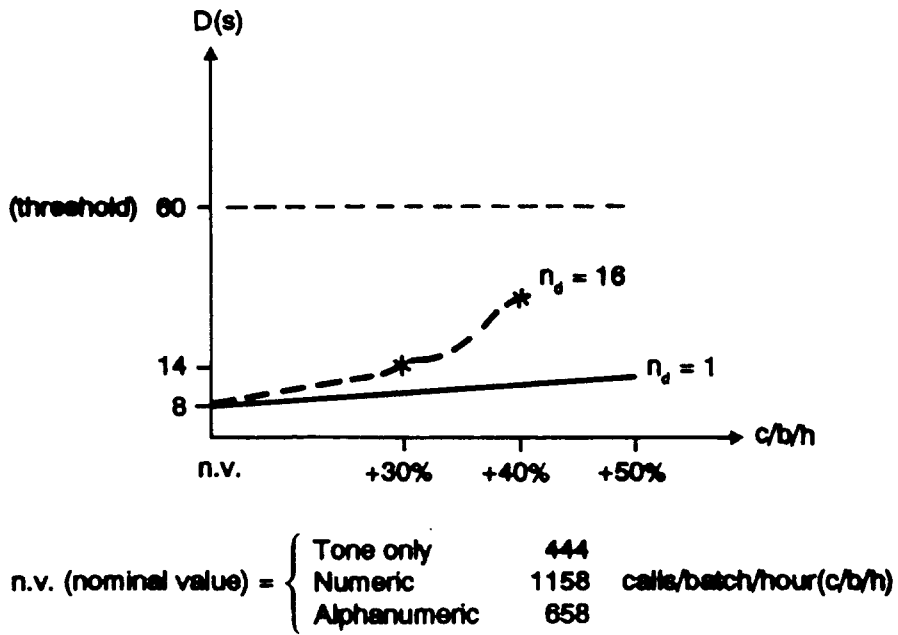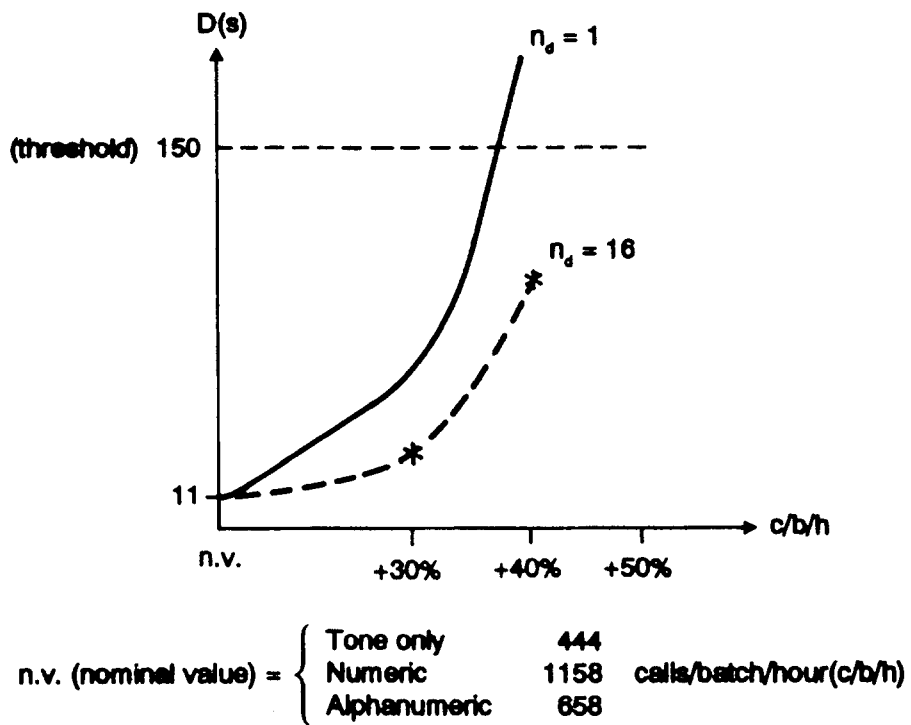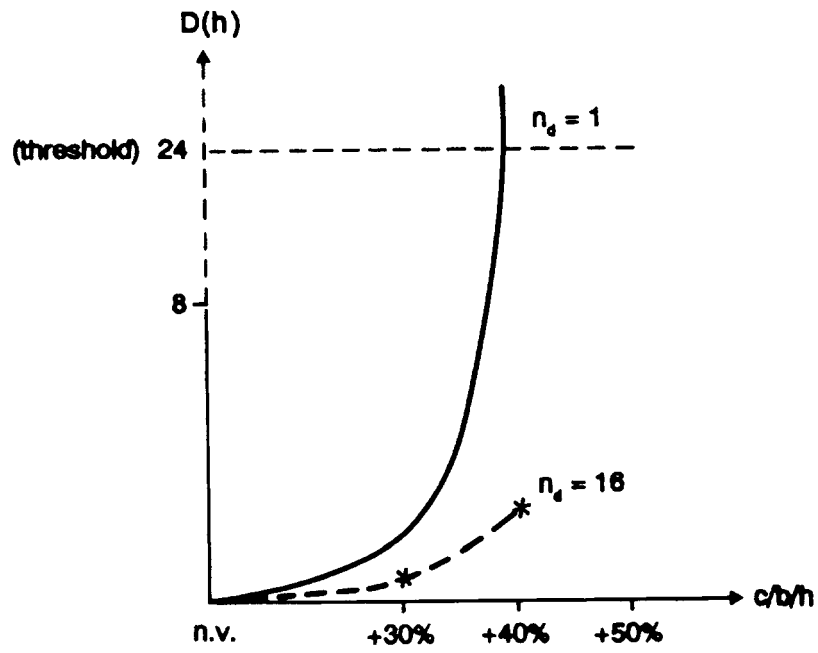[B2] n_d is applied for the message part of the batch only.

PRIORITY 1

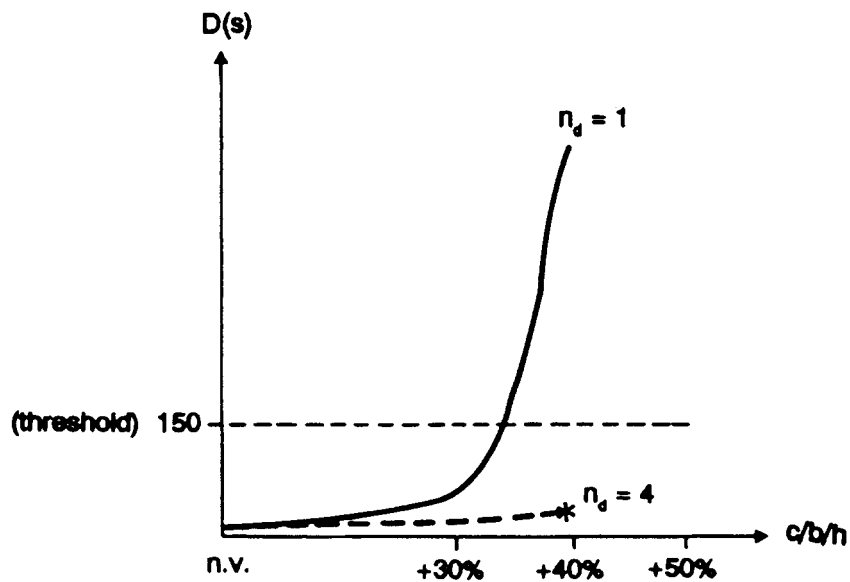n.v. (nominal value) = { Tone only   444
                         Numeric   1158   calls/batch/hour(c/b/h)
                         Alphanumeric   658

Figure B.3

PRIORITY 2

n.v. (nominal value) = { Tone only   444
                         Numeric   1158   calls/batch/hour(c/b/h)
                         Alphanumeric   658

Figure B.4

$$n.v. \ (nominal \ value) = \begin{cases} Tone \ only & 444 \\ Numeric & 1158 \\ Alphanumeric & 658 \end{cases} \quad calls/batch/hour(c/b/h)$$

Figure B.5

PRIORITY 1

$$n.v. \ (nominal \ value) = \begin{cases} Tone \ only & 444 \\ Numeric & 1158 \\ Alphanumeric & 658 \end{cases} \quad calls/batch/hour(c/b/h)$$

Figure B.6

History

Document history	
July 1992	First Edition
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