REPORT 900-2

RADIO-PAGING SYSTEMS

Standardization of code and format

(Question 12/8, Study Programme 12A/8)

(1982-1986-1990)

1. Introduction

An urgent need was expressed by some administrations for a standard code and format which could be used for systems due to enter service in the immediate future. Recommendation 584 is intended to provide advice and help to such administrations but this Report supplements the information.

2. Information on existing codes

2.1 The Swedish radio-paging system is an addition to the radio data system (RDS), recommended for the transmission of information to facilitate station or programme selection in FM receivers (see Recommendation 643). The system has been used for radio paging in Sweden since 1978. It uses a 57 kHz subcarrier on VHF/FM broadcasting transmitters. The modulation method and the code and format are specially designed to be compatible with the broadcast monophonic and stereophonic programmes. A paging address comprises six decimal digits. After that may follow an additional message, either numeric with 10 or 18 decimal digits, or alphanumeric with unlimited length [CCIR, 1978-82a, 1982-86a]. Details can be also found in Annex II.

2.2 Documents submitted by the United States of America describe a binary digital code and format with a single address capacity of up to 400 000 with non-coded battery saving and 4 000 000 with coded preamble. The code uses a Golay (23 : 12) cyclic code with two codewords representing an address. Messages are encoded using a BCH (15 : 7) code. The code and format provide queueing and numeric/alphanumeric message flexibility and ability to operate in a mixed mode of transmission with other formats. The details of this code and format are contained in Annex I [CCIR, 1978-82b; 1982-86b].

2.3 Japan uses a BCH (31 : 16) codeword with a Hamming distance of 7. The format gives approximately 65 000 addresses, 15 groups for battery economy and a total cycle length of 4185 bits. Each group includes 8 address codewords headed by a 31-bit synchronizing and group indicating signal [CCIR, 1978-82c].

2.4 The United Kingdom employs a BCH 32 : 21 plus even parity codeword with a Hamming distance of 6. The code format caters for over 8 million addresses and can be expanded. It also caters for any type of data message (hexadecimal and CCITT Alphabet No. 5 are already standardized). It is designed to share a channel with other codes and to permit mixed simultaneous and sequential multi-transmitter operation at the normal (512 bit/s) data transmission rate [CCIR, 1978-82d]. This code, sometimes referred to as POCSAG, has been adopted as CCIR Radio-Paging Code No. 1 (RPC1) (Recommendation 584).

2.5 Radio-Paging Code No.1 is also used for National paging services in Australia, Finland, New Zealand and the People's Republic of China, as well as in United States where numerous other codes and formats are currently in use.

2.6 France has implemented a public paging system in 1987 using Radio-Paging Code No. 1 and allowing, in particular, the transmission of alphanumeric messages. These messages, of up to 80 characters, are sent using "Minitel" home terminals (several millions of such terminals being available at PSTN subscriber premises). This service, called "Alphapage", also caters for the transmission of alerting tones, and numeric messages of up to 15 digits can also be sent out using DTMF telephone sets (CCITT Recommendation Q.23).

3. Factors affecting standardization

Report 499 in § 4 identifies the need to standardize the signalling format and points out that the choice of the appropriate coding technique should take into account the required capacity of code combinations, the speed of transmission, call success rate and lowest practicable false calling rate. In addition the code should be designed to allow for transmission of various types of messages (for example, single address, multiple address, address plus numeric message, address plus alphanumeric message) and should easily share a channel with other codes.

Other factors which will need to be considered are interrelated. For example the number of subscribers to be served, the number of addresses which they require, the traffic generated, including that due to the transmission of messages and the signalling rate that is technically feasible. In some cases this last may be determined by the linking land line network characteristics, particularly when simultaneous radio transmission is employed, as well as by the radio system characteristics.

The choice of a code and format cannot be made without considering the system in which they are to be used. Certain codes and formats are capable of operating in a variety of systems but this does not apply to all.

4. Considerations of different codes and formats

4.1 In the choice of a standard code and format the following system requirements are considered important and should be taken into account:

- the number of subscribers to be served;
- the number of addresses assigned to each subscriber;
- the calling rate expected including that from any included message facility;
- the zoning arrangements;
- the data transmission rates possible over the linking network and radio channel(s), taking account of the propagation factors of the radio frequencies to be used;
- the type of service, e.g. vehicular or personal, urban or rural;
- the acceptable queueing delay.

4.2 From considerations of the above, codes may be compared by their characteristics in respect of:

- Code address capacity;
- Number of bits per address;
- Code efficiency, e.g. number of information bits/total number of bits, per codeword;
- Codeword Hamming distance;
- Error detecting capability;
- Error correcting capability;
- Message capability and length;
- Battery saving capability;
- The ability to share a channel with other codes;
- The capability of meeting the needs of participating administrations with systems varying in respect of size, transmission mode, e.g. simultaneous and/or sequential, etc.

4.3 The various characteristics of coding systems described in the documents summarized in § 2 appear in Table I below.

5. Address capacity

Report 499 includes an estimate made by France that the available overall capacity on a national scale for radio-paging receivers should be at least 20 per 1000 inhabitants.

Assuming that particular national systems and international paging use the same code and format on a common frequency then the address capacity required may be large. On the other hand, if different formats and/or frequencies are chosen then the address capacity requirements could be smaller.

Further studies on the capacity required are needed urgently.

6. Additional information concerning Radio-Paging Code No. 1 (Recommendation 584)

Recommendation 584 provides details of Radio-Paging Code No. 1 but the following additional information may be useful in connection with the requirements for receivers to operate in systems using this code. [CCIR, 1978-82e].

6.1 *Loss of synchronization*

If a receiver loses synchronization, or if it commences receiving after the preamble has been completed, it is desirable that it can achieve synchronization on receipt of a number of valid batches.

6.2 *Decimal representation of pager identities*

A decimal representation of the pager identity might be useful. If so, it is suggested that it should be the decimal equivalent of the 21 bit identity.

6.3 *Message reception, display and alerting*

6.3.1 *End of message*

It is desirable that the pager ceases decoding a message when either an idle or address codeword is received or when two successive information codewords are indecipherable, even if they immediately follow a message indicating pager address.

6.3.2 *Minimum message storage capacity*

Some form of storage will be necessary for pagers which do not provide a printed output. It is suggested that the minimum storage capacity in pagers designed for the "numeric-only" format should be 20 characters and for the "alpha-numeric" format, 40 characters.

TABLE I – *Characteristics of different codes and formats*

Characteristics	Sweden	United States	RPC1	Japan
Codeword related characteristics: Codeword type	Kasami 26 : 16 Truncated cyclic code	Golay 23 : 12 (address) BCH 15 : 7 (message)	BCH 32 : 21 plus 1 bit even parity	BCH 31 : 16
Hamming distance	3 (Note 1)	7 (address) 5 (message)	6	7
Codeword error detection capability per word (Note 5)	Burst: 10 errors Random: 2 errors	Burst: 11 errors, Random: 6 errors } address Burst: 8 errors, Random: 4 errors } message	Burst: 11 errors Random: 5 errors	Burst: 15 errors Random: 6 errors
Codeword error correction capability per word (Note 5)	Burst: 5 errors Random: 1 error	Burst: 5 errors, Random: 3 errors } address Burst: 4 errors, Random: 2 errors } message	Burst: 5 errors Random: 2 errors	Burst: 7 errors Random: 3 errors
Codeword efficiency (No. of information/ total codeword bits) (Note 9)	16/26 = 0.62	12/23 = 0.52 (address) 7/15 = 0.47 (message)	21/32 = 0.66	16/31 = 0.52
System related characteristics: Code address capacity	1×10^6	409 600 non-coded preamble Over 4 000 000 coded preamble (Note 3)	Over 8×10^6 (Note 4)	65 000
Number of bits per address	52	60.5	32 (+ 3 implied) + 2 overhead + preamble	34.9 (Note 7)
System bit rate (bit/s)	1187.5	300/600 (address) (Note 2) 600 (message)	512	200
System message capability and length	Decimal, 18 digits; alphanumeric, unlimited	Dual address, 4 functions, numeric and alphanumeric: length indefinite when asynchronous	4 addresses per identity: unlimited message length, hexadecimal or alphanumeric	Dual address
Battery saving feature and type	Call grouping. Other information transmitted	Yes	No transmission. Other codes in transmission (Note 6)	Call grouping into 15 groups
Ability to share a channel with other codes	Yes	Yes	Yes	No
Suitability of format to simultaneous and/or sequential transmission	Simultaneous: yes Sequential: not relevant to system as implemented in Sweden	Yes	Yes	Yes
Radio channel in use	FM Broadcasting 87.5-104 MHz	VHF and UHF mobile 150 MHz, 450 MHz, and 800 MHz	VHF mobile 150 MHz (Note 10)	VHF mobile 250 MHz
In service since	1978	1973 (address) 1982 (message)	(Notes 8 and 10)	1978

Notes relative to Table I

Note 1. – Out of the 2600 possible 3-bit error patterns, 7 will convert any valid codeword to another valid codeword. There are known to be also some 4- and 5-bit error patterns which have the same effect.

Note 2. – The transmission system must be able to transmit the 1/2 bit duration signals at double rate, i.e. 600 bit/s.

Note 3. – With known means of expansion.

Note 4. – Although as implemented the code and format provide for more than 8×10^6 addresses, compatible methods of expansion are known.

Note 5. – The higher the error detection the greater is the protection against false calls and false messages. Conversely greater error correction will tend to increase the call success rate at the expense of protection against false calls.

The actual values of error correction and detection depend not only upon the codeword structure but also upon each particular design of receiver and upon the code and format.

Note 6. –

Transmission condition	Battery saving method
No transmission	Sampling to establish the presence of preamble
Other codes	Discrimination by chosen bit rate
Code and format	Grouping calls

Note 7. – This takes account of the 31 overhead bits shared between 8 calls in a group.

Note 8. – In service in the United Kingdom since 1980; subsequently brought into service in Australia, Finland and New Zealand, and in experimental service in the People's Republic of China.

Note 9. – Not equal to overall efficiency, which is affected by format.

Note 10. – Radio-paging services in the United States in use on 150, 450 and 900 MHz bands; also public radio-paging services in use in the People's Republic of China on 160 MHz in 1985.

6.3.3 *Alerting tones*

6.3.3.1 The following repeated alerting tone patterns as shown in Table II are suggested:

TABLE II

Function Bit Combination	Alerting Tone
00	1 beep
01	2 beeps
10	3 beeps
11	4 beeps

6.3.3.2 When digital message pagers are used the following repeated alerting tone patterns as shown in Table III are suggested:

TABLE III

Function Bit Combination	Following Message Type	Alerting Tones
00	Numeric-only	1 beep
01	No message	2 beeps
10	No message	3 beeps
11	Alphanumeric	1 beep

Thus the recipient will expect only a single beep irrespective of the type of message.

7. Comparison of codes

7.1 *Comparison by simulation*

7.1.1 In Italy both the radio paging Code No. 1 (RPC1) and Golay code are used for the public radio-paging system. In order to control environmental parameters, e.g. propagation, that affect any measurement programme, it was decided to compare the RPC1 and Golay codes by laboratory simulation and to verify this simulation by some field measurements. A computer-aided comparison between the two codes was carried out [CCIR, 1982-86c]. Performances for both address and message reception (numeric and alphanumeric) were evaluated for two radio channel models (Gaussian and Rayleigh fading).

The results indicated that, for message success rate per paging attempt, the Golay code has a better performance with respect to 1 bit error correction per code word of RPC1 and almost the same performance with respect to the foreseen RPC1 2 bit error correction algorithm under these channel conditions. The results for 1 bit error correction are summarized in Table IV in which the performances are presented in terms of S/N(RPC1) – S/N (Golay) (dB) in order to obtain the same (95%) success level per paging attempt.

TABLE IV – *Code performance comparison (dB)* (see text)

Type of signal	Channel		
	Gaussian	Rayleigh at 5 km/h	Rayleigh at 40 km/h
Alert	0.6	1	3
10 character numeric message	1	4	8.5
80 character alphanumeric message	1	8	11

For the criteria of a false message conditioned by a sucessful call, results are shown in Figs. 1 and 2. They indicate that with the 2 bit error correction algorithm of RPC1 the probability of obtaining a false message is highest, that the probability for Golay is less and that for RPC1 with 1 bit error correction is least.

7.1.2 The United States believes that the additional field tests it has carried out confirm these laboratory simulations [CCIR, 1982-86d].

7.2 *Comments on the comparison*

7.2.1 In order to obtain the equivalent results by means of field measurements it would be necessary to mount a large measurement programme, especially to distinguish results that are close to one another.

7.2.2 A bad impression of the service might be given to a subscriber who receives a false message following a successful alert; and thus the curves in Figs. 1 and 2 are of particular interest. The translation of the data from these curves into the terms suggested in Report 499, taking into account also Fig. 3, needs study. Significant pre-knowledge of the likely message content often exists, and this may ameliorate this user impression.

7.2.3 In order to identify the consequences on system planning criteria, study is needed to determine how to weight the simulation results by factors such as time spent in marginal situations.

Field tests carried out in the United Kingdom on an RPC1 alphanumeric pager utilizing a 1 bit error correction algorithm gave the sensitivity decrease between an alert and an 80 character message for a success rate of 90% as approximately;

$$3.2 + 0.055\ W \qquad \text{(dB)}$$

where W was the percentage of time spent *walking* at least 5 km/h inside a single room in each of two buildings and the streets beside one of them [CCIR, 1982-86e].

7.2.4 Message reception with new decoding methods (hard and soft decision) for both RPC1 and Golay has not yet been fully explored [CCIR, 1982-86f].

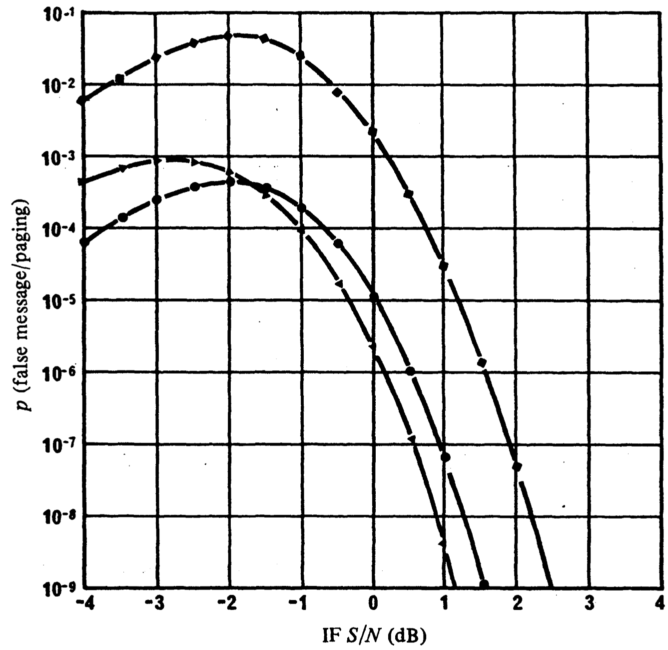


FIGURE 1 – *False numeric message rate (10 figures), conditioned to the probability of associated address reception, for a pager moving in a Gaussian channel*

POCSAG (1 bit correction)
POCSAG (2 bit correction)
GSC

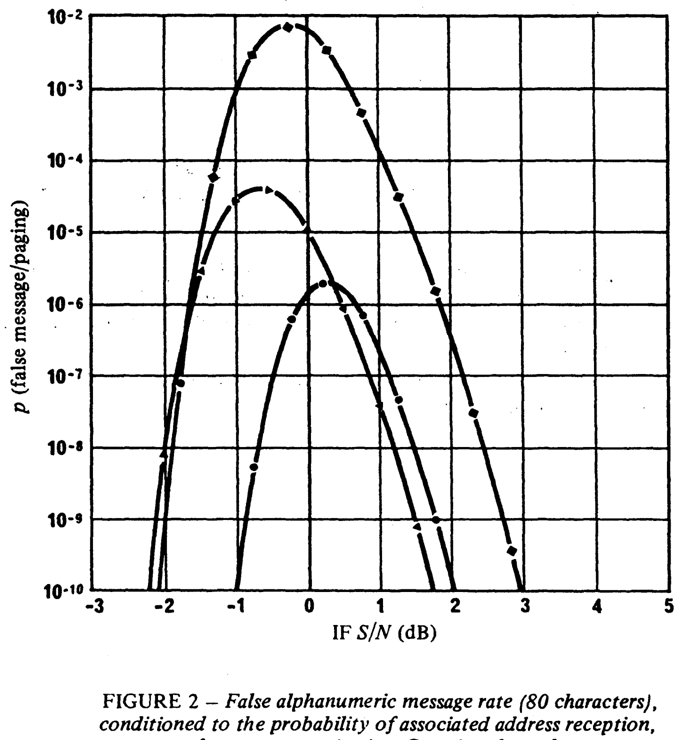


FIGURE 2 – *False alphanumeric message rate (80 characters), conditioned to the probability of associated address reception, for a pager moving in a Gaussian channel*

POCSAG (1 bit correction)
POCSAG (2 bit correction)
GSC

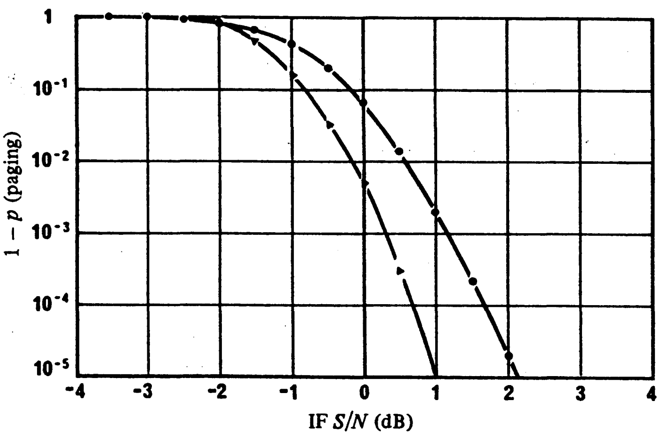


FIGURE 3 – *Paging failure rate, for a pager moving in a Gaussian channel*

—•— POCSAG
—◂— GSC

8. Conclusions

In order to reach agreement on a universal standard signalling format it is highly important to carefully identify the common bases for comparing codes and formats, taking into account the system requirements given in § 4.

However, agreement on a standard code and format will only be truly effective in international paging when agreement is also reached on radio channel assignments and modulation techniques, and on the method(s) for transferring calls between the systems in the participating countries.

REFERENCES

CCIR Documents

[1978-82]: **a.** 8/63 (Sweden); **b.** 8/82 (USA); **c.** 8/210 (Japan); **d.** 8/112 (United Kingdom); **e.** 8/397 (United Kingdom).

[1982-86]: **a.** 8/417 (Sweden); **b.** 8/112 and 8/113 (USA); **c.** 8/446 (Italy); **d.** 8/375 (USA); **e.** 8/447 (United Kingdom); **f.** 8/295 (United Kingdom).

Note. – Statement by the United Kingdom concerning the POCSAG Radio-Paging Code: The members of the Post Office Code Standardisation Advisory Group (POCSAG) have stated that they would refrain from making any patent claims for the code itself (as distinct from any means of transmitting or receiving it). So far as they are concerned, the code is free of charge for use by any administration or other service provider, manufacturer or user.

For information, solely for its own purposes British Telecom has had a reasonably thorough patent search carried out without discovering any patent which the code might infringe.

ANNEX I

GOLAY SEQUENTIAL CODE

1. Introduction

Golay paging codes are those codes that use as their basis a binary code discovered by Marcel Golay. The basic code has 23 bits, 12 of which are information bits. This code is used in a binary paging format generally characterized by 300 baud NRZ data. The original Golay code, in service since 1973, has an uncoded preamble and supports up to 400 000 individul pager addresses; it is briefly described in § 2.5. Subsequently, the Golay paging format was expanded to include data and a coded preamble, and it is entitled the Golay sequential code (GSC). The GSC code supports up to 4 million addresses and is compatible with the older Golay paging code under certain address restrictions. Some forms of GSC support voice operation also but are not discussed in this Annex.

2. Signalling format

The GSC code format allows paging calls to be transmitted individually or in batches. Transmission begins with a preamble followed by a start code and a single address or a batch of addresses as illustrated in Fig. 4. The polarity of the preamble identifies the transmission mode (single call or batch). The preamble also serves to divide the population of pagers within the system into groups for improved battery life, as well as to uniquely identify GSC transmissions. The start code delimits the end of the preamble and supplies timing information for batch mode decoding, and the address identifies the individual pager.

In the implementation of the code, a positive frequency shift represents a binary "1", and a negative frequency shift represents a binary "0".

2.1 *Batch operation*

The batch transmission format, as shown in Fig. 4, begins with an inverted preamble followed by the start code and up to 16 pager addresses or data blocks. The arriving paging requests should be grouped as a function of preamble code and transmitted on a time or traffic basis as required for the system.

Unfilled batches should be filled out with comma (see § 2.3). A new preamble batch, however, may be initiated after 11 addresses of the preceding batch have been transmitted or 3.85 s has elapsed since the start of the preceding batch. In message paging, a message (not an address) may be started at the 17th address block or before and may be continued until completion.

2.2 *Extended batch*

As defined herein, a preamble and start code must be transmitted with each additional 16, or equivalent, addresses sent. This differs from some Golay implementations which allow batch extension through the use of start code repeat only.

2.3 *Preamble, start code, and address structure*

The preamble, start code, and address codes are constructed from words selected from the Golay (23 : 12) cyclic code and transmitted at 300 bit/s.

A 1, 0 bit reversal pattern or comma transmitted at 600 bit/s acts as a separator between preamble, start code, and address. One comma bit is half the length of an address bit and identical in length to a message or data bit.

2.3.1 *Preamble structure*

The preamble as shown in Fig. 4 consists of 28 bits of comma followed by 18 repeats of the selected preamble word (ten preambles divide the population of pagers into battery saver groups). The starting polarity of the comma must be the same as the first bit of preamble. As previously noted, an inversion or complement of the preamble and its associated comma bits identifies the batch mode of transmission. The normal polarity of the preamble words is tabulated in Table V (least significant bit (LSB) to the right), and the preamble words are transmitted LSB first. The decimal representation of the information binary bit pattern is tabulated in column 2 of Table V.

TABLE V – *Preamble words*

Preamble number	Decimal	Binary bit pattern	
		Parity	Information
0	2030	10000000011	011111101110
1	1628	00001111110	011001011100
2	3198	11000001001	110001111110
3	647	01111111000	001010000111
4	191	00001111010	000010111111
5	3315	00000111001	110011110011
6	1949	00011110000	011110011101
7	2540	01000001111	100111101100
8	1560	01111111001	011000011000
9	2335	11100010001	100100011111

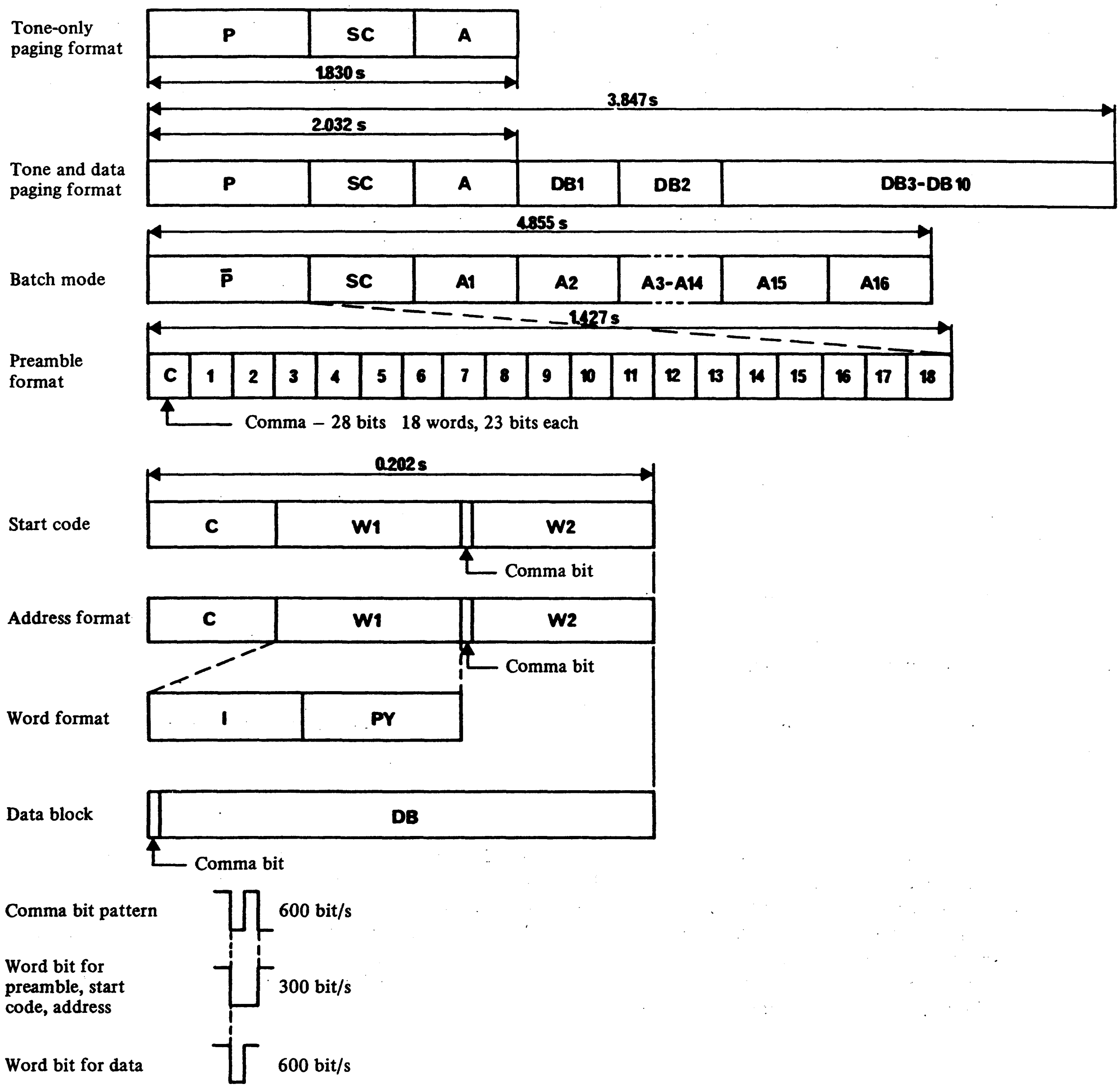


FIGURE 4 – *Golay sequential code format*

P : preamble
SC : start code
A : address
DB : data block (8 (15 : 7) BCH code words)
C : comma – 28 bits
W1 : start code or address word 1-23 bits
W2 : start code or address word 2-23 bits
I : information – 12 bits
PY : parity – 11 bits

2.3.2 *Start code*

The start code and address codes use a two-word format consisting of 28 bits of comma followed by two (23 : 12) code words separated by one comma bit. The starting polarity of the 28 bit comma must be the same as the first bit of the first word and the polarity of the single comma bit between words must be opposite to that of the second word. The start code is fixed for the system, and its Word 2 is the complement of its Word 1. The start code Word 1 is:

Start code	Decimal	Binary bit pattern	
		Parity	Information
Word 1	713	01000000011	001011001001

The start code format permits the pager's decoding circuitry to detect either the start code Word 1 or Word 2 and identify which pattern was detected, thus maximizing start code detection sensitivity.

2.3.3 *Address code*

The address format is identical to the start code format with regard to the number of bits and the rules for comma. The address Word 2 code set consists of all (23 : 12) code words except for all 0's, all 1's, and all cyclic rotations of the start code. Thus, there are approximately 4000 Word 2's. There are 100 first words (50 words and their complements) used in the GSC system. Fifty words are determined by table look-up (Table VI), and the remaining 50 are achieved by complementing the tabulated words. The Word 1 and Word 2 code words for each pager address may be derived from the pager code (see § 3).

TABLE VI – *Address Words 1's*

Word No.	Decimal	Word No.	Decimal	Word No.	Decimal	Word No.	Decimal	Word No.	Decimal
00	721	10	2692	20	2285	30	375	40	1575
01	2731	11	696	21	2608	31	1232	41	3463
02	2952	12	1667	22	899	32	2824	42	3152
03	1387	13	3800	23	3684	33	1840	43	2572
04	1578	14	3552	24	3129	34	408	44	1252
05	1708	15	3424	25	2124	35	3127	45	2592
06	2650	16	1384	26	1287	36	3387	46	1552
07	1747	17	3595	27	2616	37	882	47	835
08	2580	18	876	28	1647	38	3468	48	1440
09	1376	19	3124	29	3216	39	3267	49	160

2.3.4 *Multi-function address capability*

The two-word format of the GSC address code contains a built-in multi-function capability. There are four possible Word 1/Word 2 combinations that can be easily detected (see § 3.3). These combinations are used to designate the type of page (tone-only or data). Each pager in the GSC system is assigned at least one four-function address.

2.4 *Code word generation 23 : 12 Golay*

To generate the binary bit patterns for the (23 : 12) Golay code, the decimal representation of the code word is converted to binary. This binary representation is rewritten LSB to the left. These 12 information bits (there may be leading or trailing 0's) now correspond to the coefficients of a polynominal having terms from x^{22} down to x^{11}. This polynominal is divided, modulo 2, by the generator polynominal $x^{11} + x^9 + x^7 + x^6 + x^5 + x + 1$. The parity bits correspond to the coefficients of the terms from x^{10} to x^0 in the remainder polynominal found at the completion of this division. The complete block, consisting of the information bits followed by the parity bits, corresponds to the coefficients of a polynominal which is integrally divisible in modulo 2 fashion by the generator polynominal.

2.5 *Non-battery saver operation*

The older Golay format was based on decoding of the address words independently of any preamble or start code information. This non-battery saver operation is the simplest transmission mode and achieves the highest throughput; however, this form of operation reduces pager battery life and lacks address expansion.

In non-battery saver operation, the coded preamble and start code are not used; only the pager addresses need to be transmitted for tone only paging. However, it is suggested that a preamble consisting of a 1, 1, 0, 0 pattern (75 Hz square wave) be transmitted for at least 1.25 s after transmitter turn-on. Following the simple 75 Hz preamble, any number of consecutive paging calls may be transmitted. Any of the standard preambles can be used in place of the 75 Hz preamble.

When older Golay pagers and GSC pagers are mixed in a system, the address (Word 1, Word 2 combination) independent of the preamble must not be repeated, as is allowed in GSC only systems. Data pagers are also allowed in non-battery saver systems.

2.6 *Data paging*

A data paging consists of a pager address followed by one or more data blocks of alphanumeric characters. A data block is identical in length to an address block and may be freely substituted for addresses in the batch operating mode. The single call mode can also be used by following the pager address with the data message. Data information is transmitted at 600 bit/s using a (15 : 7) BCH code.

2.6.1 *Data block definition*

A data block consists of 8 BCH (15 : 7) code words. The data block structure is defined in Fig. 5; each block consists of 56 information bits and 64 parity bits. A single comma bit opposite in polarity to the first data bit transmitted is added at the start of each message block to make the data block identical in length to an address block.

Transmission on the channel starts with the comma bit followed by the least significant bit (LSB) of Word 1, then the LSB of Word 2 ... LSB of Word 8 then jumps back to the second bit of Word 1, etc. Assembling the data block code words by rows and then transmitting on the channel by columns protects against burst errors.

The method for embedding the information into the data block is shown in Fig. 5. One bit of the data block is used as a continue bit, and 7 bits are used for a block check character to minimize undetected message errors. The continue bit has been assigned the following meaning: a "1" indicates additional data blocks to follows, and a "0" indicates the end of message.

For ease in implementing the block check character, the 7 information words of 7 bits each of each (15 : 7) code word are added together (arithmetically), and the least significant 7 bits of the sum form the block check character.

Partially filled message blocks should be filled out with NULL characters.

2.6.2 *Symbol assignment*

The character sets for use in the numeric and alphanumeric systems are defined in Table VII. In the numeric system, information is assigned on the basis of 4 bits per symbol, and in an alphanumeric system, 6 bits per symbol are used. The numeric set includes the numeric digits (0-9), as well as all necessary control and punctuation characters. The shifted numeric set allows certain alphanumeric designators to be inserted within the numeric data. The alphanumeric set is a slight variation of the ASCII or ISO international 7 bit code with bit number 6 set equal to 1 and not transmitted. Modifications are made to this basic set only to allow insertion of the needed control characters. It is expected that the pagers themselves will display the lower case alphas as upper case alphas.

	Parity								Information						
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1									2	2	2	1	1	1	1
2									4	4	3	3	3	3	2
3									6	5	5	5	5	4	4
4									7	7	7	7	6	6	6
5									9	9	9	8	8	8	8
6									11	11	10	10	10	10	9
7									C	12	12	12	12	11	11
8									S	S	S	S	S	S	S

First bit

Check sum

Continue bit

12 character numeric data block

	Parity								Information						
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1									2	1	1	1	1	1	1
2									3	3	2	2	2	2	2
3									4	4	4	3	3	3	3
4									5	5	5	5	4	4	4
5									6	6	6	6	6	5	5
6									7	7	7	7	7	7	6
7									C	8	8	8	8	8	8
8									S	S	S	S	S	S	S

First bit

Check sum

Continue bit

8 character alphanumeric data block

FIGURE 5 – *Data block structure*

TABLE VII – *Numeric and alphanumeric character assignments*

Alphanumeric set						Unshifted (basic) numeric set	Shifted numeric set
	7	0	0	1	1	No applicable	No applicable
Bits (1)	5	0	1	0	1	No applicable	No applicable
4321							
0000		Space	0	\	p	0	A
0001		!	1	a	q	1	B
0010		"	2	b	r	2	C
0011		#	3	c	s	3	D
0100		$	4	d	t	4	E
0101		%	5	e	u	5	Space
0110		&	6	f	v	6	F
0111		'	7	g	w	7	G
1000		(	8	h	x	8	H
1001		)	9	i	y	9	J
1010		*	:	j	z	Null	Null
1011		+	;	k	{	U	L
1100		,	<	l	CR/LF	Space	N
1101		–	=	m	}	–	P
1110		.	>	n	Null/EOM	≡	R
1111		/	?	o	Spare	Shift or (E) (2)	Spare

(1) Bit No. 6 never sent.
(2) (E) is displayed by pagers not employing the shifted numeric set.

2.6.3 *Number of data blocks per message*

It is sugggested that numeric messages be limited to 2 data blocks (24 characters) and that alphanumeric messages be limited to 80 characters or 10 data blocks. A data message may follow the last address in a 16 address batch transmission and may be continued until completion.

2.6.4 *Code word generation (15 : 7) BCH code*

The generator polynominal for the (15 : 7) code is $x^8 + x^7 + x^6 + x^4 + 1$. The parity information for this code is calculated in the same fashion as was done for the (23 : 12) code. The information bit pattern is divided by the generator polynominal, modulo 2 and the parity bits are the remainder from this division.

3. Pager code structure

The pager code is a six-digit decimal number followed by a series of function digits from which the address Word 1, Word 2 and preamble information can be derived. The pager code digits are defined as follows:

I	G1 G0	A2 A1 A0	f
Preamble index	Group	Address	Function digits

The range of assigned codes is 00001 ⩽ G1 G0 A2 A1 A0 ⩽ 99999. The sixth digit (I) is used to expand the number of address codes from 100 000 to 1 000 000. The range of the preamble index is 0 ⩽ I ⩽ 9. If the letter N is used in place of the preamble index number, non-battery saver operation is specified. The function digits indicate which address functions are active for any particular pager and what type of page is represented by each function. Up to four function digits may be assigned to each pager code. In the basic large system code plan, at least one pager code is assigned per pager in a sequential fashion starting with 000001.

3.1 *Algorithm for obtaining the preamble, Word 1 and Word 2 information from the pager code*

In order to transmit a page to any pager, the preamble, Word 1 and Word 2 information must be derived from the pager code. To obtain this information, follow the flow diagram outlined in Fig. 6. For example, the preamble, Word 1, and Word 2 information for the pager code 954853 is as follows:

- the preamble number = 3 (see Table V);
- the Word 1 number = 4 (see Table VI);
- the Word 2 decimal = 1753. Convert 1753 to binary and calculate the parity information obtaining the following:

Decimal	Parity	Information
1753	00010101101	011011011001

The actual polarity of the transmitted bit patterns is determined by the function digit discussed in § 1.3 and whether the single call or batch transmission mode is to be used.

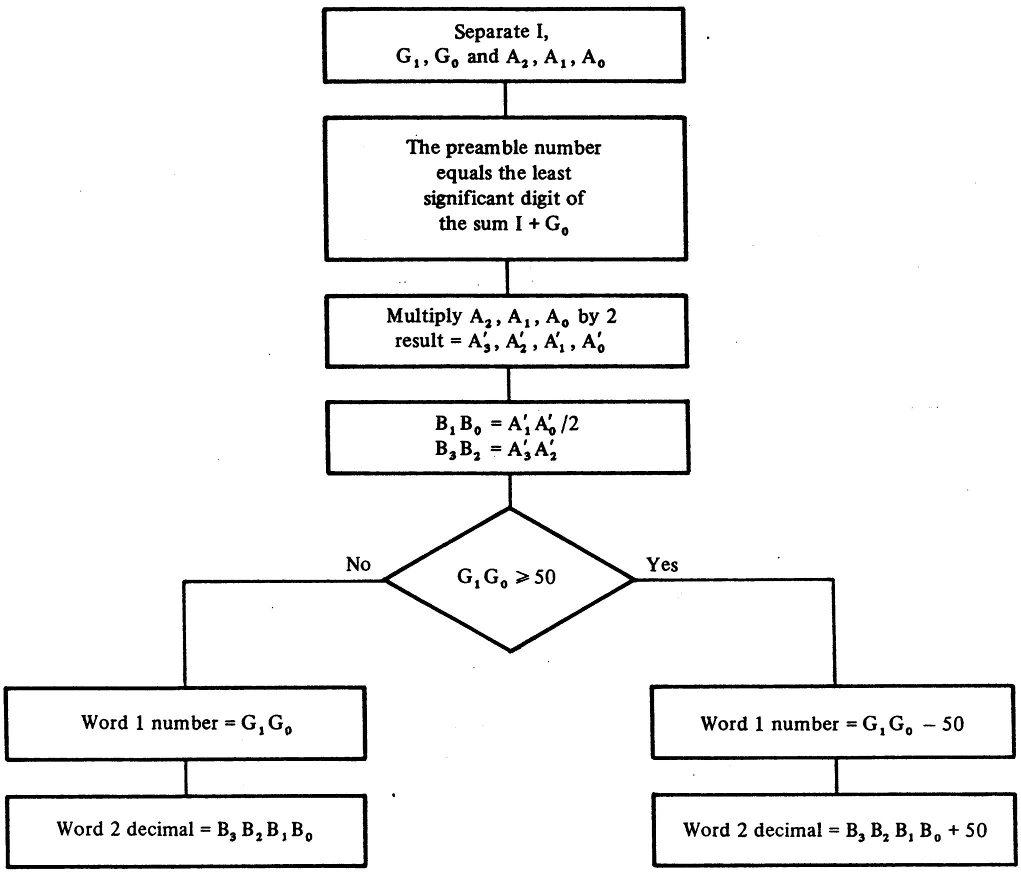


FIGURE 6 – *Algorithm for obtaining preamble, Word 1 and Word 2 information from the pager code*

3.2 *Pager code restrictions*

Since the start code is included within the range of address Word 2's, some assignable pager codes must be eliminated to prevent a false start code detection. These illegal codes are listed in Table VIII.

TABLE VIII – *Illegal pager codes*

If G_1 G_0 equals	Then do not allow A_2 A_1 A_0 to equal
00-49	000, 025, 051, 103, 206, 340, 363, 412, 445, 530, 642, 726, 782, 810, 825, 877
50-99	000, 292, 425, 584, 631, 841, 851

3.3 *Function digit assignment*

The GSC code allows four functions to be assigned to each independent pager address. In turn, each address function may be assigned independently to 1 of 2 page types (tone only or data). The f digit suffix is a means for making this assignment. Table IX relates address function (Word 1 and 2 polarity) with page type and function digit.

TABLE IX – *Function assignment (non-voice)*

Address function	Binary word format	Function suffix (f)	
		If page type is data, f =	If page type is tone only, f =
1	W1 W2	5	9
2	W1 $\overline{\text{W2}}$	6	0
3	$\overline{\text{W1}}$ W2	7	3
4	$\overline{\text{W1}}$ $\overline{\text{W2}}$	8	4

ANNEX II

RADIO PAGING USING THE RADIO DATA SYSTEM (RDS)
ON FM BROADCAST TRANSMITTERS

1. Introduction

This Annex describes the additional characteristics of the radio data system (RDS) as defined in Recommendation 643 when it is used to combine FM broadcasting with radio paging.

2. Modulation and baseband coding [EBU, 1984; Swedish Telecommunications Administration, 1976]

The modulation of the data channel and the baseband coding including message format are in accordance with Recommendation 643.

3. Additional characteristics for paging [EBU, 1984; Swedish Telecommunications Administration, 1976]

3.1 *General*

3.1.1 Group type 4A, clock-time and date (CT), is transmitted at the start of every minute.

3.1.2 Group type 1A, programme-item number (PIN), is transmitted at least once per second. The five last bits of its block 2 (spare bits) are used as follows:

- bits B4-B2 :3-bit transmitter network group designation;
- bits B1-B0 :battery saving interval synchronization and identification.

3.1.3 Group type 7A is used to convey the paging information.

3.2 *Transmitter network group designation*

The first three bits of the five spare bits of block 2 of group type 1A are used to designate the transmitter network to a group of pager group codes. Pagers not belonging to the designated group codes must not lock to the transmitter.

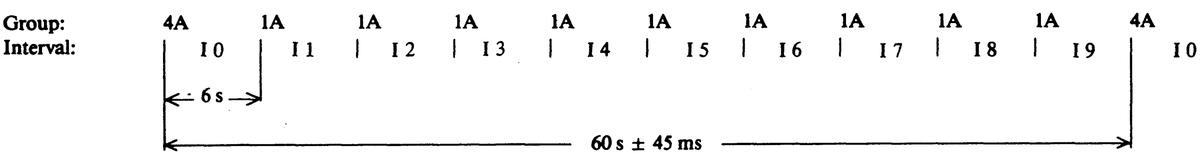
The group designations are as follows:

B4	B3	B2	Group codes	Number of group codes
0	0	0	No paging on channel	
0	0	1	00-99	100
0	1	0	00-39	40
0	1	1	40-99	60
1	0	0	40-69	30
1	0	1	70-99	30
1	1	0	00-19	20
1	1	1	20-39	20

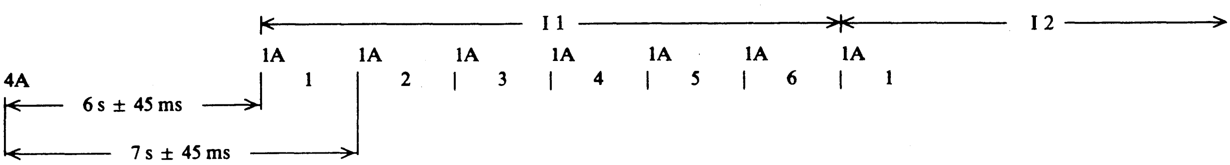
The transmitter network group designation makes it possible to distribute the paging calls over one to four networks, e.g. several networks during day-time and a single network during night-time. The number of group codes in each network are shown below for the different number of networks in operation.

Number of transmitter networks	Number of group codes respectively
1	100
2	40/60
3	40/30/30
4	20/20/30/30

3.3 *Transmission sequence (battery saving)*



Timing within intervals:



1A number within interval	1	2	3	4	5	6	1
Bit B1	1	1	0	0	0	0	1
Bit B0	0	J3	J2	J1	J0	1	0

For battery saving purposes, each minute is divided into 10 intervals of equal length (I 0 ... I 9). Each paging receiver belongs to the interval corresponding to the last digit of its individual code (digit 0 belongs to I 0 and so on). Paging calls are placed within the interval corresponding to the last digit or within the two intervals following that interval.

To enable the receivers to synchronize to the correct interval, the last two bits, B1 and B0, of the spare bits of block 2 of group type 1A are used. The start of an interval is indicated by the transmission of two 1A groups with B1 = 1 (in interval I 0 the first IA group is replaced by 4A). The first 1A (or 4A for I 0) group is transmitted at the start interval and the other 1 s later. Accuracy is ± 45 ms in relation to the medium time of the preceding 4A group. Within an interval at least 3 more 1A groups are transmitted (bit B1 = 0). Bit B0 of 1A groups number 2, 3, 4 and 5 is used to sequentially transmit the four bits J3 J2 J1 J0 of the BCD-coded interval number 0 ... 9. Excessive 1A groups within an interval have their bit B0 = 1.

The receiver may enter battery saving mode after start of its interval:

- if at least 10 groups differing from group type 7A have been received, or
- if a paging call, belonging to an interval different from the receivers' own and the two preceding intervals, has been received, or
- after the start of the third interval after its own interval.

The receiver shall be considered to have lost its interval synchronization:

- if there is a paging call within the receivers' own interval to a receiver not belonging to the interval or the two preceding intervals, or
- if an error-free reception of the interval marking (J3 J2 J1 J0) is not the one expected.

(Checking of J3 J2 J1 J0 is not necessary each time the receiver leaves battery saving mode.)

3.4 *Locking to a channel*

3.4.1 The receiver searches for one of the offset words A ... D. When this is found, it searches for the next expected offset word at a distance of $n \times 26$ bits, $n = 1 \ldots 6$. When two offset words have been found, the receiver is synchronized to both block and group.

After block and group synchronization, the receiver must find the correct country code (within the PI-code) and group designation of the transmitter network.

3.4.2 When scanning the frequency band, block and group synchronization must occur within 1 s and correct country code and group designation must be found within 2 s after block and group synchronization. Otherwise the receiver must leave the channel.

3.4.3 When locking to the channel after battery saving mode, block and group synchronization and the reception of correct country code and transmitter group designation must occur within 15 s. Otherwise the receiver shall leave the channel.

3.4.4 For quick scanning, the information about alternative frequencies in group type 0A may be used.

3.5 *Loss of synchronization*

3.5.1 Clockslip may be detected by using the fact that the program identification (PI) code is very seldom altered. By calculating the syndrome for this block and the block shifted plus/minus one bit, it is possible to see whether clockslip has occurred. If the information becomes correct after a one bit shift, it is considered that a clockslip has occurred, all received data is shifted accordingly and the receiver is correctly synchronized.

3.5.2 When 43 out of the last received 45 blocks have a syndrome different from zero (for the respective offset words), the channel locking is lost and the reeiver shall scan the band for a better channel.

3.5.3 If the group code of the receiver is no longer in accordance with the transmitter group designation code, the receiver shall leave the channel and scan the band for a new channel.

3.6 *Group type 7A message format*

3.6.1 *General*

Group type 7A:

Block 1	Block 2	Block 3	Block 4
PI ***	TP PTY ***	Paging ***	Paging ***
Offset A	Offset B	Offset C	Offset D

Block 2 bit map:

0 1 1 1 : 0		TP	PTY	AB : T3 T2 T1 T0	*Checkword*
7	A	Paging A/B		Text segment address code	

Block 1 comprises the PI code found as the first block of every RDS group type. Blocks 3 and 4 are used for paging information.

In block 2 the five last bits are used to control the paging information. Bit AB, paging A/B, is used as a flag which changes its value between different paging calls thus indicating the start of a new call. Bits T3-T0 are used as a 4-bit text segment address code and to indicate the type of additional message that follows:

T3	T2	T1	T0	
0	0	0	0	no additional message,
0	0	1	X	10 digit numeric message
0	1	X	X	18digit numeric message
1	X	X	X	alphanumeric message

X indicates state 0 or 1.

3.6.2 *Paging without additional message*

Group type 7A:

Block 1	Block 2	Block 3	Block 4	
PI ***	7A TP PTY ***	Y1Y2 Z1Z2 ***	Z3Z4	n.u. ***

Block 2 bit map:

0 1 1 1 : 0		TP	PTY	AB : 0 0 0 0	*Checkword*
7	A	Paging A/B		Text segment address code	

Text segment address code: 0 0 0 0

Y1Y2	denote the group code
Z1-Z4	denote the individual code within the group
Yn and Zn	denote BCD-coded digits 0 . . . 9
n.u.	8 last bits of block 4 not used.

3.6.3 *Paging with additional numeric message*

The additional numeric message is transmitted in 1 or 2 7A groups following the first 7A group of the call. Other group types may be transmitted in between:

Other group types	7A group 1	Other group types	7A group 2	Other group types	7A group 3

Third 7A group only transmitted in case of an 18 digit message.

7A group 1:

PI ***	7A TP PTY ***	Y1Y2 Z1Z2 ***	Z3Z4 A1A2 ***

7A group 2:

PI ***	7A TP PTY ***	A3A4 A5A6 ***	A7A8A9A10 ***

7A group 3 (only with 18 digit message):

PI ***	7A TP PTY ***	A11A12A13A14 ***	A15A16A17A18***

Block 2 bit map:

0	1	1	1	0	TP	PTY	AB	T3	T2	T1	T0	*Checkword*
7				A	Paging A/B			Text segment address code				

The text segment address code is used to indicate the contents of blocks 3 and 4 in respective groups:

T3	T2	T1	T0	Contents of blocks 3 and 4
				10 digit message:
0	0	1	0	Group and individual code Y1Y2 Z1-Z4 plus message digits A1-A2.
0	0	1	1	Message digits A3-A10.
				18 digit message:
0	1	0	0	Group and individual code Y1Y2 Z1-Z4 plus message digits A1-A2.
0	1	0	1	Message digits A3-A10.
0	1	1	0	Message digits A11-A18.

Y1Y2 denote the group code

Z1-Z4 denote the individual code within the group

Yn and Zn denote BCD-coded digits 0 . . . 9.

A1-A18 denote the numeric message.

An denotes a binary coded hexadecimal digit 0 . . . A.

Hexadecimal A is used to indicate a blank position in the message.

– A new call is marked by the altering of the "paging A/B" flag.

3.6.4 *Paging with additional alphanumeric message*

The additional message is transmitted in consecutive 7A groups. Other group types may be transmitted in between:

Other group types	7A group 1	Other group types	7A group 2	Other group types	7A group 3	. . . etc.

7A group 1:

PI ***	7A TP PTY ***	Y1Y2 Z1Z2 ***	Z3Z4	n.u. ***

Following 7A groups:

PI ***	7A TP PTY ***	Cm – Cm + 1 ***	Cm + 2 – Cm + 3 ***

Each of the groups contains 4 characters coded in 8 bits each.

Block 2 bit map:

0 1 1 1 :	0	TP PTY	AB : T3 T2 T1 T0	*Checkword*
7	A	Paging A/B	Text segment address code	

The text segment address code is used to indicate the contents of blocks 3 and 4 in respective groups:

T3	T2	T1	T0	Contents of blocks 3 and 4
1	0	0	0	Group and individual code Y1Y2 Z1-Z4.
1	0	0	1	Message characters Cn – Cn + 3.
1	0	1	0	Message characters Cn + 4 – Cn + 7.
1	0	1	1	Message characters Cn + 8 – Cn + 11.
1	1	0	0	Message characters Cn + 12 – Cn + 15.
1	1	0	1	Message characters Cn + 16 – Cn + 19.
1	1	1	0	Message characters Cn + 20 – Cn + 23.
1	1	1	1	End of alphanumeric message.

Text segment address code is repeated cyclically 1001 . . . 1110 for every 24 characters of the message transmitted (n is increased by 24 for each cycle).

End of message is indicated by the transmission of text segment address code 1111 or a new call (indicated by the altering of the "paging A/B" flag).

Maximum length of message is 80 characters.

Y1Y2	denote the group code
Z1-Z4	denote the individual code within the group
Yn and Zn	denote BCD-coded digits 0 . . . 9.
Cn	denotes a message character coded in 8 bits.
n.u.	8 last bits of block 4 of Group 1 not used.

REFERENCES

EBU [1984] Specifications of the radio data system RDS for VHF/FM sound broadcasting. Doc. Tech. 3244. European Broadcasting Union, Technical Centre, Avenue Albert Lancaster 32, B-1180 Brussels, Belgium.

SWEDISH TELECOMMUNICATIONS ADMINISTRATION [1976] Specifications for paging receivers. Doc. 1301-A6943798. Swedish Telecommunications Administration, S-123 86 Farsta, Sweden.