Tech. 3260-E

Guidelines for the implementation of the RDS system

european broadcasting union

January 1990

geneva

GUIDELINES FOR THE IMPLEMENTATION OF THE RDS SYSTEM

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CONTENTS

Chapter 1

Scope of the Guidelines

Since the RDS Specification doc. Tech 3244 (March 1984) was issued, the Radio Data System has been introduced in the large majority of West European countries. In the first stage of this implementation only the static features supporting the automated tuning process, essentially for car radios, were used. The only dynamic feature that many broadcasters used in the initial introduction phase was the traffic announcement feature TA. In many countries studies are being made on how the dynamic features can be utilized. Their introduction is more difficult, because, as such information is generally programme-related, data links will be required from the broadcast studio to the transmitter sites at which RDS encoders have been installed. In some countries (Germany, F.R.) the cost for such data links is still rather prohibitive so that the dynamic features will not be implemented rapidly, in other countries (United Kingdom and Sweden) the distribution of the dynamic RDS features is already technically feasible (and is already implemented for test purposes), and the problem of using them in the daily programmes is rather a matter of organizing this on the operational side within the broadcast studios, which is not an easy matter either.

When the RDS Specification was finalized in the EBU, work on RDS has of course continued, and much of it was carried out with the view to exchange experience on how RDS would be implemented in the various countries and what particular problems had to be solved in this context. Often this required extensive coordination with the RDS receiver and encoder manufacturing industry which resulted in a number of conventions often published by way of the RDS Newsletter of the EBU, and also in a pre-print of Chapter 4 of this publication, already in January 1988.

The present document is the result of extensive work carried out in the framework of EBU Specialist Group R/RDS. The members of this Group were practically involved in all further enhancements and conventions agreed in the context of RDS. This document therefore reflects considerable experience gathered within Europe in the context of implementing the Radio Data System since 1984.

Many meetings were held to formulate these "Guidelines" and the text published now has been drawn up to include all the recent developments so far known in the EBU. Broadcasters and industry should therefore carefully consult relevant parts of these "Guidelines" to ensure that they operate in full conformity with all the conventions agreed here.

The document is structured in four Chapters. Chapter 2 will mainly be of interest to broadcasters and encoder manufacturers; it explains a number of operational requirements relating to the installation of RDS at the transmitter sites. Chapter 3 gives on the contrary a lot of background information on the reliability of RDS data reception, the performance of the error correction and detection mechanism, its limits and advice for the receiver manufacturer to exploit the capabilities in an optimum way within the receiver. Extensive field trials made essentially in Germany, F.R., the United Kingdom and also Sweden provide further background about the good performance of RDS within the existing broadcasting coverage areas and also about the influence of various data injection levels required to achieve compatibility with already existing auxiliary signals, such as ARI.

Chapter 4, giving "Guidelines" on how to implement the various features, is perhaps the most important part of this publication. The text initially published as a pre-print has been considerably extended. The most important changes relate to more intelligent use of the PI code and AF Method B in the case where broadcasters split networks during daily broadcasts, especially to include regional programming. Another extension of the text relates to the Enhanced Other Networks information feature which will be very important for new generations of car radios. A receiver model is developed in this text offering the designer a clear concept for future development and testing in those countries that will implement the new EON feature first, i.e. the United Kingdom and Sweden. The broadcaster will also find important advice in Chapter 4 on how best to implement one or both of the two AF methods, A and B, and examples are given of how the coding should be implemented, and how the AF lists should be structured. For the receiver manufacturer such information will be beneficial as well since it provides clearer knowledge on the acquisition time required for alternative frequencies used for the automated tuning process. Finally, Chapter 4 also contains important information on the limited data transmission capacity offered by the RDS system. The problem is presented in such a way that it can easily be seen why it is impossible to implement all RDS features simultaneously in the same RDS channel and on the same programme. It becomes obvious that new, not yet defined, features will require a careful assessment of their loading of the RDS channel before agreement can be reached on specifying their transmission protocol.

As far as the RDS Specification doc. Tech 3244 of March 1984 is concerned, it is important to realise that four Supplements have so far been issued by the EBU, forming an integral part of the Specification. These are:

Supplement 1 (March 1987):	Protocols for the transmission of Alternative Frequencies
Supplement 2 (July 1988):	Radio Paging
Supplement 3 (July 1988):	Revision of Appendix 6 - Programme Type Codes
Supplement 4 (April 1989):	Enhanced Other Networks information

In the years 1988 and 89 the EBU experts were also involved in the European standardization organization CENELEC in transcribing the RDS Specification of the EBU to a European Standard (EN 50 067, January 1990). It is expected that the final version of this standard will be issued in summer 1990. It incorporates the four Supplements mentioned above and a large number of the conventions explained also in this document. Once CENELEC has adopted the RDS Standard in final form, the EBU will of course re-print it as a complete up-date and revision of the original RDS Specification which therefore in the following chapters will be always referred to as EBU doc. Tech 3244/CENELEC EN 50 067.

Chapter 2

Guidelines for the broadcaster

2.1 Modulation characteristics

In order to assure the proper performance of the RDS system, some additional information related to the modulation characteristics of the RDS signal may be found helpful.

2.1.1 Phase relation between the RDS subcarrier and the third harmonic of the pilot-tone

According to the Specification, the phase relationship between the broadcast pilot-tone and the RDS subcarrier must be fixed at either:

a) $0° \pm 10°$,
or b) $90° \pm 10°$.

In cases where the ARI system is transmitted from the same transmitter as RDS, the quadrature phase relationship (b) must be used for the RDS subcarrier in order to minimize interference between the ARI and RDS signals. In other cases the choice is left to individual broadcasters.

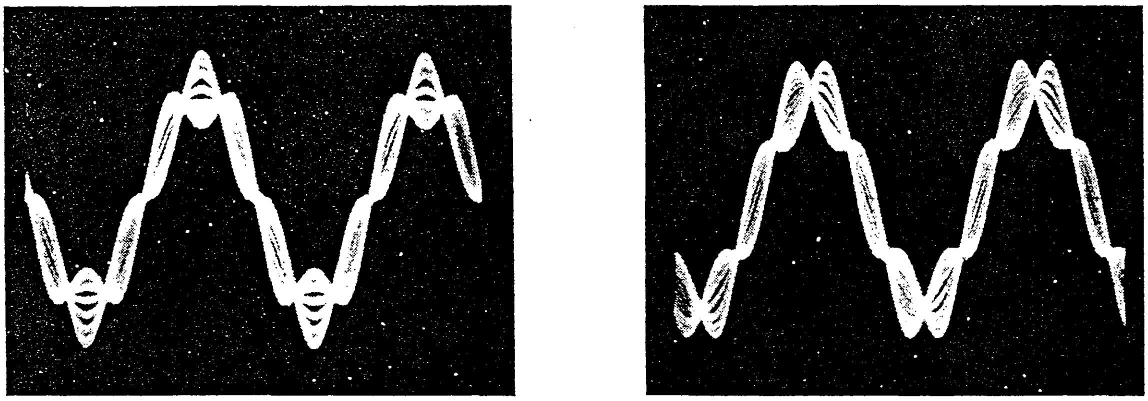
The correct phase relationship between the pilot-tone and the RDS subcarrier for the in-phase case (a) can easily be checked by using an oscilloscope to view the combined pilot-tone and RDS subcarrier modulated at ± 2 kHz deviation. The phase-error is minimized if a symmetrical figure is achieved on the oscilloscope with the time-base synchronized with the pilot-tone. Examples of the correct phase relationship are given in *Fig. 2.1a* and *b* for the in-phase case (a) and the quadrature case (b), respectively; the corresponding display with a phase-error of approximately 10° is shown in *Fig. 2.2a* and *b*. If the subcarrier phase is correctly adjusted for the in-phase case, then it may be possible to select the quadrature phase relation simply by moving an internal link in the RDS encoder, without further adjustment.

According to the RDS Specification (doc. Tech. 3244/CENELEC EN 50 067) the phase relation between the ARI and the RDS subcarriers may have a maximum error of ± 10°. In order to minimize possible mutual interference, however, this error should be kept as small as possible.

2.1.2 Deviation of the FM carrier due to RDS

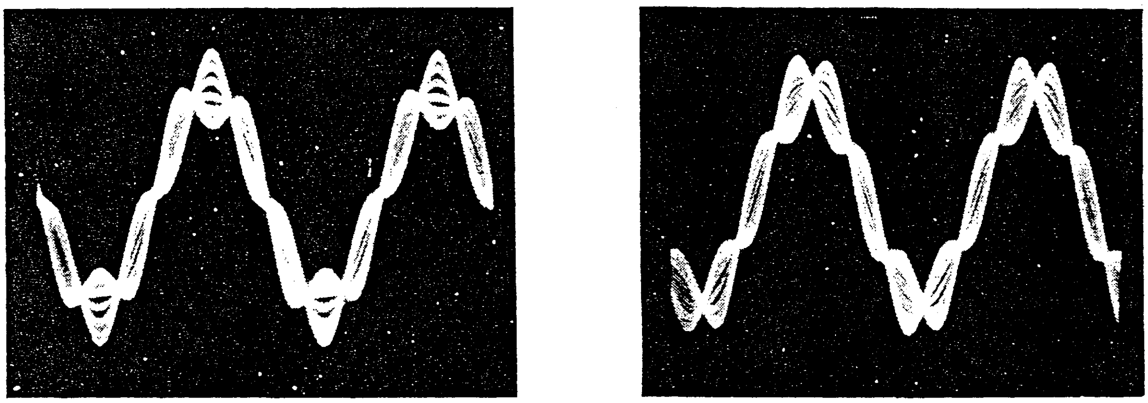
The preferred nominal deviation of the FM carrier by the RDS signal, as stated in the Specification, is:

± 2.0 kHz.



a : In phase *b:* In quadrature

Fig. 2.1: Waveform obtained at multiplex output with only 19 kHz and 57 kHz present.



a : In phase *b:* In quadrature

Fig. 2.2: Waveform obtained at multiplex output with only 19 kHz and 57 kHz present, but with a phase-error of approximately 10°

If, however, RDS is used simultaneously with the ARI traffic broadcast identification system, then the recommended nominal deviation of the main carrier is:

± 1.2 kHz due to the RDS signal,

± 3.5 kHz due to the unmodulated ARI subcarrier.

In this case the tolerance for the RDS deviation is ± 200 Hz.

In those countries which use the ARI system, the deviation due to RDS signals should be restricted to ± 1.2 kHz even for those transmitters which do not broadcast ARI signals. This is to avoid false activation of ARI decoders. As discussed in some greater detail in Chapter 3, this has, of course, an impact on the reliability of data reception.

To measure the deviation of the RDS signal, it should preferably be set to 'all-zeroes' data which leads to the maximum deviation. In the absence of a special measurement device the deviation may most easily be determined by comparison with the voltage levels of a signal which leads to a known deviation. This may most conveniently be done using an oscilloscope.

2.1.3 Spectrum shaping and time-function (of baseband)

The spectrum and the time-function of a transmitted single biphase symbol is shown in Figs. 4a and 4b of the Specification. Formulas for the spectrum and time function have been derived from the Specification and are presented below:

Spectrum of biphase coded radio-data signals

The baseband equivalent spectrum is given by

$$|U(f)| = 2\sin\left(\frac{\pi f t_d}{2}\right) \cdot \cos\left(\frac{\pi f t_d}{4}\right) \qquad -2/t_d \leqslant f \leqslant 2/t_d$$

$$= 0 \qquad \text{otherwise,}$$

where $1/t_d = 1187.5$ Hz

Time-function of a biphase symbol

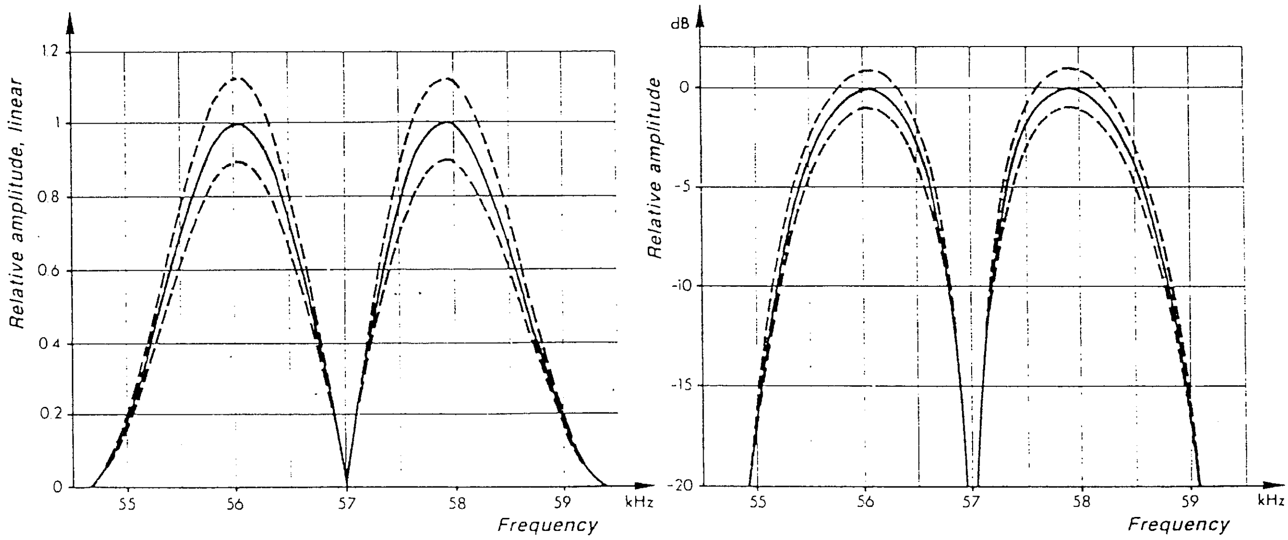
$$u(t) = \pm \frac{3}{4} \cos(4\pi x) \left(\frac{1}{1/X - 64X} - \frac{1}{9/X - 64X}\right) \qquad -\infty < t < \infty$$

where $X = t/t_d = t \cdot 1187.5$
and t is time expressed in seconds.

The spectrum of the modulated transmitted RDS signal should have a tolerance less than ± 1 dB (within the band ± 2.4 kHz centred on 57 kHz).

The asymmetries between upper and lower sidebands should be less than ± 0.5 dB.

A plotted tolerance mask for the spectrum of the modulated subcarrier relating to the baseband spectrum of Fig. 2.4a of the Specification is given in *Fig. 2.3a* and *b* below.



a : Relative amplitude, linear

b: Relative amplitude, dB

Fig. 2.3: The RDS amplitude spectrum, showing ± 1 dB tolerance mask.

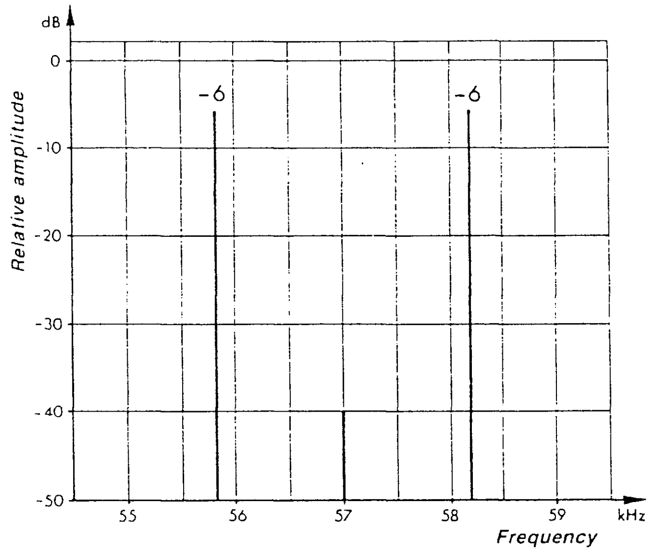


Fig. 2.4: Minimum suppression of the subcarrier relative to nominal output level. The modulation is an "all-zeroes" data stream.

The 57 kHz subcarrier should be suppressed by more than 40 dB with respect to the nominal output level corresponding to ± 2 kHz deviation, see *Fig. 2.4.*

Accurate spectrum-shaping can easily be achieved in RDS encoders by using digital techniques to generate the shaped biphase symbols directly.

2.1.4 Permissible levels of spurious sidebands at the output of the RDS encoder

In most installations the auxiliary input terminal via which RDS signals are added to the composite multiplex signal is wideband. Therefore any spurious sidebands or noise present at the output of the RDS encoder will degrade the quality of the broadcast sound-programme signal. Accordingly, it is recommended that the levels of these unwanted emissions should comply with the following specification:

— In the region below 53 kHz:

less than - 96 dB relative to a signal deviating the transmitter ± 75 kHz.

— In the region above 53 kHz:

less than - 86 dB relative to a signal deviating the transmitter ± 75 kHz.

It should also be recognized that distortions in the stereo encoder and/or transmitter equipment may also lead to unwanted crosstalk between the RDS data-signal and the main sound-programme signal (see Section 2.4).

2.2 Interface requirements

The basic configuration of the RDS source equipment at the transmitter is given in *Fig. 2.5*, and a more detailed configuration of the RDS encoder is shown in *Fig. 2.6*. When RDS encoders are introduced into existing transmitter systems the interfacing constraints will be imposed mainly by the existing equipment.

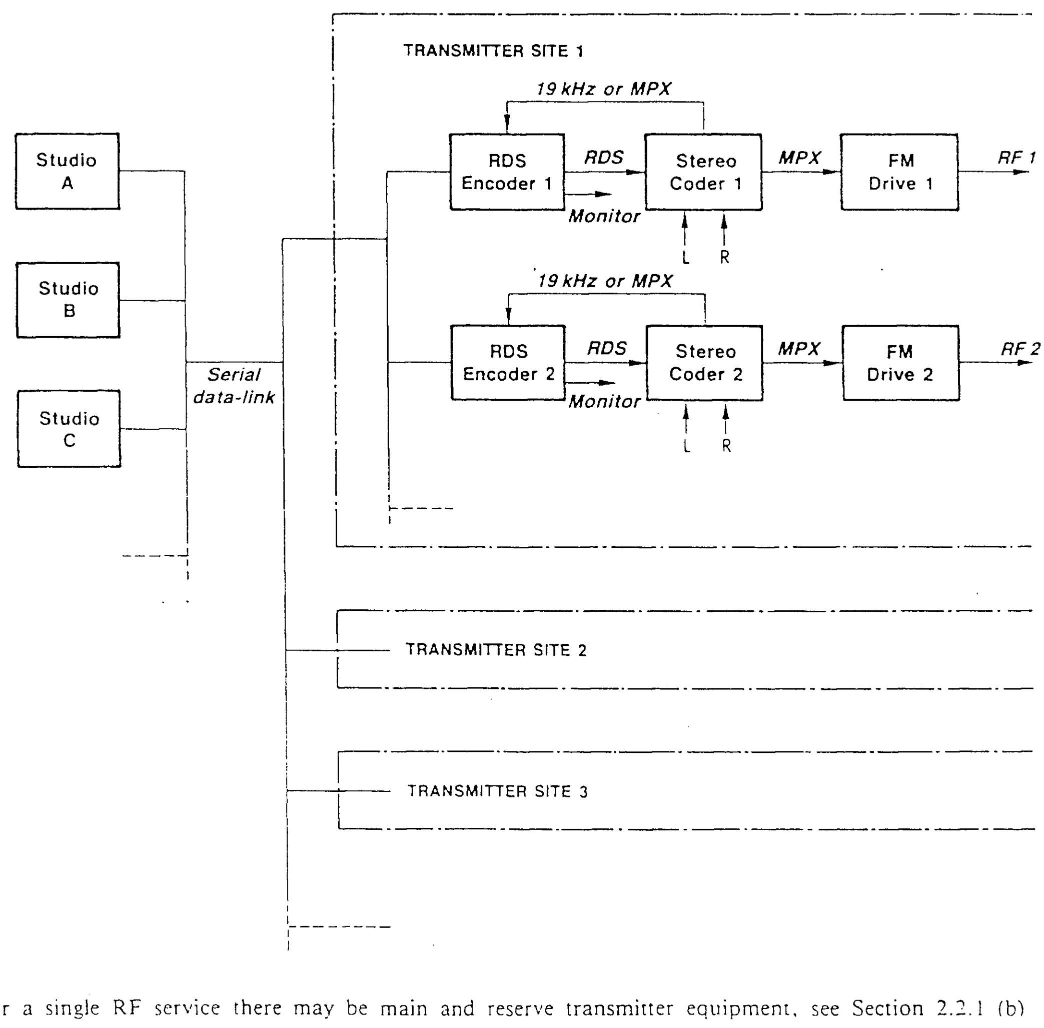
2.2.1 Synchronization of the 57 kHz subcarrier

a) Some stereo encoders do not have an output of their 19 kHz pilot-tone; in such instances the composite multiplex signal must be used as the phase-reference. This will require the RDS encoder to be able to extract the necessary phase information from such a composite signal, using, for example, a standard commercial stereo decoder integrated circuit.

b) In the interests of economy, in some installations only one RDS encoder may be used to supply both the main and reserve transmitter equipments. In this case it will be found more convenient to derive the necessary pilot-tone reference signal from the latter stages of the transmitter so that the RDS encoder is always referenced to whichever stereo encoder is on the air.

c) A simple way of selecting the in-phase or quadrature-phase locking (19/57 kHz) should be provided.

d) For monophonic transmissions, the RDS encoder will have to generate the 57 kHz subcarrier.



Note: For a single RF service there may be main and reserve transmitter equipment, see Section 2.2.1 (b)

Fig. 2.5: Typical RDS installation and data-link showing interface requirements.

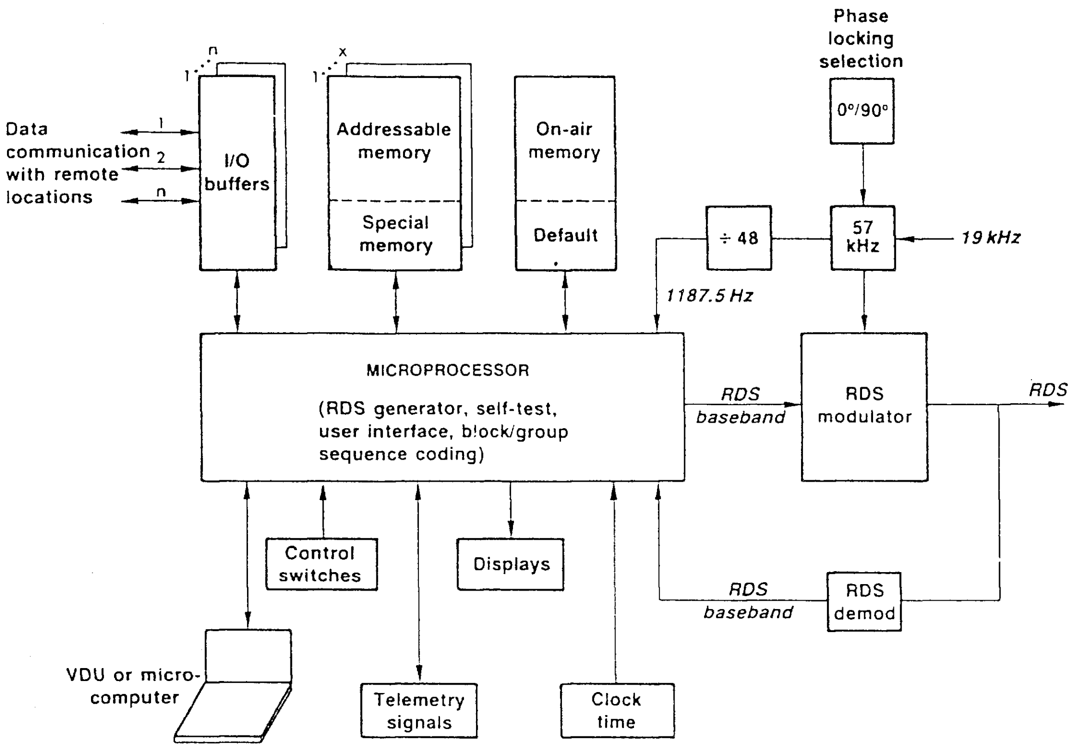


Fig. 2.6: RDS encoder block diagram.

2.2.2 Encoder output

a) The RDS signal input to the transmitter may be either an auxiliary input to the stereo encoder or an auxiliary input to the FM drive itself. In either case, however, note should be taken that if this auxiliary input is wideband, noise or other disturbances added via this input will degrade the quality of the main sound programme signal. To avoid this it is preferable to use a rather insensitive auxiliary input, and carefully screen the interconnections with the RDS encoder.

b) The RDS signal level should be adjustable between 0 and 1 Volt.

c) For monitoring purposes, the RDS encoder should preferably supply more than one output.

2.2.3 Data input

a) In many broadcasting organizations it will not be possible to provide a two-way data-link between the studio centre and the RDS encoder at the transmitter. The RDS encoder should therefore be capable of accepting up-date information without the need for a return path to the studio centre.

b) To economize on the provision of data-links, it may be necessary to up-date several encoders fed in parallel via a single data-link, even though the data for the separate encoders may originate from different areas within the studio centre. This implies that the encoders must be addressable (see also Section 2.5).

c) Since the data-link provided for the RDS information may be particular to the broadcasting network concerned, it is expected that special-purpose equipment may be needed to interface with these data-links. However, this would be made easier if a standard protocol and connector were adopted (e.g. CCITT Specification V.24 and RS 232) for the data input to the encoder.

d) In some installations the RDS encoder will need to accept data from more than one source, for example, when broadcasts do not necessarily originate from one studio centre and also when radio paging is implemented. To assist with such cases the RDS encoder should preferably have several addressable data inputs, each with an associated control and priority system. Examples for achieving this are given in *Appendices 1* and *2* of *Chapter 2.*

e) Clock-time and date, if broadcast, should be accurate and provision should therefore be made to synchronize the internal RDS clock-time generator with an external standard.

f) In addition to the normally connected data paths, an additional data input should be provided for local pre-setting and data maintenance via a standard data terminal or a micro-computer. To make this procedure user-friendly, the corresponding software has to be provided for setting the order of group types and the repetition rates of various features, creating AF lists according to Method A or B, etc.

2.2.4 Control interface

a) To enable the encoder to be connected to the telemetry systems used for control purposes in transmitter installations, a suitable connector is required. This may be used to provide an alarm output when incorrect functioning of the RDS encoder is detected.

2.3 Physical considerations

Attention is drawn to the fact that RDS encoders will often be installed at unattended transmitter sites. This implies the following constraints:

a) The encoder should never need manual resetting after an interruption to the electricity supply. Thus all essential data must be stored in ROM, or in non-volatile (or battery-backed) RAM. Furthermore, the use of a separate "watch-dog" circuit to monitor and if necessary reset the microprocessors is recommended.

b) Careful attention should be paid to the need to operate with non-standard supply voltage waveforms or transients resulting in particular from the use of standby-generator equipment.

c) Consideration should be given to the need to mount the RDS encoder in existing equipment bays; in particular this may require that the RDS equipment does not impede the flow of cooling air.

d) Possibilities for amending encoder software for expansion and maintenance should be provided.

e) Given the fact that broadcasters may not make use of certain options, RDS encoders should be designed in modular form so that the suitable options may be chosen as required. This would concern in particular an ARI module and options for paging, clock time and date functions and also in-house applications.

f) Encoders should preferably contain test programs for self-diagnosis (signature analysis, etc.).

2.4 Transmitter specifications for RDS

The principal additional parameters which need to be checked when assessing or specifying the performance of main station transmitters, rebroadcast transmitters or transposers from which it is intended to broadcast RDS signals are:

— Amplitude/frequency response in the region 54 kHz to 60 kHz.

— Group delay/frequency response in this region.

— Non-linear distortion (intermodulation and spurious signals).

The first two items will affect the performance of RDS data decoders, whilst the third item may affect both the quality of the main sound-programme signal reproduced by all receivers, and reliability of reception of the data signal.

Regarding amplitude/frequency response, reference should be made to the RDS spectrum tolerance mask given in Section 2.1. Particular attention should be paid to the cumulative effects along long chains of transposers, especially regarding RDS injection-level and amplitude/frequency slope across the bandwidth of the RDS signal.

Similarly, group delay/frequency aberrations may be cumulative along chains of transposers. In this case, however, the difficulty of measuring the relevant group delay/frequency response must be recognized, and this parameter is perhaps better assessed in terms of its effect on the eye-pattern (see below).

Non-linear distortions may produce two effects:

a) Distortion products (most notably in the region of 2.4 kHz resulting from the difference frequency between the upper and lower sidebands of the RDS signal) may cause disturbance to the reception of the main sound-programme signal (i.e. intermodulation from RDS to the sound-programme signal).

b) Distortion products which fall within the RDS data channel (i.e. harmonics of, or intermodulation products from, the sound-programme signal) which reduce the reliability of reception of the RDS signal. This may occur because of band-limiting of the FM signal (e.g. in receivers or transposers) or because of phase distortion or multipath.

It is recognized that existing transmitter installations may have to be accepted in these respects. However, it may be found helpful to refer to *Table 2.1* which gives figures relevant to these parameters measured on a transmitter network which has already successfully implemented RDS.

Table 2.1
Example specification for a transmitter network with RDS

	Main transmitter station	Rebroadcast receiver	Transposer
Amplitude/frequency response (53 kHz to 60 kHz) relative to level at 500 Hz	± 0.5 dB	± 0.5 dB (1)	± 0.5 dB (1)
Intermodulation products (in the band 15 to 75 kHz relative to ± 75 kHz deviation) 2nd order products 3rd order products	 – 50 d b – 46 d b	 – 46 dB (2) – 42 dB (2)	 – 60 dB – 44 dB
Spurious modulation expressed as signal-to-noise ratio after demodulation and decoding relative to ± 75 kHz deviation measured in audio bandwidth (4)	*Mono* unweighted: – 65 dB weighted: – 71 dB *Stereo* unweighted: – 59 dB weighted: – 65 dB	 – 65 dB (3) – 71 dB (3) – 65 dB (3) – 65 dB (3)	 – 65 dB – 65 dB – 65 dB – 65 dB

Notes:

(1) The cumulative effect of tolerances on all channels in the chain should be such that the spectrum of the broadcast RDS signal should still fit the mask given in Section 2.1.

(2) 15 to 53 kHz, above 53 kHz this is not yet specified.

(3) For available RF input power of 23 dB(pW) for mono, 43 dB(pW) for stereo.

(4) Quasi-peak values measured according to CCIR Recommendation 468.

As with the broadcasting of teletext in a television channel, the overall quality of the broadcast RDS data signal may be readily assessed by inspection and/or measurement of its eye-pattern, as recovered by a professional receiver/demodulator. At present no specialized measuring equipment exists for this purpose.

An alternative simple approach to the overall assessment of the quality of the broadcast RDS signal involves inserting a variable attenuator into the aerial input feed of a professional RDS receiver/decoder. The attenuation is then increased until an error-rate threshold (e.g. 1 in 10^3) is reached. The equivalent aerial input signal strength may then be measured and/or calculated. This may then be compared with that expected from theory for an ideal receiver/decoder (see *Chapter 3*).

2.5 Network aspects

The distribution of RDS source-data from studio centres to transmitters requires that the following aspects be considered:

a) The compilation of messages within the studio centre.

b) The provision of data-circuits to the transmitters.

c) The accommodation of local or regional splitting from national programme networks.

d) The response-time involved between originating an RDS message at the studio-centre and its broadcast.

Detailed consideration of the compilation of messages within the studio-centre lies outside the scope of this document but, in general, it will comprise two main steps:

— Information acquisition (e.g. from buttons in studio control rooms) and representation of this information in a suitable format.

— Multiplexing and formatting prior to transmission on the data-circuit.

The provision of data-circuits is often a major cost consideration, particularly if special circuits have to be leased for RDS. In such cases, messages for several co-sited transmitters may have to be multiplexed onto one data-circuit. To facilitate their demultiplexing at the transmitter, RDS encoders should be made addressable so that each can recognise its own messages on a common data-circuit without the need for separate demultiplexing equipment. An address-field of at least 8 bits is recommended for this purpose.

A variety of data-circuits may be used including CCITT V.24 circuits (with 2-wire or 4-wire modems), X.25 packet-switched networks, digital distribution circuits, audio subcarrier systems (e.g. Audiodat*), radio-links and off-air rebroadcast feeds. It should be noted, however, that in many broadcasting networks it is difficult to provide a reverse data-circuit (i.e. from the transmitter back to the studio-centre).

Attention also has to be given to the need to provide reserve feeds of RDS data; in particular it is important to be aware that when the sound-programme signal provided by a reserve feed is different from that provided by the main feed (e.g. because it is a rebroadcast of a transmission from another area), the RDS information may be incorrect. In such circumstances, it can often be useful to revert to basic default RDS data stored locally in the RDS encoder.

One of the more difficult aspects of networking RDS signals is likely to be concerned with the response-times involved in broadcasting real-time switching functions, e.g. the Traffic Announcement (TA) flag. This becomes particularly difficult when cross-referencing networks via the Enhanced Other Networks (EON) feature, especially where national networks cross-reference local stations. In these cases, provision

* Günter Löber, Jürgen Hempel, "Datenübertragung im Stereo-Multiplex-Kanal mit Audiodat-Geräten", Neues von Rohde & Schwarz, 79, Herbst 1977.

has to be made to compile messages from sources which may be outside the main studio-centre, and appropriate delays in the broadcast of such messages from the parent transmitter network (and any related messages via the main programme signal) may be needed to take account of this.

One possible solution to help minimize the response time due to limited capacity on data-circuits is to preload the RDS encoders with new information messages well in advance of their scheduled broadcast and then initiate the broadcast of this new information with a simple start pulse. The relatively low cost of storage makes it feasible to store several "pages" of messages in every encoder and to load these pages in non-real-time, thus making good use of expensive data-circuits by evening-out the peak demand on their capacity.

Appendix 1 to Chapter 2

Up-dating of RDS encoders by ARD* broadcasters

1. Introduction

The ARD Technical Standard Requirements 5/3.8, "Encoder for Radio Data System (RDS)" [1], describes an RDS encoder which is used to generate an RDS signal according to the RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067. As an option, the RDS encoder incorporates an encoder to generate the ARI signal.

The RDS encoder has memories for at least eight different data sets, also one "on-air" memory set, and one default data memory set. The information stored in these data sets is intended for use in conjunction with different network configurations and/or different programmes. A sequence control ensures that the data contained in the "on-air" memory set is transmitted in the intended sequence in accordance with the RDS specification.

Several different methods are implemented to communicate with the RDS encoder and to handle the RDS data to be transmitted.

2. Terminal interface

A serial interface as described in DIN 66020 (CCITT V.24/28) is provided at the front panel of the encoder. The encoder is regarded there as a Data Communication Equipment (DCE). The data transmission is realized according to DIN 66022 as an asynchronous full duplex communication using hardware handshaking with RTS/CTS and 7 bit code with a data rate of up to 9600 bit/s.

It is possible to use commercial terminals for local set-up. Using the specified protocol, all the possible RDS information in the different data sets can be edited, updated and listed. Furthermore the order of groups to be transmitted can be fixed. The specific data set to be transmitted can also be selected.

3. Data link interface

For the connection of data links or modems, four separate serial interfaces similar to the terminal interface, using however an 8 bit code, are provided at the rear of the unit.

For these data link interfaces a different protocol is specified, in order to provide for a compressed data input. A checkword ensures reliable communication.

The transmission of certain information for which a repetition rate can be specified (i.e. IH, RT, TDC) is acknowledged at the interface.

* ARD = Arbeitsgemeinschaft der öffentlich-rechtlichen Rundfunkanstalten in der Bundesrepublik Deutschland.

4. Switching inputs and message outputs

To provide for a hardware remote control, the RDS encoder is equipped with switching inputs and message outputs for several functions. Using the inputs it is possible, for example, to switch RDS and ARI on and off, to switch TA on and off, to control which of the different data sets shall be transmitted, and to change the least significant bit of DI (mono/stereo). Furthermore, it is possible to decide which of two different pilot tone sources should be used.

5. Priorities and data transfer

In principle, the information to be transmitted may be changed from different sources. Therefore provision is to be made in order to assign a priority to a given input to change specific information. Once a priority is assigned, the specific information can only be changed by using that privileged input. In a similar way it is also possible to exclude the change of specific information at an input.

An RDS decoder as described in Technical Standard Requirements 5/3.9, "Operational and control decoder for Radio Data System (RDS)" [2] uses the same data link protocol as the encoder. Therefore it is possible to connect the RDS encoder directly to a decoder which is connected to a rebroadcast receiver, and thus simultaneously pass on programme-related information and introduce new station-related information.

A program for an IBM PC (or compatible) has been developed in order to provide a tool which can easily be used to load and update the RDS encoder with the complex and extensive data to be transmitted.

References

[1] Technisches Pflichtenheft 5/3.8, "Coder für Radio-Daten-System (RDS)", published by Institut für Rundfunktechnik GmbH, Munich, March 1987.

[2] Techniches Pflichtenheft 5/3.9, "Betriebs- und Überwachungsdecoder für Radio-Daten-System (RDS)", published by Institut für Rundfunktechnik GmbH, Munich, June 1988.

Appendix 2 to Chapter 2

Up-dating of RDS encoders in the BBC's RDS network

1. Introduction

The BBC's RDS service as radiated from the VHF transmitters of the main programme networks, is dynamic. At present, this includes altering PS, main AFs and other network AFs (EON) to reflect the changing state of the networks during op-outs or splits. In future, the dynamic control of RDS data is likely to be extended to other features.

The BBC system consists of a central RDS computer [1], based at Broadcasting House, which controls RDS encoding equipment [2] at each major transmitting site. Relay sites merely rebroadcast the RDS signal of their parent. Communication between the computer and the encoders uses spare data capacity available on the PCM distribution system which carries the audio signals to the transmitters. This Appendix examines, briefly, how this is achieved and summarizes the factors governing the choice of a suitable communication protocol.

2. The PCM sound-distribution system

The sound signals for the main programme networks are distributed digitally. They are multiplexed, along with other signals, into an 8 Mbit/s bitstream. The basic building block of the system is the NICAM-3 coding equipment [3] which carries a pair of sound channels, with an associated data signal, in 676 kbit/s. The capacity of the data channel is just over 2400 baud and it is used to carry RDS and transmitter control information pertinent to its associated sound signal. For example, one of the 676 kbit/s channels carries Radio 4 sound (stereo), Radio 4 RDS and Radio 4 transmitter control information, to all the main Radio 4 transmitters in the UK.

3. Other sources of RDS information to the transmitters

As well as the PCM source of RDS described above, there are two other potential sources of RDS data at a transmitter. The first of these is the Rebroadcast Standby (RBS) source. If the PCM signal to a particular transmitter fails for any reason then a sound signal received off-air from a nearby transmitter is used as a reserve. In this case, at least some of the RDS information also needs to be derived from the RBS source.

The other source occurs when a transmitter opts out of carrying the main sound signal. Initially, for this situation, only static RDS data will be broadcast. In future, however, this information may also need to be dynamic. The controlling source will be the source of the opt-out programme, e.g. a local studio close to, but not at, the transmitting site. The sound feed will usually be by audio land-line which has no significant capacity to carry any extra data. The data will need to be fed to the transmitter by an RS232 type serial data link (telephone or private wire).

4. Choice of communication protocol and data format

It is obviously sensible for the RDS encoder to have a common communication protocol for the three possible sources of RDS data (PCM, RBS and local) and the most appropriate choice is RS232 serial data (unidirectional). The way in which RDS data is formatted for transmission on the serial links is influenced by a number of factors:

a) In the case of the PCM network, and possibly the local feed, one data source is controlling many transmitters via a shared data link. The RDS data will in some cases be different for each transmitter and so the link must carry several sets of data with each set addressed to one, or possibly more, encoders.

b) One source can feed many destinations and most data changes are likely to be happening at the same time, i.e. at programme junctions. A "log-jam" of information is likely to happen. This can be mitigated by sending information in advance of the time at which it is required, storing this information in the encoders, and sending data to select the stored information at the appropriate time.

c) The links are unidirectional and hence have no means of signalling back to the source to ask for repetition of errored data. The data format must allow means for detecting errored data and all data must be repeated often to ensure that it is, eventually, received correctly.

d) In some situations, it may be desirable to be able to modify the ordering of the different group types from the central source e.g. to modify the proportion of RDS groups allocated to the In-house channel. The communication format must allow for this.

e) The data format must be flexible enough to allow for the addition of future facilities not yet specified.

f) Maintenance and fault-finding is made easier if the data format can give an intelligible, and reasonably easily interpreted, display on standard RS232 equipment, i.e. terminals and/or printers.

With these criteria in mind, a suitable data format has been devised. A full description can be found in a BBC D&ED Technical Memorandum [4].

Stated briefly, the format consists of a stream of data records. Each record is delineated by a start and stop character, and contains an address code (for one or more encoders), some characters for error detection, and a command code with associated data. The commands are instructions to the addressed encoders to take some action, e.g. store data for future use, use a previously stored set of data or change to a different mix of RDS group types. The Technical Memorandum gives a detailed description of the commands recognized by the BBC RDS encoders.

References

[1] BBC D&ED Technical Memorandum A1003(86), RDS Origination Computer Equipment.

[2] BBC Engineering Design Information: "RDS transmitter equipment", CD4L/21: EDI 10553(1), June 1988.

[3] Caine, English, O'Clarey: "NICAM-3, near instantaneously companded digital transmission system for high-quality sound programmes", Radio & Electronic Engineer, October 1980, pp. 519-530.

[4] BBC D&ED Technical Memorandum No. A1032(87), RDS Service Update Specification, Issue 1, 19.7.88.

Chapter 3

Experience of the performance of the RDS system during its development

3.1 History of laboratory and field-test evaluation

During the ten years of development of the RDS system, extensive laboratory and field tests were conducted. The earlier tests were primarily intended to help optimize the choices of the modulation system and base-band coding, while the later tests were directed towards determining the performance of the overall system prior to its introduction as a service.

The results quoted here are derived from the following sources:

1. Field tests in Switzerland, 1980
2. Laboratory and field tests in Stockholm, 1981/2
3. Field tests in Germany, 1985 [1]
4. Field tests in the United Kingdom, 1985 [2]

Although some of these tests included assessments of the compatibility of the system, we shall consider here only tests of reception reliability (ruggedness). The earlier tests are included not only to provide a historical perspective but also because they illustrate some important properties of the system which are not documented elsewhere and which may be of use in its future development.

3.2 Results of measurements of reception reliability

The performance of the RDS demodulator/decoder is, of course, crucial in determining the reliability of reception of the system. The demodulator/decoder used in most of the tests described here was developed jointly by the BBC and Swedish Telecom Radio (STR) during 1981/82 (with later improvements introduced by the IRT (Germany) in 1985). This demodulator is described in outline in Reference [3] and uses a Costas loop to recover the 57 kHz subcarrier. It is expected that commercial RDS receivers will achieve similar, or even better, performance.

3.2.1 Laboratory tests

Bit-error rate

Fig. 3.1 curve (a) shows the bit-error rate of the reference RDS demodulator measured as a function of the power applied at the aerial input of the VHF/FM receiver. The VHF/FM receiver used in these measurements had a noise figure of 5.5 dB. For the purposes of comparison, the theoretical bit-error rate expected according to the theory given in *Appendix 1* to this chapter, is given as curve (b). It may be seen that the measured performance of this experimental RDS decoder is within about one decibel of that expected from theory.

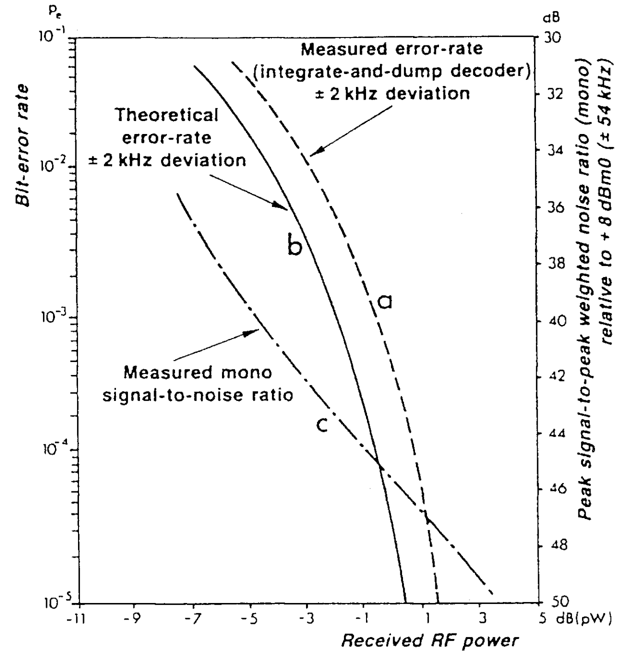


Fig. 3.1: Bit-error rate of the reference RDS demodulator (theoretical and measured results).

Note: Receiver noise figure = 5.5 dB.

Note that deviation due to the RDS signal was ± 2 kHz. For other deviations, the results may be linearly scaled. For example, for ± 1.2 kHz deviation the RF input power needed to attain a given bit-error rate would be about 4.4 dB greater.

Curves (a) and (b) in *Fig. 3.1* illustrate the rapid failure with the typical declining signal-to-noise ratio characteristic of most digital systems. For satisfactory operation, the RDS system needs a bit-error rate better than about 2 in 10^2.

Also shown in *Fig. 3.1*, as curve (c) is the mono peak-signal-to-peak-weighted-noise ratio (measured according to CCIR Recommendation 468) obtained in the sound programme channel of the same VHF/FM receiver used in the error rate measurements of curve (a). This was measured after 50 μs de-emphasis relative to a + 8 dBm tone at 440 Hz (i.e. 54 kHz deviation with standard BBC line-up levels). Stereo reception would, in theory at least, need 20 dB more RF power to achieve the same signal-to-noise ratio as that shown for mono.

Thus it is found that, when the only impairment to reception is random noise due to low field-strength, the RDS system operates satisfactorily until beyond the point at which stereo reception of the programme signal becomes unusable. At the field-strength corresponding to the failure point of the RDS system, mono reception is noisy but still intelligible and remains so for aerial input levels down to about − 10 dB (pW). In practice, this is not a problem because such low field-strengths usually occur only well outside the service area of the transmitter and it is often possible to switch to an alternative frequency carrying the same service. Furthermore, where such low field-strengths prevail, there are usually other impairments to reception, such as multipath, which render the programme signal unusable.

Block-error rate

It is important to remember that because of the use of differential decoding in the RDS demodulator, the errors usually occur in bursts spanning two bits. Single errors occur only when adjacent bits in the received data-stream, before differential decoding, are in error.

In the RDS system, the block-length for the purposes of error protection is 26 bits. Curves showing the probability of correct reception of PI codes (which are equivalent to one RDS block), when the only impairment to reception is random noise due to low field-strength and plotted as a function of RF input power to the aerial input of the VHF/FM receiver, are given in *Fig. 3.2* [1]. Curves (4) and (3) show the results with and without error correction respectively for ± 2 kHz deviation; curves (2) and (1) show the corresponding results for ± 1.2 kHz deviation. The error correction used in obtaining the results shown in curves (4) and (2) accorded with that recommended in the Specification, i.e. bursts of errors spanning only up to two bits in a block were corrected; longer bursts were detected and those blocks were rejected.

Comparing curves (3) and (4) with curves (2) and (1) it may be seen that under conditions where the received signal is impaired by low field-strength only, the use of error correction yields a maximum improvement equivalent to less than 2 dB in RF level. However, as will be shown, error correction yields a greater improvement with the burst errors characteristic of mobile reception.

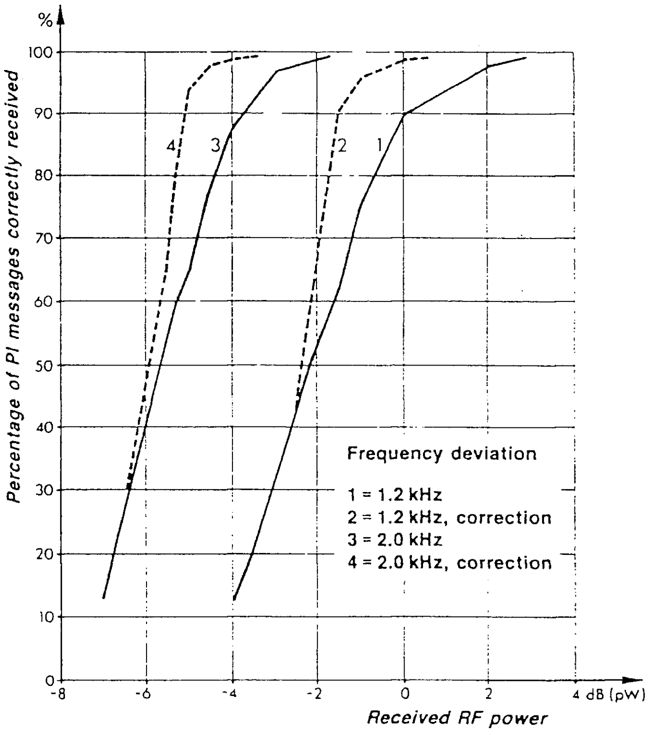


Fig. 3.2: Influence of the RF level, error correction and frequency deviation on the broadcast reliability.

Error rates for RDS messages

As was noted above, the probability of correct reception of a PI code is simply the probability of reception of an RDS block as shown by the curves in *Fig. 3.2*. The same is also true for all other kinds of messages which occupy fixed positions within *all* RDS Group types and can therefore be decoded without reference to any information outside the block which contains them. Included in this category are PI, PTY and TP. Other messages require correct decoding of the Group type address and perhaps other information such as the segment address for PS codes. Inevitably, the more RDS blocks which a message and its related addressing occupy, the lower the probability of correct reception of the complete message. However, in most applications needing long messages, e.g. RT, it is not necessary to receive the whole message correctly before making use of it; missing or erroneous characters can easily be tolerated on displayed messages.

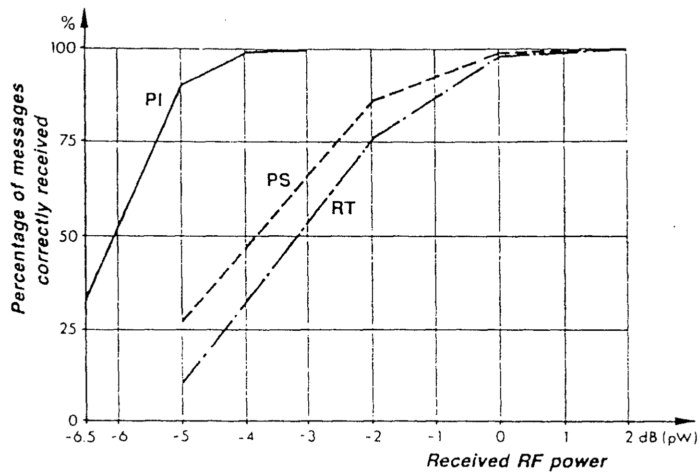


Fig. 3.3: Reliability of reception of RDS messages.

Curves showing the probability of correct reception of PI, PS and RT messages when the only impairment to reception is random noise due to low field-strength, are given in *Fig. 3.3*. The deviation due to the RDS signal was 12 kHz and two-bit burst-error correction was applied.

3.2.2 Mobile field tests

In mobile reception of RDS, multipath reception due to reflections from hills and/or tall buildings is the dominant problem rather than low field-strength. *Fig. 3.4* shows pen charts recorded during the 1980 field tests in Switzerland. *Fig. 3.4a* shows the recorded field-strength along one section of road about 12 km long. This may be seen to be uniformly strong. *Fig. 3.4b* shows the number of errors in a sequence of 1000 bits. Note that for much of the route, between 10 and 100 errors occurred in each sequence of 1000 bits.

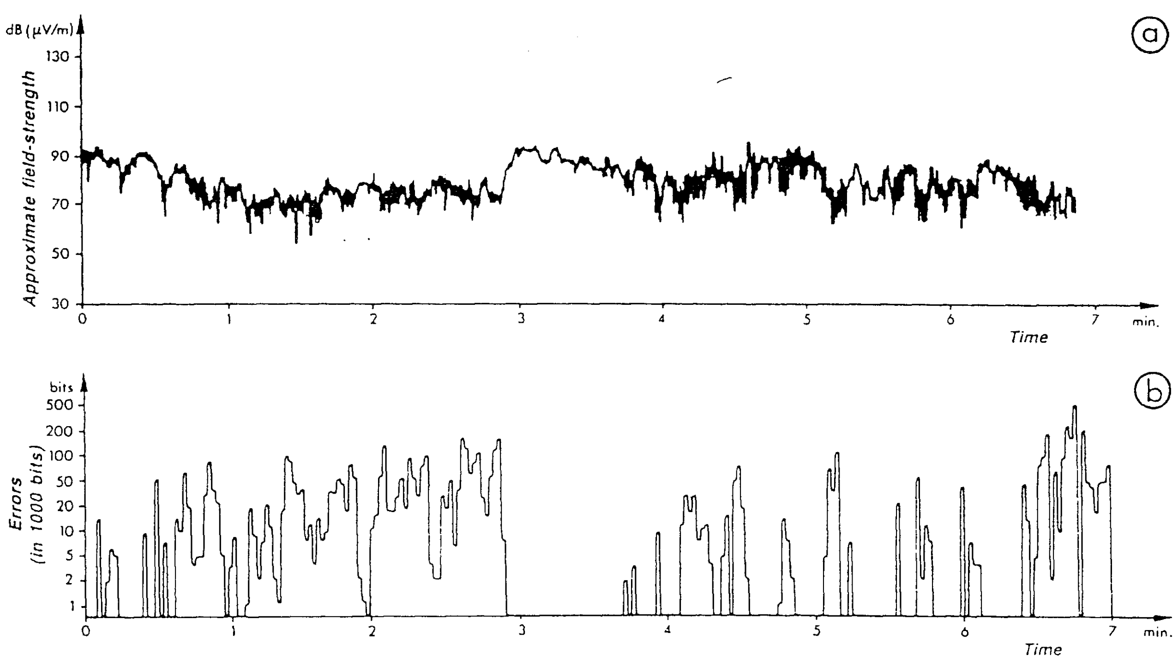


Fig. 3.4: Pen charts of field-strength and bit-error rate.

This route was characterized by strong multipath due to the mountainous surrounding terrain. In VHF/FM reception, multipath produces non-linear distortion of the demodulated FM signal. This non-linear distortion manifests itself as harmonics and intermodulation distortion products of and between the various elements of the multiplex signal. For example, harmonics of the relatively large programme signal can easily swamp the RDS signal. Because of this, the instantaneous error rate in mobile reception of RDS is found to be strongly dependent upon the instantaneous programme volume level. This is illustrated in *Fig. 3.5* for the same time and route as was used to obtain the results shown in *Fig. 3.4*. The programme material was male speech. Note that at low programme volume relatively few errors occur. To achieve this result, however, the RDS demodulator must be designed to ignore harmonics of the 19 kHz pilot-tone; this is done in the Costas loop reference demodulator by rejecting components at and close to 57 kHz in the subcarrier recovery and data-detection circuits. (This is also a prerequisite for satisfactory compatibility with signals of the ARI system.)

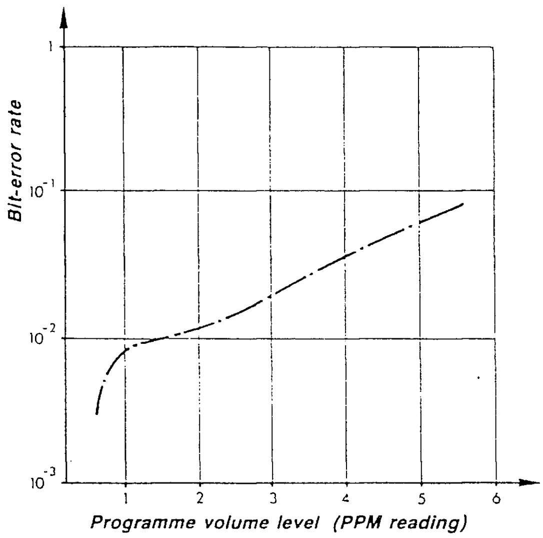


Fig. 3.5: Correlation of mean bit-error rate with programme volume level, field tests in Switzerland.

As *Fig. 3.4* indicates, for mobile reception of RDS, the mean bit-error rate (total number of errors in the received data divided by the total number of bits transmitted) is of little use as a parameter for assessing performance. This is because the errors in mobile reception of RDS tend to occur in dense bursts (or even clusters of bursts) rather than randomly. Therefore, a bit-error rate averaged over periods of several minutes will overestimate the density of errors during the periods of relatively good reception and underestimate the density during the periods of bad reception.

Statistical analysis

In order to analyze the performance of the RDS system under mobile reception conditions, a number of statistical analyses have been developed.

1) Probability of bursts of various lengths in blocks, Pv(l,n).

2) Probability of multiple random errors in blocks, P(m,n).

3) Percentage of messages received correctly and percentage received with unrecognised errors.

4) Access time to blocks and various RDS messages.

The first two analyses were mainly of use in the design of the RDS system but are quoted here to assist in understanding of the design philosophy and to help receiver designers make best use of the error protection available in RDS. The second two analyses were used in full-scale RDS field trials in Germany and the UK to assess the overall performance of the system.

Block-error analysis

The probability of bursts of errors of various lengths is of help in determining the error protection strategy to be used in the receiver; the RDS system gives the receiver designer a number of options in this respect. *Fig. 3.6* illustrates the burst lengths of errors in 26-bit blocks for two vehicle speeds, 90 km/h and 10 km/h. Note that, as would intuitively be expected, the length of the error bursts is longer at low vehicle speeds. Taking the 90 km/h results from *Fig. 3.6*, it may be seen that whereas 15 % of locks contain one or more errors, only 3 % contain bursts of errors spanning three or more bits in a ƶ6-bit block. Thus the use of two-bit burst-error correction under those conditions would have corrected 80 % of blocks with errors.

The probability of multiple random errors in a block is of less direct use than the burst length analysis because the error-protecting code in the RDS system cannot correct multiple random errors. It is, however, included here as *Fig. 3.7* for completeness. Note that the results in *Fig. 3.7* are presented as the cumulative probability of m or more errors in a block of 26 bits. This curve was plotted by noting the frequency with which m errors occurred in blocks of 26 bits each. From this the probability distribution P(≥m, n) of m or more errors in a block of 26 bits may then simply be estimated as:

$$P(\geq m,\ n) = \sum_{i=m}^{n} P(i,\ m)$$

where ≥m means the number of m or more errors in n bits.

The principal feature to note in the curve of *Fig. 3.7* is that large numbers of multiple errors in a block occur relatively frequently. Note also, however, that single-bit errors also occur more frequently ·han would have been expected given differential decoding. It is believed that the explanation for this .s that, under conditions of multipath propagation, the RDS demodulator often skips half carrier cycles (i.e. carrier phase-change of 180°) due to failure to track rapid changes in the phase of the received RDS signal. Impulsive interference from, for example, the vehicle ignition system, produces the expected paired errors.

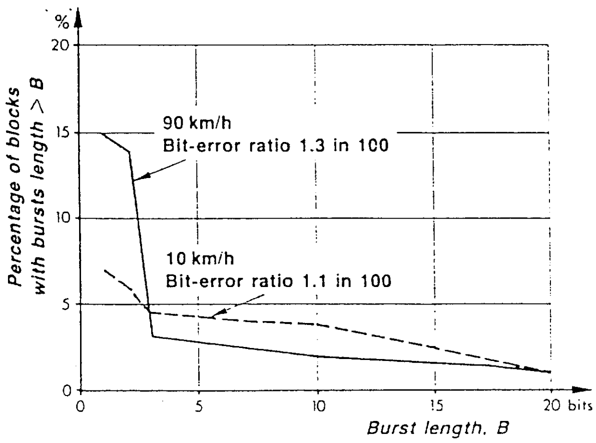


Fig. 3.6: Distribution of burst-lengths in 26-bit blocks.

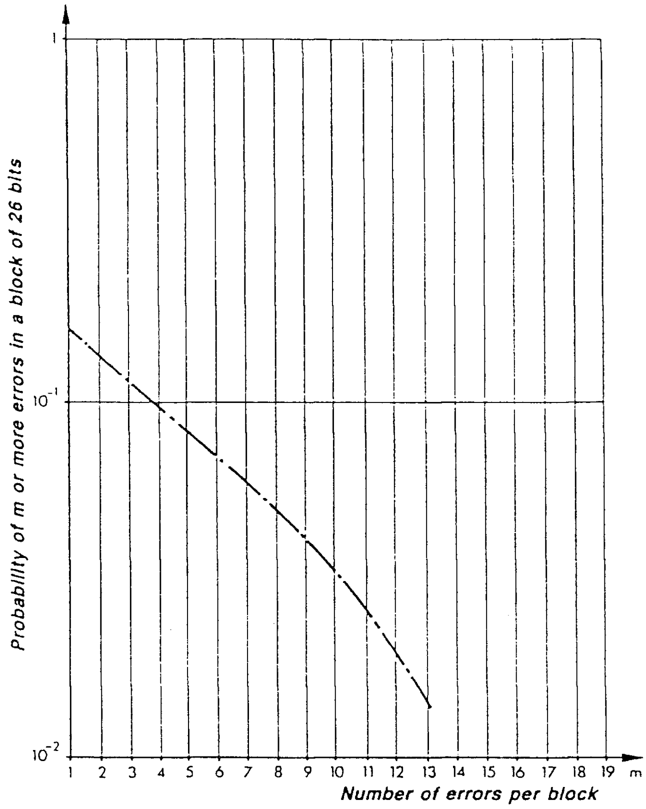


Fig. 3.7: Cumulative probability distribution of errors in 26-bit blocks, field trials in Switzerland.

Overall system performance

a) *Field trials in Germany, 1985*

To evaluate the reliability of RDS reception over large areas and including a wide variety of reception conditions, two independent large-scale field trials were undertaken during 1985, one in the Federal Republic of Germany [1] and one in the UK [2].

The field trials in Germany included service areas of transmitters broadcasting signals of the ARI motorists' information system which is used in that country. In an earlier field trial, in which ± 2 kHz deviation had been used for the RDS signal, poor compatibility with ARI receivers had been found to occur. To overcome this difficulty it had been found necessary to restrict the deviation due to the RDS signal to ± 1.2 kHz, and it was therefore of interest to investigate what impact this reduction in deviation would have upon RDS reception reliability.

Fig. 3.8 shows the percentages of correctly received Programme Identification (PI) codes and Programme Service (PS) name codes for each broadcasting organization taking part in this full-scale field trial. It also highlights the influence of error correction* and the frequency deviation used for the RDS signal. The average RF level found in the service area of each broadcasting organization is also shown. Note, however, that these RF levels indicate only the signal strength at the receiver input in these tests: in mobile reception this depends upon the type of aerial used, its location on the vehicle and the type of vehicle. Furthermore, in this case the RF levels shown are as measured after passing through an RF transformer, and are about 1.5 dB lower than the levels picked up by the antenna.

* The RDS demodulator decoder used in these tests had adaptive error correction such that if less than 40 % of the transmitted blocks were received correctly, the decoder turned off the error correction and applied error detection only.

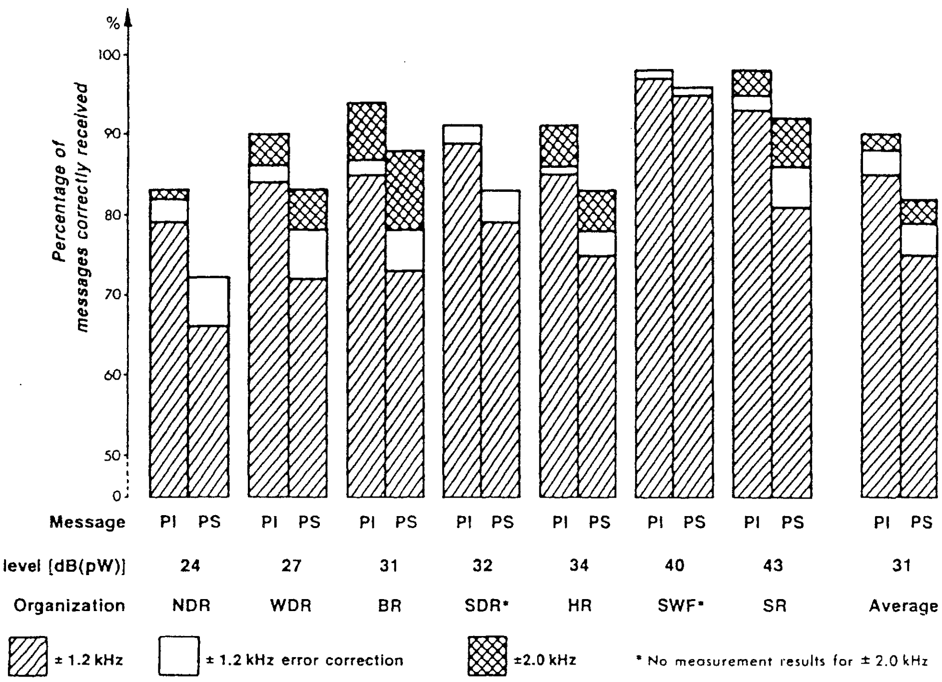


Fig. 3.8: Data broadcast reliability in the full-scale RDS field trial in Germany.

The results presented in *Fig. 3.8* represent measurements taken over routes totalling a distance of some 2300 km. Overall the following error statistics were measured:

$$\text{CRM PI} = 85\,\% \qquad \text{UE PI} = 2.6\,\%$$

$$\text{CRM PS} = 75\,\% \qquad \text{UE PS} = 0\,\%$$

where:

$$\text{CRM} = \frac{\text{Number of correctly received messages}}{\text{Number of messages transmitted}} \times 100\,\%$$

and:

$$\text{UE} = \frac{\text{Number of unrecognised errors}}{\text{Number of correctly received messages + unrecognised errors}} \times 100\,\%$$

It may be seen that with a frequency deviation of ± 1.2 kHz both the PI and PS codes were received adequately reliably. In these measurements a rebroadcast receiver was used to provide the multiplex signal for the RDS demodulator/decoder; even better results would be expected with the better RF sensitivity which is attained with normal car radios. The low percentage of undetected errors in the PS codes is characteristic of the design of the RDS demodulator/decoder used in these tests.

Through the use of error correction, it was possible to receive an average of 4 % additional correct messages, over and above those achieved with error detection alone. Far greater benefits were sometimes observed, however, and in particular when reception suffered moderately severe interference, i.e. during those periods when 20 to 40 % of transmitted blocks were received with errors (compare with *Fig. 3.2*). In such circumstances, error correction allowed correct reception of as many as 30 % of additional messages. However, this sort of propagation condition affects only a limited proportion of the coverage area so the overall influence of error correction on reliability of reception is relatively small. It should also be pointed out that, when using error correction on PS messages, an average of 0.6 % of such messages were decoded with unrecognised errors.

The influence of changing the injection level due to the RDS signal may be clearly seen in the test results for the service areas of Hessischer Rundfunk (HR), Saarländischer Rundfunk (SR) and Westdeutscher Rundfunk (WDR). Measured over the same area, and broadcasting from the same transmitters, it was found that on the basis of the results obtained for HF, SR and WDR service areas, an increase in the frequency deviation due to RDS from ± 1.2 kHz to ± 2 kHz improves the proportion of CRM by about 5 to 6 % for PI codes and about 8 to 11 % for PS codes.

Fig. 3.9 shows the distribution of reception reliability and RF level over all the measurement areas. The plotted curves indicate the percentage of time for which the indicated values of correctly received messages (CRM), unrecognized errors (UE) or RF level, in dB(pW), is exceeded. Note that the horizontal axis is plotted on a non-linear "probability" scale. The reception reliability with error detection only (no correction) is shown as the solid line curves (2, 3 and 6 in *Fig. 3.9*), and that with adaptively applied two-bit error correction appears as the dotted line curves (4 and 5, 7 and 8). There were no unrecognized errors (UE) for PS codes when error detection only was used (and therefore no UE curve is given for this condition in *Fig. 3.9*).

The reception reliability for PI and PS codes was measured at intervals covering 100 messages. Measurements of RF level were taken every 0.5 seconds. Bearing in mind that for the evaluation of reception reliability in different areas, greater importance must be attached to the distribution of errors as a function of distance rather than time, the speed of the vehicle was maintained as constant as possible (at about 85 km/h) while the measurements were being taken. Under these circumstances, with the vehicle speed practically constant, the temporal and distance distributions are virtually the same shape.

The curves of *Fig. 3.9* show that reliable RDS reception was obtained throughout about 87 % of the service areas. Of the 3 % not covered by RDS, about 0.5 % is accounted for by RF levels below − 4 dB(pW) (compare with *Fig. 3.2*) and the remainder by the effects of multipath and/or co- or adjacent-channel interference. For 72 % of the time (and thus distance) it was found that more than about 90 % of PI codes could be received correctly with error detection only in the decoder. Similarly for 48 % of the time and distance, more than about 90 % of PS codes were correctly received with error detection only.

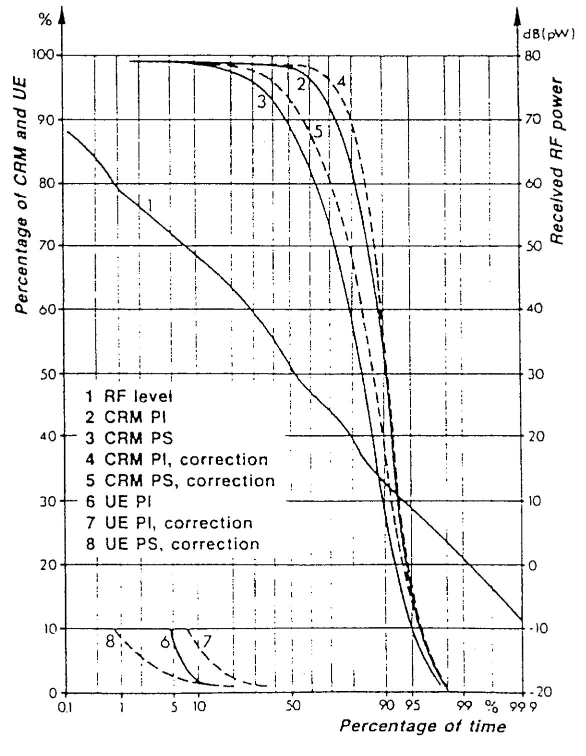


Fig. 3.9: Distribution of broadcast reliability and RF level in the presence of ARI transmitters.

The use of error correction recovered, on average, an extra 6 to 7 % of PI and PS codes, but also increased the unrecognized errors (UE). The trends for the UE above 10 % UE cannot, however, be shown because of the adaptive error correction system used.

b) *Field trials in the UK, 1985*

Field trials carried out by the BBC in the UK in January 1985 [2] adopted a different approach to measuring the reliability of RDS reception. These measurements were carried out in the service area of the Wrotham transmitter which serves London and much of the South-east of England. A wide variety of reception conditions were encountered in the survey including severe multipath interference due to the hills of the North Downs and tall buildings in central London. Routes which were well known for their adverse reception conditions were included.

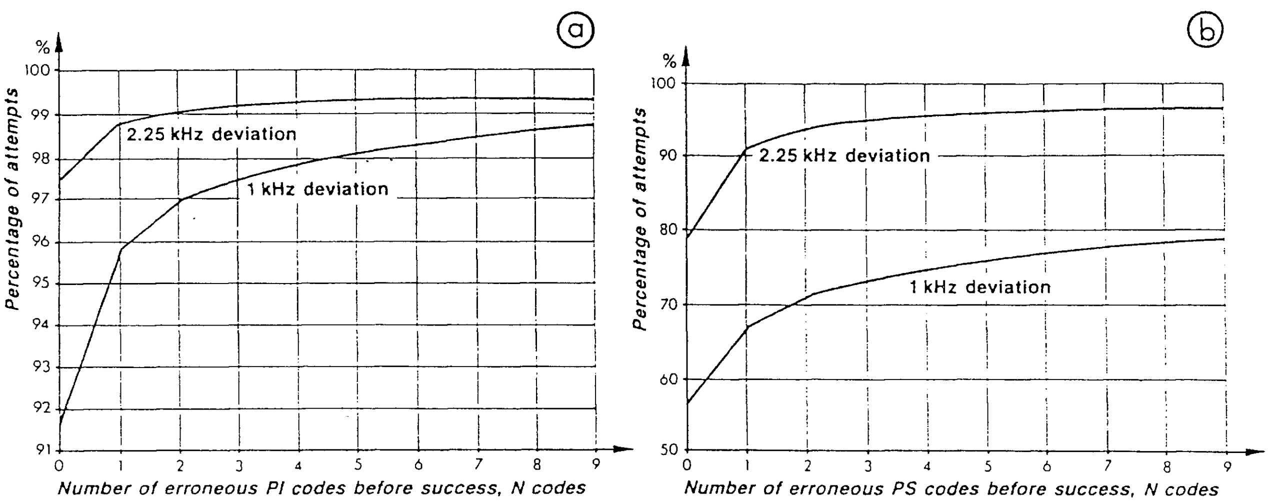
A typical high-quality modern car radio of European design and manufacture was used in this survey instead of a professional rebroadcast receiver as was used in most other surveys. Care was also taken to ensure that the whip aerial arrangement used on the survey vehicle represented the antenna characteristics of a typical private car. Thus, overall, this survey was intended to show how RDS would perform for the private motorist within the first few years of its introduction as a service.

The survey had two important objectives, which it successfully achieved:

First, the survey related RDS reception reliability to the quality of the received sound-programme signal. This accorded with the design objective for RDS that it should work reliably wherever the programme signal is usable. Furthermore it enables the results of this necessarily limited survey to be extrapolated to estimate coverage in other areas using existing data relating to the quality of the programme signal received in a vehicle. As is well known, field-strength is not the only determining factor in such cases.

Second, the survey measured the *time* intervals between successful reception of the RDS PI and PS codes. That is, the lengths of the gaps in which no correct PI (or PS, as appropriate) codes were received was measured. Using this statistical information, it was then possible to answer the important question of acquisition time for RDS data, i.e. when an RDS receiver is turned on or retuned, how long will it take to acquire correct RDS data.

The results of this survey are summarized in *Fig. 3.10* which shows, for PI and PS codes, the percentage of the attempts to acquire a code when there were N or fewer erroneous receptions before successful reception of a correct PI code. Thus, for example, with 12.25 kHz deviation, in 97.5 % of cases a correct PI code was received on the first attempt with no intervening erroneous PI codes. For 11 kHz deviation, the corresponding figure is 91.5 %.



a: Acquisition of a PI code.

b: Acquisition of a PS code.

Fig. 3.10: Percentage of the attempts when there were N or fewer erroneous receptions before successful acquisition of a correct code.

Similarly, for PS codes, in 79 % of cases, with ± 2.25 kHz deviation a correct code was acquired on the first attempt, reducing to 57 % with ± 1 kHz deviation*.

Overall, in this reception survey the percentage of correctly received messages (sample size approximately 3 million PI codes and 300 thousand PS codes) were as follows:

For PI codes: 97.3 % correct at ± 2.25 kHz deviation; 90.5 % correct at ± 1.0 kHz deviation

For PS codes: 70.7 % correct at ± 2.25 kHz deviation; 68.6 % correct at ± 1.0 kHz deviation

Note that the results presented in *Fig. 3.10* do not include the lock-up time for the RDS demodulator/decoder (which depends upon the particular design but is typically expected to be equivalent in duration to one or two RDS groups, i.e. 1/10th to 1/5th of a second, under most conditions). It should also be noted that the decoder used in these tests used two-bit burst-error correction at all error rates. Unrecognized errors were detected by the error analysis equipment used and have therefore been eliminated from the totals of correctly received messages.

These are encouraging results showing highly reliable reception of PI codes even at the lower deviation of ± 1 kHz. The results for the PS codes are as expected, poorer than for the PI code, but indicate satisfactory acquisition times in most cases. Furthermore, the results underestimate the reliability of reception of the RDS system because a large proportion of the survey was deliberately done in areas where VHF/FM reception is known to be poor. If a representative sample of test routes had been used, then even better results would have been obtained.

The correlation with the quality of the sound programme signal revealed that the RDS system performs best when the dominant impairment to reception is multipath propagation only. This is because in areas of relatively high field-strength there are frequent opportunities for the receiver to "snatch" a PI code during peaks in the standing-wave pattern caused by the multipath propagation. Short pauses in the sound-programme signal (for example, syllabic pauses in speech) also help this (see *Fig. 3.5* for the influence of programme volume level of RDS error rate). Under multipath conditions the distortion and break-up of the sound-programme signal render it unusable before the acquisition time for RDS data increases significantly from that for error-free conditions.

The RDS system was found to be weakest when the dominant impairment to reception was low field-strength in the absence of multipath interference. Under these conditions, and with ± 1 kHz deviation, the maximum delay for acquisition of a correct PI code was about one second. Under such conditions the quality of the sound-programme signal was assessed to be Grade 2 (Poor) on the CCIR 5-point Quality Scale. However, it is important to note that such conditions of low field-strength without other impairments to reception were found to be very rare. Usually multipath or co- or adjacent-channel interference also degraded the quality of the received signal. Furthermore, it was indeed found that the nature of the programme material on BBC R3 was such that it became unusable with smaller impairments to reception than were found tolerable for the other services. Thus, there is some measure of compensation for the lower deviation used on this service.

It should also be remembered that in many cases the RDS receiver will automatically retune to an alternative frequency (if one is available carrying the same service), thus avoiding some of the poor reception conditions encountered in a "fixed frequency survey" such as this.

These results clearly show that acquisition times for RDS data cannot be determined from random event models using an overall mean bit-error rate or block-error rate as a parameter. Such models will tend to overestimate the average acquisition time because they take no account of clustering of the errors.

* In these experimental test transmissions a deviation of ± 2.25 kHz was used for all services except BBC R3, for which the minimum deviation allowed by the RDS Specification (± 1 kHz) was used. The lower deviation on BBC R3 was selected because of the critical nature of the programme material (classical music) and its vulnerability to interference from RDS signals. In the BBC RDS service which commenced in the autumn of 1988, a deviation of ± 2.0 kHz is used on all services except BBC R3, for which ± 1.2 kHz deviation is used.

The acquisition times for other types of RDS messages could easily be estimated from the data provided by this survey. Information occupying fixed positions in all RDS Group types, e.g. Programme Type (PTY) code and Traffic Programme (TP) code, would be expected to have the same reception reliability as the PI codes. (Although these messages are shorter than PI codes, the smallest entity of information which can be recovered by a conventional RDS decoder is a block containing 16 information bits.) Messages such as Radiotext (which occupy several addressed segments) would be expected to be similar to the PS codes. The most vulnerable messages would be expected to be those contained in variable format Groups, e.g. Transparent Data Channel (TDC).

3.3 Conclusions and recommendations for future work

The performance of the RDS system has been investigated in a number of laboratory and field tests during its development and subsequent evaluation. The early tests were directed towards optimizing the system to convey to moving vehicles the short, frequently repeated, messages needed to assist the automatic tuning features of RDS car receivers. Later tests have confirmed that the coverage provided by the system, and the acquisition time for these short codes, are adequate even with the reduced deviation now used to overcome problems of interference to ARI receivers and/or the stereo programme signal.

The error-correcting code used in the RDS system is potentially very powerful [6, 7] and opportunities exist for further enhancing the performance of RDS by the development of new decoding techniques to exploit the power of this code. In particular, the use of soft-decision techniques [5] and/or bit-by-bit majority logic over repeated copies of the same message offer promising routes for further improving the performance of decoders.

New applications of RDS, in particular the transmission of information for voice-synthesized traffic messages, will probably necessitate further study and innovation in the decoder to gain adequate reception reliability for multiple sequence messages under mobile reception conditions.

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Appendix 1 to Chapter 3

Calculation of the bit-error rate at the output of the RDS demodulator

1. General

In this Appendix we calculate the bit-error rate to be expected at the output of an ideal radio-data decoder when the only transmission impairment is thermal noise due to low field-strength. The analysis is necessarily fairly complicated and every attempt has been made to simplify the problem by making suitable approximations.

2. Calculation of the peak-data-signal-to-r.m.s.-noise ratio

Let f_b be the bandwidth occupied by the double-sideband suppressed-carrier amplitude-modulation radio-data signal; here this is equal to 1187.5 Hz. Also let:

a = r.m.s. amplitude of the RF carrier measured as a potential difference across the receiver aerial input (volts)

p_n = spectral density of the thermal noise at the receiver input (volts^2/Hz)

f_{sc} = radio-data subcarrier frequency (Hz) = 57 000 Hz

Δf = peak deviation of the VHF carrier due to the modulated radio-data subcarrier (Hz)

for example Δf = 2000 Hz

Now the spectral density of the thermal (Johnson) noise at the receiver input is given by:

$$p_n = kTR \text{ volts}^2/\text{Hz} \tag{1}$$

where:

k = Boltzmann's constant = $1.38 \cdot 10^{-23}$ J/K

T = temperature, which we assume to be 290 K

R = effective resistance of the receiver aerial input, for example 50 ohms.

Assuming for the present an ideal FM receiver (noise figure F = 0 dB), the noise power density, S_o at frequency f, at the output of the FM discriminator is approximately given by (for high signal-to-noise ratio well above the FM thresholds, see reference [1] for derivation):

$$S_o\ (f) = \frac{2p_n\ f^2D^2}{a^2}\ \text{volts}^2/\text{Hz} \qquad (2)$$

where D is the gain constant of the FM discriminator (volts/Hz).

Thus the total noise power in the subcarrier channel (before demodulation of the signal) centred on 57 kHz and with bandwidth f_b (if $f_b << f_{sc}$) is given by:

$$N = \frac{2p_n\ D^2}{2} \int_{f_{sc} - \frac{f_b}{2}}^{f_{sc} + \frac{f_b}{2}} f^2\ df \qquad (3)$$

$$N \simeq \frac{2p_n\ f_{sc}^{\ 2}\ f_b\ D^2}{a^2}\ \text{volts}^2 \qquad (4)$$

The r.m.s. noise level at the FM discriminator output measured in bandwidth f_b centred on 57 kHz is given by:

$$\sigma_s = \frac{f_{sc}D}{a} \sqrt{2p_n\ f_b}\ \text{volts} \qquad (5)$$

The peak amplitude of the modulated radio-data subcarrier at this point is given by:

$$h_s = \Delta f \cdot D\ \text{volts} \qquad (6)$$

Now, with an ideal synchronous demodulator for the 57 kHz subcarrier and matched filtering or correlation detection for the *biphase* symbols, the r.m.s. noise at the input to the data slicer is then simply given by:

$$\sigma_b = \frac{2f_{sc}D'}{a} \sqrt{p_n\ f_b}\ \text{volts} \qquad (7)$$

where D' is the combined gain constant of the FM discriminator and the radio-data decoder up to the data slicer input.

The peak amplitude of the baseband data signal at this point is given by:

$$h_b = \Delta f \cdot D'\ \text{volts} \qquad (8)$$

Thus the peak-signal-to-r.m.s.-noise ratio for an ideal receiver/decoder is given by:

$$\frac{h_b}{\sigma_b} = \frac{a \cdot \Delta f}{2 \cdot f_{sc} \sqrt{p_n f_b}} \qquad (9)$$

With a real FM receiver having a noise figure $F \neq 0$ dB* this is degraded to:

$$\frac{h_b}{\sigma'_b} = \frac{a\ \Delta f}{2f_{sc}\ (\sqrt{p_n f_b})\ 10^{(F/20)}} \tag{10}$$

It must be noted, however, that this result is an approximation which is only valid well above the FM thresholds. At very low signal-to-noise ratios FM "clicks" (see reference [2]) rather than continuous noise will dominate, and the instantaneous noise power will show strong dependence upon the instantaneous amplitude of the (composite) modulating signal.

3. Calculation of the bit-error probability

The probability of a bit-error before differential decoding, p, can be written as:

$$p = \frac{1}{2}\ p(n(t) > h_b) \tag{11}$$

where $p(n(t) > h_b)$ = probability that n(t) has a magnitude greater than h_b and where n(t) is the instantaneous noise voltage at the data slicer input and h_b is the peak amplitude of the data signal at the sample instant.

The factor of one half arises because the probability of n(t) having the right polarity to cause an error is one half.

The quantity n(t) is Gaussian (for signal-to-noise ratios well above thresholds) with r.m.s. value σ'_b as given by equation (10). With equation (13), the probability that n(t) has a magnitude greater than the data signal peak amplitude, h_b, is:

$$p(n(t) > h_b) = 2\left(1 - P\left(\frac{h_b}{\sigma'_b}\right)\right) \tag{12}$$

where

$$P(Z) = \frac{1}{2\pi} \int_{-\infty}^{Z} \exp.\ (-Z^2/2)\ dZ \tag{13}$$

P(Z) is the normal or Gaussian distribution function and is tabulated in reference [3]. Hence from equation (11):

$$p = 1 - P\left(\frac{h_b}{\sigma'_b}\right), \text{ with } Z = \frac{h_b}{\sigma'_b} \tag{14}$$

Now h_b/σ'_b is the peak-data-signal-to-r.m.s.-noise ratio as given by equation (10). Thus, substituting in equation (14) for h_b/σ'_b and using the tabulated values of P(Z) given in reference [3], we may calculate the bit-error rate at the input to the differential decoder for any value of aerial input level, a.

Two further simple steps remain to obtain the results plotted in the graph of *Fig. 3.1*, curve (a).

First we must convert the quantity "a" (which is a measured potential difference) into received RF power P_{rf} and express it in decibels relative to one picowatt.

$$P_{rf} = 10\ \log_{10}\left(\frac{a^2}{50}\right)\ \text{dB(pW)} \tag{15}$$

* In the calculations used to derive curve (a) in Fig. 1 of Chapter 3, a noise figure of F = 5.5 dB was assumed.

Second we must take account of the effect of the differential decoder. With differential decoding an error occurs if the present or previous data bit is wrong, but not both. The probability of one error only (m = 1) in any pair (n = 2) of data bits is:

$$p(m = 1, n = 2) = 2p(1 - p) \qquad (16)$$

where p is the bit-error rate at the input to the differential decoder.

Thus the bit-error rate, P_e at the output of the radio-data decoder is given by:

$$P_e = 2p(1 - p) \qquad (17)$$

where p is found from equation (14).

For example, if the potential difference is a = 7.07 μV, the received RF power, P_{rf}, is:

$$P_{rf} = 10 \log_{10}\left(\frac{50}{50}\right) = 0 \text{ dB (pW)}$$

Substituting in equations (10), (14) and (17) for a receiver with a noise figure F = 5.5 dB and for an RDS deviation of ± 2 kHz gives a bit-error rate $P_e \simeq 2 \times 10^{-5}$.

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Chapter 4

Recommendations for the implementation of the various features

4.1 Introduction

EBU Recommendation R33-1985 and the Introduction to EBU doc.Tech 3244 (March, 1984) drew the attention of broadcasters and receiver manufacturers to the idea that when RDS is introduced, priority had to be given to the introduction of features relevant to automatic tuning.

Successive stages in implementing RDS will be necessary. This is because some of the RDS features need data to be sent from the studio centre to the transmitter; the data distribution circuits needed to do this do not yet exist in many countries. Initially therefore it will be possible in many countries to introduce only those features which can be broadcast using information permanently stored in the RDS encoder at the transmitter. These are often referred to as "static RDS features" and include features such as PI and AF, which are needed to assist automated tuning of receivers. Introduction of RDS features such as EON* and TA, which need dynamic updating from the studio centre is, nevertheless, a high priority for many broadcasters. Clearly, therefore, it will be important in receiver design to allow the gradual introduction of features by the broadcasters, without the need to modify existing RDS receivers.

Three kinds of RDS features are identified below

— Primary features
— Secondary features
— Additional features.

The primary features comprise mainly the codes such as the Programme Identification (PI) codes, which are essential to assist automatic tuning in RDS receivers. In many cases these codes are time-invariant and might be programmed into the memory of the RDS encoder connected to the transmitter equipment. In other cases, however, even this basic information has to be changed to reflect the use of the transmitter network by different programme services at different times of the day.

The secondary features comprise codes for applications such as Enhanced Other Networks information (EON), which many broadcasters expect to use but not necessarily in their first stages of implementation of RDS. As noted above, in many countries the introduction of these features is hindered by the lack of suitable data circuits between the studio centre and the transmitters.

* The EON feature is transmitted in Group type 14A or 14B and replaces the formerly defined ON feature (Group type 3A or 3B) which will no longer be used.

The additional features comprise codes for applications such as a "Traffic Message Channel" (TMC) which are essentially unrelated to the main audio programme signal, but use capacity in the RDS channel as a convenient data-transport mechanism.

The baseband coding of RDS is such that some of the secondary features such as the Programme Type (PTY) code are coded in group types which are needed for primary features. In these cases dummy codes must be sent when these features are not used. In some cases, for example the Music/Speech (MS) switch, these dummy codes are already defined in the Specification. In other cases the choice of dummy codes is left to the broadcaster. Receiver manufacturers have indicated that it would be helpful to them if the dummy codes used by individual broadcasters could be made known to them and that preferably these dummy messages should change according to a pre-programmed sequence. This would assist in testing receivers which may implement these features in the expectation that broadcasters will introduce them during the lifetime of the receivers.

Other features such as Radiotext (RT) occupy specific group types which will not need to be transmitted unless the corresponding feature is used. Again, however, receiver manufacturers have indicated that transmission of dummy messages in these group types would assist with testing RDS receivers.

An exceptional case is that of Group Type 1A which is identified in the Specification as being used for the Programme Item Number (PIN) feature, but is now also needed in some countries such as Sweden, Norway and France, which implemented the paging application of RDS. Details of this new RDS-based radio paging system are published in Supplement 2 to the RDS Specification of July 1988 (see also Section 4.4.1 below). In this new system, which is recommended for all new RDS-based paging applications, it is necessary to transmit at regular intervals a five-bit code to keep the paging receivers tuned to the channel on which their data is broadcast. It was found convenient to include this five-bit code in Type 1A groups because there were unallocated (spare) bits in that group type and the envisaged repetition rate was suitable.

4.2 Primary features

4.2.1. PI feature (Programme Identification)

The PI code is intended to distinguish between different programme services.

In order to avoid the receiver arbitrarily switching between two different programmes, the same PI code should not be assigned to transmissions carrying different programme services if, at any point, two or more of these transmissions can be received at a usable field-strength.

The PI code is very important in assisting the automatic tuning function of the receiver: when the receiver retunes to an alternative frequency it should use the PI code to confirm that the audio programme signal on the alternative frequency is the desired programme service. In order to minimize disturbance to the audio output signal during automatic retuning, the evaluation of the PI code must be done as quickly as possible, ideally within the period of one RDS group (i.e. about 0.1 seconds).

The PI code is not intended to be used directly by the listener.

Bits 1 to 4	Bits 5 to 8	Bits 9 to 16
Country identification	Programme type in terms of area coverage	Programme reference nos.

Fig. 4.1: The three elements in the PI code.

As shown in *Fig. 4.1* the PI codes consist of three elements, which are specified in the RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067. These elements are:

— country identification (15 codes)

— programme type in terms of area coverage (16 codes)

— programme reference numbers (255 codes).

It is intended that each separate programme service, regardless as to whether it is broadcast from a single transmitter or a whole network of transmitters should be allocated an appropriate PI code. The assignment codes to be used within any one country should be coordinated amongst the broadcasters concerned so as to avoid the same PI code being used by unrelated programme services.

In assigning the PI codes, the following conventions have generally been adopted by broadcasters.

Bits 1-4: Country identifier

The country codes are not unique and are for example the same for up to five countries within the European Broadcasting Area. However, the geographical distances between countries are sufficient to avoid transmissions from two countries which share a code being receivable at the same point. The country code is primarily intended to allow broadcasters to allocate the other 12 bits of the PI code on a national basis.

In connection with the TMC feature (see Section 4.4.2) it may however become necessary to distinguish between countries having the same country code. Additional information needed to distinguish between countries having the same country code may be provided within the information broadcast for the Traffic Message Channel (TMC) feature (see Section 4.4.2).

It is not intended to identify the country in which a transmitter is located, but rather the country which originates the programme service. Thus for example, some transmitters in Northern Italy relay programme services from Austria, and will accordingly radiate the PI code of those programme services including country code "A" for Austria rather than "5" for Italy.

Bits 5-8: Programme type in terms of area coverage

In principle, three levels can be distinguished:

— L (local)

Area code L (0 hex) signifies that this programme service is radiated from a single transmitter only, so that no alternative frequency exists (including MF or LF). This means for the receiver that the "follow-me" function is turned off; regardless of poor reception, the receiver will not search.

— R1 .... R12 (regional)

In the RDS system an indication of traffic areas is not necessary in order to provide assistance in tuning to a station which carries traffic information relevant to the area in which the radio is used; broadcasters using ARI* will therefore no longer need to indicate traffic areas in the RDS system. The twelve available regional area codes R1 to R12 (4 hex to F hex) may be freely used by the broadcaster.

Broadcasters who transmit regional variants of certain programme services shall indicate this by using R1 ... R12 for the area code, all other bits being identical. This concept of *generically linked networks* is of great importance, in particular in connection with Method B of the AF feature (see Section 4.2.5) and the EON feature (see Section 4.3.1).

* ARI is the broadcasts for motorists information system which is used in Germany (FR), Austria, Switzerland and Luxembourg. It is expected that ARI broadcasts will be phased out when RDS is well established in the countries concerned.

— I (international)
N (national)
S (supraregional)

Regional networks may be combined to carry a common supraregional, national or even international programme service; in those cases bits 5-8 may change from R1 ... R12 to either S (3 hex) or N (2 hex) or I (1 hex), all other bits remaining equal.

This implies that a splitting of one and the same programme service into two or more "supraregional" variants is not possible. If this occurs, the codes R1 ... R12 should be used.

Bits 9-16: Programme reference numbers

Up to 255 possible programme services within any given country may be identified (Code 00000000 is not assigned). The allocation of programme reference numbers must also, as stated above, be decided nationally.

4.2.2 PS feature (Programme Service name)

The PS code is not intended for automatic tuning purposes and is only intended for the broadcaster to send a description, in 8 alphanumeric characters, of his programme service name. The receiver has to display all these 8 alphanumeric characters. The RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067 contains the character sets desirable for coding. For a low-cost receiver, a limitation to the latin-based alphabet of the international reference version of ISO 646 (ASCII 7 bit codes) character set shall be tolerated. Lower-case characters may be displayed as upper-case characters.

The use of eight characters for PS name represents a compromise between the broadcaster's desire to fully name his station and the practical limitations of the number of characters which can be displayed. Thus, although the broadcaster will frequently vocalize his station name in full, PS in RDS is likely to become the first choice for a station identification.

A number of examples* of possible PS names follow:

OE_R-ST_	Österreich Regional - Steiermark
AVRO-R2_	Algemene Vereniging Radio Omroep - Radio 2
Jönköpng	Jönköping
YLE_OULU	Yleisradio Oulu (Finnish Local Radio)
_BBC_R4_	British Broadcasting Corporation, Radio 4
BBC_Educ	British Broadcasting Corporation, Educational Programmes**

It is recommended that broadcasters distribute the space characters in such a way that the PS name appears to be centred on an 8-character display. There exist however receivers performing this automatically.

It should not be forgotten that the PS name is not necessarily fixed for all time at the start of an RDS service. Some broadcasters significantly change (or split) their networks and will wish to use more than one PS name. Thus, for example in the case of BBC R4 and BBC Educ, both programme services use the same VHF transmitter network; the former is the news and current affairs programme and the latter comprises two periods per day during school hours when educational broadcasts are transmitted on VHF whilst the BBC R4 programmes continue to be broadcast from the LF transmitters.

* In these examples the symbol "_" represents a space.
** This PS name may be used to identify broadcasts for schools which are carried out on the BBC Radio 4 network at certain times of the day.

It is also desirable with a car radio for the PS name to be displayed on a sufficiently large and separate display in a more convenient and safe position for the driver, perhaps in the car dashboard. Adaptation of the wiring standards for car electronics may however be required to achieve this (see also *Appendix 1* to this Chapter).

4.2.3 AF feature (Alternative frequencies)

All the broadcasters intending to implement RDS have realized the great importance of the AF feature for automatic tuning of receivers, and this feature should therefore be considered as essential.

The list of alternative frequencies (the codes are in fact composed of frequency-channel numbers) should be as short as possible, i.e. the AF lists should include, in principle, only the frequencies of stations receivable at usable field-strength somewhere within the service area of the transmitter broadcasting that particular AF list. However, because of economic reasons and the use of repeater stations in mountainous areas, the generation of a unique AF list at each station is not always possible. Therefore, most of the AF lists will include, in practice, frequencies which are not really alternatives in some parts of the service areas.

For the transmission of AF lists two different solutions are described in the RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067, Methods A and B. Typical examples for the use of these codes are given in *Appendix 2 of Chapter 4*. It is strongly recommended for broadcasters to use Method B for networks using regional variants, so that receivers can determine which frequencies relate to those regional variants of the programme service.

Regardless of the method chosen by the broadcaster any RDS receiver must continuously decode the AFs and if necessary update the stored alternative frequencies.

Method A

Method A is still preferred for networks which have no regional variants and for which the AF list is short.

Each transmitter belonging to a network broadcasts only one single AF list of up to 25* frequency-channel numbers. All frequencies of transmitters and repeater stations which broadcast this list should be included in the list. The list will therefore inevitably include some frequencies which are not really alternatives in the service area of the station from which the list is received. Details for the coding of the AFs are given in the RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067.

Where Method A is used, the first code in the list indicates how many different frequencies, excluding filler words, are included in the list.

If Method A is used for a network consisting of a main transmitter and a number of repeater stations, then the frequency of the main transmitter should immediately follow the code showing the total number of frequencies in the list. In the same sense, although the RDS Specification, EBU doc. Tech 3244/CENELEC EN 50 067, does not specify the order in which the AFs are included in the list, broadcasters may insert AFs in a sequence of decreasing importance in terms of coverage area and/or radiated power, because this will then facilitate the evaluation of a relatively long list in the receiver.

If this feature is used for a local programme service which is broadcast on a single frequency only (i.e. the area coverage element in the PI codes is coded as "L"), then either code 224 (no AF exists) followed by code 205 (filler code), *or* code 225 followed by the code for that single frequency, may be used.

* The actual number of codes found in the list may be slightly higher, however, because of the particular way of coding chosen in the Specification, i.e. two AF bytes are required for one LF or MF channel.

Method B

This method is recommended for networks using long chains of repeater stations, which are typically found in mountainous areas. Method B is also recommended in the case of programme services carrying regionalised programmes.

With Method B several station-related lists, unlimited in their number, may be transmitted cyclically from the main transmitter that provides the feed of RDS signals to the chain of transposers or rebroadcast transmitter stations. These lists are structured in such a way that each list will not contain more than 25 frequencies. If this limit needs to be exceeded, several sub-lists will be used sequentially. Each list is preceded by a number showing the total number of frequencies in the list, followed by the header frequency to which following pairs can be referred. Then the frequencies are transmitted in pairs, for indirect addressing within a sequence of several pairs. The repetition of the tuning frequency in successive pairs is the criterion for identification of Method B. The only exception to this principle is the use of an AM frequency. Then, for coding reasons, the tuning frequency will not appear in the respective block*. It should however be born in mind that RDS does not permit an automatic return to any VHF/FM frequency after a receiver has switched to LF/MF. Consequently, the return to FM has to be based on testing, from time to time, whether satisfactory FM reception quality can again be achieved. Details of the coding of the AFs are given in the RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067.

The frequency pairs are normally transmitted in ascending order (see also the examples in *Appendix 2 of Chapter 4*) and their respective PI-codes must be identical in all 16 bits. If the two frequencies of the pair belong to different regional variants of one and the same programme service or network, the pairs are transmitted in descending order and consequently their PI-codes will differ, but in bits 5-8 only (see also Section 4.2.1).

With Method B it is thus, in principle, possible to broadcast an unlimited number of station-related lists; no limit is put on any individual list, except that it must be structured to contain not more than 25 frequencies, of which (due to the particular coding chosen), only 12 are codes of real alternative frequency-channel numbers. This flexibility avoids of course all the limitations encountered with Method A in those cases where a main transmitter is used as a programme link for a large number of small repeater stations.

However, new problems are created for the receivers if the broadcaster exploits such flexibility to the full. For example, if the number of station-related lists is very high, and since each individual list contains several frequencies, there will necessarily be a certain delay before the receiver can correctly establish the station-related list relevant to its tuning frequency. Furthermore, this delay will be adversely affected by incorrectly received data when multipath propagation is predominant and by the repetition rate chosen for Group type 0A. In addition, in the case of a very long station-related list, the search process for the best frequency may take quite some time in order to identify the real alternative to which switching should occur, once the signal strength of the tuning frequency becomes unsatisfactory. The length of this search process is influenced by the fact that it has to be inaudible.

In order to ensure that the automated tuning process of a car radio functions correctly from the listener's point of view, the broadcaster is advised to consider, especially in mountainous regions, the following measures, recommended by RDS experts in the car-radio manufacturing industry:

— An individual station-related list should preferably not contain more than 24 real alternative frequency channel numbers, i.e. not be composed of more than two sub-sets of 25 frequencies each.

— The total number of AF codes within a complete set of station-related lists distributed via the same transmitter, should be kept as small as is practicable. Experience indicates that up to around 125 pairs of AF codes (bytes) would be acceptable.

— Within a station-related list, the frequency-channel numbers should be given in a sequence of decreasing order of importance in terms of coverage area and/or radiated power, i.e. the most important stations should be at the beginning of the list and the least important ones at the end.

* It will be necessary to use the paired code to identify an AM frequency within the same block, i.e. it is not permitted to separate that pair between subsequent blocks.

To meet these requirements, the broadcaster may consider the advisability of rearranging large existing configurations composed of a main transmitter and several repeater stations, with a view to making use of smaller sub-units, where each of them has its own main transmitter and its individual RDS encoder. In those cases where this is not possible, the broadcaster should be aware of the fact that RDS receivers may not function properly with respect to the automated tuning process.

4.2.4 TP/TA features (Traffic Programme/Traffic Announcement)

The TP code is simply a flag to indicate that the programme service carries traffic announcements. This will be implemented on the receiver by the switching of an LED or indication on an LCD display.

The TA code is also a flag to indicate that a traffic announcement is currently present and may initiate the following receiver responses:

Normal reception mode — Increase volume for the duration of an announcement.

Cassette playing mode — Switch to radio for duration of announcement and switch back to cassette afterwards.

Audio muted mode — Switch to normal reception mode for duration of annnouncement and switch back to muted audio afterwards.

It should be noted that the TP and TA codes correspond to identical features of the ARI system so that the latter may be phased out.

In order to reduce the acquisition time for TA (especially during interference), Groups of type 15B could be transmitted up to about eight times immediately after each change of the TA (flag).

When TA is used to enable the receiver to switch to traffic announcements as described above, broadcasters may have to take into account the delay times caused by distributing the signals to the transmitters, and receiver response time. The TA code should therefore be given sufficiently in advance before a traffic announcement would start. To cover the uncertainty in the time necessary to switch the announcement, broadcasters may consider the use of traffic announcement identification jingles.

4.2.5. Ingenious use of the PI and AF features

The principal use of the PI code is to establish, when comparing transmissions on one or more alternative frequencies, whether or not those transmissions carry the same audio programme. This is necessary when exploiting the Alternative Frequency feature to avoid, in some circumstances, automatic switching to an alternative frequency carrying, in the area in which the receiver is used, a different audio programme.

In the following description it is supposed that the EON feature is not implemented. With EON information further and more favourable possibilities may be offered (see Section 4.3.1).

Three cases are envisaged:

National networks: All transmissions carrying the same national programme service have the same PI code (identical in all 16 bits). Since the programme signal carried by all these transmissions is the same, the receiver may automatically switch between any two transmissions, identified by the same PI code, in order to utilize the best frequency for optimum reception in any area.

Regional networks: Different situations are possible, mainly depending on whether or not a data link between the studio and the transmitters is available to allow for dynamic up-dating of the RDS encoder.

a) If static RDS data are transmitted, the broadcaster shall always identify all transmitters of a regional network as regional variants.* In this case the PI codes shall be generically linked, so that they differ in the area code (bits 5-8) only.

An RDS receiver will, of course, not automatically retune to any other transmitter carrying a different PI code on a different frequency, even when the programme services are identical.

However, if use is made of the option in Method B to identify frequency pairs relevant to different regional variants by transmitting them in *descending* frequency order, particular actions of an RDS receiver may be achieved:

— If during a journey the receiver goes mute, because no transmitter of a particular regional variant can be received any longer, the listener may be advised, for example, to depress the relevant preset push-button which was used to select that network, thus causing the receiver to switch directly to a receivable station belonging to an adjacent regional network. The receiver may of course not be directed unambiguously to a specific regional variant, if more than one other regional variant is receivable.

— If several regional variants are receivable at a particular location, a receiver may switch to one of these variants when manually instructed to do so, for example by the listener depressing the relevant preset push-button. Again the receiver may not be directed to a specific regional variant, if more than one further regional programme is receivable.

Some receivers implement a so-called "regional button".

— In the mode "regional on" only AFs having the same PI code, i.e. arranged in ascending order, will be used. So the receiver will remain tuned to a specific regional variant as long as it is receivable.

— In the mode "regional off" AFs having a PI code with a differing area code (bits 5 - 8) will also be accepted. In this mode the receiver shows a similar performance as described above, however instead of being activated manually, it switches automatically. This is of benefit when the regional variants just carry the same programme, but will become annoying if the receiver switches back and forth between different programmes.

b) If dynamic up-dating of the RDS encoder is possible, the broadcaster may switch the PI code (and perhaps also the PS code). This dynamic feature may be particularly advantageous if the parent network is split into regional networks only during certain hours of the day.

Also with dynamic switching of the PI code it is recommended to use Method B frequency lists and the content of each of these lists should be *static* (although the number of lists may be changed). In that case the RDS receiver should store alternative frequencies arranged in descending order, appropriately marked as regional variants.

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* The applicable rule for this can be found in the RDS Specification as up-dated by CENELEC (EN 50 067, January 1990), and it reads as follows:

"Broadcasters using splitting of a network during certain hours of the day should use AF method B, and not A. The AF lists should be static, i.e. the AFs included in the list, carrying a different programme during certain hours of the day, should be signalled by transmitting in the descending order. Their PI shall differ in the second element (bits 5 to 8) of the code and may also be static. To identify different regional networks or programmes the PI area codes R1 to R12 shall be used. If switching of information is possible, the second element of the PI code should be changed to I, N or S, as appropriate, during the transmission of a common programme.

This convention will permit a receiver to use a regional on/off mode which, when the receiver is in the mode "regional off", will lead to the acceptance of the PI with the differing second element, and thus permit switching to a different regional network. This option can be deactivated by choosing the mode "regional on". Then only AFs having the same second element of the PI (i.e. the same programme) will be used. This should also be the case for receivers without regional on/off mode. The switching of the second element of the PI to I, N or S, respectively, informs a receiver that now even AFs transmitted in descending order carry the same programme and the receiver should use this information to allow switching to these AFs."

— When a transmitter opts out to become a regional variant, it then carries the generically linked PI code of this regional programme, i.e. the second element (bits 5-8) of the PI code will then change to R1 ... R12. The receiver will of course have to remain tuned to the original tuning frequency and thus reproduce the new regional programme. It can evaluate the new PI code and switch automatically to any AF arranged in ascending order.

— When a transmitter changes to the common programme service, it then carries the PI code of the common programme. The receiver will again remain tuned to the original tuning frequency and thus reproduce the new common programme. It can evaluate the new PI code whose second element shall be S or N or I, and may additionally use those AFs arranged in descending order as part of its normal auto-tuning function.

Local stations: Local stations are defined as stations which broadcast on a single frequency only. In this special case of broadcasts bearing an area code "L", the receiver manufacturer may choose to store the frequencies of all receivable local stations against one push-button, such that repeated depression of the push-button will cause the receiver to *toggle through* the list of stored stations, even though they have different PI codes. In this case, the alternative frequency feature may, at the discretion of the broadcaster, be used to give the frequencies of other local stations that carry different programmes in the surrounding area.

Special significance of the tuning frequency

It should be noted that the tuning frequency is of special significance; it is recommended that the receiver should not change from the currently selected frequency unless that signal becomes unusable due to low signal-strength and/or multipath.

Thus, even if the PI code changes on the tuning frequency, the receiver should remain tuned to that same frequency and accept the new PI code if it differs in the regional element only (bits 5 to 8). Such a situation may occur in Austria for example, when a certain frequency is used for the radiation in a tunnel as well as for two different regional services on each side of the tunnel. When entering or leaving the tunnel, the PI code will suddenly change in bits 5 to 8 only, specifying the different regional variant which may carry a different programme. RDS receivers should not change the tuning frequency and should disregard the change of programme service encountered.

If however the PI code changes completely, the receiver should initiate a PI search for a frequency whose PI code exactly matches the PI code of the original tuning frequency. Failing an exact PI code match the receiver should search for a PI code differing from the original PI code only in the regional element (bits 5 to 8). If neither of these criteria are met, the receiver should remain on the original tuning frequency.

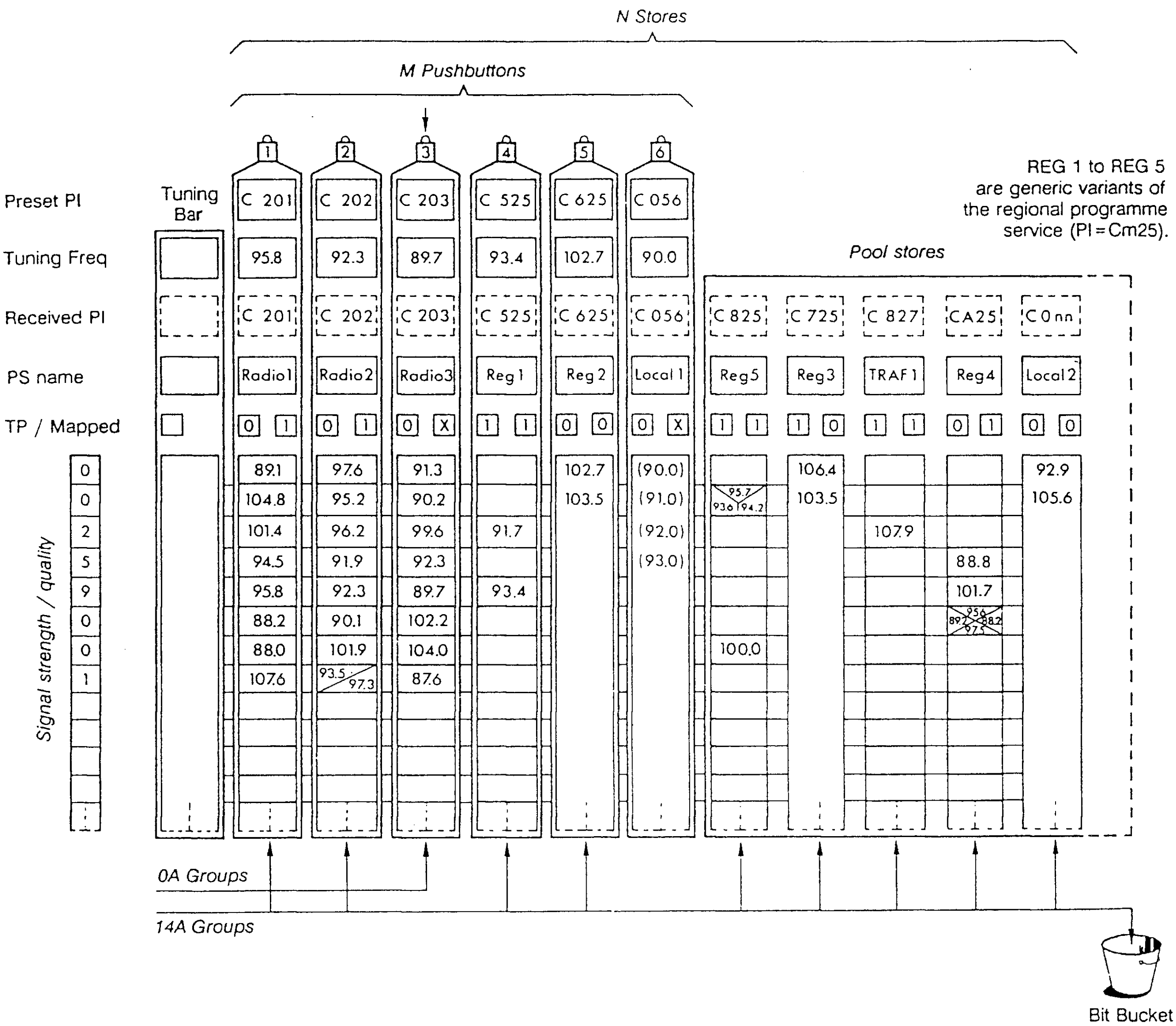
In mountainous regions there are still a number of tunnels in use where no signal is radiated and the same frequency can be received at both ends. In such cases it will also be preferable that the receiver mutes and remains on the tuning frequency until the signal will re-appears at the exit of the tunnel.

After the receiver switches to another network to use the Traffic Announcement feature TA within EON (TA), it will always return to the original tuning frequency (see also the next Section about EON).

4.3 Secondary features

4.3.1 EON feature (Enhanced Other Networks Information)

The Enhanced Other Networks feature (EON) as described in the RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067 is intended to allow updating of AF, PTY, PS, TP, TA and PIN information for programme services other than that of the tuning frequency. It is intended to allow the broadcaster to cross-reference information about all his services and indeed, if mutual agreement can be reached, also about the services of other broadcasters.



Notes:

1. "Generic" PI codes are those where the first and the last two hex codes are always the same (see Section 4.2.1).
2. When more than one frequency is entered in a box, this means that there exist more than one "mapped" frequencies.
3. For button 6, the frequencies in brackets belong to local stations in the reception area of C056 (previously delivered on 90.0 MHz via 0A groups).

Fig. 4.2: Model receiver concept using a row of stores, up-dated via information received in group types 0 and 14, essentially for using the Enhanced Other Networks Information (EON). The example shown is fictional and based on services available in the London area.

Of all the features which can be cross-referenced, the most important are the AFs for other programme services and the TP/TA traffic information features. They may be utilized even where the other information (e.g. PTY, PS, PIN) is not used on either the tuning frequency or the other programme services. Variants of type 14A groups together with the codes for elements which are not implemented (e.g. PIN or PTY) need not be transmitted. The sequence of different type 14A variants may be chosen by the broadcaster and need not necessarily comprise any fixed rhythm.

The basic function of EON information is to assist automated tuning to other programme services. This will be explained by using one distinct model concept of an RDS car radio. This model, also covering some non-EON features, is realistic but not unique. Other equally valid implementations are possible.

In this model (see *Fig. 4.2*), there are M push-buttons. Each button may be preset to a particular programme service by storing its PI code in an associated memory. This is referred to as the "preset" PI.

Also associated with each button are a set of stores containing the following:

a) The "received" PI code; this is not necessarily the same as the "preset" PI code in the case of regional variants and local stations.

b) The PS name of the programme service.

c) A flag indicating the TP state of each service.

d) A flag indicating whether the associated AF list is mapped to the tuned service.

e) An AF list for the respective programme service. For the tuned programme service the list may be ranked according to the signal strength/quality. This ranking is shown on the left-hand side of *Fig. 4.2*. Other programme services will appear in the same ranking order as the tuned service if the AFs are conveyed via the mapped-frequency method. This is shown in *Fig. 4.2* by a horizontal line under each mapped frequency.

Besides these M push-button stores are a number of additional stores with an identical structure, not directly associated with any button. These are referred to as "pool stores". The total number of parallelled stores in the receiver is N. Pool stores are used by the receiver to store information about programme services not preselected by the listener but of potential interest (traffic services and all regional variants of preset services).

Information flow (see *Fig. 4.2*)

It is assumed that button 3 is pressed, and that the receiver is tuned to the national programme service RADIO 3 (PI C203). Information carried in 0A groups updates the memory under this button (PI, PS, TP and AF list). The state of the mapped frequency flag is irrelevant. The receiver ranks these AFs in order of signal strength/quality.

Whilst tuned to this service, type 14A groups deliver information about cross-referenced programme services. This information is stored against a preset button if the received PI (ON) code contained in block 4 matches the "preset" PI exactly. Otherwise the information is stored in a pool store if the received PI (ON) code generically matches one of the "preset" PI codes or if the TP (ON) flag is set in the 14A group.

Type 14A groups which do not meet either of these conditions are of no use to the receiver and are consequently discarded.

Receiver performance (see *Fig. 4.2*)

The following analysis of the performance of the receiver under switching conditions will illustrate the practical advantages of utilizing EON groups, and the mapped frequency method in particular.

a) *Switching to another preset programme*

The receiver is currently tuned to 89.7 MHz because this frequency has the highest rank in signal strength/quality.

If the listener presses button 1 (preset to RADIO 1) the receiver already knows, through the mapped frequency lists, that 95.8 MHz is the correct frequency to use. It is not necessary to test all frequencies in the AF list of preset 1.

If the listener presses button 4 (preset to programme REG 1), the receiver behaves as above, switching instantly to 93.4 MHz. However, if the tuning frequency had been other than 89.7, for instance 104.0 MHz, in that case no mapped frequency exists for the programme REG 1. In such a case the receiver shall try out the transmitted AFs 91.7 and 93.4, and if acceptable tune to one of these. If neither of these two frequencies is receivable with acceptable quality, the receiver may then decide to select the best appropriate regional variant from the pool stores, and would then arrive at programme REG 5 on the mapped frequency 100.0 MHz, in this case. Assuming that for REG 5 there would not have existed this mapped frequency, another regional variant could have been taken then instead, for example REG 3. However in that case the AFs were transmitted in Method A, and the receiver will then have to try first which of these would be receivable, and check the PI code before switching. It could of course occur that none of them would be usable and that particular location.

If the listener presses button 5 (preset to programme REG 2) the receiver needs to test all frequencies in the AF list stored under button 5 because the list was not delivered as a mapped frequency list (Method A used instead). These frequencies need to be tested both for signal strength/quality and PI code before they can be accepted. In areas where many of these frequencies carry other programmes (not necessarily with RDS) this may take a considerable period of time. In the case where the programme is determined to be not receivable, the receiver may select an appropriate regional variant as before.

If the listener presses button 6 (preset to local programme C056), the receiver behaves in exactly the same way as with button 5 and will switch to the frequency carrying C056. In the event that this programme is not receivable, the receiver may be directed to select another local programme from its memory by successive depression of button 6 (see also item d, below).

b) *Selection of a regional variant*

If the listener is tuned to a certain regional variant and he wants to listen to another, in this receiver model concept he will press the selected button again. This will cause the receiver to look in the memory for a station with a generically related PI code and the best signal strength/quality as determined by the frequency mapping. Programme services, which are generically related but unmapped, would be treated last as these offer the lowest guarantee of reception.

By subsequent depressions of the selected button, the listener may review all the available regional variants in the current reception area.

c) *Traffic announcements via EON*

The EON feature signals traffic announcements using 14B groups that deliver in block 4 the PI (ON) code of the programme service carrying the announcement. These groups are transmitted at the start of the announcement, and repeated at least eight times within an interval of 2 seconds* to increase their reception reliability. Optionally 14B groups may also be transmitted to signal the end of such an announcement.

The receiver will only respond to 14B groups if the traffic feature is enabled (e.g. by depressing the TP button). When the receiver detects a 14B group under such circumstances relating to a service listed in its memory (either under a button or in its pool stores) it uses the mapped frequency system to determine the optimum frequency to use.

* If during a period of bad reception the receiver misses these signals, the switching to the traffic annoucement on the other programme will not occur. This will only happen exceptionally and the listener will not know that he has missed a message (which is of course less annoying than hearing just a fragment).

d) *Selection of local stations*

The listener may preset one or more local stations in exactly the same way as other programme services. In this case the frequency list under each such button (e.g. button 6 in *Fig. 4.2*) may contain one or more frequencies relating to other local radio stations conveyed via 0A groups (see Section 4.2.5). The first depression of a local button will result in the specific station being selected (precise PI code match). Subsequent depressions will select subsequent frequencies from the list.

The EON feature may optionally load an additional set of local services, under a local PI code (C0nn) which supplement the set of services loaded under the preset local buttons. The corresponding frequency list under C0nn allows for ready access to a set of local services available in a new area.

Recommendations

— *Static information*

PI codes and AF lists within the EON feature (Type 14 groups) must always be static. This does not mean that a broadcaster is prohibited from changing such lists, but means that he must not change these features as part of his regular programming.

— *Number of services*

A broadcaster should limit the number of services cross-referenced via the EON feature in any one transmission to a maximum of 20. This does not imply a maximum value for N (the total number of store sets in the receiver), because when continuing a journey, or switching to other preset programmes, additional cross-referenced services may be encountered. This may happen for example when a receiver has been preset with programmes from more than one country. Receiver manufacturers will need to implement strategies for re-allocation of pool memory not up-dated via EON for an excessive period of time.

4.3.2 CT feature (Clock time and date)

This is a comparatively easy feature to provide, even in the situation where only static RDS data is used, because it may be generated at the encoder alone. It has the advantage that RDS radios may easily display time for a moment, using the display necessary normally for PS display; this could possibly be used to advantage by the receiver designer so that when the set is initially powered, the time is displayed while the scan tune function is performed. It may well be that time output could also be standardized on an output connector (see also *Appendix 1 to Chapter 4*) to allow connection to other display devices such as are found in integrated car electronics.

Because of the possibility for the listener to pick up radio programmes from adjacent time zones, receiver design should ensure that a time display would be up-dated only when intended by the listener, and not automatically. This may require a possibility to preselect on the receiver the local time offset from universal time as a measure to adjust the respective elements used in the CT code.

4.3.3 PTY feature and Alarm code (Programme type)

Some broadcasters have indicated that they will implement this feature at an early stage, but others consider they will have some difficulties, because every programme service must be categorized and this would impose a considerable extra workload on the operational staff, especially if the programme schedule is not yet computer controlled within the production centre.

The PTY code, even if the feature is not implemented, is included in the RDS data signal very frequently. It is in all groups in the second block and in the 15B type group also in the fourth block.

The alarm code (PTY code number 31) is reserved for an alarm identification intended to switch on the audio signal when a receiver is operated in a "waiting" reception mode. Many broadcasters may use this possibility for emergency announcements under exceptional circumstances to give a warning of events causing danger of a general nature, e.g. warnings of bad weather conditions such as heavy storms, rain, snow, ice etc. This particular PTY code may be used even in the case where the other PTY codes are not implemented. For a car radio the setting of the alarm code flag should in principle have the same effect as the TA code flag, i.e. receivers should automatically switch over from cassette listening to radio, and/or increase volume if this was turned down or set to low level.

PTY code number 31 indicates a transmission of great importance, carrying information concerning a national or local emergency, and will be present in every RDS group of the programme service carrying the announcement.

The code may also be carried in variant 13 of the 14A (EON) group from transmitters cross-referencing this programme service. This group will contain the PI (ON) code of the relevant programme service in block 4.

Receivers may utilize this information in one of two ways:

a) A simple RDS receiver should initiate a search tuning for the specified PI (ON) code.

b) A more advanced receiver may use the supplied frequency list to speed up this search process.

In either case, when the receiver has retuned, PTY code number 31 will be detected in the programme service carrying the announcement. When this code is changed, at the end of the announcement, the receiver should retune back to the original programme.

4.3.4 PIN feature (Programme Item Number)

It may take some time for broadcasters to implement this feature, but it is expected to be used in some countries in the next phase of RDS developments. Although this feature would be ideal for recording, copyright problems may exist in some countries. Again, an additional workload is imposed on the broadcaster when this feature is used.

In the Specification it is proposed to transmit Group 1 at least once per second when this application is used. In order to save data capacity, Group 1 may be transmitted only once per minute. In such a case, immediately after a programme item number has been changed, Group 1 should be repeated four times with a separation of about 0.5 seconds.

Where Radio Paging is implemented with RDS, Group 1A will be transmitted in an invariable sequence, regularly once per second, except at each full minute where it is replaced by one 4A Group.

If group type 1 is transmitted without a valid PIN, the day of the month must be set to 0. A receiver which evaluates PIN must ignore this information.

4.3.5 RT feature (Radiotext)

This feature is primarily intended for home and also portable receivers, where programme-related or other information may be displayed, and it is expected to be used in some countries in the next phase of RDS developments. On a car radio, Radiotext should not be displayed since it could cause a danger to the driver.

Studies are being carried out in the EBU with a view to defining suitable control characters that would permit radiotext messages also to be output in car radios by separate external devices, e.g. small printers and/or speech synthesizers, using messages even longer than 64 characters (see also Section 4.4.2).

4.3.6 TDC feature (Transparent Data Channel)

The TDC is designed to permit the delivery of data to specialized external devices which would be connected via an output connector of an RDS receiver (see also *Appendix 1 to Chapter 4*). 32 different types of service channels are feasible. They can be specified by the broadcaster providing this service, and appropriate decoding would have to be provided within the respective external devices.

4.3.7 DI feature (Decoder Identification)

As long as DI is not fully implemented by the broadcasters a dummy code (0010), not yet assigned, will be inserted for operational purposes. Broadcasters may also indicate dynamically whether a particular programme is monophonic (0000) or stereophonic (0001). This is particularly interesting for car reception, since under adverse reception conditions (low field-strengths, high multipath distortions, co- or adjacent-channel interference) the monophonic mode yields a considerable improvement of the signal. For this reason, in a stereophonic programme, switching to the monophonic code may occur during the same period in which the TA signal is set to "1".

4.3.8 MS feature (Music/Speech switch)

Although the majority of broadcasters might not implement this feature in the near future, it is known that Sweden is planning to use it. The balance problem between music and speech has been discussed since the start of broadcasting, without reaching any final solution. The MS feature in the Radio Data System is considered to have the potential to alleviate this classic problem of various level preferences among the listeners.

As long as this feature is not implemented, the code corresponding to music, i.e. 1, will be used all the time in conformity with the RDS Specification, EBU doc. Tech 3244/CENELEC EN 50 067.

4.3.9 IH feature (In-house information)

This feature is not intended for the use of the general public and is provided solely for the use of the broadcaster. Therefore all RDS radios should ignore this feature.

4.4 Additional features

4.4.1 RP feature (Radio Paging)

The RP feature is intended to provide radio paging using the existing VHF/FM broadcasts as a transport facility, thereby avoiding the need for a dedicated network of transmitters. Since the RDS Specification was drafted, a new method of implementing radio paging using RDS has been developed in Sweden, and this offers substantial advantages over the earlier methods described in Appendix 8 to doc. Tech 3244 (March 1984). This new method of implementing the RP feature is fully described in Supplement 2 of July 1988 to EBU doc. Tech 3244 and is intended to provide a broadcast paging servi making use of the RDS channel (Group type 7A associated with the use of Group type 1A and 4A). Subscribers to a paging service will require a special pocket paging receiver in which the subscriber address code is stored. Three types of call messages are possible, in principle:

— a simple call (bleeper) without additional message;
— a 10 or 15 (international) or 18 digit numeric message;
— an alphanumeric message of 80 characters at maximum.

In the short term, only numeric pagers, mainly for 10 digit numeric messages, will be available.

4.4.2 TMC feature (Traffic Message Channel)

This feature is intended to provide a separate traffic message channel, similar to TDC, and is still under development. The Specification for using it is not yet fully defined. It is intended to provide information for motorists by means of coded messages using a unique Group type* within RDS.

* Group type 8 has been reserved for the development of the TMC feature.

The main areas which are under investigation include studies on:

- the transmission capacity needed within the RDS channel;
- the reliability of message recovery in the mobile reception mode, particularly in the presence of heavy multipath propagation;
- the performance requirements of text-to-speech voice synthesis in different languages for traffic messages, particularly under the above-mentioned difficult reception conditions;
- the use of such techniques in a wider variety of applications;
- the integration of TMC into the RDS and car environment.

4.4.3 Spare bits

According to the RDS Specification, EBU doc. Tech 3244/CENELEC EN 50 067, certain groups contain spare bits which are not yet defined, i.e. Groups 1A/B and 4A. These bits may temporarily be assigned by the broadcaster to any arbitrary value (or changing values), and should be ignored by receivers until their use has been internationally agreed.

4.5 RDS channel capacity

The use of the primary features to achieve automated tuning, essentially for mobile reception, requires a considerable part of the channel capacity, and even more if the EON feature is implemented. Clearly the use of secondary and additional features must be carefully accommodated within the remaining channel capacity which simply implies that within any given network only a limited number of the possible features can be implemented simultaneously.

As shown in *Appendix 3 to Chapter 4*, the implementation of all programme-related features together requires more than 80 % of the RDS channel capacity, leaving about 20 % for the implementation of non-programme-related features and of the so far undefined features.

To understand the restricted capacity of the RDS channel, one should also bear in mind that the effectively usable bit-rate achieved within the RDS system is only 673.7 bit/s.

Appendix 1 to Chapter 4

Scenario for the standardization of interface connections on RDS receivers

The RDS system, even if mainly used, in a first phase, for broadcast identification and automatic tuning of car radios, is potentially open to the progressive introduction in the future of a variety of other applications, most of which are envisaged for the market of a new generation of receivers.

In this context, the need to ensure a compatible evolution of RDS towards these new applications, some of which could imply external devices (e.g. printer, recorder, text display, speech synthesizer, etc.), would require the adoption of suitable international standards.

The aim of this Appendix is to provide sufficient background information to all those involved in the standardization process, i.e. broadcasters, radio manufacturers, and also the car industry.

Without wishing to specify the interface in all its details, a clear scenario has to be established concerning the use of the interface connections, for example within the car-radio environment, to stimulate agreement on a certain number of basic principles before the standardization work on the interface connector can proceed. The following observations should therefore be considered as a contribution concerning the broadcasters' view only, still requiring further endorsement by the relevant industrial partners.

Other background information required is some understanding on where the required interface standards could be agreed. Because of the number of different partners involved, this cannot be the EBU. It will be more realistic to solve the interface questions for home and portable radios within the IEC (TC84) and for car radios within the ISO (TC22). Both organizations have already established working groups with this topic on the agenda and some preliminary decisions have already been taken.

The work is in fact most advanced in the context of the car radio, where Working Group 5 of ISO TC 22 has been dealing with the matter. The stage reached is that a connector for power supply and speaker connections has been specified, containing a number of free contacts some of which may be later specified for RDS applications (Ref. Doc. 49 of ISO TC 22/WG5).

One of the basic questions arising in this context is to know which RDS applications will be required. Those under consideration in the car environment are shown in *Fig. A.1/4-1* and concern the following three different types of RDS interface.

RDS interface type 1 conveys PS and CT information to corresponding displays mounted conveniently for the driver within the car dashboard. PS is simply a repetition of the 8 alphanumeric character display available on most RDS car radios, and the CT information can either be shown on the same display or even better be used for setting a free-running quartz clock to correct clock time and date. Since a number of other control functions in the car will require similar connections with the dashboard displays, it may well be of interest to address this matter to ISO TC 22 Working Group 1 which is aiming at a data bus standard. Alternatively, a serial interface (minimum of 2 pins, but preferably 3) from the car radio to the dashboard plus one control line (1 pin) would prepare well for future integration.

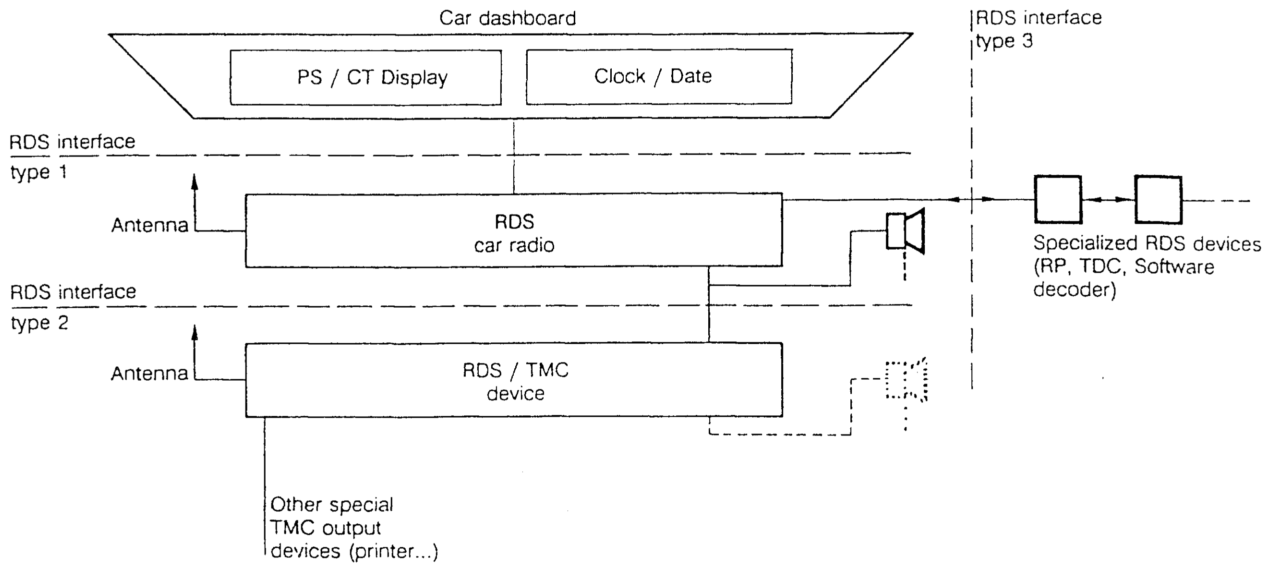


Fig. A.1/4-1: Scenario of various types of RDS interfaces in the car-radio environment.

RDS interface type 2 is related to the development of a suitable device for the decoding of coded traffic announcements within RDS on a TMC channel, as being discussed within various international committees (EBU, ECMT, CEC/DRIVE, EUREKA/CARMINAT ...). The TMC decoder will probably be too complex to be fitted within a car radio. It will require its own RF tuner anyhow to permit the car radio listener a free choice of broadcast programme without obliging him to tune to the particular programme that will carry TMC information. Similar to the TA function, the audio should then be muted for a traffic announcement or alternatively, if the audio was muted, the volume level should be raised during a traffic announcement. All this is of course to be achieved in interaction with the car radio, assuming that there will be only one set of loud speakers to be used by both units, the car radio and the TMC receiver.

Two alternative solutions can be imagined:

a) The loud speaker connections to the car radio will be made to the TMC device instead, and the TMC decoder itself will be connected to the car radio on the connectors foreseen for the loud speakers. The drawback of this solution will be that the power amplifiers for the loud speakers will probably be required in the TMC device to achieve the desired effects. The advantage of this solution is that a special interface standard for this type of connection will not be required.

b) The audio output (mono) of the TMC device will only require 2 pins to be connected to the car radio. One additional control line could be used to instruct the volume over-ride control which would exist already in ARI and RDS radios. Feeding of all loud speakers will then remain a matter for the car radio. The drawback of this solution is that existing car radios do not have these connections and could thus be unusable for use in conjunction with the new TMC device.

RDS interface type 3 is related to the connection of even more specialized devices which could include future applications, even those not yet defined. For this purpose four principles were agreed within the EBU already in 1987. The implementation will require 4 pins if used only in one direction or 7 pins if used in both. For home and portable radios this still seems to offer the most suitable solution. The principles are the following:

1. The external interface should be transparent to all RDS applications including those not yet defined.
2. The data fed to the interface should not have error correction or detection applied within the receiver. This is to allow different kinds of error correction or detection to be applied adaptively within the external device to best suit the needs of different applications.

3. The information to be conveyed from the receiver to the external device via the interface comprises:

   a) Serial data-stream at 1187.5 bit/s;

   b) Bit-rate clock (1187.5 Hz);

   c) Data valid flag which will be held high when the serial data-stream can be read by the external device, and low otherwise (for example, whilst the receiver is scanning);

   d) Up to three further pins on the interface connector may be needed to convey information *from* the external device *to* the receiver (comprising return serial data, clock and a status line);

   e) A signal ground line should be provided.

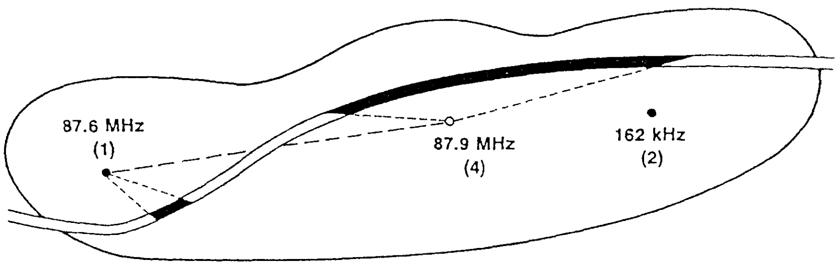
4. To permit the connection of more than one device, the peripherals should be equipped with two connectors so that all devices can be cascaded.

Appendix 2 to Chapter 4

Tutorial examples of Alternative Frequency lists

Example 1. Short AF list (Methods A and B)

These AF lists are distributed with Group type 0A.



° main transmitter
• repeater station

The LF transmitter can be received in the entire zone.

Method A

#3	(4)	← symbolic AF list	227	004
(1)	F	(F = filler code)	001	205
LF/MF	(2)	real* AF list →	250	002

* The numbers represent binary codes of 8 bit length, i.e. 001 equals 00000001, 002 equals 00000010, etc. The complete code list is contained in the RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067.

Method B (for reasons of clarity, only the symbolic codes are indicated; the real codes are based on the principles shown above for Method A)

Station-related list for Station 4

#4	(4)
(1)	(4)
LF/MF	(2)

#4 = number of frequencies (code 228)

Station-related list for Station 1

#4	(1)
(1)	(4)
LF/MF	(2)

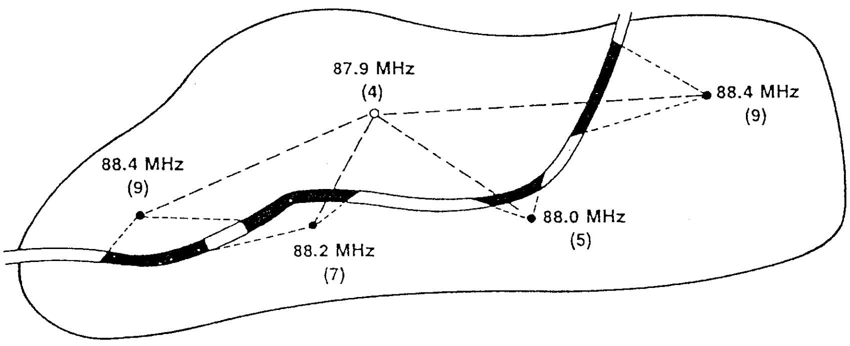
#4 = number of frequencies (code 228)

Methods A and B can be distinguished by the fact that in *Method B* the tuning frequency is repeated as a reference for an individual station-related list in successive groups (except when code 250 preceding an LF/MF channel is used). In *Method A* this repetition does not occur.

The frequency channel numbers used (shown in the figure in brackets) correspond to 87.6 MHz = 1 ... 107.9 MHz = 204, and 153 kHz = 250/1 ... 1602 kHz = 250/135. The number 250 indicates that the second AF code in this block applies to an LF or MF channel.

Example 2. The same frequency occurs twice in one region (Methods A and B)

These AF lists are distributed with Group type 0A.



° main transmitter
• repeater station

The main transmitter can be received in almost the whole zone, except in valleys covered by individual repeater stations.

In all cases only symbolic codes are indicated.

Method A: One list transmitted via all stations.

#4	4
9	7
5	F

#4 = number of frequencies (code 228)

F = filler code (code 205)

Method B: Several station-related lists transmitted via all stations.

Station 4

1.

#7	4
4	9
4	7
4	5

Station 9 (right)

2.

#3	9
4	9

Station 7

3.

#5	7
4	7
7	9

Station 9 (left)

4.

#5	9
4	9
7	9

Station 5

5.

#3	5
4	5

These lists will be transmitted in the order 1 to 5.

The two lists for Stations 9 are separated by at least one other list.

The receiver may or may not combine the lists for the same frequency.

Example 3. AF lists using Method B based on a practical case in Austria

As an example, the network of the regional programme for the most westerly Austrian federal province Vorarlberg (OER-V) has been chosen.

This network comprises 14 VHF/FM transmitters, a number which is rather low. A radio-relay link exists only to the main station Bregenz 1 located at Mount Pfänder, whereas all remaining stations are rebroadcast transmitters fed, either directly or indirectly from the main station (*Fig. A.2/4-1*).

Bearing in mind economical considerations it is sufficient to install an RDS encoder at the main station Bregenz 1 *only*. This however implies that *all information* about AFs *for the whole network* has to be transmitted from that main station.

It is well known that AF Method B has clear advantages for network structures which are typical of mountainous regions. However, when preparing the sets of AF lists one has to take into consideration the following points:

1) At what stations will RDS encoders be installed?

   In our example, only at Bregenz 1.

2) What is the structure of the rebroadcast network, i.e. which transmitters receive their programme signal either directly or indirectly from the station equipped with an RDS encoder?

   In our example all remaining 13 transmitters are fed directly or indirectly from Bregenz 1, so that 14 lists have to be programmed at the RDS encoder.

3) What are the service areas of each individual transmitter belonging to the network under consideration and how do they overlap?

   When driving from Feldkirch, for example, in different directions there are altogether 5 options to which the RDS receiver may switch; consequently, the individual AF list for Feldkirch would a priori comprise 5 AFs.

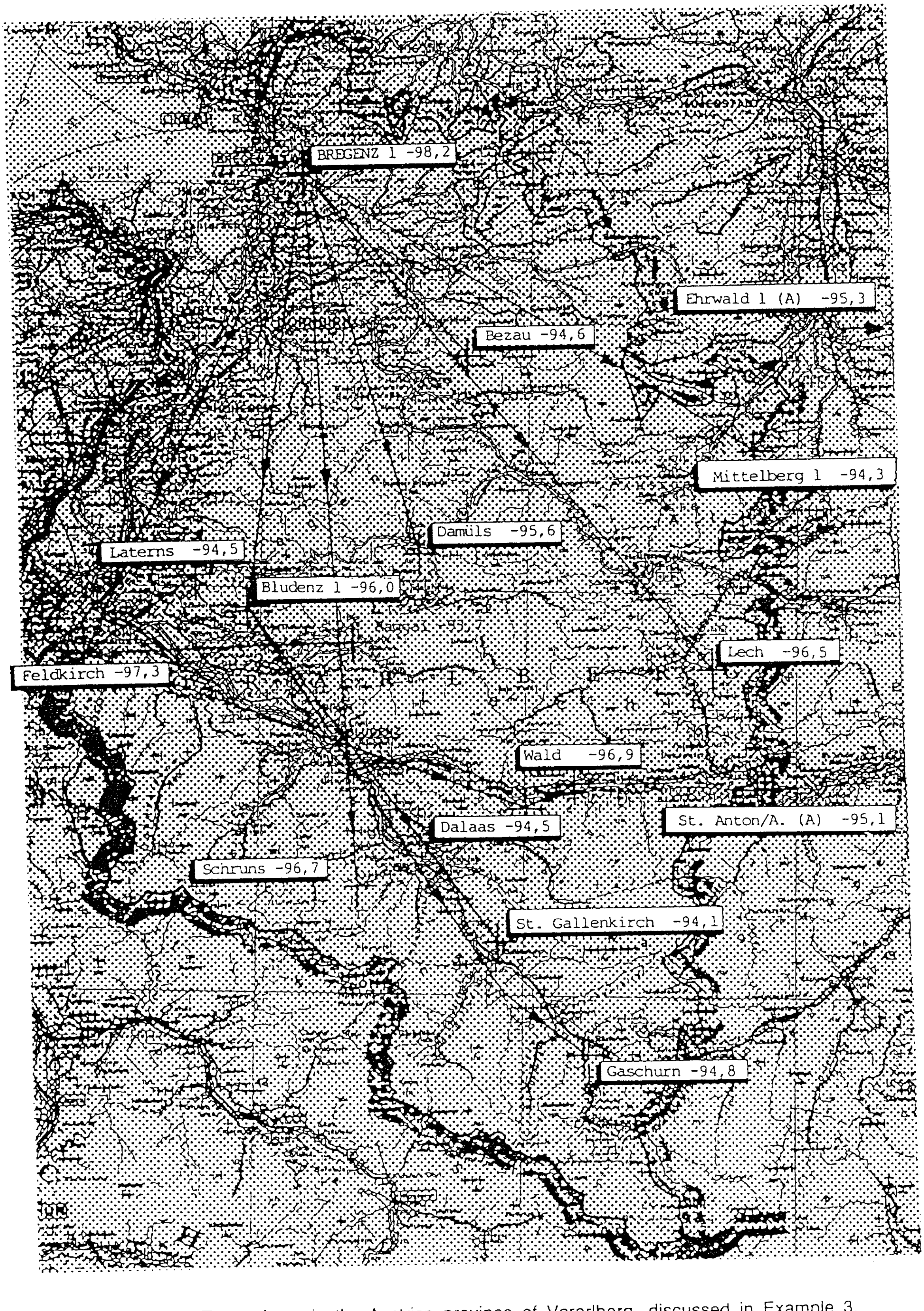


Fig. A.2/4-1. Transmitters in the Austrian province of Vorarlberg, discussed in Example 3.

4) What are the frequencies of all the transmitters which may be alternatives to the frequency to which the receiver is tuned?

   In the example selected in item 3) there are 5 transmitters whose service areas partially overlap that of Feldkirch. The AF list relating to Feldkirch would therefore contain 5 frequency pairs, all arranged in ascending order. However, the same frequency 94.5 MHz is used at two different stations, their respective service areas being geographically well separated. So this frequency appears twice in the AF list; the second pair, marked with an asterisk, is superfluous and therefore deleted.

5) Which transmitters in an adjacent area carry a different regional variant of the programme network under consideration?

   In our example there are two transmitters carrying the regional programme of the adjacent federal province Tyrol (OER-T). They are marked (A) and the frequency pairs are arranged in descending order.

Having assessed the five points mentioned above it is no problem to establish the set of AF lists for Method B according to the protocol laid down in the RDS Specification EBU doc. Tech. 3244/CENELEC EN 50 067. The final lists for the example chosen are given in *Table A.2/4-I*; it is advantageous to store the lists on magnetic media thus reducing the effort needed in programming or modifying the AF lists in the RDS encoder. As can be seen, the total number of AF codes amounts to 116, which is well below the figure of 250 (= 125 pairs of AF codes) recommended in Section 4.2.3 of these Guidelines.

Table A.2/4-I

AF list for the regional programme of Vorarlberg OER-V

Bregenz 1	#17	98.2
Feldkirch	97.3	98.2
Bludenz 1	96.0	98.2
Bezau	94.6	98.2
Ehrwald 1	98.2	95.3**
Mittelberg 1	94.3	98.2
Lech	96.5	98.2
Laterns	94.5	98.2
Damüls	95.6	98.2
Feldkirch	#9	97.3
Bregenz 1	97.3	98.2
Bludenz 1	96.0	97.3
Raggal	93.7	97.3
Dalaas	94.5	97.3
Laterns	94.5	97.3*
Bludenz 1	#15	96.0
Bregenz 1	96.0	98.2
Feldkirch	96.0	97.3
Schruns	96.0	96.7
Gaschurn	94.8	96.0
Raggal	93.7	96.0
Dalaas	94.5	96.0
St. Gallenkirch	94.1	96.0

Bezau	#3	94.6
Bregenz 1	94.5	98.2
Schruns	#5	96.7
Bludenz 1	96.0	96.7
St. Gallenkirch	94.1	96.7
Mittelberg 1	#3	94.3
Bregenz 1	94.3	98.2
Gaschurn	#5	94.8
Bludenz 1	94.8	96.0
St. Gallenkirch	94.1	94.8
Dalaas	#7	94.5
Feldkirch	94.5	97.3
Bludenz 1	94.5	96.0
Wald	94.5	96.9
Raggal	#7	93.7
Feldkirch	93.7	97.3
Bludenz 1	93.7	96.0
Damüls	93.7	95.6

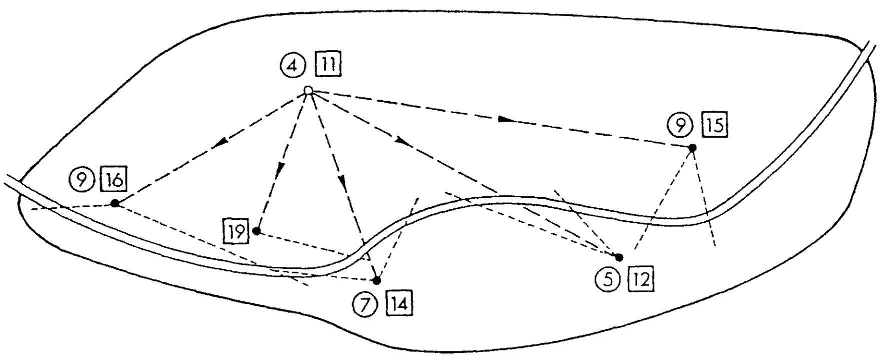
St. Gallenkirch	#7	94.1
Bludenz 1	94.1	96.0
Schruns	94.1	96.7
Gaschurn	94.1	94.8
Lech	#5	96.5
Bregenz 1	96.5	98.2
St.Anton/A	96.5	95.1**
Latrens	#7	94.5
Bregenz 1	94.5	98.2
Feldkirch	94.5	97.3
Damüls	94.5	95.6
Damüls	#7	95.6
Bregenz 1	95.6	98.2
Raggal	93.7	95.6
Latrens	94.5	95.6
Wald	#5	96.9
Dalaas	94.5	96.9
St.Anton/A	96.9	95.1**

* This pair is deleted because it is superfluous since the same information is contained in the preceding pair.

** This pair in descending order references to a regional programme for an adjacent province.

Example 4. Use of the Mapped Frequency Method for cross-referencing to frequencies of Other Networks

These frequency-lists are distributed with the 0101/0110/0111/1000 variants of group type 14A.



° main transmitter
• repeater station

○ tuned programme service
□ cross-referenced programme service

All codes are symbolic frequency channel numbers.

Note: When receiving the tuned programme on frequency 7, there are two corresponding frequencies for the cross-referenced programme, namely 14 and 19.

For the tuned programme all stations transmit the following station-related lists according to Method B in Groups 0A:

#7	4
4	9
4	7
4	5

#5	9
4	9
7	9

#5	7
4	7
7	9

#3	5
4	5

#3	9
4	9

When receiving the tuned programme, linking to the cross-referenced programme is as follows according to the Mapped Frequency Method in Groups 14 A:

0101 (Var. 5)	4	11

0101 (Var. 5)	9	16

0101 (Var. 5)	7	14
0110 (Var. 6)	7	19

0101 (Var. 5)	5	12

0101 (Var. 5)	9	15

Example: Radio receives the tuned programme on frequency 5. Then one (see Section 4.3.1) of the respective station-related lists for the tuned programme is required in the receiver. It now has to look in Group type 14A for a pair containing frequency 5 as the first frequency, to know that the cross-referenced programme can be received on frequency 12 (see also RDS Specification EBU doc. Tech 3244/CENELEC EN 50 067.

Appendix 3 to Chapter 4

RDS channel capacity

The basic bit-rate of 1187.5 bit/s of the RDS system is fairly low and therefore the RDS channel capacity is a rather limited resource. Bearing in mind that the four checkwords in each group of 104 bits occupy a total of 40 bits, and that each group address needs 5 bits, the *useful bit rate is*:

$$1187.5 - \frac{1187.5}{104} \cdot (40 + 5) = 673.7 \text{ bit/s}$$

In order to analyze the allocation of RDS capacity to each of the features, these are grouped together in categories according to their consumption of RDS channel capacity.

First we look at the capacity required for all the features relating to the broadcast programmes, and then we identify what is left over for the non-programme-related features.

As shown in *Table A.3/4-I*, the programme-related features can be divided into four categories:

— the five primary features (PI, PS, AF, TP/TA), mainly required for the automated tuning process;

— the Enhanced Other Networks information, which really is a complementary feature for automated tuning as far as networks are concerned;

— a group of features (PTY, M/S, DI, PIN, CT) which consume relatively little RDS capacity; for PIN a repetition rate of only one Type 1A Group per minute is required, although in connection with RP it must be increased to one per second;

— and finally Radiotext.

We then group together the non-programme-related features (RP, TDC, IH and TMC) and determine from the Table what capacity is left for these, if all the programme-related features are implemented.

The following can be seen from *Table A.3/4-I*:

PI, PS, AF, TP/TA : These primary functions of RDS, essentially supporting the automated tuning process, require 48.35 % of the available channel capacity.

EON: If the automated tuning process is enhanced by using the EON feature 8.24 % of the capacity would have to be set aside, bringing the total already up to 56.59 %.

PTY, M/S, DI, PIN, CT: All these features require relatively little RDS capacity. While the first three together require 9.65 % whether implemented or not, for reasons of coding, the last two require an additional 0.21 % (5.6 % if RP is implemented), bringing the total required to 66.44 % (or 71.83 % with RP).

RT: Radiotext requires an additional 17.58 %, bringing the total required for the programme-related features up to 84 % (or 89.41 % with RP).

Table A.3/4-I

Analysis of the required RDS capacity

Application	Feature	Group Types containing this info.	Appropriate min. group repetition rate (sec.$^{-1}$)	No. of occupied bits per group	No. of occupied bits per sec.	% of 673.7 bits per sec.	Accumulated RDS capacity
Automated tuning	PI	all	11.4	16	182.4	27.07	
	PS	0A	4.0	16	64.0	9.50	
	AF	0A	4.0	16	64.0	9.50	
	TP	all	11.4	1	11.4	1.69	
	TA	0A	4.0	1	4.0	0.59	48.35
Enhanced information on other networks	EON	14A(B)	1.5	37	55.5	8.24	56.59
Various other programme-related features	PTY	all	11.4	5	57.0	8.46	
	M/S	0A	4.0	1	4.0	0.59	
	DI	0A	4.0	1	4.0	0.59	
	PIN	1A(B)	0.02/1.0*	37**	0.74/37*	0.11/5.5*	
	CT	4A	0.02	34	0.68	0.10	66.44/71.83*
Radiotext	RT	2A(B)	3.2***	37	118.4	17.58	84/89.41*
Various non-programme-related features	RP	1A/4A/7A	—	—	—	—	
	TDC	5A(B)	—	—	—	—	
	IH	6A(B)	—	—	—	—	
	TMC	(8A)	—	—	—	—	

* If Radio Paging is used an increased repetition rate of 1 per second is necessary.

** Although 16 bits are actually used for PIN, the associated 16 undefined and 5 spare bits must also be taken into account, since this represents used capacity.

*** To agree with Note 3 and Table 4 of CENELEC EN 50 067, Section 3.1.3.

This leaves 16 % (10 % with RP) for the implementation of the *non-programme-related* features (RP, TDC, IH, TMC). Each of them will require, if implemented, a significant proportion of the remainder. In fact, in the case of radio paging, the paging traffic would probably account for the balance of the capacity remaining.

However, due to the time-multiplexing possibilities of many of these features, the average capacity available for other features will be greater than this indicated "peak demand", since it is unlikely, for example, that continuous radio text will be a requirement.

This form of analysis makes it quite clear that, from the broacasters' point of view it seems advisable to set aside about eighty per cent of the RDS channel capacity for the implementation of all programme-related features. This leaves about one-fifth of the channel capacity to accommodate features unrelated to the radiated programmes. This implies that only a limited number of further applications can actually be implemented within any programme service. Due consideration must therefore be given to how RP, IH, TDC and TMC can be distributed among different programme networks, e.g. a network which carries TP/TA could only accommodate in addition, for example, TMC. The same is also true with respect to so far unknown applications; their required capacity has to be carefully examined before any decision can be taken as to whether or not they justify the specification of a new Group Type.

In conclusion, RDS has a finite capacity — it is not an inexhaustible resource. That is a fundamental reality which it shares with any other communication channel, including, of course, the VHF/FM broadcast channels which RDS exploits and serves.