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Design principles for VHF/FM radio receivers using the EBU radio-data system RDS

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After giving an account of the studies conducted within the EBU leading to the definition of the radio-data system for VHF/FM broadcasting, the article lists the various functions that can be implemented in a receiver equipped to use the system. It then describes techniques that may be used for data demodulation and decoding. It gives more-comprehensive details of the methods to be used to enable the receiver to reconstitute the group-and-block structure prior to extracting the wanted information.

Design principles for VHF/FM radio receivers using the EBU radio-data system RDS

S. R. Ely and D. Kopitz*

Introduction

In 1983 the EBU completed, after about ten years' study, the specification of the radio-data system RDS, which, after its submission to the CCIR (see Report 463-3 rev.) were published in April 1984. This new system is designed to facilitate the introduction of automatic tuning features in new domestic, portable and car radios, and will additionally permit the distribution of auxiliary information within a wide range of applications.

The RDS system has been based on the modulation characteristics of the Swedish PI system, and a special method of baseband coding was developed within the EBU to enable the reliable reception of data for mobile receivers (portable and car radios), as well as a high flexibility in the use of the system with respect to varying requirements from one country to another, permitting the use of the same receiver in any of them independent of the particular applications adopted from the large range of options described in the system specification [1].

Several broadcasting organisations have shown interest in preparing the implementation of the system, which may, however, still take some time, because its inclusion in an existing network structure may be rather complex and costly, and therefore careful planning will be necessary in each of these cases. Experience gained in this particular field will continue to be exchanged within the EBU. During 1984 large-scale field trials are planned to be carried out in Sweden and Germany (FR) to try out the system from the users' point of view.

Practical technical tests of the system have been carried out since 1976 within the United Kingdom and Sweden. For the EBU experts, three demonstrations have been conducted in mountainous regions with propagation under extreme multipath conditions: these demonstrations were held in 1980 and 1982 in the region of Bern in Switzerland, and in 1983 in the region of Munich in the FR of Germany. Representatives of the European receiver manufacturers' associations were invited to participate in the finalisation of the system and to advise the EBU on the desirable applications. Furthermore, the EBU Radio Programme Committee has been asked to express itself on the proposed applications. In this manner the development has been coordinated in the widest possible sense.

At this particular time, it is important that the receiver manufacturing industry starts to develop prototypes of the desired new generation of VHF/FM receivers, putting emphasis on the new automatable tuning functions. Field trials organised by several EBU Members will then provide a sufficient number of opportunities to test these receivers from the users' point of view.

At this stage, it is not possible to forecast the date when the RDS system will first be introduced definitively in one of the countries of Europe. However, that this is going to happen in one of the coming years appears to be very likely and. for the industry, time is therefore precious at this stage. as far as the receiver development is concerned.

The purpose of this article is to encourage this work from the most general point of view. The ideas presented here are based on experience in the participation within the work of the EBU expert group which developed the system. It is thought that the expertise available on the side of the receiver manufacturers may certainly lead to more ingenious solutions than the ones presented here, and in this sense, this article is intended to stimulate the development of a new generation of receivers without necessarily imposing the solutions which should be considered as examples only. The EBU RDS system is free of patents and its principles may therefore freely be used by the

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industry. However, some of the receiver design principles mentioned here may be covered by patents outside the scope of the authors, and the way in which these can then be generally used is not a matter of their concern. In principle, the EBU would be interested to help in coordinating such questions should a major obstacle be encountered in this respect.

2. Functions of a radio-data receiver

2.1. Tuning aids

Within Europe, the density of VHF/FM coverage makes it possible at many locations to receive a large number of programmes, partially with overlapping service areas. VHF/FM broadcasting poses some of the most severe tuning problems, especially for car radios, because the coverage areas vary widely with transmitter power and terrain, and are generally quite small in comparison to LF, MF and HF transmitters. This makes it very difficult for the listener to tune, for a given programme, to the frequency which gives the best technical quality, or to find the wanted programme within a reasonable time. Although some of the problems have already been solved with pre-programmable functions which are particularly widespread in domestic receivers, a general answer enabling a technical layman to adjust his radio, in particular the portable and car radio, with great ease has not yet been found, because it would require the distribution of inaudible auxiliary data signals from the respective transmitters. This is the purpose of the RDS system for VHF/FM broadcasting.

Assuming that a listener is primarily interested in a given programme or perhaps a given type of programme, we imagine that in the new type of radio, search tuning would constitute the basic operation. The first innovation which would then be enabled through the radio-data system is the " programme service name " display, which gives a text of a group of eight alphanumeric characters coded in accordance with an agreed character repertoire. The group of characters will be displayed in similar form as the digital frequency display already used in many of the present-day receivers, and the listener will thus be informed of what programme service, for example the first programme of the national network, of course appropriately abbreviated (for example " BBC 1 "), is being broadcast by the station to which the receiver is tuned. In car receivers, a speech synthesiser which may be switched on at the choice of the listener, may complement this mode of operation, for example to announce the name of the station on retuning.

Another innovation possible in this context is tuning according to one of more than 20 possible programme types (PTY codes), a list of which is given in the RDS Specification [1]. For example, if the listener wishes to tune to a programme transmitting " news ", scan tuning can be performed in the conventional way, but only those programmes appropriately identified will be switched to the loudspeaker. Guided by the programme service name displayed, the listener is free to choose from the options available at that particular instant.

If tuning is performed along these lines, it is however not certain whether the receiver will be tuned to a frequency giving the best signal at the particular location. For this to happen, two other features are necessary: a programme-identification code (PI code) and a list of alternative frequencies (AF code), if that programme is transmitted in the respective region on a certain number of other transmitters (to set a limit for storage, 25 alternative frequencies are assumed as a maximum).

The programme-identification code is not intended for display. It is an unambiguous 16-bit number enabling the receiver to distinguish between countries, areas in which the same programme is transmitted and the identification of the programme itself. The code is designed in such a manner that individual countries may agree their own list of codes without coordinating them with their neighbours, i.e. the first part of the code contains a key to distinguish between neighbouring countries. However, within a country the list of possible codes should preferably be coordinated by a supervising authority, for example the telecommunication administration.

The programme-identification code is intended to enable the receiver to find the same programme on another frequency, evaluate its signal strength and switch inaudibly to the channel which provides the best technical quality. In this sense it will no longer be the concern of the listener to find the most appropriate frequency himself, since this will be done automatically by the receiver. For this to happen, the receiver will have to search for alternative frequencies without disturbing the listener, and it is obvious that, however this search process would be implemented in the receiver, the availability of a list of these alternative frequencies would permit a simplification of the process, since searching on channels where the programme is definitely not available would thus be avoided. However, the need to evaluate the list of alternative frequencies is not mandatory, because it would require a built-in memory for that list, which may be available only in the more sophisticated models. This is also a matter of the receiver technology in question, and, as will be shown later, a microprocessor will be assumed to be the most suitable way to permit the new functions offered by the RDS system to be implemented cost-effectively in mass production.

As far as search tuning is concerned, three kinds of receiver could be designed for this mode of operation:

a) A " scanning " receiver (with or without a memory for alternative frequencies having the same programme identification) which is muted during the search process or which would switch inaudibly to an alternative frequency.

b) A " learning " receiver equipped with a memory to store alternative frequencies. Such a receiver could remain in the data-reception mode and scan the band even if the audio output is switched off.

c) A receiver equipped with two RF front-ends, one of which would feed the AF output while the other would search for the same programme on an alternative frequency, with inaudible switch-over to the better signal.

In the " scanning " receiver, the time for finding the alternative frequency is critical and should not be longer than 8 seconds. Information concerning other networks may also be transmitted within the possibilities foreseen for the distribution of alternative frequencies.

2.2. Supplementary functions

Apart from the above-mentioned signals, the RDS system contains three other groups of signals for:
- switching information;
- radiotext and a transparent data channel;
- additional future applications.

Most of these signals are optional, and may therefore not all be implemented by a particular broadcaster. Receivers designed to use any of the features should therefore not malfunction if the corresponding signals are not available. These applications lie mainly outside the scope of this article, and it is recommended that the RDS Specification [1] be consulted should more detailed information be required.

2.2.1 Switching information

The agreed possible features for switching purposes are the following :
- Traffic-programme identification* (TP code)
- Traffic-announcement identification* (TA code)
- Decoder identification (DI code)
- Music/speech switch (M/S code)
- Programme-item number (PIN code)

2.2.2 Radiotext and transparent data channel

If required, text transmissions coded in line with an agreed alphabet repertoire could be realised. At this stage, one would imagine that such an application is primarily intended for display on suitably-equipped home receivers. In car receivers where a text display is undesirable for safety reasons, the radiotext transmission could be used to control a speech synthesiser, but details of operation in this mode still need to be agreed.

3. Radio-data demodulator/decoder techniques

3.1 Functions of the radio-data demodulator/decoder

Fig. 1 shows the radio-data demodulator/decoder in relation to the other parts of a VHF/FM receiver equipped to use the radio-data system (RDS). The decoder accepts the multiplex signal from the output of the FM discriminator as its input, and feeds its output to a microprocessor. This microprocessor drives a display, controls the tuning of the receiver, and also performs some of the later stages of decoding the radio-data signal. Microprocessor systems are, of course, already incorporated in many of the more sophisticated modern receivers where they are used to control the tuning and frequency-display functions. The RDS decoder, therefore, might be regarded as an adjunct to this existing control processor, and, indeed, might be integrated with it.

Considering the functions of the radio-data demodulator/decoder in a little more detail, six principal stages in the radio-data demodulation/decoding process can be identified:

1) Demodulation of the 57-kHz suppressed-carrier amplitude-modulated signal.

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* These correspond to the respective features of the ARI system (Autofahrer Rundfunk Information: motorists' information service). The particular area code is, in the RDS system, included in the programme-identification code.

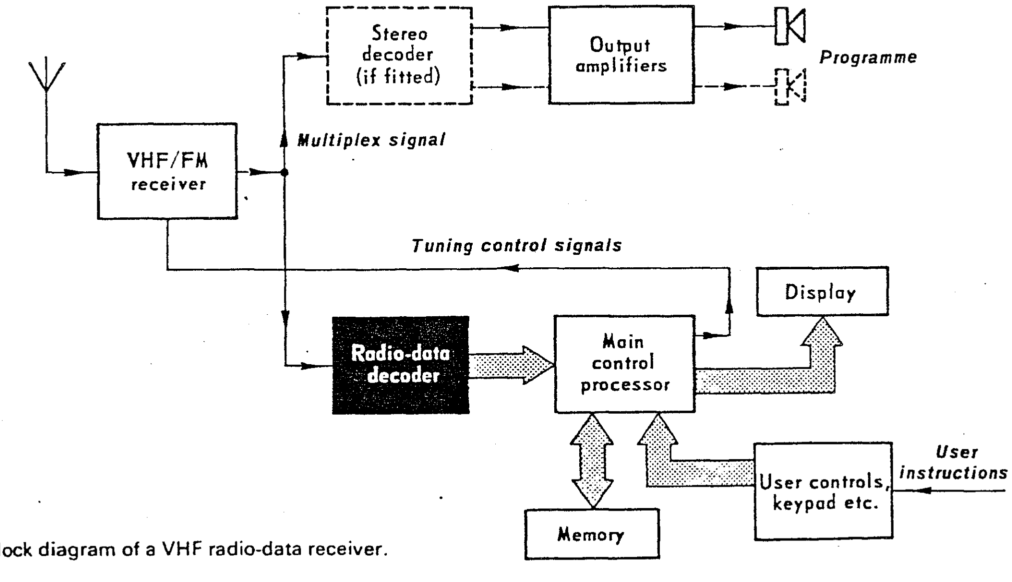

Fig. 1. - Block diagram of a VHF radio-data receiver.

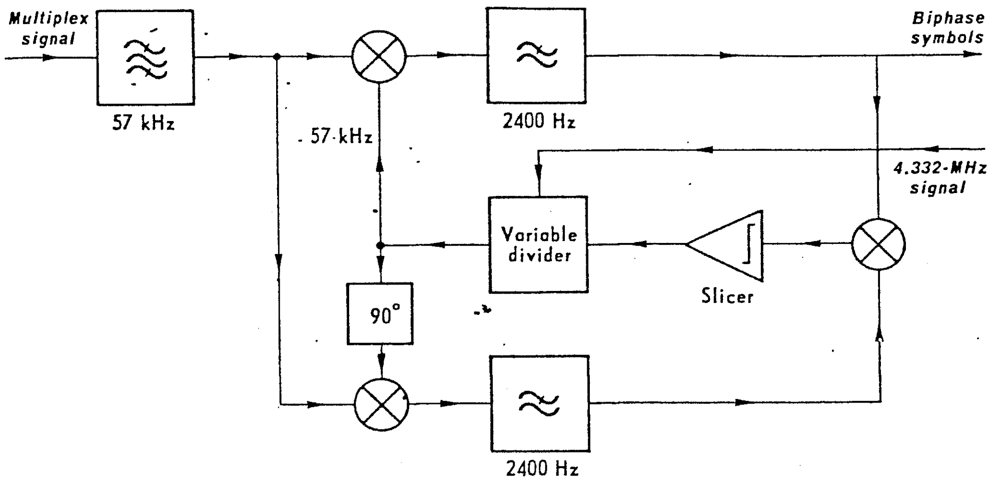

Fig. 2. - Block diagram of a " Costas Loop " 57-kHz demodulator.

2) Decoding of the biphase symbols.
3) Recovery of the bit-rate clock.
4) Recovery of group and block synchronisation.
5) Application of error detection and/or correction.
6) Decoding of address information and message codes.

All these stages may be implemented by a single microprocessor system.

We shall now proceed to describe some of the techniques which have been used to perform these functions in the experimental RDS decoders developed by members of the EBU Specialist Group which developed the system. As was mentioned earlier, these are intended only as illustrations of the design principles, and no doubt manufacturers will wish to develop their own techniques.

3.2 57-kHz demodulation

3.2.1 *Costas Loop demodulator*

Fig. 2 illustrates one possible technique for demodulating the 57-kHz subcarrier. This circuit is usually referred to as a 'Costas Loop' demodulator because it uses a Costas phase-locked loop [2] to recover a coherent 57-kHz reference subcarrier. The recovered subcarrier is used to synchronously demodulate the double-sideband suppressed-carrier amplitude-modulated 57-kHz radio-data signal.

A simple phase-locked loop would not work here because the transmitted RDS signal does not contain a coherent component at the subcarrier frequency. Instead, this Costas Loop synthesises a reference signal from the sideband energy of the data-modulated subcarrier. Even if it were possible to transmit a suitable reference signal, this Costas Loop circuit has many advantages because it locks the recovered subcarrier in exactly the correct phase relative to the wanted sidebands, even under conditions of multipath propagation. This would not be the case if the transmitted 19-kHz pilot-tone were used as a reference signal.

As indicated in *Fig. 2*, a coherent 57-kHz subcarrier may conveniently be synthesised by dividing-down a crystal-controlled microprocessor clock* using a variable ratio divider under the control of the phase-locked loop. This technique gives a more stable result than a conventional analogue voltage-controlled oscillator.

The 57-kHz bandpass filter shown at the input to the demodulator in *Fig. 2* can be very simple: a single tuned-circuit with a Q-factor of about ten would suffice. Similarly, the two 2.4-kHz low-pass filters at the outputs of the synchronous demodulators can be very simple, although here slightly more complicated (third-order) filters are desirable if optimum performance is sought.

Although the Costas Loop demodulator is not very complicated (it is, perhaps, of similar complexity to a phase-locked loop stereo decoder), even simpler demodulators are possible. One such simple demodulator is described below.

3.2.2 *Differential demodulator*

Fig. 3 illustrates a possible alternative form of demodulator which makes use of the fact that the transmitted data signal is differentially coded. Thus the data signal can be demodulated by multiplying the received data signal with a delayed version of the same signal. There is then no need to recover a coherent 57-kHz subcarrier. The necessary signal-delay of one biphase symbol interval (842 μs) can be implemented using a charge-coupled device (CCD).

One slight complication with this demodulator is that, in order for it to work when signals of the ARI traffic information system are transmitted from the same transmitter as the radio-data signals, the ARI signals must be eliminated before the RDS differential demodulator. This can be done using a notch-filter at 57 kHz, making use of the fact that the ARI signals occupy only a narrow band at and close to 57 kHz. This notch-filter can be simply implemented using another CCD delay-line, as is illustrated in

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* The frequency of this clock must, of course, be chosen to be an integer multiple of 57 kHz.

Fig. 3. - Block diagram of a differential 57-kHz demodulator with an ARI filter.

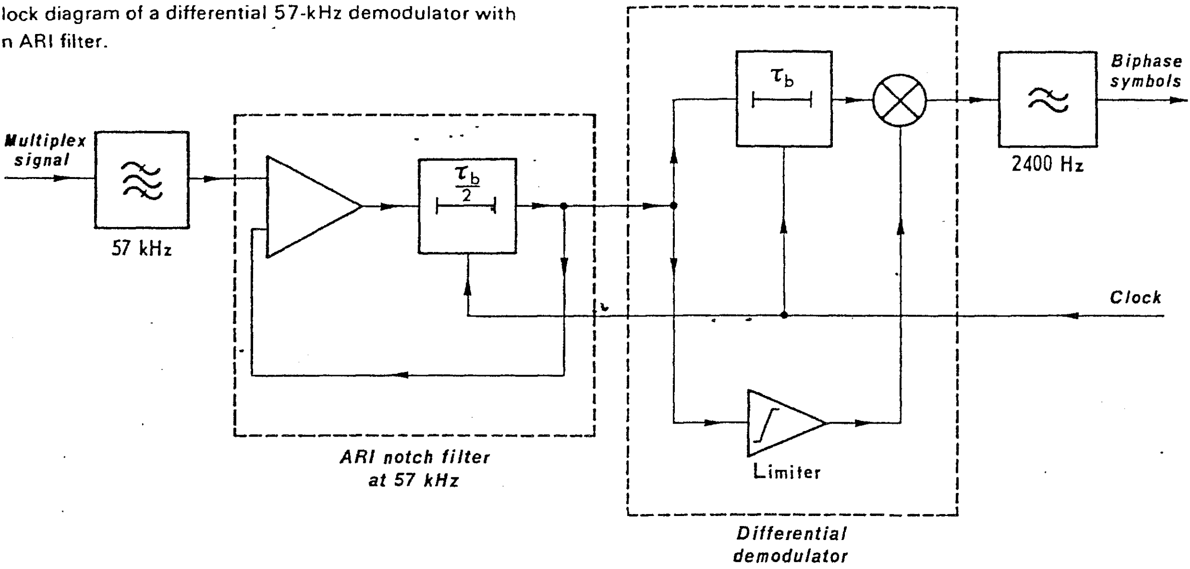

Fig. 3. This notch-filter has little effect upon the RDS signals because they contain little power at and close to the 57-kHz subcarrier. (Such a notch-filter is not necessary in the Costas Loop demodulator because that circuit inherently rejects signals at and close to the subcarrier frequency.)

Under conditions where RDS reception is impaired by low field-strength alone, this differential decoder gives slightly poorer performance than a Costas Loop demodulator. (It requires about 2 dB better signal-to-noise ratio at its input to achieve a given minimum bit error-rate.) However, for a mobile (car) receiver, and where multipath propagation is the dominant impairment to RDS reception, this differential demodulator may actually be superior to the Costas Loop demodulator because rapid changes in the phase of the received subcarrier (due to the movement of the receiver through the standing-wave pattern created by the multipath propagation) are of less consequence than in a fully coherent demodulator.

3.3 Biphase symbol decoding

The next stage in the radio-data decoding process is to decode the biphase symbols. Ideally, a matched filter or correlation detector would be used, but these techniques are complicated to implement. Fortunately, there exist several simpler techniques for biphase symbol decoding, one of which is illustrated in *Fig. 4.* A synchronous switching system is used to invert alternate halves of the received biphase symbols so as to produce a bipolar data signal. This data-signal then passes to an 'integrate-and-dump' circuit*. The integrator adds the contributions from the two halves of each symbol, and at the end of each symbol interval the integrator is reset (i.e., the charge stored by the integrating capacitor is dumped). The voltage at the output of the integrator is sampled via a slicer once per biphase symbol just before the reset

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* This integrate-and-dump circuit inherently provides much of the data shaping filtering needed in the receiver.

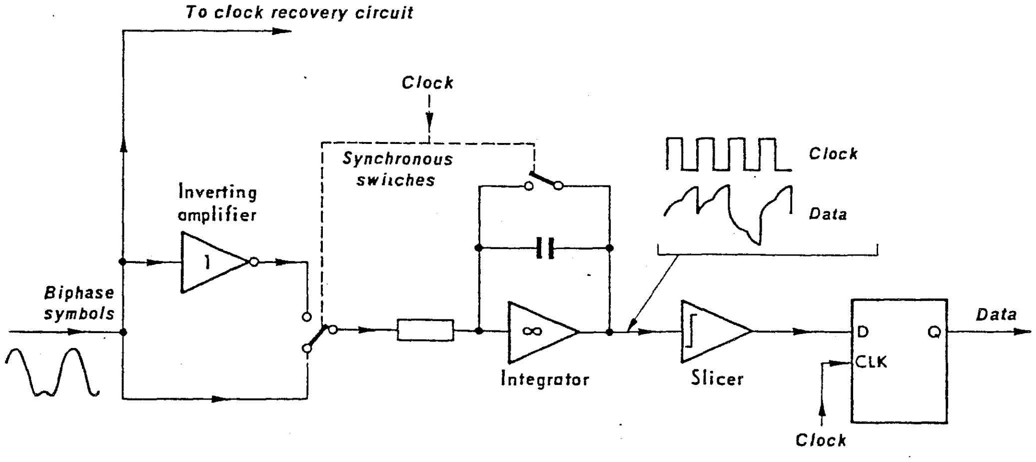


Fig. 4. - Block diagram of a biphase symbol decoder.

pulse is applied; a positive voltage at that instant gives a logic '1' at the data-output of the decoder, and a negative voltage gives a logic '0' at the output. This recovers the binary data-stream which must then be differentially decoded using a simple logic circuit.

The above biphase symbol decoder and all subsequent parts of the decoder require a synchronous bit-rate clock to be recovered.

3.4 Clock recovery

One possible technique for the recovery of a synchronous clock is illustrated in *Fig. 5*. This circuit forms a side-chain to the biphase symbol decoder of *Fig. 4* and comprises a variable radix divider operating upon the recovered 57-kHz subcarrier, and control logic which correctly phases the recovered bit-rate clock with respect to transitions in the demodulated data-signal.

A complication in this circuit results from the fact that a stream of biphase symbols has two sets of transitions: one set of transitions occurs regularly every symbol interval and each of these transitions corresponds to the centre of every biphase symbol; the other transitions occur irregularly and are the transitions present between adjacent biphase symbols when the input data to the biphase symbol generator does not change from one bit-period to the next. In order to correctly decode the received data-signal, the clock recovery circuit must identify the mid-symbol transitions and this may be done using the logic circuitry shown schematically in *Fig. 5*. This circuit makes direct use of the fact that the boundary transition between adjacent symbols is sometimes absent. The circuit would not, of course, work if the transmitted data signal was constant (all 'zeros' or all 'ones'), but the baseband coding of the data effectively prevents this condition from ever occurring.

Thus we have now reached the stage in the radio-data decoder where a binary data-signal and its associated bit-rate clock has been recovered. The remainder of the decoding process comprises mainly bit-manipulation of the received serial data-stream, and in most experimental decoders this has been done entirely within a general-purpose 8-bit microprocessor system. Indeed, with the faster 8-bit microprocessors now available it would be feasible to build an RDS decoder in which all of the functions downstream of the 57-kHz demodulator are implemented within a single 8-bit microprocessor system without any additional specialised hardware.

3.5 Recovery of group and clock synchronisation

The baseband coding format of the RDS data-signal is illustrated in *Fig. 6*. This format may be thought of as hierarchical structure as follows: the largest element in the structure is called a 'group' of 104 bits each. Each group comprises 4 'blocks' of 26 bits each. Each block comprises an 'information word' and 'checkword'. Each information word comprises 16 bits and each checkword comprises 10 bits.

For the RDS decoder to interpret correctly the data which it receives, it must be able to recognise the boundaries of the groups and the blocks, i.e. recovery of group and block synchronisation (or 'framing'). This is, of course, an essential requirement in all synchronous serial data transmission systems. Radio-data, however, require an extremely robust block synchronisation system because, in order to give an acceptable response-time to the user, the decoder must lock-up quickly when the receiver is switched-on or tuned to a different station. Furthermore, it must do so with low probability of false-lock which would yield wrong information and perhaps cause incorrect operation of an automatic search-tuning system.

These requirements have been met in the RDS by a novel block synchronisation system, which was developed largely as the result of experience gained in the 1980 radio-data field-tests in Switzerland. This system uses the RDS error-protecting code not only to detect errors in the normal way, but also to detect

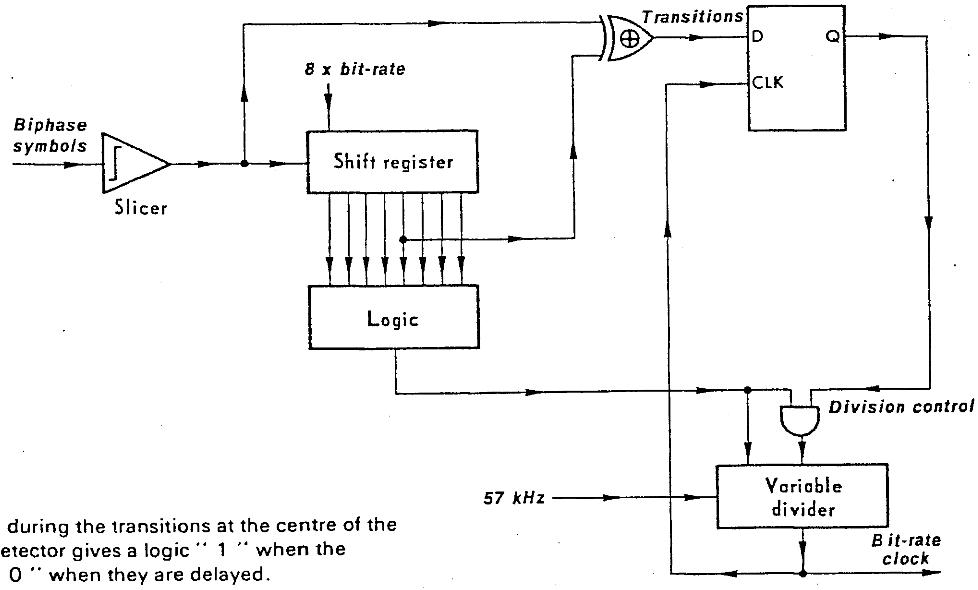


Fig. 5. - Bit-rate clock recovery.

The logic circuit produces a " 1 " during the transitions at the centre of the biphase symbols. The transition detector gives a logic " 1 " when the transitions are early, and a logic " 0 " when they are delayed.

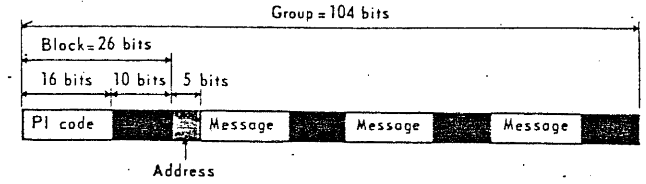
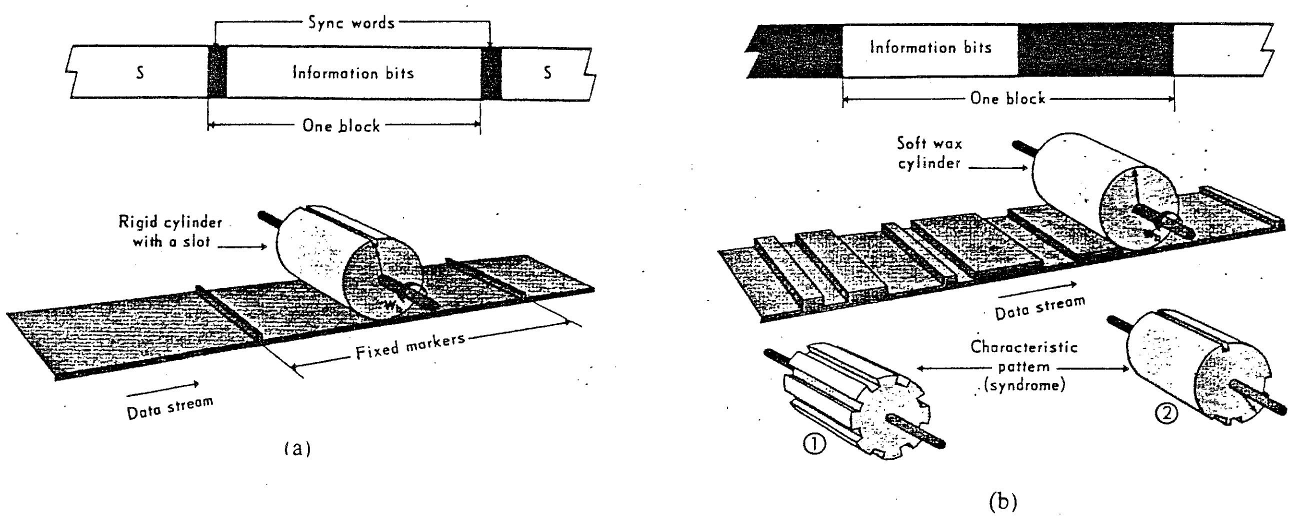


Fig. 6: - Proposed EBU baseband coding format*.
1187.5 bits, which correspond to 11.42 groups, i.e. 45.7 blocks, are broadcast per second.



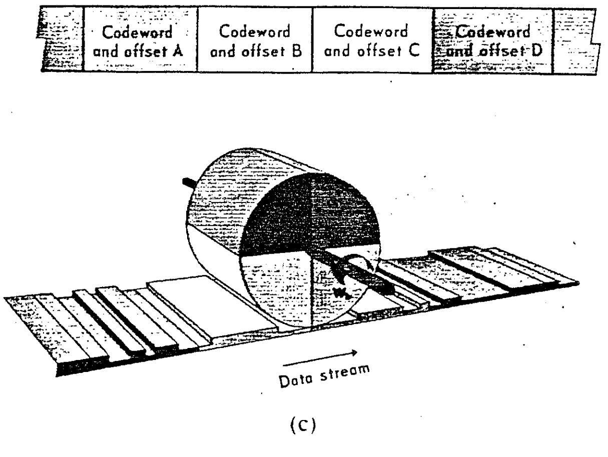


Fig. 7. Mechanical analogies for the block synchronisation system* :
a) Conventional system
b) Self-synchronisation code
   1. cyclic code: regular pattern: no synchronisation information
   2. modified cyclic code: irregular pattern; synchronisation information obtained
c) Group synchronisation

* These diagrams have been drawn by Celia Gyton, BBC Research Department.

block synchronisation slip. The details of how this system works are rather complex, though simple to implement. A description of one possible implementation for a block synchronisation decoder is given in Appendix 3 to the RDS Specification [1]. A more recently developed technique, which saves considerable processing time and/or hardware compared with the original technique described in the Specification, is described in reference [3].

The principles of the block synchronisation system may perhaps be more easily understood with the aid of the simple mechanical analogy which is described below. Firstly, in order to develop the analogy, let us consider a conventional block synchronisation system as illustrated in *Fig. 7(a)*. Here the boundaries of blocks are marked by fixed block synchronisation words.

If we represent the received data-stream as an endless belt, then these block synchronisation words may be represented as fixed markers on the belt as shown. In the decoder we must have a counter which is clocked at the bit-rate and which counts modulo the block-size. This counter may be represented as a slotted roller whose circumference is equal to the distance between the markers on the belt. It is easy to see that to synchronise the roller with the belt all that is necessary is to allow the roller to slip until the slot meshes with one of the fixed markers. Once synchronised, the roller and belt will remain in synchronism even if some of the markers are damaged or missing. This illustrates a block-synchronisation 'flywheel' system which is needed to enable the decoder to remain locked in synchronism with the received data-stream even when the latter is heavily corrupted with errors.

The disadvantages of a conventional block synchronisation system are also apparent from this analogy: space must be allocated in the data-stream for the markers, and these markers have to be clearly recognisable amongst the other data in the stream. Although these difficulties can be overcome (many data systems work this way), the particular requirements of radio-data favoured a novel approach.

Using a similar mechanical analogy, we may represent the underlying principle of this novel block synchronisation system as the system illustrated in *Fig. 7(b)*. Here the received codewords are represented as a rack with irregular teeth, and the decoder in the receiver is represented as a soft-wax roller, which is capable of taking an impression of the rack as it is rolled along it. Again, the circumference of the rotating roller is chosen to be equal to the distance between block (codeword) boundaries on the rack. If now the roller is rolled along the rack, starting at the beginning of a codeword and ending at the end, then the resulting impression on the circumference of the cylinder will contain all the information about that codeword. If now the wax roller is subject to further processing analogous to the processes performed in the error-protecting decoder, then it is possible to see that the initial impression on the roller could be converted to one which depends not upon the transmitted message but only upon the errors in the received codeword. This pattern is analogous to the characteristic pattern or 'syndrome' of an error-protecting decoder.

If now the movement of the roller is started and ended away from codeword boundaries, then the resulting first impression on the roller would comprise parts of two separate codewords. It is a remarkable fundamental property of a conventional cyclic, or shortened cyclic code, that the characteristic pattern (syndrome) obtained by applying the error-checking process to such a mixture will, with high probability, be the same as for that obtained from one complete valid codeword. In our analogy we represent this case by the cyclically symmetrical pattern shown on the lower left-hand roller in *Fig. 7(b)*. Clearly, such a pattern would not provide reliable block synchronisation information.

If, however, the cyclic nature of the code is destroyed, which is done in the RDS by adding binary offset words to each transmitted checkword, then an asymmetric pattern will result, as illustrated by analogy with the pattern on the roller in the bottom right of *Fig. 7(b)*. It is easy to see that such an irregular pattern can provide the necessary synchronisation information.

Block synchronisation is thus first obtained by trial and error; processing each received 26-bit sequence until the expected characteristic pattern results. With a high probability this will occur only when the processed 26-bit sequence comprises one complete codeword.

Different offset words added to each checkword will yield different characteristic patterns, and in the RDS four different offsets are used to identify the four blocks within each group. This may be illustrated by continuing to develop the mechanical analogy as shown in *Fig. 7(c)*. There the circumference of the wax roller has been increased by a factor of four compared with that of *Fig. 7(b)*, so that after it has been rolled along the section of rack which represents the four blocks comprising a group, then four different characteristic patterns will result around the circumference of the roller, as illustrated by the colours in the figure.

It should be noted that once one characteristic pattern has been found then the rest follow in cyclic sequence. Thus, all the necessary group synchronisation information can be obtained within one block length. This provides rapid data acquisition.

Summarising this novel group and block synchronisation system: the beginnings and ends of the data blocks may be recognised in the receiver/decoder by using the fact that the error-checking decoder will, with a high level of confidence, detect block synchronisation slip; the blocks within each group are identified by carefully chosen 8-bit binary words ('offsets') which are added (modulo-two) to the checkwords such that offset word A is added to Block 1 in each group, offset word B to Block 2 and so on.

3.6 Error correction and / or detection

The error-protecting code which is used in the RDS is an optimal single-burst-error-correcting code and is capable of correcting any single burst of errors which spans 5 bits or less. However, the use of the full error-correcting capability of the code greatly increases the undetected error-rate and thus also reduces the reliability of the block synchronisation system. In most experimental decoders implemented to date, the following restrictions have been observed when performing error-correction:

a) When the decoder is searching for block and group synchronisation (e.g., on switch-on or on retuning the receiver to a different station), the error correction capability of the code is not used at all. This allows the full error detecting capability of the code to be used to detect synchronisation slip.

b) When the decoder has acquired group and block synchronisation, the error-correction system should be enabled, but should be restricted to attempting to correct bursts of errors spanning one or two bits. The decoder should attempt to detect (and then discard) blocks with longer bursts of errors.

Any of the well-known [4, 5] standard burst-error trapping algebraic decoding techniques may be used to perform the error correction. One possible implementation is described in Appendix 2 of the RDS Specification [1]. An assembly language sub-routine for the entire error-protection process for one block may be executed on a standard 8-bit microprocessor in about 700 µs.

3.7 Address and message decoding

The final stage in the decoding process is to sort the various kinds of information presented in the received groups so that it can be sent to the appropriate peripheral device (e.g., display or tuning control circuit) for action. The received information may be conveniently divided into two kinds:

a) The information intended to help automatic tuning (the PI, PTY and TP codes: see Section 2 of this article) which can be decoded without reference to any block outside the one that contains the information. Their addressing is implicit by their occupancy of fixed positions within every group.

b) All other information: this needs the 5-bit group type and version code which is contained in the second block of every group to be decoded. This 5-bit code acts as an address which identifies the information contained within the group.

A two-stage sorting procedure can help rapid processing of the automatic tuning information. In such a procedure the automatic tuning information is first separated out from every group, then the group type and version code is checked and the remainder of the information accordingly processed.

3.8 Performance of RDS receivers

The bit error-rate to be expected at the output of an ideal RDS decoder, when the only impairment to reception is random noise due to low field-strength at the VHF receiver input, is plotted as a function of the receiver antenna input EMF as curve (a) in *Fig. 8.* (A noise figure of 7 dB was assumed for the receiver.) For the purposes of comparison, the measured bit error-rate obtained with a Costas Loop demodulator with an integrate-and-dump biphase symbol decoder is plotted as curve (b) in *Fig. 8.* (The measured noise figure of the VHF receiver used in these measurements was 7 dB.) It may be seen that the measured performance of this experimental RDS decoder is within about one decibel of that expected from theory.

4. Conclusions

The radio-data system, RDS, which has been developed in association with the EBU, would make the operation and tuning of all the categories of receiver simpler and more convenient for the listener, as well as providing capacity to convey simple messages for display. Efficient techniques for demodulating and decoding the RDS signals have been developed by members of the EBU Specialist Group which designed the system. It is believed that these techniques would be relatively easily implemented in low-cost receivers, but receiver manufacturers may wish to develop their own techniques for the mass production of future RDS receivers.

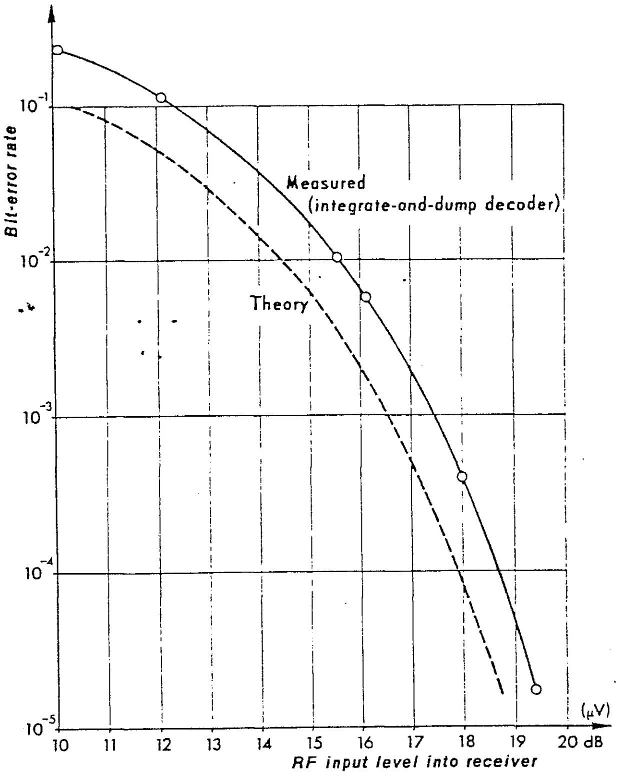


Fig. 8. - Measured and theoretical bit error-rates for the RDS decoder. The horizontal scale represents, in dbµV, the open-circuit EMF at the antenna input of the receiver, produced by a 50-Ω source.

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