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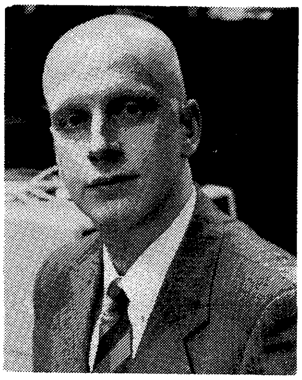

S. Parnall

Functional objectives of the Enhanced Other Networks (EON) feature

Following a review of the requirements of the motorist when listening to the radio, the article explains how a first-generation RDS car radio uses the Programme Identification (PI) and Alternative Frequency (AF) information to deliver the best signal at all times. The advantages of the Enhanced Other Networks (EON) feature are presented: faster selection of transmissions carrying the same (or related) programmes, reception of traffic information from all stations in the area around the receiver, and an extended choice of AFs to include those of transmissions of different networks which temporarily carry the selected programme service.

1. Introduction

The Radio Data System has been designed to be of value to both static and mobile listeners and, in its basic form, it offers programme-related features such as Programme Type (PTY) and Radiotext (RT) as well as the auto-tuning features: Programme Identification (PI) and Alternative Frequency (AF) lists.

The Enhanced Other Networks (EON) feature supports both programme-related and auto-tuning functions. The present article will examine the problems of auto-tuning and the benefits of EON in this context. The most significant examples of auto-tuning in action will obviously occur in the motor-car, but the techniques discussed here should be regarded as being equally applicable in the domestic "hi-fi" and portable radio listening environments.

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2. The listener's requirements

Before considering how RDS can help the mobile listener it is necessary to identify his problems. These may be summarised as follows:

a) When a listener presses a button to select a particular service, he wants to hear that service *instantly* and from the *best* transmitter. This expectation must be satisfied irrespective of his geographical location and regardless of the distance he may have travelled since his receiver was programmed.

b) He requires a readable label on the receiver display which clearly identifies the service to which the receiver is tuned (and hence confirms that his selection has been respected).

c) Once tuned to the chosen service, the receiver must remain tuned to that service, changing frequency automatically as required, in order to present the best possible signal to the listener at all times.

d) Whilst his receiver is tuned in this way to the service of his choice, the listener wants the option of hearing traffic announcements from *local* stations which are broadcasting information relevant to his current location, without the need to pre-programme the receiver in any way.

3. Receiver model

In order for broadcasters and receiver manufacturers to transmit and utilise RDS data correctly it is necessary to appreciate the function and application of each data element. This is most-easily accomplished through the use of a conceptual receiver model.

Two RDS data elements are used to identify the service: Programme Identification (PI) and Programme Service name (PS).

3.1. Programme Identification (PI) code

The PI code is a 16-bit fast machine-readable label and it is transmitted at least eleven times per second. Each transmitter which is carrying the same Programme Service carries the same PI code. The codes are represented in hexadecimal notation and there are effectively four nibbles containing different levels of information.

The most-significant nibble of each PI code is known as the country code. This code is assigned by the EBU to ensure that in border areas it is not possible to receive the same PI code from a neighbouring country.

The second nibble of the PI code identifies the sort of coverage area of the service. As defined in the RDS specification [1], code 2_{hex}, for example, indicates a national programme service whereas codes in the range 4_{hex} to F_{hex} indicate regional programmes.

The last two nibbles may be freely assigned by the broadcaster, subject to national agreement, and have no direct significance. It may be noted however, at this point, that the EBU has introduced the notion of "generic" or "family" PI codes. These may be used to indicate that one regional programme is to be regarded as being related to another, and stations related in this manner can be distinguished by the fact that their PI codes differ only in their second nibbles.

In the following examples of PI codes for BBC services in the United Kingdom, it is seen that they are all in the same country (C_{hex}), that Radios 1, 2 and 3 are national services (2_{hex}) whilst GLR and BBC Kent are regional (4_{hex} and 7_{hex}), and that GLR is regarded as being related to BBC Kent (1st, 3rd and 4th nibbles identical).

Programme Service	PI code (hex)
Radio 1	C201
Radio 2	C202
Radio 3	C203
GLR	C425
BBC Kent	C725

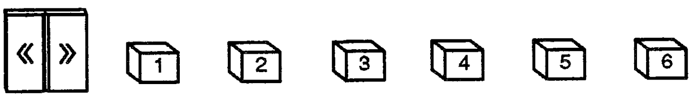
3.2. Programme Service name (PS)

The listener should never see — or even know of the existence of — the PI code. Instead, he is provided with an eight-character text known as the Programme Service name (PS). This text string is transmitted about once per second and may be shown on the front panel of the receiver instead of an indication of the tuned frequency. When he first tunes his receiver, the listener will find a station using the tuning control (often in the form of an "up/down" bar), and within two or three seconds the service will be positively identified by name.

3.3. Receiver programming and example of operation

When the listener has found the service he requires, he can attribute the service to a particular pre-set button on his receiver. This will have the effect of storing three elements — the frequency, PI code and PS name — in a section of memory associated with the button.

Operation of the basic auto-tuning system may be illustrated with an example. The receiver shown in *Fig. 1* was programmed by the listener in London. Captial Radio (a London regional station) has just



Frequency	95.8	98.8	89.1	91.3	93.5	94.9	95.8
PI	C586	C201	C202	C203	C204	C425	C586
PS	CAPITAL	BBC–R1	BBC–R2	BBC–R3	BBC–R4	GLR	CAPITAL

Fig. 1
Storage of frequency, PI and PS in a simple RDS car radio.

been found using the tuning bar and the corresponding frequency, PI and PS codes have been stored under button number 6. If the listener now drives away from London towards Cornwall he will move out of the coverage area of the Radio 4 transmitter for the London area on 93.5 MHz. In Cornwall the frequency of 93.5 MHz would be filled with a French transmission carrying a different PI code. If the listener now presses button number 4, the receiver should respond as shown in *Fig. 2* so that Radio 4 is heard again.

The search process will take about 20 seconds to complete, but the receiver will find Radio 4 on 94.1 MHz. This frequency is then stored in the memory associated with button number 4, in place of 93.5 MHz. In this way, Radio 4 will be heard immediately if button 4 is pressed again. A similar search process will be undertaken if any other button is pressed, and in each case there will be a delay of about 20 seconds while the required programme service is found in the new area.

3.4. Alternative Frequencies

To avoid the need for a periodic search every time the receiver is driven out of the coverage area of one transmitter and into another, RDS transmissions carry Alternative Frequency (AF) lists. Each transmitter informs the receiver of all frequencies which are *likely* to offer improved reception of the same programme. The receiver can then periodically evaluate the signal strength on these frequencies and switch to an alternative one if it proves to be better than the current tuning frequency. When the receiver switches, it must check the PI code to ensure that the new frequency does in fact carry the same programme service (this may take about 0.5 second); if the PI code does not match, the receiver must switch back to the original frequency. If the PI code is correct, the new frequency is over-written into the memory in the same manner as before.

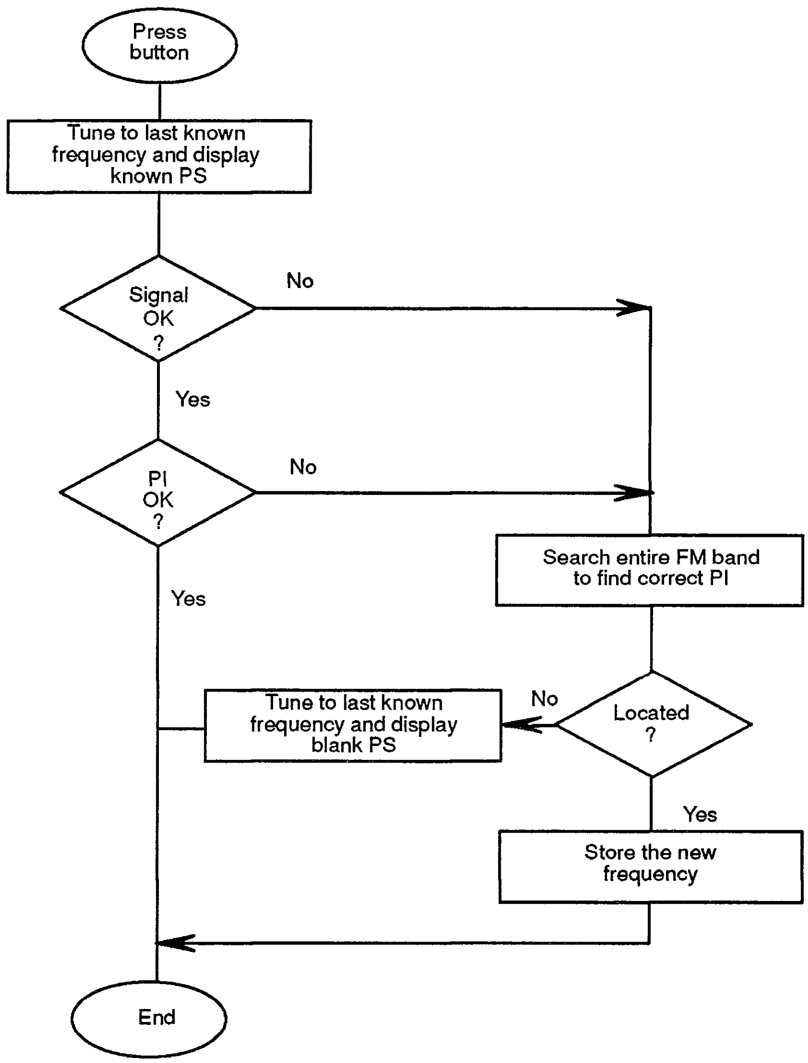


Fig. 2
Simple RDS receiver searches the FM band to find a station with the chosen PI code.

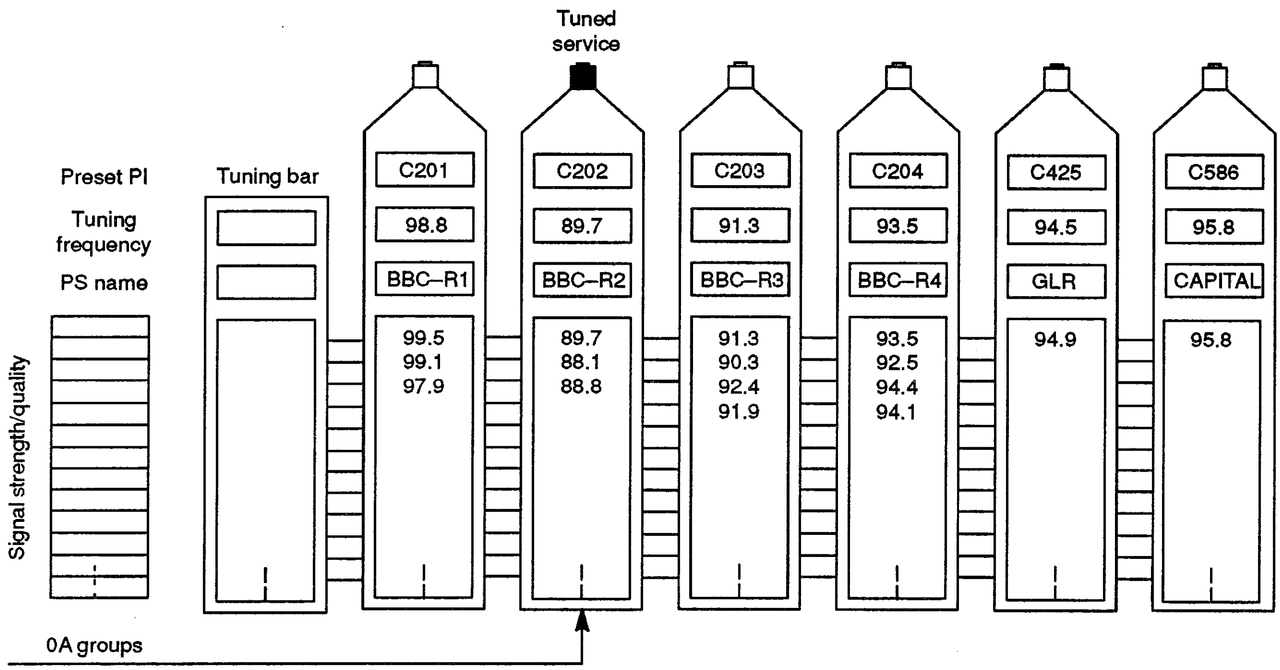


Fig. 3
When the receiver is moved, the AF lists for non-tuned buttons become out-dated.

It is clearly in the interests of both the broadcasters and the receiver manufacturers to keep the AF list transmitted from each transmitter as short as possible. This reduces the number of frequencies to be tested, ensures a rapid response, and reduces the possibility of momentary switching to a foreign or un-licenced broadcast.

The AF lists from transmitters carrying the same programme service will be different, because each list contains only the frequencies of its immediate neighbours and not those of more-distant transmitters. Therefore, as a motorist makes a long journey, the AF list in the receiver changes periodically, as the receiver switches from one transmitter to the next. It is possible for the AF list at the end of the journey to be completely different to that at the start.

The exploitation of the AF list, as an aid to rapid re-tuning of the RDS car receiver, may be illustrated with another example. The motorist whose receiver was originally programmed in London (*Fig. 1*) has made a long journey while listening to Radio 2. *Fig. 3* shows the AF lists associated with each of the pre-set buttons on his receiver at the end of the journey. The list for Radio 2 has been completely revised and is correct for the new area. In contrast, the AF lists and London-area tuning frequencies for Radios 1, 3 and 4 remain the same as they where when the journey began.

If the listener now presses button number 4, to listen to the Radio 4 news bulletin, the receiver must process the stored frequency, AF list and PI code information associated with button 4, in accordance with the algorithm shown in *Fig. 4*. The time taken to find the service depends on whether or not the new frequency is given in the stored AF list. If it *is* in the list, the best AF scan should yield success after about one second; if the journey was a long one, however, it is unlikely that the frequency will be in the list and the receiver must resort to a PI search which will increase the access time to about 21 seconds.

3.5. Enhanced Other Networks (EON) feature

To minimise the duration of audio muting, the PI search process must be avoided if at all possible. To achieve this aim the AF lists associated with every preset button should be up-dated, even though the receiver is tuned to only one of them. This is one function of the Enhanced Other Networks (EON) feature.

The algorithm shown in *Fig. 4* introduces the concept of generic linkage, as explained earlier; it will find regional equivalents of GLR and Capital Radio, if any such equivalents are available in the new area.

EON information up-dates all the push-button memories in the receiver other than the one currently in use. Therefore, while the receiver is tuned to Radio 2, EON up-dates the stores for Radio 1, 3 and 4, and BBC local radio. Frequency lists, programme-related features such as Programme Type (PTY) and Programme Item Number (PIN), and even the Programme Service name (PS) are under constant revision for all channels, when tuned to any one service.

It has been explained earlier that, as the driver moves from one area to another, the tuned AF list

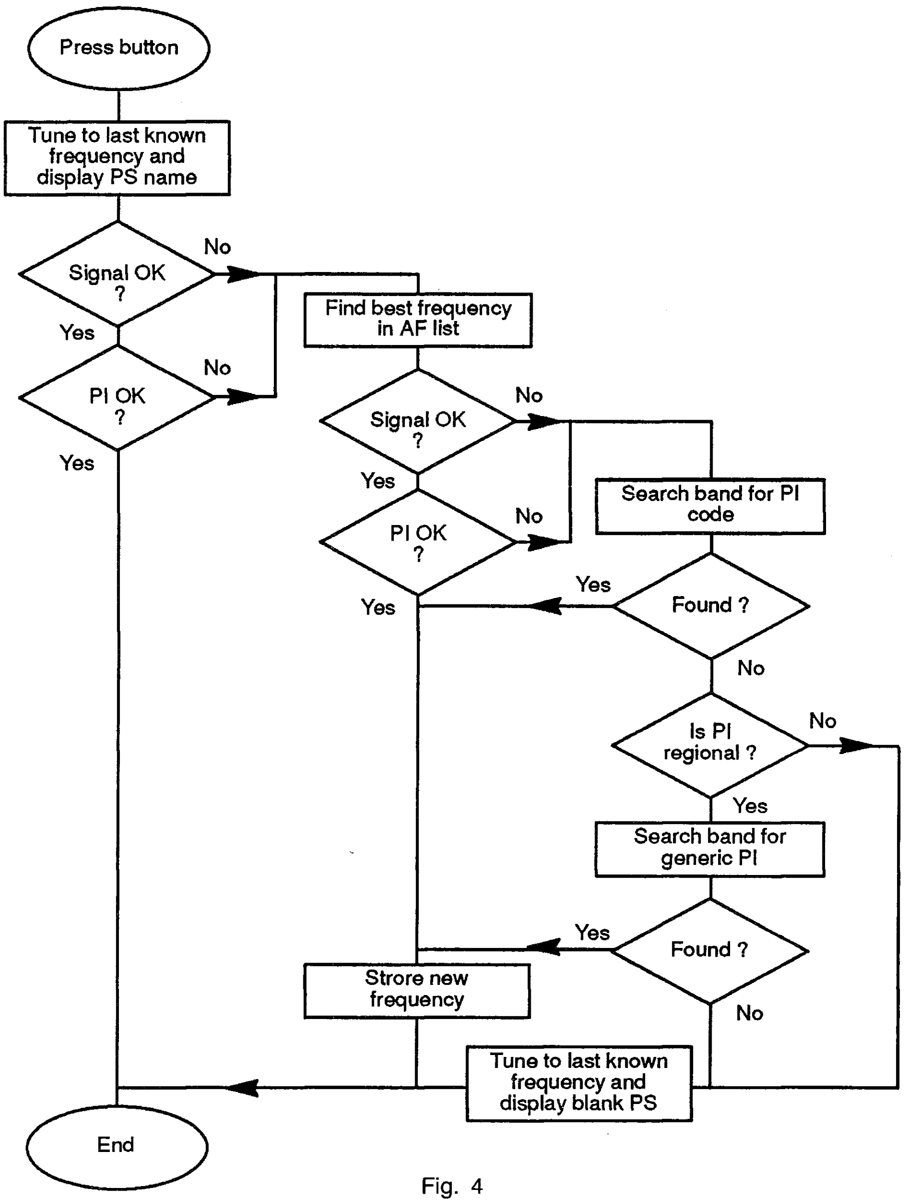


Fig. 4
Evaluation of the AF list before starting a PI search or generic search.

changes as the receiver switches between transmitters offering the selected service. With EON, not only does the AF for the tuned service change — those for other services change also. This virtually guarantees that when a different button is pressed the AF list will already contain the best frequency for the new area, thereby totally avoiding a PI search process across the whole FM band. Instead of a frustrating 20-second period of silence, the search will take less than one second. Furthermore, if the PS name had been changed during the journey, for example from "BBC R4" to "BBC R4Ed" (a daily occurrence on some BBC radio services), the new name will be displayed instantly.

EON provides two methods of delivering AF lists for other services, which are known as "Method A" and the "Mapped Method". Method A fills each AF list in no particular order, ready for the receiver to make a "best frequency" test when the corresponding button is pressed. The Mapped Method establishes a correspondence between frequencies of the tuned service and the frequencies of the other service. An example will clarify the process. In the London area, the following frequencies apply to the national BBC radio services broadcast from three different transmitting stations:

Radio 2	Radio 3	Radio 4	Transmitting station
89.1	91.3	93.5	Wrotham
88.1	90.3	92.5	Guildford
90.0	92.4	94.4	Swingate

When the receiver is tuned to Radio 2, the AF list will contain the Radio 2 frequencies in the above table (and some others). Mapped EON information will indicate corresponding frequencies for Radio 3 and Radio 4, because these services are broadcast

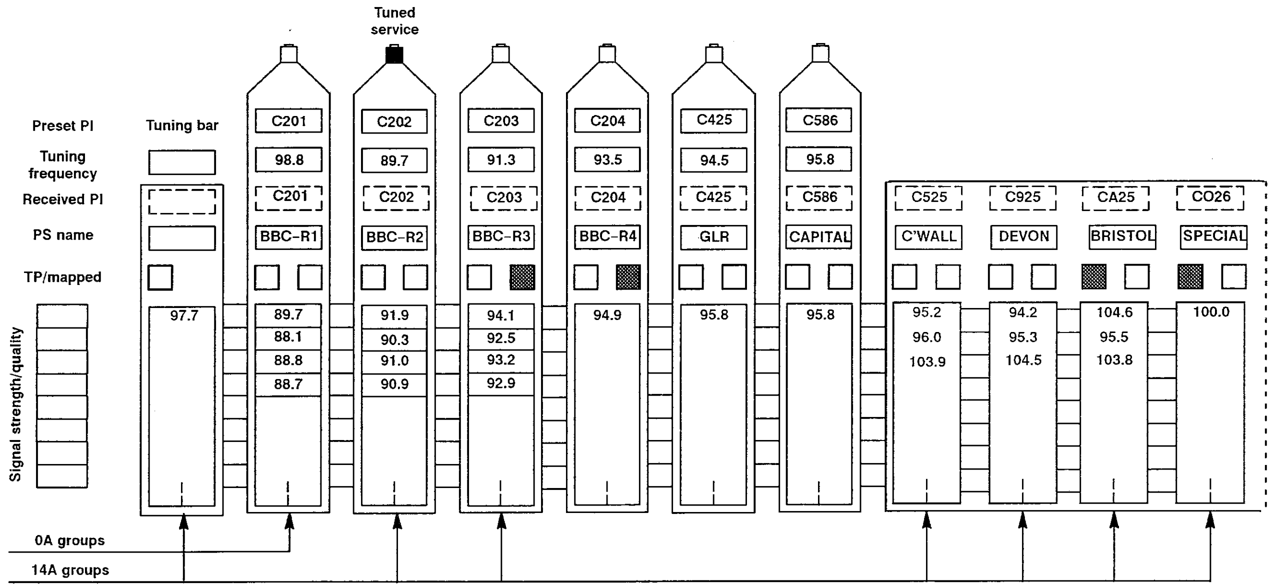


Fig. 5
EON information up-dates non-tuned services automatically.

from the *same* masts with the *same* powers. The receiver continuously evaluates the signal strength of the Radio 2 frequencies, and when it makes a switch to a better alternative frequency the receiver will also up-date the stored frequencies for Radio 3 and Radio 4 in such a way that the first frequency to be tested when a button is pressed will be the one most likely to offer the best reception. In the case of parallel networks of this sort, therefore, EON with the Mapped Method reduces the access time from 21 seconds to 0 seconds. Pressing the Radio 4 button after a long journey will bring an instant response.

In the above example, Radio 2 has been taken as the currently-tuned service. Any of the other national services could have been used instead, and would have given exactly the same result, with the inclusion of reciprocal mapping of Radio 2 frequencies.

EON information is carried in type 14A and 14B groups. Each group has, as an index, the PI code of the service to which it refers. In *Fig. 5*, information bearing the PI code C204 is directed to the fourth button, because the listener has programmed the fourth button for Radio 4. Information with the PI code C586 goes to the last (fifth) button for the same reason. PI code C431 has not been programmed on any button (presumably the listener has no interest in this service) and the receiver discards any information relating to this service.

However, there are two reasons why the receiver should store information relating to some stations which the listener has not programmed into the preset memories. First, it should store information which concerns a service which is linked generically to one of the services programmes by the listener; second, it should store information for stations which broadcast a traffic announcement service. A Traffic Programme (TP) flag is carried in each EON group to indicate whether the station referred to broadcasts traffic announcements, and the listener may wish to hear these even if he is not interested in the normal programmes of the station.

To accommodate this information, the receiver model has to include a section of memory which is similar to the stores associated with the buttons but which is under the control of the receiver, rather than the listener. This is known as "pool memory", and it is loaded with services which are generically linked to any services programmed into the preset memories, and any services whose TP flags are set. EON data in type 14A groups is transmitted cyclically, with a maximum repetition time of 2 minutes. Therefore, with suitable time constants, the receiver is able to maintain an accurate data-base of additional services which may be useful to the listener. The stored information will be relevant to the receiver's current geographical position and the current listening options, and any information which ceases to be relevant will be deleted automatically.

Pool memory is used as the first step in attempting to find a suitable generic equivalent to a preprogrammed regional service. Once again, an example will illustrate the advantages of the EON feature. The receiver of *Fig. 1*, which was programmed by the listener in the London area, is driven to Cornwall which is outside the coverage area of all the London transmitters. When it arrives in Cornwall, the EON data will have up-dated the stores for Radios 1, 3 and 4 from Radio 2 (with mapped frequencies for Radios 3 and 4). The pool memory has been loaded with information about Radio Cornwall, Radio Devon and Radio Bristol, by virtue of their generic links to GLR. Radio Special (a ficticious station) is also loaded, but only because it has its TP flag set (this might be a station which broadcasts an airport information service, for example). Radio Bristol also carries TP, in this example, and would have been loaded into the pool if GLR, or any generic equivalent, had ever been stored by the listener in one of the preset memories.

There is no reference in the EON data to Capital Radio, or to any generic equivalent for the Cornwall area. If the listener presses this button the receiver will be unable to find the service on the tuned frequency because it is outside the Capital radio coverage area. No equivalent service is loaded into the pool memory, so the receiver will have to perform a PI search across the whole FM band. This will take a long time — and may, or may not, be successful.

3.6. Vectored traffic announcements

Continuing the example, we will assume that Radio Bristol starts a Traffic Announcement. The service will set its TA flag to cause the current generation of RDS receivers (without EON processing) to adopt the conditions appropriate for listening to the announcement: un-muting, increase of volume, switching from cassette/CD player to radio, etc. The next generation of receivers, which will exploit the EON data, will receive a burst of eight EON groups of type 14B, if they are tuned to any national service or any other BBC local radio service in the Bristol area. These type 14B groups signal the start of an announcement on another channel, and are transmitted in a burst during the musical jingle which precedes all traffic announcements to attract the attention of listeners.

When the receiver successfully detects one of the groups in the burst, and if the listener has selected the Traffic Announcement mode, the receiver can exploit the data accumulated in the pool to enable it to tune to the service which is broadcasting the announcement. The reeceiver will stay tuned to this service until the TA flag on that channel is cleared, and will then return to the service which was selected previously. This mechanism provides fully-automatic local traffic information with any listening constraints.

3.7. EON linkage information

Radio stations often group together in various combinations for the transmission of a common programme. This form of link may exist for a few minutes, for several hours — or may even be the normal situation, with stations breaking away from the group only for short periods (opt-outs). In all cases the stations will wish to retain their own identities and, in RDS terms, each must carry a unique PI code and probably a unique PS name too.

A mechanism within the Enhanced Other Networks specification allows a broadcaster to transmit a special number for each referenced service. This is called a Linkage Set Number (LSN). If two or more stations carry the same programme, they will share the same LSN. The receiver is able to concatenate their AF lists when evaluating the reception conditions and can use transmitters from another programme service to present the best signal to the listener. The receiver manufacturer has the choice of displaying either the PS name of the station to which the receiver is actually tuned, or that of the selected service, since both names are available in the receiver. When the stations cease to carry the same service, the receiver can either attempt to re-locate the original service, or offer the alternative service if the original service is no longer available owing to the distance travelled.

4. Conclusions

The RDS system must achieve the objectives set out at the beginning of this article if it is to satisfy the most-demanding consumers — the non-technical radio listeners. They, rather than broadcasters or manufacturers, will judge the applicability and ease of use of RDS.

The Enhanced Other Networks feature of RDS is a vital element offering instantaneous tuning, vectored traffic announcements, fast generic station search and review, and programme linkage. These are not mere icing on the RDS cake — they are fundamental and realistic expectations.

* * *

The author wishes to thank the Director of Engineering of the BBC for permission to publish this article.

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