®
Digital Audio Broadcasting

The DAB multiplex and system support features

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This article describes the multiplex and system support features of the Eureka 147/DAB digital audio broadcasting system. It sets out the requirements of all users along the broadcast chain, from service providers and broadcaster through to the listener. The contents of the transmission frame are examined, drawing the distinction between the main service multiplex and the provision of control information in a separate fast data channel. The concept of the DAB service structure is introduced and the inherent system flexibility for altering the service arrangement is explained.

A wide range of service information features build on those provided in earlier systems, such as the Radio Data System, and are intended to make it easier for a listener to find any required service and to add a further dimension to audio broadcasting. The choices available to users in all of these areas are examined.

1. Introduction

A new Digital Audio Broadcasting (DAB) system has been developed by the European Eureka 147/DAB Project in close co–operation with the European Broadcasting Union (EBU) [1]. DAB promises high–quality sound and very rugged reception for all types of receivers – home hi–fi, portable, personal and mobile [2]. The transmission medium is capable of delivering programme services to more listeners, and more ruggedly, than is possible with VHF/FM sound broadcasting. The benefit is particularly felt by the motorist because, for the first time, the technology has been designed with the mobile user in mind and constructive use is made of multipath propagation which sometimes mars FM reception. This also makes portable receivers, in the home, less critical as regards their positioning.

The DAB broadcast channel supports a multiplex of services known as an *ensemble* containing, for example, up to six stereo programme services. However, it can be adapted to suit varying service needs. There is an opportunity to introduce new services, subject to the limit of the data–carrying capacity of the channel. The DAB channel is also efficient, both in the use of frequency spectrum and in terms of the transmission power requirements. It may be operated at any radio frequency up to 3 GHz for mobile reception (higher frequencies may be used for fixed reception) and DAB may be used on terrestrial, satellite or cable networks.

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Within the Eureka 147 Project, the system has been developed by a wide representation of broadcasters, telecommunications specialists, receiver manufacturers and related research institutes, guided by the broad requirements set out by the EBU [3,4]. A short–form specification of the resulting system has been published by the ITU, where it is known as “Digital system A” [5–7], and the complete, detailed specification has been prepared and released as a draft standard by the European Telecommunication Standards Institute (ETSI) [8].

Some aspects of DAB have already been described elsewhere: these include the digital audio bit–rate reduction strategy [9] and the channel coding, incorporating COFDM techniques [10]. The basic concepts concerning the service multiplex and its control have also been reported [11]. The present contribution concerns the system features, including the service multiplex and support features, embracing service information and non–audio data services.

The various system requirements, as drawn up at the start of the Eureka 147 project, are discussed first. The conceptual multiplex frame is introduced and different audio options are examined. The service structure is presented and the basic administration of the multiplex is described, including the more complex issue of dynamic changes to the service multiplex.

Finally, the broad range of service information features and non–audio data services are described, including an explanation of the manner in which they are integrated into the multiplex and how they may be used. The DAB multiplexing and system support infrastructure draws on broadcasters’ earlier experience with the Radio Data System (RDS) [12], which uses a data sub–channel to provide service labers and other receiver control features in conventional VHF/FM sound broadcasting. Some familiarity with RDS is therefore desirable, but it is not essential to the understanding of the DAB multiplexing arrangements.

Much of the material presented here formed the basis for a presentation to the Ad–hoc Working Party on digital audio broadcasting system standardization, of the World Conference of Broadcasting Unions, held at the Centre Commun d’Etudes de Télédiffusion et Télécommunications (CCETT), Rennes, 8–9 June 1993 [13].

2. DAB system feature requirements

A number of system users can be identified. These include (in order of involvement in the broadcast chain) service providers, ensemble manager, transmission operator, receiver manufacturer and the listener. Their needs are examined here.

2.1. Better quality reception

The audio quality, as perceived by a listener using a DAB receiver, is expected to be superior to that of any previous radio broadcasting service. Nevertheless, the benefits may be most appreciated by the motorist and by users of portable and personal recivers, who now represent an increasing share of the listening audience. The audio quality will appear to be comparable with CD and R–DAT and will benefit from the improved ruggedness of service reception which is free from the worst effects of radio interference. Reception on portable receivers in the home is expected to be more tolerant to their positioning indoors.

2.2. Different types of receiver

A full range of receivers, covering fixed home hi–fi, portables, mobile and personal use will be expected. More sophisticated (and no doubt more–expensive) receivers should be considered as well as the low–cost mass market. Indeed, it seems likely that the first DAB receivers will be aimed at the “specialist” listener, prepared to pay higher prices for listening enjoyment. Mobile receivers generally operate in a relatively noisy environment compared with the home and this presents the broadcaster with a problem of how much audio compression to apply. The problem could be solved by introducing automatic dynamic range control so that the amount of compression could be adjusted at the receiver to suit the listening conditions.

2.3. Greater choice of services

The flexibility of the service multiplex allows it to be changed dynamically. The multiplex can be re–arranged, for example by splitting a stereo component into two monophonic components, or by providing a dedicated channel for spoken announcements or a commentary on a classical music programme.

The broadcaster sees the multiplex flexibility as an opportunity to change the service mix to match current needs: for some broadcasters, multiplex re–configurations may be infrequent, but for others this is a dynamic tool which can increase listener choice. Whichever way the multiplex is used, reliable service continuity is essential.

2.4. *Straightforward access to services*

The listener's main expectation (apart from excellent sound quality) is for easy access to services. These services will be wanted quickly and they must be identifiable. This means that the receiver must have a straightforward user interface, with simple, fast, push–button service access and a display of the service and programme labels. In addition, the listener needs to feel that the receiver is operating correctly and that it will not behave in an unreasonable manner; finally, the listener will also have an interest in what other services are available, whether they are within a single ensemble, in other ensembles, or on VHF/FM channels.

Users who have experienced the Radio Data System (RDS) [12] on VHF/FM will expect DAB at least to emulate the RDS features, for example service identification and Radiotext. Also, there will be a need to include cross–linking between DAB and AM/FM services.

Different ways of selecting services are conceivable. Conventionally, a programme service label identifies the chosen service; for example BBC Radio One. Alternatively a programme in a particular language could be selected, or one of a particular type or category, such as news, Wimbledon tennis, or classical music *and* educational. These requirements represent a step beyond what is currently available with RDS.

2.5. *Additional features*

RDS already offers several additional features including the following:

– Traffic Message Channel (TMC), which carries short digital code sequences used to address a limited message bank stored in a receiver; the messages may be presented to the listener via a speech synthesizer;

– Emergency Warning Systems (EWS), which provides coded messages and control information for use in emergency situations; the data is for use by special receivers only and the coding is not standardized;

– programme delivery control;

– paging.

The flexible data capacity of DAB offers the potential for improved performance. In particular, the Interactive Text Transmission System (ITTS) [14], which provides textual and graphically–presentable information about programmes (e.g. song lyrics and artists' names), offers new opportunities for information display.

There is also a demand for the identification of individual transmitters when operating in a single frequency network (SFN), in order to enable local opt–out services and to filter traffic information, for example, by geographical region.

3. *A conceptual DAB multiplex frame*

The transmitted signal is built around a conceptual frame with time–multiplexed components comprising three channels: a synchronization channel, a fast information channel (FIC) and a main service channel (MSC), as shown in *Fig. 1*.

3.1. *Synchronization channel*

The synchronization channel incorporates basic receiver control mechanisms, such as automatic frequency control (AFC), automatic gain control (AGC) and a phase reference. It is also used to carry encoded transmitter identification codes.

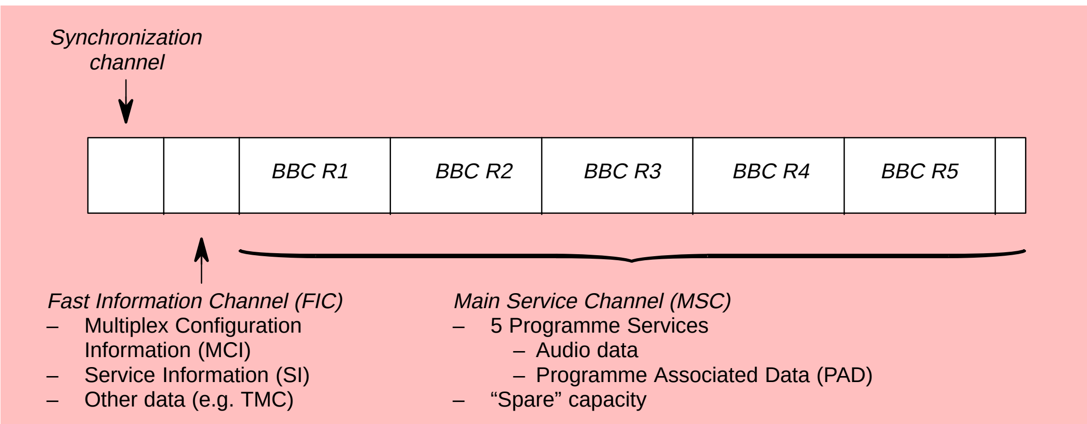


Figure 1
DAB multiplex frame.

3.2. *Main service channel*

The main service channel (MSC) is the largest portion of the DAB ensemble and it carries the audio data. *Fig. 1* shows how the ensemble could be divided into sub–channels to provide five audio service components for broadcasting the BBC national radio services. The use of the “spare” capacity and alternative arrangements of the ensemble are discussed in *Section 5*. In addition to the audio, each sub–channel also carries programme associated data (PAD), which is explained in *Section 7.4*.

The MSC has a total gross capacity of approximately 2.3 Mbit/s but this includes provision for the excellent error protection afforded by the convolutional encoding and time–interleaving mechanisms of COFDM [10]. The use of COFDM causes the net bit rate to be lower by an amount depending on the code rate[1] used (typically of the order of 1/2) and consecutive data samples of the source signal are spread over sixteen audio frame periods after COFDM demodulation in the receiver. These mechanisms may be applied to each sub–channel separately.

3.3. *Fast information channel*

The fast information channel (FIC) is strictly limited in capacity but is capable of supplying information to a receiver faster than the main service channel allows. This is possible because the FIC is not subjected to the time–interleaving part of the COFDM coding process. The degree of protection given by the convolutional coding is permanently fixed (at a code rate of about 1/3) because it would require another level of signalling, with even faster response and even better protection, to signal other possibilities. In order to achieve acceptable error performance, FIC information is repeated regularly. In the worst–case transmission mode, it is just possible to repeat the information within 100 ms.

The main application of the FIC is the administration of the multiplex configuration, defined by the multiplex configuration information (MCI). If there is sufficient capacity in the FIC, a limited amount of service information and other data services, such as TMC, may also be accommodated. From time to time, the multiplex configuration may be changed, whilst maintaining the continuity of those services that are intended to remain unchanged. In this case, two sets of configuration information need to be sent and this temporarily reduces the capacity available for other applications.

1. The code rate is the ratio of the number of useful bits of information to the number of transmitted bits. A trade–off can be made between transmission ruggedness and the number of programme service components that can be transmitted in a given channel width.

4. *Main service channel options*

The audio source coding method (Musicam) [9] is based on the ISO MPEG Audio Layer II standard 11172–3 [15]. This implies that audio information is processed in 24 ms transmission frames. The audio frame structure is extended for DAB by a further security check–word and programme associated data (PAD). Also, audio service components may be operated in one of four different modes – single channel (monophonic), dual channel (e.g. bilingual), stereophonic and joint stereophonic (in this last mode, data are allocated jointly between the left and right channels to improve the perceived audio quality at a given bit–rate).

A wide range of audio options are supported, suiting different programming requirements, different levels of reception ruggedness and, to some extent, the target audience. However, the number of options is voluntarily restricted to a set of standard packages in order to simplify the receiver. Each package combines a data–rate, in the range 32 kbit/s to 192 kbit/s for a monophonic channel, with an error protection coding overhead in the range 1/4 to 3/4. *Fig. 2* shows a number of different arrangements of service components in the main service channel.

Good broadcast–quality audio may be expected when using at least 112 kbit/s per monophonic channel (224 kbit/s for stereo). Lower data–rates may be acceptable depending on the application. For example, a data–rate of 64 kbit/s could provide acceptable speech quality for announcements.

Example (a) in *Fig. 2* shows that five stereo channels of high broadcast quality (224 kbit/s with mid–level error protection) can be fitted into the multiplex with 32 kbit/s data capacity spare. The spare capacity could be used, for example, to increase the audio bit–rate to provide a “no compromise” CD–quality service for the most critical material and audience.

Alternatively, the fifth channel could be split as shown in (b) to provide two monophonic channels which could each support, for example, local opt–outs for news at certain times of the day. The listener might select his local–area version or have it selected automatically by a local transmitter identification signal.

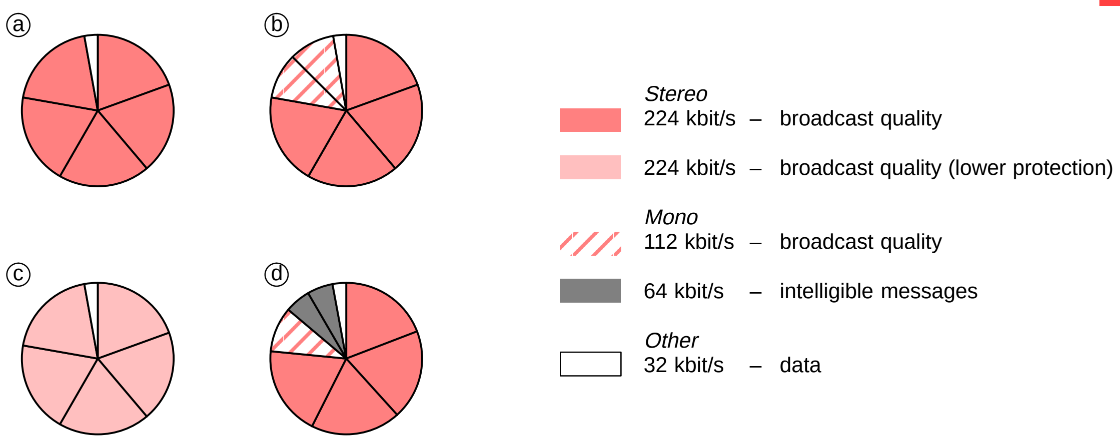


Figure 2
Main service channel (MSC) options.

A mid–level error–protection overhead of 50% is likely to be acceptable for most purposes. Lower levels may be acceptable in some circumstances and, with a mean code rate of 0.6, it is possible to fit six stereo channels into the multiplex, as shown in example (c).

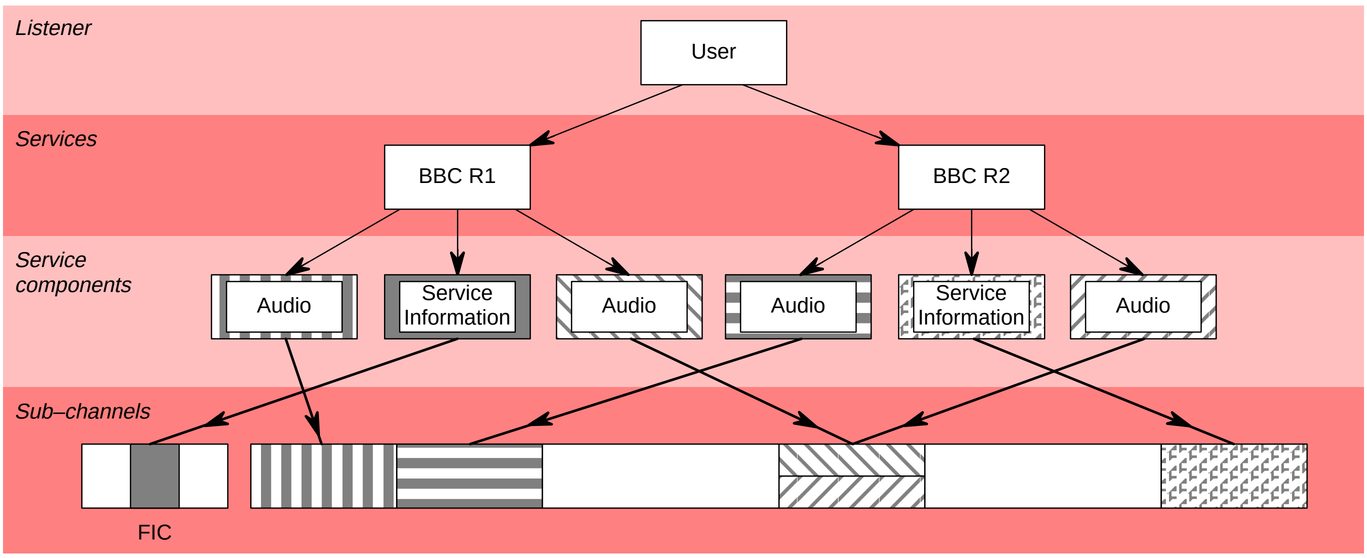
In the final example (d), four stereo channels with mid–level error protection are combined with a fifth mono channel, two 64 kbit/s channels and 32 kbit/s for data. An announcement service, including news flashes or spoken travel messages, could be supported within a data–rate of 64 kbit/s. This approach would allow a traffic information service (similar those which use the EON feature of RDS as a means of interrupting any national or regional programme selected by the listener with traffic announcements broadcast by a local radio station) to be established on DAB relatively easily. The data overhead needed to carry this service on all national ensembles might be sufficiently small so that delays, incurred by re–tuning to other ensembles, could be avoided. A more–efficient approach to the provision of travel information could readily be accommodated in the 32 kbit/s data channel in the form of TMC. It is possible to support two alternative announcement services in this way.

Whenever a data channel is employed, there is a choice in the way it is used. Data may be treated in 24–ms bursts in the same way as the standard audio or carried in addressable "packets". An advantage of this packet mode is that several small amounts of service information or other general data applications can be packaged efficiently into a single channel.

5. DAB service structure

The listener finds a programme by selecting a "service", for example, BBC Radio One (BBC R 1) or BBC Radio Two (BBC R 2). An example of a DAB service structure, shown in *Fig. 3*, illustrates how each service supports at least one, and possibly several, audio and data components. Both BBC

Figure 3
DAB service structure.



Radio One and BBC Radio Two have a stereo audio component and a data component carrying SI. In this example, the SI associated with BBC Radio One is small and is carried in the fast information channel, whereas the SI for BBC Radio Two is more extensive and is carried in a separate sub–channel, with only link–signalling carried in the FIC.

In addition, both services can be regarded as having a second audio component which shares the same sub–channel. This is an "announcement channel" carrying spoken travel messages.

Also, within each audio component there is some capacity to carry programme associated data (PAD), supporting, for example, dynamic range control information. However, this information is regarded as part of the audio service component and is not signalled explicitly.

One of the components, probably the main audio component, is chosen to be the default in case there is no specific selection by the listener. The remaining data components could be accessible to the listener either automatically, in the case of service labels, or by further listener selection, as in the case of interruption by travel messages.

6. Multiplex configuration information

The multiplex configuration information (MCI) provides essential basic control information which is intended to allow rapid receiver configuration ensuring that a reasonable sound is delivered without excessive delay. It is carried in the fast information channel, so that the receiver has almost 500 ms to process the information before the audio data becomes available. The MCI is also responsible for managing the inter–linking of all service components and handling dynamic changes to the multiplex configuration.

6.1. Basic information

Basically, the MCI provides a directory of services available in an ensemble.

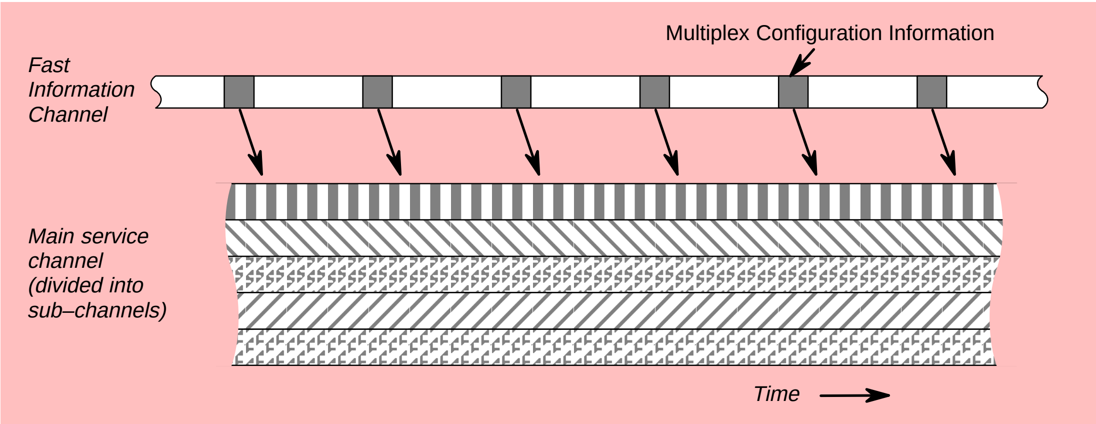
For each service, a description of each component is given so that it can be found, within the ensemble, and the appropriate decoder applied. Sub–channels are made up of smaller "capacity units" (CU) containing less than one hundred bits of information. Each of these may be allocated to one sub–channel and independently encoded and decoded. For each service component, the receiver requires information about where to find the component: this is either the position and size of a sub–channel or an address in the fast channel.

Each service has an associated machine–readable identifier. This is comparable with the programme identification (PI) code in RDS, and it is defined in the same way using a 16–bit field in which the first four bits having some relation to national areas. In addition, each service has an 8–bit extended country code (ECC) associated with it, and when this is combined with a service identifier, the identification of services (24 bits) is unique world–wide.

For standard audio components, a data–rate/ protection–level combination is chosen from the standard packages. For non–audio components, data may be treated in the 24 ms burst mode or in the packet mode. If the component is scrambled, the relevant scrambling mechanism and management keys are signalled.

The basic MCI is transmitted repetitively about ten times each second and is protected by a check–word so that it can be tested for correct and complete reception. In the event that it is not accurately received at the first opportunity, for example when passing under a bridge, there will only be a margin-

Figure 4
Multiplex signalling.



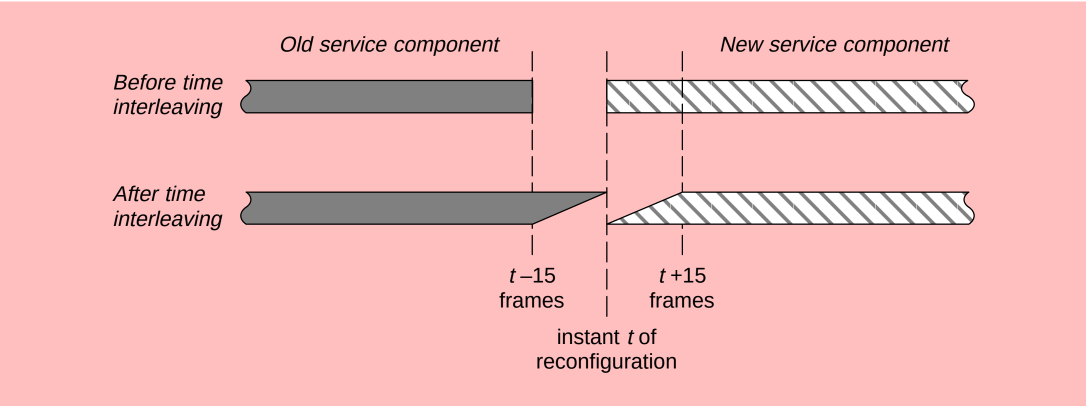


Figure 5
Effect of time–interleaving on a multiplex re–configuration.

ally extended delay before the receiver can respond.

Fig. 4 illustrates how the MCI (dark bands in the upper bar representing the FIC) is used to signal the service component organization in the lower bar representing the main service channel, where each shading pattern represents a separate component.

6.2. Changing the multiplex configuration

6.2.1. Introduction

It is expected that dynamic changes to the multiplex configuration will be carried out with very high reliability, and that service continuity will be preserved for all services which are not directly affected by the change.

A re–configuration of the multiplex is required if changes are made to:

– the size of a sub–channel (this may result from a change in a service component data–rate and/or its level of protection);

– the position of a sub–channel in the ensemble;

– the arrangement of components within the service structure.

Rearrangements of data components carried in the packet mode *may not* require a change in the multiplex if the total capacity of the associated sub–channel is unaltered.

Re–configurations may not be under the direct control of service providers (conventionally the broadcasters) because there is now an implicit new level of responsibility in the form of a “multiplex manager”. Implementation guidelines are being developed to manage the signalling between service providers and the multiplex manager.

6.2.2. Common interleaved frame

The independence of data “capacity units” in the main service channel means that each may be traded freely between one sub–channel and another at a re–configuration. However, the effect of time–interleaving, in the encoding process, is to spread the data associated with each capacity unit over a period of 384 ms (corresponding to sixteen 24 ms data bursts). This introduces an element of complexity into the multiplex re–configuration process which is resolved by the choice of an appropriate time boundary. The concept of a common interleaved frame (CIF) is introduced in the encoding process to provide a discrete boundary between one multiplex configuration and another. The CIF is created after both time interleaving and main service multiplexing and it remains valid for 24 ms. It is “common” because it is identical in all the transmission modes which have been defined to cover the wide range of terrestrial, satellite and cable operation [10].

The act of switching between one multiplex configuration and another requires the use of a carefully–timed control sequence spread over twice the interleaving delay period, as shown in *Fig. 5* which represents a single capacity unit both before and after time–interleaving. When a capacity–unit is re–allocated from one sub–channel to another, it remains dormant for fifteen 24–ms periods prior to its re–allocation. It is re–allocated to the new sub–channel at the instant of re–configuration. Following time–interleaving, the data from the first configuration “ripples” through during the interleaving process, so that all data is recovered by the instant of re–configuration. It takes a further fifteen frames after the instant of re–configuration for the full capacity of the capacity unit to be occupied by the new sub–channel.

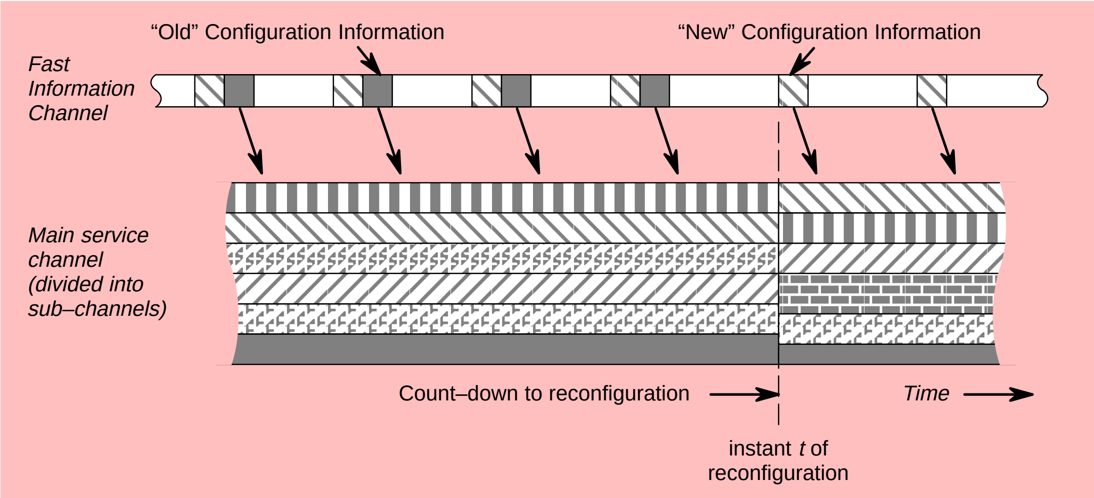


Figure 6
Multiplex re–configuration signalling.

6.2.3. Signalling

The signalling of a multiplex re–configuration is achieved by repeating a warning of the change (see *Fig. 6*). In this example, there are six active sub–channels before the change, and some spare capacity (shown as a grey bar at the bottom of the MSC). After the re–configuration, one sub–channel is removed and a larger one is added. All the other sub–channels continue with the same capacity but not necessarily in the same position in the multiplex. In upper bar, representing the FIC, there are two sets of configuration data, for the "old" and "new" situations. In addition, there is information to signal the instant of the change.

The maximum period of pre–warning for a multiplex re–configuration is about six seconds, and the instant of change can be at any CIF boundary, which is equivalent to a resolution of 24 ms. During the count–down period, the information about the instant of change, and the details of the new configuration, are repeated typically ten or more times, with greater frequency immediately before the change. This ensures that receivers already tuned to that DAB ensemble will switch reliably at the correct instant.

7. Service information

7.1. Introduction

Generally, service information (SI) features provide additional information about the services carried in an ensemble; this may extend to cross–references to information carried in other ensembles or in AM/FM services. The SI features defined for DAB are optional and broadcasters and receiver manufacturers may choose which of them to implement and when. The extent to which SI options are included in DAB services will depend on the perceived benefit of individual features to listeners, as far as the broadcaster is concerned, and the marketing potential, from the point of view of the receiver industry.

Every attempt has been made to preserve compatibility with RDS wherever possible because many service providers will, for many years, need to broadcast their services in both VHF/FM and DAB. Nevertheless, the greater capacity and flexibility which DAB offers allows existing RDS features to be improved or extended in the DAB context, and new features can be considered. The DAB service information features are described in more detail in this Section and the opportunities for future developments are briefly examined.

Table 1 summarises the available SI features. They are divided into six groups: service–related, ensemble–related, other ensembles and services, programme–related, PAD and, finally, those which are independent of the audio. For each feature, the preferred position in the multiplex is indicated, together with an indication of the data capacity required to support the feature. RDS comparisons are given where appropriate. A pointer mechanism is available to permit any SI feature or data service carried in the FIC to be re–directed to the auxiliary information channel (AIC), which is a part of the MSC allocated to service information when there is insufficient capacity in the FIC. SI data may therefore be carried in the fast channel (if the MCI, which has higher priority, leaves sufficient space), in the AIC or in the PAD.

Feature	Position of feature in mutliplex	Transmission capacity	RDS comparison
Service–related data			
Service directory (part of MCI)	FIC	High	PI, ECC
Service label	FIC	High	PS
Frequency information	FIC	Medium	AF
Conditional access	FIC / MSC	Medium	–
Programme–related data			
Programme language	FIC	Low	Lang
Programme type	FIC	Medium	PTY
Programme number	FIC	Medium	PIN
Foreground / Background	Audio	Low	–
Programme associated data (PAD)			
Dynamic range control (DRC)	PAD	Low	–
Dynamic label	PAD	Medium	RT
Music / Speech / Off	PAD	Low	M / S
Copyright	PAD	Low	–
Interactive Text Transmission System (ITTS)	PAD	Medium	–
Ensemble–related data			
Ensemble label	FIC	Very low	–
Announcements	FIC	Low	TP, TA
Alarm	FIC	Very low	PTY = 31
Other ensembles and services			
Other ensembles and AM / FM	FIC / AIC	High	EON
Non–audio features			
Time and date	FIC	Low	CT
In–house	PAD / FIC	Low / Medium	IH
Transmitter identification	FIC / AIC	Medium	–
Paging	FIC / AIC	High	RP
Traffic Message Channel (TMC)	FIC / AIC	Medium	TMC
Emergency Warning Systems (EWS)	FIC / AIC	Low	EWS

Table 1
DAB
service information
(SI) features.

The data capacities are given in very broad terms because the requirements depend on a wide range of options. Generally, “very low” means a few bit/s, whereas “high” indicates rates in the order of 10 kbit/s or more.

7.2. *Service–related features*

In DAB terminology, services are considered to be either (audio) programme services or data services and are supplied by a service provider. A programme service, such as “BBC Radio One”, carries a repertoire of programmes, for example “The Breakfast Show”. In addition to a main stereo component, there may be other service components providing, for example, auxiliary SI or TMC data. Each service is identified by a machine–readable form of the service identifier which is identical to the RDS programme identification (PI) code. A directory of all services carried within an ensemble is signalled in the MCI.

The service label is a displayable ASCII–character version of the machine–readable service identifier. It allows a listener to select a service in the conventional manner by choosing the title of a service. The label field has sixteen characters; this is longer than the equivalent RDS label and is expected to give greater freedom in describing a service. In order to maintain compatibility with RDS, the service label is accompanied by additional information that allows up to eight characters to be suppressed in a receiver with a limited display. The range of displayable characters meets the EBU requirements and covers Latin–based, Greek, Cyrillic, Hebrew and Arabic alphabets conforming to the ISO 646 international standard [16].

The frequency information feature provides a cross–reference to alternative sources of a service. It is similar to the RDS AF feature which provides a list of alternative frequencies and permits programme continuity when a mobile receiver moves across coverage area boundaries and re–tuning if better reception is possible. Although DAB is suited to operation in a network where all transmitters operate on a single frequency (SFN), DAB service multiplexes may also be available directly from satellite or from cable and these multiplexes may operate with different RF carrier frequencies. Furthermore, for a foreseeable period when DAB services duplicate those available on VHF/FM, and when DAB signals are not widely available, some services may only be available on VHF/FM. The DAB frequency information feature includes the full range of radio frequencies which support DAB, and AM/FM as well.

Additionally, it is possible to indicate the geographical area, for which the alternative sources apply, by using transmitter identification codes. This is an important consideration for a single frequency national network where hundreds of transmitters may be operating. It allows the list of frequencies, available to a receiver, to be reduced to include only those which are immediately relevant.

Using conditional access, the entitlement checking and management codes may be signalled to a receiver so that scrambled service components may be de–scrambled.

7.3. Programme–related features

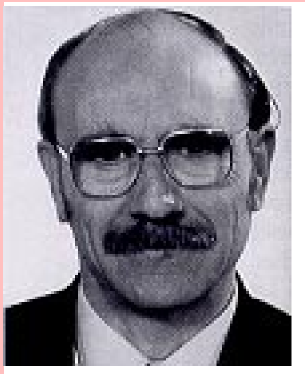
Programmes (e.g. "The Breakfast Show") are carried on specific programme services (e.g. BBC Radio 4) and are bounded by time limits (e.g. 06.30 h to 09.00 h). Each programme may be identified separately and may be associated with a particular language category and programme type classification. Additionally, such programme–related information may be used for service access, rather than selection by a service label. The possibility of implementing these mechanisms in a receiver makes it necessary to broadcast this information in the FIC for fast acquisition. Other programme–related data (for example, control of the audio dynamic range) has nothing to do with service access but needs to be synchronized to the audio. Features of this kind are termed "programme associated data" (PAD) and are carried within the audio frame. PAD features are described in *Section 7.4*.

The programme language feature is based on 256 categories, recommended by the EBU, and adopted for RDS.

The programme type feature allows a programme, carried on the primary service component, to be classified according to a specific category. This feature has been greatly extended compared with the corresponding feature in RDS in which there is a fixed set of 32 possible codes agreed by each Broadcasting Union. The EBU has defined about half of these codes for use within Europe, although the RBDS system in the United States operates with a full set. The service providers have stated their requirement for more codes, to permit programmes to be allocated to more realistic categories and to cater for categories not yet defined. DAB provides a further set of 32 "coarse" codes and a further layer of sub–categories which permit a finer division of classification. A key element of this feature is the ability to define new type categories and for these to be dynamically down–loaded to the receiver.

The programme number feature is used for programme delivery control. It is similar to the PIN feature in RDS but includes additional controls to permit interruptions and to take account of re–timed programmes. The information provided is largely based on the time at which it is intended to be broadcast.

Within the audio service component description, there is a flag that may be set to indicate "fore-



Mr. John Riley *studied electrical and electronic engineering at the universities of Leeds and Southampton and was awarded a masters degree in 1969. After a brief period of voluntary service overseas, he joined the engineering Research Department of the British Broadcasting Corporation, where he initially worked on a wide range of projects including UHF aerial development and holographic recording. His main interest has been digital techniques applied to both television and radio, embracing teletext, the Radio Data System (RDS) and latterly Digital Audio Broadcasting (DAB).*

Mr. Riley has worked within the Eureka 147/DAB project, coordinating the specification of DAB system features.

ground" or "background". The idea of this is to allow a listener to control the mix of foreground and background sound components; this facility could, for example, enable listeners with impaired hearing to produce a sound balance that suits their individual needs.

7.4. Programme associated data (PAD)

Features in this category are carried within, and at the end of, the audio frame. Therefore, there is an inherent synchronism of these data features and the audio content. The minimum available data capacity is 667 bit/s, although it can extend higher but at the expense of encroaching on the capacity available for audio coding. The following features are provided without affecting the audio.

Dynamic range control (DRC) allows control information to be sent to a receiver so that the audio dynamic range may be adjusted to suit different listening conditions. A control word is sent in every audio frame, and this is used by the receiver to vary the gain of an amplifier. Audio is broadcast with full dynamic range and the control signal acts so as to reduce the dynamic range i.e. apply compression. This is a valuable technique which makes it possible to serve audiences, without compromise, in widely differing reception environments. For example, the listener in the home can enjoy the full dynamic range and, using the same signal, a motorist can adjust his receiver to optimise his listening inside his vehicle.

The music/speech feature allows the predominant programme content to be signalled as music or speech in order to permit some receivers to treat the presentation of music and speech differently. The feature offers the listener the possibility of altering the balance between music and speech as desired, and provides a means of improving intelligibility in some listening environments. The feature is similar to the M/S switch in RDS, except that there is a condition which indicates when the feature is not in use.

A flag in the audio data stream signals whether the audio programme material is subject to copyright or not. The PAD also provides capacity for transmission of the International Standard Recording Code (ISRC) and the Universal Product Code/European Article Number (UPC/EAN).

The following features *may* affect the audio and the size of the PAD field needs to be chosen carefully. The dynamic label provides a means of sending additional textual information about a programme and may be used to emulate the radiotext (RT) feature in RDS, which supports up to 64 characters.

ITTS [14] is proposed to provide more–sophisticated text labels which may be presented in a display similar to teletext. The system is intended for world–wide application and the character sets include Japanese and Chinese as well as European and Middle Eastern alphabets. All digital compact cassette (DCC) tapes, now in pre–production, carry ITTS packets which provide the album or "work" title, the performer's name, the track list and a selection menu. Some tapes also include lyrics. Text–editing tools, developed by the music software industry, may be able to assist broadcasters to generate the PAD information.

7.5. Ensemble–related features

Each ensemble is identified by a machine–readable ensemble identifier which receivers may use to check whether alternative sources are carrying the identical ensemble. The ensemble label takes the same form as the service label.

The announcement feature allows different kinds of spoken messages to be identified on a particular service. Conceptualy, it is similar to the traffic programme (TP) feature of RDS, but it is on a larger scale, allowing a larger number of categories. Examples of announcement types are traffic and news, and other types are under consideration. Audio service components, carrying announcements within an ensemble, may be requested, by the listener, to interrupt a service he has previously selected.

The alarm flag provides an indication that the ensemble carries a service which responds in Europe to a type 31 programme type (PTY) code, from the fixed EBU set. The form of alarm triggered by this flag may be different in different types of receiver (e.g. buzzer, flashing light).

7.6. Other ensembles and services

Linking to other services (DAB & VHF/FM) allows a receiver to build up a database of the SI about those services. The feature extends to service labels and announcements and, in the case of other DAB ensembles only, to programme number and programme type. The frequency information feature is used to indicate where these services may be found.

7.7. Non–audio features

The time and date feature is similar to the RDS clock time and data (CT) feature, but in addition, local time offsets may also be signalled.

The in–house (IH) feature allows a broadcaster to specify his own data format for use with specialist receivers, for example, for network monitoring.

The TII database feature provides the geographical coordinates of transmitter locations. An area is signalled by sending a list of the identification codes for each transmitter within that area. This may be used as a geographical "filter" for use with the search for alternative service sources or to select relevant announcements, as described above.

Paging, TMC and EWS are data services for which DAB simply acts as the carrier. They are all supported on RDS but, potentially, there is a much greater capacity available with DAB. It may be possible to carry all or part of these services in the FIC. If more capacity is required, a pointer mechanism allows data to be re–directed to an overflow sub–channel in the MSC.

7.8. Future features

The DAB system is sufficiently flexible to permit further users' requirements to be considered and the addition of new features. Some of the possibilities include:

Programme "look ahead" represents a directory of forthcoming programmes on services carried within an ensemble, and possibly extendible to include other ensembles. This is an example of the use of text with graphics to provide a menu for service access via a teletext–like display and interactive control.

Still pictures with radio are becoming feasible as data bit–rates are reduced, memory and microprocessor costs fall and display technology is developed. Pictures often accompany recorded audio material (for example, on a cassette or CD case). This could provide the basis for a new "added value" service for some types of radio, for example for personal use. The feature could be accommodated at a relatively low data–rate provided the pictures are not changed too quickly. For example, the Eureka 147 project first demonstrated a picture radio service at ITU–COM'89 (Geneva) by sending JPEG–coded pictures as a 32–kbit/s DAB data channel alongside an audio channel (the picture could be changed approximately every ten seconds).

Figure 7
Simulated DAB receiver front panels:
a) Car receiver
b) Home receiver.

8. Simulated receiver

In the period before a DAB service is established, is will be useful to explore options concerning management of the receiver user–interface, in order to meet the requirement for easy service access. The BBC is developing a computer–simulated DAB receiver for this purpose and it will also be used to encourage manufacturers to implement DAB features in the manner intended by the DAB system designers. *Fig. 7* shows off–screen photographs of front–panels of simulated car and home receivers, which can be operated by selecting the required functions using a computer mouse, or with a touch–sensitive screen.

In the case of the home receiver, the display is sufficiently large to allow "soft" button labels to be accommodated and for the receiver to be operated in a "menu" mode. A general view of the DAB concept model test system is shown in *Fig. 8*.

9. Conclusion

All the known user requirements for system features have been accommodated in the DAB system specification. The DAB service multiplex is sufficiently flexible to provide a wide choice of service arrangements to suit programming needs. The multiplex may be filled with audio or data channels, or combinations of both. Multiplex configuration information, carried in a fast information channel, provides reliable control of the DAB multiplex, including the management of dynamic re–configuration. A wide range of optional service information features have been defined, maintaining compatibility with RDS wherever possible, and "hooks" are provided for future developments. By receiver simulation, the value and benefit of these system features can be evaluated before they are implemented in silicon.

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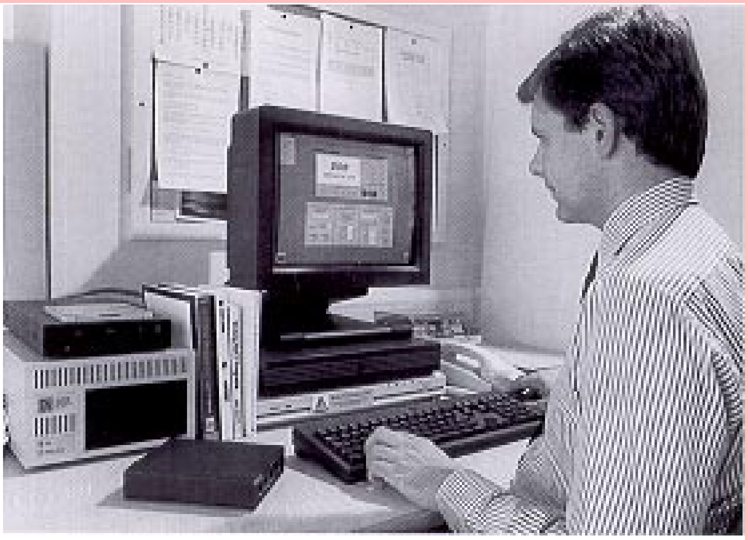

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