Digital Audio Broadcasting – radio now *and* for the future

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The world's first DAB services were launched in the United Kingdom and in Sweden at the end of September.

With several other broadcasters also preparing for the "big day", the author reports on the current status of DAB technology, and summarizes the progress being made to implement DAB services worldwide.

1. Introduction

The Eureka 147 Digital Audio Broadcasting (DAB) system is well known to readers of this journal: there is already a wealth of literature which gives information on the technical characteristics and the performance of the system[1].

Recently, some debate has started on the role that DAB could play in the future information highway. The present situation is characterized by the convergence of computer, telecommunication and broadcasting technologies, and the divergence of different delivery and storage media which use advanced digital signal-processing techniques. Consumers are overwhelmed by the new electronic gadgets which appear almost daily on the market, and they are astonished by the radically new technical innovations that are being designed to change their life-long habits. Even the broadcasting sector itself is facing profound changes, particularly a growing competition between the public and the private broadcasters.

Original language: English
Manuscript received 25/9/95.

1. See the bibliography given in issues 2 and 3 of *DAB Newsletter*, published by the EBU in 1993.

The present article reviews the current status of DAB worldwide, at a time when official services have already started in Sweden and the United Kingdom, and as broadcasters elsewhere prepare for the imminent launch of their DAB services.

2. Analogue radio

In 1895, Guglielmo Marconi (1874 – 1937) conducted his first experiments with wireless telegraphy on his father's estate in Italy. Now, a century later, analogue AM and FM emission standards have achieved technological and operational maturity; every day, radio reaches about two billion receivers worldwide, offering the listeners a large diversity of speech and music programmes.

Nevertheless, these analogue emission standards are failing to provide many listeners with the audio quality they have come to expect in this age of the compact disc.

2.1. Frequency shortages

The frequency bands available for sound broadcasting are either rapidly saturating or have already become saturated. As a result, the reception quality is suffering more and more from mutual interference between transmissions. In many countries, there are now very little or no prospects of additional radio services being provided by means of the existing analogue technologies.

2.2. Difficulties with FM radio reception

FM radio services in VHF Band II were originally planned in the 1950s and 60s for fixed reception using a directional receiving antenna at a height of 10 m above ground level. Those listeners who have installed a good outdoor (or loft-mounted) antenna are generally quite happy with the quality of their FM reception. However, the majority of radio listening today is carried out with portable and mobile receivers which use only a simple whip (or telescopic) antenna, resulting in substandard FM reception quality in many areas.

FM reception quality on a portable radio can be very variable inside large buildings such as multistorey "tower blocks". This is due to the attenuation of the FM radio signals by (and internal reflections from) the walls of the building (particularly if constructed from steel-reinforced concrete).

When listening on a portable or a mobile receiver, FM reception can be badly affected by *shadowing* (i.e. the blocking or screening of the signals by tall buildings and hills which lie in the direction of the transmitter) and by *passive echoes* (the arrival at the receiver of delayed "multipath" signals which have been reflected from tall buildings and hills). For the motorist, there is the additional problem that the strength and quality of the received FM signals can change very rapidly as the vehicle proceeds. This places an almost impossible burden on the car radio receiver.

2.3. Shortcomings of international broadcasting

International broadcasters use terrestrial AM systems on the shortwave (HF) bands as the primary means of delivering radio to wide supranational areas. These transmissions are affected by diurnal and seasonal propagation variations which cause fading and occasional loss of signal completely. Hence, as a consumer commodity in the age of the CD, international shortwave broadcasting has lost much of its former attraction.

Today, one of the main objectives of international broadcasters is to design and implement viable services which are based on a new universal digital delivery system. This could be either a satellite or a terrestrial system, possibly a combination of the two, which in time would replace shortwave broadcasting (see *Section 15.*).

3. Beginnings of digital radio

Radio is witnessing an increasingly strong competition from non-broadcast media which use digital techniques to produce the optimum performance, at a cost that is acceptable to large consumer markets.

The compact disc was the first mass-storage digital medium to offer superior sound quality in the domestic marketplace. The CD has now been joined by various other tape and disk storage formats, such as R-DAT and S-DAT, digital compact cassette (DCC), MiniDisc (MD) and CD-I.

In parallel with these mass-storage developments, digital sound-broadcasting systems – which use relatively simple source- and channel-coding techniques – have been developed. These systems have been designed for specific purposes where immunity to frequency-selective fading is not required and where reception is only via a static receiver. They do not provide reliable reception in a multipath propagation environment.

The main systems to date are now described briefly.

3.1. NICAM 728

NICAM 728 is a digital stereophonic sound system which was developed for use with PAL terrestrial television broadcasting (recently for use with SECAM also). Directional receiving antennas are used to eliminate, or at least reduce, any multipath problems.

3.2. DSR

The Digital Satellite Radio (DSR) system is a high-quality stereo satellite system which provides sixteen sound programmes in an FSS/BSS satellite channel.

3.3. ADR

The Astra Digital Radio (ADR) system has been developed recently for the satellite distribution of digital sound signals to fixed individual receivers and to feed national FM networks (and possibly DAB networks at a later date). It is planned that ADR services will commence later this year.

The ADR system makes use of unused capacity available on the existing analogue transponders of Astra satellites. Each transponder can accommodate twelve digitally-modulated subcarriers, each of which can carry a digital stereo sound programme at a data rate of 192 kbit/s.

3.4. DVB

Recently, the European Digital Video Broadcasting (DVB) Project has developed and standardized a digital television broadcasting system for satellite and cable delivery [1], [2], [3]. The DVB system makes use of ISO/IEC MPEG-2 video/audio source coding and transport packet multiplexing, in conjunction with either QPSK modulation (for satellite delivery) or multi-level QAM modulation (for cable delivery).

The DVB system allows potentially large numbers (several hundreds) of audio programmes to be carried in a BSS/FSS satellite channel, but it is only suitable for stationary reception at home.

4. Eureka 147 DAB system

The Eureka 147 DAB system has been developed by a European consortium which was established in 1987 and now has over 40 members; it is composed of manufacturers, broadcasters, network providers and research institutes. The Project Office of the Eureka 147 Consortium is managed by the DLR[2], based in Cologne, Germany. A Eureka on-line information service is available on the Internet World Wide Web and can be accessed via: http://www.dlr.de/DAB/.

The Eureka 147 DAB system has been designed to provide high-quality, multi-programme digital sound and data broadcasting services – not only for reception by fixed receivers but particularly for in-car and portable reception using a simple whip antenna.

The Eureka DAB system can operate in any dedicated broadcasting band at both VHF and UHF. Even when working in severe multipath conditions, such as in dense urban areas, the system provides an unimpaired sound quality in the DAB receiver. The system has also been designed as a flexible, general-purpose, integrated services digital broadcasting system which supports a wide range of source- and channel-coding options, as well as programme-associated and independent data services.

4.1. DAB ensembles

Unlike conventional analogue broadcasting, the DAB system enables several sound programmes to be multiplexed together and broadcast on the same radio-frequency channel. The number of programmes in an “ensemble” (i.e. a multiplex) depends on the trade-off implemented between:

1) the encoded bit rate per audio programme;
2) the channel protection that is provided against errors occurring on the propagation path;
3) the data capacity required for the various programme-associated and independent data services that are included in the ensemble.

4.2. COFDM

In the Eureka 147 system, a transmission technique called *coded orthogonal frequency division multiplex* (COFDM) is employed. In this system, the complete ensemble is transmitted via several hundred (or even several thousand) closely-spaced RF carriers which occupy a total bandwidth of around 1.5 MHz, the so-called *frequency block*. Each individual RF carrier transmits – at a fairly low data rate – only a tiny fraction of the total data which makes up the ensemble, thus providing a form of diversity reception.

With COFDM, multipath reception is practically eliminated. Due to the low data rate of each RF carrier, any delayed reflections of the signal (i.e. “passive echoes”) add in a constructive manner to the direct signal already received. The only situation where passive echoes do not contribute in a constructive manner is when the delays are much greater than the time guard interval of the DAB signal, i.e. greater than 300 μs at VHF. (Delays of this magnitude are extremely rare in most types of terrain where multipath reflections are apparent.)

4.3. A conceptual DAB transmitter and receiver

Figure 1 (top) shows a conceptual DAB transmitter drive, in which a sound and a data service are coded individually at source level, then error protected and time interleaved. Next, the sound and data services are multiplexed into the Main Service Channel, together with other services, according to a predetermined but changeable service configuration. The multiplexer output is

2. Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V.

frequency interleaved and combined with multiplex control and service information which travel in a Fast Information Channel which is not time interleaved. At this stage, very rugged synchronization pulses are added and then OFDM is applied to the signal before, finally, it is DQPSK-modulated onto a large number of RF carriers to form the complete DAB signal.

Figure 1 (bottom) shows a conceptual receiver in which the wanted DAB ensemble is selected in the analogue tuner, downconverted and quadrature demodulated before applying it to an analogue-to-digital converter. Thereafter, the receiver performs the operations of the transmitter in reverse order. The digitized output of the converter is fed to the Fast Fourier Transform (FFT) stage and then differentially demodulated. This stage is followed by a time and frequency de-interleaving process, and error correction. Next, the original coded services are further processed in an audio decoder, including an error concealment circuit, to produce the left and right audio signals.

The decoding of more than one service component from the same ensemble, such as an audio programme in parallel with a data service, is practicable and provides interesting possibilities for new receiver features.

5. Eureka 147 and Intellectual Property Rights

Recently, the Eureka 147 Consortium has resolved the issues concerning DAB and Intellectual Property Rights (IPR). The DAB system is now considered as fully open; it can be manufactured by any interested party following the fulfilment of the licence conditions. The Consortium is willing to negotiate licences with other parties on a non-discriminatory basis and on reasonable terms and conditions.

No broadcaster will be charged for implementing DAB networks based on the Eureka 147 system.

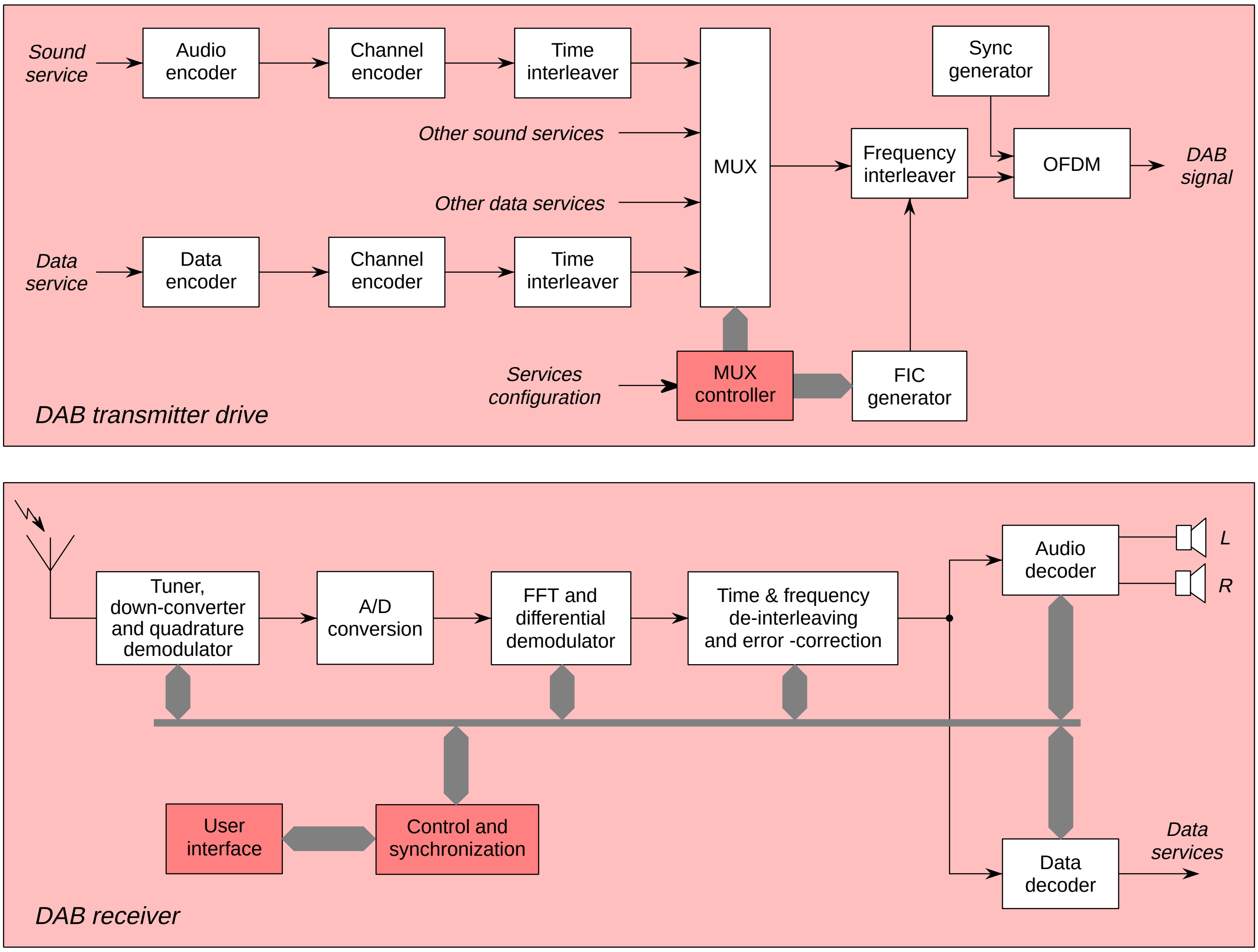


Figure 1
Conceptual DAB transmitter drive *(top)* and DAB receiver.

6. *Principal advantages of DAB*

6.1. *CD quality*

DAB has several advantages over conventional analogue AM/FM broadcasting. The main benefit is that the high sound quality, normally indistinguishable from that of the CD, is effectively free from interference. However, DAB also has a unique ability to serve the mobile audience, thus providing high-quality coverage wherever and whenever required.

6.2. *Spectrum efficiency*

A further advantage of DAB is that it is spectrum-efficient. This means that it will be possible to increase the number of radio stations – initially by a factor of at least three when compared with FM – without congesting the radio waves. As more efficient audio coding (compression) methods are introduced, it will be possible to carry even more radio programmes with no degradation to existing services, and without needing to modify existing receivers. A radio set of the future will thus make it possible to choose, for example, a favourite type of music station from among hundreds of music stations.

6.3. *"Active echoes"*

As mentioned in *Section* 4.2., the Eureka 147 DAB system is able to use "passive echoes" such that they add in a constructive manner to the direct signals already received. The Eureka system is also able to use "active echoes" constructively – i.e. delayed signals generated by other co-channel transmitters. This leads to two important concepts:

– single frequency networks (SFNs);

– co-channel gap-fillers.

The SFN concept enables all transmitters covering a particular area with the same set of sound programmes to operate on the same nominal radio-frequency channel, i.e. within the same frequency block. All SFN transmitters need to be synchronized, in terms of both frequency and time, and the transmitted bit stream must be identical. Although the signals emitted by the various transmitters are received with different time delays, the receiver recognises this as a direct signal coming from the nearest transmitter, followed by "active echoes" coming from other transmitters in the SFN.

Gap-filling represents the second type of application which makes full use of the "active echo" concept. A gap-filler acts rather like a mirror; it receives the signals from the main transmitter and retransmits them at low power on the same frequencies to provide coverage in an area where the main transmitter is not received satisfactorily. Although the listener receives signals from both the main transmitter and the gap-filler at slightly different times, the two sets of signals add together constructively to enhance the reception of the programme. The gap-filling concept is useful both for terrestrial and satellite broadcasting systems.

As a result of these two concepts, DAB eliminates the problem of having to retune car radios at frequent intervals. At present, long-distance drivers who are listening to an FM programme are forced to retune as they move away from the area covered by one transmitter to that of another. With DAB, however, a car radio does not need to be retuned because the wanted station will be in the same frequency block everywhere within a national or regional service area.

6.4. *Flexible bit rates*

The Eureka 147 DAB system is a highly flexible and dynamically reconfigurable system. It can accommodate a range of bit rates between 8 and 384 kbit/s[3], with a range of channel protection mechanisms.

Some broadcasters are interested in using low audio bit rates per audio channel, say between 16 and 64 kbit/s, in order to transmit more channels at slighly reduced quality. With a bit rate of 32 kbit/s per audio channel, the Eureka multiplex of 1.5 MHz can accommodate as many as thirty-six channels, with 1/2 channel protection level.

6.5. *DAB transmission modes*

Technically, the Euraka 147 DAB system can be used at any frequency between 30 MHz and 3 GHz. This wide range of frequencies includes VHF Bands I, II and III, UHF Bands IV and V, and L-Band (which is around 1.5 GHz). Since the propagation conditions vary with frequency, four DAB transmission modes are used (see *Table 1*).

These modes are detected automatically by the receiver and are transparent to the user. *Mode I* is suitable for SFNs operating at frequencies below

3. The Eureka 147 DAB system has been refined recently to include very low bit rates, such as 8, 16 and 24 kbit/s per monophonic audio programme. This is made possible by using a sampling frequency of 24 kbit/s, instead of 48 kbit/s.

	Mode I	Mode II	Mode III	Mode IV
Upper frequency limit (MHz)	300	1500	3000	1500
Number of carriers	1536	384	192	768
Carrier spacing (kHz)	1	4	8	2
Total symbol duration (µs)	1246	312	156	623
Guard interval duration (µs)	246	62	31	123
Frame duration (ms)	96	24	24	48
Symbols per frame	76	76	153	76
Null symbol (µs)	1297	324.2	168	648.4

Table 1
Transmission modes of the Eureka 147 DAB system.

Notes: Ensemble bandwidth = 1.536 MHz
Sampling frequency = 2.048 MHz

300 MHz. *Mode II* has been designed for local and regional services at frequencies below 1.5 GHz and *Mode III* is available for satellite broadcasting below 3 GHz. *Mode IV* has recently been introduced to enable existing transmitter sites to provide optimum and seamless coverage of large areas by means of SFNs operating in L-Band. The parameters of Mode IV lie between those of Mode I and Mode II.

6.6. Data services

Although audio has been its primary *raison d'être*, the Eureka 147 transmission system can also be used to carry a large variety of programme-associated and independent data services. Many data services of the programme-associated category will probably be transmitted from the outset and will be received by the first generation of DAB consumer-type receivers. Later on, independent data services may also appear. These would be received by dedicated data receivers, including those incorporated in desk-top and lap-top computers. Two examples of this application are the electronic delivery of newspapers and the transmission of compressed video images such as weather maps.

The Eureka system's immunity to multipath and other reception impairments will guarantee error-free data reception in the mobile environment. Hence, the Eureka 147 system is an ideal complement to the wired Information Highway distribution system now being established worldwide.

Further data-transmission possibilities of DAB are outlined in *Section 18.*

6.7. Future-proofing

The Eureka 147 DAB system is future-proof. Once the receiver has been purchased, it will not become obsolete as the digital technology develops, nor as new services and applications emerge.

In Europe, for example, DAB delivery will commence via terrestrial networks. Nevertheless, the receivers designed for use with these terrestrial services should, in principle, also be able to receive future DAB services delivered via satellite and cable. In other words, the Eureka 147 system will become a universal means to deliver sound programmes and data, irrespective of the transmission medium used[4].

7. System constraints

The design of a new system is inherently a trade-off between different technical and operational choices. Thus, when introducing DAB services, one must be aware of the technical constraints of the Eureka 147 system, which may generally be overcome by the use of suitable operational practices.

The main technical constraints are now described.

7.1. System processing delay

The DAB system chain includes several blocks which introduce a significant processing delay. For example, the time interleaver introduces a delay of 384 ms, and the audio coder/decoder introduces a delay of several tens of milliseconds. The total delay in the system may vary from one implementation to the next.

4. Studies are now being conducted on the use of the Eureka 147 system as a digital television delivery medium for mobile reception on small screens.

The system delay should be taken into account when the receiver switches between DAB and FM "simulcast" programmes, so that a seamless transition is obtained. It will become necessary for simulcast FM transmissions to be delayed by nominally the same amount, say one second, regardless of the receiver design. This nominal delay should be taken into account when signalling the current time information.

7.2. Frequency accuracy in SFNs

In order not to reduce the performance of the DAB system, the difference in frequency between geographically-adjacent transmitters must be kept to an absolute minimum – of the order of a few hertz in 10^8. Consequently, the local oscillators of all transmitters must be locked to a rubidium oscillator, or to a common reference which is distributed to all the transmitters.

7.3. Time accuracy in SFNs

The time difference between geographically-adjacent transmitters will have an implication on the system's capability to cope with "active echoes". Therefore, all the transmitters operating in an SFN should be time-synchronized with an accuracy of better than 25 µs (i.e. approximately 10 % of the guard interval in Transmission Mode I).

7.4. Bit-by-bit compliance in SFNs

In principle, the bit-streams emitted from all transmitters operating in an SFN should be identical. If this condition is not fulfilled, there will be a "mush area" (i.e. interference zone) between the transmitters where the DAB receiver may be confused. Tests are being undertaken to assess the size of the mush area in the case where a local transmitter "opts out" from an SFN, thus emitting a different bit stream to the other transmitters in the SFN.

7.5. Receiver speed limit

As the speed of a vehicle increases, the performance of an on-board DAB receiver progressively degrades, due to the Doppler effect. The "receiver speed limit" may be considered as the vehicular speed at which the RF signal-to-noise ratio degrades by 4 dB, due to the Doppler effect. While this does not affect the audio quality, it may reduce the DAB coverage area slightly – but only in a fast-moving vehicle.

In the case of an SFN operating at VHF, the receiver speed limit is about 200 km/h. When the receiver operates at 1.5 GHz and Transmission Mode IV is used, the speed limit is about 120 km/h.

8. Standardization

A common transmission standard for DAB, as opposed to a multitude of proprietory standards, has always been preferred by EBU Members. A single standard would readily lead to the mass production of DAB receivers, bringing their prices down to an affordable level. It would open the door to free market competition, resulting in a wide variety of receiver brands offering a range of qualities and features. A unique DAB standard would mean that the same core electronic circuitry in the receiver could be used in all parts of the world, as is the case today with AM and FM radio. It would also reduce the need to perform standards conversion with its inherent degradation of the signal. A single DAB standard would introduce stability in the market and the DAB technology would last for a long time.

In pursuing the above objectives, the EBU has been instrumental in establishing a unique DAB standard at both the European and the worldwide levels.

8.1. ETSI

In late 1994, the Eureka 147 DAB system was adopted by ETSI[5] as a European Standard. ETSI then published the standard – *ETS 300 401* [4] – in February 1995.

The ETSI Standard describes the technical details of the broadcast on-air signal and is applicable to terrestrial, satellite and cable delivery, in all the frequency bands that are available for broadcasting above 30 MHz. The concept of the Standard is such that it includes both mandatory and optional features of the system, and it allows for future functional refinements and additions by the application of appropriate software tools. The Standard permits different levels of implementation to meet a variety of market requirements, production costs and receiver types.

8.2. ITU

The global DAB standardization process is being conducted within the International Telecommunication Union (ITU) which, among other things, considers new developments in broadcasting technology and agrees the technical standards of broadcasting systems – for both radio and televi-

5. European Telecommunication Standards Institute.

sion – on a worldwide basis. Over the years, EBU Members have contributed extensively to different ITU working parties on the results of R&D work carried out in their own laboratories.

Since 1985, the ITU-R[6] has studied proposals for new digital sound broadcasting systems – for both satellite and terrestrial delivery to vehicular, portable and fixed receivers in the frequency range 30 – 3000 MHz. This information has been included in Report 955 for satellite sound broadcasting [5] and Report 1203 for terrestrial sound broadcasting [6]. Both reports still provide useful background information for analogue and digital system characteristics and frequency planning considerations, but they are now being superseded by a new ITU-R Special Publication on Digital Sound Broadcasting (see *Section 8.2.4.*).

Since 1987, the ITU-R has been attempting to agree on the technical and operational requirements that any digital sound broadcasting system should fulfill. In November 1991, Working Parties 10B and 10-11S adopted two new draft Recommendations on the system and service requirements. These Recommendations were slightly revised in November/December 1994 [7], [8].

Two important requirements should be highlighted here:

a) the satellite and the terrestrial systems should both provide significantly-improved performance in a multipath and shadowing environment, when compared with existing analogue systems;

b) the satellite and the terrestrial systems should both be capable of utilizing common signal-processing circuits in the receivers.

8.2.1. *Digital Systems A and B*

The most important ITU-R effort for some years has been focused on agreeing a Recommendation on the sound broadcasting system itself. The Eureka 147 system – known in ITU parlance as *Digital System A* – was first recommended by Working Party 10B (as a terrestrial system) and by Working Party 10-11S (as a satellite system) in October 1993, but only provisionally. A formal Recommendation was not possible at that time because some delegates wished to await the successful outcome of tests being conducted by the US Electronic Industry Association (EIA) on the so-called “IBOC” and “IBAC” approaches (see *Section 14.*), and on the satellite system proposed jointly by the Voice of America and the Jet Propulsion Laboratory, known as ITU-R *Digital System B*. These tests were originally planned to finish by the end of 1994 but the estimated completion date has now slipped back until well into 1996.

8.2.2. *A common worldwide standard for digital radio*

At the late-1994 meetings of ITU-R Working Parties 10B and 10-11S, it was decided unanimously to adopt two Draft Recommendations, BS.1114 [9] and BO.1130 [10]. The first of these drafts recommends to ITU members to use Digital System A for terrestrial delivery in the frequency range 30 – 3000 MHz. The second one recommends that administrations wishing, in the near future, to implement BSS (sound) which meets some or all of the requirements stated in ITU-R Recommendation BO.789 should consider the use of Digital System A.

Both these Draft Recommendations include a Note which, in principle, opens the door to other systems as well – when they are sufficiently developed and tested, and when they have shown that they would meet the agreed and approved ITU requirements given in Recommendations 774 or 789 (for terrestrial and satellite systems, respectively).

It was only possible for the ITU to adopt the above two Draft Recommendations because the EBU was able to present important evidence to the late-1994 meetings of Working Parties 10B and 10-11S. This evidence included a final Eureka 147 system specification (corresponding to the ETSI standard), as well as comprehensive EBU evaluations on the RF performance characteristics of DAB (including the subjective audio quality versus the RF signal-to-noise ratio) and the interference protection ratios required to protect other services in the same or the adjacent bands, or to protect DAB services themselves. In addition, many administrations were able to present the results of their own field tests and experiments.

The achievement of a common worldwide Standard is rare in the history of broadcasting. In the case of the Eureka 147 system, it was only possible due to the joint efforts of, and extensive cooperation between, European and Canadian broadcasters, research institutes and the radio manufacturing industry. The Eureka system also had the support of many administrations outside Europe, particularly from the developing countries.

6. ITU Radiocommunications Sector, formerly known as the CCIR.

It should be pointed out that, so far, no other digital radio system submitted to the ITU has been able to achieve the level of success of the Eureka 147 system. However, the situation may change when, or if, other systems reach a level of maturity that is comparable to the present Eureka 147 system; the proponents of these new systems could then knock at the door of the ITU and claim worldwide recognition as well!

8.2.3. A common worldwide standard for audio compression

Following extensive subjective tests, ITU-R Task Group 10/2 has adopted for emission the ISO/MPEG Layer II format at 256 kbit/s.

This audio bit-rate reduction system has been developed and implemented within the Eureka 147 Project and is known as *Musicam*. It uses a range of bit rates between 8 and 192 kbit/s per monophonic channel to allow some flexibility in optimizing the trade-off between the intrinsic audio quality and the service ruggedness. A high-quality stereo channel will generally use bit rates at the higher end of the range, e.g. 2 x 96 kbit/s.

8.2.4. ITU Special Publication on Digital Sound Broadcasting

The ITU-R has prepared a Special Publication on Digital Sound Broadcasting [11]. This comprehensive book is based on the studies performed since 1991 by ITU-R Working Parties 10B and 10-11S, and covers both terrestrial and satellite digital sound broadcasting. It contains a theoretical part on the different systems, a section on frequency planning approaches and experimental evidence derived from laboratory and field tests carried out on the different systems.

This ITU-R Special Publication is particularly useful to those who are planning DSB services in the near future, but it may also be interesting for those who have a medium- to long-term interest in DSB services, particularly in the developing countries.

8.3. CENELEC

CENELEC[7] is planning to release a receiver standard for Eureka 147 DAB, by the end of 1995. Based on a draft technical report already prepared by EACEM[8] [12], the CENELEC Standard will define only those mandatory parameters which are necessary for Eureka 147 DAB receivers to interpret correctly the received signals; non-mandatory parameters will not be specified and may be open to competition in the marketplace.

A specification of the receiver data interface (RDI) of the Eureka 147 system has been drawn up and will be converted into a CENELEC European Standard in due course. Via the RDI, it will be possible to connect computers, printers and dedicated decoders for data applications, as well as devices for audio post-processing and recording.

7. European Committee for Electrotechnical Standardization.

8. European Association of Consumer Electronics Manufacturers.

9. Role of the EBU

EBU Members have long been in agreement that a new digital radio broadcasting system should be designed to supersede AM and FM analogue technology. Towards this end, they were instrumental in initiating a series of studies in 1985, initially on satellite DAB aspects.

It was soon realised that EBU Members would not be able to design and develop a new system by themselves. Cooperation with the manufacturers and with national administrations would be necessary. Hence, the Eureka 147 Consortium was set up in 1987 and has been actively supported by EBU Members ever since. In order to guide the Eureka 147 Consortium, EBU Members initially drafted the user requirements with which the new system should comply. Although the EBU, as an association of broadcasters, could not become a formal member of the Eureka 147 Consortium, many EBU member organizations individually joined the Eureka 147 Project. Furthermore, the EBU Technical Department actively participated in the deliberations taking place within the Eureka working bodies.

The EBU has actively supported the promotion of the Eureka 147 system; many demonstrations have been organized jointly with the Eureka 147 Consortium. In particular, the EBU was instrumental in promoting the Eureka 147 system within the ITU and at the World Conference of Broadcasting Unions. The EBU also organized the work which led to the establishment of the ETSI European Standard on DAB.

In April 1994, the EBU Technical Committee adopted EBU Recommendation R79-1994 [13]. This document recommends the Eureka 147 system for terrestrial and satellite delivery of DAB services. An EBU Working Party, set up to evaluate the DAB system, prepared a comprehensive technical document on baseband and radio-frequency performance of the system, and the protection ratios required. Based on this information, it was possible to establish the sharing criteria for DAB services and other services using the same or the adjacent frequency bands.

9.1. Project Groups

As described in the previous issue of **EBU Technical Review** [14], the EBU will soon complete a major reorganization of its working groups in order to improve the efficiency of their studies and to speed up the approval procedures. Work is now entrusted to a limited number of Project Groups, comprising a minimum number of experts. Each Group is assigned a specific task to be accomplished within a limited time-frame.

The following Project Groups – all operating within the EBU Broadcast Management Committee – are involved in different aspects of DAB:

– *B/DAC* (DAB Characterization and Evaluation);

– *B/TAP* (Terrestrial Audio Planning);

– *B/INB* (International Broadcasting);

– *B/DSI* (Detailed Spectrum Investigation);

– *B/PPD* (Propagation Predictions for Digital Services).

9.2. Guidelines for implementation and operation

Based on the work carried out by the Eureka 147 Project Group, the EBU is planning to publish *Guidelines for Implementation and Operation* [15] as a companion to the ETS 300 401 Standard. This document – which is extremely important for EBU Members who wish to start DAB services – is intended to provide additional information on the system, to aid interpretation of on-air signals conforming to the ETSI Standard, and to assist the broadcasters and manufacturers to implement systems using the specification features as intended.

9.3. Interfaces

Two interface-related DAB standards, produced within the framework of the Eureka 147 DAB project, are very important for broadcasters. The first one, *Ensemble Transport Interface (ETI)* [16], has already been issued by the EBU. The second one, entitled *Service Transport Interface*, will be completed by the Eureka 147 Consortium this autumn.

9.4. Frequency planning

One area of the EBU's DAB activity which must be highlighted is its contribution to the CEPT[9] on frequency planning matters. On behalf of the CEPT, the EBU was responsible for coordinating the preparations for the CEPT Planning Meeting on terrestrial DAB services, held during July 1995 in Wiesbaden, Germany (see *Section 11.*, and also the article starting on *page 28* [17]).

The EBU issued a Technical Document [18] in June 1995 which considers all the major elements of network planning, network concepts and the main planning parameters to be taken into account (such as protection ratios, necessary field strengths and coordination parameters).

10. EuroDab Forum

In order to stimulate the transfer of technology from the laboratory to the marketplace, and following the proposal of several existing national forums, a European DAB Forum – *EuroDab* – has been set up. The aim of the EuroDab Forum is also to harmonize the activities of national DAB platforms and to encourage the establishment of new national groupings in those countries which have not yet organized their activities on DAB. The EuroDab Forum should be able to capitalize on the tremendous achievement of the Eureka 147 DAB Project and to bring Digital System A to common practice. It should also encourage cooperation, firstly at a European level but eventually worldwide, and try to avoid duplication of work within the national groupings.

The first meeting of the EuroDab Forum, held in Geneva during March 1995, was unanimous in agreeing upon the principal objective of the EuroDab Forum – to create in Europe and in other parts of the world a framework for a harmonious and market-driven development of DAB services using the terrestrial, cable and satellite broadcasting infrastructure. All major national groupings on DAB – including broadcasters, service providers and the manufacturing industry – were represented at the meeting.

A number of possible areas of activities have been identified, including:

– audio programming issues;

– programme-associated and independent data services;

9. European Conference of Postal and Telecommunications Administrations.

– marketing issues and a strategy for the introduction of DAB services;

– coordination of business plans;

– minimum requirements and optional characteristics of DAB receivers;

– legal and regulatory matters;

– monitoring of standardization activities;

– future evolution towards multimedia and interactive radio.

The EuroDab Forum will organize conferences, seminars and symposia on DAB and will launch studies, surveys and analyses on DAB markets. Initially, five working groups will be set up, covering the following topics:

– equipment;

– regulatory matters;

– marketing and promotion;

– services;

– satellite services.

The EuroDab Forum is open to potential members from all parts of the world. Since March 1995, more than 70 national forums, manufacturers, broadcasters, network providers, media regulators and administrations have joined the Forum – and the number is still increasing. Broadcasters, administrations and manufacturers from Canada, Australia, India, China, Mexico and other non-European countries have also expressed an interest in joining *EuroDab*.

Perhaps there is already a need to change the name from *EuroDab* to "WorldDab", or something similar!

11. Spectrum issues

A three-week Planning Meeting was convened in July 1995 by the CEPT (see the article starting on *page 28*). The aim of this Meeting was to produce a Special Arrangement for the introduction of terrestrial transmissions of the Eureka 147 DAB system in the frequency bands 46 – 68 MHz, 174 – 240 MHz and 1452 – 1467.5 MHz, as well as to prepare an associated Frequency Block Allotment Plan, taking into account the final requirements of the CEPT member countries. A full report on this CEPT meeting will appear in a future issue of **EBU Technical Review**.

Briefly, the Allotment Plan drawn up at the Meeting provides practically all the member countries of the CEPT with two sets of frequency blocks, each of width 1.536 MHz. This is a vital prerequisite to the wide-scale launch of terrestrial DAB services in Europe. Most of the CEPT countries opted for frequency block allotments in VHF Band III and in L-Band.

Table 2 gives a list of the 85 frequency blocks which, potentially, can be used for current and future DAB services in Europe. The distribution of these frequency blocks is as follows:

– 12 blocks in VHF Band I (47 – 68 MHz);

– 38 blocks in VHF Band III (174 MHz – 240 MHz);

– 23 blocks in L-Band (1452 – 1492 MHz);

– 12 blocks in VHF Band II (87 – 108 MHz).

DAB block numbers 1 to 59 correspond with the CEPT proposal put to the Meeting; blocks 60 to 85 have been added to the Plan by the EBU.

Each frequency block carries a two- or three-character label, which is easier to remember than the centre frequency of the block, and which is convenient for receiver manufacturers and consumers to use when initially programming their receivers.

The labelling system of the frequency blocks in VHF Band I and Band III is fully compatible with the existing VHF television channel numbers (i.e. Channels 2 to 13). Each of these television channels can accommodate four DAB blocks; six blocks in the case of Channel 13.

All the frequencies listed in the table comply with the 16 kHz raster as specified in the ETS 300 401 Standard.

One of the important results of the Meeting was a definition of the centre frequency of each ensemble (i.e. frequency block). This information is very important for receiver manufacturers and may help substantially to simplify the receiver design; before the Meeting, any frequency in the 16 kHz raster could be used as the centre frequency, resulting in a very large number of possibilities. The number of defined centre frequencies has now been reduced to match the total number of ensembles allocated in Band III and in L-Band (i.e. 61). These centre frequencies are likely to be implemented in the first-generation DAB receivers manufactured for the European market.

Frequency band	DAB block number	Frequency block label	Centre frequency (MHz)	Lower limit (MHz)	Upper limit (MHz)
VHF Band I	01	2A	47.936	47.168	48.704
	02	2B	49.648	48.880	50.416
	03	2C	51.360	50.592	52.128
	04	2D	53.072	52.304	53.840
	05	3A	54.928	54.160	55.696
	06	3B	56.640	55.872	57.408
	07	3C	58.352	57.584	59.120
	08	3D	60.064	59.296	60.832
	09	4A	61.936	61.168	62.704
	10	4B	63.648	62.880	64.416
	11	4C	65.360	64.592	66.128
	12	4D	67.072	66.304	67.840
VHF Band III	13	5A	174.428	174.160	174.696
	14	5B	176.640	175.872	177.408
	15	5C	178.352	177.584	179.120
	16	5D	180.064	179.296	180.832
	17	6A	181.936	181.168	182.704
	18	6B	183.648	182.880	184.416
	19	6C	185.360	184.592	186.128
	20	6D	187.072	186.304	187.840
	21	7A	188.928	188.160	189.696
	22	7B	190.640	189.872	191.408
	23	7C	192.352	191.584	193.120
	24	7D	194.064	193.296	194.832
	25	8A	195.936	195.168	196.704
	26	8B	197.648	196.880	198.416
	27	8C	199.360	198.592	200.128
	28	8D	201.072	200.304	201.840
	29	9A	202.928	202.160	203.696
	30	9B	204.640	203.872	205.408
	31	9C	206.352	205.584	207.120
	32	9D	208.064	207.296	208.832
	33	10A	209.936	209.168	210.704
	34	10B	211.648	210.880	212.416
	35	10C	213.360	212.592	214.128
	36	10D	215.072	214.304	215.840
	37	11A	216.928	216.160	217.696
	38	11B	218.640	217.872	219.408
	39	11C	220.352	219.584	221.120
	40	11D	222.064	221.296	222.832
	41	12A	223.936	223.168	224.704
	42	12B	225.648	224.880	226.416
	43	12C	227.360	226.592	228.128
	44	12D	229.072	228.304	229.840
	45	13A	230.784	230.016	231.552
	46	13B	232.496	231.728	233.264
	47	13C	234.208	233.440	234.976
	48	13D	235.776	235.008	236.544
	49	13E	237.488	236.720	238.256
	50	13F	239.200	238.432	239.968

Table 2a
DAB frequency blocks: 01 – 50.

Frequency band	DAB block number	Frequency block label	Centre frequency (MHz)	Lower limit (MHz)	Upper limit (MHz)
L-Band	51	L1	1452.960	1452.192	1453.728
	52	L2	1454.672	1453.904	1455.440
	53	L3	1456.384	1455.616	1457.152
	54	L4	1458.096	1457.328	1458.864
	55	L5	1459.808	1459.040	1460.576
	56	L6	1461.520	1460.752	1462.288
	57	L7	1463.232	1462.464	1464.000
	58	L8	1464.944	1464.176	1465.712
	59	L9	1466.656	1465.888	1467.424
	60	L10	1468.368	1467.600	1469.136
	61	L11	1470.080	1469.312	1470.848
	62	L12	1471.792	1471.024	1472.560
	63	L13	1473.504	1472.736	1474.272
	64	L14	1475.216	1474.448	1475.984
	65	L15	1476.928	1476.160	1477.696
	66	L16	1478.640	1477.872	1479.408
	67	L17	1480.352	1479.584	1481.120
	68	L18	1482.064	1481.296	1482.832
	69	L19	1483.776	1483.008	1484.544
	70	L20	1485.488	1484.720	1486.256
	71	L21	1487.200	1486.432	1487.968
	72	L22	1488.912	1488.144	1489.680
	73	L23	1490.624	1489.856	1491.392
VHF Band II	74	F1	87.936	87.168	88.704
	75	F2	89.648	88.880	90.416
	76	F3	91.360	90.592	92.128
	77	F4	93.072	92.304	93.840
	78	F5	94.928	94.160	95.696
	79	F6	96.640	95.872	97.408
	80	F7	98.352	97.584	99.120
	81	F8	100.064	99.296	100.832
	82	F9	101.936	101.168	102.704
	83	F10	103.648	102.880	104.416
	84	F11	105.360	104.592	106.128
	85	F12	107.072	106.304	107.840

Table 2b
DAB frequency blocks: 51 – 85.

12. European strategies for the introduction of DAB services

Currently, many pilot service trials and field tests at VHF and in L-Band are being conducted all over Europe. In many countries there are plans to commence pre-operational terrestrial services this year or in 1996/7, primarily making use of the existing transmitter and distribution infrastructure[10]. Although the situation varies very much from country to country, it is clear that the critical mass has already been achieved and that the introduction of the Eureka 147 DAB system in Europe is assured.

The following is a short summary of national plans for the introduction of DAB services, as well as progress on DAB experimental and promotional activities throughout Europe. It is recognized that this summary may not be completely up-to-date, such is the pace of DAB implementation.

12.1. Belgium

In Belgium, audiovisual and broadcasting matters (including those which relate to DAB) are considered at the level of the different cultural communities (Flemish, French and German). Therefore a

10. The world's first official DAB services were inaugurated in the UK by BBC Radio, and in Sweden by the Swedish Broadcasting Corporation, on 27 September 1995.

national DAB forum cannot be established at the federal level.

Nevertheless, an informal coordination group has been set up at the federal level to address the issues which relate to DAB and other radio matters. This group includes all the interested parties throughout the country (broadcasters, network providers, manufacturers, cable operators, administrators, etc.). Some key players such as the Flemish-language public broadcaster, BRTN, and the French-language public broadcaster, RTBF, have become direct members of the EuroDab Forum.

The BRTN is planning to start pre-operational DAB services at the end of 1997.

12.2. Denmark

Denmark is in the process of setting up a national DAB platform.

The National Telecom Agency has already decided to allocate one or two VHF frequency blocks (225 to 230 MHz) for national SFNs, and two or three blocks (235 to 240 MHz) for regional networks. The L-Band between 1452 and 1467.5 MHz has been allocated for local services and the number of frequency blocks here has yet to be decided. In the Faeroe Islands, the frequency ranges 223 – 230 MHz and 235 – 240 MHz will be used.

In September 1994, a DAB transmitter of 500 W e.r.p. began tests at 237 MHz in Copenhagen. In September 1995, the test frequency was changed to 227.360 MHz, following the CEPT Planning Meeting (see *Section 11.*). However, the transmissions on this new frequency have caused problems to the local Channel 12 cable television services and so the tests have now reverted to 237 MHz.

Further experiments are planned in Western Jutland during 1996, to test an SFN network consisting of four 1 kW e.r.p. transmitters.

Danish Radio is planning to distribute some 500 receivers for a controlled evaluation of DAB, as soon as the financial details have been agreed.

12.3. Finland

The Finnish national DAB platform has been working for some months.

The YLE started experimental transmissions in February 1994 on 105 MHz in Helsinki. Two transmitters of 2.5 and 0.8 kW e.r.p. are used. Problems in urban areas have been encountered with horizontal polarization, due to high levels of man-made noise. Further tests in Band III are foreseen. The Finnish manufacturing industry is developing a combined terrestrial/satellite DAB receiver, in cooperation with the European Space Agency (ESA).

12.4. France

The French DAB Club was established in autumn 1991. It comprises the French regulator (CSA), public and private broadcasters, professional and consumer manufacturers, and others. The activities of the DAB Club are diverse and include the promotion of DAB, communication with other DAB groupings, coordination of trials and experiments, etc. The French DAB Club has conducted experiments in Paris, both in VHF Band I and in L-Band, and has chosen in favour of L-Band.

Radio France has established a Working Party on radio programming issues, to study which specific programmes would be particularly suitable for DAB broadcasts. Radio France has also signed an agreement with TDF to provide DAB coverage of all major metropolitan areas and motorways (i.e. 25 % of the population) as soon as consumer receivers are available.

TDF is fostering close partnerships with both current and potential customers in order to define innovative multimedia applications of the DAB system. TDF has created a new “Infodiffusion” department, which is responsible for on-line and multimedia applications, and which aims to support the development of new services delivered over the air. In order to move into the consumer segment, TDF will team up with leading service providers to launch pilot services. These will be designed to assess and define the demand in key target markets such as interactive television (in conjunction with Television France and Matra-Hatchette), new radio-related services (with Radio France), electronic newspaper publishing (with *Le Monde* and *Le Républicain Lorrain*) and services for mobile users in conjunction with the French transport ministry and the City of Paris.

12.5. Germany

The German national DAB platform was formed in 1991 and consists of public and private broadcasters, manufacturers, R&D institutions, PTT/Telecom operators and others. Recently, it established a Memorandum of Understanding which concerns two principal points:

a) the implementation of pilot projects in several Länder and the carrying out of experiments;

b) the introduction of regular DAB services in time for the Berlin IFA[11] fair in 1997 and the achievement of near-complete coverage of Germany by the year 2000.

Among the pilot projects currently undertaken or in preparation are those in Baden-Württemberg, Bavaria, Berlin, Hessen, Lower Saxony, Mecklenburg-Western Pomeriana, North-Rhein Westphalia, Rheinland-Palatine, Saxony, Saxony-Anhalt, Thuringia and the border of Germany with Switzerland in the Lörrach and Basel area.

In total, some 20 000 to 25 000 receivers, produced mainly by German receiver manufacturers, will be used to test technical and programming features of the DAB system. The funding is provided in part by the States Governments. The main organizations involved in organizing these tests are: the IRT, DBP-Telekom, media authorities, regional broadcasters and some manufacturers. Both Band III (Channel 12) and L-Band are being considered.

The German platform is cooperating with neighbouring countries and has invited them to test DAB equipment and gain experience.

12.6. Hungary

The Hungarian DAB Group started in 1992 and includes all important entities in the field of DAB.

In autumn 1995, a DAB experiment using one transmitter will be installed in Budapest, carrying five different programmes and data. Regular DAB services will most probably start in 1997. However, the availability of DAB receivers in sufficient volumes, and at affordable prices, is a key issue.

12.7. Italy

In Italy, several experimental activities are ongoing. RAI is completing the development of a DAB test-bed in the Aosta Valley, which currently consists of three transmitters operating as an SFN in VHF Channel 12. An extension to four transmitters is foreseen. The band 223 – 230 MHz has been identified for DAB services but has not yet been fully approved. There is some chance that L-Band could also be used.

12.8. The Netherlands

The Dutch national DAB platform has already been established.

A frequency range 216 – 230 MHz has been identified, but not yet selected, to accommodate one frequency block for national services and four blocks for regional DAB services. L-Band may be used for local services.

Tests with an SFN are being carried out by NOZEMA in Haarlem, Hilversum and Rotterdam. In total, four transmitters operating in VHF Band III (Channel 12) provide 40 % coverage of the Dutch population. In order to increase the spectrum efficiency of DAB services (e.g. 16 stereo programmes per frequency block), extremely low coding rates (64 kbit/s and less per stereophonic programme) are of great interest. The Dutch experiments, which involve seven companies, include the datacasting of an electronic newspaper, company information, railway and travel information, etc. Recently, DAB was the subject of governmental auditing.

12.9. Norway

The Norwegian DAB Group has been in existence since 1990.

The first DAB transmitter was installed by Telenor and NRK in Oslo during April 1994. There are two transmitters at present, operating as an SFN, and a third transmitter will be added soon. A fourth transmitter will be installed in Trondheim, which lies in a very mountainous region. The tests include coverage evaluations in mountainous areas and the evaluation of programme-feed techniques.

12.10. Poland

There are plans to establish a national DAB grouping in Poland. In Warsaw, an experimental DAB service may commence at the end of 1995.

12.11. Sweden

As a result of the collaborative efforts of Teracom and Swedish Radio, the first DAB experiments started in March 1992, covering the Stockholm area. An SFN experiment in Uppsala/Enköping, comprising three stations, started in March 1994 and it now has four DAB transmitters in operation.

An official DAB service was introduced in the Stockholm area on 27 September 1995. This will be followed by the opening of three SFNs in Stockholm, Gothenburg and Malmö as soon as possible. One additional SFN may be introduced in a rural region, thus extending DAB coverage to 35 % of the population in 1996. Limited governmental support might be provided. In addition to the Swedish radio channels, which include a new

11. Internationale Funkausstellung.

classical music programme, there will be a programme in Finnish and a channel for Lapps. New data services will be tested also.

12.12. Switzerland

The Swiss national DAB platform has existed for nearly two years. For future DAB services, four frequency blocks will be allocated in VHF Channel 12 and a further nine blocks will be made available in L-Band (1452 – 1467 MHz).

Swiss Télécom PTT is currently operating two SFNs, one in VHF Channel 12 and the other in L-Band. The Channel 12 tests in the Reuss Valley started in June 1993 and initially comprised two transmitters. In the same region, a trial in L-Band started in May 1994.

Tests in the Bernese Oberland area started in April this year, using three transmitters in Channel 12. This trial is planned to become a pilot project in October 1995 which will continue for a period of two years. The official introduction of DAB services in Switzerland is planned for 1997.

12.13. United Kingdom

The UK national DAB Forum has been established since 1992.

Last year, the UK government allocated 12.5 MHz of radio spectrum in VHF Band III. This provides space for seven DAB frequency blocks. Each of those can carry an ensemble of six high-quality stereo channels plus some data, or different combinations of audio and data services depending on the bit rates used. Of the seven frequency blocks, one has been allocated to the BBC for a national network. A second will be used for national commercial radio services, yet to be decided by the UK regulatory body (the Radio Authority). The other five blocks will be used for local and regional BBC and independent radio services.

The BBC launched its official DAB service on 27 September 1995. Initially, an SFN of five transmitters serves a large area of south-east England (about 20 % of the UK population). Within two-and-a-half years, 27 transmitters will cover about 60 % of the UK population and will include the main motorway and trunk road network.

The BBC is "simulcasting" (i.e. simultaneously broadcasting) its five current national channels on DAB and will also introduce a number of new services. It plans to use the multiplex dynamically, varying the bit rate according to the programme content and the number of services available at any given time. The normal data rate is expected to be between 96 and 128 kbit/s per monophonic channel, reducing to a minimum of 64 kbit/s for some spoken material.

A new monophonic announcement channel is being considered, to be transmitted at 64 kbit/s. It will provide short spoken messages, each of around two to three minutes duration, which will be transmitted cyclically every ten minutes or so. These will be supported by the Announcements feature, within a BBC cluster, whenever new messages are introduced. Messages which are not new, but which remain relevant, will be assigned programme type (PTY) codes so that specific types of message may be requested on demand.

In August 1995, the UK Government issued a White Paper entitled *Digital Terrestrial Broadcasting*. This document outlines proposals for a new legislative framework for allocating the use of the spectrum and for licensing and regulating the transmission of both television and sound radio broadcast services. Comments or views on these proposals are awaited for early October 1995. In particular, the role of the multiplex provider is defined; this is considered very important for the development of the audio-visual broadcast market.

13. International strategies for the introduction of digital radio

Outside Europe, extensive field trials and computer simulations have also been conducted on DAB, primarily in Canada but also in Australia and the USA.

13.1. Australia

To further the awareness of the Australian broadcast industry concerning digital radio matters, the Australian administration has implemented an ongoing series of demonstrations and investigations in L-Band. These are based on the Eureka 147 DAB system. During 1994, terrestrial demonstrations of DAB were held in Canberra and Sydney and, in June 1995, the first L-Band satellite trial involving the Eureka 147 system was undertaken using the Australian Optus B3 satellite. The results of these tests have been presented to the September 1995 meeting of ITU-R Working Party 10-11S.

More recently, the Australian administration announced a major initiative to fund DAB transmitter facilities in three capital cities. This will allow the local broadcast industries to investigate operational and practical implementation issues associated with digital radio. In conjunction with a similar initiative by the national telecommunications carrier (TELSTRA), it is likely that experimental DAB facilities will be provided in Sydney and Melbourne by the end of 1996.

13.2. Canada

The first public demonstrations in Canada using the Eureka DAB 147 system were conducted in 1990. Digital Radio Research Inc. (DRRI) was then set up in 1993 to coordinate Canadian tests on digital radio systems. In 1994, Canada hosted the Second International DAB symposium in Toronto.

There are four sites where DAB experiments are currently being conducted in L-Band – Toronto/ Barrie, Trois Rivières, Montreal and Toronto – which cover more than 25 % of the Canadian population. A datacasting demonstration has been given over this network, featuring a route-guidance system developed by the Ministry of Transport of Ontario. New transmitters covering Ottawa and Vancouver were due to open by summer 1995, thus extending DAB coverage to 35 % of the Canadian population. Commercial operation will begin in 1996.

Canada is currently in the process of officially adopting the Eureka 147 DAB system.

13.3. China

In cooperation with the European Commission and the German national DAB platform, the Eureka 147 DAB system will be used in terrestrial experiments in China, starting in December 1995.

13.4. India

Terrestrial DAB transmissions in India will be in VHF Band II and the satellite emissions will be in L-Band. Attempts to bring together all the major parties involved in DAB are being pursued by All India Radio and membership of the EuroDab Forum is being sought.

DAB services in India will be implemented in three phases. In the first phase, due to commence in 1998, a limited terrestrial DAB service – based on current regional radio programmes – will be initiated in four metropolitan cities: Delhi, Bombay, Calcutta and Madras. The regional programmes will be collected at New Delhi, via satellite contribution links, and subsequently distributed from New Delhi via an S-band transponder of the INSAT satellite. The received DAB signals will be converted to VHF Band II frequencies and then simulcast using the existing FM transmitting antennas and towers. In the second phase, independent local services – carrying a mix of local, regional, national and sponsored programmes – will be added gradually to a number of FM stations by the year 2003. Finally, DAB services via satellite could commence after 2003.

So far, a number of preliminary propagation studies have been carried out in L-Band. Experiments using the Eureka 147 system will start shortly, covering both terrestrial and satellite delivery.

13.5. Mexico

A highly successful terrestrial test and demonstration of the Eureka 147 DAB system was conducted at L-Band in Mexico City during 1993. Then, in July 1995, an L-Band satellite trial was conducted using the Solidaridad 2 satellite. In the latter case, only low satellite power was available (about 43.5 dBW). Although this gave insufficient propagation margin for mobile reception at speeds of greater than 60 km/h, both fixed and mobile reception were demonstrated with an antenna of gain 7 dBi. Fixed reception with a 15-dBi antenna enabled the characteristics of the satellite channel to be defined – while successfully operating it in all the transmission modes of the Eureka 147 system. At high elevation angles, Doppler effects were less of a problem than for terrestrial transmissions, and thus Mode-II operation via the satellite was shown to be more than adequate.

13.6. The USA

A number of mobile tests and demonstrations of digital radio were given in the USA in 1991. Since 1992, the Eureka 147 system has undergone formal evaluation in a public test programme, along with several “in-band” digital proposals. The recently-published results of these tests are discussed in the next *Section*.

14. EIA tests in the USA

Independent laboratory tests on the Eureka 147 system have been conducted in the USA by the Electronics Industry Association (EIA), in association with the National Radio System Committee (NRSC). The results of these tests were presented during August 1995 in Monterey, California [19].

14.1. In-band proposals

In addition to the Eureka 147 system, the EIA tests have included five proponents of the so-called "in-band" concept, whereby the digital radio signals are transmitted in the same band as the current analogue services; the digital signals are effectively overlaid on the existing analogue signals. Two variants of the concept have been proposed: *in-band on-channel* (IBOC) and *in-band adjacent-channel* (IBAC).

The in-band proposals outlined in the EIA tests are generally of a very complex design and use advanced digital technology which is used in modern military applications for the professional market. Therefore it is likely that "in-band" receivers will be quite expensive. From the spectrum management viewpoint, the in-band digital systems currently being proposed in the USA are designed to overlay analogue signals where the channel spacing is 200 kHz. These systems are not directly applicable to Europe where the channel spacing in VHF Band II is only 100 kHz.

The following in-band systems were tested in the laboratory by the EIA (one AM-overlaid system and four FM-overlaid systems):

- USADR-AM (0.54 – 1.7 MHz) IBOC
- AT&T (FM band) IBAC
- AT&T Amati (FM band) IBOC
- USADR FM1 (FM band) IBOC
- USADR FM2 (FM band) IBOC

The main characteristics of the four FM-overlaid digital proposals are given in *Table 3*.

14.2. EIA test results

The EIA tests were divided into three categories as follows:

a) subjective quality tests on the source coding system, operating in a clear channel (i.e. with no transmission errors);

b) objective digital tests on the overall system performance;

	AT&T Amati	AT&T	USADR FM 1	USADR FM 2
On-channel (IBOC) or adjacent-channel (IBAC)	IBOC	IBAC reserved channel	IBOC	IBOC
Audio system	Joint stereo PAC	Joint stereo PAC	MUSICAM	MUSICAM
Bit rate range (kbit/s)	128 – 160	128 – 160	128 – 256	128 – 256
Error concealment	Yes	Yes	Yes	Yes
Unequal error protection		Yes	Yes	
FEC	Reed-Solomon	Reed-Solomon	Hierarchical	Hierarchical
Time interleaving depth (ms)		640	480	480
Adaptive equalization		Yes	Yes	Yes
Modulation	Discrete multitone, mixture of differential 4- and 8-PSK	4-PSK	Multi carrier	Direct sequence spread spectrum, 8-level 64 pseudo-noise sequences
Demodulation	Differential (coherent under study)	Differential		
Symbol duration (μs)	250	3	125	500
Guard interval (μs)	14.5	None		
Number of carriers	32 (18 in single side-lobe mode)	1	48 (8 kbit/s)	1
RF bandwidth of the digital component (kHz)	140	200 or 100	460 with 220 kHz void	125
A/D orthogonality	Spread spectrum, 25 dB below FM carrier	Spread spectrum	Spread spectrum	Frequency slide technique
Reference signal, pilot	One pilot in each side lobe	For carrier recovery	49th carrier	None
Total capacity (kbit/s)	256	360	384	384
System options	One double side lobe or two single side lobes	100 or 200 kHz bandwidth block		

Table 3
Main characteristics (where known) of the four FM-overlaid digital proposals submitted to the EIA.

Test	Threshold of audibility (TOA) (dB)	Point of failure (POF) (dB)
Test B1 – Gaussian noise (C_o/N_o)	8.6	6.2
Test B2 – CCI (desired/undesired)	8.3	5.8
Test B3 – Multipath (C_o/N_o) *(note 1)*		
Doppler 2 km/h, Delay spread 3 µs (Urban, Slow)	21.8	15.1
Doppler 60 km/h, Delay spread 3 µs (Urban, Fast)	17.8	12.8
Doppler 150 km/h, Delay spread 3 µs (Rural, Fast)	short or small impairments *(note 2)*	
Doppler 60 km/h, Delay spread 16 µs (Terrain obstructed)	19.2	13.5
Test C2 – CW interference (desired/undesired)	-8.2	-7.8
Test C3 – Flutter (simulated aeroplane)	5.2 at 400 km/h, 0.0 at 200 km/h 0.0 at 100 km/h	not applicable
Test C4 – Weak signal sensitivity (dBm)	-97.5	-101.5
Test C5 – Delay spread/Doppler		
Bad urban I	unimpared up to 225 km/h	
Bad urban II	unimpared up to 225 km/h	
Typical urban	POF level of impairment at 225 km/h	
Hilly terrain	POF level of impairment at 225 km/h	
Rural Area	POF level of impairment at 225 km/h	
Test C6 – Additional multipath (C_o/N_o)		
Doppler 2 km/h, Delay spread 3 µs (Urban, Slow)	7.3	2.3
Doppler 60 km/h, Delay spread 3 µs (Urban, Fast)	5.3	2.8
Doppler 150 km/h, Delay spread 3 µs (Rural, Fast)	9.8	6.3
Doppler 60 km/h, Delay spread 16 µs (Terrain obstructed)	7.3	3.3
Test D1 – CCI (desired/undesired)	9.2	7.2
Test D2 – 1st ACI (desired/undesired)	-33.0	-34.0
Test D3 – 2nd ACI (desired/undesired)	not measurable	not measurable
Test E1 – CCI + multipath		
Doppler 2 km/h, Delay spread 3 µs (Urban, Slow)	22.9	17.4
Doppler 60 km/h, Delay spread 3 µs (Urban, Fast)	21.4	15.4
Doppler 150 km/h, Delay spread 3 µs (Rural, Fast)	no CCI added	
Doppler 60 km/h, Delay spread 16 µs (Terrain obstructed)	21.1	16.1
Test E2 – 1st ACI + multipath		
Doppler 2 km/h, Delay spread 3 µs (Urban, Slow)	-22.3	-25.9
Doppler 60 km/h, Delay spread 3 µs (Urban, Fast)	-25.9	-27.9
Doppler 150 km/h, Delay spread 3 µs (Rural, Fast)	35.9	35.9
Doppler 60 km/h, Delay spread 16 µs (Terrain obstructed)	-24.9	-26.9
Test E3 – 2nd ACI + multipath		
Doppler 2 km/h, Delay spread 3 µs (Urban, Slow)	not measurable	not measurable
Doppler 60 km/h, Delay spread 3 µs (Urban, Fast)	not measurable	not measurable
Doppler 150 km/h, Delay spread 3 µs (Rural, Fast)	not measurable	not measurable
Doppler 60 km/h, Delay spread 16 µs (Terrain obstructed)	not measurable	not measurable
Test J1 – Requisition (s)	not applicable	1.0
Test J2 – Requisition + multipath (s)	not applicable	1.0

Table 4
Summary results of the EIA laboratory tests on the Eureka 147 DAB system.

Note 1: There is some debate ongoing in the EIA about the validity of this model, due to the use of a smooth spread spectrum with Doppler amplitude profiles, which is more stringent than real life.

Note 2: In a repeat of the simulated rural, fast multipath condition by the CCETT (France), the TOA corresponded to a little over 130 km/h and the POF corresponded to about 140 km/h. Experiments in Canada indicate that the real life minimum POF will occur at about 160 km/h.

c) objective and subjective compatibility tests carried out to determine the interaction between the digital audio broadcasting system and the analogue transmission system within the FM band.

The quality assessment results show that the Eureka 147 system – using ISO MPEG Layer-II Musicam at 224 kbit/s – had the highest overall rank and the most consistent ratings across the whole range of audio material which was used for the tests. Eureka 147 was the only system that never fell below the "perceptible but not annoying" range. Out of nine critical audio passages that were evaluated, four were judged to be transparent.

The published test results show that, in general, the in-band digital systems may cause intolerably high interference to, and suffer interference from, the analogue services that are overlaid – particularly in a multipath environment. Therefore, those broadcasters who wish to preserve the high broadcasting standards of their existing FM services should not opt for an in-band digital solution, given the present stage of its development.

The published test results on the Eureka 147 DAB system are more favourable. They confirm the conclusions of extensive laboratory and field tests conducted in Europe, Canada, Australia and elsewhere – that the Eureka system eliminates problems such as FM multipath and signal failure (dropout). It also enables digital radio to coexist with AM and FM services with no interference.

The results of the EIA laboratory tests on the Eureka 147 DAB system are summarized in *Table 4*.

15. *Is Eureka 147 suitable for international broadcasting?*

In order to cover large zones of the world, international broadcasters currently use:

a) high-power terrestrial transmitters to radiate AM-modulated signals at LF, MF and HF;

b) sound sub-carriers on 11/12 GHz FSS satellites (with optional local redistribution by terrestrial FM transmitters).

In January 1994, several international broadcasters established a consortium, now called "Digital Radio World-wide", whose main objective is to improve the technical quality and the availability of their radio services in the future. These broadcasters are looking into the possibility of delivering their programmes via satellite or by hybrid means (i.e. satellite and complementary terrestrial methods), using the WARC-92 frequencies. Another technical possibility would be to use a new narrow-band (nominally 9 kHz) digital system to operate at "AM" frequencies (i.e. below 30 MHz), re-using the existing terrestrial transmitter infrastructure.

Ideally, the chosen satellite system (designed to cover large areas) will have the same modulation/coding system parameters as the ground-based system (designed to cover regional/national territories), such that the same receiver could be used. An essential requirement for any new satellite system is that it should be able to provide for mobile and portable reception in all types of propagation environments (rural, urban, etc.).

The main concern of international broadcasters is whether or not the Eureka 147 DAB system is appropriate for the satellite delivery of their programmes.

Although the Eureka 147 DAB system has been developed as a terrestrial system, there is no technical reason why it could not be used for satellite delivery as well. Many computer simulations have shown that this assumption may be true, but real experiments are needed to demonstrate that satellite delivery is both a technically viable and an economically attractive proposal.

Two such experiments have been conducted recently – one in Australia, the other in Mexico. The Australian test was carried out using the Optus B3 satellite at 1552 MHz. The trial in Mexico, carried out by the BBC, used the Solidaridad satellite. Both satellites were originally launched to provide mobile phone services; they were not specifically designed for multicarrier systems such as Eureka 147. Even so, the results showed that fixed and portable reception of DAB signals via a satellite is technically feasible. Due to the low transmitting power of the test satellites, mobile reception was possible only under line-of-sight conditions.

A satellite simulation – using a helicopter – is being carried out jointly by the ESA, the IRT and the BBC in Munich, to determine the service-availability performance (i.e. percentage of coverage) for different elevation angles.

One of the outstanding issues to be clarified is whether or not it is possible to up-link from different feeder-link stations, programmes that constitute the same multiplex. Studies are being undertaken within the Eureka 147 Project to determine how on-air multiplexing at RF could be performed at the input to the satellite, in a similar manner to the well-established TDMA[12] technology used with FSS satellites. Preliminary results indicate that feeding the satellite from different uplink stations may not be a major technical problem. However, it will be necessary to coordinate between the different feeder-link stations – in terms of time synchronization (approximately only) and power control – but such coordination is quite normal in any TDMA and FDM system.

Because the Eureka 147 DAB system is a multicarrier system, some output back-off at the satellite will be necessary to reduce the amount of intermodulation. Similar back-off will be necessary with the alternative FDM systems (such as the WorldSpace system), since multichannel operation already generates multicarriers. Thus, it is fair to assume that there will be no significant difference between the DAB and the FDM systems, in terms of the output back-off required at the satellite. In the Australian DAB experiment, the transponder operated satisfactorily with an output back-off of 2.2 dB.

Digital System B is a valid candidate to become a second digital radio system recommended by the ITU-R (see *Section 8.2.1.*). Technically, Digital System B seems to be very similar to the WorldSpace system, i.e. it uses a single carrier, modulated by a relatively high bit-rate signal which carries one or more audio programmes and data. Such systems cannot generally overcome multipath problems unless very sophisticated and expensive equalization processing is used at the receiver. So far, only line-of-sight reception has been demonstrated satisfactorily with this type of system.

International broadcasters are usually interested in large coverage areas. Therefore a geostationary (GEO) satellite system could be satisfactory to cover low-latitude areas, such as most parts of Africa, Central and South America, India, Indonesia, etc. However, many regions of the world that wish to be covered are situated in the northern hemisphere (above 30 – 40 degrees latitude), including Europe, China and Japan. For such areas, the HEO[13] satellite concept – promoted currently by the Archimedes project of the European Space Agency – seems to be of interest, as it would enable greater penetration to mobile receivers in urban areas (due to the high elevation angle of the satellite, and hence less shadowing of the signals). In practice, a combination of the HEO and GEO concepts may be an attractive solution. The Eureka 147 DAB system addresses both GEO and HEO satellite solutions.

12. Time division multiple access.

13. highly-inclined elliptical orbit.

It should be pointed out that there are several technical matters associated with the HEO satellite concept which must be considered carefully, such as hand-over from one satellite to the next (with the resultant potential for signal drop-out), zooming of the beam, polarization rotation and crossing the van Allen belt. There may be difficulties also on the regulatory side (sharing of the band, notification procedures, etc.). It is understood that the ESA has been addressing the above points to find satisfactory solutions.

For international broadcasting, all WARC-92 bands (i.e. bands located at 1.5, 2.3 and 2.6 GHz) should be considered. Preference should clearly be given to the 1.5 GHz band for technical and economic reasons (the best trade-off between the size of satellite transmit antenna and its transmit power). Preliminary studies have shown that, at 2.6 GHz, considerably larger transponder output power would be required (of the order of four times greater than that required at 1.5 GHz). DAB Transmission Modes II, III or IV are suitable for use at these frequencies.

16. Which distribution system for cable?

The Eureka 147 system can also be used for the distribution of radio and data services in cable networks and SMATV installations. It may be particularly useful in cases where the quality of the cable network is poor, due to standing-wave reflections (i.e. signal echoes on the network). A standard DAB receiver could be used; apart from frequency conversion, no transcoding or remodulation would be necessary in this application.

However, when the primary objective is spectrum efficiency, the service provider will probably wish to use the DVB cable system [2] which is based on 64-QAM. In an 8-MHz cable channel, DAB can accommodate 24 stereophonic channels with a data rate of 256 kbit/s, each using the lowest protection level (i.e. 3/4). A 64-QAM system, on the other hand, would allow for some 150 channels of the same audio quality.

17. Broadcasters' expectations

The BBC has produced a document [20] which contains its expectations of first-generation consumer DAB receivers. The document is intended to assist receiver manufacturers in the production of attractive consumer sets which will respond adequately to the BBC's DAB signals and which will satisfy the UK public following the launch of the first BBC DAB services in September 1995. The document is broadly in line with an earlier EBU document [21] which published the more general requirements of first-generation DAB receivers.

The first consumer receivers are expected to be for use in vehicles and in home hi-fi units. Portable, personal and other types of receiver are expected to appear on the market somewhat later. If DAB is to achieve rapid acceptance and success, the development of all receiver types must be promoted in the early years of DAB service.

The BBC plans to include Service Information (SI) from the start, as well as the Multiplex Configuration Information (MCI). A list of the SI features which were expected to be broadcast at the start of the BBC DAB service, and in later years, is given in *Table 5*.

18. DAB as a multimedia carrier

Within the Eureka 147 Project, further developments are underway to study the use of the Eureka 147 System as a multimedia and data broadcasting system. This study is aimed at expanding the future use of the Eureka 147 DAB system beyond the provision of excellent sound reception in adverse mobile and portable environments. In addition to the conventional audio services, the system is opening up many new opportunities to carry a number of non-audio services, such as text, still pictures, moving images, etc.

The multiplex of the Eureka 147 system has been designed to carry a large number of digital services with a total bit rate of up to 1.7 Mbit/s, organized in up to 64 stream- or packet-mode subchannels. Four different data transport mechanisms have been defined in the DAB standard:

- Programme Associated Data (PAD)
- Fast Information Channel (FIC)
- Stream Mode (SM)
- Packet Mode (PM)

The choice of transport mechanism depends on the kind of data that it is necessary to transport. For example, the Programme Associated Data is suitable for services which bear a strong relationship to the audio signal. Since this data is taken from the audio frame, there is a trade-off between the intrinsic audio quality and the PAD data capacity.

The FIC Channel was originally intended to carry information on the organization of the DAB multiplex. Nevertheless, the FIC can carry a limited amount of additional information, such as paging and emergency warning messages. Dedicated (or special-purpose) receivers which only decode the FIC part of the multiplex may be significantly less complex than general-purpose DAB receivers.

In Stream Mode, a subchannel is assigned to a single data service, providing a fixed data rate (in multiples of 8 kbit/s) with specific error correction.

In Packet Mode, a number of services may share the same subchannel. Packet headers contain a service address which allows the receiver to restore the original data. The PM is a convenient way to carry asynchronous services (which use variable data rates).

Examples of DAB data services currently being implemented are given below. These services may be presented either in the form of textual information (shown, for example, on a simple receiver display of, typically, between 8 and 128 characters), still pictures or even video images.

– *Programme-associated services* such as current song title, interpreter and performer, lyrics, news headlines, CD covers, etc.;

– *News* including events, traffic messages, weather, sport, stock market, travel and tourist information;

– *Traffic navigation* by means of transmitted digitized roadmaps, combined with positional information provided via the GPS system.

– *Advertisements and sales* including sales catalogues, purchase offers, etc.;

– *Entertainment* including games and non-commercial bulletin boards;

– *Closed user group services* such as banking information, electronic newspapers, fax printouts and remote teaching.

DAB application	BBC timescale	BBC comments
Multiplex Configuration Information (MCI)	Sept 1995	Essential
Multiplex Reconfiguration	Sept 1995	Essential
Service text labels	Sept 1995	16- or 8-character formats
Ensemble text label	Sept 1995	16- or 8-character formats
Time and date	Sept 1995	Resolution in minutes
Dynamic range control	1996	BBC Radios 3 and 4 only
Programme label	1996	
Programme type: basic dynamic	Sept 1995	Source from RDS (international table of codes only)
Programme type: dynamic +	1996	Source from RDS (international table of codes) + preview
Programme type: dynamic ++	≥1997	Full coarse code range + agreed fine codes
Programme type: dynamic +++	≥1997	Extend to include programme types in other ensembles, when they have commenced
Programme type: dynamic ++++	≥1997	Re-definable codes added
Service following to FM/AM (alternative service sources)	1996	Regions to be defined and TII database to be established
Service following to other ensembles (alternative service sources)	≥1997	Required when further ensembles are available and services are linked; need to define regions and to establish TII database
Programme delivery control	Sept 1995	Source from RDS PIN
Programme language identification	Sept 1995	Statically set to “English”; may be set for dynamic operation later
Announcements within ensemble	1996	Use eight types only; there is a need to define clusters, regions and labels and to establish the TII database
Announcements from FM services	1996	Traffic only (sourced from RDS)
Announcements from other ensembles	≥1997	Required when the BBC has access to other ensembles
Public service warning	1996	Floods, bad weather, etc.
Local broadcasting	≥1997	Required when the BBC has access to other ensembles
Extended text labels	≥1997	Depends on developments in the recording industry and suitability for broadcasters’ requirements
Coded traffic messages	≥1997	Packet mode required?
National security warning	≥1997	Not for public access
In-house signalling	1996	BBC internal use
Programme service directory	≥1997	Gives the receiver information about all BBC services when there is more than one ensemble
Location finding	No plans	
Assistance to the hard of hearing	No plans	
Music / Speech	No plans	
Copyright	No plans	Unless required by international bodies
Conditional access	≥1997	
Data down-loading	No plans	
Paging service	No plans	
Satellite information	No plans	

Table 5
BBC timescale for the implementation of specific DAB applications.

The DAB Standard offers two modes for text transmission: Dynamic Label and Interractive Text Transmission (ITTS). The former mode is similar to the Radio Text feature of the Radio Data System (RDS) on the FM band. ITTS is a more sophisticated text transmission system. It allows for menu-driven operation and can also be used to transmit text at the rate a broadcaster prescribes. It can process several streams of textual information simultaneously to convey, for example, the same information in several languages or to transmit a programme schedule at the same time as giving details of the programme currently on-air.

Ideally, multimedia services should be fully interactive, in which case the consumer can communicate with the service provider's database. Since broadcasting services are one-way only, the return channel could be provided by GSM telephone (in the case of mobile DAB receivers) or via a telephone line (in the case of a fixed receiver). Nevertheless, a semi-interactive mode is also possible. In this instance, information is downloaded by the service provider to the user's data terminal and stored there as a database. All interactivity is then handled within the user's data terminal, but the database contents have to be updated regularly by the data service provider. The storage capacity of the user's terminal is a trade-off between the service transmission rate, the repetition rate and the cost of the memory.

A key factor for the success of DAB will be its ability to address each receiver individually. This will allow service providers to customize the "bouquet" of services provided to each user, and even to identify the user in an interactive transaction. This feature has some far-reaching implications, particularly for privately-funded radio.

Studies are continuing on the suitable presentation of DAB data services. Currently, data services specified in the ETSI Standard have a text-based presentation. In order to improve the man-machine interface, the Eureka 147 System will be enhanced to support a graphical user interface, such as Microsoft Windows. This will be of importance for screen-based services which seem to be more relevant for stationary and portable receivers. For mobile receivers, synthesized speech-based interfaces are a better alternative, as they would be less distracting to drivers.

For the user's data terminal, a unified transmission protocol will be very helpful, as no distinction between different transport mechanisms would be necessary. A software-based language for object-oriented page description is being developed to define a communication and a presentation layer. Such a unified protocol for the multimedia transport mechanism could be used not only with DAB services, but also in other communications systems.

Currently, within the Eureka 147 Project, a standard receiver data interface is being specified to transfer the data carried within an ensemble, from the receiver to any external devices such as a PC, tape recorder or conditional access decoder (see *Section 8.3.*).

A demonstration of both the audio and the multimedia usage of the Eureka 147 system was given during August 1995, at the IFA fair in Berlin.

19. Programming

The technology of DAB is a means of delivering audio programmes and data; it is not an objective in itself. Hence, the debate must eventually (if not soon) move away from the technical advantages of DAB to the programming issues which will actually drive this technology into the homes and cars of radio listeners.

People will buy receivers only if they can access interesting, entertaining and attractive programmes. Crisp digital sound is of course a good thing, but it is certainly not sufficient to persuade people to pay for it. Therefore, the content and the presentation of the audio, video, text and data information which is to be transmitted is of great importance. So far, insufficient new programming ideas have been put forward but it is hoped that the Eurodab Forum will help to generate some ideas on this matter.

20. Manufacturers

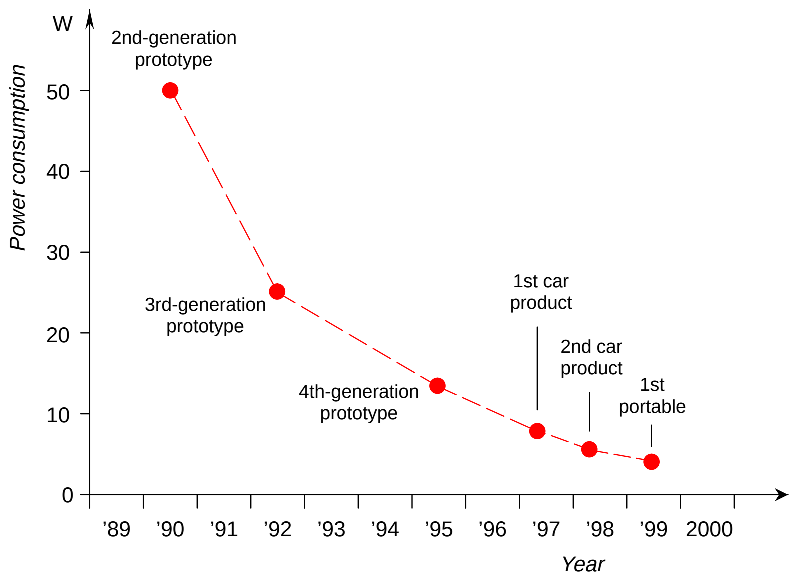
In order to receive DAB services, consumers will need to buy a new kind of receiver. The consumer DAB receivers will also contain FM and AM circuits which, initially, will be analogue. However, it will not be long before the AM and FM circuits in a DAB receiver become digital. These all-digital AM/FM/DAB receivers will be based on advanced computer technology, which will allow the downloading of large quantities of information to program the radio set and its associated equipment (digital cassette recorders, MiniDisc recorders, PCs, etc.).

At the recent IFA fair in Berlin, six manufacturers (Alpine, Bosch, Grundig, Kenwood, Philips and Sony) displayed their current DAB receivers. In fact, they look more like semi-professional equipment; the DAB part is in a separate box, mounted in the boot with a link to an FM/RDS receiver in the dashboard. These first-generation car receivers are not generally available yet; they can only be purchased on special order and in limited quantities for evaluation purposes. As shown in *Figure 2*, the first mass-produced DAB car radios are not expected until 1997; the first portable DAB receivers are projected for 1999.

The industry has been carrying out a lot of research and development on further applications of the DAB system, including:

- data-only receivers;
- picture radios and advanced teletext full bit-stream video decoders;
- navigation systems;
- differential GPS;
- traffic information systems;
- Traffic Message Control (TMC);
- real time packet-mode multiplexers / demultiplexers;
- fax;
- videotext;
- audio in conjunction with radiotext (dynamic labels);
- electronic newspaper publishing, including text and pictures in packet mode;
- high-capacity storage using MiniDisc.

Figure 2
Timescale for the availability of various DAB receivers together with their power consumption.



21. Conclusions

The Eureka 147 DAB system – now an ETSI European Standard and an ITU worldwide Standard – has all the ingredients to be converted from a brilliant technological achievement into a very successful product in the marketplace.

The Eureka system has great potential for many reasons: governments are facing the hard task of sharing out the finite radio spectrum between a mass of conflicting interests and they welcome DAB as a highly spectrum-efficient system; broadcasters see the opportunity to offer more services of better quality and presentation; manufacturers welcome the opportunity to sell large quantities of DAB receivers and associated equipment, and network operators are keen to build the new distribution and transmitter networks that are required for DAB terrestrial services. Not least, the listener welcomes a new technology which offers more choice and higher technical quality, as well as a very robust signal when listening in a vehicle or on a portable set.

A new frequency allotment plan at VHF and in L-Band has been agreed for Europe. It provides sufficient frequencies for the start of terrestrial DAB services and, at the same time, leaves the existing FM services in Band II untouched, in the short term.

Official DAB services started during September in both the UK and in Sweden and this should encourage manufacturers to bring their DAB receiver products to the marketplace as soon as possible.

The broadcasters, together with manufacturers and network providers, are continuing their cooperation to investigate how DAB can be used optimally for new applications which will be attractive for all listeners. The recently-formed EuroDab Forum will be instrumental in pursuing those objectives.

Prophecies of the death of sound radio have proved unfounded. The radio is more alive today than any other medium!

Acknowledgements

The author wishes to thank sincerely his many colleagues from the EBU, the Eureka 147 Consortium and the EuroDab Forum for their valuable contributions to the information given in this article. The Directors of the above organizations are also gratefully acknowledged for giving permission to publish this information here.

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