Digital Audio Broadcasting ®

Terrestrial Digital Audio Broadcasting in Europe

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In just eight short years, Digital Audio Broadcasting (DAB) has progressed from largely unproven theories through practical experimentation, to field trials and international standardization. So evident are the potential benefits of the new medium, for both broadcasters and – more importantly – their listeners, that a number of EBU Members are now planning to start terrestrial DAB services well in advance of the launch dates envisaged for satellite services.

With 1995 now established as the target date for operational DAB in some countries, EBU Members are defining strategies to ensure that the launch is successful; for this to happen, three essential prerequisites have been identified:

- *frequencies must be made available;*
- *transmitters and receivers must be available;*
- *attractive programme services must be offered.*

This article outlines the strategic planning being carried out by the EBU Members, in the framework of the EBU Technical Committee.

1. Introduction

During the last 20 years enormous leaps forward have been made in new broadcasting technology, in particular in digital recording, storage and transmission systems. In the recent past the EBU has been working in close cooperation with the Eureka DAB project, EU–147, to develop a successor system for VHF/FM radio broadcasting, and the result is the system known as Digital Audio Broadcasting (DAB).

Now that work on the system definition of DAB has been concluded, and is being recommended for worldwide use by the CCIR, the EBU has also finished, on the planning side, developing a basic strategy for facilitating the rapid introduction of the new service. This article briefly describes the technical ideas involved and the plans being made for a coordinated approach to a European wide implementation of DAB.

2. Why is a new service necessary?

The basic answer to the question "why?" is simply the fact that modern technology has, in effect, rendered obsolescent the conventional analogue transmission methods involving amplitude or frequency modulation. Although numerous and extensive technical improvements have been made to these analogue systems over the years (high degrees of audio compression, etc.), significant further refinements are probably no longer possible.

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The widespread use of digital technology in the audio media – compact discs, digital compact cassettes, and digital cassette recorders – has made “CD quality” the yardstick with which all audio sources are compared.

Added to these technological advances other, more practical challenges are also facing broadcasters. Now, in addition to growing interest in improved sound quality for broadcasting services, an ever–increasing number of broadcasting services are being demanded and provided (public and private), and this in turn is leading to increased congestion of the existing broadcasting frequency bands (and thus diminished programme quality). These problems are compounded under mobile reception conditions, for which the VHF/FM service was neither designed nor planned.

The allocation of new frequency bands is a very difficult and time–consuming goal to achieve. Digital transmission techniques, which, when suitably applied, can lead to a more–effective and more–efficient utilisation of the frequency spectrum, provide a means of reducing future spectrum needs, while satisfying increasing programme requirements.

3. What will the new service offer?

The new DAB system is designed to remedy the weaknesses of conventional broadcasting systems detailed in the proceeding section.

Firstly, DAB will offer a sound quality far superior to that of existing VHF/FM services. Indeed, the technical quality will be essentially equivalent to that of the CD. This bound forward in reception quality ensures the continuing viability of sound broadcasting (the “wireless”) in the sea of new media.

Secondly, a high programme transmission capacity will be possible, particularly where highest sound quality is less important, as well as complementary data transmission for additional information (eg: radio data services). Thus an increased ratio of number of programmes/MHz can be expected, making room for the entry of new servers into a presently crowded service arena.

Thirdly, virtually–perfect mobile, portable and stationary reception will be possible, in contrast to the limitations of the VHF/FM sound broadcasting service today. In particular, receivers in automobiles and also in areas susceptible to multipath reception will be assured unimpaired programme quality.

The current development of the DAB system shows that the following further advantages in comparison with VHF/FM can also be obtained:

– lower protection ratios are necessary for both co–channel and adjacent channel transmissions;

– a significantly smaller effective radiated power (ERP) is needed to cover any given area;

– more efficient spectrum utilisation is achieved, in particular when using the single frequency network (SFN) concept.

Thus, in the very long term, DAB can be expected, at least partially, to supersede VHF/FM broadcasting.

A full set of requirements that the DAB system should fulfil is given in *Table 1*.

4. How does DAB improve service quality and spectrum efficiency?

Two basic digital ingredients are included in the DAB recipe:

– MUSICAM (Masking Pattern Adapted Universal Sub–band Integrated Coding and Multiplexing), which is a data reduction technique,

– COFDM (Coded Orthogonal Frequency Division Multiplexing), which is a broadband multiplexing technique, serving to enhance reception resilience in a multipath environment.

Without going into any of the technical details, which have been published elsewhere [1], these principles are outlined in the following.

Digital techniques allow continuous (analogue) sound signals to be converted into discrete (digital) signals. The discrete nature of these signals means that they are well–defined to within a large margin of error, and thus do not loose their identity along the transmission path (under normal circumstances). Error correction methods are also available which can further increase the “fidelity” of the transmission. This is the “secret” of the compact disk.

Knowledge of the psychoacoustic properties of the human ear has enabled the development of MUSICAM at the Institut für Rundfunktechnik (IRT), Munich. MUSICAM allows a data rate of 1411 kbit/s, necessary to deliver a stereo signal on a compact disc, to be reduced to as low as 192 kbit/s (i.e. a reduction by a factor larger than 7), for delivery of a stereo broadcast programme, the quality of which is indistinguishable from that of the original source. The advantage for the broadcaster is that fewer bits per second means less bandwidth needed for transmission!

Knowledge of the propagation conditions near the earth and of the reasons why multipath propagation distorts analogue signals (narrow–band fading, etc.) has led to the proposal and development of a broadband system, COFDM, at the CCETT in Rennes, France. With such a broadcast system the information is spread over a wide bandwidth, so that only small portions of the signal are affected by multipath at any given time. The use of error correction techniques can reduce the effects of these small errors. In order to conserve bandwidth (i.e. the bandwidth/programme) many programme signals are "multiplexed" together into a single COFDM block signal, consisting of many carriers spread over the entire wide bandwidth.

Table 1

Requirements of the Digital Audio Broadcasting system for fixed, portable and mobile receivers[1]

In defining a Digital Audio Broadcasting system, the following requirements shall be taken into account. The system shall be intended for fixed as well as portable and mobile reception. The list of system requirements applies to terrestrial, cable, satellite as well as mixed/hybrid delivery.
The requirements are as follows:

1. Sound quality levels

- High quality stereo (two channels) sound with subjective quality indistinguishable from CD/R–DAT for almost all programme material.
- In order to optimize the number of sound channels, the possibility of transmitting sound programmes with a lower bit rate shall be included.

2. Sound control signals

- Transmission of control information on sound representation (loudness, dynamic range compression, matrixing, etc.)

3. Service configurations

- High–quality stereophonic sound
- High–quality monophonic sound
- For special applications, the possibility of adding further coherent sound channels to the basic system (e.g. for surround sound).
- Value added services with different data capacities and delivery time (e.g. traffic message channel, business data, paging, still picture/graphics, 1.5 Mbit/s video/sound multiplex, future Integrated Services Digital Broadcasting (ISDB) See CCIR Report 1227).
- Flexible allocation/reallocation of services, without affecting continuing services.

4. Service delivery

- Use of common signal processing in receivers for:

a) local, regional and national terrestrial VHF/UHF networks.
b) mixed use of terrestrial and national/supernational UHF satellite services
c) cable.

5. Service information

- Radio programme data[2] related to each programme signal (programme labeling, programme delivery control, copyright control, conditional access, dynamic programme linking, services for hearing–impaired).
- Multiplex system information (simple programme or service identification, selection and linking).

6. Interface

- Recording capability of sound signals (in bit–rate reduced form) and related data. This implies recording the complete programme signal including its programme related data, and the ability to access small blocks of data in the encoded signal.
- Data interface capability to Information Technology Equipment (ITE) and communication networks.

7. Service availability

- Mobile, portable and fixed reception
- High–coverage availability in location and time
- Subjectively acceptable failure characteristics
- High immunity to multipath (long and short delay) and Doppler effect (for mobile receivers)

8. Universality

- The system shall be suitable for fixed, portable and mobile reception
- Use of common signal processing in receivers for the different types of service delivery facilitating a common receiver design.

9. Spectrum efficiency

- High spectrum utilization efficiency (better than FM, maximize frequency and single frequency networking, minimize sharing constraints with other services)
- Multiple programme service provision within a contiguous frequency band.

10. Operational requirements

- Sound codec cascadability desirable (at least two codecs)
- Minimum sound signal delay and known fixed amount.

11. Complexity

- Low–cost basic receiver configuration
- Use simple, non–directional receiving antenna.

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1. This list is in accord with CCIR Recommendations.
2. Cross–referencing between corresponding DAB and VHF/FM services is required.

Due to the discrete nature of the digital signals, reflected, multipath contributions can actually enhance reception. To facilitate this possibility a "guard interval" is inserted between individual data bits, so that delays between the direct and reflected signals still allow a partial overlap of the desired information bits without causing undue interference to subsequent bits.

This "constructive interference" can also be systematically exploited in what is called a Single Frequency Network (SFN), in which a network of transmitters using identical frequencies transmits a single DAB programme block to a very wide area (the size of an entire country, for example). This wide area transmission approach effectively reduces the interference normally encountered in a conventional co–frequency network, and can yield an increased spectrum efficiency (up to a factor of three times as great!).

5. What is the EUREKA DAB system?

Complex digital circuitry has been developed in order to deal with data reduction, multiplexing (in frequency and time), error correction, etc., by the Eureka 147 DAB project, in cooperation with the EBU. By mid–1988 sufficient technical progress had been achieved to permit terrestrial broadcast tests and demonstrations. Extensive test transmissions carried out in several European countries, based on the COFDM modulation system and the MUSICAM source coding system showed that DAB could provide the expected high quality even under multipath propagation conditions.

In November 1991 the CCIR adopted two draft new Recommendations, largely based on EBU contributions, on the requirements for a digital audio broadcasting system:

– *CCIR Recommendation 774*: Digital sound broadcasting to vehicular, portable and fixed receivers using terrestrial transmitters in the VHF/UHF bands;

– *CCIR Recommendation 789*: Digital sound broadcasting to vehicular, portable and fixed receivers for BSS (sound) in the frequency range 500–3000 MHz.

The EBU/Eureka 147 DAB system is, for the time being, the only system that complies with the requirements mentioned in these Recommendations, and reproduced here in *Table 1.* A short form of the system specification is given in the Annexes to these draft Recommendations.

6. What frequencies can be used to introduce a DAB service?

As mentioned before, the acquisition of new allocations for broadcasting bands is a difficult task. During the ITU World Administrative Radio Conference, WARC–92, held in Torremolinos, Spain, (February–March, 1992) a band (1452–1492 MHz) was allocated to broadcasting for satellite sound transmissions and complementary terrestrial service, on a world wide basis, except in the United States.

These frequencies cannot be used on a primary basis, however, until the year 2007. In the meantime the main aim of broadcasters will be the introduction of terrestrial sound services using the bands already allocated to broadcasting below 1 GHz (recently, however, interest has been increasing in some countries with respect to the use of parts of the 1452–1492 MHz band to introduce limited local terrestrial services in the near future).

The frequency bands allocated to terrestrial broadcasting (Bands I, II, III, IV/V) are, with the exception of Band II, all extensively used for television. Band II is used for VHF/FM but is increasingly overloaded because of the large number of radio services being implemented.

It has been found that frequencies in Bands II and III are particularly suitable for terrestrial DAB transmissions. The spectral efficiency of DAB is most evident in a single frequency network which typically would operate with the same transmitter site separation as currently used in VHF/FM networks. Within these frequency limits, the current broadcasting station networks may then be usable without major modification and thus without large investment in transmitter site infrastructure.

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From 1979 to date Dr. O'Leary has been with the EBU Technical Department where he has been involved in many projects in the framework of EBU Working Party R. From 1984 to 1990 the IFRB benefitted from Dr. O'Leary's specialist knowledge of HF and television network planning.

Proposed frequency bands for the start of terrestrial DAB

This Table contains information concerning European broadcasters' intentions with respect to the introduction of terrestrial DAB. The significance of the data in each column is as follows:

col 1 Country
col 2–6 Possible broadcasting bands (Band I, II,III, IV/V, L), with a rating revealing the possibility or probability that frequencies in the indicated Band will be used in the initial start–up phase of DAB.
Ratings: 1 = little chance
2 = some chance
3 = good chance
4 = already decided
The numbers in the centre column for each Band give the frequencies in MHz (in some cases, the television channel numbers) in which the DAB programmes may be transmitted.
col 7 Information on the maximum number of 1.5–MHz DAB frequency blocks that may be necessary for national or local services in the initial start–up phase (assuming 5 to 6 high–quality stereo programmes available in each DAB block).
col 8 Earliest foreseen starting date for terrestrial DAB.

Country	Band I			Band II			Band III			Band IV / V			Band L (1.5 GHz)			Initial DAB block requirements/use	Date
	Rating	Freq. (MHz) or *channels*	Notes	Rating	Freq. (MHz) or *channels*	Notes	Rating	Freq. (MHz) or *channels*	Notes	Rating	Freq. (MHz) or *channels*	Notes	Rating	Freq. (MHz) or *channels*	Notes		
Algeria																	
Austria	2	–	a	1	–		2	223–230/ *ch.12*	a b	2	–	b		–		4 blocks for 9 regions	98
Belgium	2	47–54		1	–		3	223–230/ *ch.12*		2	–	c	1	–		5 blocks for 3 regions	97
Bulgaria																	
Cyprus	3	47–68			–		3	223–230/ *ch.12*			–			–		2 blocks	98
Czecho–slovakia																	
Den-mark	2	–	c	2	–		2	–	e	2	–	b c		–		1 block for national 3 blocks for regional	95
Egypt																	
Finland	1	–		3	104–108		2	223–230/ *ch.12*	a	1	–		1	–	h	1 block for national 4 blocks for regional	97
France	3 3	65–68 47–49		1	–		2	–		1	–	d	3	–	g	at least 2 blocks in Band I and further blocks in Band L	95
Ger-many	2	54–68		1	–		4	223–230/ *ch.12*	a	1	–		1	–	h	6 blocks for national, regional and local	95
Greece	1	–		1	–		1	–		2	ch. 65/68						
Hungary																	
Ireland[f]	2			1	–		2	223–230/ *ch.J*	e								
Iceland																	
Israel							3	–		2	–	c					
Italy	2	–		1	104–108		2	223–230/ *ch.12*		1	–		1	–		3 blocks for national 5 blocks for local	
Jordan																	
Lebanon																	
Libya																	

(continued)

DAB

Country	Band I Rating	Band I Freq. (MHz) or channels	Band I Notes	Band II Rating	Band II Freq. (MHz) or channels	Band II Notes	Band III Rating	Band III Freq. (MHz) or channels	Band III Notes	Band IV / V Rating	Band IV / V Freq. (MHz) or channels	Band IV / V Notes	L (1.5 GHz) Rating	L (1.5 GHz) Freq. (MHz) or channels	L (1.5 GHz) Notes	Initial DAB block requirements/use	Date
Luxembourg	3	54–68			–		3	223–230/ *ch.12*			–			–		5 blocks for national	96
Malta																	
Morocco																	
Monaco																	
Netherlands	2	61–68		1	–		3	223–230/ *ch.12*		2	–	c	2	–		2 blocks for national Further blocks for local	
Norway				1	100–108		3	230–240					2	–		1 block for national 4 blocks for regional	97
Poland		–		3	104–108												
Portugal	1	–		1	–		2	223–230/ *ch.12*		1	–	c	1	–		1 block for national 3 blocks for local and regional	97
Romania																	
Spain	1	–		1	–		2			1	–						
Sweden	1	–		3	104–108		3	223–230/ *ch.12*		2	790–854		1	–	h	1 block for national 4 blocks for regional	95
Switzerland	1	–		1	–		3	223–230/ *ch.12*		2	–						
Tunisia																	
Turkey	2	47–68		2	104–108		2	223–230/ *ch.12*		2	790–860					2 blocks for national 2 blocks for local	
United Kingdom	3	47–68		1	–		3 2 2	223–230 217.5–223 230–240		1	–		1	–	h	2 blocks for national 5 blocks for local	95
USSR[f)]	1	–		4	100–108		1	–		2	–						
Vatican	2	–		3	–		3	–		2	–						
Yugoslavia	2	54–61/ *ch.3*		1	–		2	223–230/ *ch.12*		2	–						

Notes:

a) Regional difficulties due to high–power stations in Eastern Europe
b) Further solutions might be generated if some of the channels 61–69 can be made available by Administrations
c) Some channels may be useable, but not for extensive single frequency networks
d) This information was provided by the Ministry of Communication
e) Further solutions might be generated if channel 12 can be made available by Administrations
f) Informally communicated by a representative of the USSR Communications Ministry, 1990
g) For local and "grid" coverage
h) For local coverage; significant use of existing services

Table 2
Frequency bands for the start–up of terrestrial DAB

Although Band I may also be suitable, there are some concerns about increased levels of man–made noise and significant sporadic–E propagation effects (particularly in the lower part of the band) both of which require further studies.

The use of Band IV/V, or the newly–adopted band 1452–1492 MHz, for a terrestrial DAB service may be less favourable than Bands I, II and III, due to:

– the much more dense transmitter network needed for a single–frequency network service;

– terrain effects being of greater significance at such frequencies;

– the technical implications (eg: lesser spectral efficiency) for system performance, and parameters required to serve fast moving vehicles using these carrier frequencies.

Bands IV/V and the newly–adopted band 1452–1492 MHz could in principle be of use for some smaller–scale local broadcasting services, although considerations of the economics of receiver manufacture may militate against such an approach.

An indication of the possible spectrum that could perhaps be made available in various European countries within the next few years for purposes of terrestrial DAB transmission is given in *Table 2*.

A resolution adopted by WARC–92 calls for a future Conference to consider for DAB primarily the use of the VHF broadcasting bands in Region 1 and interested countries in Region 3.

7. What is the EBU's strategy for introducing terrestrial DAB?

The broadcasters' strategy [2] for the introduction of DAB must give special consideration to ensuring there are significant advantages to listeners:

– new sound programmes not available on FM;

– high technical quality of transmission;

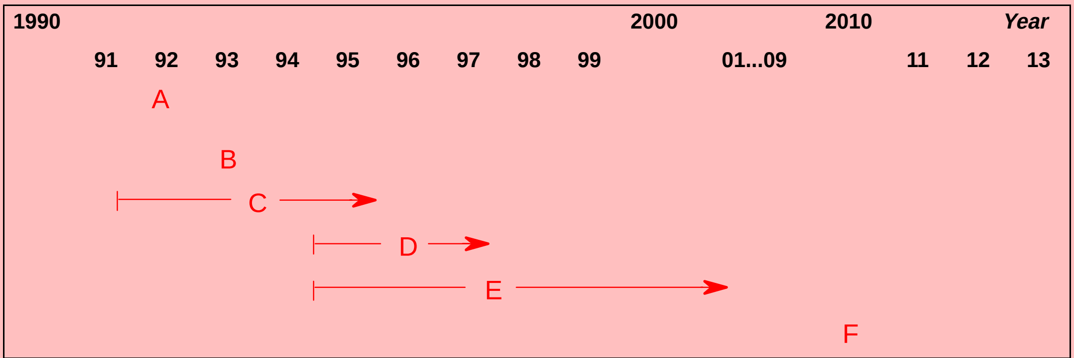
– significantly improved sound and reception quality with mobile and portable receivers;

– progressive transfer of exising AM and FM programmes to DAB;

– new data services.

Listeners buying new DAB receivers should be able to enjoy, as far as possible, their preferred existing AM and FM programme choices on the new medium.

The parallel transmission of identical programmes over AM and FM and DAB will probably result in a significant increase of expenses for broadcasting organizations without necessarily increasing the number of listeners and this must also be taken into account in the financial planning for a new broadcasting service such as DAB. On the other hand, little additional operational cost will arise in audio broadcast production and distribution since digital technology has been used extensively for the last several years. Some investment in additional new equipment may however be necessary.



Event	Date/Period	Description
A	End 1991	Preliminary definition of DAB system complete
B	End 1992	Final specification of DAB system complete
C	1991–1995	Broadcasters and Administrations take decisions concerning the broadcasting band(s) and frequency usage for DAB Industry must prepare for mass production of DAB and combined FM/DAB receivers
D	1995–1997	Introduction of initial terrestrial DAB services
E	1995–2000	DAB implementation period (i.e. simultaneous broadcast of DAB and FM programmes plus additional DAB–only services)
F	2010	Substantial replacement of FM services by DAB where appropriate

Figure 1
Schedule for the implementation of terrestrial DAB

In order to achieve better spectrum utilisation of the existing VHF/FM band in the future it seems desirable to reallocate at least part of this band for use by digital systems. This, however, would require some kind of reorganization of Band II in many countries and can be considered only as a long–term goal necessitating a prior ITU planning conference. In the meantime another frequency band will have to be made available in many countries, at least as a "starting position". It can be seen from *Table 2* that the starting solutions could range from Band I to Band V and even may include the L–Band.

With respect to frequency planning considerations it should be noted that, generally, several DAB frequency blocks are necessary to cover separate neighbouring areas without interference (eg: making systematic use of SFNs) giving one block per area. With a block–width of about 1.5 MHz (sufficient for up to six CD–quality stereo programmes) and appropriate guard bands, a total band equivalent to one 7–MHz television channel would generally permit the introduction of DAB terrestrial services, though this will probably be insufficient to meet the initial demand in some countries.

The date for starting a DAB service is mainly influenced by the following factors:

– Suitable frequencies for DAB services have to be available.

– Transmitters and receivers have to be available.

– Viable programme services have to be offered for transmission.

It is important to notice that the introduction of terrestrial DAB services will only be successful if all the above conditions are satisfied and progressed in parallel. Even if these conditions are fulfilled it is expected that a terrestrial DAB service could only start by 1995 at the earliest; even then the initial introduction may be limited in some countries to area limited experimental transmissions.

A schedule for the envisaged deadlines for the introduction of DAB is given in *Fig. 1*.

Bibliography

[1] **Advanced digital techniques for VHF satellite sound broadcasting** EBU, August 1988.

[2] EBU document Tech. 3269: **Strategy on Digital Audio Broadcasting**