DAB
– is it already out of date?

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The EBU's Technical Director poses a provocative and challenging question about the future of the Eureka-147 DAB system.

Introduction

The technical details of the DAB standard were defined by Eureka Project 147 more than 5 years ago. Given the very rapid changes in technology, we need to ask: *Is this system already out of date?*

Although the individuals in the Eureka DAB project were undoubtedly "technological pioneers", history tells us that pioneers can be overshadowed by their successors, who often "improve" on the original. In the case of DAB, there are now many competing digital radio systems. In addition, digital television transmissions, whether satellite, cable or terrestrial, can also deliver audio services. Finally, in the past few years, the Internet has unexpectedly emerged as a global delivery mechanism for audio services.

The purpose of this article is to examine the challenges to Digital Audio Broadcasting posed by these "newer" technologies.

Alternative systems

It is important to examine, very thoroughly, the technical advantages and disadvantages of competing systems for the delivery of digital audio services. However, it is even more important to recognize that many of the technical features are of little or no interest to consumers. For example, some engineers have assumed that improved audio quality, by itself, will persuade consumers to make the transition to digital radio. They point to the success of the audio CD and suggest that this is proof of a huge demand for higher audio quality. In practice, the primary motivation for most purchasers of CD players in the 1980s was that of convenience and ease of handling, compared with vinyl records. The concept of "digital" quality was undoubtedly helpful in marketing CDs, but the word "digital" is now so over-used that many consumers are totally confused. Some consumers believe that their existing FM radios are already "digital" because this word appears on the front panel – in reality, all it means is that the radio has a digital frequency display!

What will consumers expect from the next generation of radios? They certainly will not expect digital radio services to be inferior in any respect to the existing analogue services.

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Although this principle may seem very obvious, the designers of some digital radio systems seem to have forgotten it.

For example, in the analogue world, much radio listening is either “mobile” (e.g. in cars, buses or trains – or whilst walking or jogging) or “portable” (e.g. moving a radio from room to room or having several radios scattered throughout your home). Radio listening has evolved from the time when listeners gathered around their only radio to listen attentively to the programme of their choice. Nowadays, radio listening is usually done whilst doing something else, such as driving a car, reading or doing household chores – in the computer world, this is known as “multi-tasking”! One of the great strengths of analogue radio broadcasting is that it can accommodate these diverse patterns of use.

Mobility and portability are essential requirements for any system aiming to replace analogue radio broadcasts. Those digital radio systems which need a fixed satellite dish inevitably require the listener to be stationary or, at least, to stay within earshot of a fixed radio. Even worse, some system designers expect people to listen to audio services through a TV set (or a set-top box). This can cause disputes when another member of the family wishes to watch a TV programme! On the other hand, the Eureka DAB system was expressly designed from the outset to provide perfect reception on mobile and portable receivers.

The range of services offered by the new technology is, arguably, even more important in driving the consumer demand for digital audio broadcasting. Some people will be keen to obtain digital simulcasts of analogue services, but even more would be attracted by additional “digital-only” services. Digital systems must permit simulcasting of all, or most, existing services - including public service and commercial broadcasters. In addition, digital systems must also offer attractive new services, such as additional audio programming and / or multi-media services.

In summary, digital services must replicate the mobility / portability of existing analogue services, as well as allowing enhanced services, either more audio services or multimedia services. With these dual criteria in mind, we should examine the potential competitors to the Eureka DAB system.

Digital radio in the AM & FM bands

“Re-farming” the existing AM and FM broadcast bands so that they can accommodate digital services is an attractive possibility, especially in those areas where it is difficult to find new spectrum for digital services. In principle, the new digital service can operate within the analogue channel (known as *in-band on-channel* or IBOC systems) or by transmitting digital information in the adjacent channels (known as *in-band adjacent-channel* or IBAC systems).

Such co-existence is not easy to achieve in practice. To avoid mutual interference, the digital and analogue signals must be radiated from the same transmitting antenna, so as to ensure that the relative amplitudes of the analogue and digital signals remain constant throughout the service area. Furthermore, to avoid interference to the analogue service, the digital service must be transmitted at much lower power than the analogue service. However, if the digital signals are too weak, the service area of the digital transmissions will be much smaller than that of the analogue service.

The need to avoid interference to the analogue service is in direct opposition to the need to ensure good coverage of the digital service. It may be possible to find a power level for the digital service to satisfy both requirements simultaneously. If not, it will be necessary to accept an unsatisfactory compromise in which either some inter-ference to the analogue service is tolerated or the digital coverage is reduced. This problem besets the designers of both IBOC and IBAC systems.

With digital systems, it is simple to trade ruggedness for data-rate. Within a given bandwidth, a digital system with a high data-rate is more susceptible to interference than a system offering a lower data-rate. Consequently, it may be possible to select parameters that avoid interference between the analogue and digital services by accepting a lower data-rate – perhaps offering only enough capacity for a digital simulcast of the analogue service. In these circumstances, the digital transmissions would not be able to offer any enhanced services, such as additional programming. The advocates of such systems claim that this is a problem merely in the period during which the analogue and digital services are operated in parallel. When the analogue services are eventually withdrawn, there will be more capacity for enhanced digital services, including additional programming and multi-media data services.

Whereas the quality of an analogue service gets progressively worse as the signal gets weaker, digital services generally have an abrupt failure characteristic. The designers of "in-band" systems have realized that they can overcome this weakness of digital systems by ensuring that, in the event of poor reception of the digital signals, the digital receivers will be able to switch to the analogue service. Of course, this again implies that the content of the digital services must be an exact replica of that carried by the analogue services.

Although in-band digital systems may be technically possible, there does not seem to be a clear market proposition for consumers. During the period when the digital services have to co-exist with the analogue services, the digital services will not offer any new facilities – apart from improved audio quality, except when the new receivers default to reception of analogue services. It is true that this problem will disappear when the analogue services are withdrawn. However, given the lack of any real incentive for consumers to switch to digital receivers, it is obvious that analogue transmissions will have to be maintained for many years.

Some people find it hard to understand the logic behind the various digital in-band systems being developed in the USA for the AM and FM bands, especially as many Americans openly acknowledge the technological superiority of the Eureka DAB system. In practice, the preference for in-band systems is based on reasons other than technology:

- The Eureka system requires new spectrum allocations, which are not readily available in the USA.
- The Eureka system requires several broadcasters to share a DAB multiplex and the DAB transmission facilities. The perceived wisdom is that such co-operation is not possible in the USA where there is often intense competition between local radio stations.
- From the perspective of the owners of existing broadcasting stations in the USA, in-band systems are very attractive in that they offer a one-for-one equivalence between existing analogue services and digital services. In other words, the technology offers the longer-term potential for existing licensees to move from analogue to digital – but, crucially, without opening up the market to new competitors.

Nevertheless, in-band digital systems may be successful in particular "niche" markets, such as the replacement of AM short-wave (HF) transmissions. In the case of short-wave transmissions, the quality of the existing services is generally so poor that the change to digital transmission will offer a major improvement. Such a system is being developed by Digital Radio Mondiale (DRM), which is a collaborative project involving broadcasters, manufacturers, network operators and R&D groups.

More information on the DRM system is available at:

http://www.drm.org

Satellite-delivered radio services

Various systems have been developed to deliver radio services from geo-stationary satellites to receivers using fixed dish antennas. Initially, these services were analogue but various digital services are now available, such as:

- The DSR service, which was introduced in Germany in 1989. It occupied a 27 MHz transponder, originally intended for analogue DBS television services, and was also distributed through cable TV systems. It delivered 16 high-quality stereo radio services. Although it achieved enthusiastic support from hi-fi enthusiasts, the service was withdrawn at the end of 1998.
- Analogue TV services delivered by satellite have, for many years, used sub-carriers to offer analogue audio services. More recently, such sub-carriers have been used to offer digital audio services.
- Many digital TV services now being delivered by satellite also include audio programming. Some of these audio services replicate existing radio channels, but there are also subscription-based audio services offering a wide range of music services.

The one thing that all of the above services have in common is that they require a fixed receiving dish antenna. This means that consumers cannot move around their homes whilst listening to these services: in effect, those using audio services associated with TV services listen to the radio through their TV set. In practice, audience surveys reveal very low levels of listening to such services, especially when compared with traditional radio services.

Unlike the systems designed for reception on fixed satellite dishes, WorldSpace services will be receivable by portable radios. The performance of the WorldSpace system is expected to be excellent where the path from the satellite to the receiver is not obstructed. As WorldSpace is planning to use satellites in geo-stationary orbits, reception will generally be best in tropical regions of the world rather than in higher latitudes. This limitation is not a problem for WorldSpace as their primary target areas are Africa, the Middle East, Asia, the Mediterranean Basin, Latin America and the Caribbean. However, even in equatorial zones, it is unlikely that the WorldSpace signals can be reliably received within buildings – except in favourable conditions such as near a window facing towards the satellite.

More information on the WorldSpace system is available at:

http://www.worldspace.com

Although the Eureka DAB system is being currently used in its terrestrial form, it can also be employed for satellite services. As with WorldSpace, there are concerns about the performance of satellite services in urban areas at high latitudes or within buildings. A key feature of the Eureka DAB system is that it permits SFNs, which also allow on-frequency terrestrial repeaters of satellite services. This offers a solution to the intrinsic problems of mobile / portable reception of services delivered by geo-stationary satellites, without requiring additional terrestrial frequencies as would be the case with the WorldSpace system.

Digital terrestrial TV

The advent of DTT also poses a new challenge to DAB. Some of the digital capacity on DTT could be used to provide additional audio services. As discussed above, these audio services will not be available on mobile or portable receivers and, hence, are unlikely to have any real impact on traditional radio services.

Nevertheless, a more important challenge has emerged from the DVB-T system. DVB-T is based on the OFDM technology developed for DAB, but there are two major differences between DVB-T and DAB:

- DVB-T has been designed to use TV channels which are 6 - 8 MHz wide (compared with the 1.5 MHz channels used for DAB);
- As DVB-T was designed primarily for reception on roof-top antennas, it is possible to use less rugged modulation schemes for each of the individual carriers – whereas DAB uses DQPSK, DVB-T transmissions can use QPSK, 16-QAM or 64-QAM.

The overall result is that DVB-T can offer a range of data-rates, as shown in *Figs. 1* and *2*. DVB-T can provide much higher data-rates than DAB; most broadcasters expect to use DVB-T (with 16-QAM or 64-QAM OFDM) to deliver between 18 and 24 Mbit/s, compared with 1.2 Mbit/s on DAB. This means that they can deliver one HDTV service or 3 to 4 SDTV services to roof-top antennas.

If broadcasters are prepared to use DVB-T at lower data-rates, such as 8 – 12 Mbit/s, reception of digital TV becomes possible in a mobile environment, as shown by several excellent public demonstrations. This performance is not surprising because, in such circumstances, DVB-T is effectively a wide bandwidth version of the DAB system.

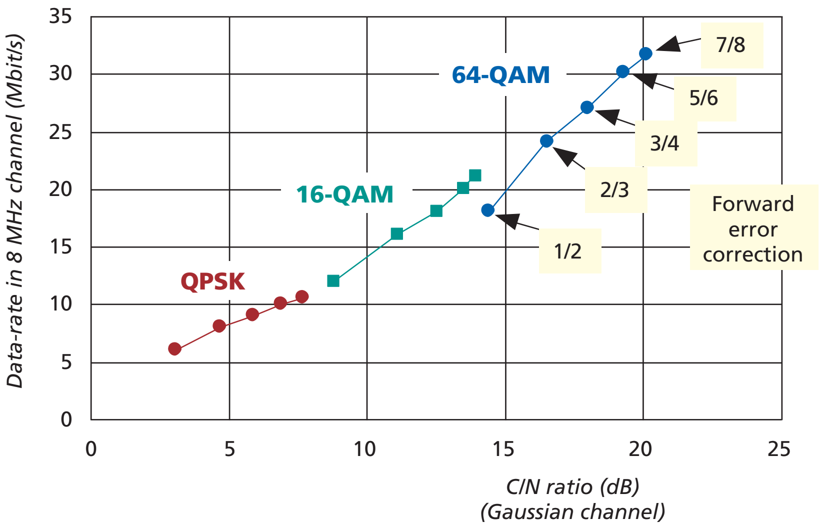

Figure 1
DVB-T options: choice of modulation scheme and forward error-correction ratio.

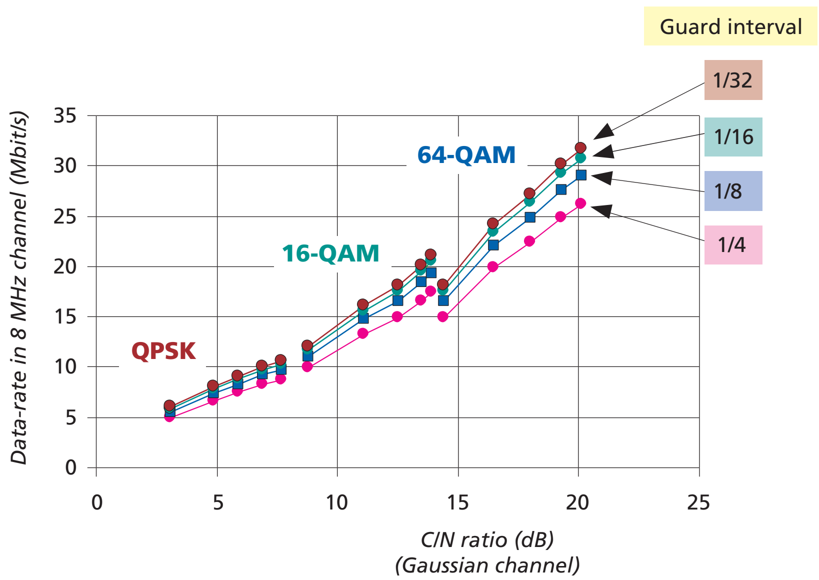

Figure 2
DVB-T options: choice of guard interval.

Despite this obvious commonality, some advocates of DVB-T claim that *"anything that DAB can do, DVB-T can do better"*. Although the DVB-T system offers a great deal of flexibility, such as data-rates of between about 5 Mbit/s and 30 Mbit/s in an 8 MHz channel, broadcasters using DVB-T must opt for a single data-rate for a given transmission. In other words, they need to choose whether to provide services with high data-rates to receivers using rooftop antennas or services with much lower data-rates to mobile receivers.

As most DVB-T services will have to share the spectrum already used by analogue TV services, the power of the DVB-T transmissions will generally be constrained by the need to avoid interference to existing TV services. In most countries, this constraint will be so severe that the power of the DVB-T transmissions will not be sufficient to provide reliable continuous coverage on mobile or portable receivers, especially within buildings.

Further information on the DVB-T system is available at:

http://www.dvb.org

The North American system for digital terrestrial TV, developed by ATSC, offers only a single data-rate of 19.2 Mbit/s in a 6 MHz channel. It, therefore, cannot match the DVB-T system in delivering signals to mobile receivers. On the other hand, the BST-OFDM system for digital terrestrial television, under development in Japan, has much in common with DAB and DVB-T. It also uses OFDM, but is based on the use of a number of separate segments, each of 432 kHz bandwidth. For example, one 432 kHz segment could be used to provide limited audio services to mobile receivers, whereas 13 segments (occupying 5.6 MHz) could be used for digital HDTV.

Further information on the North American ATSC system is available at:

http://www.atsc.org

Useful information on the BST-OFDM system is available at:

http://www.strl.nhk.or.jp/open98/1-4/ter-11e.html

It is important to recognize that both the DVB-T and the BST-OFDM systems have been developed for digital TV, mainly for the delivery of services to rooftop antennas, but also to set-top antennas. There is some interest in extending these systems to offer digital TV services to mobile receivers. The limited availability of suitable radio spectrum means that most broadcasters will opt to use such systems for the delivery of traditional TV services, at least until the analogue TV services have been withdrawn – in, perhaps, 10 - 20 years. In other words, the highest priority will be TV reception on rooftop antennas; the next priority will be TV reception on set-top antennas and, with an even lower priority, mobile TV reception. Given these priorities, it is unlikely that digital TV broadcasters will devote much capacity to delivering audio services targeted at mobile receivers, especially as there is already a purpose-built solution, namely DAB!

Audio over the Internet

The explosive growth of the Internet has surprised everybody. Only a few years ago, the Internet was dominated by the academic community. Some people predicted that e-mail would be relevant for business applications, especially for those companies with offices all over the world. However, the World Wide Web has revolutionised "navigation" around the Internet and has allowed the use of attractive graphics and images.

The concept of "streaming audio" emerged in 1995, as typified by Real-Audio ® software. Until then, audio could be transferred across the Internet, but users had to wait until the entire audio file had been downloaded before they could listen to any part of it. The result was that, after 10 minutes or more, you often discovered that the audio was not what you wanted!

The first version of the RealAudio software was intended for use with modems operating at 14.4 kbit/s. It claimed to offer "AM quality" but, in practice, the audio quality was very variable and, at times, it sounded like short-wave radio reception on a bad day. Nevertheless, it demonstrated that on-demand audio services could be delivered over the Internet. At that time, many broadcasters felt that audio over the Internet was neither a serious threat nor a serious opportunity: one broadcaster said that *"listeners used to 'FM quality' or CDs will not tolerate the poor quality offered on the Internet"*.

Since then, audio quality has been much improved by the use of better algorithms for the digital compression of audio signals and by better techniques for the handling of transmission errors. Additionally, 14.4 kbit/s mod-ems have been superseded by 28.8 or 33.6 kbit/s modems. Those with 56 kbit/s or ISDN modems can hear even better quality. Some purists may still complain about the remaining imperfections of digitally-compressed audio at low bit-rates, but the acid test is whether consumers are willing to accept lower quality audio in exchange for the benefits offered by access through the Internet.

Audio via the Internet has now become a practical reality. Several thousand broadcasters are already providing such services. More than 40 million copies of RealAudio software have been downloaded over the Internet.

For broadcasters, a big attraction is that their services can be heard globally: a local radio station's over-the-air transmissions may not be audible more than a few kilometres from the transmitter but, on the Internet, even little stations can be global players. Of course, this is also a great benefit for international broadcasters and, indeed, for those listeners travelling abroad who would like to be able to hear their favourite radio station wherever they are.

Despite these potential advantages, delivery of audio via the Internet is often unreliable because of congestion, either at the audio server or on the network itself. The infrastructure of the Internet is suitable for "one-to-one" services (e.g. for audio-on-demand services), but it is

Abbreviations

16-QAM	16-state quadrature amplitude modulation
64-QAM	64-state quadrature amplitude modulation
ATSC	Advanced Television Systems Committee (USA)
DAB	Digital Audio Broadcasting
DBS	Direct broadcast(ing) by satellite
DQPSK	Differential quadrature (quaternary) phase-shift keying
IP	Internet protocol
ISDN	Integrated services digital network
OFDM	Orthogonal frequency division multiplex
DRM	Digital Radio Mondiale
DSR	Digital Satellite Radio
DTT	Digital terrestrial television
DVB	Digital Video Broadcasting
DVB-T	DVB - Terrestrial
HDTV	High-definition television
IBAC	In-band adjacent-channel
IBOC	In-band on-channel
SDTV	Standard-definition television
SFN	Single-frequency network

not appropriate for "one-to-many" services (e.g. broadcasting). The problem is that audio servers send a separate stream of data over the Internet for each individual listener, even if they are all listening to exactly the same material. Given the problems of congestion on the Internet, it is clearly not sensible to use the Internet for large-scale broadcasting. More efficient solutions, such as "IP Multicasting" and "mirroring of web sites" have been devised, but these have not been widely implemented.

Whereas radio broadcasting is simple for listeners, accessing the Internet can be much more complicated – as well as requiring a relatively expensive computer connected to a fixed telephone line or cable network. The Internet will undoubtedly develop to offer attractive high-quality audio services, but it will be difficult to match the capabilities of "traditional" radio broadcasting in terms of cost, reliability, mobility, portability and ease of use.

Conclusions

To be successful, digital radio systems must give significant benefits to broadcasters and consumers, when compared with analogue systems. In particular, digital radio must offer excellent reception on portable and mobile radios, as well as provide additional capacity for extra audio services and / or multimedia services.

Given that the DAB system developed by the Eureka-147 consortium is now a mature technology, it is certainly appropriate to ask whether this system is out of date. Although there are many "newer" digital radio systems, it is surprising that none of the new systems can compete with DAB in delivering multiple high-quality audio services to mobile and portable receivers. Numerous systems have been devised to deliver services to "fixed" receivers. This limitation makes life much easier for system designers, but it does not reflect real life where consumers expect radio to be constantly available to them wherever they are. This situation is summarized in *Fig. 3* which indicates that DAB is the only system offering high data-rates that can readily be received on mobile and portable radios.

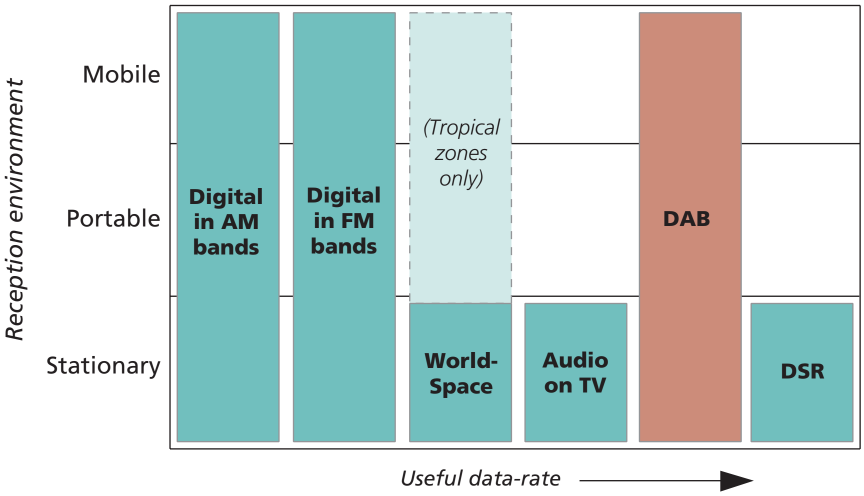

Figure 3
Comparison of systems.

Radio is essentially a mobile or portable medium. We must pay tribute to the tremendous foresight of the individuals in the Eureka-147 consortium which, from its earliest days, recognized the need to deliver digital audio services to mobile and portable receivers – even under the most difficult reception conditions. Not only did they successfully meet this challenge, they have also developed a superb flexible mechanism for the delivery of high data-rate multimedia services