Pathways to Digital Radio Broadcasting in Europe

Spectrum Aspects

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New digital landscapes

Digital Radio has succeeded when content is developed, coverage is widespread and a variety of consumer equipment is available.

Digital radio in the form of DAB has been adopted by several markets because of a strong commitment by public service broadcasters, within a conducive government planning regime supported by appropriate spectrum and multiplex allocation. Digital radio in the form of DRM has also received strong support from public service broadcasters (PSB's).

Countries with a significant investment in DAB and an installed base of consumer equipment are likely to proceed with DAB. However, the emergence of new standards may create confusion and disrupt digital radio implementation in some countries as regulators and planners re-evaluate the potential of each technology. Furthermore, enabling regulation is not yet in place in many countries.

Future Scenarios

Radio in the future is a multiplatform phenomenon. Radio will be available on a wide range of technical devices, from racks and hifi's over standalone and portables to hand-held and pocket receivers. Everything digital – from television and computers to cell phones, mobiles and PDA's – will be able to carry sound and thus radio.

Concerning standards there will be no single, winning standard for digital radio. DAB/DMB, DRM and DVB all have their strengths and weaknesses, which will make more of them co-exist. Manufactures will secure dual, triple, and eventually multi-standard radio sets for consumers. The consumers will not have to navigate through a jungle of frequencies or abbreviations, as the tuners will have easy to navigate browsers on displays with the station brands.

For the time being, however, analogue switch-over is not on the horizon for radio and it will take more than a decade until it becomes a realistic option. There are indications that FM will persist beyond 2020 in most markets.

Open questions

Without a dedicated transmission network, radio may risk being subsumed by other platforms dominated by television or other services. Radio broadcasters may in fact loose prominence if offered as supplementary service by aggregators controlling the menus, EPG's and the technical parameters of transmission.

The consensus of all key industry players is that it is necessary to drive radio digitalisation. Marketing and co-ordination at national and international levels has not been sufficient in many cases. European regulators also have a role to play to facilitate digital radio and to motivate key players.

Some of the spectrum issues are considered in the following sections of this paper.

[1] based on EBU Viewpoint, July 2007

The Radio Spectrum

New developments in broadcast and mobile communication technologies have increased the demand for radio-frequency spectrum, a finite natural resource. Pressure is growing on the regulators and current users to accommodate more and more services. Mobile television, wireless broadband and enhanced mobile phone services, additional television channels and high-definition television (HDTV) and new radio broadcasting systems are all lining up to be launched.

Experts generally agree that if all existing analogue services were provided in a digital format, their spectrum needs would be one quarter of their current take-up. In other words, three quarters of the currently-occupied spectrum could become available to be used for other services. But it is a bit more complicated than that. Different technologies work better in particular parts of the spectrum. Certain frequency bands will remain occupied by current users while others will be cleared for new uses. Historic developments, technical and economic considerations, as well as European harmonisation of spectrum use, play a part in the equation.

What is spectrum?

The electromagnetic spectrum incorporates the range of all electromagnetic radiation, and extends from electric power at the long-wavelength end to gamma radiation at the short-wavelength end. In between, we find radio waves, infra-red, visible light, ultra violet and X-rays used in medical diagnostics.

Electromagnetic waves are defined by their special characteristics, such as frequency, wavelength and amplitude. The frequency refers to the number of waves generated in a set period of time and is measured in Hertz (Hz). 1 Hz means one wave per second, 1 kHz (kilohertz) means one thousand waves per second, 1 MHz (megahertz) means one million waves per second, 1 GHz (gigahertz) means one billion waves per second and so on.

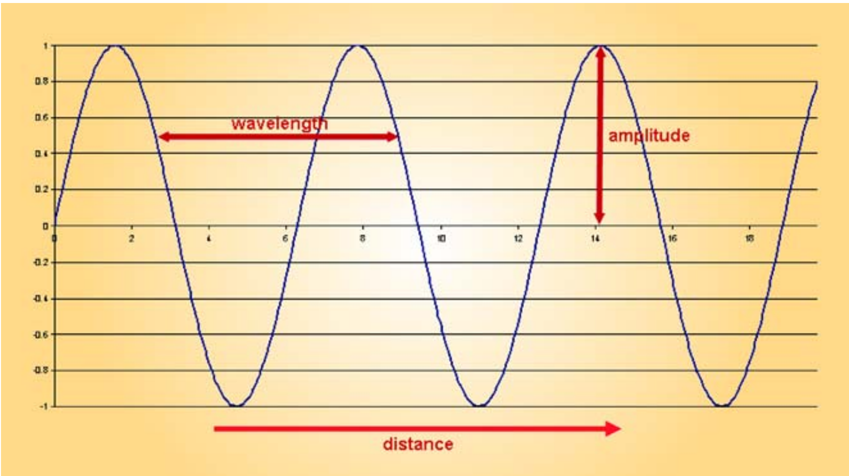

Figure 1
The electromagnetic wave

Wavelength is the distance between two waves. There is a fixed mathematical interrelation between the frequency and the wavelength. The higher frequencies have shorter wavelengths and the lower frequencies have longer wavelengths. The wavelength also indicates the ability of the wave to travel in space. A lower frequency wave can reach longer distances than a higher frequency wave. Radio waves are usually specified by frequency rather than wavelength.

The radio-frequency spectrum (which is simply referred to as spectrum) is only a comparatively small part of the electromagnetic spectrum, covering the range from 3 Hz to 300 GHz. It includes a range of a certain type of electromagnetic waves, called radio waves, generated by transmitters and received by antennas or aerials.

How radio spectrum works

The radio spectrum is the home of communication technologies such as mobile phones, radio and television broadcasting, two-way radios, broadband services, radar, fixed links, satellite communications, etc. due to its excellent ability to carry codified information (signals). It is relatively cheap to build the infrastructure which can also provide mobility and portability.

Depending on the frequency range, the radio spectrum is divided into frequency bands and sub-bands, as illustrated in Figure 2.

In theory, different communication technologies could exist in any part of the radio spectrum, but the more information a signal is to carry, the more bandwidth it needs. In simple terms, bandwidth is the range of frequencies that a signal occupies in the spectrum. For example, an FM radio station might broadcast on a frequency of 92.9 MHz but requires a bandwidth of 0.3 MHz (300 kHz) – the spectrum between 92.8 and 93.0 MHz inclusive. Other stations cannot broadcast on these frequencies within the same area without causing or receiving interference.

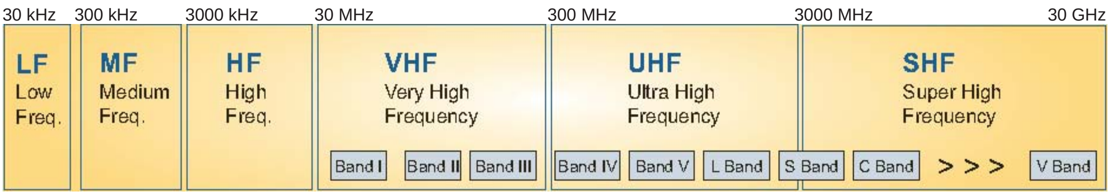

Figure 2
Frequency bands and sub-bands

For planning purposes, the spectrum bands are divided into channels. The bandwidth of spectrum channels can vary band by band. VHF Band II, the home of FM radio, for instance, is sliced up in 100 kHz-wide channels. An FM station requires 300 kHz bandwidth, therefore each FM radio station takes up three spectrum channels. In the case of television broadcasting, the agreed bandwidth of a channel in many parts of the world is 8 MHz in UHF Band IV/V. The bandwidth requirement of an analogue television programme channel is the same as the bandwidth of one spectrum television channel, i.e. 8 MHz.

Lower frequencies have less bandwidth capacity than higher frequencies. This means that signals that carry a lot of information (such as television, broadband or mobile phones) are better placed in the higher frequency bands while simple radio (audio) signals can be carried by the low-frequency waves. Since low frequencies travel long distances but have less bandwidth capacity, placing one television channel (which uses a lot of bandwidth) in the lower frequency bands would mean that most of the Long Wave and Medium Wave radio services from Northern Europe to Sub-Saharan Africa would be squeezed out.

Once a radio signal has been transmitted, it has certain propagation characteristics associated with its frequency. Propagation describes the behaviour of a radio wave in spectrum. In different bands, waves have distinct abilities to hop, spread and penetrate. Certain waves can go through or bounce off walls or curve around corners better than others. Table 1 describes the propagation characteristics of the radio frequency bands.

Table 1
Propagation characteristics of radio frequency bands

Frequency Band	Propagation mode (the way radio waves spread in spectrum)	Coverage
Very Low Frequency	Over the ground	Long distances, e.g. for submarine communications and time code signals.
Low Frequency	Over the ground and in the sky at night	Country-wide. Some reduction of coverage at night due to reflections from the ionosphere.
Medium Frequency	Over the ground and in the sky at night	Regions of a country. At night time, coverage is significantly reduced by signals reflected from the ionosphere.
High Frequency	Hopping between the ground and the sky	Long distance coverage to continents. A range of High Frequencies are needed to provide continuous coverage during the day and night and at different times of the year.
Very High Frequency	Line-of-sight, but for short periods, the wave enters the troposphere (the lowermost part of the Earth's atmosphere)	High-power broadcasting stations provide coverage up to around 50 to 70 km radius. For short periods of time, signals can propagate for long distances in the troposphere and cause interference between services on the same frequency.
Ultra High Frequency	Line-of-sight, and tropospheric for short periods	Similar range to VHF but requires many more filler stations to overcome obstructions to the signal arising from attenuation caused by terrain features.
Super High Frequency	Between focussed points with a line-of-sight	Needs a clear line-of-sight path as signals are blocked by buildings or other objects. Ideally suited for satellite communications and fixed links where highly focused antennas (dishes) can be used or for short-range coverage, e.g. inside buildings.
Extremely High Frequency	Between very focussed points with a line-of-sight	Short paths and with no possibility for penetrating building walls.

In order to understand how radio spectrum works, one more buzzword has to be remembered: modulation. Modulation is the actual process of encoding information in a radio signal by varying the characteristics (the amplitude, the frequency or the phase) of the radio wave. Simple examples of the resulting waves are illustrated in Figure 3.

Amplitude modulation (AM) is used to generate carrier waves for AM radio stations which cover large areas.

Radio services on long and medium waves (LF/MF), are carried by an amplitude modulated signal. Frequency modulation (FM) is used for FM broadcasting which provides better sound quality to AM radio but the signal does not travel as far as an AM signal.

Phase modulation (PM) and amplitude modulation is used to encode digital information (consisting of 0s and 1s) into radio signals. There are very complex advanced variants of these modulation techniques which allow for large amounts of digital data to be encoded or compressed into a signal.

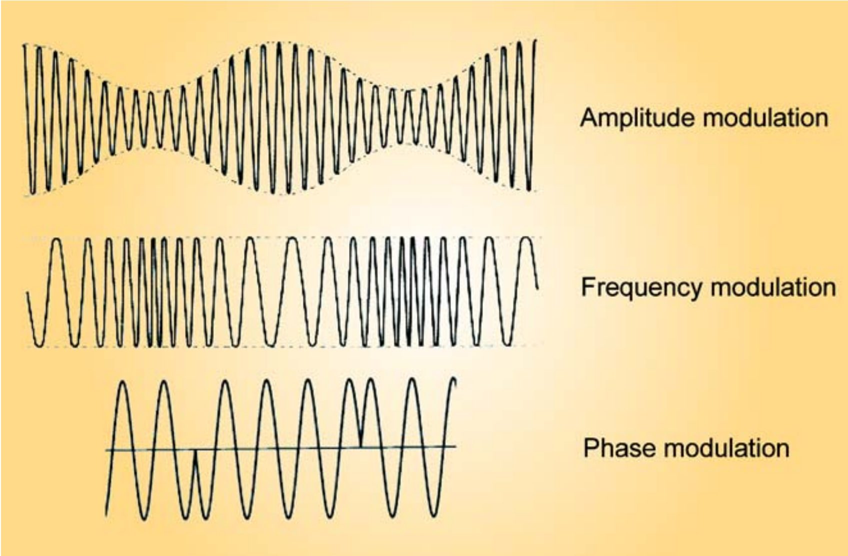

Figure 3
Types of radio wave modulation

International harmonisation

Radio waves do not respect international borders. Signals can cross boundaries easily. International harmonisation – to reduce the scope for unwelcome interference between one country and another – takes place at three levels:

- the International Telecommunication Union on a worldwide basis;
- the Conference of Postal and Telecommunications Administration (CEPT which brings together 47 countries) in Europe and, to some extent, the European Commission;
- a bilateral country-by-country basis

International harmonisation of spectrum bands for particular uses helps create valuable economies of scale. Harmonisation provides the prospect of a mass market with lower prices for the receiving equipment.

A major international planning conference (RRC-06) in the spring of 2006 agreed a harmonised plan (GE06) for digital terrestrial broadcasting in Bands III, IV and V for Europe, Africa and some adjacent countries. Almost all of the spectrum requirements of each country were met.

GE06 Agreement

The GE06 Agreement contains elements that offer flexibility to cope with future developments of digital technology including new systems. A number of these elements are also included in other agreements, such as the CEPT Agreement for the 1.5 GHz (MA02revCO07).

Such flexibility can be achieved by:

- The DVB T system itself which allows for a high number of system variants giving different data capacities that provide a range of picture qualities and for different reception modes (fixed, portable and mobile)
- The "envelope" concept introduced by the European (CEPT) countries. The idea is to consider the DVB-T and T-DAB standards as envelopes that define the interference caused by the digital transmission and the protection required by it. Planning is then carried out using these envelopes. Other terrestrial service or transmission systems can be used provided that such use does not cause more interference in any direction than would be

caused by the broadcasting assignment/allotment it replaces or require greater protection than would be given to the broadcasting assignment/allotment it replaces

- Allotment planning. In allotment planning nothing is known of the actual location of the transmitter sites, or of the specific transmission characteristics to be used. The only parameters available are: a definition of the area to be covered, the channel to be used and technical criteria to describe outgoing interference;
- Procedures for implementation of the Plan. The Article 5 'Notification of frequency assignments' of GE06 Agreement allows the implementation of a Plan entry with different characteristics, on the condition the "conformity check" has been fulfilled. The main criteria of the "conformity check" is that the interference from the implementation, calculated at numerous test points, is not more than that of the Plan entry.
- Procedures for modifications to the Plan. Article 4 of GE06 allows modifications of Plan entries or addition of new entries subject to agreement of potentially affected administrations. The Article 4 Procedures in the former ST61 Agreement (the analogue broadcasting plan of 1961), allowed the number of stations included in the plan to increase from the original 5300 stations in Bands III and IV/V to about 85 000 analogue TV stations.

Subsequently the World Radiocommunication Conference in 2007 (WRC-07) additionally allocated the 790 - 862 MHz Band to the Mobile Services for IMT systems. In the 790 - 862 MHz sub-band broadcasting and mobile services now have co-primary status.

The CEPT Special Arrangements

Within CEPT Europe the Wiesbaden Plan established in 1995 at Wiesbaden (WI95) provided two T-DAB layers on the basis of national requirements either in the 1.5 GHz band and/or VHF. At Maastricht 2002 one additional T-DAB layer was planned in the 1452 – 1479.5 MHz frequency band. Furthermore, a new Special Arrangement was established, namely the MA02 Special Arrangement.

Following the two planning conferences WI95 and MA02 a few countries had three T-DAB layers in the 1.5 GHz band and no T-DAB in VHF, most countries had two T-DAB layers in the 1.5 GHZ band and one VHF layer, while some only had one T-DAB layer in the 1.5 GHZ band and two VHF layers. The Band III layers were subsequently subsumed into the GE06 plan.

The flexibility necessary to implement new mobile multimedia services in the 1452 – 1479.5 MHz band within the framework of the MA02 Special Arrangement has recently been achieved by supplementing the MA02 Special Arrangement with additional regulatory and technical provisions specifically to allow for:

- other reception modes for T-DAB
- the application of an interference envelope concept similar to that in the GE06
- agreement on the possibility to aggregate T-DAB blocks in order to enable the operation of systems requiring a larger bandwidth

The new special arrangement was agreed at Constanta in July 2006 and is known as MA02revCO07. The WI95revMA02 Special Arrangement was also modified to contain only the provisions for DAB in the VHF bands I, II and the 230-240 MHz frequency band.

Analogue to digital – making more room in the spectrum

It is difficult to describe the "size" of the spectrum that is becoming available after analogue switch-off. Different parts of the spectrum accommodate different technologies in different ways. Generally, the spectrum scarcity of the analogue-only world is diminishing but not completely disappearing for the time being.

Some industry forecasters predict the creation of the "spectrum commons" where ubiquitous communication systems operate using cognitive or "smart" receivers which are able to distinguish and decode the different signals they receive using their propagation properties as identification tags. Spectrum scarcity would completely disappear and spectrum licensing would become redundant in this "utopian dream". At the moment, however, spectrum use is still heavily regulated to avoid chaos in the airwaves.

The terms "digital spectrum" and "analogue spectrum" often come up in debates and conversations but these words are somewhat misleading. There is just one kind of spectrum that can be used to provide both analogue and digital services. When people talk about "digital spectrum", what they really mean is spectrum used by digital technologies.

How many digital services can be fitted in the spectrum? This question is difficult to answer. It is like asking a farmer how many plants he can fit on his land. It depends if he wants to plant beetroot, raspberries or plum trees.

In analogue broadcasting, picture and sound information are carried by fluctuating radio signals and the receiver converts these fluctuations back into sound and picture. In digital broadcasting, information is transformed into digits (1s and 0s) and is carried by a radio signal to a receiver that can reproduce the original information by decoding this numerical chain. Digital compression technologies and coding systems make it possible to squeeze much more information into a radio signal than in the case of analogue technology.

A digital television multiplex – a machine which encodes, combines and transmits several television programme channels in a single broadcast signal – takes up 8 MHz bandwidth just like an analogue television channel. The difference is that, using digital compression technology, this one signal can carry the picture and sound information of not just one, but several television programme channels. That means that more television services can be provided using the same amount of spectrum as compared to analogue broadcasting.

This, however, does not mean that demand for spectrum is diminishing. There are many service providers who are eager to launch new services in the spectrum that is becoming available. Some of these new technologies, like broadband wireless access services or HDTV could prove to be quite intensive users of spectrum. While digitalisation definitely provides the foundation for more efficient use of spectrum, the room that is to be freed by analogue switch-off could potentially become very crowded indeed.

Spectrum availability

Spectrum that can be used in new and innovative ways is regularly becoming available as new technologies make more efficient use of the spectrum and obsolete technologies free up spectrum space.

Change is taking place in various frequency bands although, in some cases, analogue and digital technologies will co-exist for quite some time.

The AM broadcasting Bands

The Low Frequency (LF), Medium Frequency (MF) and High Frequency (HF) broadcasting bands (below 30 MHz) are still used in much the same way as they always have been since the birth of radio broadcasting over 80 years ago for Long Wave (LW), Medium Wave (MW) and Short Wave (SW) analogue broadcasting.

In common with other broadcasting bands there is an interest to take advantage of the opportunities and flexibility offered by digital broadcasting. The Digital Radio Mondiale (DRM) system has been developed to replace analogue amplitude modulated (AM) broadcasting in the LF, MF and HF bands. The DRM system embraces a family of compression modes which can be used to tailor the transmission characteristics to match the service requirements and radio propagation factors.

In a standard mode, the DRM system can deliver a far superior audio quality within the same bandwidth of a standard AM broadcast thereby achieving the important goal of improving the utilisation of the radio frequency spectrum. Various enhanced modes are also available which could be used to deliver stereo or dual language programming to replace a standard monophonic AM broadcast.

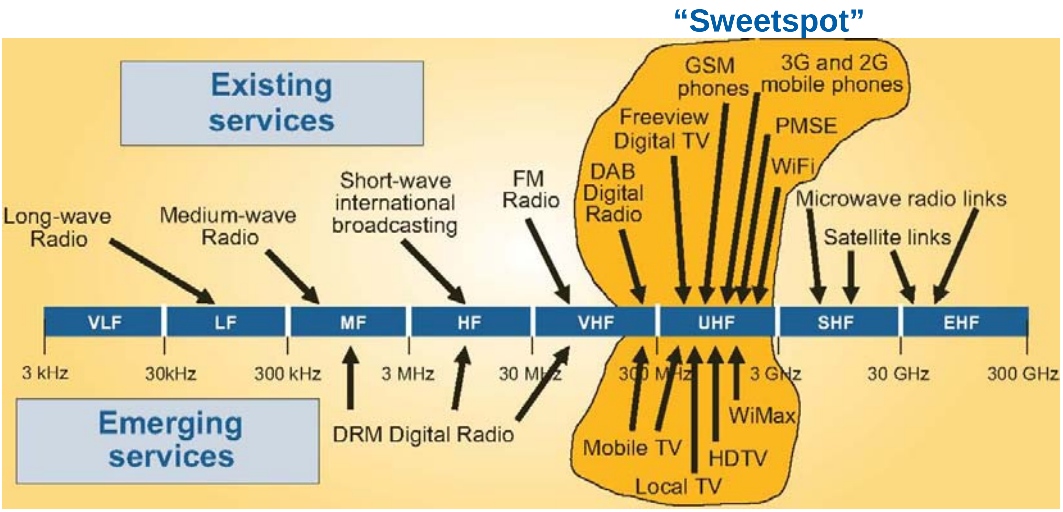

Figure 4
The "sweetspot" in the radio spectrum

A DRM station takes up the same bandwidth as an AM station, but offers improved sound quality and the ability to offer complementary data services. Current indications are that audio quality approaching mono FM on a portable receiver can be achieved within the existing co-ordinated and agreed channels. Therefore a single medium wave frequency can offer a single good sound-quality DRM service plus data, or two lower sound-quality services.

Generally, at least two medium wave frequencies are required to cover the whole of a larger country on AM, to avoid interference between adjacent transmitters, although it would be possible to cover the majority of the population with a single frequency. A number of AM filler transmitters on different frequencies (in addition to the high power frequencies) are required to achieve near-national AM coverage.

One advantage of DRM over AM is that DRM can use single frequency networks (SFNs), which means that rather than using two high-power frequencies plus a number of filler frequencies to cover a whole country, DRM signals on the same frequency at adjacent transmitters do not interfere with each other so DRM could cover the whole of a larger country with a single frequency. However, like AM, DRM on medium wave offers less good coverage in cities, particularly within steel-framed buildings. Nevertheless, the robust transmission characteristics and error correcting possibilities of DRM are particularly useful in overcoming the highly variable nature of radio wave propagation in the AM broadcasting bands.

Band II

A part of the Very High Frequency (VHF) band is used intensively for FM sound broadcasting; Band II (87.5 - 108 MHz) is widely used for FM sound broadcasting in most countries and planning of new analogue services is still being carried out although this is generally for a limited number of frequencies available for regional, local and community stations. In a few countries (including Russia) are still using this band for analogue television transmissions. Planning of this band in Europe is subject to GE84 Agreement.

The majority of radio listening today is on FM but this is changing. Some experts predict that over the next 10-15 years there may come a point where the vast majority of radio listening is done through digital platforms (including DAB/DMB and other platforms such as digital television and the internet). If and when this occurs the use of the VHF Band II spectrum might be considered for other applications.

Many of the currently known possible alternative uses for VHF Band II spectrum require the spectrum to be divided up in different ways from today. For example, a DAB or DMB multiplex requires 1.7 MHz of spectrum. Individual FM stations take up only 0.3 MHz of capacity, so unless many adjacent frequencies (both spectrally and geographically) were made available at the same time, allocation to other uses such as DAB or DMB would be impossible.

FM services may be superseded in the future by T-DAB services in other bands (either Band III or the 1.5 GHz band) or by other new digital technologies. However there is still planning and new allocation of FM services being carried out in Band II in many European countries. Therefore re-allocation of even parts of Band II cannot yet be considered.

It is foreseeable that also Band II will be used for digital audio services. However, it is too early to say which technology will be used in 10 years time. A possible candidate in addition to DAB, is DRM+, which is currently under development in the DRM Consortium and the specification is expected in 2009, at the earliest.

In some countries (France, Switzerland), IBOC (HD Radio) has been mentioned by small private radios as a possible technology for the replacement of FM. A system which makes use of AAC audio coding on a sub carrier in the FM signal is also being tested in some countries (e.g. the Netherlands, where FMextra is being tested).

Although there are regulatory provisions in WI95revMA02 for T-DAB in the 87.5 - 108 MHz band, this has never been implemented

Band III

Band III (174 - 230 MHz) is regulated by the GE-06 Agreement. At RRC-06 the band was planned for T-DAB and DVB-T. Most countries achieved three T-DAB and one DVB-T "layer". A number of countries plan to convert their DVB-T Plan entries into four T-DAB blocks and use Band III exclusively for DAB related systems (DAB, DAB+, DMB or DAB-IP).

Digital radio broadcasting in Europe can use the DAB family of standards – see Figure 5.

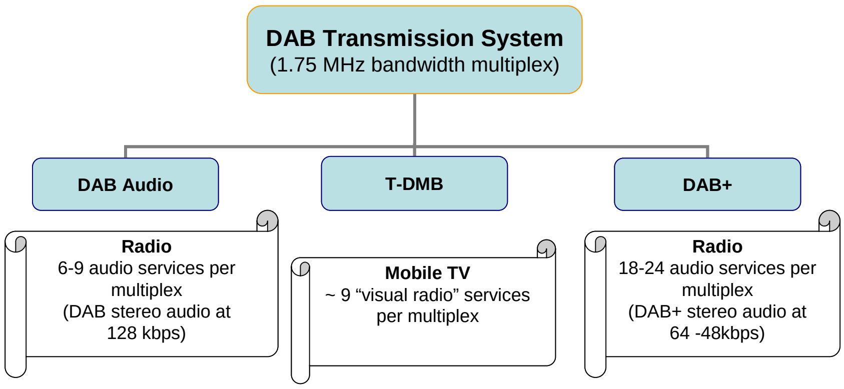

Figure 5
The DAB family

DAB, DAB+, DMB, DAB-IP are complementary and have been scaled for radio (DAB/DAB+) and mobile television broadcasting (DMB/DAB-IP). The DAB-IP variant is not shown in Figure 5 as it is almost identical in capacity to DMB, the major difference being that DMB uses MPEG-4 video and audio codecs whereas DAB-IP uses Windows Media codecs.

They all rely on the same DAB transmission layer and so can co-exist inside the same multiplex without compatibility problems. The introduction of these developments will vary from one country to another in terms of the timing and the choice of technology. Some countries are already in the process of adopting T-DMB for the provision of radio services. The ability of DMB and DAB-IP to carry video stream means they can both be used for radio with pictures (so called "visual radio")

It is currently considered that there will be no single winning standard for digital radio, DAB, DMB and even DVB may have a role. Clearly whatever mainstream system is adopted, DAB or DMB, in assessing the longer term needs it is necessary to allocate sufficient spectrum to broadcasting services to support technology upgrades. Radio broadcasters will move beyond audio-only to produce programme associated graphics and video content in order to play a key role as providers of multimedia content to digital platforms.

UHF Spectrum and above

The ongoing debate about spectrum availability in the UK is focussing on a "sweetspot" where most modern communication technologies such as DAB Digital Radio, digital television, 3G mobile phones and WiFi wireless Internet access services operate. The sweetspot, in fact, is the upper part of the Very High Frequency (VHF) band and the whole of the Ultra High Frequency (UHF) band, incorporating frequencies from around 200 MHz to 3 GHz as illustrated in Fig. 4.

The UHF band includes four named sub-bands: Band IV, Band V, L-band and S-band as shown in Figure 6. These sub-bands also differ from each other in certain characteristics, and uses are not necessarily interchangeable between them.

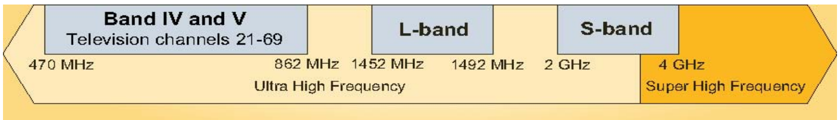

Figure 6
Sub-bands in the Ultra High Frequency Band

UHF Band IV/V is divided into 49 channels. Forty six of them are currently used for both analogue and digital television broadcasting in the UK.

After digital switchover, the six existing television multiplexes will occupy 32 channels. The "digital dividend", the spectrum to be afforded by analogue switch-off, will be equivalent to 14 spectrum television channels, each containing 8 MHz bandwidth. The total spectrum becoming available during the digital switchover process from 2008 through to 2012 will be 14 x 8 MHz = 112 MHz. Figure 7 shows what will become available in Band IV/V after digital switchover.

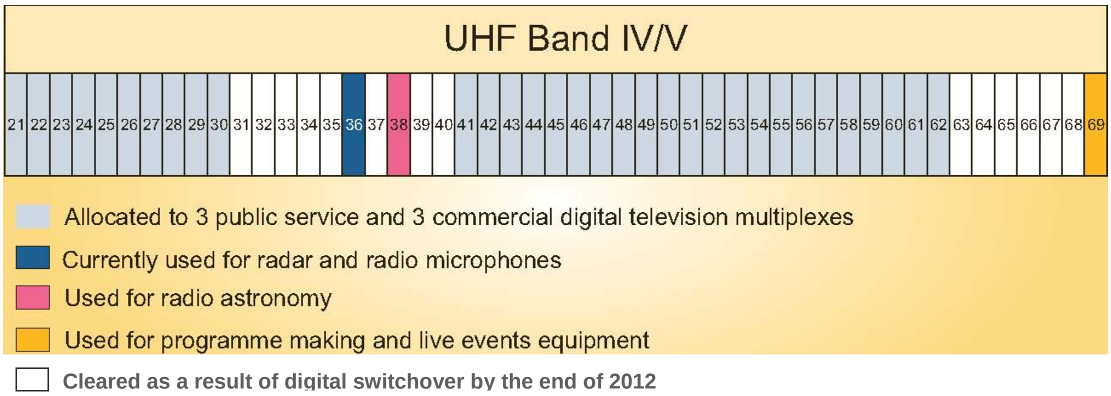

Figure 7
Spectrum availability in UHF Band IV/V in the UK

Public attention heavily focuses on the "digital dividend" as it can host a number of new and innovative services such as high-definition television, mobile television or broadband wireless access services. Ofcom is consulting on the possible uses of the "digital dividend" and is examining options to make some of the released spectrum available for other uses on a rolling basis, region by region, from late 2008 – the start of the switchover process.

Some other parts of the spectrum have become available sooner. The whole 40 MHz of L-band, was recently awarded to 'Qualcomm UK Spectrum Ltd' by an auction process for multimedia services such as mobile television, wireless broadband and satellite radio. There may be further scope for harmonisation of this band at a pan-European level.

UHF Channel 36 (until recently used for radar and radio microphones in the UK) is being considered to be released for other uses. Potential contenders for this spectrum could be mobile television, broadband wireless access and terrestrial digital broadcast services.

Competition or co-habitation?

Just as certain types of plants are best grown on particular types of soil, not all technologies are suited to all frequency ranges. Certain services may be more suitable for particular frequency bands. This may be because:

- Different services have different needs. Broadcasting, for instance, is a one-way communication: the transmitter sends a signal to the receiver. Mobile phones or WiFi devices have to "talk back" to the base station to upload as well as download information, so they need frequencies to enable this two-way communication to take place.

- The propagation is different in each frequency band. Higher frequencies can provide more rugged signals for mobile communication devices than lower frequencies. Mobile phones usually work on trains or inside buildings due to the construction of dense base station networks which are needed to provide the link from the low power mobile phone to the base station. Try to use an FM radio on a train; it probably won't work very well because the metal structure of the carriage blocks the FM signal.

- Different constraints exist on transmitter and receiver equipment design. Bigger antennas are needed to receive the signal on lower frequencies while higher frequency signals can be detected by smaller antennas. Think of your FM kitchen radio or your HiFi set at home which needs a fairly long antenna to get good reception (sometimes a rooftop aerial has to be plugged into the HiFi). Early GSM mobile phones also needed extendable antennas. Your 2G or 3G mobile phone, on the other hand, operates with a very small antenna; in most cases you can't even see it as it is hidden inside the phone.

- Moving a service from one band to another might require users to re-tune or to change the receiving device. This could undermine the sustainability of the service given the vast quantities of television and radio receivers in people's homes.

- Different international co-ordination puts constraints on different bands. (As discussed earlier)

These considerations influence the way in which different technologies are deployed. Nevertheless, some technologies have more possible outlets than others. Figure 7 indicates the different bands that could, in theory, be used to deliver a range of services.

Mobile television technologies can be deployed in several bands. DAB-based services have been optimized for Band III or the L-band, while DVB-H is designed to operate in Bands III, IV and V or even the L-band. Companies wishing to provide such services will have to examine their options carefully regarding both the technologies and the bands. Acquisition of spectrum in more heavily used bands, like Band IV/V, could prove too costly to make it an affordable service.

DMB-based mobile television services can co-exist with radio services on national, regional and local T-DAB multiplexes. They operate in Band III at present, and some capacity might be available for mobile television on the existing multiplexes. It could be used for both radio and mobile television services.

DVB-H mobile television services can be accommodated in Band IV/V. For example, in the UK, Channel 36 (until recently used for radar and radio microphones) could be assigned to mobile television as well as a few other channels which will be available as part of the "digital dividend" after digital switchover.

Local television providers could put further demand on Band IV/V as they can operate in the spectrum interleaved regionally between the channels used by national DVB-T multiplexes. But interleaved spectrum could also be used to enable Programme-Making and Special Events (PMSE) equipment and WiMax broadband wireless access services to operate in Band IV/V.

Programme Making and Special Events[2] (PMSE) is an important application for broadcasters who require good communications facilities at concerts, theatres, film and recording sets and for live broadcasts. PMSE equipment includes cordless microphones, cameras and other cordless devices. These devices can operate in various spectrum bands and can be interleaved between existing other services due to their low radiated power, thus making efficient use of the spectrum. Their signal reaches just a few meters, with very little chance to interfere with other similar devices. However, they still need their well-defined spectrum space so that other technologies do not interfere with them.

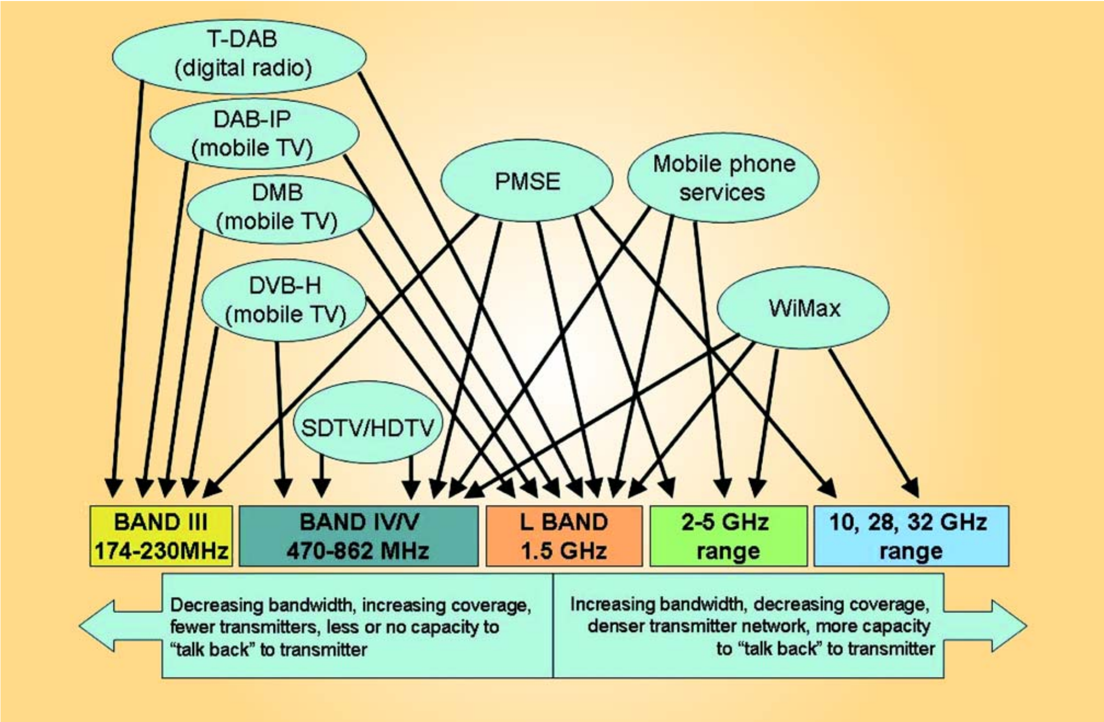

Figure 8
Alternative frequency bands for digital technologies

WiMax providers might seek to secure channels in Band IV/V for broadband wireless access services. Here, however, there has to be a trade-off between how many users can be supported in a cell, the available data transfer rate and the number of network providers.

The use of Band IV/V could make the coverage area (the cell size) bigger, due to these constraints, the channels in this band might only be required as a way of delivering WiMax services to remote rural communities where the number of users per cell could be relatively small. The proponents of WiMax have until recently seem to favouring higher frequencies such as the 2.5 and 3.5 GHz or the 10, 28 and 32 GHz bands (the latter bands only support short range indoor reception). Band IV/V, however, could improve in-building penetration of wireless access services as building penetration losses are lower at the lower frequencies.

[2] Also known as SAB/SAP (services ancillary to broadcasting and programme making) in Europe

Mobile phone services could also use Band IV/V and providers are interested in the 790-862 MHz band also allocated to broadcasting and mobile at the World Radiocommunication Conference in 2007 (WRC-07), particularly for providing coverage in rural areas and inside buildings. However, there are compatibility issues concerning sharing with broadcasting services and these are being studied. There is also a 190 MHz expansion band at 2.5 GHz which is harmonised throughout Europe for mobile phone and wireless access services.

The L-band (also known as the 1.5 GHz band) can support a number of different approaches. Propagation in this band could provide better conditions for mobile users. Radio signals in L-band go through windows and can benefit from reflections, particularly in built-up areas, so they can reach receivers "on the move" (on trains, buses etc.). But the networks would require more transmitters and therefore the infrastructure could involve higher costs.

Competition for spectrum seems to be inevitable as market players try to capture opportunities to launch new services.

Conclusions

Deploying technologies in the radio spectrum is a complex decision that takes many different factors into account. Technology design, efficient use of bandwidth, availability of spectrum for alternative deployment options, the cost of acquiring spectrum, end-user demand, availability of receiver equipment, investment in infrastructure and many other technical and market conditions have to be examined to make an appropriate judgement.

The scope for new services to be made available in many parts of the spectrum is exciting. But that adds to the challenges facing those responsible for national spectrum planning. How should national regulators balance the advantages and disadvantages of:

1. requiring that certain services are provided in those parts of the spectrum which, in technical terms, would be the most appropriate;

2. allowing the market, rather than the planners, to determine our future uses of the spectrum; and

3. meeting Government objectives to provide public services to consumers in a way which allows them to be received universally on the existing base of consumer equipment?

If regulators preferred market forces to determine how spectrum should be used, how should they take account of the social value of certain services – radio broadcasting is a classic example – whose value to society cannot be set entirely in financial terms?

Spectrum scenarios can be developed for the time after analogue broadcasting ends. How can spectrum planning at a national level take account of innovation – indeed, of services that do not exist today? We live in a world still driven by Moore's Law (in the 1970s Gordon Moore forecast that the processing power of computers would double every two years). iPods and WiFi, growing in use so quickly today, were virtually unknown six years ago. What new services will take over the world by the time that analogue broadcasting ends?

Abbreviations

CEPT	Conférence Européenne des Postes et Télécommunications (European Conference of Postal and Telecommunications Administrations)
DAB	Digital Audio Broadcasting (Eureka-147) http://www.worlddab.org/
DMB	Digital Multimedia Broadcasting http://www.t-dmb.org/
DMB-T	DMB - Terrestrial
DRM	Digital Radio Mondiale http://www.drm.org/
DVB	Digital Video Broadcasting http://www.dvb.org/
DVB-H	DVB - Handheld
DVB-T	DVB - Terrestrial
ITU	International Telecommunication Union http://www.itu.int
PMSE	Programme-Making and Special Events
SDR	Software Defined Radio
SFN	Single-Frequency Network
T-DAB	Terrestrial - DAB