Ideas on migration from analogue to DVB-T – in the European Broadcasting Area

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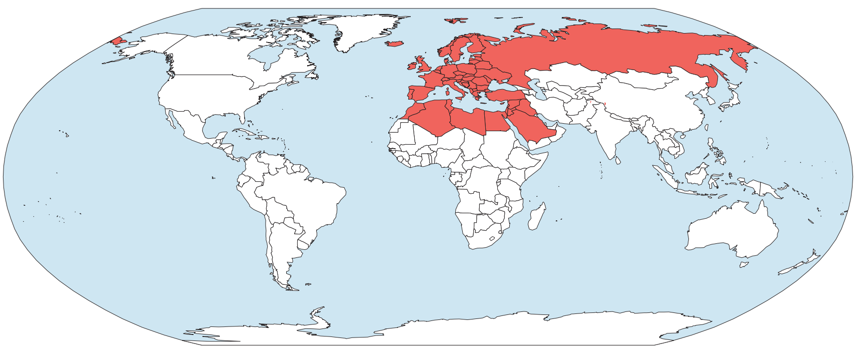
Terrestrial digital television (DVB-T) is now being launched in a growing number of European countries. However, this is only a start in what will be – for some years to come – a mixed analogue and digital environment, where the basis for planning is from an "analogue world".

This article provides some ideas on how migration from analogue to terrestrial digital TV may be achieved. It is hoped that new ideas will be stimulated and developed as a result.



Countries belonging to the European Broadcasting Area, in a global context.

In order to exploit the many opportunities offered by DVB-T, whilst at the same time maximizing the effective use of the available broadcast spectrum, it has been agreed that an all-digital frequency plan is required for Europe. To this end, it is expected that a conference will be convened by the ITU in around 2005, for those countries belonging to the European Broadcasting Area.

As yet, no definitive proposals have been made as to what is required from the all-digital plan. However it is clear that the future requirements for DVB-T can include fixed, portable and mobile reception, interactivity, multimedia, vision, sound, data services and higher-definition television. The number of multiplexes, the level of coverage and the requirements for national, regional and local services will be different for each country in Europe. In this respect it seems likely that any European all-digital plan will essentially be a framework into which individual countries can develop their own national sub-plans.

Furthermore, the new plan will have to consider how to achieve the migration of services to a digital form, without either disrupting millions of viewers or creating a non-equitable distribution of resources between countries.

This article is based on a report currently being produced by EBU Project Group B/MDT (Migration to Digital Terrestrial). The article provides some ideas on where we are now, where we want to be, and the mechanisms that might be employed in the migration to the all-digital world. Some consideration is also given to network structures and issues relating to the consumers of broadcast services. It is hoped that new ideas will be stimulated and developed as a result.

It must be emphasized that there is a range of options for most of the issues covered in the article. It is not the intention to make any decisions or recommendations at this stage. These can only be developed as and when it becomes clearer what the vast majority of countries in Europe require from their future digital services.

1. DVB-S and DVB-C penetration in Europe

In the world of television broadcasting, digital technology has brought us, among other things:

- ⇨ better video and audio quality;
- ⇨ a much higher choice of programmes;
- ⇨ numerous added services (data transmissions, interactive programmes, pay-per-view facilities, etc.);
- ⇨ more efficient usage of the frequency spectrum;
- ⇨ a more rugged system against interference.

However, in the European marketplace, the penetration of cable and satellite digital television – using the DVB-C and DVB-S standards, respectively – has differed greatly from country to country, as shown in *Fig. 1*.

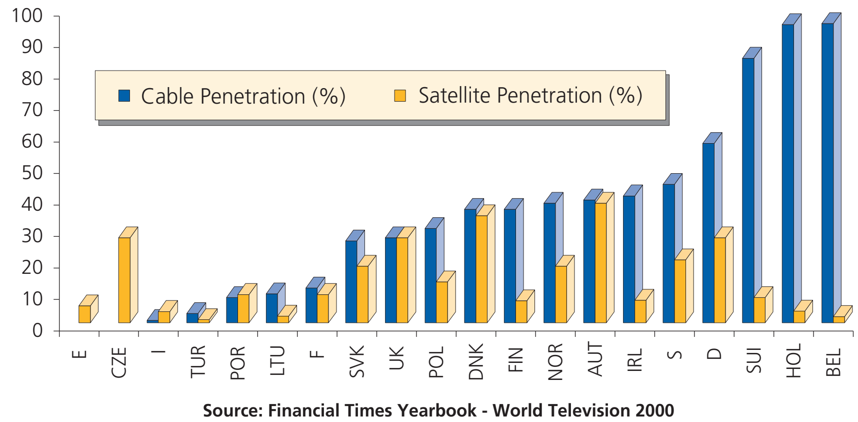


Figure 1
Penetration in Europe of DVB-C and DVB-S.

(Please note that market penetration data can vary from source to source and therefore the values given in *Fig. 1* must be taken as indicative only).

The DVB project has now brought digital technology to *terrestrial* television broadcasting, with the DVB-T standard. The future penetration rate for DVB-T services in Europe is also likely to vary greatly from country to country. However, before the broadcasters can really get to grips with migrating from analogue to digital terrestrial television, it is widely agreed that a new all-digital frequency plan is required for the European Broadcasting Area.

2. Revision of the Stockholm Plan

2.1. Background

The foundation for all television planning in Europe is the Stockholm Plan of 1961 – known as ST61 [1]. In general terms, the Stockholm Plan provided the possibility of three programme coverages in each country, although some countries had a target of four programmes. Since 1961 two major developments have taken place. The first is the building of many thousands of low power relay stations to fill in coverage holes, and the second is the introduction of new networks, usually with less than national coverage, but with a commercial target.

Obviously, no provisions were made in the Stockholm Plan for the introduction of digital television. Within "CEPT Europe" (*Fig. 2*) this has been facilitated by means of the Chester 97 Agreement [2] on the criteria and procedures to be used in the initial introduction of digital television in Europe.

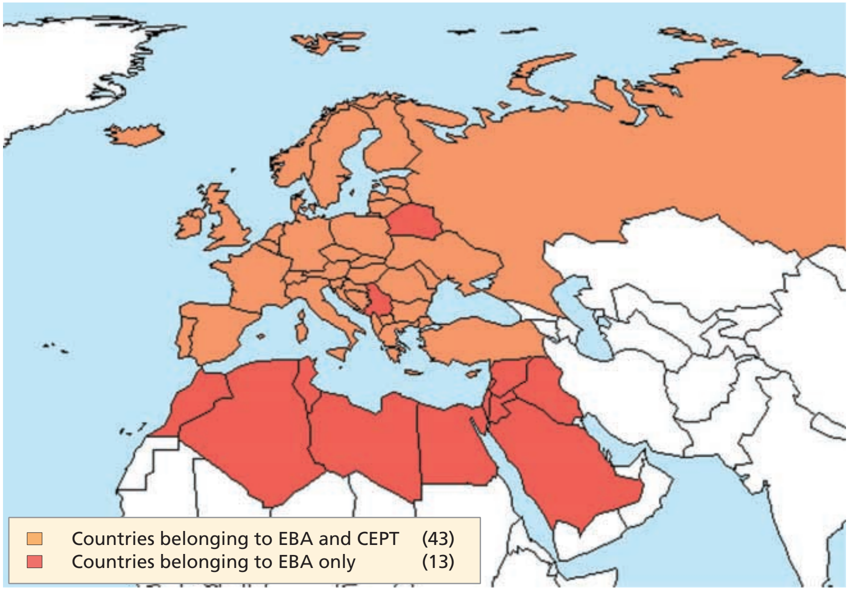


Figure 2
Countries belonging to EBA and CEPT.

The Stockholm 61 Plan and the Chester 97 Agreement are by no means ideal to meet the objectives of a

1. ITU, 1961. Final Acts of the European VHF/UHF Broadcasting Conference, Stockholm, 1961. International Telecommunication Union, 1961.

2. CEPT, 1997. The Chester 1997 Multilateral Coordination Agreement relating to Technical Criteria, Co-ordination Principles and Procedures for the introduction of Terrestrial Digital Video Broadcasting (DVB-T). CEPT Multilateral Co-ordination Agreement, 1997.

fully-digital broadcasting scenario, since they were designed for an “analogue world”. In order to make the most efficient use of the available spectrum and to release the full potential of digital television services, it is now been agreed by the majority of countries in the EBA that, in the middle part of this decade (2005 is proposed), there should be an ITU Planning Conference to replace the Stockholm 1961 Plan (ST61).

2.2. The new plan

The new plan will need to deal with the development of digital services in the absence of the constraints imposed by the transmission of analogue signals and the need to protect them from interference. It is not reasonable to consider that the conference will establish, once and forever, the all-digital environment. Rather, it will set the framework within which development can take place. Neither ST61 nor the GE84 [3] broadcasting plans represented the final words on radio and television planning and service development, and there is no reason to suppose that any new plan will do so either.

Furthermore, the new plan will have to consider how to achieve the transfer of services to a digital form without either disrupting millions of viewers (and listeners as well, as T-DAB is likely to be involved), or creating a non-equitable distribution of resources between administrations. In this respect, the process is different to previous conferences in that the new services need to be introduced into bands where existing services need to be maintained in the near future.

The equitable distribution of spectrum is likely to be a major political issue as not all countries will want to, or be able to, “move” at the same speed. Special solutions will be required in national border regions where countries which do not move at the same time. It could be argued that one of the primary tasks for the conference will be to ensure that any difficulties are only temporary and, probably, that they affect to a greater extent the country which wishes to move first. (In any case, the topic will lead to a great deal of discussion!).

3. Service requirements for an all-digital plan

3.1. Future broadcasting

DVB has added many services to the television domain: Internet, e-mail, data services, etc have been added to the traditional sound and video transmissions. Consequently, it is not just television that is being offered, but a package of multimedia services.

3. ITU Regional Administrative Conference for FM Sound Broadcasting in the VHF band (Region 1 and certain countries in Region 3) (2nd session), Geneva 1984.

Figure 3
Portable DVB-T reception on a multimedia terminal (Nokia) – combining television, Internet and mobile telephone technologies.

The same evolution is happening to GSM mobile services and the new generation of mobile phones (G3 – UMTS) which will also provide added services such as Internet, video, sound, data etc.

Manufacturers are preparing new-generation terminals to receive this convergence of services (see *Fig. 3* as an example). Hard disks are becoming very cheap and their performance now facilitates the *recording* and *replay* of video at the same time. Also, additional services, including interactivity, are being integrated in the new terminals.

In the near future, service providers and broadcasters will have a wider choice of delivery mechanisms – terrestrial, satellite and cable (see *Fig. 4*). The success of this diversity of communication systems will depend on the technical performance, the cost, the simplicity and the content (quantity and quality).

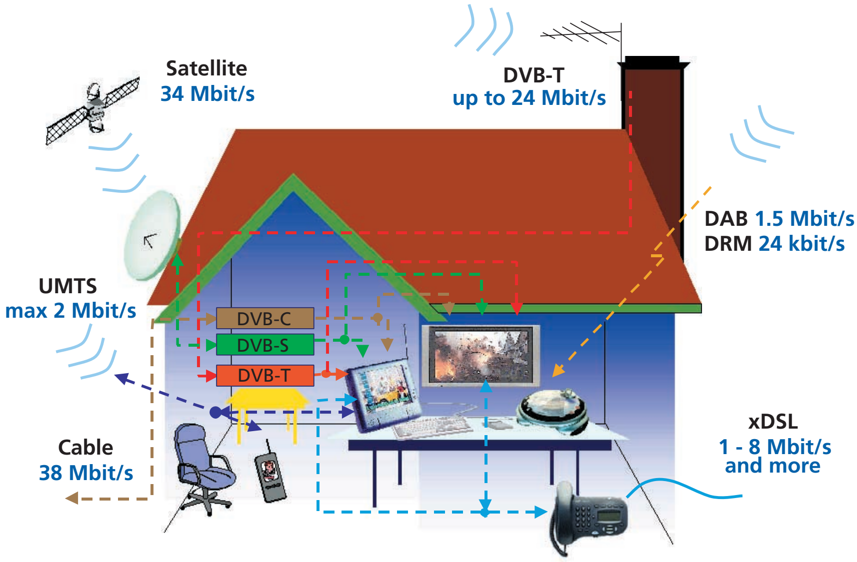
3.2. Main drivers for the introduction DVB-T

The main drivers for the introduction of DVB-T in Europe differ also from country to country. They can be summarized as follows:

- ⇨ **Additional services**: the increase of number of programmes transmitted in the same frequency band and the introduction of new types of services make digital technology very attractive for most of the countries. (EPG, teletext, interactive services (home shopping, home banking…), e-mail, internet, etc…).
- ⇨ **Portability**: for those countries where cable is the television market dominant, portable indoor reception offers and excellent opportunity for second and third television sets in a house. In that case, reception with simple antennas and minimal installation cost is required.

Figure 4
Multimedia services to the home – with a choice of delivery mechanisms.

(NB: the bit-rates shown on the diagram are typical, and not exact, for each of the delivery methods.)



- **Widescreen**: 16:9 digital, in conjunction with 14:9 analogue simulcast, is seen in some countries as an attractive and important differentiating factor because it provides a highly visible new element in a world dominated by a multiplicity of channels. Even the 14:9 (simulcast) analogue version offers a continuing good advertisement for widescreen digital.

Other drivers for DVB-T in Europe are:

- Re-use of the analogue spectrum that may potentially be released. Due to the multiplexing capabilities and the possible use of SFNs (which are described in *Section 8.2*), DVB-T may allow spare capacity to be released for other commercial activities. However, at this time it is difficult to be precise about the amount of spectrum (and its location in the frequency bands) that might be realized. In any case, it will be unlikely to happen before the analogue switch-off and it will highly depend on the network requirements of each country.
- Better quality picture: some countries have also shown interest in the high picture and sound quality, and the capacity for advanced television features such as widescreen and high-definition television (HDTV), that digital transmission can also deliver.

During the transition period, it is inevitable that the new digital services must be made attractive to the customers, in order to encourage them to equip themselves with digital receiving equipment. In some countries, the key of this encouragement would seem to be an increase in the number of programmes and also the quality and diversity of the audiovisual content on offer.

There is no clear trend in Europe concerning pay-TV or new free-to-air programmes. Some countries are launching DVB-T based on pay-TV channels only, some countries are looking for free-to-air bouquets whilst other countries will propose offers with a mix of pay-TV and free-to-air programmes. Concerning pay-TV, there seems to be widespread success with pay-per-view programmes.

In order to make their offer attractive, broadcasters are proposing a large variety of programmes: sports, cinema, news, culture, entertainment, children channels, etc.

Interactive services are also part of all the digital offers:

- EPGs;
- teletext and other programme-related services (as downloading files, etc.);
- Internet access;
- e-mail;
- home shopping;
- home banking;
- etc.

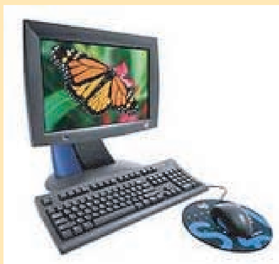
Interactivity, portability and mobility seem likely to be the main drivers of the introduction of DVB-T in Europe. However, DVB-T also has an important and complementary role in the delivery of fixed services where connection to cable and satellite systems is not possible or convenient.

3.3. *Existing known requirements*

By looking at the existing known terrestrial digital television (DVB-T) requirements for a number of countries in Europe the following requirements have emerged:

- the typical number of multiplexes at the launch of DVB-T services is in the range three to six;
- whilst population coverage in excess of 90% is desired, figures upwards of 50% may be considered sufficient for the launch of DVB-T services;

Large flat-panel display



Small flat-panel display connected to a computer

Conventional television

Figure 5
Fixed reception via satellite, cable and terrestrial channels.

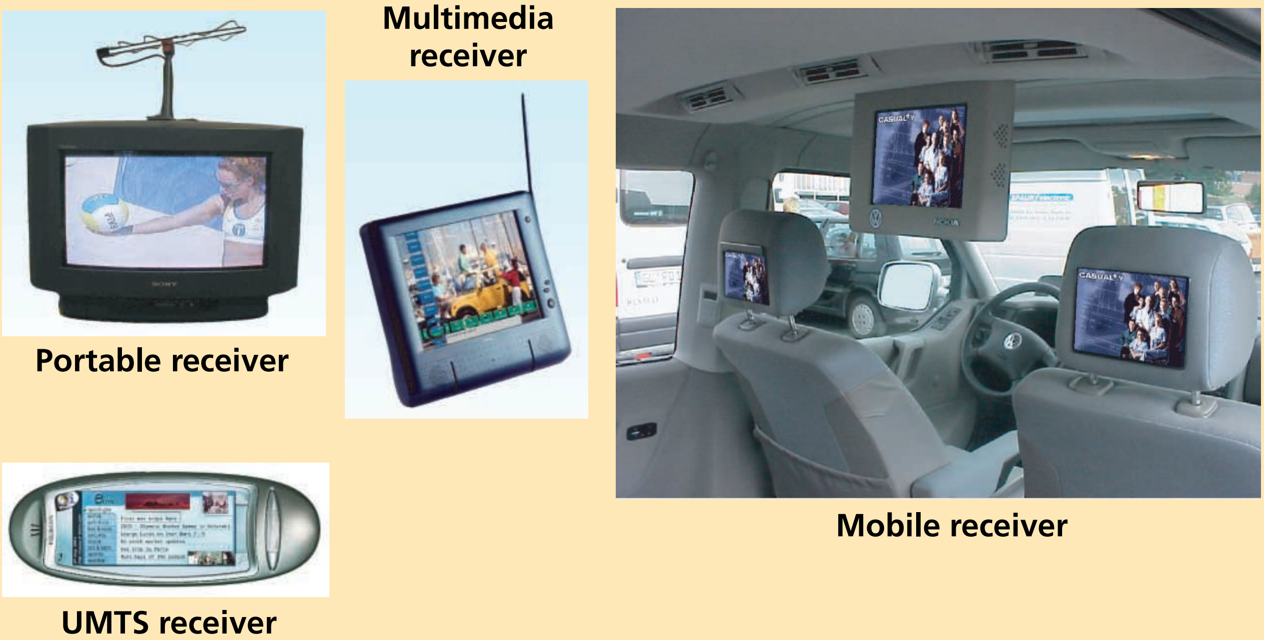


Figure 6
Portable and mobile receivers for terrestrial transmissions only.

- ⇨ reception conditions include fixed, portable and in the future mobile (see *Figs. 5 and 6*);
- ⇨ interactivity is important;
- ⇨ high-speed delivery of internet data may be a future application;
- ⇨ the extent of coverage may vary between services.

3.4. National situations

It is widely recognized that national situations differ because of:

- ⇨ different market drivers;
- ⇨ different frequency availability;
- ⇨ different network topologies;
- ⇨ different timescales.

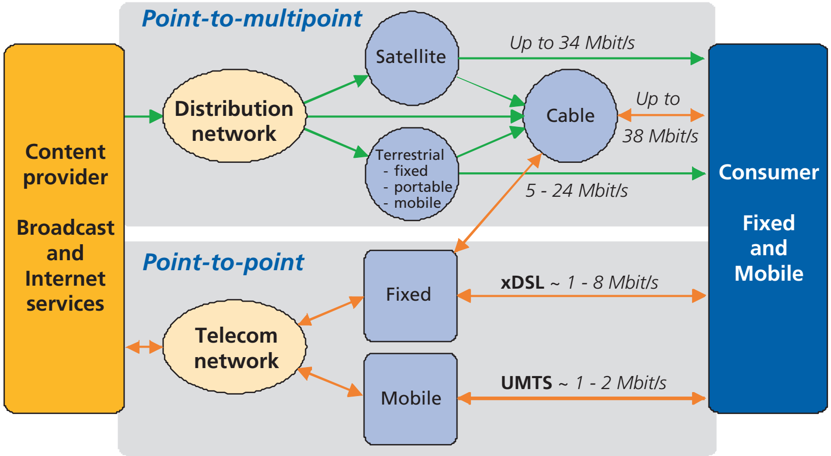
In other words, geography, history, politics and economics all have major effects on both the type of service required and the timescales for the introduction of digital services.

3.5. Convergence of services

Looking towards recent developments emerging from DigiTAG [4] members, it is becoming apparent that there are developments in the field of multimedia [5]. This

Figure 7
Convergence of broadcast and telecom services.

(NB: the bit-rates shown on the diagram are typical, and not exact, for each of the delivery methods.)



can be seen as part of the convergence process within an integrated hybrid network environment. For instance it has been proposed that DVB-T is particularly suitable for mobile Internet access because DVB-T can have a much higher data capacity (10 - 15 Mbit/s) than today's "conventional" Internet access in the home. It is considered that very fast web surfing, very fast downloading of large files (e.g. high resolution pictures or software upgrades) and streamed high quality video/ audio can all be offered using the same system and terminal. There are two issues to be considered in this respect; firstly, the trade-off between the data capacity used for video and the data services using the same multiplex. Secondly, because this is a point-to-multipoint transmission, all viewers of a given transmitter receive the same data.

All of these services can be combined with conventional DVB-T services – television and Internet within the same signal and system. Furthermore, the opportunity for interactivity embraced by DVB-T can provide interaction between the broadcaster/ service provider and the viewer. This type of interactivity requires a return link (low capacity channel of 1 kbit/s). For broadcasters planning their bouquets on pay-TV and interactive programmes, a return link connection is crucial to their business plan.

An overview of network convergence between broadcast and telecom services is shown in *Fig. 7*.

As far as the consumer is concerned, it has been predicted [6] that by 2015 we can expect the majority of Europe's adult population and many teenagers and children to be equipped with a personal communicator. It is expected that a significant proportion of these devices will be capable of receiving broadcast television and that the customer will want the service to be delivered to them, when and where they want it (assuming that they will be prepared to pay for it!)

4. Information concerning DigiTAG activities can be found at **http://www.digitag.org/**
5. Multimedia can be defined as "services arising from the convergence of computing, communications and established media".
6. No. 8 Report from the UMTS Forum: "The Future Mobile Market Global trends and developments with a focus on Western Europe" – **http://www.umts-forum.org/reports.html**

3.6. Issues for spectrum planners

In terms of the issues that will affect the way we plan networks for the all-digital world, it seems that portable and mobile reception (not necessarily at high speed in vehicles) is likely to be a key feature of DVB-T networks in many countries and that the return path (DVB-RCT [7]) is very important.

Whilst the return path might be conveniently provided by GSM or UMTS, there might also be the opportunity to provide these services within the broadcast bands. The practical implementation of the in-band option has been studied by the EU-funded INTERACT [8] project. Further consideration of this may also be found in EBU BPN 024 "The Return Channel for Interactive DVB-T".

As previously mentioned, by 2015 it is predicted that a large proportion of the population will have their own personal communicator – broadcasters could (or should) provide a high capacity input to these devices. This raises a number of questions:

- ⇨ Will the streaming of data services over DVB-T have an impact on the planning criteria? (It should be noted that there will be licensing and cost issues for Governments to consider.)
- ⇨ Will a cellular approach be necessary to supplement the coverage and capacity of existing broadcast networks?
- ⇨ How do we provide a European frequency plan in about 2005 that will meet the needs of 2015 and beyond?

3.7. Initial conclusions

It can be concluded from the discussions above that the future requirements for DVB-T are likely to include fixed, portable, and mobile reception, interactivity, multimedia (one definition for which is given in the footnote to *Section 3.5*), vision, sound, data services and higher-definition television. Furthermore, the number of multiplexes, the level of coverage and requirements for national, regional and local coverage will be different for each country in Europe.

This leads to the question: *"What level of consensus will there be on planning parameters across the whole of the European Broadcasting Area?"*

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7. Details of DVB-RCT will soon be available at: **http://www.dvb.org/standards/index.html**

8. INTERACT subsequently became iTTi and is now WITNESS at: **http://www.rte.ie/about/witness/project.html**

One option would be to specify and agree to a common set of coverage requirements (as is implied in ST61). However, as already indicated, within a country there may be multiple service requirements for, say, conventional broadcasting in part of the spectrum and multimedia services in the rest of the broadcast spectrum. In this case, it may be preferred to devise a framework in which each country could develop its own requirements whilst protecting the services in neighbouring countries.

4. Frequency bands

The frequency bands to be used for digital television are Band IV (470 to 582 MHz) and Band V (582 to 862 MHz). Nevertheless, not all of this spectrum is actually available for television broadcasting by all European countries. For example, channel 38 (606 to 614 MHz) is used in a few countries by Radio Astronomers and, in others, the channels above 60 (790 MHz upwards, that is channels 61 to 69) are used for military services.

There are also indications that the use of Band III (174 to 230 MHz) is being considered in some countries. Band III is particularly suitable for mobile services, although within this band there are several channel/frequency assignment arrangements, including the use of 7 MHz and 8 MHz bandwidth channels. The move to a uniform 8 MHz channel raster presents a long-term challenge due to the existing complex situation.

A further consideration in Band III is its use for T-DAB. Whilst the frequency band from 174 to 216 MHz is primarily used for terrestrial analogue television, there are some T-DAB allotments in this band. The frequency band 216 to 230 MHz (240 MHz in some countries) is mainly allocated to T-DAB in CEPT Europe; nevertheless there is still widespread use of part of this band for television, particularly in Central and Eastern Europe.

In order to meet the future needs of digital television and T-DAB in Band III, there will need to be a complete split of Band III between digital television and T-DAB, or some form of sharing of the available channels between these two services. Perhaps one approach to the revision of ST61 would be to plan DVB-T from the lower frequencies up and T-DAB from the top channels down. This topic will need considerable study.

5. Planning Parameters

5.1. Reception conditions

During the transition period, a number of European countries are planning their DVB-T transmissions for fixed-antenna reception. Fixed-antenna reception is defined as reception where a directional receiving antenna, mounted at roof level, is used. In other countries, where there is a high penetration of cable and satellite services, portable in-door reception is the principal requirement. Portable in-door reception is defined as reception where a portable receiver with an attached or built-in antenna is used indoors at no less than 1.5 m above floor level, in ground floor rooms, and with a window in an external wall

In those cases, portable in-door reception of DVB-T provides an opportunity for second and third television sets. Portable reception is mainly aimed at urban areas.

Currently it is not foreseen that there is a requirement to plan for mobile reception (defined as being the reception of a DVB-T signal while in motion, using an omnidirectional antenna situated at no less than 1.5 metres above ground level) during the transition period.

5.2. Number of multiplexes

The number of programmes-per-multiplex depends on the DVB-T system variant, on the definition quality required and on the programme content. It varies from 4 to 6 programmes-per-multiplex, assuming the two most common system variants used in Europe, namely 64-QAM 2/3 and 16-QAM 2/3.

The total number of programmes required to build the digital terrestrial bouquet varies from country to country. In some countries, around twenty programme services are considered to be necessary in order to provide sufficient variety to make the DVB-T service attractive to the viewer.

5.3. DVB-T variants

The DVB-T Standard allows for QPSK, different levels of QAM modulation and different code rates to be used to trade-off bit-rate against ruggedness. The system also makes allowance for two-level hierarchical channel coding and modulation, including uniform and multi-resolution constellations.

Currently, 64-QAM 2/3 is the variant most commonly used. This variant provides a high data capacity, 20 to 24 Mbit/s, but it does provide less rugged services and is particularly sensitive to self-interference effects in large-area SFNs. It is chosen by countries planning for fixed-antenna reception, the reception mode that requires the lowest minimum median field-strength values. Only a few countries planning for portable indoor reception have chosen this variant.

The system variant 16-QAM 2/3 has been chosen by countries planning for portable indoor reception. This variant has a moderate data capacity at 13 to 16 Mbit/s.

Another system variant, QPSK 2/3, has been included in many DVB-T studies. This variant provides a low data capacity, 6 to 8 Mbit/s. The main interest of this modulation may be for portable and mobile networks, or in order to have coverage that needs to be very rugged. However, it is not clear if there is a real demand (either now or in the future) for this type of network.

The high bit-rates mentioned above (i.e. 24 Mbit/s, 16 Mbit/s and 8 Mbit/s) can be achieved by using shorter guard intervals. However, this makes the transmission less resistant to delayed images, even in an MFN structure (which is described in *Section 8.2*). In an SFN network structure (also described in *Section 8.2*), this may not be acceptable, particularly for medium and large areas.

Code rates other than 2/3 can be used: 1/2, 3/4, 5/6 and 7/8 (DVB Standard). The code rate 1/2 offers a low capacity but very rugged systems. The variants using code rates higher than 3/4 offer additional capacity but may be not worthwhile as the system becomes less rugged. For code rates 5/6 and 7/8 the implementation margins may also be higher than expected making those variants even less attractive.

OFDM

The number of carriers generated by the OFDM system – 2048 (mode 2k) or 8192 (mode 8k) – has been fixed to 8k by most of the countries. The 8k systems provide a higher degree of protection against inter-symbol interference caused by multipath propagation. The use of a higher number of carriers increases the symbol period and therefore the same proportion of guard interval gives a greater protection. However, mode 8k presents a higher complexity and a higher sensitivity to tuner phase noise.

5.4. Time percentage

Analogue television planning is based on 99% time protection against interference. In view of the very rapid transition from satisfactory reception to no reception at all – which is displayed by digital systems – this seems to be a self-evident need.

5.5. Location coverage

The percentage location coverage represents, to some extent, the situation where satisfactory reception can be achieved at the edge of the coverage area.

Due to the constraints necessary to protect current analogue transmissions, location coverage percentages of 50% and 70% are planned by some European countries in the first phase (transition period) of the DVB-T introduction. In a second phase, coverage can be progressively increased to 80% and then to 95%.

It is clear that during the transition period there will not be a full coverage of terrestrial digital services in many countries. This leads to a gap of coverage between analogue and digital services that could be taken up by other delivery platforms.

6. Frequency Planning Options

6.1. Frequency planning in the transition period

The frequency plan implemented during the transition period will be different from country to country, mainly due to the different availability of frequencies in the broadcasting bands. Digital transmissions have to co-exist with and protect the existing analogue transmissions from interference.

Various ways have been used by a number of countries in Europe to find spectrum for the implementation of DVB-T and these are described in the following sections.

6.1.1. Unused analogue frequencies

Some countries have access to analogue frequencies which have been fully co-ordinated in the Stockholm '61 Plan but which are not used by analogue transmissions. Examples can be found in countries where cable services have a very high market penetration and analogue terrestrial has a limited coverage and, consequently, a reduced penetration. Provided that suitable arrangements have been made with the neighbouring countries, those channels can be converted for digital usage.

6.1.2. Channels above 60

The majority of countries in Europe have reserved the television channels in the range 61 - 69 (above 790 MHz) for non-broadcasting applications such as fixed and mobile systems operated by the military (only a few countries have access to these channels for analogue television). However, some countries are now considering the release of a number of channels above 60 for the introduction of DVB-T services.

6.1.3. Interleaved channels

The digital transmissions can be interleaved between the analogue channels [9] on a geographical basis. The digital channels can be either upper or lower adjacent to existing

9. The analogue channels from a given site are allocated for example on an n, n+3, n+6, n+10 basis to avoid the effects of adjacent and image-channel interference.

analogue services or, in some cases, both. However, care is required to respect the adjacent-channel protection ratios.

This approach is not possible in all countries because the interleaved channels have already been used for additional analogue services where complete coverage is not required.

6.1.4. Analogue channel changes

A few European countries are considering the option of frequency-channel changes for some of the existing analogue relay stations. It should be noted that this option would result in disruption for existing viewers, which in turn can lead to numerous complaints both to the broadcasters and to the politicians, and this requires a solution.

One means of achieving this option might be to plan more co-channel analogue services by taking advantage of precision offsets to reduce interference from an analogue service to another analogue service – assuming of course that this has not already been employed extensively within the country's network, and noting that this will have an adverse effect on the possibilities for conversion. Changes to some existing analogue frequency channels (which will have the effect of increasing the interference levels), can free assignments for new digital services. Countries applying this analogue channel-changing approach may need to re-allocate frequencies within their existing television transmitter network. The replacement of analogue television transmitters as a result of this frequency adjustment will lead to investment implications for the new infrastructure.

6.1.5. Island-by-Island

For countries where there is a severe shortage of television frequencies, the frequencies needed for the digital transmissions must basically be obtained by releasing frequencies used for analogue transmissions. This may be feasible in areas where there is a high penetration of satellite or cable. Because this process is unlikely to be possible on a simultaneous and nation-wide basis, it needs to be implemented in a spatially restricted and staggered fashion – within "islands". An island embraces the coverage area of the analogue transmitter to be converted or switched off.

6.2. Frequency planning for the all-digital period

Several options are under consideration by the European countries for the new all-digital frequency plan. It should be noted that not all options are available to every country. A comparison of the planning options described below is given in *Fig. 8*.

6.2.1. Analogue conversions

The conversion of existing analogue assignments into digital assignments is facilitated in CEPT countries by means of the Chester 97 Agreement. This option has the major advantage of being compatible with existing analogue services in neighbouring countries. It can be very important in the situation where countries plan to migrate to an all-digital plan at different times.

	Analogue conversions	Existing DVB-T assignments	Completely new plan
Compatibility with analogue services	▲▲▲	▲▲	▲
Additional digital service prospects	▲▲	▲	▲▲▲
Effective use of spectrum	▲▲	▲	▲▲▲
Equitable access	▲	▲	▲▲▲
European migration	▲▲	▲	▲
Co-ordination	▲▲▲	▲	▲

Relatively easy ▲▲▲ Average ▲▲ Complex ▲

Figure 8
Comparison of planning options for the all-digital period.

The full digital plan can take place by bilateral agreement between countries. Another advantage is that countries can retain the digital equivalent of their high-power assignment rights, and can then guarantee – for fixed reception – to fully match the analogue coverage for each transmitter.

The main disadvantages are; it may not be the optimum plan for efficient use of the spectrum, it may not lead to equitable access, and it may be difficult to increase the number of multiplexes and to identify blocks of spectrum for potential release. Another disadvantage is that only an abrupt analogue switch-off at any one transmitter will be possible, with consequences for the viewers, unless another channel can be used to simulcast coverage to all existing analogue viewers. The simulcast channel might later be used elsewhere on an area-by-area basis

6.2.2. Current DVB-T assignments

A plan based on current digital assignments could have an advantage for existing viewers of the digital service, and a smooth analogue switch-off would be possible thus avoiding viewers' complaints. However, whilst transmission equipment will be in place and some co-ordination agreements will have been made, these may not necessarily provide the full coverage desired, due to restrictions previously required to protect the analogue services. (An increase of power, and the resulting requirement for new transmitting equipment and new co-ordinations, will result.) Furthermore, as in the previous option; it may not be the optimum plan for efficient use of the spectrum; it may not lead to equitable access; it may be difficult to increase the number of multiplexes and to identify blocks of spectrum to be released.

6.2.3. A completely new plan

In the case of a completely new plan, it is likely that a spectrum-efficient plan could be developed, providing for equitable access and making easier the release of frequency blocks. On the other hand, the analogue switch-off would be more difficult: for fixed reception, viewers may need new receiving antennas; new transmitting equipment may also be required (noting that careful planning is necessary to avoid a break of transmission). In some cases, new transmitting stations may be considered. Completely new co-ordination agreements would also be needed, particularly in country border areas. The timing of the implementation of the new plan would require careful and detailed consideration because of the numerous interdependencies between countries and the high numbers of existing stations.

6.3. The need for a flexible approach

Due to the difficulties expected in building an optimized and efficient plan, with equitable access for all countries and without service disruption for viewers, the idea of developing a flexible approach is being considered by many European countries. This approach could be based on a computer analysis and synthesis for the final all-digital plan and also for a series of intermediate steps to allow for only a number of countries which want to go digital. The station characteristics (analogue and digital) in each interim plan will probably have to change to a certain extent. The more countries in a certain area of Europe which go digital, the more the relevant version of the interim plan could mirror the final digital plan for that area. However, it is important to note that the intermediate steps in the planning process will not necessarily provide optimum spectrum utilization as this would normally mean frequency changes at each step. This is likely to be very disruptive for both the viewers and the broadcasters.

7. Spectrum requirements

In terms of the amount of spectrum required, studies are ongoing. The number of channels required depends on many parameters including system variants (as outlined in *Section 5.3*), reception conditions, the transmit antenna height, the distance between transmitters, the target coverage and the network structure.

To date (November 2000), theoretical studies have concentrated on the spectrum requirements for fixed and portable in-door reception of terrestrial digital television transmissions, occupying spectrum in the UHF bands currently used for analogue television. Furthermore, the results deal only with MFNs (which are described in *Section 8.2*).

It has been assumed that the UHF bands will have been cleared of the existing analogue television transmissions so that it would not be necessary to consider any interactions except those between digital television services.

In summary, the results indicate that when using (i) MFNs, (ii) transmitter site separation distances in the range 50 to 100 km and (iii) an effective transmitting antenna height of 150 m, then about nine channels are needed to provide for a data capacity of 24 Mbit/s in the following two scenarios:

- fixed antenna reception (95% location and 100% overall coverage);
- portable in-door reception (70% location and 50% overall coverage).

If the overall coverage for portable in-door reception is to be increased to 80%, the channel requirement increases to about 15.

For the case of SFNs there are indications that the number of channels required is similar to MFNs but that a higher degree of coverage can be achieved for portable antenna services. (SFNs and MFNs are described in *Section 8.2*.)

Further work will be needed to evaluate the spectrum requirements for digital TV transmissions in VHF band III and for mobile TV reception at both VHF and UHF.

These are only initial conclusions – based purely on theoretical studies. Studies are still ongoing and further conclusions will be based on practical situations.

8. Network Considerations

This section is intended only to outline some of the options.

8.1. Geographical service requirements

For a large majority of countries, there is a clear need for national and regional networks. Only a few countries intend to set up either regional-only or national-only networks.

In this context, a national multiplex is assumed to cover the national territory with the same programme material throughout a region, without any sub-regional variants at any time. Similarly, a regional multiplex carries the same programme material throughout a region, without any sub-regional variants at any time.

A further planning concept is that of local networks. These are primarily intended to cover only part of the more densely populated areas.

A first estimation (from an EBU questionnaire sent out at the beginning of 1999) indicates that, presently, about half the programmes of EBU members have national coverage. For the other half, the number of regions can vary between 2 and 24 depending on the country size, among other things. The region size can vary from diameters of 20 km up to more than 100 km. The number and size of the European regions are very different from one country to another, even for countries of comparable overall size. Clearly, the size of the country and any internal linguistic or cultural conditions has a major impact on the size of the regional service areas.

8.2. Multi Frequency and Single Frequency Networks

There are two basic DVB-T network structures: Multiple Frequency Networks (MFNs) and Single frequency Networks (SFNs). Arising from the basic network structures, various alternatives can be considered such as mixed MFN-SFN scenarios, MFN with SFN gap-fillers, and dense SFNs.

MFNs can provide for large coverage areas where the individual transmitters carry different programmes and thus allow for regional or local programming. MFNs can reproduce, approximately, the coverage of existing analogue networks. This may be of great importance if maintaining an existing coverage pattern is a political or commercial requirement. It may also be possible to re-use part of the analogue network structure, making the network very cost-effective. However, for an MFN-only structure, any filler stations necessary to complete the coverage will require additional frequency channels – and these may not be available in all the European countries.

The SFN structure provides a more uniform signal distribution within the coverage area – for the same number of transmitters, less power is needed to cover the same area (compared to an MFN). Coverage may also be improved or extended by using the same frequency. However, national SFNs – providing complete coverage of a country – are generally difficult because of self-interference effects. Most of the countries currently planning for SFNs foresee regional SFNs with areas of up to 200 km diameter.

In an SFN, all the transmitters of a given programme network use the same channel. They possess a common coverage area and cannot operate independently. They require a high degree of synchronization; the emitted signal from different transmitters must be identical in content; signal emissions must take place at the same time (or with precisely controlled delays) and the RF carriers must comply with stringent frequency precision requirements.

One significant advantage of the SFN approach is the possibility of developing dense networks. These employ a different network topology, where a large number of low power stations (for instance: < 100 W and < 75 m of effective antenna height) are distributed over the service area (potentially with a main transmitter at the centre), thus providing a more even field-strength distribution. This type of network structure is chosen to provide a high level of field strength as is necessary for portable reception. Careful consideration of site height, transmitter spacing and guard interval is essential to ensure self-interference effects are not experienced.

A mixed MFN-SFN scenario could correspond to different approaches and could combine the best features of both. For example, some countries see an interest in using higher-power main stations in an MFN configuration together with lower-power relay, gap filler or in-house repeater stations – using the same frequency as the associated main station – to complete the coverage. Other countries are considering an MFN structure for transmitting a national multiplex and an SFN structure for transmitting a regional multiplex using one of the frequencies of the MFN network.

It seems certain that mixed MFN-SFN scenario configurations will be adopted widely in Europe, in some form or another.

8.3. Transmitter sites

The separation distance between transmitter sites influences the choice of guard interval which, in turn, limits the size of SFN networks. The effective height influences the e.r.p. All these parameters affect the choice of the DVB-T variant and the frequency requirements.

The transmitting stations for digital services can be classified as follows (EBU/BPN005):

High-power station: a station with an e.r.p. greater than 10 kW and an effective antenna height greater than 150 m.

Medium-power station: a station with an e.r.p. in the range from 100 W to 10 kW (inclusive) and an effective antenna height usually in the range 75 to 150 m.

Low-power station: a station with an e.r.p. less than 100 W and an effective antenna height usually less than 75 m.

Due to the fact that analogue transmissions should be protected during the transition period, medium-power stations (radiating on average 10 kW) have been planned in Europe. In many cases, low-power stations have also been planned to fill in the coverage gaps. The very high-power analogue sites will probably also be used for DVB-T transmissions – but not with the same high power levels.

In most cases, existing analogue transmitter sites will be used for the DVB-T transmissions, with the benefit of being cost and time efficient. However, in some cases, brand new sites will have to be built.

The number of transmitter sites deployed, and the separation distance between sites, varies a lot from country to country depending, among other things, on the system variant, on the reception mode (fixed, portable or mobile), on the country size and on the boundaries. In general, the number of digital transmitter sites per country varies between 50 and 100.

The separation distance between transmitters may vary between 30 and 50 km in the most populated areas, and between 75 and 125 km in the less populated areas.

8.4. Use of existing broadcast infrastructures

In considering the issues relating to practical implementations, an important question is: *how much of the existing infrastructure can be used?* Whilst it is likely that the existing broadcast sites can be used effectively, particular care is required in planning for SFNs. The coverage achieved in SFN planning is critically dependent on the distribution of sites and the antenna transmission height. In some situations, additional sites may be required to achieve the desired coverage, particularly where portable/mobile reception is the goal.

The use of conversions in MFN configurations will pose some challenges for network providers. The issues fall into two main categories – the transmitter equipment (which may not be capable of direct re-use for digital signals, and will require either modification or replacement), and the distribution network – see *Section 5.5*. It would appear that these problems can be solved, although this may involve substantial additional costs.

The distribution network may pose the greater challenge for the network providers. Currently, many of the stations in the analogue relay network are fed by off-air transmissions from parent main stations. When the main station is converted to digital, it may be that some relay stations will need to continue to transmit analogue signals for some time. These relay stations will either need to be given a separate line feed of the analogue signals (which could be very expensive), or will have to make use of digital satellite feeds or off-air digital terrestrial transmissions in conjunction with D/A converters.

9. Timescales

Different countries will have their own timescales for the implementation of DVB-T or may even wish to continue with analogue for the foreseeable future. In some countries

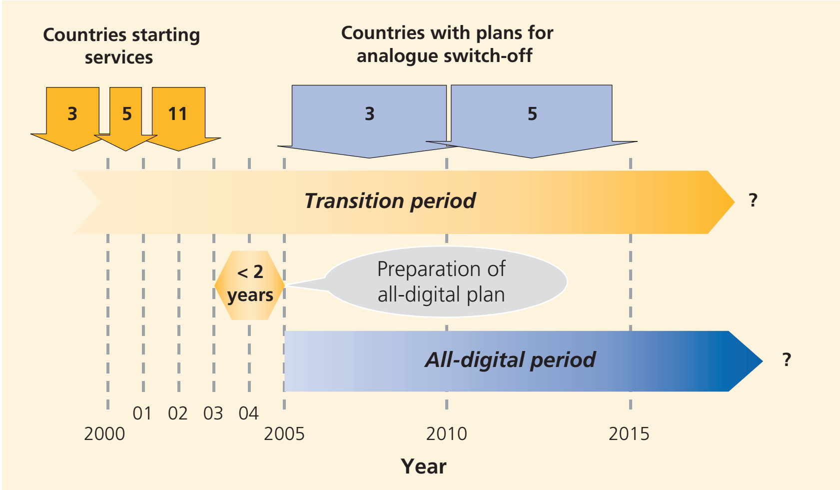

Figure 9
Timescale for the implementation of DVB-T
(as of November 2000).

the timescale for the introduction of DVB-T may be critical when faced with a rapid penetration of digital satellite and cable services.

The migration from analogue to digital terrestrial television in Europe will be implemented in two phases: the *transition period* and the *all-digital period* (see *Fig. 9*).

9.1. Transition period

The transition period will last from the commercial launch of DVB-T to the analogue switch-off date. The current (October 2000) European plans for the DVB-T launch, (taken from DigiTAG) are as follows:

- countries having already started: 3
- counties planning to start in 2000 - 2001: 5
- countries planning to start in 2002 - 2003: 11

DigiTAG

9.2. All-digital period

This is the period from the analogue switch-off date onwards. The current (September 2000) European plans for the analogue switch-off date (taken from DigiTAG) are the following:

- countries planning for 2005-2010: 3
- countries planning for 2010-2015: 5

9.3. Preliminary conclusions

It can be concluded that the introduction of digital terrestrial transmission techniques will represent a long-term process where analogue and digital transmissions will have to co-exist. There will not be a unique European analogue switch-off date because individual countries will have their own timescales. There may even be the situation where some countries wish to retain their analogue services for the foreseeable future. However, in countries where there is a long timescale for the introduction of DVB-T services, the requirement for analogue switch-off may be diminished when faced with the rapid penetration of other digital platforms.

In considering analogue switch-off, it is considered that this may be subject to the fulfilment of two conditions:

- Universal coverage – everyone who currently receives free-to-air analogue channels must be able to receive them digitally;
- Affordable cost of digital equipment.

The impact of different and possibly neighbouring countries adopting very different timescales will need to be considered.

10. Migration Process

10.1. First stage for introduction of DVB-T

In the first stage it is necessary to introduce DVB-T in parallel with analogue coverage by means of the approaches given in *Section 6.1*, namely:

- use of unused analogue assignments;
- use of interleaved services;
- conversion from analogue to digital assignments;
- use of spectrum released from other services.

Owing to spectrum constraints, it is unlikely that the desired level of digital coverage can be achieved until some or all of the analogue services can be switched off in a given country.

10.2. Simulcasting

An additional factor is the requirement to allow viewers time to migrate from analogue to digital. A period of digitally simulcasting the services currently transmitted by analogue television is, in principle, necessary. However, for reasons of cost and the shortage of frequencies (further digital programmes cannot be transmitted until the frequencies used by analogue have been released), the transitional phase must be kept as short as possible.

10.3. Approaches to switchover

Whilst three examples of the approach to switchover are given below, these are not likely to be optimal, nor will they meet the requirements of all countries. Therefore, it is anticipated that other ideas will be developed in the fullness of time.

10.3.1. Insular digitization and simulcast

A move from analogue to digital television transmission would be made substantially easier by the provision of a sufficient number of additional frequencies. These are not currently available in many countries in Europe. Therefore, frequencies needed for the digital transmissions must basically be obtained by releasing frequencies used for analogue transmissions. Where this process is not possible on a simultaneous and nationwide basis, it needs to be implemented in a spatially-restricted and staggered fashion in “islands”. An island embraces the coverage area of the analogue transmitter to be converted or switched off.

In order to supply as large a section of the population as quickly as possible, and thereby to give the manufacturers of DVB-T reception equipment the opportunity to produce price-lowering volumes of units, it makes sense to begin simultaneously in several islands containing both a high proportion of the population and transmitters with a high coverage range. However, full geographical coverage will only be achieved on the basis of the results of the Stockholm follow-up conference.

In order to protect the consumers and to ensure planning certainty, there is in principle a need for a simulcast phase. This will have to be longer at the beginning of the conversion process than at the end and may differ from island to island for various reasons. In some islands, resources may not permit full simulcast operations. The reception of the analogue programmes being broadcast may also deteriorate. For the switch-off, certain criteria must be stipulated. These can include a defined digital penetration rate, and minimum and maximum periods for the simulcast. The impact of the criteria may be subject to regional variation.

10.3.2. Receiver penetration threshold

This approach could be taken in countries where it is necessary to provide high levels of coverage of the simulcast services in order that viewers will not be deprived of their existing service. This also implies an agreed level of penetration of digital receivers – see also *Section 8* on consumer aspects.

In this scenario, DVB-T will be introduced and rolled out in parallel with analogue transmissions until the take-up of the digital services reaches a certain percentage.

Based on the "coverage reaches a certain percentage" case, one particular country is considering the following implementation model, based on conversions of analogue transmitters:

- ⇨ Continue to roll out a parallel DVB-T infrastructure alongside the analogue TV network while costs remain reasonable. It is anticipated that there could be a freeze on the parallel DVB-T network when coverage reaches about 95%.
- ⇨ Identify the regions with the highest digital take-up. For each region, arrange to make "free" basic DVB-T receivers available to analogue-only households. Broadcast information messages on analogue TV to inform the consumers that they will need to get a basic digital receiver.
- ⇨ Progressively convert analogue transmitters to digital on a region-by-region basis, beginning with those areas with the largest percentage of digital subscribers. A DVB-T coverage of 99.4% (fixed antenna reception) might ultimately be achieved (*a figure in excess of 98% may be appropriate taking Europe as a whole)*.

As an alternative to the above, the few remaining analogue viewers in an area could be provided with satellite receivers (assuming that the existing programme services are available on a satellite). In this case it may not be necessary to extend the DVB-T services to the full extent of the analogue services that are to be withdrawn.

In those countries where the provision of free digital receivers is not considered, it is clear that before the analogue switch-off, the digital equipment must be at an affordable cost for the vast majority of people, including those on low incomes and older people.

As part of the process, DVB-T is introduced first in the main cities (the most populated ones) and is then progressively introduced in other regions until the penetration (number of users or the coverage) reaches a certain percentage.

10.3.3. Forced switchover

The analogue service is simply switched off or, alternatively, an announcement is made that the analogue service will be switched off at a given date in the future. Countries where there exists a high penetration of cable and/or satellite may particularly consider this approach.

10.4. Digital satellite and terrestrial transmissions

As mentioned above and as part of the migration process, it may be considered by some countries to complete the DVB-T coverage with digital satellite transmissions. In order to achieve universal coverage, digital transmissions via satellite can reach those parts of the country (mainly rural areas) possibly not covered by the terrestrial transmissions.

However, in that case the television channels have to be duplicated, i.e. transmitted via satellite and terrestrial. It may not be a very economical solution and may only be considered by those broadcasters already transmitting via satellite. Broadcasters not considering the satellite transmissions will have to accept non-universal coverage.

On the other hand, broadcasters may also be afraid of losing control of the programme content.

Digital satellite transmissions can also be integrated into digital terrestrial transmissions in another way. In those countries where there are geographical difficulties or where the spectrum available is very limited, the main DVB-T transmitters may be fed by the DVB signal coming from the satellite. In that case, two additional technical operations are required: to re-multiplex and to re-modulate. The multiplexer adapts the bit-rate of the DVB-S carrier (around 34 Mbit/s of useful bit-rate) to the DVB-T carrier (around 20 Mbit/s for 64-QAM 2/3, TG = 1/4 TS). The modulator adapts the modulation of the DVB-S signal to the modulation of the DVB-T signal (OFDM).

Abbreviations

16-QAM	16-state quadrature amplitude modulation
64-QAM	64-state quadrature amplitude modulation
CEPT	European Conference of Postal and Telecommunications Administrations
DigiTAG	Digital Terrestrial Television Action Group
DVB	Digital Video Broadcasting
DVB-C	DVB - Cable
DVB-RCT	DVB - Return Channel via Terrestrial
DVB-S	DVB - Satellite
DVB-T	DVB - Terrestrial
EBA	European Broadcasting Area
EPG	Electronic programme guide
e.r.p.	Effective radiated power
EU	European Union
GSM	Global system for mobile communications
HDTV	High-definition television
ITU	International Telecommunication Union
MFN	Multi-frequency network
OFDM	Orthogonal frequency division multiplex
QPSK	Quadrature (quaternary) phase-shift keying
RF	Radio-frequency
SFN	Single-frequency network
T-DAB	Terrestrial - Digital Audio Broadcasting
UMTS	Universal mobile telecommunication system

10.5. Mechanics of the migration process

Considering the different service requirements, the timescales and different frequency availability, a flexible approach to the planning process is essential. It is inconceivable that the entire transmitter networks in Europe, or even part of Europe, could be converted overnight.

As previously discussed the starting point for a new plan might in practice be a combination of:

- ⇨ new assignments;
- ⇨ converted analogue assignments;
- ⇨ existing digital assignments.

One possible option is to agree an all-digital plan at a Regional Conference (2005) and then adopt a stepped approach via interim plans.

Another method of reaching the “final all-digital plan” is to consider the approach that has been successfully applied in the preparations for conferences such as the VHF Sound Broadcasting Conference (1984) and the African Broadcasting Conference (1989). For both of these conferences, the first session established the technical basis for the preparation of the Plan, and the second session drew up the agreement and the associated Plan. A similar approach is foreseen for the Revision of Stockholm 61.

This procedure offers the advantages that:

- ⇨ national requirements can be formulated on an internationally-agreed basis;
- ⇨ pre-coordination of the national requirements with neighbouring administrations is possible;
- ⇨ during the intersessional period, an inventory of requirements can be established on the basis of which interference calculations and incompatibility checks can be made;
- ⇨ progress on unresolved questions can be reached by intersessional work.

By following this procedure, the drawing up of the International Plan is facilitated, interference problems are minimized and the national requirements, i.e. the National Plan, become – after successful coordination – a part of the International Plan.

Amendments of the National Plan after the coming into force of the International Llan are of course possible, provided they are within the internationally agreed interference limits.

10.6. National planning

In formulating their national requirements, the administrations are free to use any planning method (e.g. as outlined in *Section 6.1*). By taking the local factors into account (such as terrain shielding), and using local knowledge and the analysis by computer of topographical data banks, the national planners can maximize the coverage that can be achieved within the internationally-agreed frequency assignments or allocations. Furthermore, closer co-channel spacings might in some cases be achieved, without creating unacceptable interference, than would be adopted within the context of an International Conference.

The location of significant population centres, suitable transmitter sites or existing installations will, in many cases, dictate the choice of transmitter sites for DVB-T in a particular country. The detailed planning within a country will, in general, be developed within the agreed assignments or allotment areas.

In relation to gap filling, it is important to identify that this is a second step in a detailed planning process, which is unlikely to form part of the plan agreed at a conference.

11. Consumer Aspects

The successful migration from analogue to digital television is dependent on achieving a high take-up of new or additional reception equipment by the consumers (by purchase, lease or rental). The main driving force behind such investment will initially be the content-related advantages of the new service. Only in the medium term will (i) the expected fall in the price of equipment, (ii) the greater technical maturity and functionality of the equipment and (iii) the normal cycle of equipment replacement lead to hardware advantages. Then the range of terminal equipment available will also become one of the main driving forces for the penetration of digital television.

In order to facilitate the migration from analogue to digital transmission, multi-standard appliances (analogue and DVB) should be offered right from the start of DVB-T introduction in a given country.

12. Conclusions

1) DVB-T will be introduced in a very competitive world where digital services transmitted by cable and by satellite are well developed and where a convergence process is taking place.
2) Broadcasting will change and will offer high-quality video and audio services as well as the new services already included in other digital platforms (interactive services, Internet access, etc.). DVB-T will be a complementary technology, offering the opportunity of portable reception for multiple television sets in the home and for mobile reception to serve viewers wherever and whenever they want.

3) Portable and mobile services are considered to be very important in the development of all-digital networks.

4) During the transition period, until the analogue switch-off, digital and analogue transmissions will have to co-exist. Whilst there remains a need to maintain these analogue transmissions, the development of portable and mobile services will be limited.

5) Studies are still going on concerning the frequency plan to be implemented in the all-digital period and the amount of spectrum required. It is still too early to say if the release of part of the broadcasting bands will be possible.

6) Europe is well known for its cultural, historical, geographical, political and economic diversity. The service requirements for DVB-T are no exception. There will not be a unique migration model within Europe because of different market drivers, frequency spectrum possibilities, network structures and timescales.

7) It can be expected that the migration to digital services will be on an area-by-area basis.

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In March 2000, Ms Puigrefagut joined EBU headquarters, Geneva, as an Engineer in the Technical Department, to undertake studies relating to frequency planning and spectrum management. She also co-ordinates joint technical activities undertaken by EBU members and represents the EBU in a number of international committees. She is currently participating in the preparatory studies for the forthcoming conference which will replan the Stockholm '61 Plan.

8) Conversion of existing analogue assignments to digital (according to Chester 97) will be used to a greater or lesser extent – depending on individual country requirements.

9) During the transition phase, the success of DVB-T is likely to depend on the percentage coverage achieved and the cost and penetration of receivers.

10) The migration process could be greatly assisted if the viewer is offered dual-standard sets right from the start of DVB-T transmissions.

11) The preparation of the revised plan for Europe is expected to take place at a single two-part conference; the first part to establish the sharing criteria and planning rules, and the second to agree on a Plan. This will give individual countries the opportunity to consider their requirements and then agree these requirements with neighbouring countries during the inter-conference period. Thus at the second part of the planning conference, the individual country plans – where they are known – could be incorporated.

12) The revised plan for Europe, as agreed at a planning conference, will need to provide a framework in which individual countries can continue to develop their individual and different requirements on an equitable basis. Nevertheless, the planning concepts will need to be simple such that the overall plan can be maintained with the minimum of resources.