Digital and High Definition Television

Research Paper 94/83

4 July 1994

The Government is shortly to decide whether the proposed Channel 5 television service can go ahead without adversely affecting the subsequent introduction of digital television services.

This paper examines the technology of digital and high definition television and discusses the prospects for such services both in the UK and elsewhere.

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CONTENTS

I. Introduction

In recent months there has been much debate about the introduction of digital television in the UK. This has arisen from specific discussions about the future of Channel 5 and more general interest in the digital and multimedia revolution taking place in entertainment services.

Currently, television services are based on "analogue" technology. This means that the television pictures are represented in the form of a continuously varying electrical signal. When received by a television set these signals are converted into a picture made up of 625 horizontal lines with alternate lines being broadcast every 1/50th of a second (the PAL standard)[1]. This means that 25 TV frames are broadcast every second.

Digital television, on the other hand, is represented as a series of ones and zeros called binary digits or bits. Digital technology is not new; most people are already familiar with the fact that music can be stored in digital form on a compact disc or in analogue form on a cassette. What is new, is that these digital techniques can now be applied to television pictures. Until recently it was thought that so much space would be required to store a digital version of a television programme that digital TV would not be a practical proposition for a number of years. However, recent advances in "digital compression" means that digital pictures can now be squeezed into far less space than ever considered possible.

If digital compression techniques are used together with digital transmission techniques then digital programmes can be broadcast over the airwaves taking up much less space (frequency spectrum) than analogue programmes. For instance it might be possible to squeeze anywhere between two and eight digital programmes into the space occupied by one analogue channel. This is not the only advantage. Currently in the UK there are 44 frequency channels for television programmes but these can only be used to provide 4 national television services because analogue services in adjacent areas must use different channels to avoid interference problems. These problems are not nearly so severe with digital television and so if certain technical difficulties are overcome it might be possible for each of the 44 channels to be used to carry separate services. So if analogue services were stopped overnight then there would be scope for the introduction of a great number of different digital television services, possibly as many as 100. Although this is not a practical proposition, there is still scope for the introduction of digital television alongside existing services.

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[1] There is more than one standard for analogue television. For instance, in the USA television pictures are made up of 525 lines with 30 frames broadcast every second (the NTSC standard)

Research commissioned by the Independent Television Commission (ITC) has opened up the possibility that so-called "taboo" channels could be used for digital television services alongside existing analogue services. These are channels which are not available for analogue broadcasting in a given area because they would cause interference with other services, but which might be able to be used for low-power digital transmissions. The research found that about 80% of the UK population would be able to receive at least 4 digital channels if transmissions were broadcast from the main transmission sites only. This compares with a figure of 90% for analogue PAL services from these sites. Each of the available channels might be capable of carrying more than one television service depending on the format of the services.

At this point, the discussion about the introduction of digital TV services into the UK becomes inextricably linked with the future of Channel 5. Under the *Broadcasting Act 1990*, the Independent Television Commission (ITC) is required to do all that it can to secure the provision of a fifth television channel. It is proposed that Channel 5 will make use of two spare television channels, 35 and 37, to provide an analogue television service capable of reaching about 74% of the UK population. However, some organisations, particularly the BBC and ITV, have argued that either one or both of these channels would be better used to provide digital television services. As a consequence of this the ITC has asked the Government to confirm that the necessary frequencies are still available for Channel 5 and that such a service would not be incompatible with a longer term strategy for digital television. The Government is currently considering this issue and an announcement is expected shortly.

One of the issues at the heart of the debate about the future of Channel 5 is whether digital television services can be introduced in the near future. Some proponents of digital television have argued that digital terrestrial television [a service broadcast over the airwaves] "could be with us in two or three years"[2]. However, others have argued that digital television is "technologically untried, faces all manner of international regulatory hurdles, will probably not be in widespread use until the next century and will only be open to those punters rich enough to shell out hundreds of pounds on a converter for their television set"[3].

In reality, the situation is very complicated. Digital television can actually be broadcast in three different ways: terrestrially over the airwaves; by cable; and by satellite. However, the ease and cost with which this can be done varies tremendously according to which transmission method or modulation technique is used. Consequently, the speed with digital television can be introduced depends on the type of service being considered.

Most people will be familiar with the existence of modulation schemes through the fact that

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[2] "Letters: UK must turn to digital TV" *The Independent* 29 April 1994 p.17

[3] "View from the City Road: Screen out Channel 5 interference" *The Independent* 26 April 1994 p.27

radio programmes broadcast on medium wave are amplitude modulated (AM) and VHF radio programmes are frequency modulated (FM). In conventional broadcasting, modulation is simply the process by which a carrier wave used for transmitting a signal, such as pictures or sound, is modified so that it can carry that signal. For instance, in amplitude modulation the carrier wave is modified so that the variation in its amplitude represents the signal that needs to be transmitted.

There are three main modulation schemes which have been proposed for use with digital television. All of these schemes rely on altering one or two characteristics of the signal's carrier wave to encode the necessary digital information to transmit a television picture. These schemes can be combined with another technique called Coded Orthogonal Frequency Division Multiplexing (COFDM) which reduces the problems such as "ghosting" and interference with other television channels.

The first digital television services to be introduced in the world will be those on satellite because of the simpler technology which can be used. Plans for such services are most advanced in the United States where DirecTV has just launched a service which should be available nationwide by September 1994, offering 150 different channels.

However, the prospects for introducing terrestrial television depend on the country under consideration. Europe and the US are likely to adopt different modulation schemes because problems with interference differ considerably between the two countries. Europe is much more densely populated than the US and with more countries with different broadcasting systems in close proximity. Consequently, the radio spectrum is much more crowded and interference problems more severe. Europe is therefore likely to choose a complicated modulation system using COFDM. In the US, the population is more spread out and a lot more people rely on cable television, and so the airwaves are not so congested. This has allowed the US to choose a system which, although not so efficient, should be much simpler to adopt.

In the UK, the timescale for the introduction of digital television again depends on the technology used. For instance, the BBC has advocated that one or both of Channel 5's frequencies should be used for the introduction of a national "single frequency network". Such networks are based on the concept that a single spare TV channel can be used to broadcast the same television services across the whole of the UK. The technology required for single frequency networks (SFNs) is more complicated than the technology required for broadcasting on taboo channels. Consequently, a digital television service based on SFN technology rather than on the use of taboo channel would be more difficult to introduce quickly. There are different views as to how long it will take before SFN technology becomes available. The BBC believes that commercially attractive technology "will become

possible quite rapidly" whereas the ITC believes that SFNs will not be technologically possible in the near future.

Whenever digital services are introduced, there will be considerable scope for the introduction of different types of service. One of the questions that has to be considered is the importance of the picture quality. With digital television systems there is trade-off between the number of services which can be carried and their quality. For instance, one taboo channel could be used to offer two television services of comparable quality to existing PAL analogue services or maybe up to eight services of roughly the same quality as home video recordings. If non-taboo or clear channels become available for digital broadcasting, then a single channel might be able to be used for one full-quality high definition television (HDTV) service or 8 PAL-equivalent services or around 30 video equivalent services.

High definition television (HDTV) are services which have much better picture quality than existing services. The term is usually used to describe services which are wide-screen and have double the resolution of today's television systems. So in the UK, an HDTV television picture would be most likely to have 1250 horizontal lines as compared to the current 625 lines. Wide-screen television describes services where the picture is "letterbox" shaped as seen in cinema. The aspect ratio or the ratio of the width of the screen to its height is 16:9 rather than the current ratio of 4:3.

Until recently, many countries were directing their research efforts on advanced television services towards HDTV as it was thought that digital television was a long way off. Both the EC and Japan developed analogue HDTV standards, but these have been largely unsuccessful on a commercial basis because of problems with the development of inexpensive, large-screen televisions. These are necessary for the benefits of the enhanced definition to become visible. Recent opinion suggests that viewers and consumers are more interested in a greater number of channels (made possible with digital technology) than in HDTV. In the USA the issues of HDTV and digital television are closely linked as the regulatory body there, the FCC, has decreed that the technical standard for HDTV must be a digital rather than an analogue one. This digital route is now being pursued in Europe and Japan.

II. Broadcasting technologies: a background

There are three main methods used for broadcasting television services in the UK: terrestrially over the airwaves; from satellite; and by cable. Currently, in the UK, all these methods are based on analogue transmission technology. However, plans are well advanced in some parts of the world for the introduction of digital satellite services, and much research has been undertaken on digital terrestrial broadcasting. The ease with which digital services can be introduced to replace or supplement existing analogue services varies tremendously according to the methods of transmission used. The following sections explore the technological constraints and opportunities surrounding the introduction of new digital services.

A. Analogue broadcasting

When analogue broadcasting technologies are used there is a tight restriction on the number of television channels which can be broadcast in the available radio spectrum or over cable. The reasons for this are explored below.

1. Introduction to bandwidths

The bandwidth of a telecommunications system is simply a measure of the amount of information it can carry: its capacity. All telecommunications signals are transmitted at a particular frequency. For instance, *Radio 4* is broadcast across the UK on a longwave frequency of 198 kHz. A **hertz** (1 Hz) is just one oscillation or one cycle in a (radio) wave every second. So the radio wave used to broadcast *Radio 4* oscillates 198,000 times a second. In fact it is slightly misleading to say that a radio wave has a particular frequency. To be able to carry any information, a wave must actually contain a range of frequencies within a certain band - the **bandwidth**[4]. The greater the frequency spread or bandwidth is, the greater the information which can be carried. The quoted frequency is simply the frequency at the centre of this band. For example, the bandwidth required to transmit a telephone call is about 4,000 Hz (4 kHz) whereas the bandwidth of a broadcast TV signal is 8,000,000 Hz (8 MHz)[5].

The use of different frequencies for broadcasting over the airwaves is strictly controlled, and the bandwidth available for a particular purpose is limited. Generally, the applications which need large bandwidths are broadcast at high frequencies. For instance, FM radio stations are

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[4] Brown R, *Telecommunications: The Booming Technology* 1969 p.93

[5] 1 kHz = 1,000 Hz and 1 MHz = 1,000 kHz = 1,000,000 Hz

broadcast in the Very High Frequency (VHF) band at frequencies of 88-108 MHz, whereas television channels, which require larger bandwidths, are broadcast in the Ultra High Frequency (UHF) band at frequencies of 470-854 MHz in the UK. However, because of interference problems, not all this bandwidth can be used to broadcast television programmes in any given area.

2. Broadcasting analogue television over the airwaves

The total bandwidth available for television broadcasting in the UK is 384 MHz, allowing 48 channels each of 8 MHz. These channels are numbered consecutively, starting at 21 going up to 68. Currently, channels 35-38 are not used, although they may be made available for a commercial Channel 5 station, leaving 44 channels for broadcasting. Even though there are 44 channels available, there are only 4 national television services. The reason for this apparent disparity is that if the same television station were broadcast at the same frequency from two adjacent transmitters then virtually the entire area between the two transmitters would suffer from interference[6]. Consequently, adjacent transmitters broadcasting the same television station must operate on different channels. With about 1,000 transmission sites in the UK, each broadcasting 4 programmes, each of the 44 available channels is used at roughly 100 transmitters across the country. In practice, because of interference with other telecommunication services, some channels are used more frequently than others.

3. Broadcasting television over cable

The solution to the problems with interference between different transmitters and the upper limit on the number of available channels is not to broadcast programmes over the airwaves but to transmit them over cable instead. The total available bandwidth of cable systems can be used for transmitting television programmes as interference problems do not arise in the same way. The capacity of a cable system varies according to the type of cable used to take the television pictures into the home. Currently, cable TV systems in the UK use **coaxial cable** for such connections and this has a maximum bandwidth of approximately 1,000 MHz. In practice, not all this bandwidth is used, and currently cable TV systems generally provide about 50 programmes over a frequency range of 50-550 MHz using traditional **analogue** transmission techniques. Technically, it would be possible to make use of the spare bandwidth above 550 MHz for other television or video services using digital technology, but this would require different electronics for transmitting the necessary signals, and different "set-top" boxes for decoding them.

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[6] *Report of the Committee on Financing the BBC* Cmnd 9824 July 1986 Appendix F p.173

4. Broadcasting television by satellite

Another solution to the limited spectrum available for terrestrial broadcasting is to transmit the television programmes from space. These broadcasts are transmitted at much higher frequencies, around 10 GHz, where demand for radio spectrum is much less. Television satellites are placed in geostationary orbit above the Earth. This means that the satellites orbit the Earth at the same rate as the Earth rotates, so that they are always looking down on the same area (footprint) and broadcast to the same countries. Signals travel in a direct line, so satellite dishes have to be carefully aligned towards the satellite with no obstructions between the two. Satellite dishes have to be connected to decoder boxes which convert the transmissions into a signal which can be fed into a conventional television. These set-top boxes also control "conditional access" to the television services, unscrambling encrypted channels for those viewers who have purchased an appropriate smart card.

In the UK, the main satellite television services, such as BSkyB, are available on the Astra group of satellites run by the Société Européene des Satellites (SES) based in Luxembourg. Currently, there are three Astra satellites (1A, B and C) each having 16 television channels (each channel has a bandwidth of 26 MHz). All three satellites can be received in the UK, France, West Germany, and the Benelux countries[7]. In most cases the television signals can be picked up on a 60 cm diameter satellite dish, but larger dishes may have to be used at the edges of coverage. The Astra satellites are classed as telecommunications satellites rather than broadcasting satellites. This is because they operate at medium power in a frequency range known as the Fixed Satellite Service (FSS) band[8]. This is important because in 1985 an EC directive stipulated that all Direct Broadcast Satellites (DBS) had to use the MAC transmission standard[9]. Since the Astra satellites were not classed as offering a DBS service, they could transmit their programmes using the conventional PAL standard.

The only true DBS service in the UK was run by British Satellite Broadcasting (BSB) on the Marco Polo satellite. This satellite was high-powered and so pictures could be received on the much smaller flat "squariel" dishes. The service was launched in August 1989, but following its commercial failure it merged with Sky in November 1990. The five BSB channels were transferred to the Astra satellites, although transmissions continued on the Marco Polo satellite until December 1992. The fact that the DBS service was not a success meant in turn that the MAC transmission standard has not been adopted on a large scale for television systems in the EC (see Section IV.A.1). The Marco Polo satellite was sold by BSkyB in December 1993 [10].

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[7] Astra 1C will also broadcast to Spain

[8] 10.95-11.7 GHz

[9] EC directive 86/529/EEC

[10] "BSkyB sells satellite for £21m" *Daily Telegraph* 20 December 1993

B. Digital broadcasting

Using digital technologies, particularly digital compression, it is possible to reduce the bandwidth required to transmit a television channel. The amount of bandwidth saved depends on the final quality of the television picture. Less bandwidth results in a lower quality picture. When pictures are stored in digital form then bit rates have to used as a measure of the information carrying capacity of a transmission system rather than bandwidths.

1. Introduction to bit rates

The capacity of a digital transmission system, such as an optical fibre cable, is measured in **bits per second** (bit/s) rather than as a frequency bandwidth measured in hertz (Hz) because such systems carry **digital** information rather than analogue signals. The term *bit* is shorthand for a binary digit, which can either be a 0 or a 1. Bits are the units used in all digital applications and computing. For instance, the information stored on a musical compact disc is represented in bits. The number of bits required to transmit a television picture depends on the quality (or resolution) of the image. For a picture of equivalent quality to existing analogue services, then a transmission rate of about 5 Mbit/s (5 million bits per second) is required if digital compression techniques are used[11].

If digital television services are broadcast over the airwaves, then the digital information has to be squeezed in to a particular bandwidth. The amount of digital information which can be carried in a given bandwidth depends on the way in which the digital information is encoded. This is explained further in the section on *Modulation techniques* below.

2. Digital Compression and MPEG standards

Until recently it was not thought that digital broadcast television would be a realistic prospect because of the vast amount of information required to transmit a single television channel. However, digital compression techniques have managed to reduce the 200 Mbit/s required for a studio quality picture to about 5 Mbit/s for a picture of comparable quality to today's pictures viewed in the home.

Television pictures broadcast in the UK are made up of 625 horizontal lines with alternate lines being broadcast every 1/50th of a second (the PAL standard). This means that altogether 25 frames are broadcast every second. Digital compression techniques take advantage of the fact that in any given frame there are usually areas of the picture which are

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[11] ITC *ITC Discussion Document on Digital Television* June 1993 Technical Annex p.1

very similar, and that usually there are only small differences in consecutive frames. So instead of every frame being sent in its entirety, it is possible to send one frame to start off with followed by only the differences between frames thereafter. The fact that not every frame, nor every single picture element (pixel) in every frame, needs to be transmitted to reconstruct a television image implies that there is a degree of **redundancy** in the original television data. Further details on the different types of redundancy which can occur are explained in Box 1.

Box 1: Redundancy in television pictures

There are two types of redundancy associated with television pictures:

> "**Statistical redundancy** - picture sample-values are not independent, but are correlated with their neighbours in the same line, the previous line and the previous frame [as described above]. This means that the level of the signal any time is to some extent predictable from its past.
>
> **Psychovisual redundancy** - picture sample-values do not always have to be reproduced at the receiver with the same fidelity with which they were represented at the encoder if the signal is destined for the human observer (and not for further studio processing for example). This is because the human visual system exhibits some tolerance to distortion where the level of tolerance is dependent upon the nature of the image in the locality."

In many situations where digital compression is used it is important for the uncompressed data to be identical to the original, however with television pictures this is not the case. This is clear from that the fact that although video-recorded pictures are not as high quality as the original broadcast images, such pictures are perfectly acceptable to viewers at home. In other words there is some psychovisual redundancy in broadcast-quality pictures which compression techniques can take advantage of. Obviously, it would be possible for pictures to be compressed so far that the reconstituted programmes would not be acceptable to viewers.

Digital compression techniques work by trying to reduce the redundancy in television picture to the minimum level possible for the required degree of picture quality. The industry-standard methods for digital compression are based on two standards introduced by the Moving Picture Experts Group (MPEG) of the International Standards Organisation (ISO); MPEG1 and MPEG2. Both these standards use the widely established method of **motion-compensated hybrid discrete cosine transform coding**, known as motion-compensated DCT. The mathematics of this coding method are complex, but the general principles are easier to understand and are explained in Box 2.

Box 2: Digital compression techniques

Digitisation - first the individual frames of a given video sequence are digitised. This is done by breaking down the individual lines making up the frame into a number of pixels. Each pixel has an individual luminance (brightness) level, and every 4 pixels have two chrominance (colour) values associated with them. Luminance and chrominance values are arranged into separate blocks of 8 x 8, and macroblocks representing 16 x 16 pixels are then composed from 4 luminance blocks and two chrominance blocks. The video frame is broken up into adjacent macroblocks going from left to right, from top to bottom.

DCT coding - blocks of 8 x 8 are encoded by calculating their DCT transform, producing 64 DCT coefficients for each block. The transform essentially represents the picture block in terms of one average value and 63 difference-values. Because of the way the transform works, for a given block it normally turns out that many of the coefficients are small or zero.

Compression - the data contained in the coefficients can be simplified through the techniques of thresholding and quantisation. This results in the DCT coefficients being rounded up or down so that they can only hold certain values. The information can then be compressed by coding the individual coefficients. This coding process is similar to that used in Morse code where very common coefficients (letters) are given short codes. For instance in Morse code, the letter 'e' is represented by a single short dot (.) whereas the letter 'z' is represented by two dashes and two dots (--..). Using these techniques and others, the amount of data that is need to convey the DCT coefficients can be reduced substantially.

Motion compensation - further compression rates can be achieved by using motion compensation to predicting the contents of one television frame from the contents of the previous frame. This is done by assuming that the macroblock for one frame is the same as the nearest equivalent macroblock from the previous frame after taking into account any motion which has occurred between the frames. Information on the macroblock is then transmitted in the form of a displacement vector describing the difference between its location and the location of the equivalent macroblock in the previous frame together with a prediction error which describes any differences between the equivalent and the actual macroblock. The prediction errors are DCT coded as described above.

Frame coding - individual frames in a television sequence can be encoded in different ways depending on whether motion compensation is used. The MPEG standards for video compression allow 3 different types of coding:

Intra frames are coded purely from the information contained in that frame without reference to any other frames. Consequently, these frames are the least compressed (of the three different types of frames). Intra frames have to be used at the start of any video sequence and form the basis of predictions for other frames.

Predicted frames are coded on the basis of forward predictions made from the nearest, previous intra or predicted frame. In other words, predicted frames can be used to help code subsequent predicted frames. Predicted frames achieve a higher degree of compression than intra frames.

Bi-directional frames are coded using forward and back predictions made from previous and subsequent frames. Only intra and predicted frames are used as the basis for predictions for bi-directional frames. In other words, these type of frames are never used to code any others. Because of their greater use of prediction, bi-directional frames achieve the highest degree of compression.

The fact that bi-directional pictures are partly based on subsequent pictures leads to the strange requirement that frames need to be transmitted in a different sequence than they are actually viewed in. Any intra or predicted picture needed for a back prediction will have to be transmitted before the bi-directional picture which actually uses it as a reference.

As mentioned above the degree of compression which can be achieved depends on the final picture quality required. Obviously HDTV-quality programmes require much higher data rates for transmission than programmes of the same quality as domestic video recordings (VHS-quality). Details of the data rates which can be achieved with digital compression for different types of television services have been published in an ITC discussion document on digital television [12]:

> "1. Based on the current state of the art (as considered, for example, in the ISO/IEC Moving Picture Experts Group (MPEG)), some examples of the picture quality which is likely to be available form a particular compressed digital capacity as follows (the units used to express digital capacity are millions of binary digits per second - Mbit/s):
>
> | | | |
> |---|---|---|
> | (i) | Studio high definition (HDTV) quality (1,250 lines) with no perceptible degradations | 40 Mbit/s |
> | (ii) | HDTV quality with some distortion on critical scenes | 20 Mbit/s |
> | (iii) | 625 line studio-quality with no perceptible degradation | 10 Mbit/s |
> | (iv) | 625 line studio-quality with some distortion on critical scenes | 5 Mbit/s |
> | (v) | Reduced quality (312 line) with no perceptible degradations | 2.5 Mbit/s |
> | (vi) | Reduced quality (312 line) with some distortion on critical scenes | 1.2 Mbit/s |
>
> "As a guide for comparison, the fourth example here (5 Mbit/s) is often considered as roughly equivalent to PAL and the sixth (1.2 Mbit/s) as roughly equivalent to home video (VHS) quality (although the nature of the distortions which occur in the digital and analogue systems is very different in both cases)..."

3. Modulation techniques

Once a television programme has been digitally compressed it still has to be converted into an appropriate format for transmission. There are various different transmission methods or modulation techniques which can be used their suitability depending, to some extent, on

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[12] ITC *ITC Discussion Document on Digital Television* June 1993 Technical Annex p.1

whether the programme is to be broadcast over the air waves, from satellites or along cables. Most people will be familiar with the existence of modulation schemes through the fact that radio programmes broadcast on medium wave are amplitude modulated (AM) and VHF radio programmes are frequency modulated (FM). In conventional broadcasting, modulation is simply the process by which a carrier wave used for transmitting a signal, such as pictures or sound, is modified so that it can carry that signal. For instance, in amplitude modulation the carrier wave is modified so that the variation in its amplitude represents the signal that needs to be transmitted.

There are three main modulation schemes which have been proposed for use with digital television: vestigial sideband (VSB) modulation; phase shift keying (PSK); and quadrature amplitude modulation (QAM). All these schemes rely on altering one or two characteristics of the signal's carrier wave to encode the necessary digital information to transmit a television picture. The technical details of all 3 modulation schemes are explained in Box 3.

It looks probable that all 3 modulations schemes will be used for digital television broadcasting[13,14]. VSB has been chosen in the United States for digital terrestrial HDTV, a form of PSK is to be used for digital satellite TV, and QAM is likely to be chosen as the European standard for digital terrestrial TV.

In Europe, QAM modulation is likely to be used with **Coded Orthogonal Frequency Division Multiplexing (COFDM)**. This is a technique which allows hundreds or even thousands of carrier waves to be used instead of one. These carrier waves are evenly spaced across the available bandwidth in the television channel. Without going into the technical details, these carrier waves are set up in such a way so that although they overlap they do not interfere with each other. This results in several advantages, the primary one being that signals transmitted in this way are less prone to interference such as "ghosting". Another advantage is that if there is an interference problem at a particular frequency then the carrier wave at that frequency can be avoided and not used to carry information.

Problems with interference are the reasons why Europe and the USA are likely to adopt different standards for the transmission of digital TV. Europe is much more densely populated than the US and with more countries with different broadcasting systems in close proximity. Consequently, the radio spectrum is much more crowded and interference problems more severe. In the US, the population is more spread out and a lot more people rely on cable television, and so the airwaves are not so congested. This has allowed the US to choose a VSB system which although not so efficient should be much simpler to adopt.

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[13] "Digital TV out of focus" *Electronics Weekly* 2 March 1994 p.11

[14] "Decisions are split over TV viewing" *Electronics Weekly* 9 March 1994 p.16

Box 3: Modulation schemes

To encode a digital signal onto a carrier wave one needs to be able to modify one or more characteristics of the wave so that it can be in a number of different states. For instance, it would be possible for the amplitude of the wave to be fixed at one of four levels. With 4 different available states or levels it is possible to represent two bits (binary digits) of information where each bit can either be a "0" or a "1":

level 1 = 0,0 level 2 = 0,1 level 3 = 1,0 level 4 = 1,1

The number of available states is important as it affects the information carrying capacity of a given channel. For instance, if a 4-level (2 bit) modulation scheme is used in a television channel of 8 MHz bandwidth it would be possible to transmit information at a maximum rate of 16 Mbit/s. If only a 2-level (1 bit) modulation scheme were used then the maximum data rate would be halved to 8 Mbit/s. In reality the maximum rate cannot be used for carrying television pictures alone, a significant proportion needs to be reserved for error correction codes and other data.

At first sight it would appear that as many levels as possible should be used to maximise the amount of information can be carried. However, as the number of levels increase it becomes increasingly difficult for receiver equipment to distinguish between them especially if there is interference around. Consequently, the number of modulation levels has to be determined on the basis of the likelihood of the signal suffering from interference and the type of receiver equipment to be used. This depends in turn on the type of modulation schemes used:

Vestigial sideband (VSB) modulation is a form of amplitude modulation and is currently used in analogue terrestrial television broadcasting. This is the modulation scheme chosen in the United States for terrestrial HDTV and is based on an 8-level (3 bit) system.

Phase shift keying (PSK) works by modulating the **phase** of the carrier wave rather than its amplitude. For the purposes of this paper it is not necessary to understand what the phase of a wave is apart from the fact that it is measured as angle and can take values from 0°-360° (1°=1 degree). In a standard PSK system the carrier is made to jump between two phase angles 180° apart, one of which represents a "1" and the other a "0". In other words, a 2-level or 1 bit scheme. A more sophisticated version of this is **quadrature phase shift keying (QPSK)** where four phase angles separated by 90° are used to produce a 4-level (2-bit) scheme. QPSK is the system chosen for broadcasting digital satellite television as the low level of modulation means it is relatively robust and also because the satellite transmission equipment (the transponders) are more suited to phase modulation rather than amplitude modulation.

Quadrature amplitude modulation (QAM) is a combination of amplitude and phase modulation. This means that a given state of the wave is defined by both an amplitude and a phase angle. This allows high level modulation schemes to be created. For instance, a 64-level (6 bit) system can be produced from using 8 phase angles and 8 amplitudes. Currently, it looks likely that a 16-level (4 bit) QAM system will be the standard chosen in Europe for terrestrial digital TV.

The use of COFDM also opens up the possibility of introducing **single frequency networks (SFNs)** at some point in the future. As discussed above, although there are 44 available TV broadcasting channels in the UK, using analogue technology it is only possible for there to be 4 or 5 national TV services. However, with COFDM the interference problems are very much reduced and so it might be possible for the same frequency channel to be used at

adjacent transmitters[15]. If this were the case then each of the 44 channels could be used to carry a number of national digital television services. However, the ITC believes that recent research suggests that there are severe technical difficulties which must be overcome before national SFNs become a reality. It does not believe that such services could be introduced in the near future[16]. However, it does believe that SFNs might be able to be used in local areas, to enable a main transmitter and local relay transmitters to use the same channel. This would reduce the number of channels which needed to be used in any given area, freeing up some channels for other uses.

The BBC however takes a more optimistic view about national SFNs. It believes that "the immense spectrum efficiency offered by...single frequency networks is worth pursuing vigorously" and that as far as the technical difficulties are concerned[17]:

> "Although requiring receivers to carry out more sophisticated signal processing than required by some schemes, the BBC believes that commercially attractive implementation of such processing in receivers will become possible quite rapidly using integrated circuits able to carry out the high-speed digital signal processing needed. The history of the development of this area of technology gives very good grounds for optimism"

The issue of SFNs is currently of interest, because unlike the rest of Europe, the UK still has two clear (unused) national television channels. These channels, 35 and 37, are earmarked for an analogue Channel 5 service, but the BBC has suggested that one of them should be used for national SFNs (see page 25 below). One of the consequences of national SFNs is that the programme material must be identical across the whole country. The means that regional programming or regional advertising would not be possible, which could well prove unacceptable to the regional commercial broadcasters.

C. Options for the introduction of terrestrial digital television

If analogue services were stopped overnight then there would be scope for the introduction of a great number of different digital television services, possibly as many as 100. However, it is obvious that in the short term this is not a practical possibility. Instead, the important issue is the scope for the introduction of digital television alongside existing analogue services and whether it would be possible to switch over to a totally digital system at some point in the future. If there is scope for the introduction of digital television services then the question arises as to what type of services these should be and what format they should be in. Many of these issues have been examined in an *ITC Discussion Document on Digital Television*

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[15] NK Lodge, AG Mason "A rugged and flexible digital modulation scheme for terrestrial high definition television" *EBU Technical Review* Autumn 1992 pp 34-39

[16] Oral communication ITC, 23 June 1994

[17] Written communication, BBC 23 June 1994

published in June 1993.

1. Spectrum availability for the introduction of digital TV

If Channel 5 television goes ahead then there will be no clear (unused) television channels available on a national basis within the UK. However, there are possibilities for the introduction of digital services on "taboo" channels. These are channels which are not available for analogue broadcasting in a given area because they would cause interference with other services, but which might be able to be used for low-power digital transmissions. Research sponsored by the ITC - the SPECTRE[18] project - has suggested that in some parts of the UK more than 20 digital channels might be available, while in others the availability is three channels or less[19]. The research considered digital transmissions from only the main TV transmitters in the UK, and the results are summarised in the map overleaf. The study found that about 80% of the UK population would be able to receive at least 4 channels if transmissions were broadcast from just the main transmission sites. This compares with a figure of 90% for analogue PAL services from these sites. Each of the available channels might be capable of carrying more than one television service depending on the format of the services (see below).

If Channel 5 were not to go ahead in its present predicted form, then part or all of its earmarked frequencies could be used to increase the availability of digital channels across the whole of the UK. This issue is examined in greater detail in Section III.A.2.

2. Format of new services

The number of digital services which could be broadcast in a single television channel depends on the format of those services and whether the channel was "taboo". Any transmissions in taboo channels must be at low power to reduce the problems of interference with existing analogue services. Low power transmissions mean that signals will be more susceptible to interference and so more robust modulation and/or error correction schemes have to used to ensure proper reception. The use of these schemes result in there being less capacity (lower bit rate) available for television pictures.

Another important factor is the type of equipment and aerial that is used to receive the television pictures. A roof mounted aerial (a "fixed reception" system) will be much more capable of accurately receiving a high bit rate television signal than a set-top aerial on a portable television ("portable reception") which in turn will be better than the aerial on a small screen pocket television being used in a car or train ("mobile reception").

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[18] SPECTRE - Special Purpose Extra Channels for Terrestrial Radiocommunication Enhancements

[19] ITC *ITC Discussion Document on Digital Television* June 1993 Technical Annex

The trade-offs which have to be made between bit rates and the use of clear/taboo channels and fixed/mobile/portable reception are shown in the table below[20]:

Type of Terrestrial Channel	**Digital Capacity Accommodated**	**Reception and Coverage Conditions**
Clear Channel	40 Mbit/s	Fixed reception with full coverage, and portable reception with reduced coverage
Clear Channel	15 Mbit/s	Portable reception with full coverage
Clear Channel	5 Mbit/s	Mobile reception
Taboo Channel	20 Mbit/s	Fixed reception with reduced coverage, and very limited portable reception
Taboo Channel	10 Mbit/s	Fixed reception with full coverage, and portable reception with reduced coverage
Taboo Channel	4 Mbit/s	Portable reception with full coverage

The ITC commissioned study on digital channel availability was based on taboo channels accommodating 10 Mbit/s. As can be seen from the table above such a service would offer full coverage for fixed reception, and reduced coverage for portable reception. This 10 Mbit/s of capacity would be able to offer two 5 Mbit/s television services of comparable quality to existing analogue PAL services or maybe up to eight 1.2 Mbit/s television services of roughly VHS quality (see page 11).

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[20] Taken from the *ITC Discussion Document on Digital Television* Technical Annex p.3

If clear channels were available then up to four times more capacity might be available in a single channel for reception from a roof-top aerial. Such capacity could be used for one full quality HDTV service or 8 PAL-equivalent services or around 30 VHS-equivalent services. If analogue services were stopped at some point in the future, then with 44 clear channels available for digital broadcasting using a single frequency network (SFN) this could open the possibility of there being 350 PAL-equivalent services available nationwide. In practice, there are certain technical difficulties which would need to be resolved, and the ITC has estimated that a more realistic figure for the number of PAL-equivalent channels which could be offered would be of the order of 100 [ibid]. However, the ITC believes that more recent research has indicated that the technical problems with SFNs are significant, and it that such services will not be possible on a national basis in the near future (see page 13 above).

The above figures are only a rough guide to the services that might be available in the future. More reliable predictions will only become possible once a European standard for terrestrial digital TV it agreed upon, probably later next year. Further details on this can be found in Section III.B.2.

D. Picture quality

There are two different aspects of picture quality which are important in digital television services. The first concerns how the service copes with interference or poor reception and the second concerns artifacts which may be introduced through the use of digital compression techniques.

If there is poor reception or interference with conventional analogue broadcasts then the picture degrades on the screen, maybe through "ghosting" or the appearance of "snow", but is generally still possible to watch some sort of image. With digital broadcasts this is no longer necessarily the case. If the reception is poor then it could be impossible to receive any image at all, although if the reception is good then the image should be very good. In other words digital services tend to be "all or nothing"; there is no "graceful degradation" as there is with existing services unless it is specifically designed into the system.

Digital compression techniques can create problems where a sequence of television pictures is too complicated to be able to be compressed properly. Such sequences include those which are very complex with lots of small details or where there are sudden appearances (such as a train coming out of a tunnel). Such problems will occur more frequently where high compression ratios are needed to produce a low bit rate for transmission. In these situations the compression technique will fail to work adequately and some type of distortion or artifact will be introduced.

Some research has been done on which types of programme are likely to contain scenes

which might suffer from distortion but much of this work is still at an early stage. In order to investigate these issues further, an EC research programme has been established on Methods for Optimisation and Subjective Assessment in Image Communications (MOSAIC). The research partners in the UK are the ITC and the University of Essex. The programme will focus on two fundamental questions[21]:

(a) for a particular system delivering general entertainment television, how often will distorted scenes appear?

(b) what will be the reaction of viewers to the resulting quality variation while they are watching their favourite programmes?

The programme will also examine the effects of interference on digital services and the issue of "graceful degradation". A statement on the aims of the programme notes that [ibid]:

> "...graceful degradation is actually an advantageous property of existing analogue television which has perhaps been taken for granted - it is proving difficult to achieve in the digital domain but will be helped by an improved understanding of exactly what the viewer will accept as 'graceful'."

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[21] ITC Engineering, *MOSAIC: Methods for Optimisation and Subjective Assessment in Image Communications* [information note]

III. Plans for digital television

Until recently, many countries were directing their research efforts towards high definition television rather than digital television as it was thought that digital services were a long way off (see Section IV). However, with the rapid advances that have taken place over the last few years, digital television is becoming a realistic prospect and the distinction between HDTV and digital is no longer clear cut. Transmission standards developed for digital television can be applied equally to "standard" and high definition TV.

The following sections discuss proposals for the introduction of terrestrial digital TV into Europe and the UK and proposals for digital satellite TV in the USA and Europe. Plans for digital terrestrial television in the US are focused on high definition systems and these are examined in Section IV.B.1 below.

A. Proposals for terrestrial digital TV in the UK

1. ITC discussion document

In June 1993 the ITC published a *Discussion Document on Digital Television* which suggested that if taboo channels were used for digital television then about 80% of the population would be able to receive at least 4 channels if transmissions were broadcast from just the main transmission sites (see page 15 above). Each of the available channels might be capable of carrying two services of equivalent quality to existing PAL analogue services, or more services of a lower quality.

The document suggested three possible strategies for the gradual introduction of such services over a number of years: simulcasting; new services; combination of simulcasting and new services.

> **Simulcasting:** "Under this model existing terrestrial broadcasters (ie, Channel 3, Channel 4, S4C and the BBC and - if implemented on an analogue basis - Channel 5) would be given the option of broadcasting their service in parallel on a digital channel during a transition or 'simulcasting' phase before the cessation of PAL transmissions."
>
> **New services:** "This model is based on the premise that any new digital channels should be made available to any prospective users, with none being set aside for simulcasting. Existing broadcasters who wished to simulcast would have to bid like anyone else for the necessary digital channels."
>
> **Simulcasting and new services:** "The third model combines simulcasting with the availability of new digital services. It is essentially a restatement of the

> simulcasting model, but recognising that in many areas of the UK more digital terrestrial channels are available than necessary to fulfil simulcasting requirements. Under this third model these additional channels would not lie fallow but would be made available for new services as quickly as possible."

The discussion document states that simulcasting alone would be unlikely to offer an incentive for viewers to switch to digital technology, and so there would have to be some sort of distinction offered between digital and analogues services. This could be achieved if digital services were broadcast at a higher picture quality in wide-screen format, but it would require a higher data rate for transmission which would be difficult to achieve in taboo channels. As far as the "new services" model is concerned, the discussion document states that there could be problems in achieving a transition to exclusively digital services in a fair and equitable way.

The ITC sought comments on the ideas and proposals contained in the discussion document and on 7 specific points. Submissions had to be received by the end of September 1993.

Some indications of the current views of the ITC on these issues were given c in a memorandum it submitted to the Trade and Industry Committee's inquiry into Optical Fibre Networks[22]:

> "14. One area which deserves specific mention is the development of digital terrestrial television. The ITC conducted a public consultation on this issue during the second half of 1993, which confirmed the ITC's view that the prospective long term benefits of a managed transition to all-digital terrestrial broadcasting justify the creation by Government of a legislative framework designed to encourage such a transition. The path will not be a straightforward one, however, and in particular it will be important to safeguard viewers' interests and to make available to broadcasters the necessary incentives to move over to digital transmission. The ITC is eager to contribute to the creation of such a framework in a way which will promote the availability of an ever wider range of services to viewers throughout the UK."

2. Channel 5

In recent months the future of digital television in the UK has become inextricably lined with the future of Channel 5. Under section 28(1) of the *Broadcasting Act 1990* the ITC is required to do all that it can to secure the provision of a service to be known as Channel 5, for such minimum area of the UK as it may determine. In determining that minimum area,

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[22] "ITC publishes memorandum on optical fibre networks" *ITC News Release 38/94* 2 June 1994

the ITC must have regard to the need to make the most effective use of the frequencies on which Channel 5 is to be provided. In accordance with this provision, a 33 transmitter plan was cleared internationally, allowing coverage of approximately 74% of the UK population[23].

The ITC issued an Invitation to Apply for the Channel 5 licence in April 1992, and only one company, Channel Five Holdings Ltd., submitted a bid. In December 1992, the ITC announced that the licence would not be awarded as it did not believe that the applicant would be able to maintain its proposed service throughout the 10 year licence period.. The ITC were not satisfied with a number of aspects of the applicant's business plan and with the level of investor commitment.

One of the main problems with the Channel 5 licence is that applicants have to demonstrate that they can solve the problems relating to interference with video cassette recorders (VCRs). Channel 5 will make use of frequency channels 35 and 37, but this is likely to cause interference with VCRs which use the same frequencies to transmit their signals to televisions they are connected to. Consequently, to eliminate this interference, the successful Channel 5 applicant will have to pay for the re-tuning of millions of VCRs. Cost estimates for this have varied from £20 million to £70 million[24].

In July 1993 the ITC published a paper on *Consultation Of The Future Of Channel 5*. This sought views as to whether the Channel 5 licence should be re-advertised, whether the plan for a single national service should be replaced with several local stations, or whether the Channel 5 frequencies should be used for digital television. The paper made the following comments about the digital television option:

> "28. The ITC issued a separate discussion document on 28 June 1993 which deals with implementation strategies for digital television. One possibility considered in that document is that the frequencies currently set aside for Channel 5 (mainly UHF channels 35 and 37) might be used for digital television, either to improve the coverage available for a digital simulcast version of existing services, or to provide more scope for the introduction of new services digitally, or for some combination of the two.
>
> "29. One possibility under this option is that Channel 5 itself might be used as a vehicle for the introduction of digital terrestrial television in the UK. Indeed the Invitation to Apply issued in April 1992 did not rule out the possible use of digital transmission for Channel 5. The ITC's view, however, subject to comments received in response to this consultation and to the

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[23] ITC *Consultation On The Future Of Channel 5* July 1993 p.2

[24] "Channel 5 offer at half the cost" *The Guardian* 23 April 1994

> discussion document on digital television, is that the Channel 5 of the Broadcasting Act 1990 is not the most appropriate vehicle for the introduction of digital television. Channel 5 has been framed as a single service which caries a number of programme obligations... Given the wide opportunities and the flexibility offered by digital techniques, the need for a coherent introduction strategy for digital television and the likely timescales involved, it appears to the ITC that new legislation would be more appropriate for the introduction of terrestrial services on a digital basis..."

In February 1994, the ITC announced that following the public consultation on the issue it considered that there was "a strong case for re-advertising the single national licence for Channel 5"[25]. However, it went on to state that "before the Commission can take a firm decision to re-advertise it needs confirmation from Government that the necessary frequencies will remain available, ie, that the Government accepts that a Channel 5 service is not incompatible with a longer term strategy for digital terrestrial television".

Following this request from the ITC, the Department of Trade and Industry asked the Radiocommunications Agency to conduct further tests to ensure that the introduction of an analogue Channel 5 service would not hamper the subsequent introduction of digital services. The DTI is the department responsible for the allocation of frequencies, and is also the lead department for dealing with advanced television technologies.

There is considerable debate as to whether the introduction of Channel 5 would hamper the introduction of digital television at a later date. The two main broadcasters, ITV and the BBC, have both expressed doubts about allowing Channel 5 to go ahead as originally suggested. In its response to the ITC consultation papers, ITV made three main points[26]:

> 1. ITV shares the view that to use frequencies now for another analogue channel (Channel 5) would hold back the full potential of digital television to offer viewers improved picture quality including widescreen and more choice for the future. It therefore supports one of the options set out by the ITC - to use channels 35 and 37, the frequencies originally proposed for Channel 5, for the introduction of terrestrial digital television.
>
> 2. For the introduction of terrestrial digital television ITV favours the option of providing a mix of simulcasting (the simultaneous transmission of ITV, BBC and C4 services in both analogue and higher quality digital widescreen form) and new services.

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[25] "Future of Channel 5: Current position" *ITC News Release 13/94* 21 February 1994

[26] "ITC Consultation Papers - ITV response" *Information Technology & Public Policy* Winter 1993 p.6

> 3. The introduction of terrestrial digital television should take full account of the universality of existing terrestrial services. More efficient use of the spectrum should not be pursued at a pace which would disenfranchise existing viewers. ITV believes, therefore, that the transitional period from the existing analogue (PAL) system to digital should be 15 years rather than the ITC's "at least ten years".

The BBC has not made a formal public statement on the future of Channel 5, but it has made its views clear on the issue of digital television and the use of channels 35 and 37. It believes that the concept of using single frequency networks to provide national digital services is "worth pursuing vigorously"and that[27]:

> "Establishing a single frequency network for up to four conventional quality services available throughout the UK requires one free channel to be available nationally. There are generally no such channels free of existing services in mainland Europe, but there are two currently available in the UK, and, whatever demands there may be for an additional analogue service, the BBC believes at least one of these channels should be kept free for the development of digital terrestrial television offering a number of services via a single frequency network."

There have been various press articles about the BBC's plans in this area, but the Corporation disputes the accuracy of some of them[28,29,30]. The issues of single frequency networks and whether they are technically feasible in the near future are addressed in Section II.B.3 above (page 13).

The Government's view on digital television was recently set out in its Competitiveness white paper[31]:

> "Digital technology is already transforming TV studios and is expected to reach many viewers over the coming decade:
>
> · it is likely to offer viewers more channels, better pictures, mobile TV

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[27] Written statement, BBC 23 June 1994

[28] "BBC wants 2 new TV channels" *Evening Standard* 12 April 1994 p.1

[29] "Drop fifth channel, says BBC" *Independent on Sunday* 27 March 1994

[30] "Tuning in to confusion" *The Independent* 25 April 1994 p.24

[31] *Competitiveness Helping Business to Win* Cm 2563 May 1994

and the merging of entertainment and business applications

- the UK network and consumer digital TV equipment market will be worth £5 billion to £10 billion over 15 years and considerably more world wide

- it could eventually release radio spectrum worth £5 billion a year to UK business

"The UK can capture a significant share of this market. It has a strong base of Far East investors, leading to the UK becoming a net exporter of TV sets, and some go-ahead indigenous companies. But Governments in competitor countries are developing strategies to bring digital video broadcasting to their markets. The best chance for UK based companies will come with the UK market moving ahead with the fastest of our competitors, whether by satellite, cable or terrestrial means.

"The Government has a particular role in the terrestrial means through its control of radio frequencies. Digital technology is far more efficient than analogue technology. If their is a firm commitment from broadcasters to introduce digital terrestrial television services at an early date, the Government would be prepared to give priority to frequency channels for digital technology over analogue technology. This would secure the advantages of digital technology as rapidly as possible."

The statement that "the Government would be prepared to give priority to "digital technology has been clarified by a written parliamentary answer from Peter Brooke, the Secretary of State for National Heritage[32]:

> **Mr. Gyles Brandreth:** To ask the Secretary of State for National Heritage, what priority he intends to give to digital technology in relation to the licensing of future television services.
>
> **Mr Brooke:** The Government will continue to look at how best to take advantage of the opportunities this technology offers. Studies are continuing into the feasibility of launching an analogue Channel 5 without prejudicing the development of digital terrestrial television in the United Kingdom, and an announcement on this issue will be made before long. These studies are based on technical work which has recently become available. The relevant sentence in the "Competitiveness" White Paper is

[32] HC Deb 24 May 1994 cc 98-99W PQ from Gyles Brandreth MP

overtaken by this answer.

The results of the Radiocommunications Agency study have not yet been published but press reports have indicated that a compromise is possible on the issue[33,34]. The press reports suggest that Channel 5 will be allowed to go ahead in analogue form, but that it will only be allowed to use one of the two clear television channels with the other being kept back for digital services. The *Observer* press article states that the removal of the second channel will mean that the coverage of Channel 5 will be reduced from 75% of the population to 50% which could significantly affect its commercial viability. It is expected that once the Secretary of State for National Heritage, Peter Brooke, and the President of the Board of Trade, Michael Heseltine, have come to a joint position the whole matter will be referred to the Cabinet for a final decision [ibid].

B. European proposals for digital TV

1. EC initiatives

The debate over future standards for television transmission systems in Europe has been a long and controversial one. Discussions first took pace on the issue about ten years ago and subsequent efforts focused on the adoption of a series of analogue MAC (Multiplexed Analogue Components) standards including one for high definition television (HD-MAC). The history of the development of these standards is examined in section IV.A.1 below, but essentially work on these standards has been abandoned and research efforts are now concentrated on digital television.

In July 1993, the European Council passed a resolution calling on the Commission to produce a report on digital television within Europe containing the following elements[35]:

> "(i) mechanisms for achieving early agreement on a common Community perspective on the development and needs of the market for digital television systems which can inform and guide the standardization of such systems, including the feasibility of a single (family of) digital television standard(s) and matching encryption system(s);
>
> (ii) a timetable for the development, system specification, system

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[33] "Bidders shy away from blinkered Channel 5" *The Observer* 14 June 1994 p.5

[34] "Positive verdict on impact of Channel " *Financial Times* 6 June 1994 p.8

[35] *Council Resolution 93/C209/01 of 22 July 1993 on the development of technology and standards in field of advanced television services* OJC 209 3 August 1993

implementation, evaluation and subsequent standardization;

(iii) Community funding of the above activities, if required."

The report along with a *Draft Council Resolution on a framework for Community policy on digital video broadcasting* was published by the Commission in November 1993[36] accompanied by a volume of technical papers on the issue[37]. The report analyses the current situation regarding digital television finding that:

" digital technology offers significant potential benefits in relation to television service quality, the flexibility of its provision and the more efficient use of spectrum, compared to current analogue technology and, more importantly, digital television has the potential of accelerating the implementation of global information networks delivering a wide variety of information services to consumers in a convenient and flexible manner;

" the complete transition from the existing analogue system to a digital system is a long term process requiring, perhaps, two decades to complete. This transition will have to be organized and coordinated in order to enable the full benefits of the technology to be achieved in practice. Some of the benefits of the new technology will not be fully obtained until the end of the transition period. In the meantime it will be important to avoid the situation where early or not-well-conceived implementations of digital television in the market makes it difficult or impossible to introduce subsequent more general and more advanced steps in a compatible manner - thus inhibiting future market development both for television itself and for the broader global network;

" the Community is thus faced with a major political choice: can this transition be left to the market alone, where timescales for return on investment are typically much shorter than the time needed to make this transition in an optimum fashion, or is appropriate for the Community to develop a longer term vision of the future global networks and encourage market parties to make their investments and market offerings in ways which are compatible with such a long term vision?"

The Report concludes that there are two different kinds of issue for Community policy:

"The first set of issues involve aspects where it is clear that the Community can and must act. They include:

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[36] *Communication from the Commission...on digital video broadcasting...* EC draft 10463/93 18 November 1993

[37] DG XIII, European Commission *Digital Video Broadcasting: A Volume of Technical Papers Accompanying the Commission's Communication* 1993

- the intensification and adequate coordination of Research and Development in this field;

- the encouragement of appropriate standardization of digital television systems including HDTV;

- the protection of the public interest through ensuring free and fair competition and through consumer protection;

- to continue dialogue with third parties including the United States of America and Japan with a view to identifying and agreeing common elements in the future of television systems to be implemented throughout the world.

"Another set of issues, perhaps much more important than those above, will require a more profound debate as to whether the Community possess the will and the means necessary to take the appropriate initiatives. They include:

- the development of a long term perspective for the global Integrated Broadband Communications networks of the future including but not limited to digital television aspects;

- the development and implementation of consistent migration strategies from the present analogue television situation to the future digital one, including the necessary replanning of frequency spectrum allocations in this connection;

- the desirability or otherwise of making certain standards mandatory through Community regulatory action

The Commission concludes the report by inviting the Council and the European Parliament to "debate the issues identified and to give guidance for the further development of Community policy in this area with special attention being focused on the more challenging issues outlined in the second list above".

The Telecommunications Council last met on 30 May 1994 and "agreed conclusions setting out the next steps on standards for advanced television and invited the commission to draft an article on conditional access [encryption] for pay television to be included on a draft directives on standards [see page 37 below]"[38]. The Council also agreed the text of the draft

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[38] HC Deb 21 June 1994 c.82W, PQ from Nick Hawkins MP

resolution on the development of digital broadcasting. According to the press agency Agence Europe:

> "The resolution on the framework for a community policy states that , in order to ensure the 'harmonious development' of digital technologies, the Council 'awaits with great interest' any agreement that could be concluded (on a voluntary basis) by the economic actors concerned, including broadcasting organizations. In the absence of adequate consensus in due time, and/or in the event the necessity of guaranteeing fair and open competition would so require, the Council is nevertheless prepared to "take regulatory measures, if necessary" to facilitate this realization. It welcomes the European Commission's plans to:- include actions in this area in its proposals for specific research programmes; - encourage the process of standardization of digital TV; - encourage the development of implementation scenarios for digital TV broadcasting; - encourage studies on the availability of the spectrum and strategic questions related to frequencies; - maintain a political dialogue with, notably, the United States and Japan."

The Commission's report and the draft resolution has been considered by the House's Select Committee on European Legislation on two occasions[39,40]. In both cases the Committee has decided that the "proposals raise questions of political importance, but make no recommendation for their further consideration". The second report on the issue contains answers to a series of question put to the Government in the first report. One of these comments on the industrial support for these measures:

> G. What are the reactions of broadcasters and equipment manufacturers to these proposals?
>
> "Broadcasters and consumer electronics manufacturers have welcomed the intention to repeal Directive 92/38/EEC (the so-called MAC Directive) which will take effect on the adoption of the new draft directive [see page 37 below]. To the extent that the latter now reflects market realities, the broadcasting sector is generally content...
>
> "It is the aim of the broadcasting industry as represented in the European Project to achieve the market-led introduction of digital TV systems. Members are working to reach a consensus on appropriate common technical standards. The draft Council Resolution's intention step back from this process and reserve the use of a regulation only [for] those occasions where consensus is

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[39] Select Committee on European Legislation *Fifth Report: Session 1993/94* 26 January 1994 HC 48-v 1993/94 pp xiv-xviii

[40] Select Committee on European Legislation *Fifteenth Report: Session 1993/94* 20 April 1994 HC 48-xv 1993/94 pp xxxii-xxxiv

not achieved is therefore welcomed."

2. Digital Video Broadcast group

The future of digital television in Europe is being considered by the Digital Video Broadcasting (DVB) group, an association of 120 interested parties including television manufacturers, broadcasters, satellite operators, governments and regulatory bodies. The group first came together on an informal basis at the end of 1991, but became an established body, the European Digital Video Broadcasting Project, with a formal Memorandum of Understanding (MOU) under the aegis of the German Ministry of Posts and Telecommunications in September 1993. Article 1 of the MOU defines the purpose of the DVB project [41]:

> "The purpose of this Memorandum of Understanding is to create in Europe a framework for a harmonious and market driven development of digital television via cable, satellite and terrestrial broadcasting, - the DVB project.
>
> This shall be realized through:
>
> - promoting and contributing to the definition of technical standards for digital television and their widespread utilisation/adoption.
>
> - facilitating the introduction of new services using those standards, which may include studies on associated matters such as frequency planning and conditional access.
>
> - facilitating the closest possible coordination between pre-competitive R&D and standardisation."

The group has various "modules" looking at technical issues, and different aspects of satellite, cable and terrestrial broadcasting. To begin with, the technical module (originally known as the Working Group on Digital Television Broadcasting) focused on terrestrial television, but more recently it has concentrated on satellite television because of its more imminent start-up date. The module has also proposed a provisional timetable for digital video broadcasting in Europe[42]. This envisages that the technical standards for satellite TV

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[41] DG XIII, European Commission *Digital Video Broadcasting: A Volume of Technical Papers Accompanying the Commission's Communication* 1993 pp 416-422

[42] *Communication from the Commission...on digital video broadcasting...* EC draft 10463/93 November 1993

will be completed this year with the service ready to start in 1995 and that standards for terrestrial TV will be finalised in 1995/96 with a possible start date in 1998. Recently there have been moves to try to advance the dates for terrestrial TV by about one year[43].

Substantial progress has already been made by the DVB group on the standards to be used for the different transmission methods. All three methods (satellite, cable and terrestrial) are to use the MPEG2 standard for digital compression, satellite TV will use a QPSK modulation scheme, and it looks likely that both cable terrestrial and terrestrial standards will be based on QAM modulation schemes (see above, page 12).

As discussed above there is considerable scope for choice in the development of formats for digital television. For instance, if roof aerials are used it is possible to achieve a higher bit-rate and hence a higher-quality picture (or more services) than if portable reception is required. One solution to the problem of different types of receivers only being capable of receiving different types of services is to introduce a "hierarchical" system. Such a system could have two data streams in one television channel. One stream would provide essential low-rate data capable of providing a basic picture quality on a portable receiver, whilst the second stream would carry data at a high rate which could be received with a roof-top aerial and upgrade the basic picture to high definition quality.

Hierarchical systems have also been proposed as a way of moving from simulcasting of digital services in taboo channels to transmission of a full digital service on all channels. During the taboo period data could be transmitted at low power with a low data rate (6 Mbit/s), but once analogue services had terminated this could be boosted with a higher power signal at a higher data rate (18 Mbit/s). The low data rate signal would be very rugged and capable of being received on a portable receiver, whilst the higher data rate would only be receivable with a roof-top aerial.

There may be some difficulties in introducing a uniform system for the introduction of terrestrial digital TV on taboo channels across Europe because of the different availability of frequencies in different countries. On the whole, studies are at a relatively early stage on this issue, but it has been suggested that the situation is easiest in Scandinavia but most difficult in Italy[44]. Even in a particular country, the availability of channels is expected to vary widely on a geographical basis. The situation pertaining in the UK is described in Section II.C.1.

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[43] Oral communication, DTI 22 June 1993

[44] T. Long "Implementation issues for digital television services" Chapter 4 in ref 37

It is too earlier too say what standard might be produced for digital terrestrial taboo TV, but one proposal is based on a 16-level QAM modulation scheme providing a data rate of 12 Mbit/s. This would have good coverage for roof-top aerials, but limited portable coverage. Such a system would be able to provide two services of comparable quality to existing analogue PAL services or up to ten services of roughly VHS quality.

C. Proposals for digital satellite TV

Plans for the introduction of digital satellite television are much more advanced than those for terrestrial digital TV. In the United States, DirecTV, a subsidiary of GM Hughes Electronics, has already launched one direct broadcast digital satellite and a second is due to be launched in July 1994[45,46,47]. The two satellites will be able to provide about 150 channels, and the service should be available nationwide by September. The costs of the services have been estimated at about $30 a month in subscription charges plus $700 for a satellite dish, set-top box and remote control[48].

In Europe, the owners of the Astra satellites, Société Européene des Satellites, has plans to launch two digital satellites; Astra 1E next year and Astra 1F early in 1996[49]. It is hoped that these satellites will be able to use the standard currently being developed by the European Digital Video Broadcast Group (see page 32 above). Much of the standard, such as the digital compression scheme (MPEG2) and the modulation method (QPSK) has already been agreed but further work needs to be done on "conditional access".

The term "conditional access" refers to the system by which the satellite TV companies control viewers access to different programmes and channels so that only those who have paid the appropriate charges can actual watch the service. Conditional access has been singled out as an important issue by the EC in drawing up a Council resolution on digital video broadcasting (see Section III.B.1 above). An Explanatory Memorandum on the draft resolution produced by the DTI noted that[50]:

> "7. The proposed Council Resolution singles out conditional access as an issue, noting that Community policy on it should be based on ensuring fair and open competition, on protecting the interests of the consumer, and on minimizing the possibility of piracy. Conditional access is that part of the

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45 "Small-Dish TV Offers Wireless Revolution" *The Washington Post* 18 December 1993

46 "General Dynamics Unit to Launch CM Unit Satellite" *Dow Jones* 25 February 1994

47 "Look, no wires - Satellite television in the US" *The Economist* 27 November 1993

48 "Wireless Cable-TV Sector -2-: The Largest Wireless Operator" *Dow Jones News Database* 8 June 1994

49 "The high price of buying cheap" *The Times* 25 March 1994

50 DTI Explanatory Memorandum on EC draft 10463/93 13 January 1994

> transmission system which scrambles broadcast signals and provides authorised users with the means to descramble them, The cost of providing descrambling "boxes" and the reluctance of TV owners to have more than one "box" by their receiver givers the first provider of a conditional access system a great advantage over later comers".

The issue of standards for digital television systems, including satellite, are the subject of a draft EC directive (see page 37 below). Article 3 of the draft directive states that "all completely digital systems must use a transmission system which has been standardised by a European standardisation body". The draft directive does not restrict the definition of satellite services to DBS systems, unlike the earlier MAC directives, and so it would equally apply to telecommunication satellites such as Astra. Negotiations on the directive are still ongoing, but it is possible that all future digital European satellite broadcasts will be required to adopt similar transmission standards.

IV. HDTV proposals in Europe, Japan and the USA

Following the advance in digital technologies, work on analogue HDTV systems is unlikely to be taken much further. Both Europe and Japan have invested substantial funds into analogue HDTV research, and these efforts are examined in Section IV.A below.

The USA has been investigating HDTV systems since the 1980s, but its approach has focused on digital rather than analogue technology. Its research is now well advanced and final decisions have been made on the technology which is to be used for a terrestrial HDTV service. Details of this research and the timescales involved can be found in Section IV.B.

A. Analogue systems

1. Europe and HD-MAC

The history of HDTV research in Europe is a long and tortuous one. The EC started to develop a HDTV system in the 1980s in response to Japan's MUSE HDTV system which was first demonstrated in 1982. The idea behind the EC research efforts was to provide a series of upwardly compatible standards for standard definition television (D-MAC), enhanced definition wide-screen television (wide-screen D2-MAC) and eventually HDTV (HD-MAC). All three standards were designed for satellite transmission as it was considered that there would not be sufficient bandwidth available for terrestrial broadcasts.

The MAC (Multiplexed Analogue Components) standards are essentially analogue standards but incorporate some digital signals for audio and other data. To encourage the adoption of the MAC standard, the EC passed directive 86/529/EEC in 1986 which required all Direct Broadcast Satellites (DBS) to use the MAC standards. This included BSB's Marco Polo satellite, but excluded the Astra satellites, which use the PAL standard, as they are officially classed as telecommunications satellites rather than broadcast satellites. Following the commercial failure of BSB and its merger with Sky, MAC transmissions from the Marco Polo satellite ceased at the end of 1992.

In May 1992, after long both in the European Council and Parliament a second MAC directive (92/38/EEC) was introduced. As mentioned above, the directives objective was "to establish standards for the definition from the transition from standard definition television to high definition television by means of an evolutionary approach using the D2-MAC and HD-MAC transmission systems. The directive, due to run until 1998 and applying to all satellite and cable (but not terrestrial) broadcasts, required that all wide-screen services which were not fully digital had to use the D2-MAC standard and that all non-fully digital HDTV services had to use the HD-MAC standard.

The directive was shortly followed by a Commission proposal for an Action Plan to support the introduction of advanced television services into Europe[51]. The Commission proposed that a subsidy of up to 850 mecu (£600 million) over 5 years should be made available to accelerate development of a market for wide-screen and high definition television services. Discussions on the proposal were held at a Telecommunications Council meeting in June 1992. Some states were opposed to the size of the subsidy and in particular the UK Government found it "totally unacceptable" believing that the Commission had not "come anywhere near [presenting] a convincing business case" for providing any subsidy[52,53]. At the next Council meeting in November 1992, 10 member states agreed to support the Commission's proposal in principle but some disagreed about the size of the subsidy[54]. The UK remained unconvinced about the need for any subsidy[55]. When the issue was discussed again in December 1992, the UK remained the only country opposed to the plan for a reduced subsidy of 500 mecu. It believed that the MAC technology could be overtaken by digital technology and that Europe risked going up a "technological cul-de-sac"[56]. As a compromise the UK proposed that a subsidy of 80 mecu should be made available in 1993 and that there should be a review of all advanced television technologies including HDTV, but this was rejected.

The opinion that digital television was important for the future was also held by two major electronics company in Europe. Both Philips and Thomson were conducting research into digital television and were heavily involved in US plans to develop digital HDTV (see below)[57]. However, both the companies had invested substantial research funds in developing MAC equipment and continued to support the analogue technology in Europe.

At the beginning of February 1993, the EC industry commissioner, Martin Bangemann, suggested that Europe's plans for HDTV might have to revised following the advances made in digital technologies[58]. Later the same month he virtually announced the end of the EC's HDTV strategy commenting that the EC would have to fall in line with the United States on a transmission standard for digital HDTV[59]. He stated that a digital standard did not have to be set by the EC and that global standards were always the best solution. The Commissioner suggested salvaging the best elements of the research programme conducted so far and concentrating efforts on the development of wide-screen television. At about the same time Philips announced that it was abandoning its plans for mass production of high definition television sets.

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[51] EC Draft 6242/92 [Com(92) 154 final] 5 May 1992

[52] HC Deb 18 June 1992 c. 623W, PQ from Anthony Steen MP

[53] "Wide Screen TV: EC proposals 'totally unacceptable' - Edward Leigh" *DTI press notice P/92/355* 5 June 1992

[54] "UK accused of holding up TV deal" *Financial Times* 20 November 1992 p.2

[55] HC Deb 3 December 1992 c.349W

[56] "UK blocks funding for Brussels-backed HDTV strategy" *Financial Times* 16 December 1992 p.1

[57] "The shape of TV to come?" *New Scientist* 15 August 1992 pp 21-22

[58] "New devices ruffle TV plan" *Financial Times* Financial Times 4 February 1993 p.2

[59] "Europe will follow US lead over high-definition TV" *Financial Times* 19 February 1993 p.16

At the next Telecommunications Council in May 1993 a new draft compromise plan was proposed for a 200 mecu subsidy over three and a half years. The subsidy was to be directed at wide-screen services and would be available irrespective of the standard or method of transmission used. Agreement could not be reached on the plan, with 11 member states generally in favour of the plan and the UK opposed to parts of it[60].

Agreement was finally reached on the Action Plan at a Council meeting on 16 June 1993 involving a subsidy of 228 mecu (£160 million)[61]. The plan was solely directed at promoting wide-screen services irrespective of the transmission standard used or whether the services were for terrestrial, satellite or cable broadcasting[62]. The funds were aimed at broadcasters and programme makers in Europe, subsiding the production of new programmes and the conversion of existing programmes into the wide screen format.

Following the adoption of the Action Plan with its non-prescriptive approach towards transmission standards the EC Commission has proposed the repeal of the MAC directive and the introduction of a new directive on television standards[63]. The new directive would require all wide-screen television services, however transmitted, to be in the 16:9 aspect ratio and merely requires non-digital services to use the D2-MAC transmission standards or "a transmission system which is fully compatible with PAL or SECAM [the French television standard]". It would also require HDTV services to use the HD-MAC system only if they were not fully digital. If digital services are introduced the directive requires that they use a transmission system "which has been standardised by a European standardisation body". In an Explanatory Memorandum to the proposal the Government have stated that "the provisions of the replacement directive are considerably less restrictive than those in the 'MAC directive' and, as such, are welcomed".

The Commission have also produced a "communication" on digital video broadcasting which examines the current state of research on digital television and proposes a framework for Community policy in this area[64]. Further details of these proposals can be found in section III.B.1 above.

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60 "Telecommunications Council: Draft compromise for HDTV debated" *EC Council Press Release 6381/93* 10 May 1993

61 "Council: Advanced television services" *Council Press Release 7280/93* 16 June 1993

62 *Council decision of 22 July 1993 on an action plan for the introduction of advanced television services in Europe* OJL 196 5 August 1993 pp 5448 [EC draft 7655/93]

63 *Proposal for a Directive...on the use of standards for the transmission of television signals* EC draft 10576/93 16 November 1993

64 *Communication from the Commission...on digital video broadcasting...* EC draft 10463/93 18 November 1993

The EC and other European countries have very recently agreed on a research project on digital HDTV, signifying the final abandonment of the HD-MAC programme[65]. The project on Advanced Digital Television Technologies has been organised as a pan-European Eureka research programme. It is due to last for two-and-a-half-years and has funding of 250 mecu (£195 million). The project will cover all aspects of digital television including production, transmission, reception and display equipment and their key technologies. .

2. Japan and MUSE

Work on the MUSE (Multiple Sub-Nyquist Encoding) system for HDTV began in Japan in the 1970s. It is an analogue system, designed for transmission from satellite, and is based on wide screen format with a resolution of 1,125 lines. The Japanese first demonstrated a working system in 1982, and experimental broadcasts from satellite began in 1989[66]. The system is now marketed under the name "Hi-Vision" and eight hours of programmes are broadcast every day.

Although the system is the only operational HDTV system in the world it has not been a commercial success. HDTV sets cost about £20,000 when the service was first introduced and this has only dropped to £5,000. The reason for their large cost is that sets have to be very large, say 36 inches, to take advantage of the high resolution provided by the service. It has been estimated that only 20,000 sets have been sold[67].

In February 1994, Mr Akimasa Egawa, director-general of Japan's Posts and Telecommunications Ministry's broadcasting administration bureau announced that Japan should consider many possibilities for HDTV in the context of a global trend towards digital systems and that a final decision would be made by the summer [ibid]. He is reported as having said that "the world trend is towards digital systems and the analogue approach has failed"[68]. These statements created an outcry in Japan with the broadcaster NHK saying that the remarks "hinder the progress of Hi-Vision promotion, spoil the efforts hitherto made by the concerned parties, run counter to audience expectation and are thus very regrettable". NHK is estimated to have invested $200 million in HI-Vision, and the country as a whole may have spent as much as 50 times this amount (£6.3 billion).

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65 "Europe drops HDTV project" *Broadcast* 24 June 1994 p.9

66 "The quest for a global picture" *Ariel* [BBC staff magazine] 12 January 1993 pp 12-13

67 "Japanese TV faces shake-up" *Financial Times* 23 February 1993 p.22

68 "Japan trips up over high-definition television" *Nature* 3 March 1994 p.9

According to press reports [ibid]:

> "Egawa's biggest crime appears to be his failure to win the consensus of industry and NHK before making his remarks, even though his views are in tune with many in his ministry and in industry.
>
> "He called a...press conference the next day to assure his critics that the ministry would continue to support the analogue standard, at the same time as moving towards digital systems. But that was not enough, and the Minister of Posts and Telecommunications, Takenori Kanzaki, had to step in and announce that a decision on HDTV will be postponed for a year while an advisory committee discusses the issue."

More recently, the Ministry of Posts and Telecommunications has announced that it will standardise digital television technology for satellite, terrestrial and cable broadcasting by 1996[69]. This follows a report from an advisory committee which recommended the early development of digital broadcasting technology in line with international trends. The report commented that [ibid]:

> "The standardisation of ATV (next generation TV) broadcasting in the US and satellite digital TV broadcasting in Europe is expected to progress strongly in the next year or two, while international standardisation through the ITU (International Telecommunication Union) is also planned in the future."

B. Digital systems

1. USA and the Grand Alliance

In 1987 the US Federal Communications Commission (FCC) held an inquiry into Advanced Television Systems which was followed a year later by a "tentative decision" and a further inquiry to look at terrestrial broadcasting systems. In 1990 the FCC announced that it would decide on a new high-definition television standard for terrestrial broadcasting in early 1993 and this standard would be based on the practical results of a competition to be held between rival systems[70]. By April 1991 the competition had been whittled down to six different systems proposed by four different consortia:

American TeleVision Alliance (ATVA): General Instruments Corporation

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[69] "Japan moves on digital TV plan" *Financial Times* 28 April 1994 p.8

[70] B Evans, *Digital HDTV: The way forward* 1992 p.141

	Massachusetts Institute of Technology (MIT)
Advanced Television Research Consortium:	Compression Labs David Sarnoff Research Center National Broadcasting Corporation (NBC) North American Philips Thomson Consumer Electronic Inc
Digital Spectrum Compatible (DSC):	AT&T Zenith
Japan Broadcasting Co (NHK)	

In March 1993, following exhaustive tests of the various systems the proposal from NHK was ruled out on the grounds that it was based on analogue rather than digital technology[71]. The panel examining the remaining systems, the FCC's Advisory Committee on Advance Television, found that they all had short comings and announced that further tests would have to take place. However, merger talks started between the three consortia following a recommendation from Richard Willey, the head of the Committee, that they should form a "grand alliance" to develop a standard based on the best elements of all their systems[72]. The talks were successful and the three consortia reached an agreement on 24 May 1993 to submit a single HDTV proposal to the FCC[73]. The members of the Grand Alliance were AT&T, the David Sarnoff Center, General Instrument, MIT, North American Philips, Thomson Consumer Electronics and Zenith Electronics[74].

The Grand Alliance conducted numerous tests on various systems in cooperation with the FCC and made a final decision for a digital HDTV standard in February 1994[75]. The standard is based on MPEG2 compression and an 8-level VSB modulation scheme (see above). The VSB scheme was chosen after tests showed that VSB signals were less susceptible to interference, could be received over a broader area, and had less effect on existing analogue services than a QAM modulation scheme[76]. The services are expected to be broadcast in taboo channels (6 MHz bandwidth) with a data rate of about 18 Mbit/s available for the HDTV signals (the remaining capacity being used for audio and error correction signals). The system is scheduled for final verification testing in late 1994 and field testing in early 1995.

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[71] "A blurred vision of the future" *Financial Times* 4 March 1993 p.16

[72] "USA file" *The Engineer* 11 March 1993 pp 8-9

[73] "US deal will speed start of HDTV" *Financial Times* 25 May 1993 p.22

[74] Advisory Committee on Advanced Television "HDTV 'Grand Alliance' Proposal Will Be Considered by FCC Advisory Committee" 24 May 1993

[75] "US poised to take lead in digital HDTV" *Financial Times* 17 February 1994 p.7

[76] "American cable companies tangle up new TV standards" *New Scientist* 12 March 1994 p.18

As far as the introduction of an actual HDTV service is concerned, the FCC have made the following decisions[77]:

* The new system must use 6 MHz channels (The European channel spacing practice is 7 or 8 MHz)

* The new service will be simulcast with the existing NTSC [analogue] services

* Following the setting of the standard (1995/96) broadcasters will have three years to apply for licence to broadcast the new service. If a licence is awarded they get an additional 6 MHz of spectrum per programme

* A further three years (i.e. up to 2001/2002) is envisaged for equipping the networks and studios for the new technology

* Following fifteen more years (i.e. 2016/2017) the NTSC [analogue] system would be withdrawn and the entire US terrestrial television network would be digital.

Although the proposed system only applies to terrestrial broadcasting of HDTV, it is "unthinkable" that any future US digital standard for standard definition television (SDTV) would use a different modulation scheme to the HDTV standard[78]. Currently, digital SDTV services are forbidden in the US.

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[77] *Communication from the Commission...on digital video broadcasting* EC draft 10463/93 18 November 1993 p.19

[78] "Decisions are split over TV viewing" *Electronics Weekly* 9 March 1994 p.16

V. Glossary and abbreviations

AM	Amplitude Modulation, a modulation scheme where the signals that need to be broadcast are used to alter the amplitude of a carrier wave (see modulation scheme)
analogue television	analogue television pictures are represented in the form of a continuously varying electrical signal, unlike digital television
aspect ratio	the width:height ratio of a television picture, conventional television has a 4:3 aspect ratio, whilst wide-screen television has a 16:9 aspect ratio
bandwidth	the range of frequencies need to carry a signal over the airwaves. It is used as a measure of the capacity of analogue transmission system. Measured in Hz.
bit	binary digit, ie. a "0" or a "1", digital information is stored as a sequence of bits
bit/s	bit per second - used as a measure of the capacity of a digital transmission system or the data rate needed to transmit a digital television picture. Generally, the higher the picture quality, the higher the data rate required to transmit it.
channel	small part of the frequency spectrum used to transmit a television service over the airwaves. In the UK there are 48 channels (21-68) each of 8 Mhz bandwidth. Currently, 44 of these channels are used to provide 4 national television services (BBC1, BBC2, ITV, C4).
clear channel	a television channel which is not used for television services anywhere in a given country. In the UK, channels 35 and 37 are "clear" although they have been earmarked for a future Channel 5 service.
COFDM	Coded Orthogonal Frequency Division Multiplexing - a technique that allows hundreds or even thousands of carrier waves to be used in a modulation scheme instead of one. Signals transmitted in this way are less prone to interference problems
conditional access	the system by which the satellite TV companies control viewers access to different programmes and channels so that only those who have paid the appropriate charges can actual watch the service. This achieved by scrambling the TV pictures, and having a set-top box which can only unscramble the picture if the correct smart card is present
D-MAC	a MAC television standard, based on "normal" resolution television (625 lines)
D2-MAC	a MAC television standard, based on "normal" resolution but with the capability of offering wide-screen television
digital television	television where the picture and sound information is represented in digital form as a series of ones and zeros called bits
DBS	Direct Broadcast Satellite - a high powered broadcasting satellite, operating in a specific frequency range allocated for DBS services
DVB	Digital Video Broadcast [group] - an association of 120 parties interested in the development of European standards for digital television

FCC	Federal Communications Commission - the US regulatory agency dealing with communication services (including television)
FM	Frequency Modulation - a modulation scheme where the signals that need to be broadcast are used to alter the frequency of a carrier wave (see modulation scheme)
FSS	Fixed Satellite Service - a medium powered telecommunications satellite, operating in the frequency range 10.95-11.7 GHz. The Astra satellites are FSS satellites
HD-MAC	a high definition MAC standard, based on an 1250 line television picture
HDTV	High definition television, generally meaning a wide-screen television service with double the resolution of standard systems ie. 1250 lines in the UK and Europe, 1050 lines in the US and 1125 lines in Japan
Hz	unit of frequency, one hertz is one oscillation or one cycle of a wave per second
ITC	Independent Television Commission
kHz	kilohertz - thousand hertz, 1 kHz = 1,000 Hz
MAC	Multiplexed Analogue Components - a family of mainly analogue television standard developed in Europe for satellite broadcasting. There are three main standards (D-MAC, D2-MAC and HD-MAC) used for different types of services.
MPEG	Moving Picture Experts Group - an expert group of the International Standards Organisation, responsible for drawing up standards for the digital compression of television pictures
Mbit	megabit - million bits, 1 Mbit = 1,000,000 bits
MHz	megahertz - million hertz, 1 MHz = 1,000 kHz = 1,000,000 Hz
modulation scheme	the technique by which a carrier wave used for transmitting a signal, such as pictures or sound, is modified so that it can carry that signal.
MUSE	Multiple Sub-Nyquist Encoding - Japanese analogue HDTV standard based on 1125 lines
NTSC	National Television System Committee - US and Japanese analogue television standard based on 525 lines per frame and 30 frames per second
PAL	Phase Alternate Line - analogue television standard used in the UK and Western Europe based on 625 lines per frame, and 25 frames per second
SECAM	SEquential Couleur A Memoire - analogue television standard used in France and some other countries. It is similar to PAL but differs in the method of producing colour signals
SFN	Single Frequency Network - the concept that a single clear TV channel can be used to broadcast the same digital television services nationwide
SPECTRE	Special Purpose Extra Channels for Terrestrial Radiocommunication Enhancements
taboo channel	channels which are not available for analogue broadcasting in a given area because they would cause interference with other services, but which might be able to be used for low-power digital transmissions.

UHF	Ultra High Frequency - frequency spectrum from 300 MHz to 3,000 Mhz. Television services in the UK are broadcast in the UHF spectrum between 470 MHz and 854 MHz.
VHF	Very High Frequency - frequency spectrum from 30 Mhz to 300 MHz, a small part of which is used to broadcast FM radio programmes
QAM	Quadrature amplitude modulation - a modulation scheme where the digital signals that need to be broadcast are used to alter the amplitude and phase of a carrier wave(s) (see modulation scheme)
QPSK	Quadrature phase shift keying [modulation] - a modulation scheme where the digital signals that need to be broadcast are used to alter the phase of a carrier wave(s) (see modulation scheme)
VHS	Video Hone System -a video cassette format used for domestic video recorders. Pictures recorded on a VHS video recorder are of lower quality when played back than broadcast television pictures
VSB	Vestigial side band [modulation] - a modulation scheme where the digital signals that need to be broadcast are used to alter the amplitude of a carrier wave(s) (see modulation scheme)
wide-screen	television services with an aspect ratio of 16:9 ("letterbox" or cinema-style format)

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