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Implementing a national federal digital terrestrial television network

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1. Abstract

The UK government has passed legislation which provides for the operation of national digital terrestrial television broadcasting. Within the present frequency planning system it will be possible to introduce up to six multiplexes across most of the UK. The target is to release the UHF spectrum from the occupancy by PAL analogue services so that it could be rented to other users. It is therefore important that the programmes which viewers currently enjoy should be made available in the digital services along with new programmes and digital services. Amongst the mandated requirements of the digital programme services is the need to provide for both audio description and video signing services in addition to the provision of subtitles for the hard of hearing.

This paper will outline the overall system and the technical challenges faced in setting up both the national six multiplexes and in the planning of the implementation of the Digital 3 & 4 multiplex in particular. This multiplex is required to bear services from Channel 4 - including one which will be controlled by Conditional Access - and to bear services from all of the ITV (Independent Television) contractors. These services will reflect the full regionality and character of the current analogue services.

2. Introduction

Preliminary frequency planning exercises by both BBC and NTL (National Transcommunications Ltd) had identified that satisfactory coverage of the UK could be provided for up to six multiplexes. These multiplexes would conform to DVB terrestrial standards. The long term aim of United Kingdom Government is that digital terrestrial broadcasting using Ultra High Frequencies (UHF) will replace the current analogue UHF PAL system. The timing of the switching off of the analogue service has not been fixed but it will depend on a satisfactory penetration of DTTV within the UK.

The United Kingdom Parliament 1996 Broadcasting Bill put in place the legislative framework to introduce in the United Kingdom the digital terrestrial television (DTTV) multiplexes. Operators of these multiplexes could provide a range of services. These services comprise television programmes and associated qualifying services along with additional data-based services.

Multiplex and Service Provider licences will be issued and regulated by the Independent Television Commission (ITC). Technical services such as Conditional Access (CA) are regulated by the Office for Telecommunications (OFTEL) whilst the provision of any Electronic Programme Guide (EPG) is controlled jointly. The regulators are particularly concerned that a national television system does not become a system which is subject to a single dominant gateway control. This is consistent with

persuading the current viewers to choose a digital television receiver to replace an analogue PAL one. This will assist in moving all of the nation's viewing to digital terrestrial television reception within a relatively short time.

The 1996 Act provides for six multiplexes with population coverage ranging, initially, from 90% to 65% (gross coverage). The existing analogue terrestrial broadcasters - BBC, ITV, Channel 4, Channel 5 and (in Wales) S4C are guaranteed capacity on the multiplexes with the best coverage on condition that they carry a simulcast of their existing programme services. They will then be free to launch new services on DTTV in the remaining capacity within those multiplexes.

Multiplex 1 has been assigned to the BBC and will carry wide screen simulcasts of the BBC1 & 2 analogue services plus a range of new additional services. These will not be subject to conditional access (CA).

Multiplex 2 has been assigned to DIGITAL 3&4 Ltd, a joint venture company set up by Channel 3[1] (ITV) and Channel 4[2]. This will carry the wide screen simulcasts of the analogue services of Channel 4 the regional analogue services of ITV companies the multiplex shall also bear an enhanced information service from Teletext Ltd[3]. In addition ITV plans a second independent free to air (FTA) service and Channel 4 plans a second, subscription service which will be subject to CA.

Multiplex A has been assigned to SDN Ltd. It will carry a national simulcast of the analogue service of Channel 5, a simulcast of the analogue service S4C in Wales, a new Gaelic service in Scotland. Additional new services can be carried in the remaining capacity

Multiplexes B, C, D have been assigned to British Digital Broadcasting Ltd, a consortium set up by Carlton Communications and Granada Group. This is planned to introduce a national service containing a range of new subscription programme and inter-active services. The establishment of a network of digital terrestrial transmitters will allow the eventual switch-off of the current analogue PAL network so freeing up a substantial amount of the UHF spectrum for future exploitation. This could include additional DTTV broadcasting. The UK Government intends that DTTV broadcasting will commence in 1998.

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[1] Channel 3 - also called Independent Television (ITV) - is a federal network of 15 Independent Television Companies. Each is licensed to provide a regional service embedded within a national prime time schedule. Most regions also sub-divide their region into sub-regions for which the commercial and some of the programming is different. Each ITV company operates from a regional playout centre (RPOC) from which it feeds a network of transmitters designed to provide coverage over its licensed area. Regional playout centres are connected by a national terrestrial contribution network which is used for programme exchange. Most of the national network programmes are played out from a joint facility located in London, see Figure 1.

[2] Channel 4 provides a single national programme service from the same transmitter sites as Channel 3 but with six "macro" regional variations in commercials. This is achieved by feeding a transmitter distribution network from its London playout centre which is configured to feed six groups of transmitters across the UK.

[3] Teletext Ltd provides a national teletext service on Vertical Blanking Interval (VBI) lines within the Channel 3 video signal. Data is sent from the editorial centre in London to VBI inserters at transmitter sites so as to provide the same regional granularity as Channel 3.

At the time of writing Digital 3&4 is working to produce a document which sets out the functional requirement specifications for the implementation of the multiplex. Within the available technology it is required that the flexibility of the current operational practices shall be retained for the digital services. This forms one of the major differences between conventional digital satellite installations and cable head ends. Though there may be negligible revenue earned from the digital services in the early years it is a requirement that the digital installation shall be capable of adaptation to new functionality as the services develop. At the present time there are still more problems than there are solutions.

3. Background to ITV and Channel 4 operations

3.1 The Technical Rules to the Operation of DVB Terrestrial Services

The ITC has set out the technical rules for the operation of DTTV services in the UK[4]. These set out the essential characteristics of the transmitted signal and detail the use of a 2k COFDM signal.

The Rules also set out the basic requirements of the audio, video and data coding. The video shall conform to MPEG2 MP@ML coding. A stereo sound signal shall be provided. Subtitles for the hard of hearing shall be provided through the use of DVB subtitles using bit map graphics (BMG) mode[5]. Data services shall be played out using standards determined by the DVB SI-DAT working group. These are the DSM-CC-UU object carousel standards.

There is no provision for standard EBU teletext either as a means of providing for subtitles or as a means of providing a data delivery service. There is thus no requirement for the receiver to implement any form of VBI processing.

The rules also require two further services for those persons with sensory disabilities. The target for all of these services is to provide them as instances of "closed caption " services in which the ocularly and aurally normal viewer is able to select not to decode them. The first is an audio description service for the visually impaired and the second is a video signing service for the deaf. This has focused some attention onto the methods of providing both the production at the playout centre or programme origination and the presentation at the receiver of these services. At the present time the optimal presentation of both services requires a second audio and video decoder at the receiver. For the audio description service this can be easily provided through the use of a suitable Common Interface (CI) module[6]. A crude approximation to the service can, however, be obtained using a single decoder within the receiver. For the signing service a second video decoder would appear to be ideal and the resulting image can be applied, as an example of video within video, to the image seen by the viewer. This can be achieved, in principle, through the use of a suitable MPEG2 coded picture. An alternative approach considers the provision of a signing service as an instance of a graphics presentation. This may require more processing power than is planned for receivers and it may also raise the need to resolve new IPR (Intellectual Property Rights) issues.

Figure 1 indicates that the generalised model of digital television operation is bounded by a number of other data service considerations.

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[4] The ITC Rules were first published on 31 October 1996.

[5] The DVB standard is ETR 300 743. Although this does allow for the use of character reference mode (CRM) as an option it is felt that there is no feasible method of ensuring that all receiver manufacturers will implement a readable built-in font.

[6] Papers describing this module, and examples of many others, have been tabled at DVB and UK DTG meetings over the past year.

Implementing a national federal digital terrestial televsion network

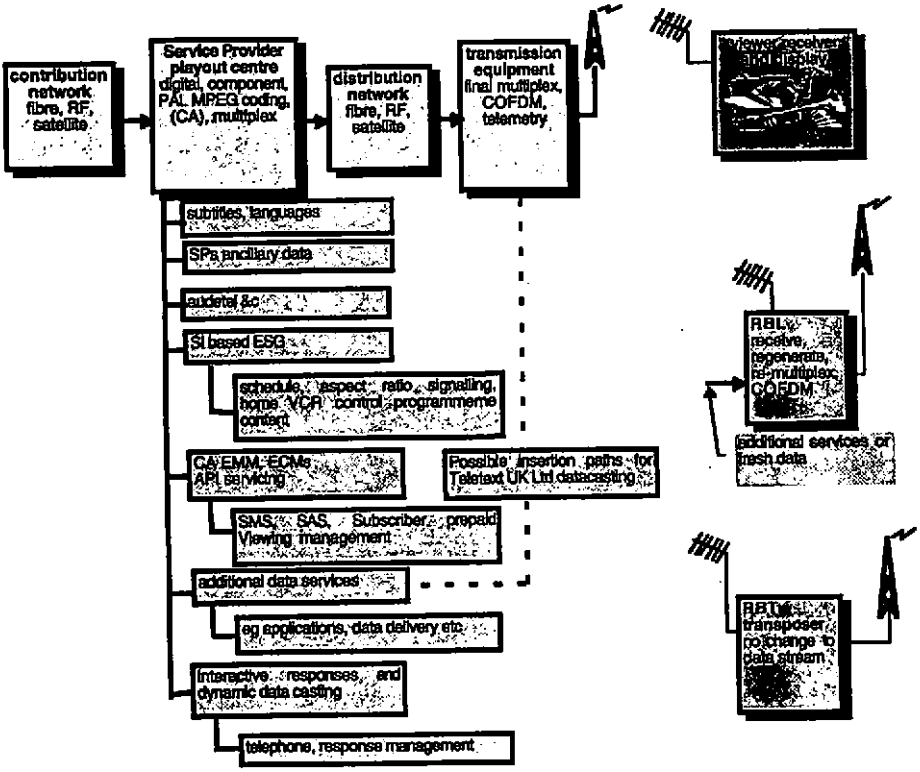

Figure 1: The generic model for terrestrail playout centres.

3.2 Service granularity

The service granularity is determined by the sub-regionality which is operated by the ITV companies. Each of these regions is connected to form a national network. This is summarised and shown in Figure 2. There are 34 sub-regions which can be provided with independent commercials and local programming. Each of these sub-regions drives a transmitter chain. An example of a region with its sub-regional divisions is summarised in Figure 3.

The macro-regions selected by Channel 4 can be mapped onto the basic ITV regionality. This makes the problems of signal distribution a little simpler.

The combination of the sub-regionality and the need to maintain complex broadcast equipment close to operational activities produces the requirement that the encoding of the ITV simulcast signals takes place at the RPOC. It is logical to provide the relevant signals for the Channel 4 digital services to the same location and to ensure that the data content service of Teletext Ltd can also be played out from a data carousel at this same location. This then is the location of the final multiplexer for the services carried on the Digital 3 & 4 multiplex.

3.3 Service flexibility

The second service for ITV is planned to be distributed nationally. Because this may still require the insertion of commercials locally and because some ITV companies may wish to provide alternatives or additions to this service it will be necessary to provide for further encoders at each RPOC.

The scrambling for Channel 4's second service is most cost effectively carried out at the playout centre operated by Channel 4 in London. The scrambled signal and its associated entitlement management messages (EMMs) and entitlement control words (ECMs) can then be securely generated at a single location.

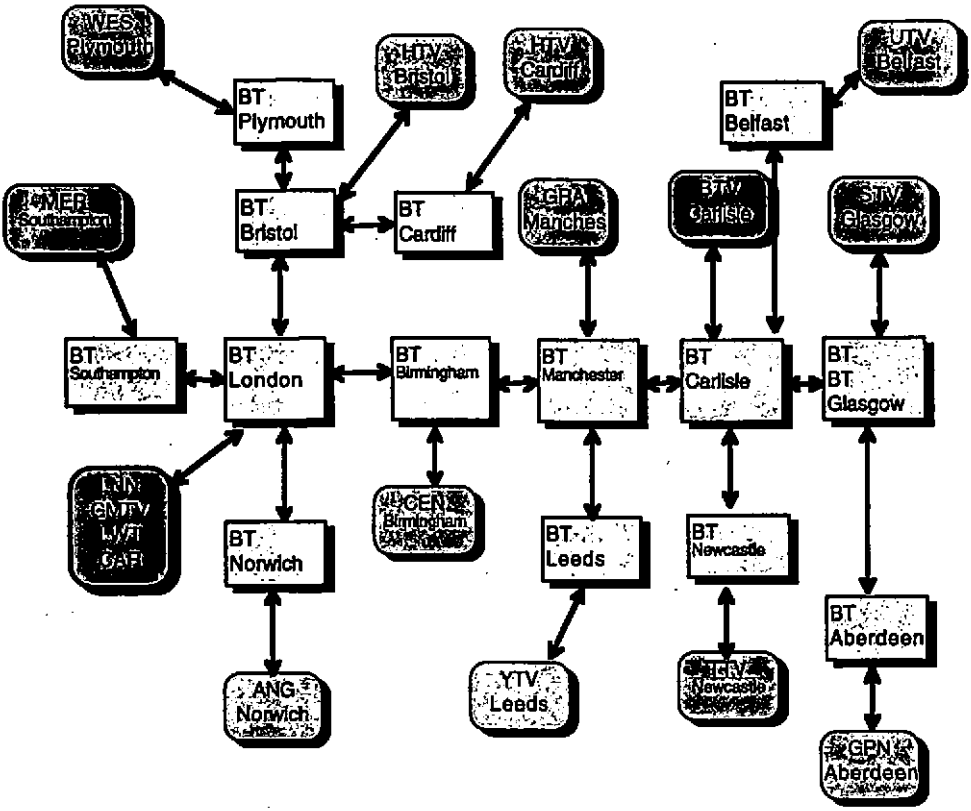

Figure 2. A summary of the contribution network used by ITV companies

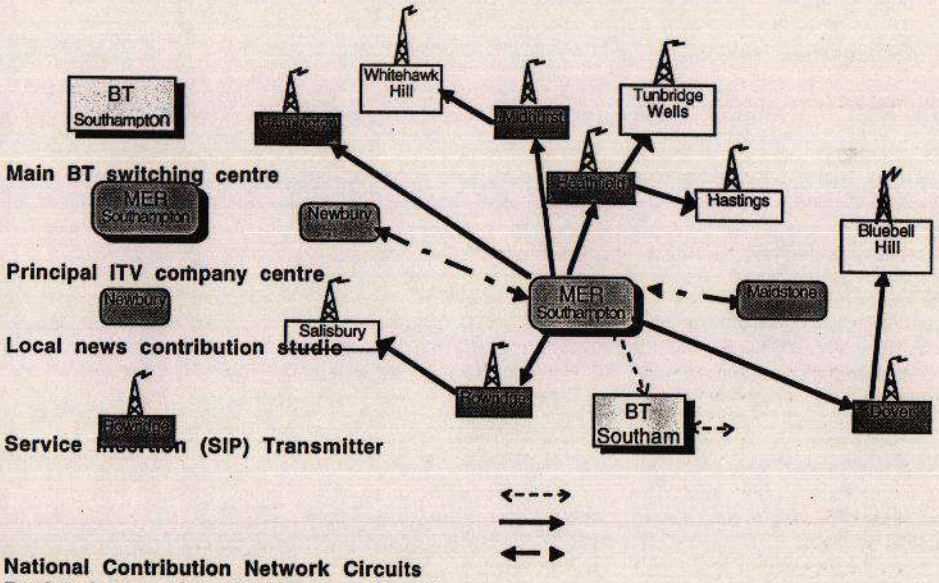

Figure 3: A typical ITV Regional/Sub-Regional Transmitter Network - Meridian Television in the south of England

4. Managing the Bit Budget

4.1 Subjective requirements

In addition to setting out the technical parameters relating to DTTV the ITC has also determined that the subjective quality of the programme content should reach minimum standards. This is an area where the providers of commercials also have an interest and thus ITV has conducted an extensive series of subjective tests of current video encoders in order to determine the matching of coding bit-rate with subjective performance for different types of programme.

The video coding rate is the largest user of available bit-rate and this sets the practical limit on the number of services which can be provided within a multiplex. Because of the nature of the principal service providers in the Digital 3 & 4 multiplex there is no gain to be had in providing for statistical multplexing. An additional problem would arise in the way in which multiplex efficiency could be co-ordinated around the large number of independently operating ITV RPOCs.

4.2 A terrestrial bit budget

The value of the terrestrial bit-space has been variously estimated at about 15 times that of available to satellite systems. It is thus important that the bit budget of the multiplex is carefully planned. It also requires the very best of encoders and multiplexers to ensure that wastage and inaccessible bit-space is kept to an absolute minimum.

The principal use of the bit-space is set out, as an example, in the table below. There is a significant overhead resulting from the need to provide for Program Specific Information (PSI) and for the cross carriage of Service Information (SI). It is a condition of the multiplex licence that Teletext Ltd be provided with a guaranteed access to 724kbit/s - 3% of overall multiplex capacity - for the provision of a data content service. In the case of the Digital 3 & 4 multiplex the EMM and ECM needs[7] also need to be considered before the primary partition between the ITV and Channel 4 service providers can be made.

[7] In addition to this it might be necessary to add in any special data stream which comprised an EPG from which the Channel 4 CA service could be operated

description	allowance	comment
Teletext Ltd direct allowance	724kbit/s	this is the total allowance for Teletext Ltd
PSI and "waste"	700kbit/s	this includes the very optimistic estimate of 350bit/s to cover the waste arising from the conversion from PES to TS.
SI_Actual and SI_Other	360kbit/s	cross carriage of SI involves carying 40kbit/s from each multiplex
balance for Ch4 and ITV each	11 200kbit/s	of which it is estimated that some 600kbit/s will be needed to operate the CA system within Channel 4's partition. It is to be hoped that the CA system can rely on the data in SI.
ITV partition		
primary video inc related PTR and PCS	6 300kbit/s	this will usually code a sports programme such as racing adequately
primary stereo audio	262kbit/s	this rate is adequate for Dolby ProLogic coded sources
DVB subtitle	44kbit/s	for a single Latin_1 based language using DVB-ST BMG
audio description	65kbit/s	this provides for just the description audio. An alternative presentation in which stereo dialogue is present as well has been discussed. It would require up to 192kbit/s.
signing service	262kbit/s	based on the assumption of a _ screen MPEG2 coding of a non-patterned slowly moving image
ITV2		
video audio, subtitle	3 800kbit/s 300kbit/s	includes DVB ST- BMG. Although subtitles are required for 80% of all programme material, audio description is only required for 10% within 10 years. Signing has to be presnet for 5% by that time.
ITV ancillary DataContent Data Content "pages"	130kbit/s or whatever makes up the balance	this could provide around 50 TV screen pages of MHEG5 content, perhaps encapsulating suitable HTML content
Total	24 085kbit/s	

Certain ITV regions have indicated that they may wish to produce a third service within the ITV partition. This can only be done by reducing the bit-rate required for the other two services. The technology to achieve this is still under development and the planned installation will need to be able to accommodate the revised operating software as it becomes available.

5. Interoperability Issues

5.1 Signal Issues

The UK DTG was set up with the aim of ensuring that all of the nation's digital television systems would be capable of interoperation. This is likely to be true only to the limited extent of being able to decode and present legal DVB signals representing the primary audio and video signals which are present in a transport stream (TS) and which are transmitted clear to air (CTA). A service provider who scrambles these signals can expect only to be receivable in a receiver which implements the relevant CA descrambler. A more serious issue is the use within some "closed" systems of a particular instance of an application programming interface (API). Unless a receiver implements exactly the same API it is unlikely that there will be interoperability at that level.

It remains to be proved but it does seem that the most interoperable signals are likely to be found at the Peritelevision SCART socket.

The digital television operational commercial model to date has been based on a service provider determining both the details of the transmitted signal and of the details of the receiver which is to decode it. This usually involves the service provider in subsidising the cost of the receiver and, typically this cost is recovered through the service subscription. Naturally such an operator will wish to ensure that the subsidised receiver is not used by the viewer to decode the services of a competing service provider[8] or other uninvited guest. One method which can be used to ensure uniquity of access is to require that any provision of application - whether of programme or of data - shall require the use of the CA system. This is a common feature of a "closed" system.

An "open" system will require that this does not become a burden on a population which does not agree to be bound by such restrictions particularly in respect of receiving apparatus which it may own outright. Receiver manufacturers also may wish to be able to manufacture receivers for such an open market without the need to conform a closed system specification. Such a model is the normal one for public access television systems.

The delivery system used for digital television broadcasting also has an impact on the interoperability. A closed system has little need to use the SI data in order to provide the viewer with information of its services and schedule and this function is usually provided by a specific instance of an electronic program guide (EPG). This is also supportable in satellite and cable systems where there exists sufficient bit-rate capacity to make such a service graphically and functionally useful. In an open system where there the available bit-rate is scarce it is preferable to use the existing SI data and to propose that a fundamental property of receivers is the provision of a native resident Event Schedule Guide.

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[8] An EU Directive requires that the basic audio and video streams shall, if they are CTA, be presented at the terminals of any receiver marketed within the EU. This does not extend to decoding any of the qualifying services - such as subtitles - or application dependent services which may also be present.

In the terrestrial domain there are additional problems which arise through both the nature of transmission propagation and the ineluctable vagaries of the frequency planning processes.

5.2 Cross carriage of SI data

The requirement exists to present to the viewer a uniform access to the ability to choose services, the events within them and the components of which they are composed. This can be greatly facilitated through the carriage of SI_Other within each multiplex. The SI data can be configured to provide a forward schedule for at least eight days[9] for each multiplex and the data repetition rate can still remain within the DVB guidelines at a low data rate of around 40kbit/s.

Cross carriage can be achieved either through the direct presentation of SI data or, often much more cost effectively, through the use of a locally decoded SI stream from an IRD tuned to the particular multiplex.

This is a primary public service approach to open gateway access.

6. Multiplex monitoring

6.1 Monitoring within each RPOC

Each RPOC will need to have knowledge of the status of the apparatus installed. This will reflect the responsibility for carrying the commercial signals of two other service providers - Channel 4 and Teletext Ltd - and ensuring that these are faithfully presented to the transmitter interfaces.

The ITC requires that multiplex operators shall monitor and maintain records of the data integrity. It is customary for television service providers to maintain a record of transmission (ROT) usually on a VHS tape. This will continue to suffice for analogue transmissions but for the digital transmissions some compromises are called for. It will be necessary to retain some record of any data content which is transmitted and, the need to assure the regulator, ITC, that the qualifying services have been correctly provided will exist. It is not feasible to propose that each of the output 24Mbit/s data streams is applied to a data recorder.

6.2 Monitoring the national operation

It is proposed that key parameters of the operation of encoders, multiplexers and of the line distribution and contribution circuits are also returned to a central monitoring site. At this location it will be possible to gather the data nationally and to produce the necessary monthly reports on reliability and quality of service which are required.

The companion concept of overall centralised remote control of all of the apparatus is not required.

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[9] This is a limit imposed in part by competitive pressures, programme planning and the legal requirements of the press to be able to have the advance schedule available sufficiently early to be able to publish it in printed media.

7. Application of Conditional Access

Within the multiplex only one service - the second service from Channel 4 - will be subject to scrambling. This allows for a single point of scrambling and for inserting the EMMs ad the ECMs. If, at some future date, it were to be proposed that ITV operated a CA system then this would require quite substantial modification of the whole system. The decision not to use CA within ITV is thus very significant in terms of system design. However it remains possible that certina ITV companies may wish to employ CA at some time in the future. The effect on the system will depend on the operational requirements of the proposed system.

8. Operational service requirements

8.1 The impact on planning and scheduling

The programme planning and scheduling systems used will require significant change. A number of new parameters will affect the planning process. These include the need to determine the video coding requirement for a particular type of programme and the need to budget for the qualifying services. Since the available bit-rate is limited there will be some restrictions and one might be that it will not be possible to programme two simultaneous sports event within one partition of the multiplex.

Some of the coding parameters could also make an appearance in the contracts with programme content providers. The most obvious ones are those dealing with picture coding accuracy and aspect ratio.

8.2 Simulcasting

The requirement to provide a simulcast of the analogue service is important. It is widely appreciated that the UK has a special opportunity which may result in the adoption by the general viewing public of digital terrestrial television. This arises from the fact that the current market penetration of widescreen[10] displays is almost invisibly low. The principal service providers have indicated that they will be featuring widescreen coded television for their digital services. This is hoped to support the adoption of true widescreen integrated receivers in preference to the purchase of Set Top Boxes (STB). It will also assist the business model of those service providers who propose to subsidise the initial STB.

There are two way of achieving this. If the digital service is a simulcast of the analog one then an aspect ratio converter (ARC) will be needed prior to the MPEG encoder. If the analog service is a simulcast of the digital one then an ARC will be needed prior to the analog drive to the transmitter.

8.3 Wide Screen Compatibility

Broadcasters committed to simulcasting their existing (4:3) services in wide screen (16:9) format on DTTV must address the issue of compatibility of aspect ratio on both services.

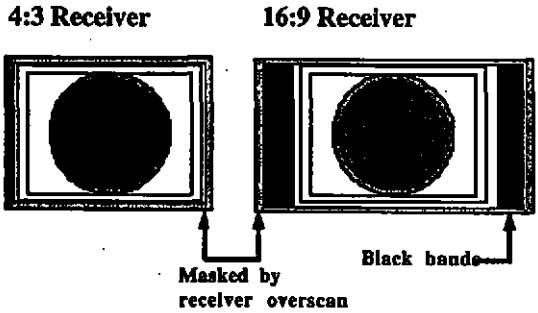
It is likely that all future programme production will be in 16:9 aspect ratio. In fact existing broadcasting organisations have already started wide screen production and some of these programmes have been shown in "letter box" on current services. Wide screen production camera picture framing must be

[10] The term widescreen is used to indicate a display device whose aspect ratio is 16:9.

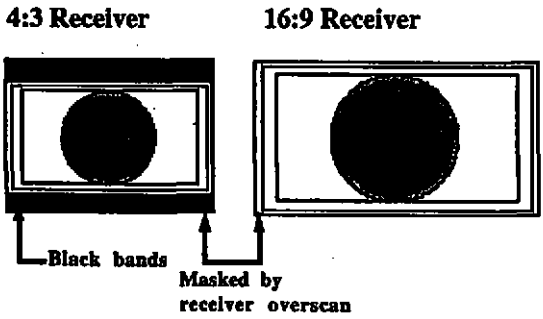
suitable for reproduction on both 4:3 and 16:9 displays. Existing programme libraries contain programmes made in 4:3 aspect ratio and these libraries will provide a substantial part of programme schedules after the start of DTTV broadcasting. A philosophy for the showing of mixed format material on both 4:3 and 16:9 services is therefore required.

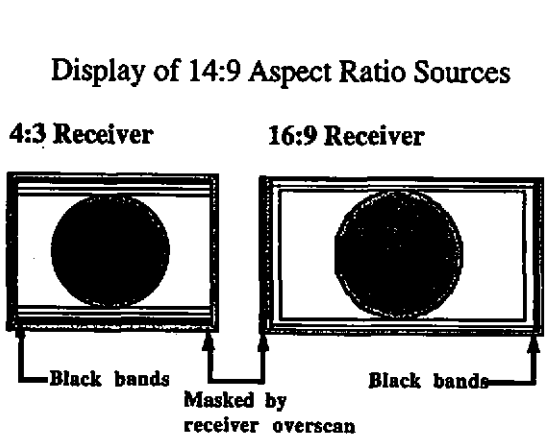
The compromise aspect ratio, 14:9, although unlikely to be used in programme production, offers one solution to the compatibility problem for transmission chains and receivers. As can be seen in the following illustrations minimum black edges result on both 16:9 and 4:3 displays when the source format is 14:9 or the set-top box modifies the received picture format from 16:9 to 14:9 for display on 4:3 television receivers.

Display of 4:3 Aspect Ratio Sources



Display of 16:9 Aspect Ratio Sources





Current thinking in ITV is that play-out centres, inter-studio and transmission circuits will be converted to be 16:9 capable and aspect ratio switching to maintain compatibility for existing 4:3 viewers will occur at the input to analogue transmitters whilst DTTV transmitters will pass through the source aspect ratio unaltered. Distributed programmes will be "flagged" in the vertical blanking interval (VBI) with source aspect ratio indicators which will automatically switch the aspect ratio converter at the analogue transmitter to the appropriate format. These "flags", which will be compatible with those already used in analogue wide screen television receivers, will also be transmitted on the analogue service for the benefit of those receivers and on the DTTV service for the benefit of set-top boxes.

The following table shows the aspect ratios to be transmitted on ITV compared with the source material.

16:9	16:9	14:9
14:9	14:9	14:9
4:3	4:3	4:3

Account has been taken that DTTV wide screen television receivers and set-top boxes will offer viewer choice of aspect ratio as do currently available analogue wide screen television receivers.

The greatest challenge to simulcast broadcasters is in presentation where interstitial material such as logos, promotions (which will be mixed format) and commercials must sit between programmes of mixed format.

9. Acknowledgements

The whole process of co-ordinating the design of the UK terrestrial digital multiplex system has been a hugely collaborative effort between colleagues in affiliated and mutually competitive organisations. Within ITV and Channel 4 colleagues, amongst them Chris Hibbert, Neil Brydon, Peter Marshall, Brian Thomas and Tim Cook, have also been very formative in shaping aspects of both the general multiplex operation and the Digital 3 & 4 multiplex.

10. References and further reading

DVB specifications and supporting documents can be obtained from the DVB Project Office at the EBU headquarters in Geneva.