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Accommodation of HDTV in the GE06 Plan

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1. Introduction

The purpose of this document is to assess the potential of the GE06 Plan to accommodate HDTV services. In a recent study carried out for the EBU Technical Committee it is considered that in the future all TV programmes will be in HD quality and that a minimum of 20 to 25 HDTV programmes will need to be provided on the terrestrial platform in order to make it attractive for the viewers.

The GE06 digital broadcasting plan allows for implementation of HDTV services, i.e. using DVB-T. However, not all DVB-T plan entries offer the same opportunity for HDTV, primarily because of different reference planning configurations (RPCs) or system variants used to establish the GE06 Plan. Nevertheless, the GE06 Plan permits a significant degree of flexibility in the implementation of transmission networks that may be used in favour of HDTV.

Using advanced transmission systems such as DVB-T2 it is possible to provide a higher transmission capacity than DVB-T without changes to the GE06 Plan[2].

2. Data rate capacity required to deliver HDTV

One element of choice for HDTV broadcasting (or for HDTV delivery by other means) will be the data rate used for delivering the compressed HDTV video signal. This is a critical factor that affects both the quality the viewer experiences as well as the transmission costs.

The digital transmission capacity needed to deliver HDTV depends on a number of factors, such as:

- The type of compression used (e.g. MPEG-2, MPEG-4[3]).
- The HDTV scanning format used.
- The degree to which picture impairments are acceptable.
- Whether the compression has to be done as the programme unfolds -'on the fly'- or not.

1 Geneva, 2006 Agreement and Plan

2 The GE06 Agreement allows only DVB-T and T-DAB entries to be recorded in the Plan. However, other digital television system, such as DVB-H and DVB-T2 can be implemented using the 'envelope concept'.

3 H.264/AVC (MPEG-4 Part 10)

- There may or may not be time for several passes through the encoder for quality optimisation scene-by-scene. At least some broadcast material will always demand 'real time' encoding because the material is live.
- Whether the HDTV signal is part of a 'statistical multiplex'.
- The performance of the particular manufacturer's encoding equipment.
- The type, size of the display and viewing distance in the home.
- Predominant type of content

All European broadcasters that have to date announced plans to broadcast HDTV on the terrestrial platform will use MPEG-4 compression.

The EBU has identified and specified[4] four HDTV production formats: 720p/50, 1080p/25, 1080i/25, and 1080p/50. The 1080i/25 and the 720p/50 formats can also be used for broadcasting, or other forms of secondary distribution, whereas 1080p/25 is currently a production format only. 1080p/50 is termed a '3rd generation' HDTV format, which may be used in future for production, and possibly distribution, purposes.

EBU tests of stand-alone MPEG-4 encoders of different vendors have suggested[5] the following minimum fixed bitrates in order achieve an HDTV image quality providing a significantly better quality perception compared to good quality SDTV (e.g. 6 Mbit/s MPEG-2) for a wide range, including critical content:

- For the 1080i/25 HDTV format and horizontal sub-sampling to 1440 samples a minimum bitrate of 12 Mbit/s is recommended
- For the 1080i/25 HDTV format and no horizontal sub-sampling a minimum bitrate of 12 - 14 Mbit/s is recommended
- For the 720p/50 HDTV format and no horizontal sub-sampling a minimum bitrate of 10 Mbit/s is recommended.

The choice of bit rate for HDTV needs to take into account a number of factors, and there will be a trade-off of advantages and disadvantages.

For various reasons, administrations or members of EBU may decide to launch HD at a level of quality beneath the above recommendations. These reasons may be due to strategic decision, or the requirement to respect a given time schedule. Whilst the quality of such HD services may be less than expected by EBU recommendations several broadcasters consider that they are providing or will provide a significantly better offering than SD. Nevertheless, it should not prevent an EBU member look for further improvements of the quality as far as they are available (more spectrum, better compression, statistical multiplexing and so on...). Some examples of such implementation are given in the **Annex**.

Whatever bit rate is employed, there will always be less risk of compression artefacts if 720p/50 is used rather than 1080i/25, and thus there will be advantages in using 720p/50 for terrestrial HDTV broadcasting, until the 1080p/50 standard eventually becomes available[6].

The bit rate used for current HDTV services is constrained by commercially available encoder performance, which is constantly evolving.

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4 EBU document Tech 3299

5 EBU BPN085, BPN086 and BPN087 (EBU Members only)

6 EBU – Recommendation R 124: *Choice of HDTV Compression Algorithm and Bitrate for Acquisition, Production & Distribution;* June 2008

In practice a range of bitrates is currently used for HDTV broadcasting, including, for example, about 13 Mbit/s by the SRG for their 720p/50 service in Switzerland. In Germany, since July 2008, ARTE has transmitted a 720p/50 satellite service with a video data rate of 12 Mbit/s. In Belgium, HDTV services are available in cable and over IP, 720p/50 and 1080i/25, depending on the programme, and with a bit rate of about 9 Mbit/s. In France **TF1**, **France 2**, **Canal+**, **ARTE** and **M6 are offering terrestrial HDTV services in the 720p/50 and 1080i/25 format.** One HD multiplex uses 64 QAM ¾ GI 1/8 over SFN with 3 HD programmes in the statistical multiplex with an average video bit rate of 7.3 Mbit/s per programme.

MPEG-4 transmissions (as with other advanced coding systems) will particularly benefit from statistical multiplexing. In a large statistical multiplex, with mature encoders, future HD services may be able to operate with an average bit rate of about 8-10 Mbit/s. In a standalone service, up to 16 Mbit/s will be needed, depending on the development of encoders in the future. In a small statistical multiplex, the bit rate needed will lie between the two.

Finally, when calculating the overall bit rate for an HDTV service, additional capacity needs to be added to the video bit rate for 5.1 audio (about 0.5 Mbit/s with the DD system and 0.25 with DD+ or HE-AAC) and also interactive multimedia services (MHP, OpenTV, MHEG).

3. Features of the GE06 Plan

The GE06 Plan covers the frequency band 174 - 230 MHz (Band III - arranged into seven or eight channels with 8 or 7 MHz bandwidth, respectively, depending on the country,) and the frequency band 470 - 862 MHz (Bands IV/V - subdivided into 49 channels, each with 8 MHz bandwidth).

Whilst a large number of combinations of DVB-T system variants and the reception modes (fixed, portable and mobile reception) are possible, their use would make the frequency planning extremely complicated. Furthermore, not all of these combinations are used in practice.

In order to simplify the Conference planning process a limited number of Reference Planning Configurations (RPCs) was defined[7] representing, in an approximate way, the most common types of coverage. As a result, for each GE06 Plan entry an associated RPC (mainly in case of allotments), or a chosen combination of system variant and reception modes, are recorded in the Plan. In the implementation phase, broadcasters and network operators have the freedom to choose a system variant that best fits the real coverage requirements, while taking account of the recorded RPC of the corresponding digital entry in the Plan.

The three following RPCs have been defined for DVB-T:

- RPC1 - for fixed roof-level reception
- RPC2 - for portable outdoor, lower coverage quality portable indoor, or mobile reception
- RPC3 - for higher coverage quality for portable indoor reception

Some examples of typical implementation parameters corresponding to these three RPCs are shown in the table below. Other system variants may be implemented under certain conditions.

7 **Final Acts of the RRC-06,** ANNEX2, CHAPTER 2, Annex 3.5, §3.5.1

Reference planning configuration	**RPC1**	**RPC2**					**RPC3**
Reception mode	Fixed	Portable outdoor		Mobile		Portable indoor	Portable indoor
Modulation	64-QAM	16-QAM	64-QAM	QPSK	16-QAM	16-QAM	16-QAM
Code rate	3/4	2/3	2/3	2/3	1/2	2/3	2/3
Location probability for planning	95%	95%	95%	99%	99%	70%	95%
Max. net bit rate* (Mbit/s)	27.14	16.09	24.13	8.04	12.06	16.09	16.09

* Source: EBU BPN005 - *Terrestrial Digital Television: Planning and Implementation Considerations*, Third issue, Summer 2001

Figure 1 indicates the reception modes that are recorded in the GE06 Plan based on the national requirements:

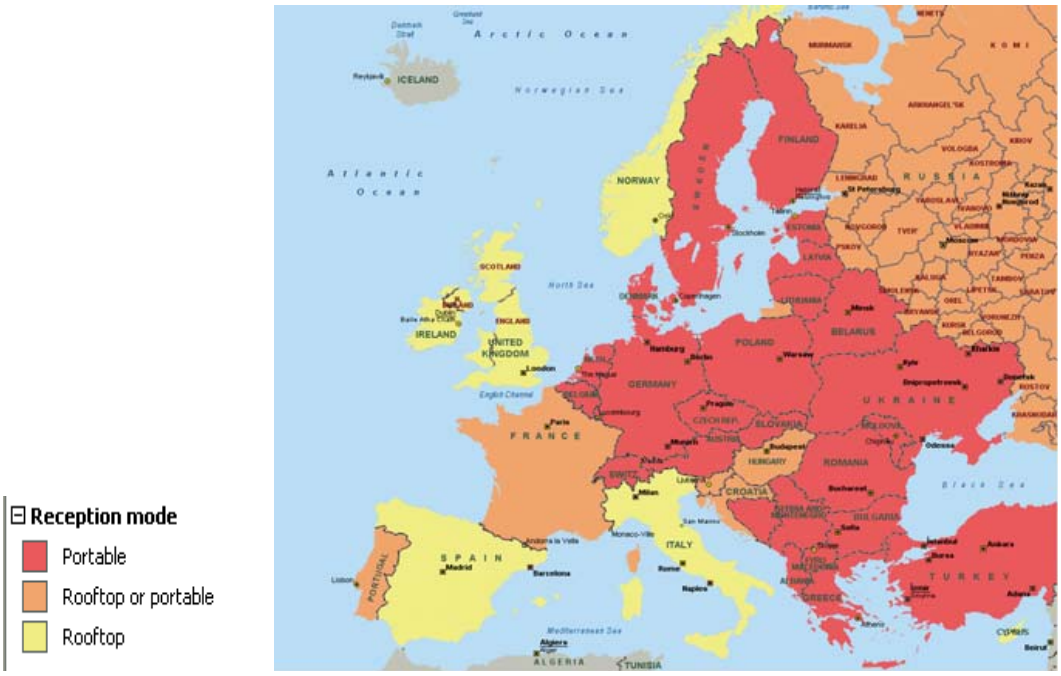

Figure 1: Reception modes as recorded in the GE06 Plan

It is not obvious from GE06 how the Plan entries will be used in practice, since national objectives for DTT are different across Europe. The total capacity available in the GE06 Plan is often expressed in the number of multiplexes ('layers') that could be provided over the whole national territory. One layer represents a set of channels that can be used to provide one full, or partial, nationwide coverage. For most European countries this is equivalent to

- three T-DAB layers in Band III
- one DVB-T layer in Band III
- seven to eight DVB-T layers in Bands IV/V

It is up to the national administrations to decide how this capacity will be used. Some of the Plan entries are likely to be used to provide nationwide coverages while the other entries will be used for regional or local coverages.

The number of multiplexes that can be achieved in practice sometimes exceeds the capacity that is theoretically available in the GE06 Plan. In most cases this will be at the expense of accepting higher levels of interference that may result in reduced coverage or lower quality of

service. Moreover, variations in the overall coverage that can be achieved by a given country arise due to the different situations that occur within Europe; for example geographical size, proximity and number of neighbouring countries, type of reception mode adopted (fixed or portable).

For the purpose of this document the theoretical capacity available in the GE06 Plan will be used.

4. Assumptions on the technology evolution

There are important developments taking place that would provide for a significant increase in the transmission capacity on the terrestrial platform. These relate to improvements in the standards used for coding (compressing) information and in transmission systems.

- **MPEG-4** is an improved video and audio coding compression standard. This is expected to operate at up to double the efficiency of the coding standard MPEG-2 that is currently used for most of the digital terrestrial transmissions. This means that a DTT multiplex could carry up to twice as many services using MPEG-4 as can currently be achieved using MPEG-2, whilst maintaining similar picture quality.
- **DVB-T2** is a new transmission standard. Early estimates of performance of the baseline specification suggest over 45% bit rate capacity gain for a typical application for the same reception conditions.

It has been estimated[8] that the introduction of these two technologies could, if combined, increase the capacity of a multiplex by up to 160% for fixed reception although some experts consider 100% to be a more realistic estimate. It is also assumed that the capacity gain in the case of portable or mobile reception will be similar to that of fixed reception.

Furthermore, as a trade off, implementation of new DTT systems such as DVB-T2 may:

- require different approaches concerning network planning and may also have an impact on the frequency planning. In particular, if GE06 Plan entries are to be used for DVB-T2 instead of DVB-T the conditions for such substitution need to be determined and the implications in terms of interference, protection requirements and coverage parameters have to be investigated
- induce extra cost for the broadcaster (transmitter, aerial if MISO) and for the viewers (new set up box) which should be taken into account regarding other available digital television platforms at the time of the considered introduction of DVB-T2.

5. Conclusions

A GE06 Plan entry is implemented as one DVB-T multiplex transmitted over a corresponding coverage area. This applies to both assignments and allotments. Allotments are normally converted into a single assignment or a set of assignments that operate as an SFN.

A DVB-T multiplex is essentially a 'container' with a given bit rate capacity, which in practice ranges between 8 Mbit/s (QPSK, 2/3) and 27 Mbit/s (64 QAM, 3/4). Whilst the choice of the system variant is in some cases constrained by the RPC recorded in the Plan, there is the possibility for the Plan to be modified to include a different system variant.

8 UK Ofcom, November 2007, "The Future of Digital Terrestrial Television"

In principle, the container (multiplex) can be used to deliver any picture quality, including HDTV providing that the services fit into the available channel capacity and are receivable at an adequate bit error rate.

One HD programme currently requires a fixed bit rate of 10-20 Mbit/s depending on the format and compression method used (e.g. MPEG-2 or MPEG-4). If statistical multiplex is applied an average bit rate of 7-8 Mbit/s per programme can be achieved (e.g. if 3 HD services are multiplexed together in a DVB-T multiplex with around 24 Mbit/s). Careful design of the production chain and high quality MPEG-4 encoders in combination with statistical multiplexing and horizontal sub-sampling will allow that these bit-rates provide perceptible improvements over state-of-the-art MPEG-2 based SDTV services on DTT. Consequently, one GE06-based DTT multiplex can theoretically carry one to three HD programmes for fixed reception and a maximum of one or two HD programme for the more robust system variants that allow for portable or mobile reception. Some system variants do not have sufficient capacity for HDTV.

In the future, with the expected future developments in video coding, it is assumed that HD fixed bit rate requirements will be reduced to 8-10 Mbit/s per programme. There will also be advances in the transmission system such as DVB-T2. The GE06 Agreement allows for implementation of DVB-T2 under the envelope concept; i.e. provided that it does not cause more interference nor require higher protection that the original Plan entry. This may restrict the choice of DVB-T2 system variants available for such implementation and will need further investigation.

By combining the expected advances in the transmission systems and using statistical multiplexing it should be possible to aggregate up to 4 or 5 HDTV programmes per multiplex for fixed reception, or 2 to 3 HDTV programmes in a multiplex for portable or mobile reception.

This leads to the conclusion that the maximum capacity currently available in the GE06 Plan in terms of number of programmes is as follows:

	Fixed reception		Portable reception	
	UHF Bands IV/V	VHF Band III	UHF Bands IV/V	VHF Band III
DVB-T	7-24	1-3	7-16	1-2
DVB-T2	21[9]-40	4-5	14-24	2-3

The figures in the table above are based on the following assumptions:

- most countries have 7-8 layers in UHF and 1 layer in VHF in the GE06 Plan
- all DVB-T Plan entries will be used to provide HDTV services
- the performance MPEG-4 encoders, which are continuously evolving, are sufficiently advanced by the time when DVB-T2 is implemented

It should be understood that these conditions may not always be applicable in practice. The abovementioned maximum bit rates for DVB-T can only be achieved with MFNs or SFNs using short guard intervals, otherwise the actual net bit rates are less than the stated maximum.

It should be noted that many European countries may not be able to launch a full HDTV offering on the terrestrial platform until they and their neighbours have completed analogue switch-off.

Practical examples of HDTV implementation in individual countries are included in the **Annex**.

9 A minimum of 3 programmes per multiplex has been assumed

Glossary of terms used

1080i/25-30 An HDTV image format with 1920 horizontal pixel x 1080 vertical lines interlaced scanning at 25 or 30 frames per second or 50 or 60 fields per second.

720p/50-60 An HDTV image format with 1280 horizontal pixel x 720 vertical lines progressive scanning at 50 or 60 frames per second.

DAB-IP DAB - Internet Protocol

DTT Digital Terrestrial Television

DVB Digital Video Broadcasting http://www.dvb.org/

DVB-T DVB – Terrestrial

DVB-T2 Will be a state of the art terrestrial transmission system taking advantage of advanced modulation and forward error correction techniques. It is set to deliver at least 30% performance premium over DVB-T, and possibly significantly more.

GE06 GE06 Agreement, Geneva 2006

HDTV High-Definition Television

ITU International Telecommunication Union http://www.itu.int

ITU-T H.264 Technically the same as MPEG4 AVC

MPEG Moving Picture Experts Group http://www.chiariglione.org/mpeg/

MPEG2

MPEG4 AVC Refers to ISO/IEC 14496-10, 2003. Information Technology – Advanced Video Coding: A codec for video signals that is also called AVC and is technically identical to the ITU-T H.264 standard. 14496-10. Geneva: ISO/IEC.

MHEG Multimedia and Hypermedia Experts Group - a multimedia presentation standard

MHP Multimedia Home Platform

MISO Multiple Input Single Output - smart antenna technology in which multiple antennas are used at the source (transmitter). The destination (receiver) has only one antenna. The antennas are combined to minimize errors and optimize data speed. MISO is one of several forms of smart antenna technology, the others being MIMO (multiple input, multiple output) and SIMO (single input, multiple output)

OpenTV Interactive television technology offering a variety of enhanced applications including EPG, HD, VoD, PVR, and home networking.

SDTV Standard Definition Television

UHF Ultra High Frequency

VHF Very High Frequency

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[7] Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands174-230 MHz and 470-862 MHz (RRC-06)

[8] EBU Technical Review: *GE06 - Overview of the second session (RRC-06) and the main features for broadcasters;* Terry O'Leary, Elena Puigrefagut and Walid Sami, October 2006 http://tech.ebu.ch/docs/techreview/trev_308-rrc-06.pdf

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[15] EBU Recommendation R 124: *Choice of HDTV Compression Algorithm and Bitrate for Acquisition, Production & Distribution;* June 2008

[16] EBU BPNs 085, 086 and 087: *New HDTV Distribution Compression System Analysis;* May 2008 [EBU Members only]

Annex: Examples of HDTV implementation in individual countries

December 2008

This annex contains some practical examples of providing HDTV. It is to be noted that a choice of bit-rates and other parameters varies between countries, depending on specific national situations.

Croatia

The first HDTV service started with one transmitter site located in Zagreb in March 2007. HDTV content was produced by HRT (public service broadcaster). Seven additional transmitter locations were installed in 2008 providing HDTV service in Zagreb, Rijeka, Osijek and Split (30% of the population of Croatia covered).

Zagreb is covered with 3 transmitters in a SFN on Ch-56 (HRT Dom ERP = 1500 W, Sesvete ERP = 1 kW, and Sv. Nedjelja ERP= 500 W) as shown in Figure 2, below.

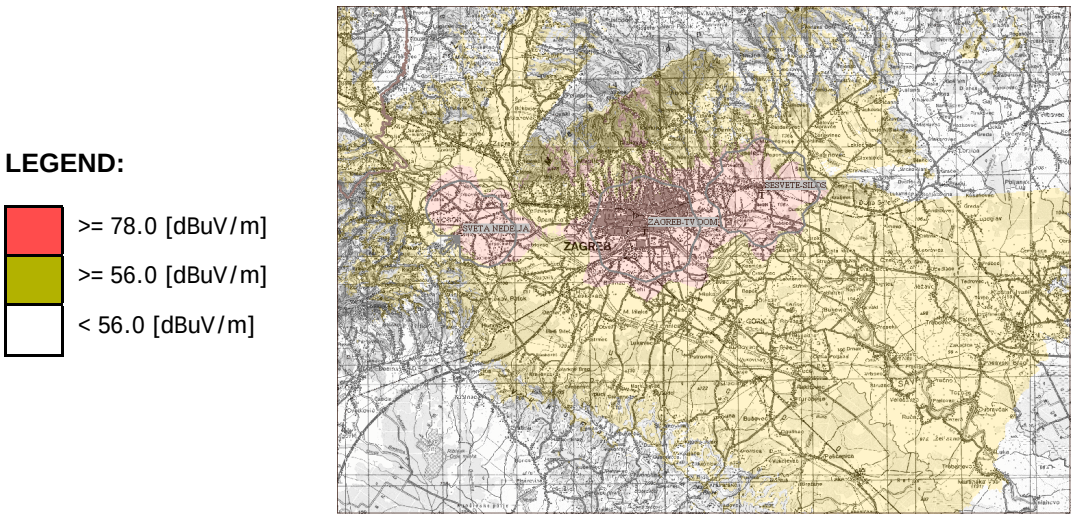

Figure 2: HDTV coverage on channel 56 in Zagreb

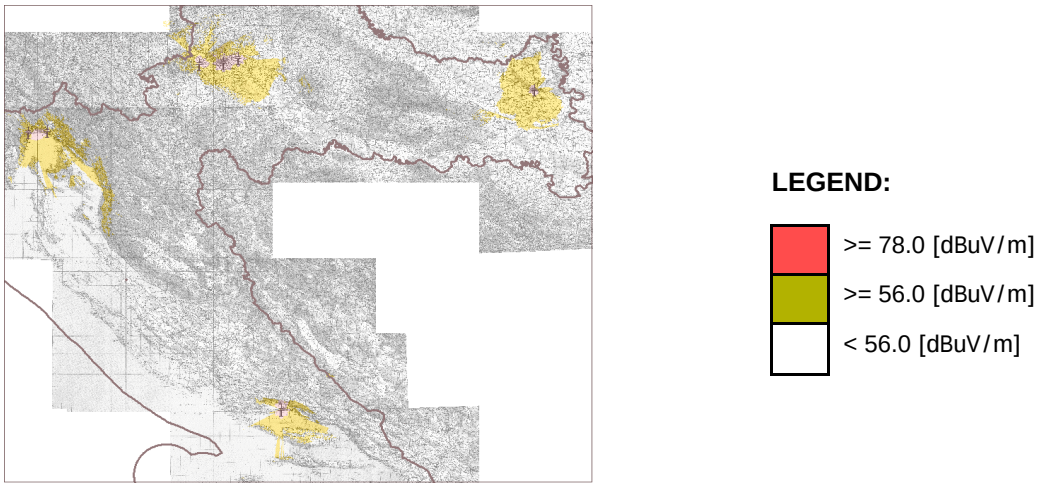

Figure 3: HDTV coverage in Croatia

At the moment the HDTV content consists of pre-recorded panorama scans of Croatian landscape on the carousel server, with the addition of occasional special events, such as the Euro 2008 Football Championship and the Beijing Olympic Games.

HDTV transmitters parameters:

64 QAM, CR=2/3 and GI=1/8 with max. Net bit-rate of 22.12 Mbit/s.

Technical parameters:

- Video resolution: 1080i (1920x1080)
- Picture format: 16:9
- Video compression: MPEG-4
- Video bit rate: 18.5 Mbit/s
- Audio compression: MPEG-1 Layer 2 (in future AAC)
- Audio bit rate: 320 kbit/s
- Modulation: 64 QAM
- Code rate: 2/3
- Guard interval: 1/8
- Bandwidth: 8 MHz (8k carriers)

Equipment:

- Signal source: HD SDI from HRT HD server
- Encoder: Scientific Atlanta D9054 MPEG-4 HD
- Decoder: Scientific Atlanta D9887 MPEG-4 HD
- Multiplexer: Scientific Atlanta – Pegasus (for additional programme services)
- Control decoder: Tektronix VFM700
- Commercial receiver (Set-Top-Box): Topfield TF7710 HTCI
- Distribution via digital microwave links

Finland

The pilot Finnish DVB-T HD network was introduced during the Beijing Olympic Games to test and promote terrestrial HDTV. The HDTV network consists of one transmitter in the main station of Espoo to cover the Helsinki Metropolitan Area on Ch-8 with the parameter set: 8k, 64 QAM, CR=2/3, GI=1/8, B = 7 MHz and with MPEG-4 compression.

The GE06 Plan contains two DVB-T "layers" in VHF across Finland. Based on a Finnish Government decision, two national HDTV multiplexes will be allocated in the VHF frequency band and one HDTV multiplex covering the Helsinki Metropolitan Area in the UHF band.

France

From the introduction of DVB-T services in the UHF band, six frequencies were planned (wherever possible - cohabitation with the analogue transmissions being necessary) in each area.

Of these 6 frequencies, only 5 have been used to broadcast SD programmes up until recently.

A call for tender in mid-2007 led the CSA to authorize two programmes (TF1 and M6) to share the remaining 6th frequency with France 2 for HDTV. The first sites were put into service in late October 2007. It is expected that future MPEG-4 compression gains will permit the introduction of a 4th programme in this multiplex.

In addition, a rearrangement of the two existing multiplexes has allowed the introduction of another HD service along with SD services. Another call for tender in early 2008 led the CSA to authorize a commercial programme (Canal +) to be broadcast in HD in its existing multiplex.

The HDTV programmes use MPEG-4 (in 1440x1080i as a first step, with a move to 1920x1080i/p as the encoding performance improves with DD+ audio components), and there will be a HD/SD simulcast due to the different MPEG standards used for SD and HD.

It is also expected that a full transition to HD will happen sometime between 2012 and 2015, along with the digital switch-over process.

Germany

There are no terrestrial HDTV transmissions in Germany at the moment. HDTV is only available via satellite and via cable.

There is some discussion going on with respect to MPEG-4, mainly by representatives of private broadcasters who are interested in this standard because it would permit the transmission of more programmes in conventional quality. At the instigation of the Bavarian Broadcasting Company, the IRT recently examined the operability of DVB-T receivers designed for the German market (without MPEG-4 capability) in the presence of MPEG-4 signals.

There are no other MPEG-4 or HDTV terrestrial transmission tests in Germany at the moment.

Slovenia

RTVSLO performed test transmissions of DVB-T HD programme on UHF channel 26 for the centre of Slovenia during the Beijing Olympic Games. The transmissions were in 1080i/25 using MPEG-4 compression encoding to test the behaviour of TV receivers and STBs. Other transmission parameters are: 64 QAM modulation, 8k mode, 1/8 guard interval, 2/3 code rate. The sound coding used was MPEG-1 Layer2 for the stereo down-mix and Dolby Digital AAC for the surround sound. A decision will subsequently be taken on providing HD programme contents to further test the possibilities of introducing terrestrial HDTV.

United Kingdom

The GE06 Plan contains 8 "layers" in UHF across the UK, recorded as assignments with RPC1. Of these eight, two at each site fall into spectrum identified by the regulator to be cleared by the broadcasters and to be auctioned for other uses.

Of the remaining 6 layers, 3 are allocated to Public Service Broadcasters with universal coverage obligations (taken to mean that coverage must exceed 98.5% population). The remaining 3 are

allocated to commercial multiplex operators who are free to determine the extent of coverage obtained by their networks. In practice, this means that these three multiplexes will cover just over 90% of the population.

The broadcasters and regulators have now agreed that one of the public service multiplexes (Multiplex B) will be operated at DVB-T2, and will carry up to 4 or 5 HD services. It is expected that the DVB-T2 mode selected for use will be such as to match the coverage of the DVB-T multiplex it replaces, hence removing the need for re-planning and re-assessment of the coverage of the multiplex. The HD services should therefore be available to around 98% of the UK population, although more work is required to confirm what transmission parameters will be used.

It is expected that the DVB-T2 multiplex will be first launched in the Greater Manchester & Merseyside area when that region's analogue TV is switched off in November 2009. Regions that have already been switched off by that time will be retro-fitted shortly thereafter, and subsequent regions will have DVB-T2 available from the date of analogue switch-off.

A DVB-T2 Technical pilot is planned in 2009 with the main objectives to:

- Validate whether coverage, capacity and performance expectations of DVB-T2 are met.
- Support the adoption of a DVB-T2 transmission chain for multiplex B in the UK
- Support DVB-T2 receiver development
- Publish and disseminate plans, results and findings from the UK trials to relevant standards bodies and industry.

Further information can be found at:

http://www.ofcom.org.uk/radiocomms/digital/hd_on_dtt/

http://www.ofcom.org.uk/consult/condocs/dttfuture/statement/summary/

Additional Country Information

Additional information on HDTV implementation in individual countries is available on the DigiTAG web site at: www.digitag.org/DTTMaps/europeanMap.html