Development of satellite high-definition television in Europe

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This article presents the results of an analysis of high-definition television (HDTV) channels transmitted by European satellites during the period from first day of regular broadcasting (2004) until 1 January 2015. The data cut-off date was on 1 January each year, including 1 January 2015. The article also explains how the channels changed during each year, in relation to both the country where they were broadcast and the satellite position from which they were transmitted. It shows how these HDTV channels changed to comply with broadcasting standards and coding principles. The changes in the number of satellite HDTV channels of different genres are given for each year, as well as the percentage of channels of each genre in the countries with the largest satellite HDTV markets.

Keywords: Broad casting, digital television, high-definition channels, satellite.

SATELLITE television (TV) signals are transmitted to a ground-based station, wherefrom they are sent towards a satellite. The received signals are processed to obtain the 14 GHz frequency, and such signals are transmitted to a satellite. The signals which reach the satellite go into the transponder control unit where they are amplified and converted to the frequency range extending from 10.700 to 12.750 GHz (Ku-band) by the local oscillator. Such signals are then routed via antenna towards the surface of the Earth, where they can be received using a parabolic antenna[1–3].

The analogue satellite TV was the forerunner of the present digital satellite TV broadcasting. In analogue TV, one channel uses one dedicated frequency, i.e. one satellite transponder. Such a method of distribution resulted in high transponder lease prices. Therefore, a smaller number of TV channels was broadcast in comparison with digital transmission. Unlike the analogue reception, digital transmission allows broadcasting of a larger number of programmes with digital picture and sound quality[4,5]. With the arrival of digital TV, the number of available frequencies in a transponder increased significantly, thus substantially reducing the price of using a frequency. Subsequently, the number of TV and radio channels, as well as other forms of communication, increased significantly[6].

The development of digital telecommunications has led not only to standard digital television (SDTV; also standard definition television), but also to the use of high-definition television (HDTV)[7]. HDTV is a technology that offers better picture and sound quality in comparison with the traditional picture and sound technologies (the analogue PAL, NTSC, SECAM and digital SDTV). Because of its higher resolution, the picture is sharper, less blurry and generally closer to reality. HDTV offers smoother motion, more detailed and vivid colours, whereas high-quality multi-channel sound makes the viewing experience even better[8].

Table 1 provides the basic characteristics of primary digital TV standards[9].

HDTV offers signals of two different qualities: 720 and 1080 are their basic codes, to which the letters 'i' or the 'p' can be added to denote how an image is 'drawn' (i, interlaced – every second line is drawn; p, progressive – line after line is drawn). The numbers 720 and 1080 represent the image 'height', whereas the image width equals 1280 or 1920 pixels. The number of frames per second is given next, e.g. 720p50, which refers to the resolution of 1280 × 720, the progressive method of image drawing and frame rate of 50 frames per second[10].

The transmission of a TV/video signal in its uncompressed form requires an extremely wide bandwidth, wider than that supported by the modern VDLS technology

Table 1. Primary DTV standards

DTV	Resolution	Aspect ratio	Number of frames per second
HDTV	1920 × 1080	16 : 9	25p, 50i
	1280 × 720	16 : 9	25p, 50i
SDTV	720 × 576	16 : 9	25p, 50i
	720 × 576	4 : 3	25p, 50i

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HD and 3D video signals especially require a large bit rate. The transmission of an uncompressed HD video signal at its full, 1920 × 1080 resolution, and in the 4 : 2 : 2 format, requires a bit rate of about 3 GB/s, whereas the bit rate requirements for a 3D image are even higher. Because of this, different video compression algorithms are used. Depending on the compression algorithm used (MPEG-2, MPEG-4, etc.), compression degrees can vary[11]. If the MPEG-2 standard is used, the required bit rate for transmission of an HD signal is about 20 Mb/s, whereas for SDTV it is about 4 MB/s for the resolution of 720 × 576 lines. If the MPEG-4 standard is used, the required bit rate for the same image quality is twice as low. European TV systems mostly use the MPEG-2 standard. However, the MPEG-4 standard is being increasingly used nowadays[7,11].

Table 2 shows the bit rates of compressed TV signals used in practice for diffused broadcasting, determined in compliance with the MPEG-2 and MPEG-4 standards[12].

Ultra high-definition television (UHDTV) includes 4 K UHDTV (2160p) and 8 K UHDTV (4320p), which represent two digital video formats proposed by the NHK Science and Technology Research Laboratories and approved by the International Telecommunication Union (ITU). The minimum resolution of this format is 3.840 × 2.160 pixels (ref. 13).

DVB-S (digital video broadcasting-satellite) is the oldest DVB standard proposed by the DVB project[14–16]. It was developed during 1993, and ratified by the European Telecommunication Standards Institute (ETSI) in 1994. It is satellite transmission of the digitized audio and video contents over long distances by a complex system of geostationary satellites and the corresponding receivers. The second generation of this standard, ratified by the ETSI, is DVB-S2 (refs 17–19) (which has a higher capacity, uses more efficient modulation techniques and the H.264/VC-1 compression, and can support the HD content – HDTV). In comparison with DVB-S, DVB-S2 can achieve about 30% better performance, which, in combination with the MPEG-4 AVC (H.264) compression, makes it possible to deliver an HDTV programme in the same bandwidth required for SDTV[20].

TV reception models in Europe

Satellite TV services in Europe began transmitting Ku-band signals in the late 1980s. In 1988, a Luxembourg company SES Astra launched the first medium-powered satellite Astra 1A[21] intended for the reception of signals using individual small-diameter antennas (90 cm).

In European countries, different TV distribution methods are used. Table 3 provides the number of European households (millions) receiving TV channels via satellite, terrestrial, cable and IPTV distribution form[22–24]. Satellite reception, which is the dominant TV reception model, is continuing its growing trend year after year. At the end of 2014, there were more than 90 million households receiving TV channels via satellite. Terrestrial reception, with a falling trend year after year, is the second most common reception model after satellite reception. TV reception through a cable, with an insignificantly falling trend lately, occupies the third place. The latest IPTV reception model is least common in Europe, but its use is increasing rapidly compared with other reception models.

The satellite TV market is the most common TV reception model in Europe, mostly, owing to the possibility of launching a greater number of HDTV channels. While the terrestrial and cable reception models have certain limitations regarding frequency ranges, with satellite reception this problem is overcome by launching new satellites with a greater number of transponders.

Table 4 provides the number of European households (in millions) receiving SDTV and HDTV channels via satellite[23]. The number of households viewing HDTV channels via satellite is constantly growing. There has been a sudden expansion in satellite HDTV reception recently. At the end of 2014, there were more than 47 million households viewing HDTV channels via satellite, i.e. the households viewing SDTV channels were outnumbered.

HDTV channels per satellite position

Unlike other TV distribution methods (terrestrial, cable, IPTV), signals distributed via satellite are available on a wider territory and cover regions inaccessible to other

Table 2. Bit rates of compressed video/audio signals for specific standards

Video compression standards	TV video resolution	Bit rates of compressed video signals (Mb/s)
MPEG-2	SDTV	2–4
	HDTV	15–20
MPEG-4	SDTV	1.5–2
	HDTV	6–8

Table 3. Number of households (millions) using satellite, terrestrial, cable and IPTV reception of TV channels

Year	2009	2010	2011	2012	2013	2014
Satellite	77.41	79.13	83.6	84.56	86.2	90.03
Terrestrial	86.46	83.71	79.4	78.14	72.98	68.97
Cable	71.34	70.99	69.25	68.42	68.24	67.98
IPTV	8.98	12.06	15.99	17.48	21.89	27.18

Table 4. Number of households (millions) viewing SDTV and HDTV channels via satellite

Year	2010	2011	2012	2013	2014
SDTV	55.15	52.04	49.90	47.86	42.84
HDTV	20.04	29.39	34.66	38.34	47.18

Table 5. Number of HDTV channels per satellite position

Satellite position	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
52.5°E	–	–	–	–	–	–	–	–	6	31	33	33
46°E	–	–	–	–	–	–	–	–	–	–	1	–
45°E	–	–	–	1	1	1	1	–	1	9	12	15
42°E	–	–	–	1	–	4	8	14	25	31	44	61
39°E	–	–	–	–	1	4	5	14	16	17	19	27
36°E	–	–	–	1	–	–	–	–	–	–	1	1
31.5°E	–	–	–	–	–	–	–	1	4	–	43	47
30.5°E	–	–	–	–	–	–	–	2	2	2	2	2
28.2°E	–	–	1	14	14	30	37	59	66	78	85	94
26°E	–	–	–	–	2	5	1	18	25	31	46	42
25.5°E	–	–	–	–	–	–	–	–	–	–	–	20
23.5°E	–	1	4	7	4	8	21	42	72	58	52	60
21.5°E	–	–	–	–	–	–	–	–	–	–	7	–
19.2°E	1	2	11	10	13	25	44	68	102	158	202	228
16°E	–	–	–	–	–	7	7	7	18	28	38	58
13°E	–	1	1	11	13	27	39	75	113	150	156	179
10°E	–	–	–	–	–	–	–	1	1	3	3	4
9°E	–	–	–	–	2	16	27	40	52	54	63	85
7°E	–	–	1	5	7	8	9	14	22	32	38	46
4.8°E	–	–	2	3	1	8	7	18	24	49	53	53
3°E	–	–	–	–	–	–	–	–	–	–	2	3
0.8°W	–	–	1	4	11	15	17	34	44	53	75	97
4°W	–	–	–	–	–	4	8	8	8	11	17	30
5°W	–	–	1	3	1	3	6	6	6	19	24	28
7°W	–	–	–	–	–	–	2	25	41	52	67	92
12.5°W	–	–	–	–	1	1	1	1	4	5	4	–
15°W	–	–	–	–	–	–	1	2	3	3	3	4
24.5°W	–	–	–	–	–	–	–	–	–	–	–	1
27.5°W	–	–	–	–	–	–	–	3	6	7	5	5
30°W	–	–	–	1	1	17	25	18	34	33	26	25
Total	1	4	22	61	72	183	266	470	695	914	1121	1340

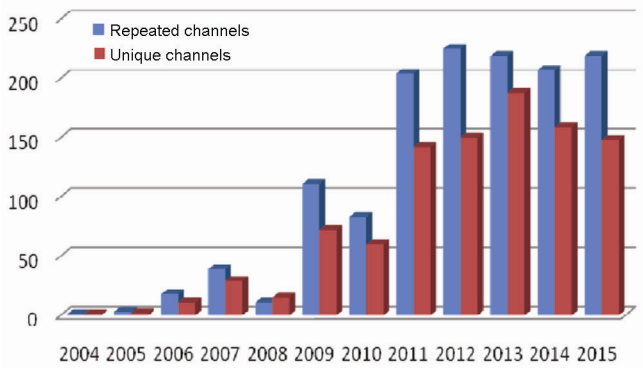

Figure 1. Number of new HDTV channels launched each year.

distribution methods[3,9]. On the other hand, owing to its much higher technical capacity in comparison with other transmission methods, satellite transmission was ideal for the development of HDTV.

All the satellites covering the European territory in the Ku-band frequency range were included in the analysis[25,26]. The analysis also included all HDTV channels (encrypted, unencrypted, those using different DVB-S standards) received from European satellites. The data cut-off date was on 1 January each year, starting from 2004 and ending on 1 January 2015.

HDTV channels broadcast by European satellites were tested for the first time at the end of 2003, and on 1 January 2004, the regular broadcasting of the first European HDTV channel began. It was the Belgian Euro 1080, from an Astra satellite at 19.2° East, later known as HD1 (ref. 27).

Table 5 provides an overview of the number of HDTV channels per satellite position. In this case, multiple repetitions of the same channel at different satellite positions were taken into consideration.

The most popular satellite position from which HDTV channels are broadcast is definitely 19.2° East, where the Astra satellites are located. It is closely followed by 13°, 28.2°, 9°, 4.8°, 23.5°, 26° East and 0.8° West. These are the positions from which the most popular satellite direct-to-home (DTH) platforms are broadcast. Therefore, it can be mentioned that the greatest contribution to the development of both satellite HDTV and SDTV has been made by DTH platforms.

Table 6 provides an overview of satellite names (those from which HDTV channels are broadcast) per satellite position on 1 January 2015.

Figure 1 provides an overview of new HDTV channels launched each year. The term ‘unique channels’ refers to the total number of different channels, i.e. only one occurrence of a channel at one satellite position is taken into consideration. The term ‘repeated channels’ refers to

the total number of active HDTV channels at all satellite positions and in all frequencies. Some HDTV channels are available at several satellite positions and the number of such 'duplicates' represents the difference between 'unique channels' and 'repeated channels'.

Over time the number of HDTV channels has been increasing. The real expansion took place in 2008 when, during the period from 1 January 2008 to 1 January 2009, the number of active HDTV frequencies increased by more than 100. Recently, more than 200 new HDTV satellite frequencies have appeared.

Table 6. Satellite name per satellite position

Satellite position	Satellite name
52.5°E	Yahsat 1A
46°E	Azerspace-1
45°E	Intelsat 12
42°E	Turksat 2A/3A/4A
39°E	Helass Sat 2
36°E	Eutelsat 36A/36B
31.5°E	Astra 1G
30.5°E	Arabsat 5A
28.2°E	Astra 2E/2F/, Eutelsat 28A
26°E	Badr 4, Badr 5, Badr 6
25.5°E	Eutelsat 25B
23.5°E	Astra 3B
21.5°E	Eutelsat 21B
19.2°E	Astra 1KR/1L/1M/1N
16°E	Eutelat 16A
13°E	Hot Bird 13B/13C/13D
10°E	Eutelsat 10A
9°E	Eutelsat 9A
7°E	Eutelsat 7A
4.8°E	Astra 4A, SES 5
3°E	Eutelsat 3B
0.8°W	Thor 5/6, Intelsat 10-02
4°W	Amos 2, Amos 3
5°W	Eutelsat 5E A
7°W	Eutelsat 7E A, Nilesat 102/201
12.5°W	Eutelsat 12E A
15°W	Telstar 12
24.5°W	Intelsat 905
27.5°W	Intelsat 907
30°W	Hispast 1D/1E

Table 7. Number of HDTV channels per broadcasting standard

Year	DVB-S	DVB-S2	Total
2004	1	–	1
2005	4	–	4
2006	13	9	22
2007	23	38	61
2008	18	54	72
2009	30	153	183
2010	30	236	266
2011	57	413	470
2012	65	630	695
2013	60	854	914
2014	68	1053	1121
2015	73	1267	1340

HDTV channels per broadcasting standard

Table 7 provides an overview of the number of HDTV channels per broadcasting standard. Figure 2 shows the percentage of HDTV channels using the DVB-S and DVB-S2 standards.

The oldest HDTV channels were broadcast using only the DVB-S standard. However, over time, a more advanced broadcasting standard, DVB-S2, began to be used. Lately, less than 10% of HDTV channels are broadcast using the DVB-S standard.

Table 8. Number of HDTV channels per broadcasting type (free-to-air and encrypted)

Year	Free-to-air	Encrypted	Total
2004	1	–	1
2005	4	–	4
2006	18	4	22
2007	21	40	61
2008	17	55	72
2009	21	162	183
2010	21	245	266
2011	37	433	470
2012	71	624	695
2013	136	778	914
2014	180	941	1121
2015	205	1135	1340

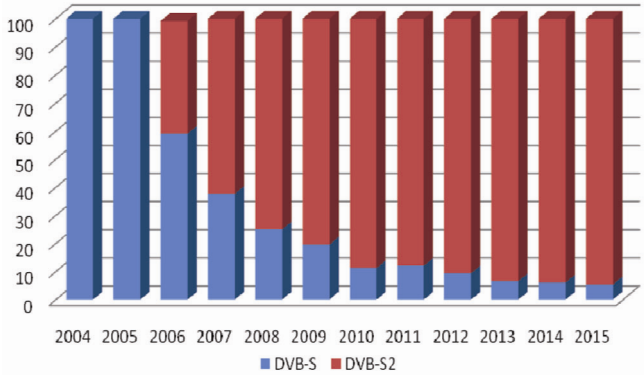

Figure 2. Percentage of HDTV channels using the DVB-S and DVB-S2 standards.

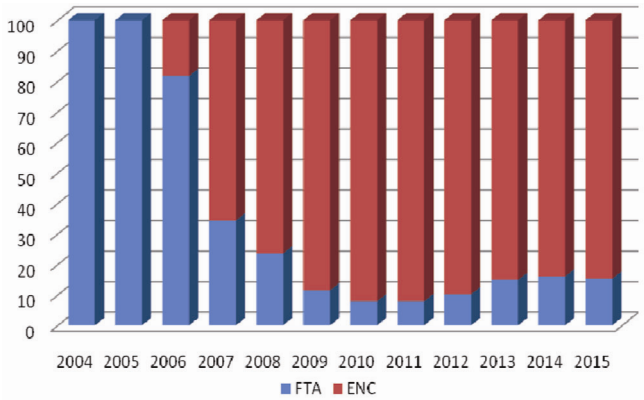

Figure 3. Percentage of HDTV channels per broadcasting type (free-to-air and encrypted).

Table 9. Number of HDTV channels per broadcasting country

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Belgium	1	1	2	5	3	4	4	3	3	5	5	5
France	–	1	3	9	9	18	20	26	36	57	72	83
Luxembourg	–	1	1	1	1	1	1	1	1	1	1	2
Germany	–	–	6	5	5	5	15	30	48	65	92	110
Sweden	–	–	1	2	7	9	9	10	16	28	33	35
United Kingdom	–	–	1	13	13	28	43	66	79	95	110	122
Italy	–	–	–	4	5	7	17	39	46	67	82	87
Poland	–	–	–	2	6	10	13	18	37	44	46	46
Spain	–	–	–	1	1	4	8	17	24	32	35	33
USA	–	–	–	1	1	2	2	6	10	15	14	15
Denmark	–	–	–	–	1	3	4	6	7	9	12	16
Switzerland	–	–	–	–	1	1	1	1	5	6	6	6
Turkey	–	–	–	–	4	6	10	19	31	41	59	78
Cyprus	–	–	–	–	1	1	–	–	–	–	–	–
Albania	–	–	–	–	–	5	5	5	8	10	11	12
Austria	–	–	–	–	–	1	3	4	8	12	15	17
Bulgaria	–	–	–	–	–	1	2	3	4	8	10	12
Czech Republic	–	–	–	–	–	1	4	4	5	6	9	13
Hungary	–	–	–	–	–	5	4	5	5	6	13	18
Norway	–	–	–	–	–	1	1	7	10	14	17	20
The Netherlands	–	–	–	–	–	1	4	16	17	17	18	18
Portugal	–	–	–	–	–	8	8	9	14	15	17	20
Romania	–	–	–	–	–	1	2	4	6	9	15	20
Russia	–	–	–	–	–	3	7	9	9	6	8	8
Qatar	–	–	–	–	–	2	1	4	5	7	11	33
Finland	–	–	–	–	–	1	1	–	–	2	2	5
Greece	–	–	–	–	–	1	–	2	4	10	13	21
Egypt	–	–	–	–	–	–	1	1	1	–	–	–
Japan	–	–	–	–	–	–	–	1	1	1	1	1
United Arab Emirates	–	–	–	–	–	–	–	14	30	49	56	67
Saudi Arabia	–	–	–	–	–	–	–	2	8	15	13	11
Croatia	–	–	–	–	–	–	–	–	1	4	8	8
Slovakia	–	–	–	–	–	–	–	–	2	2	2	11
Ukraine	–	–	–	–	–	–	–	–	1	2	4	3
Ireland	–	–	–	–	–	–	–	–	–	1	1	1
Serbia	–	–	–	–	–	–	–	–	–	4	4	4
Georgia	–	–	–	–	–	–	–	–	–	1	2	–
South Korea	–	–	–	–	–	–	–	–	–	1	1	1
Lebanon	–	–	–	–	–	–	–	–	–	1	1	1
Oman	–	–	–	–	–	–	–	–	–	1	3	3
Kuwait	–	–	–	–	–	–	–	–	–	1	4	3
Libya	–	–	–	–	–	–	–	–	–	–	1	2
Iraq	–	–	–	–	–	–	–	–	–	–	2	2
Bosnia and Herzegovina	–	–	–	–	–	–	–	–	–	–	–	2
Iran	–	–	–	–	–	–	–	–	–	–	–	1
Brazil	–	–	–	–	–	–	–	–	–	–	–	1
Total	1	3	14	43	58	130	190	332	482	670	829	977

Table 8 shows the number of HDTV channels per broadcasting type – free (free-to-air) and encrypted channels. Figure 3 shows the percentage of free and encrypted channels.

After the first three years of HDTV broadcasting, the number of free channels decreased to less than 50%, and on 1 January 2010, it was less than 10%. Since 2011, the number of free channels has insignificantly increased.

Satellite HDTV channels per broadcasting country

Table 9 provides an overview of the number of HDTV channels per broadcasting country. Since a channel from one country may appear at several satellite positions, only one 'occurrence' of an HDTV channel was taken into consideration.

As can be seen from the table, the first channels came from Belgium, France and Luxembourg. With each year, the number of channels also increased. Great Britain has been the leader in the number of HDTV channels, closely followed by Germany, France and Italy. Poland, Turkey, Spain and Sweden have also exceptional satellite HDTV markets. Recently, there has been an increasing number of channels coming from the Near East, especially from the satellites which cover not only Europe, but also

Table 10. The number of HDTV channels per each category

Category	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
General	1	1	3	13	17	36	47	85	118	177	215	253
Movies	–	–	2	8	13	36	56	93	132	166	205	227
Sports	–	–	1	7	10	21	29	75	104	143	181	230
Entertainment	–	–	–	2	3	6	7	15	28	41	55	69
Music	–	–	–	–	–	4	6	9	12	19	26	27
Children	–	–	–	–	–	4	4	8	20	24	28	30
News	–	–	–	–	–	–	–	1	4	13	18	26
Documentary	–	–	1	7	11	17	31	36	47	70	87	98
Adult	–	–	–	–	–	1	4	4	9	10	9	11
HD promotional	–	2	7	6	4	5	6	6	8	7	5	6
Total	1	3	14	43	58	130	190	332	482	670	829	977

Table 11. Number of HDTV channels per category on 1 January 2015

Country	General	Movies	Sports	Entertainment	Music	Children	News	Documentary	Adult	HD promotion	Total
Belgium	5	–	–	–	–	–	–	–	–	–	5
France	16	20	14	5	11	6	–	9	1	1	83
Luxembourg	–	–	–	–	–	–	–	–	1	1	2
Germany	31	19	19	13	5	5	3	13	1	1	110
Sweden	11	7	11	–	–	–	–	6	–	–	35
United Kingdom	23	19	23	13	2	8	5	25	3	1	122
Italy	9	27	30	5	2	2	1	10	1	–	87
Poland	7	18	6	5	–	2	2	6	–	–	46
Spain	2	16	8	2	–	1	–	4	–	–	33
USA	–	1	4	4	–	–	1	2	3	–	15
Denmark	10	1	4	–	–	–	–	1	–	–	16
Switzerland	6	–	–	–	–	–	–	–	–	–	6
Turkey	20	35	11	3	–	–	3	4	–	2	78
Albania	4	2	5	1	–	–	–	–	–	–	12
Austria	13	–	1	2	1	–	–	–	–	–	17
Bulgaria	5	4	1	–	1	–	1	–	–	–	12
Czech Republic	6	2	3	–	–	–	–	2	–	–	13
Hungary	9	3	4	1	–	–	–	1	–	–	18
Norway	11	–	8	–	–	–	–	1	–	–	20
The Netherlands	9	2	3	1	1	1	–	1	–	–	18
Portugal	2	12	4	1	–	–	–	1	–	–	20
Romania	7	3	4	1	3	–	–	1	1	–	20
Russia	–	3	1	–	–	–	3	1	–	–	8
Qatar	4	–	27	–	–	1	1	–	–	–	33
Finland	4	–	1	–	–	–	–	–	–	–	5
Greece	1	5	10	1	1	–	–	3	–	–	21
Japan	1	–	–	–	–	–	–	–	–	–	1
United Arab Emirates	11	21	14	10	–	3	4	4	–	–	67
Saudi Arabia	4	–	3	–	–	–	1	3	–	–	11
Croatia	1	3	4	–	–	–	–	–	–	–	8
Slovakia	6	4	–	–	–	1	–	–	–	–	11
Ukraine	2	–	–	1	–	–	–	–	–	–	3
Ireland	1	–	–	–	–	–	–	–	–	–	1
Serbia	–	–	4	–	–	–	–	–	–	–	4
South Korea	1	–	–	–	–	–	–	–	–	–	1
Lebanon	1	–	–	–	–	–	–	–	–	–	1
Oman	1	–	2	–	–	–	–	–	–	–	3
Kuwait	2	–	1	–	–	–	–	–	–	–	3
Libya	2	–	–	–	–	–	–	–	–	–	2
Iraq	2	–	–	–	–	–	–	–	–	–	2
Bosnia and Herzegovina	2	–	–	–	–	–	–	–	–	–	2
Iran	–	–	–	–	–	–	1	–	–	–	1
Brazil	1	–	–	–	–	–	–	–	–	–	1
Total	253	227	230	69	27	30	26	98	11	6	977

Table 12. Number of SDTV, HDTV and 4K UHDTV channels for different transmission parameters

Satellite transmission	Carrier data rate (Mbps)	Number of channels		
		SDTV (p25/p30)	HDTV (p25/p30)	4K UHDTV (p50/p60)
DVB-S, QPSK, FEC 3/4	38	4–5 in MPEG-2	4–5 in MPEG-4	–
DVB-S2, 8PSK, FEC 5/6	72	24+ in MPEG-4	7–9 in MPEG-4 14–18 in HEVC	2–5 in HEVC
DVB-S2, 16APSK, FEC 2/3	79	–	7–9 in MPEG-4 15–19 in HEVC	1 in MPEG-4 3–5 in HEVC
DVB-S2X, 16APSK, FEC 3/4	83	–	8–10 in MPEG-4 16–20 in HEVC	1 in MPEG-4 3–5 in HEVC
DVB-S2X, 16APSK, FEC 135/180	99	–	9–12 in MPEG-4 19–24 in HEVC	1 in MPEG-4 3–6 in HEVC

Table 13. Overview of 4K UHDTV satellite channels

Position	Band	Standard	Compression standard	Modulation	Forward error correction	Simbol rate	Channel	Country
42.0°E	Ku	DVB-S2	HEVC	8PSK	3/4	15000	Turksat 4K tests	Turkey
36.0°E	Ku	DVB-S2	HEVC	8PSK	3/4	27500	Tricolor 4K tests	Russia
31.5°E	Ku	DVB-S2	HEVC	8PSK	3/4	30000	SES UHD Demo channel	Luxembourg
28.2°E	Ku	DVB-S2	HEVC	8PSK	3/4	29500	Astra Promo UHD	Luxembourg
26°E	Ku	DVB-S2	HEVC	QPSK	5/6	27500	Selavision 4K	
19.2°E	Ku	DVB-S2	HEVC	QPSK	9/10	22000	SES UHD Demo channel	Luxembourg
19.2°E	Ku	DVB-S2	HEVC	QPSK	9/10	22000	Astra Promo UHD	Luxembourg
19.2°E	Ku	DVB-S2	HEVC	8PSK	2/3	22000	Fashion 4K	France
19.2°E	Ku	DVB-S2	HEVC	8PSK	2/3	22000	Canal + UHD	France
19.2°E	Ku	DVB-S2	HEVC	8PSK	2/3	30000	Pearl TV	Germany
19.2°E	Ku	DVB-S2	HEVC	8PSK	2/3	30000	Insight Promo	The Netherlands
13.0°E	Ku	DVB-S2	HEVC	8PSK	3/4	30000	Fun Box 4K	USA
13.0°E	Ku	DVB-S2	HEVC	8PSK	3/4	30000	Hot Bird 4K	France
13.0°E	Ku	DVB-S2	HEVC	8PSK	3/4	27500	Eutelsat 4K Demo channel	France
4.8°E	Ku	DVB-S2	HEVC	8PSK	3/4	30000	SES UHD Demo channel	Luxembuorg
5.0°W	Ku	DVB-S2	HEVC	8PSK	3/4	29950	Fransat Info UHD	France
30.0°W	Ku	DVB-S2	HEVC	8PSK	3/4	30000	Hispasat 4K TV	Spain
30.0°W	Ku	DVB-S2	HEVC	8PSK	3/4	27500	Ultra HD 4K	Portugal

regions of the Near East and North Africa. Among these countries, the United Arab Emirates (UAE) has the greatest number of HDTV channels – 67.

Satellite HDTV channels per category

Table 10 provides an overview of the number of satellite channels per category in all European countries. Most satellite HDTV channels fall under the 'general' category, but there are also sports, movie and documentary channels.

Table 11 shows the number of HDTV channels available in Europe on 1 January 2015 per category and in each country.

In countries with a greater number of HDTV channels (the United Kingdom, Germany, France), general, movie and sports channels are present in almost the same percentage. In countries with a smaller number of HDTV channels, the percentage of general channels is lower. Specialized channels, such as movies and sports are prevalent.

4K UHDTV via satellite

There is still not much UHD content available, but it is growing rapidly. Broadband services (Netflix and YouTube) made the first 4K UHD content available, and in 2013 and 2014, the first experimental TV channels with 4K UHD content were launched. Sporting events which took place during 2012–2014 represented the first UHD content transmitted via satellite[28]. The following leading satellite companies took part in the distribution of UHD content: Eutelsat, SES Astra, Measat, Intelsat, Hispasat. Although the first testing was related to H.264/AVC video compression, HEVC is currently the most commonly used compression standard[29].

Table 12 provides an overview of the number of SDTV, HDTV and 4K UHDTV channels transmitted via satellites for different transmission parameters (transponder specifications)[30].

In order to ensure transmission of the greatest possible number of HDTV and UHDTV channels via satellites, it is necessary to convert the satellite DVB-S transponders to

DVB-S2 transponders. Conversion to the 16APSK modulation will result in the increased capacity for HDTV channels. Furthermore, in order to use satellite capacity as cost effectively as possible, the MPEG-4 compression standard should also be used for the transmission of SDTV channels.

The first experimental transmission of UHD content in Europe was done in 2012, from satellites belonging to the SES Astra company, located at 23.5° East, using the H.264/AVC video coding and at the bit rate of 50 Mbit/s (ref. 31). The company has launched several promotional HDTV channels from its satellites located in different positions.

Table 13 provides an overview of 4K UHDTV channels which are delivered worldwide using satellites with basic parameters, starting from 1 January 2015. The overview is in compliance with the available data[25,26].

Conclusion

The first satellite HDTV channel in Europe was launched on 1 January 2004. After several years of moderate development, the expansion of HDTV channels started after 2007. Today, more than 1300 active signals are delivered by satellites broadcasting HDTV programmes. The leading countries in the number of HDTV channels are Great Britain (122 channels) and Germany (110 channels). France, Italy, Poland, Turkey, Spain and UAE have also developed satellite HDTV markets.

The most popular satellite position for HDTV broadcasting is at 19.2° East, with more than 200 channels at present. Over time, HDTV channels have ceased to use the DVB-S standard; so broadcasting today is done using the DVB-S2 standard (more than 90%). Most HDTV channels are general in category, but there are also specialized channels such as sports, movies and documentary.

Thus we can conclude that the European satellite HDTV market is developing at a remarkable pace. The next step is the launching of an ultra HDTV channel.

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