

Satellite television transmission in the world - broadcasting systems and standards

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ABSTRACT. This paper considers the characteristics of satellite television transmission in the world. An overview of the development of satellite television is given through the following characteristics: broadcasting systems - analog and digital (SDTV, HDTV, UHDTV), frequency band (C, Ku, Ka), broadcasting standards (DVB-S, DVB-S2, DigiCipher, DSS), as well as the availability of TV services Free-To-Air TV (FTA) and PAY TV. All of these characteristics were considered both at the global and at the regional level: North America, South America, Europe, Africa, Russia, Asia, and Australia. The gathered data are presented in tabular form and presented graphically for the period from 1996 to 2018. Based on the presented results, an analysis of the development of satellite television transmission was carried out in accordance with the characteristics of the broadcast.

Keywords: C Band; Ku Band; Ka Band; SDTV; HDTV; UHDTV.

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Introduction

Distribution of the television signal with its accompanying services to end-users is done through various platforms: satellite, terrestrial, cable, and IPTV (Internet Protocol Television). When compared to other forms of TV signal distribution, the use of satellites has significant advantages for the broadcasting and distribution of a television program. These advantages are, primarily, the large territory coverage area, the lack of need for a network of transmitters and repeaters, the ability to transmit multiple channels over the same satellite, the interconnection of remote TV studios, the ability of international transmission and exchange of programs (Maral & Bousquet, 2009). Furthermore, due to the much greater technical capacity compared to the other forms of transmission, satellite transmission was ideal for the development of HDTV (High Definition Television).

Satellites are deployed in a geostationary orbit, at the distance of 35,871 km from the Earth, where they are spaced apart a couple of degrees (Minoli, 2015). At one position, one satellite or several grouped satellites can be placed. The positions of satellites in the geostationary orbit are given in degrees (°) in relation to the Greenwich meridian (0°). The satellites that are positioned east of Greenwich, in addition to the number of degrees they also have the mark E (east), and westward positioned satellites have the mark W (west) (Martin, Anderson, & Bartamian, 2006; Minoli, 2015).

Most signals are broadcast in the Ku band. With the need to broadcast as many channels as possible from a single channel, the commercial range of the broadcast of channels in the Ku band was expanded, so that today it is the most frequent scope for broadcasting satellite TV programs (Petrovic, 2007; Landeros-Ayala, Chávez-Cárdenas, & González-Sánchez, 2013; Wittig, 2014). Its main characteristic is that it gives a very strong signal, but on a relatively small territory. In contrast to the Ku band, the C band covers a substantially larger territory, but with a much weaker signal, so an antenna of at least 3 meters in diameter is required for the reception of the signal from the C band. Only a few satellites are an exception to this and their signals can be received even with significantly smaller antennas. C band, as the forerunner of the Ku band, is present on all continents, and it is the least present in Europe (Wu, Hirakawa, Reimers, & Whitaker, 2006). Apart from these two bands, Ka band is also used for the distribution of TV programs, and it is present in the USA, where it is used for some DTH (direct-to-home) services (Dulac, 2006).

Direct-to-Home (DTH) technology refers to the process of broadcasting satellite TV signals and other services that are designed exclusively for home reception through personal antennas. This technology has

been previously referred to as Direct Broadcast Satellite (DBS) technology (Godwin, 1999). DTH technology has been developed with the intention of being competitive with TV operators of cable operators, so it can broadcast high-quality satellite signals with a large number of TV channels. The most suitable and the most common transmission of DTH services is in the Ku band, although there are services that work in the C and Ka band. TV channels that are broadcast via DTH are in digital format and are generally encrypted, so that in order to access it, a receiver/decoder of protected channels is required (Dulac, 2006; Spaliaras & Dokouzyannis, 2013).

Broadcasting systems and resolution

The first satellite TV broadcast was done in analog format. The main characteristic of analog distribution is that one TV channel uses one frequency, i.e. one satellite transponder. This method of distribution resulted in the broadcast of a smaller number of TV channels compared to the digital transmission (Alencar, 2009).

Unlike analog, digital signal transmissions allow for a greater number of programs, and these programs additionally have a digital quality of picture and sound. With the arrival of digital technology, the number of free frequencies on one transponder significantly increased, and with it the number of television and radio channels (as well as other forms of communication). This has resulted in a direct impact on the development of DTH services (Jaksic, Petrovic, Jaksic, Milosevic, & Marinkovic, 2016).

Analog transmission was the standard until the 1990s, after which it was steadily suppressed by the digital transmission. Eventually, at the beginning of the 21st century, the analog transmission was completely removed from use (Dulac, 2006).

The development of digital telecommunications, in addition to SDTV (Standard Definition Television), has enabled the use of high-definition HDTV (High Definition Television) television. HDTV is a technology that offers considerably higher quality of the picture and sound compared to the traditional image and sound reproduction technologies. One can notice a significant increase in the number of HDTV channels, which are suppressing SDTV channels (Jaksic et al., 2016). In recent years, in addition to HDTV, UHD TV (Ultra High Definition Television) televisions have also appeared, they are divided into 4K UHD TV and 8K UHD TV with twice the number of pixels and four times the number of pixels, respectively, compared to HDTV (Masaoka et al., 2016).

Standards

In analog transmission, several standards for the broadcast of TV signal were available, such as PAL, SECAM, and NTSC (Wu et al., 2006).

DVB-S (Digital Video Broadcasting - Satellite) is the oldest DVB standard, and it was proposed by the DVB Project (Morello & Mignone, 2006). It was developed in 1993, and was adopted in 1994 by the European Telecommunications Standards Institute (ETSI). The second generation of this standard, DVB-S2, has been ratified by ETSI, and it supports the high definition content (HDTV) (Cornejo & Landeros, 2016). Compared to DVB-S, DVB-S2 delivers about 30% better performance, which in combination with MPEG-4 AVC (H.264) compression provides the ability to broadcast HDTV with the same data flow that was previously needed for SDTV (Mignone, Vazquez-Castro, & Stockhammer, 2011; Vazquez-Castro & Vieira, 2012).

During the 1990s, DigiCipher standard was developed in the United States (USA) for the needs DBS requirements. DigiCipher 2 is a proprietary standard format of digital signal transmission and it doubles as an encryption standard with MPEG-2/MPEG-4 signal video compression (El-Hajjar & Hanzo, 2013). DTH operator DirecTV in the US uses DSS (Digital Satellite System) standard for transmission of SDTV and HDTV services to end users (Wu et al., 2006).

Material and methods

Table 1 gives the number of households (in millions) in the world that use different platforms for receiving TV signals. Analog services of cable and terrestrial transmission will be suppressed by digital services in the near future. From the given data, it can be seen that the number of users of digital services is on the rise, and that the cable reception is closely followed by the satellite reception. IPTV reception is the latest model, therefore it is the least represented in Europe, but it has the fastest growth compared to other reception models. The representation of certain platforms differs from region to region around the world, so, for example, satellite reception is the most popular in Europe and parts of Asia.

Table 1. Global TV households.

Platform	2010	2011	2012	2013	2014	2015	2016	2017
Satellite (Digital)	266.9	293.1	319.3	337.3	359.2	369.3	392.4	416.0
Terrestrial (Analog)	526.6	473.5	419.5	364.6	319.8	261.9	184.1	136.0
Terrestrial (Digital)	86.3	108.6	130.1	164.7	203.3	252.0	271.9	311.0
Cable (Analog)	334.1	315.6	283.4	239.9	188.2	135.6	117.1	90.0
Cable (Digital)	193.9	227.8	271.0	325.7	374.1	424.9	448.8	462.0
IPTV	36.3	53.1	70.8	86.7	101.8	123.9	170.8	214.0

The paper presents the results obtained by collecting data related to the contents of satellite transponders using platforms Lyngsat (<http://www.lyngsat.com/>), Satbeams (<https://www.satbeams.com>), and Tbs-Satellite (<https://www.tbs-satellite.com>), accessed via <https://web.archive.org/>. The data is collected from web pages related to the structure of satellite transponders, satellite TV channels and their technical characteristics. Data refer to December 31st in each year, except for 2018, where the situation refers to 1st of September.

According to the International Telecommunication Union (ITU), the world is divided into three regions: Region 1 - Europe, Africa, Middle East and Russia, Region 2 - North America and South America, and Region 3 - Asia, Pacific, Australia and Oceania. In Figure 1, the ITU regions are marked with full lines.

In theory, if the transmitting antenna on the satellite transmitter emits equally in all directions, it could cover about 40% of the Earth's surface (Martin et al., 2006). However, the transmitting antenna on the satellite does not broadcast equally in all directions, it is focused on a narrower area of the so-called service zone (footprint) of a particular transponder on a communications satellite. In Figure 1, dashed lines define specific coverage zones for Ku transponders: Region A - North America, Region B - South America, Region C - Europe (Middle East and North Africa), Region D - Africa (Central and South Africa), Region E - Russia (Central and East Russia), Region F - Asia (Asia and Pacific), and Region G - Australia (Australia and Oceania). Regions of Australia, Asia, and Russia are covered by satellites at satellite positions from 180 east to 73° east, the Europe and Africa regions from 73 east to 61° west, and the North America and South America regions from 61 west to 160° west.

Results and discussions

Satellite TV transmission according to broadcasting systems and resolution

Table 2 provides an overview of the number of TV channels in the world for different broadcasting systems (analog, and digital in SDTV, HDTV, and UHD TV format) as well as in different bands (C, Ku, and Ka).

The first broadcast of the digital satellite TV services began in the mid-nineties of the 20th century. Prior to this, satellite TV services were exclusively analog. Satellite TV transmission was initially intended for the exchange of TV content between TV companies from different continents, and then, in the 1980s, after the launch of satellites equipped with transponders in the Ku band, the commercial use of satellites for the distribution of TV channels to end users began. Analog satellite TV has peaked in the mid-nineties, after which there has been a continuous decline in the number of analog TV channels, and in 2010, the analog TV broadcasting in the Ku band was completely suspended. These days, a small number of analog TV channels in the C band are still broadcast.

The number of digital services is in the continual rise, primarily in SDTV format, but also in HDTV format. In 2014, the broadcast of the first UHD TV channels via satellite began. In recent years, there has been a noticeable stagnation of the SDTV services, and a significant increase of the HDTV services. The majority of TV channels are broadcast in Ku band, while C and Ka band are less present.

Figure 2 shows the percentage of analog and digital channels (SDTV, HDTV, and UHD TV) in the C and Ku band. SDTV channels have the largest share, both in the C band and the Ku band. Analog TV channels are significantly more represented in the C band than in the Ku band. HDTV channels are slightly more represented in the Ku band. From the given data, it can be seen that the presence of SDTV channels is reduced in both bands, and that the growth of HDTV channels is increasing with each passing year.

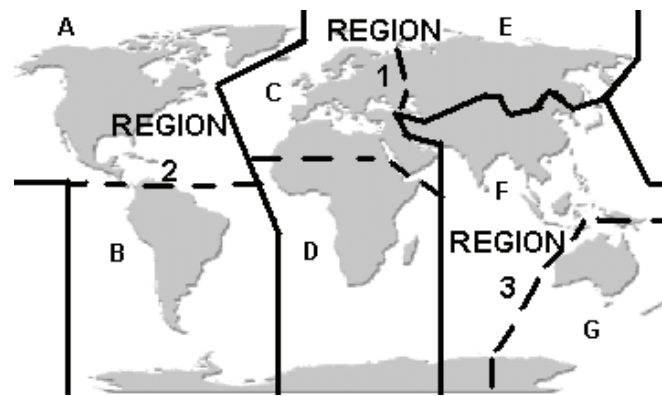


Figure 1. ITU regions and satellite coverage regions.

Table 2. The number of TV channels in the world.

	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018
Analog (C)	492	447	317	234	173	101	56	44	40	38	33	33
Analog (Ku)	367	310	240	123	88	62	51	43	0	0	0	0
SDTV (C)	253	846	1554	1936	2407	3125	3980	4405	4867	5491	5747	5767
SDTV (Ku)	1105	2622	5529	8107	11399	14052	17026	19938	21353	24057	25080	25030
SDTV (Ka)	0	0	0	0	0	26	26	32	44	77	84	101
HDTV (C)	0	0	4	8	27	38	147	326	519	860	1331	1675
HDTV (Ku)	0	0	12	26	105	267	608	2764	4190	6024	7466	8691
HDTV (Ka)	0	0	0	0	0	41	367	442	554	544	539	537
UHDTV (C)	0	0	0	0	0	0	0	0	0	0	29	37
UHDTV (Ku)	0	0	0	0	0	0	0	0	0	15	51	79
UHDTV (Ka)	0	0	0	0	0	0	0	0	0	0	2	2

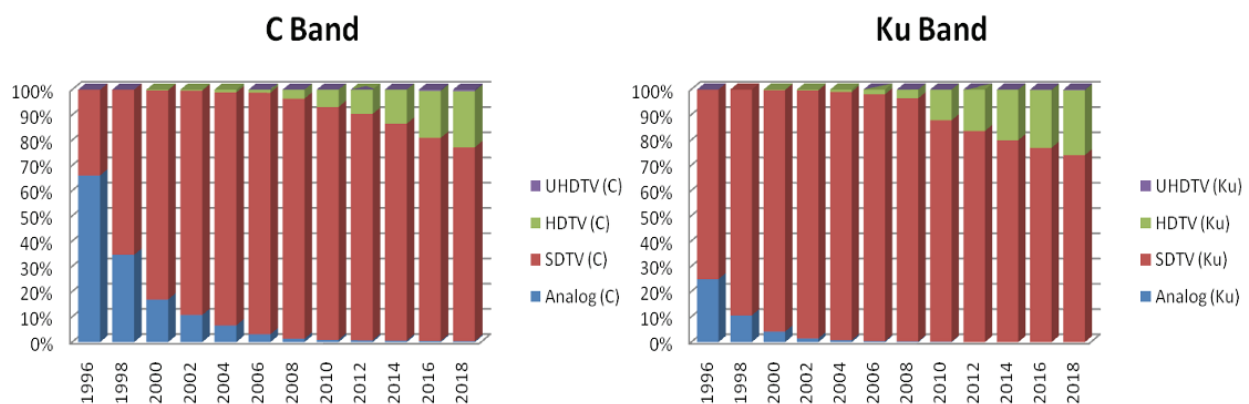


Figure 2. The share of analog and digital SDTV, HDTV, and UHDTV channels in the C band and Ku band.

Figure 3 shows the share percentage of TV channels from C band, Ku Band, and Ka Band relative to the total number of SDTV and HDTV channels. The largest part of the SDTV channels is broadcast in Ku band (more than 80%), followed by the C band. Broadcasting in Ka band is the least present. As for the HDTV channels, their broadcasting is also most represented in the Ku band (about 70%). The broadcast of the HDTV channels in the Ka band is considerably more present than in the broadcast of the SDTV channels, but the share of the broadcast in Ka band has been decreasing for years, primarily due to the increase in the broadcasting of HDTV services in the Ku band.

Satellite TV transmission by region of coverage

Figure 4 and 5 depict graphs of change in the number of SDTV and HDTV channels in the C band, respectively.

The number of SDTV channels is the highest in Asia region, while the North America region has the highest number of HDTV channels. It can be seen that in recent years there has been a significant drop in the number of SDTV channels in the North America region, and the rise in the number of HDTV channels.

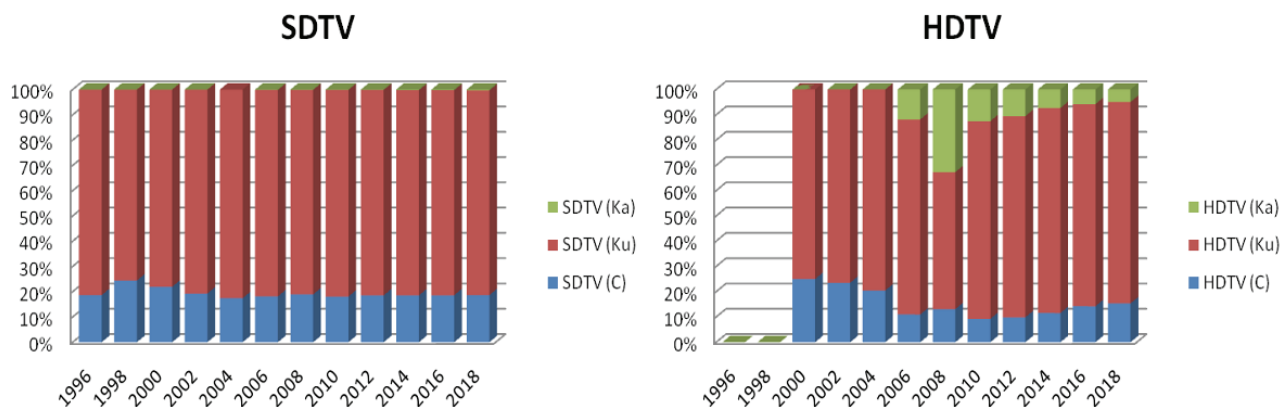


Figure 3. The share of TV channels from C band, Ku band, and Ka band relative to the total number of SDTV and HDTV channels.

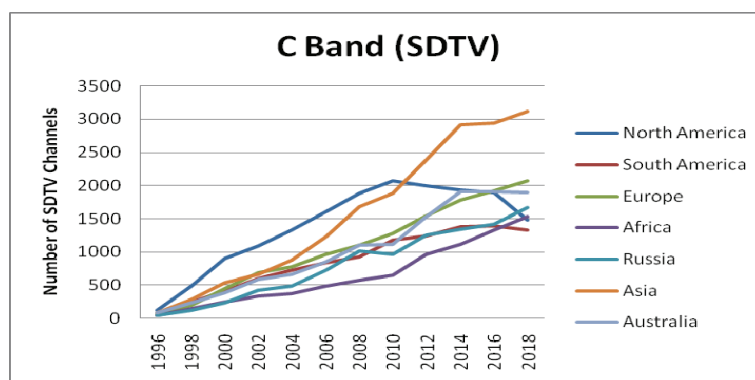


Figure 4. The number of SDTV channels in the C band.

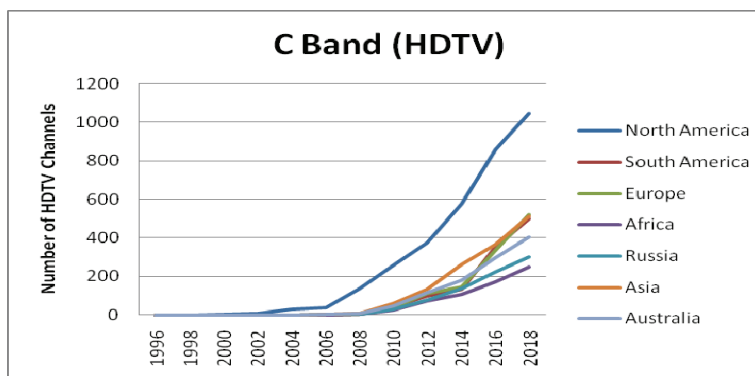


Figure 5. The number of HDTV channels in the C band.

Figure 6 and 7 depict graphs of change in the number of SDTV and HDTV channels in the Ku band, respectively. From the given charts, it can be seen that there is a noticeable stagnation of the number of SDTV channels in the Ku band in most of the regions, while there is a clear increase in the number of HDTV channels. The number of SDTV channels is the highest in Europe region, while the North America region has the highest number of HDTV channels. In recent years, there has been a noticeable expansion of satellite TV services in the Africa region, primarily due to an increase in the number of DTH operators distributing SDTV and HDTV services.

Broadcast of TV signals in the Ka band is generally available in the North America region, and this is mainly for HDTV. In addition, there is a slight presence of it in Europe region. Since 2014, services have also been available in the UHD format, with most of them being in Europe and North America regions. When comparing TV channels in the C band and the Ku band, it can be seen that in the region of Europe, the broadcast of signals in the Ku band is significantly more present than the broadcast in the C band. A similar trend, but to a lesser extent, can be seen in the regions of North America, South America, and Asia. On the contrary, in the regions of Australia and Russia, TV channels in the C band are more numerous.

Broadcasting of the HDTV services was first started in 2000 in the North America region, and in the regions of Europe and Australia in 2004. Later, broadcasting began in the remaining regions.

Satellite TV transmission according to the broadcasting standards

Figure 8 and 9 show the share of digital broadcasting standards for SDTV and HDTV in the C band and Ku band, respectively. Initially, the DVB-S standard was the most prevalent for the broadcast of SDTV channels in the C band, but, over time, the DVB-S2 standard took over the primacy. In 2018, more than 60% of the SDTV channels in the C band are broadcast in the DVB-S2 standard. Over time, the share of DigiCipher standard has also decreased. For the broadcast of HDTV channels in the C band, the most commonly used standard is DVB-S2 (with a share greater than 90%). Prior to the introduction of DVB-S2 standard in 2008, HDTV channels were broadcast either using the DigiCipher standard or the DVB-S standard.

Unlike the C band, one part of the TV channels in the Ku band is broadcast using DSS standards, but its share decreases from year to year. The same is the case with DigiCipher standards. As with the C band, the broadcast of the SDTV channels in the Ku band through the DVB-S2 standard is increasing, although in the course of 2018, about 50% of the SDTV channel are still broadcast in the DVB-S standard. The broadcast of the HDTV channels in the Ku band using DSS and DigiCipher standards is insignificant. In 2018, about 60% of HDTV channels in the Ku band are broadcast via DVB-S2 standards.

Figure 10 shows the share of digital broadcasting standards for SDTV and HDTV channels in the Ku band at the regional level. From the given results, it can be seen that the highest representation of DigiCipher and DSS standards is in the North America region, where more than 30% of SDTV channels are broadcast in the DSS standard. Over time, DSS broadcasting standard for the HDTV channels has been discontinued. In contrast to the other regions, where the DVB-S2 standard is mainly used for the broadcast of HDTV channels, the North America region uses the DVB-S standard. Further, it can be seen that, as time goes by, the DVB-S2 standard is being used more and more for broadcasting SDTV channels as well. It is only in the regions of North America, South America, and Australia that the share of the SDTV channels broadcast via DVB-S standards is higher than 50%. HDTV channels broadcasting exclusively uses DVB-S2 standard, with the exception of the North America and South America regions. Two additional local standards are available in the Asia region - ISDB for the Sky Perfect DTH operator in Japan, and ABS standard for the Asia Broadcast Satellite company's satellite.

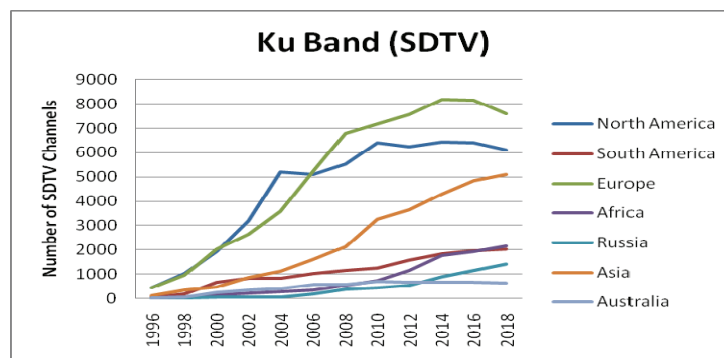


Figure 6. The number of SDTV channels in the Ku band.

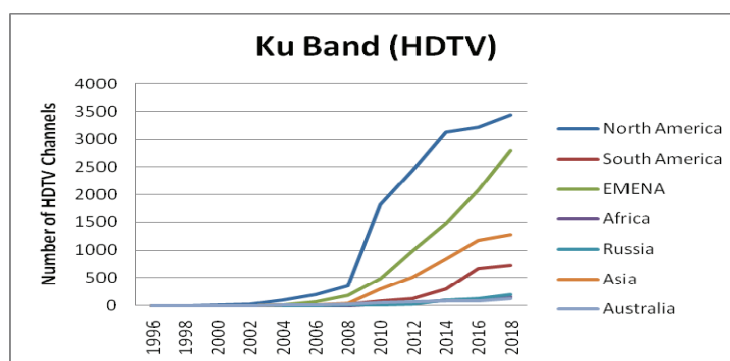


Figure 7. The number of SDTV channels in the Ku band.

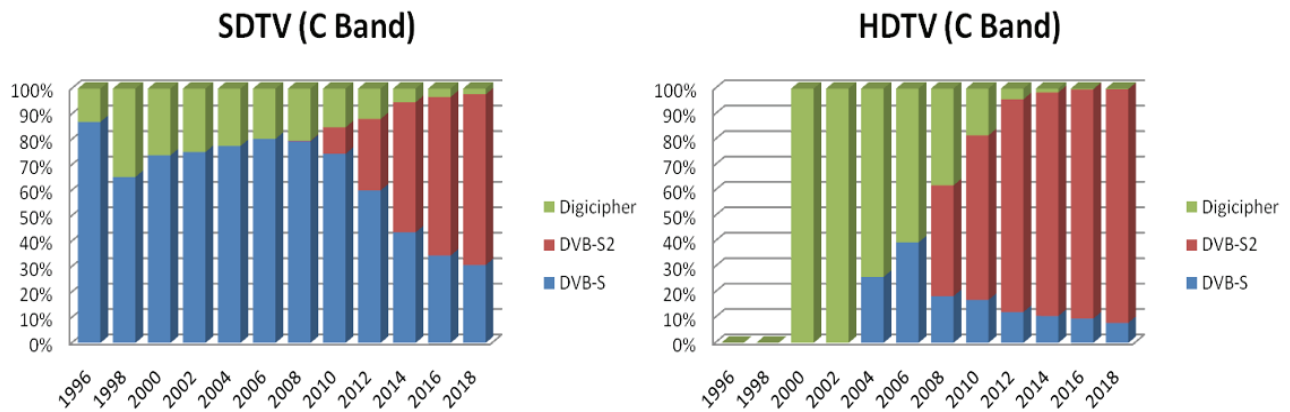


Figure 8. The share of digital broadcasting standards for SDTV and HDTV in the C.

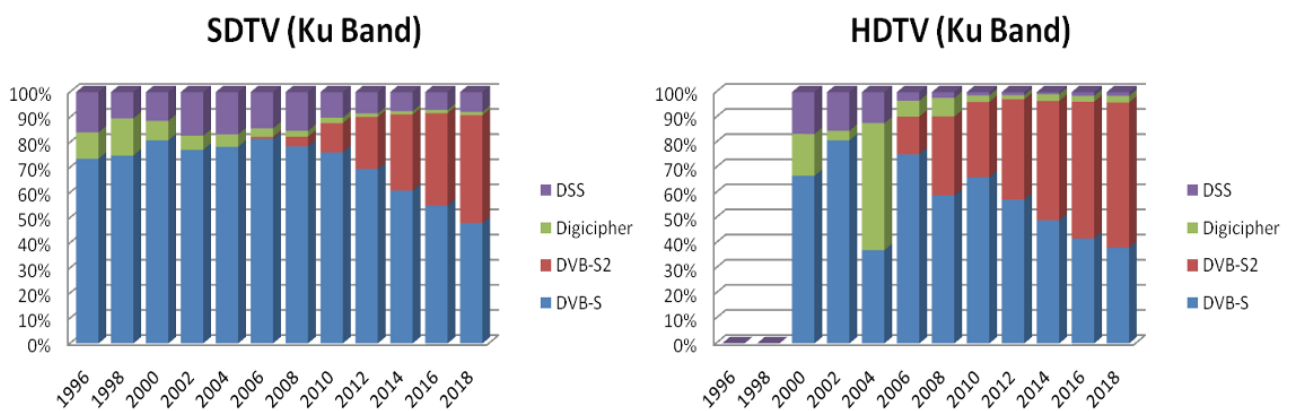
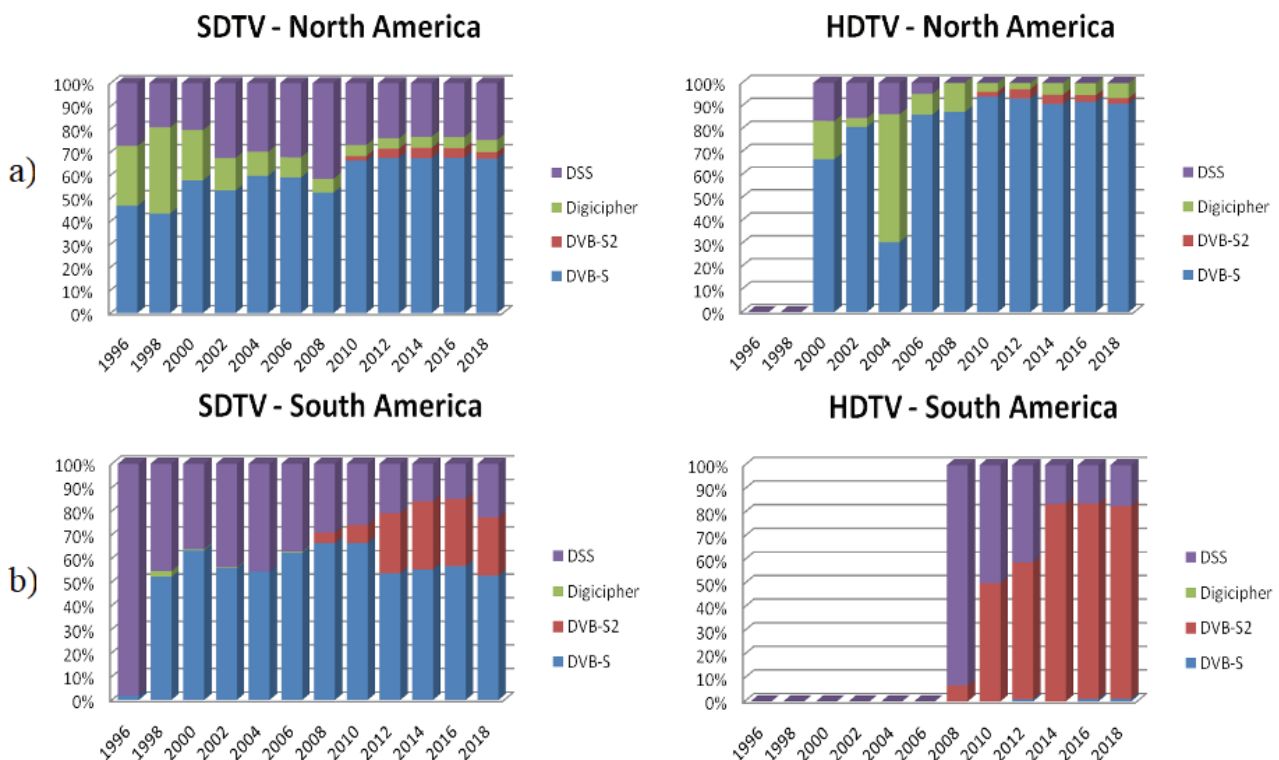


Figure 9. The share of digital broadcasting standards for SDTV and HDTV in the Ku band.



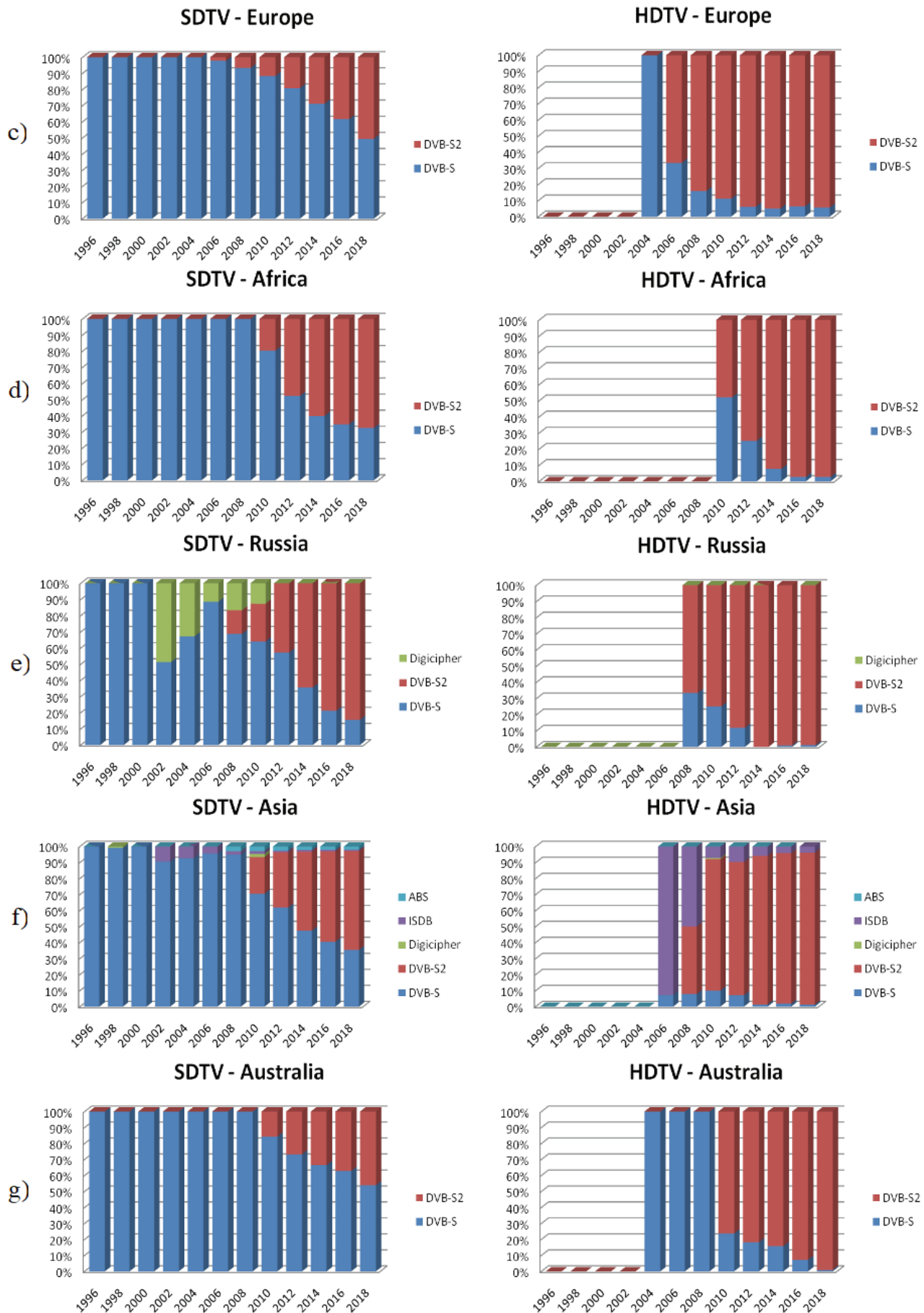


Figure 10. The share of digital broadcasting standards for SDTV and HDTV in the Ku band at the regional level: a) North America, b) South America, c) Europe, d) Africa, e) Russia, f) Asia, and g) Australia.

Free and pay TV

Television programs can be divided into two groups, the first consists of programs that can be viewed freely, without paying a subscription - FTA (Free-to-Air), the second is a group of coded programs that can be accessed only through a decoder system, which implies payment - PAY TV. Subscription payment is realized through the purchase of a decoder card that is inserted into the decoder.

Figure 11 and 12 show the share of FTA TV and PAY TV for SDTV and HDTV in the C band and the Ku band at the global level, respectively. Most of the SDTV and HDTV channels both in the C band and in the Ku band are broadcast in the form of PAY TV. Slightly over 40% of SDTV channels in the C band are broadcast as FTA, while in Ku band it is about 20%. The percentage of FTA HDTV channels in the C band is slightly less than 20%, and in the Ku band it is less than 10%.

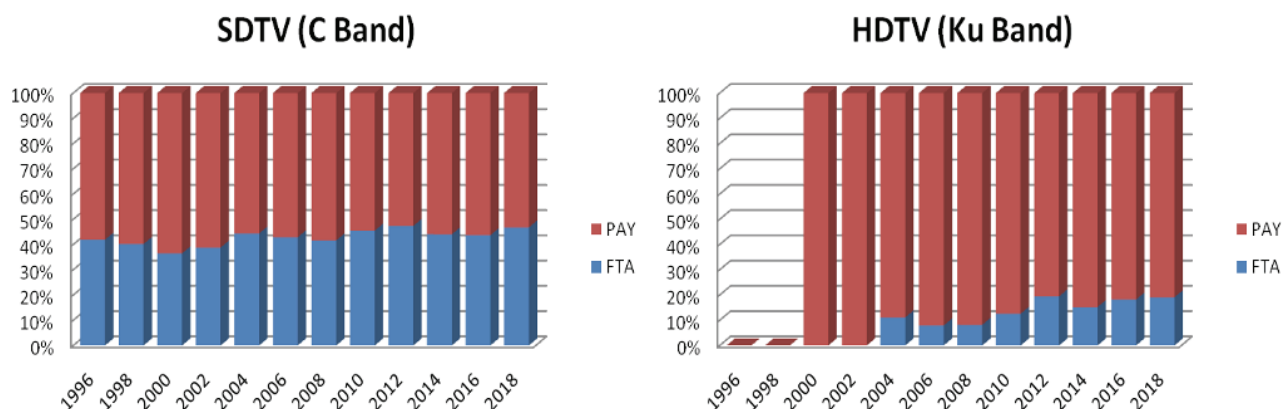


Figure 11. The share of FTA TV and PAY TV for SDTV and HDTV in the C band.

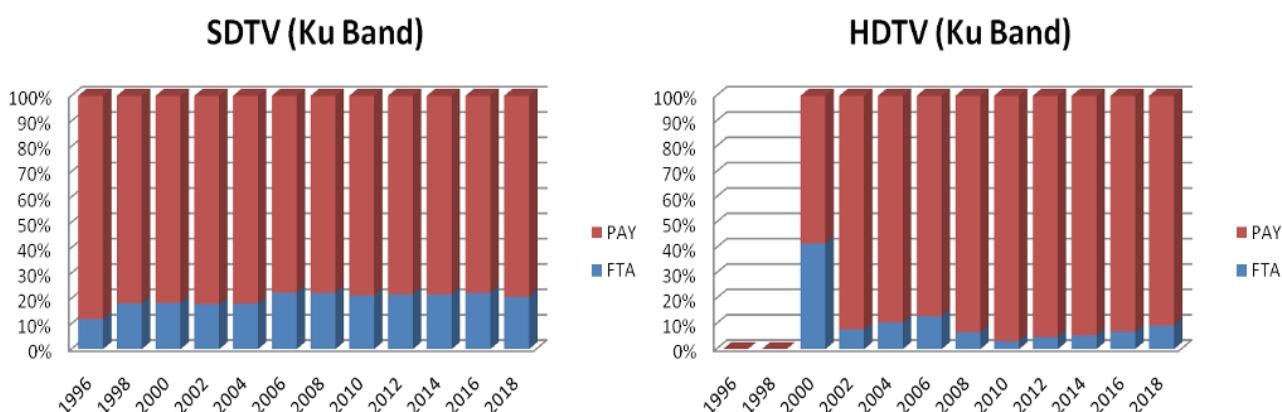


Figure 12. The share of FTA TV and PAY TV for SDTV and HDTV in the Ku band.

Conclusion

Satellite TV transmission is one of the most common forms of transmission of TV signals to end users. During the 1990s, analog satellite TV transmission was replaced with the more advanced digital broadcasting systems. This paper presents the characteristics of satellite digital TV in terms of number of TV services for different bands, standards, and broadcasting formats. Based on the presented results, it can be concluded that satellite TV operators are increasing the number of TV services. It can also be noted that this is the market where the broadcasting of the HDTV service has started earlier, and that lately there has been a noticeable decline of SDTV services, and that operators are turning to the distribution of services in HD format. DTH operators mainly use Ku band for broadcasting TV services to end users, so the majority of SDTV and HDTV channels are broadcasted in the Ku band. C band is mainly used to cover larger geographic areas. Broadcasting of the TV channels in Ka band is mainly available in the North America region. The bulk of the HDTV and SDTV channels in all bands are broadcast as PAY TV.

Based on the results presented, it can be concluded that the North America region is specific in relation to the other regions, primarily due to the use of additional standards for broadcasting SDTV and HDTV

channels, such as DSS and DigiCipher. Due to its advantage in the utilization of bit-rate, an increasing number of TV channels are broadcast using DVB-S2 standards. During the year of 2018, tests of the more advanced DVB-S2X standard have started, so that in the coming period, one can expect a tendency of switching to the newest broadcasting standard, primarily with HDTV channels, as well as an even greater increase in the number of satellite TV operators and TV services.

In 2014, broadcasting of TV channels in UHD TV format began. Due to its specificity, the satellite transmission format has great potential in broadcasting TV channels in UHD format, primarily due to the higher frequency band, and, thus, higher bit-rate compared to other forms of transmission. Therefore, the expansion of TV channels in UHD format is expected in the coming years.

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