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Development Overview Of Communication Satellites For Television Transmission

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Abstract:
This paper presents a survey of data related to development of the communication satellites for TV broadcasting, located in the geostationary orbit, for the period starting with the emergence of the first commercial satellite television broadcasting in 1965 up to 2023. It presents development of the satellite network technology through the number of satellites and active satellite transponders in the Ku and C bands at the end of each year for the mentioned period. These numbers are presented graphically for different geographical zones
Key Word*: satellite, TV, transponder, Ku band, C band.*

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I. Introduction

Ever since the launch of the first artificial satellite Sputnik in 1957, or, that is, since the launch of the first satellite for communications – Echo 1 in 1960, and up to date, thousands of satellites have been launched in several of Earth orbits[1,2]. In geostationary orbit, there are currently hundreds of active satellites operating in a wide range of frequencies; they are used for various purposes: meteorology, navigation, earth resources research, space exploration, fast data transfer, fixed and mobile telephony, for military purposes, etc. A number of satellites is used to transmit radio and TV programs. Satellite TV is a system for distribution of television signals via the communication satellites to end users[3].

The basic components of a satellite TV system are signal source, emission centre (uplink antenna), satellite, downlink antenna, and a receiver. Signals are sent from earth stations to the satellite via uplink antennas of an emission object whose dimensions range from 9 to 12 meters. Satellites used for transmission of TV signals are located in geostationary orbit, 37,000 km above the Earth's equator. There may be one or more satellites grouped in one position. In case when there are more satellites in one position, that situation is called satellite composition.

A satellite broadcasting system carries a larger number of transponders, mostly from 24 to 56, whose task is to receive receives a television signal beamed from large satellite uplink stations on the ground, then processes, encodes, amplifies and rebroadcasts the signal over a large area of the Earth's surface at a different frequency than the uplink signal to avoid interference. A transponder bandwidth is usually limited to the range from 27 to 72 MHz, depending on the satellite[4]. Transponders of the modern TV broadcasting satellites are specified to operate over the spectrum range of 36 MHz or 72 MHz. The uplink and downlink frequency ranges for C, Ku, and Ka bands are given in Table 1[3].

Table 1: Satellite uplink and downlink frequency bands.

Frequency band	Downlink	Uplink
C	3.7 - 4.2 GHz	5.925 - 6.425 GHz
Ku	11.7 - 12.2 GHz	14.0 - 14.5 GHz
Ka	17.7 - 21.2 GHz	27.5 - 31.0 GHz

Downlink signals, weakened after propagation over long distances, are collected by parabolic satellite antenna. Dimensions of the receiving antennas depend on the transponder power and satellite coverage area. Signals are reflected by the satellite dish of the receiving antenna into one point, after which the low-noise block converter (LNB) amplifies and shifts them from the C and Ku bands to the receiver's frequency band. The signal converted and amplified in this manner is then carried by coaxial cable (which should have a slight attenuation) into the satellite receiver where it is further processed[5,6].

Most of the signals are broadcasted in the Ku band. With the need to broadcast as many channels as possible from a single position, the commercial broadcasting bandwidth of the Ku band has expanded, so that today it represents the most common bandwidth for broadcasting satellite TV programs. It gives a very strong signal, but on a relatively small territory. This feature was used to promote the so-called smaller offset antennas (60 to 90 cm) that are very simple to set up and use a combined universal LNB converter. Unlike the Ku band, the C band covers a significantly larger area (it can even cover several continents simultaneously), but with a much weaker signal, so that an antenna of at least 3 meters in diameter is required for C band signal reception. C band is a precursor of the Ku band, and, as such, it is present on all continents.

Ku band is used in the USA for some DTH (direct-to-home) services, primarily for Internet services, and partly for TV programs distribution.

In theory, if satellite transponder antenna would emit signal equally in all directions, it could cover about 40% of the Earth's surface. However, in practice it's not the case, since it does not emit signal equally in all directions, it is rather focused to a narrower area which represents the so-called service zone (footprint) of the particular transponder of a communications satellite. By using the satellite transponder antenna, it is achieved that electromagnetic waves are not sent everywhere, including unnecessary directions, but are sent solely to the area for which the signal is emitted from the satellite. At the same time, a much better reception in the coverage area is achieved with the available transmitter power; these energy savings are achieved at the expense of poor reception outside the coverage area. Power of the received signal is usually given in dBW, e.g. 36 dBW, and is labelled as EIRP (Effective Isotropic Radiated Power). A satellite signal can be emitted in several different bands, and it can have several different coverage areas (footprints)[5,7].

Contribution of this paper can be summarized as follows:

- Readers are provided with a detailed insight into the number of active satellites year by year - from launching the first TV broadcasting satellite in 1965 up to the end of 2023.
- For the same period, the data on the number of active Ku and C transponders, the number of available satellites carrying Ku and C transponders, and satellite TV broadcasting operators are collected and presented per geographical regions: Region 1 - the positions between 180 ° W and 40 ° W (North America, South America), Region 2 - the positions between 40 ° W and 70 ° E (Europe, Africa, Middle East) and Region 3 - the positions between 70 ° E and 180 ° E (Asia, Australia and Oceania).
- The data are gathered from many different sources, classified, discussed and presented at one place. No similar survey can be found in the open literature or internet sources.

Section 2 provides an overview of the standards for satellite TV channels distribution. Section 3 contains the data on the number of active satellites, C and Ku transponders, as well as a graphic representation of these numbers by region for the period 1965-2023. Satellite TV broadcasting per coverage areas is analyzed in Section 4. Conclusions are given in Section 5.

II. Standards For Satellite Television

The first satellite television broadcast was done in an analog format. Its main characteristic is that one TV channel uses one frequency and one satellite transponder. This method of signal distribution resulted in broadcasting a smaller number of TV channels compared to digital transmission. Unlike analogue transmission, digital signal transmission allows for a greater number of programs that, furthermore, have digital quality of picture and tone. With the introduction of digital technology, the number of free frequencies on one transponder increased significantly, and, therefore, the number of television and radio channels (as well as other forms of communication) increased in like manner. This has consequently had a decisive impact on the development of DTH services[8,9].

The analog transmission was widespread until the nineties of the 20th century, after which it was steadily suppressed by the digital transmission. Ultimately, at the beginning of the 21st century, the analog transmission was completely taken out of use[10].

DVB-S (Digital Video Broadcasting – Satellite) is the oldest DVB standard, adopted by the European Telecommunications Standards Institute (ETSI) in 1994. This is a satellite transmission of digitized audio and video content through the system of geostationary satellites and adequate receivers. The second generation of this standard, DVB-S2, has a higher capacity, and it uses more efficient modulation and compression. DVB-S2 achieves about 30% better performance compared to DVB-S, and that allows HDTV (High Definition Television) program to be emitted at the same rate that was previously needed for SDTV (Standard Digital Television)[7].

HDTV is a technology that provides a picture and sound quality significantly higher compared to traditional image and sound display technologies (analog PAL, NTSC, SECAM, and digital SDTV)[11]. There is also a noticeable increase in the number of HDTV channels, and, as a consequence, suppressing SDTV channels[12]. In the last few years, in addition to HDTV, first UHDTV (Ultra High Definition Television)

channels have also appeared. It includes 4K UHDTV and 8K UHDTV, with twice the number of pixels and four times the number of pixels, respectively, compared to HDTV[13].

III. Communication Satellites For TV Distribution According To Transponders

The first satellite television signal was transmitted from Europe to North America via Telstar satellite in 1962[14,15]. The first commercial communications satellite, Intelsat I (nicknamed Early Bird), was launched into a geostationary orbit in 1965[14]. At the very beginnings, satellites that were not in the geostationary orbit were also used for satellite TV transmission, as was the case with the Russian system of Molnia[16]. Initial satellite TV signals distributions were exclusively intended for the exchange of TV programs between the TV companies themselves, and not for the transmission of signals to end users[17]. Using the available sources data were collected on communication satellites placed in geostationary orbit and intended for the distribution of TV signals[14,17,18-23].

Figure 1 shows the number of active satellites for TV transmission since 1965, the year when the first commercial satellite was launched. There is an evident steady increase in the number of satellites, and the real expansion of the satellites occurred during the nineties of the twentieth century. At the end of 2023, there were more than 270 active communications satellites for TV distribution in the geostationary orbit.

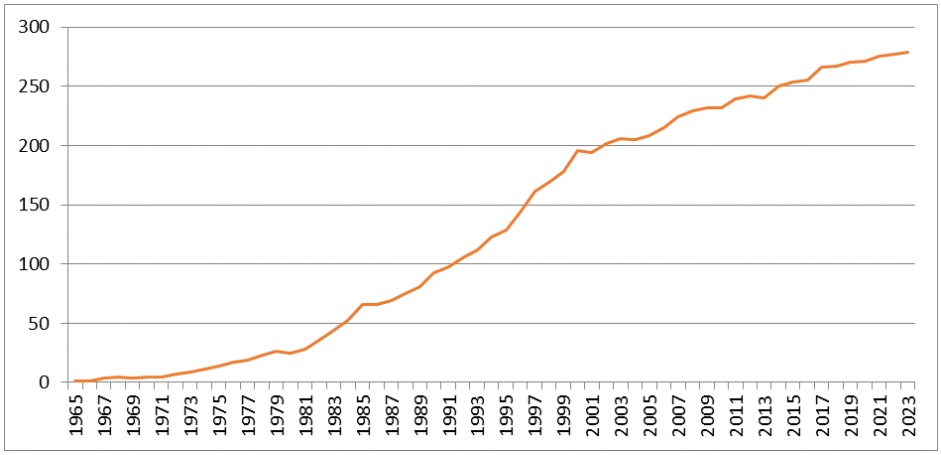

Figure 1: The number of active satellites.

In order to gain a better insight into the capacity of communication satellites, Figure 2 shows the number of active C and Ku transponders, and in Figure 3, the percentage of representation of C and Ku transponders is given in relation to the total number of active transponders.

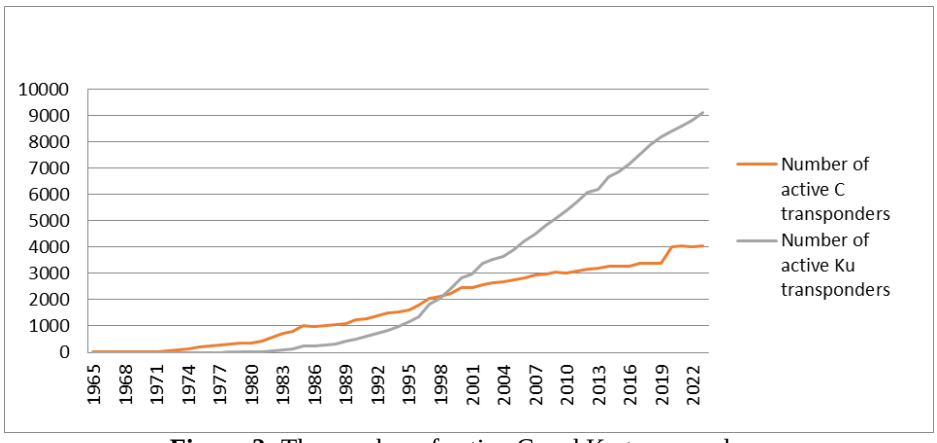

Figure 2: The number of active C and Ku transponders.

From the given pictures, it can be seen that, at the very beginning of satellite television, there were only transponders working in the C band, and only in the 1980s has come to the emergence of satellites containing transponders working in the Ku band. The number of active Ku transponders grew from year to year, and in 1998 it exceeded the number of active C transponders. The growth of the number of active C transponders has stagnated compared to the number of Ku transponders, primarily because Ku frequency band is used to send TV signals to end users (DTH services)

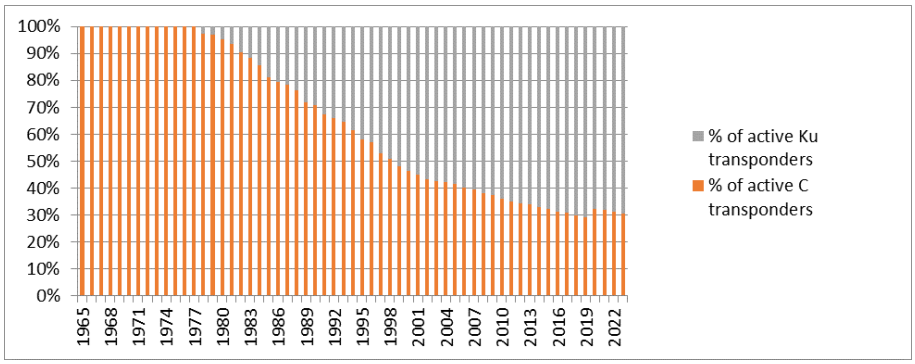

Figure 3: The share of active Ku and C transponders.

Figure 4 shows a graph of a change in the average number of active C and Ku transponders relative to the number of active satellites. From Figure 4 it can be seen that, after the emergence of the Ku transponders, the average number of C transponders per satellite began to decline and stagnate, while the average number of Ku transponders per active satellite has grown steadily. At the end of 2023, the average number of active Ku transponders per satellite was about 35, while the average number of active C transponders per satellite was about 11. Also, modern satellites are designed to contain a greater number of transponders than in older versions.

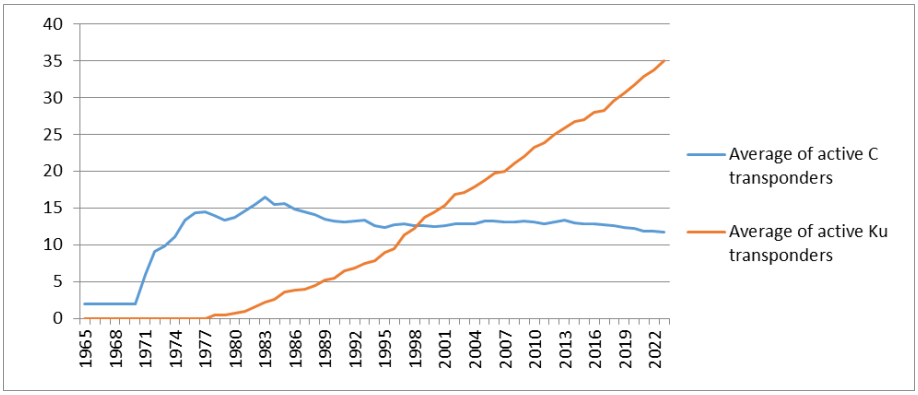

Figure 4: The average number of active C and Ku transponders.

Satellites intended for TV distribution are designed to contain exclusively either C or Ku transponders, or to contain both C and Ku transponders. Figure 5 shows the number of active satellites according to the type of transponders they contain, and Figure 6 shows the percentage of active satellites according to the type of transponders they contain. Based on the given data, it can be seen that the number of satellites that are designed to contain exclusively transponders in C band has been declining since the mid-1990s. Satellites operating in both C and Ku band appeared in the 1980s, and their number has been steadily increasing ever since. Furthermore, the number of satellites working exclusively with transponders in Ku band has also increased, so in 2007 they surpassed the number of satellites working in both Ku and C band.

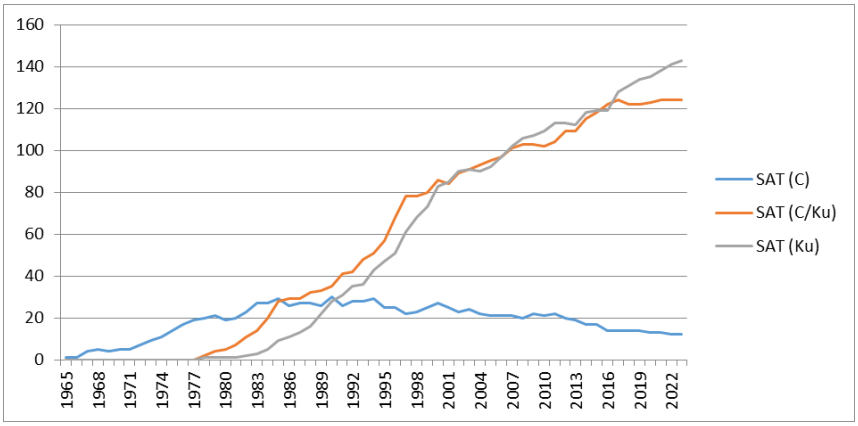

Figure 5: The number of active satellites according to the type of transponder.

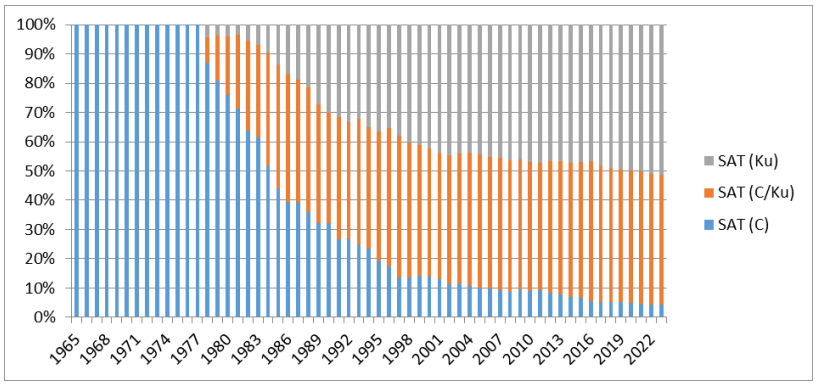

Figure 6: The share of active satellites according to the type of transponder.

IV. Communication Satellites For TV Distribution According To Coverage Areas

The positions of satellites in the geostationary orbit are indicated by degrees (°) in relation to the Greenwich meridian (0°). The satellites that are positioned east of Greenwich, in addition to the number of degrees have the mark E (east), and west positioned satellites have the mark W (west).

In order to gain a better insight into the distribution of satellites according to their positions, satellites are divided into three geographical groups: America – the positions between 180°W and 40°W (North America, South America), Europe – the positions between 40°W and 70°E (Europe, Africa, Middle East), and Asia – the positions between 70°E and 180°E (Asia, Australia, and Oceania).

Figure 7 shows the number of active satellites, and Figure 8 shows the number of active transponders by geographic areas: America, Europe, and Asia. The largest number of active satellites is in the geographical region of Europe. The largest number of active Ku transponders is located in the Europe zone, and a slightly smaller number is in the America zone. The number of active Ku transponders in the Asia zone is considerably lower. Further, from Figure 9 it can be seen that the number of active C transponders is the largest in the America zone, followed by the Asia zone, while the smallest number is in the Europe zone.

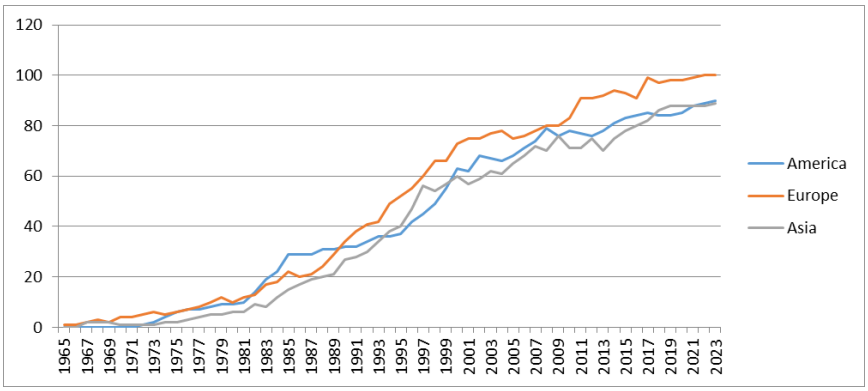

Figure 7: The number of active satellites by geographical area.

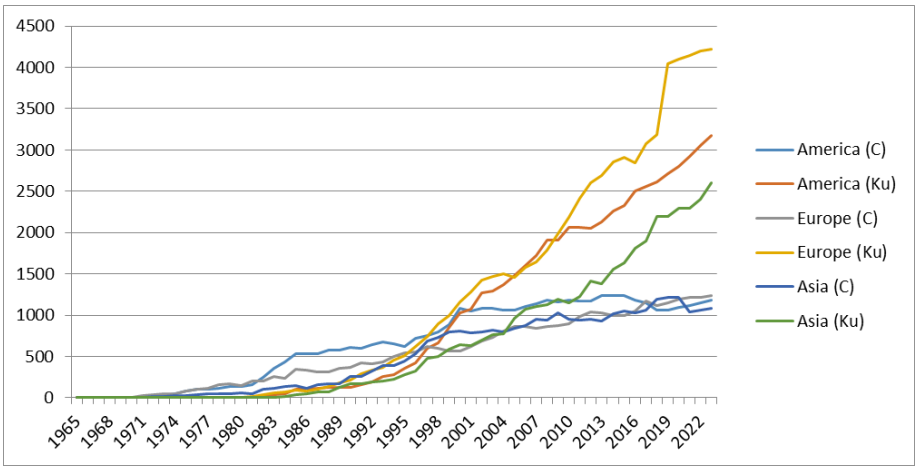

Figure 8: The number of active transponders by geographical area.

In Figure 9, Figure 10, and Figure 11, the percentage share of the Ku and C transponders in the zone of America, Europe, and Asia is given respectively.

From the given figures, it can be seen that the fastest decline of the representation of C transponders is in the Europe zone; at the end of 2023, the share of the C transponders was less than 30%. The slowest decline of the representation of C transponders relative to Ku transponders is in the Asia zone (the share of C transponders at the end of 2023 was 30%).

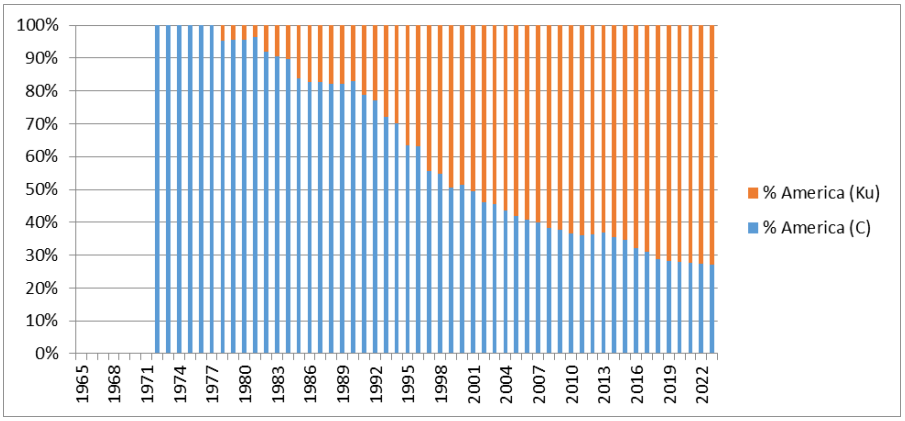

Figure 9 - The share of Ku and C transponders in the America zone.

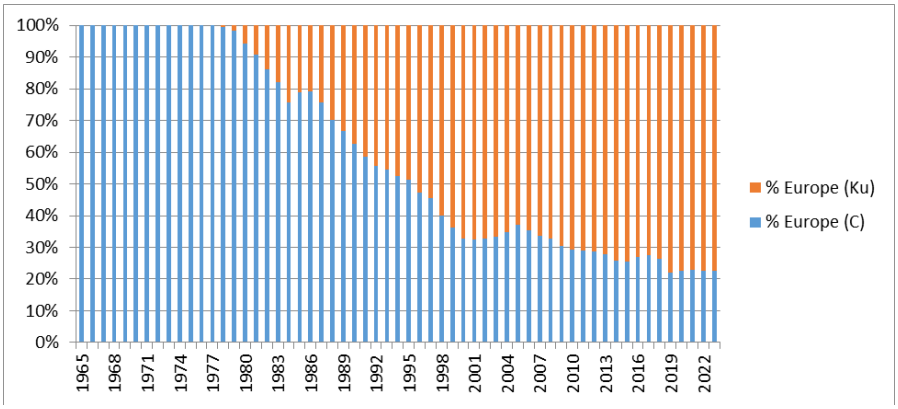

Figure 10 - The share of Ku and C transponders in the Europe zone.

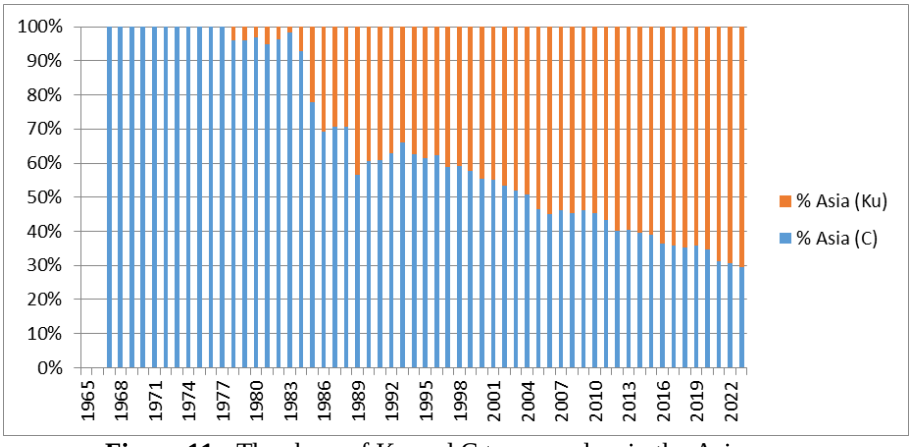

Figure 11 - The share of Ku and C transponders in the Asia zone.

V. Conclusion

The use of satellites has significant advantages in broadcasting and distribution of television programs, these advantages are reflected primarily in the coverage of the large area of the territory, the lack of need for the infrastructure construction, and the possibility of transmitting a larger number of channels using the same satellite. Since the emergence of the first commercial satellites for TV transmission in 1965, there has been an evident increase in the number of satellites and their technical capacities for providing services. Furthermore,

due to the much higher frequency capacity compared to the other types of transmission, satellite transmission is ideal for the development of HDTV (High Definition Television) and UHDTV (Ultra High Definition Television).

The beginnings of satellite TV were directed towards the distribution of TV programs to other providers of TV services, and towards the exchange of TV programs between several TV companies, and less towards indirect distribution to end users. The first satellite TV services were broadcast exclusively in the C frequency band. Thanks to the rapid development of digital technology, DTH (direct to home) services have spread. DTH operators around the world, in addition to continuously increasing the number of TV channels in SDTV and HDTV format, are introducing new services, including interactive applications, video on demand, satellite internet, and others. DTH services are emitted from high power satellites so that the reception is possible directly in homes using antennas of smaller diameter, from 60 to 90 cm. The most appropriate and the most common way of transmitting satellite TV services is in Ku band, although there are services in C band. There is an evident decrease in the number of services provided in C frequency band, especially in Europe and North America, while it is still significantly present in Asia and Africa. From year to year, the number of satellite operators offering TV distribution services is also increasing, so more and more national operators are involved in satellite TV transmission.

References

[1]. Choi CQ. 1st Communication Satellite: A Giant Space Balloon 50 Years Ago, 1998; Https://Www.Space.Com/8973-1st-Communication-Satellite-Giant-Space-Balloon-50-Years.Html
[2]. Maral G, Bousquet, M. Satellite Communications Systems: Systems, Techniques And Technology, 5th Edition, John Wiley & Sons Ltd., Newyork, 2009.
[3]. Valenti MC. Modern Digital Satellite Television: How It Works. 2011; Http://Www.Csee.Wvu.Edu/~Mvalenti/Documents/USNA2011.Pdf
[4]. Pattan B. Satellite Systems: Principles And Technologies, Springer Science & Business Media. Berlin, 1993.
[5]. Mirabito M, Morgenstern, B., Satellites: Operations And Applications - The New Communication Technologies, 5th Edition, Focal Press, Burlington, 2004
[6]. Tirro S. Satellite Communication Systems Design, Springer Science & Business Media. Berlin, 1993.
[7]. Jaksic B, Miljkovic D, Maksimovic V, Petrovic M, Gvozdic B. Satellite Television Transmission In The World - Broadcasting Systems And Standards. Acta Scientiarum Technology. 2020;42(1):E44957. DOI: 10.4025/Actascitechnol.V42i1.44957
[8]. Jaksic B, Milosevic I, Todorovic J. Structure And Share Of Satellite TV Channels And DTH Platforms In Europe. Chapter In "Tecnologia, Comunicação E Gestão Da Inovação Contribuições Para O Desenvolvimento De Novos Conhecimentos - Volume 1". Científica Digital, São Paulo, Brazil, 2024:138-155. DOI: 10.37885/240516724
[9]. Jaksic B, Petrovic M, Spalevic P, Milosavljevic B, Smilic M. Direct-To-Home Television Services In Europe. In Proceedings Of International Scientific Conference Of IT And Business - Synthesis 2016, Belgrade, Serbia, 2016:237-245.
[10]. Mignone V, Vazquez-Castro MA, Stockhammer T. The Future Of Satellite TV: The Wide Range Of Applications Of The DVB-S2 Standard And Perspectives. Proceedings Of The IEEE. 2011;99(11):1905-1921.
[11]. Pechard, S., Carnec, M., Callet, M. L. And Barba, D., From SD To HD Television: Effects Of H.264 Distortions Versus Display Size On Quality Of Experience. In Proceedings Of IEEE International Conference On Image Processing, Atlanta, USA, 2006, Pp. 409-412.
[12]. Jaksic B, Petrovic M, Jaksic K, Milosevic I, Marinkovic I. Development Of Satellite High-Definition Television In Europe. Current Science. 2016;111(6):1037-1044.
[13]. Jaksic B, Petrovic M, Milosevic I, Ivkovic R, Bjelovic S. UHDTV Into Terrestrial And Satellite Systems. In Proceedings Of International Scientific Conference UNITECH 2015, Gabrovo, Bulgaria, 2015:II112-II118.
[14]. Martin DH, Anderson PR, Bartamian L. Communication Satellites, 5th Edition, The Aerospace Press, El Segundo, California, 2006.
[15]. Martin DH. Communication Satellites 1958-1992. The Aerospace Corporation, El Segundo, California, 1991.
[16]. Satellite Molniya: Http://Www.Daviddarling.Info/Encyclopedia/M/Molniya.Html
[17]. Chaplin, J. Development Of Satellite TV Distribution And Broadcasting. Electronics & Communication Engineering Journal 1992;4(1):33- 41.
[18]. Astronautix: Http://Www.Astronautix.Com/
[19]. 1Chronology Of Space Launches: Http://Space.Skyrocket.De/Directories/Chronology.Htm
[20]. TV Satellites: Http://Www.N2yo.Com/Satellites/?C=34
[21]. TV Satellites: Http://Www.Lyngsat.Com/
[22]. TV Satellites: Https://Www.Satbeams.Com/Satellites
[23]. Geostationary Telecommunication Satellites: Https://Www.Tbs-Satellite.Com/Tse/Online/Mis_Telecom_Geo.Html