DOI: 10.65322/j.srd.05192026.127

TECHNOLOGIES FOR TRANSMITTING ANALOG AND DIGITAL TELEVISION SIGNALS IN SATELLITE TELEVISION

Aripova M.X., *associate professor,*
e-mail: maxpuza1963@gmail.com
Korotkova L.A., *senior lecturer,*
e-mail: korotkova.larisa1967@mail.ru
Tashkent State Technical University named after Islam Karimov
Mirismankulov O., *student of group 50-25, Faculty of Management,*
Tashkent University of Architecture and Civil Engineering

Abstract. *This article examines the operating principles of satellite television, the processes of television signal transmission and reception, and the structure of receiving equipment. The main components of a satellite television reception system, including the parabolic antenna, polarizer, low-noise block converter, coaxial cable, and receiver, are described along with their functions in signal reception and processing. A comparative analysis of analog and digital television signal transmission methods is presented, highlighting their specific characteristics, advantages, and technical capabilities. Particular attention is paid to digital signal coding, compression, and modulation, including the QPSK, 8PSK, 16APSK and 32APSK modes of the DVB-S2 standard. A comparison of DVB-S2 modulation and coding modes shows that in a 36 MHz transponder the useful bit rate increases from about 30 Mbit/s (QPSK 1/2) to 111 Mbit/s (32APSK 3/4), while the required E_s/N_0 rises from 1.0 to 12.7 dB; an illustrative Ku-band link budget for a 0.6 m antenna gives a clear-sky C/N of about 15.5 dB. The analysis demonstrates the importance of satellite television in providing extensive geographical coverage, transmitting multiple television channels, and enabling individual signal reception by subscribers.*

Annotatsiya. *Maqolada sun'iy yo'ldosh televideniyesining ishlash tamoyillari, televizion signallarni uzatish va qabul qilish jarayonlari hamda qabul qilish uskunasining tuzilishi o'rganilgan. Qabul qilish tizimining asosiy tarkibiy qismlari – parabolik antenna, polyarizator, past shovqinli blok-konverter (LNB), koaksial kabel va resiver – hamda ularning signalni qabul qilish va qayta ishlashdagi vazifalari tavsiflangan. Analog va raqamli televizion signallarni uzatish usullari ularning xususiyatlari, afzalliklari va texnik imkoniyatlari bo'yicha qiyosiy tahlil qilingan. Raqamli signallarni kodlash, siqish va modulyatsiyalashga, jumladan DVB-S2 standartidagi QPSK, 8PSK, 16APSK va 32APSK rejimlariga alohida e'tibor qaratilgan. Modulyatsiya va kodlash rejimlarini taqqoslash 36 MHz li transponderda foydali bit tezligi QPSK 1/2 da taxminan 30 Mbit/s dan 32APSK 3/4 da 111 Mbit/s gacha oshishini, talab etiladigan E_s/N_0 esa 1,0 dB dan 12,7 dB gacha ortishini ko'rsatdi; 0,6 m li antenna uchun Ku-diapazondagi namunaviy energetik hisob ochiq havoda C/N ≈ 15,5 dB ni berdi. Tahlil sun'iy yo'ldosh televideniyesining keng hududni qamrab olish, ko'plab kanallarni uzatish va abonentlarga individual qabul qilish imkoniyatini berishdagi ahamiyatini ko'rsatadi.*

Аннотация. *В статье рассмотрены принципы работы спутникового телевидения, процессы передачи и приёма телевизионных сигналов и структура приёмного оборудования. Описаны основные элементы приёмной системы – параболическая антенна, поляризатор, малошумящий блок-конвертер (LNB), коаксиальный кабель и ресивер – и их функции при приёме и обработке сигнала. Проведён сравнительный анализ аналоговых и цифровых методов передачи телевизионных сигналов, их особенностей, преимуществ и технических возможностей. Особое внимание уделено кодированию, сжатию и модуляции цифровых сигналов, в том числе режимам QPSK, 8PSK, 16APSK и 32APSK стандарта DVB-S2. Сравнение режимов модуляции и кодирования показало, что в транспондере 36 МГц полезная скорость возрастает примерно с 30 Мбит/с (QPSK 1/2) до 111 Мбит/с (32APSK*

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3/4), а требуемое E_s/N_0 – с 1,0 до 12,7 дБ; иллюстративный энергетический расчёт линии Ки-диапазона для антенны 0,6 м дал отношение C/N около 15,5 дБ в ясную погоду. Анализ показывает значение спутникового телевидения для широкого географического охвата, передачи множества каналов и индивидуального приёма сигналов абонентами.

Keywords: *satellite television, analog transmission, digital transmission, LNB converter, DVB-S2, modulation, spectral efficiency, link budget.*

Kalit so‘zlar: *sun’iy yo‘ldosh televideniyesi, analog uzatish, raqamli uzatish, LNB konverter, DVB-S2, modulyatsiya, spektral samaradorlik, energetik hisob.*

Ключевые слова: *спутниковое телевидение, аналоговая передача, цифровая передача, конвертер LNB, DVB-S2, модуляция, спектральная эффективность, энергетический расчёт.*

Introduction. Television is an important component of modern information and communication systems and has played a significant role in people's daily lives for many years. Television broadcasts deliver information, news, scientific and educational programs, and entertainment content to a wide audience. However, the coverage area of traditional terrestrial television is limited by the technical capabilities of transmitting stations and radio communication conditions. Satellite television technologies play an important role in reducing these limitations. Satellite television is a system for transmitting television signals and radio programs from terrestrial transmitting stations to receiving stations via a space-based communication satellite-retransmitter. While terrestrial television viewers typically receive signals from television centers located within the radio coverage area, satellite systems make it possible to organize television broadcasting across large geographical areas [1, 2].

In addition, this technology makes it possible to transmit numerous television channels, provide high-quality images and sound, and receive free-to-air programs without additional subscription fees. The efficiency of satellite television broadcasting depends on the processes of signal generation, modulation, transmission, reception, and processing [3].

Therefore, studying the structure of receiving devices, the characteristics of analog and digital transmission methods, and their technical capabilities is of current relevance. The aim of this article is to analyze the operating principles of satellite television systems, the structure of subscriber-side receiving devices, and the specific characteristics of television signal transmission methods.

Literature Review and Methodology. In the study of television signal transmission systems, modulation methods, the signal frequency spectrum, transmitter power, and the technical capabilities of receiving devices constitute important theoretical foundations. In satellite television systems, these factors are directly related to the efficient use of the communication channel and the reliable reception of television signals. Analog television transmission uses continuous signals that represent the distribution of image brightness. In terrestrial analog broadcasting, amplitude modulation (AM) with a partially suppressed sideband is generally used. In analog satellite television systems, frequency modulation (FM) plays an important role. This method makes it possible to use transmitter power efficiently and reduce the requirements for the amplitude characteristics of the transmission path. However, frequency modulation requires a relatively wide frequency bandwidth for signal transmission [4, 5].

The main parameters of a television signal include the number of lines and frames, signal polarity, the duration and shape of synchronizing pulses, the difference between the image and sound carrier frequencies, as well as the methods used to encode color and brightness signals. The specified values of these parameters constitute the television signal standard [6]. The development of digital transmission technologies contributes to the efficient use of frequency resources and the expansion of data transmission capabilities in satellite communication systems. The proper

DOI: 10.65322/j.srd.05192026.127

selection of modulation and coding methods, consideration of the statistical characteristics of the transmitted message, and efficient transmission of discrete signals help increase the bandwidth capacity of the communication channel [7–9].

Descriptive, systematic, and comparative analysis methods were used in the article to study the technical characteristics of satellite television systems. Descriptive analysis was used to examine the main components of the system and their functions. In addition, the spectral efficiency of DVB-S2 modulation and coding modes was compared using the reference values of ETSI EN 302 307-1 [7], and an illustrative clear-sky link budget for Ku-band direct-to-home reception was calculated using the standard link equation [1, 3].

Results and Analysis. There are two main methods of organizing satellite television broadcasting. In the first method, the signal received from the satellite is transmitted to a local television center, from where further retransmission is carried out. Such a system may require specialized stations for signal reception and retransmission. Therefore, subscribers may not always be able to receive television programs directly through individual devices.

In the second method, the signal is transmitted directly from the satellite to the subscriber's individual receiving device. This method is known as direct-to-home television broadcasting. Its efficient operation depends on the power of the satellite transmitter, the coverage area, and the accuracy of maintaining the satellite's orbital position [10]. In such a system, subscribers can independently receive television signals using a relatively small antenna. A simplified diagram of the subscriber-side receiving equipment is presented in Figure 1.

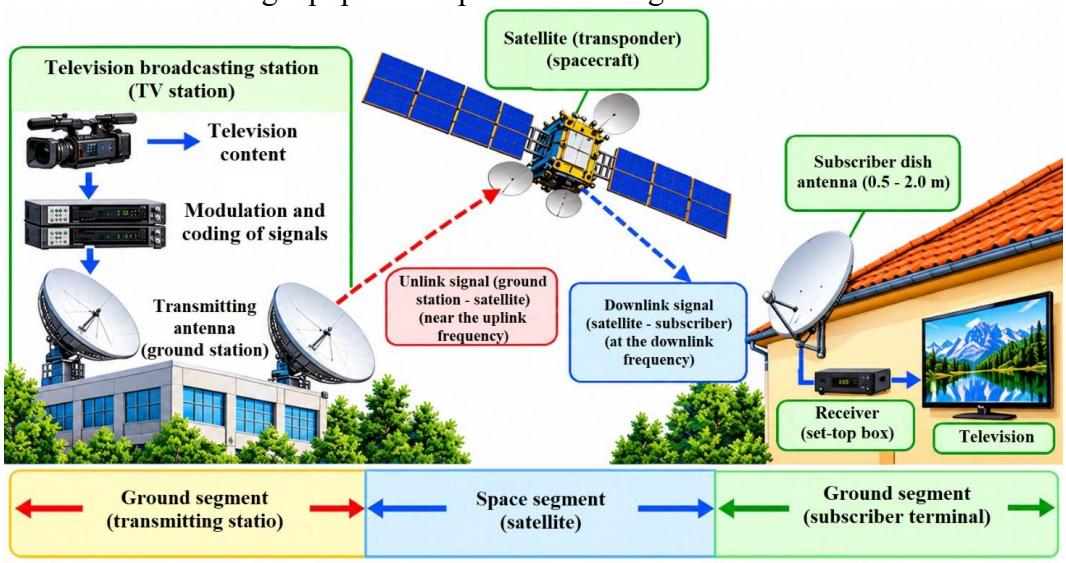

Figure 1. Simplified diagram of a satellite television receiving device

The receiving device consists of a parabolic antenna, a polarizer, a converter, a coaxial cable, and a receiver. The diameter of the parabolic antenna is usually in the range of 0.5–2.0 m, and it can be installed on the roof, balcony, or wall of a building. The antenna receives electromagnetic waves transmitted by the satellite and directs them toward the receiving feed. The signal received by the antenna is transmitted to the polarizer. The polarizer serves to separate the required signal component according to the type of polarization. Vertical, horizontal, or circular polarization may be used in satellite television systems. In the next stage, the signal reaches the converter. The converter amplifies the signal and converts it to the first intermediate frequency. For a universal Ku-band LNB, this frequency range is typically between 0.95 and 2.15 GHz [1, 5]. The feed, polarizer, and converter together form the receiving head. This unit is enclosed in a hermetically sealed housing to prevent moisture from entering. The frequency-converted signal is

DOI: 10.65322/j.srd.05192026.127

transmitted to the receiver via a coaxial cable. The cable not only carries the signal but also supplies the required power voltage from the receiver to the receiving head.

The signal is processed in the receiver, the desired channel is selected, and demodulation is performed. As a result, the information is separated into video and audio signals and displayed on the television as images and sound.

Thus, each element of the receiving system performs a specific stage of the overall process, and their coordinated operation is essential for proper signal reception.

Characteristics of Analog Television Signal Transmission. An analog television signal represents changes in image brightness distribution in a continuous form. While amplitude modulation is used in terrestrial analog broadcasting, frequency modulation is widely used in analog satellite systems. The main advantage of frequency modulation is the ability to use transmitter power efficiently. In addition, the relatively low requirements for the amplitude characteristics of the transmission path allow the output stage of the satellite transmitter to operate in saturation mode. This operating mode is important for achieving high efficiency. At the same time, the main limitation of frequency modulation is its requirement for a wide frequency bandwidth [4, 5].

Capabilities of Digital Transmission Technologies. In modern satellite communication systems, digital transmission methods are an important approach to improving the efficiency of information transmission. In digital systems, the transmission capacity of the communication channel can be increased and available frequency resources can be used efficiently by appropriately selecting modulation and coding methods, utilizing the statistical characteristics of messages, and transmitting discrete signals efficiently. In addition, digital technologies make it possible to encode, compress, and prepare information about television images and sound for transmission [6]. This enables more efficient use of the communication channel and creates conditions for transmitting more information simultaneously.

Comparing the specific characteristics of analog and digital transmission methods helps to better understand their technical capabilities and limitations. Analog systems are distinguished by the relative simplicity of their technical equipment.

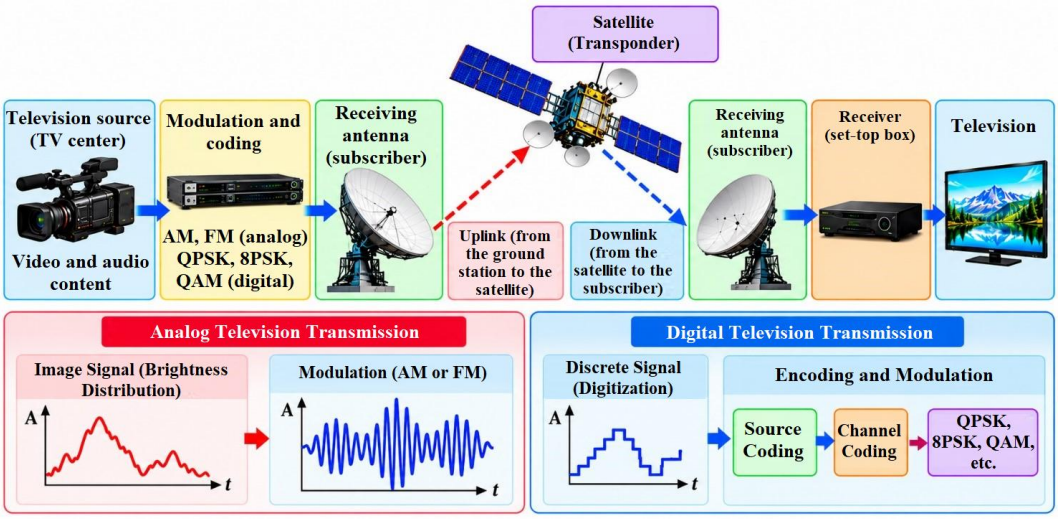

Figure 2. Comparative diagram of analog and digital television signal transmission processes in satellite television

However, during signal transmission, noise and other external influences may affect image and sound quality. In digital systems, the channel capacity can be used more efficiently by appropriately selecting information encoding, compression, and modulation parameters. In

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addition, the use of appropriate coding methods makes it possible to detect and, in some cases, correct errors that occur during transmission.

The signal transmission process in satellite television includes the stages of generating television content, modulating or encoding the signal, transmitting it to the satellite via a transmitting antenna, and retransmitting it to the subscriber. In analog transmission, information is represented as a continuous signal, whereas in digital transmission, the original information is transmitted as a sequence of discrete values. In the DVB-S2 standard, QPSK, 8PSK, 16APSK and 32APSK modulations are used [7], whereas QAM is employed mainly in cable networks. Their selection depends on the characteristics of the communication channel, the required transmission rate, and the level of noise immunity. The main stages of analog and digital television signal transmission in satellite television and their differences are illustrated in Figure 2.

The figure comparatively illustrates the stages of image signal modulation in an analog system and signal digitization, encoding, and modulation in a digital system. This comparison helps to better understand the capabilities of digital transmission technologies in information processing and the utilization of communication channel resources. At the same time, the efficiency of digital transmission depends on the selected modulation and coding methods, as well as the actual conditions of the communication channel.

Quantitative Comparison of Transmission Modes. To move from a qualitative description to a quantitative comparison, the useful bit rate of a transponder and the energy margin of a typical direct-to-home link were estimated. For a transponder with bandwidth B and roll-off factor α, the symbol rate and the useful bit rate are [7, 8]:

$$R_{\mathrm{s}} = \frac{B}{1+\alpha}, \quad R_{\mathrm{b}} = \eta \cdot R_{\mathrm{s}}, \tag{1}$$

where η is the spectral efficiency of the selected modulation and coding mode (MODCOD), bit/symbol. Table 1 gives η and the required E_s/N_0 for quasi-error-free reception (PER = 10^{-7}, AWGN channel) according to [7], and the bit rate calculated for B = 36 MHz and α = 0.20 (R_s = 30 Mbaud).

Table 1

Spectral efficiency, required E_s/N_0 and useful bit rate of DVB-S2 modes in a 36 MHz transponder

MODCOD	η, bit/symbol	Required E_s/N_0, dB	R_b, Mbit/s	Margin at C/N = 15.5 dB, dB
QPSK 1/2	0.989	1.00	29.7	14.5
QPSK 3/4	1.487	4.03	44.6	11.5
8PSK 2/3	1.981	6.62	59.4	8.9
8PSK 3/4	2.228	7.91	66.8	7.6
16APSK 3/4	2.967	10.21	89.0	5.3
32APSK 3/4	3.703	12.73	111.1	2.8

For comparison, in analog FM satellite broadcasting one transponder usually carried a single television programme [5], whereas a digital stream of 30–111 Mbit/s can carry several compressed programmes simultaneously.

The carrier-to-noise ratio at the receiver input is determined by the link budget equation [1, 3]:

$$C/N_0 = EIRP - L_{\mathrm{fs}} - L_{\mathrm{a}} + G/T + 228.6, \tag{2}$$

$$L_{\mathrm{fs}} = 20\lg\frac{4\pi d}{\lambda}, \quad G = 10\lg[\eta_{\mathrm{a}}(\frac{\pi D}{\lambda})^2], \tag{3}$$

$$C/N = C/N_0 - 10\lg R_{\mathrm{s}}, \tag{4}$$

where $EIRP$ is the equivalent isotropically radiated power of the satellite, dBW; L_{fs} is the free-space loss, dB; L_{a} is the atmospheric loss, dB; G/T is the figure of merit of the receiving station,

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dB/K; 228.6 dB is the Boltzmann constant term; d is the slant range; λ is the wavelength; D and η_a are the antenna diameter and efficiency. The assumed illustrative parameters and the results are given in Table 2; actual values depend on the satellite and the reception site.

Table 2

Illustrative clear-sky Ku-band link budget for direct-to-home reception

Parameter	Value	Result	Value
Frequency f	12 GHz	Free-space loss L_{fs}	205.6 dB
Slant range d	38 000 km	Antenna gain G	35.7 dBi
Satellite EIRP	50 dBW	LNB noise temperature	20.7 K
Atmospheric loss L_a	0.5 dB	System noise temperature	60.7 K
Antenna diameter D / efficiency η_a	0.6 m / 0.65	Figure of merit G/T	17.8 dB/K
LNB noise figure	0.3 dB	C/N_0	90.3 dB·Hz
Antenna noise temperature	40 K	C/N (R_s = 30 Mbaud)	15.5 dB

Under clear-sky conditions, all modes up to 16APSK 3/4 retain a margin of more than 5 dB, while 32APSK 3/4 keeps only 2.8 dB, which is insufficient to compensate for rain fading in the Ku band. Therefore, in practice the MODCOD is chosen as a trade-off between transponder capacity and link availability. The DVB-S2X extension, with finer MODCOD steps and roll-off factors down to 0.05, makes it possible to increase transponder throughput further [11, 12].

Conclusion. The operating principles of satellite television systems, the structure of receiving devices, and television signal transmission methods were analyzed. The main advantages of satellite broadcasting include wide geographical coverage, the transmission of numerous television channels, and the provision of individual reception capabilities for subscribers. The receiving device consists of a parabolic antenna, a polarizer, a converter, a coaxial cable, and a receiver, enabling the sequential implementation of processes from signal reception to its display on a television. The function of each component is to ensure the proper processing of the signal at the corresponding stage.

The analysis of analog and digital transmission methods revealed their specific characteristics. While technical simplicity and the ability of frequency modulation to use transmitter power efficiently are important in analog systems, modulation, coding, and data compression methods in digital transmission help utilize communication channel capabilities more efficiently. In general, improving the efficiency of satellite television systems requires the proper selection of receiving devices, coordination of signal processing stages, and the use of modern digital transmission methods. These approaches contribute to the reliable delivery of television information and the expansion of the technical capabilities of broadcasting systems.

The quantitative comparison showed that in a 36 MHz transponder the useful bit rate of DVB-S2 increases from about 30 to 111 Mbit/s when moving from QPSK 1/2 to 32APSK 3/4, while the required E_s/N_0 rises from 1.0 to 12.7 dB. For an illustrative Ku-band link with a 0.6 m antenna ($C/N \approx 15.5$ dB), modes up to 16APSK 3/4 provide a sufficient energy margin.

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