

Analysis and Estimation of the Field Strength of Digital Terrestrial Television Broadcasting

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Abstract: DVB-T is the most widely used standard for digital television broadcast. With its introduction in 1997, it is used in more than 70 countries. Almost all of these countries adopted the new standard for digital terrestrial television broadcasting – DVB-T2. DVB-T2 is the best technology for digital television broadcasting, which offers better signal robustness, flexibility and more than 50% more efficiency, compared with other digital terrestrial television broadcast systems. This paper focuses on ways to deliver MPEG TS to transmitters and estimation of the field strength.

Received 13 March 2021

Accepted 10 May 2021

Published 03 June 2021

Keywords: DVB, transmission, signal strength, modulation.

1. Introduction

The system of digital terrestrial television broadcasting is realized on the basis of the Orthogonal Frequency Division Multiplex (OFDM). In terms of the number of the carrier frequencies, two modes of operation are applied [1, 2]:

2k mode, which supports 1705 OFDM carrier frequencies (of which 1512 with useful information and 193 for data and synchronization) with useful time slot of 224 μ s, which under the rate of information flow 7.608 Mb/s means data transmission speed about 4462 b/s;

8k mode, which supports 6817 OFDM carrier frequencies (of which 6048 with useful information and 769 for data and synchronization) with useful time slot of 896 μ s, which under the rate of information flow 7.608 Mb/s means data transmission speed about 1116 b/s.

The following modulation schemes are applied: QPSK; 16-QAM and 64-QAM. 16-QAM and 64-QAM [3]. These can be realized simultaneously in combination under some rules, allowing specification of hierarchical model of the transmission of data, namely:

A – low-speed data transmission with a higher degree of error protection, which provides basic video quality, guaranteeing a playable television in more adverse conditions, as is the case of mobile reception;

B – high-speed data transmission at a lower degree of error protection, providing a higher quality of the video image.

The introduction of the hierarchical model of transmission apparently determines the necessity of realization of the hierarchical model in terms of encoding quality of manufactured TV products [4].

With a modulator parameter α is defined the

magnitude of the ratio of the spacing of two adjacent constellation points from two neighboring quadrants at the magnitude of the spacing of two adjacent constellation points in one quadrant. For the modulator parameter α are defined three values: 1 (for non-hierarchical model), 2 and 4 (for hierarchical model).

For the avoidance of interference caused by echo signals and with other signals of adjacent transmitters in SFN networks (Single Frequency Network) among OFDM symbol period fits guard interval, during which no information is broadcasted.

In order to protect the channel from errors for transmission channel coding applies OFDM (COFDM-Coded Orthogonal Frequency Digital Modulation), which includes defensive coding procedures in and out of the transport structure [5, 6].

2. Approaches to deliver MPEG TS to transmitters

2.1. Using RTP / UDP / IP to deliver MPEG

In fact, there are two such possibilities: terrestrial communication networks and communication networks using the space segment. In some cases, a version of gap filler cascading can be used, but this option will lead to gradual degradation of the signal, due to the accumulation of errors [7]. In the case of using terrestrial networks, it is most rational to use data networks capable of transmitting multicast streams using RTP/UDP or only UDP protocols. These networks can be implemented using a variety of technical means: via relay links, using various data transmission technologies [8, 9].

At this point, we should pay attention to that it is necessary to provide data transmission in real time, synchronously, which is impossible with the help of TCP/IP protocols. That's why the choice of UDP or RTP / UDP for use in multicast mode seems to be the most rational.



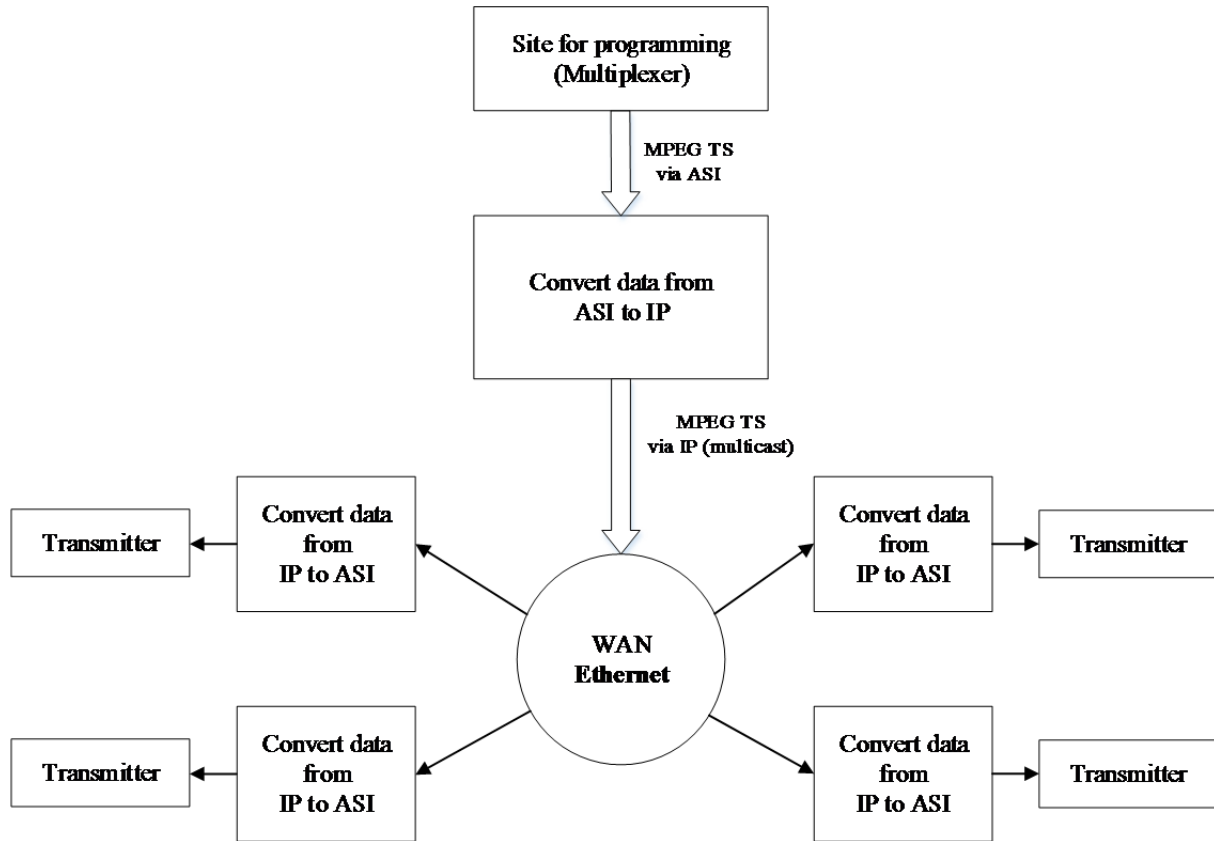


Fig. 1. Structure of the DVB network using IP transmission.

The RTP protocol is inherently an add-on over the UDP protocol, several additional data fields for giving information about the contents of the package. In particular, RTP allows the sequence number of the frame to be transmitted in a sequence and a timestamp indicating the time at which the packet was generated. Frame number field and time stamp field can help in the control of the integrity of the flow, as well as in the measurement by the variation of speed when transmitted over a network. In particular, if the packet numbering sequence is violated, the RTP protocol will indicate that one or more packets have not been transmitted.

In the case of using data networks using multicast traffic, it must be taken into account that the network will always introduce some delays, with non-permanent delays. The size of the memory allocated for buffering is limited, so the technical data always indicate how much jitter can handle a particular device. As a rule, devices can handle jitter of 100-200 msec.

Time stamps of RTP are generated using an internal clock device that generates RTP packets. Such a device can be an ASI-IP converter or a multiplexer. In standard RTP (RFC 3550), the frequency of the internal clock (timebase) is equal to 90 kHz [10]. Thus, the time stamp of the RTP is equal to the base portion of the MPEG TS. Some multiplexers generate temporary stamps based on 27-MHz clock, which is accepted for full PCR (i.e., the base part plus the extension). If the receiving equipment requires the presence of temporary RTP stamps generated by a clock of a certain frequency, this need to be taken into account in order to avoid synchronization errors.

When configuring ASI-IP conversion hardware, it must be considered change the speed of the digital stream by adding network packet headers, as shown on Figure 1. Because the MPEG TS transport stream is (encapsulated) within RTP / UDP / IP network packets, the overall speed of the digital stream will be greater. Because the payload size of the Ethernet frame is 1518 bytes, and the packet size of the transport stream is 188 bytes, then an RTP packet containing up to 7 MPEG TS packets can fit into one Ethernet frame. When encapsulating 7 packets, the speed change will be minimal. Since the delivery of traffic to the transmitters always requires the most reliable communication channel with the minimum number of errors, it is rational to choose the number of encapsulated packets to be maximal, i.e., equal to 7.

Otherwise, it should be taken into account that if one RTP packet will not be delivered in any way, then all packages will be "lost" MPEG TS, which are encapsulated in it. Thus, if there is a probability of RTP packets being lost on the network, then the number of encapsulated MPEG TS packets should be selected as minimal (1-5). However, once again I will focus your attention to the fact that in a properly configured network, the delivery of packets must be 100%. Otherwise, the network is simply not suitable for delivering the signal to the transmitters [11].

Recalculate the transport stream speed of MPEG TS and MPEG TS over IP can be as follows:

$$S_{UDP} = S_{MPEGTS} \left(1 + \frac{224}{1504N} \right) \quad (1)$$

$$S_{RTP} = S_{MPEGTS} \left(1 + \frac{320}{1504N} \right), \quad (2)$$

where N is the number of MPEG TS packets in one RTP packet; 1504 is the number of bits in one MPEG TS packet $1504=188 \times 8$; 320 is the header size RTP / UDP in bits; 224 is the header size UDP in bits.

2.2. Using satellite communication

The second possibility of signal delivery to local repeaters is use of the satellite segment (Figure 2) This scheme can be more expensive than the use of terrestrial networks. In addition, this scheme may not be suitable for the organization networks of digital television, limited to small regions, due to the limited orbital-frequency resource [12].

The standard bandwidth of the transponder of the television satellite is 32 MHz, and when using QPSK modulation, a digital stream with a speed of 32 Mbit / s, which is approximately equal to the maximum flow rate that DVB can provide (in the mode 64QAM with FEC = 7/8 and a guard interval of 1/32). On the one hand, it can allow the organization of digital television networks without resorting to the transformation of the traffic flow on repeaters [13]. As a rule, such transformation is always required within the region, due to the different broadcasting policies of the channels, the size of the required zones radio coverage, the need to use conditional access systems, etc. In any case, the use of these or other means of delivery is a complex task and should be addressed within the overall network structure [5, 6].

The satellite transmitting station is necessary for organizing and distributing program packages from the main multiplexing station to the local transmitting stations located throughout the country. The satellite station is most often located in an area remote from the main station. Multiplexes transmit to the satellite transmitting station over an IP network or other telecommunication channels. Decoder receivers with IP-inputs and ASI-outputs accomplish acceptance of transport flows. For optimal use of leased satellite capacity, it is advisable to merge multiple multiplexes into one transponder. The modulated signal is transferred to the required bandwidth by means of an up converter, then amplified by amplifiers and emitted to a satellite with a transmitting antenna with a diameter of 9 m.

3. State of digital terrestrial television in Bulgaria

In order to ensure the quality and reliability of the transmission of the television signal to the main broadcasting sites for digital broadcasting on the territory of Bulgaria, the NEC Company's iPASOLINK radio-relay platform has been selected.

The topology of the transmission network consists of 6 main radio relay rings connecting the main sites in the country. An XPIC solution is used to more efficiently use the frequency resource by operating two polarizations, both horizontal and vertical, at the same carrier frequency.

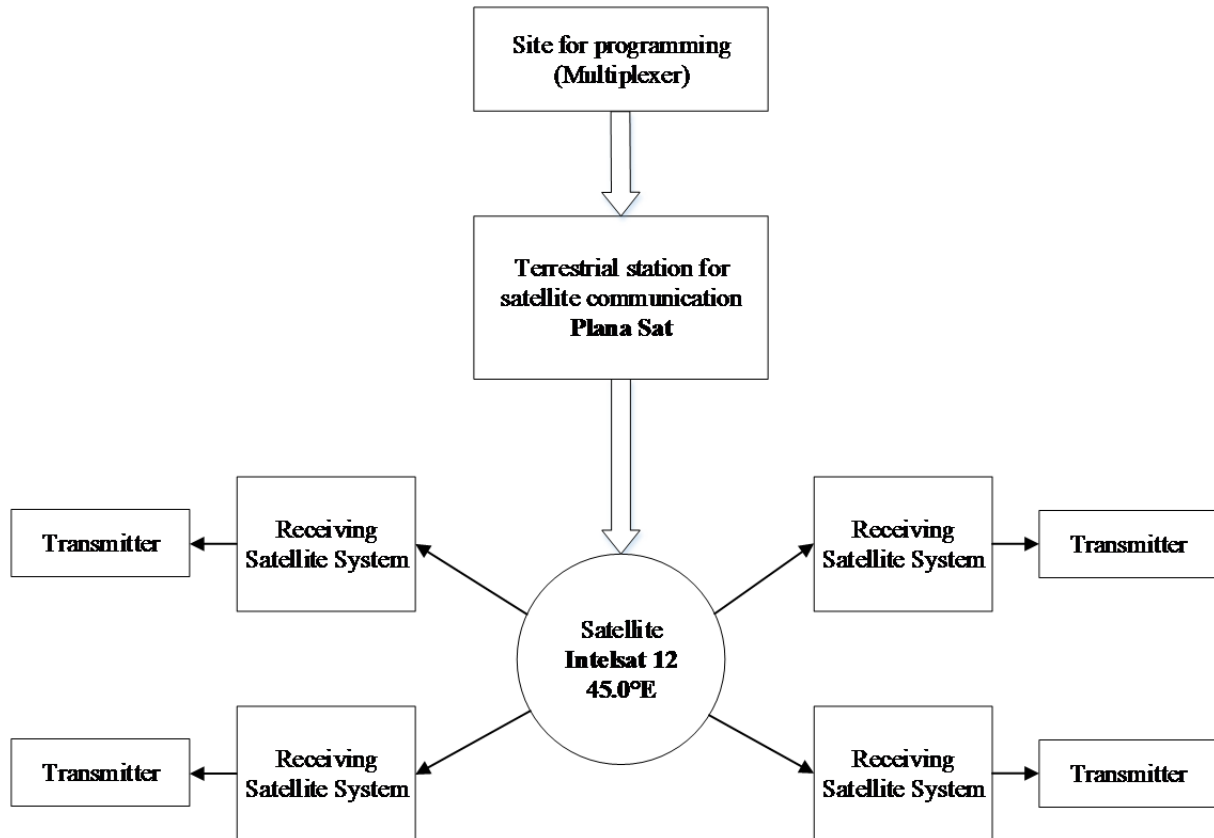


Fig. 2. Structure of the DVB network using satellite communications.

The system maintains adaptive modulation (AMR) and automatic output power control (ATPS) to achieve higher line reliability in adverse weather conditions. At each point, a back-up power supply is provided. The NURTS radio network provides the transmission of a television signal through a set of 1 Gb Ethernet interfaces, both electrical and optical, enabling quick and easy connection of the equipment to different types of devices [14].

When building the network are used antennas with a high degree of separation of the two polarizations (XPD > 34 dB) of the ANDREW company.

Low latency and synchronization are essential for the functionality of relay networks, and QoS and traffic distribution are a prerequisite for the efficient operation of the system. With link aggregation support and iPASOLINK connectivity, an increase in network capacity and reliability, and a reduction in the amount of hardware used, are achieved.

Advantages of the digital radio relay network:

- full independence from external suppliers;
- complete control and network management at every point;
- IP based solution allowing flexible traffic management and provision of different types of services;
- modular platform architecture with the ability to quickly and easily upgrade the network and increase capacity;
- low signal latency, synchronization, high capacity utilization of the network.

4. Measurements

4.1. Measurements of the transmitted signals

Bit error rate is regulated in the relevant standards and in designing the transmitters, measures have been taken to reduce the influence of a variety of distortions on this parameter. For good reception of signals for digital television broadcasting in UHF is necessary to ensure the field strength not less than 900 $\mu\text{V}/\text{m}$. 1 μV corresponding to 59 dB [11, 12].

The radiated power of the transmitter is the product of the average power of the transmitter and the coefficient of amplification of the transmitting antenna:

$$P_R = P_{AVR} * G_{ANT} \quad (3)$$

The most significant factors affecting the field strength at the point of adoption are as follows:

- The relief of the Earth's surface and shadowing obstacles;
- Interference losses, caused by reflected signals;
- Absorption of radio waves from water vapor and fogs;
- Losses as a result of refraction in the atmosphere;
- Losses from natural and artificial origin.

On Tables 1 to 3 are shown the of acceptance in percentages at different PAVR and coefficient of amplification of the transmitting antenna $G = 10 \text{ dB}$, $G = 5 \text{ dB}$ and $G = 0 \text{ dB}$ respectively.

Table 1. Probability of acceptance in percentages at $P_{AVR} = 100\text{W}$.

Distance to the antenna r, km	10	12	14	16	18	20
G=10 dB	99	98	94	91	85	78
G=5 dB	95	93	88	78	70	50
G=0 dB	92	85	72	55	45	30

Table 2. Probability of acceptance in percentages at $P_{AVR} = 200\text{W}$.

Distance to the antenna r, km	10	12	14	16	18	20
G=10 dB	99.5	99	97	94.5	91.5	78
G=5 dB	97	95	82	88	78	75
G=0 dB	95	91	88	72	60	50

Table 3. Probability of acceptance in percentages at $P_{AVR} = 500\text{W}$.

Distance to the antenna r, km	10	12	14	16	18	20
G=10 dB	99.8	99.5	99	98	94	85
G=5 dB	99	98	96	93	90	85
G=0 dB	98	95	91.5	85	77	70

4.2. Measurement of television transmitter

To carry out the experimental research was used the following equipment: Rohde & Schwarz ETL TV analyzer and power meter Rohde & Schwarz NRP-Z22 [15, 16].

The measuring of video signals broadcasted through the DVB-T system in Bulgaria shall be performed in compliance with the requirements of ITU and ETSI standard EN 300 744 [5, 6, 17]. The objective assessment of the quality of the broadcasted digital signal shall be determined by measuring and analyzing the following technical parameters:

- values of the field strength at points located on the border of the theoretically determined service area, in order to analyze the actual coverage with a normal digital signal;
- BER (bit error ratio) - evaluation of the quality of the demodulated signal;
- MER (modulation error ratio) - quality assessment of each carrier of the complex OFDM signal;
- delay in signal propagation between two transmitters, part of an SFN network, at a corresponding reception point;
- monitoring the synchronization of the complex OFDM signal;
- Minimum average field strength - for territories (settlements) with over 30,000 inhabitants - 85dB $\mu\text{V}/\text{m}$; for other settlements - 56dB $\mu\text{V}/\text{m}$.

All performed measurements are for SFN zone in south-west Bulgaria, for channels 29, 31 and 33.

The Figure 3 shows the measurement of the synchronization of one transmitter with another, it is necessary that their levels are significantly above the threshold "Echo Detection Threshold").

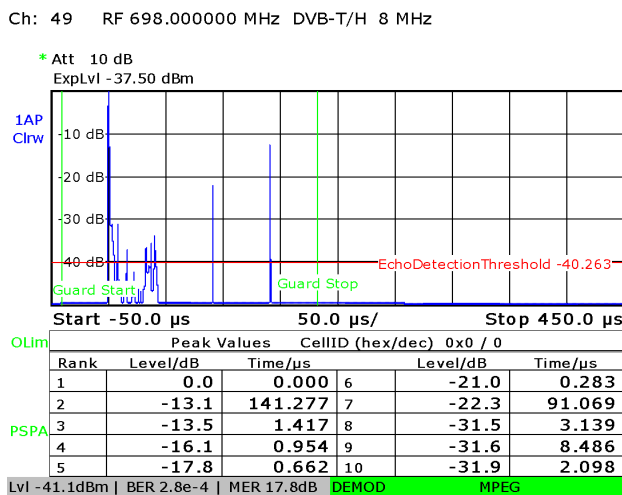


Fig. 3. Transmitter synchronization.

On Figure 4 is showed the out of band emissions and the I/Q imbalance on Figure 5, respectively.

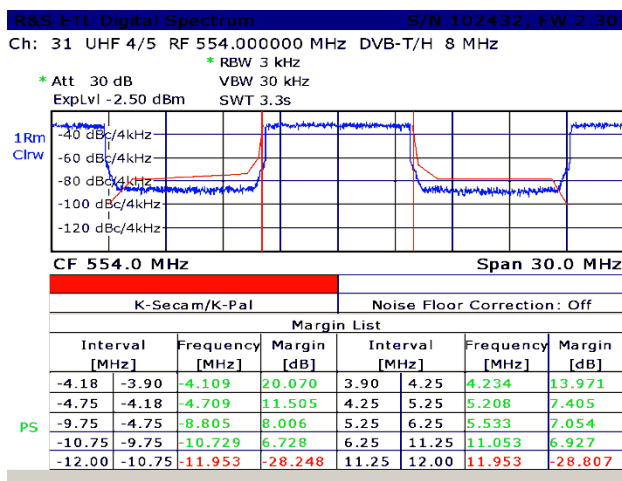


Fig. 4. Out of band emissions.

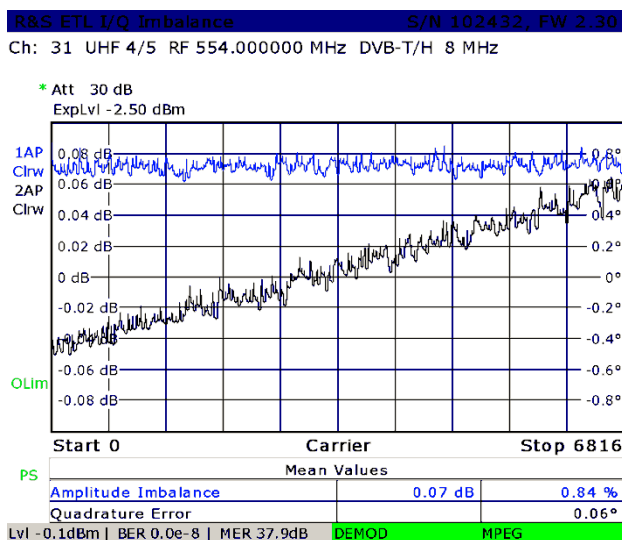


Fig. 5. I/Q imbalance.

The measurements showed that the television transmitters provide above the minimum average field strength of 56dB μ V/m and work in synchronization in the same SFN network.

5. Conclusion

In recent years, significant attention has been paid in Europe to the development and deployment of digital television broadcasting on a terrestrial, satellite and cable ways, based on DVB-T, DVB-C and DVB-S standards. In Bulgaria, the market for digital terrestrial, cable and satellite radio and television broadcasting is liberalized. The national radio spectrum allocation plan shall determine the authorized frequency bands for satellite and terrestrial television broadcasting. The development of national digital television broadcasting networks should be as a combination of single-frequency networks forming a multi-frequency network.

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