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Andreja Samčović
University of Belgrade
Faculty of Transport and Traffic Engineering

ADOPTION OF DIGITAL TELEVISION IN EX-YUGOSLAVIAN COUNTRIES

Abstract. The aim of this paper is to describe digital television broadcasting, where the emphasis was set on the second generation - DVB-T2 standard and the adoption of digital television in the ex-Yugoslavian countries. The principle of operation, main characteristics, the area of application, advantages and disadvantages, the type of coding, as well as the implementation of DVB-T standard in the region were pointed out. Also, there will be given the conditions to be met by user in order to receive DVB-T signal, compatibility with other standards and how the system requirements to be met. The process of invoking DVB-T in the region is discussed, providing that the DVB-T2 has been implemented in Serbia. The time and speed of the transition from analogue to digital terrestrial television signal will be discussed, too.
Keywords. Digital television, DVB-T, standards, coding, modulation, multiplex, spectrum

1 Introduction

Digital television is the successor to analogue television (TV) and soon all broadcasting will be done in this way. It represents the future of television and invokes a whole new way of transmission. It is a medium that requires new thinking and business models that can make a profit. Operators around the world whether cable, satellite or wireless, cross into the digital environment. Connecting of the four major networks in the United States - ABC, NBC, CBS and FOX was the condition for the start of digital broadcasting in November 1999. In Europe, it was planned to completely turn into digital television broadcasting, where the broadcasters in France, Ireland, Spain, Germany, the Netherlands and the UK have initiated the development of digital television in 1999. Convergence among personal computers, TV and the Internet has already begun, so that manufacturers and service providers in this area have a strong position to achieve maximum profit from this integration.

As for users, the digital age will improve their visual experiences through theater-quality images and surround sound quality, hundreds of new channels, the possibility of changing camera angles and improved access to a range of exciting new services. Digital television also allows to subscribers to enjoy in larger number of television channels with theater-wide screen format. Television will become more powerful and fun, while at the same time simpler and easier to use [1].

For broadcasters, the transition to the digital environment reduces the occupation of bandwidth per channel enabling Internet applications for new subscribers and opening a new era of business opportunities. The great potential of digital television is fact that provides a wide range of different services, such as high-speed Internet access, *Pay Per View* video on demand, cable television, electronic commerce and so on even though much better quality of picture and sound. Such a diversity of services achieved great success among customers, affecting the telecommunications service providers and electronic industries around the world to invest resources increasingly in the development of this area and quickly return the invested funds.

The concept of the paper is as follows. Section 1 introduces the digital television, Section 2 describes the main notions and principles of DVB-T, Section 3 gives some technical details on DVB-T2 standard, Section 4 compares DVB-T and DVB-T2, Section 5 gives the current state and future plans for invoking digital television in the region, and Section 6 gives some conclusions.

2 DVB-T standard

First digital standard adopted by the DVB (*Digital Video Broadcasting*) Project in December 1993 was refered to satellite transmission (DVB-Satellite). This type of service is available for years in all European countries. On the other hand, many existing cable television distributors acquire numerous programs from the satellite. This fact was the impetus for the development of the first digital cable standard, DVB-C (DVB-Cable), adopted in 1994 [2].

The further development of the DVB Project spread to the problem of television broadcasting by terrestrial links in free space, which was followed by potential interference, particularly multipath propagation. Therefore, the standard for the transmission of digital terrestrial television was developed – DVB-T (DVB-Terrestrial) [3]. This standard provides the technique called *Orthogonal Frequency Division Multiplexing* (OFDM). In telecommunications and computer networks **multiplexing** is a method by which multiple analogue signals or digital data streams are combined into one signal over a shared medium. The OFDM, as a kind of multi-transmission modulation, makes possible the transfer of signal by using a large number of supporting frequencies, which carry information content of the signal. Used very successfully in the digital audio bradcasting (DAB), the main advantage of OFDM is that it works well in dynamic environments. It makes possible to work with the overlay networks for broadcasting stations, as well as in term of mobile receipt [4].

Bearing it in mind, it is possible to design single-frequency or multi-frequency network. Single-frequency network (SFN) allows more efficient use of spectrum, but requires precise synchronization of the transmitter. Multi-frequency network (MFN) is common for analogue terrestrial transmission systems. The combination of single and multy-frequency network is usual in the design of digital networks.

DVB Project adopted a number of key commitments for the development of the system for the transmission of digital television signal. The most important way was related to the compression of video and audio signals. The first generation of DVB standards was based on MPEG-2 (*Moving Picture Experts Group*) compression of video signal and multiplexing of compressed audio signal. This multiplex was added to the service data and information related to the television program.

The development of hardware and software technologies and relatively long time in the formation of the first standards led to the definition of modern and more efficient and suitable solutions of the DVB Project, namely the second generation of DVB-T. The chronology of DVB standards is illustrated in Figure 1.

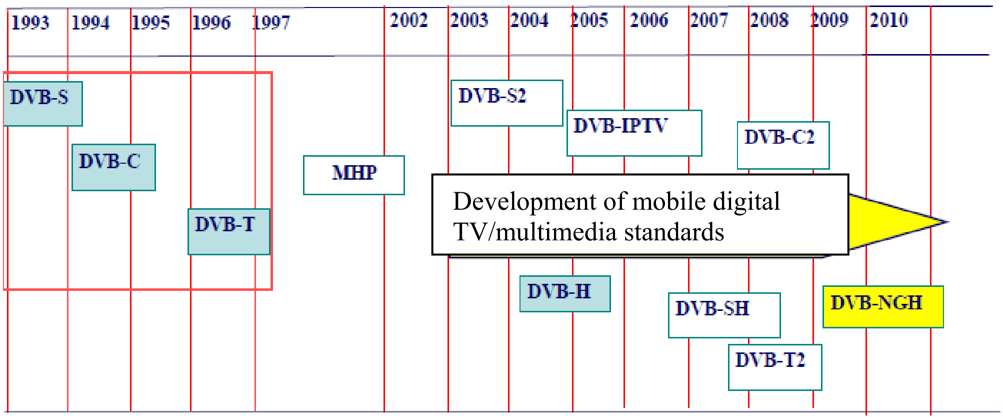

Figure 1. The chronology of DVB standards

3 DVB-T2 standard

DVB-T2 standard is published by the DVB Project in June 2008 for reception of terrestrial digital television, which has a much wider range of parameters compared to the DVB-T, the earlier version of this standard [3]. This section will describe the structure of the signal, how the system requirements to be met and its advantages over DVB-T.

Approaching the time of analogue switch-off of the television signals in Europe and other DTT (*Digital Terrestrial Television*) markets prompted the modernization standards. It will be a lot of competing demands for spectrum to be freed with analogue turn-off, and the DVB-T2 standard broadcasters will offer the most efficient use of funds for the frequency spectrum by using the latest technology [5].

DVB-T2 digital terrestrial transmission is a second generation system designed for use in the environment after the abolition of broadcast analogue signals. The system combines the latest modulation and coding techniques to enable highly efficient use of frequency spectrum for terrestrial delivery of audio, video and other data by fixed, portable and mobile devices. DVB-T2 standard is not designed to replace the DVB-T, but both standards will coexist in many markets for many years.

More than 60 member companies from DVB Project participated in this standard. Like all other DVB standards, the final specification is based on carefully considered commercial requirements. The key requirements are to increase capacity and improve robustness of the system. The new standard must also be able to use existing receiving antennas and links. DVB-T2 standard has brought about more efficient utilization of 30-50% of the frequency spectrum compared to DVB-T. Detailed technical specification standards is given in "DVB Blue Book" [5]. Commercial use of this standard began in late 2009 year.

The main factor which contributed to the success of the current DVB-T system was the ease of customer migration from analogue systems. In most cases, users simply need to incorporate DVB-T receiver without having to modify existing cables and antennas. It is of great importance for the conservation of success to provide similar ease of migration from DVB-T to DVB-T2 standard, as well as that DVB-T2 standard must be applicable to the existing DVB-T installation.

DVB-T2 network can be designed to support the following three categories of admission requirements:

¬ Fixed reception, which will typically be done via the roof antenna or some other form of outside antenna system, where the reception quality depends on the orientation and position of the antenna system. The most frequent reception of TV services will be on TV sets that will be powered from the network, although there are other types of services and presentations.

¬ Portable reception, which will typically be performed by built-in or internal antenna and with the help of device that will be powered from the network or batteries. A portable receiver is defined as a device that provides services to the static user, and receiving quality may vary if moving.

¬ Mobile reception, which will usually be done via the built-in antenna in device which is powered by batteries. Mobile receiver is a device that allows a service to a user who is on the move.

In developing the standards, the DVB project has explored and defined the basic requirements that must accomplish the DVB-T2 standard to meet the needs of a growing market:

- DVB-T2 standard is designed for stationary reception, but it must be possible to design DVB-T2 networks for all three conditions: fixed, portable and mobile receipt;
- DVB-T2 transmission type may not cause higher levels of interference from the DVB-T type;
- DVB-T2 standard must provide a minimum 30% higher data throughput over the DVB-T for any channel under similar conditions;
- DVB-T2 standard should allow lower cost transmission than DVB-T standard;
- DVB-T2 standard should ensure that the maximum distance between adjacent emitters within the same SFN should be 30% higher than the DVB-T 8k mode;
- DVB-T2 standard has to provide local, regional and national coverage in a cost effective manner while satisfying the conditions and limitations in the use of frequency spectrum that are defined by international treaties;
- Any changes in the delivery of service information caused by DVB-T2 standard must be incorporated into the common DVB specification;
- Receipt of the DVB-T2 signal must be possible on the existing DVB-T antenna and cable installations.

Like its predecessor, the DVB-T2 uses OFDM modulation system, with large number of the carriers. Also, the new standard offers a large number of modes which makes it very flexible. When it comes to error correction system, DVB-T2 uses the same coding techniques that are used in DVB-S2 (*Satellite*) standard. LDPC (*Low Density Parity Check*) codes combined with BCH (*Bose and Ray Chaudhuri*) codes provide excellent performance in the presence of high levels of signal noise and interference, resulting in a very robust signal.

More options are enabled when it comes to the number of carriers, the size of the protective interval and pilot signals. The new technique, called the *Rotated Constellations* provides significant additional protection of channels. There are also mechanisms for separately setting the quality of each service within the channel to meet the receiving requirements. The same mechanism allows the transmission to be configured so that the receiver saves power by only decoding the requested program, and not a whole multiplex of the programs.

DVB-T2 standard also specifies a diversity method known as *Alamouti coding*, to improve coverage in small SFN networks. Finally, the DVB-T2 is a way to define the standard to be compatible in the future by using improved *Future Extension* frames.

4 Advantages of DVB-T2 over DVB-T system

Table 1 shows compared characteristics of DVB-T and DVB-T2 standard.

Table 1. Comparison of DVB-T and DVB-T2

Parameter	DVB-T	DVB-T2
Channel coding	1/2, 2/3, 3/4, 5/6, 7/8	1/2, 3/5, 2/3, 3/4,4/5, 5/6
Modulation schemes	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM, 256QAM
Protection interval	1/4, 1/8, 1/16, 1/32	1/4, 19/256, 1/8, 19/128, 1/16, 1/32, 1/128
Operating mode	2k, 8k	1k, 2k, 4k, 8k, 16k, 32k

Here, **channel coding** is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The **modulation** is the process of varying one or more properties of a high-frequency periodic waveform, with a *modulating signal* which typically contains information to be transmitted. The **protection interval** is the period between changes in the time-of-day portion of the time-varying randomization data used for protecting transmissions. The **operating mode** defines number of carriers modulated to spread the information content of the signal across the bandwidth of the channel.

We can see the existence of extra code ratios 3/5 and 4/5 which don't exist in DVB-T, but also the lack of code-quotient 7/8 which exists in DVB-T technology. In this way, we achieved a wider range of choice of transmission parameters for different conditions of receipt. DVB-T2 has three new protective ranges (19/256, 19/128, 1/128). The new modulation scheme (256QAM – *Quadrature Amplitude Modulation*) is also invoked, which allows much higher image quality with 8 bits per sample (for 64QAM is 6 bits per sample). DVB-T2 offers the opportunity to work with additional modes (1k, 4k, 16k, 32k). Generally, a number of OFDM carriers in the higher mode increases the spectral utilization, enabling broadcasting of multiple programs within a single TV channel. A greater number of OFDM carriers increases the length of guard interval, so that the maximum separation between the DVB-T transmitters in the single-frequency network is higher, which means fewer channels to cover the same area. Also, with the number of OFDM carriers immunity to impulse noise is higher.

Theoretically speaking, in the 32k mode and in the UHF (*Ultra High Frequency*) area the whole area of Serbia could be covered with only three UHF channels in the SFN network, because the distance between the DVB-T2 transmitters is 267 km. Of course, in practice this is not the case since the planning was made with DVB-T channels and alotment zones in the SFN network, with a maximum distance of 67,2 km. Due to the large separation of DVB-T2 transmitters and very long symbol duration, for the 32k mode 1/4 protection interval is not used.

Dependence of the number of multiplexes by the number of TV programs for DVB-T and DVB-T2 is shown in Figure 2 [6].

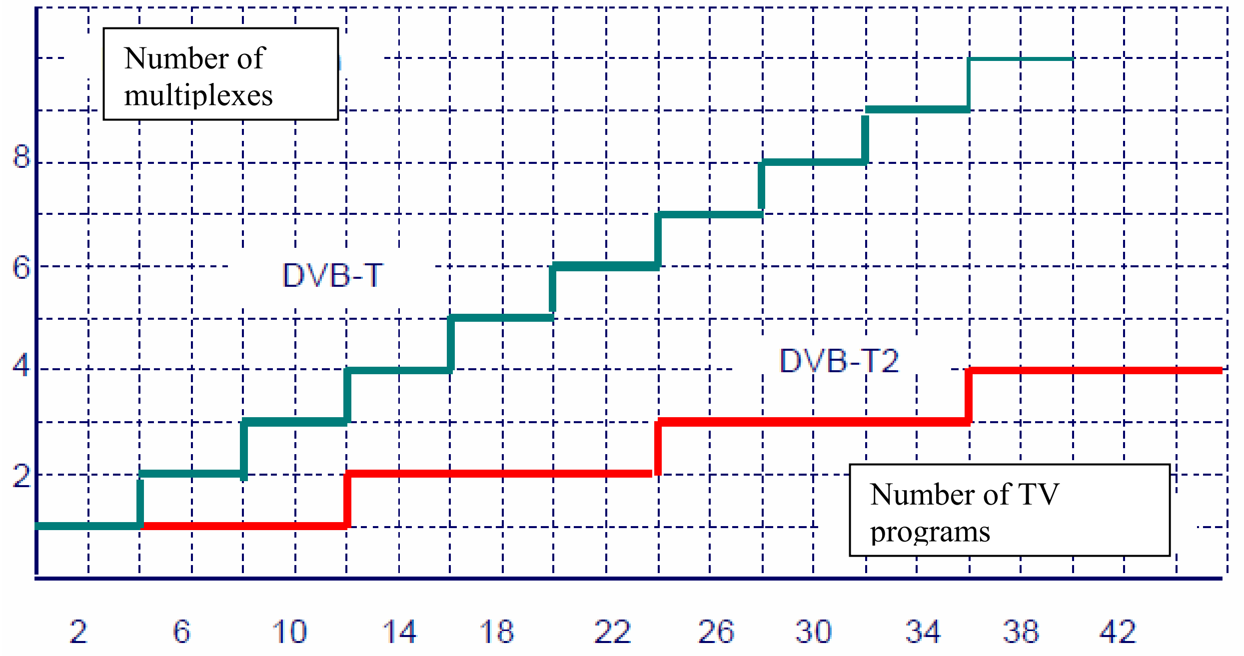

Figure 2. Dependence of the number of multiplexes by the number of TV programs

We can see that for the DVB-T2 a small number of necessary multiplexes provides higher digital dividend (frequency bandwidth that will be released with complete transfer to digital broadcasting of television programs), and therefore less expenses of transmitter equipment. Also, for the providers of the broadcasting equipment DVB-T2 standard provides support for a great number of programs within a multiplex.

As with DVB-T, it is possible to configure the transmitter side, depending on the type of desired receiving service. Unlike DVB-T, in DVB-T2 only one program within a complex multiplex can be decoded. This is useful from the point of an autonomous power supply, and is analogous to the possibilities of DVB-H (*Handheld*).

DVB-T2 uses MIMO (*Multiple Input Multiple Output*) option, which refers to the application of multiple antennas at both ends. The advantage of MIMO is that the capacity increases according to the number of antennas. To correct errors in DVB-T2 the LPDC (*Low-Density Parity-Check*) coding is used, thus providing excellent performance in the presence of receiver noise and interference of high levels, resulting in high signal robustness. DVB-T2 has to provide good quality reception of HDTV (*High Definition Television*) and SDTV (*Standard Definition Television*) so over a period of one hour not more than one error should be registered.

From the user's side, DVB-T2 receiver must allow automatic transfer to another mode and detect it for up to 500 ms. Also, receiver for DVB-T2 should not further increase the delay (compared to DVB-T) for more than 300 ms when changing TV channels or selecting the service. DVB-T2 directly supports MPEG-2 (*Motion Picture Expert Group*) transport stream, and thus all other DVB transports.

DVB-T2 with its direct application avoids the two phases of the digital transition, and therefore the use of two-STBs (*Set-Top-Boxes*). DVB-T2 is less sensitive to noise and provides more reliable planning. It is compatible with IPTV (*Internet Protocol Television*), requires less power for broadcasting, and last but not least it is energy-efficient (reduces power when not using the full multiplex).

In the near future, in the countries where DVB-T service is well established, the goal is to achieve a fully switch-off of analogue signal, and to liberate considerable UHF and VHF (*Very High Frequency*) spectrum for other purposes. Some countries have already ruled out an analogue signal. In their case, one option would be the introduction of new services using DVB-T2 technology. This could allow the ejection of new multiplexes by offering multichannel HDTV services or any new innovative service. As DVB-T, the new standard is aimed not only to be received over home and roof antenna, but also over personal computers, laptops, car receivers, as well as through the entire range of new innovative receiving devices. Migration from DVB-T to DVB-T2 standard has to be carefully implemented in these countries, if a transition occurs. It is expected that DVB-T and DVB-T2 services coexist for a long time.

In 2006, at the conference in Geneva, the transitional period in which will be able parallel work of digital and analogue TV systems was established. For the UHF band in the world and the VHF band in Europe, the deadline will expire on 17.06.2015. Upon expiry of the transitional period, the analogue system will be withdrawn from use. If countries do not switch to broadcasting digital signals within the specified period, they will be able to continue broadcasting analogue signals, but the channels on which they will broadcast will not be internationally protected. As DVB-T much more interferes the analogue TV than in the opposite case, countries that do not meet the set deadlines will face insurmountable difficulties in the reception.

5 Digital television in region

This section describes the process of invoking the digital television in the ex-Yugoslavian (YU) countries, according to corresponding subsections. Table 2 gives comparative analysis of the technical parameters for different ex-Yugoslavian countries. All countries choose to use standard MPEG-4 for the video compression.

Table 2. Comparative analysis of the technical parameters in ex-YU

	Modulation scheme	Mode	Code quotient	Protection interval
Slovenia	64QAM	8k	2/3; 3/4	1/4
Macedonia	64QAM	8k	2/3	1/8; 1/16
Montenegro	64QAM	8k	3/4	1/8
Bosnia and Herzegowina	64QAM	8k	2/3	1/4
Serbia	256QAM	8k	2/3	1/16

5.1. Slovenia. The process of transition to digital television in Slovenia is covered by the "Strategy of the Republic of Slovenia for the switchover from analogue to digital broadcasting" [7]. Analogue switch-off occurred in Slovenia in December 2010. All the major analogue TV transmitters are turned off, while only a small number of transmitters are still in use.

Slovenia uses the MPEG-4 standard for digital terrestrial television. MPEG-4 Part 10 and MPEG-4 part 3 standards were chosen because of their efficiency and better compression compared to MPEG-2 and the ability to fit more channels in the multiplex. It is expected that other countries that are now using the MPEG-2, sooner or later will switch to MPEG-4.

At a conference in Geneva in 2006, Slovenia is divided into three geographical regions (West, Centre, East), and digital terrestrial broadcasting zone signals. Each zone will have UHF channels for eight national alotments, that is each point in Slovenia will be covered with eight multiplexes. Since it is divided into three zones of alotments, it is possible to transmit different multiplexes in each zone. The exception is the West zone, which will dispose with additional local and regional coverage, so it will be able to transfer a total of 24 multiplexes. Additional channels are the result of an agreement with the Republic of Italy over the division of frequencies.

5.2. Macedonia. Macedonia began with experimental broadcasting of digital television on 14.12.2004. The function of the transmitter, which is owned by the Macedonian state television, is to cover an area of Skoplje and its surroundings. Macedonia is divided into nine geographical regions for digital broadcasting. Three terrestrial broadcast channels and public television satellite channel MKTV SAT have ability to transmit one video signal on one or more languages, which is seen as a major advantage of digital technology, because about 25% of the population in Macedonia speak Albanian. In November 2005 the new law was passed to regulate radio-broadcasting, but it was no clear strategic development and implementation of DVB-T standard. Therefore, the Telecommunications Council in November 2008 adopted the ”Strategy of Development of Broadcasting in the Republic of Macedonia for the period 2007-2012” [8]. It was defined to use COFDM (*Coded* OFDM) modulation with 64QAM modulation scheme in the 8k mode, code-quotient 2/3, a protective interval between 1/8 and 1/16, as well as with MPEG-4 compression.

5.3. Montenegro. Broadcasting agency of Montenegro adopted in April 2008 the “Digital switchover strategy of Montenegro” [9]. This document defined the necessary policy frameworks and action of broadcasters, in order to use more efficiently and implement the transition of broadcast television signals with little cost. The territory of Montenegro is divided into three distinct geographic areas (zones), each of which is covered with seven channels in the UHF range. Digital Plan includes an additional sub-zone to cover Podgorica, in addition to the seven main channels defined with an additional eleven UHF frequency bands.

4.4. Bosnia and Herzegowina (BiH). Council of Ministers of Bosnia and Herzegowina, adopted on 17.06.2009. the “Strategy of switch-over to digital broadcasting in Bosnia and Herzegovina” [10]. The purpose of the strategy of transition from analogue to digital terrestrial broadcasting is that the expert analysis of the current situation, identification of needs and opportunities for development of the communications sector in BiH, defined the optimal solution, fundamental strategic guidelines and requirements for the transition period and thus achieve a successful termination of analogue terrestrial radio-diffusion in these bands. Furthermore, the strategy should meet the prerequisites for sustainable development of the communications sector, effective use of digital radio-broadcasting and the digital dividend, the promotion of information society in Bosnia and Herzegowina and protect the interests of all users and operators in the communications sector in terms of non-discriminatory access, quality and price services and to achieve better conditions for improving the opportunities of information, education and entertainment of the citizens of Bosnia and Herzegowina.

According to the Strategy, the territory of BiH is divided into nine geographical regions for digital broadcasting.

5.5. Croatia. Croatia is, if we compare with the previous states, the most advanced in the introduction of terrestrial digital television. The company “Transmitters and Links” deals with the transmission and broadcasting of radio and television programs at the expense of others. It was first in Croatia which recognized the importance of the introduction of DVB-T standard. The company has now 350 transmitters, 16 of which make the basic network, while others are used for additional coverage. After separation from the Croatian Radio Television, the new management of company focused their attention precisely on the implementation of new technologies.

Receiving the consent of the Croatian Telecommunications Agency, it began with experimental broadcasting of DVB-T in 2002. The first transmitters that are released into the work were in Zagreb, and the signal is broadcasted on the 27. UHF channel. A multiplex is made up of four TV programs (HRT1, HRT2, RTL and Nova TV). In July 2008 The Croatian government adopted the “Analogue to digital television broadcasting switchover strategy for the Republic of Croatia” [11]. The strategy is detailed in the transition process. The territory of Croatia is divided into nine zones of broadcasting the digital signals. In each zone a broadcast multiplex is carried on one frequency (SFN networks).

5.6. Serbia. In 2005. the expert team of Radio Television of Serbia launched an experimental digital broadcasting of TV signals in standard definition (SDTV) with 64QAM modulation scheme, protection interval 1/4, code-quotient 2/3, in the 8k mode, with DVB-T transmitters at the following locations:

- Avala, on the 27. UHF channel, in two directions (to Pančevo and Sremčica); 06.04.2005.
- Iriški venac, on the 31. UHF channel in the direction of Novi Sad; 17.11.2005.

The software package included four TV channels (RTS1, RTS 2, TV Avala and experimental program Digital in 16:9 format). The package transmitted also four independent radio channels (Radio 1, 2 and 202, as well as commercial radio stations). In addition, the teletext in RTS1 and RTS 2 programs is also transmitted.

In July 2009, the Government of the Republic of Serbia adopted the “Strategy for the transition from analogue to digital broadcasting of radio and television programs” [12]. The strategy defined the framework for the transition from analogue to digital broadcasting of radio and television programs, based on the latest developments in digital broadcasting, as well as in areas affecting it in order to efficiently deliver the television, radio, multimedia and other content of good quality relevant to the end user. This Strategy defined the main strategic guidelines for the introduction of digital and analogue switch-off of the television and radio programs in the Republic of Serbia, which will adequately realize the fundamental national interest in the introduction and development of digital electronic communications [12]. The territory of Serbia is divided into ten geographical regions for digital broadcasting.

The digitalisation will enable to the citizens better sound and picture quality, diverse content, more radio and television programs, new services for people with disabilities and the elderly, improved additional services, portable and mobile reception of programs, as well as the convergence of services. The digitalisation will provide to service providers the ability to adapt content to the needs of different target groups, interactivity and ability to provide services on demand, lower costs and broadcasting convergence services. The State will enable more efficient use of radio-frequency spectrum, the use of free spectrum for new services, promotion of technology development and new jobs, improved competition and more opportunities for promotion creation and preservation of cultural identity. At the same time, the transition to digital broadcasting will introduce a turn in the air since the place in multiplexes will be allowed only to broadcasters with valid licenses.

6 Conclusion

It was necessary to make standardization in the area of digital broadcasting, because of the enormous potential of this technology in the modern society. DVB project has provided specifications for a variety of digital transmission systems (satellite, cable and terrestrial). Due to different local characteristics, DVB terrestrial systems are the most complicated of all DVB standards. In the case of DVB-T systems, interference due to multiple paths is mitigated by applying OFDM transmission technology. Due to the limitations of terrestrial frequency spectrum, slightly lower speeds of signal transmission are achieved. DVB-T2 standard has provided at least 30% higher transmission speeds, more economical use of bandwidth, less susceptibility to interference and a large number of new services that were not feasible by the old system. The commercial application of this standard began in 2009.
The importance of the development of DVB standards and the advantages of digital broadcasting can be viewed from several perspectives:

¬ For the viewer, a better picture and sound quality are provided, greater choice of content, more radio and television programs, more advanced services, portable and mobile reception of programs, as well as the convergence of services;

¬ Service providers can customize the content to the needs of different target groups, allowing them interactivity, ability to provide services on demand, lower costs and broadcasting convergence services;

¬ For the state, digitalisation enables more efficient use of radio frequency spectrum by utilization of available spectrum for new services, promotion of technology development and new jobs, improved competition and more opportunities for promotion creation and preservation of cultural identity.

Digitalisation in some countries in the region has already been completed. Slovenia and Croatia abolished analogue signal, Macedonia is currently under simultaneous broadcasting of analogue and digital signals, Montenegro should extinguishe the analogue signal in 2013. All these countries use DVB-T standard. Serbia is involved with slight delay in the story of digitalisation and it is only one in the region that will use DVB-T2 standard, which has many advantages over DVB-T. It is expected that the analogue signal will be shut down in 2013.

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andrej@sf.bg.ac.rs