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Planning the Migration of Digital Terrestrial Broadcasting in Croatia to DVB-T2 Standard

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SUMMARY

On 31 December 2010 analogue television in Croatia was completely switched off and was replaced by DVB-T television standard. Because of that, it became possible to provide more TV programs with higher quality and it freed up the frequency band for first digital dividend, which is now used for LTE mobile broadband services. Nowadays, newer and more advanced standard DVB-T2, which is extension of DVB-T, is being implemented in many countries. In Croatia DVB-T2 is used for terrestrial pay TV platform. DVB-T2 offers significantly higher network capacity in the same frequency band which enables more television programs, easier migration to HD services and possibility to free up additional frequencies for second digital dividend. Second dividend frequencies are fitted for covering broad rural areas with wireless broadband services that can reduce the digital gap. Such benefits will have a positive impact on economic sustainability of traditional broadcasting media in a competitive digital economy.

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In this paper we give an overview and analysis of digitalisation process in Croatia in terms of technology and regulation, costs and benefits for the state budget and media campaign with lessons learned, in order to enumerate motivation factors for further migration to the DVB-T2 standard. With the help of simulation, a practical example of useful bit rate increase between the DVB-T and DVB-T2 systems is given. Predicted reduction of TV broadcasting costs, migration costs, need for government subsidy to buy new DVB-T2 receivers and other cost factors of the transition to DVB-T2 are discussed. This analysis is a basis for identifying key prerequisites, benefits, obstacles and stakeholders in migration to DVB-T2 and gives further areas that have to be researched in order to prepare the optimal plan for migration to DVB-T2 from technical, economic, market and social perspectives.

Key words: Digital terrestrial television, migration to DVB-T2, media literacy, broadcasting media market, economic sustainability, digital gap, network capacity

Introduction

The transition to digital signal is a step forward in contemporary media landscape which brings a better and clearer picture without the interference as well as electronic program guide and faster teletext, but most importantly a space to broadcast a large number of national and regional television programs, including specialized ones.

Digital television is much more efficient in terms of radio spectrum use: multiple TV programs are broadcasted instead of one analogue program and, as a consequence, the spectrum is released for new purposes, including mobile broadband and pay TV services.

Croatia was one of the leading countries in switching to digital terrestrial television with the technology that was available at that time. The current state of technology development enables a much better use of the radio spectrum than digital terrestrial television technologies that were implemented in Croatia, which calls for revising of the digital terrestrial television strategy and considering of the benefits and shortcomings of migration to the latest and more efficient digital terrestrial television technologies. Planning and implementation of such migration requires interdisciplinary approach and involvement of all stakeholders on the media market starting from the academia, regulatory bodies, government, public media as well as commercial media. In order to contribute to the discourse we discuss the following: what are the costs of changing the transmission technology from analogue to digital

and the consequences? Is digitalisation profitable? Does "the second digitalisation" make sense from technology, cost, revenue and market development perspectives? What is the impact on citizens of Croatia?

This paper is organized as follows: In the first section, the analogue switch off and lessons learned are being discussed. The second section explains benefits and adoption of the DVB-T2 standard, followed by the section with considerations and recommendations for the second digitalisation and conclusions.

Analogue television switch-off and lessons learned

Digitalisation in Croatia

Transmitters and Communications Ltd. (Odašiljači i veze d.o.o. – OiV) started experimental DVB-T broadcasting from locations Sljeme and Zagreb - Prisavlje 3 in May 2002[1], continued with coverage extensions to all major cities in Croatia (Split, Rijeka and Osijek) and other dense populated areas. The project "Digital Istria" carried out during 2007, aimed to solve TV reception problems caused by illegal Italian interference, and enabled Istria to be the first county in Croatia covered with digital terrestrial television broadcast from additional 15 locations. Experimental DVB-T network coverage was significant: 85% of the population was able to receive digital terrestrial television before the actual start of Analogue Switch Off (ASO) process.

In July 2008 the Government of the Republic of Croatia adopted a Strategy for Transition from Analogue to Digital TV Broadcasting in the Republic of Croatia (The Government of the Republic of Croatia, 2008). It required the digitalisation of program content broadcasted via digital terrestrial television to be performed in accordance with the ISO/IEC IS 13818 standard (MPEG-2 standard)/ITU-T H.262 recommendation for at least three nationwide multiplexes and one multiplex at local/regional level until 01 January 2011. The Strategy covered in details the technical aspects of the terrestrial television digitalisation, without much consideration of public service content in future digital media (T. Perišin, 2011).

In April 2009 OiV won the international public tender issued by HAKOM (Croatian Post and Electronic Communications Agency) and became the network operator for two national DVB-T multiplexes (MUX A and MUX B - standard definition, MPEG-2) and in July 2010 for the third DVB-T multiplex (MUX D - combined national/regional and local multiplex - standard definition, MPEG-2).[2]

On 05 October 2010 the digital switch over was completed. MUX A network covers over 98% of the population of the Republic of Croatia and over 95% of each allotment, MUX B network covers over 95% of the population of each allotment, and MUX D approximately 90% of the population and at least 70% of the population within each allotment.

Croatian Digital Terrestrial Television networks are currently divided in 9 Single Frequency Networks (SFNs) or digital regions. SFN is a broadcast network where several transmitters simultaneously send the same signal over the same frequency channel. SFNs are very efficient in fading channels (channels with e.g. multipath propagation) with an excellent spectrum saving and very good power utilization.

In each digital region, 5 multiplexes are allocated: Multiplex A and Multiplex B for Free-To-Air (FTA) national programs, Multiplex D for FTA national and regional programs and Multiplex C and E for pay-tv platform. Multiplexes A, B and D are using the DVB-T, while multiplexes C and E are using the DVB-T2 standard. In DVB-T2, four regions are connected in two, which effectively gives 7 SFNs and additional savings in the number of frequencies required to operate the nationwide network.

Media campaign

The Central State Office for e-Croatia, as a coordinating body, prepared an extensive two-year campaign to motivate citizens to prepare for the new era of digital television named "Get off the roof and become a part of the digital age". That was the basic message printed on brochures and of one-minute promotional TV spot broadcasted from 01 September 2008 on all three national televisions.[3] TV spot's message was technically misleading, since it insinuated that rooftop antennas were no longer needed for digital television (T. Perišin, 2011). The misunderstanding had to be corrected by other means of communication: new TV spots explaining how to technically connect new digital equipment, OiV's call centre and frequently asked questions[4].

IPTV and cable pay TV operators used digitalisation to promote their services as digital television using "the wire" and raised the pay TV penetration from 21.2% at the end of year 2007 to 39.8% at the end of year 2012.[5]

Subsidies

Everyone who regularly paid TV tax was eligible for financial support from the Croatian Government. A special coupon was issued to co-finance 2/3rds of the cost of the digital terrestrial receiver. The Government and the largest retailers and wholesalers agreed that the price of digital receivers would be 180 kunas. That meant

that anyone who buys a digital receiver to add another 45 kunas. The coupon could be also used as a discount when buying a new TV set if it contains a digital tuner. For that purpose the Government spent 15 million kunas in 2007 to subsidize receivers for the "Digital Istria" project and planned to spend 45 million kunas in 2008 and 106 million in 2009.

The coupons were distributed gradually per digital region in accordance with the ASO schedule. For "Digital Istria" project (the first digitalised region) coupons worth 135 kunas (18 euros) were distributed in 2007 and 2008 and had to be used by the end of the year 2008, while later on the coupon value dropped to 75 kunas (10 euros) with validity till the end of year 2010. Retail prices of the receivers did not drop proportionally to coupons value and the rest of households received only around 50% of co-financing.

By the end of the digitalisation, 563,000 coupons were used. Taking into account a total number of 1,535,000 households, we can conclude that 63% of households financed the digitalisation by themselves by purchasing receiver or digital TV without subsidy, or by using or signing up for pay TV service. Instead of the initially planned 166 million kunas, the Government spent only 49 million kunas for subsidies (around 40 million if we exclude the VAT).[6]

Use of frequencies for new services

Because in DVB-T in one frequency channel there can be more programs within one digital multiplex instead of one analogue frequency for single TV program, some parts of the radio-frequency spectrum (VHF III, 174-230 MHz; UHF IV, 470-614 MHz and UHF V, 614-862 MHz) had become free and could be used for other purposes.

The benefits of analogue to digital TV transition can be summarized:

– frequency spectrum 790-862 MHz is being used for LTE (Long Term Evolution) services by 2 Croatian telecommunication operators (VIPNET and T-HT) (called the first digital dividend),
– new TV programs with national coverage are added, and coverage of regional channels is extended,
– evotv - new digital platform in DVB-T2 standard, in multiplexes C and E is implemented,
– VHF III band is released and can be used for digital radio or other purposes.

Some of the possible scenarios for free frequency spectrum, as well as re-planning of the existing DVB-T network, explained in (S. Grgic et all, 2012) are:

VHF III:

– implementing TV programs for digital television (SDTV - Standard Definition Television, HDTV - High Definition TV, 3DTV, UHDTV - Ultra HD-TV), by implementing the DVB-T or DVB-T2 standard
– digital radio (DAB - Digital Audio Broadcasting, DAB+, DRM - Digital Radio Mondiale, DRM+)

UHF IV and part of UHF V (470-790 MHz):

– usage of all existing multiplexes, according to the GE06 plan[7] (currently, multiplexes F, G and H are empty), for more TV programs (SD, HD, 3D, …)
– re-planning of SFN network coverage by using different parameters in DVB-T2 standard (especially by using longer guard interval): nowadays in Croatia there are 9 SFN networks, which could be reduced to about 4-5 regions. Although useful bit rate would drop when guard interval is longer, the overall useful bit rate in all regions would be higher (by about 20 Mbit/s, according to (S. Grgic et all, 2012), because of the bigger coverage of one SFN region
– implementing DVB-T2 standard in all multiplexes; thus enabling the second digital dividend (frequency spectrum 694-790 MHz)

Part of UHF V (790-862 MHz):

– mobile operators are already using this spectrum for LTE services

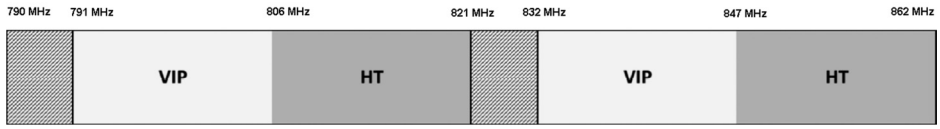
The current spectrum usage in Croatia for VHF III, UHF IV and UHF V bands is shown in Table 1.

Table 1 VHF III, UHF IV and UHF V current spectrum usage in Croatia
Tablica 1. VHF III, UHF IV I UHF V trenutna raspodjela spektra u Hrvatskoj

Channel	5	12	21	60	61	69
Frequency (MHz)	174	230	470	790	790	862
Service type	Empty		DVB-T/-T2		LTE	

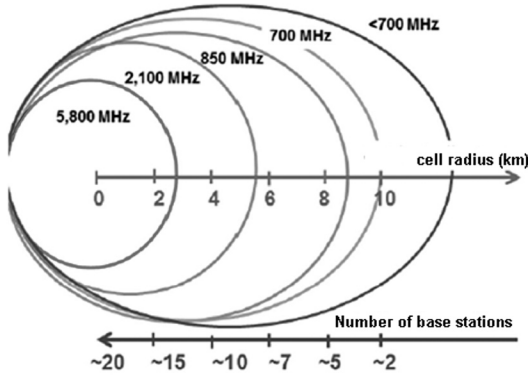
The first digital dividend, frequency spectrum 790-862 MHz (one part of UHF V), is nowadays fully divided between two Croatian mobile operators for LTE services: Hrvatski Telekom and VIPnet (Cullen International, 2014). Licences for both providers were awarded in two stages, in years 2012 and 2013. First digital dividend auctions resulted in 580 million kuna revenues for the state budget in the first year and 48.8 million kunas per year. Frequency spectrum 790-862 MHz usage in Croatia is shown in Figure 1.

Figure 1 Frequency spectrum 790-862 MHz for LTE services in Croatia
Prikaz 1. Frekvencijski spektar 790-862 MHz za LTE usluge u Hrvatskoj



The first digital dividend was very interesting for mobile operators because of the additional bandwidth but also because in lower frequency bands (compared to 1800 MHz and 2100 MHz bands used for mobile services) operators need less base stations to cover the same area because of the free space path losses. Free-space path loss is proportional to the square of the distance between the transmitter and receiver, and also proportional to the square of the frequency of the radio signal. This means that on lower frequencies the free-space path losses will be lower and because of that, the transmitter needs lower EIRP (Effectively Isotropic Radiated Power) to cover the same area. Alternatively, a transmitter operating with the same EIRP can cover larger area on lower frequencies. EIRP is the amount of power that a theoretical isotropic antenna (which evenly distributes power in all directions, e.g. point source) would emit to produce the peak power density observed in the direction of maximum antenna gain. An example from (S. Grgic et all, 2012) is shown in Figure 2. However, it should be noted that the particular number of base stations needed to cover an area also greatly depends on the type of area (urban, suburban, rural, etc.), because area type introduces different additional losses to the free-space path losses.

Figure 2 Number of base stations needed for covering allotted area, in different frequency bands
Prikaz 2. Potreban broj baznih stanica za pokrivanje određenog područja, za različite frekvencijske pojaseve



Digitalisation results

The digitalisation in Croatia was technically well planned and is considered very successful in terms of seamless migration to the new technology. It did not bring only benefits to the Croatian citizens, but it also enabled and induced new services and business models along with the monetisation of radio spectrum resources. Early digitalisation has drawbacks in terms of spectrum efficiency and consequently higher cost of TV program transmission. We summarise the main results of and consequences of digitalisation as follows:

1. The first and the least efficient generation of digital terrestrial television is used

Croatia was the 15th European country to switch off analogue television. Because of such early digitalisation H.262 (MPEG-2) video coding standard was used, although the more advanced H.264 was already commercially available. Such approach was used also by the most of other countries that had early digitalisation, primarily because of availability and high cost of digital receivers and digital TV sets with H.264 support at that time. The use of H.262 allows 4-6 SD programs per multiplex compared to 8-12 SD programs in case of H.264. Additional technique – statistical multiplexing could also be used to further improve the number of programs per one multiplex.

2. Telecommunications market is further developed with new services and business models

Digitalisation enabled development of the 4G mobile broadband services and the digital terrestrial pay TV platform "evotv". It also supported the high growth of other (primarily IPTV) pay TV services.

3. Very profitable for the state budget

The digitalisation cost included 49 million kunas for the digital receiver subsidy and costs of media campaign. Direct revenues for the state budget include 580 million of one-time digital dividend revenue, 48.8 million of annual revenues and the frequency fees for digital terrestrial pay TV services.

4. Benefits for citizens

Nowadays Croatian citizens have up to 16 free to air programs available on their antennas[8], a better choice of pay TV services, and the ability to use the fastest mobile broadband services technology can offer.

5. High transmission cost

Although the use of cheap H.262 STBs enabled a successful digitalisation, there is a drawback in cost of transmission that is charged per used megabit. It roughly doubles the cost per broadcasted TV program in comparison to a case where more advanced H.264 coding is used. Although digitalisation, due to spectrum efficiency, reduces transmission costs, this is not a case for regional and local televisions which used their own analogue transmitters before the digitalisation and optimised their transmission costs in cooperation with municipalities and local businesses. Digitalisation enabled regional televisions larger population coverage, but with multiplied transmission costs that are hardly sustainable in the long run.[9]

Benefits and adoption of the DVB-T2 standard

DVB-T2 system description

The main benefit of the DVB-T2 over DVB-T is the possibility to increase the capacity of digital terrestrial television (DTT) (ETSI EN 302 755, 2009; D. Tralic et all, 2012; EBU tech 3348, 2013). It provides a minimum increase in capacity of at least 30% in comparison to the DVB-T standard in equivalent reception condition using the existing receiving equipment. Although it has been fundamentally designed for fixed reception, the DVB-T2 standard is also feasible in portable and mobile devices if an appropriate set of parameters is used.

Similarly to DVB-T, the DVB-T2 uses Coded Orthogonal Frequency Division Multiplex (COFDM), with new modulation - 256QAM. This allows higher number of bits to be carried per data cell, which increases the spectral efficiency and bitrate. The support for the 16K and 32K transmission modes allowed increase of the guard interval length without decreasing the spectral efficiency of the system, due to longer useful OFDM symbol duration, than in 8K mode. This allows broader SFN (Single Frequency Network) networks in DVB-T2 standard.

DVB-T versus DVB-T2; comparison of Croatian DVB network

A simple comparison of available modes in DVB-T and DVB-T2 specifications (DVB Project Office, 2012) is shown in Table 2. Bolded numbers in DVB-T2 column mean that they are freshly introduced in this standard.

Table 2 Comparison of DVB-T and DVB-T2 systems
Tablica 2. Usporedba DVB-T i DVB-T2 standarda

	DVB-T	DVB-T2
FEC	Convolutional Coding + Reed Solomon 1/2, 2/3, 3/4, 5/6, 7/8	LPDC + BCH 1/2, **3/5**, 2/3, 3/4, **4/5**, 5/6
Modes	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM, **256QAM**
Guard Interval	1/4, 1/8, 1/16, 1/32	1/4, **19/256**, 1/8, **19/128**, 1/16, 1/32, **1/128**
FFT size	2K, 8K	**1K**, 2K, **4K**, 8K, **16K**, **32K**
Scattered Pilots	8% of total	**1%**, **2%**, **4%**, 8% of total
Continual Pilots	2,6 % of total	**0,35%** of total

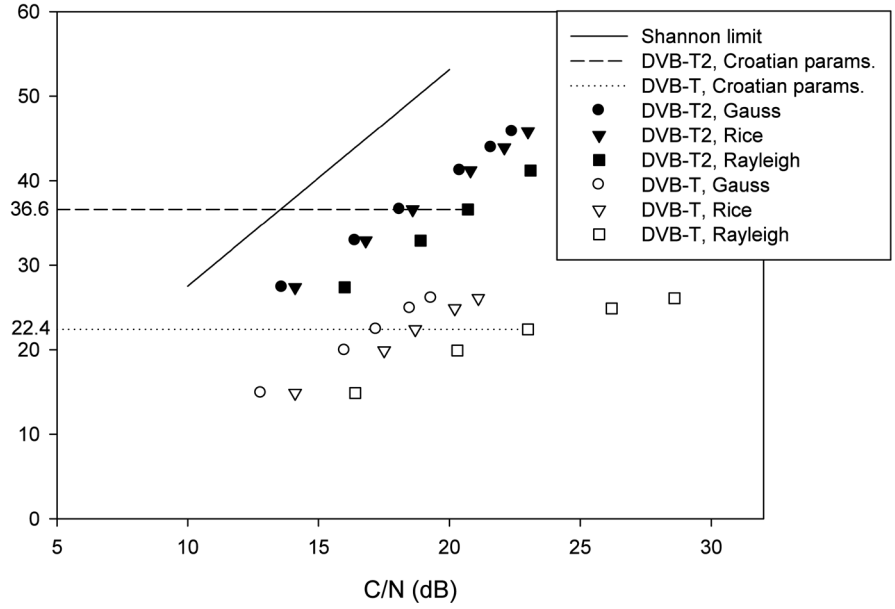
Practical example of useful bit rate increase between the DVB-T and DVB-T2 systems is shown in Figure 3. Simulated channel types were Gaussian (one direct ray), Ricean (one direct ray and 20 delayed rays) and Rayleigh (20 delayed rays with no line of sight ray). The tested parameters were similar to Croatian DVB-T and DVB-T2 networks, with different FEC (Forward Error Correction) correction codes. Results have been obtained from (E. Dumic et all, 2014) and are based on two simulators: for DVB-T system (E. Dumic et all, 2012) and DVB-T2 system (BBC R&D, 2011).

In Figure 3, apart from the overall results, specific parameters which are used in Croatia for DVB-T and DVB-T2 are shown with thicker marks (FEC=3/4 for DVB-T and FEC=2/3 for DVB-T2).

It can be seen that, for practically the same C/N (Carrier to Noise ratio), gain in useful bit rate is about 63% for DVB-T2, compared to DVB-T (22.4 Mbit/s in DVB-T versus 36.6 Mbit/s in DVB-T2).

Shannon limit tells the maximum rate at which useful information can be transmitted over a communication channel of a specified bandwidth in presence of noise. It can be seen that in the case of Gaussian channel, the DVB-T2 system gets results which are relatively near this limit.

Figure 3 DVB-T versus DVB-T2
Prikaz 3. Usporedba DVB-T i DVB-T2 standarda



Also, H.264/AVC is used as video compression in Croatian DVB-T2 pay TV network, together with statistical multiplexing. In comparison to H.262, which is currently used in Croatian DVB-T network, H.264/AVC is approximately twice as efficient as H.262, while maintaining same visual quality. HEVC (High Efficiency Video Coding), new compression standard which is still in the development phase, can be expected to be widely commercially available in a few years. It is expected that HEVC compression could double the data compression ratio compared to H.264/MPEG-4 AVC at the same level of video quality (T. K. Tan et all, 2014). By using statistical multiplexing, depending on the number of programs in one multiplex, gain can be up to 50% (in comparison with constant bit rate case) in large DVB-T2 networks (Envivio, 2011). With statistical multiplexing and H.264/AVC video compression, it can be concluded that up to 5 times more programs could be transmitted in the same frequency band (up to 10 times if HEVC compression would be used). Alternatively, HD and 3D programs could be implemented, or a certain part of the frequency spectrum could be also used for second digital dividend (e.g. for LTE). This would have positive impact on end user.

Existing implementation of DVB-T2 in Croatia – EvoTV

Currently, EvoTV is the first terrestrial digital pay TV television offering its services in Croatia. It is implemented in 2 multiplexes (MUX C and MUX E) and covers around 85% of the territory with 17 transmitters. It currently offers 44 programs in both multiplexes, some of which are HDTV and 3DTV. Transmitting parameters in both multiplexes are: single PLP (Physical Layer Pipe), modulation 256QAM, guard interval 19/256, FFT mode 32k extended, scattered pilots Pilot Pattern 4, code rate 2/3 (useful bit rate 36.6 Mbit/s).

Implementation of DVB-T2 in the world

According to (DVB Project Office, 2012), currently 24 countries (including Croatia) have already implemented the DVB-T2 standard, 10 countries have DVB-T2 as experimental broadcasting standard and 34 countries are planning to implement DVB-T2. Currently used broadcasting standards in the world are shown in Figure 4.

Figure 4 Television broadcasting standards currently used in the world
Prikaz 4. Trenutno korišteni standardi za televizijsko odašiljanje u svijetu

Considerations and recommendations for the second digitalisation

On the basis of features of the latest commercially available broadcasting technologies, worldwide adoption that ensures economies of scale and cheap receiving equipment (TV sets and digital receivers) and lessons learned from the first digitalisation in Croatia, we can discuss the potential impacts of replacing the currently used DVB-T/H.262 implementation of the digital terrestrial television with the DVB-T2 network and H.264 coding. This is a basis for further analysis and study that would calculate and predict the reduction of TV broadcasting costs, migration costs, need for government subsidy to buy new DVB-T2 receivers and other cost factors of the transition to DVB-T2.

Second digital dividend

Second digital dividend (694-790 MHz frequency band) could become free by switching all multiplexes (A, B and D) from DVB-T to DVB-T2 standard and from H.262 to H.264 or HEVC compression. Although DVB-T supports H.264/AVC video compression standard, H.262 is currently used in DVB-T in Croatia. In DVB-T2, H.264/AVC could be used, in which bit rate can be halved in comparison with H.262, for the same video quality. This also means that 2 TV programs could be streamed instead of one (with the same quality and frame size), by using the same bit rate. If HEVC would be used as video compression, 4 TV programs could be streamed instead of one, also with the same quality and frame size. Additionally, DVB-T2 can transmit at higher bit rate, than DVB-T, using the same frequency band and similar C/N (e.g. 63% when comparing DVB-T and DVB-T2 with parameters currently used in Croatia, section III.B). With introduction of DVB-T2 standard in all multiplexes, statistical multiplexing and H.264/AVC video compression, it can be concluded that up to 5 times more programs could be transmitted in the same frequency band (up to 10 times if HEVC compression would be used), in comparison with the current situation in Croatian DVB-T network, so "second digital dividend" frequencies would become free and thus could be used by mobile operators. A discussion on Second digital dividend started at the World Radiocommunication Conference 2012 (WRC-12) and there it was concluded that new mobile allocation in the band from 694–790 MHz (second digital dividend) should be created, which is proposed to come into force at WRC-15 (Z. Tabakovic, 2014). As in the first digital dividend, those frequencies are also particularly interesting to mobile operators because in lower frequency bands (compared to1800 MHz and 2100 MHz bands used for mobile services) operators in general need less base sta-

tions to cover the same area (3-4 times less in comparison with 2100 MHz band, according to (S. Grgic et all, 2012), Figure 2, but also depending on area type).

Impact of the second digitalisation on end user

The first digitalisation, the change from analogue to digital transmission, required education and increased media literacy of the whole population in Croatia. It was a major change, since most citizens had to adopt the use of digital receiver in addition to analogue TV set which was not able to receive TV programming after analogue switch off. For citizens who still use a separate digital receiver (which is not integrated in the TV set), the second digitalisation would require replacement of the current receiver with a new one, which supports DVB-T2 broadcasting standard and H.264 decoding. Those who use newer TV sets with DVB-T digital tuners would have to install an additional DVB-T2 receiver, similarly as it was required with analogue TV sets during the first digitalisation. The aforementioned actions required from the whole population are not trivial and migration to DVB-T2 network would have to be carefully planned taking into account:

1. The availability and cost of DVB-T2 receivers. DVB-T2 television sets and digital receivers are already available on the Croatian market with retail price of DVB-T2 receivers ranging from 250 to 450 kunas (June 2014) as well as digital TV sets with T2 tuners from all major brands. Moreover, users of "evotv" pay TV service already have DVB-T2 compatible receivers.
2. Simulcast, or simultaneous transmission of the same programs in DVB-T and DVB-T2, is necessary to enable the transition similar to simulcast of analogue and digital television during the first digitalisation. In order to motivate citizens to migrate, programs initially transmitted in T2 network should be in high definition (HD).
3. Media campaign should focus on increasing the media literacy of the overall population so that they are able to understand the benefits of migration to T2 network (mainly transition to HD programming from the end user's perspective), solve typical technical problems with user equipment and that TV programs received on the regular terrestrial antenna are free of charge.

Costs and revenues for the state budget

The first digitalisation lessons learned taught us that monetisation of the released spectrum, especially because of the first digital dividend used for mobile broad-

band services, is very profitable for the state budget and that 2/3 of the households did not require subsidy for digital receivers.

Given that the second digital dividend has even better technical characteristics for mobile broadband than the first one, we can assume that the released spectrum would be sold at least at the similar price, enabling around 500 million kunas one time revenues for the budget plus the subsequent annual revenues.

The total subsidy for the DVB-T2 digital receivers depends on migration dynamics – later migration requires fewer subsidies because the technical equipment gets cheaper and people would purchase more TV sets and digital receivers by themselves. However, prolongation diminishes positive effects and the optimum migration schedule has to be prepared, also taking into account the costs of simulcast, upgrade of existing transmitters and cost of campaign.

Cost of broadcasting

The efficiency of DVB-T2 standard with H.264 coding and statistical multiplexing allows around 4 times lower transmission cost for the standard definition TV program compared to current DVB-T/H.262 costs. The cost of HD broadcasting, in case of replacement of current standard definition TV program with high definition, could be around 30% lower than the current cost of SD broadcasting. For example, currently, the transmission costs per annum of single TV program with national coverage in MUX A (98.5%), MUX B (96%) and MUX D (90%) are around 12.1 million, 7.4 million and 2.5 million kunas respectively. For example, cost of HD transmission in the future network we estimate to 6.8 million kunas per annum for 98.5% coverage and 5.2 million kunas per annum for 96% coverage. The cost of national SD transmission would be 2.4 million kunas for 98.5% coverage 1.8 million for 96%, and only 0.6 million kunas per annum for 90% coverage.

It is important to note that, even with HD transmission for all national TV programs, there would be a need for only two DVB-T2 multiplexes instead of the current three DVB-T multiplexes to carry HD national programs and all regional TV programs in SD.

Such cost reduction would have a positive impact on sustainability of specialised and regional televisions' business cases, while increasing the quality of national TV programs and, as a consequence, it would enable availability of free to view content to Croatian citizens in the long run.

Conclusions

In this paper we have analysed lessons learned from analogue switch off, as well as motivation for further migration to DVB-T2 standard from market, regulatory, technical and economic perspectives.

From the technical perspective, analogue switch off resulted in many benefits, some of which are the first digital dividend, new TV programs for regional and national coverage, new digital pay TV platform in DVB-T2 standard and empty VHF III band. Similarly, second digitalisation – migration of free to air broadcasting from DVB-T to DVB-T2 standard would release even more of the frequency spectrum and would enable the second digital dividend, while enabling broadcasting of national programs in high definition instead of standard definition. With the introduction of DVB-T2 standard, statistical multiplexing and H.264/AVC video compression, it can be concluded that up to 5 times more programs could be transmitted in the same frequency band (up to 10 times if HEVC compression would be used), in comparison with current situation in Croatian DVB-T network, so second digital dividend frequencies could be used for mobile broadband services.

Second digitalisation would also enable an approximately fourfold decrease of transmission cost for regional and specialised programs, as well as national programs if they continue broadcasting in standard definition. Such cost reduction would have a great positive impact on sustainability of specialised and regional televisions' business cases and consequently, would enable availability of local free to view content to Croatian citizens in the long run.

From the economic perspective, with analogue switch off, one part of the frequency spectrum - first digital dividend was assigned to mobile operators. Auctions resulted in 580 million kuna revenues for the state budget in the first year and 48.8 million kunas per every subsequent year. Given that the second digital dividend has even better technical characteristics for mobile broadband than the first one, we can assume that the released spectrum would be sold at least at the similar price, enabling around 500 million kunas of one-time revenue for the budget plus the subsequent annual revenues.

The costs of second digitalisation depend on migration dynamics, where later migration requires fewer subsidies because the technical equipment gets cheaper and people would purchase more TV sets and digital receivers by themselves. However, prolongation diminishes positive effects and the optimum migration schedule has to be prepared, also taking into account the costs of simulcast, upgrade of existing transmitters and cost of campaign.

ENDNOTES

1 See: http://www.oiv.hr/broadcasting/terrestrial/dtv/dtv_en.aspx and http://www.oiv.hr/broadcasting/terrestrial/terrestrial_en.aspx

2 It is important to notice that, due to open and transparent process of international public tender, other bidders could have won the right to operate national multiplexes in Croatia. In that case, OiV's investment in experimental network and project Digital Istria could have been lost. However, expertise and experience within a company gained through experimental phase proved to be the key factor and the main differentiator to competitors.

3 A witty TV spot warned the citizens that the time of climbing the roofs of houses, in order to adjust the antenna and secure themselves a better reception of the TV signal and a better picture, is over and to be forgotten.

4 See: http://www.oiv.hr/broadcasting/dvbt/pitanja/pitanja_hr.aspx and http://www.hrt.hr/najcesca-pitanja/o-digitalnom-signalu-i-dotaciji-vlade-rh

5 Official HAKOM data. See also: http://www.hakom.hr/UserDocsImages/2012/radiokomunikacije/Gosta%20-Medijska%20usluga%20televizije%20u%20Republici%20Hrvatskoj-20121129.pdf

6 Calculations are based on data collected during author's professional work and direct involvement in the process of digitalization.

7 International coordination of VHF and UHF frequencies.

8 For the list of available programs per digital region see: http://www.oiv.hr/broadcasting/tables/dtv_channel_hr.aspx

9 Kapital network is an example of unsustainable business. It started as the first free to air channel that was transmitted only on digital (DVB-T) network, and was the first to close. OiV turned off Kapital network because of their debt and because of not being on air, KN lost the concession and went bankrupt in 2013.

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Planiranje migracije digitalnog zemaljskog odašiljanja u Hrvatskoj na DVB-T2 standard

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SAŽETAK

Analogno televizijsko odašiljanje u Hrvatskoj u potpunosti je isključeno 31. prosinca 2010., a zamijenilo ga je odašiljanje u DVB-T standardu. To je donijelo veći broj televizijskih programa s boljom kvalitetom slike te oslobodilo frekvencijski pojas za prvu digitalnu dividendu koja se sada koristi za LTE mobilne širokopojasne usluge. U današnje vrijeme se u mnogim zemljama uvodi noviji i napredniji standard DVB-T2 koji je proširenje DVB-T standarda. U Hrvatskoj se DVB-T2 već koristi za uslugu zemaljske naplatne televizije. DVB-T2, u istom frekvencijskom pojasu, nudi znatno veći kapacitet prijenosa koji omogućuje još više televizijskih programa, lakšu mogućnost prelaska na HD usluge i mogućnost oslobađanja dodatnih frekvencija za drugu digitalnu dividendu. To će imati pozitivan utjecaj na ekonomsku održivost tradicionalnih elektroničkih medija u tržišnoj digitalnoj ekonomiji, a frekvencije druge dividende su posebice prikladne za pokrivanje ruralnih područja bežičnim širokopojasnim uslugama kako bi se prevladao digitalni jaz.

U ovom radu dajemo pregled i analizu procesa isključenja analogne televizije u pogledu tehnologije i regulacije, troškova i koristi za državni budžet te medijske kampanje s poukama u svrhu definiranja motivacije za daljnju migraciju prema DVB-T2 standardu. Pomoću simulacije je dan praktični primjer povećanja korisne brzine prijenosa DVB-T2 sustava u odnosu na DVB-T. Razmotreni su predviđeni troškovi migracije, smanjenje troškova odašiljanja, potrebe za državnim subvencijama za kupnju novih DVB-T2 prijamnika kao i drugi čimbenici prelaska na DVB-T2 standard. Ova analiza je temelj za identificiranje ključnih preduvjeta, koristi, prepreka i dionika u migraciji na DVB-T2. Bit će naznačena daljnja područja istraživanja i postavljena pitanja koja treba odgovoriti kako bi se pripremio optimalan plan za migraciju na DVB-T2 iz tehničke, ekonomske, tržišne i društvene perspektive.

Ključne riječi: digitalna zemaljska televizija, migracija na DVB-T2, medijska pismenost, tržište odašiljanja televizije, ekonomska održivost, digitalni jaz, kapacitet mreže