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Digital Broadcasting Techno-Economic Efficiency Simulation Model

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Introduction

Digital television (TV) is the first major change to the terrestrial broadcast of TV since the introduction of color (about four decades ago). There are three main transmission systems for delivering TV service to end-users, by satellite, cable or terrestrial. The digital terrestrial television (DTT) system can deliver television even to the mobile devices [1]. Data-casting services and high-definition (HD) television content is available via satellite and cable but, until now, terrestrial users have not received data and HD content because its transmission requires a wider data channel than that used for standard definition (SD) TV - Digital Video Broadcasting Terrestrial (DVB-T) and Moving Picture Expert Group MPEG-2 coding and compression standard. The new technologies, like MPEG-4/H.264 and DVB-T2, provide increased capacity and ruggedness in the terrestrial transmission environment.

Digital terrestrial broadcasting infrastructure using the latest technologies can introduce the services to un-served or under-served regions and upgrade networks to very-high-speed access. The researchers who fail to introduce a multidisciplinary approach to the problem, are likely to omit a cost items when evaluate the application of new technology. Therefore, this paper develops a method of estimating the benefits of digital dividend gained by using new (DVB-T2 and MPEG-4/H.264) technologies.

Reasons and technologies for estimating cost of the system

The main reason for estimating the cost of the system, revenue and break–even point is to find out the magnitude of scale economies which depend on increasing dilemma about choosing DTT technology as since 2009 different options are available [2]. These kinds of results are important for broadcasting industry. Using these information, broadcasters can introduce new services (data and HDTV) without increasing capacity usage, regulators can increase broadband penetration, effectively introduce services important to government administration like e-Government, etc. On the other side business managers can calculate the optimal size of their business in terms of return on investment.

There is a choice of different broadcasting standards for DTT. The standards that are used and adopted the most are MPEG-2 and DVB-T. Couple of years ago a new, more efficient standard for TV signal compression, MPEG-4 v.10, or H.264/AVC (in the following text will be quoted simply as MPEG-4), entered into broadcasting systems around the world and it can be combined with DVB-T as well. Besides that, we can predict and control the quality of MPEG-4 video stream within mobile environment [3]. In many countries that launched DTT after 2007, Lithuania [4] and others, there is an experience of hot discussions after which MPEG-4 was adopted in almost all cases. On the other hand, more than 15 countries, that launched DTT before 2007, broadcast their services in MPEG-2/DVB-T. In June 2008, DVB-T2 a new standard for transmission of broadcasting content is approved by DVB. As this paper estimates the benefits of using the latest technologies, we focused in our research on these two new, more efficient technologies. Here are basic explanations of those two.

• *MPEG-4.* The improved video and audio coding compression standard. Its usage will result in more efficient compression of video and audio content. MPEG-4 is based on the MPEG-2 standard but it is not backward compatible with MPEG-2 receivers. A TV program package-multiplex can carry twice as many data using MPEG-4 as can currently be achieved using MPEG-2, while keeping a similar service quality. Important feature is the option for mixing MPEG-4 and MPEG-2 streams on a single multiplex. MPEG-4 compression system is applied on the satellite and cable networks and is increasingly being used on DTT worldwide.

• *DVB-T2.* A newest broadcast transmission standard. First, the DVB Project created commercial guidelines for evaluating how to implement the latest technology developments into new DVB-T specification. The DVB-T2 standard uses the experience from the current DVB-T, which was implemented first in the UK twelve years ago. DVB-T2 is capable to increase by at least a 30% the transmission capacity over the current standard while keeping the same TV coverage including transport of Internet Protocol (IP) data. The resulting standard exceeds the target for capacity increase and achieves 40-50% and in some scenarios over 65% increase.

Table 1. DVB-T vs. DVB-T2 - Capacity comparison

	DVB-T	DVB-T2
Modulation	64QAM	256QAM
Carrier number	2K	32K
Guard Interval	1/32	1/128
Forward Error Correction	2/3CC + RS	3/5LDPC + BCH
Scattered Pilots	8.3%	1.0%
Continual Pilots	2.0%	0.53%
Signaling overhead	1.0%	0.53%
Carrier mode	Standard	Extended
Capacity	24.1Mbit/s	36.1Mbit/s

We point out at the UK DVB-T example of the potential gain in capacity, which could be achieved in DTT network as shown on Table 1. DVB-T2 predicts the increase of the DTT system capacity of nearly 50% compared to the current UK mode of DVB-T. Besides the increased bit-rate, the proposed DVB-T2 mode would provide better QoS (Quality of Service). After UK DVB-T2 technical pilot, it was decided that in initial phase of project roll-out, the transmission mode will carry even higher bit rate (40.1 Mbps) but it is less robust and it provides smaller coverage area than 36.1 Mbps transmission.

The model of technology evaluation

The new technologies beside technical benefits, increased room for new services and higher speed for accessing them, bring also higher prices of equipment needed for achieving those benefits. The model presented in this paper estimates the cost of the broadcasting system which uses the latest technologies in two variants, MPEG-4/DVB-T and MPEG-4/DVB-T2, compare it with the cost of standard DTT system (MPEG-2/DVB-T), calculate the potential revenue from new services brought by new technologies and estimate break-even point where the revenue meet the level of invested capital in broadcast infrastructure.

Broadcast system cost estimation is based on the assumption that a distribution network is already in place and the calculation is performed for the case of broadcasting one TV package-multiplex. Distribution network is excluded from the model as its configuration can take numerous different topologies and technologies, and including all of them could lower the simplicity and flexibility of the universal model. The model treat only the TV broadcasting subsystem of the whole network assuming that the multiplex is transported from playout/headend center to transmitter location by existing infrastructure (Fig.1). As the distribution infrastructure in most cases really already exist and because distribution network don't affect directly the new broadcasting technology issues, the exclusion of this infrastructure doesn't lower the generality of the model. One part of the whole system, which is not included in the model, is end user receiver, Integrated Receiver Decoder (IRD). The intention of this research was to estimate the efficiency of the infrastructure that is owned by investor. The end user equipment in TV broadcast business is in many cases owned by citizens and doesn't affect profit/loss analysis in our scenario. If we would like to introduce the influence of IRDs in to the model by for instance, subsidizing new technology IRD for some categories of the population, this is a different scenario that is a subject for the further research.

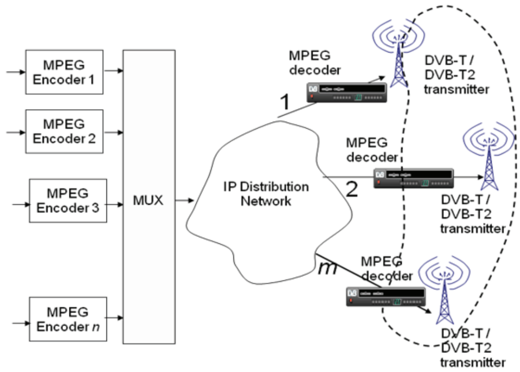

Fig. 1. Telecommunications network topology for broadcasting purposes

By definition, economic profit (*EP*) is equal to the difference of total revenue (*TR*) and total cost (*TC*)

$$EP = TR - TC, \quad (1)$$

where *TC* is regarded as a fixed cost including capital investment in equipment required for the DTT system and those expenses occur at the beginning of the project implementation. Variable cost as expenses that change in proportion to the activity of a business, are not included in *TC* because those expenses are typically not dependent on type of technology used. The model starts from the idea that *TC* can be estimated by using annual pricing data from sales records of most influential broadcast technology vendors. This is the way when a general estimation is required. If the estimation is needed for a particular project and in the case of known vendor, than concrete data from the project could be applied to the model for estimating system cost, generated revenue and profit/loss timing. On the other side, the revenue is collected within each time unit as leased capacity fee. The general diagram of contributions from the revenue and fixed cost shows the level of revenue/cost (in Euro) related to time units (Fig. 2). Before break-even point the revenue from services enabled by new technologies is lower than *TC* (loss) and after that point the profit is achieved.

As we want to estimate the economic efficiency of new technologies compared to current/standard DTT technology, we will calculate *TC* in this model as the cost difference of new and current system, and *TR* is the revenue gained from the usage of new technologies compared to current technology. Having on mind this approach, TC is calculated by the following formula

$$TC = \Delta HeadEnd + \Delta Transmitter, \quad (2)$$

where Δ *HeadEnd* and Δ *Transmitter* are the cost differences of the headend and transmitter equipment (differences between the latest technology equipment and standard DTT). As mentioned earlier, the latest technologies appear in two variants, MPEG-4/DVB-T (we will denote it as **Case 1**) and MPEG-4/DVB-T2 (**Case 2**), and we compare them with the cost of standard DTT system (MPEG-2/DVB-T) assuming the same number of TV channels (*n*) per one multiplex.

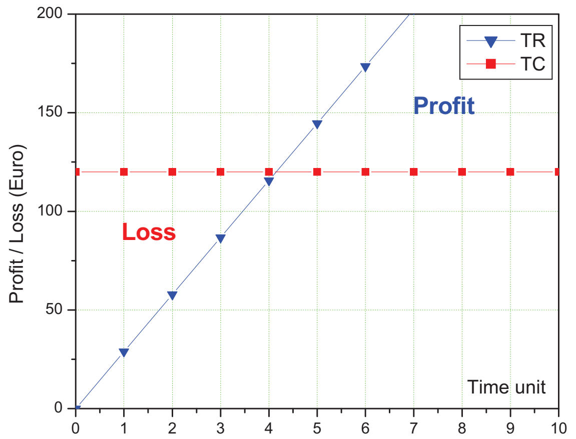

Fig. 2. Break-even point in profit/loss analysis

Case 1:

$$\Delta HeadEnd = n \times Cencmpg4 + + MUX - (n \times Cencmpg2 + MUX) = = n \times (Cencmpg4 - Cencmpg2), \quad (3)$$

$$\Delta Transmitter = m \times (Cdecmpg4 + Cdvbt) - m \times \times (Cdecmpg2 + Cdvbt) = = m \times (Cdecmpg4 - Cdecmpg2). \quad (4)$$

Case 2:

$$\Delta HeadEnd = n \times Cencmpg4 + MUX - (n \times \times Cencmpg2 + MUX) = = n \times (Cencmpg4 - Cencmpg2), \quad (5)$$

$$\Delta Transmitter = m \times (Cdecmpg4 + Cdvbt2) - m \times \times (Cdecmpg2 + Cdvbt), \quad (6)$$

where *n* – number of SD TV programs per multiplex; *Cencmpg2* – cost of MPEG-2 encoder; *Cencmpg4* – cost of MPEG-4 encoder; *MUX* – cost of the multiplexer; *m* – number of transmitter sites; *Cdecmpg2* – cost of MPEG-2 decoder; *Cdecmpg4* – cost of MPEG-4 decoder; *Cdvbt* – cost of DVB-T transmitter; *Cdvbt2* – cost of DVB-T2 transmitter.

Except the variable *n*, all other are independent variables. Variable *n* depend on transmission mode/profile which gives system useful bit-rate (*UBR*) and depend on the bit rate of one compressed TV program

$$n = UBRdvbt/MPG2SD, \quad (7)$$

where *UBRdvbt* refers to Useful Bit Rate for DVB-T equivalent profile (input data from DTT network planners) and *MPG2SD* is SD TV program MPEG-2 bit rate (input defined by content provider). After dividing, we need to round this ratio to the nearest integer. This is the number of TV programs for standard current DTT system. As in this model we calculate efficiency within ONE MULTIPLEX/TRANSMISSION CHANNEL, we apply the same number of TV programs (*n*) to new technology variants and calculate how much more of the capacity (in Mbps) left (within ONE MULTIPLEX/TRANSMISSION CHANNEL) due to more or less efficient technology in terms of required bit rate for achieving the same QoS, compared to standard technology. That calculated capacity in Mbps we will denote as *advanced digital dividend* (variable *a*) and can be calculated as follows.

Case 1

$$a = UBRdvbt - n \times MPG4SD - (UBRdvbt - n \times \times MPG2SD). \quad (8)$$

Case 2

$$a = UBRdvbt2 - n \times MPG4SD - (UBRdvbt - n \times \times MPG2SD), \quad (9)$$

where *UBRdvbt2* is Useful Bit Rate for DVB-T2 chosen profile (input data from DTT network planners) and *MPG4SD* is SD TV program MPEG-4 bit rate (input defined by content provider).

If the network operator invest in broadcasting infrastructure, that operator can benefit from the spare capacity *a* gained by using new technologies. That benefit is the revenue from leasing capacity *a* from DVB system to other interested parties (for instance to service providers) using the pricing model of wholesale Internet access, which is the bandwidth sold to Internet service providers and content companies. It makes sense to apply the same pricing model because the subscription fee for today known DVB data services (DVB-H, mobile TV or data access) is similar like subscription fee for Internet access, so the wholesale pricing is similar as well. If the DTT operator using DVB system offers IP-datacasting-like-service capacity within very attractive frequency band (VHF/UHF) with the introduction of mobility and interactivity (DVB-H, DVB-NGH, return channel using GPRS/3G), that capacity price per Mbps can easily even overcome the current wholesale Internet access prices.

Now we can calculate *TR* as

$$TR = a \times REV \times Y \times 12, \quad (10)$$

where variable *REV* is new pay-service wholesale monthly price per Mbps and *Y* is the number of years for which *TR* is calculated.

From this calculation we can easily find out the break-even point, i.e., the period from which the investment becomes profitable. *TC* is given by (2) and has constant value over time, while *TR*, given by (10) is linear function of time (Fig. 2).

There are two observed limitations in the model, it assumes constant fee per time unit (month/year) and it assumes that the capacity available (traffic capacity) is equal to the capacity sold.

In order to remove those limitations we updated formula (10) and now we calculate *TR* as:

$$REV_1 = REV, \tag{11}$$

$$REV_i = 0.7 \times REV_{i-1}, \tag{12}$$

$$TR = REV \times 12 \times D + \sum_{i=2}^{Y} REV_i \times 12 \times D. \tag{13}$$

If $Y \times D \geq a$, then we calculate *TR* as

$$TR = REV \times 12 \times D + \sum_{i=2}^{i_k-1} REV_i \times 12 \times D +$$

$$+ \sum_{i=i_k}^{Y} REV_i \times 12 \times a, \tag{14}$$

where i_k is the first integer which fulfill inequality $i_k \geq a/D$.

Variable *D* represent annual capacity demand in Mbps of service provider which buys DVB capacity.

First, if we assume there is an evolution of broadband subscription over time, we can use as a source OECD Organization and their Broadband Portal. If we analyse data from that source, we can conclude that for the countries of similar size as Serbia, which recently have had transition to market economy system and deregulation of telecom market, the compound annual growth rate of broadband subscription is around -30% over time (2005-2008). That means each year subscription fee drops by 30%. This is why in formula (12) we calculate next year revenue as 70% of the previous year revenue.

Second, if we assume that advanced digital dividend is not sold at once (the capacity available is NOT equal to the capacity sold) then we calculate total revenue gradually like it is done in formula (13). If the available capacity is sold before the end of the calculation period *Y*, we apply formula (14).

Simulation results: an application to the Serbian case

Except the input data that are provided by DTT network planners and content providers, the key variables for the model are cost of the equipment (appropriate encoders, decoders, multiplexers, and transmitters). In order to apply the model to the real broadcast industry, the authors selected source of data according to their best knowledge of influential vendors in this field and according to level of vendor willingness to cooperate on this research. For above-mentioned equipment, valuable information has gotten from Serbian local representatives of Rohde & Schwarz, Tandberg Television and Harris Corporation. The variable *REV*, as explained earlier, takes the pricing model of wholesale Internet access and data source is OECD Organization.

This section estimates the *TC* and *TR* of the network operator, following the process described in the previous section. Regarding *TR*, in this section we applied formula (10), not formulas (11) – (14) which define *TR* of the general model. Doing this we got simulation results for the special case, with constant revenue over time and that the whole available spare capacity is sold at once. Of course, we could also apply the general model to this example of the Serbian broadcast industry market. Cost of the equipment is taken from the current price lists for the technologies right now available within the appropriate equipment. For the other input variables for the model described, we have taken the values that match to the market in Serbia but they can apply to some other country with similar size, technical requirements and economic power. Those variables take the following values: *MPG2SD* = 5 Mbps; *MPG4SD* = 2.5 Mbps; *UBRdvbt* = 24.1 Mbps (DVB-T configuration Table 1); *UBRdvbt2* = 40.1 Mbps (UK DVB-T2 configuration); *m* = 12 (approximate number of main transmitter sites of public service broadcaster in Serbia, different national broadcasters in Serbia own different number of transmitters); *REV* = 100 Euro (broadband wholesale price per Mbps access for Serbia [5]).

The current DVB-T Pilot Project in Serbia uses the configuration with Carrier number 8K and Guard Interval ¼ [6]. The rest is the same as in Table 1. If we use 8K mode, for the simulation purpose it is justified instead ¼ to use Guard Interval 1/32 (duration of 28 μs that is four times longer than in the UK), and change from ¼ to 1/32 increase bit rate for more than 4 Mbps. As the change of Carrier number from 2K to 8K do not affect useful bit rate, we can use the same *UBRdvbt* value from Table 1 for DVB-T (UK parameters) as well as for Serbian case.

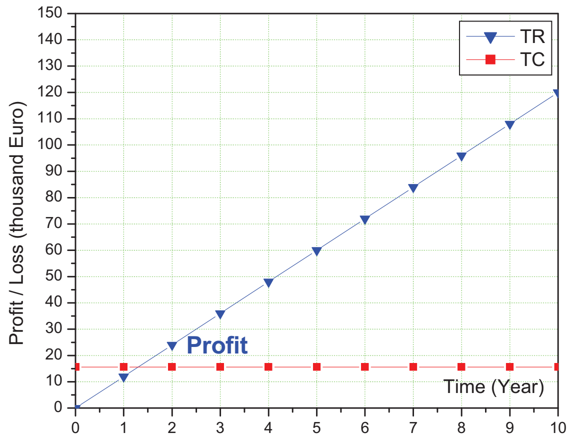

Fig. 3. Profit/loss analysis for Case 1: MPEG-4/DVB-T vs. MPEG-2/DVB-T

When we apply the model to the Serbian Case 1 with listed values for the appropriate variables, we get the diagram showing break-even point (Fig. 3). It could be seen that in the Case 1 the break-even point is reached after period slightly longer than one year from the network and service launch date. The number of SD TV programs per multiplex is 4 and the advanced digital dividend capacity *a* is 10 Mbps.

The Case 1 diagram changes after applying the model to the Serbian Case 2 with listed values for the appropriate variables. It could be seen that in the Case 2 the break-even point is reached after less than two and a half years from the network and service launch date (Fig. 4). The number of SD TV programs per multiplex is again 4 but the advanced digital dividend capacity *a* now increased up to 26 Mbps.

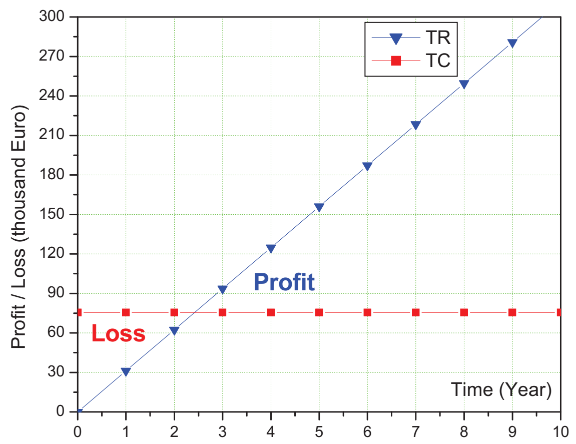

Fig. 4. Profit/loss analysis for Case 2: MPEG-4/DVB-T2 vs. MPEG-2/DVB-T

Analyzing the results of profit/loss calculations for Serbian Cases 1 and 2, we can conclude the following:

Case 1: The difference of compared technologies is only in encoding system (the transmission system is the same - DVB-T). Given the very small cost difference, the choice of MPEG-4 compression would almost certainly be the best one, and there will be significant economies of scale in being able to carry more services compared with MPEG-2 only system. The revenue from more services reaches the increased investment (due to new technology) after around one year, so MPEG-2 compression system doesn't seem attractive in this comparison.

Case 2: When we introduce DVB-T2 technologies we see that cost difference is higher than in Case 1 but still the system reaches profitability after less than two and a half years (the service revenue is gained from more efficient MPEG-4 and 50% more services that allow DVB-T2 compared to DVB-T).

After the discussion above it seems that MPEG-2/DVB-T technology combination cannot be any more easily justified for using in DTT networks. It is now reasonable to compare directly MPEG-4/DVB-T2 vs. MPEG-4/DVB-T, which we did, using the same set of parameters for input variables (Fig. 5).

The number of SD TV programs per multiplex in both systems is now 9 (one full DVB-T multiplex with MPEG-4 compression), and in this case advanced digital dividend is 16 Mbps. The profitability is reached after three years and it makes sense to be longer than in Case 2 because now we compare new technologies where capacity benefits (and revenues) are not so high as it was when comparing them with previous generation technology. Of course, the choice should we use MPEG-4/DVB-T2 or MPEG-4/DVB-T depends primarily on plans for the investment funds and its allocation within a decade after the decision is made.

If we want to compare economic efficiency of technologies for more than one multiplex, we should first calculate the number of RF channels/multiplexes necessary for carrying specific number of TV programs [2] using the values of variables that we used in previous examples (Fig 6.). When we adapt our model of technology evaluation to multiple-multiplex broadcast system, and apply input variables in order to compare directly MPEG-4/DVB-T2 vs. MPEG-4/DVB-T, the conclusion is: if we go beyond 9 TV programs for national coverage then *even without revenue* the new technology (MPEG-4/DVB-T2) is profitable from the day one after deployment because when we use new technology we need less capacity, in fact less RF channels and appropriate equipment to fulfill the same requirement for the number of TV programs (Fig. 6). This is not true only for the cases of 17 and 18 TV programs as then for both technologies we need the same number of multiplexes (two) and the profitability is achieved like with one multiplex (after three years).

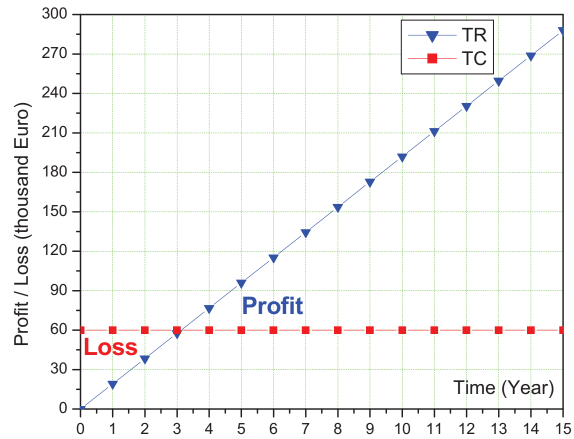

Fig. 5. Profit/loss analysis for MPEG-4/DVB-T2 vs. MPEG-4/DVB-T

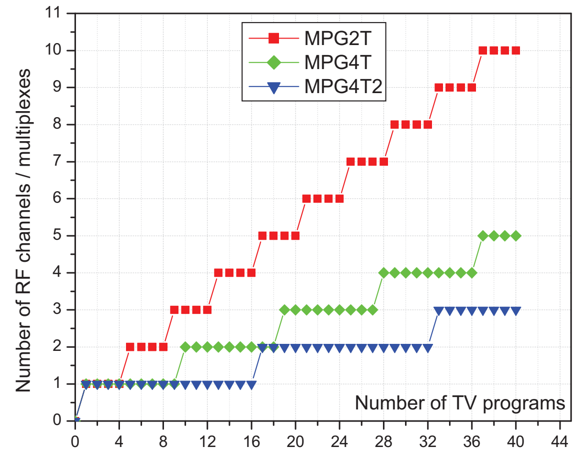

Fig. 6. How numbers of RF channels depend on number of TV programs using different technologies

Conclusions

This paper analyses the technical parameters for deploying the latest broadcast technologies and proposes a model that evaluates the economic efficiency of the latest broadcast technologies (MPEG-4/DVB-T and MPEG-4/DVB-T2). The proposed model is simple and flexible, but it is also very useful for estimating economic efficiency of technology and for short-term decisions. This break-even analysis can be an initial calculation that precedes more detailed cost-profit analysis. More detailed analysis could include much profitable new service (e. g. PayTV) than Internet wholesale which is used in our model, and with, for instance, PayTV the profitability for the same period could be achieved for the whole investment, not for cost difference case only (like we used in our model), but this research is the subject for the further studies.

The model is applied to the Serbian broadcast market. If MPEG-4 and DVB-T2 standards are used, the results from simulation show that the broadcast network profitability could be achieved: in less than three years for one multiplex system or immediately for multiple-multiplex system.

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An estimation method of system cost, associated revenue and estimated profitability that applies to the broadcasting standards used in digital terrestrial networks is presented. The purpose of this research is to support and promote the adoption of innovative technologies that improve spectrum efficiency and flexible usage. The model presented should help key players to make choice on digital terrestrial broadcasting technologies driven by optimal investment cost and the techno-economic analysis. The results clearly show the early (in realistic multiple-multiplex cases even immediate) profitability of broadcast network if MPEG-4 and DVB-T2 standards are used. Ill. 6, bibl. 6, tabl. 1 (in English; abstracts in English and Lithuanian).

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Šio tyrimo tikslas yra remti ir skatinti inovatyvias technologijas, leidžiančias padidinti spektro efektyvumą ir naudojimo lankstumą. Siūlomas metodas paremtas optimaliomis investicijomis ir technine ekonomine analize, turi padėti įvertinti ir pasirinkti skaitmeninio antžeminio transliavimo technologijas. Nustatyta, kad efektas bus akivaizdus, jei bus transliuojama vienu metu taikant MPEG-4 ir DVB-T2 standartus. Il. 6, bibl. 6, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).