V Feasibility Study of a sensor network for digital TV quality monitoring

INTRODUCTION

The process of switchover of electronic media in the Republic of Serbia from analog to digital terrestrial broadcasting was carried out in accordance with the DVB-T2 standard and using MPEG-4 video compression method. The basic strategic document for the switchover from analog to digital television signal broadcasting, „Strategy for switchover from analog to digital radio and television program broadcasting in the Republic of Serbia", [1], of 2009, was adopted by the then competent Ministry of Telecommunications and Information Society. In the document, all the necessary requirements for switchover to digital terrestrial broadcasting, among which the most important being: application of the DVB-T2 standard, MPEG-4 (H.264 AVC) video compression method and use of broadcasting signal network by SFN (*Single Frequency Network*) allotment areas, were defined. Additionally, it was decided not to use radio-frequency (RF) channels from 57 to 69 within the digital terrestrial television broadcasting system, so that they could subsequently be used for digital dividend purposes.

Based on subsequently elaborated design documents and regulatory frame established by the Governemnt of the Republic of Serbia, Ministry responsible for the area of telecommunications and information, Republic Agency for Electronic Communications and Postal Services (RATEL) and Republic Broadcasting Agency (RRA), the first phase of TV broadcasting digitalization proces via the network of terrestrial broadcasting transmitters in the Republic of Serbia started with the establishment of an initial network put in operation on March 21, 2012. The initial network consisted of 15 locations in total (13 transmitter locations and 2 repeater locations) and was constructed by the Public Enterprise „Broadcasting Technique and Links" Belgrade (hereinafter: PE BTL), entrusted with the broadcasting infrastructure management in the Republic of Serbia. Pursuant to the public authorization awarded by the Government of the Republic of Serbia, the PE BTL acts as, among other, an authorized system operator for Digital Terrestrial Television Broadcasting (DTTB) in the Republic of Serbia.

Within the process of the DTTB system development in the Republic of Serbia, frequency planning for digital broadcasting was carried out in accordance with the provisions of an international agreement adopted at the ITU Regional Conference on Radio-Communications held in Geneva in 2006 (RRC-06) and an adopted international Allotment Plan for the radio-frequencies for digital terrestrial transmission of radio and TV program (so-called GE06 Digital Broadcasting Plan). Formally, this document, under the name „Final Acts of the Regional Conference on Radio-Communications for Planning of Digital Terrestrial Broadcasting Service in Parts of Regions 1 and 3, in frequency bands 174-230 MHz and 470-862 MHz (RRC-06)", was duly ratified by the National Assembly of the Republic of Serbia, [2].

After the construction of the initial network covering the territory with approximately 40% of the population in Serbia, a further development of the TV network continued. This network, according to the publicly available data on the PE BTL web site, now consists of more than 200 transmitter and repeater locations, [3]. According to the officially published data (by the PE BTL), the population coverage of 97.82%, 96.77% and 96.03% in the Republic

of Serbia was achieved, with the required quality level, for the first multiplex (MUX1), second multiplex (MUX2) and third multiplex (MUX3) signals, respectively, [3].

Based on the previously described process of switchover from analogue to digital terrestrial TV program broadcasting, for each of the three mentioned multiplexes specific quality levels in their respective provision areas have been achieved. The initial planning followed by TV program distribution transmitter network optimization were to enable the fulfillment of requirements prescribed by the „Rulebook on switchover from analogue to digital terrestrial TV program broadcasting and access to multiplex“ of 2014, [4], proposed by RATEL and adopted by the Ministry of Trade, Tourism and Telecommunications (MTTT). That being said, all the necessary requirements for the beginning of activities pertaining to maintenance and improvement of the achieved quality level of the DTTB system reception signal in the provision areas, as well as the QoS harmonization are presently fulfilled. This also means that the DTTB system reception signal, from the time point of view, should be maintained on an approximately constant quality level, equable in all areas, independently of atmospheric and other conditions.

Still, the above activities can ensure an efficient and reliable monitoring of the reception signal quality of DTTB systems in Serbia, only in the periods of time when measurements of essential signal parameters are carried out, and within specific locations on the territory of the Republic of Serbia – representing virtually small percentage of the zone of provision at a certain time. On the other hand, the use of specialized software tools (those which are available to RATEL) enables quality assesment within the limits of mathematical models accuracy. Beside the above mentioned and taking into account the current technical equipment and structure of employees in the Monitoring Section of RATEL's Electronic Communications Department, where the mentioned activities are carried out, including the multitude of business activities being performed at the moment, intensive and frequent quality measurement campaigns regarding the reception signal quality of DTTB systems in the overall area of provision are unfortunately not possible.

A reliable and continuous monitoring of the reception signal quality of DTTB systems in the Republic of Serbia, which should reveal, identify and record occasional, periodical or rare events that decrease the quality of the DTTB reception signal in specific periods of time and parts of the provision area, could be realized through stationary network of remote-controlled measurement receivers (probes and sensors). Particularly, by using the above network for digital TV quality monitoring enabling reception and measurement of important DTTB signal parameters on a larger number of locations, a representative sample for quality and DTTB system operations validity would be generated at every moment on the entire or majority of the provision area. This would ensure a continuous insight into the current state of receiver network and into the validity of its operations. Implementation of this type of monitoring system would make it possible to detect and record even brief, short-time changes in the DTTB system quality and by means of analysis of the gathered data possibly the causes of these changes. This would enable the use of documented indices regarding inhomogeneous, volatile or deteriorated DTTB system quality in specific time periods and/ or parts of the planned area of provision, and would also improve the quality of DTTB system operations on the territory of the Republic of Serbia, since the DTTB system operator's work (the PE BTL being the only broadcaster) would be contiuously monitored. Additional positive effects of the implementation of such a system could be realized in cooperation with the PE BTL, by highlighting possible causes of detected negative events based on statistical and

comparative analysis of the gathered measurement data, and their removal by the PE BTL. Besides, the application of the DTTB system quality monitoring, developed on the basis of such sensor network, enables continuous gathering and analysis of all necessary data potentially indicative of specific errors in the DTTB system design in certain parts of provision area. All of this contributes to a better maintenance, harmonization and improvement of the currently achieved level of signal reception in parts or the entirety of the provision area.

The above mentioned possible improvements of the DTTB system service quality in Serbia represent basic reasons for elaboraion of this *Feasibility Study of a sensor network for digital TV quality monitoring* (hereinafter: Study). In the process, the Study should define, among other, the work concept and main characteristics of the technical solution regarding complexity, configuration and spacing of the sensor network serving as a monitoring system. Additionally, the subject of the Study includes the problem of defining basic necessary parameters of digital TV signals whose reception and measurement are to be performed, as well as the necessary technical features of measurement devices and accompanying measurement stations' installations and other components in the planned system for the DTTB system signal monitoring.

Practical realization of the quality monitoring DTTB system on the entire area of provision, covering virtually 90% up to 98% of the territory of the Republic of Serbia – depending on the observed multiplex – requires installation of a specific number of stationary *Fixed Remote Controlled Measuring Stations* (FRCMS). These measuring stations need to be equipped with appropriate measuring devices and other equipment enabling internal system networking. This system's operations additionally imply establishment of a centre for collection, storage and processing of measurement data and an FRCMS operations management centre, as well as establishment and permanent maintenance of a communication link network for communication between the FRCMS and management centre.

Realization of such monitoring system can be percieved as a need for an accurate continuous collection of current data on the reception quality in local areas where service users are situated (i.e. in populated areas, virtually on the entire state territory). In this case, bulk installation of sensors, capable of similar signal reception as end users, with variable spacing density (DVB-T2 signal measuring receivers) on end users' facilities should be performed. This way, we could benefit from a sensor network with an extremely big number of sensors (FRCMS), distributed over the entire territory and connected to the management centre for the purpose of activity monitoring and provision of measured values.

On the other hand, realization of the monitoring system can also be seen as a necessity to monitor the operation of transmitters, whereby the transmitter operation disturbances possibly causing degradation of the reception quality in the service area would be detected. Such a solution requires installation of a specific number of measurement stations, equipped with measuring and communications devices for system networking, enabling monitoring of all or of specific DTTB network transmitter sets. The above described manner of realization of the system implies considerably lower number of measurement stations compared to the previous solution, therefore this type of monitoring system realization is particularly analyzed in this Study.

In the process of analysis and decision making regarding the design of DTTB quality monitoring system operations, it should be taken into acoount that installation of big

number of measurment stations requires substantial capital investments, including expected significant operational costs due to a long necessary exploitation and maintenance of such a system.

Therefore, in accordance with the Project task, this Study will assess economic and social construction justifiability of the monitoring system, consisting of a management center and a *Fixed Remote Controlled Measuring Stations* network (FRCMS) and performing continious tracking and monitoring of the digital television signal quality, i.e. existing DTTB system's QoS, on the territory of the Republic of Serbia. Obviously, since the assessment of the economic cost effectiveness and social justifiability significantly depends on the assessment of the investment value, as well as on other economic and financial aspects linked to the system construction realization project, one of the objectives of this Study must include the definition and consideration of possible monitoring system variants (referring to the two previously defined concepts), which would be examined from the point of view of an optimal ratio between expected investments and possible (realistic) post-realization system performances, i.e. gains obtained if the system is applied, based on the continuous DTTB system quality monitoring in Serbia.

In line with the defined purpose and objectives of the Study, the subject of the Study includes the definition of the concept solution for the DTTB system quality monitoring on the territory of the Republic of Serbia based on the network of fixed remote controlled measuring stations, whereby it shall be necessary, in accordance with the nature of the designed solution and requirements of the Project task, to include:

- overview of features and different realizations of similar solutions in the region and throughout Europe, as well as experiences regarding the effects of the implementation of such systems on the improvement and maintenance of the DTTB system quality;
- overview, description of technical features and possibilities, application requirements, available hardware and software solutions for related system components on the national and European market;
- definition of the basic operation concept, monitoring system configuration and components and technical requirements for measuring station components on typical measurement location, as well as basic technical requirements for the management centre software and hardware;
- definition of DVB-T2 signal parameter sets that need to be measured, measurement periodicity and definition of limit values based on which operation malfunctions or deterioration of the DTTB system QoS can be detected;
- proposition of the operations organization, processing of measurement data and presentation of the obtained results, as well as the necessity to store these results, accompanied by an assessment of the required management centre memory capacity;
- definition of basic technical requirements for realization of communications links between the measuring stations and management centre;
- description and general spacing of measurement locations, whereby the data from the Frequency allotment plan for terrestrial digital TV broadcasting stations and RATEL's database on the RF spectrum usage are taken as entry data for the analysis; and

- proposition and dynamics of the system realization, along with assessment of the amount and structure of the system realization costs and maintenance costs.

CONCLUSION

The process of switchover of electronic media in the Republic of Serbia from analog to digital terrestrial broadcasting was carried out in accordance with the DVB-T2 standard. Formally, the process of analogue to digital broadcasting switchover was completed on May 15, 2015. So far, a TV transmitter network with more than 200 transmitter and repeater locations has been constructed. According to the data published by the PE BTL, the sole authorized DTTB system operator in the Republic of Serbia, this network accounts for 97.82%, 96.77% and 96.03% of the population coverage within the required quality level, for the first multiplex (MUX1), second multiplex (MUX2) and third multiplex (MUX3) signals respectively. That being said, the current basic preconditions for the beginning of activities pertaining to maintenance and improvement of the achieved quality level of the DTTB system reception signal in areas of provision, as well as service quality harmonization are met.

It should be noted that the terrestrial TV digital broadcasting system, managed by the PE BTL, is the only system of this type on the territory of the Republic of Serbia. This means that the great majority of population can only receive local TV programs through this system, or possibly by using satellite TV receivers. This is particularly the case in rural areas, smaller urban settlements, but also in parts of larger cities with no adequate telecommunications infrastructure, i.e. functional CDS, xDSL or optical access network. The terrestrial TV digital broadcasting system in Serbia has a very important social role, since it fulfills the needs and rights of citizens to be timely and reliably informed, including other significant aspects of public availability and importance of television service. Therefore, the maintenance and improvement of the quality of this system's signal reception as well as an even QoS of this system on the whole national territory represent a general social interest.

In accordance with its legal obligations and authorization, and in line with the Law on Electronic Communications („Official Gazette of RS" Nos. 44/2010 and 62/2014), RATEL carries out activities pertaining to RF spectrum monitoring, including, among other, control and establishment of area of coverage and wireless electronic communications service quality control, and performs other tasks from this domain defined in the Law and relevant bylaws. At this moment, RATEL performs its entrusted tasks of monitoring of accomplished DTTB network radio coverage and quality of provided service, by periodical measurements on part of the territory, the analysis of the results obtained by coverage prediction using software tools and by regular technical control of the DTTB system transmitters.

On the other hand, a reliable and continuous DTTB system quality control on the territory of the Republic of Serbia can be performed by constructing a stationary network of remote-controlled sensors (measurement receivers). By using such network, in cooperation with the PE BTL, preconditions for continuous gathering and analysis of all necessary data potentially indicative of specific errors in the DTTB system design in certain parts of provision area would be fulfilled, and conditions for maintenance, alignment and improvement of the

currently achieved quality level on the whole territory of the Republic of Serbia would be created. The DTTB system is relatively new in Serbia and, based on the current experience, it has provided a very reliable quality of service, reflected in the relatively small number of citizens' complaints. However, during its long time exploitation, problems can expected, such as quality of service deterioration due to obsolescence and failure of the transmitter network components, failure or discrepancy in operations within the distribution network, or possible decreased system maintenance investments. For that reason, the development of a system enabling continuous monitoring of DTTB system operations quality would make possible for an external control to enable permanent, reliable and quality provision of the extremely important digital TV service in the following period, in conditions of no market competition in this area. Therefore, there is certain social justifiability in the development of the sensor network based system for digital TV quality monitoring. On the other hand, since no big challenges regarding the existing DTTB network QoS have been recorded so far, and taking into account relatively scarce presence of the DTTB system for continuos quality monitoring in the surrounding countries, the construction of such a non-profitable system must not require too much investment, meaning that the system needs to be economically justified as well.

For the mentioned reasons, an analysis in this Study was carried out and a proposition on digital TV quality monitoring technical solution was adopted, comprsing of 10 stationary remote-controlled measuring stations (sensors) and one management centre. In the proposed system, with the aim of developing an economically justified solution, the stationary measuring stations (sensors) are to be deployed on already built and prepared Investor's monitoring and measurement station locations for RF spectrum monitoring (which are planned and will be constructed independently of this study's system for continuous monitoring of DTTB quality). This decreases significantly the costs of system construction, since resolution of legal ownership issues, installation of antenna poles, provision of electric power supply and air conditioning is not necessary, nor the establishment of a separate transmission system for connecting the sensor network with the management centre. Additionally, the Investor would have significantly less operational costs if the system is run on a long-term basis. Therefore, in the proposed technical solution, total capital investment for the system construction is basically is dedicated to the procurement of measuring devices and equipment, with ceratin equipment installation costs. The system is designed in such a way that the Investor's primary system's (RF spectrum monitoring system) performances are in no way compromised. By adopting a relatively small number of measuring stations, continuous monitoring of all DVB-T2 signal transmitters with effective radiated power above 3 kW is enabled and coverage of the majority of the national territory is achieved, with the proposed solution requiring only a reasonably small investment. Furthermore, extention of the set of monitored DVB-T2 signal transmitters to the transmitters of lower power would challenge the economic justifiability of the solution, causing a manyfold greater investment, with relatively small increase of the territory share covered by the set of monitored transmitters. For that reason, the system for digital TV quality control has been upgraded with two portable measuring stations that can be used for periodical or *ad hoc* QoS control in the areas covered by lower-power transmitters, or alternatively these measuring stations can be used for monitoring and identification of the achieved coverage quality level and provided service in case of complaint. That way, a solution has been set up, with efficient performance and minimum investment costs required for the system construction and maintenance.

The plan is to realize the project of sensor network for digital television quality monitoring in 2 phases, in the duration of 12 months each (total 2 years). The total capital investment for implementation of the DTTB quality continuous monitoring system in the amount of 206,000 EUR has been foreseen. In the Study, an overview of capital investments per implementation phases and corresponding resources is given, including an overview of all operational costs for network maintenace, projected for a future ten-year period.

The construction of sensor network for digital television quality monitoring is a non-profit, socially responsible investment project in the network endowed with a purpose to enable transparent monitoring of the broadcasted digital TV signal quality on the territory of the Republic of Serbia. The considered Project for digital TV quality monitoring sensor network construction is one of the projects with the strategic goal to protect the quality of impemented telecommunications networks and services and to provide adequate service quality and availability for the users on the territory of the Republic of Serbia. The core of the project is to enable active participation of RATEL in this process and its full commitment in this strategic area, in accordance with RATEL's legal obligations. An efficient project realization through a successful performance of measuring activities, as well as duly and active informing and notifying the digital TV transmitter network operators, will contribute to the good reputation of RATEL in public, as an institution responsibly conducting its business operations, while paying special attention to citizens. In the initial phase, with only one digital TV provider present in the market, QoS monitoring is important in order to offer to the citizens a service of quality and long-time consistency provided on an appropriate territorial share. In case of an increase of potential number of service providers, the constructed sensor network can be used for comparative quality analysis of digital TV signals belonging to different operators.

From the financial aspect of the project's value assessment, it should be noted that even though the project, by its nature, does not yield any operating profits, its value, from the accounting point of view, is reflected in the balance sheet as increased inalienable intangible gains boosting the agency's market value. An improved reputation of RATEL, strengthened expertise of its employees, public trust, along with cooperation in the domain of broadcasting digital TV signal quality measurement and monitoring, contribute all together to the increase of RATEL's significance. These inalienable intangible assets have a strategic importance for the agency's future business operations and its success at the national and international level.