Extend geographical area of single frequency network configuration for DVB-T2 in Albania

Aleksandër Biberaj[1,*], Enida Sheme[2], Sonila Xhaferllari[1], Olimpjon Shurdi[1], Alban Rakipi[1], Elson Agastra[1]

[1]*Department of Electronics and Telecommunication, Faculty of Information Technology, Polytechnic University of Tirana, Bulevardi "Dëshmorët e Kombit", Sheshi "Nënë Tereza"4, 1001, Tirana, Albania*

[2]*Department of Informatic Engineering, Faculty of Information Technology, Polytechnic University of Tirana, Sheshi Nënë Tereza 1, 1004, Tirana, Albania*

***Abstract*—Digital dividend and UHF frequency are changing daily from broadcast television to mobile communication, changes that needs to coordinate all over the Europe. The necessity of higher spectrum efficiency is a mandatory requirement for designing terrestrial digital video broadcasting servicing. In this context, extending higher servicing area in a single frequency network configuration, remains one of the most important goals for the spectrum efficiency for TV broadcasting. In our research paper we try to analyze four different DVB-T2 modulator configurations for margining two existing SFN's (which are using two frequency channels) to a new one, extended SFN by comprising both existing areas and a single frequency channel. The goal in the analyzed case is to reduce at minimum physical network change as transmitting antenna sites, antenna radiation pattern, transmitter radiated power for both allotments, in order not to increase the cost and not to decrease the quality of service. The proposed analysis is not limited only in strengthening the received signal in the new SFN but ensuring as well the signal quality. Self-interfering definitions have been described and simulated for the real test case in Albanian allotments. The proposed solutions show the applicability of the designing method for extending the SFN area also beyond the theoretical permitted by Guard Interval choice.**

Keywords - Digital Dividend (DD), Large SFN, Second Generation of Terrestrial Digital Video Broadcasting (DVB-T2), Single Frequency Network (SFN).

I. INTRODUCTION

Terrestrial Digital Video Broadcasting in its second generation (DVB-T2) was firstly drafted as a standard in 2006 and first test implementations started in 2008. One of the biggest advantages of the DVB-T2 is spectrum efficiency usage respect to the analog television or to the DVB-T (first generation). Due to the scarcity of the available spectrum, higher efficiency techniques are required to be implemented. Now a days, with the push of mobile communications and of 5G network solutions soon and the required higher bandwidth all over the world, international coordination bodies as ITU (International Telecommunication Union) and CEPT (European Conference of Postal and Telecommunications Administrations) have successfully coordinated in collaboration with local authorities the Digital Dividend Process [1] for releasing frequency bands 790-862 MHz from TV usage to mobile usage [2][3]. This process in Albania was concluded in January 2021.

Due to the higher demand for spectrum, also, ITU and CEPT are globally coordinating in European countries the second process of digital dividend (DD2) to also release the frequency band of 694-790 MHz [4] form television to mobile use. Due to the first digital dividend process and converting from analog to digital television [5], the Albanian territory is configured as 11 SFN (Single Frequency Network) each with different frequency channels (see Fig. 1). Also, in all the allotments are performing 7 national multiplexers, each in different UHF channels in the same allotment. Due to the need of DD2 process, other UHF channels, in use, need to be released. This process results in augmented stress for technical designing the same network capacity with reduced spectrum resource [6].

One of the attempts to release spectrum without reducing broadcasting TV capacity, is to use the same frequencies in larger areas designing bigger SFN's configurations [7][8][9].

Designing larger SFN configurations in DVB-T2, despite there are more parameters that can be configured than in DVB-T, not always can be obtained the same quality of signal coverage than in smaller SFN areas. Due to a greater distance between transmitters and a larger number of transmitters than in small SFN, an increased probability of self-interfering is noticed [cite] which cannot be easily avoided.

This work is preliminary study according to the DD2 agenda for Albanian territory to release CH53 used in allotment AL005D area. The propose is to use instead of CH53, CH28 which is used in the next confining allotment AL007D (see Fig.1).

This is a first attempt to extend an existing SFN area to a bigger one as outlined in Table I. In this design, reducing at minimum modifications on existing transmitter sites as antenna design or transmitter power are considered as to reduce, if possible, investment cost for the operator in response to DD2 frequency release.

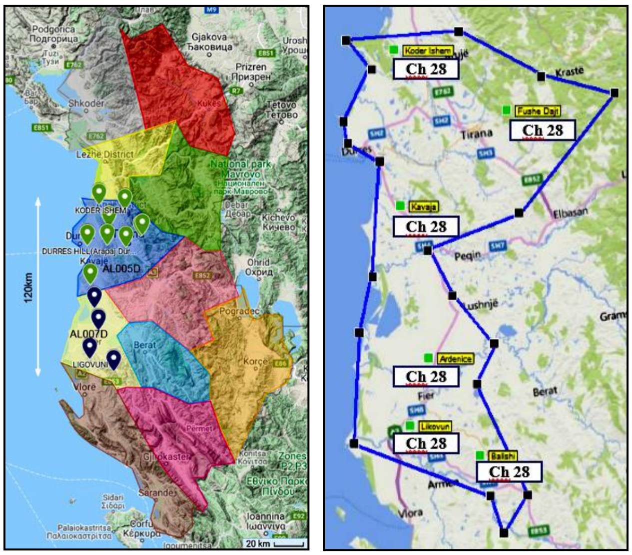
In this work, DVB-T2 modulator parameters as Guard Interval (GI), Pilot Pattern (PP) and Forward Error Correction (FEC) will be analyzed for received signal quality over the new proposed SFN area [10][11]. To better explain design SFN quality, the self interfering will be described and analyzed

Manuscript received December 07, 2022; accepted January 12, 2023.
*Corresponding author: abiberaj@fti.edu.al

for proposed solutions. At the end, some conclusions will be outlined regarding larger DVB-T2 SFN design.

TABLE I. EXISTING AND PROPOSED ALLOTMENT DIMENSIONS

Allotment	AL005D Tirana	AL007D Fier	Proposal
Perimeter (km)	230	192	386
Area (km^2)	2600	1800	4400
Extension South – North (km)	56	57	120
Extension East – West (km)	68	35	68
Tx – Tx max distance (km)	43	42	105



(a) Actual (b) Proposed

Fig. 1. SFN configuration and transmitter location in Albania: (a) AL005D, Ch 53 (green placemark) and AL007D, Ch 28 (Blue placemark); (b) proposed solution as single SFN on Ch 28.

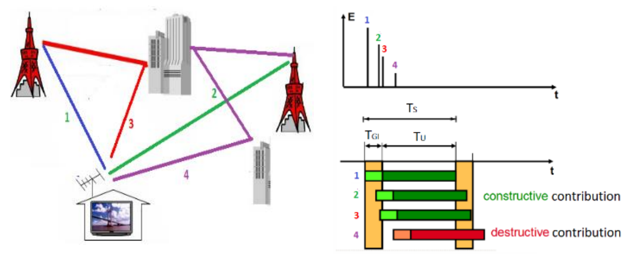
II. METHODOLOGY

Network coverage design is not an easy task as the number of parameters to be optimized is limited, but their combinations are limitless. As a test case, terrestrial Digital Broadcast Television configuration parameters are shown in Table II. To those signal parameters, for real implementation, additional configurations are required as antenna type, transmitter power and static delay of each transmitter [12].

Due to theoretically exceptionally large combinations of parameters, is impossible to make a network design without an automated simulation tool, where obviously, some constraints must be defined as to have practical and implementable solutions.

TABLE II. DVB-T/T2/H TRANSMITTER PARAMETERS

System	Pilot Pattern	RF Channel Bandwidth (MHz)	OFDM Mode	Guard Interval	Carrier Modulation	Forward Error Correction
DVB-T	PP1	1.7	1k	1/4	QPSK	1/2
DVB-H	PP2	5	2k	19/128	16QAM	3/5
DVB-T2	PP3	6	4k	1/8	64QAM	2/3
	PP4	7	8k	19/256	256QAM	3/4
	PP5	8	8k-ext	1/16		4/5
	PP6	10	16k	1/32	Hierarchically (DVB-T):	5/6
	PP7		16k-ext	1/128	QPSK in 16QAM	7/8
	PP8		32k		QPSK in 64QAM	
			32k-ext			



(a) (b)

Fig. 2. Multiple signals at receiver in SFN configuration: (a) SFN multipath & multiple transmitters; (b) multiple signals (echo's) at receiver

In this work, DVB-T2 configuration variations are considered only for three parameters: Pilot Pattern (PP), Guard Interval (GI) and Forward Error Correction (FEC). If necessary, the possibility of adding new transmitter sites as gap filler will be considered too.

Antenna site's locations, radiation pattern and transmitters power are maintained the same as the actual configuration of two existing SFN-s.

Pilot Pattern and Guard Interval choice are sensitive parameter in DVB-T2 network design and deploy. Receiver capabilities to equalize multiple received signals (echo's) is related to Pilots and guard interval choice. Greater GI, greater is the Equalization Interval (EI) or equalization window capable of constructively combining multiple received signals with different phase and time delay at receiver site [12]. In Fig. 2 is shown schematically the Echo and guard interval meaning.

Neglecting other interference sources, the equivalent total available C/(N+I) (Carrier to Noise + Interference ratio) in each location can be determined by Equation (1).

$$
\begin{aligned}
C &= \sum_i w_i C_i \\
I &= \sum_i (1-w_i) C_i
\end{aligned}
\tag{1}
$$

Where the relative weighting function is given in Equation (2) and shown in Fig. 3 [13]:

$$w_i = \begin{cases} 0 & if \quad t \notin EI \\ \left(\dfrac{T_u + t}{T_u}\right)^2 & if \quad t \in EI \,\&\, t < 0 \\ 1 & if \quad t \in EI \,\&\, 0 \le t \le T_g \\ \left(\dfrac{\left(T_u + T_g\right) - t}{T_u}\right)^2 & if \quad t \in EI \,\&\, t > T_g \end{cases} \qquad (2)$$

Where:

C_i : power contribution from the i^{ts} signal at the receiver input
C : total power of the effective useful signal
I : total effective interfering power
w_i : weighting coefficient for the i^{ts} component
T_u : useful symbol length
T_g : guard interval length
T : signal arrival time relative to the beginning of the FFT window
EI : equalization interval during which signals can be correctly equalized and therefore usefully contribute
T_p : length of the equalization interval EI

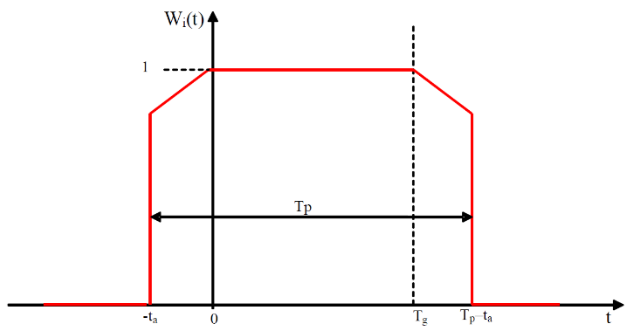


Fig. 3. Receiver weigting function for DVB-T2 signal equalization.

Due to the combination (constructively or destructively) of multiple copies of the same signal, is important to note that the equalization window is a time interval chosen time by time by the receiver (decoder) and is a logical function of the pilot pattern and guard interval choice.

For this purpose, in designing a coverage analysis of DVB-T2, is not sufficient to evaluate only received field strength by the receiver as shown in equation (3) and based in ITU-R P.1546 model [14][15][16][17].

This model is used in the simulation of coverage to evaluate the total field strength at each receiver location as function of all transmitters in the designed area.

$$E_{min} = P_{min} - A_a + L_f + 120 + 10\log_{10}(120\pi) \qquad (3)$$

Where:

E_{min} : Equivalent minimum field strength at receiving place [dBμV/m]
P_{min} : Minimum receiver input power [dBW]
A_a : Effective antenna aperture [dBm^2] [A_a = G_{iso} + $10\log_{10}(\lambda^2/4\pi)$]. G_{iso} is the antenna gain relative to an isotropic antenna measured in dB.
L_f : Feeder loss [dB]

Using only the ITU-R recommendation P.1546 only a partial view of coverage analysis can be done, because, as introduced in this paragraph, knowing only received filed strength is not sufficient to define coverage quality as can be better explained using C/(N+I) definition with regarding to multiple echo's [12].

Both equalization interval formulation and ITU-R P.1546 model are combined in ATDI - HTZ communications software for simulation and analysis of this work [18]. In Fig. 4 is shown a configuration window of the chosen analysis software.

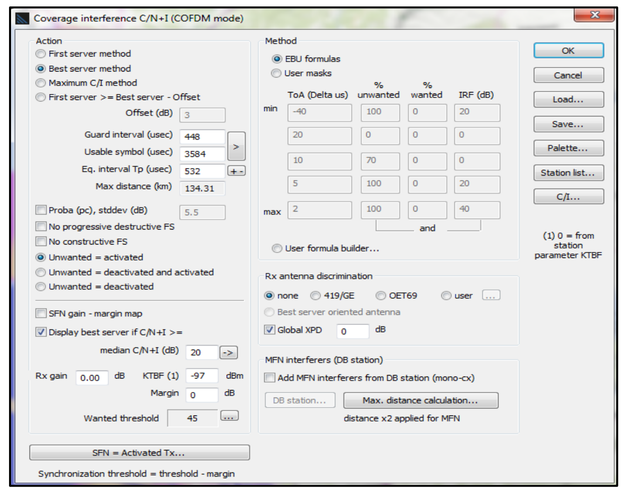


Fig. 4. Software configuration for Case 4 as example.

III. RESULTS

The goal of creating a new Single Frequency Network area in DVB-T2 configuration in Albania, which will extend to cover two different existing SFN's is a must for Albanian broadcast providers as due to the international coordination and the evolution of 5G network, frequency channels above ch50 (694 MHz) need to be released for mobile communication [4].

This new configuration has a result of a better spectrum efficiency as for serving the same area, less frequency spectrum is used. The extended SFN area increases the stress on DVB-T2 network design as bigger SFN's configurations means higher possibilities of self-interfering signals on receiver locations. There are several attempts in scientific literature to address different issues in SFN design without a unique and optimal solution [19][20][21][22].

The analysis provided in this work is based on the actual network capacity of 33 Mbps in two local SFN areas. The goal in this new configuration is to maintain at least this network capacity or improve it, but not making it worse, by decreasing the existing coverage quality.

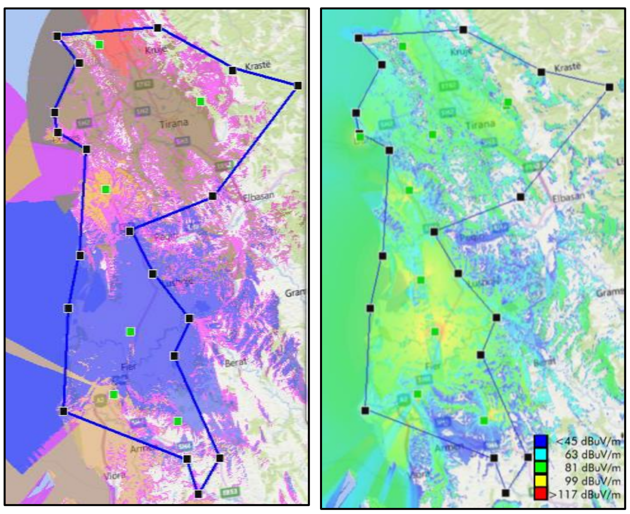
During the optimization process, part of DVB-T2 modulator parameters is set as: 8MHz channel bandwidth, channel 28 (530 MHz of central frequency); 32k-ext for the

OFDM mode and 256QAM carrier modulation. The variable parameters changes are highlighted in Table III.

TABLE III. TEST CASE PARAMETERS CHOICE

Test case	Case 1	Case 2	Case 3	Case 4
Pilot Pattern	PP2	**PP4**	PP2	PP2
Guard Interval	19/256	19/256	19/256	**1/8**
Forward Error Correction	2/3	2/3	**3/4**	2/3

Coverage of the entire area has been performed for all the four cases using ITU-R P.1546-5 model. Coverage area of each transmitter is presented in Fig. 5a and the best compressive coverage from all the transmitters are shown in Fig. 5b.



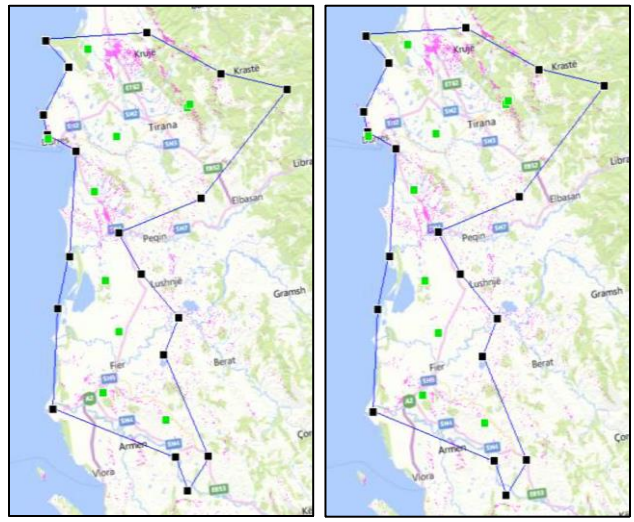
(a) TX coverage (b) Overall coverage

Fig. 5. Alotment coverage: (a) Coverage area from each transmitter (different colour); (b) Overall Electrical Field strength from the best transmitter in each area.

Received field strength, still beyond the minimum required for each configuration, in Fig. 6 and Fig. 7 are shown mutual interference between transmitters as given in equation (1). This also confirms the insufficient of ITU-R P.1546-5 model for quality DVB-T2 network design.

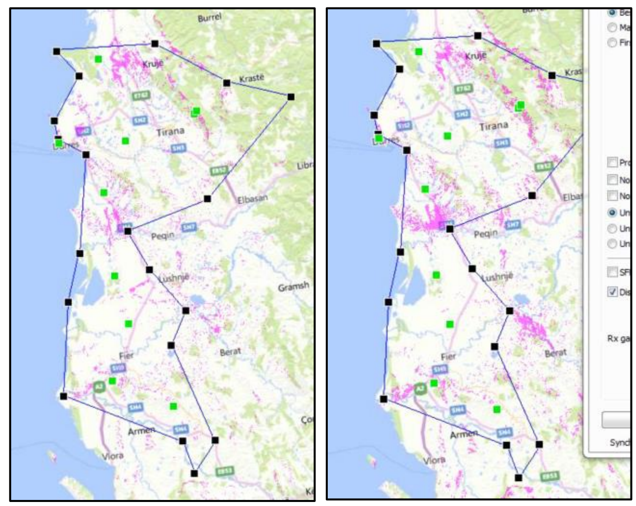
Fig. 6 and Fig. 7 shows intersymbol interferences for test cases and parameter combinations as presented in Table III.

The new proposed SFN configurations has maximum transmitter – transmitter distance of 105 km. This distance is higher than theoretical maximum allowed for the first three combinations proposed of 79.8 km for GI = 19/256 and is in the maximum allowed range of 134.4 km for GI = 1/8 [CITE]. This limitation, in the proposed design can be overcome due to the geographic relief of the designed area (valley, hills, mountains) where mutual interference can partially be avoided.



(a) Case 1 (b) Case 2

Fig. 6. ISI analysis for: (a) Case 1: FEC = 2/3, GI = 19/256, pilot = PP2; (b) Case 2: FEC = 2/3, GI = 19/256, pilot = PP4



(a) Case 3 (b) Case 4

Fig. 7. ISI analysis for: (a) Case 3: FEC = 3/4, GI = 19/256, pilot = PP2; (b) Case 4: FEC = 2/3, GI = 1/8, pilot = PP2.

Analyzing the ISI area extension, but also analyzing them with the actual populated area, higher ISI is observed for the fourth configuration (Fig. 7b) referred to the other three configurations.

The best trade-off solutions chosen among the four proposed is the second one, where the required minimum C/N ratio of 18.3dB is like the first case but permits an increased data rate of 1.6 Mbps more with the same intra transmitter distance. Case 3 can be a valid solution but requires a higher C/N ratio which will result in higher areas with less coverage or will require a higher transmitted power for the same coverage.

Case four, despite it natively permits bigger SFN's area and bigger distance transmitter to transmitter, requires higher efforts on defining static transmitters delay to carefully avoid or change the ISI area in less populated region.

Simulated results are resumed in the Table IV where there is a comparison of Case 2, Case 3 and Case 4 with the Case 1, which is the actual configuration of the existing two SFN's.

TABLE IV. TEST CASE PARAMETERS CHOICE

	Case 1	Case 2	Case 3	Case 4
Rician C/N (dB)	18.2	18.3	20.6	18.2
Required transmitted power, variations referred to Case 1	–	+1%	+74%	0%
Data rate (Mbps)	35	36.6	37.6	33.4
Data rate variations to Case 1	–	+4.6%	+7.3%	–4.6%

Using DVB-T2 configuration as on case 3, a higher transmitter power of more than 2.3 dB is required to obtain the same coverage area with the same C/N ratio as in case 2. This configuration will require e transmitted power for each site 70% higher than the second case just to increase bit rate with just 1 Mbps (2.3 % higher)

In this work, as shown in Table III and mathematical analysis performed in the previous paragraph, three parameters are being considered as variable: Pilot Pattern, Guard Interval and FEC.

IV. CONCLUSIONS AND RECOMMENDATION

In this research paper is presented the possibility of increasing a SFN area on DVB-T2 network in Albanian territory. Despite theoretical limitations on transmitter distance for various GI choices, carefully combining pilot patterns, Guard Interval, Forward Error Correction code and static delay for each transmitter parameters, larger SFN's can be realized beyond the theoretical one.

To carefully simulate and analyze RF signal coverage and received signal quality, is necessary to use proper simulation tools, which must be capable for analyzing the strength of radio frequency field, as well as modulations and self-interferences on OFDM modulation techniques.

For DVB-T2 configurations, using higher order pilot patterns also permits a better knowledge of propagation channel and a better echo equalization at receiver site, but also this result in a reduced data rate.

Increasing GI value also increases the equalization window, and helpfully will reduce intersymbol interference (ISI), but also this reduces the data rate too.

Higher values for FEC ratio, increases data rate but there is less information for receiver to recover lost or interfered data, this combination requires higher carrier to noise ratio and consecutively, higher transmitted power.

Audio-Visual Media Authority (AMA), together with Authority of Electronic and Postal Communications (AEPC), which are regulatory authorities in Albania, and both depends on the Albanian Parliament and supposed to be independent agencies, must take into consideration and to maintain such problems as they are responsible for the frequency specter management.

All recommendation coming from International Telecommunication Union (ITU) and European Broadcasting Union (EBU) needs to be implemented in Albania by AMA, AEPC and all operators (broad casting and telecommunication) regarding frequency specter management.

All the operators must avoid the conflict of interest among them self and the regulatory authorities must play their key role in this very specific market, by avoiding the political interference and protecting the customer interest by ensuring the public information as European citizens.

REFERENCES

[1] J. Doeven, P. Walop, E. Zilles, J. Guitot and S. Ripley, "ITU Report. Digital Dividend. Insights for spectrum decisions", 2012.

[2] L. Polak, O. Kaller, L. Klozar, M. Slanina, J. Sebesta and T. Kratochvil, "Coexistence Between DVB-T/T2 and LTE Standards in Common Frequency Bands," Wireless Personal Communication, Vol. 88, Nr. 3, pp 669–684, 2016.

[3] A. Tekovic, D. Bonefacic, G. Sisul and R. Nad, "Interference analysis between mobile radio and digital terrestrial television in the digital dividend spectrum," Radioengineering, Vol. 26, No. 1, pp. 211-220, 2017.

[4] B. Kamo, E. Agastra, Sh. Cakaj, "DVB-T2 Radio Frequency Signal Observation and Parameter Correlation," International Journal of Advanced Computer Science and Applications (IJACSA), Vol.11, No. 6, pp. 132 – 136, September 2020, ISSN: 2156-5570.

[5] N. Subodh, D. Q. Thang, T. Higashino and M. Okada, "Nationwide radio coverage prediction and optimization for DVB-T2 in Nepal," Proc. IEEE Broadcast Symp. (BTS), pp. 1-4, 2018.

[6] S. Nepal, D. Q. Thang, T. Higashino and M. Okada, "Optimization of Multi-Frequency Network With DVB-T2 Services for Regions With Complex Geographies: A Case Study of Nepal," in IEEE Transactions on Broadcasting, vol. 67, no. 1, pp. 299-312, March 2021.

[7] M. Lanza, A.L. Gutiérrez, I. Barriuso, J.R. Pérez, M. Domingo, L. Valle, J. Basterrechea, J. Morgade, and P. Angueira , "Coverage optimization in single frequency networks using simulated annealing," IEEE International Symposium on Antennas and Propagation (APSURSI), Spokane, USA, pp. 2789- 2792, 2011.

[8] I. Eizmendi, G. Prieto, G. Berjon-Eriz, I. Landa and M. Velez, "Empirical DVB-T2 Thresholds for Fixed Reception," in IEEE Transactions on Broadcasting, vol. 59, no. 2, pp. 306-316, June 2013.

[9] B. Ruckveratham and S. Promwong, "Empirical single frequency network threshold for DVB-T2 based on laboratory experiments" Turkish Journal of Electrical Engineering & Computer Sciences, pp: 3342 – 3355, 2019.

[10] M. Anedda, A. Anedda and M. Murroni, "Coverage optimization for DVB-T2 SFNs using ITU-R P.1546 and ITU-R P.1812," 2015 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, pp. 1-5, Ghent, 2015.

[11] P. Keawbunsong and S. Promwong, "Comparison study on path loss model for DVB-T2 propagation in urban area," 2015 IEEE Conference on Antenna Measurements & Applications (CAMA), pp. 1-4, Chiang Mai, 2015.

[12] B. Ruckveratham and S. Promwong, "Performance evaluation of DVBT2 propagation for fixed reception," 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), pp. 1-5, Chiang Mai, 2016.

[13] A. Martian, M. Dambeanu, C. Oprea, C. Vladeanu and I. Marghescu, "DVB-T2 radio coverage analysis in Romania", 25th Telecommunication Forum (TELFOR), pp. 1-4, Belgrade, 2017.

[14] M. Slimani et al., "Results of the DVB-T2 Field Trial in Germany," in IEEE Transactions on Broadcasting, vol. 61, no. 2, pp. 177-194, June 2015.

[15] S. Jeon, S. Kim, J.-D. Kim, et. al., "Field Trial Results of 4K-UHD over DVB-T2 Single Frequency Network in Republic of Korea," 11th IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB 2016), Nara, Japan, June 2016.

[16] H. Bawab, P. Mary, J. Hlard, Y. Nasser, and O. Bazzi, “Spectral overlap optimization for DVB-T2 and LTE Coexistence”, IEEE Transactions on Broadcasting, vol. 64, no. 1, pp. 70-84, March 2018.