Coverage Estimation for Advanced Terrestrial Television ATSC 3.0

Fernanda Marinho Magalhães
Arismar Cerqueira Sodré Junior

CITE THIS ARTICLE
Magalhães, Fernanda Marinho Magalhães and Sodré Junior, Arismar Cerqueira; 2019. Coverage Estimation for Advanced Terrestrial Television ATSC 3.0. SET INTERNATIONAL JOURNAL OF BROADCAST ENGINEERING. ISSN Print: 2446-9246 ISSN Online: 2446-9432. doi: 10.18580/setijbe.2019.5. Web Link: http://dx.doi.org/10.18580/setijbe.2019.5

Coverage Estimation for Advanced Terrestrial Television – ATSC 3.0

Fernanda Marinho Magalhães [1] & Arismar Cerqueira Sodré Junior[2]

Summary - The ATSC 3.0 standard allows for the provision of new high data rate services, so it has been considered as a benchmark in television broadcasting technology worldwide. This paper presents a numerical study of coverage prediction using Progira software. Coverage is evaluated using ISDB-Tb and ATSC 3.0 digital terrestrial television standards in the cities of Santa Rita do Sapucaí-MG and São Paulo-SP.

Keywords — ATSC 3.0, ISDB-TB, Propagation, and TV

I. INTRODUCTION

The growing development of wireless technologies makes it necessary to ensure sufficient transmission capacity to provide various high-quality services. The improvement of multimedia content with the emergence of cutting-edge technologies such as 4K UHDTV or the new HEVC video encoding standard is pushing the limits of network capacity.

In the case of Digital Terrestrial Television (DTTV), the importance of improving spectral efficiency is critical to maintaining it as an attractive and competitive platform against cable or wireless solutions. The launch of television broadcast spectrum for the fourth generation of mobile broadband (4G) services in the 700 MHz band has limited the spectrum dedicated to terrestrial broadcasting. Therefore, TDT enhancement involves an improvement in spectral efficiency.

As such, recent digital television standards are focused on improving these two aspects of broadcasting, such as ATSC 3.0. This standard was developed by the Advanced Television Systems Committee and considers rates of 50 Mb/s, in order to receive the best definition content available today and have great flexibility depending on the desired service.

Additionally new transmission techniques have been developed, in particular different multiplexing modes for digital television networks. Layered Division Multiplexing (LDM) allows the allocation of fixed and mobile services divided into energy. Channel Bonding enables the use of two independent RF channels for a single data stream. ATSC 3.0 provides for the use of 2x2 Multiple Input Multiple Output (MIMO) with cross-polarization antennas [1]. This paper reports simulations performed on Progira software, which runs on the ArcGis geoprocessing platform [2], to assess the coverage of the new ATSC 3.0 digital television system.

II. ATSC 3.0

ATSC 3.0 is the new Terrestrial Digital Television standard developed by the Advanced Television Systems Committee (ATSC). This standard is based on Orthogonal Frequency Division Multiplexing (OFDM) and the use of Low Density Parity Check (LDPC) for low density parity checking. The physical layer implemented is aimed at greater robustness, flexibility and efficiency than previous standards due to the use of non-uniform constellations, LDPC codes and LDM.

The main parameters of an ATSC 3.0 transmission mode are:

- Bandwidth 6 to 8 MHz;
- FFT 8, 16 and 32K;
- Guard interval from 27.78 µsec to 703.70 µsec in twelve patterns;
- Scattered pilot frequency spacing: Normal or Dense are the values used;
- Scattered pilot time spacing - The values available are 2 or 4;
- Constellation size - The orders 4, 16, 64, 256, 1024 and 4096-QAM are defined;
- LDPC with 16200 or 64800 bit FEC internal code;
- LDPC code rate between 2/15 and 13/15;
- BCH: Bose,Ray-Chaudhuri and Hocquenghem FEC outer code used in the BICM module. ON y OFF are the options;
- Frame length of 100, 150, 200 or 250 ms.
- Typical LD injection level of -4dB [1].

ATSC 3.0 standardization features Order Two MIMO (MIMO 2x2) with cross-polarized technology. In other words, it is a technology in which two antennas are used, one vertically polarized and one horizontally polarized, both on the transmitter side and the receiver side. In addition, on the receiver side, two tuners are required to receive and decode the MIMO signal. In particular, this standard applies MIMO to make use of spatial diversity to minimize the effects of small and large scale fading, shading and path loss. Systems with spatial diversity can be splitted into four classes: SISO (Single Input Single Output); SIMO (Single Input Multiple Output); MISO (Multiple Input Single Output); MIMO (Multiply Input Multiply Output) [3].

ISDB-Tb was developed from the evolution of the Japanese ISDB-T (Integrated Services Digital Broadcasting Terrestrial) standard and was officially launched in Brazil in 2007. This

http://www.set.org.br/ijbe/ doi: 10.18580/setijbe.2019.5 Web Link: http://dx.doi.org/10.18580/setijbe.2019.5

system is flexible and designed to deliver high quality audio and high definition image for fixed and mobile reception. The transmission of digital terrestrial television service is divided into source coding, channel coding, OFDM modulation and broadcasting [4]. Table I presents a comparison between ISDB-Tb and ATSC 3.0 systems.

TABLE I
COMPARISON OVERVIEW BETWEEN ISDB-Tb E ATSC 3.0 [1] [4].

PARAMETERS	SYSTEM	
	ISDB-Tb	ATSC 3.0
Transport Protocol	TS	IP
Guard Range	1/4; 1/8; 1/16 e 1/32	3/512, 3/256, 1/64, 3/128, 1/32, 3/64, 1/16, 19/256, 3/32, 57.512, 3/16, 1/8, 19/128, 1/4
Video Compression	H.264	H.265
Audio Compression	MPEG-4 HE AAC	MPEG-H
Diversity	SISO	SISO;MISO;MIMO
Band	6; 7 ; 8 MHz	6; 7; 8 MHz
Internal decoder	CC: 1/2; 2/3; 3/4; 4/5; 5/6; 7/8	LDPC: {2,3,4,5,6,7,8,9,10,11,12,13}/15
Modulation	DQPSK, QPSK, 16-QAM, 64-QAM	QPSK, 2D-16NUC, 2D- 64NUC, 2D-256NUC, 1D- 1024NUC, 1D-4096NUC
Frame size	1632 bits	16200 e 64800 bits
External Decoder	RS(204,188,8)	BCH, CRC OU NENHUM
Rotated Constellation	`---	não
IFFT Size	2K; 4K; 8K	8K; 16K; 32K

III. PROGIRA SOFTWARE

Coverage prediction software should have a land and construction map to calculate the field strength of each pixel of the area of interest, taking into account diffraction, tropospheric dispersion, reflection, refraction, and land and construction entry loss.

In this study, the Progira coverage prediction software was used, which works on the ArcGis geoprocessing platform [2]. Fig. 1 reports the ISDB-T standard parameters, which were considered in the numerical simulations, including 64-QAM modulation, FEC 3/4, 10m reception antenna height and 10dBd reception antenna gain [5]. Fig. 2 shows the ATSC 3.0 system parameters, such as FFT of 32K, 4096-QAM modulation, 13/15 code rate and 28ms guard interval, which result in a rate of 55.25 Mb/s.

Progira software provides the most important propagation models in the literature: CRC – Predict, ITUR P.1546-5, ITUR GE06, ITUR P.370-7, ITUR P.526-13, ITUR P.1812-3, Deygout- Assisi, Longley-Rice and Okumura-Hata. The propagation model used in the simulations was the CRC-Predic, which implements calculation of the diffraction attenuation on the terrain and part of the loss caused by terrain reflections. The loss due to reflection is estimated using a clutter, which is a set of polygons with the region classification, such as degree of urbanization and vegetation. There is an attenuation value associated with each polygon class [6].

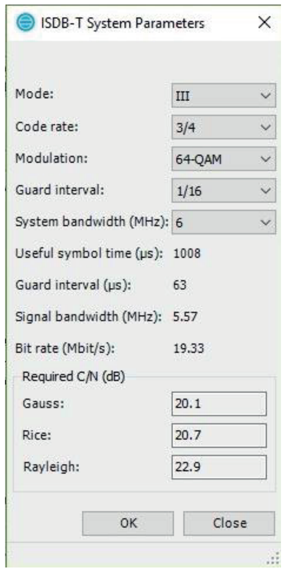


Fig. 1 - ISDB-TB Patterns used on simulation

The electric field intensity of television and retransmission stations using digital technology will be determined on the basis of Tables E (50,90), which correspond to field strength values exceeded in 50% of locations for 90% of the time, at distances from 1km to 1,000km from the irradiation center of a dipole antenna powered by 1kW of effective power [5]. The service area of a digital terrestrial television broadcast or retransmission station corresponds to the area bounded by the service contour, characterized by the values of electric field strength [5]. Finally, the software uses IBGE data to determine the population covered by the TV signal.

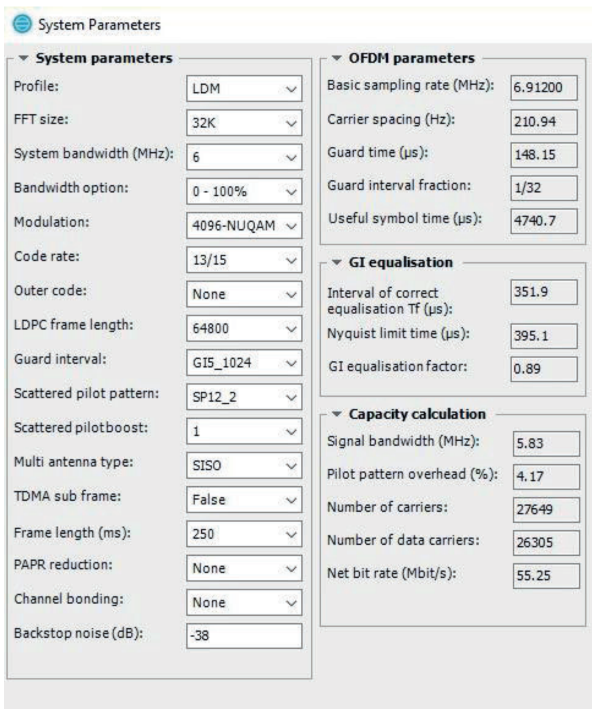


Fig. 2 - ATSC 3.0 Patterns used on simulation

IV. RESULTS

The cities Santa Rita do Sapucaí-MG and São Paulo-SP were chosen for the study of Digital Terrestrial Television using ISDB-T and ATSC 3.0 standards, under the propagation conditions shown in Fig. 3 and Fig. 4, respectively. The specifications of each of the city broadcasting sites are described in Tab. II.

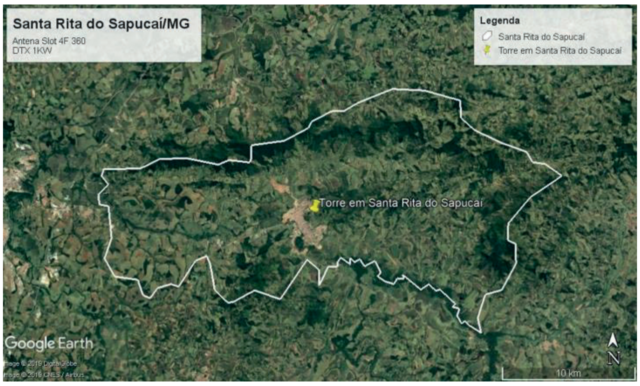


Fig. 3 – Map of Santa Rita do Sapucaí-MG, with the broadcast site identified with the yellow mark.

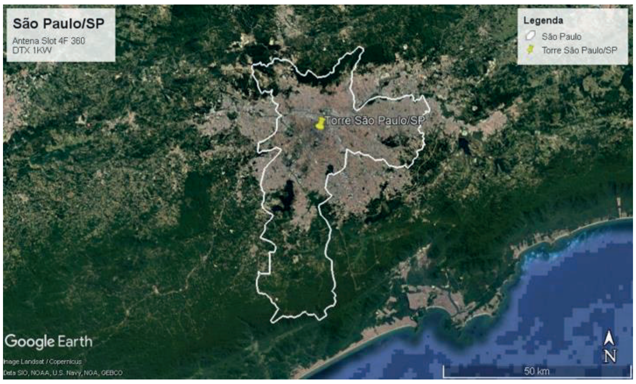


Fig. 4 – Map of São Paulo-SP, with the broadcast site identified with the yellow mark.

TABLE II
TECHNICAL SPECIFICATIONS OF SANTA RITA E SÃO PAULO SITES

LOCALIDADE / ESPECIFICAÇÕES		Sta Rita do Sapucaí/MG	São Paulo/SP
CANAL (UHF)		20	20
POTÊNCIA TRANSMISSOR DIGITAL		1KW	1KW
COORDENADAS DE INSTALAÇÃO	Latitude	22° 14' 36,74" S	23° 33' 43,43" S
	Longitude	45° 41' 53,26" W	46° 39' 13,94" W
SISTEMA IRRADIANTE	Tipo	Slot 4 Fendas omni	Slot 4 Fendas omni
	Polarização	Horizontal	Horizontal
	Ganho	7,6 dBd	7,6 dBd
	HCI	32 m	155 m
	Azimute	260° NV	140° NV
	Tilt	0°	0°
LINHA DE TRANSMISSÃO	Tipo	1 5/8"	1 5/8"
	Comprimento	37 m	80 m
	Atenuação	0,5701 dB/37m	1,2328 dB/80m
ERP (W)	Horizontal	4497,8	
	Vertical	---	

The ISDB-TB standard data used in the simulations are presented in Table III to provide a rate of 19.33 Mb/s for a signal-noise ratio (SNR) of 20.1 dB [7], as shown in the coverage map of Figure 5, considering fixed reception (10/0dBd) and a 51dBuV/m field. In this way, a population of about 167,566 inhabitants of the South of Minas Gerais, distributed in cities near Santa Rita Station, can be served, as reported in Table V. The results for the city of São Paulo are presented in Figure 6 and Table VI, which identifies a population served of 13,825,116 inhabitants.

TABLE III
PARAMETERS OF THE TRANSMISSION MODE USED
ISDB-T FIXED SERVICE

BAND	6 MHz
FEC	3/4
MODULATION	64-QAM
GUARD INTERVAL	1/16

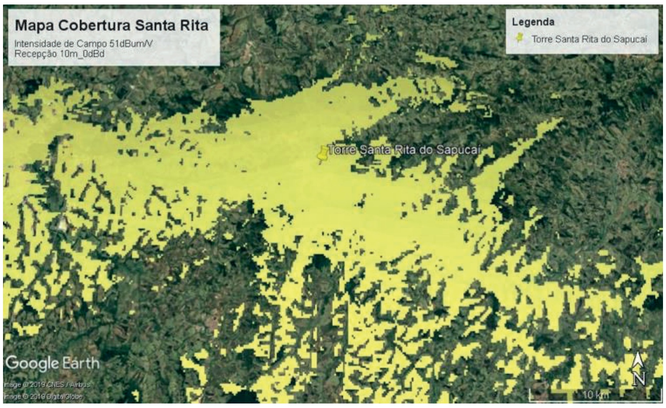


Fig. 5- Coverage Map on Santa Rita do Sapucaí-MG site considering fixed reception (10m / 0dBd) and field of 51dBuV / m.

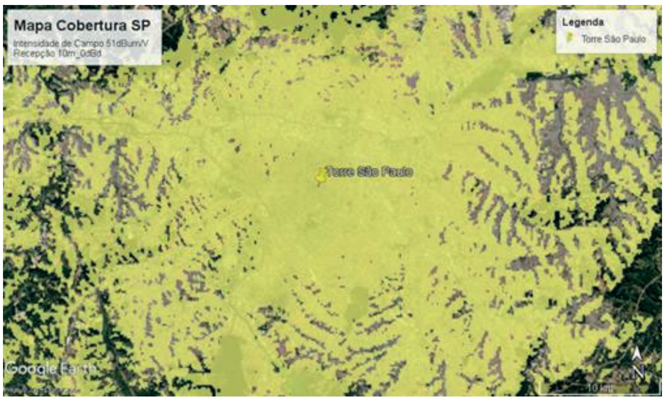


Fig. 6 – Coverage Map on São Paulo/SP site considering fixed reception (10m / 0dBd) and field of 51dBuV / m.

ATSC 3.0 coverage prediction simulations were also performed, according to the parameters of Table IV, using SISO.

TABLE IV

SET INTERNATIONAL JOURNAL OF BROADCAST ENGINEERING - SET IJBE V.5, 2019, Article 5, 6p.
2019 SET - Brazilian Society of Television Engineering / ISSN (Print): 2446-9246/ISSN (Online): 2446-9432

PARAMETERS OF THE TRANSMISSION MODE USED IN ATSC FIXED SERVICE 3.0

BW	6 MHz	QAM	1024
FFT	32K	LDPC	64800 bits
GI	148.148 µs	LDPC (Code Rate)	13/15
DX	Normal	BCH	ON
DY	2	Frame	200 ms

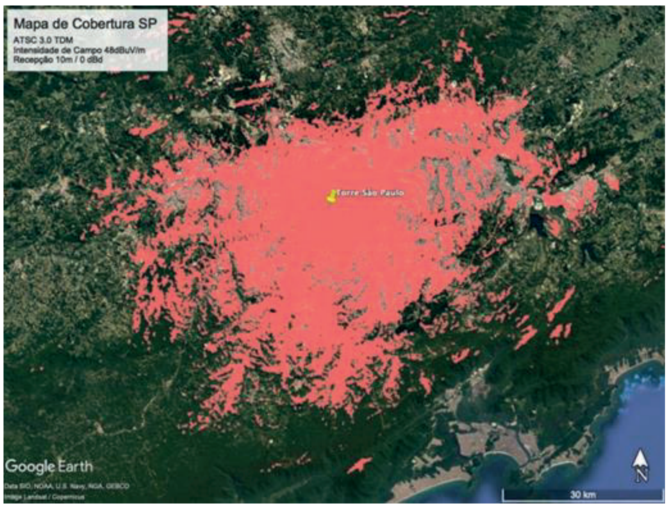
Thus, a rate of 45.64 Mb/s was obtained for SNR = 30.18 dB. Figure 7 and Table VII report the results for ATSC 3.0 with SISO, where a large coverage area with population served of 15,086,762 in habitants is observed.

TABLE V
POPULATION COVERED BY ISDB-Tb STANDARD IN SOUTH MINAS GERAIS

City	Total pop	Served Pop	Served Pop %
Santa Rita do Sapucaí	37.436	35.497	94,8
Pouso Alegre	129.581	108.784	84
São José do Alegre	3.989	2.959	74,2
Brasópolis	14.517	4.041	27,8
Piranguinho	7.976	2.095	26,3
Paraisópolis	19.262	3.472	18
Conceição dos Ouros	10.340	1.800	17,4
Cachoeira de Minas	10.970	1.153	10,5
Senador José Bento	1.865	135	7,2
Tocos do Moji	3.948	251	6,4
Itajubá	90.019	4.713	5,2
Wenceslau Braz	2.547	130	5,1
Gonçalves	4.194	176	4,2
Piranguçu	5.179	203	3,9
São Sebastião da Bela Vista	4.912	157	3,2
Borda da Mata	17.020	514	3
Pedralva	11.402	342	3
Córrego Do Bom Jesus	3.725	101	2,7
Delfim Moreira	7.943	172	2,2
Estiva	10.826	215	2
Bom Repouso	10.427	173	1,7
Maria Da Fé	14.156	151	1,1
Careaçu	6.254	57	0,9
Congonhal	10.361	85	0,8
Consolação	1.719	6	0,3
Inconfidentes	6.905	18	0,3
Natércia	4.611	14	0,3
Heliodora	6.094	10	0,2
Ipuiúna	9.444	19	0,2
Ouro Fino	31.370	61	0,2
Camanducaia	20.839	25	0,1
Cristina	10.146	14	0,1
Santa Rita De Caldas	8.975	10	0,1
Sapucaí-Mirim	6.227	7	0,1
Silvianópolis	5.985	6	0,1
TOTAL POPULATION COVERAGE		167.566	---

TABLE VI
SÃO PAULO SERVED POPULATION WITH THE ISDB-TB STANDARD.

City	Total pop	Served Pop	Served Pop %
São Paulo	11.206.957	8.855.507	79
Guarulhos	1.214.007	900.934	74,2
São Bernardo Do Campo	761.735	613.777	80,6
Santo André	673.645	555.901	82,5
Osasco	665.402	480.177	72,2
Diadema	385.513	291.872	75,7
Mauá	415.103	275.618	66,4
Carapicuíba	369.020	247.955	67,2
Taboão Da Serra	244.149	221.159	90,6
Embu	239.994	193.005	80,4
Itaquaquecetuba	321.384	176.120	54,8
Barueri	240.595	163.416	67,9
São Caetano do Sul	148.474	137.599	92,7
Mogi das Cruzes	386.517	119.933	31
Cotia	200.042	109.731	54,9
Itapecerica da Serra	149.039	83.229	55,8
Ferraz De Vasconcelos	168.016	73.524	43,8
Suzano	261.487	64.019	24,5
Itapevi	200.626	56.262	28
Jandira	108.283	50.623	46,8
Arujá	74.669	35.703	47,8
Ribeirão Pires	112.752	26.677	23,7
Embu-Guaçu	62.446	26.015	41,7
Santana De Parnaíba	108.747	25.084	23,1
Poá	105.779	22.045	20,8
Vargem Grande Paulista	42.806	8.622	20,1
Rio Grande Da Serra	43.776	3.148	7,2
São Roque	78.642	2.514	3,2
Mairiporã	80.615	1.634	2
Caieiras	86.352	1.534	1,8
Pirapora Do Bom Jesus	15.691	883	5,6
Cajamar	64.044	505	0,8
Nazaré Paulista	16.390	122	0,7
Franco Da Rocha	123.467	102	0,1
São Lourenço Da Serra	13.885	92	0,7
Araçariguama	16.920	40	0,2
Cabreúva	41.518	35	0,1
TOTAL POPULATION COVERAGE		13.825.116	---



http://www.set.org.br/ijbe/ doi: 10.18580/setijbe.2019.5 Web Link: http://dx.doi.org/10.18580/setijbe.2019.5

Fig. 7 - Coverage Map on São Paulo/SP site using ATSC 3.0 standard, TDM and SISO antenna.

TABLE VII
SÃO PAULO / SP SERVED POPULATION FOR ATSC 3.0

City	Total pop	Served Pop	Served Pop %
São Paulo	11.206.957	9.514.798	84,9
Guarulhos	1.214.007	997.592	82,2
São Bernardo Do Campo	761.735	656.091	86,1
Santo André	673.645	597.024	88,6
Osasco	665.402	530.961	79,8
Diadema	385.513	325.191	84,4
Mauá	415.103	304.855	73,4
Carapicuíba	369.020	277.651	75,2
Taboão Da Serra	244.149	231.842	95
Embu	239.994	207.728	86,6
Itaquaquecetuba	321.384	203.201	63,2
Barueri	240.595	184.884	76,8
Mogi Das Cruzes	386.517	166.551	43,1
São Caetano Do Sul	148.474	142.883	96,2
Cotia	200.042	123.987	62
Itapecerica Da Serra	149.039	98.126	65,8
Ferraz De Vasconcelos	168.016	90.152	53,7
Suzano	261.487	89.446	34,2
Itapevi	200.626	79.844	39,8
Jandira	108.283	63.517	58,7
Arujá	74.669	41.997	56,2
Ribeirão Pires	112.752	38.256	33,9
Embu-Guaçu	62.446	31.525	50,5
Santana De Parnaíba	108.747	30.595	28,1
Poá	105.779	28.954	27,4
Vargem Grande Paulista	42.806	10.792	25,2
Rio Grande Da Serra	43.776	7.695	17,6
São Roque	78.642	3.301	4,2
Mairiporã	80.615	2.348	2,9
Caieiras	86.352	2.048	2,4
Pirapora Do Bom Jesus	15.691	1.215	7,7
Cajamar	64.044	713	1,1
Jundiaí	368.998	241	0,1
Franco Da Rocha	123.467	219	0,2
Nazaré Paulista	16.390	164	1
São Lourenço Da Serra	13.885	158	1,1
Araçariguama	16.920	55	0,3
Biritiba-Mirim	28.541	55	0,2
Cabreúva	41.518	49	0,1
Salesópolis	15.580	27	0,2
Campos Do Jordão	47.289	25	0,1
Igaratá	8.799	6	0,1
TOTAL POPULATION COVERAGE		15.086.762	---

After numerous simulations, it was found that the coverage map and population served for MIMO mode was identical to SISO mode. We contacted Progira and they confirmed to us that the MIMO function is available in the software but is still in the implementation phase.

V. CONCLUSIONS

This work reported numerical coverage prediction simulations performed with the Progira software in the context of the cities of Santa Rita do Sapucaí-MG and São Paulo-SP. The simulations showed that the ATSC 3.0 system, compared to the ISDB-T, can deliver twice the usable rate for a 6MHz band, as well as greater coverage for both the city of Santa Rita do Sapucaí and São Paulo. Specifically, the ISDB-T standard obtained a rate of 19.33 Mb/s for SNR=20.1 dB, while for the ATSC 3.0 standard a rate of 45.64 Mb/s for SNR=30.18 dB.

For the ISDB-T standard, a population of about 167,566 inhabitants of Southern Minas Gerais, distributed in cities near Santa Rita do Sapucaí-MG station and 13.825,116 inhabitants distributed in cities near São Paulo-SP Station, can be served. For the ATSC 3.0 standard, in addition to the useful rate gain, a significant coverage gain was observed in cities near the São Paulo-SP Station that resulted in a population of 15.086,762 inhabitants.

VI. REFERENCES.

[1] Advanced Television Systems Committee. "ATSC Standard: Physical Layer Protocol (A/322). Doc. A/322:2106." Washington, D.C, USA, September 2016.

[2] ARCGIS. Online. Disponível em https://www.esri.com/en-us/arcgis/about-arcgis/overview, acesso em 28 de abril de 2019.

[3] G. Lorenzo Cifuentes “Coverage estimation for the next-generation digital terrestrial television standard atsc 3.0: ldm, channel bonding and mimo”, Universidade Politécnica de Valência.2016. unplushed.

[4] P. G. Esperante, C. Akamine, G. Bedicks Jr “Comparison of Terrestrial DTV Systems: isdb-tb and dvb-t2 in 6 mhz”, IEEE latin america transactions, volume 14, páginas 45 à 56, 2016.

[5] Ministério das Comunicações Gabinete do Ministro “Portaria nº 925, de 22 de agosto de 2014”, DOU de 27/08/2014 (nº 164, Seção 1, pág. 93).

[6] F. S. Silva, L. J. Matos, F. A. C. Peres, G. L Siqueira, “Coverage prediction models fitted to the signal measurements of digital TV in Brazilian cities”, 2013 SBMO/IEEE MTT-S International Microwave & Optoelectronics Conference (IMOC), 2013.

[7] ARIB STD-B31, Versão 1.6, traduzida para o inglês, 2005. Online. Disponível em: https://www.arib.or.jp/english/index.html, acesso em 28 de fevereiro de 2019.

Fernanda Marinho Magalhães is attending postgraduate course in Network and Telecommunications Engineering from INATEL. Graduated in Electrical Engineering from Nove de Julho University, graduated in Economics from UESC and Electronic Technician from CEFET / BA. Has been working in the area of television broadcasting for over 15 years, closely following the birth and implementation of the digital terrestrial TV standard in Brazil. Her topics of interest are broadband multimedia communications, digital broadcasting and communication systems engineering.

Arismar Cerqueira Sodré Junior has a Scholarship of CNPq 1D Research Productivity , holds a degree in Electrical Engineering from the Federal University of Bahia (2001), a Master's degree in Electrical Engineering from the State University of Campinas (2002), a Ph.D. in Telecommunications Engineering from Scuola Superiore Sant´ Anna - Italy and University of Bath - England (2006) and Post-Doctorate in Electrical Engineering from UNICAMP (2009). Currently works as Assistant Professor IV of Inatel. Arismar has 10 patents, 19 products transferred to industry and 223 articles published in international and national journals and congresses.

Received in 2019-07-15 | Approved in 2019-09-21

http://www.set.org.br/ijbe/ doi: 10.18580/setijbe.2019.5 Web Link: http://dx.doi.org/10.18580/setijbe.2019.5