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SUMMARY

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Current Issue **EDITORIAL**

Dear reader,

In the edition IJBE 2017, we continue presenting several articles that deal with the thematic of digital television. The topics covered include various aspects pertinent to the digital TV system from conception, transmission, performance, robustness, amplification and reception of signals. In this way, the ISDB-Tb system and the new ATSC 3.0 system are compared, as well as diversity in reception and antenna configurations for digital TV reception. An article deals with a Brazilian radio broadcasting system in time. Another image-processing article has been included to address audio-visual animation. Articles involving social aspects concerning the analog TV switch off and digital inclusion of the population were also included. An article that discusses the reasons for the failure of broadcasting using SFN provides a constructive debate.

Moreover, we would like to add that the activities and events organized by SET (Brazilian Society of Television Engineering) receive support from international organizations. We take this opportunity to thank these entities and reiterate our pride for the support given by them to our work.

Best wishes,

SET IJBE Staff

Comparison of Terrestrial DTV Systems: ISDB-TB and ATSC 3.0

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Comparison of Terrestrial DTV Systems: ISDB-T_B and ATSC 3.0

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***Abstract*—This review discusses the ISDB-T_B and ATSC 3.0 systems, comparing the differences between the Input Formatting, passing by video compression, data multiplexing and encapsulation, the Channel coding, Interleavers, Constellation Mappers, Multiplexing methods, Framing, Waveform generation and synchronism. Finally, a performance comparison, using similar parameters, between bitrate and required Carrier-to-Noise ratio is presented.**

***Index Terms*—Digital Terrestrial Television Broadcasting, Making Better use of spectrum, Next generation of broadcasting systems, ISDB-T, ATSC 3.0.**

I. Introduction

The Integrated Services Digital Broadcasting – Terrestrial version B (ISDB-T_B) system was officially launched in 2007, in Brazil. Throughout this time, the innovative technologies for Communications systems and new services that were developed are no longer compatible with the ISDB-T_B.

These modern technologies were created due to the new scenario the Communications systems are in, mainly provided by the internet, smartphones, image quality – Ultra High Definition (UHD) (4K and 8K) – and consequently increase of generated data. Processing this data so it can be transmitted within the limited bandwidth that broadcasters have is the goal of these technologies since part of the spectrum is being reclaimed for broadband wireless services by spectrum authorities [1].

The ISDB-T_B uses Reed Solomon (RS), Convolutional codes, modulation orders up to 64 constellation points in Quadrature Amplitude Modulation (QAM) and the video compression standard H.264. When compared to recent technologies, the ones used in ISDB-T_B does not support the scenario mentioned earlier [2].

The need to use the remaining spectrum more efficiently led the Advanced Television Systems Committee (ATSC) and other Standard Development Organizations (SDO) to start researches for new systems using the state-of-the-art technologies. In September 2016, the ATSC released the new system Physical Layer standard, called ATSC 3.0.

The system was adopted by South Korea, which started the transmissions in May 2017 [3].

ATSC 3.0 uses the state-of-the-art technologies to achieve the goal of efficient use of the spectrum such as the Low-Density Parity Check (LDPC) codes along with Bose, Ray-Chaudhuri, and Hocquenghem (BCH) codes, the non-uniform constellations (NUC), and the Layered Division Multiplexing (LDM) that provide a way to transmit different signals, separated by layers, at the same time and frequency [3], [4].

The Physical Layer Pipes (PLP) concept, introduced in the Digital Video Broadcasting - Terrestrial 2 (DVB-T2), is used in ATSC 3.0. Each PLP can be configured independently and it is possible to transmit two PLPs, one in each layer of the LDM.

The system also incorporates the video compression standard H.265, the Dynamic Adaptive Stream over Hyper-text Transfer Protocol (DASH) and the MPEG Media Transport (MMT) technologies [3], [4], [5].

This work presents a comparison between ATSC 3.0 and ISDB-T_B. The relevance of this study lies in research ATSC 3.0 so the technologies used in it can serve as a guide to the development of a new broadcast system for Brazil, considering the Analog Switch Off (ASO) that is happening in the country since 2016.

This review is organized in four sections: Section II presents the comparisons between the systems, Section III presents the comparisons between bitrate and required Carrier-to-Noise ratio (CNR), Section IV is the review's conclusion.

II. System Comparisons

A. Input Formatting

ISDB-T_B uses the Broadcast Transport Stream (BTS) as the system input. The BTS is created by the re-multiplexing of MPEG-2 TS from the source coding scheme, data carousel etc. so they are in a synchronized order.

This work was supported in part by the Coordination for the Improvement of Higher Education Personnel (CAPES), National Research and Educational Network (RNP), National Counsel of Technological and Scientific Development (CNPq) and MackPesquisa.

The video is compressed using the H.264 standard, and the audio utilizes the MPEG-4 HE AAC audio standard [2][6].

The ATSC 3.0 system uses a general packet called ATSC Link-layer Protocol (ALP). ALP allows the encapsulation of any packet, such as IP or MPEG-2 TS packets, which means it only processes one type of container. These packets are transported by logic channels called PLPs. Each PLP has its configuration for coding and modulation, and the receiver can recover a maximum of 4 PLPs per frame.

For the video compression, the standard used is the H.265, which has a 50% improved performance when compared to the H.264. For the audio, the AC-4 audio codec and the MPEG-H audio system are used [3-5], [7-11].

B. Channel Coding

The codes used in the ISDB-T_B system are the Reed Solomon (RS), which is a block code considered a subclass of the Bose Ray-Chaudhuri e Hocquenghem (BCH) code for non-binary symbols, and the Convolutional codes, which make use of memories to code the message.

The RS code used in the system is a shortened version from the (n = 255, k = 239, t = 8), being (n = 204, k = 188, t = 8) since the MPEG-2 TS is standardized at 188 bytes. The generator polynomial $g(x)_{RS}$ is given by (1) [6].

$$g(x)_{RS} = x^{16} + 59x^{15} + 13x^{14} + 104x^{13} + 189x^{12} + 68x^{11} + 209x^{10} + 30x^{9} + 8x^{8} + 163x^{7} + 65x^{6} + 41x^{5} + 229x^{4} + 98x^{3} + 50x^{2} + 36x^{1} + 59 \quad (1)$$

For the Convolutional codes, in ISDB-T_B they are implemented as a circuit using flip-flops, module 2 adders and multiplexers. Also, a puncturing technique is used to allow a variable code rate. The code rates available are 1/2, 2/3, 3/4, 5/6 and 7/8 [1], [6], [12].

In the ATSC 3.0 system, there are three block codes available: Cyclic Redundancy Check (CRC), BCH, both for outer coding, and Low-Density Parity Check (LDPC) for inner coding. Some studies point out that the LDPC code performance can achieve 0.43 dB of difference from Shannon's theoretical limit [4], [13-15].

There are three possible configurations to use the codes in the system: LDPC only, LDPC concatenated with BCH, which improves the error correction and detection, and LDPC concatenated with CRC, which improves the error detection.

The LDPC codes have two lengths: 16200 and 64800 bits. The 64800 has superior performance but higher latency compared to the 16200 bits. There are 12 different code rates for it: 2/15, 3/15, 4/15, 5/15, 6/15, 7/15, 8/15, 9/15, 10/15, 11/15, 12/15 and 13/15. Also, there are two types of algorithms, A and B, to code the message which is dependent on the code rates. Table I lists the code rates and its algorithms [4], [13-15].

The BCH codes are used to reduce the LDPC error floor correcting up to 12 bits, therefore improving the error correction as well as error detection capability. It adds 192 parity bits to the message when the LDPC length is 64800 bits and 168 bits when LDPC length is 16200 bits. The generator polynomial $g(x)_{BCH}$ is given by $g(x)_{BCH} = g1(x)g2(x) \ldots g12(x)$ and the polynomials for LDPC length 64800 bits are listed in Table II.

CRC codes are only used to improve the error detection capacity of the system. These block codes adds 32 parity bits to the message [4], [13-15].

TABLE I
LDPC CODE RATES FOR ATSC 3.0. ADAPTED FROM [4]

Rate	Code length (N_{inner} = 16200)	Code Length (N_{inner} = 64800)
2/15	A	A
3/15	A	A
4/15	A	A
5/15	A	A
6/15	B	B
7/15	B	A
8/15	B	B
9/15	B	B
10/15	B	B
11/15	B	B
12/15	B	B
13/15	B	B

TABLE II
BCH POLYNOMIALS. ADAPTED FROM [4]

g(x)	Code length (N_{inner} = 64800)
$g_1(x)$	$x^{14} + x^5 + x^3 + x^2 + x$
$g_2(x)$	$x^{16} + x^8 + x^6 + x^5 + x^4 + x + 1$
$g_3(x)$	$x^{16} + x^{11} + x^{10} + x^9 + x^8 + x^7 + x^5 + x^4 + x^3 + x^2 + 1$
$g_4(x)$	$x^{16} + x^{14} + x^{12} + x^{11} + x^9 + x^6 + x^4 + x^2 + 1$
$g_5(x)$	$x^{16} + x^{12} + x^{11} + x^{10} + x^9 + x^8 + x^5 + x^3 + x^2 + x^1 + 1$
$g_6(x)$	$x^{16} + x^{15} + x^{14} + x^{13} + x^{12} + x^{10} + x^9 + x^8 + x^7 + x^5 + x^4 + x^2 + 1$
$g_7(x)$	$x^{16} + x^{15} + x^{13} + x^{11} + x^{10} + x^9 + x^8 + x^6 + x^5 + x^2 + 1$
$g_8(x)$	$x^{16} + x^{14} + x^{13} + x^{12} + x^9 + x_8 + x^6 + x^5 + x^2 + x + 1$
$g_9(x)$	$x^{16} + x^{11} + x^{10} + x^9 + x^7 + x^5 + 1$
$g_{10}(x)$	$x^{16} + x^{14} + x^{13} + x^{12} + x^{10} + x^8 + x^7 + x^5 + x^2 + x + 1$
$g_{11}(x)$	$x^{16} + x^{13} + x^{12} + x^{11} + x^9 + x^5 + x^3 + x^2 + x + 1$
$g_{12}(x)$	$x^{16} + x^{12} + x^{11} + x^9 + x^7 + x^6 + x^5 + x + 1$

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C. Bit Interleavers

After coding the message, in the ISDB-T_B system, there is an energy dispersal block, used to reduce interference between symbols that were generated by repetitive transmission. Connected to the output of the energy dispersal is the byte interleaver.

The byte interleaver is a convolutional interleaver where each input has a delay element (shift register) to delay the bits and group them in a different order in the output. This interleaver has twelve branches and seventeen delay elements as shown in Fig. 1 [6], [12].

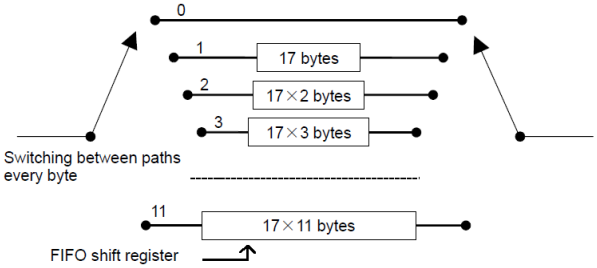

Fig. 1. ISDB-T_B byte interleaver. From [12].

The bit interleaver for ISDB-T_B is located after the convolutional encoder. It has a serial to parallel converter, so the input bits are divided into branches. The number of branches and the number of bits per branch depends on the modulation order, for example, a QPSK modulation requires two bits per branch. These groups of bits, called "symbols" at this point of the system, will later be mapped into the constellation points [6], [12].

ATSC 3.0 has only one-bit interleaver that is divided into three parts: Parity interleaver, Group-wise interleaver and Block interleaver.

The parity interleaver role in the system is to convert the staircase structure of the LDPC parity-check matrix into a quasi-cyclic structure that is similar to the information-part of the matrix [4], [14-15].

The Group-wise interleaver divides the code-word into groups of 360 bits and interleave these groups in an order defined in Annex B of [4].

Finally, the Block interleaver, which has two types, A and B, will interleave the groups – the type of block interleaver depends on the LDPC code rate. All the algorithms of the ATSC 3.0 bit interleaver are described in sections 6.2 of [4].

D. Constellations Mapper

For the ISDB-T_B system, there are four types of constellations: DQPSK, QPSK, 16QAM, and 64QAM. All four follow a table with the values of the constellation points, which are independent of the code rate used for the message. Fig. 2 illustrates the 64QAM constellation in the ISDB-T_B system [6], [12].

The constellations used in the ATSC 3.0 system are the NUC, due to the shapes of the constellations. Like in the ISDB-T_B system, these constellations follow a table with the values of the points, but the points vary according to the LDPC code rate [4], [14-15]. The available types are: QPSK, 16NUC, 64NUC, 256NUC, 1024NUC, and 4096NUC.

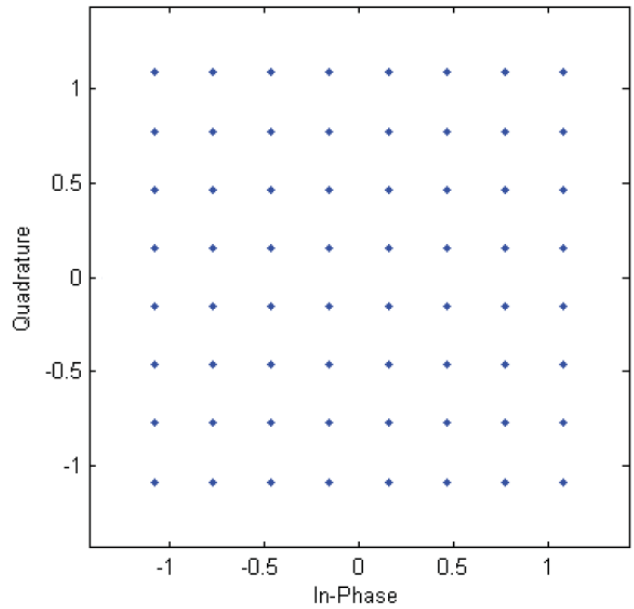

Fig. 2. ISDB-T_B 64QAM Constellation. Adapted from [6].

Each constellation is optimized for the LDPC code rate, and the shapes generate a gain at the reception.

[16] shows that the 16NUC has a gain of 0,2 dB over the 16QAM when compared to the same signal-to-noise ratio. This gain increases along with the modulation order, for example, the 256NUC that has 1 dB gain over the 256QAM.

Fig. 3 illustrates the shape of a 64NUC for LDPC code rate of 10/15.

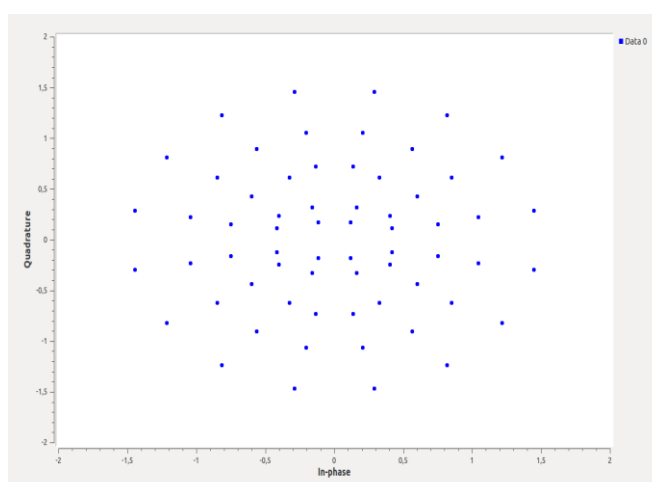

Fig. 3. ATSC 3.0 64NUC for 10/15 LDPC code rate. From [15].

E. Spectrum Adjustment and LDM

As ISDB-T_B works with band segmentation, the spectrum adjustment stage is required to place de segments in order, as specified by [12]. Fig. 4 illustrates the order of the segments.

The segments can be arranged in up to three layers: A, B, and C. Each layer is configured independently from another. The most common configuration used in Brazil is layer A to one segment (mobile) and layer B with twelve segments to HDTV [12], [17].

11	9	7	5	3	1	0	2	4	6	8	10	12

Fig. 4. ISDB-T_B Segment Positions. Adapted from [6].

In ATSC 3.0, the LDM is used to multiplex the PLPs for transmission. Usually, there is the Core Layer (CL) PLP, which has a more robust configuration and the Enhanced Layer has a higher capacity setting.

The method used by the LDM to multiplex the two PLPs is attenuating the EL relatively to the CL using a factor alpha. After the attenuation, both layers are summed, and after the sum, a beta factor is applied to the resulting signal, so the overall power is normalized to 1W. The combination of both factors is called Injection Level (IL). That way both signals occupy the channel at the same time with a difference in power [4].

Fig. 5 illustrates the combination of the signals with the difference in power.

The ATSC 3.0 system also has the Frequency Division Multiplexing (FDM) and Time Frequency Division Multiplexing (TFDM) methods for multiples PLPs [4].

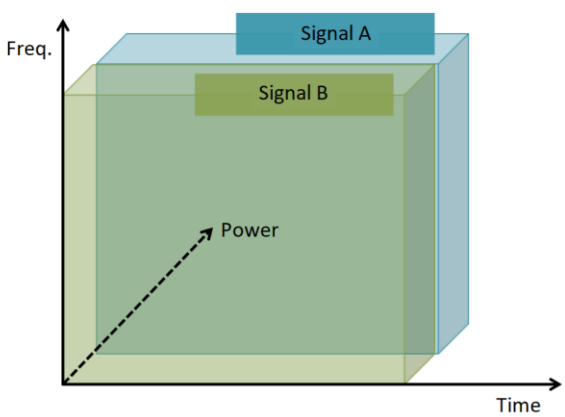

Fig. 5. Combined Signals with LDM. Adapted from [18]

F. Time and Frequency Interleavers

Both time and frequency interleaver stages are used to increase the error correction efficiency. Time interleaver increases robustness against impulsive noise and frequency interleaver against selective frequency fading [6].

In ISDB-T_B, the time interleaver is a convolutional interleaver (CI) that operates in all band segments separately, and they are cyclically combined in the output.

The frequency interleaver can be considered a block interleaver where the symbols are written in a memory and read in a certain order. It is divided into three parts: carrier interleaving between segments, intra-segment carrier rotation and carrier randomization. The three interleaving elements are detailed in [12].

The time interleaver in the ATSC 3.0 system has two types: CI and the hybrid time interleaver (HTI). The CI is similar to the time interleaver used in ISDB-T_B. More details about the CI and HTI can be found in section 7.1 of [4].

Frequency interleaving in the ATSC 3.0 system is made in all carriers of the OFDM symbol. Like the ISDB-T_B, the symbols are written in the memory. On the output, for each IFFT size, there is a circuit that generates the interleaving order that the carriers are read. The address generating circuits are shown in section 7.3 of [4].

G. Frame Structure

The signal to be transmitted is organized in frames in both systems.

The OFDM symbols of the ISDB-T_B frames have three fixed sizes according to the IFFT used: Mode 1 K = 1405 (2k), Mode 2 K = 2809 (4k) and Mode 3 K = 5617 (8k) carriers in ISDB-T_B. One frame consists in 204 OFDM symbols with 13 segments. The Scattered pilots (SP), continual pilots (CP), TMCC and Auxiliary Channel (AC) are inserted in the frame for transmission. Fig. 6 illustrates the frame structure for a coherent modulation [6], [12].

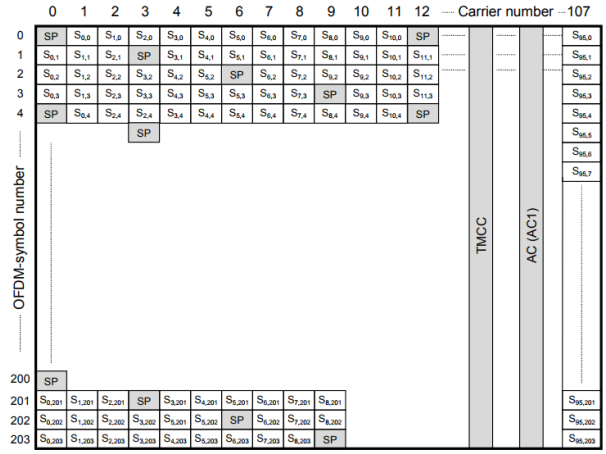

Fig. 6. ISDB-T_B frame structure for a coherent modulation. From [12].

In ATSC 3.0, there are three IFFT sizes: 8k, 16k, and 32k. For each size, there are several useful carriers, 6913 for 8k, 13825 for 16k and 27649 for 32k. These numbers are variable according to a carrier reduction factor [4].

The signaling and control information is inserted in the first symbols of the frame, called preamble symbols. The

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useful data is included in the subframes. The pilots have inserted all symbols. Fig. 7 illustrates the frame structure for the ATSC 3.0 system [4], [14-15].

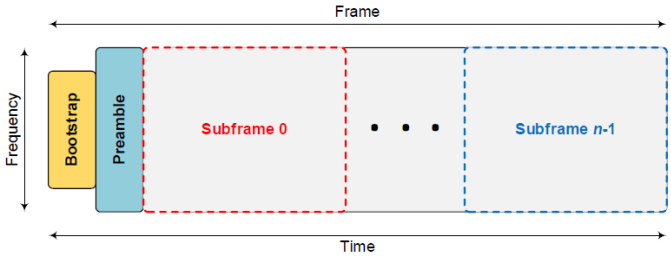

Fig. 7. ATSC 3.0 frame structure. From [4].

The first part of the frame is a signal called Bootstrap. This signal is added at the beginning of every frame, and it has different characteristics from the frame, for example, a smaller bandwidth, 4.5 MHz, and smaller sampling rate, 6.144 Ms/s for a 6 MHz channel and shorter IFFT, 2k.

The bootstrap signal is responsible for the synchronism; signal recovery; frequency and channel offset estimation and signaling information necessary to decode the rest of the frame [19].

H. MISO and Peak-to-Average Power Ratio

Since ATSC 3.0 supports not only SISO applications, it has a Transmit Diversity Code Filter Set that is a MISO pre-distortion technique that artificially decorrelates signals from multiple transmitters in SFN, minimizing the potential destructive interference.

There are two Peak-to-Average Power Ratio (PAPR) reduction technologies in the system: the Tone Reservation (TR) and the Active Constellation Extension (ACE). The TR reduces the PAPR by inserting specific cells in the OFDM symbols. The ACE reduces the PAPR by modifying the transmitted constellation points [4].

I. Guard Interval

The ISDB-T_B and ATSC 3.0 systems utilize the guard interval after the IFFT. There are four options in the ISDB-T_B: 1/4, 1/8, 1/16, and 1/32.

In the ATSC 3.0 systems, the guard interval is expressed in samples of the OFDM symbol. There are twelve options: 192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, and 4864 samples.

The system also supports extra guard interval samples to make the total actual frame length equal to the signaled frame length. This configuration is used if the frame is time-aligned.

III. Bit Rate and CNR Comparisons

The ATSC 3.0 system utilizes video compression standard H.265. The available literature and commercial disclosures suggest that bit rate requirements associated with various image qualities are similar to the ones listed in Table VI [20].

TABLE VI
Service Bitrates. Adapted from [20]

Service	Bitrate (Mbps)
Standard Definition (SD)	0.8-1.8
High Definition (HD)	2.0-3.5
Ultra High Definition (UHD)	15.0-20.0

The UHD service bitrate depends on the use of complementary techniques such as High Frame Rate (HFR), High Dynamic Range (HDR) and Wide Colour Gamut (WCG), therefore requires further specification [20].

Table V lists the system parameters and CNR requirements of both systems from tests in [21] and [22].

TABLE V
System Parameters and CNR requirements. Adapted from [21] and [22].

Configuration	ISDB-T_B	ATSC 3.0	
	HD	Mobile HD	Fixed UHD
Modulation	64-QAM	QPSK	64-QNUC
FEC	3/4	4/15	10/15
Segments	13	-	-
IFFT	8k	16k	16k
LDM Injection Level (dB)	-	0	- 4
Required CNR (dB)	20.1	-0.2	18.7
R_b (Mbps)	19.32	2.5	21.4

The tests show that with similar CNR it is possible to transmit UHDTV using ATSC 3.0 due to technologies applied in the system, while in ISDB-T_B using all the segments it is possible to carry an HDTV signal. HDTV can be broadcasted in the CL of ATSC 3.0 with low CNR and bitrate.

Another important information is that configuring the ISDB-T_B system layer A with one segment for Low Definition TV (LDTV) and layer B with twelve segments for HDTV, the CNR does not change for layer B. In the ATSC 3.0 system, the CNR would decrease without LDM transmission.

IV. Conclusion

This review presented a comparison between the physical layer of the ISDB-T_B and ATSC 3.0 systems.

The technologies implemented in ATSC 3.0, for example, 32k IFFT, LDPC and BCH codes, NUC, LDM and H.265 video compression enable robustness and high transmission rates, which are proper for the transmission of UHDTV signals and satisfies the current scenario of Communications systems.

The ISDB-T_B system presents fewer settings options when compared to the ATSC 3.0. Therefore, the present work serves as a guide to the development of a new broadcast system for Brazil.

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References

[1] Y. Wu, B. Rong, K. Salehian and G. Gagnon, "Cloud Transmission: A New Spectrum-Reuse Friendly Digital Terrestrial Broadcasting Transmission System," in IEEE Transactions on Broadcasting, vol. 58, no. 3, pp. 329-337, September 2012.

[2] Y. Wu *et al.*, "Comparison of Terrestrial DTV Transmission Systems: The ATSC 8-VSB, the DVB-T COFDM, and the ISDB-T BST-OFDM," in *IEEE Transactions on Broadcasting*, vol 46, no. 2, pp.101-113, June 2000.

[3] L. Fay, L. Michael, D. Gómez-Barquero, N. Ammar and M. W. Caldwell, "An Overview of the ATSC 3.0 Physical Layer Specification," in *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 159-171, March 2016.

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

[5] Digital Video Broadcasting. "Frame Structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2)." France, 2011.

[6] C. Akamine and Y. Iano, "Simulation Software for the ISDB-T_B Modulation System," in *SET International Journal of Broadcast Engineering – SET IJBE* v. 1, Article 3, 11p, 2015.

[7] Advanced Television Systems Committee. "ATSC Standard: Link-Layer Protocol (A/330). Doc. A/330:2016." Washington, D.C, September 2016.

[8] Advanced Television Systems Committee. "ATSC Standard: Audio Common Elements (A/342-1). Doc. A/342-1:2017." Washington, D.C, January 2017.

[9] Advanced Television Systems Committee. "ATSC Standard: AC-4 System (A/342-2). Doc. A/342-2:2017." Washington, D.C, February 2017.

[10] Advanced Television Systems Committee. "ATSC Standard: MPEG-H System (A/342-3). Doc. A/342-3:2017." Washington, D.C, March 2017.

[11] Advanced Television Systems Committee. "ATSC Standard: Video - HEVC (A/341). Doc. A/341:2017." Washington, D.C, May 2017.

[12] Associação Brasileira de Normas Técnicas. "Televisão Digital terrestre – Sistema de Transmissão," ABNT NBR 15601:2007, 2007.

[13] I. E. Bocharova, B. D. Kudryashov and R. Johannesson, "LDPC convolutional codes versus QC LDPC block codes in communication standard scenarios," *2014 IEEE International Symposium on Information Theory*, Honolulu, HI, 2014, pp. 2774-2778.

[14] V. Dionísio, C. Akamine, "Desmistificando o padrão de TV digital ATSC 3.0," *2016 Brazilian Technology Symposium*, Campinas, 6p.

[15] V. Dionísio, C. Akamine, "ATSC 3.0 implementation in GNURadio Companion," *2017 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, Cagliari, 2017, 6p.

[16] N. S. Loghin, J. Zöllner, B. Mouhouche, D. Ansorregui, J. Kim and S. I. Park, "Non-Uniform Constellations for ATSC 3.0," in *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 197-203, March 2016.

[17] G. H. M. G. de Oliveira, C. Akamine, and Y. P. Maciel, "Implementation of ISDB-T LDM broadcast system using LDPC codes," *2016 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, Nara, 2016, pp. 1-4.

[18] S. I. Park *et al.*, "Low Complexity Layered Division Multiplexing for ATSC 3.0," in *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 233-243, March 2016.

[19] Advanced Television Systems Committee. "ATSC Standard: System Discovery and Signaling (A/321). Doc. A/321:2106." Washington, D.C, March 2016.

[20] C. Regueiro *et al.*, "Network planning for local service in ATSC 3.0 single frequency networks," *2017 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, Cagliari, Italy, 2017, pp. 1-5.

[21] P. Guedes Esperante, C. Akamine, and G. Bedicks, "Comparison of Terrestrial DTV Systems: ISDB-TB and DVB-T2 in 6 MHz," in *IEEE Latin America Transactions*, vol. 14, no. 1, pp. 45-56, Jan. 2016.

[22] ETRI, "NAB 2017 ATSC 3.0 Presentation," Las Vegas, United States of America, 2017.

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Transport Stream Files Assembling and Analysis of BER Performance into ISDB-Tb Standard

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Transport Stream Files Assembling and Analysis of BER Performance into ISDB-Tb Standard

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***Abstract*—This work presents a technique for assembling a TS (Transport Stream) file, in accordance with the ISDB-Tb (Integrated Services Digital Broadcasting Terrestrial Brazilian) standard, in order to transmit it through a digital TV signal generator to analyze the parameters variation effects of the ISDB-Tb system in the BER (Bit Error Rate) performance. For this analysis, measurements were taken in three different communication channels, with distinct features. In each channel, the 16QAM and 64QAM modulations were evaluated, and several combinations were tested among the following parameters: operating mode, code rate, guard interval and time interleaving. Also, BER measurements were taken for a C/N (Carrier to Noise) range, set from transmitter, then the E_b/N_o ratio was calculated, which allowed to plot curves for each measure.**

***Index Terms*—Bit Error Rate, Communication Channels, Digital TV, ISDB-Tb, Transport Stream.**

I. Introduction

In recent years, Brazil has developed and adopted the ISDB-Tb (Integrated Services Digital Broadcasting Terrestrial Brazilian) standard for digital TV transmission. A transition from analog to digital transmission is being conducted slowly, although some Brazilian cities already are using only digital signal. Since this system became a standard for TV broadcasters in Brazil, techniques have been popularized to create files to be transmitted, also, it has become required a study of how each standard parameter changes the transmission system robustness.

The ISDB-Tb standard determines broadcasting characteristics, such as the use of OFDM (Orthogonal Frequency Division Modulation) for its transmission. One of the main advantages of OFDM is that its transmission is based on band segmentation, which allows flexibility of operation by segment as well as greater robustness regarding the frequency selectivity of the communication channel [1].

The broadcasting of the different segments originates the hierarchical transmission term. Segments are composed of subcarriers, since they are independent, they can send different data in the same channel. ISDB-Tb standard imposes a 6 MHz band for each channel, with 14 segments, and one of them is used as a security interval in the channel edges. Therefore, there remain 13 segments to be distributed in up to three independent layers (A, B and C) [2].

The ISDB-Tb system also allows setting several transmission parameters in the transmitter. Each parameter can be defined in order to fit the transmission application and the desired robustness of the system [2]. Between the parameters that can be defined in the transmission, the following ones were analyzed in this paper: number of segments, modulation type, hierarchical processing, code rate, time interleaving, operating mode and guard interval. The last two modify all the segments of the channel, while the others can be selected for each layer of the hierarchical transmission.

In addition to ISDB-Tb standard defines broadcasting features, it specifies rules for TS (Transport Stream) files that are transmitted. Since devices that are able to assemble TS files are expensive Software implementation has become a low cost alternative which also allows laboratory testing beforehand. As proposed in [3], it is possible through the free software FFMPEG [4] coding files, which can be used for this purpose. In this work, it was proposed a way with few configurations of assembling TS to transmit the desired video to a TV.

As proposed in [5] and [6], one of the ways to evaluate the performance of the modulation is to plot the BER (Bit Error Rate) by E_b/N_o curve. This work proposes to perform BER (Bit Error Rate) measurements by varying the E_b/N_o through a digital TV signal transmitter, in order to verify the relation of the parameters that are flexible in the ISDB-Tb standard with the BER measured by the receiver.

II. Methodology

To carry out the tests of different channel settings, it was necessary to assemble a TS file as the input of the digital TV signal transmission equipment. With the input file, three different communication channels were tested. The possible parameters of the system were varied and the bit error rate were measured.

The bit error rate (BER) is an important measure to characterize the statistical performance of a digital communication system, and it is defined as the ratio of the error number of bits detected to the total number of bits received [7].

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A. Assembling of TS

The assembling of TS was done through the free software FFMPEG [4], which allows an H.264 video encoding and AAC audio encoding, requisites for ISDB-Tb standard [3]. In addition, a multiplexing of the audio and video signals was done by setting up a TS file in the MPEG-2 standard. The MPEG-2 standard defines how audio, video and data components can be combined into a single file, which is called multiplexing [8]. The multiplexing, besides being done with audio, video and data components can be used to multiplex more than one TS to take advantage of the hierarchical transmission, and to send one or more programs at the same time. In this work, only one TS file was used in the final transmission because of the characteristics of the transmitter that was used, which implies in the use of just one layer.

In addition to the audio and video encodings, an important definition in this step is the output bit rate of the multiplexing, since it is the value which will be the bit transfer rate. Hence, as the variation of channel parameters influences the available band, it influences the possible bit rate to be transmitted.

Therefore, a TS file with HD resolution was assembled (1280x720), with a bit rate of 4 Mbps. This rate allows the use of this file in different configurations. Fig. 1 shows how FFMPEG was used to assemble the described file. In addition to the parameters mentioned, other settings have been performed to fit to in the ISDB-Tb standard. Also, it was changed the channel name information, in this case, GEMCO, and, the output file was named *HD.ts*.

```
ffmpeg -i hd.MOV
       -c:v libx264
       -vf scale=1280:720
       -c:a copy
       -mpegts_service_id 0x70e0
       -mpegts_flags 'latm'
       -pes_payload_size 188
       -metadata service_name="GEMCO"
       -muxrate 4000k
       HD.ts
```

Fig. 1. Assembling of TS. Source code used to assemble the TS file to be transmitted as digital TV signal.

B. Transmission Frequency

In order to transmit the digital TV signal, the SFE100 (Rohde & Schwarz) was used as a transmission signal generator for testing systems. In this transmitter, it is necessary to determine the frequency at which the signal will be transmitted. In this case, it was verified a frequency that was not occupied to carry out the tests, and it was chosen the value of 491.143 MHz.

From this definition, the assembled TS file was transmitted to a digital TV device in order to validate it. In the Fig. 2, it is possible to observe that the video is being transmitted to channel 17, which matches with the 491.143 MHz frequency. Another data, visible in the Fig. 2, is the name of the channel, given from coding as GEMCO.

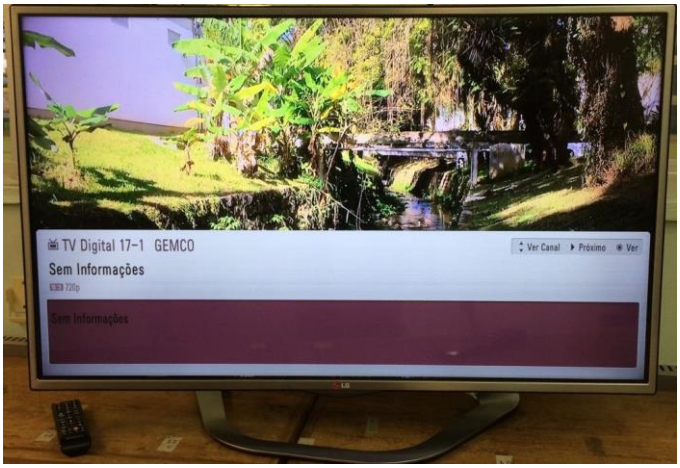

Fig. 2. TS file validation. Transmission of TS assembled to a TV to verify the correct file encoding.

C. C/N Variation

SFE100 allows transmitting the signal desired along with controlled AWGN (Additive White Gaussian Noise) noise. This control can be done through the C/N (Carrier to Noise) ratio in dB (decibel). The C/N variation values were different for each channel, since this affects the decoding and BER measurement done by the receptor.

D. Channels Under Tests

BER measurements were performed in three different communication channels. The first channel tested was the ideal channel. To simulate this idealization the transmitter was connected directly to the receiver through a cable, in this way, the errors detected by the receiver would be only from the noise generated by the transmitter.

For the second channel tested, the receiver was kept near the transmitter, to avoid reflection, and to simulate an environment where there was no multipath.

Finally, the third channel tested was with the receiver away from the transmitter, with several metallic obstacles along to simulate a multipath environment.

E. The Varied Parameters

To use the SFE100, the TS input file has to be transmitted in just one layer. Thereby, it was chosen to perform the tests with layer C, with 9 segments of the hierarchical transmission of the ISDB-Tb standard. In addition, the parameters of operation mode, guard interval, code rate, time interleaving, and modulation type were varied. For the measurements, the minimum and maximum values of each parameter were used. Table 1 shows the parameters tested in channels 1 and 2, totaling 32 measurements for these two channels. Also, Table 2 shows the parameters tested in channel 3, which were tested for the necessary variations for further comparison, totaling 16 measurements.

Table 1 – Varied Parameters in Channels 1 and 2.

	Parameters				
	Code Rate	Time Int.	Op. Mode	Guar. Inte.	Modula.
Variation	1/2	0	3	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
			1	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
		4	3	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
			1	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
	7/8	0	3	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
			1	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
		4	3	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
			1	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM

Table 2 – Varied Parameters in Channel 3

	Parameters				
	Code Rate	Time Int.	Op. Mode	Guar. Inte.	Modula.
Variation	1/2	0	3	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
			1	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
		4	3	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM
			3	1/32	64QAM
					16QAM
				1/4	64QAM
					16QAM

F. *BER Measurement*

To measure the BER of each tested digital TV system configuration, on each channel, a digital TV signal analyzer equipment – ETH Handheld TV Analyzer, Rohde & Schwarz – was used. This equipment decodes the received digital TV signal, taking measurements of BER and MER, and allowing to verify the received settings. Particularly in the BER measurements, ETH emulates two error correction codes: Viterbi and Reed Solomon [9] [10], used in digital TV receivers, and the bit error rate can be evaluated before and after each of these codes. As this work intends to analyze how the variations of the parameters of the ISDB-Tb system influence the bit error rate, it was observed the measure before error correction codes.

G. *Analysis of the BER to E_b/N_o Relation*

An important way to analyze the BER is its relation to the E_b/N_o ratio, and this ratio is defined as the SNR (Signal Noise Ratio) normalized per bit, without taking the bandwidth into consideration.

Since SFE100 allows the variation of C/N, the equation presented in (1) was used to obtain the E_b/N_o [11].

$$\frac{E_b}{N_o} = \frac{C}{N} * \frac{B}{f_b} \tag{1}$$

With:

B = Channel Bandwidth
f_b = Net Bitrate

In line with that, it was used an f_b of 4.01 Mbps, that was the bit rate set in the TS assembled file. In addition, the bandwidth was used which belonged only to the C layer, that is, the bandwidth that corresponds to 9 segments, which is 3.86MHz.

After the measurements were taken, the data was compiled and the curves were plotted in MATLAB® software [12].

III. Results

The results will be presented first referring to software assembled TS, followed by the BER curves plotted for each communication channel tested (1, 2 and 3) with 16QAM and 64QAM modulations.

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A. *TS File Assembled*

The *ffprobe* tool, of FFMPEG, allows taking information about multimedia streams. In the Fig. 3, this tool was used to show the details about the source file, used to created TS final file. As can be seen, several features are presented, including audio and video coding, highlighting its high resolution and bitrate, which make impossible to multiplex this file directly in a TS.

```
 Duration: 00:00:16.24, start: 0.000000, bitrate: 17652 kb/s
   Stream #0:0(und): Video: h264 (High) (avc1 / 0x31637661),
 yuv420p(tv, bt709), 1920x1080, 17576 kb/s, 29.98 fps, 29.97
tbr, 600 tbn, 1200 tbc (default)
   Metadata:
     creation_time   : 2017-05-17T13:32:39.000000Z
     handler_name    : Core Media Data Handler
     encoder         : H.264
   Stream #0:1(und): Audio: aac (LC) (mp4a / 0x6134706D), 44
100 Hz, mono, fltp, 63 kb/s (default)
```

Fig. 3. Source file features taken from *ffprobe*. Coding characteristics of the source file used to assemble the TS file.

Using the same tool (*ffprobe)*, Fig. 4 shows the file encoded in audio and video, and multiplexed in the MPEG-2 standard, as required. In this file, it is possible to observe an HD resolution set, bitrate at 4.01 Mbps, also it has a channel name information.

```
 Duration: 00:00:16.25, start: 1.466733, bitrate: 4010 kb/s
 Program 28896
   Metadata:
     service_name    : GEMCO
     service_provider: MAGLAB
   Stream #0:0[0x100]: Video: h264 (High) ([27][0][0][0] / 0
x001B), yuv420p(progressive), 1280x720, 29.97 fps, 29.97 tbr,
 90k tbn, 59.94 tbc
   Stream #0:1[0x101](und): Audio: aac_latm (LC) ([17][0][0]
[0] / 0x0011), 44100 Hz, mono, fltp
```

Fig. 4. TS Assembled File. File encoded in conform to ISDB-Tb standard, HD resolution, multiplexed, ready to be transmitted.

B. *Comparison of Different Parameters in the Channels Tested*

All the curves obtained in channel 1 with 16QAM modulation were plotted; the results are shown in Fig. 5, where can be noticed that the variation of BER is only perceived when varied between modes of operation 1 and 3. Other variations originated values close to and even equal to each other, which indicates that the variation of the others ISDB-Tb system parameters do not change the bit error rate.

In these measurements, the greatest change observed in the bit error rate is when it is varied between operating modes 1 and 3. Even as 16QAM modulation, in general, other parameters do not change bit error rate performance as much. However, in this case, one curve did not follow the same pattern, which has the guard interval of 1/32, code rate of 1/2 and time interleaving of 0, belongs to mode of operation 3. This means this parameters combination is the one that has the best BER performance between the operating mode 3, since the other ones need more power to have the same bit error rate.

Comparing Fig. 5 and Fig 6, it can be seen that 16QAM modulation has a more robust configuration, requiring less energy to have the same BER as 64QAM.

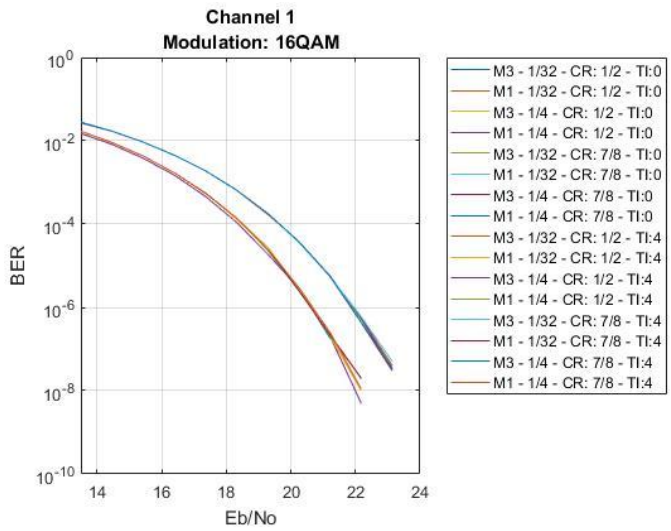

Fig. 5. Channel 1. Modulation 16QAM. Plotted curves for 16QAM modulation of the measurements performed on channel 1.

For the 64QAM modulation, the curves of channel 1 were plotted as and are shown in Fig. 6.

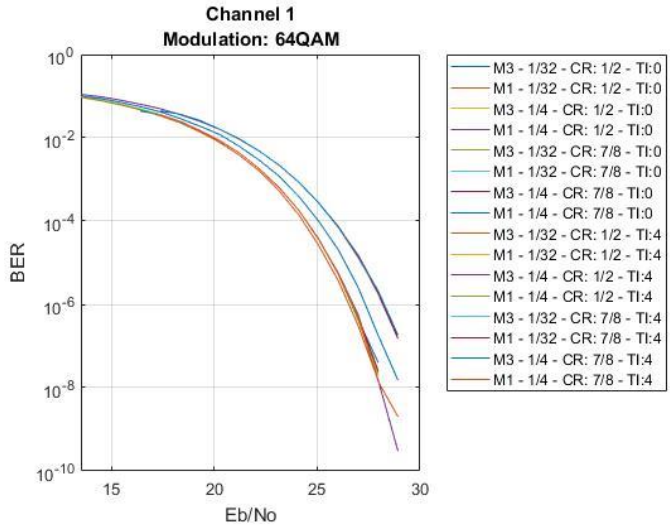

Fig. 6. Channel 1. Modulation 64QAM. Plotted curves for 64QAM modulation of the measurements performed on channel 1.

In the same way as the previous one, curves were plotted for channel 2, which is the measurement with the transmitting and receiving antennas close and with direct view. Fig. 7 shows the measurements taken for this channel with 16QAM modulation.

As in channel 1, it is noticed, in this case, the changes in parameters, except operating mode, do not affect the BER. In comparison with channel 1, with the same modulation, it is noticed that the BER remained almost with the same values.

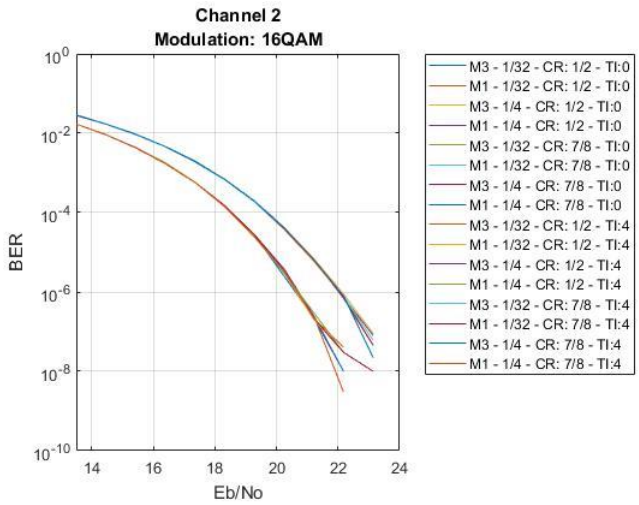

Fig. 7. Channel 2. Modulation 16QAM. Plotted curves for 16QAM modulation of the measurements performed on channel 2.

Also for channel 2, the curves for 64QAM modulation, were plotted and are shown in Fig. 8.

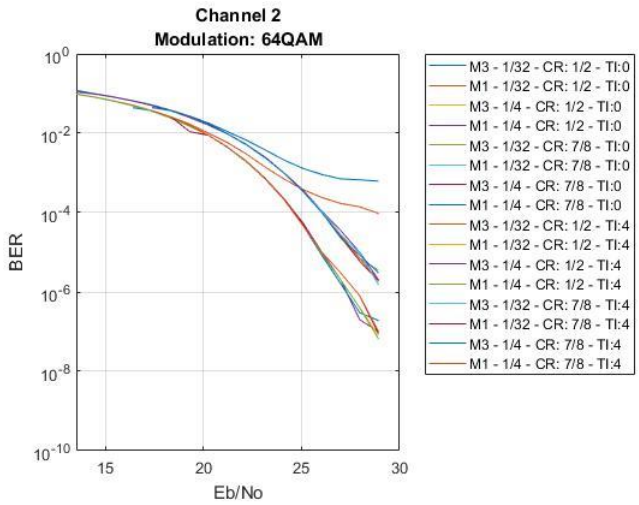

Fig. 8. Channel 2. Modulation 64QAM. Plotted curves for 64QAM modulation of the measurements performed on channel 2.

In this case, it can be observed the previously verified pattern. The most effective way of improving the BER is by changing the operating mode, since other parameters did not change it significantly. However, there are two curves that do not follow the same characteristics as the other ones. These curves have the same combination of curve parameters highlighted in channel 1 (guard interval of 1/32, code rate of 1/2 and time interleaving of 0), but now for mode 1 as well. On the other hand, in this channel this combination proved to be less efficient than the others in BER performance.

As in channel 1, higher power is required with a 64QAM modulation to have the same 16QAM bit error rate.

When measurements were taken for channel 3, it was possible to measure a lower C/N value when compared to the other two channels. This occurred since at a particular threshold value (depending on parameters) the AWGN noise added by the transmitter generated a BER that was equal to the existing BER in the communication channel, which made it impossible to decrease the BER by increasing only the C/N of the transmitter. The alternative to increase the power transmission was not used to maintain the standard used in the other two channels measurements.

The measurements performed for channel 3, with 16QAM and 64QAM modulations, were plotted and are shown in Fig. 9 and Fig. 10, respectively.

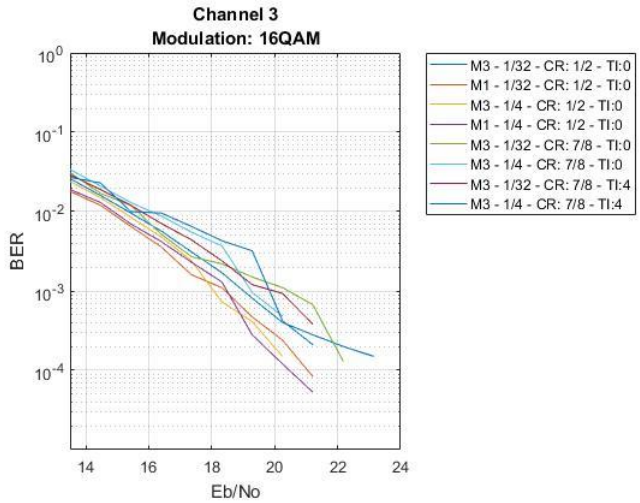

Fig. 9. Channel 3. Modulation 16QAM. Plotted curves for 16QAM modulation of the measurements performed on channel 3.

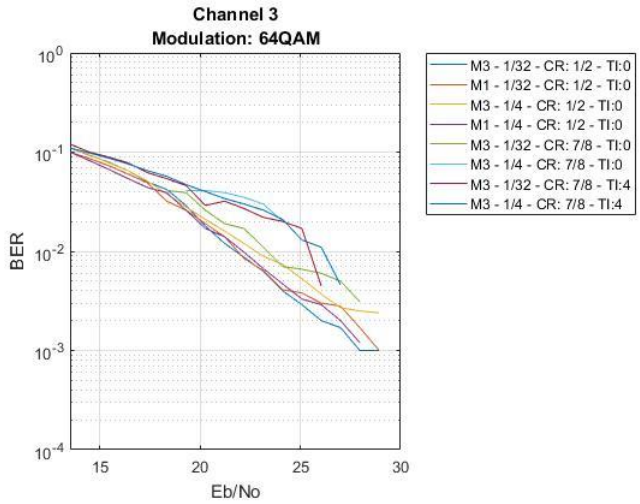

Fig. 10. Channel 3. Modulation 64QAM. Plotted curves for 64QAM modulation of the measurements performed on channel 3.

In channel 3, it cannot be perceived a curve pattern, like channels 1 and 2. In addition, while in a BER of 10^{-3} in channels 1 and 2, the E_b/N_o value varied from 17 dB to 18 DB at 16 QAM, in channel 3 the E_b/N_o value for this BER value ranged from 18 dB to 21 dB.

This comparison shows that in channel 3 there is more AWGN noise that degrades the signal, and there are noises from different natures. The presence of other types of noise, which changes the pattern of previously obtained curves, leads to the conclusion that there is no direct relationship between the improvement of BER and the change of some specific ISDB-Tb system parameter. In channel 3, which is equivalent to a real case where there are losses and noise of different natures, no evidence was found of a combination that provides

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a better performance of BER. If it is desired to improve the BER in a certain transmission, it would be better to take measurements for each communication channel specifically, in order to find the best combination that provides this efficacy.

IV. Conclusion

In this paper, BER measurements were presented for different combinations of ISDB-Tb transmission system configurations. In addition, to achieve these measures, a TS file was assembled for transmission using only the FFMPEG software.

With the implementation of the ISDB-Tb standard, the FFMPEG software tool proved effective for the assembling of TS test files for laboratory measurements. The TS file could be transmitted to a TV; also it was correctly decoded and analyzed by a digital TV signal analyzer.

With the measurements of BER x E_b/N_o in this paper, it can be seen that if there is a high bit error rate problem in the digital TV transmission, changes in the parameters of the ISDB-Tb system may or may not improve the performance. Since in a controlled environment where there was only AWGN noise, a pattern could be observed, whereby using operation mode 1 (where a smaller number of subcarriers are used) the performance of the BER improves. However, in the case of channel 3, where there was signal degradation for reasons other than the AWGN, the behavior of the curves did not follow a pattern. With this, it is concluded that in real transmission environments, which resemble channel 3, to find the best combination for a good performance of BER, new measurements and tests should be carried out for the specific communication channel.

References

[1] D. Villamarín, M. A. Illescas, G. Olmedo and R. L. Cueva, "Generating a transport stream for digital terrestrial television system in conformance with ISDB-Tb standard," presented at IEEE Colombian Conference on Communications and Computing (COLCOM), Medellin, Colombia, May 22-24, 2013.

[2] FFMPEG software. [Online]. Available on https://ffmpeg.org/download.html.

[3] Digital terrestrial television – Transmission system, ABNT NBR 15601, 2007.

[4] P. G. Esperante, C. Akamine, G. Bedicks, "Comparison of Terrestrial DTV Systems: ISDB-TB and DVB-T2 in 6 MHz," in IEEE Latin America Transactions, 2016, pp 45-56.

[5] R. Paderna, D. Q. Thang, Y. Hou, T. Higashino, M. Okada, "Low-Complexity Compressed Sensing-Based Channel Estimation With Virtual Oversampling for Digital Terrestrial Television Broadcasting," in IEEE Transactions on Broadcasting, 2016, pp 82-91.

[6] Y. Iano, D. G. Caetano, R. Arthur, E. Carrara, C. Akamine, "Performance comparison of convolutional and turbo convolutional codes for ISDB-T in AWGN and Brazilian channels," presented at Telecommunications Symposium, Fortaleza, Ceará, Brazil, Sept. 3-6, 2006.

[7] Álvaro J. Almeida , Nuno A. Silva, Nelson J. Muga, Paulo S. André, Armando N. Pinto, "Calculation of the number of bits required for the estimation of the bit error ratio", in Proc. SPIE 9286, Portugal, 2014.

[8] M. Uehara, "Application of MPEG-2 Systems to Terrestrial ISDB (ISDB-T)," in Proc. of IEEE, 2006, pp 261-268.

[9] Longlong Wu, Yongjie Xie, Daping Xu, Li Ren, "Ballistic Missile Precession Frequency Extraction Based on the Viterbi & Kalman Algorithm", in Proc. SPIE 9812, Enshi, China, 2015.

[10] [6] Oksana Volivach, Anatoly Beletsky, "Reed-Solomon's algorithm and software for correcting errors in a text", in Proc. SPIE 8008, Wilga, Poland, 2008.

[11] H. J. Santos, C. Sturm, J. Pontes. "Modulation and Detectation", in *Radio Systems Engineering – A Tutorial Approach*, 1st ed. New York, USA.

[12] (2017) MATLAB software. [Online]. Available on: https://www.mathworks.com/products/matlab.html.

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Digital TV signal reception and amplification system

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Digital TV signal reception and amplification system

A. Raizer and M. P. Fonseca

***Abstract* — This paper presents the development of an amplification system and two antennas for the reception of Digital TV signals. The proposed antennas are based on the half-wave dipole topology (λ/2) with geometry inspired by the meander line antenna (MLA) and magnetic loop antenna. Simulations using software based on the finite element method were performed. The antenna reception and efficiency of amplification system were evaluated through measurements.**

***Index Terms*—Antenna Development, ISBT-Tb, HDTV, Meander Line Antenna (MLA), Radio-Frequency Amplifier Development**

I. Introduction

The Digital TV market has recently experienced substantial growth due to the transition from analogue to digital television transmission. In line with this change, the demanded reception of Digital TV signals increase researches for reception systems that can span large frequency ranges with low production costs.

The development and production of antennas with these characteristics impose the modification and use of high cost tools and mechanical processes, where directivity and gain of the antennas are opposed to the costs of production.

However, with the advancement of electronics and microelectronics, the costs of developing and manufacturing high-performance electronic devices for reception and amplification of Digital TV signals became lower than the amount invested to improve mechanical manufacturing processes for antennas, achieving better performances and versatility in their use.

This paper presents the development and testing of a radio frequency amplifier and two reference antennas, operating in the range of 470 MHz to 806 MHz, intended for reception and amplification of the Digital TV signal in ISDB-Tb standard (Integrated Services Digital Broadcasting Terrestrial Brazilian), also known as SBTVD (Brazilian Digital Television System). To verify amplifier circuit performance, measurements were performed using specific test and measurement equipment for radio frequency and digital TV reception systems.

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II. Development of the Radio Frequency Amplifier Circuit

The amplifier circuit has been developed to increase the levels of received Digital TV signals that are transmitted in the range of 470 MHz to 806 MHz, based on ISDB-Tb standards. In addition to increase the signal level, the amplifier was designed in a way to not degrade the value of Bit Error Rate (BER) or Modulation Error Rate (MER).

The electronic circuit was developed using the ERA-3SM + monolithic amplifier as its basis. This component is a broadband amplifier that offers high dynamic range, with Micro-X encapsulation, using the transistors in Darlington configuration and manufactured using the InGaP HBT technology (indium-gallium-phosphide heterojunction bipolar transistor). This integrated circuit operates in the frequency range of 0 Hz (DC) to 3 GHz, with noise figure <2,9 dB, maximum gain variation with temperature rise of -0.013 dB/° C and operation in temperature range from -45°C to 85ºC.

With these specifications, the amplifier circuit was elaborated as shown in Fig.1.

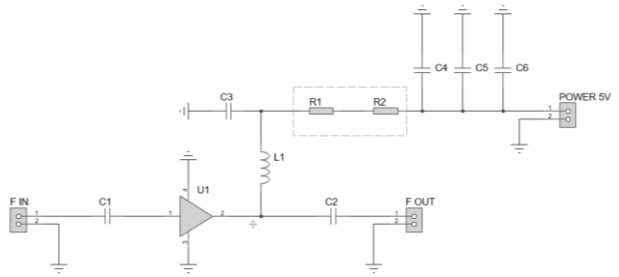

Fig. 1. Radio frequency amplifier electrical circuit.

A. Circuit Supply

Based on the availability of inputs and outputs of current televisions, the circuit power was designed to operate with nominal voltage of 5 V_{DC}. With this level of voltage for operation, it can power the device directly through a USB port included on television, without an external power supply. In this circuit configuration, it is also possible to power the amplifier circuit with voltages between 3.2 V_{DC} to 12 V_{DC}, which allows operation in different scenarios.

B. Input and Output Impedance of Amplifier Circuit

ERA-3SM+ integrated circuit operates with 50 Ω input and output impedance, where an impedance matching was required to maximize power transfer of the signal, since the nominal impedance of TV system is 75 Ω. For this end, an L-network matching impedance was elaborated at the input and output of the integrated circuit. The simplified circuit is shown in Fig. 2.

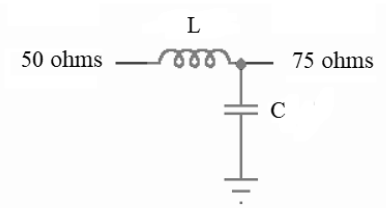

Fig. 2 – Simplified circuit of an L-network impedance matching.

This circuit was developed using the microstrip impedance matching technique [1], which uses the layout of the printed circuit board (PCB) to produce capacitive and inductive effects, which dispense use of physical components, as shown in Fig. 3.

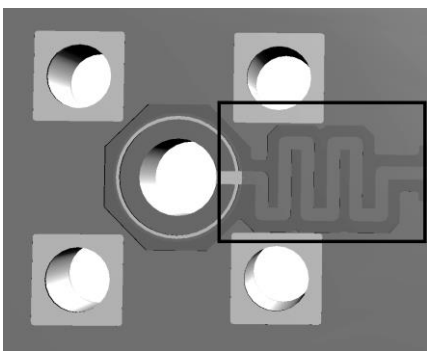

Fig. 3. L-network impedance matching using microstrip on PCI.

III. Development of Antennas for Digital TV

Two antennas were developed to be used as references for the reception of Digital TV signals. These antennas were based on two common topologies: half-wave electric dipole with (λ/2) with meander line topology and magnetic dipole (loop).

A. Half-Wave Electric Dipole (λ/2) with Meander Line Topology

For the development of this antenna, the half-wave electric dipole (λ/2) was used. This configuration consists of two conductors with a central signal supply, where the distribution of the electromagnetic fields is generated by the potential difference between the two constituent antenna elements [2]. The radiation pattern of a theoretical half-wave dipole is shown in Fig. 4, where the upper and lower lobes can be observed, which demonstrates the maximum antenna directivity.

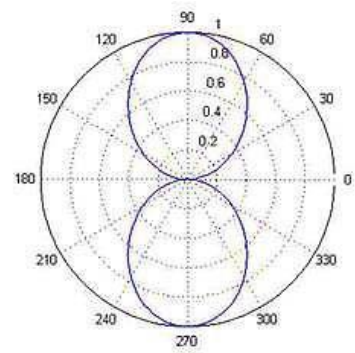

Fig. 4. Theoretical half-wave dipole (λ/2) radiation pattern.

Based on the exposed theory and antenna topology meander line [2], [3], the antenna for reception of Digital TV signals in the frequencies of 470 MHz to 806 MHz was developed. This type of topology has been widely used, since it helps reduce antenna length [2], [3]. This dimensional reduction is obtained due to the fact that the structure is constituted by a set of rectangular arrays, which possibilities the reduction of the resonance frequency and the increase of the radiation resistance in relation to a conventional dipole.

To calculate dimensions of this structure, the theory presented in [2] was used. The obtained antenna structure is shown in Fig. 5.

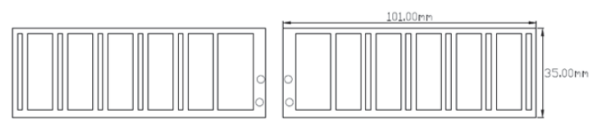

Fig. 5. Developed meander line antenna.

B. Magnetic Dipole Antenna (loop)

The magnetic dipole antenna (loop) was developed based on the theory exposed in [4]. It is constituted by a radiant element that is divided, usually in the center, to allow a feeder to apply energy from a transmitter, or to be transferred to a receiver. The length of the radiant element determines many of the dipole antenna properties, such as impedance and central frequency of operation. This is an important characteristic of the antenna, which allows various configurations and antenna formats.

Based on the exposed theory, the antenna for the reception of Digital TV signals, shown in Fig. 6, was developed in the frequencies of Digital TV.

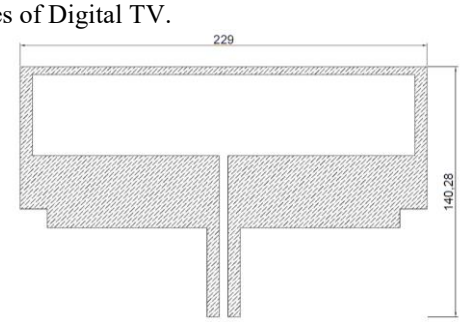

Fig. 6. Developed magnetic dipole antenna.

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C. Modeling by Finite Elements

For perform the modeling of the antennas developed, software based on the finite element method [5] was utilized. As can be seen in Fig. 7 and Fig. 8, the antennas were modeled and simulated with the physical and geometrical characteristics according to the development described previously.

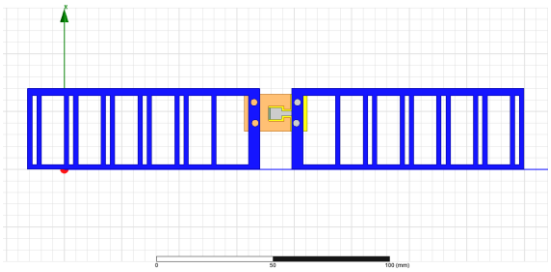

Fig. 7. Simulated meander line antenna.

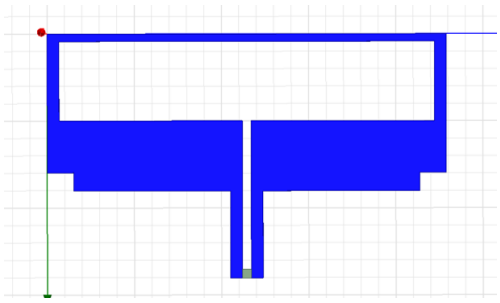

Fig. 8. Simulated magnetic dipole antenna.

D. Simulation of Radiation Pattern

With antennas modeling, simulations of radiation pattern were performed for 470 MHz and 806 MHz frequencies, as can be seen in Fig. 9 and Fig. 10 for the electric dipole antenna with meander line topology, and Fig. 11 and Fig. 12 for the Magnetic dipole antenna with loop topology. From the analysis of the presented radiation pattern, it is possible to verify through the lobes of $\phi = 0°$ (red) and $\phi = 90°$ (blue), that in the plane y = 0, both developed antennas have maximum directivity, and angulation with respect to the y axis indicates the presence of higher modes.

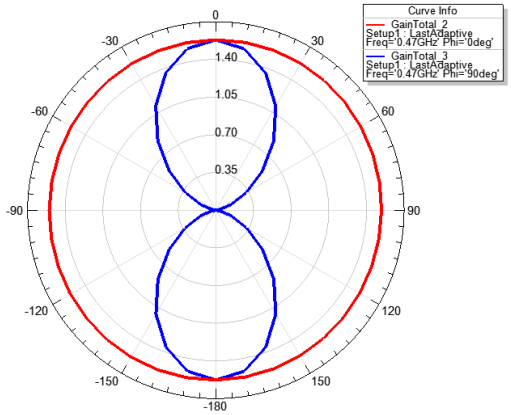

Fig. 9. Meander line antenna radiation pattern for frequency 470 MHz, ϕ=0° and ϕ=90°.

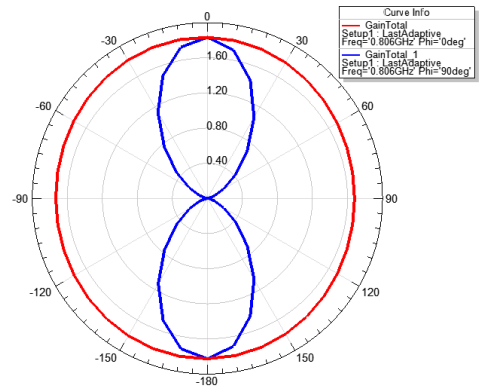

Fig. 10. Meander line antenna radiation pattern for frequency 806 MHz, ϕ=0° and ϕ=90°.

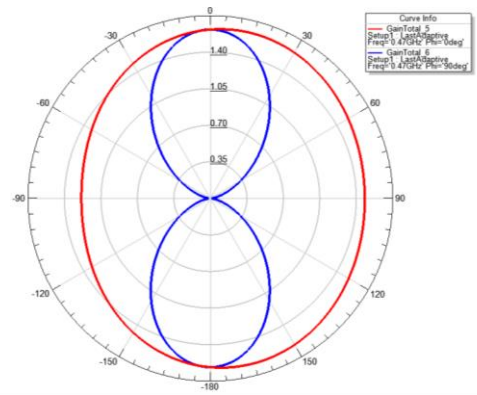

Fig. 11. Loop antenna radiation pattern for frequency 470 MHz, ϕ=0° and ϕ=90°.

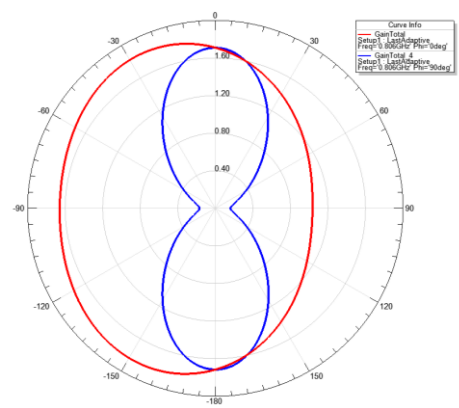

Fig. 12. Loop antenna radiation pattern for frequency 806 MHz, ϕ=0° and ϕ=90°.

Compared with the theoretical pattern presented in Fig. 4, it can be observed that the developed antennas have their performance according to the characteristics of respective types of topology. After the simulations and parameters extraction, both antennas were made in aluminum.

IV. Measurements

For amplifier circuit evaluation, measurements were performed of return loss, gain in continuous wave (CW), gain in Digital TV channel, MER and BER. Measurements of gains in Digital TV channel, MER and BER were performed in two steps. Initially were performed only with antennas, in order to verify the values of each parameter without the use of the amplifier circuit. Afterwards, same measurements were performed using the amplifier circuit and the variations of the measured parameters were analyzed.

A. Measurements of Return Loss

Using a vector network analyzer, model ZNB4 (Rohde & Schwarz), return loss was measured as shown in Fig. 13. This measurement presents the S_{11} parameter, which characterize the reflection coefficient of the amplifier circuit input, and can be presented in logarithmic scale as return loss.

As shown in Fig. 13, the result presents a return loss ≤ -15dB, which guarantee ≥97% power transfer.

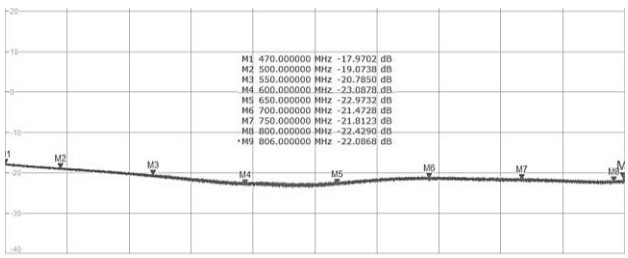

Fig. 13 – Circuit amplifier return loss (S_{11}).

B. Gain in Continuous Wave (CW)

Using the same equipment, the amplifier circuit gain in continuous wave (CW), was measured, as shown in Fig. 14. This measurement characterizes the S_{21} parameter of the amplifier circuit, which indicates the voltage gain value of output signal in relation to the input signal for the Digital TV frequency range.

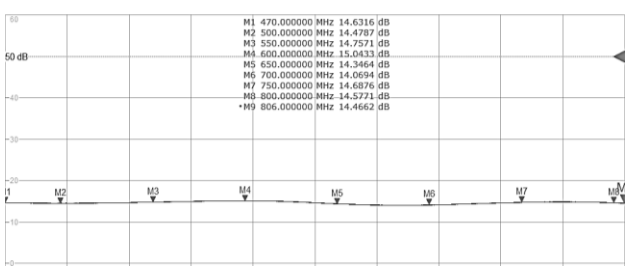

Fig. 14 – Gain in CW (S_{21})

As can be observed in Fig. 14, the amplifier circuit gain in continuous wave (CW) has a mean value of 14.58 dB in Digital TV frequency range.

C. Measurements of Gain in Open Digital TV Channel

Gain in open Digital TV channels available between the frequencies of 470 MHz to 806 MHz, shown in table 1, were measured.

For this measurement, a Digital TV Analyzer, model ETH (Rohde & Schwarz), was used for measure the power of open channels of Digital TV. Measurements were performed using only the receiving antennas and subsequent measurement of channel power using the amplifier circuit. The results obtained are described in table 2 with meander line antenna use and in table 3 with loop antenna use.

Table 1 – Open Digital TV Channels

Transmitter	Frequency (MHz)	Virtual Channel	Physical Channel
1	515.143	20.1	21
2	521.143	23.1	22
3	569.143	4.1	30
4	575.143	6.1	31
5	581.143	9.1	32
6	587.143	12.1	33
7	641.143	43.1	42
8	665.143	45.1	46
9	755.143	61.1	61
10	767.143	63.1	63

Table 2 – Measurement of power in the open channels of Digital TV with meander line antenna.

Transmitter	Power without amplifier (dBm)	Power with amplifier (dBm)	Gain (dB)
1	-67.34	-55.99	11.35
2	-76.34	-61.29	15.05
3	-60.80	-46.77	14.03
4	-73.37	-60.32	13.05
5	-58.57	-45.62	12.95
6	-60.40	-45.85	14.55
7	-72.56	-60.54	12.02
8	-66.80	-54.73	12.07
9	-62.08	-46.36	15.72
10	-75.95	-62.01	13.94

Table 3 – Measurement of power gain in the open channels of Digital TV with loop antenna

Transmitter	Power without amplifier (dBm)	Power with amplifier (dBm)	Gain (dB)
1	-69.80	-57.06	12.74
2	-76.45	-62.46	13.99
3	-58.76	-44.07	14.69
4	-74.81	-61.81	13.00
5	-66.01	-48.65	17.36
6	-62.79	-46.39	16.40
7	-73.86	-60.06	13.80
8	-65.30	-48.73	16.57
9	-68.66	-53.89	14.77
10	-78.52	-63.46	15.06

The power gain in the open channels of Digital TV with meander line antenna has a mean value of 13.47 dB, and power gain in the open channels of Digital TV with loop antenna has a mean value of 14.84 dB, as presented in table 2 and table 3.

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D. MER Measurements

The Modulation Error Rate (MER) is defined as the ratio between the square of the ideal pairs of the digital modulation symbols measured and the square of the error pairs [4]. Therefore, the MER is related to the SNR (Signal Noise Ratio) and allows the evaluation of the quality of the received signal.

Using the ETH, the values of MER were measured for the transmission layers A and B. Initially the measurement was performed only with the receiving antennas and subsequently measured using the amplifier circuit. The values measured with the meander line antenna are shown in Tables 4 and 5, and the values measured with the loop antenna are shown in Tables 6 and 7.

Table 4 - Measurement of MER with and without the amplifier in open channels of Digital TV for layer A with meander line antenna

Transmitter (layer A)	MER without amplifier (dB)	MER with amplifier (dB)
1	19.4	19.5
2	11.6	15.9
3	24.2	28.8
4	13.7	14.7
5	20.0	20.0
6	22.4	30.9
7	7.1	15.9
8	20.9	21.1
9	23.5	33.5
10	15.9	23,9

Table 5 - Measurement of MER with and without the amplifier in open channels of Digital TV for layer B with meander line antenna

Transmitter (layer B)	MER without amplifier (dB)	MER with amplifier (dB)
1	17.6	20.1
2	11.9	15.3
3	19.6	26.7
4	12.1	15.4
5	20.2	20.5
6	26.8	27.6
7	16.1	19.0
8	17.1	22.3
9	22.7	28.2
10	11.3	17.4

Table 6 - Measurement of MER with and without the amplifier in open channels of Digital TV for layer A with loop antenna

Transmitter (layer A)	MER without amplifier (dB)	MER with amplifier (dB)
1	11.6	15.4
2	11.5	13.3
3	16.3	27.2
4	12.2	12.3
5	10.6	29.8
6	18.3	30.9
7	16.5	19.2
8	19.4	32.7
9	16.2	22.0
10	11.7	18.0

Table 7 - Measurement of MER with and without the amplifier in open channels of Digital TV for layer B with loop antenna

Transmitter (layer B)	MER without amplifier (dB)	MER with amplifier (dB)
1	13.9	19.0
2	11.7	14.6
3	25.2	27.8
4	12.6	17.0
5	18.3	24.6
6	22.3	28.8
7	16.0	18.8
8	20.6	30.3
9	15.6	20.6
10	10.5	14.6

E. BER Measurements

The Bit Error Rate (BER) is one of the measures to characterize the statistical performance of a digital communication system. It is defined as the ratio between the number of error bits detected and the total number of bits received [7].

ETH emulates two error correction codes that receivers use, Viterbi and Reed Solomon [8] [9], which allows to perform BER measurements on each open digital TV channel, with and without the amplifier circuit. The measurements are presented in tables 8 and 9 using the meander line antenna, and table 10 and 11 using the loop antenna.

Table 7 – BER measurement with and without the amplifier in open channels of Digital TV for layer A with meander line antenna

Transmitter (layer A)	BER without amplifier (ppm)	BER with amplifier (ppm)
1	0.0	0.0
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
6	0.0	0.0
7	0.0	0.0
8	0.0	0.0
9	0.0	0.0
10	0.0	0.0

Table 8 – BER measurement with and without the amplifier in open channels of Digital TV for layer B with meander line antenna

Transmitter (layer B)	BER without amplifier (ppm)	BER with amplifier (ppm)
1	0.0	0.0
2	0.0	0.0
3	0.0	0.0
4	5,900	900
5	0.2	0.0
6	0.0	0.0
7	5,900	840
8	0.0	0.0
9	0.0	0.0
10	2,200	0.0

Table 9 – BER measurement with and without the amplifier in open channels of Digital TV for layer a with loop antenna

Transmitter (layer B)	BER without amplifier (ppm)	BER with amplifier (ppm)
1	0.0	0.0
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
6	0.0	0.0
7	0.0	0.0
8	0.0	0.0
9	0.0	0.0
10	0.0	0.0

Table 10 – BER measurement with and without the amplifier in open channels of Digital TV for layer B with loop antenna

Transmitter (layer B)	BER without amplifier (ppm)	BER with amplifier (ppm)
1	0.0	0.0
2	0.0	0.0
3	0.0	0.0
4	3,700	50
5	3.7	53
6	0.0	0.0
7	5,900	1.300
8	0.0	0.0
9	3.8	0.0
10	5,900	0.0

V. Conclusion

In this paper are shown the development and measurements of an amplifier circuit , a half-wave dipole antenna (λ/2) with a geometric structure based on the meander line antenna and a magnetic loop dipole antenna, all with the purpose of receiving digital TV signals.

The development and measurements of amplifier circuit allowed the amplification of the signals and presented linearity in gain in the frequency range of operation. With the gain values, the amplifier circuit demonstrated versatility in its use, since it can be used in environments where there is low signal quality, such as non-metropolitan environments.

Through the simulations and measurements performed in the antennas, it can be verified that the structures present satisfactory results in relation to the reception of Digital TV signals.

The use of the amplifier circuit has contributed to increase the levels of MER for the open channels of Digital TV, improving the quality of the signals received. BER levels were also improved, which reduce the amount of wrong bits received using the same circuit.

In this way, the use of amplified Digital TV signal reception systems is encouraged, in order to improve the amplitude and quality of the signals received and the low cost for the development of electronic systems.

Therefore, it is important to note that studies related to the Digital TV reception system of small size and high performance should become more important in the present times, especially considering the imminent end of analog signals.

References

[1] R. Fralich, J. Wang, J. Litva, "An optimized impedance-matching technique for increasing the bandwidth of microstrip antenna", in Symposium on Antenna Technology and Applied Electromagnetics, 1990. Antem 1990.

[2] K. W CHEN, C. L. YANG , A Method for Input Impendence Matching of PIFA based on Meander Line Antenna, International Symposium on Antennas and Propagation (ISAP), 2- 5 December , 2014.

[3] D. MISMAN, M.N. HUSAIN; M.Z.A ABD AZIZ,., I.A. KADIR, M.F.A. SALAMAT, M.R.C. ROSE; M. SHAH; P.J. SOH, The Study of a Different Impedance Meander Line for Microstrip Antenna Design, 6th National Conference on Telecommunication Technologies 2008 and 2008 2nd Malaysia Conference on Photonics. NCTT-MCP, 26-28 August, 2008.

[4]Balanis, C.A., "Wire Elements: Dipoles, Monopoles and Loops" in Modern Antenna Handbook, USA, 2008

[5] (2014). ANSYS HFSS website. [Online]. Available: http://www.ansys.com/Products/Simulation+Technology/Electronics/Signal+Integrity/ANSYS+HFSS

[6] Hui Tang, Xianrong Wan, Lina Hong, Wei Chen, Jianxin Yi, "Detection improvement by modified modulation error rate of Reference signal in passive radar", in URSI GASS, Beijing, China, 2014.

[7] A. J. Almeida , N. A. Silva, N. J. Muga, P. S. André, A. N. Pinto, "Calculation of the number of bits required for the estimation of the bit error ratio", in Proc. SPIE 9286, Portugal, 2014.

[8] Longlong Wu, Yongjie Xie, Daping Xu, Li Ren, "Ballistic Missile Precession Frequency Extraction Based on the Viterbi & Kalman Algorithm", in Proc. SPIE 9812, Enshi, China, 2015.

[9] Oksana Volivach, Anatoly Beletsky, "Reed-Solomon's algorithm and software for correcting errors in a text", in Proc. SPIE 8008, Wilga, Poland, 2008.

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A Technical Study on the Transmission of HDR Content over a Broadcast Channel

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A Technical Study on the Transmission of HDR Content over a Broadcast Channel

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***Abstract*—High Dynamic Range Television is a topic of current interest in academia and industry since can attribute the same level of realism without the need to increase the resolution. The reference end-to end HDR system is based on HDR10 System due to its encoding efficiency and visual quality. However, it cannot be directed apply for the current Standard Dynamic Range television system. This paper makes a technical study about the system requirements to be considered for transmitting a HDR service in broadcast television and presents objective metrics in different coding scenarios regarding the HDR10 System and a subjective assessment of the generated tone-mapped videos.**

***Index Terms*—High Dynamic Range, Broadcasting, Television System.**

I. Introduction

THE current broadcast television systems still works on 8-bit infrastructure. Each stage of a television system is governed by the traditional television standards. For instance, the BT.709 OETF (Opto-Electrical Transfer Function [1]) converts scene-referred natural images into electrical signals. Likewise, the BT.1886 EOTF (Elecro-Optical Transfer Function [2] converts electrical signals into light. This architecture is known as the "Gamma System".

Today's television systems are known as Standard Dynamic Range (SDR) systems because supports a range of luminance of around 0.1 to 100 nits, about of three orders of magnitude or 10 f-stops. High Dynamic Range(HDR) is defined as any signal or device that has a dynamic range greater than SDR. An Enhanced Dynamic Range (EDR) system covers between 10 f-stops and 16 f-stops and a High Dynamic Range system supports a dynamic range of more than 16 f-stops or five orders of magnitude [3].

HDR proposals are well referenced by International Standard Committees such as the ITU–R Study Group 6 and VCEG/JCT-VC/MPEG. The ITU-R Report 2390 [4] defines the HDR signal parameters for programme production and international programme exchange. There are two proposals widely accepted by the academic and industry community. These are the Hybrid Log-Gamma (HLG), which is a scene-referred signal, and the Perceptual Quantization (PQ), which is a display-referred signal format. The HLG signal is based on a transfer function close to the gamma curve in the range of 0 to 100 nits. After this range, the curve has a logarithmic behaviour. On this basis, this signal is SDR-compatible. Nevertheless, when is displayed the HLG signal into a SDR rendering device, the appearance of distortions, such as color shifting, is noticeable, altering the rendering-intent of the TV producer [5]. The PQ approach proposes a new perceptual uniform coding scheme based on the contrast sensitivity function of the human eye, measured by Barten [6]. This method efficiently encodes the absolute luminance of a real scene in 10 bits [7] with no banding effects. However, the main disadvantage is the non-direct SDR compatibility, since its transfer function does not follow the gamma function. Our previous work ([8] and [9]) proposed the use of a altered HDR10 encoding stage, a H.264 codec (Main Profile) at 8 bits as core. The three HDR sequences proved that the PQ encoding efficiency in 8 bits compared to the 10-bit system reached similar results regarding the objective metrics. However, the encoding is only applicable for PQ-enabled display devices.

The remainder of this paper is organized as follows: an overview of the proposed system is presented in Section II, the objective and subjective results in Section III and the study case in Section IV. Finally, the conclusions are presented in Section V.

II. HDR Television System

Figure 1 shows the general scheme of the proposed system. For reusing the current television head-end infrastructure a 10 bit PQ-TF is applied to the uncompressed video generated at the production and Post-Production stage. Producers can use PQ-enabled displays, such as the HDR SIM2 [10], to reference and adjust technical details of the video, having in mind the representation of the real scene. Then, this PQ signal is redirected to the High Dynamic Range Reducer process, which performs the tone mapping process of the HDR samples and generates the gamma-corrected video samples according to the BT.709 OETF. Likewise, the HDR Reducer process generates the metadata information, which is then encapsulated in a Program Elementary Stream (PES) Packet, signaled by the Packet Identification (PID) according to the MPEG Systems Standard [11]. This PID warrants the video infrastructure be independent of the customizable development of video encoders manufacturers. It is also proposed that the carrying of this information be via an IP network to an MPEG multiplexer.

At the processing stage, the uncompressed YCbCr video samples pass through the 8-bit infrastructure towards the H.264 codec, which compresses the input video in lower bitrates. The output signal can be carried via a IP network or asynchronous physical interfaces directly connected to the MPEG multiplexer, which assigns the number of the metadata PID with the Output Transport Stream (TS) of the matched

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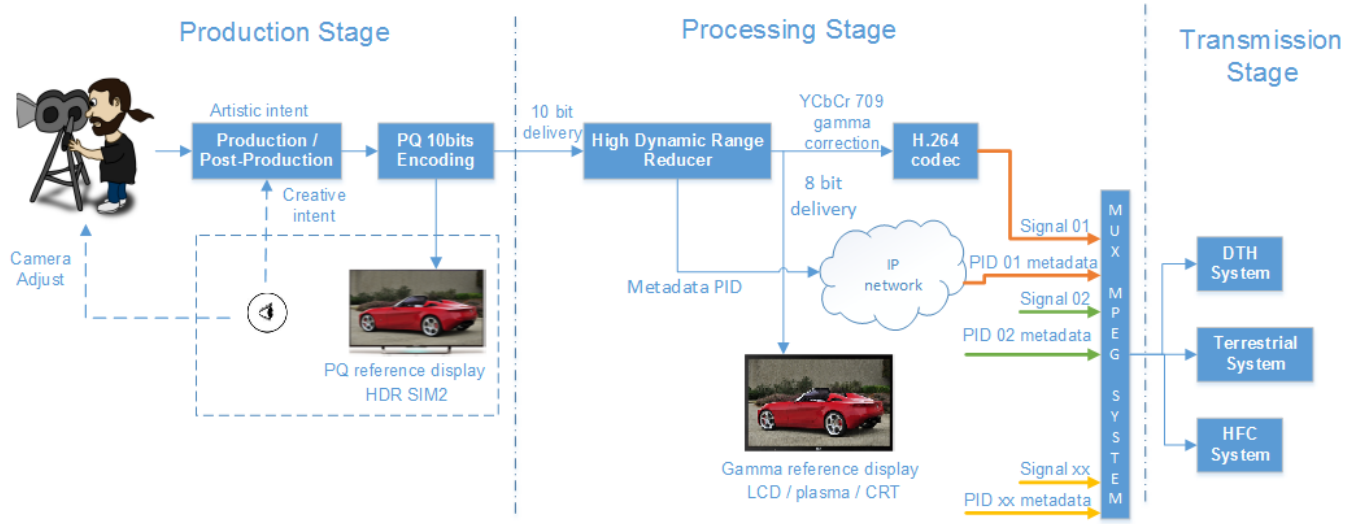


Fig. 1. General Proposed Scheme

service. Finally, the TS could feed different transmission system, either a Direct to Home (DTH), Terrestrial or a Hybrid-Fiber-Coaxial (HFC) service.

In Figure 2 , the reception process is shown, either RF or Fiber. It is considered two type of Set-Top Box (STB), the HDR STB and the Standard Dynamic Range STB. In order to maintain the STB legacy and the compatibility with the existing 8-bit display devices, the current (STB) decodes the video samples and displays the video on Standard Definition (SD) - SDR and High Definition (HD)- SDR television sets. In Figure 2 , the reception process is shown, either RF or Fiber. It is considered two type of Set-Top Box (STB), the HDR STB and the Standard Dynamic Range STB. In order to maintain the STB legacy and the compatibility with the existing 8-bit display devices, the current (STB) decodes the video samples and displays the video on Standard Definition (SD) - SDR and High Definition (HD)- SDR television sets. The HDR STB performs the inverse tone mapping process in order to retrieve the HDR Samples and be displayed on HD - HDR television set.

Some final considerations of the final proposal are: It is known that commercial HDR distribution pipeline is not yet viable because only propotype devices exist [3], it means that current HDR displays are only a glimpse into what future displays can achieve. This work tries to simulate the real problems and address the concerns about future deployments of a HDR TV System. That is why, science and researching are always ahead of the development. Furthermore, this proposal is a scalable solution because when the HDR10 system is being deployed, the Reducer process may be replaced, as well as the H.264 video codec. The 10-bit PQ signal can enter directly to the newest codec, such as the HEVC. Until then, a compatible television infrastructure is of high importance and imperative.

III. Objective and Subjective Results

For the laboratory experiments, the Test Sequences [12] used as an anchor in the ITU-R SG06 group are processed.

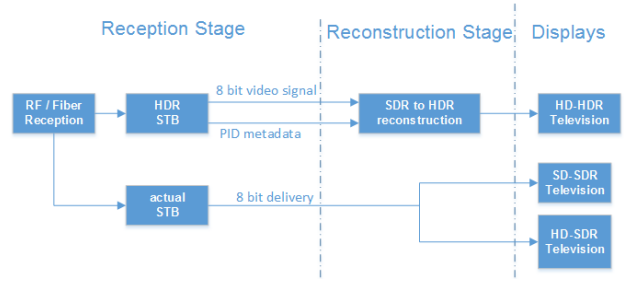


Fig. 2. Reception Scheme

These are: *FireEater*, *Market*, *ShowGirl2*, *Balloon Festival*, *EBU_04_Hurdles*, *EBU_06_Starting*, and *Sunrise*.

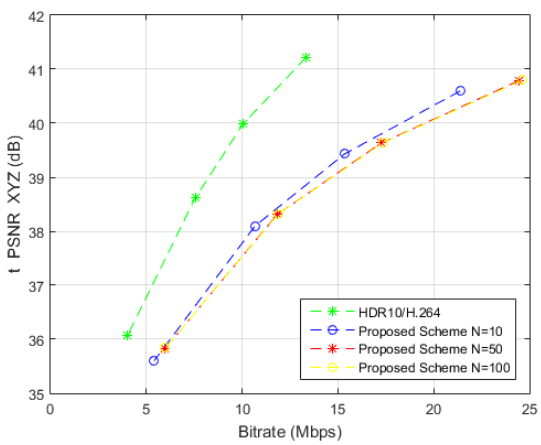
A modified version of the software HDRTools v-15 [13] is used to implement the proposed High Dynamic Range Reducer and the SDR to HDR Reconstruction process and the JM 19.0 H.264/AVC reference software [14] for the compression process. Additionally, the HDRMetrics option is used to generate the following objective metrics: $tPSNR\_XYZ$, t_OSNR_XYZ, $PSNR\_MD0100$, $PSNR\_L0100$ and $PSNR\_DE100$.

The final proposal and the HDR10 System [15] are compared, considering the video codec, H.264, in both cases. The simulation of different coding scenarios is reached by modifying the Quantization Parameter (QP): 20, 22, 24 and 28. The assessments that are made to the proposed scheme try to know if it fulfills one of the main features of a HDR Video encoding proposal, which is to preserve the quality of the SDR and HDR contents.

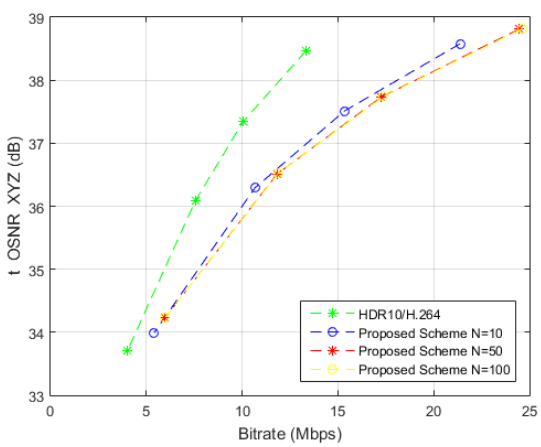
In the HDR domain, as expected, the HDR10 System presents a better compression efficiency than the proposed system for transformed domain-based metrics that involves the tristimulus values of the CIE1930 colorspace, the t_PSNR_XYZ and t_OSNR_XYZ. However, for *Market*, *BalloonFestival*, *ShowGirl* and *EBU_06* sequences, the proposed scheme presents a better compression effi-

ciency than the HDR10 System for color-oriented metrics, the $PSNR\_DE100$ and $PSNR\_MD0100$. Also the metric $PSNR\_L0100$, which evaluates the luminance quality only, has similar behavioral curves between the two systems except for the *FireEater* sequence. Figure 3 and Figure 4 are the results for the *Market* Sequence.

The *FireEater* sequence is a special case because the HDR10 System presents noticeable superior results in all the metrics used in this work. This can be explained by the fact that the histogram of this image has centered in low luminance levels, between 0.00001 and 1 nit. In this range, the PQ signal redistributes the code levels of low luminances of the more efficient way, however, the gamma system exhibits a coarse quantization in the darker regions, since it is well above the visual limits. For this reason, is expected better results for the HDR10 System.



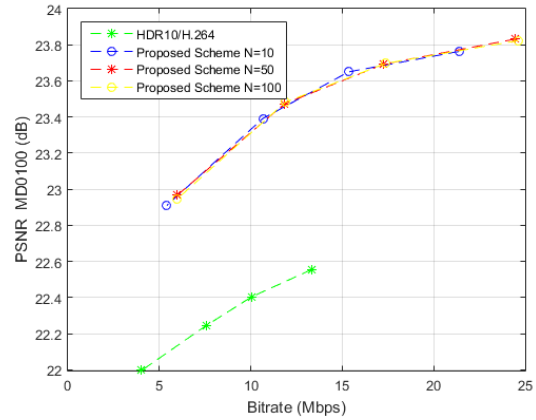
(a)



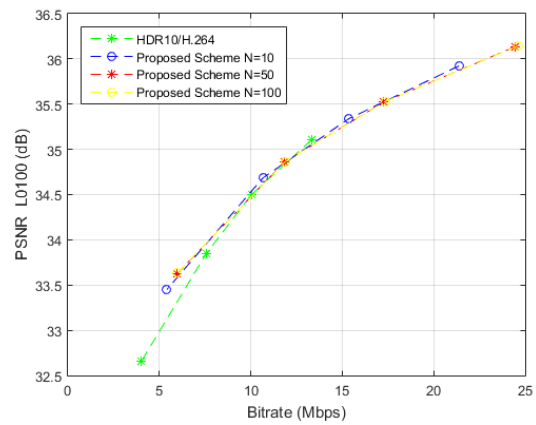
(b)

Fig. 3. (a) t_PSNR_XYZ; (b) t_OSNR_XYZ

In the SDR domain, this work used the $PSNR\_Y'$ metric of the luma component of the $Y'Cb'Cr$ color model. Figure 5a presents the curves of all the tone-mapped sequences with a slope value of 10. Each sequence has different rate-distortion curves. These dissimilarities are caused by the artistic intent of the producer. Also, the high motion scenes generates high bitrates such as depicted in the *EBU_04* sequence. The



(a)



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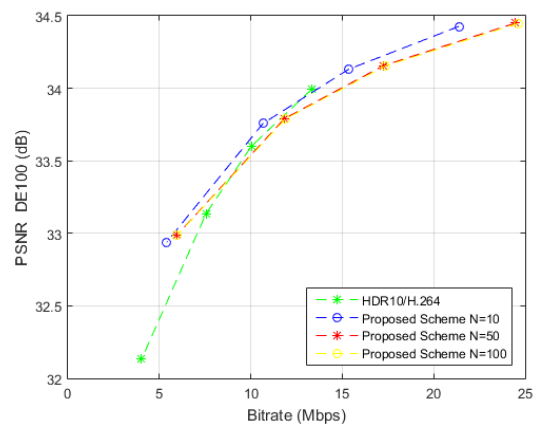

(c)

Fig. 4. (a) PSNR_MD0100 (b) PSNR_L0100 (c) PSNR_DE100

Market sequence also, presents higher bitrates due to the high presence of complex textures. The *BalloonFestival*, *ShowGirl* and *Sunrise* sequences have a moderate bitrate since the three sequences have a moderate contrast and high presence of planar regions. Finally, the *FireEater* and *EBU_06* sequences have the lower bitrates because present low motion scenes and planar regions.

This work used the Absolute Category Rating (ACR)

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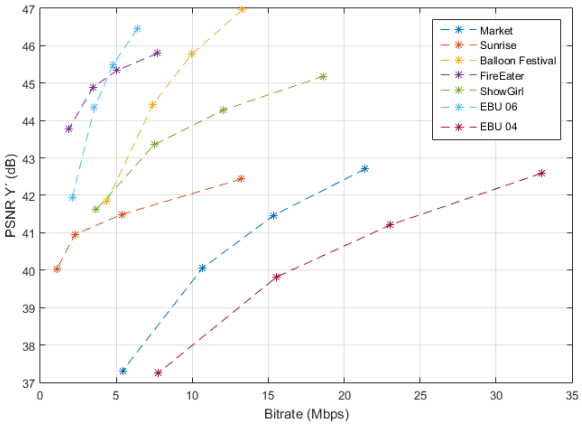
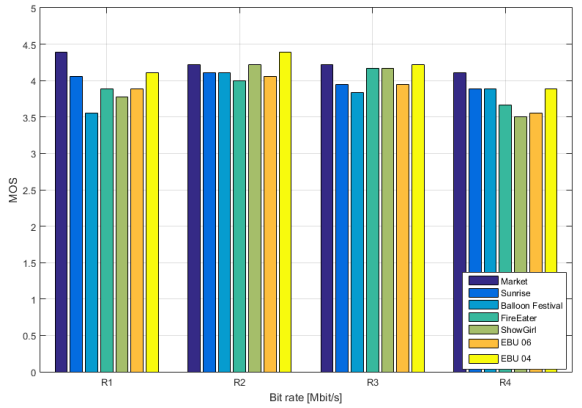


(a)



(b)

Fig. 5. (a) Objective metrics of the tone-mapped sequences; (b) Subjective metrics of the tone-mapped sequences

method as specified in the ITU-T Recommendation P.910 [16] for the subjective assessment. In total, were 18 participants with an average age of 31 years. When showing the sequence of images to the participant, the first seven videos were the ones with the highest bitrate, which means a QP of 20. Then, the videos with a QP value of 24, 28 and 22 were projected progressively. The results contrasted that on average all images were evaluated above a value of MOS 3. The sequences with the poorer results were *ShowGirl* and *EBU_06* sequences with a bitrate *R4*. The MOS values against the different bitrates are depicted in Figure 5b. Table I presents the reached bitrates, *R1, R2, R3 and R4*, of the tone-mapped sequences. This information will be of great help in the design of a HDR TV system in the short term.

IV. Study Case

According to the bitrates obtained in Table I, video engineers could estimate the overhead bitrate that would suppose the deployment of a HDR TV system with backward compatibility, considering the legacy television system.

This study case considers the measured bitrates of the main Brazilian broadcast television in the City of Campinas, Sao Paulo [17]. Table II presents the bitrate of the video PID of each station. The bitrate range is between 8.7 and 15.6 $Mbps$. Usually, when it is designed a television system, the broadcasters resolve to label the type of television programming offered by a channel. These are known as specialty channels and are focused on a single genre, subject or targeted television market. For example, the sports channel broadcasts sporting events, sport news and other related programming. For this content, higher bitrates are assigned. For a cartoon channel, normally, lower bitrates are assigned.

Currently this channel allocation is widely used by companies that develop video encoders. A statistical multiplexing is defined as the compression of a group of services that share information about the variability of their images. It is possible a coding gain of the order of 20 to 30%, in comparison with the coding efficiency when compressing a channel independently.

The bitrate tagged as *R3* reaches good results and mantain a optimal trade-off between bitrate and distortion. The maximum bitrate is 15.537 $Mbps$ and the lowest is 2.285 $Mbps$. The Station B could be designed to broadcast a HDR service of a sport event and other natural images with no distortions, however the station F may be designed to process more natural images with no high motion, such a news channel. Finally, the station C may be designed to process content with much texture and detailed regions such as a documentary channel. Consider that, the kind of programming that presents scenes such as the *FireEater* sequence is unlikely to display on broadcast channels.

From a technical point of view, in order to upgrade the television infraestructure, it is recomendable to change first the video cameras by those one that can record HDR native content. The HDR Reducer process can be added as an option by the future video encoders. They could support two types of video input, a digital video interface with gamma correction and a PQ signal. Whether the HDR version is used, a network interface would be necessary to distribute the metadata information via an IP network towards the MPEG Multiplexer, which assigns it to a certain channel. Finally, this new PID can be standardized according to the chosen digital television standard.

V. Conclusion

The main contribution of the work relies on the design of a HDR TV system with backward compatibility. This is a cost-effective solution because are reusing the current allocated bandwidth, enabling the deployment of a new multimedia service in a television system.

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References

[1] ITU-R BT.709-6, "Parameter values for the HDTV standards for production and international programme exchange," 2015.

TABLE I
BITRATE OF THE SEQUENCES

Sequence	R1 ($Mbps$)	R2 ($Mbps$)	R3 ($Mbps$)	R4 ($Mbps$)
Market	21.379	15.347	10.661	5.407
FireEater	7.721	5.023	3.463	1.891
Sunrise	13.242	5.366	2.285	1.075
ShowGirl	17.169	11.005	6.965	3.550
EBU_06	6.383	4.779	3.560	2.101
BalloonFestival	13.299	9.956	7.418	4.378
EBU_04	32.983	23.025	15.537	7.779

TABLE II
BITRATE OF DIGITAL TELEVISION CHANNELS [17]

Station	Transmission Modes	Channel ($Mbps$)	Layer B ($Mbps$)	Video HD ($Mbps$)	Null PID ($Mbps$)
A	64QAM - 3/4 - 1/16	18.3	17.8	15.2	2.0
B	64QAM - 3/4 - 1/8	17.3	16.9	15.6	1.0
C	64QAM - 3/4 - 1/16	18.3	17.8	11.8	4.0
D	64QAM - 3/4 - 1/8	17.4	16.9	10.5	5.9
E	64QAM - 3/4 - 1/16	18.4	17.8	14.5	2.9
F	16QAM - 5/6 - 1/16	13.6	13.2	8.7	3.6
G	16QAM - 2/3 - 1/8	10.4	10.0	9.7	0.1
H	64QAM - 3/4 - 1/8	17.3	16.9	14.2	1.7
I	64QAM - 3/4 - 1/8	17.3	16.9	12.3	4.2

[2] ITU-R BT.1886, "Reference electro-optical transfer function for flat panel displays used in HDTV studio production," 2011.

[3] P. Nasiopoulos, "Demystifying High-Dynamic-Range Technology," *IEEE Consumer Electronics Magazine*, pp. 72–86, 2015.

[4] ITU-R BT.2390, "High dynamic range television for production and international programme exchange," 2016.

[5] E. Francois and L. van de Kerkhof, "A Single-Layer HDR Video Coding Framework with SDR Compatibility," *SMPTE Motion Imaging Journal*, vol. 126, no. 3, pp. 16–22, apr 2017.

[6] P. G. J. Barten, "Formula for the contrast sensitivity of the human eye," in *Conference on Image Quality and System Performance*, Y. Miyake and D. R. Rasmussen, Eds., vol. 5294, dec 2003, pp. 231–238.

[7] S. Miller, M. Nezamabadi, and S. Daly, "Perceptual Signal Coding for More Efficient Usage of Bit Codes," in *The 2012 Annual Technical Conference & Exhibition*, vol. 122, no. 4. IEEE, oct 2012, pp. 1–9.

[8] D. Pajuelo, P. Cardoso, R. Barbieri, S. Carvalho, and Y. Iano, "Proposal for broadcast high dynamic range content transmission," in *2016 IEEE 5th Global Conference on Consumer Electronics*, vol. 03. IEEE, oct 2016, pp. 1–2.

[9] D. A. Pajuelo Castro, P. E. R. Cardoso, R. O. Barbieri, and Y. Iano, "High Dynamic Range Content in ISDB-Tb System," *SET INTERNATIONAL JOURNAL OF BROADCAST ENGINEERING*, vol. 2, no. 2016, pp. 23–29, aug 2016.

[10] Sim2, "SIM2 specifications," 2016. [Online]. Available: http://hdr.sim2.it/

[11] ISO/IEC 13818-1 and ITU-T Recommendation H.222.0, "Information technology-generic coding of moving pictures and associated audio information: systems," 2006.

[12] P. Y. E. François, J. Sole, J. Ström, "Common Test Conditions for HDR/WCG video coding experiments," in *ISO/IEC JTC 1/SC 29/WG 11/JCTVC-X1020*, 2016.

[13] A. Tourapis and D. Singer, "Hdrtools v15: Software updates," *ISO/IEC JTC1/SC29/WG11 MPEG2014/N15083. Geneva, Switzerland*, 2015.

[14] Joint Video Model Reference Software JM 19.0. [Online]. Available: http://iphome.hhi.de/suehring/tml/download/

[15] F. E. Luthra A. and H. W., "Call for Evidence (CfE) for HDR and WCG Video Coding," in *ISO/IEC JTC1/SC29/WG11 MPEG2015/N15083*, 2015.

[16] ITU-T P.910, "Subjective video quality assessment methods for multimedia applications," 2008.

[17] P. E. R. Cardoso, Y. Iano, D. A. Pajuelo, and R. O. Barbieri, "We Measured and Have Expanded the Space for More Services in Digital Television," *SET INTERNATIONAL JOURNAL OF BROADCAST ENGINEERING*, vol. 2, no. 2016, pp. 66–71, aug 2016.

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Robustness against the effects of multipath in an ISDB-T LDM broadcast system using diversity at reception

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***Abstract*— This paper presents the ISDB-T LDM system, with the Core Layer fully compatible with the traditional ISDB-T and the Enhanced Layer using the Non-Uniform Constellation 64-QNUC, in order to improve spectral efficiency, performance, robustness and useful bit rate, so that it is possible to use it for UHDTV applications. In order to reach these goals, in addition to the LDM technique, the LDPC encoder/decoder concatenated with the BCH were used. The SDR/GRC implementation was used and the reception diversity was achieved by the use of the MRC method. To prove its efficiency, some tests were performed using the proposed system in environments with AWGN and multipath channels.**

***Index Terms*— Integrated Services Digital Broadcasting Terrestrial (ISDB-T), Layer Division Multiplexing (LDM), Maximal Ratio Combining (MRC), Low-Density Parity Check (LDPC), Software Defined Radio (SDR), GNU Radio Companion (GRC), multipath channels.**

I. INTRODUCTION

The demand for better transmission and reception conditions, as well as higher transmission rates on wireless networks, has led to the need for more in-depth studies about the benefits that can be obtained with the use of more than one transmission/reception antenna in communication systems, in case they are under the fading effect [1].

The transmissions of terrestrial broadcasting are reflected by buildings and mountains; i.e., the propagation tends to be multipath environment. To resist multipath interference, the ISDB-T uses the orthogonal frequency division multiplexing (OFDM) modulation scheme. However, its robustness is not as good in severe multipath environments with long-delay waves exceeding the guard interval (GI) or high power multipath waves [2]. Therefore, additional techniques are required, such as the use of the MRC method (diversity at reception) and the use of LDM.

The evolution of Digital Terrestrial Television Broadcasting (DTTB) also requires greater robustness against interference. The new terrestrial broadcasters challenge is to transmit in Ultra High Definition Television (UHDTV). Therefore, it is necessary to use efficiently the spectrum since part of the DTV spectrum is used by wireless broadband services [3].

Some DTV systems are not able to support the requested bit rate and are not robust enough to transmit/receive UHDTV services. However, the substitution of a broadcasting system is not economically viable because it requires the exchange of receivers by all the population [4]. With the communication system created by [4], it is possible to maintain the compatibility of the receivers already installed and increase spectral efficiency by using new modulation, coding and diversity techniques, even in several types of transmission channels with multipath.

The modern Advanced Television Systems Committee (ATSC) 3.0 recommends the use of multiple antennas for transmission and reception besides allowing UHDTV transmission with the use of the LDM modulation technique [5].

The diversity can be defined as a set of versions of the signal transmitted which suffers different attenuations by the channel. This technique consists in the handling of these independent versions of the same signal in order to minimize the effects of the selective fading and also of the transmission channel [6]. An example of interference that occurs in the transmission channel and which commonly appears in digital TV systems is caused by reflection of the signals before they are received by the receiving antennas (multipath). There are some methods of diversity that can be used, such as, time diversity, space diversity and frequency diversity [7].

The purpose of this paper is to test the effect of multipath in the modified version of ISDB-T created by [8]. The system uses LDM technique and Non-Uniform Constellation (NUC). The Core Layer (CL) is compatible with the traditional ISDB-T [9] and the Enhanced Layer (EL) uses Bose, Chaudhuri, and Hocquenghem (BCH) and LPDC codes. Moreover, the MRC method at reception is used in order to improve robustness, bit rate and spectral efficiency [4].

These parameters are requirements for new services such as

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UHDTV without the need to replace the current system in the process of implementing the new technology [4].

The system proposed was implemented in SDR by using GNU Radio Companion (GRC) software. The GRC is a free and open-source software development toolkit that provides signal processing blocks to implement software radios. It can be used with readily-available low-cost external RF hardware to create software-defined radios, or without hardware in a simulation-like environment [10].

This paper is organized into seven sections. In Section II, the main characteristics and advantages of the LDM are presented. Section III contains the most relevant information about the ISDB-T. Section IV presents the characteristics of the maximal ratio combining and the benefits it brings to the system. Section V shows the main characteristics about the transmission channel. Section VI shows the implementation and results of the modified version of ISDB-T with diversity at the reception. And finally, Section VII presents the conclusion of this paper.

II. LAYER DIVISION MULTIPLEXING

The LDM technology allows the transmission of data divided by layers using different power levels, at the same time and frequency. The LDM's main advantages are its efficient use of the spectrum, the increase in the amount of data transmitted [11], robustness against co-channel interference and multipath distortion. Furthermore, the lowest level layer is compatible with any high rate digital broadcasting technology [12].

The EL suffers an attenuation of (Injection Level) dB compared to the CL. This attenuation is performed by multiplying the EL per alpha factor, which has been defined in the ATSC 3.0 standard [13]. Each layer is encoded and mapped separately and then added together. After this step, the combined signal has a power equivalent to the sum of the CL and EL signal powers. Therefore, a power normalization of the combined signal is required, which is performed by its multiplication per beta factor. After this process, the resulting signal is modulated in (OFDM) and the guard interval is inserted [4]. The LDM demodulation is the inverse process: the guard interval is removed, the OFDM demodulation is applied, channel estimation, equalization and the MRC method are realized. A power denormalization is required, so a (beta factor)$^{-1}$ multiplication is applied and then the CL is demapped and decoded [8]. To decode the EL, it is necessary to encode the CL again and then subtract it from the received signal (this process requires a buffer). The EL level is recovered by the (alpha factor)$^{-1}$ multiplication and then this layer can be demapped and decoded [14]. However, for a good performance of the LDM technique, an efficient error correction code is required. Therefore, the concatenated BCH and LDPC codes were used in order to reduce the error floor (phenomenon encountered in modern iterated sparse graph-based error correction codes) [8], [15].

III. INTEGRATED SERVICES DIGITAL BROADCASTING TERRESTRIAL

The ISDB-T is a broadcast system based on Band Segmented Transmission-OFDM (BST-OFDM) which makes use of 13 segments to transmit data and 1 segment as guard band [8]. These segments create up to 3 different layers: A, B and C. Layer A is used to 1seg (mobile), layer B to Standard Definition Television (SDTV) and layer C to High Definition Television (HDTV), but most TV channel transmitters use layer A for 1seg and layer B to HDTV [15], [4]. The bandwidth required for the system can be of 6, 7 or 8 MHz. The ISDB-T uses shortened Reed Solomon (RS) (188, 204, 8) and convolutional coder with rate of 1/2 (G1 = 171 oct; G2 = 133 oct) and puncture of 1/2, 2/3, 3/4, 5/6 or 7/8 [16], [17].

After the RS encoder, the CL uses an energy dispersal to prevent errors due to long sequence of bits with the same value. Then, it is realized a byte interleaving in order to increase the efficiency of RS encoder [16], [17].

The ISDB-T standard uses modulation methods as DQPSK, QPSK, 16-QAM and 64-QAM. A time interleaver is used to increase robustness against impulsive noise and a frequency interleaver is applied to prevent errors from selective fading [4]. The time interleaving length, considering mode 3 (8k) and guard interval 1/16, can be adjusted for 0, 102, 204 or 407 ms. After this step, which scrambles the segments to ensure the appropriate segment structure, some delays are used in order to maintain synchronism [4]. Finally, the frame structure is built using 204 symbols OFDM [8].

After OFDM modulation, a part of the original signal (Guard Interval), is inserted to prevent errors due to multipath. The rates can be 1/4, 1/8, 1/16 or 1/32 [16], [17].

IV. MAXIMAL RATIO COMBINING

In order to achieve improvements in transmission and reception with the use of the ISDB-T, the MRC method can be used where the receiver assigns a gain, proportional to the signal-to-noise ratio (SNR), to each of the signals of each available antenna and then combines them [7].

The attributed gain to each signal is given by Equation 1, where r is the signal envelope in question and σ^2 is the noise variance [18].

$$g = \frac{r}{\sigma^2} \tag{1}$$

The SNR after the combination is given by Equation 2 [18].

$$SNR = \frac{\sqrt{r_1 + \cdots + r_n}}{\sqrt{\sigma^2}} \tag{2}$$

To calculate the gain of each antenna, Equation 3 is used, where SNR_x is the signal-to-noise ratio of the antenna in question [18].

$$g_x = 10^{SNR_x/10} \tag{3}$$

After this process, the linear combination is performed by means of Equation 4, where R is a line matrix composed by the

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symbol received by each antenna, G is a line matrix composed by the gains of each antenna and N_{ant} is the total number of antennas in the system [18].

$$MRC = \frac{RG'}{\sum_{x=1}^{N_{ant}} g_x} \quad (4)$$

The information about all the channels is used with this technique to obtain a more reliable received signal [7]. The drawback of this method is that it requires accurate estimates of the instantaneous signal level and average noise power for a better performance. In addition, it requires the use of more than one channel estimator working in parallel [4].

The SNR estimation for each branch is performed digitally using the pilot carriers [4]. In order to do so, the difference between the pilot carriers positions received and their ideal positions in the scatter diagram are calculated according to Equation 5, where I is the number of pilot carriers known as Auxiliary Channel (AC) and Transmission and Multiplexing Configuration Control (TMCC) and Y is the vector containing the value of the pilot carriers AC and TMCC [19].

$$SNR = 10 \cdot \log_{10} \frac{1}{I} \cdot \sum_{i=1}^{I} \left[\min \left(\left| Y(i) + \frac{4}{3} \right|^2, \left| Y(i) - \frac{4}{3} \right|^2 \right) \right] \quad (5)$$

V. TRANSMISSION CHANNEL

In a wireless transmission system, the transmission channel introduces interferences and noise into the desired signal, limiting the capacity of the system. For the proper functioning of a given digital television standard, it is essential that it presents techniques that minimize these effects in order to the transmission to be viable. The two main causes of quality loss of a wireless transmission system are: the Additive White Gaussian Noise (AWGN) and the multipath [20].

The AWGN is present across the frequency spectrum, and cannot be avoided. In analog transmission, white noise causes quality loss of the received signal. As the desired signal power and the noise power ratio decreases, the image quality loss can be noticed. In digital television systems, the decrease in SNR causes an increase in the bit error probability [20].

In broadcasting systems, it is common for multiple copies of the same transmitted signal to arrive at the receiving antenna via different paths. Each of these paths has different attenuation and delay, which causes the received signal to be formed by the overlapping versions of various symbols coming from different paths [20].

For the simulation of different channels, in order to evaluate the behavior of the ISDB-T LDM system with diversity reception in conditions closer to the real situations, some channels representing the combination of reflected signals at different points must be tested [21].

- Channel A: simulates a reception situation with external antenna in places where the reflected signals are greatly attenuated.
- Channel B: Simulates signal with multiple echoes and large delays.
- Channel C: represents an intermediate reception condition between the channel A and channel D, where there are reflected signals with longer delays than in the Channel D.
- Channel D: represents a reception situation with internal antenna, considered of difficult reception due to the presence of strong reflected signals.

VI. IMPLEMENTATION AND RESULTS

A. Implementation

The Core Layer, used in the transmission, was encoded with CC and RS codes. The coded signal was modulated in QPSK with Code Rate = 1/2 [4].

The Enhanced Layer used the LDPC and BCH codes [22] and then was mapped with 64-QNUC, that has higher performance due to its symbols distribution and has significant gain in comparison to the traditional 64-QAM [13], [23]. The ISDB-T system operates with different code rates compared to the CRs used by the ATSC 3.0 system. Therefore, an adjustment was made in order to make the Non-Uniform Constellation compatible with ISDB-T system that uses the original 64-QAM with CR = 1/2, so the constellation was changed to 64-QNUC with CR = 8/15 because this is the constellation that has the most similar code rate [4].

The Fig. 1 shows the LDM constellation for CL using QPSK with CR = 1/2, EL using 64-QNUC with CR = 1/2 and IL= 6 dB [4].

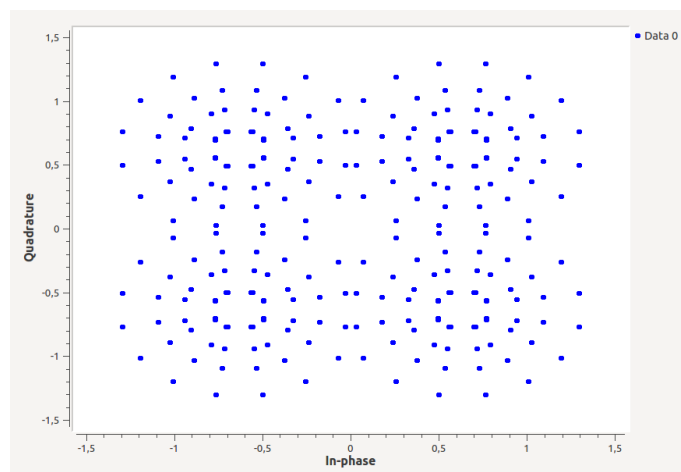

Fig. 1. Constellation with CR = 1/2 and IL = 6dB (Combined signal) [4].

The Fig. 2 shows the constellations of the four receiving branches in the LDM system with QPSK (CL), 64-QNUC (EL), CR = 1/2, IL = 6 dB and SNR = 20 dB before the MRC method [4]. These signals were transmitted by a GRC simulation.

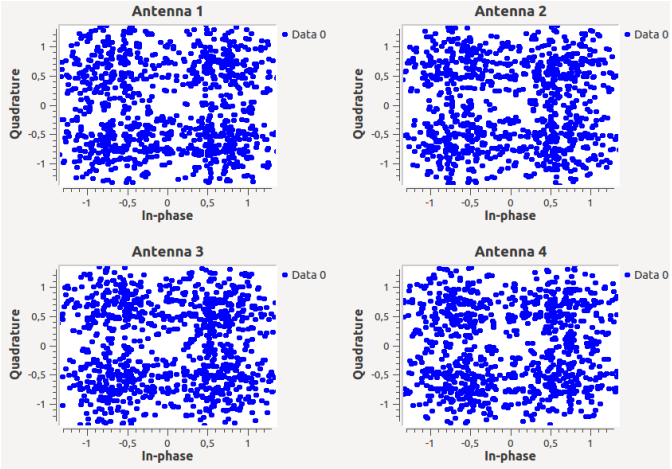

Fig. 2. Constellation (Combined signal) with CR = 1/2, IL = 6 dB and SNR = 20 dB [4].

The Fig. 3 shows the constellation of the resulting signal at the output of the module that performs the MRC [4].

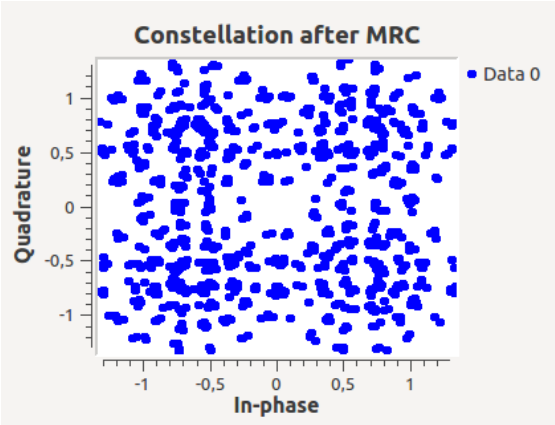

Fig. 3. Constellation (Combined signal) after MRC [4].

The ISDB-T LDM transmitter is presented in the Fig. 4 [4].

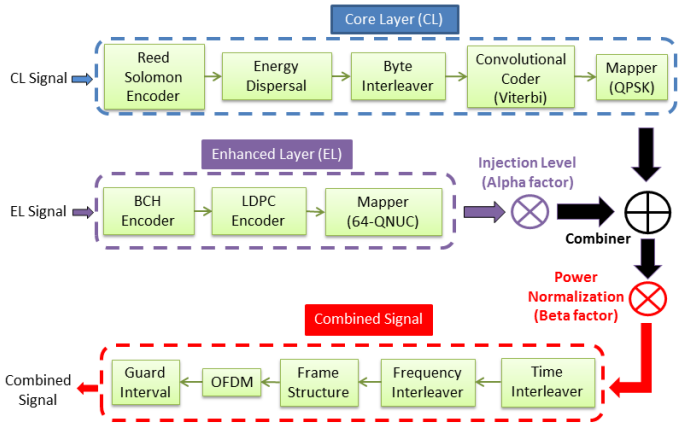

Fig. 4. ISDB-T LDM Transmitter [4].

In order to simulate the multipath effects, the channels A, B, C, and D were used, as well as the addition of AWGN to find the SNR thresholds for each multipath channel configuration. The Fig. 5 shows the block diagram of the GRC that adds AWGN noise (Noise Source) with the signal (File Source) as well as the simulation of the multipath channels (Channel Model).

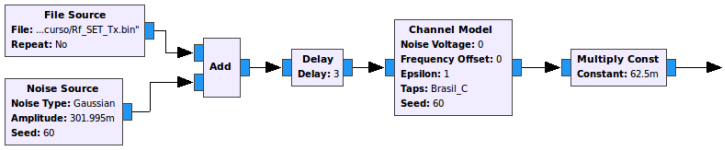

Fig. 5. Multipath channel block diagram.

After this process, the combined signals with Gaussian noise and multipath are sent to the demodulation module of the ISDB-T LDM system.

The ISDB-T LDM receiver with reception diversity is shown in the Fig. 6 [4].

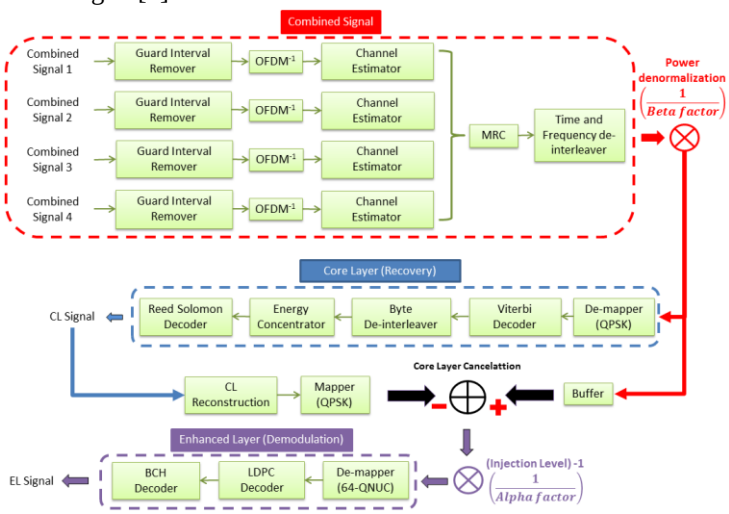

Fig. 6. ISDB-T LDM Receiver with MRC [4].

After the removal of the guard interval and OFDM demodulation, the signal is sent to the channel estimation stage. For a good performance in multipath environments, a 2D (two dimensions) channel estimator was used. It performs time and frequency interpolation. In addition, the interpolation method used was the Cubic Spline, which worked well, concatenated, with the maximal ratio combining stage [24].

To recover the Core Layer signal, a soft de-mapper, a Viterbi soft decoder, an energy concentrator, a RS decoder and a byte de-interleaving were used [4].

In the Enhanced Layer demodulator, a 64-QNUC de-mapper that uses approximately log-likelihood ratio was implemented [8]. These ratios are decoded with a LDPC decoder using N = 64800 and CR = 1/2. The BCH decoder used the same rate and followed the ATSC 3.0 standard for message and code word size, primitive and generator polynomials [13].

For the CL configuration with QPSK, CR = 1/2 and RS + Viterbi, the data rate is 4.295 Mbps. For the EL configuration with 64-QNUC, CR = 1/2 and BCH + LDPC, the data rate is 12.886 Mbps. Thus, with the use of LDM it is possible to reach the data rate of 17.181 Mbps, but there is also an increase in the minimum SNR for use in digital TV systems [8]. The MRC method reduces the negative effects of the use of LDM. With this method, the minimum SNR value decreases as the number of receiving antennas increases.

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B. Results

The source used was a Pseudo Random Binary Sequence 23 (PRBS 23). The number 23 came from the degree of the polynomial used to create this sequence. The maximum number of iterations on LDPC soft decoder was 50.

The tests consisted in measuring the SNR threshold for BER equals 3×10^{-6} using QPSK with CR = 1/2 and 64-QNUC with CR = 1/2 for 1, 2, 3 and 4 receive antennas in an Additive White Gaussian Noise (AWGN) channel with the multipath channels A, B, C and D.

The delay, inherent in the LDM technique, for CL was 437.04 ms and for EL was 655.56 ms, which, respectively, correspond to 2 and 3 frames OFDM [8], [9]. It was also used GI = 1/16, TI = 200 ms, 13 segments, and mode 3 from ISDB-T standard [17].

The SNR was measured by [4] for each configuration without using the LDM technique and multipath. In this case, just the AWGN was inserted by the channel. The results are presented in Table I [4]. The results shown were obtained for the QPSK using only the Layer A of the ISDB-T (Full Seg) with RS + Viterbi and for the 64-QNUC using BCH + LDPC. For the QPSK a gain of 5 dB was obtained with the use of MRC with 4 antennas. For the 64-QNUC, a gain of 6.9 dB was obtained in the same configuration of diversity.

TABLE I
MRC RESULTS IN AWGN CHANNEL.

Number of receive antennas	*Modulation*	*Channel Coder*	*Code Rate*	*SNR (dB)*
1	QPSK	RS+Viterbi	1/2	5.4
2	QPSK	RS+Viterbi	1/2	3.5
3	QPSK	RS+Viterbi	1/2	1.7
4	QPSK	RS+Viterbi	1/2	0.4
1	64-QNUC	BCH+LDPC	1/2	10.9
2	64-QNUC	BCH+LDPC	1/2	7.8
3	64-QNUC	BCH+LDPC	1/2	5.9
4	64-QNUC	BCH+LDPC	1/2	4.0

Table II shows the results for LDM tests without multipath, that used CL with QPSK and CR = 1/2 and EL with 64-QNUC and CR = 1/2 for 1, 2, 3 and 4 receive antennas [4]. For the QPSK (CL) a gain of 5.8 dB was obtained with the use of MRC with 4 antennas. For the 64-QNUC (EL), a gain of 3.8 dB was obtained in the same configuration of diversity.

TABLE II
MRC RESULTS USING LDM IN AWGN CHANNEL.

Number of receive antennas	*Modulation*	*Channel Coder*	*Code Rate*	*IL (dB)*	*SNR (dB)*
1	QPSK (CL)	RS+Viterbi	1/2	6	15.4
2	QPSK (CL)	RS+Viterbi	1/2	6	12.5
3	QPSK (CL)	RS+Viterbi	1/2	6	10.7
4	QPSK (CL)	RS+Viterbi	1/2	6	9.6
1	64-QNUC (EL)	BCH+LDPC	1/2	6	20.4
2	64-QNUC (EL)	BCH+LDPC	1/2	6	20
3	64-QNUC (EL)	BCH+LDPC	1/2	6	19.1
4	64-QNUC (EL)	BCH+LDPC	1/2	6	16.6

Table III shows the results for the configuration without LDM technique and with multipath, for 1, 2, 3 and 4 receiving antennas and CR = 1/2.

For the QPSK with Channel A a gain of 0.8 dB was obtained with the use of MRC with 4 antennas. For Channel B the gain was 1.7 dB, for the Channel C was 0.8 dB and for Channel D was 1.6 dB.

For the 64-QNUC with Channel A a gain of 4.9 dB was obtained in the same configuration of diversity. For Channel B the gain was 3.2 dB, for the Channel C was 4.6 dB and for Channel D was 2.5 dB.

TABLE III
MRC RESULTS IN AWGN/MULTIPATH CHANNELS.

Number of receive antennas	*Modulation*	*Channel Coder*	*SNR (dB)*			
			Channel A	*Channel B*	*Channel C*	*Channel D*
1	QPSK	RS+Viterbi	8.1	14.3	8.2	15.7
2	QPSK	RS+Viterbi	7.6	13.7	7.6	15.1
3	QPSK	RS+Viterbi	7.4	12.8	7.5	14.5
4	QPSK	RS+Viterbi	7.3	12.6	7.4	14.1
1	64-QNUC	BCH+LDPC	12.0	15.5	12.1	16.6
2	64-QNUC	BCH+LDPC	9.5	15.1	9.7	15.5
3	64-QNUC	BCH+LDPC	8.0	13.6	8.3	14.6
4	64-QNUC	BCH+LDPC	7.1	12.3	7.5	14.1

Table IV shows the results for LDM tests with multipath, that used CL with QPSK and CR = 1/2, EL with 64-QNUC and CR = 1/2 and Injection Level = 6 dB.

For the QPSK (CL) with Channel A a gain of 5.8 dB was obtained with the use of MRC with 4 antennas. For Channel B the gain was 2.5 dB, for the Channel C was 5.8 dB and for Channel D was 2.1 dB.

For the 64-QNUC (EL) with Channel A a gain of 2.2 dB was obtained in the same configuration of diversity. For Channel B the gain was 2.8 dB, for the Channel C was 2.3 dB and for Channel D was 2.5 dB.

TABLE IV
MRC RESULTS USING LDM IN AWGN/MULTIPATH CHANNELS.

Number of receive antennas	***Modulation***	***Channel Coder***	***IL (dB)***	***SNR (dB)***			
				Channel A	***Channel B***	***Channel C***	***Channel D***
1	QPSK (CL)	RS+Viterbi	6	16.1	16.6	16.2	17.4
2	QPSK (CL)	RS+Viterbi	6	13.1	15.0	13.1	16.2
3	QPSK (CL)	RS+Viterbi	6	11.3	14.3	11.4	15.7
4	QPSK (CL)	RS+Viterbi	6	10.3	14.1	10.4	15.3
1	64-QNUC (EL)	BCH+LDPC	6	19.9	20.0	20.1	20.7
2	64-QNUC (EL)	BCH+LDPC	6	19.3	18.9	19.2	19.5
3	64-QNUC (EL)	BCH+LDPC	6	18.1	17.8	18.2	18.7
4	64-QNUC (EL)	BCH+LDPC	6	17.7	17.2	17.8	18.2

VII. CONCLUSION

The LDM implementation into ISDB-T is important to secure the compatibility with the traditional system in case of new broadcast technology transition. However, there is an increase of the minimum SNR values required for the correct reception of the transmitted signal when the LDM technique is used. Thus, it would be possible to use the CL of the LDM to transmit the ISDB-T and, at the same time, transmit a new technology in the EL.

With the use of more than one receiving antenna using the MRC method, it is possible to improve robustness and the data rates of each layer of the system. For each added antenna, a gain was obtained as shown in Tables I, II, III and IV.

The implementation of NUC modulators, demodulators and the BCH and LDPC codes contributed to the system's improvement.

The enhanced version of ISDB-T LDM system with reception diversity allows to transmit more data and it is more robust against noise and multipath interferences. With its use, it was possible to reach a data rate of 17.181 Mbps with CR = 1/2. This data rate can be increased with the use of different code rates [8]. With the use of multiple receiving antennas and the MRC method, it is possible to compensate for the increase the minimum SNR value for the correct reception of the signals in a digital TV broadcast system.

The tests showed that even in a multipath environment with extreme degradations in the transmitted signal, it was possible to recover it efficiently with the use of MRC, LDM, Non-Uniform Constellations, as well as powerful codes such as LDPC.

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REFERENCES

[1] G. J. Foschini and M. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," *Wireless Personal Communications,* vol. 6, pp. 311-335, 1998.

[2] A. Sato, T. Shitomi, T. Takeuchi, M. Okano and K. Tsuchida, "Transmission performance evaluation of LDPC coded OFDM over actual propagation channels in urban area. Examination for next-generation ISDB-T," *2017 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB),* pp. 1-5, June 2017.

[3] Y. Wu, B. Rong, K. Salehian and G. Gagnon, "Cloud Transmission: A New Spectrum-Reuse Friendly Digital Terrestrial Broadcasting Transmission System," *IEEE Transactions on Broadcasting,* vol. 58, no. 3, pp. 329-337, September 2012.

[4] R. S. Rabaça, C. Akamine, G. H. M. G. d. Oliveira and Y. P. Maciel, "Implementation of LDM/ISDB-T broadcast system using diversity at reception," *2017 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB),* pp. 1-4, 8 June 2017.

[5] L. Fay, L. Michael, D. Gómez-Barquero, N. Ammar and M. W. Caldwell, "An Overview of the ATSC 3.0 Physical Layer Specification," *IEEE Transactions on Broadcasting,* vol. 62, pp. 159-171, March 2016.

[6] T. K. Roy and M. Morshed, "Performance analysis of pdc over rayleigh fading channel for ofdm system," *International Journal of Computing Communication and Networking Research,* vol. 2, pp. 1-6, January 2013.

[7] B. Vucetic and J. Yuan, Space-time Coding, 1 ed., John Wiley and Sons Ltd, 2003.

[8] G. H. M. G. d. Oliveira, C. Akamine and Y. P. Maciel, "Implementation of ISDB-T LDM broadcast system using LDPC codes," *2016 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB),* pp. 1-4, June 2016.

[9] L. F. d. Silva, C. Akamine, Y. P. Maciel, G. Bedicks and E. L. Horta, "A proposal to use cloud transmission technique into the ISDB-T system," *2015 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting,* pp. 1-5, 2015.

[10] GNU Radio, "GNU Radio Companion," [Online]. Available: https://wiki.gnuradio.org/index.php/Main_Page. [Accessed 29 July 2017].

[11] S. I. Park, H. M. Kim, P. Angueira and Y. Wu, "Hardware Implementation and Complexity Analysis of Layered Division Multiplexing (LDM) System for ATSC 3.0," *NAB Broadcast Engineering Conference,* pp. 77-81, 2015.

[12] L. Zhang, Y. Wu, W. Li, H. M. Kim, S. Park, P. Angueira, J. Montalban and M. Velez, "Channel capacity distribution of Layer-Division-Multiplexing system for next generation digital broadcasting transmission," *2014 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting,* pp. 1-6, 2014.

[13] Advanced Television Systems Commitee (ATSC), *ATSC Candidate Standard: Physical Layer Protocol,* A/322, Apr. 2016.

http://www.set.org.br/ijbe/ doi: 10.18580/setijbe.2017.5 Web Link: http://dx.doi.org/10.18580/setijbe.2017.5

[14] J. Montalban, B. Rong, Y. Wu, L. Zhang, P. Angueira and M. Velez, "Cloud Transmission frequency domain cancellation," *2013 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, pp. 1-4, 2013.

[15] R. Asvadi, A. H. Banihashemi and M. Ahmadian-Attari, "Lowering the Error Floor of LDPC Codes Using Cyclic Liftings," *IEEE Transactions on Information Theory*, vol. 57, no. 4, pp. 2213-2224, April, 2011.

[16] C. Akamine, Y. Iano, G. d. M. Valeira and G. Bedicks, "Re-Multiplexing ISDB-T BTS Into DVB TS for SFN," *IEEE Transactions on Broadcasting*, vol. 55, no. 4, pp. 802-809, December 2009.

[17] Association of Radio Industries and Businesses (ARIB), *Transmission System for Digital Terrestrial Broadcasting*, STD-B31, V1.6 E2, Nov. 2005.

[18] Brazilian Association of Technical Standards - Associação Brasileira de Normas Técnicas (ABNT), *Digital terrestrial television – Transmission system*, NBR 15601, Nov. 2007.

[19] R. J. L. Olandim and C. Akamine, "Spatial diversity at reception in ISDB-Tb systems," *Proceedings of the Symposium on Signal Processing of UNICAMP*, vol. 1, pp. 1-4, 2014.

[20] R. J. L. Olandim, *Spatial diversity at reception in ISDB-Tb systems*, Sao Paulo: Mackenzie Presbyterian University, 2015.

[21] L. L. Mendes and S. A. Fasolo, "Introduction to Digital Television," pp. 1-6, Technical report, INATEL, 2002.

[22] Mackenzie Presbyterian University, "Robustness of digital TV systems to interference," *Journal of Engineering and Computing*, vol. 5, nº 5, 2004.

[23] European Telecommunications Standards Institute (ETSI), *Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)*, EN 302 307, V1.2.1, Aug. 2009.

[24] N. S. Loghin, J. Zöllner, B. Mouhouche, D. Ansorregui, J. Kim and S. I. Park, "Non-Uniform Constellations for ATSC 3.0," *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 197-203, March 2016.

[25] T. M. Sapia and C. Akamine, "Channel estimation evaluation in an ISDB-T system using GNU Radio," *Conference on Electronics, Telecommunications and Computers*, pp. 1-2, Dec. 2016.

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Dual-Polarized Indoor Antenna for Digital TV Reception

Guilherme B. dos Santos, Cristiano Akamine, and Edson T. C. dos Santos

***Abstract*—This paper presents the design and simulations of a dual-polarized indoor antenna to receive the signal provided by the traditional ISDB-T system, operating in Ultra-High Frequency range destined to the radio-frequency channels after analog switch-off. The design goals were towards low cost, simple construction and implementation computational for indoor applications and with good performance in terms return loss within the frequency band. The antenna was designed and optimized using a full wave electromagnetic solver, and the results indicated that the proposed antenna has a good performance, simple structure and is a suitable candidate to be employed in the current digital television standard as in the next-generation of digital broadcasting.**

***Index Terms*—dual-polarized antenna, indoor antenna, integrated services digital broadcasting terrestrial (ISDB-T), MWS-CST Studio.**

I. Introduction

With the establishment of the digital television system, improvements emerged compared to the analog television system, such as bringing users better quality picture, audio and video. This transition of the analog/digital system is already a reality in Brazil so that organs linked to the Brazilian government are performing the process of Analog Switch-Off (ASO). The ASO aims to release the electromagnetic spectrum in the Ultra-High Frequency (UHF) band to allow the expansion of mobile broadband. Due to this operation in adjacent bands, there is a possibility that the Long-Term Evolution (LTE) signal interferes Digital Terrestrial Television Broadcasting (DTTB).

As the LTE uplink and downlink operating range use the same channels used for television, 52 to 69, the saturation of the tuner or the image frequency can degrade the reception of DTTB signal [1]. This means an interruption in receiving programming, frozen images or black screen. In critical cases, to preserve the quality of DTTB signal reception is required a combination of several mitigation measures. The filter installation on LTE transmitters is intended to reduce interfering emissions as much as possible. Furthermore, the installation of filters on DTTB receivers aims to increase their protection against degradation [2]. However, the resources needed to minimize the impact on the viewer are not limited to the development and manufacture of filters, but also in new changes in the configuration of the antennas.

The new DTTB requires a high spectrum efficiency since Ultra High Definition Television (UHDTV) transmission is necessary and part of the spectrum are used to wireless broadband services [3].

When designed with dual polarization, such antennas represent an alternative which may allow the increase of the efficiency of the spectrum. There is an improvement of the robustness of the wireless link against the polarization differences between the transmitter and the receiver of the current communications systems. Furthermore, they may also bring the proposal to replace a conventional system of the type Multiple-Input Multiple-Output (MIMO) with geographically spaced antennas for antennas that have a diversity of polarization in the same physical space [4].

Dual-polarized antennas are antennas that have the characteristic of radiating dual orthogonal linear polarization from the same structure. Such polarizations are defined as horizontal polarization and vertical polarization. Each polarization is lagged at an angle of 90 degrees to another. Any dual polarization antenna is fed using two “ports”, so the resulting radiation pattern is horizontally polarized when applying a signal to one port and vertically polarized when applying a signal to other port [5].

Some DTTB transmission tests have already been performed using dual-polarized antennas, such as in Japan, where it was possible to transmit 8K-quality images between two experimental stations in the Hitoyoshi area in Kumamoto [6]. Moreover, during the Rio de Janeiro Olympics Games, the TV Globo in collaboration with NHK (Japan Broadcasting Corporation) provided the first public broadcast of 8K UHDTV images at the Museum of Tomorrow using, among various technologies for transmission, dual-polarized antennas [7].

The purpose of this paper is to present the design and simulations of a dual-polarized antenna model for indoor applications. The antenna operates in the radio-frequency range of DTTB after the ASO, as well as in the current TV system and the next-generation of digital broadcasting. This antenna can improve the quality of the signal received at any position in the environment besides being used as filter to reduce possible interferences provided by the LTE signal

This paper is organized into six sections. Section II, presents the concepts of the fundamental parameters analyzed that characterize an antenna. Section III presents the development of antenna design with a single polarization. The Section IV shows the development and the Section V presents the results of dual-polarized antenna simulations. Moreover, Section VI draw the conclusions.

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II. Fundamental Parameters of Antennas

A. Definition of the term antenna

IEEE Standard Definitions of Terms for Antennas defines antenna as an element that radiates and receives radio waves. However, [8] describes an antenna as a transitional structure between the free space and the transmission line. In other words, an antenna is a device that converts electromagnetic energy guided by the transmission line into radiated electromagnetic energy in the free space.

B. Radiation pattern

The radiation pattern of an antenna is the graphical representations of its radiation and power properties as a function of the angle at a fixed distance [8]. The electric and magnetic fields are some types of diagrams. In the case of dual-polarized antennas, it is interesting to present an omnidirectional irradiation pattern, Fig. 1 [8], as reported [4].

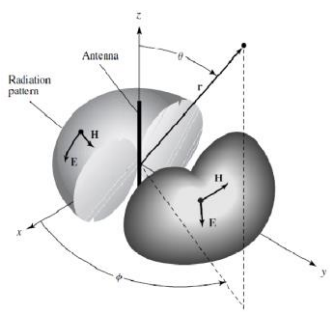

Fig. 1. Omnidirectional Irradiation Pattern.

C. Return loss

Return loss represents the quantities of power reflected from the antenna. This parameter can be obtained using Equation 1, where Γ(ω) is the reflection coefficient [8].

$$S_{11} = 20\log(|\Gamma(\omega)|) \tag{1}$$

D. Bandwidth

Bandwidth is the antenna operating range, where performance meets specific standards such as gain, directivity, impedance, among others [8]. The good performance of the antenna is within the frequency range close to the center frequency, which makes it necessary for the frequency variations of the upper and lower frequencies to be acceptable. The bandwidth is calculated using the Equation 2.

$$BW = f_{upper} - f_{lower} \tag{2}$$

E. Fractional bandwidth

The fractional bandwidth of an antenna is a measure of how wideband the antenna is. This parameter is calculated by Equation 3.

$$FBW = \frac{BW}{f_{central}} \tag{3}$$

F. Polarization

Per [9], the signal polarization can be defined regarding a signal transmitted or received by an antenna in one direction. The antenna polarization radiated a signal considered as the trajectory described by the electric field vector when viewed by an observer who sees the wave moving away from itself. The total electric field of this radiated wave is composed of orthogonal components that differ in amplitudes (E_{xo} and E_{yo}) and phases ($\phi_x$and ϕ_y), Equations 4 and 5, where through the orientation it is possible to determine the type of polarization that the antenna radiates. The total electric field of this plane wave propagating in the z direction can be represented by Equation 6.

$$E_x(z,t) = E_{xo}.\cos(\omega t + \beta z + \phi_x) \tag{4}$$

$$E_y(z,t) = E_{yo}.\cos(\omega t + \beta z + \phi_y) \tag{5}$$

$$E(z,t) = E_x(z,t) + E_y(z,t) \tag{6}$$

In general, most antennas radiate either linear or circular polarization. A linear polarized antenna radiates wholly in one plane containing the direction of propagation. In a circular polarized antenna, the plane of polarization rotates in a circle making one complete revolution during one period of the wave. An antenna is said to be vertically polarized (linear) when its electric field is perpendicular to the Earth's surface and horizontally polarized (linear) when their electric field is parallel to the face of the earth. A circular polarized wave radiates energy in both the horizontal and vertical planes and all planes in between. The difference, if any, between the maximum and the minimum peaks as the antenna, is rotated through all angles, is called the axial ratio and is usually specified in decibels (dB). If the axial ratio is near 0 dB, the antenna is said to be circular polarized. The polarization is linear if the axial ratio is greater than 3 dB [10].

III. Development Antenna Design with Single-Polarization

With the availability of software for modeling and simulation of antennas, it is possible to predict the resulting characteristics very close to the confection of a real antenna. The software chosen to perform all the simulations was the MWS-CST Studio version 2014 [11].

The simulations served to identify which model of antenna presented the bandwidth closest to the intended, to select the most viable for the final confection model.

All metal structures are perfect electrical conductors (PEC), the ground plane is a thin sheet (thickness 0.035 mm), the feeding was performed with an impedance 50Ω and range of interest $S_{11} \leq$ - 10 dB.

A. Quarter-wavelength filament monopole structure

The project started from a monopole antenna consisting of a cylindrical filamentary radiating element supported by a ground plane. The calculation of the antenna height was made to meet the center frequency. This value is the averaging DTV

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frequency range 470 MHz to 698 MHz. By calculating the average of this frequency range, the center frequency value was found to be 584 MHz, and it was possible to calculate the antenna height using Equation 7. Where λ_m is the average wavelength, and *v* is the speed of light.

$$\lambda_m = \frac{v}{f_{central}} \tag{7}$$

The obtained value of the average wavelength was equal to 513.7 mm. A quarter-wavelength structure is the characteristic of the monopole antenna. The final metric dimension was assumed with a height of H = 130 mm and a ground plane with length 500 x 500 mm. After performing some simulations, it was observed limitations in bandwidth this structure, BW = 0.11781 GHz. A cylindrical monopole replaced this structure and verified its influence on bandwidth.

B. *Quarter-wavelength cylindrical monopole structure*

The filament antenna was superseded by a cylindrical antenna to increase bandwidth. Per [8], as the cylinder radius increases, the bandwidth also tends to grow. Simulations were performed, where the radius of the cylindrical antenna and the length of the ground plane were varied, and an increase of bandwidth was observed, resulting in BW = 0.14573 GHz, Fig. 2, using radius = 4 mm and the ground plane of 500 x 500 mm, Fig. 3.

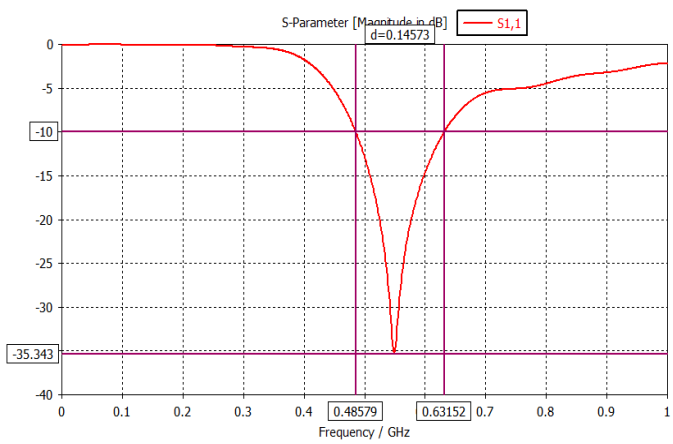


Fig. 2. Bandwidth obtained BW = 0.14573 GHz of the cylindrical monopole antenna.

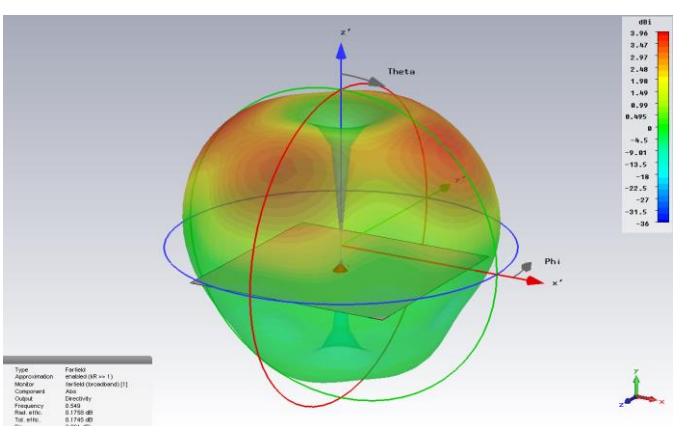


Fig. 3. Tridimensional radiation pattern of the cylindrical monopole antenna.

It has been observed that at first, the cylindrical antenna cannot satisfactorily cover the entire band, as well as the filamentary form. Although it has excellent omnidirectional characteristics, what is desirable, new structures must be sought to meet both bandwidth and omnidirectionality.

C. *Planar monopole structure*

The planar monopole antenna is an antenna model that has been extensively studied in the literature. According to [12], this type of antenna can cover a bandwidth of the order of 1:18, also serve as a reference for antenna designs that operate in the S, X and C bands. In most cases, this structure is formed by a square radiating element supported by a ground plane and fed by an SMA connector. Fig. 4 [13], where W is the width and L is the length of the square radiating element, and the h is the distance between the ground plane and the radiating element, called gap.

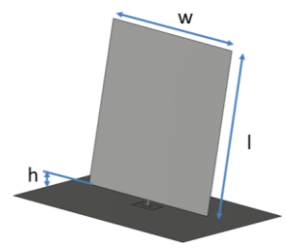


Fig. 4. Planar monopole antenna over a ground plane and its geometric parameters.

With the results of the simulations, it was observed that the gap distance substantially influences the bandwidth and operating point of the center frequency. Thus, the value of the optimal gap is between the null value and 1 mm of distance. Larger gap distances strongly deviate the center frequency and the beginning of the resonant frequency. The results of the simulations indicated the value of gap = 1 mm, which is closer to 1 of the Smith Chart, that is, matched with the feed impedance of 50Ω. The W, L, and ground plane dimensions were also varied and analyzed through the Smith Chart, and the results of the simulations indicated W = 80 mm, L = 150 mm and ground plane 200 x 200 mm, Fig. 6, as the combination that resulted in a bandwidth close to the desired, Fig 5.

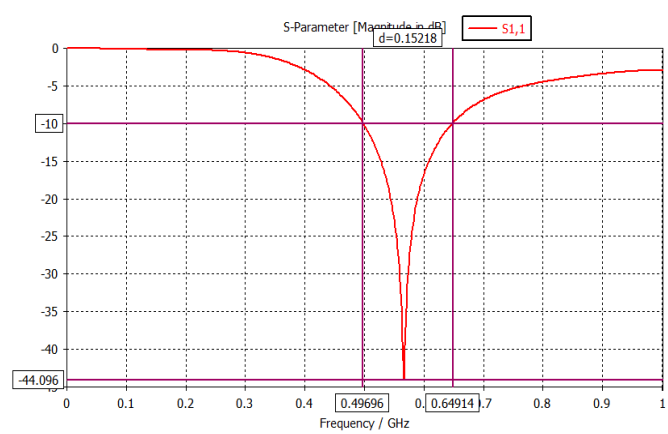


Fig. 5. Bandwidth obtained BW = 0.15218 GHz of the planar monopole antenna.

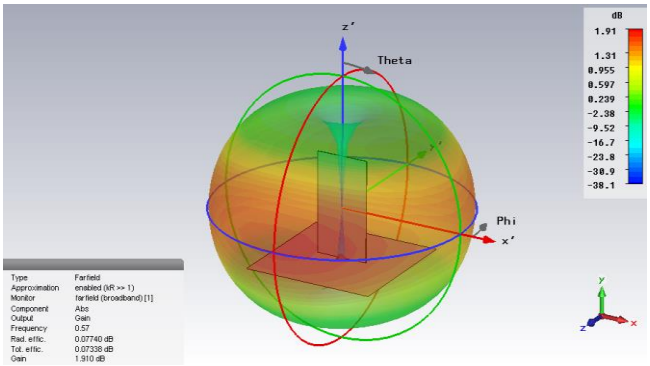


Fig. 6. Tridimensional radiation pattern of the planar monopole antenna.

D. *Planar monopole structure with parasitic elements*

Among the three structures designed and simulated, the planar monopole antenna was the structure that presented the best response, in the band criterion, and in the guarantee of omnidirectionality. Table I indicates that the planar monopole antenna still has a fractional band higher than the others simulated.

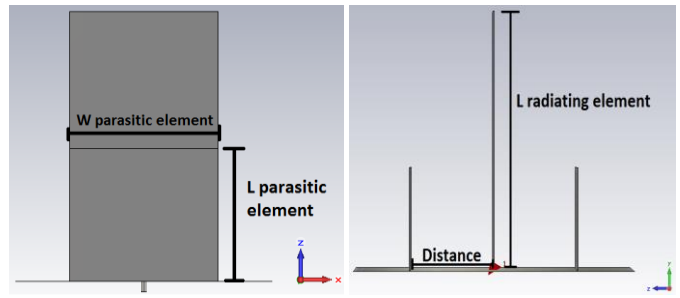
TABLE I
PERFORMANCE COMPARISON OF PROJECTED STRUCTURES (FREQUENCIES IN GHz)

Structures	f_{lower}	$f_{central}$	f_{upper}	BW	FBW (%)
Filament	0.492	0.543	0.610	0.118	21.7
Cylindrical	0.485	0.549	0.631	0.146	26.6
Planar	0.496	0.564	0.649	0.153	27.1

However, the planar monopole antenna in this configuration also cannot cover all the desired bandwidth. For this reason, it was necessary to redeem in the literature some techniques that could increase the bandwidth of an antenna. Among the most used are: resistive load, alteration in structure and addition of parasitic elements and elements of matching or structures of matching [14]. The technique chosen for this project was to the addition of parasitic elements in the structure.

It was first inserted into the planar monopole structure a single rectangular parasitic element and verified its influence on the bandwidth. Similarly, to the previous simulations, the metric dimensions of the parasite element, as well as its distance to the rectangular radiating element, were varied and analyzed by Smith Chart. After successive simulations, the results indicated that with a single parasitic element attached to the structure it was possible to increase the bandwidth around 0.023 GHz, leading to a total bandwidth of 0.181 GHz.

A second identical rectangular parasitic element, Fig. 7, was attached to the structure and through the simulations, an increase of band was verified compared to the structure with a single parasitic element. With the parasitic elements designed in the dimensions W = 110 mm, L = 100 mm and its distance to the rectangular radiating element = 55 mm, was possible to increase the bandwidth around 0.069 GHz, resulting in a total bandwidth of 0.250 GHz, Fig. 8. Fig. 9 shows the tridimensional radiation pattern this new structure.



(a) (b)

Fig. 7. Planar monopole structure with two parasitic elements (a) its geometric parameters, (b) distance to the rectangular radiating element.

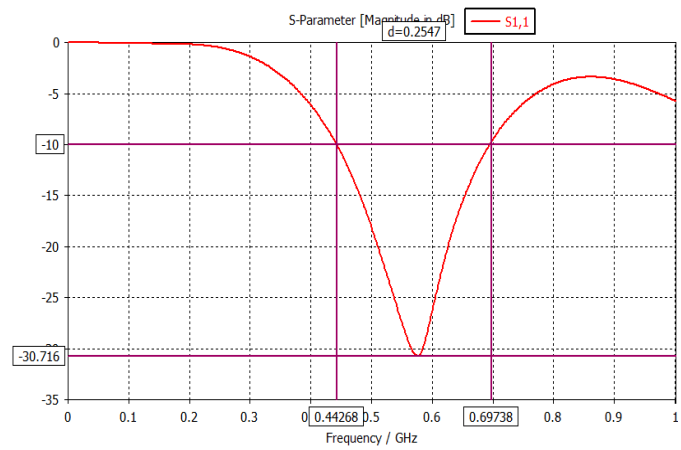


Fig. 8. Bandwidth obtained BW = 0.25470 GHz of the planar monopole structure with two parasitic elements.

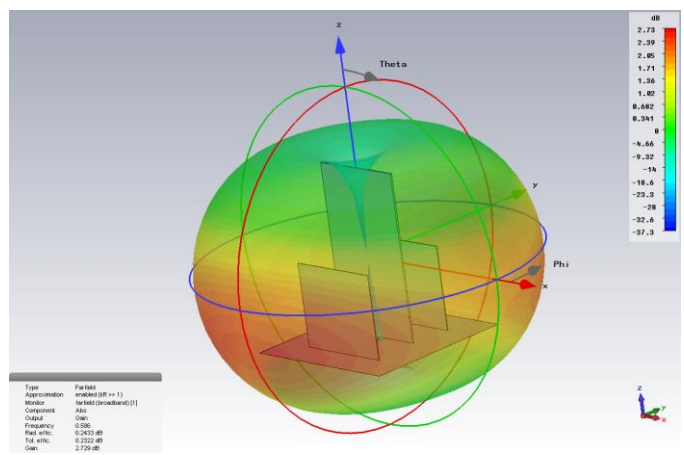


Fig. 9. Tridimensional radiation pattern of the planar monopole structure with two parasitic elements.

Table II compares the performance of the simulated anterior structures with the planar monopole antenna with parasitic elements. Comparing the performances was verified that the planar monopole antenna with two parasitic elements exceeded in all the criteria previously discussed. The structure presented the highest bandwidth and percentage of a fractional band, besides to satisfying optimal values of lower, central and upper frequency. Given the reasons offered, this structure

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proved to be the most feasible for the confection of the dual-polarized antenna that is presented in the Section IV.

TABLE II
PERFORMANCE COMPARISON OF THE PREVIOUS STRUCTURES SIMULATED WITH THE PLANAR MONOPOLE ANTENNA WITH PARASITIC ELEMENTS (FREQUENCIES IN GHz)

Structures	f_{lower}	$f_{central}$	f_{upper}	*BW*	*FBW* (%)
Filament	0.492	0.543	0.610	0.118	21.7
Cylindrical	0.485	0.549	0.631	0.146	26.6
Planar	0.496	0.564	0.649	0.153	27.1
Planar (single parasitic element)	0.511	0.588	0.693	0.181	30.7
Planar (two parasitic elements)	0.442	0.586	0.697	0.255	43.5

IV. Dual-Polarized Antenna Design

Based on the analysis of the single-polarized antenna in the previous section, it was verified that the planar monopole antenna with two parasite elements was the structure that presented the best results and for this reason was the structure chosen for the modeling of the dual-polarized antenna.

According [5] dual-polarized antennas are antennas that have the characteristic of radiating dual orthogonal linear polarization from the same structure, Fig. 10 [15], where each polarization is lagged at an angle of 90 degrees to another.

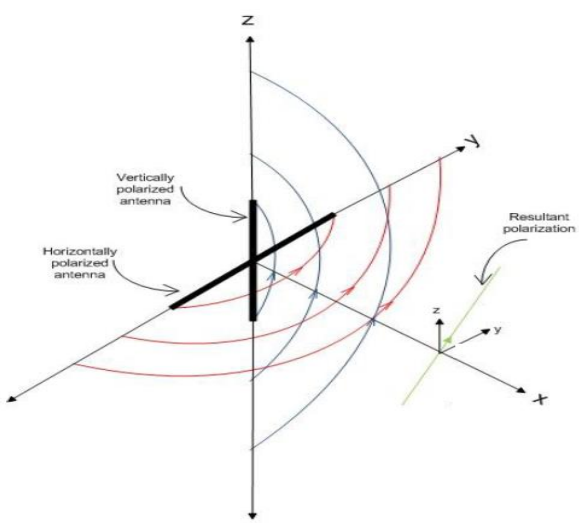
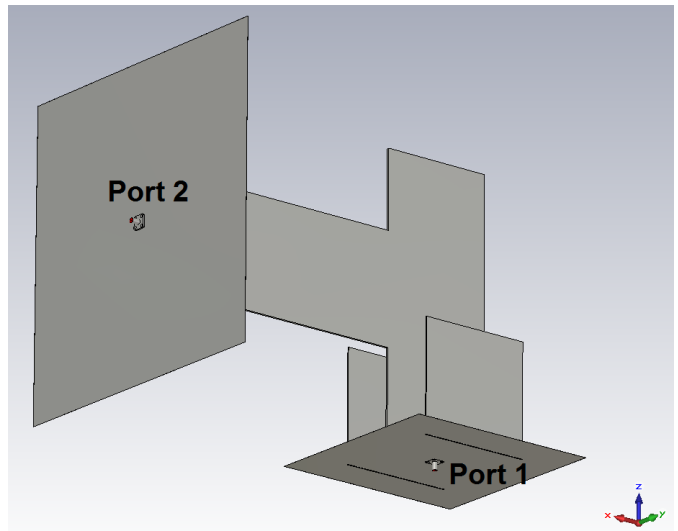
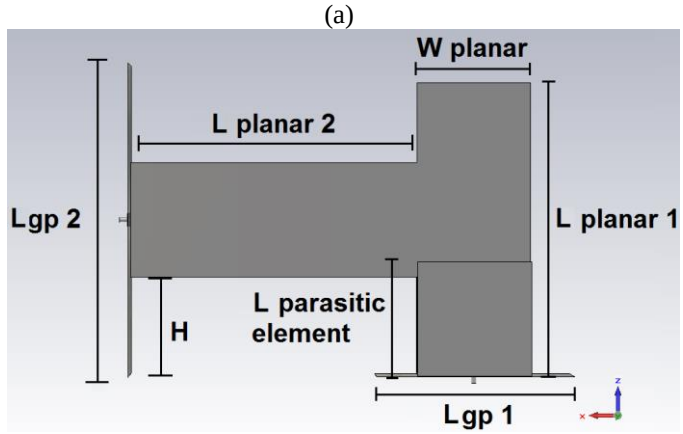


Fig. 10. Orthogonal linear polarizations of a dual-polarized antenna.

The planar monopole structure with two parasitic elements has a vertical radiating element supported by a ground plane, characterizing a vertical polarization. As a way of obtaining the horizontal polarization, a second planar monopole structure was attached chosen the structure. The main radiating element of the second structure was placed in an orthogonal position to the radiating element of the selected structure. Thus, when one of the ports is activated, and the other is matched with the feed impedance of 50Ω, one polarization is obtained. The other polarization, orthogonal to the first, occurs when the situation is the reverse: the second port is active, and the other port is matched. The basic design of proposed dual-polarized antenna is shown in Fig. 11.



(a)



(b)

Fig. 11. Dual-polarized antenna proposed (a) view of the ports, (b) its geometric parameters.

V. Simulation and Results

The dimensions of the proposed antenna after optimization are follows: L planar 1 = 280 mm, L planar 2 = 170 mm, L parasitic element = 110 mm, W planar = 110 mm, Lgp 1 = 190 x 190 mm, Lgp 2 = 300 x 300 mm, H = 100 mm and the distances of the parasitic elements to the radiating element were maintained in 55 mm. Fig. 12 shows return loss curves of both port 1 (S_{11}) and port 2 (S_{22}). At the operating frequency, both ports have return loss values lower than -10 dB. The isolation between two ports is higher which varies between 11 to 20 dB in operating band. The results show that the proposed antenna obtains enough bandwidth at port 1, but the bandwidth at port 2 is inferior to port 1 to ensure the high isolation performance.

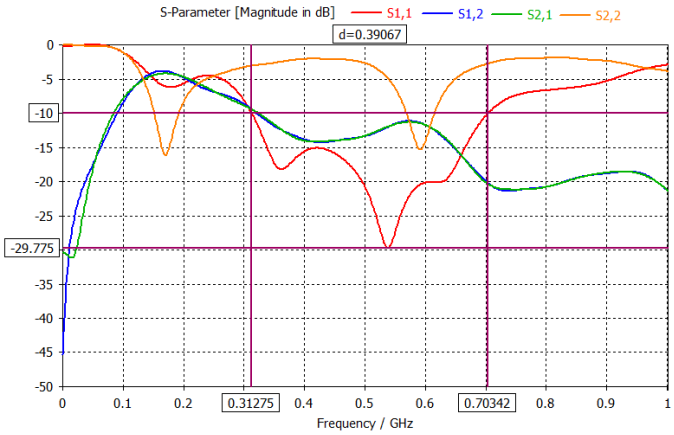
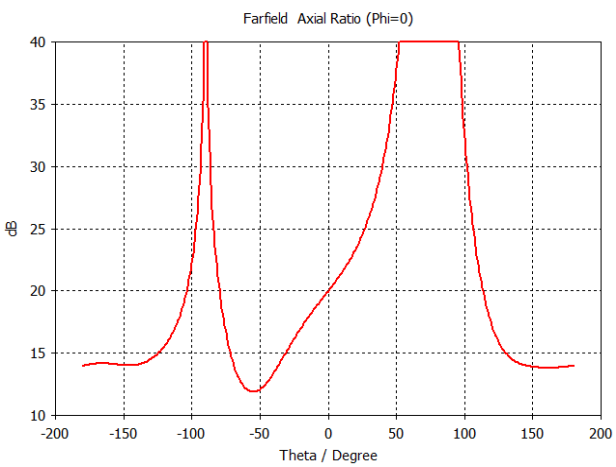
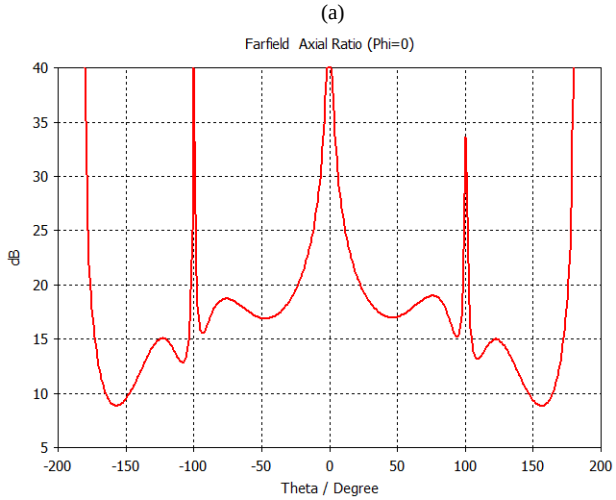


Fig. 12. Return loss of the dual-polarized antenna, S_{11} (port 1) and S_{22} (port 2).

Fig. 13 shows the axial ratio of the port 1 and the port 2. Through the axial ratio curves, a minimum peak of 11 dB was observed for port 1 and a minimum peak of 9 dB for port 2. Both ports obtained minimum peak values much higher than 3 dB, that is, both planar monopole structures can be referred to as linear polarizations.



(a)



(b)

Fig. 13. Axial ratio curves (a) port 1, (b) port 2.

When the direction is not stated, the polarization is taken to be the polarization in the direction of maximum gain. There are several choices of the axis. From these, spherical and Ludwig 3 coordinates seem more relevant. To see polarization gains Ludwig 3 coordinate system is better [15]. Fig. 14 compares the Ludwig 3 [16] gain values in linear polarization. It was observed that the vertical gain value is higher than the horizontal gain value in port 1. Therefore, it can be concluded that this structure radiates a polarization in vertical mode. In port 2, the horizontal gain value is greater than the vertical gain value, so we can conclude that this antenna irradiates a polarization in the horizontal mode.

Type	Farfield	Type	Farfield
Approximation	enabled (kR >> 1)	Approximation	enabled (kR >> 1)
Monitor	farfield (broadband) [1]	Monitor	farfield (broadband) [1]
Component	Ludwig 3 Horizontal	Component	Ludwig 3 Vertical
Output	Gain	Output	Gain
Frequency	0.584	Frequency	0.584
Rad. effic.	0.2474 dB	Rad. effic.	0.2474 dB
Tot. effic.	-0.1199 dB	Tot. effic.	-0.1199 dB
Gain(Abs)	4.924 dB	Gain(Abs)	4.924 dB
Gain(Horizo.)	4.529 dB	Gain(Vertic.)	4.776 dB

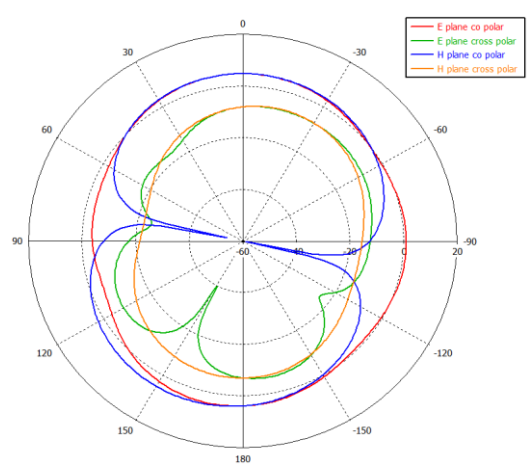
(a)

Type	Farfield	Type	Farfield
Approximation	enabled (kR >> 1)	Approximation	enabled (kR >> 1)
Monitor	farfield (broadband) [2]	Monitor	farfield (broadband) [2]
Component	Ludwig 3 Horizontal	Component	Ludwig 3 Vertical
Output	Gain	Output	Gain
Frequency	0.584	Frequency	0.584
Rad. effic.	-0.3368 dB	Rad. effic.	-0.3368 dB
Tot. effic.	-0.8607 dB	Tot. effic.	-0.8607 dB
Gain(Abs)	4.080 dB	Gain(Abs)	4.080 dB
Gain(Horizo.)	4.076 dB	Gain(Vertic.)	2.896 dB

b)

Fig. 14. Ludwig 3 gain comparison in linear polarization (a) port 1, (b) port 2.

The horizontal and vertical polarization components can be matched to the co and cross-polarization. Co-polarization it as the polarization that an antenna is desired to radiate and cross-polarization is the polarization orthogonal to co-polarization [15]. From Fig. 14, it can be understood that port 1 has low Ludwig 3 in horizontal gain and higher Ludwig 3 in vertical gain. Therefore, for this port, a horizontal gain is the cross-polarization gain, and vertical gain is the co-polarization gain. The opposite is seen on port 2, where Ludwig 3 horizontal is the co-polarization gain and the Ludwig 3 vertical is the cross-polarization gain. Fig. 15 presents the co and cross-polarization radiation patterns in E and H planes.



(a)

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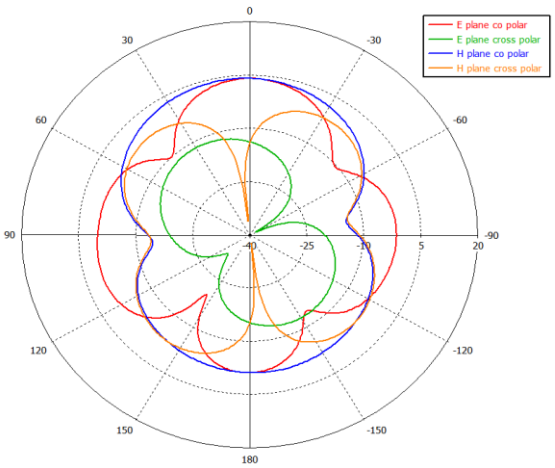


(b)

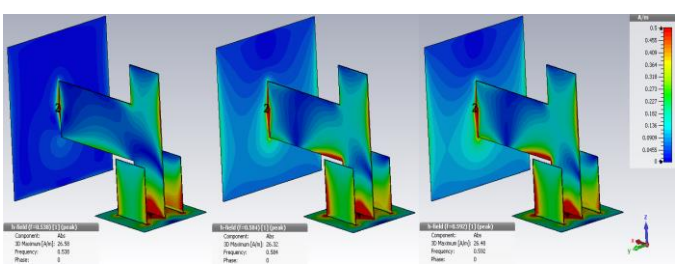
Fig. 15. Co and cross-polarization radiation patterns in E and H planes (a) port 1, (b) port 2.

Table III shows the simulated values of half-power beam width (HPBW) in E and H planes.

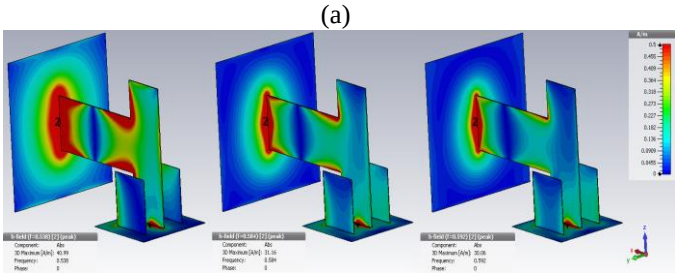
TABLE III
SIMULATED VALUES OF HPBW

Frequency (GHz)	E-Plane	H-Plane
0.538	67.8°	80.7°
0.584	65.5°	86.5°
0.592	65.2°	85.8°

Fig. 16 shows the current distributions of the proposed antenna in the RMS value in the frequencies 0.538 GHz, 0.584 GHz and 0.592 GHz in the port 1 and port 2.



(a)



(b)

Fig. 16. Simulated surface current in dB (RMS) in the frequencies 0.538 GHz, 0.584 GHz and 0.592 GHz (a) port 1, (b) port 2.

Table IV shows the results of the proposed dual-polarized antenna.

TABLE IV
RESULTS OF THE DUAL-POLARIZED ANTENNA

Parameters	Port 1	Port 2
$f_{central}$(GHz)	0.538	0.592
S-Parameter (dB)	-29.77	-15.31
Axial Ratio (dB)	11	9
Gain (dB)	4.776	4.076
Linear Polarization	Vertical	Horizontal

VI. Conclusion

In this work, we describe the design and simulations of a dual-polarized antenna for indoor applications. From the simulations developed, we verified that the planar monopole structure presented the best response both in the band criterion and omnidirectionally. Using the technique of addition of parasitic elements in the structure, it was possible to acquire the necessary bandwidth to cover the UHF band. Preliminary results of the simulations were favorable for the modeling of the dual-polarized antenna. A second planar monopole structure was orthogonally attached to the chosen structure, and the results were promising. Through the axial ratio curves, we proved that both structures presented linear polarizations. The Ludwig 3 gain values it was confirmed that the proposed antenna radiates two distinct polarizations. Through of the port 1, the vertical polarization was obtained and through the port 2 the horizontal polarization. Thus, the results indicate that the proposed antenna satisfy the requirements of bandwidth, HPBW, omnidirectionality, and polarization for being used in the current digital television standard as in the next-generation of digital broadcasting.

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References

[1] SET - Sociedade Brasileira de Engenharia de Televisão, “Testes de Interferência do Sinal LTE na Recepção de TV Digital na Faixa de UHF.” [Online]. Available: http://set.org.br/tecnologia/SET%20-%20Resultados%20dos%20testes%20de%20interfer%C3%AAncia_do_4G_LTE__10.02.2014.pdf.

[2] F. Moura, (2016, Sept), “Testes da SET revelam interferências do 4G na TV Digital.” [Online]. Available: http://www.set.org.br/revista-da-set/testes-da-set-revelam-interferencias-do-4g-na-tv-digital/.

[3] Y. Wu *et al.*, “Cloud Transmission: A New Spectrum-Reuse Friendly Digital Terrestrial Broadcasting Transmission System”.

In *IEEE Transactions on Broadcasting*, vol. 58, no. 3, pp. 329-337, Sept. 2012.

[4] M. M. Bontempo *et al.*, "Desenvolvimento e implementação de uma antena impressa com polarização dupla", in *2016Brazilian Congress of Electromagnetism*, Porto Alegre, 2016, pp. 1-6.

[5] K. Woelders and J. Granholm, "Cross-Polarization and Sidelobe Suppression in Dual Linear Polarization Antenna Arrays". In *IEEE Transactions on Antennas and Propagation*, vol. 45, no. 12, pp. 1727-1740, Dec. 1997.

[6] S. Saito *et al.*, "8K Terrestrial Transmission Field Tests Using Dual-Polarized MIMO and Higher-Order Modulation OFDM". In *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 306-315, Mar. 2016.

[7] ITU - International Telecommunication Union, "Collection of field trials of UHDTV over DTT networks", Attachment: BT.2343-2, Oct. 2016.

[8] C. A. Balanis, "Antenna Theory: Analysis and Design", 3rd ed., New Jersey of John Wiley and Sons, Inc, 2005, pp. 1117.

[9] M. N. O. Sadiku, "Electromagnetism Elements", 3rd ed., New York of Bookman, 2004, pp. 694.

[10] Z. Berkat and N. B. Hacene, "Design of New Combined Antenna for Dual Polarization Using Crossed Dipole at 2.23 GHz and 5 GHz", In ARPN Journal of Engineering and Applied Sciences, vol. 10, no. 12, pp. 5164-5168, July, 2015.

[11] CST MICROWAVE STUDIO™. Available: http://www.cst.com, version 2014.

[12] M. J. Ammann and Z. N. Chen, "Wideband monopole antennas for multi-band wireless systems". In *IEEE Transactions on Antennas and Propagation*, vol. 45, no. 22, pp. 146.150, June, 2003.

[13] M. B. Perotoni, M. V. Stefanelli and E. T. C. dos Santos, "Wideband Planar Monopole Antennas for the Brazilian Digital TV System". In *IEEE Latin America Transactions*, vol. 13, no. 1, pp. 102-106, Jan, 2015.

[14] E. T. C. dos Santos, "Uma Nova Proposta de Antena Banda Larga para Recepção do Sinal de TV Digital do Padrão ISDB-T_B", Thesis (Ph.D. Degree), Mackenzie Presbyterian University, 2016.

[15] N. T. Awano, "Dual Polarized Patch Antenna for UHF RFID Readers", Dissertation (M.Sc. Degree), Tampere University of Technology, 2010.

[16] A. Ludwig, "The definition of cross polarization". In *IEEE Transactions on Antennas and Propagation*, vol. 21, no. 1, pp. 116-119, Jan, 1973.

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Development and Optimization of Antennas for HDTV Reception

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Development and Optimization of Antennas for HDTV Reception

A. Raizer and L. B. Lazare

***Abstract* — This paper presents the development and optimization of antennas for reception of high-definition digital television (HDTV). An efficient simulation method will be presented, which uses finite element software to develop antennas without the need for complex calculations. The comparisons were made based on the main parameters related to the antennas, in order to establish a better choice both from the technical and economic point of view.**

***Index Terms*—Development and Optimization of Antennas, HDTV, Numerical Simulation.**

I. Introduction

Currently, high definition digital television (HDTV) is an important television broadcasting system in Brazil due to the large investments for the transition from analogue to digital television. To carry out the transmission and reception of the HDTV signals, UHF band (Ultra High Frequency) is used, more specifically between the frequencies of 470 MHz and 806 MHz. A crucial item in transmission and reception systems for digital TV signals is the receiving antenna. Therefore, HDTV antenna solutions with efficient reception and low production cost are sought.

An omnidirectional antenna is important for the HDTV reception system [1], because for non-satellite transmission systems, the transmitted signal is not directional and the receiving antenna must receive signals from several directions, ideally from all directions.

From the reception efficiency point of view, is required an antenna that couples the highest possible power as well can receive signals from several directions, whether installed indoors or outdoors. From the point of view of production cost, a small antenna that uses less material is required.

According these characteristics, it is presented in this paper the development and optimization of four antennas models for HDTV. A loop antenna and an antenna with meander Line structure based on [1] were developed for HDTV. The antennas improvement process and an antenna obtained from the junction of the developed antennas are presented, as the simulation of electrical characteristics and parameters. A comparison between the performances of the four antennas is also presented.

In order to reach the desired results, a software based on the finite element method (FEM) [2][3] was used, significantly reducing the development time of the process.

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II. Magnetic Dipole Antenna

The magnetic dipole antenna (loop) was developed based on the theory exposed in [4]. It is constituted by a radiant element that is divided, usually in the center, to allow a feeder to apply energy from a transmitter, or to be transferred to a receiver. The length of the radiant element determines many of the dipole antenna properties, such as impedance and central frequency of operation. This is an important characteristic of the antenna, which allows various configurations and antenna formats.

A. Antenna Presentation

The loop antenna is based on the theory of folded dipoles. As presented in [1], the length of the antenna, or loop, is directly proportional to the wavelength as well its area. As also presented in [1], one of the ways to increase the resistance of a loop antenna is by adding other loops to it. Therefore, knowing that the frequency range of Digital TV is from 470 MHz to 806 MHz, and using the concepts mentioned, the antenna developed is shown in Fig. 1. The antenna was constructed in stainless steel with thickness of 0.8 mm.

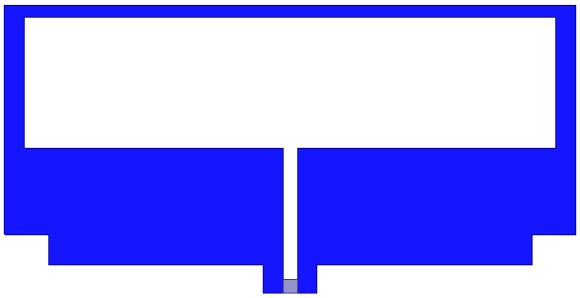

Fig. 1. Loop antenna.

B. Modeling and Simulation

To verify the performance of the antenna, its model was simulated using software based on the finite element method [3] in frequency range of HDTV. It was simulated the return loss, Voltage Standing Wave Ratio (VSWR), Smith chart, antenna impedance and radiation patterns.

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1) Return Loss and VSWR

The return loss, measured in decibel (dB), of an antenna shows the relationship between the power reflected and the power transmitted. It is a relation that arises from the measure of S_{11} parameter [5]. Thus, with a reference impedance of 75 **Ω**, the loop antenna has the return loss shown in Fig. 2.

A return loss of ≤-10 dB is conventionally considered satisfactory, which guarantee ≥90% power transfer. Therefore, this will be the criterion used to determine if the antenna performs satisfactorily or not in HDTV frequency range.

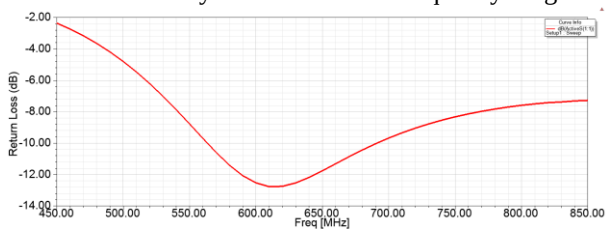

Fig.2. Loop antenna return loss.

As shown in Fig. 2, is observed that the antenna performs satisfactorily only in the range of 562 MHz to 690 MHz. However, it is expected to obtain the return loss below -10 dB for the entire Digital TV frequency range.

2) Smith Chart and Antenna Impedance

The Smith chart is a graphical system that visually displays the impedance of an antenna for a frequency range. It may present normalized impedance through a reference, which is the most common case, or it may present a non-normalized impedance [4]. Based on nominal impedance of TV system, the Smith chart of 75 Ω will be presented on this paper.

Knowing that the circles represent constant resistances and the curves represent constant reactances, it is desirable that the antenna impedance curve be as close as possible to the unity resistance circle and the zero reactance curve. The normalized Smith chart to 75 Ω of the original shaped loop antenna is shown in Fig. 3 for frequency range of 450 MHz to 850 MHz.

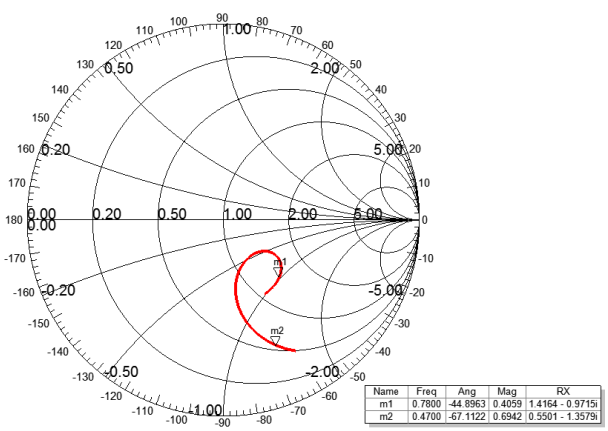

Fig.3. Loop antenna Smith chart.

It is noted that the antenna has a resistance close to 75 Ω for almost the entire HDTV frequency range, but the antenna has a high negative reactance practically the same frequency range. The resistance and reactance of the antenna are shown in Fig. 4 and Fig. 5, respectively.

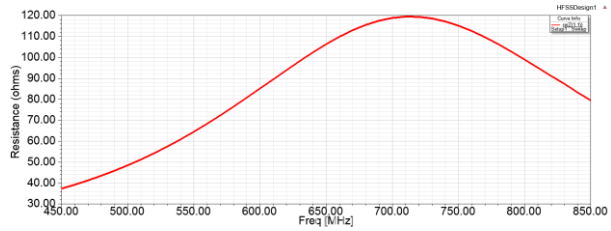

Fig.4. Loop antenna resistance.

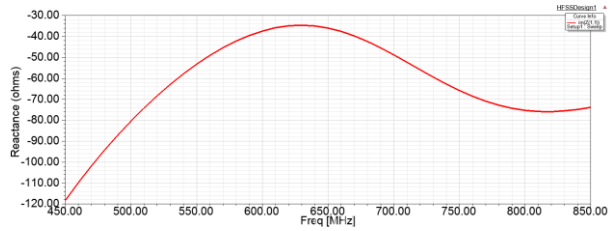

Fig. 5. Loop antenna reactance.

3) Radiation Patterns

The radiation patterns of an antenna graphically show the gain and the directivity of the antenna in measured directions [4]. These patterns usually present the gain value for each direction and are plotted in two dimensions. The spherical coordinate system is used as a reference for plotting and the same graph shows the curve for Φ = 0° and for Φ = 0°, while the angle θ varies in 360º.

The radiation pattern of loop antenna for frequency of 470 MHz and 806 MHz are shown in Fig. 6 and Fig. 7, respectively.

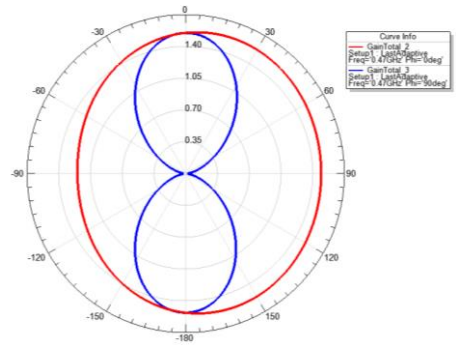

Fig. 6. Loop antenna radiation pattern for 470 MHz.

It is observed that the antenna has practically an omnidirectional behavior, which is desirable when the direction of the signal reception is not known.

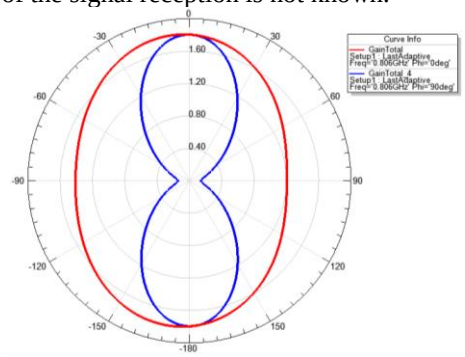

Fig. 7. Loop antenna radiation pattern for 806 MHz.

III. Loop Antenna Optimization

The first step to improve the antenna is to analyze the shape of the return loss curve shown in Fig. 2 and check if there is any behavior that can be used. It can be observed that there is a resonance at approximately 615 MHz. At frequencies greater than that, the return loss increases slowly compared to the increase in the return loss at frequencies smaller than the resonance frequency. It is possible to decrease the resonance frequency of the antenna to better take advantage of this feature of the return loss curve of the original loop antenna.

In order to reduce the resonance frequency, was used the direct relation between the loop length and the area of the antenna with the wavelength for resonance. Therefore, in order to decrease the resonant frequency, that is, to increase the resonant wavelength, the length of the loop must increase.

With an increase of 60 mm in the length of the loop according to the model of the antenna shown in Fig. 8, return loss shown in Fig. 9 was obtained.

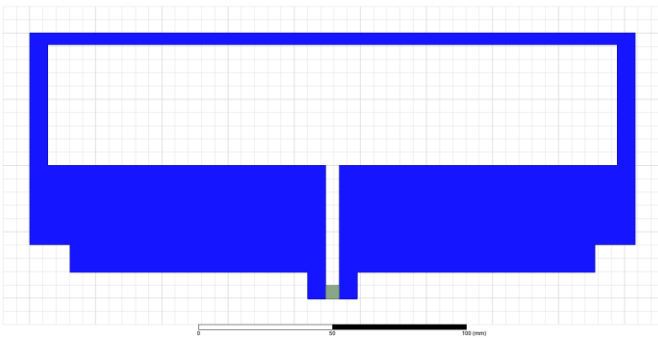

Fig. 8. Loop antenna with 60 mm increased length.

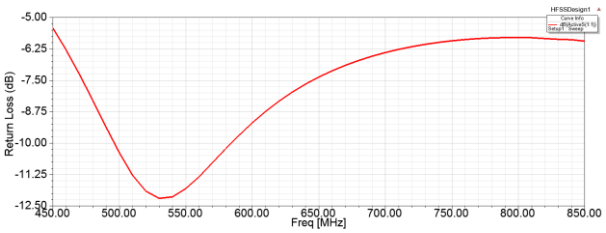

Fig. 9. Return loss with increased length.

It is observed that, as expected, the resonance frequency has decreased approximately to 530 MHz. It is also noted that for frequencies greater than the resonance frequency there is a slow decay, but there is still an undesirable return loss for the most frequency range of HDTV. This is explained by the Smith chart of this new antenna, as shown in Fig. 10.

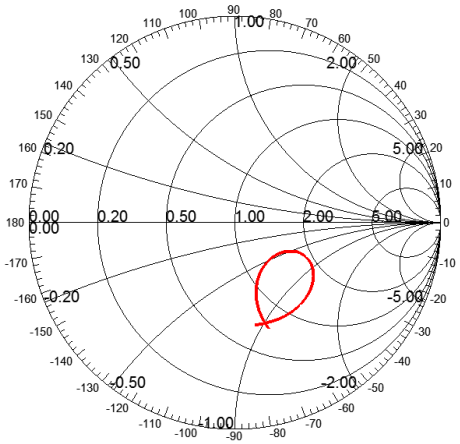

Fig. 10. Smith chart with increased length.

It is observed that the antenna continues with a negative reactance for most frequencies of operation. However, it can also be seen, compared to the Smith chart of the initial antenna shown in Fig. 3, the curve is with a smaller variation of the impedance in HDTV frequency range. This characteristic is important because the curve is centered on a point of the unit resistance circle of the Smith chart. Therefore, it is only necessary to complement this negative reactance with a positive one, that is, with a series inductor element, so that the reactance increases as much as possible to the largest frequency range possible.

Observing the Smith chart shown in Fig. 10, it can be concluded that the inductive element have an average normalized impedance at 75 Ω of approximately 0.8i Ω.

A method to match the impedance by adding an inductive element is shown in [1]. It is a method based on stubs, which consists of increasing the length of loop antenna terminal. The loop antenna terminal would be the place where the antenna feed is done. Therefore, using this technique, tests have been done. Initially it was attempted to increase the length of the terminal by 20 mm according to the antenna shown in Fig. 11. With this, the return loss shown in Fig. 12 was obtained.

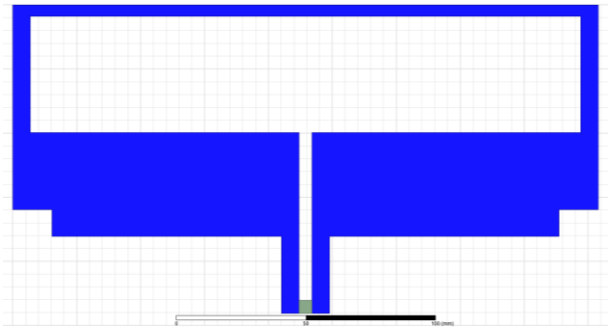

Fig. 11. Loop antenna with increase of 60 mm in length and increase of 20 mm in terminal.

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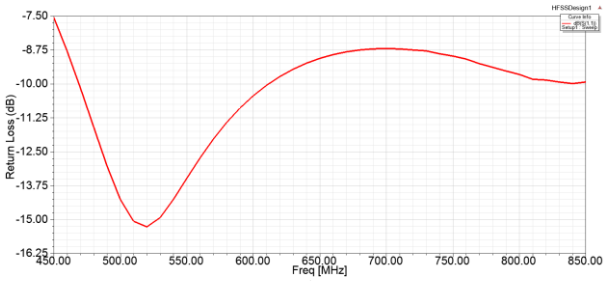

Fig. 12. Return loss with increase of 20 mm in the terminal.

It is noted that a generalized decrease of the return loss was achieved with a significant improvement in the antenna performance. However, there is still a frequency range that does not meet the return loss requirement of less than -10 dB. This is again explained by Smith chart of that antenna with a longer loop length and a longer terminal length as shown in Fig. 13.

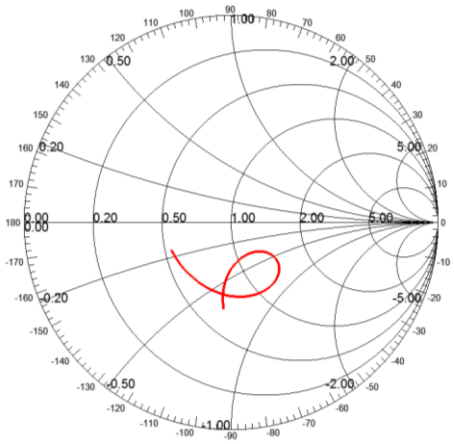
Fig. 13. Smith chart with 20mm increased in the terminal.

Although there is an increase in the value of the reactance for the HDTV band, it is not yet centered at zero. Thus, the next step was to increase the terminal length even further. Therefore, an increase of more 20 mm corresponding to an increase of 40 mm in relation to the original loop antenna was made. Thus, the antenna model obtained is shown in Fig. 14 and the return loss for this new antenna is shown in Fig. 15.

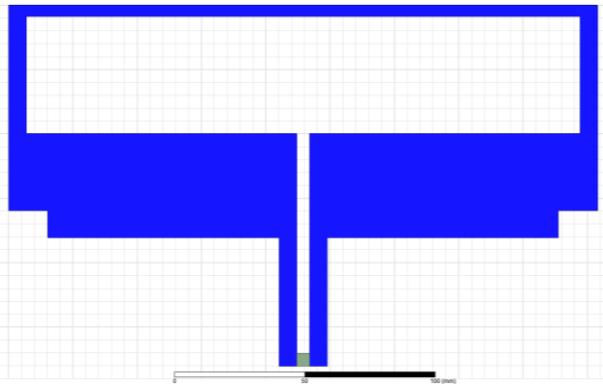
Fig. 14. Loop antenna with 60mm increased in length and increased 40mm in the terminal.

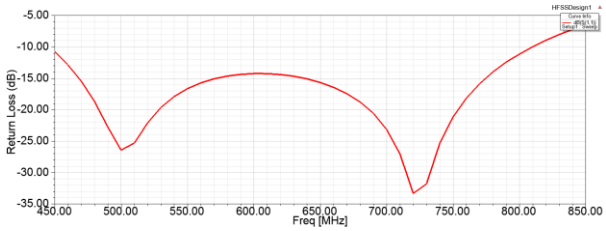

Fig. 15. Return loss with increase of 40 mm in the terminal.

As can be observed in Fig. 15, there was again a generalized improvement in the return loss of the antenna, with values below -10 dB for the entire HDTV frequency range. This is explained by observing the Smith chart to this new antenna shown in Fig. 16.

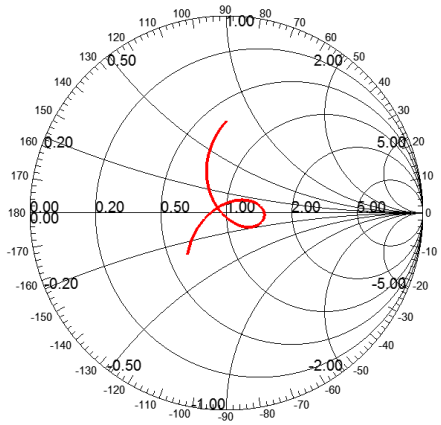
Fig. 16. Smith chart with increase of 40 mm in the terminal.

It is observed that the initial objective is reached, getting a close resistance 1 and a close reactance 0 for most of the simulated frequency range getting a very good impedance matching. Also tried to further increase the length of the antenna terminal, however this causes deterioration in impedance matching.

It is important to note the change that there are in the radiation patterns in relation to the initial loop antenna. The radiation patterns of new loop antenna with 60mm increased in length and 40 mm in the terminal compared, for the frequencies of 470 MHz and 806 MHz are shown in Fig. 18 and Fig. 17, respectively.

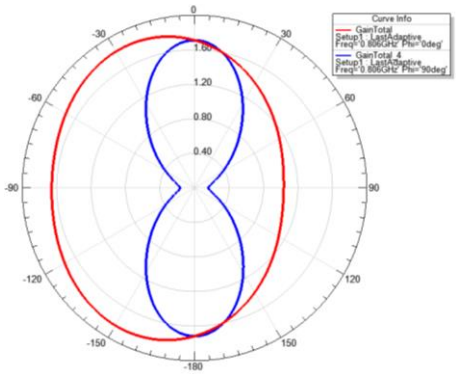
Fig. 17. Antenna radiation pattern for 806 MHz with 40 mm increased in terminal.

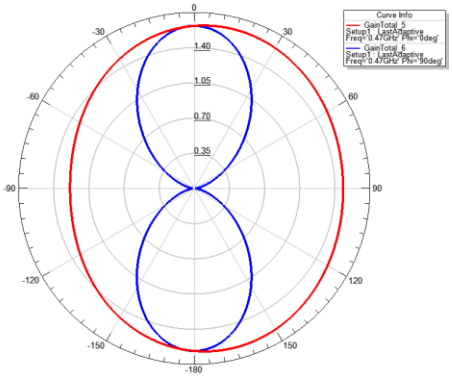

Fig. 18. Antenna radiation pattern for 470 MHz with 40 mm increased in terminal.

It is observed that although the format of the radiation pattern has changed a bit due mainly to the change in the antenna terminal, the gains have remained practically the same.

IV. Meander Line Electric Dipole Antenna

An electric dipole antenna was developed based on theory expose in [6], with inclusion of a PCB (Printed Circuit Board) for connection of the antenna connector with a coaxial cable.

A. Antenna Presentation

The developed antenna has the same characteristics as the presented in [6], which is based on the concept of electric dipole antennas, as well as meander line antennas. For connection of the antenna to HDTV reception system, it is necessary to use a radio frequency connector on a PCB. The used connector is shown in Fig. 19. It has four pins on the sides that connect to the reference or ground of the antenna and a center pin that connects to the antenna signal.

Fig. 19. Radio frequency connector.

A PCB was modeled through software [3] which has appropriate connections for both the antenna and the connector which is shown in Fig. 20.

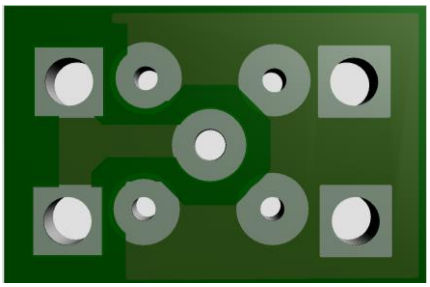

Fig. 20. PCB Project.

B. Simulation Results Including the PCB

Using the software [3], the meander line electric dipole with PCB inclusion was simulated, as shown in Fig. 21. With this, it was possible to obtain the most important antenna parameters such as radiation patterns, return loss and Smith chart, with reference impedance for matching as 75 Ω.

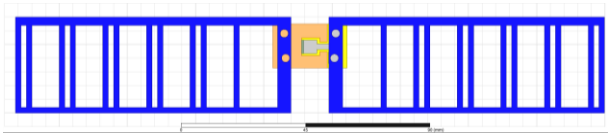

Fig. 21. Meander line electric dipole with PCB.

In Fig. 22 can be observed that the antenna return loss, with a similar behavior to the original loop antenna presented. This is explained by the impedance mismatch that exists for a certain frequency range presented by the Smith chart of Fig. 23.

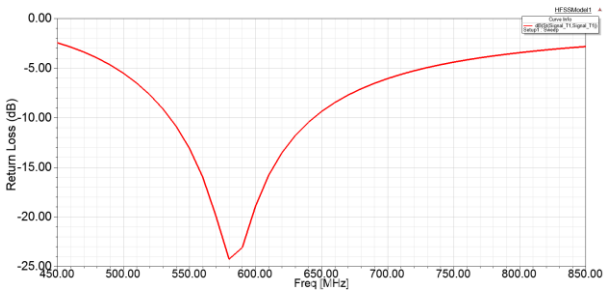

Fig. 22. Meander line electric dipole return loss.

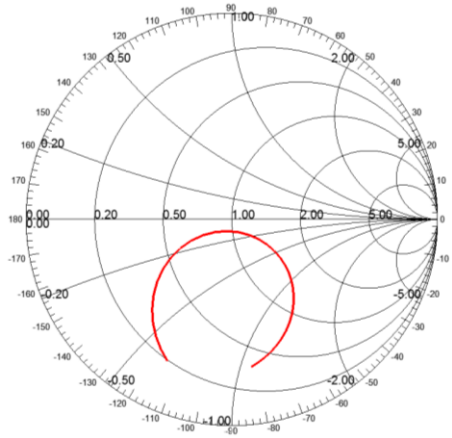

Fig. 23. Smith chart of the meander line electric dipole antenna for frequencies from 450 MHz up to 850 MHz.

The radiation patterns for this antenna at the frequencies of 470 MHz and 806 MHz are shown in Fig. 24 and Fig. 25, respectively.

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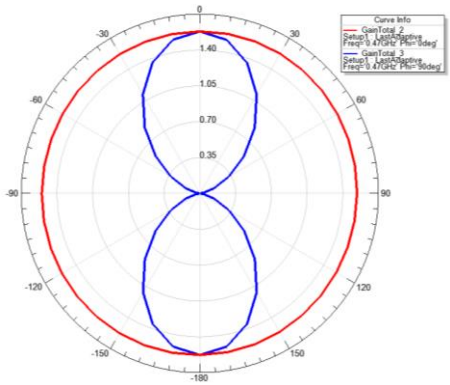

Fig. 24. Meander line electric dipole antenna radiation pattern for 470 MHz.

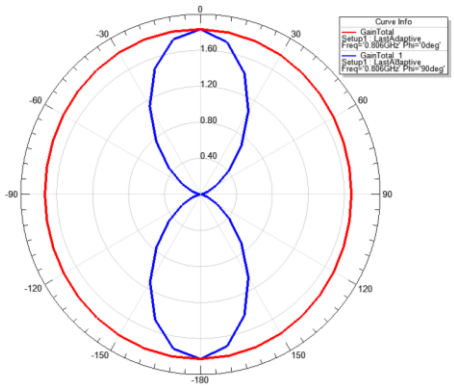

Fig. 25. Meander line electric dipole antenna radiation pattern for 806 MHz.

It is observed that the radiation pattern is practically equal to that of an electric dipole, that is, it is an omnidirectional antenna and has a gain greater than a standard electric dipole.

V. Magnetic Loop Antenna With Meander Line

After obtaining the results with the modified loop antenna in the return loss and verifying the omnidirectional behavior of the meander line electrical dipole antenna, the two antennas were united to take advantage of the individual characteristics in only one antenna. This union was made and modeled as shown in Fig. 26.

Using the software [3], simulation was made and obtained results of radiation patterns, return loss, Smith chart for this antenna. The return loss and Smith chart are presented in Fig. 27 and Fig. 28, respectively. Radiation patterns for the 470 MHz and 806 MHz frequencies are shown in Fig. 29 and Fig. 30, respectively.

It is observed that, just like the modified loop antenna, the presented antenna maintains a return loss below -10 dB for the entire frequency range used for HDTV. This is explained by the impedance matching with the nominal impedance of the television systems, presented by the Smith chart in Fig. 28.

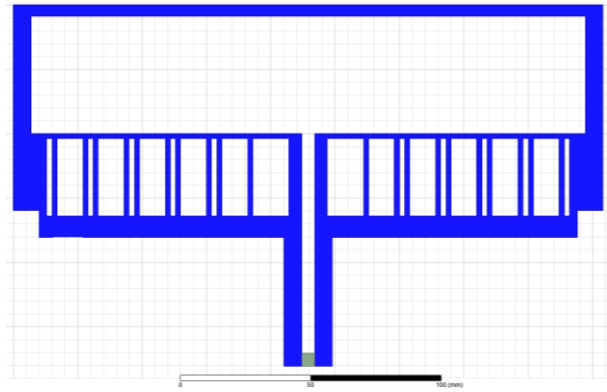

Fig. 26. Modified loop antenna with meander line electrical dipole antenna.

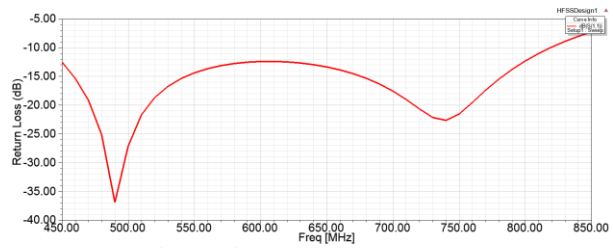

Fig. 27. Return loss for modified loop antenna with meander line electrical dipole antenna.

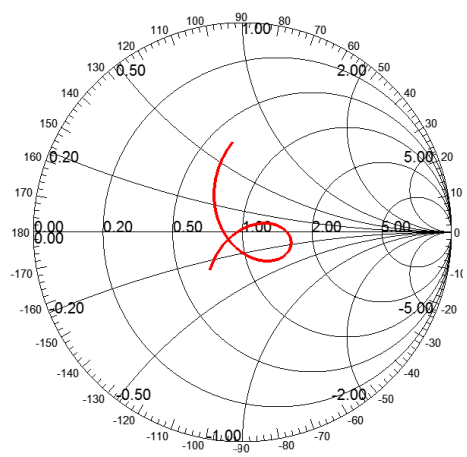

Fig. 28. Modified loop antenna with meander line electrical dipole antenna Smith chart.

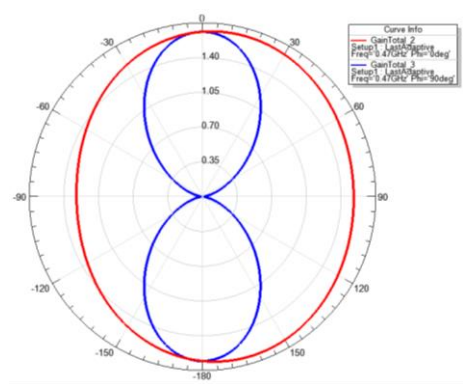

Fig. 29. Modified loop antenna with meander line electrical dipole antenna radiation pattern for 470 MHz.

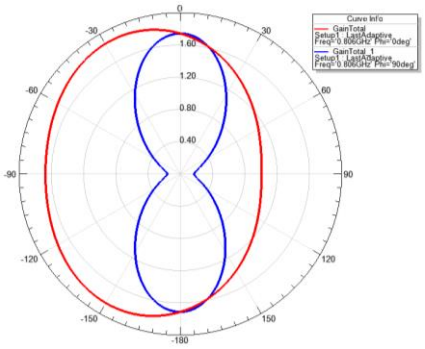

Fig. 30. Modified loop antenna with meander line electrical dipole antenna radiation pattern for 806 MHz.

As shown in Fig. 30, the radiation patterns of the loop antenna modified with meander line are very similar to those of the modified loop antenna.

VI. Comparison Between the Four Presented Antennas

A graph comparing the return loss for the four antennas presented in this paper is presented in Fig. 31. It can be observed that both modified loop antenna and modified loop antenna with meander line satisfy the criterion of having a return loss below -10 dB for the frequency range used for HDTV. The original loop antenna and the electric dipole meander line antenna satisfy the criteria only for a short frequency range.

Therefore, for an application where the amount of material used is one of the criteria for choosing the antenna, the modified loop antenna with meander line would be the best choice, because besides having a good return loss curve, it uses less material than the modified loop antenna. For an application where the complexity of the antenna manufacturing, such as the amount of cuts that must be made in the material used, is an important characteristic, the modified loop antenna would be the best option.

Still in a criterion of material saving for manufacturing and cost reduction, the meander line antenna developed is presented as a viable option, even with technical characteristics slightly lower than the antenna presented previously.

Fig. 6, 7, 17, 18, 24, 25, 29 and 30 show the radiation patterns and hence the gain of the antenna loop original, modified loop, meander line and modified loop with meander line. It is possible to note that the maximum gain is practically the same for all antennas. However the modified loop and modified loop antenna with meander line have a reduced gain in the direction of the terminal with increased length.

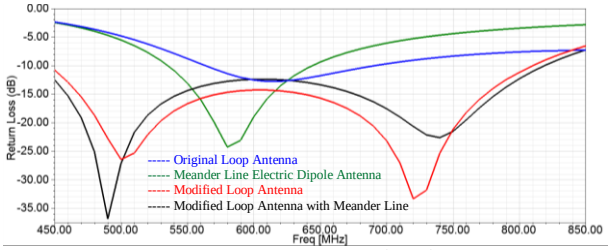

Fig. 31. Comparison between the return losses of the four antennas presented.

Thus, for an application in which the closest proximity to an omnidirectional antenna is desired, the original loop antenna and the meander line antenna are the best options.

VII. Conclusion

In this paper was presented the behavior for four different antennas in the frequency range used for HDTV through numerical simulations. Depending on the manufacturing process available and the costs involved, it can be chosen one of the configurations presented, maintaining to a large extent the expected technical performance.

References

[1] Balanis, C.A., “Wire Elements: Dipoles, Monopoles and Loops” in Modern Antenna Handbook, USA, 2008

[2] John L. Volakis; Arindam Chatterjee; Leo C. Kempel, "Overview of the Finite Element Method: OneDimensional Examples," in *Finite Element Method Electromagnetics:Antennas, Microwave Circuits, and Scattering Applications* , 1, Wiley-IEEE Press, 1998, pp.65-92

[3] (2017). ANSYS HFSS website. [Online]. Available: http://www.ansys.com/products/electronics/ansys-hfss

[4] Matthew N. O. Sadiku, Elements of Electromagnetics, 3rd ed., 2000

[5] Elya B. Joffe; Kai-Sang Lock, "Appendix F: Overview of S Parameters," in *Grounds for Grounding:A Circuit to System Handbook* , 1, Wiley-IEEE Press, 2010, pp.1045-1055

[6] de Moura, D., Cezário, I., Raizer, A.; 2015. Desenvolvimento de Sistema de Recepção com Amplificação do Nível de Sinal Digital de Alta Definição. SET EXPO PROCEEDINGS. ISNN Print: 2447-0481.ISSN Online: 2447-049X. v.i.doi: 10.18580/setep.2015.1.13 Web-link: http://dx.doi.org/10.18580/setep.2015.1.13

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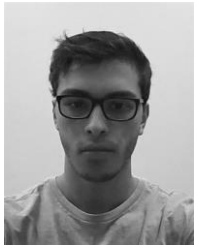

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A Novel UWB Antenna for a Broadcasting Television System

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A Novel UWB Antenna for a Broadcasting Television System

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***Abstract*— An ultra-wideband (UWB) discone antenna with an omnidirectional radiation pattern is proposed in order to be used in a broadcasting television system. It is an ultra-wideband antenna with an omnidirectional radiation pattern, using a single antenna to receive TV signals from several transmitting stations across various geographic locations. The UWB antenna proposed in this study covers a frequency range of 0.32-1.65 GHz with a gain of 1.7 dB. It operates in both conditions: indoor and outdoor.**

***Index Terms*—antenna, UWB, TV, broadcasting, television, ultra-wideband.**

I. Introduction

TELEVISION broadcasting stations are spread across many locations. Therefore, the reception of TV signals by using only one directional antenna is not an easy task. To receive all the nearby signals, it is necessary to use several directional antennas. This fact makes such a system complex and expensive to implement. Besides, the reception system is sensible to signal loss owing to the use of external components such as mixers that experience insertion loss.

The use of an antenna with an omnidirectional radiation pattern could potentially provide a solution in a situation where it is necessary to receive signals from all directions. In this case, the antenna must also be able to receive these signals over a wide frequency range. For example, in Brazil, digital television (DTV) operates mainly in the UHF band between 470–800 MHz with a bandwidth of 6 MHz, as shown in Table I [1].

This paper proposes the use of a discone antenna. This paper presents the design, simulation, implementation and evaluation of that antenna. We chose a discone antenna because it has an omnidirectional radiation pattern and exceptional wideband [2] [3].

In this work, we study the discone antenna with an omnidirectional radiation pattern that covers the frequency range of 0.32-1.65 GHz, thus it is an UWB antenna. Over time, UWB has become a widely adopted term. Federal Communications Commission (FCC) rules [4] state the UWB band when fractional bandwidth is equal to or greater than 0.20. The fractional bandwidth is given as follows:

$$\text{fractional bandwidth} = 2(f_H - f_L)/(f_H + f_L) \quad (1)$$

Where, f_H is the upper boundary frequency and f_L is the lower boundary frequency. The bandwidth is equal to or greater than 500 MHz, regardless of the fractional bandwidth.

TABLE I
UHF DTV Channel Assignments in Brazil

Channel	Frequency (MHz)	Channel	Frequency (MHz)
14	470 – 476	43	644 – 650
15	476 – 482	44	650 – 656
16	482 – 488	45	656 – 662
17	488 – 494	46	662 – 668
18	494 – 500	47	668 – 674
19	500 – 506	48	674 – 680
20	506 – 512	49	680 – 686
21	512 – 518	50	686 – 692
22	518 – 524	51	692 – 698
23	524 – 530	52	698 – 704
24	530 – 536	53	704 – 710
25	536 – 542	54	710 – 716
26	542 – 548	55	716 – 722
27	548 – 554	56	722 – 728
28	554 – 560	57	728 – 734
29	560 – 566	58	734 – 740
30	566 – 572	59	740 – 746
31	572 – 578	60	746 – 752
32	578 – 584	61	752 – 758
33	584 – 590	62	758 – 764
34	590 – 596	63	764 – 770
35	596 – 602	64	770 – 776
36	602 – 608	65	776 – 782
38	614 – 620	66	782 – 788
39	620 – 626	67	788 – 794
40	626 – 632	68	794 – 800
41	632 – 638		
42	638 – 644		

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II. Antenna design

It is possible to analyze the discone antenna as a modification of the biconical antenna in which a disk replaces a cone [2]. The antenna feed is a coax located in the center of the cone that connects the outer shield to the lower cone. Besides, we connect the disk to the coax center conductor [3]. Fig. 1 shows a discone antenna with coaxial feed.

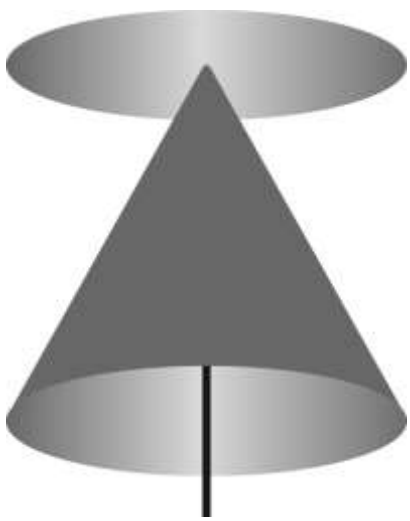

Fig. 1. A typical discone antenna.

The wide impedance bandwidth and dipole-like pattern occur because the discone antenna uses a biconical structure in which a diameter that varies smoothly at a fixed angle replaces the fixed wire diameter of the dipole [2].

A discone antenna for wideband impedance with acceptable frequency patterns can be designed using the dimensions shown in Fig. 2 such that $H = 0.7\lambda$, $B = 0.6\lambda$, $D = 0.4\lambda$, $\theta_h = 25^o$ e $\delta << D$, where λ is the wavelength of the operating frequency [2] [5].

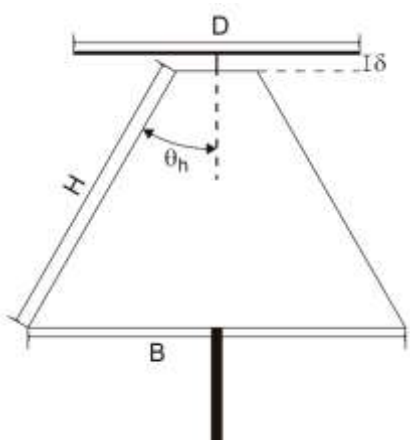

Fig. 2. Typical dimensions in the discone antenna.

We can improve the accuracy of the discone antenna by adjusting the antenna dimensions. We performed the antenna simulations using a full wave simulator Ansoft HFSS.

The discone antenna studied in this paper utilized the dimensions given in Fig. 3. We present the construction of the discone antenna in Fig. 4. A copper foil of 0.1 mm thickness was used to make the cone; the disk was made from single-sided FR-4 pcb with $\varepsilon_r = 4.4$ and a thickness of 1.6 mm. Therefore, to obtain the doubled dimensions of $\delta = 3.2$ mm, we used the following two disks of FR-4 pcb: the copper top disk had a diameter of 160 mm and the smaller non-copper bottom disk had a diameter of 40 mm.

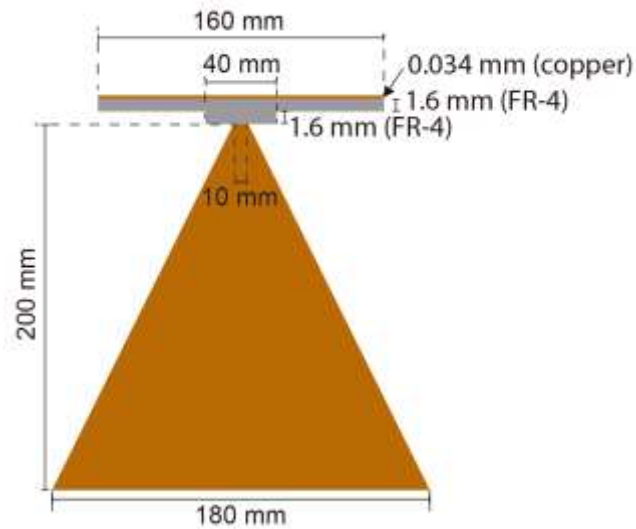

Fig. 3. Dimensions used in the discone antenna of this work.

Fig. 4. Discone antenna construction.

Fig. 5 shows the S_{11} parameters simulated and measured with a HP 8714B vector network analyzer.

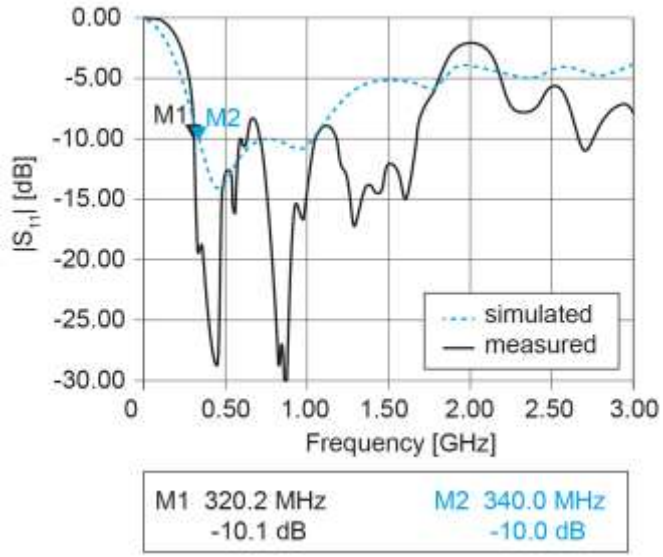

Fig. 5. Simulated and measured S_{11} of the proposed antenna.

Fig. 6 shows the simulated radiation pattern. Fig. 7 shows the simulated 3D radiation pattern.

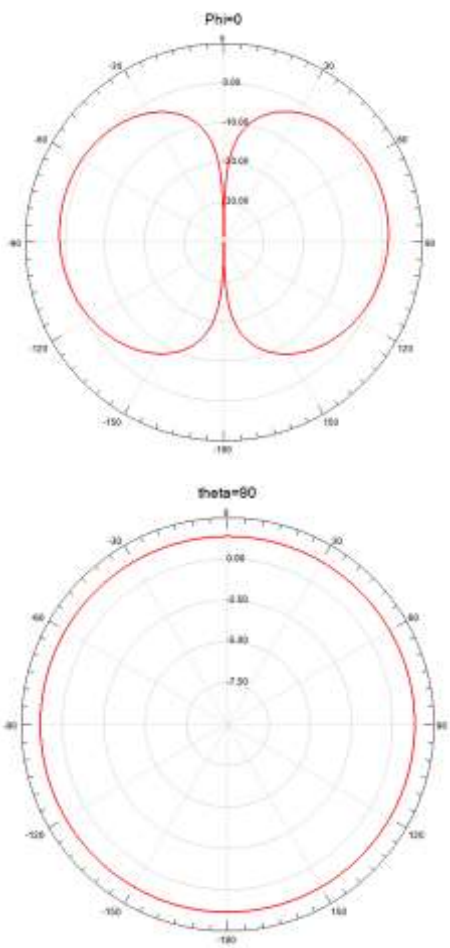

Fig. 6. The simulated radiation pattern.

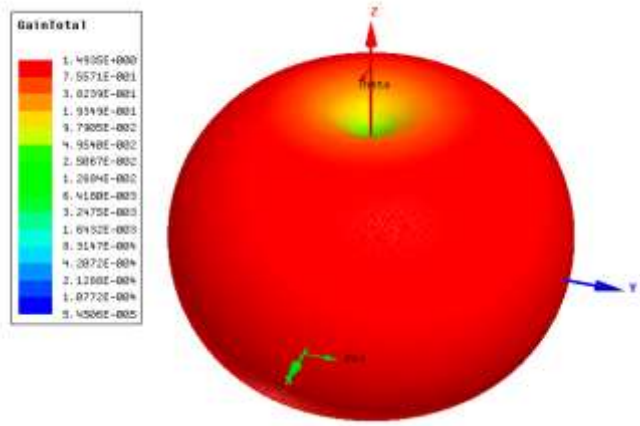

Fig. 7. The simulated 3D radiation pattern.

The Jsurf field vector at a center frequency of 635 MHz is shown in Fig. 8.

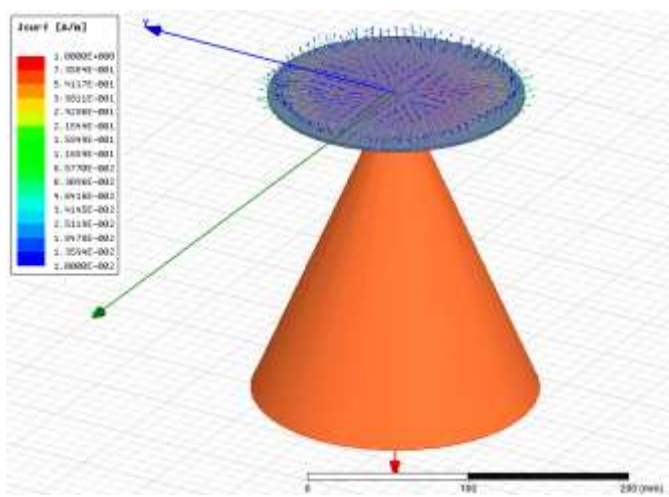

Fig. 8. Simulated Jsurf field vector of the proposed antenna.

Fig. 9 shows the discone antenna working with television. A balun matching transformer is used.

Fig. 9. A discone antenna working with a television.

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IV. Conclusions

We developed and tested an UWB omnidirectional discone antenna that was capable of operating over a frequency range of 0.32-1.65 GHz with a gain of 1.7 dB. The proposed antenna works in both conditions, namely indoors and outdoors. This research presents a proven qualitative agreement between the experimental results and the numerical simulations. The small differences are owing to effects caused by parasitic capacitances and inductances and by adapters and connectors, not considered in the simulations.

References

[1] ANATEL – Agência Nacional de Telecomunicações. Resolução nº583 de 27 de março de 2012. Available: http://www.anatel.gov.br/legislacao/resolucoes/2012/146-resolucao-583

[2] W. L. Stutzman, G. A. Thiele, "Antenna Theory and Design", 2nd ed., John Wiley & Sons Inc., 1998, pp. 243-246.

[3] T. A. Milligan, "Modern Antenna Design", 2nd ed., John Wiley & Sons Inc., 2005, pp. 249-250.

[4] G. Breed. "A Summary of FCC Rules for Ultra Wideband Communications", High Frequency Electronics, 2005 Summit Technical Media, pp. 42

[5] J. J. Nail, "Designing Discone Antennas", Electronics, v. 26, pp. 167-169, aug. 1953.

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Isofrequency broadcast FM System, a RF spectrum optimization experience in Brasil

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Isofrequency broadcast FM System, a RF spectrum optimization experience in Brasil

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This article proposes the description of a 16-year experience of the isofrequency FM operation in Brazil. Starting in Rio de Janeiro (2000). Inclusion of the technology as part of technical rules in the Brazilian Technical Standard (1999)[1]. Recognition by CONFEA[2] (2014) as local intellectual property[3] and operation by several FM stations. Solving a coverage problem due to local geography, using same frequency of the main transmission system with no interference in common coverage signal areas and coverage extension using complimentary low power cells. Engineering planning and implementation challenges.

***Index Terms*— Broadcast, FM, Isofrequency.**

I. Introduction

The isofrequency technique used in Brazilian FM broadcast market was mainly proposed as solution for coverage blocked by geological obstacles in Rio de Janeiro, RJ, Brazil. This is a city with 3 mountains height 1.000 m, within urban area. The restriction is the use of no extra RF spectrum due to local legislation and we could not propose different frequencies like done in RTV analog systems. Considering a *new solution*, the isofrequency option needed initial tests. Lab system was an option to carry out this task. A restructuration of technical rules linked the evaluation by government. The proposed technology predicted FM analog gap filling and the possibility of coverage enlargement using low power cells. The other idea behind the perspective was the drop of interference caused by intermodulation or harmonic levels present in high power systems.

II. Proposal and First Steps

Firstly, we detected a problem to promote an analysis and subsequent solution synthesis.

The problem: Even 30 KW ERP broadcast FM transmitting systems could not reach a significant population 15 km away from main transmitter site (720 m high). Indeed, in the west side of Rio de Janeiro city there are about 2 million people in (8 million in total population), blocked by two mountains 1.000 m high, located west 5 km and 15 km respectively from main transmitters. This topography creates an attenuation cone for the "Campo Grande" urban area with 2.000.000 potential listeners near see level. Besides, even the 5 km block has 500.000 potential listeners in the "Jacarepaguá" area not totally attended by good FM signal.

Fig. 1 Unattended coverage areas by main 30 Kw transmitter indicated by "*Catedral Torre Sumaré" (723 m high).*

The analysis continued, measuring field strength in the areas with bad signal and the area with good signal nearby. Those areas would be the *common area* where both signals would be relevant for reception. We selected this area in a Road called Av. Brasil in a neighbor called Vila Kennedy.

A. Solution synthesis steps

In all innovative solutions, some parameters were essential:

- Technical capability – design, lab and field skills.
- Opportunity – a real case and legal authorization.
- Financing – a sponsor to support.

[1] Resolution 67 ANATEL, item 5.2.9
[2] CONFEA (Brazilian Federal Engineering and Agronomy Council)
[3] CONFEA Certificate n° 2269, 2014 (validating actions since 2000).

1.1. Technical parameters, Design…

To be able to sum two signals on air it was essential the *PRECISION*. How to reach and keep transmission parameters within severe precise status and maintain this precision along time, in order to have identical signals when both FM signals reach each other. How phase, level and frequency would affect receiver demodulation capability in an asynchronous system? Considering no sync signal reference at receiver side. After some research a company called PTF[4], CEO David Briggs bought the idea and joined us in the research and tests.

1.2. Lab Tests, Equipment challenges:

In order to establish some parameters, a model was necessary. The tools used were modified low-level synthesizers, calibrated cables, common oscillator reference, spectrum analyzer and a reliable receiver, with controlled input level. We supply audio via a common source, mono in the beginning, then stereo mpx.

Once concluded, when no audio distortion was noticeable, a new step popped up: available market equipment and RF final tests (in the field).The step next was to establish a method of correcting phase in the field. Considering a TUBE transmitter as the main source, changing characteristics as tube goes. The option was build several defined angle cables to be connected in series in the field…considering the FM test frequency 106.7 MHz. For precision, we used GPS with 10 MHz reference, calibrated by local Stratum Zero Lab.

1.3. Final System, Field challenges

Once approved by client, the Catholic Church Foundation[5] was time to build a commercial system. We put together new FM exciters, designed antennas to fulfill the desired area and lab equipment for field measurements.

Installation setup: we defined firstly the set at main transmitter site and then the gap filler, a point in the middle of equal FM signal levels in Av. Brasil, both signals reaching the same intensity, around 40 dBµV, confirmed latter using a field strength meter (useful good reception level). First observation: activating the gap filler, the field drop in the common area, the next observation was an audio distortion. We decided to correct phase at gap filler of transmission site. The gap filler station is located inside the radius of the theoretical contour 74.0 DBu of the main station and must be equal or above class A1. We made several tests until the right result appear. Done, field strength increased at same point and distortion disappeared, so the first on air asynchronous isofrequency FM in Brazil was operational, time to drive back and forth, passing the *common area* observing any possible disturbance. Days after, we were testing different receivers. The other days, we were inviting the sponsors, other colleagues and finally announcing to the audience.

We achieved success after 90 days of hard labor tests when system operates satisfactory since then.

B. *Other Recommendations*

As time passes, we have learned more about those systems. One of the learned lessons was the possibility to have different modulation levels, to be able to identify what system was predominant in certain areas, if the gap filler was predominant, or main signal or vice versa.

Further, we tested different gap filler of antenna configurations, with no significant changes. Different powers were tested and due to ground limits, we can say no significant change was noticeable throughout attended area.

III. MATH

We do not consider Math analysis here, because it is an experience description with field and system assembly steps.

A. *Equations*

The relevant equation that resume the experience is:

$$a = a$$

This is the description of an experience were frequency and phase are equal, referenced to GPS. Interesting to know that level is not necessarily equal…We really use different levels until now.

IV. CONCLUSION

It was an achievement of good results, followed by dozens of radio stations, reaching as result an audience increase using small structures, low power FM broadcast gap fillers and no extra spectrum.

REFERENCES

[1] E. F. Tiziano, "Registro de Obra Intelectual 2269, " CONFEA, Oct 30, 2014

[2] Resolução 67, 1 ed, ANATEL,Brasilia, DF, 1998, www.**anatel**.gov.br/…olucoes/13-1998/168-resolucao-**67**

[4] PTF, Precise Time & Frequency Inc, Boston, USA

[5] Fundação Cultural, Educacional e de Radiodifusão Catedral de São Sebastião do Rio de Janeiro – Rd Catedral – Rio de Janeiro – RJ – 106,7 MHz

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Reasons for SFN Failure in Broadcast

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Reasons for SFN Failure in Broadcast

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***Abstract*— To deliver the content of a TV network, ensuring efficient spectrum usage, filling not covered and shadow areas, and with energy savings are the advantages of Single Frequency Networks. Thus, in this study we sought to measure information, frequency, and time synchronism to evaluate the status of SFN implementation in Brazilian broadcasting. We took as base of analysis the Digital TV stations of the Campinas/SP area. Through this paper, we demonstrate that one of the great advantages of ISDB-Tb, the formation of a single frequency network, still cannot be implemented in Brazil.**

***Index Terms*— Coverage, Digital Broadcast, Quality, SFN.**

I. Introduction

SFNs are the solution for efficient spectrum usage; improvement of coverage in digital systems; and transmitters energy savings [1]. Efficient use of spectrum is achieved by replacing MFNs – Multiple Frequencies Networks, when an entity requires multiple channels to distribute its content to a particular region, by only one channel, allowing the other channels to be used by other entities. As with MFNs, but with efficient spectrum usage, overlapping service areas, as well as the use of gap-fillers for filling shadow areas allow the broadcaster to have greater control of where its signals are present, resulting in an improvement in the coverage of the entities. And the use of several stations and gap-fillers ends with the paradigm of high power [2], mainly derived from the analog legacy, where only one transmitting station covered the whole service area compared to several stations with lower transmission power generates an energy saving for the same coverage in SFN.

Brazil is currently at the beginning of the switch-off of the analog TV signal [3], in some cities only the signal with digital modulation is present. In this scenario, the next step in improving the broadcasting services quality is to guarantee coverage, which should be based on the efficient use of spectrum, the maximization of coverage, and energy efficiency, therefore the use of SFNs is fundamental for this next step.

In this paper, we show the results of an evaluation, in the region of Campinas/SP, where we verified if the conditions for the implementation of SFNs are being respected. This evaluation considers technical, commercial, and regulatory aspects, and we show, in general, it is not yet possible to fully implement SFNs.

II. SFN Solution in ISDB-Tb

A. Technical

A SFN is formed when two or more stations transmit the same content in a region of interest, at the same frequency. SFNs can be formed between transmitters (TX-TX), and between transmitters and gap-fillers (TX-GF) [4]. In the first case, the objective is to expand a coverage area, whereas in the second it is to eliminate shadow areas inside a transmitter coverage. Both solutions can be used by a broadcaster. Figure 1 illustrates these two possibilities.

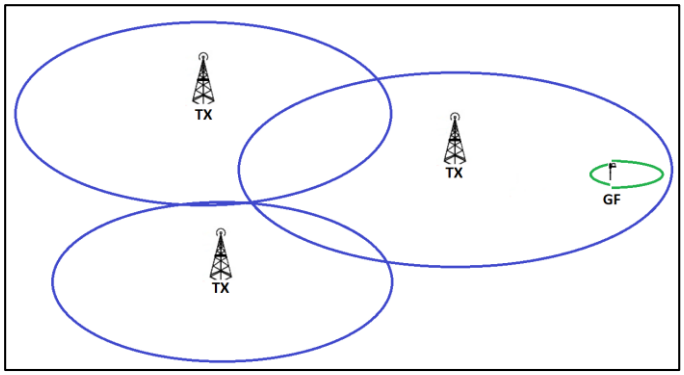

Fig. 1. TX-TX and TX-GF SFN.

We can also classify a SFN in Distributed, where the BTS – Broadcast Transport Stream signal is received by all stations and is transmitted simultaneously, or with minor adjustments to fit the reception within the guard interval. It is necessary to synchronize the transmission in 1 pps in these networks [1], which is obtained from the GPS synchronism (10 MHz); and in Repeated, in which a transmitter or gap-filler receives the signal

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via air from another transmitter and retransmits it. The retransmitted signal already contains the delay corresponding to the path of the first transmitter to the second one where signal is retransmitting [2].

As they operate on the same frequency, potentially there are regions where the signals from several transmitters do not respect the 19 dB co-channel protection ratio determined by Resolution [5]. However, the BST-COFDM modulation, used in ISDB-Tb [6], allows the formation of single frequency networks, because the guard interval that guarantees immunity to intersymbol interference of reflections and multipath, can also be used to generate constructive combinations with the signals of several transmitters. In this case, the concern is no longer the difference of field strength between the signals of several transmitters, but rather the delay with which these signals are delivery to the receiver.

For SFN to work, there must be synchronism in frequency, that is, the same channel should be used; the temporal, the various transmissions must be received by the receiver within the guard interval; and of information, where each received QPSK, 16QAM, or 64QAM symbol must be identical [1] [3].

However, the use of SFN also entails some disadvantages [7]: The TS – Transport Stream must be equal in all transmitters of the network, forbidding the generation of local content; if any transmitter violates the rules of the network, it will act as a jammer, creating interference; and, finally, the need for synchronism, in time, frequency, and information.

B. *Laws and Regulation*

The channeling developed for Digital TV over the last years [8] has planned the adoption of the reuse frequency, i.e. the television networks occupy a same channel in certain regions of the country. This was the first attempt to adapt the regulation to the technological novelty allowed by SFN. This initiative was called *Bus Channel*.

With the needs for the new digital channel and simulcast, a re-channeling was carried out (both with the change of the analog channels and the inclusion of the digital, with possibility of using digital channels adjacent co-located) that the single channel was used for the digital content of a TV network (even) and the adjacent channel for the analog (odd) [8]. However, at this stage there was still the thought of a single station covering the entire service area of the entity. Reinforcers would be used only to cover shadow areas.

Updates of the legislation on Digital TV in Brazil, particularly the Portaria nº 932/2014 of MCTIC – Ministério da Ciência, Tecnologia, Inovações e Comunicações, foresee the implementation of SFNs [9]. This document allows the installation of stations within the service area of the main station, the gap-fillers, and additionally, allows retransmitter stations to be created outside the service area, but in the same channel, if this channel is unfeasible to be used by another entity [5] [9]. In Figure 2 we present a situation where it is not possible to include a station of the same frequency, but with a different content, because the Interferential Contour (red line) makes it impossible to include this station. In this case the entity that already holds the authorization of the three stations may request an additional station, to cover the area between existing stations.

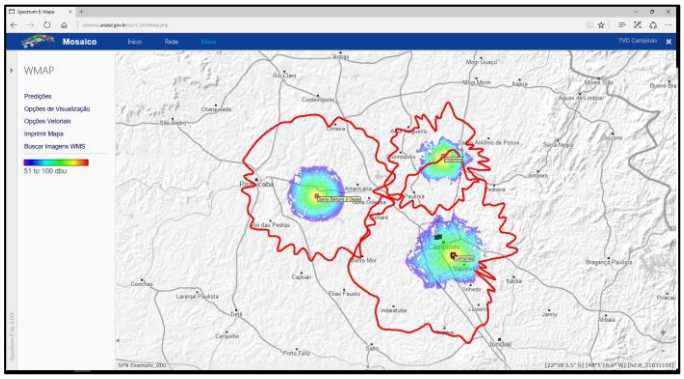

Fig. 2. "Unfeasible" Station inclusion inside a SFN.

In practice, the legislation authorizes the entity executing the television service to "fill" the empty spaces, whether they are shadow areas within the service area or uncovered areas between the service areas of the main stations of the same frequency and the same content, allowing the entity, through SFN, improve the coverage of its content by using several stations.

III. SFN Evaluation

According to the conditions established for SFN, the transmission modes of each station composing a network must be identical, as well as the content, ensuring that the same symbol will be received by the receiver, within the guard interval. Thus, in this study we sought to measure the transmission modes and transmitted content (information synchronism), of each channel (frequency synchronism), verifying whether these conditions were met, allowing the execution of SFN. We also measured the delays of the various signals that were received, in some cases it is possible to determine if this signal is reflection / multipath or from another station of network, allowing to check if these signals are within the guard interval (time synchronism).

To evaluate the viability of SFN implementation in Brazilian broadcasting, we took as base of analysis the Digital TV stations of the city of Campinas/SP. According to Basic Plan of Anatel – Agência Nacional de Telecomunicações, there are 15 stations in Campinas/SP, of which 5 are generators (TVD) and 10 are re-transmitters (RTVD), with 12 currently in operation.

Evaluation points were chosen within the city of Campinas/SP and close to the theoretical average coverage limit of the stations of Campinas/SP, observing if the reception occurred through the station of Campinas/SP or another station in the same frequency of another city. As the channeling for Digital TV was developed on the concept of the Bus Channel, there are in the municipalities around Campinas/SP several stations forming a network of affiliations using the same channel. One of the objectives of this evaluation is to verify how these channels at the same frequency are being used for the distribution of the audiovisual content of a TV network.

We used the DIVICATCH ISDB-T/Tb device to measure the transmission modes, check the transmitted content and, the

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delays between the various received signals. This equipment allows you to measure RF signal parameters (Level, MER, SNR, BER), indicates the transmission modes (TMCC, Layers A/B/C), and the constellation, besides allowing the decoding and recording of the transmitted content of the channel under analysis. The DIVICATCH ISDB-T/Tb was connected to the Schaffner UPA6192 antenna and measurements were taken at 2 meters from ground.

The coverage and interference simulations presented in this paper were performed in the ANATEL-MOSAICO System, which uses the approved installation data of each station and the Basic Plan of Anatel.

IV. Results

The geographical points where we perform the evaluation of the channels are shown in Figure 3.

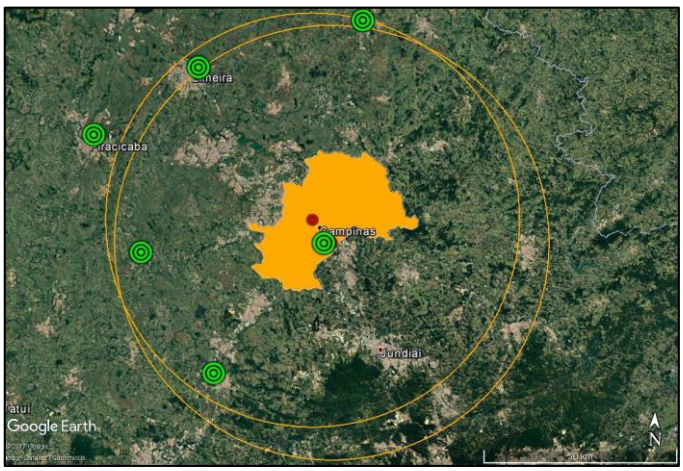

Fig. 3. Evaluation Points.

We chose six evaluation points, searching for a variability of possible alternative stations for reception. The points are in the cities and in the geographical coordinates:

Campinas/SP: 22ºS 56’ 44.69” / 47ºW 03’ 00.87”,
Mogi-Mirim/SP: 22ºS 25’ 38.80” / 46ºW 58’ 31.70”,
Limeira/SP: 22ºS 33’ 04.20” / 47ºW 22’ 55.30”,
Piracicaba/SP: 22ºS 42’ 56.10” / 47ºW 38’ 19.70”,
Capivari/SP: 22ºS 59’ 00.90” / 47ºW 30’ 31.00” and
Itu/SP: 23ºS 15’ 23.60” / 47ºW 18’ 51.80”.

At each measurement point, we point the directional antenna to the nearest transmission site as an attempt to receive the signal from the nearest station with greater intensity.

In TABLE I we present the transmission modes obtained in each point for each channel.

TABLE I
Transmission modes and Content

Channel	Layer	Campinas	Itu	Limeira	Mogi-Mirim	Piracicaba	Capivari
I	A	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8
	B	16QAM - 7/8 - 1/8	16QAM - 7/8- 1/8	16QAM - 7/8 - 1/8	16QAM - 7/8 - 1/8	16QAM - 7/8 - 1/8	16QAM - 7/8 - 1/8
II	A	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	-	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8
	B	16QAM - 2/3 - 1/8	16QAM - 2/3 - 1/8	16QAM - 2/3 - 1/8	-	16QAM -2/3 - 1/8	16QAM - 2/3 - 1/8
III	A	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	-
	B	64QAM - 3/4 - 1/8	64QAM - 3/4 - 1/8	64QAM - 3/4 - 1/8	64QAM - 3/4 - 1/8	64QAM - 3/4 - 1/8	-
IV	A	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	-
	B	64QAM - 3/4 - 1/8	16QAM - 1/2 - 1/8	16QAM - 1/2 - 1/8	16QAM - 1/2 - 1/8	16QAM - 1/2 - 1/8	-
V	A	QPSK - 2/3 - 1/16	QPSK - 2/3 - 1/16	-	QPSK - 2/3 - 1/8	-	QPSK - 2/3 - 1/16
	B	64QAM - 3/4 - 1/16	64QAM - 3/4 - 1/16	-	16QAM - 7/8 - 1/8	-	64QAM - 3/4 - 1/16
VI	A	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	-	QPSK - 3/4 - 1/16	-
	B	16QAM - 2/3 - 1/8	16QAM - 2/3 - 1/8	64QAM - 3/4 - 1/8	-	64QAM - 3/4 - 1/16	-
VII	A	QPSK - 2/3 - 1/4	QPSK - 2/3 - 1/4	QPSK - 2/3 - 1/4	-	-	-
	B	16QAM - 3/4 - 1/4	16QAM - 3/4 - 1/4	16QAM - 3/4 - 1/4	-	-	-
VIII	A	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	-	-	-	-
	B	64QAM - 3/4 - 1/8	64QAM - 3/4 - 1/8	-	-	-	-
IX	A	QPSK - 2/3 - 1/16	QPSK - 2/3 - 1/16	-	-	-	-
	B	16QAM - 3/4 - 1/16	16QAM - 3/4 - 1/16	-	-	-	-
X	A	QPSK - 2/3 - 1/8	QPSK - 2/3 - 1/8	-	-	-	-
	B	16QAM - 2/3 - 1/8	16QAM - 2/3 - 1/8	-	-	-	-
XI	A	QPSK - 2/3 - 1/16	-	QPSK - 2/3 - 1/16	-	-	-
	B	64QAM - 3/4 - 1/16	-	64QAM - 3/4 - 1/16	-	-	-
XII	A	QPSK - 2/3 - 1/16	QPSK - 2/3 - 1/8	-	-	-	-
	B	64QAM- 3/4 - 1/16	16QAM - 2/3 - 1/8	-	-	-	-
XIII	A	QPSK - 2/3 - 1/16	-	-	-	-	-
	B	64QAM - 3/4 - 1/16	-	-	-	-	-
XIV	A	-	-	-	QPSK - 2/3 - 1/8	-	-
	B	-	-	-	16QAM - 2/3 - 1/8	-	-
XV	A	-	-	-	-	-	-
	B	-	-	-	-	-	-

We note that the TMCC information (Transmission and Multiplexing Configuration Control signal loads all the information of the transmission modes, and must be sent by a specific carrier to assist in the identification of the operating modes by receiver.) was decoded in just under half of the possibilities. The non-decoding of the TMCC can be explained by the inexistence of the transmitting station in the channel near the measurement point and by the low signal strength of more distant stations.

In TABLE I, the gray ones mark the receptions taken as reference for each channel, almost all are stations installed and transmitting from Campinas/SP. In the case of channel XI we verified that this one is installed in the city of Limeira/SP and the station of this channel in Campinas/SP is not yet in operation, so, the reception in Campinas/SP was of the signal coming from Limeira/SP. For channel XIV, reception was only possible in Mogi-Mirim/SP. It was not possible to decode channel XV at any of the measured points.

In yellow are indicated the receptions that despite being obtained in a municipality different from the reference, were obtained from the reference station signals. In green are the station receptions different from the reference station and with transmission modes and content identical of the reference station. The formation of SFN among the receptions highlighted in gray, yellow, and green is possible.

The receptions highlighted in orange are from another station, with the same content, but with different transmission modes. And in red are highlighted the receptions in which there are differences in the content. In these cases, SFN formation is not possible.

We show the measurements of the echoes in TABLE II. We present the worst-case scenario, that is, the echo with the lowest attenuation (in dB) in relation to the main signal (with the highest intensity) and the delay (in µs).

TABLE II
ATTENUATION AND DELAY OF ECHOES

Channel	Parameter	Campinas	Itu	Limeira	Piracicaba	Capivari
I	Attenuation (dB)	33.50	15.70	25.5	24.20	21.40
	Delay (µs)	7.88	3.94	21.00	6.56	26.25
II	Attenuation (dB)	36.80	24.30	30.9	20.80	-
	Delay (µs)	9.19	3.94	13.12	6.56	-
III	Attenuation (dB)	38.30	7.60	27.90	19.10	-
	Delay (µs)	6.56	2.63	22.31	9.19	-
IV	Attenuation (dB)	32.70	32.40	30.80	16.50	-
	Delay (µs)	9.19	7.88	14.44	7.87	-
V	Attenuation (dB)	38.10	23.40	-	-	26.60
	Delay (µs)	10.50	14.44	-	-	3.94
VI	Attenuation (dB)	-	8.80	32.90	20.10	-
	Delay (µs)	-	-210.00	22.31	7.88	-
VII	Attenuation (dB)	38.00	9.30	31.00	-	-
	Delay (µs)	9.19	2.62	22.31	-	-
VIII	Attenuation (dB)	35.00	17.60	-	-	-
	Delay (µs)	6.56	3.94	-	-	-
IX	Attenuation (dB)	32.60	12.00	-	-	-
	Delay (µs)	3.94	2.63	-	-	-
X	Attenuation (dB)	28.90	10.20	-	-	-
	Delay (µs)	7.88	2.63	-	-	-
XI	Attenuation (dB)	30.90	-	17.80	-	-
	Delay (µs)	-85.31	-	13.13	-	-
XII	Attenuation (dB)	21.20	9.90	-	-	-
	Delay (µs)	-19.69	2.63	-	-	-
XIII	Attenuation (dB)	37.30	-	-	-	-
	Delay (µs)	5.25	-	-	-	-
XIV	Attenuation (dB)	-	-	-	-	-
	Delay (µs)	-	-	-	-	-
XV	Attenuation (dB)	-	-	-	-	-
	Delay (µs)	-	-	-	-	-

The situation where the echo respects both the protection ratio and the guard interval is highlighted in green; yellow highlights when the protection ratio is not respected, but the guard interval is. In these situations, it is possible the formation of SFN. In red we highlight the situation where neither the protection ratio nor the guard interval are respected, causing the intersymbol interference and not allowing the formation of SFN.

V. DISCUSSIONS

Observing the results of TABLE I, we verified that channels VIII, IX, X, XI, XIII, and XIV had only one station in operation and together with channel XV, which has no station in operation, so it is not possible to evaluate the formation of SFN for these 7 channels.

Channels I, II, III, and VII have more than one station in operation and both the transmission configuration and the content are identical, guaranteeing the synchronism of information, i.e. the same symbol arrives at the receiver. In TABLE II we observe that these channels also have the temporal synchronism, therefore the SFN can be implemented without any problem.

Since we did not measure the information on programmed transmission delays on the transmitters, which defines, in the interests of the broadcaster, the areas where there will be reception of signals with echoes outside the guard interval, it is not possible to simulate the real situation of the coverage of channels I, II, III, and VII. This is a technical freedom offered by SFN and has not yet been regulated by Brazilian legislation.

In relation to channels IV, V, VI, and XII, we observe that there is no synchronism of information, because or the setting of transmission modes (IV and V channels) or the content (channels VI and XII) is different between stations of the same frequency, impeding the implementation of SFN.

In the case of channels IV and V, with configuration of the different transmission modes between the stations, this is a merely technical problem, where simple standardization quickly solves the problem. However, this difference causes the station of Campinas/SP, in the case of channel IV, to operate as a jammer, causing mutual interference with other network stations. In Figure 4, we present the simulation of this interference, showing its extension, which has a very large area when compared to the simulation of the coverage desired through the SFN, shown in Figure 5.

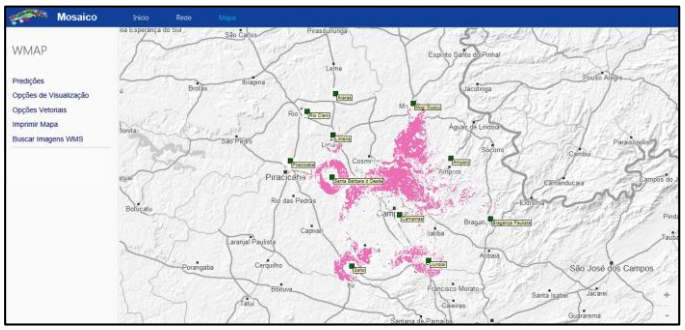

Fig. 4. "Jammer" station of channel IV in Campinas/SP.

As the Campinas/SP station is configured with transmission modes different from the others, the received symbols are different, in this way signals that do not respect the protection ratio of 19 dB become interfering. And the entire area highlighted in Figure 4 no longer has the reception of channel IV, implying in the loss of network quality.

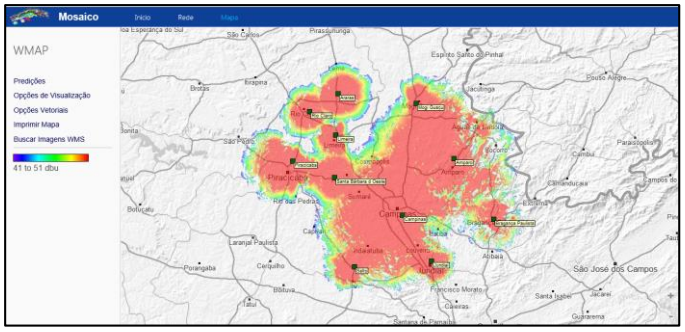

Fig. 5. SFN Coverage of channel IV.

We present in Figure 5 the simulation of the coverage of the stations of channel IV, if the SFN was configured correctly. In red, signals with field strength above 51 dBµV/m are presented.

In the case of channels VI and XII, the transmission of different contents also causes a region with interferences, as demonstrated previously, but the cause of this problem ceases to be technical and passes to the commercial / business sphere.

When the digital channeling and the use of the Bus Channel were planned, the current entity of channel V station of Campinas/SP has been assigned to occupy the channel VI. After the channeling, there was a contractual change between networks and the Campinas/SP station started to have a different content.

As the stations of the V and VI channels in Campinas/SP have different technical characteristics it is not possible, from

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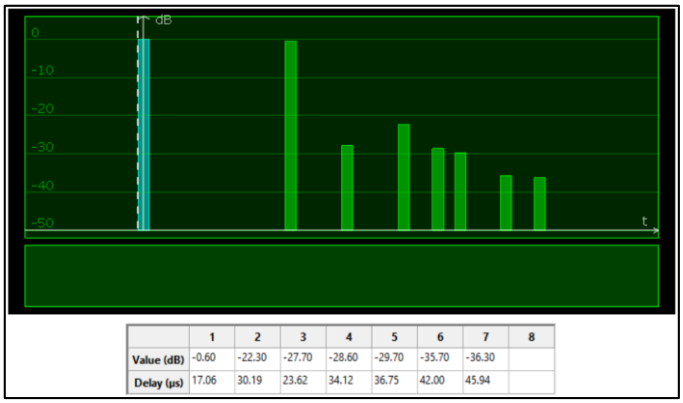
the regulatory point of view, to change the technical characteristics of the whole network to maintain the possibility of SFN. In this case, the execution of the SFN is really compromised, since the content of this entity began to be distributed by an MFN.

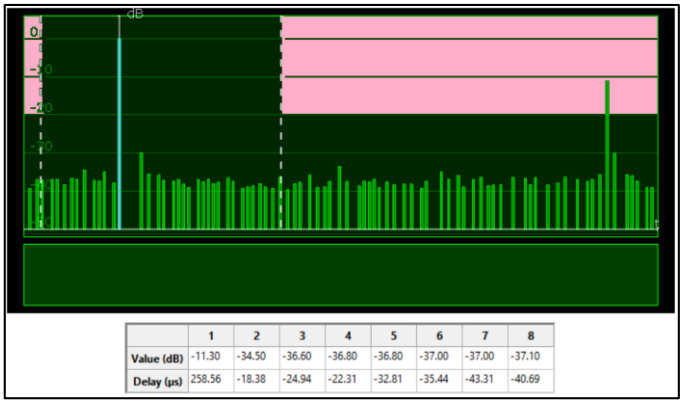
Additionally, we measured the echoes for each channel at points between stations. Figure 6 shows a situation in which there is an echo with attenuation of -0.6 dB relative to the main signal, a case where the protection ratio is not being respected, but the delay is 17.06 µs, respecting the guard interval. The content was decoded in this situation.



	1	2	3	4	5	6	7	8
Value (dB)	-0.60	-22.30	-27.70	-28.60	-29.70	-35.70	-36.30	
Delay (µs)	17.06	30.19	23.62	34.12	36.75	42.00	45.94	

Fig. 6. Echoes inside Guard Interval.

We took the opportunity to illustrate, through Figure 7, the situation where there is no content decoding: when the echoes reach the highlighted region in pink of the graph, neither the protection ratio nor the guard interval were respected.

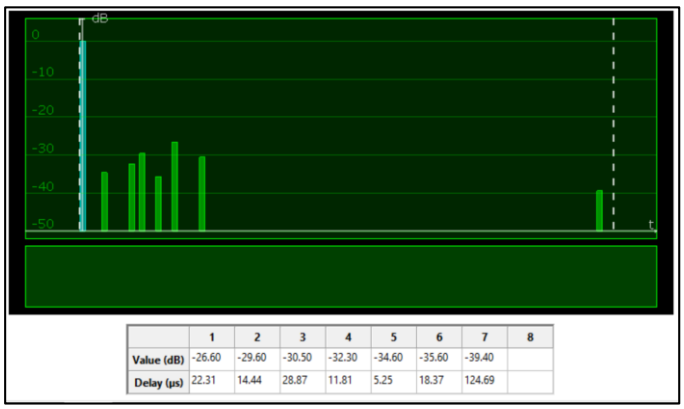


	1	2	3	4	5	6	7	8
Value (dB)	-11.30	-34.50	-36.60	-36.80	-36.80	-37.00	-37.00	-37.10
Delay (µs)	258.56	-18.38	-24.94	-22.31	-32.81	-35.44	-43.31	-40.69

Fig. 7. Echoes in SFN with ISI.

In Figure 7 we pointed to an echo that is attenuated at only 11.3 dB, thus interfering, and delayed at 258.56 µs, i.e., outside the guard interval (dashed lines). In this case intersymbol interference occurs.

In some cases, it was possible to observe the echoes coming from other stations within the guard interval. Figure 8 shows the situation described.



	1	2	3	4	5	6	7	8
Value (dB)	-26.60	-29.60	-30.50	-32.30	-34.60	-35.60	-39.40	
Delay (µs)	22.31	14.44	28.87	11.81	5.25	18.37	124.69	

Fig. 8. Echoes in SFN from different stations.

In Figure 8, obtained in Limeira/SP, we observed almost at the limit of the guard interval the signal coming from the station of Campinas/SP. In this case, the directional antenna used in the evaluation was pointed to the Campinas/SP station, so the blue signal, which is the main signal of the station of Limeira/SP, despite having a higher intensity, was still attenuated by the antenna front-back ratio, which is 15 dB. The content was decoded at this reception. It is noteworthy that as the measurement presented in Figure 8 was collected at a position close to the Limeira/SP station, the signal strength of the Campinas/SP station is below the limit of the protection ratio, which would not cause interference in any way despite being within the guard interval.

VI. CONCLUSION

For a single frequency network to work, it is essential that the same channel being used, that the settings being identical and that the same content being transmitted, all within the guard interval. In the tests performed we observed that several of these conditions were not respected by the stations of the Campinas/SP region.

Through this paper, we demonstrate that one of the great advantages of ISDB-Tb, the formation of a single frequency network, still cannot be implemented in Brazil.

We conclude that for the implementation of SFNs the following points should still be improved:

- Technical training of the teams to configure the network;
- Stable commercial contracts between the generators of the network;
- Regulatory changes that do not tie the technical characteristics of the network stations.

In this sense, despite recent improvements, the regulation of Digital TV in Brazil still needs improvements. We have pointed to Portaria nº 932/2014 as a beneficial approximation of technical needs with legislation, but the concept of main station is still very much present in the legislation. It is necessary to change the current standards so the main station, whose technical characteristics are authorized and inspected by the granting authority (Anatel and MCTIC), can be subdivided and distributed in several stations, being that the regulator would worry about the limits of the area of service rendering and with the possible interferences generated by the stations.

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REFERENCES

[1] A. Mattsson, *Single Frequency Networks in DTV*, IEEE Transactions on Broadcasting, Vol. 51, N°. 4, Dec. 2005.

[2] S. R. M. Carvalho, *Contribuições para Melhoria na Confiabilidade de Redes de Frequência Única em Sistemas de Transmissão de TV Digital*, Tese de Doutorado, Universidade Estadual de Campinas, Jul. 2014.

[3] Portaria nº 2.992, Ministério da Ciência, Tecnologia, Inovações e Comunicações - *Estabelece o cronograma de transição da transmissão analógica dos serviços de radiodifusão de sons e imagens e de retransmissão de televisão para o SBTVD-T*, 26/05/2017.

[4] J. F. Rehme, and M. A. Martins, *Cobertura de TV Digital com uso de redes MFN e SFN*, Revista da SET, nº 149, Mar. 2015.

[5] Resolução Anatel nº 398, *Aprova as alterações do Regulamento Técnico para Emissoras de Radiodifusão Sonora em Frequência Modulada, e do Regulamento Técnico para a Prestação do Serviço de Radiodifusão de Sons e Imagens e do Serviço de Retransmissão de Televisão*, 07/04/2005.

[6] M. Takada and M. Saito, *Transmission systems for ISDB-T*, Proceedings of the IEEE, Special Issue on Global Digital Television: Technology and Emerging Services, pp. 251–256, Jan. 2006.

[7] F. Rottensteiner, *Technical Realisation of Digital TV Transmitter Systems*, ITU inter-regional seminar, Kiev, Ukraine, 13-15 Nov. 2000

[8] T. Mondino, and V. Donzelli, Canalization Study For Digital TV in Brazil, Revista da SET, English Special Edition, Mar. 2010.

[9] Portaria nº 932, Ministério da Ciência, Tecnologia, Inovações e Comunicações, Aug. 2014.

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Face recognition techniques using artificial intelligence for audio-visual animations

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Face recognition techniques using artificial intelligence for audio-visual animations

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***Abstract*—This work developed an artificial intelligence based web tool that uses face recognition for computer animation applications. It enables that the producers can simulate the face movements of the actors in a digital environment. All the inherent applications of the tool favor the area of computer-animated films and television series.**

***Index Terms*—Artificial Intelligence, Computer Animation, and Expressive Facial Animation.**

I. Introduction

Computer facial animation based on artificial intelligence is a very challenging topic and has become one of the most used techniques for the development of cartoons and film productions. Among the most well-known computer graphic techniques, the stop motion technique was one of the first technique used in filmmaking, animations and live-actions. This technology consisted in the reproduction of objects in a scene thought of a series of aligned static images. Due to the advent of new technologies, 3D animated graphics allowed to the creators have access to different perspectives and layers of an object, however the time spent used to create this type of animations increases because of its high complexity. [1][2]

For this reason, new computer facial animation techniques should include artificial intelligence and machine learning based methods. For instance, it is possible to extract information using face recognition algorithms based on the movements of the interpreter's own face. In base on this premise, this work will explain the developed web tool in a sequential order of steps. The first process is to record the movements and expressions of interpreter's face. These samples are the input of the training process and learn how each interpreter facial movement is performed. Then, the respective weights extracted from the past process are stored in the database for later use. The next step is to create a 3D pre-modeling of the face to generate the computer animation of the character.

Item II explains the stages involved in the development of the application and its functionalities. Item III, presents the final results. Finally, Item IV presents the conclusions and future works.

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II. Development of the Application

This tool enables to create animations based on the author's face interpretation in real time. As a part of the development, the HTML5 (HyperText Markup Language) [3], CSS3 (Cascading Style Sheets) [4] and JavaScript [5] programming languages were used.

The first stage is the dubbing process of the animated character; this process consists of giving life to animated characters. Actors interpret scenes in front of screens and microphones for many hours in order to recreate the more real expression of character's feelings required on the scene. The application detects and captures the facial movement and stores the feature points as is shown in Fig. 1.

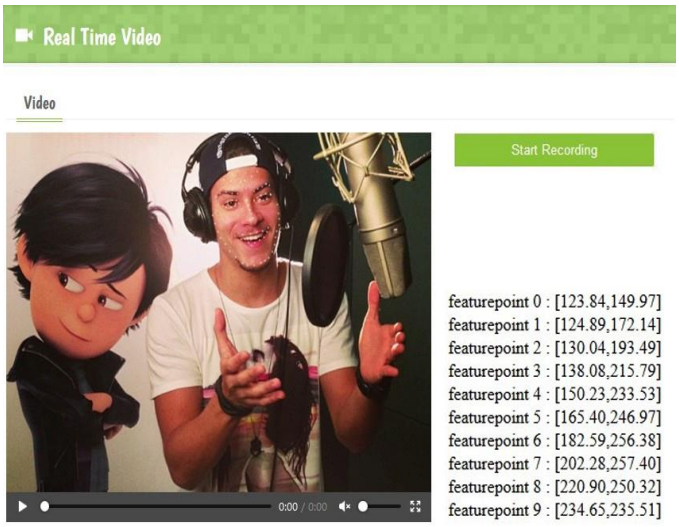

Fig. 1. Character dubbing and capturing facial points.

Despite these feature points are used to pre-model the animated character. This work used this information to train the neural network, it means that a computer could create an animated character as a combination of these features. For this application, is constructed after 7 steps, as seen in Fig. 2. The developed tool uses spreadsheets of models, which are precisely groups of images created by points that show all the possible expressions that a character can have, and all the different positions that they can adopt according to the recorded images. [6] Thus, the tool can generate a modeled face with the expressions of the actor when talking in stage 5 of the development process, reducing the time spent of audio-visual productions.

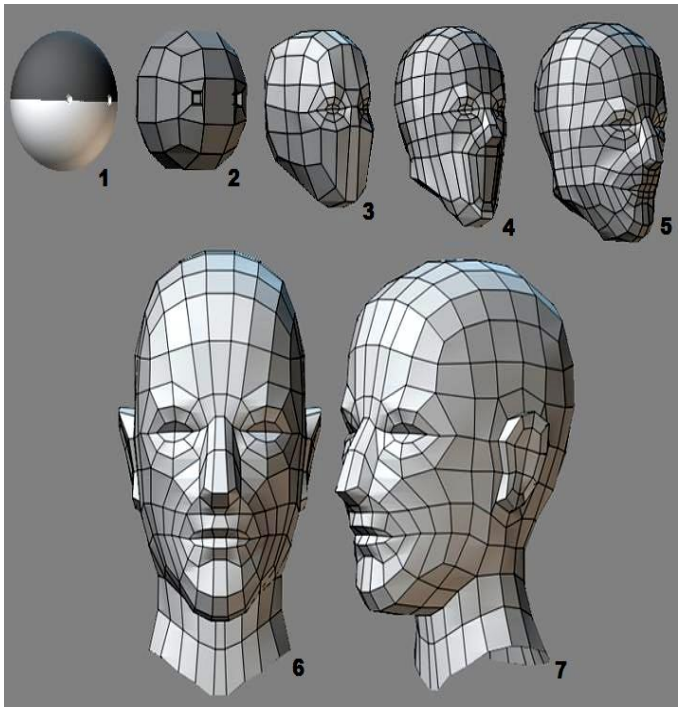

Fig. 2. Standard modeling of a character in 7 steps.

The spreadsheets are created to remain the character's details and the drawing be uniform. The captured expressions are categorized and stored as specific frames, as is shown in Fig. 3. Thus, animators, along the course of the editions, can choose a state of the character's face for a given scene, simplifying the entire creation stage.

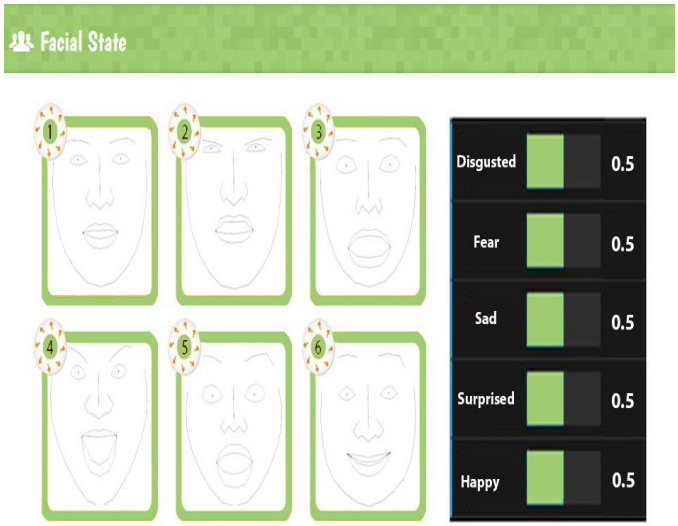

Fig. 3. Standard facial modeling with adjustment panel.

Once the modeling stage is finished, the creation of layer-upon-layer color using the RGB color model is performed. The tool enables to the user to insert the 3 layers created by the color histogram, also known as color frequency distribution, which is a graphical representation in columns with the data sets previously tabulated and divided into classes automatically to check the possible discrepancies of the image, as shown in Fig. 4.

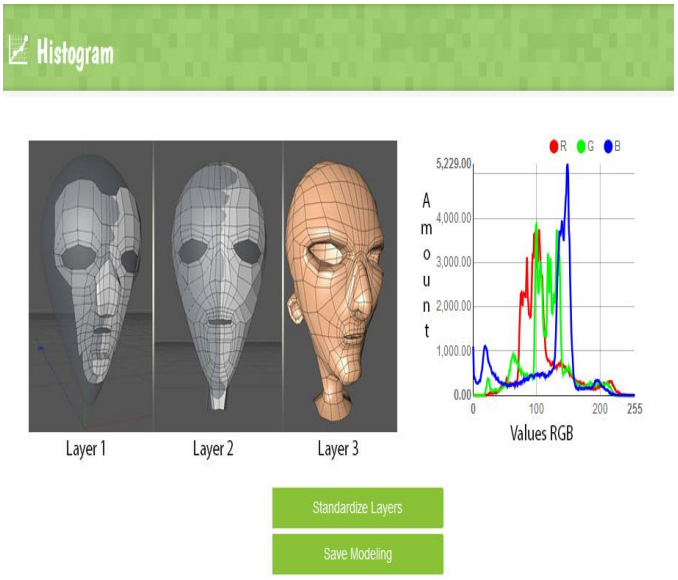

Fig. 4. Histogram of color for each layer.

If there is any discrepancy, the system acknowledges and prevents the user to select a wrong model. After the correction, the model can be saved and the next step is applied.

The modeling in this stage is raw, only the layer was made with the colors by frequencies, and it is now necessary to add the textures, which are created to fit the artistic concepts planned with the plot created by the scripter of the film. These textures are created in the form of maps and associated with the model, as is shown in Fig. 5.

Fig. 5. Texture created in map form.

Finally, the application allows uploading the created face with texture, unifying theme, and forming the final file, as is shown in Fig. 6.

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Fig. 6. Examples of facial modeling, with mapped texture applied.

The entire system has restoring points at each stage of creation of the animations to recover valuable information if were the case of errors during the playing.

A. Artificial Intelligence based method

An Artificial Intelligence (AI) system is not only capable of storing and manipulating data, but of acquiring, representing, and manipulating knowledge. This manipulation includes the ability to deduce or infer new knowledge (new relationships about facts and concepts) from prior knowledge, to solve complex problems. [7] Thus, the main goal of the tool is the application of machine learning techniques. By doing so, the system can learn the movements made by the author at the time of the interpretation of the character using the feature points previously stored.

In total, there are 312 captured and stored facial points represented by the vector (x, y, z) in the recorded environment. These values are binaries to apply machine instructions among the samples [8].

Once the tool can gain more knowledge, the system will be increasingly accurate and efficient, since it is a slow learning process, and requires a high number of data to perform actions close to reality. Due to this, this tool stores the dots and movements to train the neural network, but it is not able to generate an entire computer animation with all the molded movements. However, the diagram with all the steps covered by the developed tool is shown in Fig. 7.

The current arquitecture of the neural network consists of a finite amount of data for the training process. In mathematical

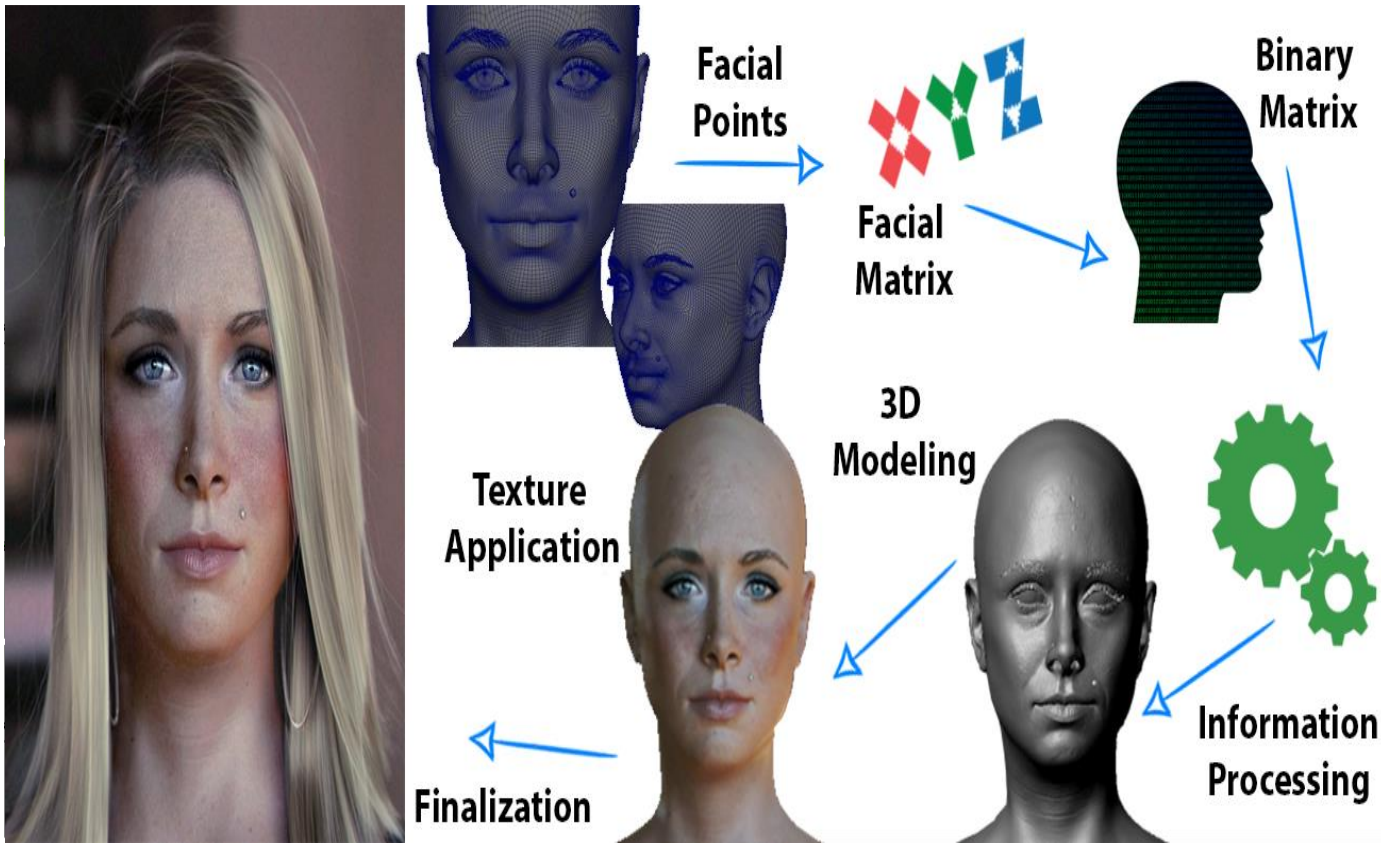

Fig. 7. Diagram of the complete technique.

function f(x) (which generated the data), this function would have many errors, as shown in Fig. 8.

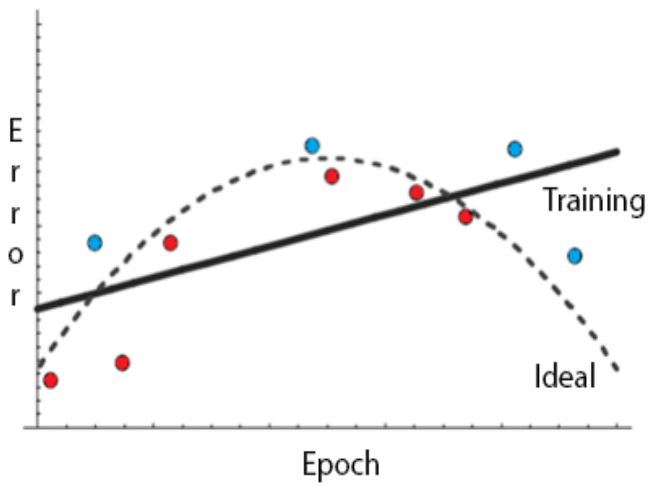

Fig. 8. Example of learning with many cataloged errors.

By the use of the developed tool, the application will be able to be adequately trained to an ideal level. Consequently, the errors will be lesser during the entire process and those would be imperceptible, as shown in Fig. 9.

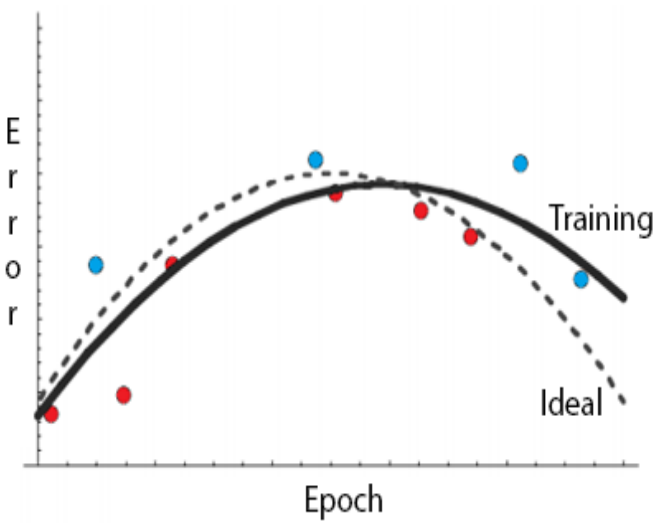

Fig. 9. Example of ideal learning for the application.

B. Neural Network based method

Artificial neural networks are computational techniques that present a mathematical model inspired by the neural structure of intelligent organisms and that acquire knowledge through experience. They are used to solve AI problems where a human brain is simulated, including its behavior, which is, learning, making mistakes and making discoveries. [9]

This work used the Hopfield model as neural network model. This network serves as a content memory system that can be addressed with binary limit nodes. It is ensured that the animation is converted to a local minimum, but sometimes converge to a false standard through mathematical analysis tests, the latter case appears in only 12% of all content generated, without distortion of the final results [10].

The overall network consists of feeding its output into its own inputs, a feedback process. For instance, the units assume a binary state (active or inactive) and these units are connected together by symmetrical edges with different weights. Whether the edge has positive weight, it indicates that the two units tend to activate by itself. By the contrary, negative values indicates that an active unit can deactivate another unit. [11] The mathematical model for this representation is (1):

$$s_i \leftarrow \begin{Bmatrix} +1 \therefore \sum_j \omega_{ij} s_j \geq \theta_i \\ -1 \therefore \qquad \rho \end{Bmatrix} \tag{1}$$

Where:

ω_{ij} is the weight of the unit connection weight j the unity i;

s_j is the state of unity j;

θ_i is the limit of unity i;

ρ is otherwise;

The last analysis is the energy configuration of the network, highlighting the current state of the network (above the valley). This work looks for an attractive state to which it would converge. The minimum energy level and a shaded attraction area is shown in Fig. 10.

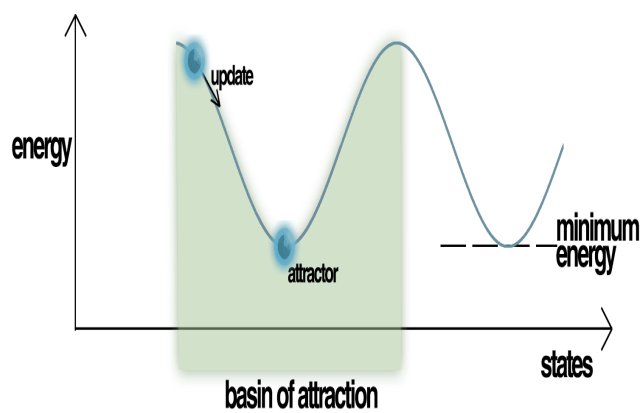

Fig. 10. Example of power configuration in the Hopfield network.

The energy (E) represented in (2) guarantees that, when the units to be updated are randomly chosen, the energy will decrease in value or remain the same. [11]

$$E = -\frac{1}{2}\sum_{i,j} \omega_{ij} s_i s_j + \sum_i \theta_i s_i \tag{2}$$

III. Results

The developed tool allows to the user approximate the contour of a face. This can be adjusted regarding to the perspective of the animation being used in the scene. After the facial mapping process generated by a computer, it is possible to change the points to the desired pattern, creating a tabulation, as shown in Fig. 11.

http://www.set.org.br/ijbe/ doi: 10.18580/setijbe.2017.11 Web Link: http://dx.doi.org/10.18580/setijbe.2017.11

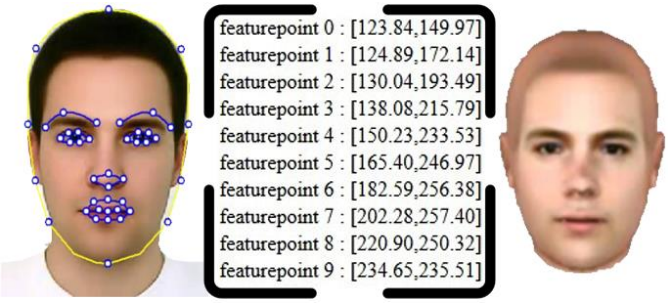

Fig. 11. Expected result.

IV. Conclusion

This article discusses a simple tool, easy to implement and of high importance in the cinematographic industries. The incorporation of an artificial intelligence based proposal is emerging and is expected to be part of the next-generation of animation techniques. As a future work, the application would create pre-models of faces and movements using the generated patterns after applying artificial intelligence based methods, making the computer animation process a more simple task for producers.

References

[1] P. Gulati, "Step-by-Step: How to Make an Animated Movie", Envato Tuts+. Available in: <https://cgi.tutsplus.com/articles/step-by-step-how-to-make-an-animated-movie--cg-3257>. Access in: 22 July 2017.
[2] N. M. Thalmann; D. Thalmann, "Complex Models for Animating Synthetic Actors", Journal IEEE Computer Graphics and Applications archive, vol. 1, pages 32-44, 1991.
[3] J. Keith; R. Andrew, "HTML5 for Web Designers", 2nd ed., A Book Apart, 2016.
[4] D. Cederholm, "CSS3 for Web Designers", 2nd ed., A Book Apart, 2015.
[5] D. Flanagan, "JavaScript: The Definitive Guide", 6th ed., O'Reilly Media, 2011.
[6] S. Bouaziz; Y. Wang; M. Pauly, "Online Modeling For Realtime Facial Animation", Journal ACM Transactions on Graphics, vol. 32, 2013.
[7] J. Harlan; J. Struthers; C. Baker, "Artificial Intelligence", 1st ed., Thames and Hudson, 2009.
[8] Rein-Lien Hsu; M. Abdel-Mottaleb; A.K. Jain, "Face detection in color images", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 290, pages 696 - 706, 2002.
[9] M. T. Hagan; H. B. Demuth; M. H. Beale, "Neural Network Design", 2nd ed., Martin Hagan, 2014.
[10] H. Akça; R. Alassar; V. Covachev; Z. Covacheva; E. Al-Zahrani, "Continuous-time additive Hopfield-type neural networks with impulses", Journal of Mathematical Analysis and Applications, vol. 290, pages 436-451, 2004.
[11] H.A. Rowley; S. Baluja; T. Kanade, "Neural network-based face detection", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 20, pages 23 - 38, 1998.

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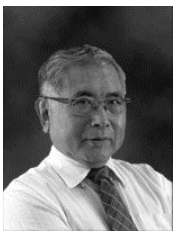

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Social awareness as a support tool for analog TV switch off and humanization process: Seja Digital's experience in Rio Verde and Brasília (Brazil)

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Social awareness as a support tool for analog TV *switch off* and humanization process: Seja Digital's experience in Rio Verde and Brasília (Brazil)

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***Abstract* — In order to attend regulatory order, Brazil's analog TV signal is in the process of switching off. The expectation is to switch off the analog signal of all major and medium-sized cities in Brazil until 2018. If everything goes according to plan, the digitalization of the entire country will complete by 2023. To ensure this, Seja Digital - EAD (entity responsible for the operation and analog signal switch off) has undertaken many actions guided by social mobilization. This article presents the blueprints of a project based on this methodology applied in Rio Verde city (Goiás State) and tested on other cities. It aims to support the population throughout the transition process by answering questions and scheduling the distribution of converter kits to families that receive social aid from federal government programs. Additionally, it presents a conceptual reflection on the meaning of social mobilization and justification for why it is so highly valued for TV switch off projects.**

***Index Terms* — Brazilian Switch off; Digital TV; Analog TV; Seja Digital.**

I. INTRODUCTION

To mobilize means to invoke the desire to partake in the search of a common purpose, under a shared interpretation and meaning. (TORO; WERNECK, 1996, p.5)

By regulatory order, Brazil's analog TV signal is in the process of being switched off. The project's kickoff city was Rio Verde, in the Brazilian state of Goiás, on March 1 of last year. The second cluster[2] to have completed the digitalization process was in Brasília, on November 18. "Cluster" refers to the conglomerate of cities that will undergo the process according to the Brazilian analog switch off timeline. In this case, it refers to the Federal District plus its nine surrounding cities (Cristalina, Luziânia, Águas Lindas, Novo Gama, Valparaíso de Goiás, Formosa, Santo Antônio do Descoberto, Cidade Ocidental, and Planaltina de Goiás). The expectation is switching off the analog signal of all major and medium-sized cities in Brazil by 2018. If everything goes according to plan, the digitalization of the entire country will reach completion by 2023. To ensure this, Seja Digital - EAD (entity responsible for the operation and analog signal switch off) has undertaken many courses of action, some of which are guided by social awareness.

Seja Digital's social mobilization project is sensitive to the population's awareness about the analog signal switch off and driven towards taking over this process and developing tools and mobilization solutions within its community. What we have done is established dialogue so that our participation may be as effective as possible and generate commitment, love, involvement, and a sense of community. All this adds value to the process, which in turn, no longer seen as merely technological change, also adds a sense of wellbeing and an awareness of the benefits offered by digital TV and technology. More and more it awakens a desire for digital inclusion. It has become a project of public use and we can only complete it through a chain of solidarity and collective effort, even more so because of a single truth we hold on to and have confirmed through our field experiences: the Brazilian people love television very much.

Image 1– Seja Digital mobilizers during the event in "Cristalina" (GO).

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We have noticed that these actors feel valued and important to the process and in turn collaborate with us more freely and are more emotionally willing when we make them aware of the importance that television still holds to many families. We argue, and admit, that we cannot reach our goal alone. We need everyone's help and multipliers and volunteers are essential to guarantee that these families have access to digital TV signal.

This article presents the blueprints of a project based on this methodology applied in Rio Verde and tested on other clusters. It aims to support the population throughout the transition by answering questions and scheduling the distribution of converter kits to families that receive social aid from federal government programs. Additionally, it presents a conceptual reflection on the meaning of social mobilization and justification for why it is so highly valued for TV switch off projects.

This document is the first linked to the Brazilian Digital TV and Technological Convergence Observatory (Obted), a LabArteMídia research group project. Almir Almas, from the Cinema, Radio and Television Department at the School of Art and Communications of the University of São Paulo, is the coordinator at LabArteMídia (Laboratory of Art, Media and Digital Technology)[1]. The creation of Obted had the purpose of following the Digital TV implementation scenario in Brazil closely, while simultaneously making observations of television in the digital production era, reflecting on social changes and implications brought on by the digital system to this vehicle, which is currently going through a technological integration phase beyond broadcasting. Note that the Observatory is not limited to analyzing digital TV or the processes related to it with a critical eye. Instead, it has a collaborative nature to also offer solutions and increase knowledge. In other words, the project proposes to observe technological enhancements while identifying new possibilities for entertainment and discourse.

II. SEJA DIGITAL: COMMUNICATION, MOBILIZING, AND MULTIPLYING IN ORDER TO DIGITALIZE

Image 2 – A volunteer of the Door-To-Door campaign during a joint community effort in Brazlândia (Brasília).

The collaboration with the switch off project in Brazil began during the study for a doctorate degree. We challenged 10 young adults from São Paulo city's East Zone to organize a community campaign to raise awareness about digital TV, which, the Government had delayed in doing. The young people were members of *Intermídia Cidadã*, a collaboration pertaining to the Public Communications Nucleus of the Tide Setubal Foundation (NCC-FTAS), which runs a social project in the Jardim Lapenna neighborhood. They immediately agreed to go door-to-door and teach families about how to better prepare for the analog signal switch off. In addition, we created a project called *Cidade Adentro* to explore interactivity on TV as a tool for social awareness.

After this, a research internship in Italy (Universitá Sapienza) and in the UK (University of Brighton) allowed public identification of policies used to help populations migrate to digital signal. In the UK, the country resorted to an important plan of action to provide technical support for its population during the permanent migration process to digital TV.[3] It engaged the government, civilians, TV equipment manufacturers, and small businesses. The project achieved relevant results due especially to volunteers who assisted elderly, impaired, and immigrant citizens. (FEITOSA, 2015).

When Antônio Carlos Martelletto, general director of Seja Digital (entity responsible for managing the switch off in Brazil), heard of this research, he decided to design and execute *a similar project in Brazil. It was an opportunity to apply the* social awareness method to the project and went to Rio Verde (Goiás, Brazil), which was preparing to undergo the analog TV signal switch off in the second semester of 2015. The switch off was initially scheduled for the 29 November, but was postponed to March of 2016. At the end of the process, the Mobilization Management team had recruited approximately 700 volunteers and partners, among which were community, political and religious leaders, as well as educators, artists and university students. It is safe to say that the population, overcome by a sense of solidarity and pure citizenship, took over the project once realizing its public value and nature.

When its switch off process ended, the UK issued a booklet called "101 Stories" [4] that contained 101 testimonies of the experience through the eyes of team members, volunteers, and beneficiaries. Not that there is any significant competition with the brilliant project executed in the UK, but, it is possible to guarantee that the project in Rio Verde, our first, produced even more inspiring stories than those found in the British document. The challenges faced here are greater: we deal with social vulnerability, poor education, functional illiteracy, and little access to information. Some of these stories were shared on the

[3] I had the opportunity to amply study this involvement process in the United Kingdom during my doctoral research, financed by Fapesp, Process No. 2012/20856-4, *Fundação de Amparo à Pesquisa do Estado de São Paulo* (FAPESP).

[4] BBC. 101 Stories: The switchover help scheme/BBC. 2012. Available at: <http://downloads.bbc.co.uk/aboutthebbc/insidethebbc/howwework/partnerships/helpscheme/SHS_101_stories.pdf>. Accessed on: November 20, 2016.

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"Brazil towards Digital TV" (*Brasil rumo à TV Digital*) blog[5] that narrates TV's transition process through the perspective of Seja Digital's Mobilization Management team. Therefore, one of the purposes of this article is to share a little of what has been applied to our daily lives and the impact it has made. The results of our initial switch off tests can inspire other South American and African countries with similar socioeconomic profiles to that of Brazil and that will undergo the same process in upcoming years.

About mobilizing and sharing space in the world

The root of the word "mobilization", widely used by theorists Bernardo Toro and Nisia Werneck [1], comes from the term *mobilis*, which in Latin means to move or dislodge someone or something from one place to another. According to Toro and Werneck, mobilization stems from a collective desire and shared perspectives and goals. I can say that to mobilize means to leave some form of comfort zone and move towards solidarity, a common good. It means returning to the essence of communal living; leaving gated communities otherwise described by Zygmunt Bauman as places of individual protection, with walls that progressively prohibit the person from occupying and living in collective spaces, and valuing others by opening oneself to the essence of man-man-nature-society interactions.

This only increases what Bauman [2] referred to as "mixophobia", or "the fear of mixing" (BAUMAN, 2009, p. 43).[6] This is the opposite of mobilization, especially when taking into consideration Bairon and Petry's ideals on the matter (2000, p. 32): "It is possible to comprehend the totality in which we find ourselves through those around us. To be of this world means to live by pre-giving ourselves to the relationship between subject-object. Therefore, it means to live in the anticipation of any objectivity or subjectivity". In other words, mobilization is to promote dialogue too in order to reach an understanding. It means to mix with others, experience the world, and participate in it through the complete exercise of freedom. It is to position oneself about it, take care of it, share its space, be vigilant and, if need be, fight for it. Civil society, with all its daily demands, offers the ideal place to apply the notion of mobilization. All one has to do is to look at the concept developed by Martín-Barbero and Rey (2004, p.90) in the book "*The Exercise of Seeing: the hegemony of television audiovisual and fiction*". [3]

> [Civil Society is] … a public space where interactions of many different natures take place between different social actors, who are more or less organized. The concept of a civil society is strongly tied to the realities of social debate (in the context of communication), discourse, pluralism, independence to form personal interests, and the ability to reach social, cultural and political goals. Civil Society is a space of resistance against authoritarianism and the framework for the configurations of cultural policies, the socialization of its citizens, conflict resolution, and the expression of opposition (MARTÍN-BARBERO; REY, 2004, p. 90)

In the book *Social awareness: One Way of Building Democracy and Participation*, Bernardo Toro and Nisia Werneck (1996) [1] emphasize that participating in a social awareness process is "an act of choice", thus an expression of "freedom". According to them, people are "summoned", but the affiliation to a specific project conditioned to the point of view that one has, to the rational way that the person sees him or herself within the process; it is about the commitment to the issue at hand and to the group.

> Summoning desires means to summon discourse, decisions, and actions towards a common goal; towards an act of passion, to make a choice that "contaminates" the daily life. Any mobilization is thus towards something, to reach a pre-defined goal, a common purpose, and is therefore an act of reason (TORO; WERNECK, 1996, p. 5)

According to the authors, "desire and awareness" and "action" are the two steps that mobilization depends on to occur within a specific group or community. "The first is of awakening the desire or awareness of the need for an attitude or change. The second is the transformation of this desire and awareness into a readiness of action and the action itself", they explain. (TORO; WERNECK, 1996, p. 43) [1]. According to them, these steps can be experienced concurrently by the members or groups involved in the mobilization project, which can be highly advantageous due to how the current members attract new people to the process by providing real references and assurance that will entice them to join.

In line with Toro and Werneck (1996) [1], the configuration of a mobilization project should provide a list of clear, open, and stimulating suggestions in order that, in the following moment, people may discover and invent new ways to participate, thus avoiding becoming accommodated, feeling manipulated, or somehow sensing that their independence has been compromised. Some steps offered by Toro and Werneck to stimulate people to join a mobilization project, and that objectively help them understand how they may contribute, are as follows: (1)Provide a clear description of the project, its goals/objectives, and the importance of each phase; (2)Pass on a sense of assurance, value, and freedom to act and express oneself in the area he or she participates in because it is important for people to "feel assured of recognition, value and respect for the way he or she is and thinks, no one wants to run

[5] Webpage: http://brasilrumoatvdigital.blogspot.com.br/

[6] Initially, the architectonic distance within cities and privacy walls of houses were the causes of mixophobia. When Bauman mentions gated communities, he is specifically referring to the housing models of gated and heavily guarded communities (BAUMAN, 2009).

the risk of not being understood or rejected" (TORO; WERNECK, 1996, p. 26) [1]. In addition to this, it is necessary that the members feel confident of the actions and capacities shown by others in their respective roles. The delivery of basic materials is a *sine qua non* condition for the execution of the project. It is also equally important to keep a register of processes, actions, and results and to disclose them in order that all may learn from them.

Social Actors of the Mobilization Process

> Mobilization teaches us to learn to communicate with each other, to recognize the meaning and messages sent, and desire for messages and emotions to be captured (TORO; WERNECK, 1996, p. 59)

Toro and Werneck (1996) [1] mention that the ideal mobilization process involves the participation of four types of social actors who understand how fundamental they are for reaching the intended goals of a specific project. These four types are the multipliers, social producers, editors, and social re-editors. Below, a summary is given by the researchers of each classification and examples of how to interpret these concepts within the current structure at Seja Digital.

> **Social Producer** – the institution and/or person that provides the economic, structural, institutional, professional, and technical conditions necessary for the mobilization to happen. . "The [Social Producer] has the intent of transforming the current reality. He has certain goals for change and makes himself available to present and share these goals with others, who in turn will help him clarify, amplify, and of course, reach them." (TORO; WERNECK, 1996, p.22) [1]. In order for the mobilization process to actually happen and reach good results, it is necessary that the social producer respect the principles of democracy, collectivity, and sensibility. He must also have broad knowledge of the reality he wants to change and the good sense to make decisions in collaboration with the editors about the material necessary for the mobilization process. i.e., Seja Digital board of directors and the Seja Digital Mobilization team. The social producer is responsible for identifying *re-editors*, who are able to reach pre-defined goals and demands of the project and guarantee the distribution of the material to them.

It is essential that the social producer be able to provide guidance to an editor about producing appropriate material and must have thorough knowledge about the possibilities and limitations of using social communication as a mobilization tool. Very often, goals within the mobilization process result in failure because the capacities of communication vehicles and mass communication are underestimated. Positioning the social producer well can guarantee using them to their full advantage.

> **Editor –** embodies how to send out messages; in other words, this entity prepares the communication material and adapts it to different types of languages and media (codes) for the re-editor to understand, embrace, and use in the community. "The success of the mobilization depends on the way that the message is produced and reaches the *re-editor's* line of work […] the better [the editor's] knowledge of the *re-editor's* line of work, the higher the chances of success." (TORO; WERNECK, 1996, p.25) [1]. For this role, one should consider professionals who work in Communications, Events, Design, Creation, and Marketing at Seja Digital.

> **Re-editor** (term coined by Juan Camilo Jaramillo, in 1991) **–** should have legitimacy and recognition within the community to promote certain messages and adapt them to the current reality of daily experiences. In addition to this, this role summons and prepares the community network to continue the flow of information. Once the entity takes over the message, the *re-editor* is able to transform the content received by the editor into something that the population can relate to, "through the use of codes, values, and experiences pertaining to that group" (TORO; WERNECK, 1996, p.24) [1], so that they may be convinced of the theme. "He has the ability to deny, transform, introduce, and create meanings for his audience, thus contributing to how it changes its way of thinking, feeling, and behavior." (TORO; WERNECK, 1996, p.24) [1] i.e., NPO's; community, academic, political and religious leadership; educators, teachers, and health professionals

> **Multipliers** – reproduce information in the manner received from the social producer and editor. i.e., Media, Seja Digital volunteers, and young people from *Antenista Amigo*.

In regards to how the *re-editors* work to convince people to join the mobilization, Toro and Werneck (1996) [1] explain that the "arguments" tend to become better or modified throughout the process because "everything is alive and dynamic". We can say, based on field experiences that if the project involves different audiences, then we should make arguments according to the demands, needs, and interests of each. For example, we can use different arguments in daily field experiences depending to whom we speak to because the change from analog to digital TV signal may be good for very different reasons to young people, adults, and elderly people.

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Toro and Werneck (1996, p. 45) [1] state that the first three steps needed for planning and preparing a social awareness process are: (1) "structure the *re-editor* networks", (2) "convert the abstract product into material and messages that can be used in the *re-editor's* line of work", and (3) "structure the collectivization systems". Four basic dimensions make up the mobilization process: the imagination, line of work, collectivization, and follow-up. These "should be built and operated simultaneously" so that the process may run in its complexity and reach the expected goals and audiences. The imagination links to the goal desired and the paths taken to reach it. "It [imagination] should express the meaning and purpose of the mobilization. It should touch people's emotions. It should not only be rational, but also able to produce passion", Toro emphasizes (1996). The field of work is the location where the actors involved can develop their daily tasks and where they can execute a mobilization project.

According to Toro and Werneck (1996) [1], the mobilization process should also depend on planning and defining not only the roles of the social actors involved, but also a results control plan for evaluating the impacts of its actions and that of the community; in other words, to provide a follow-up. For this to happen, they propose the creation of criteria and indicators that will help social producers and editors understand the results achieved, or decide if it will be necessary to make adjustments to the process, or maybe even come up with new strategies. They defend to build these criteria and indicators collaboratively, "discussed and defined in a democratic manner" (TORO; WERNECK, 1996, p.31) [1]. This must be done among the actors involved, producing social exposure of the project through sharing and distributing its results in order to "maintain the enthusiasm of those involved, stimulate growth in the number of participants, and possibly present arguments for possible funders of the project" (TORO; WERNECK, 1996, p.31) [1].

III. COMMUNICATION AND MOBILIZATION AT THE SERVICE OF A COMMON GOOD

A participative mobilization should have, in its essence, a differentiated form and humanized language that brings it closer to the population. In doing this, it generates a feeling of ownership of the process in the actors involved. It also produces spontaneous participation and natural commitment, without seeming artificial or imposed. "Many times, the vehicles and types of materials used in collectivization are the same as those of an advertising or marketing campaign; however, its content is different because it is directed towards a different type of commitment", Toro and Werneck defend (1996, p.30) [1]. Even if they do recognize social awareness as "an act of communication" and communication as an important instrument for collectivization, the authors stress the use of communication is not the only instrument available.

> Since we mentioned shared interpretations and meanings, we recognize that social awareness is an act of communication. It should not be a mistake for advertising and marketing, but it does require certain acts of communication in the broad sense. Thus, it can be understandable through sharing process of discourse, visuals, and information. What gives stability to a social awareness process is knowing that what I do and decide within my field of daily work is being done and decided by others in their own lines of work with the same purpose and meaning. (TORO; WERNECK, 1996, p.5)

The authors call "collectivization" or "collective action" that which comes from a common desire and interest in order to reach a goal. "Strength in numbers" is the translation for the feeling defined by Toro and Werneck (1996) [1], which by producing social empowerment, should be valued and fed through a mobilization process. The sharing and promoting of actions is one way to mobilize people, they defend.

> What sets collectivization apart from simple spreading of information is its commitment to results. The spread of information is many times for promotional or simply informational purposes. The expected result is that people know or are made aware of the information. Mobilization focus on sharing information (not simply spreading it). The desired result is that people form individual opinions and take action based on these opinions. Furthermore, it is so that the audience feels ownership of the information and passes it forward, uses it, and thus becomes itself a source. It is necessary that all who participate and engage in communicative behavior be interested and willing to receive and give information in order for a mobilization project to be successful. (TORO; WERNECK, 1996, p. 30)

One of the strategies mentioned by the authors to collectivize leadership action is to hand out kits with informative material and identification to the summoned actors (*re-editors*) for their use. They cite the example of a specific campaign run in collaboration with the leaders of *Pastoral da Criança (Pastoral Care of the Child),* who received planners and T-shirts with the *Pastoral* symbol. "When they put on the shirt, they feel and are seen by the community as members of a larger group that transcends community and legitimizes their actions and rewards them with social recognition. […] They feel connected and develop a sense of belonging". (TORO; WERNECK, 1996, p. 30) [1]

Seja Digital leaders and partners gave the health and endemic agents in Rio Verde campaign T-shirts in favor of the switch off. The artwork design made to accompany health campaigns going on at the time were: November Blue (men's health) and Combat Dengue, respectively. We did this in order to give meaning to their participation in the project. They embraced our

cause and we embraced theirs. In addition to this, they received a questionnaire to fill out. The questions included the access to digital signal with information on families that they met and talked with. The other volunteers also received T-shirts to officially recognize their participation in the project. At the end of the project, participating leaders in the campaign received a certificate for the hours they had dedicated to it.

IV. THE SWITCH OFF IN RIO VERDE (GOIÁS, BRAZIL)

Image 3 - Mosaic with photographs of the mobilization action in "Rio Verde" – Goiás, Brazil (2015 and 2016). Source: Brasil Rumo à TV Digital [7].

Already considering that the change of TV signal is more than a technological step, we must also see it as more advantageous for the population in terms of image and sound, services, and available possibilities. Therefore, the social awareness project applied in Rio Verde (Goiás, Brazil) contemplated these four pillars: awareness education, humanization of the process, multiplication of the message, and social and digital inclusion. For this, it underwent three strategic phases:

1 – Mapping out local entities;

2 – Bringing these entities into contact with opinion influencers;

3 – Communicational and artistic interventions in favor of the analog switch off (decentralized conversation circles, small forums, participation in open fairs, community events, cultural events, neighborhood cleanups).

In the third strategic phase, we used different types of dialogue adapted to our key audience. Some messages reinforced during discussions were about the mobilization project such as the importance of television in the city's politics, education, and culture; and how television is the only source of entertainment and access to information for many families. We also stressed how fundamental it was for the conclusion of the switch off process for people to participate due to how it depended on their migration to digital signal. It was customary to elaborate collaborative plans in community forums to mobilize the population and take advantage of city events, linked to our partners, to spread our message.

The mobilization project in Rio Verde reached approximately 70,000 people from almost every neighborhood in different city zones. The people were reached through not only the direct actions of Mobilization, but also by parallel actions taken by multipliers and *re-editors* such as religious, community, and political leaders, as well as university students and health professionals. We are especially grateful for the collaboration of the *Assembleia de Deus* church, which is the largest and has the highest number of members in Rio Verde. Churches shared and transmitted the switch off schedule shared bulletins and at meetings and services, which were also transmitted on the Internet. Through this medium alone, we reached approximately 20,000 churchgoers, from almost every single neighborhood in Rio Verde. For all this to happen, we had the help of 200-trained pastors. We also received support from local NGOs, the Community Development Council that unites all neighborhood associations, approximately 140 Public Communications and Medical students from the University Rio Verde (UniRV) and Objetivo University, 118 health and endemic agents, and 30 art educators from the Municipal Secretary of Youth (*capoeira*, hip hop, percussion and graffiti instructors).

Health and Endemic Agents

We ran a two-week campaign in October in collaboration with the Endemic Health Agents and their coordinators. They introduced the switch off theme in their daily home visits. They talked about digital TV, answered the population's questions, distributed informative material, and scheduled times to pick up converter kits distributed by Seja Digital for families enrolled in federal government social programs. For this, we received the help of 118 professionals. This campaign alone reached

[7] Brazil in Direction of Digital TV. Available at: <http://brasilrumoatvdigital.blogspot.com/>. Accessed on: Jun, 20th, 2017.

http://www.set.org.br/ijbe/ doi: 10.18580/setijbe.2017.12 Web Link: http://dx.doi.org/10.18580/setijbe.2017.12

approximately 16,100 families. Note that a great number of participants agreed to continue collaborating with the project up to the analog signal switch off.

The campaign had an important role in the process, especially when taking into consideration the strategies defended by Toro and Werneck (1996) [1], who understand that although mobilization should not limit itself nor be understood as a temporary campaign, it as a way to consolidate actions and bring exposure to the project. All actions are valid and many require very little if any financial resource. As the number of partners grew, doors opened, especially because people now understood the purpose of our work and grew to value it, contemplating its social value. At the end of the process, we even promoted events that resulted in rewards for the partnering entities.

The health and endemic agents that participated in the campaign reported that they sensed a lack of solutions for the more needy population that would not receive free converter kits. According to them, these families continued to complain about the high cost of the essential equipment needed to digitalize TVs and lack of public policies that assist those who are not eligible for *Bolsa Família (Family Purse)*. (Note: Many families did not have enough credit to buy converters). Seja Digital was authorized to distribute converters to families enlisted in the *Cadastro Único*, a list of families that benefit from federal government social programs. This solution was extremely helpful. The mobilization will have greater effect and return when, in addition to supporting families during the migration process and making them aware of the distribution of converter kits, we also provide practical migration solutions for those facing difficulties and who do not fall under the necessary categories of social programs. Perhaps we can make a partnership with banks to finance the costs purchasing equipment.[8]

According to reports given by participants, our actions, especially that of collaborating with health agents, served to give direction to many families about where to purchase converters, the price of gadgets, and what to do in order to migrate to digital signal. They told us that they met with many families who knew about the switch off, but did not know how to prepare themselves for it. This is why meeting face-to-face is so important. According to the health professionals and the experiences that we had with other volunteers and field partners, the questions that most families asked were “I have a satellite dish. Will I not be able to watch TV after the land analog signal switch off?”, “How do I tune into digital channels?” and “What’s the ideal antenna for where I live?”

Also based on the experience in Rio Verde, we noticed the need to establish partnerships in the other clusters through agreements, be it with universities and other institutions. This allows for the role of each and project goals to be well established. We also came to realize that in order for the health professionals to do their part and for the mobilization team to have access to public devices, the correct manner is to establish an agreement with the city executives, taking into consideration the project’s nature of public use.

In addition to T-shirts, Seja Digital also gave a converter kit to each health and endemic agent and called them “enabling kits”. Through these, they had the opportunity to learn how to practically use and install the equipment in order to teach the population better. The outskirts of the Federal District copied this action. One thing that caught our attention is that due to the communal health agents, the Strategic Family Health stations (ESF’s) also became, in a spontaneous manner, locations in neighborhoods where people could get information about digital TV.

It is important to note that we received fundamental help from local communication vehicles (radio and TV) that helped spread the news on the analog signal switch off. The reporters’ performance in local media was essential to spread the word about Seja Digital’s mobilization actions and, at the same time, legitimize our work with partners in this territory. We would like to highlight TV Anhanguera, associated to Rede Globo Goiás that followed up on us on an almost daily basis.

Some observations from field experiences

• It’s important that the scheduling posts be amplified and as close as possible to the population;
• It is clear that the volunteers’ work is not only fundamental and essential, but also that its success does not always depend on them alone. Specific mobilization processes such as this need to be able to rely on different partners and strategies;
• The performance of health and endemic agents and Center of Public Assistance Reference (CRAS) professionals offers great potential to execute Seja Digital’s Mobilization project in large scale all across Brazil. In order for this to happen, it is important that this front be explored in the following clusters because they know the families well and have earned their trust;
• The results of the scheduling action at health stations show us that these locations (in collaboration with the health and endemic agents in the community) can be important locations for spreading our campaign message and a great alternative to gain proximity with families receiving the kits (and even those who don’t) at different places in the city;
• Religious centers are fundamental allies in the process of spreading information about the switch off;
• The most convincing argument we’ve used to convince young people of our campaign has been that the switch off will favor the quality of service in 4G broadband and access possibilities offered through digital technology;
• Using cars with speakers installed in them is still a strategic medium to use in the mobilization campaigns due to the

[8] A first step could be financing converters, with automatic payroll deduction, for public employees whose salaries are equal to three minimum wages.

immediate impact they have. In Rio Verde, we used them to inform people about the locations where they could schedule to obtain their set-top box;

• Community leaders add a lot of value to our work and give credibility to what we do in the citizens` eyes. Fifteen neighborhood leaders in Rio Verde opened their homes for us to do the scheduling campaigns. They performed home visits to answer questions, spread the word about converter kits to families registered in the *Cadastro Único (Single Register)* program, and some even installed antennae in the homes of low-income families and elderly persons. We also received reports of leaders who drove senior citizens to stations to pick up their kits. These partnerships have contributed significantly to mobilizing the population and spreading information about the *Cadastro Único* program and the NIS number, two resources that many times are unknown to the population;

• The support we received from the public education system management and actions held at educational institutions were significant for spreading information and awareness of the switch off project and news about the technological characteristics of digital TV;

• Volunteers are a driving force for Seja Digital Mobilization because they stimulated new actors to enter the migration campaign process. They were an important source of switch off information and support for the population and added credibility to our local work. After some time, volunteers were able to work independently and only reached out to us if they had any questions themselves;

The philanthropic entities have a huge influence over the low-income population and those with less access to information, such as the elderly, those with any form of impairment, young people in high-risk situations, and children from low-income families. For example, they helped us locate and contact families who were eligible to receive the kit but had not known about it until then.

I would also like to mention that when we take a look at the scope of work proposed for the Seja Digital Mobilization Project in Rio Verde, it is clear that all suggested projects were executed and that the courses of action taken were the best. The best part of it all is that the "real" experience in Rio Verde showed us various dynamic ways to switch off the analog TV signal in the task still to be completed and accomplished throughout Brazil.

V. NEXT STEPS: FEDERAL DISTRICT AND SURROUNDING CITIES

Image 4 - TV Digital Tower in Brasília, better known as "Flor do Cerrado" (the Savannah Desert Flower).

In light of the success obtained by the social awareness switch off Project in Rio Verde, Seja Digital has amplified its project in Brasilia. A team was hired to capitalize on the potential of the message outreach and establish goals. A specific work plan has been designed, new projects created and adapted, agreements have been established with many partners, including 9 counties surrounding and in Brasilia; all this to enable the project currently underway. We later amplified and structured the project developed for Brasilia and based it on the experience in Rio Verde. We also collaborated with a team that created its execution strategies that were aligned with the basic principles defined by the local mobilization team:

1. Promote collaborative performance between mobilization team and partners.
2. Form multiplier groups able to spread the message and support the more vulnerable population during the digitalization process through qualitative, collective, and sustainable actions.
3. Create projects that we can reproduce in other clusters and use resources and attractive strategies of high, social interest that promote the execution and reaching of established goals.
4. Optimize human, natural, material, and financial resources.
5. Integrate the performance of all work groups at Seja Digital.
6. Value and include less privileged persons.

In addition to this, we thought of a few performance strategies:

1. Promote informative, entertaining, and motivational projects, training, and projects that

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have social interest to capture the public's attention.

2. Identify and contact public and private institutions (including NPO's) that develop activities targeted towards low-income families.
3. Optimize on existing events and meetings like associations, councils, and church meetings.
4. Explore environments to hand out media and pamphlets, such as banks, urban ecological parks, health stations, hospitals, local businesses, CRA's, farmer's markets, and neighborhood restaurants[9].
5. Infiltrate certain territories by means of community leaders, confirming their legitimacy and trustworthiness, in addition to promptness to adhere to the process of spreading information.

Description of the main projects applied to the Federal District and its surroundings:

1. Door-To-Door: campaign led by health professionals and volunteers to provide orientation to families about the migration to digital TV and the switch off process during home visits. In the Brasilia cluster, the campaign relied on the help of 830 health and endemic professionals from 7 counties. It also received the collaboration of 2,296 volunteers from Brasilia to inform families about the migration to digital TV and the analog signal switch off. Health professionals used the daily home visits to provide the population with support during the migration to digital signal, informing them about how they could receive free kits from Seja Digital and instructions for installing the equipment. The total number of homes that were directly impacted by this movement is 97,9660.

Image 5 – A patient finds out during a health agent's home visit that her name is on Seja Digital's list to receive a free converter kit.

2. Community Dialogues: an initiative designed to involve community leaders with the campaign supporting analog signal switch off. Two NGOs – R.U.A.S. and Planning the Future – were important partners that supported us in each of the cities and neighborhoods we tended to in Brasilia. These mobilized NGO leaders were responsible for spreading information at local gatherings such as homeowner association meetings, religious events (mass and church services), senior citizen meetings, CRAs, and health centers. They helped us engage with communities and contributed to events promoted by Seja Digital. The NGOs organized the mobilization, selection, and training phases as well as defined and followed up with each leader's impact group. Each leader was expected to promote and participate in at least 3 (three) weekly meetings and 1 (one) monthly, community collaboration. Seja Digital's Mobilization team also received support from neighborhood presidents, leaders of diverse religions and spiritual centers, educators, and representatives from associations focused on community assistance.

Image 6 – Community Panel by the leaders of RUAS in the "Estrutural" (Brasília) neighborhood during a Parent-Teacher meeting.

3. Seja Digital Volunteer Campaigns: events held to spread information with the help of volunteers. Marquinhos Soares, of Seja Digital's mobilization team, mobilized the volunteers from Brasilia. They got together and formed a body of people to spread awareness to populations in areas with average flow of information (businesses, fairs, bus stations, cultural and sports events, subway stations, neighborhood parks and restaurants) or going door-to-door.

[9] The government established a restaurant project in Brasilia to offer meals at affordable prices to low-income families.

Image 8 – Volunteers from "Vale do Amanhecer" neighborhood in Planaltina (Brasília) during a Door-to-Door community campaign.

Image 7 – We rely on the participation of many senior citizen volunteers, especially women. In the image, volunteers from "Planaltina" (Brasília) during a neighborhood campaign.

4. Community Counseling Centers: strategic locations in more vulnerable neighborhoods with an average flow of people that guided the population and informed them about obtaining free kits. The senior citizens involved in the *Melhor Idade (Golden Age)* Digital program led this movement. Seja Digital established 12 Community Counseling Centers in neighborhoods with lesser digitalization. These centers received elderly citizens selected by the *Melhor Idade* Digital program devised by Seja Digital to involve senior citizens in the switch off mobilization campaigns. Our general-director, Antônio Carlos Martelletto, was inspired by initiatives promoted by the Canadian government aimed at stimulating volunteer work among senior citizens. It is a way of respecting them, allowing them to exercise their rights as citizens, and giving value to their participation, making them feel important and needed by the project. The intention is to also transform the migration project to digital TV into an opportunity of inclusion and digitalization because each participating volunteer received a free converter kit and so became digitalized! The United Kingdom developed a similar project.

Image 9 – Volunteers in action at PDA located at PIMEV [10], a "Vale do Amanhecer" entity (Planaltina – Brasília).

5. Digital TV Caravans: a community communication tool dedicated to providing interaction with the population. Events held in neighborhoods and schools:

5.1 Caravans at School: activities directed towards public school students and employees with the intent of making them aware of the complete migration to digital TV. This was the solution that Seja Digital found for this particular audience to spread the news to family members and friends and inform them about how families who benefitted from federal government social programs could obtain free converter kits. The activities offered by 120 caravans influenced in all, 40,000 students in all. The events lasted up to 2 hours and were held mornings and afternoons for elementary schoolchildren. They learned about tuning the digital TV signal in the *"Sintonize-se" "(Tune in)"* workshop and how to prepare for the analog signal switch off through fun cultural presentations.

Image 10 – "Digitalzinho", Seja Digital's mascot, made special appearances at the caravans.

5.2 Neighborhood Caravans: this involved a custom-made bus equipped with handicap access and TV sets that showed the difference between transmission by analog and digital signal. The *"Sintonize-se"* workshop informed visitors about how to install the converter kit and tune the channels, inside the bus. The event included skits, dance presentations, workshops on art and urban gardening, hair cutting services, blood pressure measuring, graffiti presentations, character drawings, and face

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painting. These caravans circulated mainly through open markets on weekends. It was a great opportunity for the community to verify if it could have access to the free converter kits. If so, people could schedule right then and there to receive the necessary equipment. Some caravans even offered transportation services to locations where the population could withdraw kits and go home practically digitalized. One of the audience's favorite characters was the Digital mascot, who helped get observers excited and interact with the percussion group, Batuque Cerrano. In addition, the caravan also made collectors available where people could consciously dispose of electronic waste or unused or broken TV sets. The NGO, *Programando o Futuro (Planning the Future)* supported this caravan.

Image 11 – The percussion band "Batuque" no Digital paraded with the caravans in the neighborhoods.

Image 12 – Results from the caravans: 17,000 people serviced and over 50,000 reached.

6. Academic Mobilization: an interdisciplinary project that engaged university students and the academic community in the analog TV switch off. This project, executed in partnership with the Catholic University of Brasilia (UCB), rallied the academic community to the analog TV switch off movement and influenced about 7,500 people. In order to get them involved in the switch off process in the Federal District, Seja Digital held a convention in partnership with UCB. The project was named "Migration to Digital TV" (MTVD) and relied on the participation of professors and students from the schools of IT, Social Communications, Languages, Education, Medicine, Dentistry, Healthcare, Social Services, and from the postgraduate "*strictu sensu*" Masters in Communication program. Alexandre Kieling (from the Department of Social Communications and Journalism) directed the project and brought together 681 students (22 scholarship receivers and 659 volunteers) that directly and indirectly assisted in routine academic activities and contact with the regions in which they lived.

Image 13 – A dentistry student talks to a patient about the analog signal switch off.

7. My Old New TV Campaign[11]: a campaign directed towards reducing socio-environmental risks resulting from the inappropriate disposal of old TV sets, which may increase with the switch off processes. In addition to informing the population of the risks of throwing out old devices inappropriately, the campaign encouraged the donation of old equipment and collected them at 50 different drop-off points throughout the cities of the Brasilia cluster. Another NGO, Programando o Futuro reconditioned the old equipment and later donated to families who received the converter kit, but did not have TVs at home. The cathode-ray tube in television sets, made up of heavy metals such as lead and mercury, can be extremely toxic. They cause high levels of land and river contamination if they are disposed of and dissembled incorrectly. For this reason, if they cannot be re-used, they need to be destroyed by companies specialized in the matter and that use the necessary techniques to decontaminate the TV screen. Once crushed, it is used to manufacture flooring, ceramics, tiles, and paint used for road markings. We collected 1,894 TV sets total and reconditioned 26 of them. All this generated a volume of 39,123 tons of residue. Seja Digital's project of disposing electronic waste currently counts on partners throughout the entire country. One can find the closest drop-off point by typing in his or her zipcode on the sejadigital.com.br/recicle webpage.

[11] Within the seven basic lessons for an education on social interaction, by Toro e Werneck (1996, p.61), are "Learning to interact socially means, foremost, to learn to be in the world". According to them, social interaction means taking care of the environment and accepting that we are all part of it.

Image 14 –TV Digital's Neighborhood Caravan is also a movement to collect electronic waste.

8. **Outstanding Social Mobilizer Award:** motivational strategy/incentive for volunteer teams to encourage the qualified and continuous participation of different teams in the mobilization project such as NGO volunteers, health professionals, health and endemic agents, community leaders, university students, and *Antenista Amigo* (*Antenna Technician Friend)*. This participant relation is away to recognize all those who stand out in their participation in our project.
9. ***Antenista Amigo*[12]:** professional training for people in the community to meet the growing demands of antennae and digital TV converter installation services. The project aims to create employment and income opportunities, making it possible for lower-income families to hire the services of an installation technician. It also seeks to support families and neighbors by installing the converter kit free for a limited number of those who receive support from federal government social programs and raise awareness on how to avoid home accidents caused by people installing the antenna on their own. Proeletronic, a Seja Digital partner, trained ten students from the Ceilândia campus of the Federal Institute of Brasilia (IFB), most from the School of Electronics. They went on to offer workshops for 351 people in the community. These were free of charge and each participant earned a tool kit at the end of the course to work with installing antennae and converters. In return, each technician received the mission of digitalizing 10 low-income homes. Thus, we estimate that 3,510 families benefitted directly from this project.

Image 15 – A technician from Proeletronic, a partnering company, teaches the students.

Image 16 – Women were important participants in the project.

10. **Training:** conceptual and technical training for all digital TV volunteers and project partners. We created a Social Mobilizer Handbook[13] and a Pocket Guide[14] that contains information on how to better support communities. In all, we offer 160 qualifications.

Image 17 – Training for health agents from Cristalina (Goiás).

Social Development Secretariat Campaigns: Seja Digital's Mobilization team executed an important part of the job in partnership with the Social Assistance Reference Center (Cras), *Bolsa Família*, and neighborhood restaurants. The information given to the families reached by these outlets was about how to schedule to receive the free converter kit from Seja Digital. For example, in the Brasilia cluster, 123 Cras

[12] "Antenista Amigo" refers to the antennae installation technician.
[13] Available at: <http://www.sejadigital.com.br/pdf/sejavoluntario/guia-do-mobilizador-02.pdf>. Accessed on: Jan, 10th, 2017

[14] Available at: <http://www.sejadigital.com.br/pdf/sejavoluntario/perguntasfrequentesguiadebolso.pdf>. Accessed on: Jan, 10th,. 2017

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employees, joined our cause and thanks to them, we reached almost 90,000 families.

11. **Escuta Jovem Digital:** a get-together organized to understand young people's perspectives and their different languages from cities involved in the switch off process to better deal with the information received during our group communications campaigns. In addition to respecting and recognizing each community's language style, the initiative legitimizes its participation in our project and plans to generate a sense of ownership by basing itself on the premises of participative, engaging, and two-way communication and mobilization.

Image 18 – We talked to young people and adults in Brasilia about the TV Reflexo Digital project.[15]

12. **Digital Student Contest:** a fun and educational strategy for motivating the public school community, and especially elementary students, teachers, and employees to get involved with the switch off process and spread the news about the distribution of free converter kits. It is a way to value the cooperation of these individuals and, at the same time, a request made by Seja Digital to know more and explore the theme better. It is also a call for these participants to lend support to those who need it the most, providing them with the knowledge of the changes that are happening in the scenario of TV technology in a didactic, clear, humanized, and loving manner. In the Brasilia cluster, children explored the theme, "Go Digital" and "Leave No Man Behind! Brazilian TV Will Be Completely Digital". The purpose was to emphasize the analog TV switch off date in the Federal District and explain the advantages of digital TV. The competition awarded the following categories: drawing, video, jingles, and essay writing. The winner of each category won a 42-inch screen TV.

Image 19 – Winners of the Digital Student Award.

FINAL NOTES

> Daily life is that which is given to us each day (or that is ours to share); it pressures us day after day, overwhelms us, because there is a present oppression. […] Daily life is that which intimately binds us, from the inside out. […] It is the developing story about us, almost in withdrawal, sometimes hidden. What interests the daily historian is the invisible (DE CERTEAU, 1996, p. 31) [4]

Image 20 – Campaign volunteers at Trecho III – Sol Nascente/ Ceilândia, in Brasília: All together so that no one gets left behind.

Jesús Martín-Barbero and Germán Rey, in their book Os Exercícios do Ver: hegemonia audiovisual e ficção (The Exercises of See: audiovisual hegemony and fiction), defend that the potential that exists with TV goes beyond what we explored in the past few years, within the cycle of transmission and receipt. "[…] some fictional authors […] start to understand that television is not a mere instrument of diffusion, but a medium of its own expressive properties; a medium searching for its own language (MARTÍN-BARBERO; REY, 2004, p. 155) [3]. This search seems to be only beginning. Arlindo Machado (2000) [5], in the book Television Taken Seriously, offers us a strategy for looking at this medium differently,

[15] The TV Reflexo Digital project began at a public school in Recanto das Emas as a means to discuss the relationship between Education and Communication. The project's main purpose is be a virtual environment where young people, students, and former students from the Ensino Médio (High School) 111 Center ("Recanto das Emas"), can produce, spread, and share information.

similar to what was done with cinema and literature, so that it too can be analyzed from a positive point of view: "It's all a matter of changing one's focus. Instead of paying attention to the lesser forms of television, the idea is to change focus to the highlighted differential, which expands the expressive possibilities of this medium" (MACHADO, 2000, p. 10) [5]. Machado understands that only after we remove the social prejudice against television, especially in part of intellectuals, technologists, and sociologists, will it be possible to discover potentials that go beyond those that offered by it so far. All our mobilization campaigns have this concept at their core and leave the population with this question: What can we do to have the TV we desire? The communities reflected upon this question with us and they understand that we already have the technological means to meet the request.

Martín-Barbero and Rey (2004) [3] put communication as an instrument to obtain exposure by society. It is able to promote debates, raise questions, search for different interpretations about facts, and multiply the different means of social debate and the quality thereof. They recognize, however, that this is not a rule because interests also direct communication. "[…] communication has distortions, restricted fields of expression, themes that are still intentionally left in the shadows." (MARTÍN-BARBERO; REY, 2004, p. 86) [3]. When they wrote the book, 11 years ago, they realized the need of a plural environment for collective expression that would be able to fill in civil society's communicative blanks, one that is difficult to find in mass media, according to the following statement. "The consolidation of an 'us' in civil society in the face of authoritarian manifestations, the formation of a common space for revelation where civil society expresses itself without plurality, are challenges that currently collide with the media in search of exposure." (MARTÍN-BARBERO; REY, 2004, p. 87).

Seja Digital's Social Awareness project is a place for this. An environment that is sensitive to the population's communitarian awareness and its ownership of the digital TV migration process. It's a tool made by the community for the community. We opened a channel of a discussion so that this involvement occurs in the most effective way possible to generate commitment, love, participation, and a sense of collectivity. I can guarantee that all this adds value to the process; it adds humanization, stimulating popular imagination, because it is true that television is still dearly beloved by Brazilians. My observation is that social agenda has a lot of power. It allows the population to own the process and sees it not as a simple technological change, but a project of public use that can only be accomplished through a chain of solidarity and by collective effort.

This project makes it so that, by using different public communication tools and languages, we establish a connection between city and citizens. We are doing an "urban exchange program" (in the words of Martín-Barbero and Rey [3]) between TV digitalization processes and its members, updating them about the latest local events that will affect their daily lives. The experiences of this mobilization carry beautiful stories of daily life and relationships that families have with television. In almost two years since we began the race towards the analog signal switch off, we have experienced touching stories and already have so much to tell about the following chapters of this historic process now happening in Brazil.

Rio Verde, the Federal District and surrounding counties were enormous learning grounds, with favorable conditions for building beautiful partnerships and friendships. In all, it is a place with welcoming people. They are willing to help each other. Our partners and volunteers dedicated hours, even weeks, to our project in order to guarantee that a portion of the population would have the opportunity, if not the right, to open television signal, a public asset that is free and for all Brazilians.

The analog signal switch off in Rio Verde reached exceptional conditions and 93% of the goal established by Anatel and MCTIC. After suffering two postponements, the switch off was authorized and 87% of homes are now digitalized. We noticed that a part of the population showed a certain level of wariness, strongly resisting the conversion. Furthermore, the distribution of free converter kits had been initially limited only to families that were registered in the federal government social project, Bolsa Familia. The change to include those registered in the Cadastro Único program, a mere two months away from switch off, made a big difference. One month after switch off, a survey commissioned by Seja Digital performed by Ibope pointed out that only 2% of Rio Verde's population were yet without access to television.

Between January and November 2016, Seja Digital proposed the aforementioned projects in order to provide support during the migration phase of analog to digital signal for the population living in the Federal District and 9 surrounding cities in Goiás (Valparaíso de Goiás, Novo Gama, Cidade Ocidental, Luziânia, Cristalina, Formosa, Planaltina de Goiás, Santo Antônio do Descoberto, and Águas Lindas). Almost 5,000 volunteers, among which were 2,296 community leaders, 120 schools, and 4 partnering institutions (Programando o Futuro, R.U.A.S., UCB, and IFB), collaborated with 11 projects that aimed to inform, mobilize, and prepare all layers of these cities for the analog signal switch off. Through this, we reached 650,000 people directly and contributed to the Brasilia cluster switch off process. The Federal District and surrounding cities switched off 22 days in advance, and reached 92% of digitalized population. (Ibope, 2016). Two month after switch off, a survey requested by Seja Digital showed that 99.44% of the population had access to television signal. In other words, only 0.66% could not watch TV.

This success is the result of work done by many hands: partners, volunteers, and Seja Digital teams (Logistics, Engineering, Management, Legal, Purchasing, Customer Service, Events, and Communications) that diligently and daily applied themselves to guarantee that the more needy population would be included in the digital signal migration process. These people gathered hundreds of families to the heart of our project, lifted them up, and truly did not leave them behind. Thus, the digitalization process is now complete in Rio Verde, Brasília, São Paulo, Goiânia and its metropolitan regions. Our journey

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has only just begun and we still have many roads to travel on before the entirety of Brazil is finally digitalized.

"We have noticed that when we make people aware of how important television still is for many families; when I argue and accept that we will never achieve our goals on our own and that we need everyone's help; when I realize that volunteer roles are essential to guarantee that these families have access to TV signal; the actors feel valued and important to the process and begin to collaborate more freely and passionately".

REFERENCES

[1] J. B. Toro and N. M. D. Werneck, (1996) Social awareness: One Way of Building Democracy and Participation. Available on-line at http://www.compreender.com.br/gestao/files/biblioteca/5b1eeb01411d764ed1046eea1b92be10.pdf

[2] Z. Bauman, Trust and Fear in the City. Translated by Eliana Aguiar. Rio de Janeiro: Jorge Zahar Ed. 2009

[3] J. MARTÍN-BARBERO and G. Rey, The exercises of seeing: audiovisual hegemony and television fiction. Translation by Jacob Gorender. 2.ed. São Paulo: Edit. Senac, 2004

[4] M. de Certeau, The Invention of Daily Life: The Art of Doing. 21. ed. Petrópolis, RJ: Vozes, 2014

[5] A. Machado, Television Taken Seriously. 4. ed. São Paulo: Edit. Senac, 244 p., 2000

[6] D. F. Feitosa (2014) Television in the Age of the Digital Convergence of Media. A reflection on public communication. 2015. Thesis (Doctor in Communication Theory and Research) – School of Communications and Art, University of São Paulo, São Paulo, 2015. Available at: <http://www.teses.usp.br/teses/disponiveis/27/27152/tde-24112015-101553/>. Acessed on: May, 27th, 2016.

[7] BBC. 101 Stories: The switchover help scheme/BBC. 2012. Available at: <http://downloads.bbc.co.uk/aboutthebbc/insidethebbc/howwework/partnerships/helpscheme/SHS_101_stories.pdf>. Accessed on: Nov, 20th, 2016.

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Crowdfunded Journalism: Innovation in Communication?

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Abstract. This work treats the innovation in journalism with the crowdfunding analysis as a premise. The justification for this research is a recent practice under construction and the lack of theory analysis of theories that could reach beyond the studies in communication. The innovation considered in this article is a practice built by various elements. Thus, we perform a multidisciplinary evaluation by using the contributions from communication, administration, machine technology philosophy and computing machine. To perform this, we make a bibliographic review and apply it to an exploratory research. Among the results achieved, we found out that the crowdfunding is an innovation under the different theoretical currents' points of view.

***Index Terms*— Journalism, Crowdfunding, Innovation**

I. Introduction

In the early 21st century, when Castells (2000) [1] and other scholars dealt with network society, the consequences of the Internet advancement over the communication media and other matters related to the recent changes in human interactions, it is questioned what the future of journalism within this context will be. As it is an ongoing process, there are far more questions than answers. Many questionings concern the ubiquity, convergence and changes in hearing caused by new media (SERRA *et al*, 2015) [2]. Other authors discusses with more depth on the ways to produce, distribute and consume information from the integration of new scenarios and the media productions hybridity, as in the example of Canavilhas and Satuf (2015) [3].

The discussion regarding how to produce journalistic content in this new scenario of connected media with integration between media and users enjoying greater freedom of choice still presents various aspects that need further insight. One aspect revolves around the crowdfunded journalism. Even in countries like the United States where this practice is already more widespread, the ideas exchanges are still incipient, notably because they involve basic aspects of journalism, such as the costing of activity, the journalist ethics and the relationship of target groups with the communication media (KANEYA, 2015; ADLER, 2015) [4].

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For many crowdfunding enthusiasts, this would be an innovation due to the need of changes in journalism in face of the current reality (ADLER, 2015) [5]. In turn, innovating is still not part of many academic studies in the communication field, although there is considerable debate about the changes in vogue. Around a decade ago, Alves (2006) [6] regretted on the lack of innovative initiatives in the media and urged the digital journalism into changing its ways of operation. In this context, the aim of this article is to discuss innovation in journalism from the crowdfunding's point of view and the basic characteristics of the practice. To this end, we use a bibliographical research (GERHARDT, SILVEIRA, 2009) [7]. This type of study was classified by Santaella (2001, p. 43). 139) [8] as theoretical, whose "role is to fill gaps in knowledge, uncover and build conceptual reference frameworks".

In order to avoid a misjudge, the purpose of this work, the names and addresses of websites and other sources from the Internet will not be listed, which currently complies with the practice in Brazil and other countries in the world. We believe that the focus of crowdfunding in the analysis as a possible innovation for journalism turns the concern in mentioning addresses and names unnecessary. We must emphasize that the assessment for the act of innovating should take place based on the research in management, communication and technology fields, because they are guidelines for this article.

II. Theoretical Framework and Discussion

A. *Innovation*

Innovation is a recurrent term in many books, business manuals and news published by the press. Together with the term "entrepreneurship", innovation has become synonymous of what we understand as different from the current situation. However, authors such as Drucker (2003) [9] and Meira (2013) [10] evaluate the subject under a more technical and academic point of view, beyond cunning explanations. Drucker demystifies the common recurrent mentality, also present in the literature, that certain personal abilities and even a stroke of luck are enough for an individual considered as innovative. To the North American culture, the innovation usually requires typically entrepreneurial conduct, such as organization and planning.

Meira defines innovation with seven aspects, which represent the characteristics of innovation. According to Meira, innovation is purpose, conversation, change, social

performance, power, synchronization and ideal awareness. The scope of definition for this term is so broad that the author summarizes innovation from what he calls the '3Is' **(Impermanence, Imperfection and Incompleteness), which are** "basic characteristics of all things" (2013, p. 300) [10], including the organizations. According to Meira's understanding, such aspects would be part of the innovation (p. 301) [10], because whoever does it, is someone "that suffers, by nature, from those three limitations".

Considered as the precursor of innovation studies, Schumpeter (1961) [11] introduced the concept of "creative destruction" to refer to the innovation process. He made an analysis from a historical perspective, which would indicate changes in the organization of production and the opening or closing of new markets. Those evidences, in turn, would be that capitalism changes the economic structure from within; that is, "unceasingly destroying the old and creating new elements" (1961, p. 110) [11]. As this process occurred within capitalism and in the long-term, the economist criticizes the superficial way some scholars use to assess the changes in the system, which would be misleading due to the focus on facts outside of a historical context.

Drucker endorses Schumpeter's statements concerning the premise that "the dynamic imbalance caused by the innovative entrepreneur, instead of balance and optimization, is the 'standard' for a healthy economy and the central reality for economic theory and practice" (2003, p. 35) [9]. Thus, Drucker asserts, the entrepreneurial behavior performs the work of changing the structures in vogue. "The entrepreneur is always looking for the change, reacts to it, and explores it as an opportunity" (2003, p. 36) [9].

Drucker also associates entrepreneurship and innovation because these would be "the specific instrument of the entrepreneurial spirit" (2003, p. 39) [9]. Hence, innovation would be the manner in which an entrepreneur carries out the task of interfering in the system. According to Drucker, "systematic innovation therefore consists in the purposeful and organized search for changes, and in the systematic analysis of the opportunities such changes might offer for economic or social innovation" (2003, p. 45) [9]. However, it is worth noting that Drucker does not see the innovation only under the technical and scientific point of view. On the contrary, to him, innovation "is an economic or social term, rather than technical" (2003, p. 43) [9], because changing can be of human level. Drucker brings the example of Japan, which would be an imitator and not innovative due to the fact it did not stand out by technical or scientific innovations in the field.

B. Communication, Innovation and Technology

Drucker's vision regarding social innovation corroborates with the studies on innovation and communication in Brazil. In one of the few works dedicated exclusively to the conceptual and deontological aspects of these two areas, Giacomini Filho and Santos (2008, p. 16) [12] affirm that the "Social Communication seems better suited to consider 'innovation' according to their effects, impacts, appropriation and social benefits". Such proposition endorses not only Drucker's statements (2003) [9], but also Wolton's affirmation (2010) [13] according to whom communication is characterized by the relationship that is established from the exchange of information among agents.

Approximations between innovation and communication, however, can move forward even further. One of those approximations is the fact that communication counts on appropriation mechanisms of technological changes in progress that can be performed not only under the cultural bias (GIACOMINI FILHO; SANTOS, 2008) [12] but also by the philosophy of technology, which correlates technology to the context, a basic aspect of the journalistic work. Vargas (1994) [14] points out that the term "technology" derives from the Greek word "*techné"*, which makes reference to the body of knowledge and professional skills passed on from generation to generation in Ancient Greece. In the same way, *"techné"* comprised the technique of manufacturing machines or devices used daily by people.

Since then, Lima (2007) [15] states that a dichotomy was created around the conceptions of technique and technology, from epistemology to metaphysics. Lima mentions Mario Bunge when saying that it is necessary to differentiate technology from pure science because the former would be, for example, the human ability to manufacture tools, while the latter would seek for knowledge. Dusek (2006) [16] deepens those discussions by bringing three definitions for the term "technology". According to the author, "in order to turn an artifact or piece of instrumental into technology, it must be placed in the context of those who use, maintain and repair it" (2006, p. 50) [16].

This definition threatens the instrumentalist vision of technology and shows how essential the human factor is. Furthermore, Dusek's statement endorses other technology philosophy' scholars such as Vargas, to whom "the technique is originally a know-how which characterizes the presence of a human culture. (...) Man, doing and culture are aspects originating in human nature" (1994, p. 19) [14]. Vargas also argues that imbued with the instrumental technology, man can build a culture, "which is the field of reality populated by family organization or social and economic groups, classes, philosophy, science, the technique and all the products originating from these human activities" (1994, p. 23) [14].

Dusek stresses that a man subordinates completely the technology as a tool. Man designates the destination of this tool, which can lead to good or evil. The author mentions the hammer as an example, which hits a nail and even crushes a skull. However, when there is a technological system, the human being is within it, therefore has no control. "The technological systems that include advertising, propaganda and implementation of government can persuade, seduce or force users to accept them" (2006, p. 54) [16].

Dusek's idea about technological system corroborates with the proposition by Mitchell (2010) [17] for complex system, which does not have a central system of control because each part is interoperable. This idea brought by Mitchell ratifies Dusek's perspective because technology would be a complex

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system, as it would add several distinct elements, under which man can interact but never control completely. At the same time, technology would not represent the whole because it would only be a part of another system. This is also complex, and others elements would also be complex with several variants, as for instance the cultural factor.

Therefore, inserted in this context, technology has become a reflection of a drastic change. Drucker (2003, p. 5) [9] makes an analogy with a biological process to explain these changes: "The processes are not arranged from energy, the physical meaning of the word; they are arranged taking information as an origin". Although it is not the central purpose of this article to tackle with the science of data and information, it is worth making a brief addendum to situate these aspects in the discussion on innovation and communication, since they permeate various terms and ideas from this present work.

Cybernetics was the first line of thought to characterize the information as one of the pillars of contemporary society. Long before hearing about the information society as we know commonly nowadays, cybernetics proposed to develop a specific language and techniques. Those "enable us, in fact, so we can deal with the problem of control and communication in general, and to discover the repertoire of techniques and ideas appropriate to classify the specific manifestations under the rubric of certain concepts" (WIENER, 1954, p. 17) [18]. More than one branch focused on technology, Cybernetics believed that the information "designates the content of what we exchange with the external world to adjust ourselves to it, and that makes our adjustments be perceived in it" (p.18) [18].

Wiener's expression solidifies not only with what means "technology" in the philosophy of technology proposed by Dusek (2006) [16] and Vargas (1994) [14], but also with Drucker's proposition (2003). It reaffirms as well as the vision of communication as an exchange among agents as proposed by Wolton (2010) [13] and the relationship between innovation and communication of Giacomimi and Santos (2008) [12]. This is possible because the information is the raw material that moves people, machines and other systems, such as companies.

Concomitantly and in tune with surveys such as conducted by Wiener, other scholars like Claude Shannon (1948) [19] and Alan Turing (1950) [20], developed studies that were crucial to the development of machines, which mimic human behavior because they perform tasks formerly reserved for the brain (GLEICK, 2013) [21]. Another North American scientist may help us to understand why information is the basis of technology and how it interferes in the way humans deduce reality. When doing a study in the1950's on the functioning of the brain and computer, John Von Neumann concluded that the nervous system has the characteristics that "lead to a low level of arithmetic precision, but at a high level of logic reliability" (1958, p. 53) [22].

Wrapping up the addendum on the origins of the studies on information and endorsing the reasoning of Von Neumann, there is another proposition of Drucker. According to him, the high technology is "what the software used to call *ratio "cognoscendi"*, the reason why we perceive and understand a phenomenon, instead of explaining why it arises and the cause of its existence" (2003, p. 6) [9]. Thus, we could think that man understands the technology by means of logical mental systems, since it performs associations among the facts around him. However, the man has difficulty in understanding and identifying the origins of all variables available in this regard.

Such mentality finds subsides in complex systems mentioned by Mitchell (2010) [17] and it can be found also in the very definitions of what is innovation in the wake of applied social sciences, such as communication. Frascatti's manual, one of the most rudimentary publications about innovation in the world, establishes some relationships among technology (especially information technology), research and development (R&D) and the degree of innovation in studies in applied social sciences:

> The development of software, by its nature, does not allow to discerning and identifying easily the element of P&D where it does not exist. It is a part integral of many projects that are not part, themselves, of any element of R&D. From these improvements, usually, an evolution arises rather than a revolution. We classify as R&D, the transition to a more powerful version, an addition or a modification of a program or an existing system, if they incorporate the scientific progress and/or aids, which lead to an enrichment of knowledge (FRASCATTI MANUAL, 2002, p. 60) [23].

The mention of the overlaps between technology and the humanities in this manual derives from the concern that "social sciences and humanities are taken into account in the Manual, which incorporates the definition of P&D: 'knowledge of man, culture and society'"(p. 62) [23].

Thus, journalism, being a part of social sciences, can generate innovation from the moment that modifies and renews technology (SCHUMPETER, 1961) [11]. When it has a meaning by the context used (DUSEK, 2006 [16]; VARGAS, 1994 [14]; LIMA, 2007 [15]). When it allows the exchange of information among agents (WOLTON, 2010 [13]; GIACOMINI, SANTOS, 2008 [12]), in a society dominated by computational machines (TURING, 1950 [20]; SHANNON, 1948 [19]; VON NEUMANN, 1958 [22]), from the Information (DRUCKER, 2003 [9]; GLEICK, 2013 [21]) in a system without central control (MITCHELL, 2010 [17]). Besides, the interaction among the parties evaluates innovation (WIENER, 1954 [18]).

C. Crowdfunded Journalism

After setting up similarities between innovation and communication, it is important to analyze an example that can be a point of intersection between them. The crowdfunded journalism is a recent practice in Brazil and the world. The concept of that, defined by Felinto is:

> A process in which the public itself contributes to the financing of a project. Through websites on the Internet, producers announce their ideas (for a film, a work of art or product of any kind) and ask for financial aid to web surfers, who then make donations through the intermediation of those

sites (2012, p. 140) [24].

This way of working finds scope in various elements of fandom culture, mentioned by Jenkins *et al* (2006) [25], which is based on the premise that the fan of a determined person, film, subject or another cultural element creates, distributes content and still collaborates, often financially, for a certain cause it deems fair. Jenkins reminds us that human behavior is not a technological invention, but this last influences it, since "these new technologies play a crucial role in enabling the changes described in this book" (JENKINS et al, 2006, p. 25).

This proposition by Jenkins also endorses Tapscott's ideas (1997) [26] regarding to the "Internet generation", a term created by him to refer to people born between 1977 and 1997. According to Tapscott, this group would have among its characteristics strong assimilation with technology, notably with the web, which brought many possibilities. One of them is that "allows people to create their own content, collaborate and build communities. Internet has become a self-organization tool " (1997, p. 29) [26].

Felinto explains that these changes brought about the creation of tools for the web, in which people can create and share content from external resources. That is, anyone who has interest in making a report, for example, and does not have the resources for it, can use Internet tools where it is possible to rally money through strangers' donations:

> For the creators, crowdfunding opens up a whole range of new financing possibilities of their ideas. For the public, it provides a sense of participation never thought before. The fan feels as a co-creator, authentic collaborator of the productive process, able even to help set the destinations of works/products that he or she wonders (2012, p. 141) [24].

One aspect that stands out in this aspect is that the collaborative practice of gathering resources from the Internet for journalistic purposes is quite associated with the mentality of rupture with traditional media patterns. Xavier (2014) [27] and Nonato (2015) [28] emphasize that the crowdfunding mainly performed on blogs represents a freer journalism than the one practiced by the mass communication media, as they do not allow more work autonomy to the trader. The authors justify the existence of an undervaluing of the journalistic professional operation backed up by political and economic interests, that media vehicles traditionally maintain with advertisers and governments as a way to maintain the power hegemony.

In spite of not discarding the crowdfunding in other media, Xavier (2014) [27] and Nonato (2015) [28] emphasize its use on the internet because they believe that the World Wide Web allows greater freedom of operation by not having a centralizing power, which occurs with other vehicles. To Nonato (2015) [28], crowdfunding inn the web can even represent an alternative to the crisis affecting the sector.

Many articles and other works are published on the subject in journalism, however, do not join the discussion around whether the practice is being or not considered innovative. In this article, we believe that this question is very important, since innovation represents a way of breaking with the traditional practices and still exhibiting some evolution in the sector. The book "*Conhecimento e inovação para a competitividade" ("Knowledge and innovation for competitiveness")* is a World Bank publication that is a result of several studies and data collection made all over the planet. Created to help countries develop public policies and other instruments to foster innovation as a way of contributing to economic development, the work conceptualizes innovation as "the progress made on the border of global knowledge, but also as the first time it uses or adapts the technology to new contexts" (RODRIGUEZ *et al*, 2008, p 92) [29].

It is interesting to note the reference to the term adaptation, something applicable to the completion of the crowdfunding due to this, based on Internet platform, which *a priori*, it is a platform not designed with this purpose. As Jenkins (2006) [25] pointed out, it was not the technology that has created the collaborative and participatory approach to material production and distribution, although potentiated it. In addition, it is worth remembering that military intentions during the Cold War period developed the Internet. Therefore, totally at odds, with attributes such as the ones touted today.

The publication of the World Bank also made another relevant contribution when stated that innovation "is not limited in any way to the formal activities of research and development (...). On the contrary, the invention and the creation of knowledge can be produced by constant efforts to improve the production" (2008, p. 94) [29]. Relative to this aspect the report points out that there are different ways to innovate. We classify those ways according to some models.

Carvalho (2009) [30] classifies innovation in four types: Product, Process, Organizational, and Marketing. The first is the product type and would be the introduction of a new or significantly improved product or service. In this modality, we adopt new knowledge or new technologies based on new uses or new combinations of knowledge or existing technologies. The second, process innovation, concerns to the implementation of the new or significantly improved method of production or distribution. Whereas the third confines a new organizational method, a new negotiation practice, a new organization at the place of work or of external relations to organizational innovation. The fourth and last, marketing refers to changes in the product design or packaging, promotion, and pricing for strategic repositioning.

The crowdfunded journalism has a new process for the news production as its most striking feature, since it changes, at least in part, how to distribute the journalistic material and the form of financing the activity. As journalism is a service, the product of the relationship between company and consumer is not a physical commodity but public relevant information. Bearing in mind that crowdfunding changes the payment way of the service, so it is possible to evaluate it as a process innovation.

In this aspect, however, there are many questions. One is of ethical order, which does not comprise the classification of innovation, although deserves reflection. According to Adler (2015) [5], many citizens of the United States put into doubt the validity of crowdfunding when the organization that seeks

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resources for the achievement of a reportage is a profitable private company. He brings the example of the *Huffington Post* journal, which belongs to a group with revenues of 3.4 billion dollars and asked readers for money to perform a special report. According to Adler, the initiative aroused the indignation of non-governmental and other nonprofit organizations that seek in crowdfunding a way of making a freer and more investigative journalism.

Despite the criticism, the project raised a value greater than was originally envisaged. The company carried out the reportage, as announced. However, the amount invested did not overcome the initial projections, which generated more complaints from non-profit entities that rely on crowdfunding to survive. In addition, those organizations are a reminder that private companies profit on sales of advertising space with news sponsored by collective financing. However, the profit on advertising does not shared with the same people who helped to pay for the production of the reportage that brought the announcer to the vehicle of communication (Adler, 2015) [5].

This ambiguous behavior of private communication companies is not preventing the growth of the activity, which seems almost perpetual despite of the divergences between the public and ethical issues. In this matter, Adler (2015) [5] points out another delicate point of the relationship between communication media, journalists and readers. The question is to what extent the indirect crowdfunding financing is ethical, as the wages of many journalists originate from private companies while still getting income with the sale of advertising space and subscriptions.

If on the one hand this relationship jeopardizes the transparency of communications companies, on the other hand it generates a delicate situation with the reader who indirectly becomes the boss of the journalist, as there is a direct relationship of economic dependence. Adler (2015) [5] points out that a good part of non-governmental organizations does not establish a direct relationship between crowdfunding and subscriptions because the reports sponsored by them are generally divulgated without restriction, Being different from the traditional model of subscriptions in which only those who pay have access to the content.

Because it is not all about subscription, then how those who contributed with the crowdfunding could be evaluated? According to Adler, we can call the advocators "supporters" because they are citizens sharing the same ideas with journalists and seeking information that will be accessible only if they cooperate in some way.

Kaneya (2015) [4], however, brings another aspect that highlights a weakness and an opportunity of journalism in the face of the intensive use of technology in the making of reports, with innovations in the production and distribution of content. As many reportages supported by crowdfunding are investigative, including some institutions that get involved in making reportages only with this bias in the United States and in Brazil, a job search and data verification is necessary, requiring a large amount of time and knowledge from the journalist. Not by chance, some third sector entities is formed exclusively by programmers, systems analysts, and other information technology professionals who are dedicated to locating, collecting and treating data.

Called “civic hackers", many of these professionals are helping journalists to a great extent into creating stories that bring quality information to society, using the meta-data extracted from the Internet. Given that this practice is beneficial to society, it exposes the pillars of journalism as the need for a professional press to be the mediator between the company and the news. According to Kaneya Adler (2015) [4], even though the "civic hackers" themselves admit that they need a journalist to assist in various tasks, their possibility of operating as protagonists in the production of news is a sign of change. Such tasks could be the creation of a narrative that takes the matter to the attention of people in a believable and concise manner,

Far from being a threat, this situation can be a path for transformation in journalism. If innovation is a creative destruction, as Schumpeter stated (1961) [11], it is necessary to ensure that institutions and professionals renew themselves constantly, even more in a moment in which the journalism, as Nonato said (2015) [28], has been looking for ways to tackle employment crisis and prospects. Therefore, we can see crowdfunding as an innovation that came to integrate new skills to journalism, create new job opportunities, change and even break radically the flow of information with the structure of subordination between journalist and vehicles of communication.

By the way, those characteristics make it possible to classify crowdfunding as a radical innovation. According to the model by Davila, Epstein and Shelton (2007) [31], there is a level of novelty accomplished in innovation, which is incremental and radical. The factors that characterize the former are optimization and cumulative gains in efficiency. The latter, in turn, is a source of discontinuity as it breaks with the traditional patterns. In the case of crowdfunding, it concerns, for example, the emergence of a deregulation in the journalistic sector by breaking with the traditional logic of financing the journalistic activity and even with the production flow of news, previously fully focused on the figure of the journalist.

Precisely by breaking many structures of journalism, we can consider also the crowdfunding as a disruptive innovation. The modality proposed by Christensen (1997) [32] points to situations in which the new participants of the market, powered by simpler technological solutions, can advance ahead of companies that are the market leaders. While the new journalistic practice has not overcome the major media groups, the characteristics identified by the author as disruptive technology corroborate with many aspects of crowdfunding journalism.

In truth, the very fact that the novelty is not reaching a large consumer market and is restricting itself to certain niches currently is an indication that this scenario is all about rupture innovation.

According to Christensen:

> The technologies of rupture are usually marketable first in emerging and insignificant markets. The more profitable consumers from leading companies do not want to, and indeed, they cannot initially, use products offered by rupture technologies. In general, consumers of lower profitability in the market initially adopt a rupture technology. (1997, p. 26) [32].

Such notes corroborate a good part of the characteristics of crowdfunded journalism formation, such as the fact that the readers have a high degree of demand for a certain kind of reportage that discusses about a subject previously chosen. The ratio of people paying for news that could be for free or even the fact that this new journalistic practice currently is synonymous of quality and personalization in the face of massive content and pasteurized from traditional press.

III. Conclusion

It would be possible to extend the analysis for the application of theoretical concepts of innovation in the light of crowdfunded journalism for many other lines but the analysis performed has already proved that the classification for what is innovative is undisputed to this new journalistic practice. More than a new term, this observation proves that journalism is under a process of change from human practices and technological development.

Just as we should not deny the human fact as the trigger of practices, such as collaboration and sharing, it is highly recommended to realize how human being and vice-versa shape technology. In this two-way relationship, man and machine alternate in the task of creating new communication mechanisms. Thus, it is important that humans take control of machinery operation systems to promote the changes that innovation requires. Without their will, innovation in machines is an ongoing and one-way ticket process.

References

[1] M. Castells. “A sociedade em rede”. São Paulo: Paz e Terra, 2000, pp. 54-92.

[2] P. Serra; S. Sá; W. Souza Filho (Orgs). “A televisão ubíqua”. Covilhã: LabCom, 2015, pp. 11-39.

[3] J. Canavilhas; I. Satuf. “Jornalismo para dispositivos móveis**:** produção, distribuição e consume”. Covilhã: LabCom, 2015, pp. 24-41.

[4] R. Kaneya, “Hackers do bem”. *Revista de Jornalismo ESPM*, vol. 4, n. 12, pp. 20-23, Jan. Fev. Mar. 2015.

[5] B. Adler. ‘O povo que pague”. *Revista de Jornalismo ESPM*, vol.4, n. 12, pp. 64-67, Jan. Fev. Mar. 2015.

[6] R. C. Alves. “Jornalismo digital: Dez anos de web… e a revolução continua”. *Comunicação e Sociedade*, vol. 9, pp. 93-102, 2006.

[7] T. E. Gerhardt; D. T. Silveira. “Métodos de pesquisa”. Porto Alegre: Editora da UFRGS, 2009, pp. 34-38.

[8] L. Santaella. “Comunicação e pesquisa: projetos para mestrado e doutorado”. São Paulo: Hacker Editores, 2001, p. 97-98.

[9] P. Drucker. “Inovação e espírito empreendedor (entrepreneurship)”. São Paulo: Pioneira Thomson, 2003. pp. 15-85.

[10] S. Meira. “Novos negócios inovadores de crescimento empreendedor no Brasil”. Rio de Janeiro: Casa da Palavra, 2013, pp. 86-131.

[11] J. Schumpeter. “Capitalismo, Socialismo e Democracia”. Rio de Janeiro: Editora Fundo de Cultura, 1961, pp. 54-61.

[12] G. Giacomini Filho; R. E. Santos. “Convergências conceituais e teóricas entre comunicação e inovação”. In: *Comunicação e inovação: reflexões contemporâneas.* M. P. Caprino (Org.). São Paulo: Paulus, 2008, pp. 47-54.

[13] D. Wolton. *Informar não é comunicar*. Porto Alegre: Editora Sulina, 2010, pp. 87-98.

[14] M. Vargas. *Para uma filosofia da tecnologia*. São Paulo: Editora Alfa Ômega, 1994, 154-190.

[15] J. E. R. Lima (2007). Considerações sobre filosofia da tecnologia. Paper apresentado na I Conferência Brasileira de Comunicação e Tecnologias Digitais da Universidade Metodista de São Paulo. [Online]. Available: https://goo.gl/A6Uiz3

[16] V. Dusek. *Filosofia da tecnologia*. São Paulo: Edições Loyola, 2006, pp. 98-115.

[17] M. Mitchell. *Complexity: an introduction*. Nova York: Oxford University Press, 2010, pp. 201-210.

[18] N. Wiener. The human use of human beings: Cybernetics and society. Perseus Books Group, 1954, pp. 15-28.

[19] C. Shannon. “A Mathematical Theory of Communication”. *Bell System Technical Journal*, vol. 27, pp. 379–423, July, October, 1948.

[20] A. M. Turing. “Computing Machinery and Intelligence”. *Mind, New Series*, vol. 59, n.236, p. 433-460, 1950.

[21] J. Gleick. *The Information: A History, a Theory, a Flood*. New York: Pantheon Books, 2011, pp. 351-389.

[22] J. V. Neumann. *The Computer and the Brain.* New Haven/London: Yale Univesity Press 1958, pp. 48-91.

[23] *Frascati Manual*, Organisation for Economic Co-operation and Development, Geneve, Switzerland, pp. 58-76.

[24] E. Felinto. “Crowdfunding: entre as multidões e as corporações”. *Revista Comunicação, Mídia e Consumo*, v. 9, n. 26, p. 137-150, nov. 2012.

[25] H. Jenkins. *Culture of convergence*. New York University Press, 2006, pp. 22-61.

[26] D. Tapscott. *Grown Up Digital: How the Net Generation Is Changing Your World*. New York: McGraw Hill, 1997, pp. 20-46.

[27] A. C. R. Xavier. Alternativas para o financiamento do jornalismo: Crowndfunding e a campanha Reportagem Pública. In: 12º Encontro Nacional de Pesquisadores em Jornalismo. **Anais...** Santa Cruz do Sul: SBPJor, 2014, p. 1-17.

[28] C. Nonato. “Blogs, colaborativismo e *crowdfunding*: novos arranjos para o livre exercício do jornalismo e a prática da cidadania”. *Revista Alterjor***,** v. 2, n. 12, p. 1-14, 2015.

[29] A. Rodriguez; C. Dahlman; J. Salmi (2008). Knowledge and innovation for competitiveness in Brazil. Washington, DC: The International Bank for Reconstruction and Development; World Bank. [Online]. Available: https://goo.gl/YscSW6.

[30] M. Carvalho. *Inovação: Estratégias e comunidades de conhecimento*. São Paulo: Atlas, 2009, pp. 75-110.

[31] T. Davila; M. Epstein; R. Shelton. *As regras da inovação: Como gerenciar, como medir e como lucrar*. Porto Alegre: Bookman, 2007, pp. 86-91.

[32] C. Christensen. “The innovator´s dilemma. When New Technologies Cause Great Firms to Fail”. Harvard Business Review Press, 1997, pp. 25-56.

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