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We Measured and Have Expanded the Space for More Services in Digital Television

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***Abstract*— Digital TV stations transmissions can be configured so that the useful bit rate can accommodate a variable amount of information. We observed that the ISDB-Tb (Integrated Services Digital Broadcasting - Terrestrial, version B) bit rate is not fully utilized by the broadcasters. Hence, services can be added beyond to the content of television without this being hindered.**

Index Terms— Bit rate, ISDB-Tb, Services, TV broadcasting

I. Introduction

THE ISDB-Tb - Integrated Services Digital Broadcasting, Terrestrial, Version B - is the most flexible among the Digital Television standards in the world [1], and this feature provides to the broadcaster various possibilities of operation, and may go beyond standard audiovisual television content transmission.

Multi-program, additional audio channels, emergency alerts, electronic programming guide, notices of public utility, and interactivity are some of the options that the broadcaster may rely to attract more audience. But is there space available for all these services on TV channels?

This paper goes beyond the theoretical constraints. We use measures from some TV stations to show that these have configured its transmission systems in order not to maximize the use of bit rate and propose new ways of expansion and transmission capacity of the bit rate.

II. ISDB-Tb

A. *The ISDB-Tb flexibility*

The ISDB-Tb was developed to allow video, audio, and data transmission, configuring, as its name says, a multimedia broadcasting system [1], which has technical flexibility for the most diverse types of content, with 3 three different types of reception: fixed, portable, and mobile [1].

This flexibility is reached due to the configuration of the transmission mode by means of the Number of Carriers; the Carrier Modulation; the Convolutional Code; and Guard Interval Width. The Standard [2] presents configurations allowed for the ISDB-Tb.

The Number of Carriers is linked to the amount of used OFDM carriers, being 1,405 for Mode 1; 2,809 for Mode 2; and 5,617 for Mode 3, causing the spacing between the carriers in approximately 4, 2, and 1 kHz respectively, causing a slight difference in the bandwidth of each mode of 5.575, 5.573, and 5.572 MHz for modes 1, 2, and 3, respectively [2].

The digital carrier modulations are DQPSK, QPSK, 16QAM, or 64QAM, where each possible setting affects the coverage of the station with more or less robustness. The Convolutional Code of 1/2, 2/3, 3/4, 5/6, or 7/8, changes the redundancy in the error bit correction, causing changes in the rate of useful bits in each setting. The Guard Interval Width of 1/4, 1/8, 1/16, or 1/32 of the duration of the symbol, allows the increase or decrease the immunity of the multipath and serves in the planning of Single Frequency Network – SFN.

TABLE I
ISDB-Tb Configurations

Carrier Modulation	Convolutional Code	Number of Transmitting TSPs (Mode 1 / 2 / 3)	Information Rates (Mbps)			
			Guard Interval Ratio 1/4	Guard Interval Ratio 1/8	Guard Interval Ratio 1/16	Guard Interval Ratio 1/32
DQPSK QPSK	1/2	156/ 312 / 624	3.651	4.056	4.295	4.425
	2/3	208 / 216 / 832	4.868	5.409	5.727	5.900
	3/4	234 / 468 / 936	5.476	6.085	6.443	6.638
	5/6	260 / 520 / 1040	6.085	6.761	7.159	7.376
	7/8	273 / 546 / 1092	6.389	7.099	7.517	7.744
16QAM	1/2	312 / 624 / 1248	7.302	8.113	8.590	8.851
	2/3	416/ 832 / 1664	9.736	10.818	11.454	11.801
	3/4	468 / 936 / 1872	10.953	12.170	12.886	13.276
	5/6	520/ 1040 / 2080	12.170	13.522	14.318	14.752
	7/8	546/ 1092 / 2184	12.779	14.198	15.034	15.489
64QAM	1/2	468 / 936 / 1872	10.953	12.170	12.886	13.276
	2/3	624 / 1248 / 2496	14.604	16.227	17.181	17.702
	3/4	702 / 1404 / 2808	16.430	18.255	19.329	19.915
	5/6	780 / 1560 / 3120	18.255	20.284	21.477	22.128
	7/8	819 / 1638 / 3276	19.168	21.298	22.551	23.234

The broadcast engineer, who is responsible for setting the transmission mode, has to analyze what services will be available to the audience (one-seg, SDTV, EDTV, HDTV, multi-program, audio, data, etc.) and which network structure will be used (single transmitter or SFN), configuring then the transmission from those data, so that everything fit within the 6 MHz available, and bearing in mind that the transmission mode that defines the available bit rate (Table I).

Despite being multimedia, the main purpose of the ISDB-Tb is the transmission of audiovisual content of television, especially the high-definition content, adjusted for the resolution of 1920x1080 pixels at a ratio of 16:9. This content must be compatible with the restrictions imposed by H.264 High profile and level 4.0 (high@L4.0), or any other lower level and can be transmitted at bit rates up to 25 Mbps [3]. However is possible to reduce more the bit rate thanks to video compression methods, assuring the same visual quality without noticeable distortion perceived by the viewer.

B. *Hierarchical Transmission*

The 6 MHz of available spectrum for each channel is segmented into 14 parts (one of them being used for bandwidth guard) grouped into three hierarchical layers A, B, and C [1]. Each layer can have a different number of

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segments, and they must respect the rule that the quantity of segments of the Layer A must be lesser than the Layer B, which also must be lesser than the Layer C [1]. One of the major innovations of the ISDB-T is to accept, for each layer, that the transmission modes can be configured differently, simplifying the adequacy of the transmission for the content to be sent [1].

Usually the central segment is reserved for the reception of mobile TV, forming the Layer A, using the most robust digital modulation (DQPSK/QPSK), which carry only 2 bits per symbol, causing the bit rate varies from 280.8 to 595.7 kbps, depending on the convolutional code and guard interval width [2]. The other 12 segments can be freely configured, leaving a useful bit rate from 3.3 to 21.4 Mbps [2].

By way of comparison, in Japan, the country that has developed the ISDB-T System, most of the broadcasters would use only the configuration of modulation in 64QAM, convolutional code of 3/4, and guard interval width of 1/8 [1], causing the available bit rate for broadcasters, cover all the 12 segments dedicated to HDTV programming, would be fixed at 16.851 Mbps [2].

The TMCC - 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 [2].

III. Stations Evaluation

To analyze if there are some space available, in terms of bit rate, in ISDB-Tb transmissions, so that would be possible to add more information and services, first at all we check how the TV broadcasters, which transmit content in high definition (HD) video, has configured the transmission modes for its station and observe how the available bit rate is being used. For that, it was used an ISDB-Tb professional receiver and a Transport Stream analyzer.

The ISDB-Tb professional receiver (EiTV - DecoderIPBox) captures the digital TV channel, demodulates the signal and transmitting the entire content received via IP (TSoverUDP), including null packets of valid layers, i.e. all useful data rate of the signal. The stream of data is sent to the Transport Stream analyzer software (Dektec - StreamXpert), who extracts the transmission modes and separate the bit rates of each channel content.

In accordance with the measures extracted from TV stations, is possible to determine what is the bit rate not used and with this data, we propose new settings to make more efficiency the use of this bit rate. In this scenario, we will evaluate the possibilities for: the use of greater compression techniques in HD video; reconfiguration of transmission modes; and amendment of the hierarchical layers, aiming at the increase of its transmission capacity.

IV. Results

Analyzing for about 5 minutes the transmissions of nine TV stations in the São Paulo/SP and Campinas/SP municipalities, on 06/03/2016, we observed that all stations use only two of the hierarchical layers, being the central segment the Layer A and the other 12 for the Layer B. Only four distinct configurations were used for Layer B: the A, C, and E stations use 64QAM modulation, convolutional code of 3/4, and guard interval width of 1/16; the B, D, H, and I stations use 64QAM modulation, convolutional code of 3/4, and guard interval width of 1/8; the F station uses 16QAM modulation, convolutional code of 5/6, and guard interval width of 1/16; and the G station uses 16QAM modulation, convolutional code of 2/3, and guard interval width of 1/8, corresponding to the total bit rates of 18.3, 17.3, 13.6, and 10.4 Mbps, respectively. We measured the transmission modes, the total bit rate of the channel (Channel), the bit rate used by HD video (VideoHD), and the rate of null PIDs (Null PID) (Table II). The Layer B column was determined from the parameters of transmission [2].

TABLE II
Measured Configurations and BIT Rates

Station	Transmission Modes	Channel (Mbps)	Layer B (Mbps)	VideoHD (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

The data shows that the VideoHD content uses bit rates that vary from 8.7 to 15.6 Mbps, while the transmission modes have been configured to allow useful rates from 10.0 to 17.8 Mbps, in a system that allows rates up to 21.4 Mbps for 12 segments [2]. We can demonstrate, by means of column VideoHD of Table II, that broadcasters are using different video compressions and are not using the entire available bit rate.

It is worth noting that in addition to the content of HD video, there are other information transmitted by the broadcaster, such as audio channels to the main programming of television, subtitles, EPG, information of interactivity, and various data for the provision of TV service. The bit rate occupied by these other information was calculated by (2) and is presented in column Others of Table IV.

V. Discussions

There is a percentage of the bit rate provided by the ISDB-Tb that is not used by the broadcasters. Analyzing the collected data, we observed that the column Null PID Bitrate presents the bit rate of null PIDs (Table III), i.e., packets with the PID 0x1FFF that are filled with 0xFF bytes (stuff bytes), simply because there was no content to send [4]. The addition of these data is necessary to maintain a constant bit rate. Thus, we can observe directly that it is already available from 0.1 to 5.9 Mbps.

On average, are directly available 2.8 Mbps per station and the sum of the nine analyzed broadcasters totals 25.4 Mbps, which is greater than the total possible for a channel that has the 13 segments configured on your maximum rate, i.e., 23.234 Mbps [2]. And this spare bandwidth can be better exploited, making some changes in the modes of the transmission.

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A. Expansion of the not used bit rate

First, we analyzed the rates used by VideoHD. We found rates from 8.7 to 15.6 Mbps. According to [5] it is necessary to assess the issue of subjective quality perceived by the viewer with the change of HD video bit rate. A subjective evaluation of note 4 (5-point MOS), still corresponds to a video of good quality, that under these conditions it uses a bit rate of 8.0 to 16.0 Mbps [5]. Thus, depending on the interest of the broadcaster to expand its transmission capacity, you can use higher video compression, without loss of the subjective quality of HD video.

As the bit rate of the HD video can be reduced up to 8 Mbps, without reduce the subjective quality, the gain that each station may obtain with this reduction was calculated (Table III).

TABLE III
IMPROVEMENT WITH VIDEO COMPRESSION

Station	VideoHD (Mbps)	New VideoHD (Mbps)	New Null PID I (Mbps)
A	15.2	8.0	9.2
B	15.6	8.0	8.6
C	11.8	8.0	7.8
D	10.5	8.0	8.4
E	14.5	8.0	9.4
F	8.7	8.0	4.3
G	9.7	8.0	1.8
H	14.2	8.0	7.9
I	12.3	8.0	8.5

We have reduced the bit rate of VideoHD to 8.0 Mbps and the difference of the previous rate was added to the Null PID. We can say that all broadcasters won bit rate with the strategy of reducing the rate of HD video (New Null PID I column in Table III).

In relation to the reconfiguration of the transmission modes, if we apply the configuration that offers the highest bit rate per segment, i.e., Modulation at 64QAM, Code Convolutional 7/8 and Guard Interval Width of 1/32 [2], for each broadcaster analyzed, we observed that can also be obtained gains in terms of bit rate (New Null PID II column in Table IV).

TABLE IV
IMPROVEMENT WITH TRANSMISSION MODES

Station	VideoHD (Mbps)	Layer A (Mbps)	Others (Mbps)	New Layer B (Mbps)	New Null PID II (Mbps)
A	15.2	0.46	0.64	21.4	5.6
B	15.6	0.45	0.25	21.4	5.5
C	11.8	0.46	2.04	21.4	7.6
D	10.5	0.55	0.45	21.4	10.4
E	14.5	0.56	0.44	21.4	6.5
F	8.7	0.38	0.92	21.4	11.8
G	9.7	0.41	0.19	21.4	11.5
H	14.2	0.45	0.95	21.4	6.2
I	12.3	0.45	0.35	21.4	8.7

We calculated the data with the following equations:

$$Layer\ A = Channel - \ Layer\ B \quad (1)$$

$$Others = Layer\ B - VideoHD - Null\ PID \quad (2)$$

$$New\ Null\ PID\ II = New\ Layer\ B - VideoHD - Others \quad (3)$$

We observed a significant gain in the not used bit rate, as in the case of the station F that reached 11.8 Mbps, higher even than the bit rate used for VideoHD. However it is necessary to evaluate the costs of this gain, because if you would change the modulation from 16QAM to 64QAM, you lose strength in the transmission, which is directly related to the coverage of the station (F and G stations). The increase of the Code Convolutional causes a reduction in terms of redundancy, allowing the occurrence of more bit errors, which also causes a reduction of the station coverage (All stations). The reduction in the guard interval width causes the reduction of the immunity to multipath, that in urban environments may cause zones of intersymbol interference, resulting in areas with no possibility of channel reception (All stations). In these cases it is necessary to evaluate how the coverage is reduced and if this loss can be compensated by an increase in the transmission power.

Finally, using the hierarchical layers possibilities from ISDB-Tb, we can split the layer B, composed of 12 segments, in layers B and C. Thus the not used bit rate of each broadcaster can be treated in terms of segments that are not used, allowing that these not used segments can be allocated in Layer B, and can even be reconfigured to increase the transmission capacity of these segments, by moving the used segments for the HD content to the Layer C, without it being necessary to reconfigure them, avoiding the problems with the reduction of coverage previously mentioned.

TABLE V
IMPROVEMENT WITH LAYERS RECONFIGURATION

Station	Bit Rate per Segment	Number of unused segments	New Layer B (Mbps)	New Layers Configuration	New Null PID III (Mbps)
A	1.4869	1	1.8	A: 1 B: 1 C: 11	2.31
B	1.40429	0	0	A: 1 B: 12	1.0
C	1.4869	2	3.6	A: 1 B: 2 C: 10	6.11
D	1.40429	4	7.1	A: 1 B: 4 C: 8	11.6
E	1.4869	1	1.8	A: 1 B: 1 C: 11	3.21
F	1.1014	3	5.4	A: 1 B: 3 C: 9	7.9
G	0.83217	0	0	A: 1 B: 12	0.1
H	1.40429	1	1.8	A: 1 B: 1 C: 11	2.1
I	1.40429	3	5.4	A: 1 B: 3 C: 9	8.2

Note that this reconfiguration proposal (New Null PID III column in Table V) can generate three situations: the first where it was not possible to create a third hierarchical layer, because the remainder of not used bit rate was smaller than the minimum bit rate of the segment (B and G stations); the second, in which the gain is lesser than 1.0 Mbps (A, E, and

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H stations); and finally the third situation, where the gain in not used bit rate is greater than 2.0 Mbps (C, D, F, and I stations).

It is worth noting that this reconfiguration needs to be evaluated on a case by case basis by the broadcast engineer, since the creation of the third hierarchical layer, with consequent new configuration of transmission modes can cause different areas of coverage, which already occurs between programming in one-seg (Layer A) and a high definition (Layer B).

Each of the proposed changes may affect some particular characteristic of the ISDB-Tb, therefore must be carefully studied to ensure that the expansion of the not used bit rate for the inclusion of new services does not affect the availability of the main signal of TV in its coverage area.

We observed in Fig. 1 that all the proposed techniques can be applied to maximize the space available for more services. In addition, the proposals mentioned that there are some alternatives between the techniques leaving to that the broadcast engineer could make the right decision to configure the system of the station.

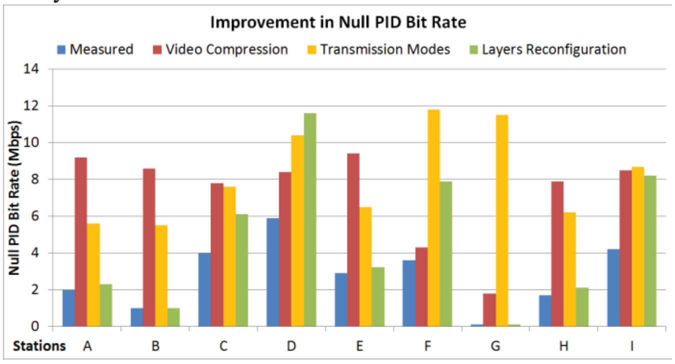

Figure 1 – Null PID Improvement Comparison

VI. Conclusions

The TV broadcasters do not utilize the entire bit rate provided by the ISDB-Tb, either by not configuring the transmissions at the maximum rate permitted by the system, or even by not using the entire bit rate configured.

The bit rate not used may be increased, depending on the need of the TV broadcaster, changing it whether or not the current characteristics of coverage, redundancy, and immunity to the multipath.

It is a TV broadcaster responsibility to evaluate the application of this not used bit rate, implementing other services in addition to the TV Service, or even, improving the robustness of your station.

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