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SUMMARY

[Journal Page Number located at the bottom right of the footnote] - Content

Current Issue **EDITORIAL**

Dear reader,

In this 2016 Edition, we have prepared an issue with the most compelling demands for the future of our Broadcast Engineering segment. The chosen articles range from filter development for enhancing distortion, to the unceasing challenge to monitor the IP edge. In addition, we have selected attention-grabbing research involving the future of ISBD-Tb with High Dynamic Range content implementation, Data Channel for Services currently available and its expansion applications in Digital Television (TV), as well as the behavior of receivers in a Single Frequency Network. We have also received original contributions regarding the state-of-the-art technology on High Definition, with Photometric and Colorimetric analysis for TV monitors. The current on-going migration of traditional AM Radio to the FM-Extended range is also covered, introducing our readers to the possibilities of Software Defined Radio for receivers. Also on the question of Radio, we have an approach related to digital radio development, detailing implementations and comparisons of such engineering solution standards. We hope you enjoy and take advantage of these papers and feel motivated to submit us yours in the future.

We wish to inform you that the activities, events and publications of the Brazilian Society of Television Engineering – SET, including this one, enjoy international support, under formal agreements, from the following international organizations. We also take this opportunity to thank them and reiterate how proud we are that they support our work.

Society of Motion Picture & Television Engineers - SMPTE (USA)

International Broadcast Equipment Exhibition - Inter BEE (Japan)

National Association of Broadcasters - NAB - (USA)

International trade Association for suppliers of Broadcast and Media technology - IABM (UK)

World Wide Web Consortium - W3C - (USA)

Argentine Association of Broadcasting Equipment Manufacturers and Suppliers - CAPER (Argentina)

International Association of Broadcasting - AIR & IAB (Uruguay)

Broadcast India Show

International Convention of Communicators in Radio and Television & National Congress of Broadcasters - Expotec (Peru)

Audio Engineering Society

Best wishes,

SET IJBE Staff

SET INTERNATIONAL JOURNAL OF BROADCAST ENGINEERING – SET IJBE v. 2, Article 1, 3p.

Application of Distortion Reduction in FIR Filters in Dynamic Systems through Computational Methods

Sergio Bimbi Junior

Agenor de Toledo Fleury

Ronaldo Ruas

Vitor Chaves de Oliveira

SET INTERNATIONAL JOURNAL OF BROADCAST ENGINEERING – SET IJBE v. 2, Article 1, 3p.

Application of Distortion Reduction in FIR Filters in Dynamic Systems through Computational Methods

Sergio Bimbi Junior, Agenor de Toledo Fleury, Ronaldo Ruas, Vitor Chaves de Oliveira

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***Abstract*— The article shows a development methodology in the operation of finite impulse response (FIR) digital filters when built on computational methods based on general use processors.**

***Key Words*- Digital Filter, Digital Signal Processing, Low Pass Filter.**

I. INTRODUCTION

Digital systems generally contain advantages when compared to analog systems; among those features are elements such as high reliability, flexibility of system upgrades and cost-related issues. In addition to this feature, there is a growing number of applications that use large integration scale technology (4). As a result of many computational applications requiring frequent changes in their functionality or an increase in behavioral flexibility, it is often possible to rapidly built prototypes for digital systems. In this article, we seek to develop an FIR digital filter from a modified Hamming window (1), wherein the computer system is based on a queue where the first elements inserted are the first to be removed (FIFO).

II. FIR DIGITAL FILTER

An FIR filter can be represented by Equation 1.

$$y[k] = \sum_{n=0}^{N-1} \mathrm{h[n]} * \mathrm{x[k-n]} (1)$$

Where *x* represents the input signal, *h* represents the filter coefficients and *y is* the result, i.e., the filtered output signal. In this implementation, a series of multiply-accumulate (MAC) operations are applied to each sample of the input signal; this occurs by multiplying the *N* input samples by the system coefficients and finally adding the results for obtaining the output signal (2).

III. FIFO

FIFO is a special type of list characterized by how its elements are inserted or removed. In a queue, the first elements inserted are the first to be removed (first in, first out), characterizing the original term FIFO. The architecture of a FIFO structure can be demonstrated in Figure 1.

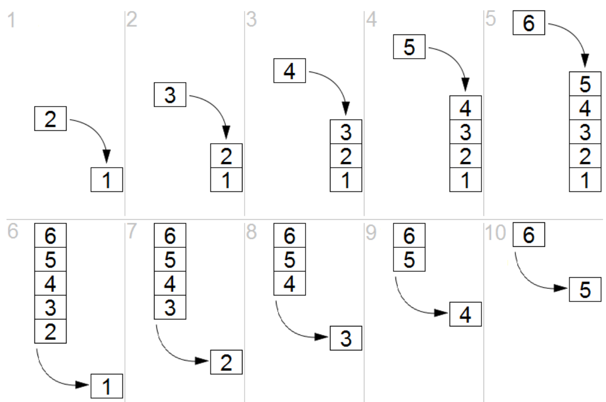

Figure 1. Architecture of a FIFO structure.

IV. SYSTEM ARITHMETIC

In digital filters, it is possible to develop alternative structures that do not apply the use of multipliers directly. These systems use distributed arithmetic (2), where the sum of products between the filter coefficients and the input signals is made without multipliers. In this way, the hardware is minimized, as well as consumption (6). This technique can be seen in Equation 2.

$$y[k] = \sum_{i=0}^{B-1} \left(\sum_{n=0}^{N-1} h(n) * b_{k-n,i} \right) * 2^{-i} + \left(\sum_{n=0}^{N-1} h(n) * -b_{k-n,0} \right) (2)$$

Where $b_{k,i}$ are bits 0 or 1 of signal $x(n)$ represented in two's complements with $(B+1)$ bits and $b_{k,0}$ the sign bit.

V. FILTERS HAVING WINDOW

Digital filters having window apply rejections at undesired points in the system at present lobules, i.e., those that are not acceptable beyond the main lobe. This phenomenon occurs due to having frequencies that are not required for that filter. In the proposed development, the modified Hamming window will be used as seen in equation 3.

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$$w[n] = [0{,}54 - 0{,}46^{nx-1}\cos(\frac{2^{nx-1}\pi n}{M})]$$
$$+[0{,}54 - 0{,}46^{nx-2}\cos(\frac{2^{nx-2}\pi n}{M})]$$
$$+[0{,}54 - 0{,}46^{nx-3}\cos(\frac{2^{nx-3}\pi n}{M})]$$
$$+[0{,}54 - 0{,}46^{nx-mx}\cos(\frac{2^{nx-mx}\pi n}{M})] \quad (3)$$

Where factor 2π represents the entire spectrum of the radian axes. The technique allows the insertion of new points in the windowing; this occurs by dividing the 2π radian spectrum into smaller points in order to more efficiently produce a filter. This occurs with the implementation of an *n*-th polynomial applied to 2π in addition to the 0.46 factor in order to maintain linearity.

VI. APPLICATION OF DISTORTION REDUCTION IN FIR FILTERS BY APPROXIMATION THROUGH WINDOW FACTOR ON FUNCTION COEFFICIENTS

The development of a low-pass filter having Hamming window computationally consists in implementing a FIFO structure in which its coefficients are accumulated in the time domain and multiplied by the calculated filter coefficient (5). The example shown in Figure 2 consists of a low-pass filter having Hamming window, with cut-off frequency 1Hz and sampling frequency 100Hz. To that filter, 136 coefficients are applied to a signal that emulates a harmonic developed by using an approximation sequence of the number π.

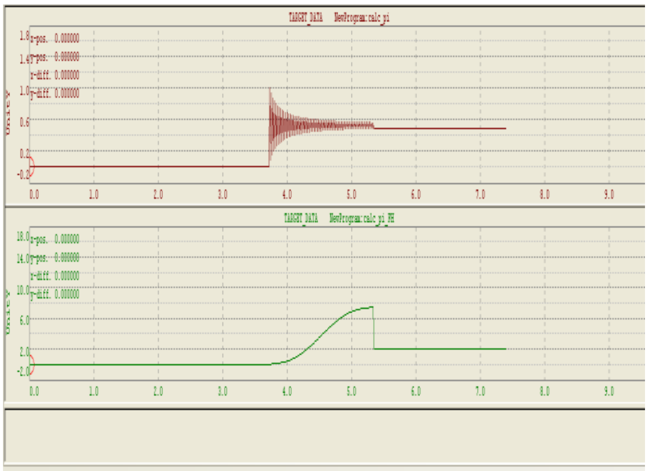

Figure 2. Filter having Hamming window in the time domain.

Figure 3 shows the same computational implementation cited in Figure 2 with the modification of the calculated coefficients according to Equation 3. This will demonstrate the increase in linearity and speed of convergence to the target point.

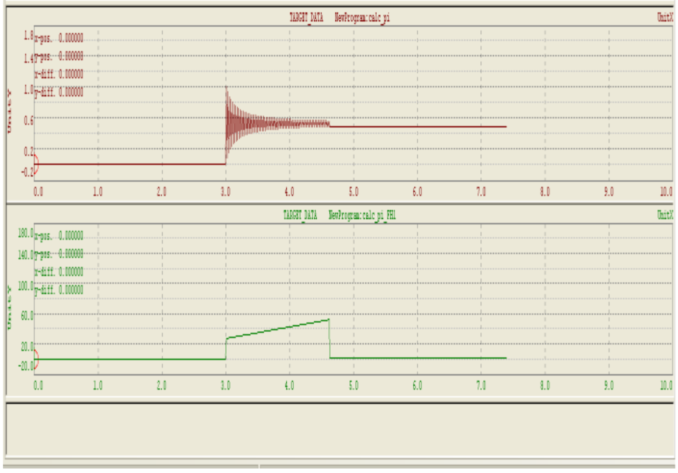

Figure 3. Filter having modified Hamming window in the time domain.

Figure 4 shows the same computational implementation mentioned in Figures 2 and 3 with a computational modification that proposes not to apply the filters to the first samples, causing the response to accelerate with respect to the target point. This effect increases the capacity of repeatability of the system by virtue of providing samples that are more stable in time.

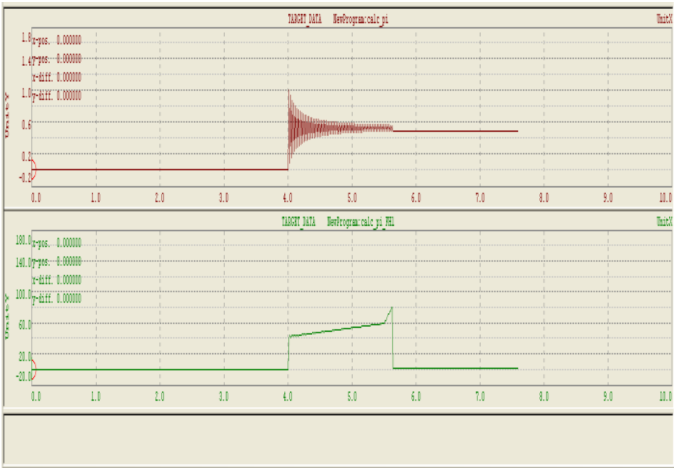

Figure 4. Filter having modified Hamming window in the time domain with computational methods.

VII. CONCLUSION

The implementation of Equation 3 with the computational changes aiming to have a no-action rejection window of the filter causes the system to have a much more effective conversion to the target point; as a downside, it is possible to notice the occurrence of a peak at the end of the sample due to the amount of samples rejected early in the process. With the implementation of averages, this phenomenon may be easily remedied, as well as the reduction in the number of coefficients rejected by the filter early in the process.

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Capturing Video Stream Audience Over IP Networks

Vitor Chaves de Oliveira

Paulo B. Lopes

Gunnar Bedicks Jr

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Capturing Video Stream Audience Over IP Networks

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***Abstract*—In recent years, the transmission of audiovisual content presented substantial growth in the context of on-demand delivery, made possible through networks based on Internet Protocol, IP. This increase, boosted by internet access omnipresence and new consumption habits of this content, makes this category of communication to be continuously rivaled with traditional broadcasting technologies of Television (TV) signals. Thus, developing techniques to assess the efficacy and risks that the use of IP networks for this purpose imposes becomes relevant. Moreover, while for the named Broadcast TV has technical mechanisms that ensure the quality of this communication are well established, the same does not occur for video stream over IP, or IP Stream. The reason for this is that, for one of them, its technology is equipped with quality guarantees based on a circuit-switching operation in a connection-oriented systematic. While the other, once the web is considered, is unable to ensure quality due to its packet-switching architecture. And this is what sets it as a model called 'best effort' which, besides the features to allow channel sharing and systems interconnection, enables precisely what makes its increase in its use for audiovisual transmission, the application-oriented provision. Thereby attending the consumer's desire for on demand content, subsequently amplifies the role of what and who is on the edge, ultimately placing the user as protagonist. In this IP scenario, it is underlined the lack of mechanisms, related to the Internet, capable of recording two technical parameters that influence the commercial chain that sustains this entire ecosystem, they are: availability and audience. Keeping this in mind and with the goal of evaluating this new method for audiovisual offering, this work has developed methodologies to acquire such information at this consumption edge. And this has been accomplished through the construction of a software tool. It was implemented as an extension to one of the most used browsers, Google Chrome, to capture the audience of Internet videos on the leading supplier of videos exists today, Google's YouTube. In this work, the abstractions of considerations around the Quality of Service (QoS) concept, is proposed to be interpreted as a measure of Quality of Experience (QoE) assimilated from time viewed compared against the total time of a video. This justification is founded on the concept that quality translates into a particular subjectivity for each user and their individual expectations, so a measure of time is shown to be an effective thermometer. This effectiveness is justified by a principle consolidated within TV broadcast for decades, audience measurement. Thus, the construction of something analogous to the 'People's meter' in a similar scheme of 'Television Rating Points', TRP, running to capture of information in order to convey assertiveness to all stakeholders involved in this new delivery method.**

Keywords— IP Stream, Audience, Connection Availability, Quality of Service (QoS), Quality of Experience (QoE), Software Development.

I. Introduction

To assess the audience of a delivered content over TV Broadcast it is used an equipment called People meter or Audience meter. This is installed at the home of certain viewers and connected to the TV continuously recording and sending information to a central regarding which channel is being watched, at what time and for how long. These members are chosen to have such devices installed in their homes so that their measures represent a sample of the whole society or people segment to be monitored. This complete equipment scheme is called Television Rating Points (TRP), or Gauging points for Television Audience, which aggregates all this measuring system. Thus, it estimates statistically the number of successful audiovisual content watched. The importance of measuring the audience is justified because it is the engine of the commercial part of a broadcaster station to choose which programs to invest or not and what impact or the reachability of advertising campaigns. Existing thus a significant commercial interest for pricing purposes of transmission periods in this and other segments, such as IP Streaming. [1][2]

II. Requirements Analysis

To capture Video Stream Audience, it was designed a solution considering aforementioned importance of obtaining this information at the user end of the video delivered via IP from the largest online media provider in the Internet, i.e. YouTube [3][4]. Also, it was delineated that the application is compatible with one of the most widely used browsers, Google Chrome [5]. Considering the requirements, in order to capture the audience of an audiovisual content it was decided on a project in which the program should be composed of two parts, described as follows. The client part or Front-end, it is an application to be installed in the browser in the format of an extension that could be installed on any device with the Google Chrome browser. This collects and sends certain data to a centralizer. These data are statistics (measures and information) of videos accessed, or viewed by users. It is emphasized that this is done from data present in the public codes of the website when a YouTube video page is accessed, time which the application is active. Such selected data which is captured and sent automatically to the centralizer are: Watched Time; Total Video Time; Video URL; Number of Video Views and Number of Channel Subscribers. In addition, other data considered relevant is captured through a brief questionnaire for completion by the user when the software is installed. These are: City; Age and Gender. The part of the centralizer, or server that receives, stores, manipulates and displays all these data, is called the back-end. Software that acts as a server on the Internet, which provides a service that receives, saves, records and consults the data captured by segmenting them in database tables.

III. System Functioning

To develop a software that is able to interact with the so-called API, Application Programming Interface, or Youtube Application Programming Interface JavaScript was selected. And to store the data used a MySQL database, and hence the Structured Query Language to manipulate and process the

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data. The following Figure 1 displays the main parts of the code that was implemented for the Front-end which is the extension installed on the user device browser to monitor audiovisual content. Meanwhile Figure 2 shows the Software Operation Flowchart.

```
//FUNCTION TO SAVE THE COLLECTED DATA ON THE WEBSERVICE
function SetData (origem){
    var nomeVideo = '';
    var tempoAssistido = '';
    var tempoTotal = '';
    var numeroVisualizacao = '';
    var nomeCanal = '';
    var numeroInscrito = '';
    //COLLECTS VIDEO INFORMATION
    $(document).ready(function() {
        nomeVideo = $('.watch-title').text();
        var element = $('.ytp-progress-bar');
        $(element[0].attributes).each(function() {
            if (this.nodeName == 'aria-valuenow') {
                tempoAssistido = this.nodeValue;
            } else if (this.nodeName == 'aria-valuemax') {
                tempoTotal = this.nodeValue;}});
        numeroVisualizacao = $('.watch-view-count').text();
        nomeCanal = $('.yt-user-info').text();
        numeroInscrito = $('.yt-subscriber-count').text();    });
    if (tempoTotal != "0"){
        //SENDS DATA TO THE WEBSERVICE
        $.ajax({
            type: "POST",
            url: 'https://tetconsultoria.com.br/WS.asmx/SetStats',
            data: "{ nomeVideo:'" + nomeVideo.trim() + "',"+
                  "  tempoAssistido:'" + tempoAssistido + "',"+
                  "  tempoTotal:'" + tempoTotal + "',"+
                  "  urlVideo:'" + window.location.href + "',"+
                  "  numeroVisualizacao:'" + numeroVisualizacao + "',"+
                  "  nomeCanal:'" + nomeCanal.trim() + "',"+
                  "  numeroInscrito:'" + numeroInscrito + "',"+
                  "  cidadeUsuario:'" + localStorage.getItem('cidadeUsuario') + "',"+
                  "  idadeUsuario:'" + localStorage.getItem('ageUsuario') + "',"+
                  "  sexoUsuario:'" + localStorage.getItem('sexoUsuario') + "'"  +" }",
            contentType: "application/json; charset=utf-8",
            dataType: "json", success: function (msg) {},
            error: function (e) {alert('Mensagem WS03 - WebSerivce unreachable');}});}}
```

Fig. 1. Extension core coding demonstrating the capture of monitored data and dispatching it to the Back-end Web service.

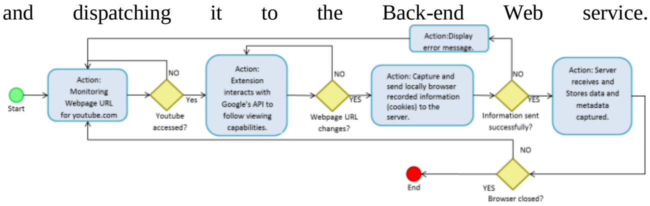

Fig. 2. Software Operation Flowchart

For the developed application, first the user needs via Chrome browser, access the Internet at 'Chrome Web Store - Extensions' or 'Chrome Extension Store'. Once there, search for 'Youtube Data Stats' which is name designated to this software, the icon and application described in Figure 3 will appear to be installed on the user's browser, available by accessing the address: 'https://chrome.google.com/webstore/detail/youtube-data-stats/nmnaacknlpckjpccicgekcnogaeoaipi'.

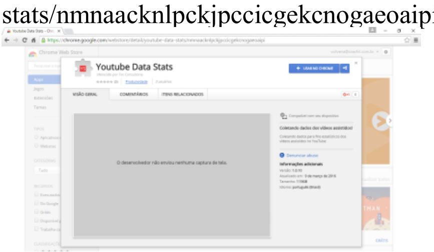

Fig. 3. Webpage to install the extension from the 'Chrome Web Store - Extensions'.

IV. RESULTS AND CONCLUSION

In order to detail the results from the monitoring carried out, then it is shown, in Figure 4, clearly all data captured from two tests sent to the back-end. From left to right we have the columns with the name information, Assisted Time, Total Time, URL, View, Canal, Subscribers, City, Age, Gender, Date.

LISTA

Nome	Tempo Assistido	Tempo Total	Url	Visualizacao	Canal	Inscritos	Cidade	Idade	Sexo	Data
Ivete Sangalo - Quando A Chuva Passar	92	325	https://www.youtube.com/watch?v=OrVFYsc6gAI	4.446.897	IveteSangaloVEVO	214.948	São Paulo	28	M	4/12/201 10:54:09
Ivete Sangalo - Quando A Chuva Passar	4	325	https://www.youtube.com/watch?v=OrVFYsc6gAI	4.446.897	IveteSangaloVEVO	214.948	São Paulo	28	M	4/12/201 10:52:51 F

Fig. 4. Detailing search results from the database with the captured data at the Software's Back-end.

The technical and commercial motivation for verifying the audience is the same as the traditional TV and that the IP demand for content grows daily. The results show that this is a tool that meets this feature, allowing to bring to the IP world some of the assertiveness present only on TV so far, according to the literature. [6] [7] [8] [9]

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Distortion Reduction in FIR Filters by Approximation through Window Factor on Function Coefficients

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Distortion Reduction in FIR Filters by Approximation through Window Factor on Function Coefficients

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***Abstract*—Filters are time-invariant linear systems which are able to modify the characteristics of the signals connected to their input, so that only a specific portion of the frequency components in a signal can reach the output of the filter. In dynamic systems, digital filters are applied in order to improve system measurements with regards to performance and stability. The present article demonstrates a modification in a low pass filters having Hamming window within the sample space π. In this development, the sample space π is subdivided, wherein equation plots are added within a polynomial of order *n*. This technique provides the removal of unwanted frequency components in small angular frequency windows, providing the signal with acceleration towards the target when as compared to a low pass filter having Hamming window. In dynamic measurement systems, this feature is relevant, considering that the system shall have grater approximation to its target values, thus implementing an average which indicates the value being acquired in a more accurate and repetitive manner.**

***Key Words*- Digital Filter, Digital Signal Processing, Low Pass Filter, High Pass Filter, Filter Pass Band, Band Reject Filter.**

I. INTRODUCTION

Filters are time-invariant linear systems which are able to modify the characteristics of signals connected to their input, so that only a specific portion of the frequency components in a signal can reach the output of the filter. Considering analog signals $x(t)$ and $y(t)$ and a filter having impulse response function $h(t)$, as shown in Equation 1:

$$y(t) = h(t) * x(t) (1)$$

In the frequency domain, the equation can be solved as seen in Equation 2.

$$Y(j\omega) = H(j\omega) * X(j\omega) (2)$$

Assuming an implemented digital filter is a Digital Signal Processor (DSP) and the goal is to process an analog signal $x(t)$, a digital filter system can be characterized as shown in Figure 1 (21).

Figure 1. Digital filter architecture.

If the signals to be processed are digital, the diagram can be shown in summary form, as seen in Figure 2 (21).

Figure 2. Digital filter architecture in summary form.

In order to implement a digital and time-invariant (LTI) filter, a DSP is required, in which computational algorithms are arranged. These can be represented in the form of block diagrams using basic structures such as unit delays, gains, adders, feedbacks and delay structures in the block diagram, which is similar to the order of difference equations (transfer function) of the filter known as Canonical structure.

II. DIGITAL FILTERS VERSUS ANALOG FILTERS

The comparison relationship between an analog and a digital filter is directly linked to the complexity, precision and design adaptability (22). An analog filter is economically more recommended than a digital filter, but once the system is implemented, due to its discrete components, the system becomes too complex for adaptations and improvements. Another interesting feature of analog filters, given that the system is implemented by external components, is the change in the characteristics of these devices with respect to environmental factors such as temperature and humidity, thus compromising their best theoretical performance. In turn, digital filters, with respect to Analog to Digital conversion (AD) and Digital to Analog (DA) conversion and the processing itself, have a poorer response time as compared to the analog filter. Digital filters also have errors inherent to the quantization process (performed in AD conversion) and rounding errors due to the use of digital words having finite length. In recursive filters, this phenomenon can lead to greater instability (23). On the other hand, the ability to implement this filter within a processed system leads to greater flexibility in the updating and maintenance of the

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project. The architecture of a digital filter can be seen in Figure 1.

III. IIR FILTER

Infinite Impulse Response (IIR) filters are those which have an infinitely long-lasting response to an impulse and having recursive nature, thus, it can be concluded that this filter is characterized by relying on both the current input and the previous input. Figure 3 illustrates the structure for developing an IIR filter, function $x(k)$ is the input signal, values *a1* to *aQ* and *b0* to *bP* are coefficients representing the type of filtering that is being performed (high-pass, low-pass, band-pass) and function $y(k)$ is the output signal as a result of the filtering of signal $x(k)$ (24).

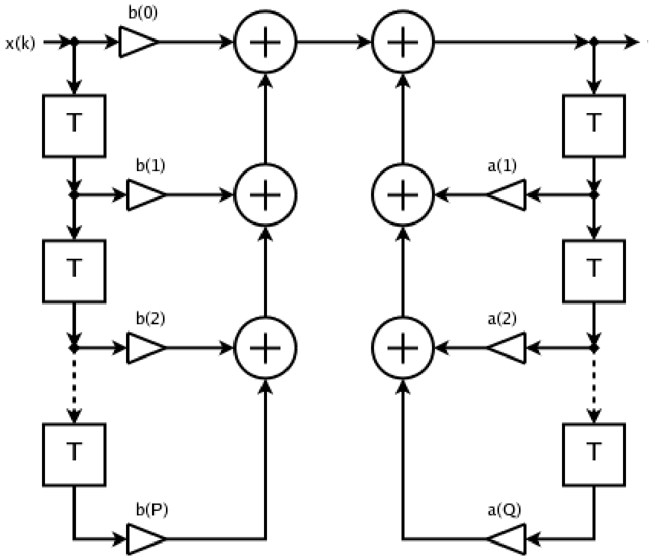

Figure 3. Structure for developing a digital IIR filter.

In mathematical aspects, the output of a digital IIR filter is represented recursively as seen in Equation 3, where *ak* and *bk* are filter coefficients.

$$y[n] = \sum_{k=0}^{\infty} \mathrm{h[k]} * \mathrm{[n-k]} =$$

$$\sum_{k=0}^{n} b_k * \; [n-k] =$$

$$\textstyle\sum_{k=1}^{M} a_k y * \; [n-k] = (3)$$

By applying the z-transform we obtain the transfer functions shown in Equation 4.

$$H(z) = \frac{Y(z)}{X(z)} (4)$$

By breaking down $Y(z)$ and $X(z)$, the transfer function equation in an IIR filter is obtained as seen in Equation 5.

$$H(z) = \frac{\sum_{k=0}^{N} b_k z^{-k}}{1+\sum_{k=1}^{M} a_k z^{-k}} (5)$$

IV. FIR FILTER

Finite Impulse Response (FIR) filters are those which show a finitely long-lasting impulse response (25). This filter is characterized by a discrete transfer function which can be seen in Equation 6.

$$\frac{Y(z)}{X(z)} = \frac{\sum_{k=0}^{M} a_k z^{(M-k)}}{z^M} (6)$$

This discrete function can be rewritten as a polynomial function of negative powers of z. FIR filters have well-defined characteristics, which are:

1) Finite memory, which stipulates that any transient has limited duration.
2) Always developed as stable Bounded Input, Bounded Output (BIBO).
3) It is possible to develop a desired magnitude response having linear phase response.

In Figure 4, the structure of an FIR filter can be seen.

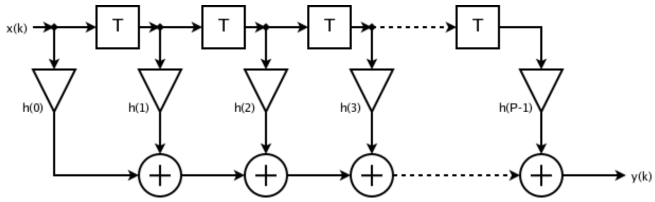

Figure 4.Structure for developing a digital FIR filter.

V. FILTER OR FIR IIR

The decision to evaluate which filter is the best for the application, i.e., whether to use an FIR filter or an IIR filter, is directly connected to project-specific features. FIR filters have linear phase response, which implies that no phase distortion is produced in the filtered signal. This feature is important in applications such as audio and image processing, biomedicine and data transmission (26).

FIR filters are developed in non-recursive mode, thus they are always stable. This characteristic cannot be guaranteed for IIR filters. The effects of finite precision and quantization errors are less severe for FIR filters (27).

IIR filters generally require less coefficients than FIR in order to meet the same design specification. A lower order filter has a shorter runtime. Analog filters may be converted to IIR digital filters fairly easily. In general, one can use an IIR filter when the largest relevance is a very selective response in the frequency domain, or when the implementation an analog filter is required. FIR filters may be used when the number of coefficients is not very high (FIR structure stability is guaranteed), and especially when the desired phase distortion is small (28).

VI. DESIGNING DIGITAL FILTERS

Digital Filter designs consist in determining a transfer function that fits the frequency response specifications

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required for a particular project or application. Within filter applications, elements with well-defined characteristics exist:

1) Low-Pass Filter (LPF).
2) High-Pass Filter (HPF).
3) Band-Pass Filter (BPF).
4) Band-Stop Filter (BSF).

Impulse responses to the ideal transfer functions are not digitally achievable given that they have infinite length and are not causal. For FIR filters, one approach used is the truncation of the impulse response of ideal filters (29).

For IIR filters, it is possible to map transfer functions originally designed to analog filters to the z domain.

VII. APPROXIMATION FOR FIR FILTERS

For implementing a filter, it is necessary to develop from its transfer function, as shown in Equation 7.

$$H[z] = \sum_{n=-\infty}^{\infty} \mathrm{h[n]} z^{-n} (7)$$

However, its behavior is best characterized as a function of its frequency response as shown in Equation 8.

$$H[e^{j\omega}] = \sum_{n=-\infty}^{\infty} \mathrm{h[n]} e^{-j\omega n} (8)$$

Whereas $h[n]$ can be shown by Equation 9.

$$h[n] = \int_{-\pi}^{\pi} \mathrm{H}(e^{j\omega}) e^{j\omega} d\omega (9)$$

With these determinations, $H(e^{j\omega})$ and $h[n]$ pairs are obtained for ideal filters shown in Table 1.

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Filter type	Response magnitude $\lvert H(e^{j\omega})\rvert$	Impulse response $h[n]$
LPF	1 for $0 \le \lvert\omega\rvert \le \omega_c$ 0 for $\omega_c < \lvert\omega\rvert \le \pi$	$\frac{\omega_c}{\pi}$ for n = 0 $\frac{1}{\pi n}\text{SIN}(\omega_c\, n)$for n 0≠
HPF	0 for $0 \le \lvert\omega\rvert \le \omega_c$ 1 for $\omega_c < \lvert\omega\rvert \le \pi$	$\frac{\omega_c}{\pi}$ for n = 0 $-\frac{1}{\pi n}\text{SIN}(\omega_c\, n)$ for n ≠ 0
BPF	0 for $0 \le \lvert\omega\rvert \le \omega_{c1}$ 1 for $\omega_{c1} \le \lvert\omega\rvert \le \omega_{c2}$ 0 for $\omega_{c2} < \lvert\omega\rvert \le \pi$	$\frac{\omega_{c2}-\omega_{c1}}{\pi}$ for n = 0 $-\frac{1}{\pi n}[\text{SIN}(\omega_{c2}\, n) - [\text{SIN}(\omega_{c1}\, n)]$ for n ≠ 0
BSF	1 for $0 \le \lvert\omega\rvert \le \omega_{c1}$ 0 for $\omega_{c1} \le \lvert\omega\rvert \le \omega_{c2}$ 1 for $\omega_{c2} < \lvert\omega\rvert \le \pi$	$1-\left(\frac{\omega_{c2}-\omega_{c1}}{\pi}\right)$ for n = 0 $\frac{1}{\pi n}[\text{SIN}(\omega_{c1}\, n) - [\text{SIN}(\omega_{c2}\, n)]$ for n ≠ 0

Table 1. Characteristics of ideal filters.

With Table 1 specifying the response behavior in magnitude and the impulse response, one is able to check the behavior of LPF, HPF, BPF and BSF filters respectively in Figures 5, 6, 7 and 8.

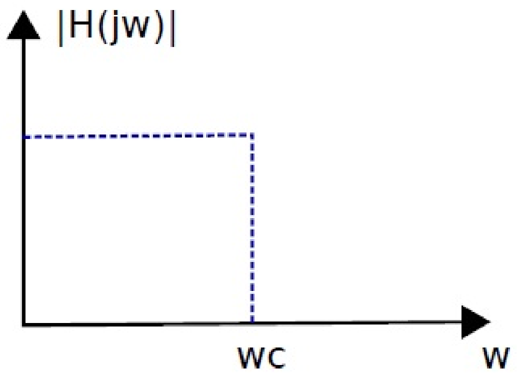

Figure 5. LPF behavior in the frequency domain.

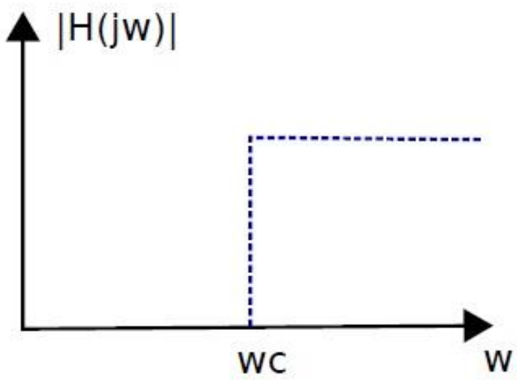

Figure 6. HPF behavior in the frequency domain.

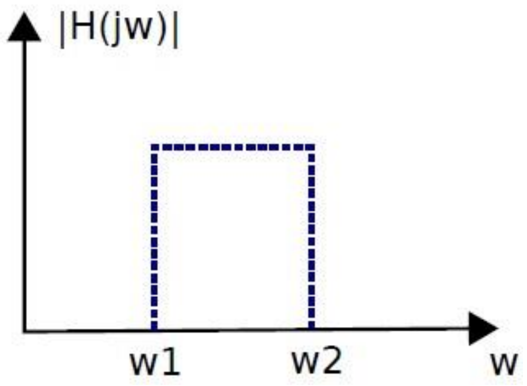

Figure 7. BPF behavior in the frequency domain.

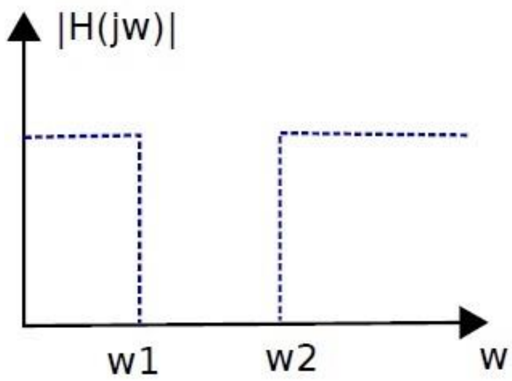

Figure 8. BSF behavior in the frequency domain.

VIII. APPROXIMATION FOR FIR FILTERS BY USING WINDOW FUNCTIONS

One way to have a better performance and overcome limitations inherent to the realization of the impulse response function $h[n]$ of ideal filters is to define an auxiliary sequence $h'(n)$ having a finite length of order M as described in Equation 10.

$$h'(n) = \begin{cases} \{H[n]W[n], & |n| \le \frac{M}{2} \\ 0, |n| > \frac{M}{2} \end{cases} \quad (10)$$

The obtained response, despite having finite length, is not causal. However, it can be transformed into causal by multiplying by $z^{-M/2}$, without distorting the magnitude response and without destroying the linear phase property. Sequence $w[n]$ is known as the "window function" (30).

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IX. FIR FILTERS USING WINDOW

The central idea of digital filter design by using windows is to select a suitable filter having an ideal frequency (which is always non-causal and has infinite impulse response) and then truncate its impulse response in a window in order to get a causal FIR, linear phase filter. Considering an ideal low pass filter $Hd(e^{jw})$ having magnitude 1 and linear phase with a pass band and zero response at the cutoff band, as seen in Equation 11 (31):

$$Hd(e^{jw}) = \begin{cases} 1.e^{-j\alpha w}, & |W| \le W_C \\ 0, W_C < |W| \le \pi \end{cases} \quad (11)$$

The impulse response of this filter is infinite, given by Equation 12 and 13.

$$hd[n] = \mathcal{I}^{-1}[H_d(e^{jw})] = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(e^{j\omega})e^{j\omega}d\omega (12)$$

$$hd[n] = \frac{1}{2\pi}\int_{-\omega_c}^{\omega_c} 1.e^{j\omega}\ e^{j\omega}d\omega = \frac{sen[\omega_c(n-\alpha)]}{\pi(n-\alpha)} (13)$$

In order to obtain a causal linear phase FIR filter $h[n]$ of length M, as shown in Equation 14.

$$h(n) = \begin{cases} h_d[n], & 0 \le n \le M-1 \\ 0, & else \end{cases} \quad (14)$$

Where α is represented by Equation 15.

$$\alpha = \frac{(M-1)}{2} (15)$$

This operation is called windowing. In general, $h[n]$ may be characterized by the product of $H_d[n]$ in a window $w[n]$ as shown in Equation 16.

$$h[n] = H_d[n].w[n] (16)$$

Where $w[n]$ is a symmetric function with respect to α within the range $0 \le n \le M-1$, with zero being absent from this range. It is useful to mention that, depending on how $w[n]$ is obtained, different filter techniques can be obtained as shown in Equation 17, defining a rectangular window (32).

$$w(n) = \begin{cases} 1, & 0 \le n \le M-1 \\ 0, & else \end{cases} \quad (17)$$

Thus, it is necessary to define a finite $h[n]$ sequence for the digital filter from $H_d[n]$. The Fourier transform is a discrete sequence in time, whereas $H(e^{jw})$ is continuous. The causal FIR filter $H(e^{jw})$ response is obtained in the frequency domain by the convolution of $H(e^{jw})$ and the window response $W(e^{jw})$, as shown in Equation 18.

$$H[e^{j\omega}] = H(e^{jw}) * W(e^{jw}) = \frac{1}{2\pi}\int_{-\pi}^{\pi} W(e^{j\omega})H_d(e^{j(w-\lambda)})d\lambda (18)$$

X. DISTORTION REDUCTION WITHIN WINDOW IN AN FIR FILTER WITH POLYNOMIAL APPLIED IN RADIANS

The distortion reduction within the window performed in a filter is an important factor with regards to rejection of unwanted points in present lobes, which are not acceptable beyond the main lobe; this is because they represent frequencies that are not required for that filter. As the number of M coefficients increases, the width of each sidelobe decreases, but the area over them remains constant. This causes ripples to experience peaks near band edges. This fact is referred to as "*Gibbs Phenomenon*."

In order to perform the proposed distortion reduction within one window out of the many applicable, adaptation of the window equation is necessary; in this article, the window used is the Hamming window shown in Equation 19, where n is equal to the current filter coefficient and M is the total number of coefficients.

$$w[n] = 0{,}54 - 046\cos(\tfrac{2\pi n}{M}) (19)$$

The 2π factor represents the entire spectrum of radian axes. The technique enables the inclusion of new points to the windowing; this occurs by dividing the 2π radian spectrum into smaller points in order to obtain a more efficient filter. This takes place with the implementation of an n-th polynomial applied to 2π, in addition to the 0.46 factor in order to maintain linearity. In Figure 9 and 10, respectively, the full radian axis and the division of the total radian spectrum can be viewed (33).

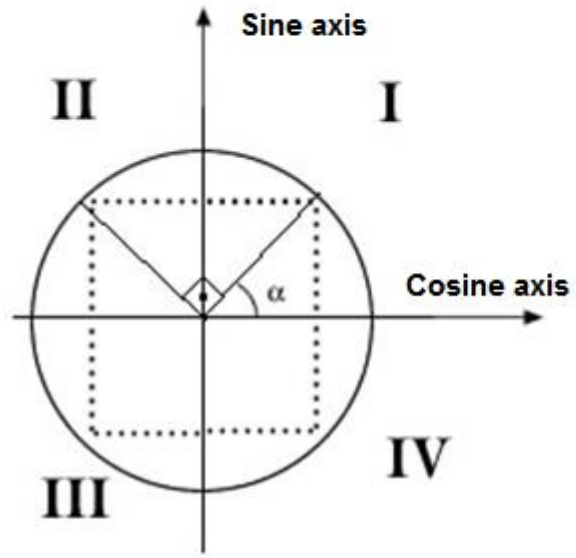

Figure 9. Full 2 π radian spectrum.

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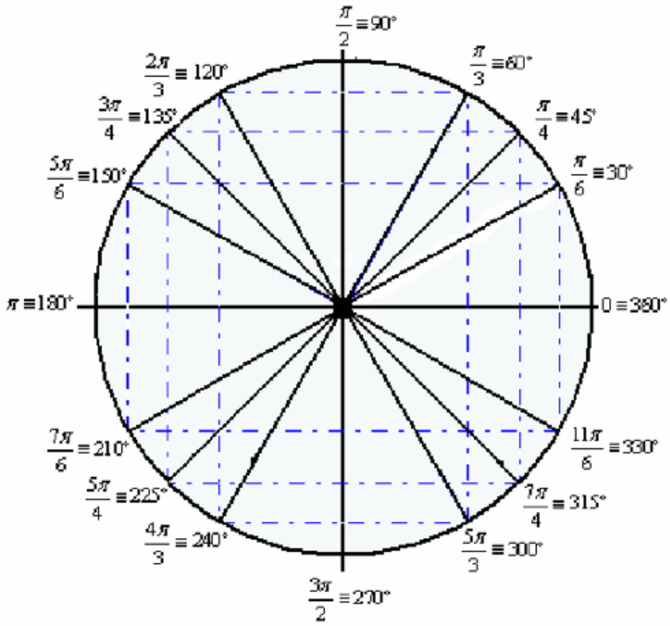

Figure 10. Full 2 π radian spectrum divided into smaller points.

The central focus of this process is to minimize the effect of lower lobes not included in the cutoff frequency determined within the system, which consists of the sum of window $w[n]$ in a polynomial having factor *nx-1* for $nx \leq 1$. The described implementation can be seen in Equation 20.

$$w[n] = [0{,}54 - 0{,}46^{nx-1}\cos(\frac{2^{nx-1}\pi n}{M})]$$
$$+[0{,}54 - 0{,}46^{nx-2}\cos(\frac{2^{nx-2}\pi n}{M})]$$
$$+ [0{,}54 - 0{,}46^{nx-3}\cos(\frac{2^{nx-3}\pi n}{M})]$$
$$+[0{,}54 - 0{,}46^{nx-mx}\cos(\frac{2^{nx-mx}\pi n}{M})] \quad (20)$$

Equation 20 describes the sum of a polynomial applied to $w[n]$ applied to a Hamming window as an example.

In Figures 11 and 12, respectively, the driving windows can be seen in the time domain, applied to Equation 19 and 20, respectively.

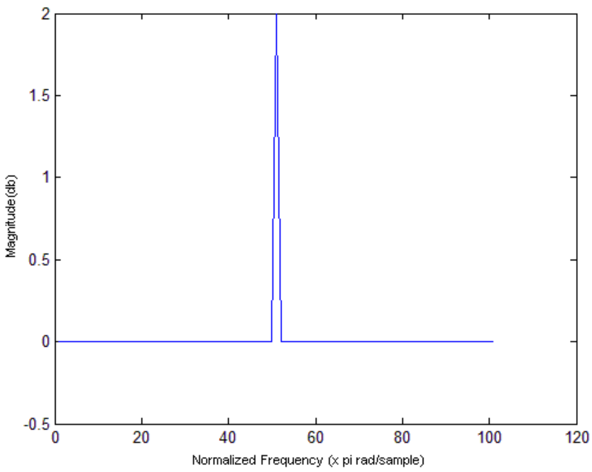

Figure 11. Conduction window in the time domain without changing w[n] (Equation 19).

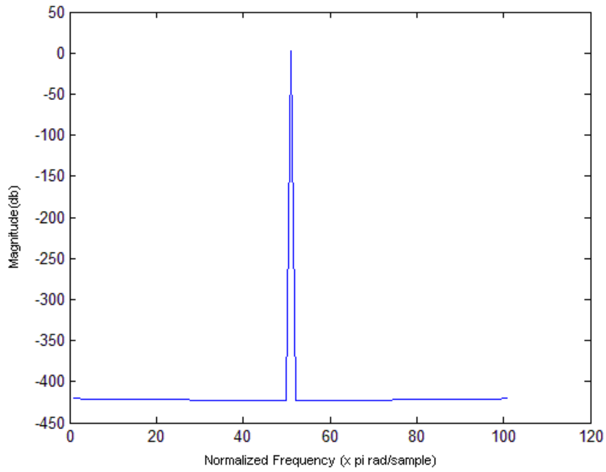

Figure 12. Conduction window in the time domain when changing $w[n]$ (Equation 20).

By applying the discrete Fourier transform, one is able to verify the behavior of both implementations in the frequency domain. In Figure 13, the filter behavior in the frequency domain can be seen; it is possible to check the pass region and cut-off frequency as a function of system specifications. One can also verify peaks at band regions, or "*Gibbs phenomenon*" (34).

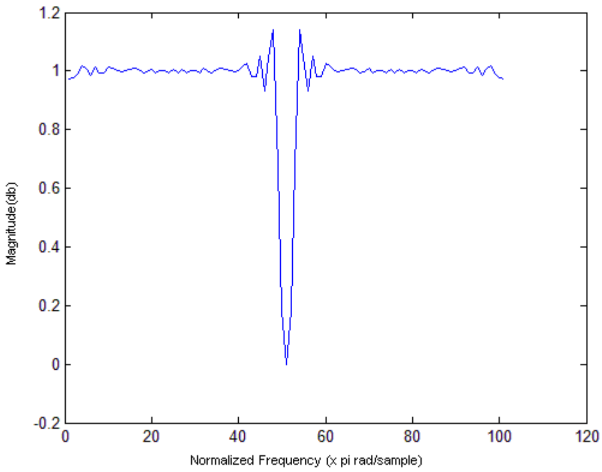

Figure 13. Filter having Hamming window in the frequency domain, with $w[n]$ unchanged.

In Figure 14, the filter behavior in the frequency domain can be seen, with a pass frequency region better defined at its cutoff frequency, as well as the reduction in "*Gibbs phenomenon*" effects, where it is present in the lower than zero region, so that, by applying the modulus, this phenomenon will be eliminated.

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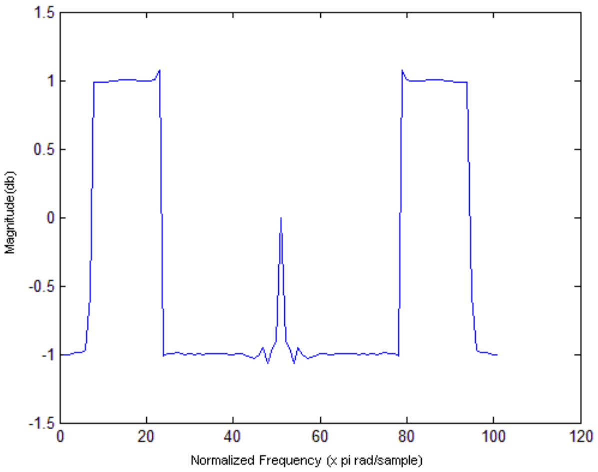

Figure 14. Filter having Hamming window in the frequency domain with changes in $w[n]$.

XI. EQUATION APPLICATION IN THE TIME DOMAIN

The development of a low pass filter with Hamming window computationally consists of the implementation of a "First In - First Out", wherein its coefficients are accumulated in the time domain and multiplied by the calculated filter coefficient. The example shown in Figure 15 consists of a low pass filter having Hamming window, with a cutoff frequency of 1Hz and 100Hz sampling rate. To that filter, 136 coefficients are applied to a signal that emulates a harmonic developed by using an approximation sequence of the number π.

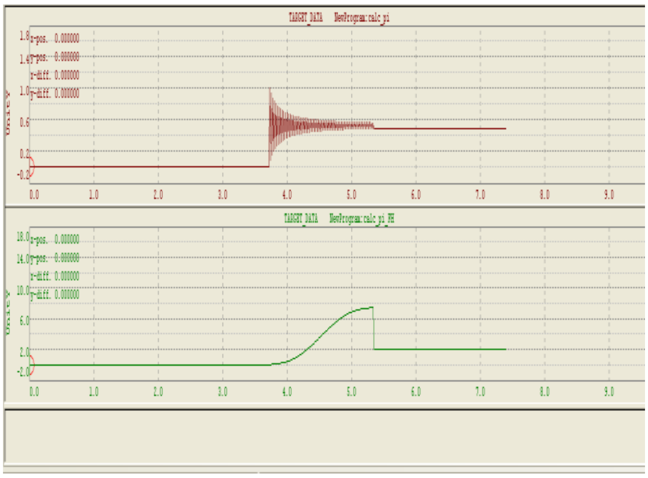

Figure 15. Filter having Hamming window in the time domain.

Figure 16 shows the same computational implementation mentioned in Figure 14 with the modification of the coefficients calculated in accordance with Equation 20 (modified Hamming - Bimbi). This will demonstrate the increased linearity and speed of convergence to the target point.

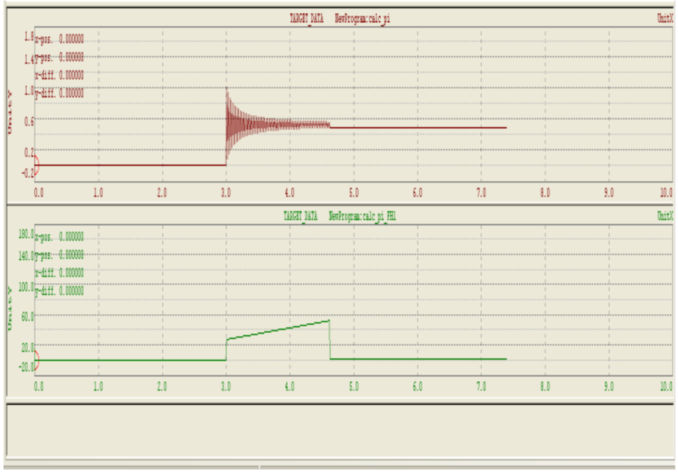

Figure 16. Filter having modified Hamming window in the time domain.

XII. CONCLUSION

The inclusion of a modification in Equation 19, turning it into Equation 20, provides benefits in the implementation of digital filters having windowing, which one is able to verify in the plots shown in Figures 13 and 14 with respect to the frequency spectrum, in addition to a reduction of the "Gibbs phenomenon". The minimization of spurious frequencies with the polynomial calculation within the filter window minimizes the passing of spurious frequencies and enables the reduction of the number of coefficients applied; this aspect computationally reduces processing time in what we envision as dynamic systems that require limited time, such as dynamic measurement systems. From a time domain point of view, one can verify the increase in response time and linearity with regards to the faster convergence of the obtained reading towards the actual value to be measured, thus removing spurious frequencies from these samples.

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High Dynamic Range Content in ISDB-Tb System

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High Dynamic Range Content in ISDB-Tb System

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***Abstract*—Nowadays, the industry is discussing the different requirements for High Dynamic Range television systems. There is no global standard of HDR Content Broadcast yet, which opens countless opportunities for global consumer's electronics in the future. For this reason, we propose an efficient use for Broadcast with backwards compatibility considering to actual standards. Additionally, each processing stage within a broadcast environment is further discussed, considering its limitations. Further objective measures are presented, evaluating different HDR tests.**

***Keywords*—Broadcasting; High Dynamic Range; ISDB-Tb; Video System.**

I. Introduction

Since the Television birth, the need of transmission of the more realistic scene-referred has always been a challenge in broadcasting service. New technologies and studies have been developed along the last twenty years, as the evolution of the display technology, the advance of broadcast digital television, faster algorithms in the video processing field, and the newest proposals on perceptual coding area. As result, the consumer's electronics demand better user experience and new multimedia content.

High Dynamic Range Content Transmission is the next-hop technology that must be provided to consumer's electronics to reach a better user experience. This technology involves many stages, since capturing, post-processing, coding, and transmission. Each stage may need the development of new standards, digital interfaces, and metadata to ensure the interconnection between different brands. Some industry proposals have been presented along the last years. The BBC and NHK have combined their approaches, the Dolby Labs-Dolby Vision, the Philips, the Samsung, and the Technicolor proposals are well explained in [1], but official global HDR Standard has not been published by the ISO or the ITU.

This paper discusses the possibilities and limitations of Broadcast HDR Content, using the state-of-the art about this subject. Some proposals could be implemented on Broadcast System, reaching better subjective quality and ensure backward compatibility with the actual system.

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The remainder of this paper is organized as follows; Section II presents fundamental concepts of HDR technology, the features of actual broadcast transmission and its limitations. Section III describes the laboratory experiments. Section IV describes the results of objective measurements and Section V the conclusions of the paper.

II. Fundamental concepts

This section describes the fundamental concepts of HDR Technology, as well as the principal topics in terms of brightness and color. First of all, is important to differentiate four important terms that generates confusion. *Luminance, "Y"*, is a linear-light quantity; proportional to physical intensity weighted by the spectral sensitivity of human vision and is expressed in units of cd/m^2 ("nits"). *Lightness* is a non-linear transfer function of luminance that approximates the perception of brightness. This last word, *brightness*, is the attribute of a visual sensation according to which an area appears to exhibit more or less light, but cannot be measured. *Luma Samples* has a symbol *Y'*, and is an approximation of lightness and indirectly related to the relative luminance, form part of the *Y'Cb'Cr'* Color Model. [2].

When is referring to Hygh Dynamic Range of human vision, the correct measure is the luminance. Human vision operates between [100μ -10k] nits and regular TV display operates between [0-100] nits as showed in Fig. 1. According with this idea, the concept of contrast ratio is very important and much discussed topic in HDR displays technology. This factor is the ratio of luminance of the lightest and darkest elements of a scene, or an image, in practical terms, is the brightness difference between white and black. The human perception judged sharper an image reproduced with high simultaneous contrast ratio than another that has higher measured spatial frequency content.

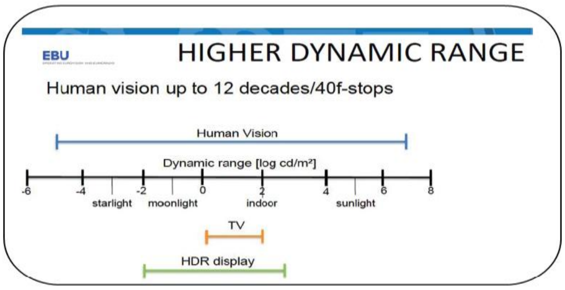

Figure 1 Hygh Dynamic Range

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In accordance with the colorimetry, CIE XYZ tristimulus values form the mathematical coordinates of color space. Each color can be specified by these tristimulus against to its spectrum. CIE 1931 chromaticity diagram represents all the possible colors that a human eye can perceived [2]. Each color is a coordinate in the chromaticity diagram as showed in Fig. 2, actual color space recommendations are just a part of the entire gamut. However, there are enhanced approaches such as the Rec.2020 [3] compared to the Rec.709 [4] in terms of gamut. An intermediate color space is the DCI P3 that is used for digital movie projection from the US-American film Industry [5]. The Rec. 709 is commonly used in broadcast transmissions, and form part as MPEG video Standards, such as H.264 [6] and H.265 [7]. HDR technology uses the concept of Wide Color Gamut to represent a color from a scene-referred into a display-referred reliably.

Transfer Function of Tristimulus values responds to physical matter that occurs between the luminance values and human perception. It is demonstrated that luminance is a linear-light quantity and linear-intensity, but has a non-linear response with respect to human perception [2]. Thus, displaying the XYZ linear-values would have a negative subjective perception. Besides, the quantization of this type of material would be inefficient and of worse quality.

Perceptual uniformity is the process of linearize the luminance with respect to human perception; it is when the concept of lightness is created. This idea is based on the property of human contrast sensitivity, which is the ratio of luminance between two adjacent patches of similar luminance [2]. The first correction of luminance values widely adopted is gamma [8], which takes advantage of nonlinearity of the oldest display's CRT.

Perception is the act of extracting meaning from noisy and uncertain sensory signals, many studies have been proposed in the academic community such as [9] that is a human-perception oriented research. One of their advantages is related to the Perceptual domain because is an optimal balance between brightness and coding. For this reason, new standards have proposed new Electrical-Optical Transfer Funcion (EOTF) that works better for actual HDR TV displays and some of them have backward compatibility with regular TV display, as in the case of HLG (Hybrid Log Gamma) [1]. The next proposal is the standard SMPTE ST-2084 [10], called PQ-TF. This was developed following the contrast sensitivity function of the human eye as measured by Barten [11]. This system along with metadata can reach backward compatibility in terms of color space, transfer function, white points, and dynamic ranges devices. Another EOTF proposal is done by Philips [1], which follows the Barten curve more smoothly. Phillips proposes its own end-to-end transfer characteristic. However it still is not a universal standard or the only one proposal, quite to the contrary, may be necessary a system with end-to-end compatibility. For example an end-to-end Dolby System, with PQ-TF, DCI P3 colour primaries and 5000 nits as peak luminance can be compatible with 100 nits displays and Rec.709 color gamut, or with 1000 nits displays and HLG Transfer Function.

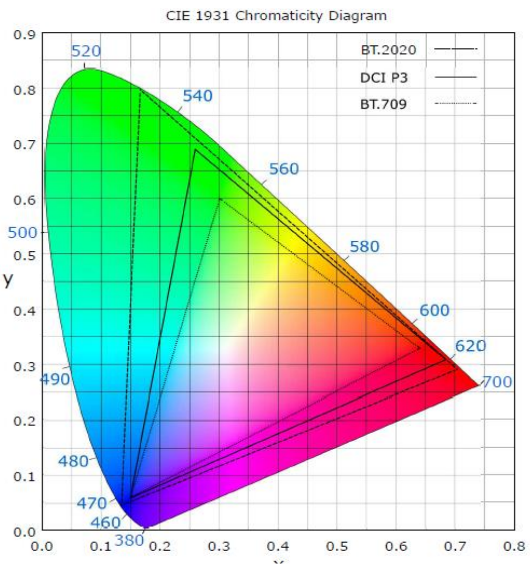

Figure 2 CIE 1931 Chromaticity Diagram

There are many possibilities, because nowadays there are many sorts of TV displays, the SDR-SDTV such as the CRT Television, the SDR-HDTV, such as LCD or Plasmas, the SDR-UHDTV, such as LED, the HDR-UHDTV, such as SIM2 [12], for content producers, and OLED for end-users, hence that the future global standard of HDR Content Broadcast Transmission should be manageable and to be designed to the user, ensuring the perceptual rendering intent.

The Broadcast Transmission of digital television is a distinctiveness service that has a large coverage and robustness against the noise. There are four digital television standards mostly used in the world, ISDB-T (Integrated Services Digital Broadcasting or ISDB-Tb, a Brazilian adaptation, ATSC (Advanced Television System Committee), DVB (Digital Video Broadcasting), and DMB (Digital Multimedia Broadcasting). These have been successfully implemented in different countries over recent years. Differences between them are subject to modulation, video codec, and mobility. The last one parameter is implemented with success in ISDB-Tb System, whose main core is the orthogonal frequency domain modulation (OFDM). However broadcast digital television systems are not very flexible respect to scalability, because a Set-top box (STB) is necessary to decode the digital signal and in most cases is not reconfigurable and have limited Profiles and Levels in terms of video codec, bit depth, color model, color space, and digital interface. Due to this, HDR Technology should have the capacity of interact with actual broadcast system and future HDR Systems, as in the past was the color television system with respect to black-and-white television system in the beginnings of broadcast transmission. Each step in the evolution of television always has been thought to have a backward compatibility with old systems.

The actual ISDB-Tb system or the transmission of LDR (Low Dynamic Range) Content has its own features, considering the high definition content. It uses a gamma EOTF, a Rec.709 OETF, sometimes Rec.2020 OETF it is applied, but these are very similar, Rec.709 Color Primaries, and cover display luminance from [0-100] nits. According to the bit depth, it only allows 8 bit encoding, and a H.264 codec with the following constraints: High/Main Profile and Level 4.0. Theoretically, LDR has limited color gamut and even more limited dynamic range.

Consistent with the above explanation, it is clear that is required additional information to allow different conversions, such as color space conversion, tone mapping operation, Transfer function Conversion, color management, white point conversion, and dynamic range devices

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information for interacting between different displays with different nits (luminance).

This paper proposes an efficient Broadcast use for HDR with backwards compatibility considering to actual standards and the limitation of the actual LDR system.

III. LABORATORY EXPERIMENTS

For the laboratory experiments, Test Sequences from [13] is used. It is important to note that the capture's process key is to record as much f-stops dynamic range. The resultant data sequences are stored in TIFF files, using the PQ-TF perceptual coding. In Table I, shows the principal details of each Test Sequence and Fig. 4 shows each one of them.

TABLE I. TIFF FILES

Sequence	*Fps*	*Resolution*	*Color Primaries*	*Min-Max luminance (nits)*
ShowGirl2Teaser	25	1920x1080	DCI P3	0.005-4000
FirePlaceTeaser	24	1920x1080	DCI P3	0.005-4000
BeerFestTeaser	25	1920x1080	DCI P3	0.005-4000

According to the Call For Evidence (CfE) proposed by the ISO group of study [14], the processing of the HDR Test Sequences requires two types of processing to code and decode each sample, the pre and the post processing. The Preprocessing process consists of the following steps:

- Conversion from TIFF to EXR format.

- Apply the PQ-TF on the input video, to work at perceptual domain.

- Conversion of non-linear tristimulus to non-linear color space *Y'Cb'Cr'*.

- Quantization data from 16 bit floating-point to ***Bit Depth (8 or 10 bits)***.

- Finally, Chroma downsampling from 4:4:4 to 4:2:0 is applied on the input video.

The post processing is done in a similar way to the preprocessing, but in reverse. The last process is to apply inverse PQ-TF as shown in Fig. 3. The software 'HDRtools' was used to perform each process [15]. The entire system is shown in Fig. 3.

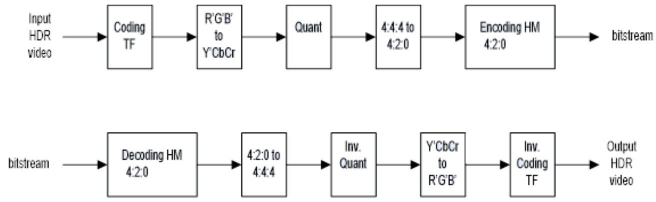

Figure 3 HRD Preprocessing and PostProcessing

The process of quantization from 16 to 8 or 10 bits uses the *clipping* process to quantize from 8 to 16 bits as well as the inverse process. The conversion from TIFF to EXR format is done because, this format are the 'digital negative' in the HDR environment, because their samples are in linear-response respect to intensity, this means that it stores the luminance values from the source in comparison to the TIFF Format, who stores the samples after the perceptual encoding, in this case, PQ-TF. Thus it has non-linear samples but a linear-response with respect to human perception.

To backward compatibility with the actual LDR System is important to keep using the Profile and Level allowed in actual ISDB-Tb. The principal parameters are summarized in the Table II. To simulate the stage of encoding 4:2:0, the JM 19.0 H.264/AVC reference [16] software is used.

TABLE II. AVC/H.264 PARAMETERS

Profile	Main/High
Level	4.0
Chroma Format	4:2:0
Bit Depth	8
Resolution	HDTV (1920x180)
Coding	Frame
NumberBFrames	2

The goal of the tests is to simulate all the processing stages according to the Fig. 3, taking into consideration the ISDB-Tb constraints, well explained in the fundamental concepts, using different QP (Quantization parameters) for H.264 video codec: 20, 22, 24, 28, 32, 36, and 40 and measure objectively difference between Output HDR content respects to the HDR Source. Additional to these results, a 10 bit coding system is used to compare with the 8 bit depth setting.

For a fair comparison, the color primaries used in the laboratory experiments is obtained by the Rec.2020. As it stated above, the Rec.709 is the mostly used at the ISDB-Tb system [17], but it is assumed that it might be a conversion process at the decoder level, which transforms from Rec.709

TABLE III. 8 BIT CODING SYSTEM

HDR Test Sequence	QP	Bit-Rate (Mbps)	Min-BR (Mbps)	Max-BR (Mbps)	m-PSNR	t-PSNR XYZ	tOSNR XYZ	PSNR DE100	PSNR MD0100	PSNR L0100
ShowGirl	20	11,53	5,02	18,87	31,29	42,15	39,64	36,29	21,91	40,95
	22	7,17	3,85	11,30	30,84	41,59	39,11	36,11	21,72	40,52
	24	4,63	2,91	7,05	30,44	40,95	38,49	35,84	21,52	40,05
	28	2,58	1,46	3,97	29,46	39,44	36,71	34,90	21,38	39,10

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	32	1,53	0,80	2,39	28,34	37,72	34,99	34,15	21,22	37,97
	36	0,94	0,46	1,48	26,65	35,48	32,72	32,80	20,96	36,81
	40	0,58	0,27	0,91	25,20	33,34	30,78	31,89	20,65	35,57
FirePlace	20	14,59	13,19	16,62	31,10	38,66	35,37	34,73	22,22	40,15
	22	9,03	7,98	10,13	30,68	38,16	34,89	34,57	21,97	39,72
	24	5,81	4,89	6,62	30,26	37,61	34,36	34,37	21,79	39,30
	28	3,07	2,45	3,68	29,44	36,49	33,26	33,89	21,46	38,44
	32	1,72	1,32	2,17	28,40	35,21	32,04	33,25	21,36	37,46
	36	1,00	0,73	1,32	27,06	33,61	30,49	32,46	21,11	36,45
	40	0,57	0,40	0,79	25,72	31,93	28,90	31,77	20,74	35,35
BeerFest	20	9,98	5,52	11,49	36,74	43,18	40,66	37,72	21,79	42,82
	22	7,87	4,31	9,07	36,22	42,50	40,05	37,40	21,52	42,43
	24	6,02	3,29	6,97	35,50	41,61	39,24	36,95	21,19	41,94
	28	3,60	1,97	4,20	33,88	39,67	37,39	35,89	20,64	40,91
	32	2,12	1,20	2,52	32,27	37,75	35,57	34,94	20,24	39,76
	36	1,26	0,74	1,53	30,22	35,57	32,25	33,66	19,85	38,55
	40	0,72	0,45	0,91	28,61	33,67	31,38	32,82	19,51	37,29

TABLE IV. 10 BIT CODING SYSTEM

HDR Test Sequence	QP	Bit-Rate (Mbps)	Min-BR (Mbps)	Max-BR (Mbps)	m-PSNR	t-PSNR XYZ	tOSNR XYZ	PSNR DE100	PSNR MD0100	PSNR L0100
ShowGirl	20	10,63	4,53	17,58	31,56	42,41	39,60	36,55	22,06	41,16
	22	6,71	3,55	10,68	31,04	41,73	38,81	36,24	21,85	40,68
	24	4,40	2,73	6,74	30,55	41,01	38,09	35,88	21,69	40,17
	28	2,50	1,38	3,83	29,56	39,54	36,68	35,05	21,49	39,17
	32	1,50	0,78	2,34	28,43	37,77	34,99	34,21	21,37	38,02
	36	0,93	0,46	1,47	26,98	35,78	33,12	33,21	21,13	36,88
	40	0,57	0,27	0,90	25,49	33,57	31,04	32,37	20,78	35,60
FirePlace	20	13,48	12,06	15,45	31,25	38,82	35,57	34,87	22,35	40,26
	22	8,50	7,40	9,61	30,83	38,29	35,05	34,69	22,14	39,80
	24	5,54	4,65	6,35	30,43	37,75	34,52	34,48	21,87	39,36
	28	2,99	2,38	3,58	29,58	36,60	33,40	33,98	21,56	38,47
	32	1,70	1,30	2,13	28,59	35,34	32,19	33,38	21,44	37,49
	36	1,00	0,73	1,31	27,33	33,80	30,73	32,68	21,19	36,49
	40	0,56	0,40	0,78	26,04	32,12	29,17	32,05	20,78	35,37
BeerFest	20	9,34	5,01	10,82	37,08	43,50	41,10	37,96	21,80	43,05
	22	7,42	3,97	8,61	36,47	42,75	40,40	37,55	21,52	42,60
	24	5,72	3,07	6,64	35,72	41,80	39,53	37,07	21,20	42,05
	28	3,47	1,89	4,07	34,08	39,80	37,64	35,98	20,65	40,97
	32	2,08	1,16	2,48	32,44	37,86	35,77	34,99	20,26	39,81
	36	1,25	0,73	1,53	30,68	35,84	33,73	33,97	19,87	38,65
	40	0,72	0,45	0,90	29,03	33,90	31,81	33,16	19,53	37,33

(a) (b) (c)

Figure 4 HDR Test Sequences, (a) ShowGirl; (b) FirePlace; (c) BeerFest

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Color Primaries to Rec.2020 Color Primaries, ensuring the perceptual rendering and artistic intent. The objective measures have been successfully used in [18] and the software 'HDRTools' is also used to get the HDR Metrics.

IV. Results

Objective results for an 8-bit coding system, are showed in Table III for the three type of sequences, *ShowGirl, FirePlace and BeerFest* for different QP parameters. These values are acceptable according to [18], and have no noticeable distortions. It is clear when the QP value increases its value, the objective values (measured in dB) are lower and it is possible to evaluate the content as poorer quality, however the bit-rate could be optimal for situations when bandwidth is limited. It is important to note that encoding with 10 bits generates less bit-rate than 8 bits [19]. The difference between the best m-PSNR value and the worst m- PSNR value is 6.09 dB for *ShowGirl*, 5.38 dB for *FirePlace*, and 8.73 dB for *BeerFest* because they have different brightness and artistic intent.

When is tested the same process above, but with a 10 bit coding system, using the same test sequences, the objective results are showed in Table IV, the same behavior is repeated when QP increases as explained above, but the reason of this additional test is to measure if there is a great difference respect to a 8 coding system. Hence, according to the results, the difference oscillates between 0.2 and 0.3 dB. The main reason is well explained in [20], the minimal bits requires for no visible banding or artifacts depends on the source content, using the Just Noticeable Difference (JND) theory [21]. In this case, the 3 types of sequences have no difficult images and are adequate for a ISDB-Tb System.

An 8-bit system is still useful to send HDR Content with backward compatibility; however the use of extra-information could be a compatible option for darker images, better than moving to 10-bit system. Also, may be unaffordable and technically unfeasible in the short term.

V. Conclusion

In this paper, we have presented a proposal to adapt the High Dynamic Range Content with backward compatibility in the ISDB-Tb System. For this, we use the perceptual coding called PQ-TF [10]. As part of the validations, we evaluate the whole processing objectively, comparing the Output HDR content respects to the HDR Source in an 8-bit system with different QP. For higher QPs, the objectives results are acceptable and demonstrate a reliable system, reaching the possibility of taking advantage of the actual system. Additional comparison with a 10-bit system, demonstrates that for adequate source content, the objective difference are minimal and does not justify moving to that system.

Besides it is important to mention that the HDR full-user experience will depend on OOTF (Opto-optical Transfer Function), which has the function of applying the rendering intent of the content producer.

VI. Future Works

The development of a new universal standard to carry the information of transform function, peak luminance, white point or tone mapping operators to interact between distinct sort of displays, inside the SEI (Supplemental Enhanced Information) messages. Furthermore, test the HLG (Hybrid-Log Gamma) with the ISDB-Tb System for backward compatibility purposes and compare different EOTF's subjectively in different displays.

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News production by machines and ethics: possible implications

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News production by machines and ethics: possible implications

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***Abstract*— This article seeks to question the production of news by machines in the light of journalistic ethics. Justified such study by the importance of the issue for journalism, as well as to broaden the debate on this issue in Brazil. The methodology was an exploratory research from interdisciplinary bibliography in order to carry out a theoretical discussion. Among the results, we envision is a certain incompatibility robots to exercise ethics, given its original limitations.**

***Index Terms*— Ethics, News, Machines, Journalism.**

I. Introduction

JOURNALISM has taken an important space in society for many years. Since the emergence of the first mass vehicles in the 19th centrury, the press performs a fundamental work to the democracy consolidation. In Brazil case, the emphasis is over the period of military dictatorship, from 1964 to 1984, when the repression against the journalistic work was more accentuated. Countless authors such as Kushnir (2004) [13] and Markun (2005) [15], with several academic papers, got down to the issue of brutality of the totalitarian regime and how much the resistance of some jornalists was essential to the downfall of the military from power and the return of the popular will on choosing the rulers.

However now, a day's journalism has been suffering questionings not only about the shifts in form, technique and productions of the news but also on its own future of the practice of social mediation. It was what made it possible for one of the most striking changes on journalism history: the use of machines on the news production For being a recent reality, this fact still generates controversy and a lot of doubts. Among them, if there are limits in this relationship, if the journalism practiced by a machine has the same value as made by a man and if that is ethical. This article does not have the expectation to respond satisfactorily to all these questions, but it aims to shed lights on some issues. To accomplish these discussions, this text will make use of the fundamental contributions of the scientists like Turing (1948) [20], Von Neumann (2006) [16], Wiener (1950) [21], and authors such as Gleick (2013) [11], Abbagnano (2007) [3], Bucci (2000) [5], Abramo (1988) [4], Rachels (2004) [18] and Allhoff (2007) [2]. This study is characterized by a theoretical-exploratory research, which saw an epistemological discussion on ethics and journalism.

II. Theoretical Framework and Discution

A. Ethics

Ethics is the Conduct Sciences that discusses how the man relates to the society. Then it studies the values and principles of human behavior. The etymologycal word formation leads to two lines of ethics study. The first, called philosophic has a normative character and tries to stablish the universally valid principles for a good life in society. About it, we discuss an ideal universal moral. The second line of study, called scientific ethics, has explanatory character and tries to understand the historical morals on a reflection about the habits. At this point arises the morals study (RACHELS, 2004) [18].

Bucci (2000) [5] complements the idea of two facets of ethics that one sits on an individual and its conduct, and the other on society. After a brief explanation of the theoretical bases of the two chains, differentiating the normative ethics, which he attributed to Kant the greatest exponent, of the more general ethics, whose one of the representatives would be Espinosa, Bucci argues that the way of acting of each person will determine the ethical behaviour. Abbagnano's dictionary of philosophy (2007) [3] summarizes ethics, much like a synthetic science of conduct, which would be guided by standards derived from the man himself, the result of his rationality, or precepts of which he obeys. Japiassú and Marcondes (2001) [12], however, address the ethics under a more practical bias. . The authors stated that the ethics does not approach the morals as the latter would be in charge of creating regulations. For them, while ethics would be in a more phylosophic-reflexive level, moral would deal with the day by day dilemmas faced by the man. Thus, the authors approach the utilitarian ethics or applied ethics to journalism.

Bucci has a very critical stance in relation to the role of the mass media, preponderantly to Rede Globo de Televisão. Stance corroborated by a significant share of the Academy. Hegemony and domination on the part of this debate, the professor argues that since the Universal Declaration of human rights, 1948, there is the indefeasible right to freedom of opinion and expression. The declaration, along with the article five from the Constitution of Brazil provides broad and unrestricted access to information. In this way, the media have an obligation to serve the public with fairness and accountability, virtues that would help the exercise of ethics of the companies and professionals who work for them. The former Ethics Carlos Alberto Di Franco makes passionate

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defense of the quest for profit on the part of the communication companies and heavily criticizes the ethics scholars above business interests. Di Franco reverses the order by stating: "making money with information is an offence. It is an ethical duty "(1995, p. 35) [7]. However, just after he adds: "I am not, obviously, defending an utilitarian ethic. It has a value in itself and should be practiced regardless of profit. However, ethics and profit, in the media, should not be antagonistic realities "(1995, p. 35) [7].

The code of ethics of Brazilian Journalists is definite to treat possible interference in the production of news with disrespect. At the very first article the code says "access to public information is a right inherent in the life condition in society, which cannot be prevented by any kind of interest" (CÓDIGO DE ÉTICA, 1987) [6]. Another defender of ethics is the respected journalist Cláudio Abramo. He doesn't make a distinction between the ethics of the company and the employee. For him, there is the joiner ethics. Abramo confesses a deep taste for joinery and states that there are not two different ways to act when it comes to ethics. On the contrary, for him it is erroneous to expect a different conduct just because the person is a journalist, since there is no difference between the professional who produces news and citizen who reads news. "In journalism, the boundary between the professional as a citizen and as an employee is the same in any other profession. (...) The ethics of a journalist's ethics. What is bad for the citizen is bad for the journalist "(ABRAMO, 1988, p. 109) [4].

Abramo argues further that journalists should require ethics from the companies with regard to the processing with the class and not in relation to the public reader, viewer or listener. Totally contrasting opinion with Bucci, which calls it "alien" the posture of many journalists who refuse to discuss the media’s modus operandi. "It's like the press proclaiming: my job is to inform the public, but my values are not in dispute, my methods of account of anyone else – they are good, correct and fair by definition" (2000, p. 39) [5]. It is interesting to note, however, that the writing and style Manual of the prestigious newspaper O Estado de S. Paulo does not mention how the journalists should proceed in their profession. The journal brings only the entry "internal Ethics" in the Manual, which brings several guidelines on standards of writing, for example, what is the correct way to a journalist refer to different newspaper O Estado (MARTINS FILHO, 1997) [14].

B. Journalism and Machines

Figure until recently common in science fiction movies or books, the machines are taking over more and more functions typically human. One is journalism (EMPRESA, 2012) [10]. A robot can be defined as an mechanical system integrated of rigid, articulated sets between themselves and claw or device specialized served to perform complex or high-risk activities for man in processes (ORTEGA; SPONG, 1989) [17]. Although it seems very far from the reality of the newsrooms, a lot of changes have been in progress. If in the industry, in General, the robot does not approach the intellectual work of producing a text, Ortega and Spong (1989) [17] feature the machine in a way closer to the daily life of a journalist. For them these objects are built to handle materials, parts, tools, or specialized devices through variable programmed motions for the performance of various tasks. This means that when a software produces a text from statistics collected during a football match, for example, is conducting a routine for which it was programmed by handling materials, in case the game numbers.

In this way, it is possible to have a glimpse of the reasons why some companies are already adopting information producing machines in the production of news and why this is a very likely trend for the future. From the point of view of the management strategy for companies, is quite advantageous to replace human labor by machinery. The most visible is on high risk activities, preventing the real risk to the health of workers. However, in intellectual activities there are also several benefits, including lower costs and optimization of the production process. If until recently the employment of machinery was subject to the execution of specific tasks in the production process, such as painting or handling of objects, recently the using of robots moved also into intellectual works (TACHIZAWA et al., 2009) [19]. These, in turn, became ubiquitous in contemporary society, being one of the latest areas to step into journalism. For now, the machines are present, often through the production of textual reports, notably in the sport and economics editorials. 2011 dates the beginning of that process, but recently the practice has spread substantially

This practice has been raising heated debates between supporters and detractors of the practice. In the United States the blog Journalism in the Americas, from the University of Texas at Austin, brought up several clashes between researchers, journalists, politicians and legal experts on the ethics surrounding the use of remote devices for gathering information. A post in 2013 listed several initiatives that are academic debating new ways of doing journalism without human intervention. The Robotic Journalism Lab of the University of Nebraska-Lincoln's, for example, built unmanned aerial vehicles (UAV), known as drones, to perform reporting. The Missouri School of Journalism, information technology program at the University of Missouri, and the station of national public radio (NPR), KBIA launched a project in partnership that provides for the use of drones to carry out scientific investigative reports.

Proponents of these projects have argued that the use of these machines is something inexorable, reducing the media companies costs, already quite battered by internet competition. In addition, journalists and researchers defend the use of machines in locations of difficult access for humans, which would benefit with more complete reports. The detractors, as politicians and legal experts, are questioning this practice by the absence of legal provisions governing the sector. Without standards, they argue, these experiences should not be carried out (DYER, 2013) [9].

In Brazil the ethical discussions are also gaining prominence, especially, about the responsibility that a machine can take in certain circumstances. The portal Observatório da Imprensa, of remarkable credibility in the area, brought an article that uses a fact occurred in the United States to show the dilemmas that involve the participation of machines in the production of news (DIAKOPOULOS, 2014) [8]. According to the article, a robot created to detect scoops has replicated the information disclosed by a newspaper about the alleged death of a basketball player. Aware of the

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mistake, moments after the news was corrected by the original source, a human, but not by the robot, which is not scheduled for this kind of situation (ALBUQUERQUE, 2015) [1].

Though the practice of gathering information is increasingly recurrent and there is a defense around the freedom of the market, there are limits to certain practices. Allhoff (2007) [2] defends stricter measures to avoid excesses. He have greater concern about nanotechnology, however the Professor's questions can be extended to the use of machines in human activities in general. He states that there are two specific threats in relation to nano-robots that cannot be ignored, namely: a) they can be controlled by hostile entities of various types; b) they can self-replicate as autonomous bodies and cause immense damage to humanity. Despite of this field of scientific knowledge has not entered journalistic practices yet, this subject to the Professor is extremely relevant because it plays in ontological questions, due to the fact the man to be able to replicate and amplify feelings from others, but he still encounters ethical situations apparently without satisfactory answers.

Bucci (2000) [5] quotes some cases common at the journalist's day by day, in which a machine would hardly have conditions to replace a human being, even with all the precision and rationality that characterizes it. The Professor brings the example of a supposed radio reporter who would have witnessed a landslide upon returning home after a day's work. At the time it was raining hard and there were points of flooding. Yet as the fact in question, the journalist tries to narrate by cellphone on live the fact with very few impressions, but what is visible to your his and from his experience. In another situation, a fictional reporter interview a mayor accused of illicit enrichment. The politician uses the room to defend himself, but the journalist doesn't know to what extent the defense is true. In both examples, there is the possibility of transmitting parts of truth, since both the professionals would have little control over what is being said to the citizen.

In both situations, Bucci makes an elementary basic recommendation over a situation like this: do not lie. "The -partial truth -is something the reporter mustn not do. All you can do is act according to their conscience, trying to look at the world with objectivity and not mask its limitations with arrogance of someone who sees everything "(2000, p. 88-89) [5]. In principle, it gives the impression that the professor's suggestion would be easily applied by a machine, since objectivity and precision are inherent characteristics of computers. However, it is to be questioned how far a robot could follow the recommendations from terms like partial truth, conscience and arrogance.

The way a machine operates is different from the way humans think. The eminent American scientist John Von Neumann published an important work on this aspect. In The computer and the brain, Neumann explained that the machines require calculations to perform the tasks required by humans, because the same generally relate to responses to Yes and no, that is, automated processes, in which abstract skills are required (2006, p. 108-109) [16]. Thus, in commented examples, if a computer had to say a partial truth, it simply would not say, because it was not programmed to do so. The problem would be even bigger if you consider the word consciousness. According to Abbagnano, consciousness is not only to be aware of what to do or not to do, as it comprises common sense. In terms of philosophy, consciousness presupposes: "a relation of the soul with itself, an intrinsic relationship to the man, "inner" or "spiritual", by which he can know himself in an immediate and privileged way, thus judge himself safely and infallibly (2007, p. 185) [3].

To enter on philosophical conception, so it would be impractical to think that the machine could be conscious, although significant advances have occurred in recent years in terms of speeding up information processing and storage capacity. Another great scholar of the machines and sharer of the same ideas as Von Neumann (2006) [16], contributed to the creation of the first computers was Alan Touring (1948). He was known for creating a mechanical and electrical device which performed mathematical calculations like few others in History. Called later as the Turing machine, the automaton was instrumental in World War II to decipher Nazi codes for the allied countries, along with a team which brought together chess players from champions up in crossword puzzles and puzzle solving. The importance of this work was so expressive that he kept secret for more than 30 years (GLEICK, 2013, p. 222) [11].

Turing wrote a seminal article for studies about computer machines in 1950 when he describes a game that would have aimed to find out if a machine can think. Denominated the Imitation game, the idea is to identify a human being between two people and a machine from questions and answers. The English researcher carries out a few categorical conclusions in his article, but asks a question which can be understood as an answer: "they can't accomplish something that machines should be described as thinking, but that is very different than what a man does." (1950, p. 435) [20]. That is, it may be that the machines don't do exactly what a human being does when it comes to thinking, however, they can do something with similar mechanism which is not necessarily the same.

Throughout the article, including, Turing seeks to dispel myths around which orbit and probably still exist, many doubts. One of them was that thinking was an essentially human assignment, assigned by God (1950, p. 443) [20]. More than simply to reject them, Turing prophesied what today is fully noticeable: "at the end of the century, the use of words and polite general opinions will have changed so much that one will be able to speak of machines thinking without waiting to be challenged" (1950, p. 442) [20]. Turing's conclusions reinforce the impression that a machine could hardly stand on the ethical dilemmas suggested by Bucci, given the fact that the thinking of the machine is different from human. Norbert Wiener in *Cybernetics and Society*, says that the digital camera works from all or nothing and that "the sharpness of the decision between ' yes ' and ' no ' allows us to collect information in order to provide us one way to discriminate very small differences in very large quantities" (1950, p. 64) [21]. So, as vouched by Von Neumann, the human brain does not have the precision of a computing machine with regard to discern information in the midst of many others, but can Excel in certain tasks. "The deterioration of arithmetic was exchanged for an enhancement of logic" (2006, p. 113) [16], concluded Neumann.

The logic is essential for the pillars of journalism and

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ethics, as evidenced by Bucci in saying that "the ethics is in praxis. There is a harmony between the customs and the good conduct, as the ethics is not nor could be outside of customs "(2000, p. 17) [5]. If ethics lies in the acting of the journalist, it is essential the vision of life in society so it can exist. Being ethics dependent on external factors, it is improbable that a machine have sufficient external information to make a decision based on opinions of others. Or even more distant from the reality it would be to imagine that a robot would be able to interact with humans in such a way that you could understand their behavior and take a logical conclusion from hat. About the ability of the machine to learn with itself and with the environment, Wiener made an enlightening explanation: “You can build it with a statistical preference for a certain kind of behavior which, however, admits the possibility of another behavior; or, certain characteristics of this behavior can be rigid and unalterably determined” (1950, p. 175) [21].

Even if a robot can learn, this learning will be limited by statistics, that is, as probability factors because it is inherent in the automata mechanism guided by mathematical calculations as a way of learning. This would be the core to understand why a machine will hardly perform human functions, such as ethical decisions. Every form of knowledge of a robot is intrinsically linked to its mathematical Genesis, but human relations are not. As Wiener, "the greatest weakness of the machine – such weakness which saved us so far to be dominated by it-is that it can't still take into account the wide range of probabilities that characterizes the human situation" (1950, p. 178) [21]. In other words, it is unlikely that mathematical calculations can map the numerous human idiosyncrasies to the point of a machine make accurate decisions from there.

Neumann goes to the heart of this issue when he says about the language of the brain and the Mathematics language: “the nervous system is based on two types of communications: those that do not involve arithmetic formalisms and the ones that involve, that is, order communications (logic) and numbers communications (arithmetic). The first may be described as a language and the second as mathematics” (2006, p. 114) [16].

Being different from the way the brain understands numbers and orders, it is believed that an ethical decision probably is not going to be a part of the mathematical framework, as ethics concerns individual behavior in a social context. Soon, a machine designed to perform commands, even if it can learn from the environment , it is unable to draw up a reasoning at this level of complexity. In the words of Neumann, "when we talk about mathematics, we could be discussing a secondary language, built on primary language actually used by the central nervous system" (2006, p. 116) [16].

It is noteworthy that the “primary” and the “secondary” terms used by Von Neumann do not concern the order of importance, but the manner with which the processes take place in the human brain. It is also important to remember that the language does not represent necessarily the alphabet, but the drafting logic which our brain emerges the world. Besides the human relations being fortuitous and unpredictable enough to practically makes it impossible precision in mathematical calculations of a machine, the calculation would not be the most appropriate way to make ethical decisions, since that the human brain performs better with the logic compared to mathematics.

In the dictates of Bucci, "journalism is conflict, and when there is no conflict in journalism, an alarm should go off. In fact, the ethics exists only because communication is a place of conflict "(2000, p. 11) [5]. So, being the conflict an opposition or fight of principles (ABBAGNANO, p. 173) [3] human brain finds it easier to deal with different situations that machine designed to make accurate decisions based on mathematical calculations.

III. CONCLUSION

The development of machinery and the subsequent use of it in the activities currently performed by humans is an inexorable reality. The dissemination, including in journalism, needs to be accompanied by discussions about the limits of use of drones, because it is clear that there are unquestionable differences towards humans, which implies aspects that cannot be disregarded. Ethics is one of those fields, because a robot will hardly be able to evaluate certain situations of the everyday life of a human journalist due to the own machine’s atavistic conditions. Thus, it is important to evaluate which person could be held liable for Misconceptions or omissions of machines created to replace people in daily newsrooms, as companies have already begun this process.

This article does not want to create a stigmatized and prejudiced visionin relation to news producers robots. However, it is believed that it is necessary to point out certain aspects of this reality, such as the features and the inherent limitations of the machines, to be able to evaluate ways of dealing with journalistic ethical dilemmas. As this is a recent topic, the idea of this text is to start the debate in order to create deeper discussions .

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Photometric and Colorimetric Comparison of OLED, NANOSP, and LCD Television

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Photometric and Colorimetric Comparison of OLED, NANOSP, and LCD Television

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***Abstract*— The LCD - Liquid Crystal Display technology is currently the best known of flat screens TVs. However, two innovative and advanced technologies are emerging to the public: the OLED - Organic Lighting Emission Devices, and the NANOSP - Nano Spectrum, also known as Quantum Dot. The aim of this paper is to present a photometric and colorimetric comparison between LCD, OLED and NANOSP. Radiometric-spectrum measurements in TVs under test allow a direct comparison of their main characteristics and objectives parameters. Our results bring a detailed understanding of these new technologies performance and their outstanding qualities in the market.**

***Index Terms*— TV receivers, HDTV, Photometry**

I. Introduction

TELEVISION sets using flat-screen monitors are becoming increasingly cheap and popular. Since they make use of microelectronics technologies, flat screens are also increasingly thin and advanced. This feature allow a number of variation such as 3D screens, the curved screens, the ultra-high-definition screens, i.e. 4K and 8K, and the screens of large dimensions. The PDP - Plasma Display Panel technology and the LCD - Liquid Crystal Display technology are currently the most popular in flat screens. However, innovative and advanced technologies are emerging, which are the OLED technology [1] and the Nano Spectrum technology, also known as Quantum Dot [2]. The acronym OLED is the designation for Organic Light Emitting Devices, which is a novel and disruptive technology of flat screens with many advantages in color and contrast response [3][4]. Nano Spectrum is a technology where nanocrystals of semiconductor materials, such as silicon, have quantum mechanical properties. One application of the nano spectrum technology is the manufacture of film that can correct color distortions allowing the construction of LCD-LED flat screens with much better color response [5][6][7]. Both the OLED and the technologies were introduced in the TV world market in 2015 [8]. Thus, considering the diversity of options currently available for flat panel technologies, the comprehension of the OLED and NANOSP features, advantages and disadvantages is desirable. The aim of this paper is to show technology features by a photometric and colorimetric comparison between LCD, OLED and NANOSP television. We have carried out radiometric-spectrum measurements in these three types of TV sets, and we present a direct comparison of their main characteristics and objectives parameters. The results bring a detailed understanding of these new technologies performance and their outstanding qualities in the market. The remaining of this paper presents the related work, the measurement methodology, the results, and the conclusion.

II. Related Work

A monitor for computer desktops build with OLED technology was evaluated by Ito *et al*. [9], and their article reports the technical performance of the display model Sony PVM-2541. The measurements approach is similar to ours in which the OLED monitor is driven by a computer connected to the HDMI input port. So, precise image and video are displayed on the screen. Then, the measurements of luminance, color and spectral characteristics of the display were done by a colorimeter and by a spectral radiometer. The authors present an analysis of these parameters: luminance gradation, additivity of RGB luminance values, color space and spectral distribution, luminance/color uniformity, differences between individual displays, difference in luminance between vertical and horizontal gratings, and temporal characteristics. The conclusion highlights for this particular OLED display are: excellent luminance and color uniformity, wide color space, and rapid luminance rise/fall times.

The work by Luo *et al*. [10] has a detailed description of the nano spectrum technology for television display construction and the working principle of color enhancement on the display screen. In the last part, the authors briefly discuss the performance of a NANOSP TVs build with QD-BPLC (Blue Phase Liquid Crystal, one of the most recent quantum dot technology type) in comparison with OLED TVs. The QD-BPLC TV has advantages in lifetime, power consumption, resolution density, color gamut, and cost. On the other hand, OLED has advantages in true black state, thin profile and flexibility.

Since both technologies of OLED and NANOSP are evolving, the performance reported in related work need to state the television set model. Our evaluation was carried out in the year of 2015 with new television sets by that time. The methodology for the performance evaluation is described in the next section.

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III. Methodology

This section describes the procedure of radiometric-spectrum measurements in the OLED, NANOSP, and LCD types of TV sets.

The measurements were conducted in a room sealed against entry of light, so that the environment remains completely dark during the measurement procedure.

A computer with a graphics card is connected to the HDMI input of the TV under evaluation. A set of specific videos for measurements are displayed on the TV screen, one at a time, as needed for each measurement. The video image occupies the entire screen area.

- The spectroradiometer - CS-1000A device, is placed at approximately 80 cm apart, in a line perpendicular to the TV screen, as illustrated in Figure 1. This distance is not relevant to the test, but rather the direction to the screen is important to the measurements. Thus, the CS-1000A lens was perpendicularly aimed to one positioning mark on the image used for the ANSI contrast measurement of Fig. 1.

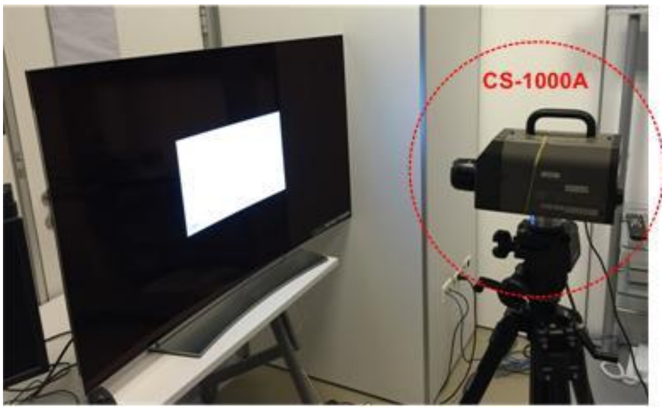


Fig. 1. Position of CS-1000A, perpendicular to an OLED television set.

Initially, just after turning on the TV, a video is continuously played for at least 30 minutes before starting the measurements. After this period, measurements are performed within the totally dark environment.

The luminance measurements are carried out with eleven gray images ranging from 100% to 0% of the pixel scale in steps of 10%. The image of 100% grayscale corresponds to the maximum luminance, i.e., totally white. The image of 0% grayscale corresponds to the minimum luminance, i.e., the black image. The other images are in grayscale.

The TV color emission measurements are performed with images of the three primary colors RGB (Red, Green, and Blue) and the images of the three secondary colors CMY (Cyan, Magenta, and Yellow).

Measurements of the ANSI contrast are conducted with images containing white and black rectangles in a 4x4 arrangement. With the CS-1000A equipment always in the same position, we measure the emission from white area in the first image, followed by the emission from black area in the second image. In this second measurement, in the black area, the screen does not turn off because there are white areas in the image. The ANSI contrast is the ratio of the luminance of these two measurements.

Additionally, the same ANSI contrast calculation procedure was performed with measurements obtained from the spectrophotometer i1Pro 2. The difference from the above procedure is the position of the equipment. The i1Pro 2 is placed onto the TV screen surface, as illustrated in Fig. 2.

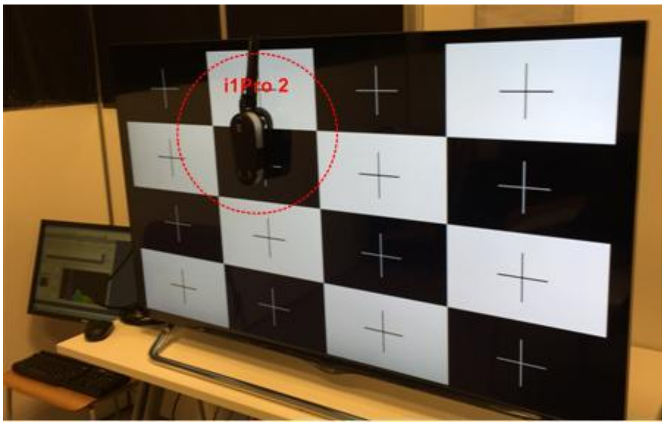
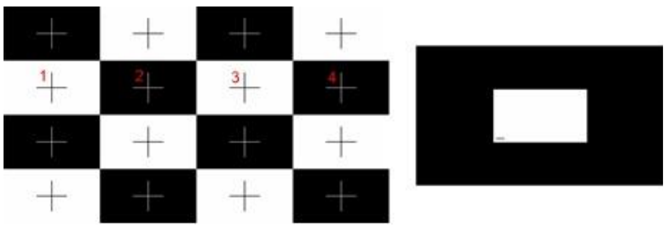


Fig. 2. Position of i1Pro 2 on the TV screen surface, of a NANOSP television set.

In the next step, all the same luminance measurements are performed with room light environment.

The viewing angle measurements were carried out in a dark environment, repositioning the CS-1000A equipment, moving it angularly at a 15 degree angle radius from the previous position, and keeping the lens pointed at the same point of the screen. Thus, it measures the luminance emitted at angles of 15, 30, 45, 60, and 75, in relation to the starting position perpendicular to the screen.

Measurements of horizontal luminance uniformity were performed in dark environment, repositioning the CS-1000A equipment, moving it horizontally, but keeping it perpendicular to the TV screen test. The measured screen points are indicated as marks 1, 2, 3, and 4 in Fig. 3 (a). The 100% white pattern shown in Fig. 3 (b) was used in this measurement. The white area of this image was moved in the TV screen accordingly to the point marks, so that it lies in the center of each measurement position.



(a) Position marks for the uniformity test (b) Image of 100% white

Fig. 3. Points of luminance measures and the image used to perform measurement.

The three evaluated television sets have 55-inch screen and 4K (3840x2160) pixel resolution. The evaluated models are:

(i) OLED model: 55EG9600-SA,

(ii) NANOSP model: 55UF9500-SA, and

(iii) LCD model: 55UB8500-SA,

All these TV sets are made by LG Electronics.

The radiometric-spectrum measurements with the equipment Konica Minolta CS-1000A, all photometric and

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colorimetric values are based on spectral measurements of radiance in W / (m2.sr.nm) in the range of 380nm to 780nm.

Table I presents the television adjustment of parameters settings used on the TVs under test.

TABLE I
TELEVISION ADJUSTMENT PARAMETERS

Parameter	OLED	NANOSP	LCD
IMAGE Menu			
- Image Mode	Photo (User)	Photo (User)	Photo (User)
- Energy Saving	OFF	OFF	OFF
IMAGE MODE Menu			
- LED Light	100	----	----
- Backlight	----	100	100
- Contrast	100	100	100
- Brightness	50	50	50
- Sharpness	10	10	10
- Color	50	50	50
- Tone	0	0	0
ADVANCED CONTROL Menu			
- Dynamic Contrast	OFF	OFF	OFF
- Super Resolution	OFF	OFF	OFF
- Color Range	Wide	Wide	Wide
- Contour Enhance	OFF	OFF	OFF
- Color Filter	OFF	OFF	OFF
- Advanced Pattern	OFF	OFF	OFF
- Gamma	2.2	2.2	2.2
WHITE BALANCE Menu			
- Color Temperature	Medium	Medium	Medium
GENERAL Menu			
- Timer	OFF	OFF	OFF
- Wait Light	OFF	OFF	OFF
- HD ECO Mode	OFF	OFF	OFF
- Software Version	03.00.06	03.00.13	04.65.05

IV. RESULTS

From the measurements of parameters obtained in the previous sections, a comparative analysis was made considering the following parameters shown below:

Luminance: luminance is a measure of the brightness of the white color, in this regard the NANOSP TV showed performance near the OLED TV and far superior to LCD TV;

Angular Luminance: angular luminance is the brightness of the white color seen from a certain angle, in this study we decided to adopt the extent of 45 degree tilt angle. In this case it is observed that NANOSP TV performance is almost equal to the LCD TV, however OLED TV has much higher performance;

Gamma 2.2: the Gamma 2.2 curve is the standard measure of grayscale brightness in flat panel TVs; and the higher adherence to Gamma 2.2 curve the better the contrast of images in grayscale. In these measurements, the OLED TV has almost total adherence to the Gamma 2.2 curve. The LCD TV has median performance and NANOSP TV has lower performance;

Uniformity: this measure evaluates the brightness distribution along the panel. The three TVs have a very great uniformity, and the outstanding uniformity of OLED TV is less than 3%.

Room Light Reflection: the flat screen reflection index at room light is an important parameter to measure the influence of ambient room light on the image. In this aspect the OLED TV showed a superior performance than the LCD TV and NANOSP TV.

Contrast: Contrast measures the difference between white and black levels. The contrast of the OLED TV is far superior to the LCD and the NANOSP TVs.

RGB Interference: the RGB interference measures the degree of spectral overlapping between colors, the smaller the interference of R color on the G color, and the interference of G color on B color, the greater is the separability and fidelity of colors in the screen image. In this aspect the OLED TV showed far superior performance than LCD and NANOSP TVs.

Color Gamut: the color gamut represented in the form of a triangle in the CIE diagram represents all the possible space of colors that can be displayed by a Flat screen. In this aspect the TV OLED presented the color gamut with the largest area, followed by NANOSP TV and the LCD TV.

A comparative radar diagram is shown in Fig. 4, which was constructed by normalization of numerical measurements results. The next subsections discuss the performance results for each of these parameters.

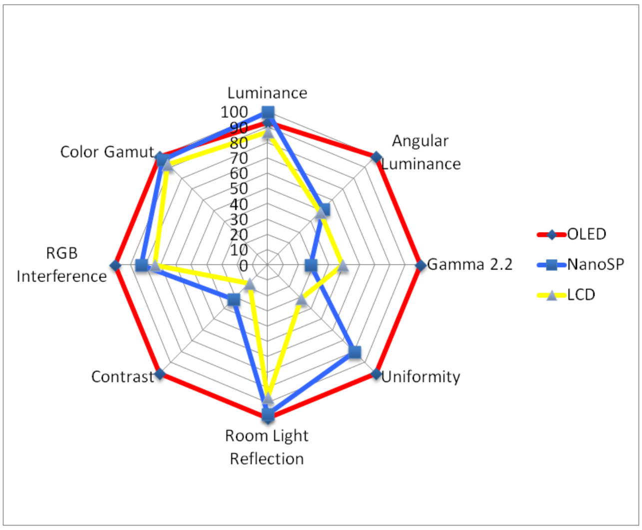

Fig. 4. Radar Diagram of Analyzed Parameters.

A. *Maximum luminance*

The maximum luminance measurement was made for the 100% white image. Fig. 5 presents the absolute measurements.

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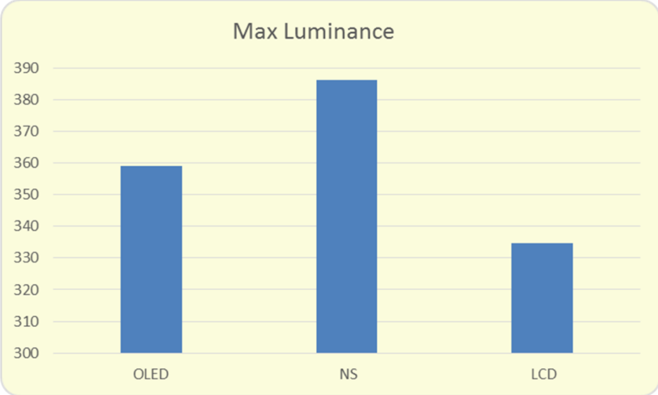

Fig. 5. Maximum luminance results graph.

B. *Luminance angular dependence*

The OLED TV showed a significantly lower angle dependence of the luminance with the change in viewing angle, as shown in Fig. 6.

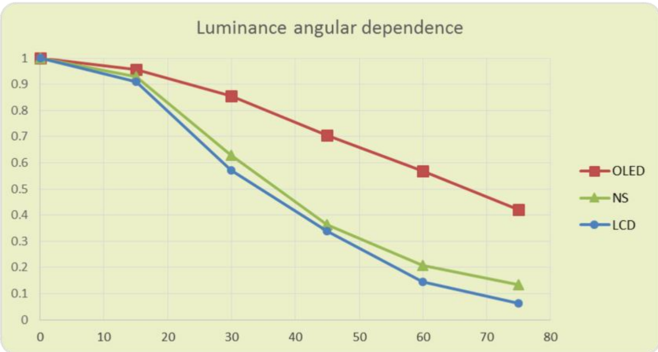

Fig. 6. Luminance angular dependence measures.

C. *Gamma correction: Luminance tracking versus grayscale*

The luminance tracking curve in relation to Grayscale adopted by the industry is the 2.2 Gamma correction curve. The better the TV the closer to Gamma 2.2 function curve. The OLED TV presented the best approximation to the Gamma 2.2 curve, as shown in Fig. 7.

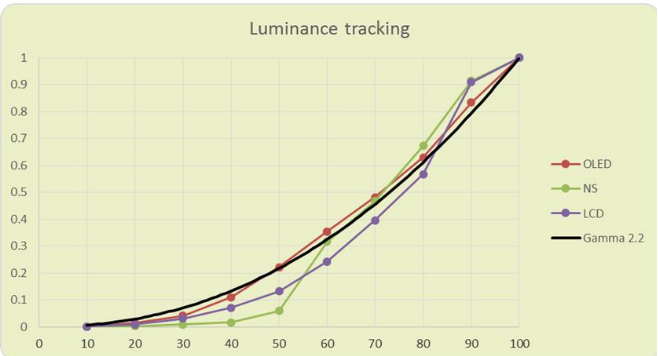

Fig. 7. Luminance tracking graphs.

D. *Horizontal luminance uniformity*

The results of the horizontal luminance uniformity test have few significant differences for all the tested televisions, as shown in Fig. 8.

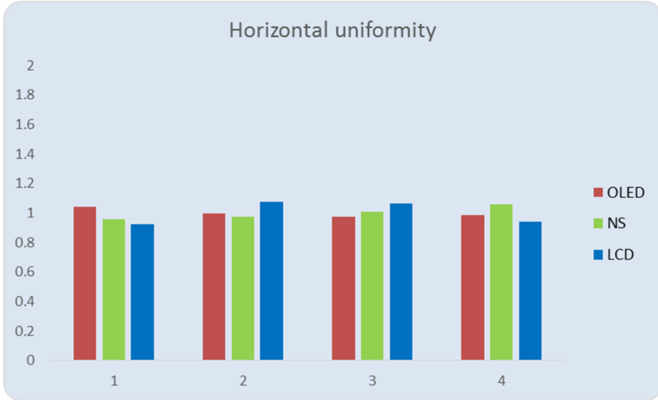

Fig. 8. Results of the horizontal luminance uniformity test.

E. *Room lighting reflection effect*

When tested in typical room lighting environment, with the screen turned off, the screen reflection was significantly lower in the case of OLED TV, as shown in Fig. 9.

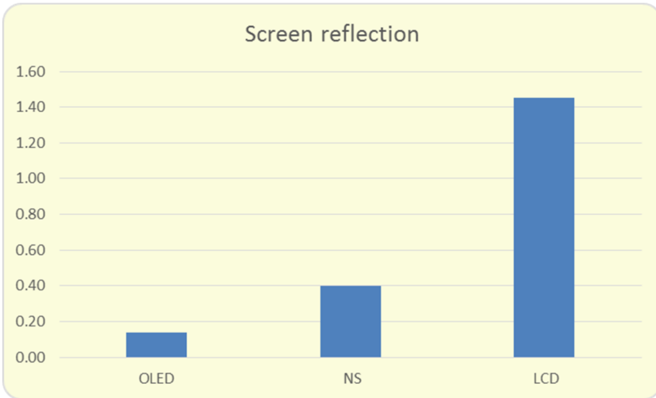

Fig. 9. Screen Reflection with room lighting.

F. *ANSI Contrast*

The contrast values, calculated as the ratio between white and black luminance of ANSI standard in the same measuring point were greater on the TV screen OLED as shown in the graph of Fig. 10, with the i1Pro 2.

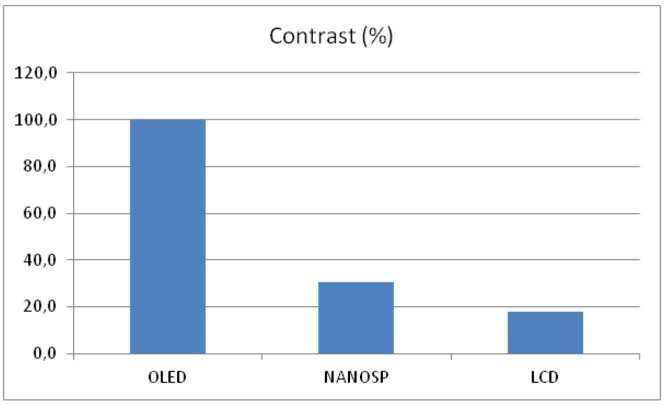

Fig. 10. Contrast ratio of ANSI standard, measured by i1Pro 2..

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G. RGB Spectral crosstalk

This study shows a calculation of the power interference ratio of each individual channel and the other two channels within each color band. This value is called the signal-to-interference ratio (SIR), and it is calculated in decibels (dB). The higher the value of SIR, the smaller is the spectral interference.

Fig. 11 shows the interference on the G channel for OLED TV set, and the calculated SIR is 12.2dB. Fig. 12 shows the interference on the G channel for NANOSP TV set, and the calculated SIR is 10.1dB. Fig. 13 shows the interference on the G channel for LCD TV set, and the calculated SIR is 8.9dB. Thus, we conclude that OLED TV presents a better performance regarding RGB spectral interference than other two TVs.

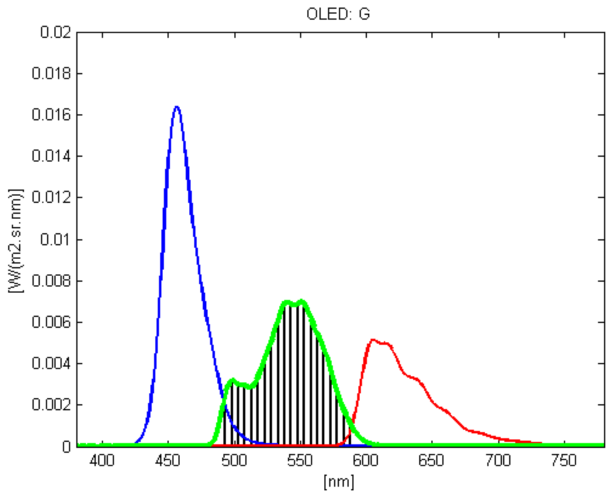

Fig. 11: Interference on G channel for OLED TV.

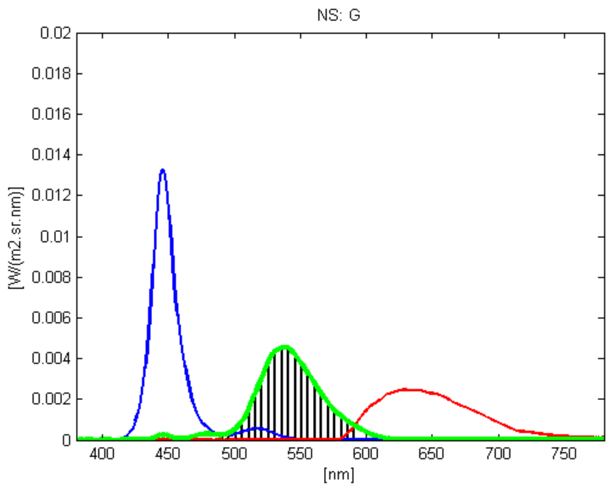

Fig. 12: Interference on G channel for NANOSP TV.

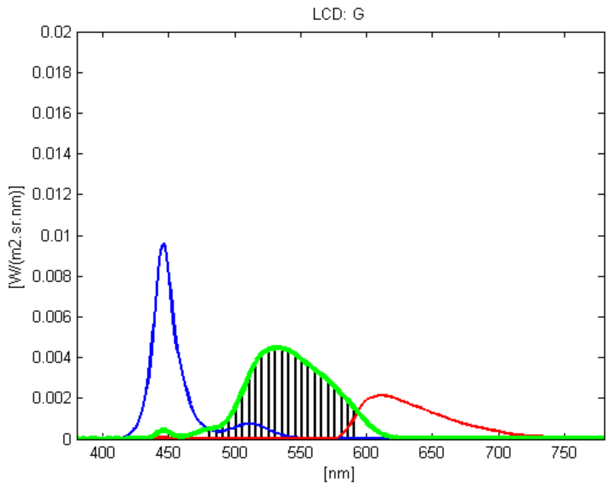

Fig. 13: Interference on G channel for LCD TV.

We also calculated the interference on R channel and on B channel, and both had similar comparative results. However, the interference on G channel is stronger in all TVs.

H. Color Gamut

The OLED TV gamut is larger towards the R-G and G-B axes while the NANOSP TV gamut is larger towards the R-B axis, as shown in Fig. 14.

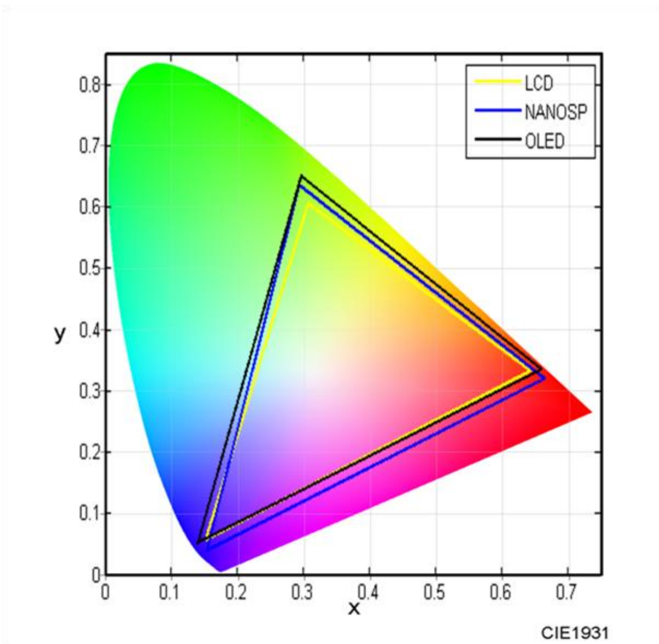

Fig. 14. Comparison of color gamut in the CIE xy diagram.

V. Conclusions

This paper presents a photometric and colorimetric comparison of OLED, NANOSP, and LCD television sets. We have carried out radiometric-spectrum measurements in these three types of TV sets, and we presented a comparison of their main characteristics and objectives parameters. We conclude that the OLED TV showed an overall better photometric and colorimetric performance in all parameters. We also noticed that either OLED and NANOSP

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technologies offer a superior perceived image quality than LCD TVs. In future work we plan to extend the measurements to more parameters, and also we plan to evaluate newer models of television receivers in the market. In regard to television receivers' lifetime estimation, we also plan to carry out measurements in the same models by checking colorimetric and photometric changes after excessive usage time.

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Receivers Behavior in a ISDB-T's Single Frequency Network

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Receivers Behavior in a ISDB-T's Single Frequency Network

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***Abstract* — Former television receivers were unable to demodulate signals under very adverse conditions. In order to mitigate some reception problems, the so-called multiple frequency networks were used for television broadcasting. The advance in broadcast technology to digital transmission, using Orthogonal Frequency Division Multiplexing, allows digital television broadcasting networks to employ a smaller number of frequency channels as compared to former analog networks. A common appealing case is the use of a single frequency channel for the whole digital broadcasting network, the so-called single frequency networks. These became an important requirement, as they allow the improvement of spectrum usage, since contiguous regions are covered using a smaller fraction of the spectrum as compared to the former existing broadcasting systems and considering the same quantity of broadcasting transmitters. The advances in digital television broadcasting and improvements in receivers mainly pushed this. Both allowed the increase in the receiver's capability to demodulate signals under adverse conditions. This work investigates some aspects of receiver's performance and behavior in single frequency networks. The tests encompass five digital television receptors. Using a laboratory setup inspired in the single frequency network's reception scenario, we present results of the performance of digital television commercial receivers. One assumes that signals from two transmitters arrive jointly in line-of-sight conditions at the receiver. Several settings in terms of power ratios between primary and secondary signals and their relative delays are evaluated. In comparison to data in previous works, one observes an improvement in the performance of receptors in terms of the required electric field strength for successful reception. The effect of the guard interval setup on the reception is also evaluated and reported. We also evaluate the loss in the reception margin, which is inherent to the deployment of single frequency networks. In addition, using a default reception model, we translate the power density values measured on laboratory to the minimal electrical field strength necessary for reception. The results show a general degradation in receptor's performance due to the SFN and we conclude that the specified minimum electric field strength needs a revision to accommodate these types of project.**

Index Terms* — *Digital Broadcasting, Receiver's Performance, Single Frequency Networks, Orthogonal Frequency Division Multiplexing

I. Introduction

With the current shortage of the electromagnetic spectrum, broadcasters and regulators seek to optimize its use [1]. This is a requirement as the demands for frequency spectrum increase for the delivery of different and diverse communication services. An alternative to optimize the spectrum usage is to make each service provider use the same frequency band everywhere. For television delivery networks, this is known as a Single Frequency Network (SFN) and became a requirement for DTV (Digital Television) systems. In the traditional MFN (Multiple Frequency Networks), that are being shut down all around the globe, each transmitter employs a different broadcast channel in each coverage area; that is, in adjacent areas, the same channel is not used for transmission; this prevents strong interference at reception. In an SFN, spectrum is saved because multiple areas are covered using a single broadcast channel; the consequent optimization in spectrum easily follows.

MFNs were widely used in analog television coverage system design for large areas, mainly due to the limitations of analog receivers to avoid multipath propagation derived problems. For example, the basic plan developed by Anatel (Brazilian national telecommunications agency) [2] restricts the use of a single RF channel for each coverage area for analog television broadcaster. One of the main concerns in the development and standardization of some digital television systems was to provide a physical layer for the transmission and reception with the necessary tools for implementing SFN. That has made the deployment SFN DTV networks plausible. The shift from analog to digital data allows to implement some transmission and reception improvements such as efficient channel coding schemes [2]. That is intended for improving

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reception fidelity and to make it possible to deploy SFNs in scenarios with interference leading to transmission errors within the channel coding correction capabilities. These are often given in terms of power ratios between the main and the secondary signals (interfering ones) and relative signal's delay among them. SFNs are each day more imposed, due to the save in bandwidth they provide. In this sense, their study is necessary in order to provide tools for realistic and reliable analysis and design of such networks.

Actual SFN technology allows to control multipath effects by means of transmitter synchronization [1,2->3,3->4]. That is, the broadcast signal by the different transmitters can be delayed in order to avoid significant inter-symbol interference at some coverage area, enabling demodulation of the OFDM signal. In areas where two or more signals arrive from different transmitting stations, signals must be kept within bounds so that the receiver is capable to deal with. That means that one should ensure that: 1) secondary signals have delays within the main signal guard interval setup; 2) if one or more secondary signals are received outside the predefined guard interval, then their relative power to the main signal must be such that they do not prevent correct recovery of OFDM symbols.

To make a DTV receiver to function properly it is necessary that: 1) it is not saturated by the incident signals; 2) it succeeds in demodulation, even under multipath. In the case of SFNs, one has control on the second effect since the transmitters can be synchronized.

With the development and evolution of the DTV, the use of SFNs for DTV broadcasting signal became plausible. The improvement in the receivers, which began to equalize more efficiently multipath impaired signals, allowed SFN DTV broadcasting.

This study aims to determine and analyze the threshold reception in line-of-sight conditions (for primary and secondary signals), which is the worst-case scenario for DTV broadcasting projects in a SFN network. This is accomplished through laboratory measurements, in scenarios that mimic those reception conditions. With this work, one aims at facilitating the design and deployment of SFN for DTV broadcasting.

The SFN'S design is not a trivial task. It is necessary to adjust the transmitters' power and network synchronization, this must consider all coverage area and transmitters but also all possible receivers at which signals from different broadcasting sites may arrive. This is important for the interference suffered by these receivers to be within acceptable bounds, i.e., not preventing the recovering of the data stream. [1]. That is, one must ensure that secondary signals are received with delays within the main signal's guard interval. On the other hand, if one or more secondary signals are received outside the guard interval, the relative power differences between the main signal and the secondary ones must be such that they do prevent the correct reception of the primary OFDM signal.

II. TESTS SPECIFICATIONS AND SFN PERFORMANCE MEASURES

The proposed experiments allow to analyze the combined effects of intersymbol interference and fading by multipath in an SFN network with two transmitters in line-of-sight with the receiver. Initially, we will examine the symbol constellation of the an OFDM carrier, in the presence of the two signals generated by the exciters. Then we analyze the performance of the receivers, their signal demodulation capability and the presence or not of blocks in the images reproduced by the televisions, with the presence of two signals and noise at their input. In both cases, different conditions were evaluated by varying the delay parameters between signals and the power difference between them.

The diagrams in Figure 1 and Figure 2 were designed in order to simulate different conditions of reception, relative delay and signal amplitudes that a received in an SFN may be subject to. This allows empirical measures and the evaluation of the receiver performance and constellation's behavior in different reception conditions. The transmission system settings used are presented in Table 1. It considers the SBTVD (Sistema Brasileiro de TV Digital). For more information on the parameters of SBTVD channelization and coding, the reader should refer to [2].

TABLE 1

DIGITAL SYSTEM CONFIGURATION USED IN THE EXPERIMENTS

System	SBTVD
Chanel	29 (560 ~566 MHz)
Bandwidth	6Mhz
Layer B Modulation	64QAM
FEC (foward error correction)	3/4
Guard Interval	1/8(126μs)
Sincronization Mode	Static Delay (offset)

A. *Symbol Reception – Constallation's Behavior Evaluation*

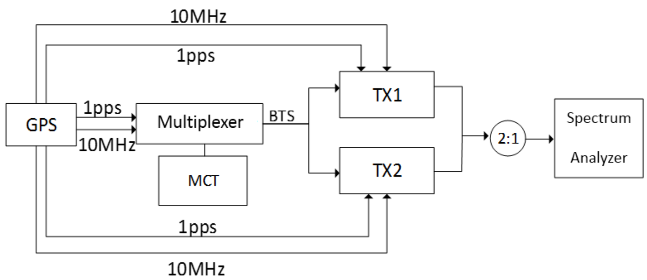

Figure 1. Laboratory setup employed to analyze symbol constellation at the receiver.

The laboratory setup (Figure 1) was designed to analyze the constellation behavior (symbol mapping) at the receiver, using a TV analyzer. The diagram consists in a multiplexer fed by the time and frequency network references

(1pps, pulse per second, and 10MHz) and by the ASI (Asynchronous Serial Interface) steam that comes from the Mux Controller (MCT). The broadcast transport stream is generated and will feed the exciters (Tx1 and Tx2) that generate channel 29 RF signals (560 to 566 MHz).

The MCT is responsible for the network synchronism parameters. It composes the broadcast transport stream with the synchronism bits and the delay of each transmitter in the network.

The TV analyzer was employed to capture the constellation of the OFDM symbols. This was done varying power levels between the received signals to be 0, 5, 10, 15 and 20 dB and relative delay of 0 to 200 µs in steps of 20 µs.

Section III presents the results and the concerning analyses of the receiver constellation behavior.

B. Diagram 2 – Digital Television Comercial Receptors Behavior

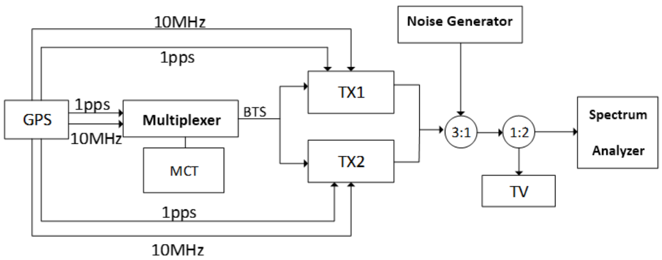

Figure 2. Laboratory setup used to analyze error in symbol reception, observed decoding errors in the displayed video point to the minimal signal to noise ratio (or signal to interference ratio) for correct signal decoding.

The diagram in Figure 2 is very similar to the one presented in Figure 1 with the addition of the noise generator plugged in the transmitter RF output to decrease its quality and the DTV receiver (i.e., a display and its built-in receiver) to decode the stream and present the decoded video and audio. This allows analyzing the behavior of the built-in receiver in conditions that are similar to a reception in SFN with 2 transmitters in line-of-sight with the receiver. Transmitters are configured as presented in Table 1. This allows to vary the noise power in order to obtain the required signal to noise ratio (C/N) required for good reception. The C/N is defined as:

$$C/N = 10 \cdot \log_{10}\left(\frac{P_S}{P_N}\right) \tag{1}$$

where P_S is the signal power and P_N is the noise power.

The minimal signal to noise ratio (C/N) required for good reception is the smallest one that still provides acceptable reception. Firstly, only one transmitter may be present therefore one can observe the C/N at which the displayed video starts to be corrupted; we have employed the emergence of blocks in the display for that purpose, since the appearing of blocks indicates a degradation of the video decoding indicating reception errors.

Another experiment (that occurs in continuation) encompasses varying the signal power difference (or ratio) between the signals arriving from the two “carriers” and searching for the same effect. This provides an estimate of the built-in receiver demodulation capability under inter-symbol interference. This was done for transmitter power ratios in the range from 0 to 21 dB, in steps of 3 dB. This is also evaluated for different relative delays in the range from 30 to 120µs, in steps of 30 µs, and in the range from 120 to 200 µs, in steps of 10 µs. For each relative delay and power difference setting, the minimal C/N required for accurate reception is measured, for each of the televisions sets available in laboratory.

Besides the obvious evaluation of the signal quality requirements for SFN deployment (in terms of required strength and maximal interference), the above discussed strategy provides a manner to evaluate and compare the performance of commercial DTV sets.

The experiments, its aspects and results concerning the diagram in Figure 2 are presented in Section IV.

C. Equipment

To implement the experiments illustrated in Figures 1 and 2, different equipment were necessary. For completeness, we present and describe the ones employed.

1) Exciter: it receivers the ASI streams from a multiplexer, timing, and frequency references of 1 pps and 10 MHz, respectively, and generates the OFDM signal to be transmitted by the DTV broadcasting network. We employed two exciters (TX1 and TX2 in Figure 1 and Figure 2) from Hitachi Linear IS7001 in order to build the SFN, they are show in Figure 3;

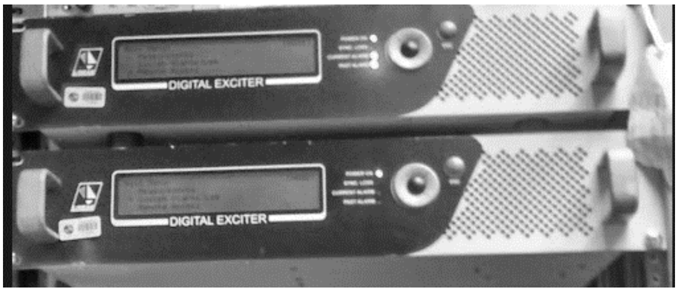

Figure 3. Hitachi Linear IS7001 Exciters Used in the Experiments.

2) Clock: an SFN requires precise timing and frequency references, i.e., “a master clock” [1]. We employ an EC22S Epsilon Clock GPS to produce those references using Global Positioning System signals. The EC225 is shown in Figure 4, in the diagrams in Figure 1 and Figure 2 it is denoted by the acronym GPS;

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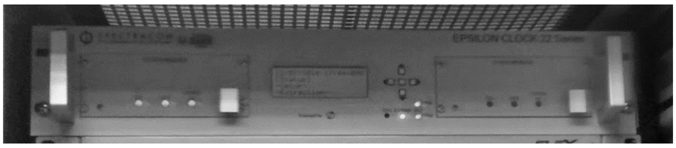

Figure 4. EC225 GPS clock and frequency references generator.

3) Multiplexer: in the diagrams in Figure 1 and Figure 2, the exciters are fed with the stream to be transmitted (TS). The BTS is produced by a multiplexer from NEC, model MX-1500, with the aid of the mux controller (MCT) which produces network and stream configuration paramenters;

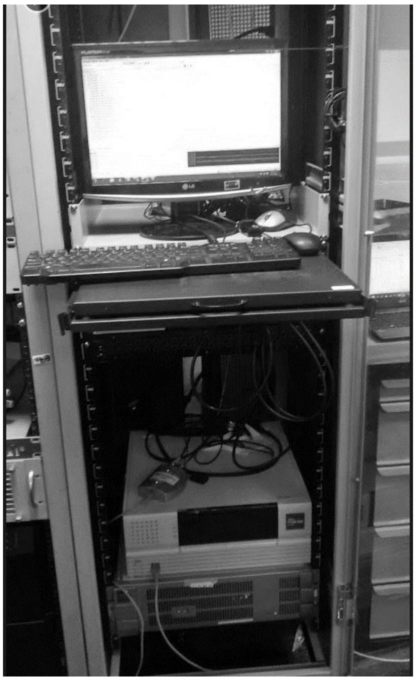

Figure 5. Picture of the Multiplexer and MCT used in the experiments.

4) Noise Generator: a “test transmitter” is used to generate pass-band white noise in order to simulate real transmission conditions. We employed a Rohde & Schwarz SFE100 for that purpose, this is shown in Figure 6;

Figure 6. Rohde & Schwarz SFE100 Test Transmitter used to generate noise and mimic real transmission conditions in the experiments.

5) TV Analyzer: the multipath OFDM signal produced using the experimental setup in Figure 1 is analyzed using a ISDBT signal analyzer, a Rohde & Schwarz ETH TV analyzer was employed;

6) DTV Receivers: a series of displays/TV sets from different manufactures (produced between 2012 and 2013) were used in the experiments corresponding to Figure 2; the TV sets are presented in Figure 7.

Figure 7. TV sets used in the experiments.

III. CONSTELLATION BEHAVIOR: RESULTS AND ANALYSIS

If a single electromagnetic wave from only one transmitter arrives at a receiver, without any channel distortion, then it is easy for the receiver circuitry to estimate the in-phase and quadrature components of the symbols carried by each OFDM frequency carrier. Figure 8 illustrates the symbol constellation for the 64 QAM (64 symbols Quadrature Amplitude Modulation [5] set of possible symbols. There are 64 different symbols meaning that each 6 bits are carried by a symbol in each OFDM carrier. This constellation is obtained by applying a TV analyzer to the received SBTVD signal in order to analyze a carrier of the layer-B of the OFDM (SBTVD [6]) broadcast signal using 64 QAM. Some amplitude and phase spreads can be observed at the received signal that are due to different channel distortions and inherent system noise.

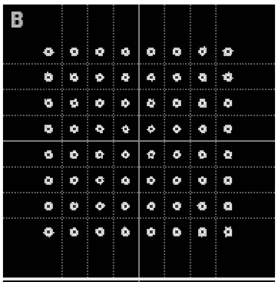

Figure 8. Received constellation of the 64 QAM in an OFDM carrier in the layer-B of the SBTVD signal.

As previously mentioned, the aim of the first experimental setup (the diagram in Figure 1) is to evaluate how the different power ratios and relative delays between a signal (a primary signal) and a "copy" of itself (the secondary signal) affect the reception in SFNs. Therefore, we analyzed the constellations that are obtained for some power ratios (or differences in dB) and some relative delays or time alignment of the signals in the receiver input. This is intended trying to evaluate the reception in some usual and possible SFN scenarios. Figures 9, 10, 11, 12 and 13 show the behavior observed in laboratory for the 64 QAM constellation for increasing power ratios between the two signals. The symbol distributions in Figure 9 are obtained for signals arriving at the receiver with the same power while the ones in Figure 13 are obtained for the primary signal having a power that is 20

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dB greater than the secondary one. Each of these 5 figures present 11 constellations. Each of those 11 constellation in each figure corresponds to a different relative delay between the primary and secondary signals at the receiver.

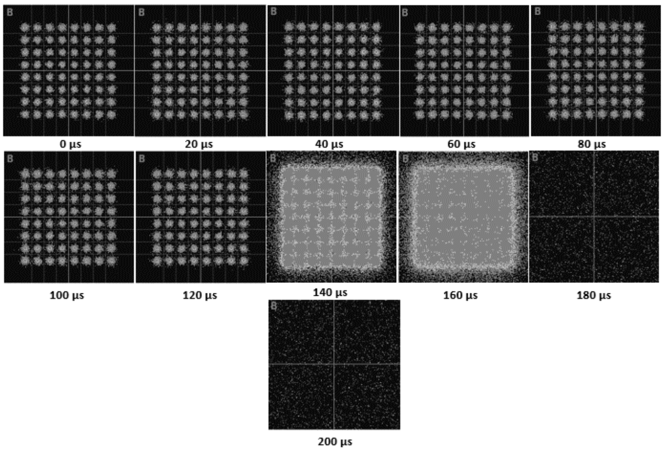

Figure 9. Received constellation of the 64 QAM in an OFDM carrier in the layer-B of the SBTVD signal when two signals of equal power are received for different relative delays between the received signals.

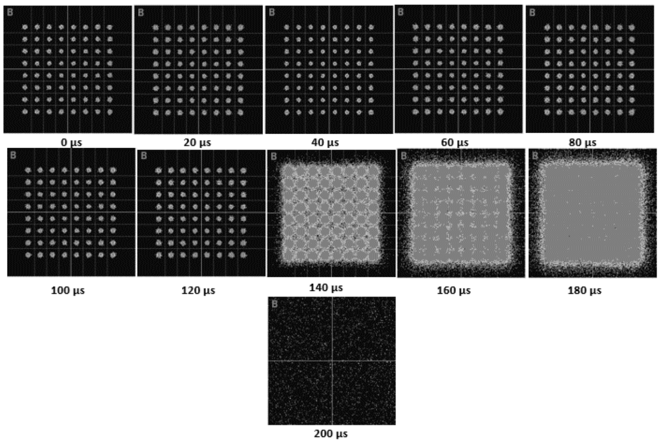

Figure 10. Received constellation of the 64 QAM in an OFDM carrier in the layer-B of the SBTVD signal when two signals having a power level difference of 5 dB are received for different relative delays between the received signals.

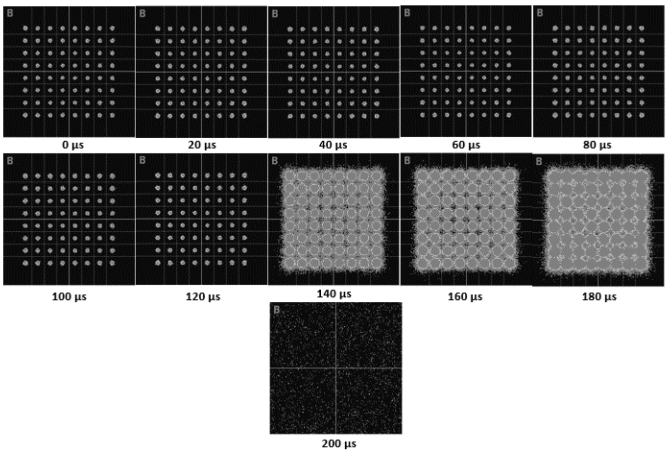

Figure 11. Received constellation of the 64 QAM in an OFDM carrier in the layer-B of the SBTVD signal when two signals having a power level difference of 10 dB are received for different relative delays between the received signals.

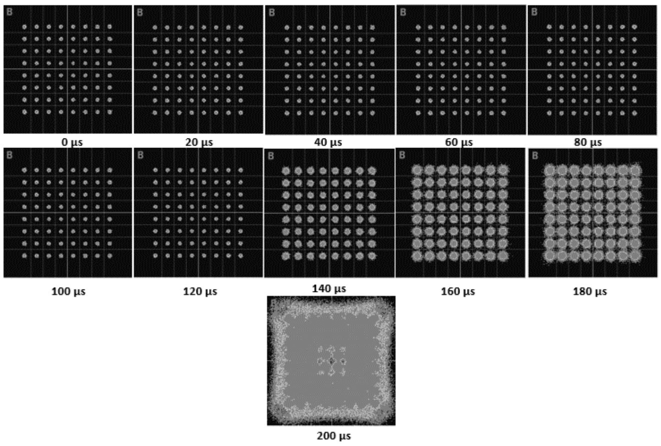

Figure 12. Received constellation of the 64 QAM in an OFDM carrier in the layer-B of the SBTVD signal when two signals having a power level difference of 15 dB are received for different relative delays between the received signals.

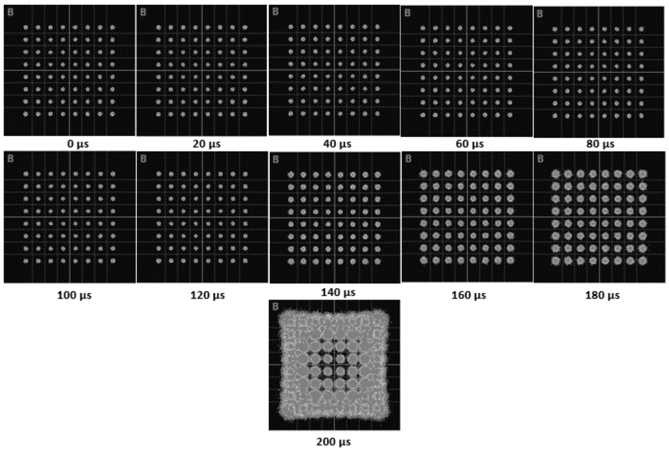

Figure 13. Received constellation of the 64 QAM in an OFDM carrier in the layer-B of the SBTVD signal when two signals having a power level difference of 20 dB are received for different relative delays between the received signals.

Figure 8 shows the effects of symbol recovery at the receiver that are already seen in the laboratory, i.e., even under controlled conditions. If carefully analyzed, it is observed that the symbols' recovery becomes harder as the symbol energy increases, i.e., as the symbol is more far from the origin of the IxQ plane. This is most probably due to the fact that the larger the amplitude of the components are, the more severe are the effects of circuitry non-linearities. The consequence is an increase on the symbol dispersion at the receiver as the symbol energy increases. This effect is also observable in the plots in Figure 9 to Figure 13 and it is further explained in Figure 14. Figure 14 presents the results and analysis on symbol dispersion presented in [3]. These show that symbol dispersion remarkably increases at the constellation symbols having greater energy levels, the outer ones of constellation symbols, what may hinder the signal's

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detection as the symbol's energy increases.

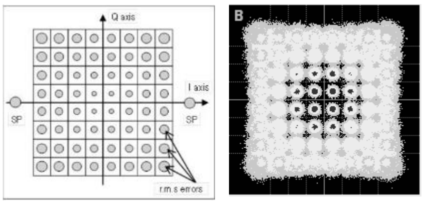

Figure 14. ITU study on the expected constellation behavior in a case of large constellation dispersion [3].

Observing the symbol constellations in Figure 9 to Figure 13, something that pops-up is that is that as the power difference between primary and secondary signals decrease, the dispersions of constellation symbols enlarge. For example, if one analyzes the case of the relative delay being 120 µs, for a difference of 0 dB between the signals, the dispersion of the symbol is much larger than for differences of 5, 10, 15 and 20 dB. Actually, one readily sees that the symbol dispersions reduces as the power ratio increases.

From Figures 9, 10, 11, 12 and 13, one can also see that the dispersion of the symbols increases as the relative delay between the two signals increases, independently of their relative powers. We have also empirically observed that as soon as the delay surpasses 126 µs the dispersion drastically jumps up. This is an effect of the OFDM symbol guard interval [4]. Until that relative delay, reception under multipath condition (primary plus secondary signals) is achieved. Above that value, reception is not possible anymore in the worse conditions, i.e., small power level difference between primary and secondary signals.

Combining the above analyses (delay and power ratio influences on constellation dispersion), on notes that the influence or even the presence of the secondary signal can be disregarded if the difference between the power of the transmitters is larger than 15 dB. That derives from the fact that in these cases the secondary signal is too small as compared to the primary one, resulting that it can be considered to be negligible, not imperiling (at least in the constellation analyzer) symbol detection. It shall be said that the behavior observed in the laboratory, which are illustrated in Figures 9, 10, 11, 12 and 13 are in consonance with the results and analysis reported in [3]. However, what is the real impact of SFN on actual DTV sets and in more realistic reception scenarios where noise is present?

IV. DTV SIGNAL RECEPTION IN A SINGLE FREQUENCY NETWORK: RESULTS AND ANALYSIS

A. *Undertaken Measures*

After evaluating how the received signal copies relative time alignment and power ratio influence reception, typical of an SFN, of the 64 QAM symbol constellation, we must move forward and evaluate the influence of the receiving conditions on actual commercial TV sets. For that purpose, five different TV sets were tried out as receivers in an SFN with two transmitters according to the diagram in Figure 2.

Before proceeding to receiver evaluation under SFN conditions, we measure the receiver performance for a non-distorting channel, that is, we evaluate the receiver's sensibility [6]. We measure the minimum signal power that guarantees correct reception of the OFDM symbols, this is done for each TV set. For that purpose one simply observes the decoded video and evaluates if there are blocks freezing effects (i.e., effects that would be perceived by common non-specialist viewers). The last column at Table 2 presents these power levels for the different TV sets. We present them as required input power levels, as one feds the TV set input directly, ignoring the antenna although assuming impedance matching. For sake of non-disclosure of the TV sets brands they are represented by capital letters A to E. Table 2 presents in the second column the carrier to noise ratio C/N_{min} required for correct reception. The [C/N] is measured assuming a received signal power of -40 dBm and the added noise power (see Figure 2) is varied so that the minimal C/N for the one transmitter case is obtained, which is the simple difference between the C (dBm) and N (dBm) (thus C/N is given in dB).

TABLE 2
MINIMUM C/N AND MINIMUM INPUT POWER FOR CORRECT SYMBOL RECEPTION

TV Set	Input C/N_{min} (dB)	Required Input Power (C_{min})(dBm)
A	17.8	-80.6
B	17.8	-81.1
C	16.7	-83.2
D	16.7	-82.2
E	16.7	-84.8

B. *Receiver Characteristics in an SFN Scenario*

So far, we have conducted and presented results for two different experiments with TV sets that evaluate their receiving performances for the single transmitter case. Now we advance to evaluate TV set receiver performances in an SFN scenario. For that, we consider an SFN composed of two transmitters as in Figure 2. The most basic objective is to obtain the minimum C/N for different reception conditions. The primary transmitter power (P.Tx1) is set at -40 dBm while the second one (P.Tx2) is varied

$$DL[\text{dB}] = P.Tx1[\text{dBm}] - P.Tx2[\text{dBm}] = -40[dBm] - P.Tx2[\text{dBm}]. \quad (2)$$

Another aspect that is changed is the time alignment / relative delay between the two SFN signals at the receiver input. The SFN is configured to work (as in Table I) with a Guard Interval (GI) of 126 µs (1/8 of the OFDM symbol duration). For each combination of different power level from the primary to the secondary signal and relative delay between them, we evaluate the minimum value of C/N that guarantees an acceptable reception. Table 3 to 7 present the measured C/N_{min} for the combinations of relative power and relative delay tested. In these tables, an "X" denotes that reception was impossible for the correspondent combination of power level difference and relative signal alignment between primary and secondary signals. In Tables 3 to 7, the C/N is defined as

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$$C/N_{min} = \frac{Pow_{Tx1+Tx2}}{N_{max}} \quad (3)$$

as it is impossible to separate the two carriers in the TV set input in the present scenario.

TABLE 3
MINIMUM C/N GUARANTEEING ACCEPTABLE SIGNAL DECODING FOR THE TV SET A

Minimum C/N for different configurations of level and relative delay relations between carriers (dB)								
	Relative delay between carriers (μs) (GI 126μs)							
Diff. Lv.(dB)	**30**	**60**	**90**	**120**	**130**	**150**	**170**	**200**
0	23	25.5	24.7	24	X	X	X	X
3	20.6	21.6	20.6	20.6	X	X	X	X
6	18.8	20.8	19.8	19.8	X	X	X	X
9	18.2	18.2	18.2	18.2	23.9	X	21.2	25.7
12	17.9	17.9	17.9	17.9	18.9	19.9	19.9	20.9
15	17.8	17.8	17.9	17.8	18.8	19.8	19.8	20.8
18	17.8	17.8	17.8	17.8	17.8	19.8	19.8	20.8
21	17.8	17.8	17.8	17.8	17.8	17.8	17.8	18.8

TABLE 4
MINIMUM C/N GUARANTEEING ACCEPTABLE SIGNAL DECODING FOR THE TV SET B

Minimum C/N for different configurations of level and relative delay relations between carriers (dB)								
	Relative delay between carriers (μs) (GI 126μs)							
Diff. Lv(dB)	**30**	**60**	**90**	**120**	**130**	**150**	**170**	**200**
0	23	23	23	23	X	X	X	X
3	20.6	20.6	21.6	21.6	21.6	21.6	21.6	21.6
6	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
9	18.2	18.2	18.2	18.2	18.2	19.2	19.2	19.2
12	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
15	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
18	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
21	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8

TABLE 5
MINIMUM C/N GUARANTEEING ACCEPTABLE SIGNAL DECODING FOR THE TV SET C

Minimum C/N for different configurations of level and relative delay relations between carriers (dB)								
	Relative delay between carriers (μs) (GI 126μs)							
Diff. Lv.(dB)	**30**	**60**	**90**	**120**	**130**	**150**	**170**	**200**
0	23	23	23	23	X	X	X	X
3	20.6	20.6	20.6	20.6	20.6	20.6	21.6	21.6
6	18.8	18.8	18.8	18.8	18.8	18.8	19.8	19.8
9	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
12	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
15	16.7	16.7	17.8	17.8	17.8	17.8	17.8	17.8
18	16.7	16.7	17.8	17.8	17.8	17.8	17.8	17.8
21	16.7	16.7	16.7	16.7	16.7	16.7	17.8	17.8

TABLE 6
MINIMUM C/N GUARANTEEING ACCEPTABLE SIGNAL DECODING FOR THE TV SET D

Minimum C/N for different configurations of level and relative delay relations between carriers (dB)								
	Relative delay between carriers (μs) (GI 126μs)							
Diff. Lv.(dB)	**30**	**60**	**90**	**120**	**130**	**150**	**170**	**200**
0	22	22	22	23	X	X	X	X
3	19.6	19.6	19.6	19.6	20.6	20.6	20.6	20.6
6	18.8	18.8	18.8	18.8	19.8	19.8	19.8	19.8
9	18.2	18.2	18.2	18.2	19.2	19.2	19.2	19.2
12	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
15	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
18	17.8	17.8	17.8	17.8	16.7	16.7	16.7	17.8
21	17.8	16.7	17.8	16.7	16.7	16.7	16.7	16.7

TABLE 7
MINIMUM C/N GUARANTEEING ACCEPTABLE SIGNAL DECODING FOR THE TV SET E

Minimum C/N for different configurations of level and relative delay relations between carriers (dB)								
	Relative delay between carriers (μs) (GI 126μs)							
Diff. Lv.(dB)	**30**	**60**	**90**	**120**	**130**	**150**	**170**	**200**
0	22	22	22	22	25.5	X	X	X
3	19.6	19.6	19.6	20.6	21.6	24.1	23.9	24.9
6	18.8	18.8	18.8	19.8	19.8	19.8	19.8	19.8
9	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
12	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
15	16.7	16.7	17.8	17.8	17.8	17.8	17.8	17.8
18	16.7	16.7	17.8	17.8	17.8	17.8	17.8	17.8
21	16.7	16.7	17.8	17.8	17.8	17.8	17.8	17.8

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All TV sets provided an acceptable reception at both signal arriving at it with the same power level, i.e, the TV sets were able to demodulate the received signal, as far as the time shift between the signals is smaller than the OFDM guard interval; TV set E that could do that even for a relative delay a bit larger than the guard interval. Almost all TV sets evaluated were capable to receive the signal in all the remaining cases when the power levels difference between primary and secondary waves larger than 0 dB; the was the TV set A. In addition, from the results one also observes the reduction of the required C/N as the power level difference between the two SFN signals increases.

C. Margin Loss Due to SFN

We investigate now if there is any difference in receiver performance between the cases when there is only one signal copy arriving at the receiver input and when there are multiple copies. A simple comparison between the entries in Table 2 and the ones in Tables 3 to 7 shows that in the SFN scenario the required C/N for acceptable reception is larger than the one that is required in the single arriving signal scenario. That is, there is a reception margin loss [3,4] when the TV broadcast network shifts from an MFN paradigm to the SFN paradigm. This margin loss can be computed by means of

$$Margin\ Loss(dB) = {}^{C}/_{N_{min.1Tx}}(dB) - {}^{C}/_{N_{min.SFN}}\ (dB) \tag{4}$$

Table 8 presents the SFN margin losses in the worst-case scenario, the most demanding one in terms of the C/N required for acceptable reception in the two-transmitter SFN case, for each of the five tested TV receivers. In the second column of Table 8 contains the SFN margin loss when the secondary signal arrives within the OFDM guard interval (for exception of TV set A) the margin loss when the secondary signal arrives after the guard interval.

TABLE 8
C/N MARGIM LOSS IN AN SFN FOR DIFFERENT TV SETS

Model	Inside GI	Outside GI
A	5	9
B	5	3
C	6	4
D	4	4
E	5	7

From the simple average of the values in Table 8, we averaged the SFN's margin loss for commercial receptors (Table 9).

TABLE 9
LOSS OF C/N MARGIN DUE THE PRESENCE OF A SECOND SIGNAL IN THE SFN

Loss of C/N margin (dB)	
Inside GI	5
Outside GI	5.4

The TV sets tested could not demodulate the signal, except for television E, once the relative delay between the signal surpassed the GI (126 µs) and for a difference level of 0 dB between the two signals arriving at the receiver. However, in all other cases (for exception of TV set A) it was possible to correctly recover the signal in all other conditions even with the decrease of C/N.

V. Minimum Field Strength for Reception in an SFN

The use of SFN instead of MFN broadcasting provokes a reception margin loss, meaning that a larger C/N is required for reception than in an SFN. Tables 3, 4, 5, 6 and 7 present the minimum C/N values for each tested receiver in different reception conditions. These compared with the values in Table 2, provide the C/N margin loss which can in turn be converted into the minimal signal power required for reception in an SFN, deriving from its multipath reception scenario.

A. Calculation model

To calculate the minimum electric field strength that reaches the reception antennas, considering only external antennas in SFN area, the factors pointed in Table 10 are partly related to external reception conditions (after the receiver) considered in the CPqD's Digital Channel Planning [7].

TABLE 10
RECEIVER MODEL USED TO OBTAIN FIELD STRENGTH FROM POWER

Factor	Symbol	Value
Bandwidth (MHz)	B	6
Boltzmann constant (Ws/K)	K	1.38E-23
Absolute temperature (K)	T	290
Thermal noise (dBm)	Nt	-106.20
Central frequency (MHz)	fc	563
Carrier wavelength (m)	l	0.53
Effect area of isotropic antenna (dBm²)	Ai	-16.46
Half-wavelength dipole gain w.r.t the isotropic antenna (dBi)	Gi	2.15
Antenna gain w.r.t the half-wave dipole (dBd)	G	10
Effective area of antenna (dBm2)	A	-6.31
Instrinsic impendance (Ω)	h	377
Dipole fator (dBm-dBµV/m)	Kd	-130.07
Cable loss (dB)	Lf	4
Margin against man-made noise (dB)	Mm	0

B. MFN Reception Margin Loss

Based on the values of Tables 3, 4, 5, 6 and 7, the minimum C/N values, the receptor's noise figure land the SFN's multipath margin were measured, and, with Equation 5, the minimum signal power was calculated (Table 11).

$$P_s(dBm) = N_t(dBm) + F_r(dBm) + C/N(dB) + M_{SFN}(dB) \tag{5}$$

The SFN margin loss is given by the values in the fourth column of Table 8, considering reception in proper conditions (inside the guard interval). These values are the increase in the minimum required signal power at the antenna (for correct reception) w.r.t. the single case scenario (MFN).

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In Equation (5) N_t refers to the thermal noise, that will obviously be present. We consider it equal to the one provide by the external DTV reception conditions in [4], i.e. N_t = -106.20 dBm (temperature of T = 290 K, both of these are in Table 10). Fr refers to the receiver noise figure that is calculated using the minimum C/N, minimum input power (C_{min}), being given by

$$F_r(dBm) = C_{min}(dBm) - C/N(dB) + N_t(dBm) \quad (6)$$

TABLE 11
PERFORMANCES OF DIGITAL TV RECEIVERS EVALUATED

Receiver	Digital System C/N Threshold (dB)	Receiver's Noise Figure (dB)	SFN Multipath Margin Loss(dB)	Minimun Signal Power (dBm)
	Symbol			
	C/N	Fr	Msfn	Ps
A	17.8	7.8	5.2	-75.40
B	17.8	7.3	5.2	-75.90
C	16.7	6.3	6.3	-76.90
D	16.7	6.3	4.2	-79.00
E	16.7	4.7	5.3	-79.50

C. Minimum electric field strength for reception

Above, we derived the required signal power for reception in an SFN (two-path reception). This is the necessary excitation at each receiver RF (Radio Frequency) input. However, this excitation will depend on several other factors as internal or external reception, antenna size, impedance matching, etc. That is, how is the propagated energy captured and input into the receiver RF input.

Using the reception model in Table 9 and the required signal power in Table 11, we can compute the minimum electric field strength arriving at the antenna that is required for correct reception of the DTV in an SFN network. The minimum field strength that shall arrive at the reception antenna can be calculated using [7]

$$E_{min}(dB\mu V/m) = P_s(dBm) + L_f(dB) + M_m(dB) - G(dB) - k_d(dBm - dB\mu V/m) \quad (7)$$

For the evaluated DTV receivers the required field strength at the antenna (for the above model: Equation (7) and Table 10) are presented in Table 12, where one observes that they fit reasonably within a +- 3dB range.

TABLE 12
MINIMUM FIELD STRENGTH BY THE DTV RECEIVERS TESTED

Receiver	Minimum filed strength (E_{min}) (dBm)
A	48.68
B	48.18
C	47.18
D	45.08
E	44.58

D. Correction factor for locations

The values in Table 12 were obtained using a laboratory setup mimicking a two path reception scenario, which is a reasonable assumption for SFN DTV broadcasting. However, obviously in a real reception scenario the strength of the electric field may wander due to several factors (climatology, humidity, etc). Consequently, the field strength is assumed to vary with the considered location/site and time/date. Therefore, one must introduce a margin in the minimum required electric field strength to guarantee that the wave can be correctly received and decoded with acceptable quality, that is for the DTV broadcast being available for the receiver/viewer/consumer. Obviously, this margin increases as the resilience of the system to field strength variation rises, that is, as system availability increases.

$$\Delta L(dB) = \mu \cdot \sigma m(dB). \quad (8)$$

Following the methodology in [7], we compute the correction factor (margin) as Equation (8). Again, as in [7], the employed ΔL is such that at 95% of the SFN coverage area the electric field meets the required electric field strength at least at 90% of the time. In this case, it is necessary to have a margin (apply a correction factor) ΔL that is computed considering a distribution μ of 1.64 times the standard deviation σm at large scale, presented in Figure 15. If one considers that the system has a large number of elements, then the latter is 5.5 dB [7]. Putting together, this results in a correction of the normal curve given by a factor, $\Delta L = 1.64 \cdot 5.5 = 9$ dB.

Each one of the tested DTV receivers can use the correction factor / margin above to compute the required field strength. Those are obtained by means of

$$E_{corrected}(dB\mu V/m) = E_{min}(dB\mu V/m) + \Delta L(dB) \quad (9)$$

Which are presented in the last column in Table 12.

These values bring a worst-case scenario for the field strength of 58 dBμV/m. Thus, when planning SFN DTV broadcasting the field strength must consider that in order for providing a reasonable DTV signal availability. It is worth noticing that our analysis produces an electrical field requirement that is 7 dB larger than the actual minimum field strength considered for DTV system deployment in Brazil (51 dBμV/m) [7].

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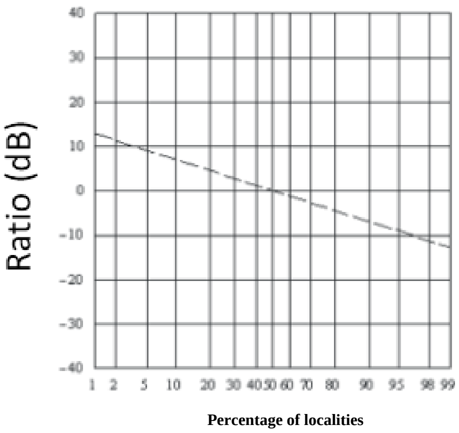

Figure 15. Field rate for a given percentage of time for a field for 50% of locations, also known as standard deviation at large scale σm.

TABLE 13
MINIMUM PROPOSAL FIELD STRENGTH FOR SEVERAL DIGITAL TELEVISION RECEIVERS

Receiver	**Minimum proposal field strength** $(dB\mu V/m)$
Samsung UN32D5500RGXZD	57.7
Philips 32PFL7606D/78	57.2
LG 32CS460	56.2
Sony KDL-32EX525	54.1
Panasonic TC-L32X30B	53.6

VI. CONCLUSIONS

The results Table 13 show the feasibility of SFN for the actual scenario and technology of DTV, but a slight performance variation between them. Another important aspect brought by these results is that it may be necessary to revise the minimum electric field strength for designing SFN DTV broadcast networks. When comparing them to the results presented in [7], there is the need for a 7dB increment for the minimum electric field strength default value used in projects (51dBµV/m) seems to be necessary. This increment may be required in general DTV coverage design, as SFN gets increasingly common. The minimum field strength value of 58dBµV/m obtained in our analysis incorporated both the margin loss due to SFN usage and the 95% correction factor (according to international standards for digital television planning).

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SDR-WBFM Receiver as an alternative to replace equipment in FM extended

Ramon Mayor Martins

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SDR-WBFM Receiver as an alternative to replace equipment in FM extended

Ramon Mayor Martins

***Abstract*— A presidential decree in Brazil authorizing the migration of AM broadcast to FM. To accommodate these stations, the FM band will receive the frequencies of the channels 5 and 6 of analog TV, which became known as “FM extended”. One of the barriers found in migration is the acquisition of equipment by the users, as the current equipment does not have the expected range in FM extended. To mitigate this problem, the implementation of an FM receiver using the Software Defined Radio (SDR) for its flexibility is proposed. The receiver was developed in GNU Radio environment, with a simple programming was possible to create a low-cost receiver and can serve as an alternative to users for receiving the new band.**

***Index Terms*—Broadcast, migration, receiver, Software Defined Radio.**

I. Introduction

In Brazil, the presidential decree 8139/2013 [1] authorizes the migration of radio stations operating in the AM band (525 kHz a 1705 kHz) [2] to the FM band. The rules were set by the Ministry of Communications in the order 127 of 12 March 2014 [3]. Currently exist in Brazil 1,781 AM radio stations, of this total, 1,386 have asked to move to the FM band [4]. Channels 5 and 6, which are now occupied by analog TV channels will be vacated and intended for FM stations to accommodate migrate [5]. Today, the FMs are tuned in the range of 87.9 MHz to 107.9 MHz. With the release of channels, this frequency will be extended from 76 MHz to 107.9 MHz. One of the issues for broadcasters is in changing the infrastructure to suit this new range, known as “FM extended”, and one of the impasses for users is to purchase new equipment that have the FM band starting at 76 MHz, today most equipment such as vehicular radios, portable radios, radios in smartphones, among others start at 87.9 MHz. The concept of Software-defined radio (SDR) allows replace the traditional implementation of hardware communication devices for a more flexible implementation that makes use of programmable devices controlled by software, such as a personal computer or an embedded processor [6].

Reconfigurable radio technologies provides an opportunity to reduce infrastructure costs, provide more efficient wireless connectivity across various networks, and offer a new dimension of operational flexibility that can ultimately enhance network performance [7].

SDR has emerged as a revolutionary approach to developing and operating communication radios for a broad range of domains including commercial, military, and public service. Advances in digital signal processing and computing power have enabled the evolution of radio implementations from primarily electronically (i.e., hardware) based to firmware and/or software-based. Each of these application domains has leveraged reconfigurable hardware to satisfy the specific desired operating requirements [8].

The purpose of this letter is to use the SDR inexpensive device to implement WBFM (wideband FM) receiver as an alternative to replace the equipment in AM- FM migration, this implementation will be use the GNU Radio environment.

In the second section will be presented the features and architecture of an SDR. In the third section will present the GNU Radio environment and the implementation of the receiver WBFM. Finally it will be completed on resources.

II. Software Defined Radio and GNU Radio Environment

Wireless Innovation Forum defined SDR as "radio in which some or all of the functions of the physical layer are defined by software", in other words SDR refers to technology which software modules are executed in real-time generic platforms microprocessors, digital signal processors or programmable logic circuitry to implement functions the signal to be transmitted generation (modulation) or detection of the received radio signal (demodulation) [6].

SDR technology has emerged as a solution for prototyping wireless transceivers and networks by taking advantage of its customizable features to accelerate development time. As a result, a growing number of applications, such as national defense, public safety, connected vehicles, and education, can benefit from SDR technology [7].

The SDR technology may be employed in several radio frequency applications, such as Bluetooth, WLAN, GPS, Radar, WiMAX, LTE, etc. A SDR is nothing more than a communication system software-based, the main characteristics of operation can be modified at run time: the system can be easily re-configured to perform different functions according to need [6].

A. SDR Architecture

SDR technology implements radio functionalities like modulation/demodulation, signal generation, signal processing and signal coding in software instead of hardware as in conventional radio systems. The software implementation provides a higher degree of flexibility and reconfigurability and many benefits including the capability to change the channel assignments, to change the provided communication services or modify the transmission parameters or communication protocols [9]. The SDR

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operates as follows, as can be seen in Figure 1.

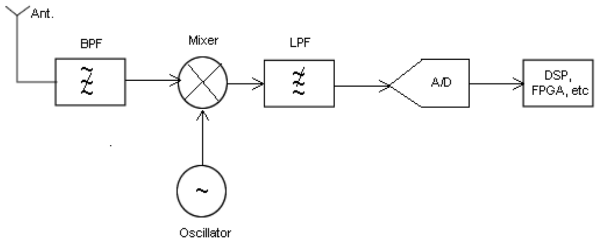

Fig. 1. SDR receiver block diagram.

As explain [10] low-noise amplifier is placed immediately after an antenna or filter, followed by a block of intermediate frequency (IF), this block deals with downconversion and translating the frequency of interest into a generic IF. Moreover, some filters could be inserted in this block to reduce the bandwidth of interest in a range that agrees with the next block of sampling/generation (in order to satisfy the Nyquist theorem). An analog-to-digital converter (ADC) fixes the range of frequency within which the SDR will work. After the conversion block, signal samples can be processed by a processing unit (i.e. a digital signal processor (DSP), a field-programmable gate array (FPGA), or personal computer (PC), giving extreme flexibility to the system.

For the development of reconfigurable SDR application was used for the experiment the GNU Radio environment.

B. GNU Radio

GNU Radio is a free software toolkit licensed under the GPL for implementing SDR. Initially, it was mainly used by amateur radio enthusiasts, but it later gained significant interest from wireless researchers, and today it has a large community of users and contributors [7]. The GNU Radio provides a development environment and note processing to implement SDR [6]. Several software algorithms include filters, channel codes, synchronization elements, equalizers, demodulators, decoders, and many other elements. It’s possible to use these components as building blocks of a communication system [7].

The applications were developed using GNU Radio the Python programming language, which were built connections between the processing units. The block itself, they were developed in C ++ for performance reasons [6]. With the set of blocks already provided by GNU Radio, a large number of applications can be resolved without need to create specific blocks, which makes the faster and easier development.

III. Receiver System WBFM for FM extended

Application possibilities are huge when using a low-cost SDR device and a programming environment such as GNU Radio. In this sense it’s possible to create and manage a FM receiver system for extend FM bands from 76 MHz to 107.9. It’s even possible to develop a robust system using filters, gain setting, bandwidth control, and other improvements in software, giving to the user the possibility to customize their system.

Initially it used the “*RTL- SDR Source*” block, this block will collect the signals in a range of 2.88 MHz received from the dongle, this is also adjusted the reception gains to 30 dB and frequency with a variable called "*freq*". That variable has a band ranging from 76 MHz to 107.9 MHz, it’s possible to scan steps of 200. This value is the bandwidth that a commercial FM station occupies according to the Carson’s bandwidth rules, which takes into account the frequency offset of 75 kHz and a maximum frequency modulating of 15 kHz.

After these adjustments, the data flow is directed to block "*Low Pass Filter (LPF)*", that block will filter the total signal of 200 kHz for 100 kHz cutoff frequency, and a transition band of 10 kHz, which concentrates information stereo FM signal. An stereo FM signal has the following composition as in Figure 2 below.

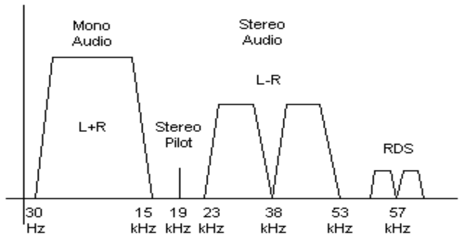

Fig. 2. Stereo FM Spectrum.

In this LPF block is also performed a decimation, according Nyquist enough to the 200 kHz of the stations. After this treatment the way, is included a block "*WBFM Receiver*". This block is responsible for the demodulation of the FM signal itself. An important issue in this block is the audio decimation to suit the device's sound card where it’s implementing in our case 48 kHz.

The next step is the inclusion of a deemphasis with FM “*deemphasis block*”, this block is necessary because the noise has a greater effect at higher modulating frequency than the lower, accordingly, the transmission is performed a preemphasis in high frequencies (i.e., the higher frequencies are artificially enhanced or reinforced at the transmitter to provide greater noise immunity), and reception takes place a deemphasis.

After deemphasis, another filter is included, optional, to remove the carrier from 15 kHz, to simplify reception, in this case, would be received only the “L + R” FM spectrum portion. In the final step, is included “*Multiply Const*” block with a variable call volume to adjust the intensity of the audio and finally, is included a block called “Audio Sink”, which will allow the signal conversion for proper audio to sound card computer.

The system screen in GNU Radio with blocks can be seen in Figure 3, the spectrographic screen and the waterfall can be seen in Figure 4.

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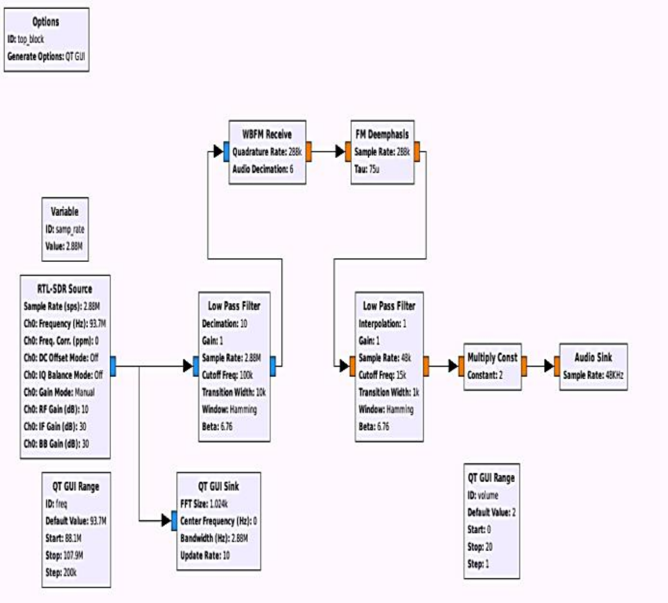

Fig. 3. WBFM receiver in GNU Radio environment

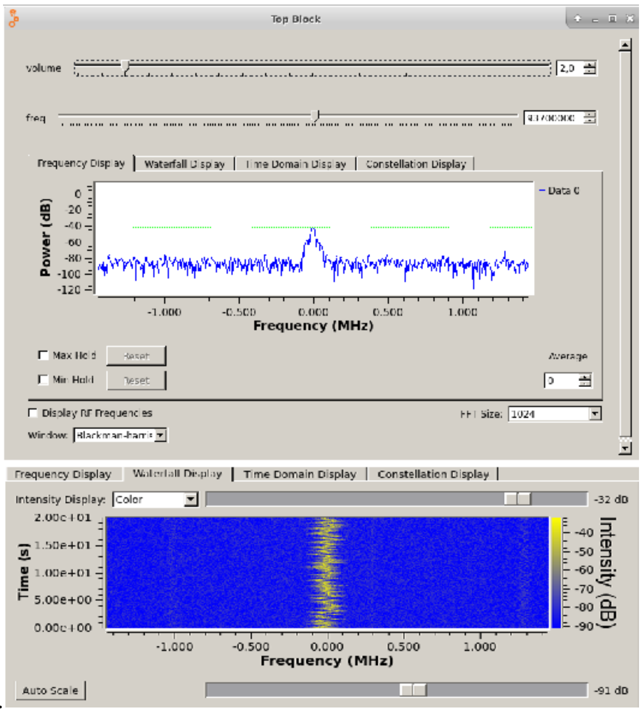

Fig. 4. Spectrographic and waterfall of WBFM Receiver.

IV. Conclusion

SDR technology has many applications in radio environments and is becoming increasingly popular among all type of users. The versatility of SDR allows it to be built flexible receivers covering the extended FM band from 76 to 107.9 MHz and meet the demand for new equipment for the migration of AM stations to FM. Thus the user himself, with a low-cost SDR receiver can program simply WBFM your receiving system. The level of customization will adjust the gain, filter, bandwidth, and other radio frequency characteristics so as to make the system more robust.

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Survey of digital radio standards and updating for rollout in Brazil

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Survey of digital radio standards and updating for rollout in Brazil

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***Abstract*—Currently, the spectrum resource is sparse, requiring a system that optimizes use this. An option for radio broadcast is the use of digital radio techniques. These techniques are available standards DAB, DRM, IBOC and have extensive advantage over analog systems, for example, flexibility and audio quality. The choice of the most appropriate digital radio technique is a very important problem, and check of multilateral performances is necessary to countries considering the release of digital radio broadcasting service. In Brazil some tests with digital radio were performed, but no further definition of what standard to use.**

This paper aims establish some technical comparison of the leading digital radio standards available. Another goal is to present the movements of activities with digital radio in Brazil. Performing some direct comparisons between the patterns, it was observed that DRM is interesting in order to coverage and being open source, while IBOC (HD Radio) is a hybrid system, however proprietary.

***Index Terms*—Broadcast, Digital Radio, Engineering, Telecommunications.**

I. Introduction

Brazil has experienced some discussions and optimization strategies of the electromagnetic spectrum resources and improvement of the telecommunications system. The most current strategies correspond as follows: migration of AM radio stations to FM in decree of November 7, 2013 signed by President Dilma Rousseff, which enables higher audio quality and robustness to interference stations that currently operate in AM; the incorporation of the channels 5 and 6 of analog TV to accommodate the FM bands, which became known as extended FM; the migration from analogue TV to digital TV, which according to the Ministry of Communications has changed the analog TV shutdown schedule for 2018. In this context, another strategy was taken in 2014 where Anatel (National Agency of Telecommunications) published notice of auction of the 700 MHz band, which focused channels (52-69) TV UHF to meet the demands of 4G telephony, rearranging the UHF channels 14 to 51.

Adequacy of these initiatives, it also highlights the discussion on the introduction of digital technology in radio broadcasting system in Brazil. The digital radio standards has extensive advantage over analog systems. Among some of these include: audio quality, service reliability, programming, coverage flexibility receiver, spectrum, and power efficiency, as well as new business opportunities for the broadcaster. Due to inadequate spectrum resources and increasing demands for high-quality multimedia services, traditional analog audio broadcasting is being migrated into digital radio around the world [1].

Recently various digital radio broadcasting techniques and standards have been proposed, and many countries have been considering converting their analog radio broadcasting into digital broadcasting. However, since a small number of countries have achieved the digital conversion of their analog radio broadcasting (some European countries and the U.S.), most countries still face converting their analog radio broadcasting service into digital service [2].

In Brazil, in March 2007, the advisory board of the Digital Radio was created in order to advise the Ministry of Communications in planning the implementation of digital radio in Brazil. The board is composed of representatives of civil society, the federal government, including Anatel and the Ministry of Communications; broadcasting sectors (commercial, educational, community and public); industry (reception, transmission and audiovisual); academic institutions, and advertisers.

In 2010, the Brazilian Digital Radio System (SBRD) was established by Ministry of Communications decree number 290 [3]. According to Anatel, in partnership with performers of different stations broadcasting services, the Ministry of Communications has performed technical tests to check the performance of different models [4].

The choice of the most appropriate digital radio technique is a very important problem, and check of multilateral performances is necessary to countries considering the release of digital radio broadcasting service [2]. This paper aims establish some technical comparison of the leading digital radio standards available. In the section 2 will be presented techniques and their characteristics, they being the DAB (Digital Audio Broadcasting), DRM (Digital Radio Mondiale) and IBOC (HDRadio) and FMeXtra. In section 3, the comparisons between these techniques. In section 4 the implementation perspective in Brazil. Finally, in section 5, the conclusions about the digital radio standards.

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II. Survey of digital radio standards

There are currently four types of Digital Radio (DR) systems deployed throughout the world. These systems are known as digital audio broadcasting (DAB) system, digital radio mondiale (DRM), in-band on-channel (IBOC), and satellite digital audio radio. These system offer the following advantages according to [5]. DR reception is largely immune to interference, they provide fixed, mobile, and portable reception using simple low-gain antennas. DR is efficient in the use of the limited radio frequency spectrum and they have the capability of operation from terrestrial and/or satellite transmitters. Besides that, value-added system feature will allow enhancements such as text, graphics, and still-pictures.

These features provide the opportunity to introduce new innovative services, such as multimedia radio-with-pictures and broadcast web sites on commercial amplitude-modulation (AM) and frequency-modulation (FM) receivers.

A. DAB (Digital Audio Broadcast)

The DAB (Digital Audio Broadcast) family includes DAB and DAB+ for digital radio and DMB (Digital Multimedia Broadcasting) for mobile TV.

The original DAB started its development in 1981 on *Institut für Rundfunktechnik* (IRT) and was completed by the EUREKA 147/DAB project. The specification was finalized after some public demonstration on early 90's in 1993. It was adopted by ITU-R as a standard in 1994, the european community in 1995 and by ETSI in 1997. This first standard uses the MPEG Audio Layer II codec.

It was the first standard based on OFDM (Orthogonal Frequency Divison Multiplexing), technique that was not very known in communication systems.

According to [7], DAB is very well suited for mobile reception and provides very high robustness against multipath reception. It allows use of single frequency networks (SFNs) for high frequency efficiency. This technique is also able to transmit personalized data, based on the program, radio station and other service like traffic information.

The frequency bands in DAB according with [7] is band III (174-230 MHz / 240 MHz in some countries). An external antenna is needed for a high quality reception however the band provides a wide range of coverage and provides high penetration on buildings. Band L (1452-1479.5 MHz) is used in some countries where Band III is not available or as a backup band. It does not need an external antenna, what is an advantage for mobile phones. Band L is used on urban areas with high buildings on both side of streets due to a reflective characteristic of this band. It allows a good reception without line of sight, but the reception at indoor ambient is limited. Even so, this band can be useful for some applications like local information distribution systems inside buildings, e.g. in department store, railway stations.

The benefits of DAB, according with [6] is: quality of service, superior sound quality (close to CD quality), perfect reception condictions; wide range of value-added services, in other words, information services (news headline, urgent information); universal system layout, high level of standardization of basic principles and transmission tools, unique system design (services available on terrestrial, cable and satellite networks providing national, regional, local and international coverage), wide choice receivers (it possible to access DAB services from fixed equipment, mobile and portable radio); flexibility of multiplex configuration (the arrangement of services may be changed to match the need of the providers of programs or data services, without interrupting ongoing services), bit rate flexibility (the programmer provider can choose the bit rate for an audio program according to its quality, for instance less than 100 kbit/s for a pure speech, 128 kbit/s for mono and 256 kbit/s for stereo music); transmission efficiency, lower transmission costs for broadcasters and transmitter (DAB needs only a fraction of the electrical energy compared to conventional AM and FM transmitter).

The future of DAB is the DAB+ development, even with the MPEG Audio Layer III (MP3) popularization in digital music player market, the standard was overcome in efficiency (same audio quality with lower bit rate) and performance by MPEG-4 (HE AAC v2 codec). Because of this, there was an integration of AAC (Advanced Audio Coding) with DAB and in 2007 February, DAB+ was developed. The physical layer remained the same of DAB, with only a few new applications, transport protocols and a second error correction layer. Therefore it is possible an structure able to multiplex both technologies [8]. DAB+ uses a Reed Solomon coding, a more sophisticated technique than the Viterbi encoder used by DAB. This guarantee a better bit error ratio in the reception [2]. Recently, a new audio codec has been developed: the USAC (Unified Speech and Audio Coding), and it has been implemented in new DAB+ systems. "To maximize the performance of USAC audio codec, variable bit rate (VBR) delivery scheme instead of constant bit rate (CBR) scheme used in DAB+ is designed and USAC decoder is inserted to the receiver" [9].

Many countries, mainly in Europe, eastern Asia and Oceania, have DAB regularized or are interested on implementing this systems. Norway, Switzerland and the United Kingdom have almost 100% of DAB coverage. Others like Turkey, China and South Africa are on trial and some are interested like Russia and Ukraine [10].

B. DRM (Digital Radio Mondiale)

DRM is a digital radio standard developed and managed by an open international consortium. Therefore it is possible to develop free software for adoption and customization of default. Businesses and universities can create, optimize and deploy it in various electronic devices. The DRM works with high quality both in the AM medium and shortwave using DRM30 mode, as the FM/VHF band, using the DRM+ [11].

The International Telecommunications Union (ITU) recognized the DRM to broadcasting bands below 30 MHz in the year of 2002 by the recommendation BS1514-1. The European Telecommunications Standards Institute (ETSI) also recognized the DRM like a digital sound broadcasting system which can be used as a replacement of the analogue AM sound broadcasting services. Finally in 2003, the International Electrotechnical Committee (IEC) approves the DRM like International Standard [12].

The DRM system uses COFDM (Coded Orthogonal Frequency Division Multiplex). Then all analog data is digitized and divided into several slightly spaced subcarriers within the broadcast channel. The parameter coding and OFDM can be altered to allow the DRM function in different environments with different propagation characteristics. With the right choice of parameters you can adjust the transmission with the best combination of power, robustness and

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transmission rate. The modulations used in DRM are 4QAM, 16QAM and 64QAM depending on the transmission mode. There are five transmission modes, according to [11], as shown in the Table 1.

TABLE I
TRANSMISSION MODES USED IN DRM

Mode	MSC QAM options	Bandwidth options (kHz)	Typical uses	
A	16, 64	4.5, 5, 9, 10, 18, 20	LF & MF ground-wave, 26MHz band line-of-sight	DRM30 modes
B	16, 64	4.5, 5, 9, 10, 18, 20	HF & MF transmission on sky-wave	
C	16, 64	10, 20	Difficult sky-wave channels on HF	
D	16, 64	10, 20	NVIS sky-wave (highest Doppler & delay spread)	
E	4, 16	100	VHF transmissions in the bands above 30 MHz	DRM+

The A mode is used for a higher transmission rate using ground-waves and line-of-sight. The B-mode is generally used forsky-wave. The C and D modes are used when propagation conditions are more severe like in long distances with multiple hops or when very strong reflections occur. The E mode is used in the VHF band.

The DRM can use the Meltzer-Moser MPEG-4 HE AAC v2 (ISO / IEC), but with a greater robustness against fading channel the HE-AAC v2 is the most widely used standard. DRM system is formed by the service description channel (SDC) which carries the information for decoding the main service channel (MSC), the fast-access channel (FAC) containing the OFDM signal properties and the SDC and MSC configuration and the MSC itself, which encodes the frame generated by the multiplexer [13]. Some of the most important feature of the DRM are the possibility of reuse of the radio spectrum, CD quality sound, terrestrial based DR, wireless data services, backward compatibility with analog radio and interference immunity.[5]

Currently the main radio stations operating with DRM are Vatican Radio , Radio Exterior of Spain , Radio New Zealand International and BBC Radio in England.

C. IBOC (HDRadio)

IBOC (in-band on-channel) refers to a method of transmitting DR broadcast signals centered on the same frequency as an existing AM or FM station (referred to as AM and FM systems) but occupying the sidebands above and below the station's center frequency. IBOC is a hybrid method, transmitting digital and analog radio on the same frequency. A major IBOC system is called HDRadio, proprietary of Ibiquity.

IBOC systems are comprised of four building blocks according to [5]: audio source coding, channel coding, modulation/demodulation techniques and blending.

The first is audio source coding, that means: an audio codec is a source encoding device that filters out those parts of an analog signal that are irrelevant to the human ear. When decoded, the signal will not be identical to the original but will be perceived to be the same.

The second, output stream from the audio codec is encoded using forward error correction (FEC) and interleaving in the transmission system. This greatly improves the reliability of the transmitted information by carefully adding redundant information used to correct errors occurring in the transmission path. Advanced FEC coding techniques have been specifically designed for AM systems based on detailed interference studies to exploit the non-uniform nature of interference in the AM bands.

The third block, modulation/demodulation techniques: a modem is a device that modulates a signal or demodulates it. AM systems use quadrature AM scheme in conjunction with orthogonal frequency division multiplexing (OFDM). FM systems also uses OFDM modulation but with the carriers modulated with quadrature phase-shift keying (QPSK) modulation scheme.

The last block is blending: this is a technique employed in IBOC DAB systems to seamlessly switch between digital-to-analog signals. Essentially, blending allows transition from the instantly acquired analog signal (such as when the receiver is first turned on) to the digital signal (after the receiver has acquired, decoded, and processed the signal). Once the digital signal is acquired, the receiver will transition to it in a seamless fashion. Should the digital signal become corrupted the receiver will seamlessly switch to the analog signal.

The typical coherent bandwidth in wide area applications is more than 1 MHz. Therefore, even with aggregation, the IBOC is a relatively narrowband system and does not possess sufficient frequency diversity in a fading environment. As a result, its performance is particularly poor for stationary and low-mobility receivers where limited time domain diversity can be explored. In order to improve the performance, a frequency hopping option is adopted to introduce frequency diversity into the system [1].

IBOC uses LDPC codes, that is widely adopted in nowadays wireless communication standards for their Shannon-limit approaching performance and their inherent parallel structure for fast decoding [1].

Currently, several radio stations in the United States use the HD Radio.

D. FMeXtra (VuCast)

FMeXtra was an in-band on-channel system created by Digital Radio Express now marked as VuCast. This system uses the remaining capacity with FM radio frequency spectrum. Usually each frequency is a portion from 0 to 59 kHz for audio, the stereo pilot carrier and the Radio Data System (RDS) [14].

FMeXtra makes use of free present spectrum portion allowing that the digital signal is transmitted in addition to the analog signal, like SCA, between 53 kHz and 99 kHz.

FMeXtra technology can deliver 128k bits/second in stereo configurations. According to [18], the most powerful realization of FMeXtra occurs when the analog broadcast is mono audio as shown below. In this configuration, FMeXtra can use all the bandwidth between 20kHz and 99kHz, and can deliver over 256 kbits/sec, which is more bits than a dedicated ISDN data line.

By using AAC+ codec in combination with MPEG 4, the sound quality is greatly improved. The quality moreover it depends on the number of stations that digitally broadcast on the same frequency. The more stations, becomes all the less the sound quality [14].

Currently, some stations in China and United States using FMeXtra (VuCast).

III. COMPARISON BETWEEN THE DIGITAL RADIO STANDARDS

Some factors can serve as a comparison between the digital radio standards available in the market such as radio spectrum

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reuse, specific allocation of radio spectrum for digital radio, audio quality, multimedia features, compatibility with the analog system, immunity to interference, power requirement, coverage and cost of deployment.

The radio spectrum reuse: DAB is the only system that does not reuse. DRM is able to transmit up to four programs at the same frequency. The DRM occupies the same bandwidth of an analog signal. HD Radio does the reuse, but uses 2 digital side carriers, as well as analog, occupying the range of 3 channels.

The specific radio spectrum allocation: DAB requires a specific range for your signal.

In the audio quality: all patterns have higher quality than FM stereo. In HD Radio, being a hybrid standard, performs FM broadcasts with CD quality and AM broadcasts with the quality of a stereo FM. About multimedia features: all patterns have this feature. About compatibility with the analog system: the DAB is not compatible, all others are.

Concerning a immunity to interference: all patterns are immune to interference, as are digital standards. As to power requirement: The DRM works with low power, the HD Radio does not work. In terms of coverage: the DRM works on shortwave with DRM30 (AM), the HD Radio does not work on shortwave.The DRM allows different transmission modes can function MF, HF and VHF, and may be configured so as to adapt the transmission according to the need, HDRadio does not use HF.

About the modulation scheme: DRM uses COFDM and QAM modulation according to the mode of transmission and to improve the requisites of the power and transmission rate. The use AM HD Radio systems QAM modulation scheme and the OFDM, since the FM and QPSK systems use OFDM modulation schemes. Both DRM and DAB uses MPEG-4 codec HE AAC v2 codec, to give greater robustness against fading in the channel. Other comparisons can be made, like technology available: DRM is an open, standards and publicly available standards. The HD Radio is a proprietary system with closed technology.

The IBOC systems to seamlessly switch between digital-to-analog signals. Essentially, blending Allows transition from the instantly acquired analog signal (such as When the receiver is first turned on) to the digital signal (after the receiver has acquired, decoded, and the processed signal).

Finally, the difference between HD Radio and FMeXtra is mainly the techniques. FMeXtra, makes use of the subcarrier of an FM signal, while HD Radio makes use of the side band. This allows the signal is not transmitted exactly on the FM frequency of the station, but actually next to the signal. Another big difference is that FMeXtra much cheaper than HD Radio. In addition, HDRadio stations also requires royalties additional pay for the mere use of the system. This involves an amount of thousands of dollars per year. The coverage is similar to FM Stereo, but higher ERP is required in larger urban areas, as with normal FM transmissions [14]. Some comparisons are shown in Table 2.

TABLE II
COMPARISON BETWEEN THE RADIO STANDARDS

	DAB	DRM	IBOC (HDRADIO)	FMEXTRA (VUCAST)
Technique	OFDM	COFDM/4-16-64 QAM	OFDM/ QPSK	FM Stereo with SCA portion
Radio Spectrum Reuse	no	yes	yes	yes
Specific Allocation of Radio Spectrum	yes	no	no	no
Audio Quality	yes	yes	yes	yes
Multimedia Features	yes	yes	yes	yes
Compatibility with the Analog System	no	yes	yes	yes
Bands	VHF/ L Band	MF,HF,VHF	VHF	VHF

IV. IMPLEMENTATION PERSPECTIVE IN BRAZIL

Brazil is looking for a flexible standard for scanning radio stations, just as happened with the Digital TV standard choice. The digital radio guidelines in Brazil are given by decree No. 290/2010 of the Ministry of Communications [3]. According to [15], the SBRD (Digital Radio Brazilian System) joined as technical basis signals standards IBOC (HD Radio) standard used in the United States and created by American iBiquity Digital Consortium and DRM (Digital Radio Mondiale), used in Europe. In this respect, the DAB and FMeXtra systems were not listed for testing.

In this paper it was not listed ISDB Japanese standard for digital radio ISDB-Tsb (Integrated Services Digital Broadcasting Terrestrial, Segmented Band). This system was not considered in Brazil to occupy a very broadband, and thus would have to use its own range, which opposite way to spectrum optimization.

In Brazil, digital broadcasts are still in progress, new emissions tests were approved in 2005 and since 2007 tests are conducted using the two signals. Anatel approved 12 stations to perform the tests. Broadcasters who tested the HD Radio were: Sistema Globo de Rádio, Rádio Jovem Pan, RBS, and El Dorado for the regions of São Paulo, Rio de Janeiro, Belo Horizonte, Porto Alegre, Curitiba and Brasília. Broadcasters who tested the DRM were Radiobrás and the Faculty of Technology of Brasília University [15]. The planning of the tests, listed in 2007, with the DRM system in medium waves can be found at [16]. Conforming to [15] by 2014 no decision had been made about the standards. According to the results of the tests none of the standards were satisfactory, the delay in the decision by the two standards did concern among broadcasters grow. In 2013, the chief of staff EBC (Brazilian public broadcaster) stated at the public hearing of the Committee on Science and Technology of the Senate, that no good implementation of digital radio in Brazil if the cost of the equipment is high making limited access.

According to [17], both the AM of the migration process for the FM as well the digital radio deployment process in Brazil is stagnant. Delaying process shutdown of analog TV, decelerate further migration and digital radio has been abandoned by the thought that radio and web radios applications will be the future. In Brazil, the only development of digital radio is supported by EBC, which has been trying for more than a year put a solid and robust DRM shortwave in the Amazon National Radio [17].

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The latest initiatives in Brazil were testing the EBC with DRM in the frequency of 9755 kHz in 2015. In 2016, an EBC request to the Ministry of Communications on a definition for Digital Radio Brazilian and the foundation of the ABRADIG (Digital Radio Brazilian Association) with the aim of promoting the implementation of Digital Radio in Brazil.

V. Conclusions

The Digital Radio allows digital audio with higher quality than an analog FM station allows multiprogramming, interactivity, multimedia content, among others. In Brazil there is still the current decree AM migration to FM, which does not provide for the use of digital radio techniques.

For Brazil, the most suitable system is the DRM, it is the only system that meets all frequency bands (MF, HF and VHF), and is an open source system, strengthening the domestic industry in the aspect of development transmitters and receivers. The IBOC (HD Radio) developed and owned by US company Ibiquity is a closed, proprietary system. The audio encoder and protocols for transmission of multimedia content and digital services are also closed.

The system also charges system usage license, broadcasters pay for Ibiquity use rate. HD Radio, being a standard hybrid, keeps with the analog signal, which does not solve the spectrum optimization. Despite the DRM comply with the digital radio guidelines in Brazil given by decree 290/2010 [3], such as social inclusion, cultural diversity, democratization of information , technology transfer for the Brazilian industry, among others, and also provide the efficient use of radio frequency spectrum, with the DRM membership, people will have to buy new appliances. The prices of these new devices may not be accessible.

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

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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:

$$Layer\ A = Channel - Layer\ B \tag{1}$$

$$Others = Layer\ B - VideoHD - Null\ PID \tag{2}$$

$$New\ Null\ PID\ II = New\ Layer\ B - VideoHD - Others \tag{3}$$

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.

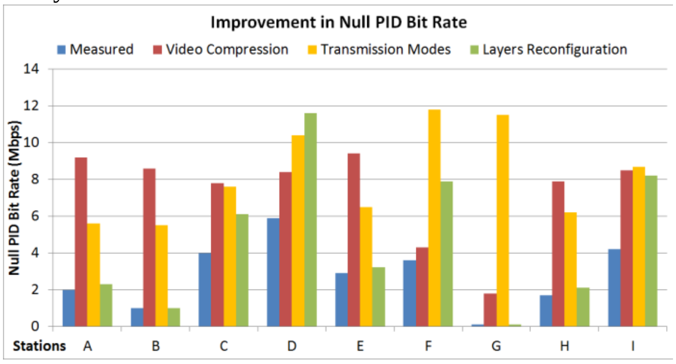

Figure 1 – Null PID Improvement Comparison

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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