Development of an Antenna Tracking Electronic System for Digital Terrestrial TV based on Image in Real Time

Carlos Alberto Ramirez Behaine and Bernardo Dambrós Neckel

***Abstract*— This development paper intends to assist the evolution of digital terrestrial TV signals in Brazil by increasing the quality of reception in distant areas of large centers. Aiming at this, we illustrate the construction of a cognitive tracking electronic system in real time, suitable to receive the waves of the signals of digital terrestrial TV, by rotations of the spatial axis of an antenna based on image filtering. The antenna used is a log-periodic for the frequencies between 470 MHz and 890 MHz, and the intelligent electronic used in the automation is based on the non-coherent analysis of Composite Video Burst Signal (CVBS). The results obtained with the tests of this project prove their effectiveness, and the importance of the use of an antenna for the tuning of the digital TV channels in Passo Fundo/RS, as well as the functionality of the circuits designed for the automation of the antenna.**

***Keywords*— Cognitive receivers, Digital TV receivers, Antenna tracking positioning.**

I. INTRODUCTION

The digital terrestrial TV transmission in Brazil has been implemented gradually since 2007. This evolution is not applying in all area of Brazil due to several reasons: because of the expensive cost of the digital TV broadcast transmitters system, the attenuation effect of propagation in extensive areas and the lack of digital contents on the offer-demand scenario for economic balance. Technically, the level of the digital TV signals in some distant regions is not sufficient to ensure a good quality in the Ultra-High Frequency band (UHF) because of the effect of propagation loss when compared with the Very High-Frequency band (VHF) utilized in the old analog TV system. The digital TV modulation scheme is the Coded Orthogonal Frequency Division Multiplexing (COFDM), it has a wide frequency spectrum, which offers code gain improvements when compared with the basic OFDM scheme. Classical schemes of channel tuning and tracking in receivers operate on high frequency space in order to determinate optimal level of power, that is acceptable for flat fading, but is not a suitable strategy in very selective channels as occurring in distant terrestrial regions where the selective frequency distortion and attenuation effect are strong even in COFDM signals, producing unstable images in the receiver that are not desirable.

There are many strategies in satellite TV receivers to improve signal quality in signals utilizing tracking of antennas for satellites based of maximum gain [1], Global Positioning System (GPS) aide [2], controlling automated application [3] and multiple selection of parameters: GPS, carrier frequency and gain using phase look locked (PLL) in high frequency [4], but is not widely utilized for terrestrial TV receivers. A novel solution for antenna tracking analog terrestrial TV system was proposed by analyzing the synchronization condition on Composite Video Burst Signal (CVBS) [5]. The method that utilizes CVBS shows superiority and effectiveness, however, it was designed and tested for analog TV receiver and needs complex coherent analysis and synchronization on the image, becoming not suitable for practical implementation for the case of unstable images in fuzzy space [6].

We propose an antenna tracking electronic system for digital terrestrial TV based on non-coherent analysis on the image in real time, that can be approached by simple filtering of CVBS present in practical digital TV converters. The core of this approach is cognitive in the sense of the filtering of the image signal in the baseband. The tests of this project prove their effectiveness for images that come from digital TV receivers. The proposed implementation is explained step by step in this paper on the next sections: materials and methods, results and conclusions.

II. MATERIALS AND METHODS

The proposed development is illustrated in a schematic diagram expressed by four functional blocks as showed in the Fig. 1 (a). The fundamental block is the antenna, the second block is the digital TV converter receiver where the CVBS is captured, the third block is the signal processing and the fourth block is the mechanical device operator activated by an electronic power interface. The second block, the digital TV converter receiver, can be connected to digital standard TV display or monitor by High-Definition Multimedia Interface (HDMI) as illustrated in the Fig. 1 (b).

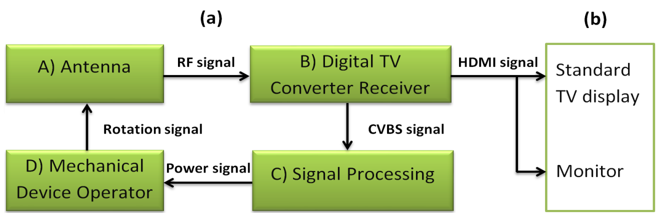

Fig. 1. Schematic diagram of the proposed development (a) and the connectivity to standard TV display or monitor (b).

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A. Antenna Project

An antenna suitable for digital TV signals is the Log-periodic type, which classical project is clearly illustrated in [7] as follows. The frequency spectral band for digital terrestrial TV in Brazil is in UHF band, specifically between 470 MHz and 890 MHz, and then a Log-periodic antenna dipole array was projected for this specific band. The Log-periodic antenna was projected for 9 dB of gain, with the α apex half-angle parameter expressed in the Eq. (1)

$$\alpha = \arctan\left(\frac{1-\tau}{4\sigma}\right) \tag{1}$$

where σ is the relative spacing and τ is the scale factor parameter. The frequency bandwidth of the project B_s is related to

$$B_s = B\left(1.1 + 7.7(1-\tau)^2 \cot(\alpha)\right) \tag{2}$$

where B is the ratio frequency of interest. The numbers of dipoles elements N is calculated as

$$N = 1 + \frac{\ln(B_s)}{\ln(1/\tau)} \tag{3}$$

For the specific UHF frequency band desired, B = 890 MHz / 470 MHz, $\sigma = 0.171$, $\tau = 0.918$, then we utilize the Eq. (3) $N \approx 13$ dipoles for the array, also considering an input impedance of 75 ohms for optimal matching with the digital TV converter receiver. The antenna was built in the practice with the dimensions of fabrication in millimeters illustrated in the Fig. 2 (a), (b), (c), (d) and (e).

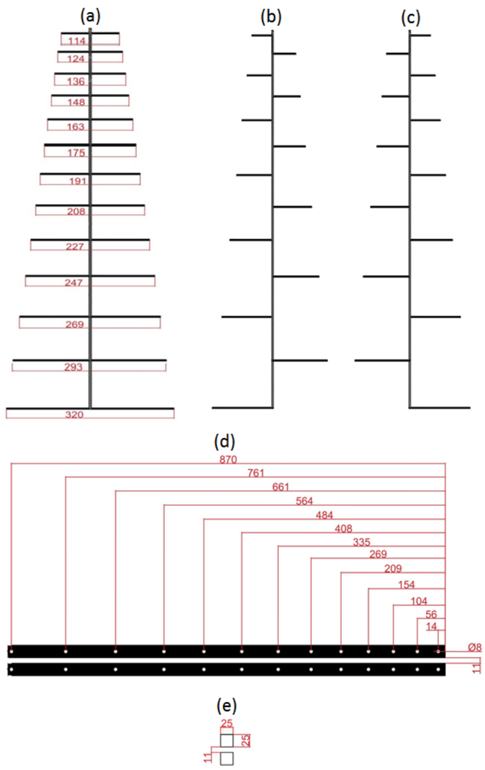

Fig. 2. Antenna dimensions in (mm) of the full upper view (a), top upper view (b), bottom upper view (c), side view (d) and front view of basis (e).

B. Digital TV Converter Receiver

Since the antenna bandwidth is addressed to UHF TV channels, we utilize a standard digital TV converter receiver type intelBras CD636, which has a CVBS output and an HDMI output interface. The CVBS output is a 1D signal compressed that represent a 2D image. When the RF signal received is lack of quality the CVBS is represented by a black or freeze image during an interval of time. The CVBS can be processed in the step C.

C. Signal Processing

The initial stage of processing is to capture the CVBS signal from the hardware interface. The shape of CVBS in time is illustrated in the Fig. 3 (a), where the negative level is only for synchronization and positive level represent scales of colors and luminance. The signal processing in real time proposed is focused on non-coherent reception based on filtering on DC level for intervals of time, in order to identify a black image. A full black image in CVBS is represented as minimum DC level in terms of voltage, and during a persistence of interval of time, is a characteristic of lack of quality of the image, as illustrated in the Fig. 3 (b). A superior level of voltage during a window time is identified as a true value of cognitive image signal, it is:

$$J_{re} = 0 \quad \texttt{if} \;\; \overline{s}_a \leq L \tag{4}$$

$$J_{re} = 1 \;\; \texttt{if} \;\; \overline{s}_a > s_L + L \tag{5}$$

where $\overline{s}_a$ is the mean of the DC signal filtered during an a time of window analysis, L is a level threshold and s_L is the amplitude of Additive White Gaussian Noise (AWGN) estimated as standard deviation $s_L = \sqrt{\sigma_n^2}$ during the zero signal transmission. Then, $J_{re} = 0$ means not cognitive image and $J_{re} = 1$ means a positive candidate for cognitive image.

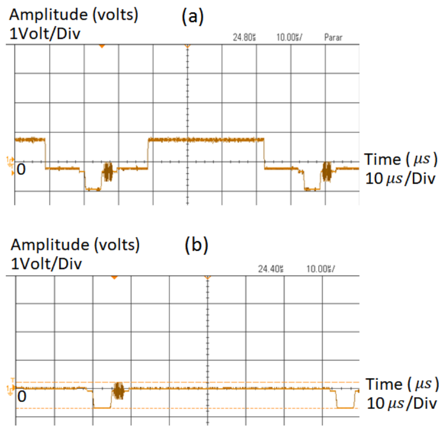

Fig. 3. CVBS with image information (a) and CVBS with full black image in term of volts versus time (b).

We project an envelope detector filter with gain for non-coherent analysis considering the discharge time of approximately 6 seconds. The envelope detector filter circuit is illustrated in the Fig. 4 (a) and the result of s output signal is illustrated in the Fig. 4 (b) when the DC level is 1.33 V, meaning the value of $J_{re} = 1$ with $L = 0.5$ V and $s_L = 0.1$

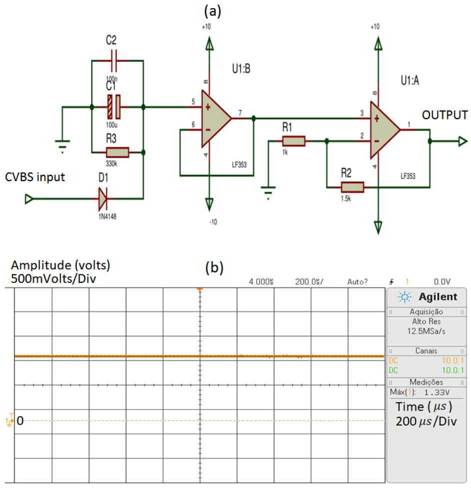

Fig. 4. Envelope detector filter circuit (a) and s output signal from envelope detector filter circuit in term of volts versus time (b).

V. The analysis for persistence for the values of $J_{re} = 0$ or $J_{re} = 1$ is done for a window of time higher than a typical channel commutation, it is estimated at $a = 500$ ms.

We utilize a cortex M4F ARM micro-controller for analysis of persistence on output signal filtered and for the operation of the power activation of the stepper motor. The logic diagram of the firmware developed is illustrated in the Fig. 5. The logical micro-controller signals are coupling through an optical interface (4N25 devices) and the power activation interface is in Darlington configuration (ULN2803 devices) [8]. The circuit of the power pulse interface for the stepper motor that is coupled to an antenna for rotation is illustrated in the Fig. 6, where the logic sequence is represented by the input set (PB0, PB1, PB2, PB3) and the power pulses activation are represented by the output set (B1, B2, B3, B4).

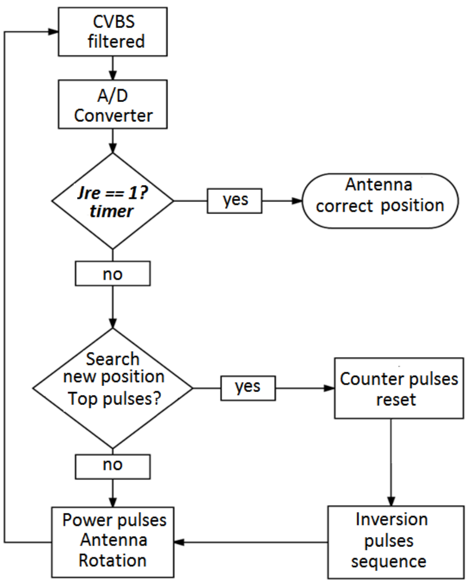

Fig. 5. Logic diagram of the firmware developed.

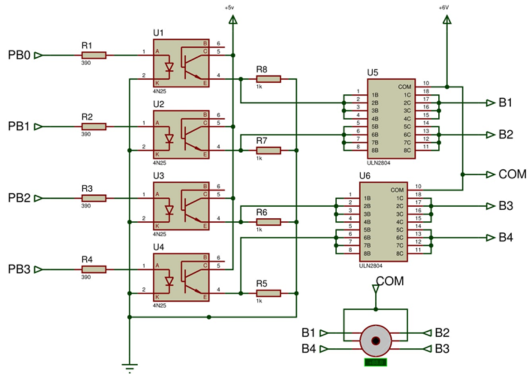

Fig. 6. Power pulse interface for the stepper motor.

D. Mechanical Device Operator

We utilize a direct mechanical coupling between the stepper motor and the antenna. The characteristics of the stepper motor are: National Electrical Manufactured Association (NEMA) type 23 - 19 kgf, angle of precision 1.8°, number of step positions 200, nominal voltage 6 V and nominal current 1.2 A. The rotation of 360° is achieved in 8 seconds.

III. Experimental Results

We utilize the standard set of coordinates for test that represent the north, south, east and west. The location of the test was the Communication Laboratory in the University of Passo Fundo/RS-Brazil, where a non-directive antenna (half-wavelength dipole antenna) was utilized as reference utilizing several resonance frequencies (512 MHz, 596 MHz, 680 MHz, 764 MHz and 848 MHz). The antenna of reference only can tuning one channel (RBS channel frequency 591.25 MHz) and the proposed antenna electronic tracking system can tuning all digital TV channels available in the region, this was achieved with the tracking at 46.8° northeast direction as illustrated in the Fig. 7. The digital TV image channels in Passo Fundo are illustrated in the Fig. 8 (a), (b), (c), (d) and (e), which are tracked utilizing the electronic system developed illustrated in the Fig. 8 (f).

Fig. 7. Proposed antenna electronic tracking system for full channels reception in 46.8° north east direction.

A comparative test was done for the half-wavelength dipole antenna without tracking positioning (as reference) and the proposed antenna tracking electronic system, in two environments of receptions: laboratory outdoor and laboratory indoor. The comparative results, in terms of a number of image channels tuned, are illustrated in the Tab. I. Such results suggest that the proposed antenna tracking electronic system achieve a better performance in term of the number of image channels tuned (5 and 5) than the reference (1 and 0).

Fig. 8. Digital TV image channels: RBS (a), BAND (b), Record (c), Rede Vida (d), SBT (e), tracked utilizing the electronic system developed in (f).

TABLE I

COMPARATIVE RESULTS.

Location	Feature	Half-wavelength dipole antenna without tracking	Proposed antenna tracking electronic system
Laboratory Outdoor	Number of image channels tuned	1	5
Laboratory Indoor	Number of image channels tuned	0	5

IV. CONCLUSIONS

The proposed antenna tracking electronic system was developed considering signals in the UHF spectrum for digital TV signals through a suitable antenna, also it was developed analyzing CVBS with cognitive meaning utilizing filtering in baseband. The results obtained with the tests of this project, suggest the effectiveness of an antenna with cognitive electronic positioning capabilities in real time, for digital TV channels in Passo Fundo/RS-Brazil.

ACKNOWLEDGEMENTS

The authors would like to thank the Laboratory of Communication (LACOM) and the Laboratory of Electronic Maintenance of the University of Passo Fundo (UPF) / RS- Brazil.

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