# Characterization of TVWS on radio spectrum at the UHF band in emerging countries: Case study Mérida - Venezuela.

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**Abstract: TVWS represent an alternative to various problems, such as spectrum scarcity; The challenge of connecting to remote locations or even the deployment of community networks through the use of portions of unused spectrum. TVWS are spaces that have been left unoccupied by the transition from analogue to digital television or simply because in some regions television operators do not see a return on investment and as a consequence these frequencies are available for use; However in order to declare them as underutilized space, a technical verification of the spectrum must be carried out.**

**I made a census of the electromagnetic spectrum of 300 MHz to 900 MHz, belonging to the band Ultra High Frequency (UHF), that was realized with low cost measurement devices so that these measurements are replicable, in developing countries, which lack of the costly technology generally required to perform such censuses. A measurement framework based on this experience and previous experiences is constructed, taking a census of the spectrum with different low cost devices that show that it is possible to carry out an organized and structured census of a portion of the spectrum that serves as a valid source of the state of the art, and therefore a valid source for the justification of the use of these frequencies in function of the deployment of community networks or cognitive radio.**

## I. Intro

Added to large variables, the transition from analogue television to digital television allows the growth of such blank spaces by presenting them more strongly as an alternative to spectrum saturation. All this creates the perfect scenario for transforming the disuse of certain frequency bands into an advantage for the deployment of wireless networks, community networks, data platforms[1], university campus networks[2] and sensor networks for countless uses such as disaster prevention systems Such as water pollution[3], among others.

The superior propagation characteristics of the TVWS technology make it especially suitable for connecting to remote communities and consequently enable there the deployment of community networks or communication with the last mile. Because of their range and affordability, wireless technologies offer the most hope to bridge the digital divide effectively. Having real measurements of the occupation of the real spectrum can pave the way for a more efficient use of the spectrum. Activity detection is of fundamental importance to many wireless applications, including channel assignment of cognitive radio and radiolocation. Therefore, unused spectrum spaces could be dynamically used by those who have been assigned for the use of said frequency band. For the planning and implementation of these networks, it is crucial to know the current use of the electromagnetic spectrum.

This work is based on the use and configuration of low-cost devices that can perform scanning processes of a certain portion of the radio spectrum, since this is a fundamental piece for the exploitation of the sub-used frequencies.

This paper is organized as follows, I. Introduction. It contains the background and theoretical framework. II. Presents the devices III. Collection frame. IV. Results of measurements and simulation of the local

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1 Realtek, RTL2832U DVB-T COFDM Demodulator + USB 2.0 http://www.realtek.com.tw/products/productsView.aspx?Langid=1&PFid=35&Level=4&Conn=3&ProdID=257.

2 M. Bagula, M. Zennaro. "WHITENET: A WHITE SPACE NETWORK FOR CAMPUS CONNECTIVITY USING SPECTRUM SENSING DESIGN PRINCIPLES"

3 A. Khan y L. Jenkins. Undersea wireless sensor network for ocean pollution prevention.

TV broadcaster (ULA-TV) where characterizations of the portion of the selected spectrum are shown. IV. Conclusions and recommendations
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### I.I Background

**A.** Arcia-Moret et al. Presented in several investigations a set of measures made with a device of low cost called WhispPi. The campaign consisted in measurements between 300 MHz and 960 MHz, on that occasion it was found that the spectrum was largely underutilized. These measurements showed that there are more than 80% blanks in rural regions and in urban regions there are more than 60% blanks located in the frequencies between 300 MHz and 900 MHz.

**B.** A data collection made with a low cost device called RF Explorer is presented, which allows the analysis of frequency bands from 240 MHz to 960 MHz, an external omnidirectional antenna, a laptop and a GPS. This campaign consisted of the measurement of 14 specific points of the city of Trieste in Italy, which covered rural, semi-rural and urban areas measuring from 400 MHz to 800 MHz, where spectral activity in the area was well known. Measurements were in agreement with the expected activity.

This and other experiences, such as that carried out in similar investigations, indicated that the measurements made with these devices would have a high degree of reliability. This work performs a verification between measurements and expected behavior in section V. Result, Simulation of TV channel: ULA TV

Although A and B are made with low cost devices comparable to those used in this work a simultaneous check with both types of devices was not performed, on the other hand there was no spectral survey with continuous bells for a certain period of time in A Because it consists of campaigns of collection of a single route and in B because they treated of measurements in specific positions during a specific day.

The way to check the spectrum can vary in relation to many characteristics, there are spectrum analyzers that have non-favorable characteristics in the environment of this work, for example, its cost is unassailable for an investigation and secondly, most have physical characteristics such as size, weight and power requirement that profile them as static devices.

### I.II Theoretical framework.

It is considered that the readers of this document are familiar with the terms frequency, power, guard bands, electromagnetic spectrum and UHF band, in addition to this the following concepts are considered necessary.

A. TVWS.

Television White Spaces (TVWS) is a term that refers to parts of the licensed radio spectrum that licensees do not use all the time or in all geographic locations. Blank television spaces are identified in three ways:

- Spectrum detection by census.
- Beacon channel.
- Geographic location database.

## II. Devices

A. ASCII 32

As described in 4, it is a low-cost device used to identify and geo-tag the radio frequency spectrum in the sub 1 GHz band and has embedded a GPS (Global Positioning System) chip for capturing the geographical position .

B. WhispPi

Arcia-Moret et al. Pose in 4 a system that meets these requirements, easy to handle and low power consumption. The system has four components: A Raspberry Pi (RPI), a spectrum analyzer: RF Explorer, a GPS and a small battery.

C. RTL-SDR Dongle

It is a software-defined radio device based on Realtek's DVB-T (Digital Video Broadcasting) chip and the Rafael Micro's R820T tuner chip. With this specific model it can be tuned from 24 MHz to 1766 MHz.

| Device | ASCII 32 | WhispPi | RTLSDR D. |
|---|---|---|---|
| **Cost (USD)** | < 200 | 340 | 25 |
| **Scanning speed[4]*** | 1,31 muestras/s | 0,41 muestras/s | 0,22 muestras/s |
| **Setup enviroment.** | ARDUINO IDE[5] | Bash Scripts | Bash Scripts |
| **Dependencies** | Battery.<br><br>Environme nt variables[6] | Devices cohersion. Battery charger. | Use of external Osmo RTL[7] o GNURadio Libraries.<br><br>USB Reading speed. |

Table 1. Device comparacy

Table 1 shows a general comparison of the devices used in this work in order to locate the reader with respect to the characteristics of each one.

## III. Data gatehering

In the city of Mérida, two zones were chosen: an upper zone identified as A (Figure 1), which represents the measurement sector of the Avenida Los Próceres, in the city of Mérida, which is classified as a suburban area based on criteria Exposed by Brown et al. , Has a low and low population density, consisting of a net maximum density of 265 inhabitants per hectare. The route of this area was 7.2 km.

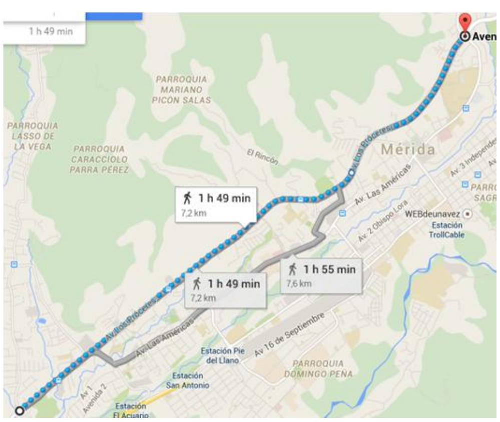


Figure 1. Route for the collection of spectral activity in the sub-urban area: Av. Los Próceres. (Mapped in Google Maps)

The second sector represents an urban area identified as B, located in the central hull of the city. It has a fairly high population density, with a net density of 590 inhabitants per hectare14. The distance of the total route for this zone is of 5 km.

### III.I Procedure

A measurement campaign was then carried out as follows:

1. **Choose the area to measure.** The measurement campaigns were carried out sequentially.
2. **Choose the frequencies to be analyzed.** It was measured from 300 MHz to 900 MHz**.**
3. **Prepare the devices to use.** We proceed to verify that we have the devices with the minimum characteristics necessary for their proper functioning
4. **Perform measurement.** The planned route is performed with the selected devices simultaneously.
5. **Analysis.** Once the campaign is completed, the results are analyzed. Subsequent and previous justification, other campaigns can be carried out to verify previous results:
   5.1. **Make specific measurements to compare results.** In order to inquire in certain ranges of interest the same route is carried out measuring with a device different from the one used in the previous measure.
6. **Get conclusions.** Final process of data science according to results.

In this work step 5.1 corresponded to a comparison measurement using the Dongle, focusing on a smaller range of frequencies. The portion of the spectrum used by the ULA TV television channel located on channel 29 of UHF, ranging from 560 MHz to 566 MHz, was chosen.

[4] Modificables mediante mejoras propuestas en conclusiones.
[5] https://www.arduino.cc/
[6] ascii32.h, SPI.h, SD.h, gps.h.
[7] http://sdr.osmocom.org/trac/wiki/rtl-sdr

## IV. Results

**Analysis of results in measurement campaigns with simultaneous ASCII 32 and WhispPi devices**

In Table 2 we observe the comparison of the results obtained by the devices in the urban zone. It is observed a similarity between almost all the results of the measurement, only the results differ in the average of the maximum power where the ASCII 32 shows to have captured more powerful signals, this same behavior is observed in the suburban zone.

| Device | WhispPi | ASCII |
|---|---|---|
| Av. min power (dBm) | -114,08 | -115, 33 |
| Av. max power (dBm) | -52 | -40,16 |
| Average power (dBm) | -105,2 | -105,6 |
| Av. % StdDev | 0,84 | 1 |

Tabla 2. Comparison of results: ASCII 32 versus WhispPi in urban areas

A. ASCII 32 versus WhispPi.: 1/12/2015 - (Urban zone)

Similarities are observed with respect to occupancy in the first observation, where a high occupation is presented in the central and final channels of the portion of the census spectrum, comparing the behavior of the occupation with respect to the variation of the threshold is evidenced that This behavior is maintained by taking the threshold several decibels milliwatts below the initially estimated value where there are channels that definitely remain occupied, such as frequencies between channel 80 (868 MHz - 872 MHz) and 900 MHz Frequencies of cell phone use, as shown in Figure 2.

The variation of the threshold shows consistent results throughout the campaigns carried out, that is to say, no spurious or false positives (or negatives) are found in the analyzed bells, this is done as a confirmation of the reliability of the census. On the other hand it is evident that the devices show similar results, beyond small variations due to their own characteristics.

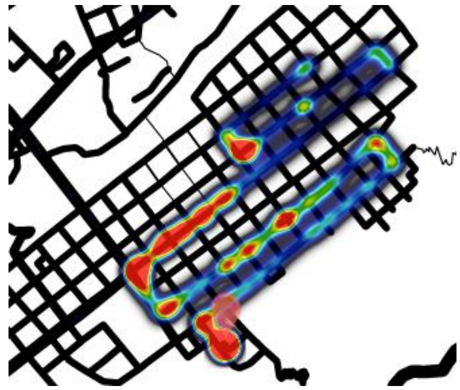

Figure 2. Heat map with Zebra RFO showing occupation of channel 23 (524 MHz to 530 MHz) in urban area of the City of Merida, with the ASCII 32 device.

Finally, the results obtained are presented in consistency with previous campaigns in the same location and under similar conditions [4] remembering of course that this time a triple verification (one per device) of the results is being carried out.

**Simulation TV channel: ULA TV**

It was decided, based on the well-known information about the TV channel "ULA TV" that operates in the city of Mérida, to make a simulation of the coverage of this television station through its transmission base plant around the Andean city, with the In order to compare the results obtained with the devices and the expected ones with respect to the information on the broadcasting of this local television station.

ULA TV is the television station of the University of the Andes, which transmits in channel 29 UHF. The plant where the signal is transmitted is located about 10 km from the center of the city.

In this case we can observe the mountainous relief, which characterizes the Andean city, which shows the areas where the signal does not reach, as shown in Figure 3.The green zone corresponds to a signal power around -95 dBm. The yellow zone corresponds to approximately -76 dBm or values that oscillate around the same, while the orange zone represents approximate values to -63 dBm. Finally the red zone represents -50 dBm or higher values

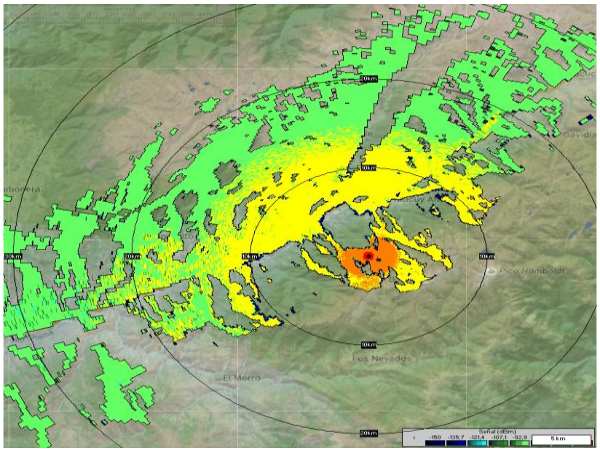

Figure 3. Radio coverage from a satellite view over the city of Merida.

**Approach with RTL Dongle**

In order to observe the spectral behavior in the frequencies of the ULA TV television channel, a test was carried out on the same routes (urban and suburban).

This test was performed with the Dongle using a small script system developed by myself called DongleWhiteScanner (DWS) reducing the measurement bandwidth to 6 MHz between the frequencies from 560 MHz to 566 MHz, corresponding to channel 29 UHF where it transmits the television. The average power obtained between the two scenarios was -47.1 dBm

It can be observed that the UHF channel 29 has a high occupation, with peaks in the frequencies around 561 MHz and 566 MHz and almost total occupation, which would be in agreement with the results expected in this simulation.

## V. Conclusions and next steps.

A census of the radioelectric spectrum was carried out in the city of Mérida, with the use of low cost devices, easy acquisition and configuration; Taking into account previous experiences, a simultaneous comparison was made to verify the reliability of the results, and strategies such as threshold variation and comparison with the local frequency allocation table were also addressed, all to confirm that the use of these devices for the Census is a strategy not only valid but a real alternative that can accelerate the process of requesting frequency bands for use in community networks and cognitive radio.

It was possible to highlight the challenges in the measurement process, such as: calibration of equipment, need for minimally trained personnel, cost of devices to implement physical improvements, among others. However, it is intended to generate expectations in the near future regarding the use of low cost devices, such as those used in this work (no known lower cost configurations so far) in measurement processes that serve as collaborating entities either For use by communities, governments or the verification of access policies and spectrum sharing.

Measurement campaigns, mostly done with the WhispPi device and the ASCII 32 device simultaneously, showed that the results can vary by some decibels. This depends on the appreciation characteristics of the devices, for example, the ASCII 32 has a sensitivity greater than that of the RF Explorer, device in charge, in said configuration, to realize the power pickup. This observation about the sensitivity of the ASCII device 32 may be due to the fact that the sampling frequency of the device is greater than that of the WhispPi thus allowing the device to capture more noise than normal, this is intended to be adjusted in future investigations.

It is important to note that in some cases, the blanks found are not contiguous, so it is said that "blank space", as a whole, is presented in a fragmented way; The use of a specific frequency to be used with wireless devices is affected by their contiguity and this must be taken into account when quantifying the spaces. Just because a channel does not have activity, does not mean that it is a white space capable of being used for some services, it should be investigated for which service it wants to be used and based on this to decide whether its use is appropriate or not , As proposed by a 20 MHz channel for the IEEE 802.11 standard can not operate in a given location if the 8 MHz channel blanks are not contiguous.