Monitoring System of the Radio-electric Spectrum in the Bands 88-108 MHz using Software Defined Radio

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***Abstract*— Monitoring radioelectric spectrum is a fundamental task that must be carried out for the proper use of wireless technologies in a country. It is particularly important for governments to regulate and control efficiently the use of this resource, as it is a strategic resource.**

The governments carry out the management of the radioelectric spectrum, but the demand for it, the increase of new wireless technologies and the misuse that certain clandestine companies make with the spectrum, require monitoring systems that are more efficient and sustained than the conventional equipment many times can not satisfy. Therefore, there are currently alternatives based on the concept of open source hardware and software that can be used to support spectrum monitoring activities using new concepts and architectures.

This article presents an alternative for these measurements, which is known as software defined radio. This is a technique to build devices in which part of the hardware can be replaced by software routines, which reduces costs.

The case of electromagnetic spectrum monitoring in the FM radio band in the city of Guayaquil in Ecuador is presented, using the parameters defined by the ARCOTEL local regulatory entity.

***Index Terms*— Radio Spectrum Monitoring, Ecuadorian Regulation, Software Defined Radio.**

I. Introduction

ACCORDING to the monitoring manual for the radio spectrum issued by the International Telecommunication Union, a specialized agency of the United Nations for information and communication technologies - ICT, spectrum management is a set of indispensable administrative, scientific and technical instructions for ensure the efficient operation of radiocommunication equipment and services without causing interference. The objective of spectrum management is to maximize the efficiency of spectrum use, reducing interference and eliminating illegal or unauthorized uses [1] – [2].

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The radio spectrum is an essential resource in the telecommunications sector worldwide, through which a variety of telecommunications services are provided, which are of great importance for the social and economic development of a country. The growing advance of technology demands that the regulating entities of the radioelectric spectrum improve the ways of monitoring it, in order to make use of this resource in a rational, equitable, efficient and economical manner [3].

Interest in effective spectrum control increases, especially on the part of certain telecommunications operators, interested in expanding their services using higher capacity technologies, such as Long-Term Evolution (LTE), which represents a key element in the evolution of mobile networks, because this technology allows to solve certain capacity and connectivity problems that are currently present [4].

All these demands of new technologies demand increasingly efficient spectrum management systems, which conventional monitoring equipment can not satisfy, because the functions of these are restricted by their configuration in hardware, this implies that to guarantee the capacity of control and reaction of the system to illegal uses, it is necessary to partially or totally change these equipment, which represents high investment costs [1].

ARCOTEL is the government entity of Ecuador responsible for the administration, regulation and control of telecommunications and the radio spectrum and its management, as well as the technical aspects of the management of social communication media that use radio spectrum frequencies or that install and operate networks. In the rendering of accounts of the Agency of Regulation and Control of Telecommunications (ARCOTEL) of the year 2016, regarding Control Management to Broadcasting and Television Systems, around 1,025 Radio and Television stations were verified, which corresponds only 63% of the national total in order to verify compliance with the technical parameters, as a result of this process, 18 unauthorized stations were detected, 13 cases of retransmission and unauthorized operations. [5].

II. METHODOLOGY

A. Technical Rules

The regulations stipulated by ARCOTEL mention four technical parameters to be considered, which are mentioned below:

1. For the assignment of consecutive (adjacent) frequencies, intended to serve the same independent

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operation area or area of zonal operation, a minimum separation of 400 KHz must be observed between the carrier frequencies of each station [6].

2. Bandwidth is 220 KHz for stereo and 180 KHz for monophonic, with a tolerance up to 5% [6].
3. Frequency Tolerance: the maximum allowable frequency variation for the main carrier will be ± 2 kHz [6].
4. Normal and local power stations must operate with minimum field strength of ≥54 dBμV/m for stereophonic and ≥48 dBμV/m for monophonic [6].

B. RTL-SDR

Review will be the functioning and libraries of the RTL-SDR that are compatible with Matlab mathematical software. For purposes of this project, the book Software Defined Radio using Matlab & Simulink and the RTL-SDR will be used as a text guide, which shows in detail the use of the RTL-SDR device, along with the process to install Matlab compatibility packages. and the operation of the device with several examples of applications.

To implement the system, there are some hardware and software requirements that must be taken into consideration.

For a good operation of the RTLSDR device it is recommended to have a modern computer with an acceptable processor, such as Intel i3 or higher, a RAM of at least 4 GB and a space of 30 GB on the hard disk. You will also need a USB 2.0 port or higher, free to connect to the RTL device. [7]

These requirements are important because the system in which you work will have to support a large amount of information and data processing, which will be done Matlab mathematical software.

The hardware compatibility package of the RTL-SDR must be downloaded as a requirement for the operation of all libraries of the RTL-SDR and for the device to be compatible with Matlab. This package can be downloaded from the same Matlab software in the Add Ons option found in the program's toolbar. Additionally, some MathWorks toolboxes will be required to be installed in Matlab, these will provide complementary features, such as filter tool design and frequency domain scope, the necessary tool boxes are:

- DSP System Toolbox.
- Communications System Toolbox.
- Signal Processing Toolbox.

These toolboxes provide the necessary means for the implementation of any desired receiver algorithm [7].

C. Software

After installing all the compatibility packages and the necessary tool boxes for Matlab, we will proceed to the third step in which the programming of the system will be performed, for that we will need to perform several functions that aim to perform a complete sweep in the FM band, which is in the frequency range 88-108MHZ, to then take and process the data that will be verified with respect to the ARCOTEL regulations.

The algorithm developed for the system is divided into 2 parts. The first part will be the main program, which will include variable names, the opening of an Excel sheet in which the frequencies that the RTL- will be saved in a first instance SDR will analyze, and finally there will be calls to functions. The second part is all the functions developed to obtain the technical parameters of each FM radio station. For this project, 9 functions were implemented, 4 of which were taken from Software Defined Radio using Matlab & Simulink and the RTL-SDR, which will provide us with Power vs. Frequency graphs.

Main program and functions.

Figure 1 shows the flow diagram of the main program of the project, which is divided into 5 blocks. The main purpose of the main program is to establish the scenario where the variables that will be used by the rest of the program will be initialized, and the Excel program will be activated where all the measurement data will be saved. Then, the operation of the main program is specified in an enumerated series of ideas.

1. Assignment of variables and configuration of parameters for the RTL.
2. Creating graphics Power vs. Frequency.
3. Executing a spreadsheet in Excel.
4. Call functions.

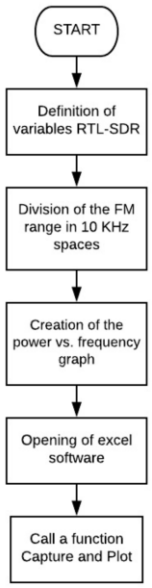

Fig. 1. Flow diagram of the main program.

III. RESULTS

To verify the operation of the project, carried out tests in different places of the city of Guayaquil, one of them is north of the city Km. 8 ½ via Daule, Juan Montalvo. Obtaining the following results:

A. Power.

Figure 2 shows the results with three graphics of power data obtained from different places in Guayaquil city. The first one

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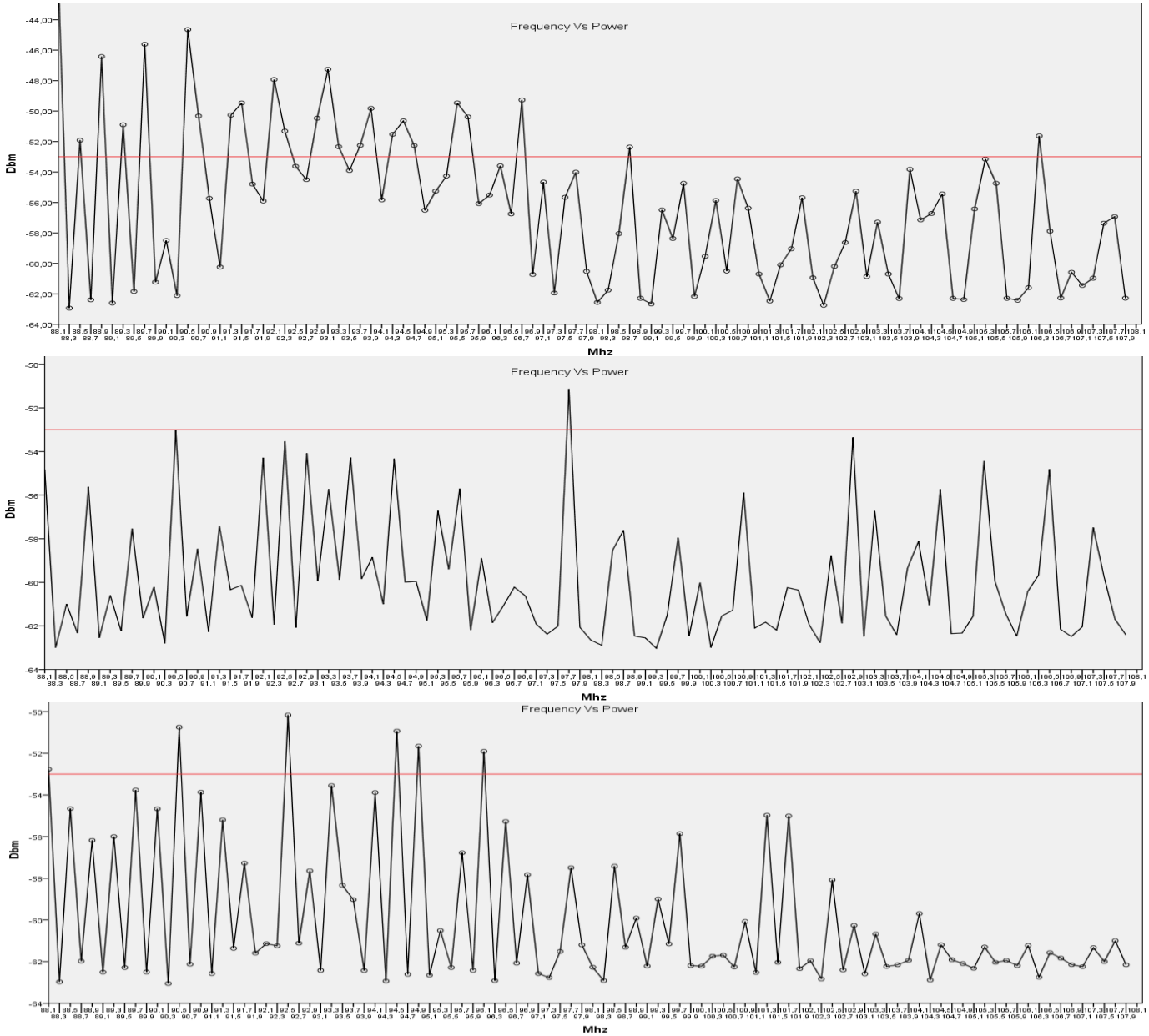

Fig. 2. Results of power data from different places in Guayaquil city.

depicts the power data from north of the city. The second graphic depicts the power data in the Gustavo Galindo campus of ESPOL, and in the third one depicts the power data from the center of Guayaquil. The red line indicates the threshold established by the standard, the power of each channel should be above that threshold for there to be an acceptable signal strength.

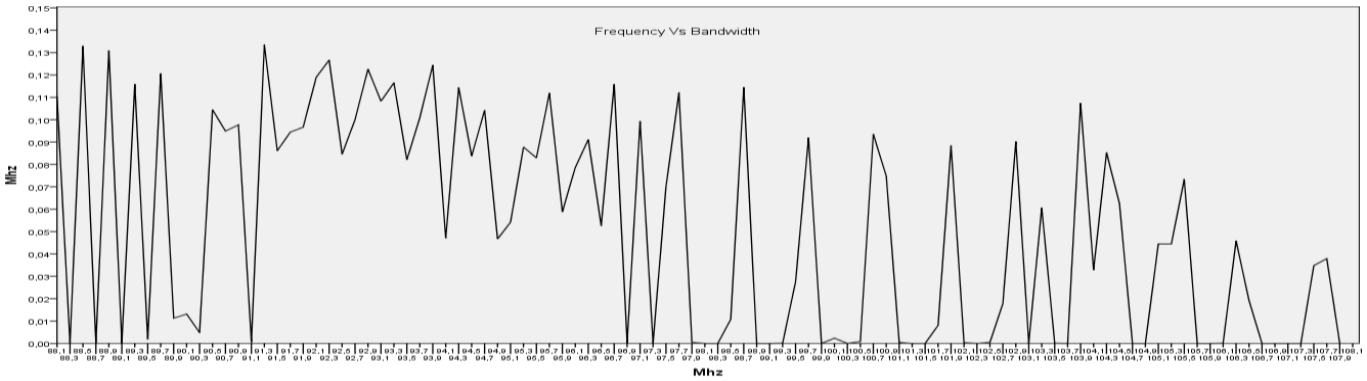

Fig. 3. Frequency vs. Bandwidth taken from the north of Guayaquil.

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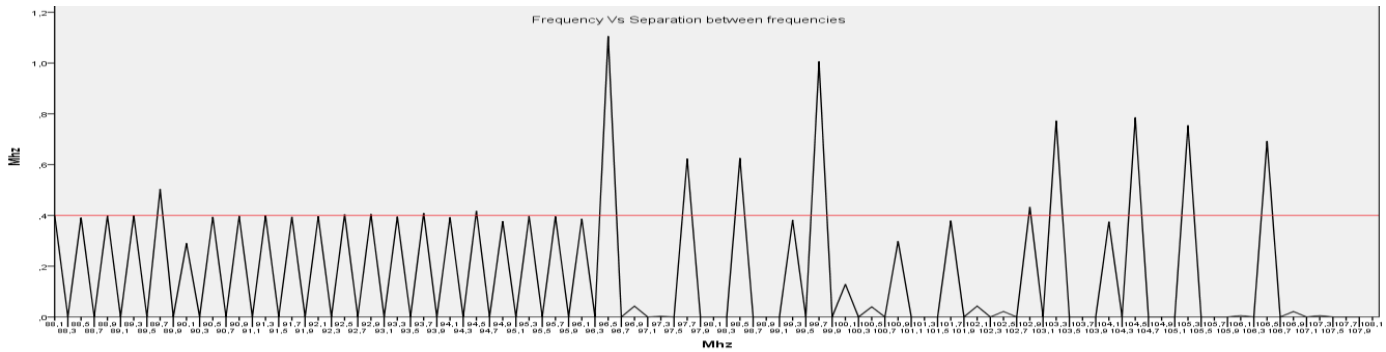

Fig. 4. Frequency vs. Separation between frequencies taken from the north of Guayaquil.

B. Bandwidth

In Figure 3 we can see the bandwidth data of each FM station measured from the north of the city, the limit for the bandwidth is 220Khz as indicated in the standard, so we can observe by the figure that all stations have bandwidth values below 220Khz.

C. Frequency separation

Figure 4 shows the data of consecutive or adjacent frequency separation, according to the technical standard this must be greater than or equal to 400Khz, which is referenced with a red line. This means that the stations that comply with the regulations are above or on the line and those that are not below it.

D. Frequency tolerance

Figure 5 shows the Frequency Tolerance data of the FM stations in the northern sector of the city of Guayaquil, the technical standard says that the maximum variation for the main carrier must be ± 2Khz, in which the graph shows that no station complies with the regulations. The range in which the carrier frequencies of the FM stations vary is between 50KHZ and 80KHZ, for example, the carrier frequency of channel 1 is 88.165MHZ and the regulation says that its carrier should be at 88.102MHZ, having an advance of 63 KHz.

The station that comes closest to the regulation is the frequency 103.3MHZ, with a frequency tolerance of 50KHZ. A reason for which none comply with the regulation could be due to the gain of the antenna or some inconvenience with the device, since for these data we take the value that is most repeated.

IV. CONCLUSION

The implemented system made it possible to verify that the technical parameters set by the ARCOTEL are being fulfilled by the FM radio stations. This system provides a reserve equipment, in case the Automatic Control System of the Radioelectric Spectrum suffers some damage, allowing the monitoring of the spectrum until the replacement of the same.

The measurements taken at the proposed sites for this project showed that most FM radio stations comply with the guidelines established by the Telecommunications Regulation and Control Agency. A large number of stations were also found, close to the regulation limit, while there were other stations that did not comply with the regulations, because the great part of the city consists of large structures preventing good reception of data in the RTL-SDR, or because of the distance between the transmitter and receiver.

Due to the distance between some FM radio transmitters and the RTL-SDR equipment, low power levels were detected in the data collection, performed at the Gustavo Galindo campus of ESPOL, which is why it can be seen in Figure 3 low power levels in the vast majority of FM channels.

Some areas of Guayaquil presented obstacles such as buildings or trees, which prevented good technical parameters, which is why some frequency ranges did not comply with the parameters stipulated by the Regulation and Control Agency. This was the case of the power data taken in the center of Guayaquil, the latter presented low levels of power, at high frequencies as we can see in figure 4, since at higher frequencies it is easy for the signal to lose energy rapidly through cause of obstacles in the journey.

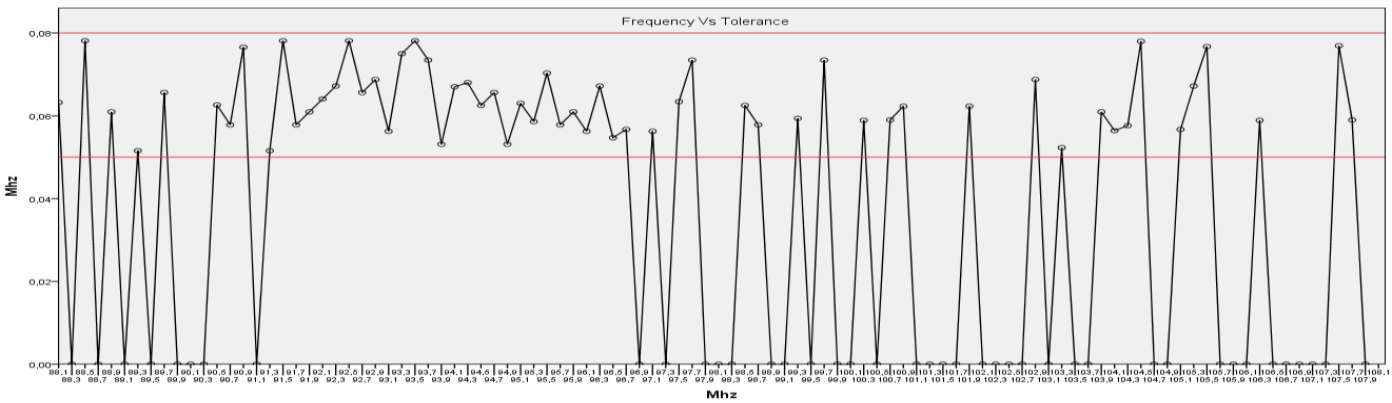

Fig. 5. Frequency vs. Frequency Tolerance taken from the north of Guayaquil.

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