



Autonomous Electromagnetic Signal Analysis and Measurement System

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Abstract. Lately, there is a notable increase in devices connectivity and wireless telecommunication applications which generate a huge amount of electromagnetic emissions which may cause adverse effects to human health and other nearby devices due to Electromagnetic Interference; making the area of electromagnetic emissions to attract the attention of many researchers. In this work, we implemented a monitoring system, using a sound card and heterodyne receiver for scanning frequencies of interest and generating an event when detecting emission at these specific bands above threshold. The system triggers an alarm, saves the detected events in a database with relevant information including time, level of the signal, and frequency. The spectrum of the signal detected is stored for further analysis. Experimental validation of the proposed system shows promising results with increased efficacy and with reduced cost. The proposed system can be used as essential building block towards adoption of the artificial intelligence algorithms in electromagnetic data analysis and measurements.

Keywords: Electromagnetic Interference · Electromagnetic signals · Fourier Transform · Digital Signal Processing · Measurements

1 Introduction

The increased demand in wireless telecommunication systems and the current trend of smart things and connectivity between devices puts the space around us with a huge amount of electromagnetic emissions [1–4]. Unfortunately, monitoring of the electromagnetic (EM) emission is relatively challenging due to its relatively high cost and hence making effective real-time EM monitoring impractical [5, 6]. In such circumstances, a system with a reasonable cost that allows monitoring of the EM spectrum to detect possible disturbing emissions is urgently needed. In addition, the possibility of being able to analyze this data automatically, store it and be able to make decisions in real time could add a considerable value to this field.

Recently, sound cards have been used in several applications and demonstrated promising results. In most cases, the sound card was used with high-level programming, using some pre-existing tools and libraries available in software like LabVIEW and MATLAB. Sound card has a very good capability, but it is necessary to execute the low-level programming, to manage the parameters which affect the capturing process [7–13]. In this work, we implemented a monitoring system, using a sound card and heterodyne receiver, for scanning frequencies of interest. When detecting emission at these specific bands above a threshold level, the system generates an event, triggers an alarm, saves the detected event in a database with relevant information including time, level of the signal, and frequency. The spectrum of the signal detected is stored for further analysis. Our objective was to collect data of interest, through prior programming, which feeds a database with information of interest about emissions in specific bands. Subsequently, process the collected data using Artificial intelligence (AI) based algorithms.

2 Proposed System

The proposed system is a computer-based measurement system that takes a continuous signal at its input and samples it to obtain a sequence of discrete data $x(n)$. This periodic sampling is achieved using the PC's sound card. The discrete temporal signal is then converted from the time domain to the frequency domain by calculating the Discrete Fourier Transform (DFT) to estimate the spectrum. We use the Fast Fourier Transform (FFT) algorithm to implement the DFT [15, 16]. To reduce the leakage effect, we have implemented the windowing technique. With the presence of background noise, it is very difficult to detect the signal of interest, for this reason some averaging techniques have been implemented to reduce the background noise and extract the signal of interest.

The main parts of the proposed system are depicted in Fig. 1 and is composed of the following elements:

- Receiver control IC-PCR1000
- Signal capture
- Signal analysis
- Visualization (GUI)
- Database

The challenge at this stage is to be able to capture the signal received by the IC-PCR1000, make the sampling process by the soundcard to achieve a real-time measurement system. The coordination process between the two devices and the implementation of a technique using several buffers with real-time synchronization management make the system efficient by doing the tasks in the optimal way without losing relevant information [17]. Signal analysis is performed with the help of a user-friendly graphic interface.

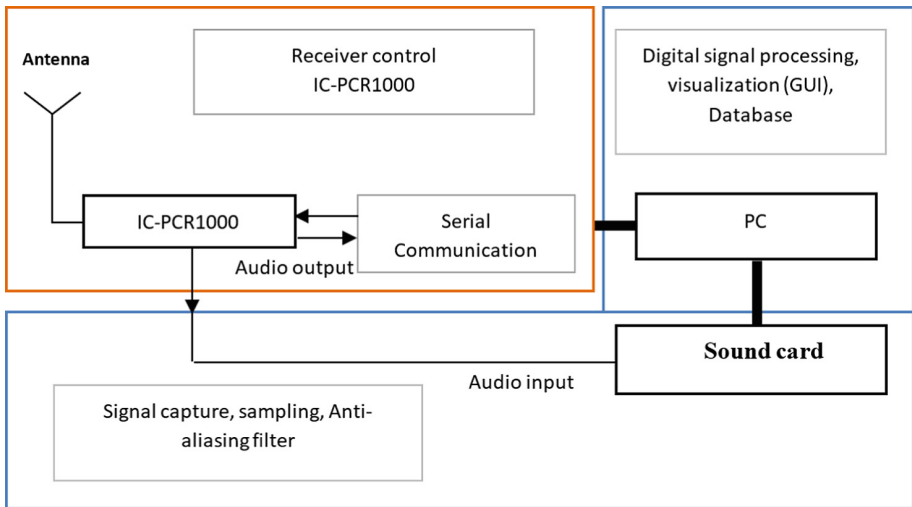


Fig. 1. The simplified scheme for the proposed system measurement

Figure 2 represents the connection between the IC-PCR1000 receiver and the sound card that performs the task of periodic sampling of the input signal $x(t)$. For this, a low-level programming algorithm was implemented in order to access the sound card, control the capture of the signal and manage the buffers that will be used to store the signal in the optimal way without losing data.

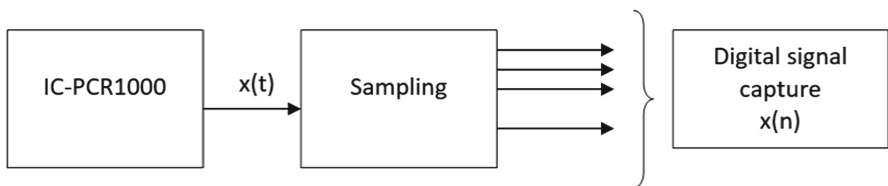


Fig. 2. Connection between IC-PCR1000 receiver and sound card

To implement the process of capturing the signal from the receiver using the PC's sound card, Microsoft's "waveform-audio" structures for audio data was used to perform the following tasks:

- Capture the audio signal coming from the microphone input of the sound card, which in turn comes from the output of the receiver;
- Manage the storage of samples in buffers;
- Save the captured signal in WAV format.

Figure 4 shows a simplified representation of the implemented algorithm that performs an automatic scan of the receiver to monitor frequencies within a band of interest. The developed application allows setting a scanning start frequency (F_{start}) and another scanning end frequency (F_{end}), the jump (F_{step}), the sweep duration time (T_i). Once the process has started, the receiver is tuned to the frequency F_{start} after each time T_i , the frequency is increased by F_{step} , until reaching the frequency F_{Fin} , and thus the automatic scanning with frequency sweep will continue until this function is deactivated.

During the automatic scanning process, a function can be activated to monitor the level marked by the cursor, and each time this signal level is exceeded, a "BMP" type image is saved with the file name "SPECTRUM_DAY_MONTH_YEAR_HOUR_MINUTE_SECONDS.BMP" and the corresponding data will be stored in a database with the relevant information.

This system allows us to monitor a certain area of the spectrum, monitor the entire area of interest, and to detect all the possible interferences that have occurred; the time of their repetition, their frequency, and characteristics in amplitude and bandwidth.

3 Graphical User Interface

In the first version, we implemented a system to perform a sequential scan of up to 10 different user-defined channels. A different frequency can be defined for each channel, as well as a different mode and bandwidth filter. Scan time is also user defined. It is also possible to define an interval of interest with a steep frequency increase. Parameter setting is achieved via a graphic user interface shown in Fig. 3.



Fig. 3. Display of the User interface

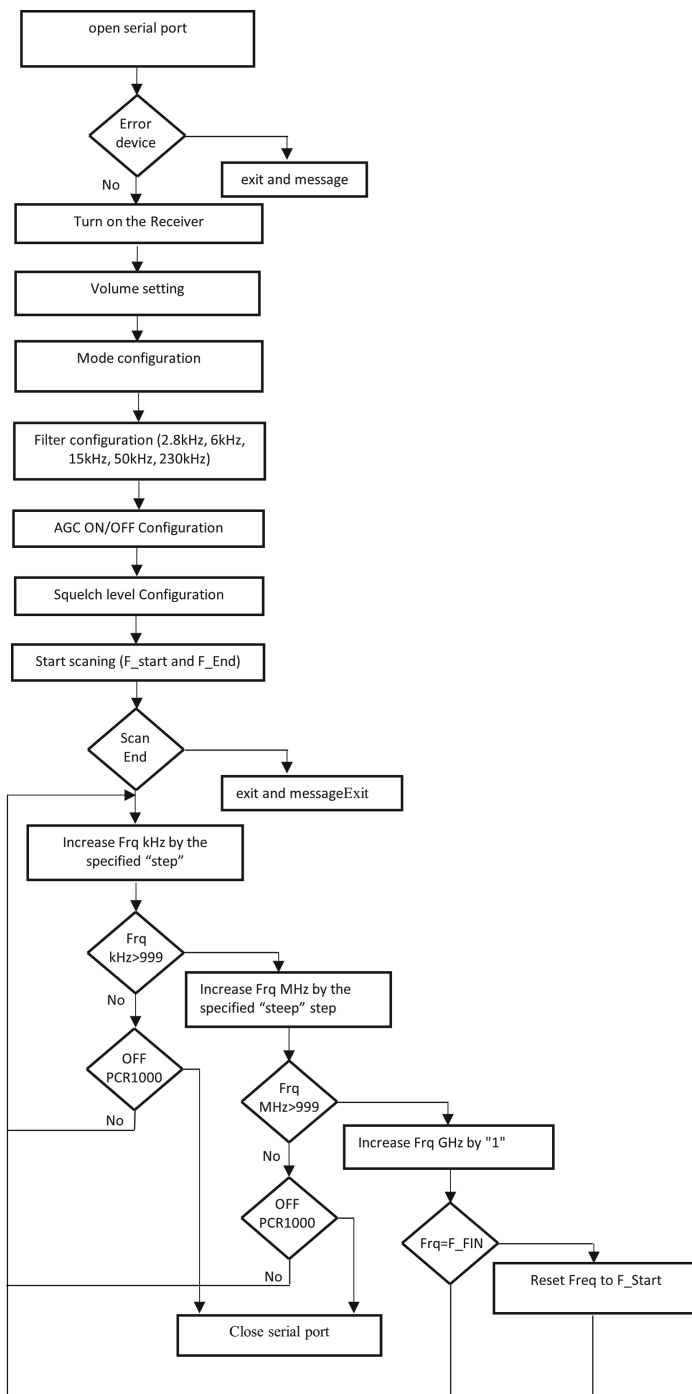


Fig. 4. Simplified algorithms of automatic scan of the receiver to monitor frequencies within a band of interest

4 System Validation

4.1 Equipment Used to Do the Measurement Validation

ICOM IC-PCR1000 Receiver. We used the IC-PCR1000 receiver that covers frequencies between 10 kHz and 1300 MHz in various broadcast modes (WFM, FM, AM, CW, LSB, and USB). This receiver is our main interface with the radio frequencies. We used its audio output to have an Intermediate Frequency to perform the spectral analysis and thus, at most we can have a bandwidth of 20 kHz. Another receiver or even other control devices could be used as in [18].

Baofeng UV-5R Portable Radiotelephone. Is a radiotelephone that transmits and receives in the VHF and UHF bands from 136 MHz to 480 MHz in the 12K5F3EJN and 16K0F3EJN emission classes corresponding to the narrowband and wideband designations in its user manual. The Baofeng UV-5R was shown to be very effective in controlled tests in the said bands when test broadcasts have been carried out with natural human voice and with analog (CCTS) or digital (DCS) subtones.

Signal Generator PCE-SDG1010. Generates signals up to 10 MHz. The function generator can produce five output waveforms and it can also produce its own waveforms (arbitrary function).

4.2 Detection of AM Signal Emission

Several measurements and tests were carried out to validate the developed system. A known signal was first generated, through a signal generator, and a VHF/UHF transmitter is used to provide other test signals. Experimental setup is shown in Fig. 5. The following parameters were used during the validation process:

Signal Generator: sine: 530 kHz, amplitude $2.30 V_{pp}$, Phase 0.0° , Mod AM 10 kHz.

Receiving antenna: AN200 E1–124819 Etón, freq 520–1710 kHz.

ICOM: 530 kHz, AM, 15 kHz,

We used a Black-Harris windows and adjusted the sound card sampling rates to 44.1 kHz.

The detected signal in the frequency domain and its corresponding averaged signal are shown in Fig. 6 (a) and (b), respectively.



Fig. 5. Equipment used to do the measurement validation

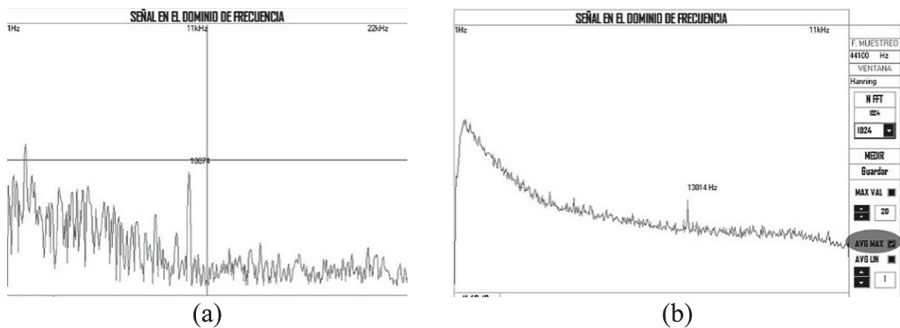


Fig. 6. Signal detected by our system (a) signal detected in frequency domain (b) signal detected in frequency domain applying exponential averaging

4.3 Detection of VHF/UHF Emission

In this measurement, a Baofeng VHF/UHF radiotelephone residing 10 m from IC-PCR1000 was used to generate a known FM signal with frequency of 144.010 MHz and NB mode (Fig. 7.) and then the signal was propagated through space. A monitoring frequency interval has been marked in the band of 140 MHz to 150 MHz.

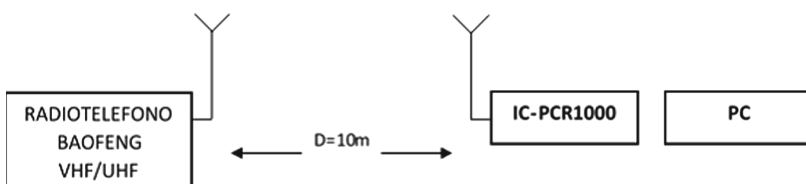


Fig. 7. VHF emission detection test

The signal was detected by using our proposed method at 144.007MHz (Fig. 8). We used Lower Side Band (LSB) mode with a bandwidth of 15 kHz. This detection was improved by adjusting the Digital Signal Processing (DSP) parameters of our measurement system by increasing the number of FFT from 512 to 8192 and adding a HANNING window (Fig. 9).

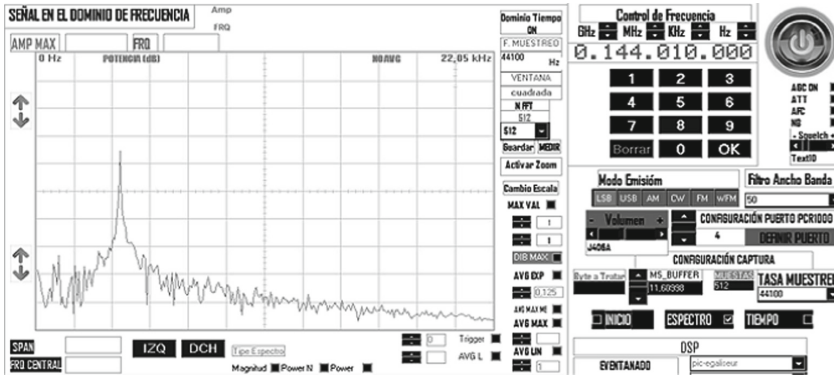


Fig. 8. Signal detected using proposed system at NFFT 512 with no windows

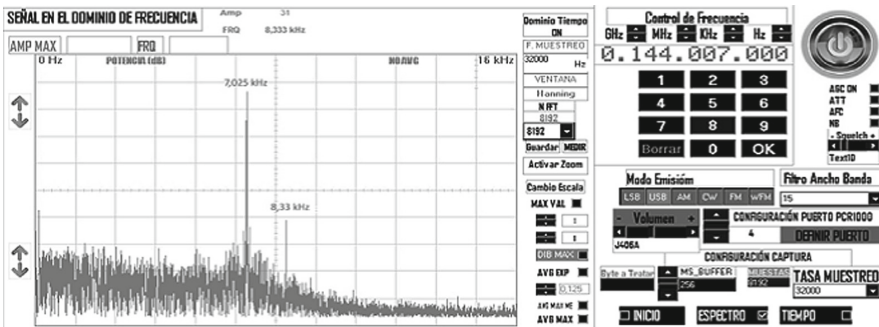


Fig. 9. Signal detected using proposed system at NFFT 8192 with HANNING windows

4.4 Detection of EMI Emission

Knowing that any electrical wires can transport electromagnetic signals interference and play the role of an Electromagnetic Interference (henceforth EMI) antenna [1, 2], our proposed smart signal analysis and measurement system managed to detect if any device containing an AC motor is running or stopped, as for example the case of the air conditioning unit containing an AC compressor.

Figure 10 shows detected signal using our proposed system using a 1 kHz signal generated by the PCE-SDG1010 in two scenarios: Air-conditioning OFF and Air-conditioning in operation. In Fig. 10b we can appreciate the spectrum of the air-conditioning interference detected at the frequencies of 7 kHz and 14 kHz with an

amplitude level of approximately $300 \mu\text{V}$ when the compressor of the Air-conditioning is in operation.

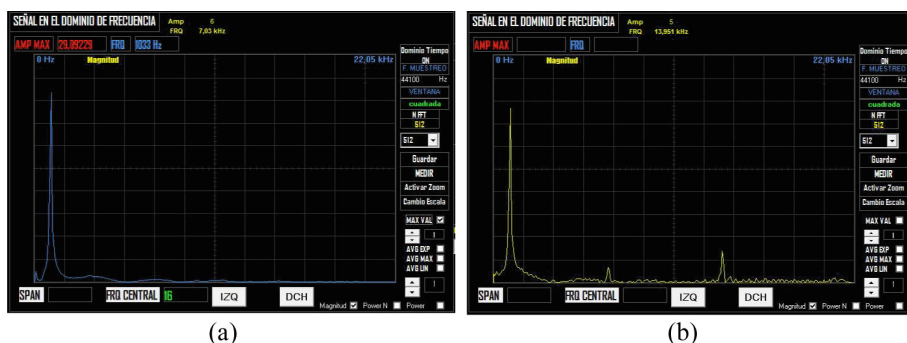


Fig. 10. Signal detected using proposed system (a) measurement of 1 kHz signal with Air-conditioning OFF. (b) Air-conditioning in operation at the frequencies of 7 kHz and 14 kHz

5 Conclusion

Electromagnetic emissions have been an area of interest for many researchers due to its adverse effects particularly to human health. In this work, the possibility of obtaining reliable data of electromagnetic signals of interest, at different spectral coverages, using an automated system is proposed and validated. Experiments show promising results towards realization of a full smart EM measuring device which is relatively cost effective. Our ongoing work is to enable this system to perform the whole smart processing in real-time and make informed decisions by incorporating effective Artificial Intelligence based algorithms [14].

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