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A CASE-STUDY VISION

Raspberry PI 3 RF signal generation system

Sistema de generación de señales RF mediante raspberry PI 3

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ABSTRACT

Radio frequency signal generators (RF) are instruments used to test reception equipment and RF components like filters, amplifiers, attenuators, among others. On the other hand, they reinforce the teaching-learning processes and they are widely used in research in the telecommunications field. This document provides the first stage of a low-cost signal generator design by using RaspBerry Pi 3, with the documentary exploration about this kind of applications. After that, a recognition of the RaspBerry Pi 3 is done at hardware and software level. Finally, an application of an FM signal generator with RaspBerry in a frequency of 101.3 MHz is evaluated, which does not require any additional hardware. This signal was captured using a spectrum analyzer, which determined good quality of the modulated signal in terms of power, bandwidth and SNR (Signal Noise Ratio). However, there are some unwanted harmonic components.

RESUMEN

Los generadores de señal de Radio Frecuencia (RF) son instrumentos usados para probar equipos de recepción y componentes RF como filtros, amplificadores, atenuadores, entre otros. Por otro lado, refuerzan procesos de enseñanza-aprendizaje y son ampliamente usados en investigación en el área de telecomunicaciones. Este documento evidencia la primera etapa para el diseño de un generador de señal de bajo costo mediante RaspBerry Pi 3, con la exploración documental sobre este tipo de aplicaciones, posteriormente se procede al reconocimiento de la RaspBerry Pi 3 a nivel de hardware y software, finalmente se evalúa una aplicación de generador de señal FM con RaspBerry a una frecuencia de 101.3 MHz, la cual no requiere hardware adicional. Esta señal fue captada mediante un analizador de espectros determinando una buena calidad de la señal modulada en términos de potencia, ancho de banda y SNR (Signal Noise Ratio), sin embargo, se evidencian fuertes componentes armónicos no deseados.

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1. Introduction

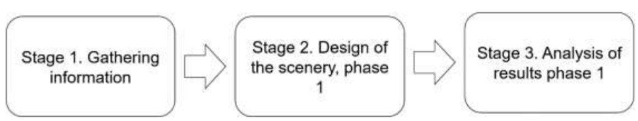
Telecommunication instrumentation equipment, due to their high cost are difficult to afford. The proposal of new instrumentation equipment which have advantages in factors like implementation, cost and operation over the existing ones, can be considered as a good alternative in terms of versatility, operation and cost using platforms in hardware like RTL and Raspberry. In the case of RF signal generators, they are considered as important elements for the process in the teaching-learning process in the telecommunications field because they allow to secure student's knowledge about the process that is carried out in a radio link.

Nevertheless, the acquisition of these devices implies high costs, so most of the students do not have the budget to acquire this equipment. Additionally, universities have this equipment, but their free use can be hindered due to their high use between professors and students. For this reason, an initiative to design a low-cost signal generator is made, using a Raspberry Pi card.

2. Methodology

To develop this research project, it is proposed a methodology that is shown in Figure 1. First, a documentary exploration is made. After that, a design of a scenery base on gathered background and finally the analysis of the obtained results.

Figure 1: Methodology proposed to develop the Project.



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2.1. *Stage 1. Gathering information*

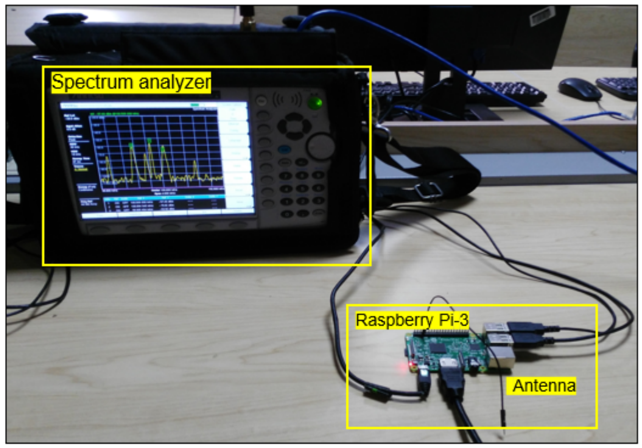
RaspBerry Pi 3 is a low-cost computer equipment and small size, it is designed for applications of rapid prototyping of medium complexity, it counts with a 4-core processor with ARM Cortex- A53 architecture with a 1.2GHz frequency, embedded RAM memory of 1Gb, LAN and WLAN network adapters and connection ports for different peripherals like mouse, keyboard and other USB devices, etc. This board besides working as a conventional PC, permits the use of general purpose in/out pins called GPIO, timers and PWM modules managing to have the functionality of a microcontroller in the same board. Raspberry Pi stands out for being a board with local high frequency oscillators and permits the possibility of working with different LINUX versions that are adapted to its features like Raspbian, Ubuntu, etc. [1–3]. Once its most important features are known, an analysis is made about research related to the design of telecommunication instrumentation, especially RF generators and applications developed with RaspBerry. Below, some of these investigations are shown. In [4] it is proposed a design of a RF generator test with limit operation frequency of 400MHz and a power range of 130 dB. The design is based on DDS (Direct Digital Synthesizer) controlled by a microprocessor, which produces a wave with a reference clock. The sampled signal goes through a process of analog to digital conversion and filtering and uses software tools like IAR Embedded Workbench 4.0, Flash Magic and Visual Basic. In [5] it is shown a design of a GNNS generator based on SDR. A low-noise signal amplifier is implemented, and antenna and a USRP N210, the signals are generated using MATLAB and processes of filtering and converting are made. The prototype's operation is validated by a spectrum analyzer to monitor the generated and transmitted signal, checking the effectiveness of the system by means of the definitions of test cases varying the sampling frequency and the center frequency to be monitored, determining high accuracy between the generated signal and the monitored signal. In [6] it is described the design and implementation of a RF signal generator for an application called BIST, which consists in replacing the high-cost external RF generator for an integrated one, with a power range of 17dB and its frequency varies from 17.5GHz to 23.1GHz. In [7] it is shown the development and the performance of a processor and generator of pulses Chirp for Pi-SAR-L2. This device can generate a pulse of 85 MHz of bandwidth and it can process the same video signal with a small phase error. In [8] it is proposed a signal generator of multichannel frequency. The platform counts with 5 channels with synchronous and asynchronous functions. For the asynchronous case, different random wave forms are generated independently. For the synchronous case, the digital data of the output signal must be adjusted by a clock cycle. Filtering is used to suppress harmonic distortion, phase detectors to compare signals of other channels and a constant temperature crystal is used, which has high frequency stability. In the results it is verified the viability of a multichannel DDS parallel signal generator.

Additionally, for Raspberry Pi research's, the following are highlighted: In [9] it is described the design and implementation of a reconfigurable virtual instrumentation equipment. With this kind of equipment, it is possible to emulate multiple functionalities like signal generators, oscilloscope, multimeter, logic analyzers, among others. Its hardware is made by a hardware core using a reconfigurable Spartan-3E FPGA, inputs and outputs and a physical interface which connects the hardware interface to the RaspBerry Pi, it counts with a software application which controls the hardware in real time. In [10] it is made the design and implementation of a positioning smart antenna system that is able to direct the beam with maximum gain and low cost, working on 2.45GHz as test frequency and OFDM of multiplexing scheme. The control of the radiation direction of the system is made by RaspBerry Pi 2, through a smart electromagnetic detection and blocking algorithm. The control pins of the RF switch are connected the general purpose in/out pins of the RaspBerry Pi, which give the needed control polarization and commutation voltages. In [11] it is shown the design and implementation of a radar system on 6 GHz by Raspberry Pi to make real-time FTT signal processing. The system detects distances and frequency operation range.

2.2. *Stage 2. Design of Scenery Phase 1. Requirements identification and scenery description*

The RaspBerry Pi RF signal generation has been worked in free software projects like PiFM and rpitx [12, 13]. These projects use internal clock sources of ARM BCM2835 integrated circuit. The manufacturer of this device wants to provide different clock signal sources for the different devices that can be connected to RaspBerry, among them video devices, audio and other integrated circuits. These clock sources can reach 1 GHz of frequency with the possibility of using simple frequency divisors or fractional, to obtain a wide range of frequency generation. It is noteworthy that the generated frequencies are square signals, which in many cases their clock cycles are suppressed to achieve the fractional frequency to obtain more accuracy in the output frequencies. In the frequency domain, a square signal would have many odd infinite harmonics. However, as fractional divisors are used, it is evident the appearance of odd and even harmonics. In conclusion, in these two projects, it is used signals that originally have the function to be applied in other circuits as clock to be transmitted as RF radiofrequency signals being modulated in some cases or being transmitted without any modulation in others. In both cases, it is used an internal clock signal of 500MHz coming from the PLLD module. For the done tests, it is used the software PiFM, with the aim of transmitting a modulated audio signal to be received by a conventional FM radio. Figure 2 below, shows the test scenery implemented for a frequency of 101.3 MHz using a 10cm cable approximately which works as an antenna, which will give a small coverage in its surrounding. To detect the signal, it was used a spectrum analyzer Anritsu MS2722C, which counts with a parameter identification software for FM commercial radio stations and a conventional mobile phone to check if the signal is being generated with the programmed sound in order to verify the quality

Figure 2: Implemented scenery.



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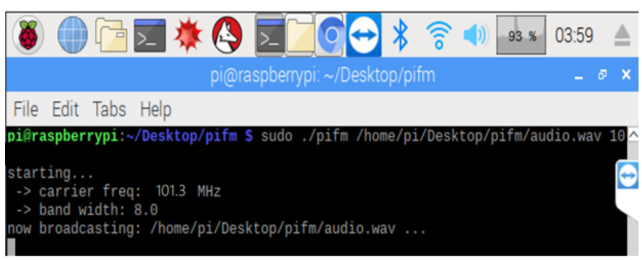
A wav extension file was used as modulating signal, which is read but the PiFM code made in C++ to be modulated over the clock signal aforementioned. The antenna must be connected to the GPIO 4 output. Which is the output pin for the used clock source. As for the software that makes the modulation, the Pifm.c [12] file was acquired, which was compiled and executed in the RaspBerry terminal as shown in Figure 3.

Figure 3: pifm.c code execution.



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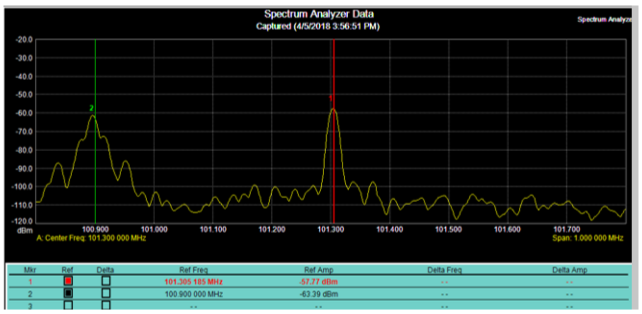
2.3. *Stage 3. Results Analysis Phase 1*

When executing the code, it is specified the center frequency in the transmission to 103.1 MHz, the audio is verified using the mobile phone tuned in the aforementioned frequency. The perception of the sound is good, and it would difficult to identify that it is not a commercial radio station, however, in some occasions it is possible to hear some interference. When measuring the signal with the spectrum analyzer, it was observed a bandwidth comparatively inferior with the one of the commercial radio station in 100.9 MHz on the left of the generated signal as shown in Figure 4.

Figure 4: Spectrum analyzer checking RaspBerry Pi transmission.



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Using the FM analysis function in the spectrum analyzer, it is obtained the data shown in Table 1, analyzing the commercial FM radio station and the PiFM radio station.

In Table 1, it is seen an error in the frequency of 5 KHz in the PiFM radio station, compared to a 1 kHz error in the commercial radio station, additionally, it is shown a lower signal-to-noise ratio compared to the commercial radio station, but with a higher power level given the closeness between the spectrum analyzer and the RaspBerry.

In Figure 5a, it is observed the evolution in time of the spectrum before and after beginning the transmission. In the close frequencies to the emission, it is not appreciated a big change in most of the generated signal. In Figures 5b and 5c, it is appreciated the spectrogram taken in a frequency range from 9 kHz to 1GHz. Before beginning the transmission, it is clearly seen the different wireless services in the spectrum, it is taken as a reference the FM commercial band on the bottom part of the spectrum and the GSM 850 band on the top with power levels around -50dBm in the first case and -40dBm in the second. When the emission is started, harmonics with considerable amplitude are generated every 100MHz approximately as shown on the bottom part of Figure 5c, having some of these a power greater than the one of the desired signal (-35dBm in the third harmonic). In case of increasing the power of this signal, different services could be affected, even in the top part of GSM 850 it is possible to see an interference generation.

Table 1: Spectrum analyzer measurements.

Radio station	Center Frequency (MHz)	Bandwidth (kHz)	Number of carriers	SNR (dB)	Channel power (dB)
Commercial 100.9	100.899	173	1	27.3	-57.3
Raspberry Pi	101.305	145.45	1	19.8	-48

Source: own.

3. Conclusions

With these results is possible to conclude that the quality of the generated signal with the RaspBerry is acceptable and it can be used in different laboratory tests in academic applications or research. It is noteworthy that this use is subject to RF filter design that decrease considerably the quantity of harmonics and unwanted interference, so as not to affect other signals in the different distributed applications in the spectrum. Through the proper design of filter and an optional variable amplification it is possible to build a low-cost RF generator.

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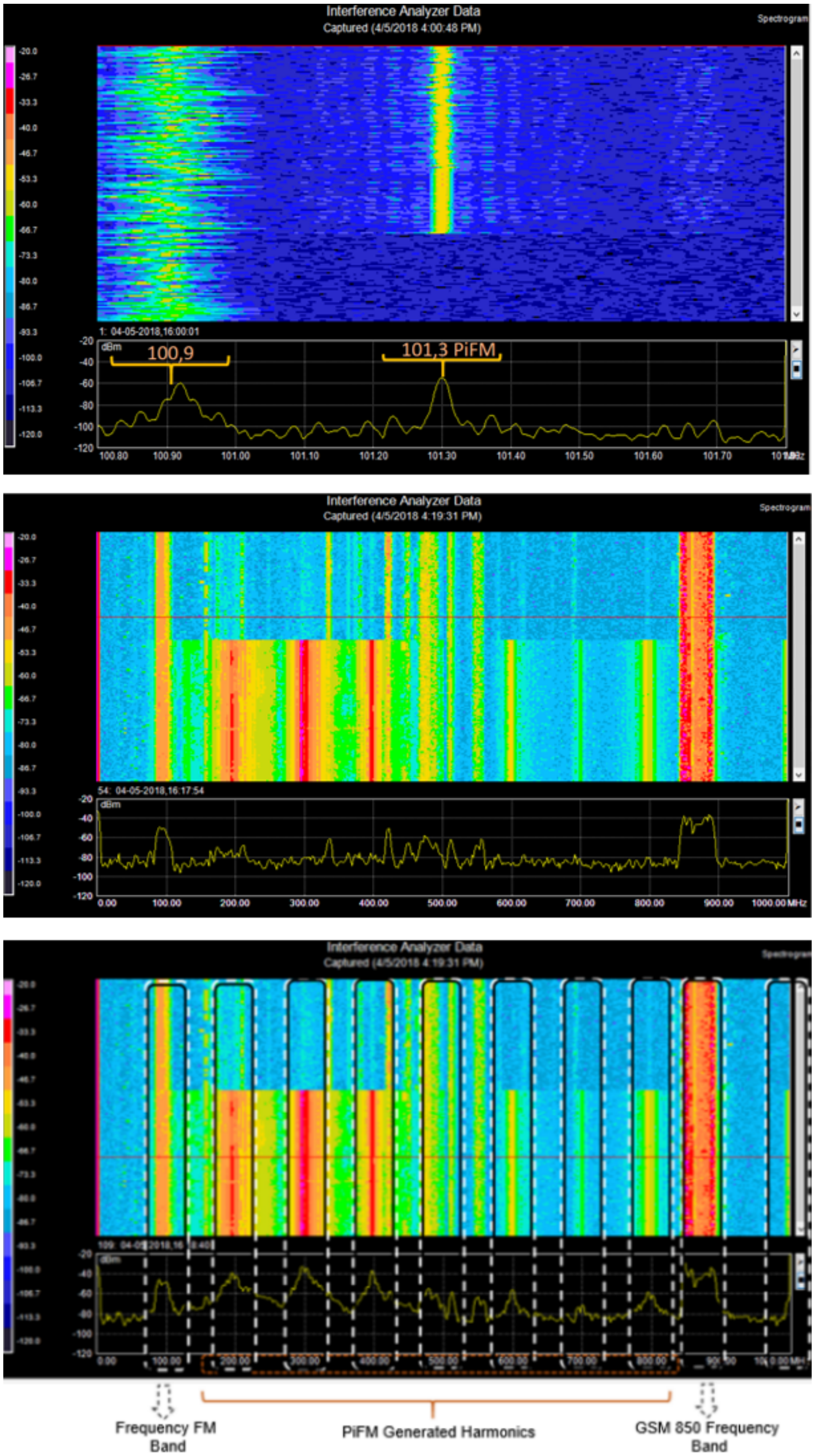
Figure 5: Spectrogram a) Spectrogram before and after turning on the generator (1 MHz of SPAM). b) Timeline with RaspBerry off (Spectrum from 9 KHz to 1 GHz). c) Timeline with RaspBerry on (spectrum from 9 KHz to 1 GHz).



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