# Experimental investigation on spectrum sensing testbed using GNU Radio and SDR

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**ABSTRACT.** Spectrum sensing is one of the major annexes in modern communication systems. It is the basis of a cognitive radio system. Implementation of an efficient spectrum-sensing machine involves many challenges, such as processing delay, false alarms, misdetection, detection of weak signals in a noisy environment, etc. The present work reports a physical experimental setup on spectrum sensing. An energy detection-based spectrum-sensing machine is implemented with a software-defined radio and an open-source software toolkit GNU Radio. Design of the device is thoroughly deliberated. The result proves the proficiency of the device. The scope of this work is to implement the backbone of a spectrum sensing test bench that can be further utilized for executing and testing new emerging studies.

**KEYWORDS:** Spectrum Sensing Testbed, GNU Radio, Software Defined Radio, Cognitive Radio.

## 1. INTRODUCTION

The frequency bands of the wireless communication spectrum are not being proficiently utilized, primarily because of the predominant inflexible frequency distribution strategy. In that methodology, different frequency bands are relegated to various clients and specialist co-ops, and licenses are expected to work inside those bands. According to the specialized perspective, this approach causes the plan and execution of a communication framework simpler. The developing interest in wireless applications has placed a ton of requirements on the use of accessible radio spectrum, which is a restricted and valuable asset. Cognitive radio (CR) [1] is a promising innovation, which gives an original method for further developing the use effectiveness of accessible electromagnetic spectrum. Spectrum detecting assists with distinguishing the spectrum openings (underutilized bands of the spectrum) giving high unearthly goal ability.

CR clients are unlicensed [2] who find unused authorized spectrum progressively for their own utilization without making any obstruction authorized users. Some of the current strategies utilized in CR incorporate spectrum detection, spectrum data set, and pilot channel. These procedures either overwhelmingly require a high computational ability to distinguish unused spectrums or neglect to benefit from spectrum space made progressively.

Energy Detection (ED) [3] is one of the vastly recognized spectrum sensing techniques. This is a non-reasonable detection technique that distinguishes the essential sign in view of the detected energy. The energy of the received signal is compared with the threshold value to detect the presence of the transmitting signal at that moment and location.

The reported research is based on the design and testing of a practical spectrum sensing module and verifying results. The module can be used as a test bench for further developments in this emerging area.

## 2. LITERATURE SURVEY

Spectrum detecting, spectrum choice, spectrum sharing, and spectrum portability are four significant elements of cognitive radio frameworks [4]. The cognitive radio-based Internet of Things (IoT) framework is a viable move toward a universe of shrewd innovation. Effective spectrum detecting and sharing are the vitally practical parts of the CR-based IoT [5]. CR innovation can possibly address the deficiency of accessible radio spectrum by empowering dynamic spectrum access. Authors of the paper [6] feature the productivity and limits of both narrowband and wideband spectrum-sensing strategies as well as the difficulties engaged with their execution. The CR is a compelling method for improving the utilization of spectrum assets. The paper [7] reported the cooperative spectrum-sensing algorithm based on face compensation in a cognitive radio cloud network, zeroed in on the spectrum sensing in cognitive radio cloud networks. The authors proposed a cooperative spectrum-sensing algorithm based on stage compensation to further develop the spectrum sensing execution. The throughput for the cooperative spectrum-sensing scheme is determined using a Game-theoretic model in [8]. In the paper [9], three explicit machine learning strategies (neural organizations, assumption expansion, and k-implies) are applied to a multiband spectrum detecting procedure for cognitive radios. The CR assumes a key part in distinguishing free transfer speeds in the Radio Frequency (RF) spectrum. The CR4S calculation pointed toward further developing CR spectrum detection by using procedures, for example, Real-esteemed FFT, Sparse Fast Fourier Transform, and cooperative spectrum detecting. It has been supported by recreation to above 95% identification execution [10]. Similarly, the paper [11] fostered a two-step compressive spectrum detecting calculation for wideband cognitive radios. The sub-Nyquist wideband spectrum-detecting plan can accomplish great recognition execution as well as decrease the calculation and execution intricacy [12]. The CR innovation is certainly standing out enough to be noticed to take out the issue of spectrum shortage. This innovation depends on Software Defined Radio (SDR) [13] and a few coordinated perceptive works, for example, spectrum detection. The paper [14] presents trial consequences of the equipment execution of the Goodness of Fit (GoF) based detecting for CR. Secondary Users (SU)/ CRs may employ Artificial Intelligence (AI) to detect the Primary user's (PU) band [15].

## 3. OBJECTIVE AND METHODOLOGY

The work represents the experimental setup of an efficient spectrum-sensing scheme for the new-generation communication system. Amitec-made Software Defined Radios (SDRs) are used for practical implementation of the PUs and sensing SU. The device is driven by an open source software JNU Radio. At the SU end, the received signal is transformed into the frequency domain. Therefore, its power spectrum is compared with a predetermined threshold to implement Energy Detection (ED).

The objectives of the present work are represented as follows:

- To implement a prototype model of transmitting PU and sensing SU using GNU radio.
- To physically implement the spectrum sensing model using SDR.
- To verify the experimental result and determine the efficiency of the system.

A fundamental architecture of a CR network is considered the system model for experimentation. Some licensed PUs are assumed to transmit signals at different frequencies of the licensed band. A SU, which intends to opportunistically use the licensed spectrum, is sensing the band for vacant spectrum. Both, the PUs and SU are implemented using GNU Radio.

GNU Radio is an open-source toolkit that supports users to implement SDRs using signal-processing blocks. It is used with Amitec-made SDR, which is a readily available low-cost RF hardware.

## 4. EXPERIMENTATION SETUP

Multiple PUs are implemented in the same block of the toolkit (Fig.1). For experimentation, four signal sources are used as the PU. Their transmitted signals are added and transmitted through SDR.

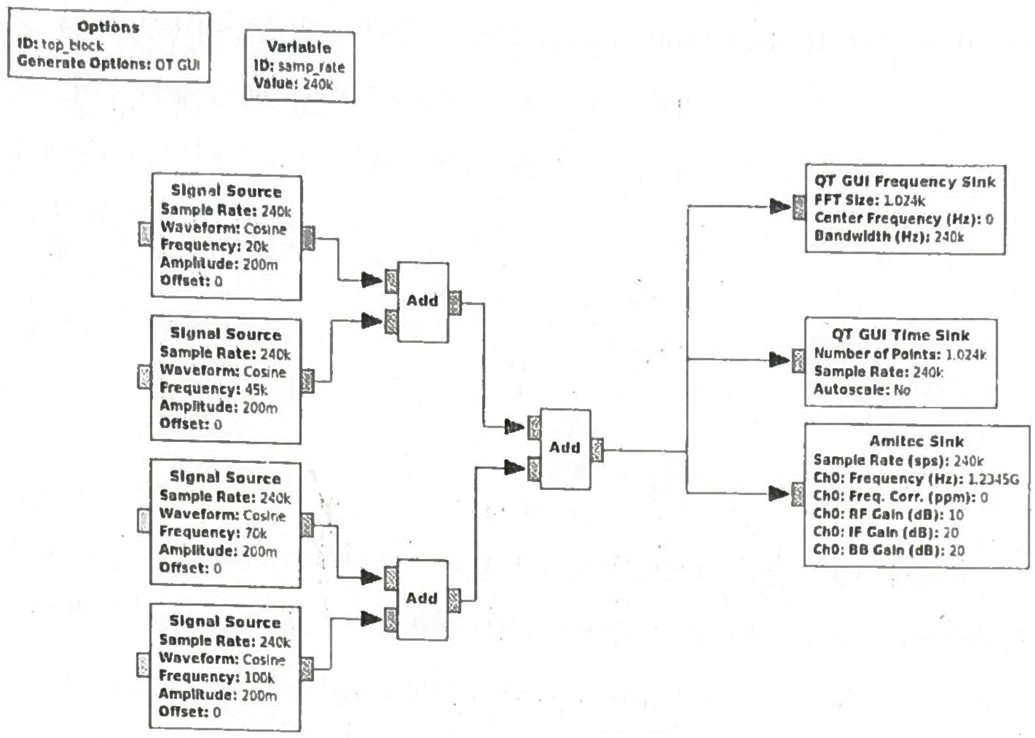


**Fig.1:** Primary Users' flow-graph at GNU Radio

The SU block is designed with an inbuilt Energy detection spectrum sensing mechanism (Fig.2). The SU senses the environment for available spectrum using an SDR. A particular licensed band is scanned and the power spectrum is estimated using FFT. Therefore, the received power spectrum is compared with a predetermined threshold. The result is shown via File Sink in a GNU Radio. Python codes are used to customize the design blocks at GNU Radio.

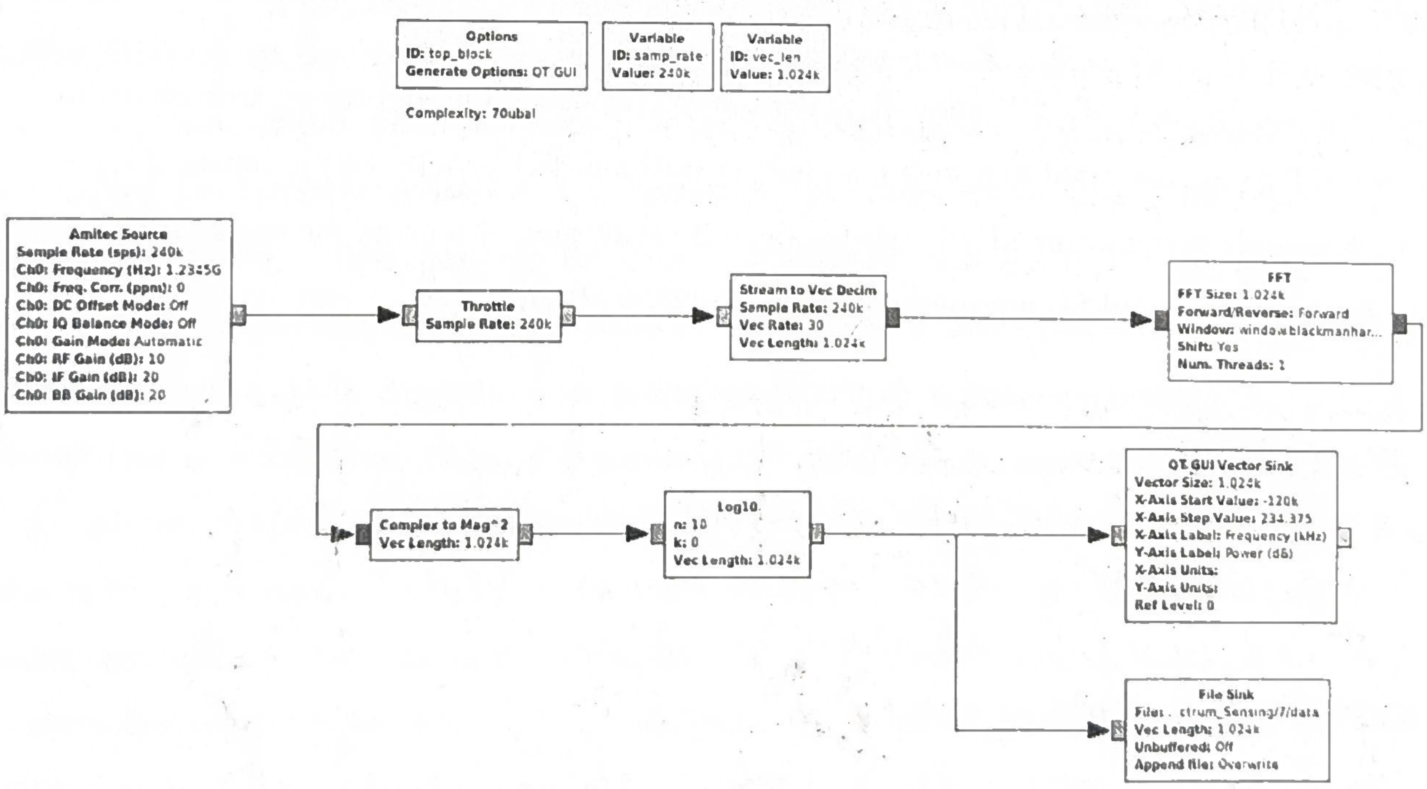


**Fig.2:** Secondary Users' flow-graph at GNU Radio

The experimental setup includes two Amitec-made SDRs and two computers with GNU Radio and the driver of SDR installed in it. The SDRs are the transceiver with one transmitter and one receiver channel with 0.3-3.8 GHz bandwidth. Baseband bandwidth is up to 15 MHz and ADC, and the DAC sampling rate is 40 MS, 12 bits. The device output amplitude is 250mV p/p differential with a receive gain of 50 dB. The experimental arrangement is shown in fig.3.

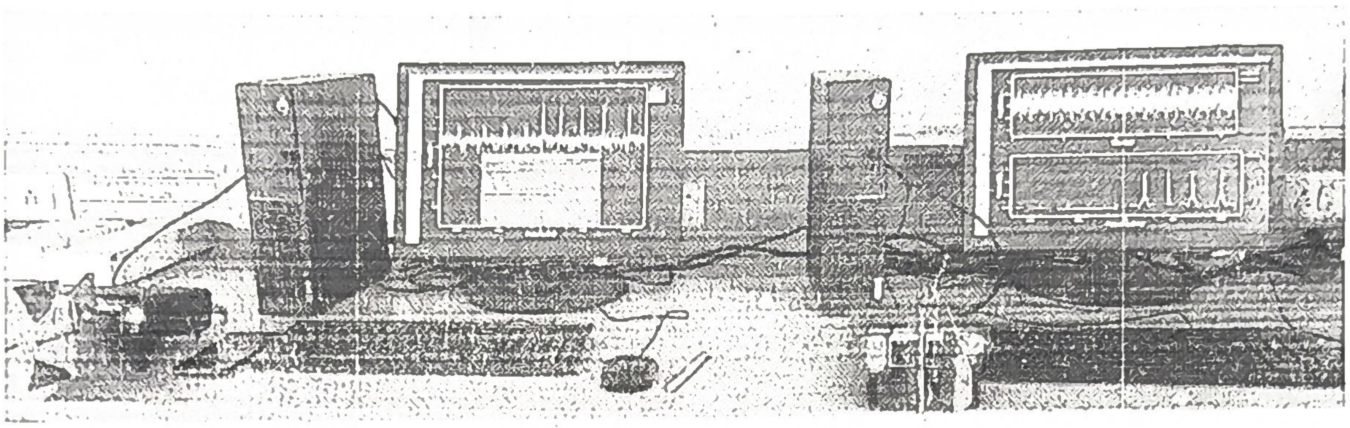

Fig.3: Experimental arrangement during operation

## 5. RESULT ANALYSIS

For ease of execution, we took four channels with carrier frequencies 20KHz, 45KHz, 70KHz, and 100KHz.these signals are added and transmitted through the same SDR. The other SDR scans the frequency band. The received stream is first converted into vector data to the compute power spectrum of the signal. FFT block is used to transform the time domain to the frequency domain. The square of the magnitude of FFT, which represents the power spectrum, is taken to compare with the threshold. If the signal power is more than the threshold for a particular channel, then the sensing CR will consider that the PU occupies the channel at that moment. We tested our system for the variety of PU frequencies and the system detects the PU-occupied spectrum almost perfectly and with an insignificant delay. For the mentioned channel frequencies, the result at the file sink is shown in fig.4.

```
amitec@amitec-master: ~/Documents/Spectrum_Sensing/7
amitec@amitec-master:~/Documents/Spectrum_Sensing/7$ python read_v4.py

                    Frequencies :
Inital Range, Final Range :

-1.0, -120042.0
-468.0, 468.0
20358.0, 21060.0
45396.0, 45864.0
70434.0, 70902.0
100386.0, 100854.0
amitec@amitec-master:~/Documents/Spectrum_Sensing/7$
```

Fig-4: Detected occupied PU frequencies

The result shows the initial and final frequencies of the occupied bands. Some of the frequencies are wrongly detected as busy, which indicates false alarm possibilities. The probability of false alarm may be reduced by choosing the proper threshold for the energy detection segment.

## 6. CONCLUSION

The present work reports an experimental spectrum sensing arrangement and its result. An open-source software toolkit, GNU Radio, and Amitec-made software-defined radio are used to implement the setup. The results show that the system can competently detect busy channels. Therefore, it can be utilized by researchers as a prototype spectrum sensing device. Further, new algorithms of similar research are easily implementable by modifying flow-graph. The system can be further improved with the addition of noise cancellation and delay mitigation mechanisms.

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