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Testbed for Cognitive Radio

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Abstract:

Dedicated to the development of a robust cognitive radio testbed, we aim to evaluate the technology's effectiveness in alleviating spectral congestion challenges. The testbed encompasses various scenarios, including direct line of sight for near and far distances, and indirect line of sight. Leveraging Orthogonal Frequency Division Multiplexing (OFDM) modulation and implemented through LabVIEW software and Universal Software Radio Peripheral (USRP), the testbed provides a practical environment for real-world simulations The overarching goal is to evaluate the adaptability and robustness of cognitive radio in managing spectrum efficiently. By simulating three distinct scenarios, this research contributes insights into the practical applicability of cognitive radio, providing a hands-on approach for testing its capabilities. The potential applications of this technology range from mitigating spectral congestion to optimising spectrum utilisation in diverse communication scenarios.

Keywords: Cognitive radio, Spectrum efficiency, Energy Detection, Threshold, MathScript, Testbed development, QPSK, LabVIEW, USRP.

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I. INTRODUCTION

Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e., the outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit power, carries-frequency, and modulation strategy) in real time, with two primary objectives in mind: highly reliable communication, whenever and wherever needed, and efficient utilization of the radio spectrum[1]. Cognitive Radio Networks (CRNs) are foreseen as the future wireless ICT that exploit dynamic and opportunistic spectrum access strategies to provide wireless connectivity. CRNs are considered as the key technology to alleviate the severe spectrum underutilization and provide a solution for spectrum scarcity [2]. The SDR can adapt itself to the transmission scenario in order to minimize interference to other signals that are present in the air interface. Implementation of such a system requires the ability to scan the spectrum from low to high frequencies using software. This concept has driven many researchers to study cognitive radio (CR) approaches, an idea also proposed by Mitola, where the radio adapts itself to the air interface by optimizing the carrier frequency, modulation, and choice of radio standard to minimize interference and maintain communication [3].

One of the most commonly used SDR hardware platforms is the Universal Software Radio Peripheral (USRP). Before SDR, radio developers used to build tailored radio system: one radio platform supports one particular frequency. The SDR platform is generic, means one platform supports multiple signals of different frequencies. Thus, the number of platforms required for communication is reduced. So, we can say in Hardware Intensive Radio, capability fully depends on hardware [4]. This thesis is dedicated to the development and evaluation of a robust cognitive radio testbed, aimed at assessing the effectiveness of CR in alleviating spectral congestion challenges.

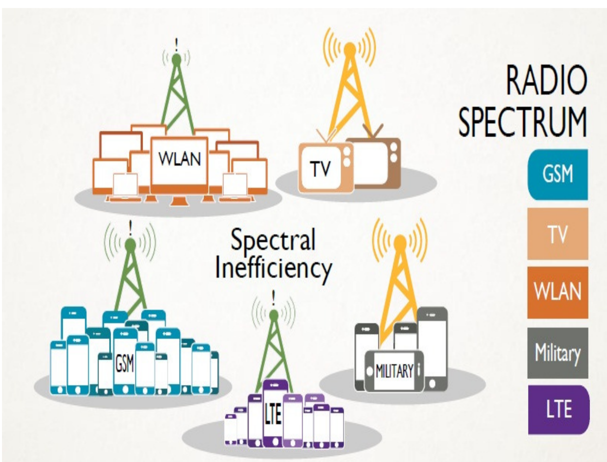

Fig. 1Communication of primary and secondary network users through CR

II. LITERATURE SURVEY

At first, cognitive radio was pioneered by Mitola from software defined radio (SDR). [1].

CR is a wireless device that senses the surrounding radio environments and opportunistically access unutilized spectrum bands based on the activities of the surrounding primary licensed networks [2]. Software-defined radios (SDRs) are wireless communication devices that use software-based techniques for signal processing and modulation, enabling flexible and adaptable wireless communication systems. Unlike traditional radios, SDRs separate the hardware and software components, allowing for reconfiguration and customization of radio functionalities through software updates. SDRs will play a key role in future radio configurations because the emergence of new wireless technologies and their integration in a fourth generation of communication standards will necessitate the use of multistranded and multiband radios.[3] SDRs use a single hardware front end but can change their frequency of operation, occupied bandwidth, and adherence to various wireless standards by calling various software algorithms. Such a solution allows inexpensive, efficient interoperability between the available standards and frequency bands [3].

SDRs employ a range of signal processing techniques to achieve desired functionality. Digital down conversion, digital up conversion, and digital filtering are commonly used techniques for baseband processing.Modulation and demodulation algorithms, such as quadrature amplitude modulation (QAM) and phase-shift keying (PSK), enable data transmission. Additionally, researchers have explored advanced signal processing techniques like software-defined antenna arrays and adaptive filtering to enhance system performance.

In SDR, most of the signal processing, channel selection, tuning, modulation, and demodulation are performed in digital domain through software. Thus, the ultimate goal of SDR is to move the Analog-to-Digital Converter (ADC) / Digital-to-Analog Converter (DAC) as close as possible to the antenna so that all signal processing can be done digitally via software. An SDR transceiver is divided into four main parts: intelligent antenna/smart antenna, an analog/RF front-end, digital front end and the digital signal processing unit [4].

Researchers have proposed various SDR architectures and platforms. One prominent architecture is the Universal Software Radio Peripheral (USRP), which provides a flexible and programmable hardware interface for SDR development. Another architecture is the GNU

Radio, an open-source software development toolkit that enables the implementation of SDR applications on general-purpose computers.

III. EXISTING PROBLEM

Spectral congestion is an intricate problem rooted in the finite nature of the electromagnetic spectrum. As the demand for wireless connectivity continues to surge, traditional static spectrum allocation methods struggle to accommodate the dynamic and unpredictable nature of modern communication systems. The consequences of spectral congestion manifest in inefficiencies, increased interference, and compromised service quality, thereby necessitating a paradigm shift in our approach to spectrum management. Cognitive Radio (CR) is an innovative and transformative solution to the challenges posed by spectral congestion. CR systems stand out for their cognitive capabilities, allowing them to dynamically sense the radio environment, identify available spectrum opportunities, often referred to as spectrum holes, and intelligently exploit them for transmission without causing detrimental interference to primary users. Existing testbeds for cognitive radio, such as GNU Radio, WUT Cognitive Radio Testbed, ORBIT Testbed, WARP, and GENI Testbed, serve as crucial platforms for research and development in cognitive radio technology. By offering a combination of simulation and real-world experimentation capabilities, they enable the prototyping and validation of cognitive radio systems in diverse wireless environments. Researchers leverage these testbeds to explore advanced cognitive radio techniques, including machine learning-based spectrum sensing and adaptive spectrum sharing algorithms. Through experimentation on these platforms, insights are gained into optimizing spectrum utilization, enhancing spectrum efficiency, and improving wireless communication reliability, paving the way for the deployment of cognitive radio networks in future wireless communication ecosystems.

IV. PROPOSED SOLUTION

The proposed cognitive radio testbed offers several advantages for spectrum management and wireless communication research. By leveraging QPSK modulation and integrating MATLAB, MathScript, and LabVIEW, it provides a versatile platform for dynamic spectrum access experimentation. The use of USRP hardware enables real-time signal transmission and reception, allowing for rapid prototyping and validation of cognitive radio algorithms. Additionally, the integration of MATLAB facilitates advanced signal processing tasks and algorithm development, while LabVIEW offers intuitive control and monitoring capabilities. The system's ability to visualize QPSK modulation through constellation diagrams aids in understanding signal behaviours. Overall, the testbed enables researchers to explore adaptive spectrum access strategies, optimize spectrum utilization, and enhance wireless communication reliability, contributing to advancements in cognitive radio technology.

Cognitive radio testbed includes real-time signal transmission and reception using USRP hardware, advanced signal processing capabilities facilitated by MATLAB and MathScript integration, intuitive control and monitoring functionalities provided by LabVIEW, support for QPSK modulation with visualization through constellation diagrams, and the ability to prototype and validate cognitive radio algorithms for dynamic spectrum access. These features collectively offer researchers a versatile platform to explore and innovate in spectrum management and wireless communication research. The cognitive radio testbed integrates USRP hardware with MATLAB, MathScript, and LabVIEW for real-time signal processing and control. Leveraging QPSK modulation, it enables dynamic spectrum access experimentation and algorithm development. This versatile platform facilitates rapid prototyping and validation of cognitive radio systems, advancing research in spectrum management and wireless communication.

The proposed solution integrates energy detection for spectrum sensing, a crucial aspect of cognitive radio technology. This technique allows for the intelligent detection and analysis of radio frequency signals, enabling dynamic spectrum access and utilization within the testbed.

V. IMPLEMENTATION

In our practical implementation of a cognitive radio testbed, MATLAB played a crucial role in generating constellation diagrams, specifically tailored for visualizing the QPSK modulation scheme. These diagrams provided invaluable insights into the phase and amplitude relationships of the QPSK-modulated signals, enhancing our understanding of modulation intricacies essential for cognitive radio operations.MATLAB was utilized for QPSK modulation, spectrum sensing.

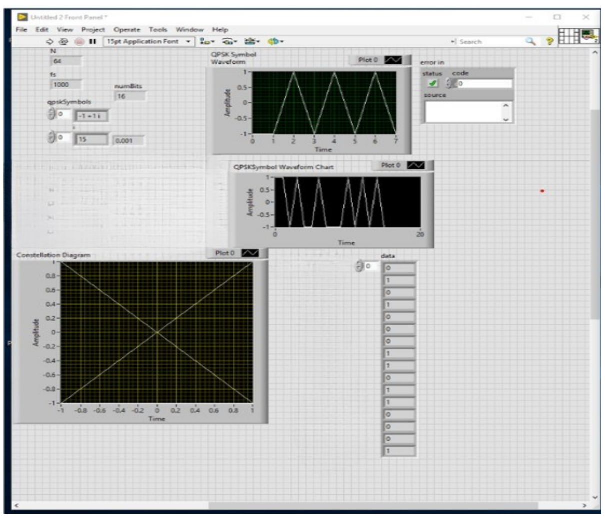

Fig. 2.Constellation figure of QPSK in LabView.

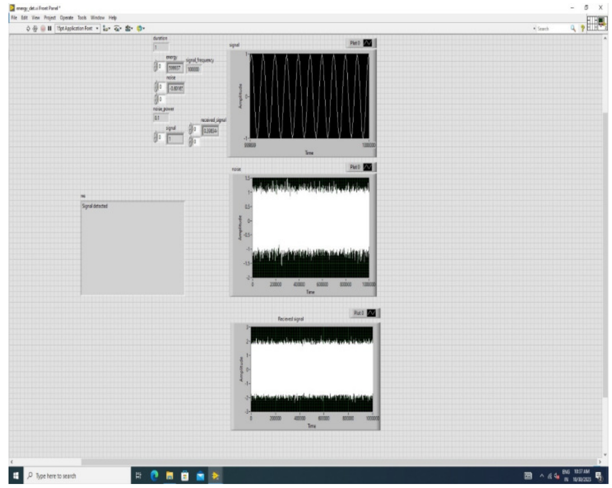

Fig. 3. Energy Detection

Simultaneously, LabVIEW's robust capabilities facilitated the orchestration of signal transmission and reception processes using USRP hardware. Integration testing ensured seamless interaction between components and platforms, validating the testbed's capability for dynamic spectrum access. This involved iterative refinement of system functionalities, including spectrum sensing, channel estimation, and cognitive radio algorithm implementation.

Leveraging LabVIEW's real-time control features, we seamlessly interacted with the USRP devices, ensuring efficient signal transmission and reception throughout the experimentation phase.

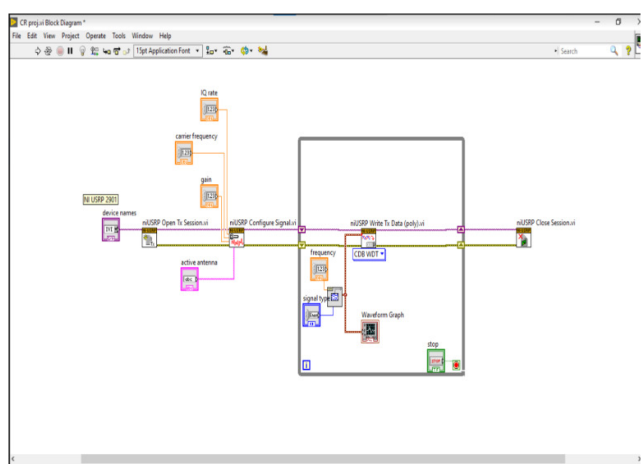

Fig. 4. USRP transmission

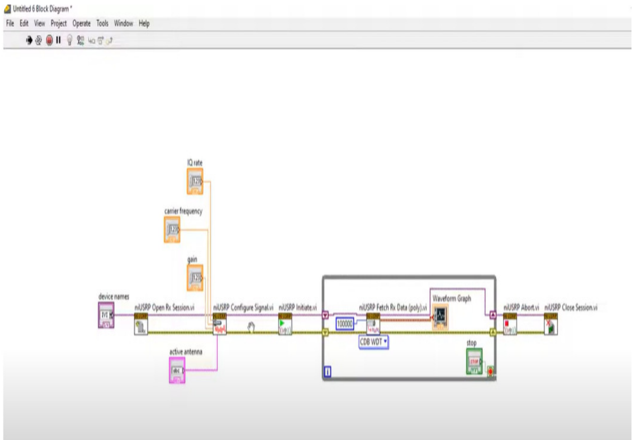

Fig. 5. USRP reception

VI. RESULTS AND ANALYSIS

In our project, the successful transmission and reception of signals using two USRP devices, facilitated by LabVIEW software, yielded insightful results, observations, and analysis. We observed robust signal transmission and reception capabilities, with signals being reliably transmitted and accurately received. Through energy detection techniques implemented in LabVIEW, we effectively distinguished signal energy from background noise, demonstrating the testbed's ability to detect and analyse received signals. The constellation figures generated by MATLAB provided visual confirmation of successful QPSK modulation and demodulation, validating the integrity of transmitted signals. Additionally, our analysis revealed the impact of environmental factors on signal quality and performance, highlighting the importance of adaptive algorithms for dynamic spectrum access. Overall, our results underscore the effectiveness of our cognitive radio testbed in facilitating signal transmission, reception, and analysis, laying the foundation for further research in cognitive radio technology and spectrum management.

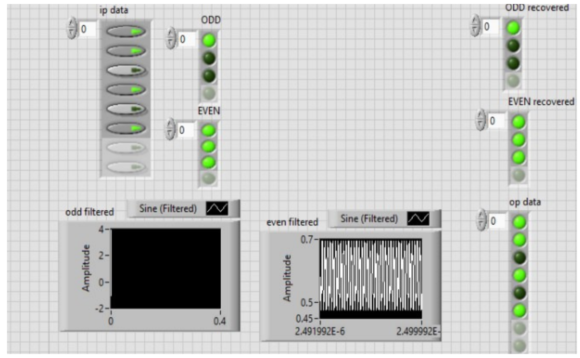

Fig. 5. QPSK transmitting data

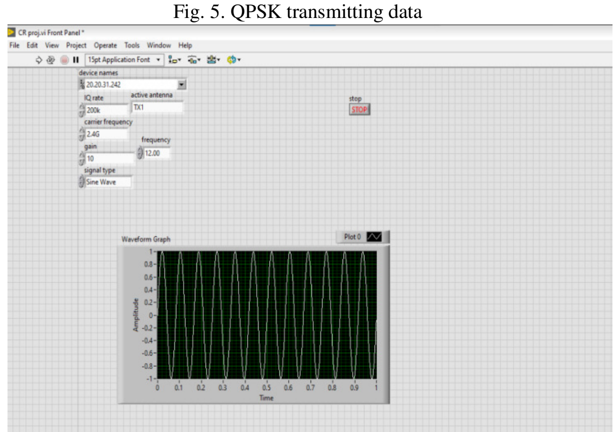

Fig. 6. USRP Transmission signal

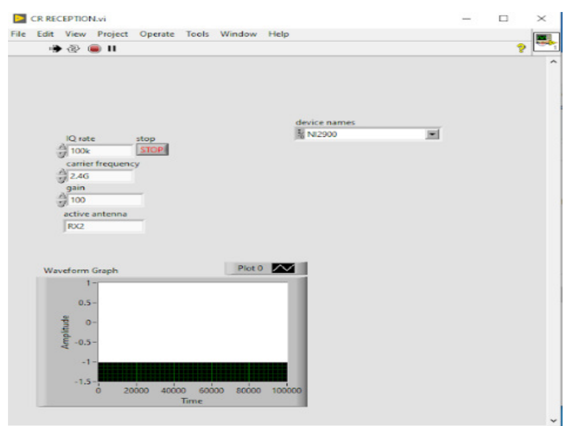

Fig. 7. USRP Received Signal

VII. CONCLUSION

In conclusion, creating a testbed for cognitive radio using QPSK modulation in LabVIEW allows for the experimental validation and assessment of cognitive radio systems. QPSK modulation, with its spectral efficiency and robustness, serves as a suitable modulation scheme for dynamic spectrum access. The LabVIEW environment provides a versatile platform for developing and testing cognitive radio functionalities. By integrating QPSK modulation into the testbed, one can evaluate the system's ability to sense and adapt to varying spectrum conditions, ensuring efficient utilization of available resources while avoiding interference with primary users. Such a testbed facilitates the exploration of cognitive radio algorithms, spectrum sensing techniques, and dynamic spectrum access strategies, contributing to the advancement and optimization of cognitive radio networks.

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