WaveBox: Software-Defined RF Generator with Seamless Waveform Switching and Open Integration

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***Abstract*—This demo introduces *WaveBox*, a dynamic, software-defined waveform generation system developed to assess the resilience of communication networks against many types of interference scenarios. WaveBox features seamless waveform switching, allowing users to efficiently adjust interference patterns to adapt to diverse operational scenarios. We will showcase the system's effectiveness and versatility, highlighting its ability to adapt to evolving mission requirements. Additionally, the system's intuitive graphical user interface (GUI) supports rapid waveform adjustments, enhancing its responsiveness in dynamic environments. WaveBox can provide a flexible software-defined tool for evaluating the robustness of wireless systems.**

***Index Terms*—Software-defined Radio, Network Resilience, Waveform Adaptation.**

I. Introduction

Understanding the impact of various RF interference generation techniques is critical for developing resilient wireless communication strategies in performance-critical wireless communications [1]–[3]. Traditional hardware-based interference generation systems often require extensive reconfiguration to alter their RF patterns, leading to higher costs and longer deployment times. These systems are typically bulky and challenging to deploy, especially in outdoor environments where rapid adaptation to changing weather conditions is crucial. Consequently, their lack of flexibility and responsiveness significantly decreases their effectiveness, especially in contested environments.

In this demonstration, we introduce *WaveBox*, a software-defined RF interference generation platform designed to test the resilience of communication networks and devices against a wide range of challenging or contested RF scenarios. WaveBox's key innovation lies in its flexibility, seamless waveform switching, and the open integration of custom waveforms. With advanced software controls, WaveBox can emulate various mission scenarios, from basic interference to sophisticated, targeted interference on specific communication channels. This allows researchers and engineers to assess the robustness of different network configurations, and evaluate wireless protocols under diverse conditions.

II. WaveBox Design

The architecture of the WaveBox system is illustrated in Fig. 1. The hardware design includes essential elements for signal transmission, monitoring, and uninterrupted operation, while the software framework offers advanced control and configuration capabilities through a user-friendly interface.

Hardware Design. At the core of the WaveBox system is an Intel NUC running Ubuntu 22.04, featuring GNU Radio v3.10.1.1 and UHD 4.1.0.0, with Python 3.10 for dynamic control of the interference generation operations as well as generating baseband samples for the software radio module.

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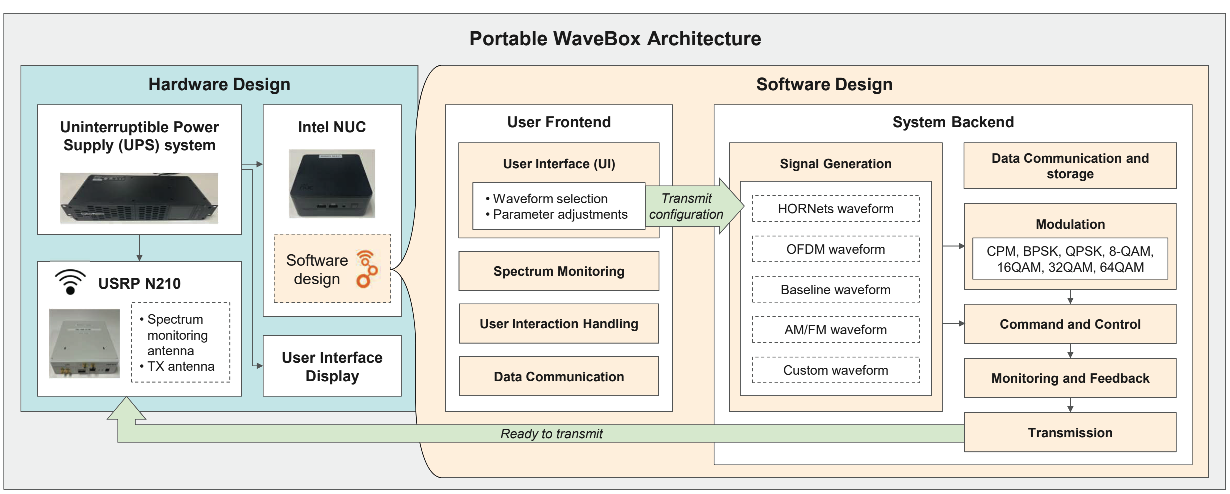
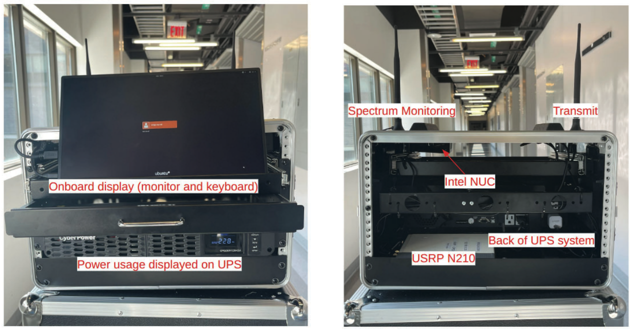


Fig. 1: Overall System Architecture of WaveBox.

TABLE I: Summary of Key Hardware Components.

Module Name	Equipment	Description
Software system	Intel NUC with Ubuntu 22.04	GNU Radio: v3.10.1.1, UHD: 4.1.0.0, with Python 3.10
Software radio	USRP N210 w/ CBX	Frequency: 1.2 GHz to 6 GHz with bandwidth of 10 MHz
Uninterruptible Power Supply (UPS)	CyberPower PFC sinewave UPS system	1500VA/1000W with 8 outlets and supply up to 1 hour of runtime
Onboard display system	Portable monitor and Logitech keyboard	System ideal for network inefficiency or unavailable remote access



(a) (b)

Fig. 2: Hardware Architecture of WaveBox.

WaveBox employs a USRP N210 software radio with a CBX daughterboard for RF signal generation across a frequency range of 1.2 GHz to 6 GHz with a maximum bandwidth of 40 MHz. The power stability of the WaveBox system is ensured by a CyberPower PFC sinewave UPS system, providing 1500VA/1000W and up to one hour of runtime. For onboard monitoring and control, a portable display and Logitech keyboard allow direct interaction with the system in case of network disruptions or when remote access is unavailable. These integrated components are housed in a robust and portable design, making the system ideal for versatile deployment and testing scenarios. Additionally, the system features a waterproof casing that protects it from harsh weather conditions and rugged terrain. Table I summarizes the key hardware components, and Fig. 2 shows the snapshots of the WaveBox prototype.

Software Design. As illustrated in Fig. 1, the software design follows a two-tier architecture, consisting of a front end and a back end. The front end features a user-friendly GUI that allows users to select predefined waveforms, including random interference, colored interference such as HORNets[1], Orthogonal Frequency Division Multiplexing (OFDM), AM/FM waveforms, as well as other custom waveform profiles. Users can specify parameters such as frequency, transmit gain and modulation type to enable various waveform patterns. The User Interaction Handling module facilitates smooth navigation and interaction with the GUI, while the Data Communication module ensures real-time communication between the front end and back end. Each waveform can be configured to operate with a fixed carrier frequency or to sweep across a wide spectrum band.

The back end comprises several modules: the Signal Generation module is designed for waveform creation; the Modulation module supports various modulation types, including CPM, BPSK, QPSK, 16QAM, 32QAM and 64QAM; the Control and Command module oversees system operations, and the Monitoring and Feedback module provides real-time spectrum data for the Spectrum Monitoring module in the front end, allowing users to visualize the impact of the waveform on the communication environment. This architecture ensures a cohesive integration between software and hardware, making the system adaptable to various testing and research scenarios.

[1]HORNets utilizes spread spectrum coding to modulate RF signals and dynamically adapts the coding signature to generate time-varying power spectrum patterns [4], [5].

III. Demonstration

We will demonstrate the effectiveness and flexibility of WaveBox, highlighting its seamless waveform switching and open integration capabilities.

Demo 1: Software-Defined Waveform Generation and Switching. In this demonstration, WaveBox will be configured to disrupt a communication link operating on a predefined protocol and frequency band. Specifically, we will utilize the HORNets waveform, with preset transmission frequencies, gain, and modulation parameters, to interfere with an active communication link using the same HORNets waveform. The receiver's response to the interference will be visualized, illustrating the effect of the interference waveform on the incumbent signal. Additionally, using the WaveBox GUI, we will demonstrate the ability to seamlessly switch between multiple interference waveforms, showcasing how different interference patterns affect communication system performance.

Demo 2: Dynamic Waveform Integration. We will demonstrate the system's capability to allow users to upload and select custom waveform profiles through the front-end GUI. The WaveBox will dynamically load the user-defined waveform into the back end, transmit the interference signal based on the specified parameters, and update the GUI to display the newly integrated waveform. For this demo, we will use a narrowband Gaussian Minimum-Shift Keying (GMSK) waveform as an example, showcasing how the system rapidly adapts to custom waveforms and immediately incorporates these changes into the generated interference pattern.

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