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ADVANCED MILITARY RADIO CHANNELS MONITORING SYSTEM BASED ON SOFTWARE DEFINED RADIO PLATFORM: PRELIMINARY ANALYSIS

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Abstract: *The use of electromagnetic spectrum monitoring for military emissions is essential due to the mobility and diversity of military operations. A tactical communications system used in the military domain includes encrypted and unencrypted data, voice and video communications using wideband and narrowband waveforms. This research focuses on the development of a high capability monitoring system based on Software-Defined Radio (SDR) technology for monitoring military waveforms. The implemented system has been tested for its ability to detect both wideband military waveforms and narrowband frequency hopping waveforms. The proposed SDR-based system provides a cost-effective solution for military waveform monitoring that can be used for real-time monitoring and analysis of the electromagnetic spectrum.*

Keywords: SDR, electromagnetic spectrum monitoring, wideband waveform, narrowband waveform, real-time monitoring

1. Introduction

Electromagnetic spectrum monitoring for military emissions has specific elements due to the diversity and dynamics of military actions. One of the fundamental characteristics of a communications system used in the military domain is mobility. The user profile of a tactical communications system includes both encrypted and unencrypted data, voice and video communications capabilities using broadband and narrowband waveforms. The term "waveform" is used to describe the entire set of radio function types that occur from user input to RF output and back again [1]. Such a description includes the main characteristics of the signal such as: the modulation scheme used, the data rate, the codes used to achieve the hopping sequence in the case of frequency hopping or to achieve the protection of the transmitted information. Four requirements are considered essential to characterize a waveform [2]:

- Data transmission rate. The data transfer rate must be high enough to allow full connection of all sensors in the field without delay.
- Coverage. The range of the mobile radio stations shall be large enough to ensure access to continuous radio service, including mobile operation.
- Robustness. The waveform shall be designed to withstand the effects of various

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types of interference, both in the information processing and in the propagation environment.

➢ Protection against jamming and detection/recognition. Measures to ensure the protection of communications and transmitted information may include: encryption, optimization of transmit power according to the minimum signal-to-interference ratio at reception in order to transmit only within the coverage area of own forces, use of directional antennas or information spectrum spreading techniques such as frequency hopping.

These requirements have led to solutions that are at odds with each other. High data rates require high bandwidth, resulting in a smaller coverage area for the same transmit power. The optimization in this situation is to use multiple waveforms, each adapted to a specific requirement. An example of this is the Joint Tactical Radio System (JTRS) program launched by the US Army. Different waveforms are proposed for different categories of forces [1], [3].

Data rate is a key issue in any communication system. This is often defined in terms of bandwidth. The category that represents the 'backbone' of a tactical communications system is wideband waveforms [2]. These wideband waveforms (WBWFs) are intended to be used in the range 200 MHz to 400 MHz and even 2 GHz, with a channel width of 5 MHz or a multiple of that, providing data rates in the order of 2 Mbps.

In the following, we will consider an electromagnetic spectrum measurement system with both wideband waveform monitoring and real-time monitoring capabilities. This covers both broadband channels (minimum 20 MHz) in the higher frequency ranges (hundreds of MHz, GHz) and narrowband channels in the VHF range using frequency hopping spectrum spreading techniques for protection. Technical analysis of a frequency hopping signal involves real-time acquisition of the signal throughout the VHF band.

Electromagnetic spectrum monitoring systems with real-time broadband channel monitoring capabilities are based on real-time vector spectrum analyzers, which are expensive. A cost-effective solution is a monitoring system based on software defined radio (SDR) platforms. The critical parameters of an SDR platform for use in a monitoring system are the maximum sampling frequency and the resolution of the analogue-to-digital conversion [4], [9]. The sampling frequency limits the real-time acquisition bandwidth, while the resolution of the analogue-to-digital converter affects the sensitivity of the monitoring system [8].

This work will analyze in detail a system based on SDR technology for monitoring military waveforms. The capabilities of the system are tested for the acquisition of wideband military waveforms as well as narrowband frequency hopping waveforms.

The structure of the paper is as follows: Section 2 describes the measurement system and methodology for monitoring the electromagnetic spectrum. Section 3 presents and analyses the test results for monitoring military waveforms. Section 4 presents the conclusions of the paper.

2. Materials and Methods

The SDR system used in the setup consisted of a USRP N310 Software Defined Radio device with a frequency range of 10 MHz to 6 GHz. The N310 USRP is a high-performance software-defined radio platform designed for advanced wireless research and development applications. It is designed and manufactured by Ettus Research.

Figure 1: N310 Detailed component view [10]

It features 4 RX, 4TX channels with up to 100 MHz of instantaneous bandwidth per channel. It also features high performance converters with up to 16-bit ADC and 14-bit DAC resolution. A PC was used as the host processing system with GNU Radio software installed for SDR programming and control. The connection between the two devices was made using fiber optic cables and SFP connectors to ensure an adequate data transfer rate. The antenna used in the experiment was a SCHWARZBECK UBAA 9115 with biconical elements.

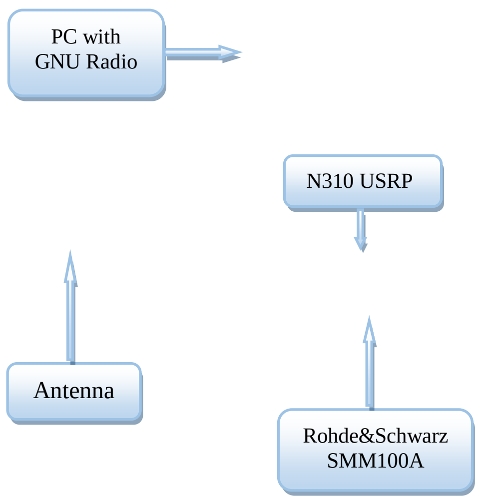

Figure 2: Experimental setup for testing spectrum monitoring systems

The GNU Radio Companion (GRC) software was used to design the signal processing flowchart, which consisted of a series of signal processing blocks used to control the SDR equipment and adjusting the signal amplitude level (Figure 3), display the spectrum in the frequency domain and spectrogram (Figure 4), and controlled storage of IQ or FFT data (Figure 5).

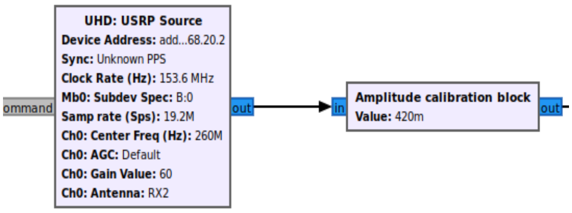

Figure 3: N310 GNU Radio management and control blocks

Figure 4: Configuration of frequency domain and spectrogram spectrum display settings

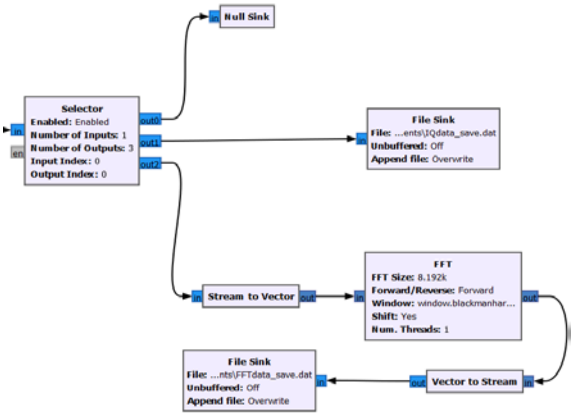

Figure 5: Graph configuration for IQ and FFT data storage

In the first phase, data generated by a high-performance Rohde & Schwarz SMM100A signal generator was collected to evaluate the performance of the SDR and GNU Radio system for monitoring radio channels. The generated signals were varied from narrowband signals to wideband signals and even frequency hopping with different hopping rates.

To evaluate the performance of the SDR system together with the GNU Radio system for monitoring radio channels, we compared the capabilities obtained by the SDR system under controlled generated signals with those obtained by receiving different channels generated by military radio stations.

The experiments were performed with minimal interference from other radio signals. The SDR and GNU radio system was placed in a location with a clear line of sight to the radio stations. The dipole antenna was pointed toward the radio stations and mounted on a tripod to maintain a fixed position.

3. Results and Discussions

Understanding the radio spectrum is essential to designing, managing and optimizing the performance of military radio networks. The frequency domain is one way to look at the radio spectrum. In the frequency domain, the spectrum is plotted as a graph with the frequency of the electromagnetic waves on the x-axis and the signal strength on the y-axis.

Another way to view the radio frequency spectrum is in the cascade format. The cascade format plots the spectrum over time, with frequency on the y-axis and time on the x-axis. Each frequency is represented by a vertical line, and the color of the line represents the signal strength at that frequency at a given time. Visualizing changes in the spectrum over time, such as changes in the intensity or frequency of a signal, is particularly useful in the cascade format.

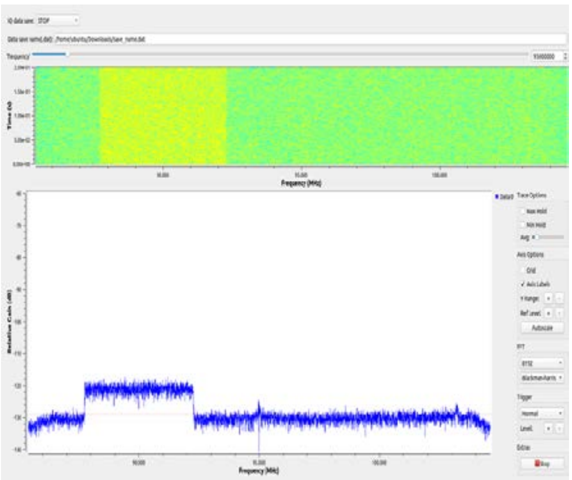

Figure 6: View the spectrum simultaneously in the frequency domain and as a waterfall spectrogram

The system presented in this paper is capable of displaying the electromagnetic spectrum in real time in both the frequency and waterfall domains. Real-time spectrum monitoring is essential in some applications and can be used for various purposes, such as detecting and identifying sources of interference, monitoring the use of radio frequency (RF) spectrum by various devices, and identifying unauthorized spectrum use. Due to the use of SDR N310 equipment the system can monitor real time up to 100MHz per channel. Because it has 4 independent channels it can monitor up to 400MHz bandwidth. The limitations of such a system are the processing power offered by the processing system (PC/Server/Laptop) which must be top performance to allow processing at very high speeds.

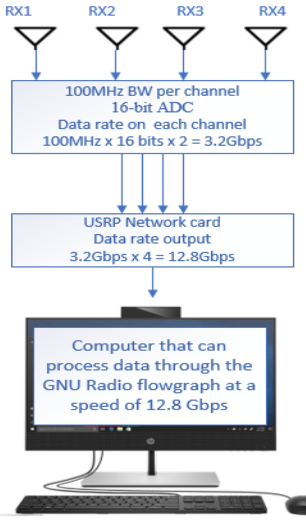

Figure 7: Data transfer rate through the system at full capacity

The processing system (in our case PC) is equipped with Intel® Core™ Pro i7 processor gen 8th and 32 Gb of RAM. For this configuration and using the application developed in GNU Radio it was found that the maximum value of bandwidth that can be monitored without errors, in real time and simultaneously in the frequency domain and waterfall is about 76MHz. This value is not unreasonable considering that most spectrum analyzers do not have this capability and the prices are higher than the proposed system.

Another factor to consider when designing an RF monitoring system is the sensitivity of the receiver. Also known as the noise floor, this is the minimum level of input power that the system can measure because all other signal is lost in the noise. This noise floor depends on instrument specifications, IF bandwidth, averaging, and configuration. As the monitored bandwidth increases, the noise floor increases. If the bandwidth is doubled, the noise floor will increase by 3dB. In the case of the proposed system, the noise floor for BW=1.5MHz is approximately -140dBm (Figure 8), and for BW=76MHz it is approximately -122dBm (Figure 9).

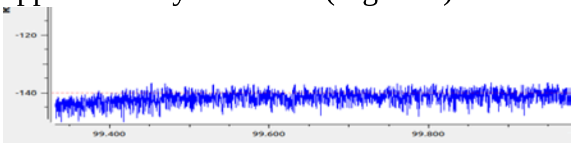

Figure 8: Noise floor level for BW=1.5MHz

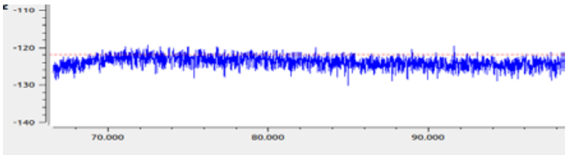

Figure 9: Noise floor level for BW=76MHz

To test the system under real conditions, different types of channels were broadcast using military radio stations, as can be seen in Figure 10, where it was broadcast on three FM channels at different power levels and in Figure 11 monitoring a wideband channel with 5MHz bandwidth.

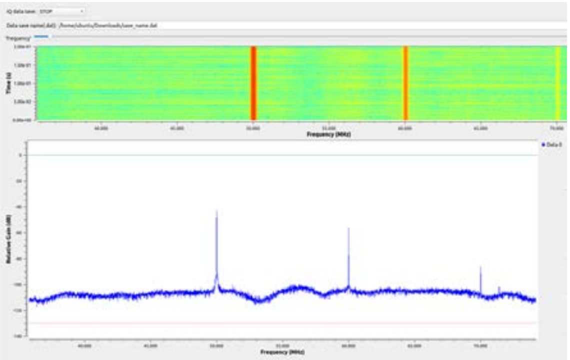

Figure 10: Monitoring multiple FM channels

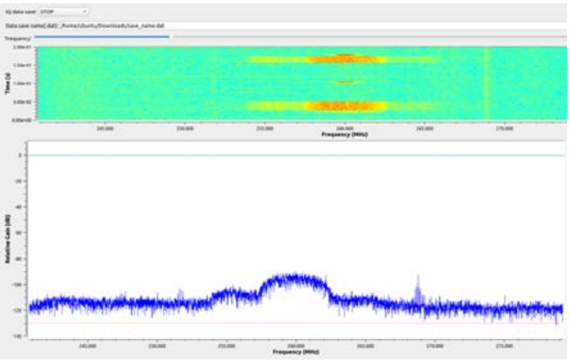

Figure 11: Monitoring wideband data channel

Since most military radio stations have frequency hopping communication capabilities, the ability to monitor such channels was also tested.

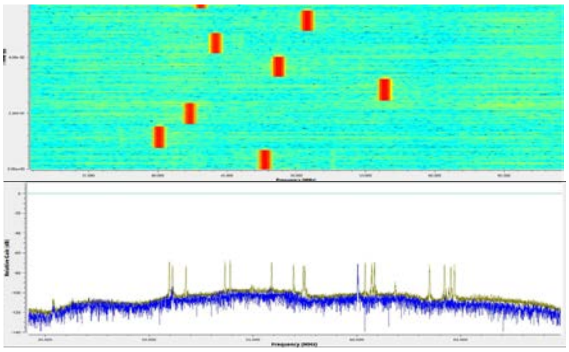

Figure 12: Monitoring hopping communication channel (100 hops/s)

Frequency hopping is widely used in military communications to provide secure and reliable communication channels. By randomly hopping between frequencies, military communications systems can avoid detection and jamming. As shown in the Figures 12 and 13, the system is very good at monitoring such channels, even for advanced waveforms with hopping frequencies of up to 1000 hops per second.

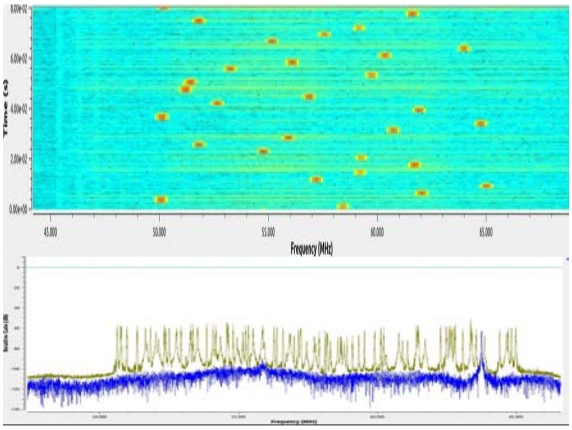

Figure 13: Monitoring hopping communication channel (1000 hops/s)

When monitoring frequency hopping at very high speeds, because the processing system (the computer) does not have very high capabilities, we had to make a compromise between span, frequency resolution and time resolution. In the case of 1000 hops per second, in order to correctly visualise the hop intervals without interruption (Figure 14), a good time resolution was required and this was achieved by reducing the FFT size to a small number - 256 points, resulting in a low frequency resolution (Figure 15).

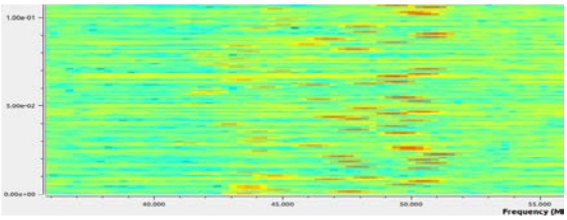

Figure 14: Monitoring 1000 hops/s with low time resolution and FFT=2048

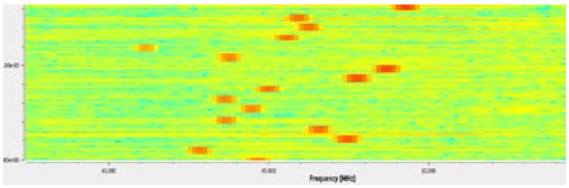

Figure 15: Monitoring 1000 hops/s with high time resolution and FFT=256

4. Conclusions

The system proposed in this paper, based on the USRP N310 SDR radio station and the GNU Radio digital processing application, has demonstrated a high level of capability in real-time monitoring of the electromagnetic spectrum, comparable to or better than many spectrum analyzers. Future research will include testing the system under different real-world conditions of radio network monitoring in different military exercises, and also increasing the performance of the computer for better system capabilities.

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