Waveforms for Interference Testing of Emergency Responder Safety Devices

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Abstract— **In this paper we describe the process used to create the interference waveform used in radiated interference testing and demonstrate two examples of how such a signal may be used in testing the performance of wireless devices. Our goal is to simulate, in a laboratory environment, typical to worst-case conditions for wireless electronic safety devices used by emergency responders. The methods discussed were developed with repeatability in mind and are general enough to be applicable to a wide variety of interference tests.**

I. Introduction

This work is in support of the National Institute of Standards and Technology (NIST) effort to establish a general framework for testing new wireless products used by the public-safety community. First responders carry with them RF-based electronic safety devices, which come in a variety of configurations, but are primarily tasked with emitting a loud audible alarm and a corresponding wireless notification if a wearer is motionless for 30 seconds [1]. The wireless notification is sent to a command station that is capable of receiving and transmitting alarms, notifications, and commands, such as evacuation orders, to the mobile safety devices. These devices for the most part operate within the Industrial, Scientific, and Medical (ISM) bands and are thus subject to interference from a variety of sources. The challenge in testing wireless devices (with respect to interference) in the ISM bands is accounting for the wide variety of channel interference possibilities. We demonstrate that we are able to replicate several types of interference waveforms in a controlled manner suitable for testing the performance of the first responder's wireless electronic safety devices. General metrics for performance are not discussed in detail in this paper but may be one of or more of the following: application status/failure, achieved data rate, connection status, error vector magnitude, signal-to-noise ratio, bit error rate, etc. For the electronic safety devices discussed here, the success/failure of an evacuation alarm sent to the firefighter or the reception of a motion alarm from the firefighter are the measurands of interest.

II. Method

To generate an interference waveform we begin by creating a vector of complex normally-distributed IQ data. From this, we can filter to the desired interference bandwidth and spectral shape using a digital filter. Given that the power spectral density of a Gaussian white noise signal is constant for all frequencies, the interference signal will take the shape of whichever filter is implemented. The freedom in designing the spectral shape is the primary appeal of this process. The resulting complex IQ data is then uploaded to an arbitrary signal generator with the capability to up-convert and transmit IQ data. After filtering, the interference signal will have the following form:

$$s_i[n] = \sum_{k=0}^{M_i-1} h_i(k\tau) \cdot N_i(n-k\tau) \tag{1}$$

$$\rightarrow S_i(f) \propto H_i(f) \tag{2}$$

where i corresponds to the i^{th} digital filter of length M_i, and $N_i(k\tau)$ is a white Gaussian noise vector of equal length M_i. The time occupancy of the interference signal subset is equal to the product of M_i and step size τ.

III. Wideband Interference Example

A. Signal Description

For the purpose of subjecting a wireless device to an artificially elevated noise floor, we created a spectrally flat signal occupying the extent of the ISM band at 2.4 GHz with a 100 % duty cycle. This wideband interference waveform forces

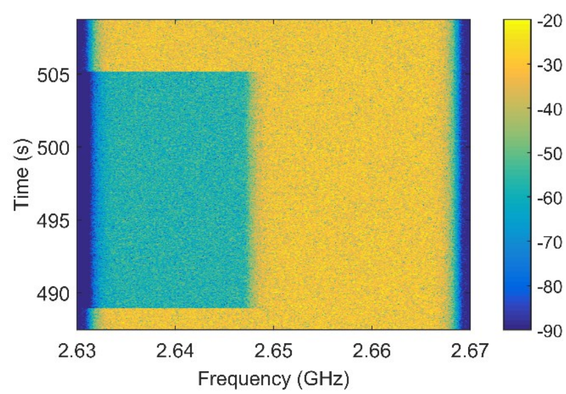

Figure 2: Measured specrogram of overlapped wideband interference signals persistent across time and frequency. The low carrier waveform was momentarily turned off to highlight the transition boundary smoothness.

the device under test (DUT) to operate within a uniformly congested channel, which is a common interference test for wireless devices [2]. We can then observe system performance for varying interference signal power levels. Such a scenario may be realized when a wireless device is operated within close proximity to a high-power cell tower or radio tower. The total bandwidth of this interference waveform is 100 MHz and was created by combining two arbitrary waveform transmitters, each having a bandwidth of 50 MHz, offset from each other. Power levels of each transmitter were adjusted to maintain uniformity across the transition region where the signals overlapped (Fig. 1). This method may be extended to occupy an arbitrarily large bandwidth as needed. Note that the data from Fig. 1 and Fig. 2 were taken from a measurement device with a limited bandwidth of 40MHz, the effect of which can be seen in the edges of the spectrogram.

B. Laboratory-Based Test Procedure

The following is a proposed procedure for the RF personal-alert safety-system (PASS) high-power interference test for the 2.4 GHz system. Two anechoic chambers are connected as shown in Fig. 2. An RF PASS is placed vertically on the platform within one anechoic chamber, and the corresponding base station is placed on the platform in the other anechoic chamber. All doors are closed and the connection status is verified with the RF PASS software's connection icon. The RF PASS is kept from alarming by simulating motion of the device as needed. The chosen interference waveform is transmitted into the chamber containing the device DUT via a coax to patch antenna connection. The RF PASS is left motionless for a sufficient amount of time such that the alarm sounds. We then check the base station software for whether or not the alarm was received. The test is repeated for various power level conditions resulting in a plot that demonstrates RF PASS performance with respect to interference power. A broadband signal, such as the one show in Fig. 1, is needed when the DUT has a frequency hopping scheme enabled.

IV. Random Interferers Example

The rate at which new wireless devices are introduced in the ISM bands makes it unwieldy to consider the interference characteristics of each on an individual basis. Furthermore, there are a near infinite number of combinations of devices that

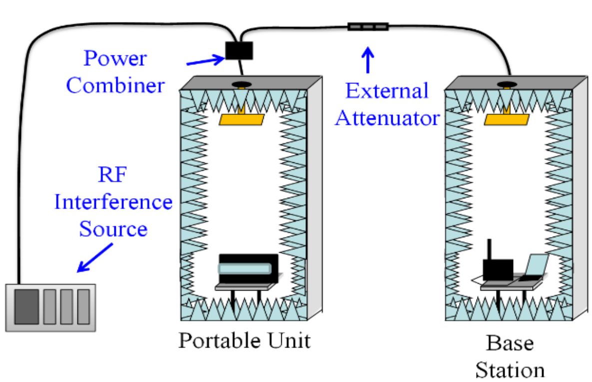

Figure 2: Measurement setup for radiated interference test using two anechoic chambers.

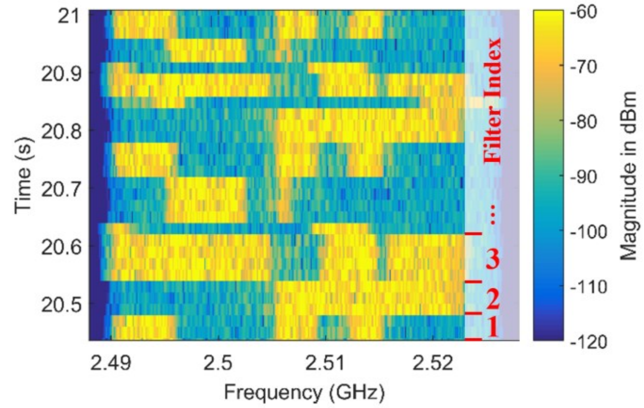

Figure 3: Measured spectrogram of an ensemble of random interferers used to model the 2.4 GHz ISM channel.

may all contribute to the wireless channel that a given DUT experiences in the field. Testing device performance in a complex multi-source interference environment requires the generation of a dynamic waveform which mimics the given channel. The waveform generation method presented in this paper gives us the flexibility to model any combination of interferers based on their spectral occupancy characteristics. By applying a superposition of notch filters to a Gaussian white noise signal we can produce signal that looks much like an ensemble of random interferers in the frequency domain. To demonstrate this, we generated a scenario that replicates a series of interferers with varying duty cycles, bandwidths, and carrier frequencies (Fig. 3). We can also vary power levels, but for the sake of clarity, we have left power levels constant for all interference sources.

V. Conclusion

In this paper, we developed a general method for generating interference signals useful for the evaluation of wireless devices in the ISM bands. The choice of digital filter gives complete control over spectral shaping and time domain occupancy so that a series of interferes may be modeled by a single waveform. The basis waveform is an approximation of a complex Guassian white-noise signal which is well suited for testing devices employing any modulation scheme. We also discuss a proposed test procedure and an initial application for this interference testing. Further work may include a spectrum monitoring survey of typical operating environments for wireless safety devices used by first responders to ensure the interference waveforms accurately model the real world environment.

References

[1] Remley, K.A.; Young, W.F., "Test methods for RF-based electronic safety equipment: Part 2 — Development of laboratory-based tests," in Electromagnetic Compatibility Magazine, IEEE , vol.2, no.1, pp.70-80, 1St Quarter 2013.

[2] Xian Wang; Banerjee, D.; Chatterjee, A., "Low cost high frequency signal synthesis: Application to RF channel interference testing," in VLSI Test Symposium (VTS), 2015 IEEE 33rd , vol., no., pp.1-6, 27-29 April 2015