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RF Dataset of Incumbent Radar Signals in the 3.5 GHz CBRS Band

Raied Caromi, Michael Souryal, and Timothy A. Hall

National Institute of Standards and Technology,
Gaithersburg, MD 20899, USA

raied.caromi@nist.gov
michael.souryal@nist.gov
tim.hall@nist.gov

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1. Summary

This Radio Frequency (RF) dataset consists of synthetically generated waveforms of incumbent 3.5 GHz radar systems. The intended use of the dataset is for developing and evaluating detectors for the 3.5 GHz Citizens Broadband Radio Service (CBRS) [1] or similar bands where the primary users of the band are Federal radar systems. The dataset can be used for developing and testing radar detection algorithms using machine learning/deep learning techniques. The algorithm aims to detect whether the radar signal is present or absent regardless of the signal type. The target signals have a variety of modulation types and parameters chosen from wide ranges. In addition, the start time and the center frequency of the radar signals are randomized in the waveform. The variety of signals and their random parameters makes the detection problem more challenging when using non-naive (e.g., energy detector is a naive signal detector) classical signal processing techniques.

2. Data Specifications

NIST Operating Unit	CTL, Wireless Network Division
Format	In-phase/Quadrature (IQ) data in complex format, (.mat) files with HDF5 format
Instrument	Synthetically generated with a software tool built with MATLAB[1]
Data Dictionary	Data Dictionary of 3.5 GHz Radar Waveforms, available at https://doi.org/10.18434/M32116
Accessibility	All datasets submitted to *Journal of Research of NIST* are publicly available.
License	https://www.nist.gov/director/licensing

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Table 1. Radar signal parameter bounds for 3.5 GHz Environmental Sensing Capability (ESC) compliance testing [2].

Pulse Modulation	Pulse Width (μs)	Chirp Width (MHz)	Pulse Repetition Rate (pulses per second)	Pulses per Burst (Min to Max)	Comments
P0N #1	0.5 to 2.5 $\Delta = 0.1$	N/A	900-1100 $\Delta = 10.0$	15 to 40 Min $\Delta = 5$	Similar to currently deployed Radar 1
P0N #2	13-52 $\Delta = 13$	N/A	300-3000 $\Delta = 10.0$	5 to 20 $\Delta = 5$	Simulates possible phase-coded waveforms that could be used in future radar modulations
Q3N #1	3-5 $\Delta = 1.0$	50-100 $\Delta = 10$	300-3000 $\Delta = 30$	8 to 24 $\Delta = 2$	Simulates possible future multifunction Q3N-type radar • Short τ • Wide Bc
Q3N #2	10-30 $\Delta = 1.0$	1-10 $\Delta = 1$	300-3000 $\Delta = 50$	2 to 8 $\Delta = 2$	Simulates possible future multifunction Q3N-type radar • Intermediate τ • Intermediate Bc
Q3N #3	50-100 $\Delta = 5.0$	50-100 $\Delta = 10$	300-3000 $\Delta = 100$	8 to 24 $\Delta = 2$	Simulates possible future multifunction Q3N-type radar • Wide τ • Wide Bc

3. Methods

The RF dataset described here includes radar waveforms with two pulse modulation types and a range of parameters similar to the waveforms proposed in [2] and shown in Table 1. In addition to the aforementioned parameters, white Gaussian noise (WGN) is added and the peak power of the radar signal is varied to produce a range of values for the signal to noise ratio (SNR) [3]. The parameters of each radar waveform are randomly chosen for each pulse modulation type from the bounds shown in Table 1. Due to varying pulse width, pulses per second, and pulses per burst, the radar signals have unequal durations. However, we fix the duration for all the waveforms in the RF dataset by choosing a duration larger or equal to the largest duration of all radar signals in the set. In order to make the detection problem more challenging and closer to real-world scenarios, we place the radar signals at randomly chosen times within the fixed duration. In addition, we shift the center frequency of the radar signal in the baseband if the signal bandwidth is less than the sampling rate.

The RF dataset consists of a large number of waveforms divided equally between waveforms with and without a radar signal, i.e., waveforms with radar plus noise and waveforms with noise only. The order of the waveforms is randomized across the set and the status (presence/absence) of the radar signal is saved in a separate boolean variable. The complex In-phase/Quadrature (IQ) data of the waveforms along with radar status variable may be used for training, validation and testing. In addition to test accuracy, receiver operating characteristic (ROC) curves are of interest for evaluating detection performance. Therefore, we chose a relatively large number of waveforms for the dataset in order to provide enough test points per SNR

[1]Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

value to generate ROC curves. More details about the dataset and the metadata of the waveforms are presented in the data dictionary of 3.5 GHz radar waveforms.

4. Impact

We created the 3.5 GHz radar waveform RF dataset as part of our ongoing effort to facilitate and support the use of machine learning/deep learning techniques in next generation shared spectrum communications systems [3]. We anticipate that the RF dataset will be used to accelerate the development and testing of detection algorithms for the 3.5 GHz CBRS and similar shared spectrum bands in the future. Furthermore, the supplied RF dataset serves as a robust real-world example for developing detection algorithms for communication systems based on machine/deep learning techniques.

5. References

[1] Citizens broadband radio service, 47 C.F.R. § 96 (2016).

[2] Sanders FH, Carroll JE, Sanders GA, Sole RL, Devereux JS, Drocella EF (2017) Procedures for laboratory testing of environmental sensing capability sensor devices (National Telecommunications and Information Administration, Boulder, CO), Technical Memorandum TM 18-527. Available at http://www.its.bldrdoc.gov/publications/3184.aspx.

[3] Hall T, Caromi R, Souryal M, Wunderlich A (2019) Reference datasets for training and evaluating RF signal detection and classification models. Paper presented at *IEEE GLOBECOM Workshop on Advancements in Spectrum Sharing* (IEEE, Waikoloa, HI).

About the authors: *Raied Caromi is an electronics engineer, and Michael Souryal is a supervisory electronics engineer in the Wireless Network Division within NIST's Communication Technology Laboratory (CTL). Timothy A. Hall is an electronics engineer in the Computer Security Division within the NIST Information Technology Laboratory (ITL). The National Institute of Standards and Technology is an agency of the U.S. Department of Commerce.*