Simulated Radar Waveform and RF Dataset Generator for Incumbent Signals in the 3.5 GHz CBRS Band

"Software manual"

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This manual describes the usage of the waveform and RF dataset generator software tool and provides a glossary for all the parameters needed for the generation process.

- **Waveform generation:**

The graphical user interface (GUI) consists of two tabs, Fig. 1 shows the waveform generation tab. The description of the parameters in this tab are summarized in Table 1.

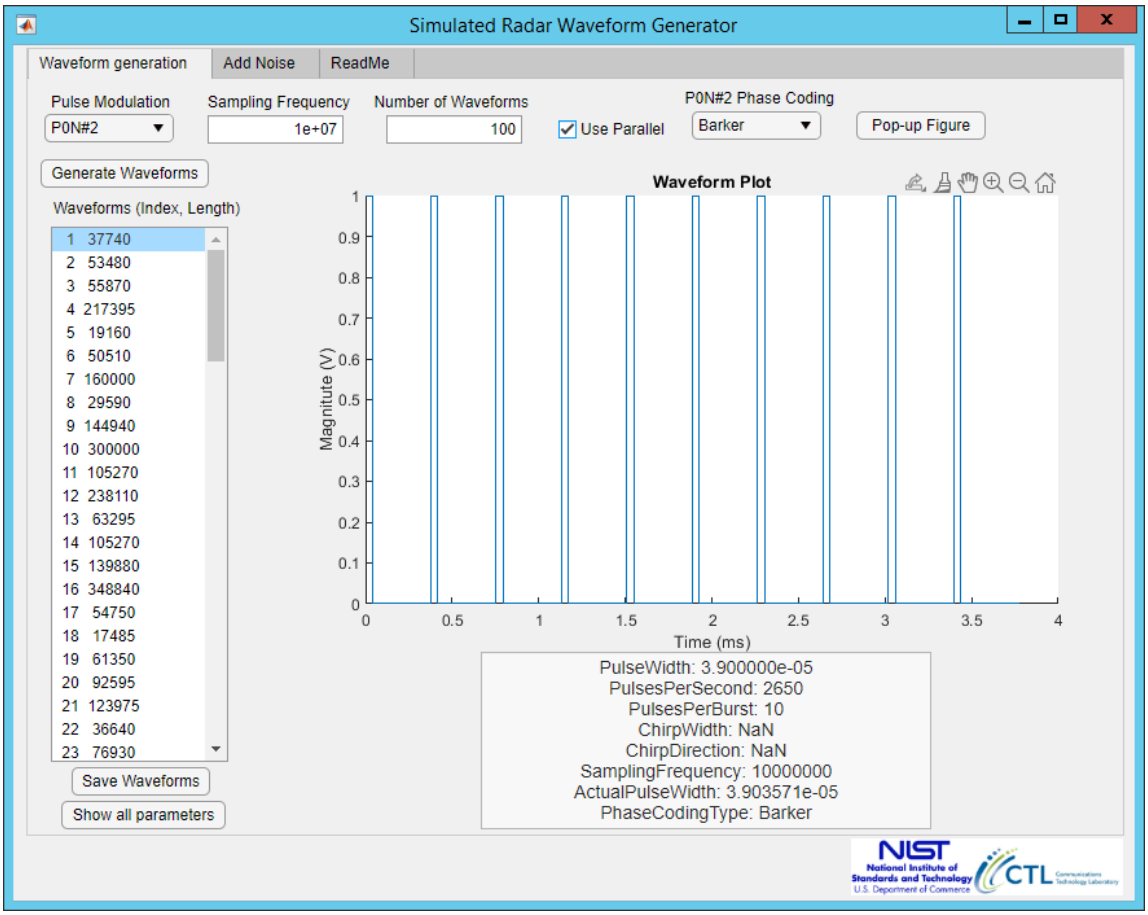

Fig. 1. Waveform generation example.

Parameter or function	Possible values	Description
Pulse Modulation	Pulse modulation type from Table 2.	Select pulse modulation type from drop down menu.
Sampling Frequency	A number > 2000	The sampling frequency of the generated waveforms (Hz).
Number of Waveforms	Integer number	The number of the waveforms.
Use Parallel	N/A	Whether to use parallel processing in the generation process.
P0N#2 Phase Coding	Barker, Frank, P1, P2, P3, P4, Px, Zadoff-Chu	Select phase coding for pulse modulation type P0N#2.
Generate Waveforms	N/A	Generate a set of waveforms. For each pulse modulation, the other parameters (Pulse Width, Chirp Width, pulses per second, Pulses per Burst) are randomly selected with constraints from Table 1 for each bin.
Save waveforms	N/A	Save all generated waveforms in MATLAB cell format .mat file including generation parameters.
Show all parameters	N/A	Displays the generation parameters in a table.

Table 1. Waveform generation glossary

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

Table 2. Proposed radar signal parameters for FCC 3.5 GHz ESC compliance testing. *NTIA Technical Memorandum 18-527 Available at http://www.its.bldrdoc.gov/publications/3184.aspx.*

- **Add Noise:**

The add noise tab in the GUI enables the addition of white Gaussian noise (WGN) and the generation of the dataset from the waveforms that were generated in the first tab. Fig. 1 and Fig. 2 show two examples of this process. The parameters in this tab are summarized in Table 3.

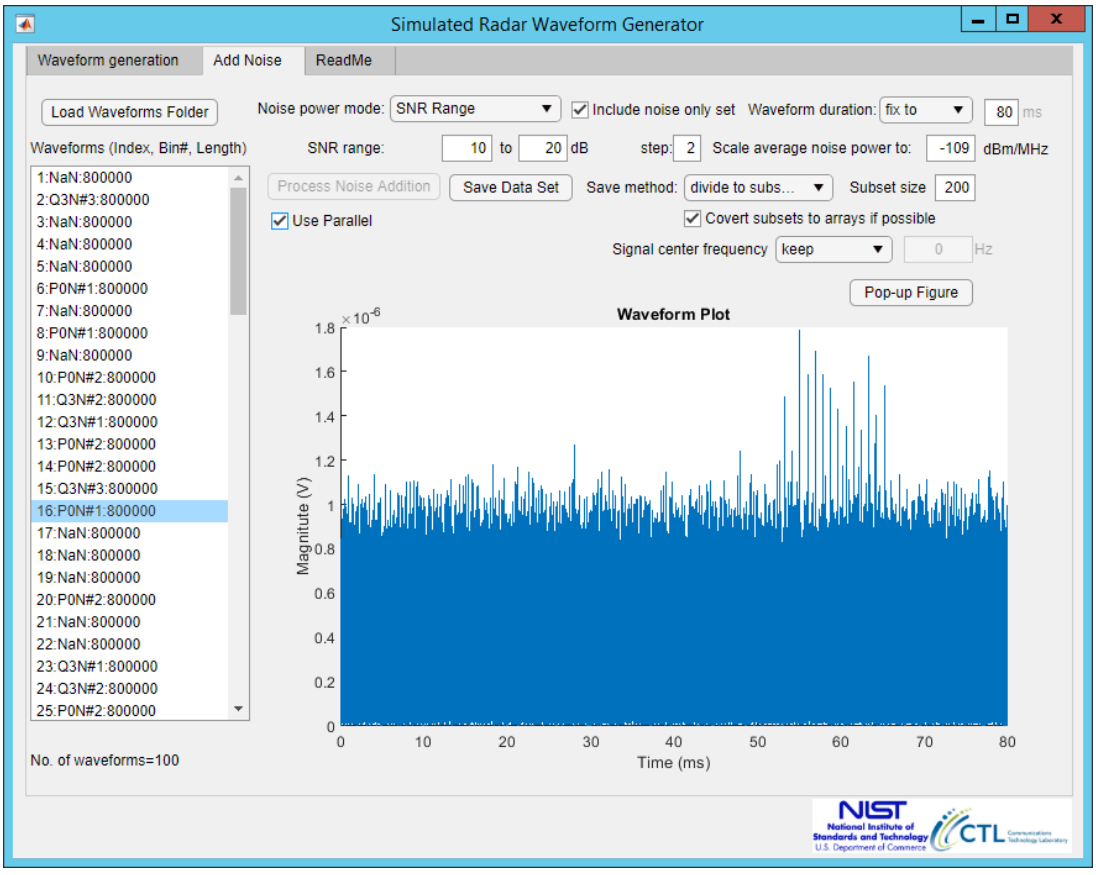

Fig. 2. Example of dataset generation with SNR range.

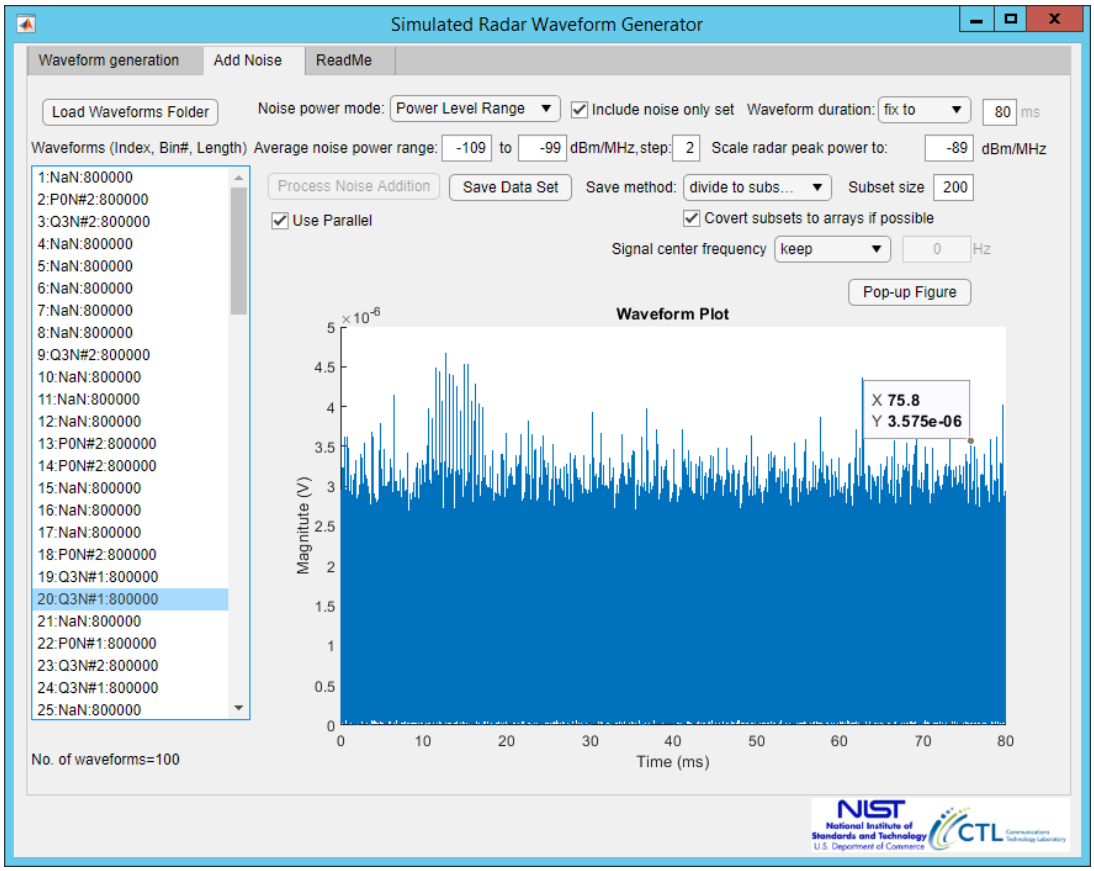

Fig. 3. Example of dataset generation with power level range.

Parameter or function	Possible values	Description
Load waveform Folder	N/A	Load waveforms from a folder. The folder may have more than one file. Usually many waveforms for each bin are saved in one file. The folder can have more than one file with same bin.
Noise power mode	Power Level Range, SNR Range	A method for how to set the power of the noise. After selecting one of these modes, the values in the next line changes according the mode. Power setting require measurement of radar peak power dBm per 1 MHz, and noise power dBm per 1 MHz. In all calculations, the reference load is assumed to be 1 ohm.
Power Level Range	Range of values (dBm/MHz)	The noise power is varied according to a range of values and each waveform noise level will be selected randomly from that range. On the other hand, the peak power of the radar is set at a fixed value dBm/MHz.
SNR Range	Range of values (dB)	The SNR is varied according to a range of values and each waveform SNR value will be selected randomly from that range. On the other hand, the noise power is set at a fixed value dBm/MHz.
Waveform duration	Keep, Fix to max, Fix to	Generally, the waveforms generated with this app has different durations due to the variations of the number of pulses per bursts and pulse repetitions between the bins.
Keep	N/A	keeps the duration of the original waveforms as is.
Fix to max	N/A	Fix the duration of the waveforms to the maximum duration of a waveform in the set. If a waveform has shorter duration, it is placed randomly at some time and the rest of samples are filled with noise.

Parameter or function	Possible values	Description
Fix to	Number	Fix the waveform duration to a fixed value in (ms). If a waveform is longer, then it is trimmed from the end. On the other hand, if a waveform is shorter, it is placed randomly at some time from the beginning and the rest of the samples are filled with noise.
Include noise only set	N/A	Adds a subset of waveforms with noise only (no radar signal present) to the original waveform set. The number of noise only waveforms is equal to the number of the waveforms in the original set. The total number of waveforms is now double of the original set with half of them having no radar signal.
Signal center frequency	keep, set at, random	Select a method for the center frequency of the radar signal in the baseband.
keep	N/A	Do not change the center frequency (usually at zero Hz baseband).
Set at	Integer number	Set the center frequency at a specific value.
random	N/A	Set the center frequency at a random value.
Process Noise Addition	N/A	After setting all the parameters, click this button to add noise and create the dataset
Save method	One set, divide to subsets	How to save the waveforms in the dataset.
One set	N/A	Save all the waveforms in one dataset.
divide to subsets	N/A	Divide all the waveforms into multiple subsets according to subset size.
Subset size	Integer number	The size of the subset.
Convert subsets to arrays if possible	N/A	Convert the waveforms in the subset to one array instead of multiple MATLAB cell arrays. This is not possible if the waveforms have different durations.
Save dataset	N/A	Save the entire dataset to files. A popup dialog appears to set prefix names for the files and the variables of the dataset.

Table 3. Add noise glossary

- **Requirements and limitations:**

The waveform generator requires enough free memory to process the generated set at once, or twice the size of the loaded waveform set when (include noise only set) check box is selected. The amount of the required memory dependents on the number of the waveforms, their sampling frequency, and the desired waveform duration. For parallel processing, the program requires multi cores. Parallel processing is only useful when generating very large datasets.
For example, a set of 5000 waveforms (1000 of each bin X 5 bins) sampled at 10 MHz and 80 ms long per waveform requires more than 60 GB of free memory for noise addition processing. If you don't have enough the required resources, generate and process small sets of waveforms at each time.

- **Example of an RF dataset:**

A reference RF dataset was generated using this software. The RF dataset is published at https://doi.org/10.18434/M32116.
The dataset consists of four groups. The parameters for the groups are identical. The following table shows the parameters used for generating the reference dataset for one group.

Parameter	Value
Pulse Modulation	P0N #1, P0N #2, Q3N #1, Q3N #2, Q3N #3
Sampling Frequency (Hz)	10000
Number of Waveforms	1000 for each pulse modulation type.
Generate Waveforms	Generate waveforms for each pulse modulation type separately.
Save waveforms	Save each pulse modulation type to the same folder after generation.

Parameter	Value
Load waveform Folder	Select the folder where the waveforms were saved (1000 for each pulse modulation type, 5000 total).
Noise power mode	SNR Range
SNR Range	10 to 20, step 2. Scale noise power to -109 dBm/MHz.
Include noise only set	Check
Waveform duration	Fix to 80 ms
Save method	Divide to subsets
Subset size	200
Convert subsets to arrays if possible	Check
Signal center frequency	Random
Process Noise Addition	Click to process.
Save data Set	After finishing the process, click to save.

Table 4. Dataset parameters for generating one group similar to the groups in the dataset “RF Dataset of Incumbent Radar Systems in the 3.5 GHz CBRS Band”