

# 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.

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- **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.

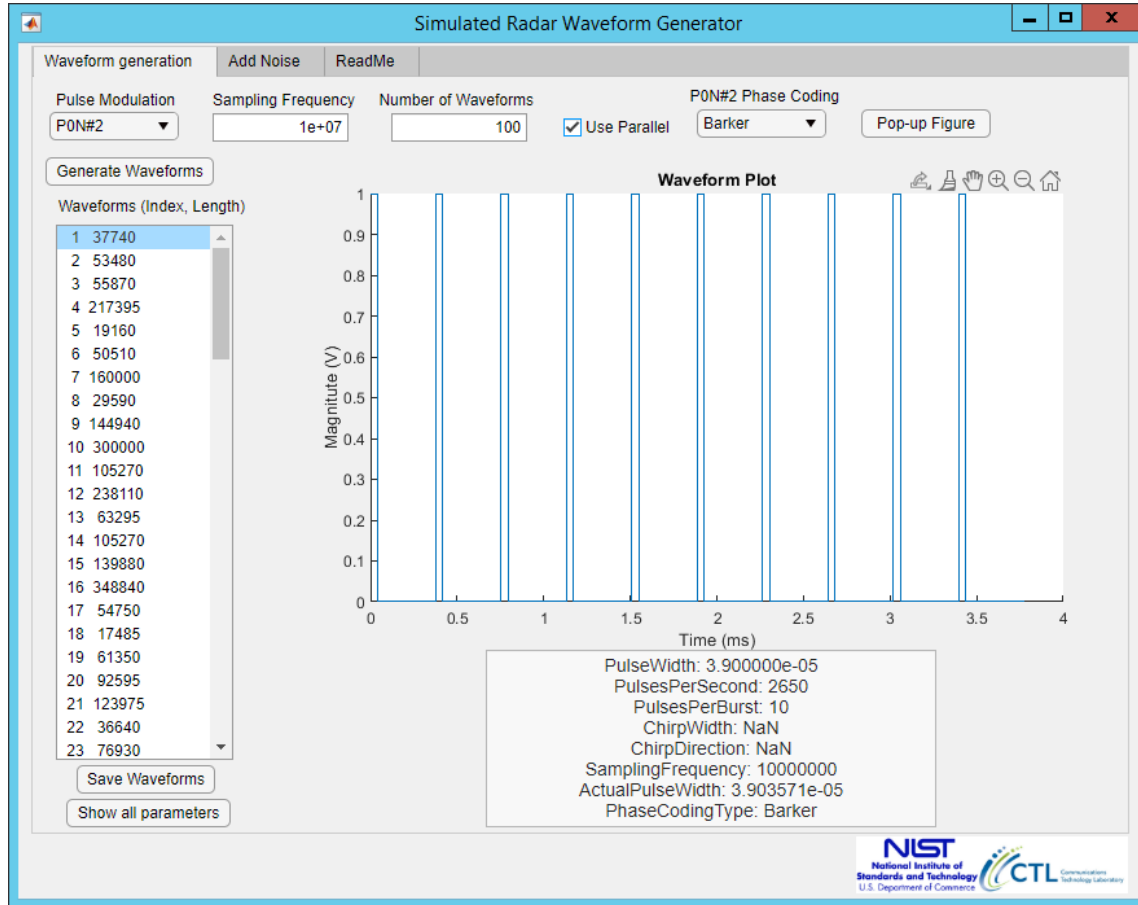


Fig. 1. Waveform generation example.

Parameter or function	Possible values	Description
<b>Pulse Modulation</b>	Pulse modulation type from Table 2	Select pulse modulation type from drop down menu.
<b>Sampling Frequency (Hz)</b>	A number > 2000	The sampling frequency of the generated waveforms
<b>Number of Waveforms</b>	Integer number	The number of waveforms
<b>Use Parallel</b>	N/A	Whether to use parallel processing in the generation process
<b>P0N#2 Phase Coding</b>	Barker, Frank, P1, P2, P3, P4, Px, Zadoff-Chu	Select phase coding for pulse modulation type P0N#2.
<b>Generate Waveforms</b>	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.
<b>Save waveforms</b>	N/A	Save all generated waveforms in MATLAB cell format to a .mat file including generation parameters.
<b>Show all parameters</b>	N/A	Display the generation parameters in a table.

Table 1. Waveform generation glossary

Pulse Modulation	Pulse Width ( $\mu$ s)	Chirp Width (MHz)	PRR (pulses per second)	Pulses per Burst (Min to Max)	Comments
PON #1	0.5 to 2.5 $\Delta = 0.1$	N/A	900-1100 $\Delta \geq 10.0$	15 to 40 Min $\Delta = 5$	Similar to currently deployed Radar 1
PON #2	13-52 $\Delta = 13$	N/A	300-3000 $\Delta \geq 10.0$	5 to 20 $\Delta \geq 5$	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 $\Delta \geq 30$	8 to 24 $\Delta \geq 2$	Simulates possible future multi-function Q3N-type radar <ul style="list-style-type: none"> <li>• Short <math>\tau</math></li> <li>• Wide Bc</li> </ul>
Q3N #2	10-30 $\Delta = 1.0$	1-10 $\Delta = 1$	300-3000 $\Delta \geq 50$	2 to 8 $\Delta \geq 2$	Simulates possible future multi-function Q3N-type radar <ul style="list-style-type: none"> <li>• Intermediate <math>\tau</math></li> <li>• Intermediate Bc</li> </ul>
Q3N #3	50-100 $\Delta = 5.0$	50-100 $\Delta = 10$	300-3000 $\Delta \geq 100$	8 to 24 $\Delta \geq 2$	Simulates possible future multi-function Q3N-type radar <ul style="list-style-type: none"> <li>• Wide <math>\tau</math></li> <li>• Wide Bc</li> </ul>

Table 2. Proposed radar signal parameters for FCC 3.5 GHz ESC compliance testing. Source: 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.

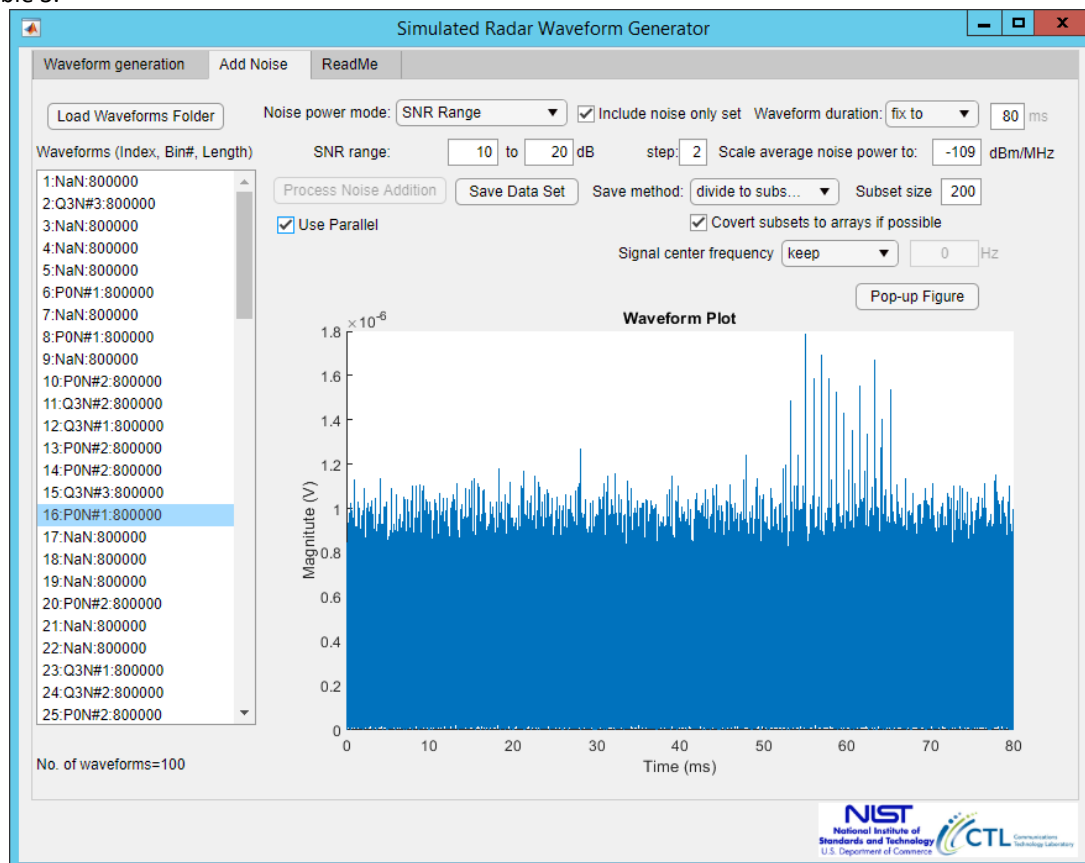


Fig. 2. Example of dataset generation with SNR range.

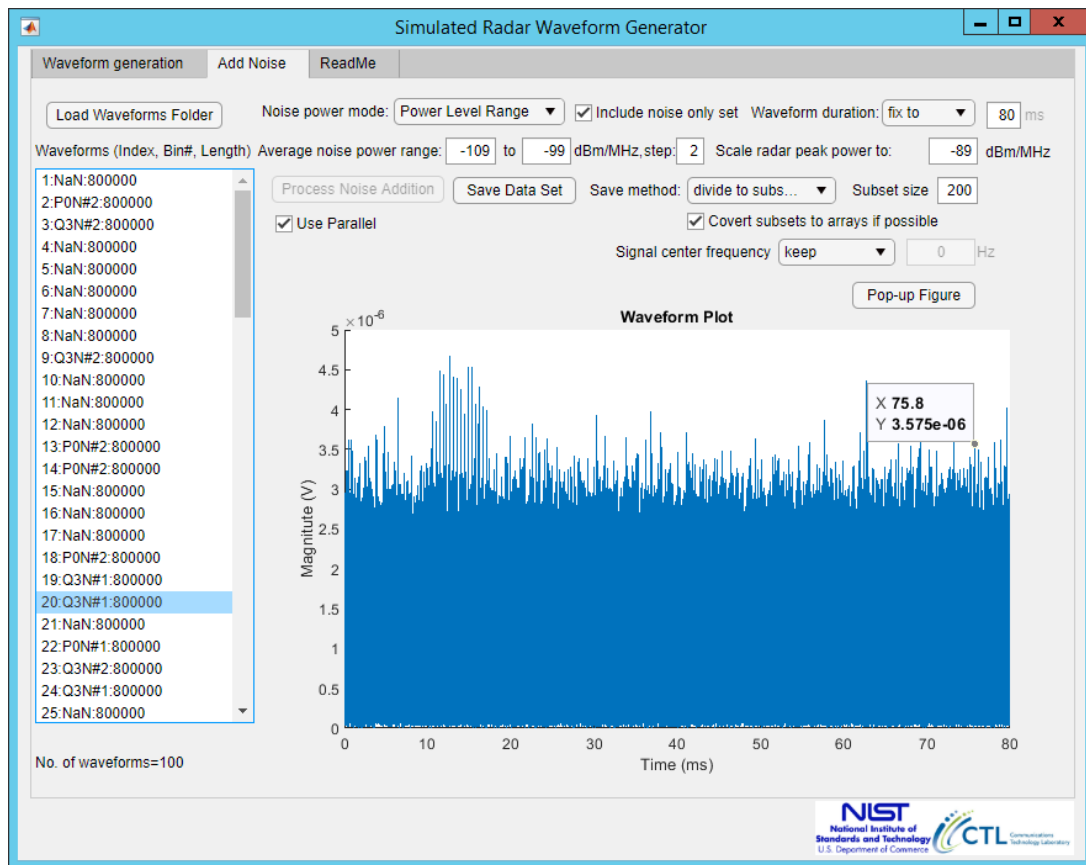


Fig. 3. Example of dataset generation with power level range.

Parameter or function	Possible values	Description
<b>Load Waveforms Folder</b>	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 the same bin.
<b>Noise power mode</b>	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 change according to the mode. Power setting requires measurement of radar peak power (dBm/MHz), and noise power (dBm/MHz). In all calculations, the reference load is assumed to be 1 ohm.
<b>Power Level Range</b>	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 to a fixed value (dBm/MHz).
<b>SNR Range</b>	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).
<b>Waveform duration</b>	Keep, Fix to max, Fix to	Generally, the waveforms generated with this app have different durations due to the varying number of pulses per burst and pulse repetitions between the bins.
<b>Keep</b>	N/A	Keeps the duration of the original waveforms as is.
<b>Fix to max</b>	N/A	Fix the duration of the waveforms to the maximum duration of a waveform in the set. If a waveform has a shorter duration, it starts at a random time, and the remaining samples are noise.

Parameter or function	Possible values	Description
<b>Fix to</b>	Number (ms)	Fix the waveform duration to a fixed value (ms). If a waveform is longer, then it is trimmed from the end. On the other hand, if a waveform is shorter, it starts at a random time, and the remaining samples are noise.
<b>Include noise only set</b>	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 waveforms in the original set. This doubles the number of waveforms in the original set, with half of them having no radar signal.
<b>Signal center frequency</b>	keep, set at, random	Select a method for setting the center frequency of the radar signal in the baseband.
<b>keep</b>	N/A	Do not change the center frequency (usually at zero Hz baseband).
<b>Set at</b>	Integer number (Hz)	Set the center frequency to a specific value (Hz).
<b>random</b>	N/A	Set the center frequency to a random value (Hz).
<b>Process Noise Addition</b>	N/A	After setting all the parameters, click this button to add noise and create the dataset.
<b>Save method</b>	One set, divide to subsets	How to save the waveforms in the dataset
<b>One set</b>	N/A	Save all the waveforms in one dataset.
<b>divide to subsets</b>	N/A	Divide all the waveforms into multiple subsets according to subset size.
<b>Subset size</b>	Integer number	The size of the subset
<b>Convert subsets to arrays if possible</b>	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.
<b>Save dataset</b>	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 the “Include noise only set” check box is selected. The amount of the required memory depends on the number of waveforms, their sampling frequency, and the desired waveform duration. For parallel processing, the program requires multiple 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 of 80 ms duration requires more than 60 GB of free memory for noise addition processing. If you do not have the required resources, generate and process small sets of waveforms.

#### • 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
<b>Pulse Modulation</b>	P0N #1, P0N #2, Q3N #1, Q3N #2, Q3N #3
<b>Sampling Frequency (Hz)</b>	10e6
<b>Number of Waveforms</b>	1000 for each pulse modulation type

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

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