CIELO™ MOCKINGBIRD RF TEST SYSTEM

USER GUIDE | RELEASE_2.0

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Mockingbird RF Test System

1. Product Overview

As a RF signal processing and test engineer, you need a RF test system that enables agile test-driven development at the pace of your development. Mockingbird provides RF signal generation, spectral analysis and signal capture in a compact, rugged, software defined RF test system that enables rapid testing and verification of RF systems in the lab and in the field. Verify wireless data links, signal detectors and demodulators, and complex spectral sensing algorithms throughout your development cycle from design prototypes to outdoor Over-the-Air (OTA) testing. The simple and intuitive web interface enables collaborative testing and remote monitoring applications, and Mockingbird integrates with the tools you use today like MATLAB and GNURadio.

1.1. System Use Cases

The primary system uses cases include:

- RF Signal and Traffic Emulation
- RF Spectral Analysis and Monitoring
- RF Signal Capture

1.2. Key Features

Table 1: Mockingbird Key Features and Benefits

Feature	Benefit

Waveform Toolkits	Direct emulation of specific signals, “radio personalities”, using configurable built-in waveform generators.
	• CW Test Signals: Tone, Two-Tone, Stepped Frequency, Sweep
	• Analog Modulation: AM, FM
	• Digital Modulation:
	  • FSK (MFSK, GFSK, MSK, GMSK)
	  • PSK (MPSK OQPSK, PI/4, QPSK, DPSK)
	  • QAM (QAM16, QAM64)
	• Frequency Hopper
	• OFDM

Arbitrary Waveform Generation	Import custom baseband I/Q waveforms from MATLAB and GNU Radio.
RF Scene Creation	Create realistic traffic patterns and mixtures of RF signals to create sophisticated RF scenes (i.e. emulated RF environments).
Spectrum Analyzer	Wideband dual-channel spectrum analyzer including Power Spectrum, and time-frequency falling raster with typical spectral analysis functions such as max hold, dual markers and peak search.
Spectrum Monitoring	Disjoint multi-band spectrum monitoring (e.g. 915 MHz ISM band and 2.4 GHz WiFi). Ability to create user configurable frequency scan lists.
Signal Capture	Capture narrowband and wideband signals up to 40 MHz BW, and 50 million complex baseband I/Q samples for detailed signal processing and analysis.
Wideband Dual-Channel Transceiver (50-6000 MHz RF range, 40 MHz IBW)	Wideband 2x2 MIMO Software Defined Radio: Dual transmit or receive channels. Rugged Low SWAP form factor: Enables OTA field testing as well as lab operation. GPS Enabled: Provides location information for field testing scenarios
Network Attached Software Defined Instrument	Ethernet attached device with simple and intuitive web interface. No software installation required. Configure for your network and start testing immediately. Create multiple system deployments, for more sophisticated testing scenarios or multi-user access. Supports remote operation.

2. Document Overview

This document provides guidance on how to configure and operate the system. Section 3 provides an overview of the Mockingbird RF test application. Section 4 describes how to launch the application, followed by Section 5 on how to configure the system. The remaining sections describe how to operate the system through the presentation of the system use cases.

3. Mockingbird Application

Mockingbird includes a web application that enables a user to interact with the system, including the ability to execute the following use cases:

- RF Signal and Traffic Emulation
  - Create and configure waveforms in Waveform Library
  - Create arbitrary waveforms from baseband I/Q files
  - Create and transmit RF scenes
- Monitor the RF Spectrum
  - Manually tune the radio for single band spectrum analysis and monitoring (bandwidths up to 40 MHz)
  - Create frequency scans to monitor specific frequency bands, including wide bandwidths (> 40 MHz) and multiple disjoint spectral bands (e.g. 915 MHz, and 2.4 GHz).
  - Provides access to common spectral analysis tools: PSD, time-frequency falling raster, dual markers, max hold, zoom
- Capture RF signals: Configure and capture RF signals (up to 40 MHz bandwidth and 50M samples)
- System Management and Monitoring

3.1. Definitions

Term	Definition
Waveform	Transmitted signal
Baseband I/Q File	Baseband I/Q files that can be used to create arbitrary waveforms from internal signal captures or external signal data
Traffic Pattern	Defines the transmission ON time and OFF time (communications battle rhythm)
Waveform Library	Collection of defined waveforms and associated traffic patterns
RF Scene	Defines the transmission schedule which includes a mixture of specific waveform / traffic pattern pairs
Waveform Workspace	Set of waveform / traffic pattern pairs from the Waveform Library to be included in the RF Scene
Transmission Schedule	Timeline used to schedule waveform transmissions in the RF Scene
RF Scene Archive	Collection of defined RF scenes available to load and execute

4. How to Launch the Application

The Mockingbird application is started via a standard web browser. Assuming the system is powered on and the initial network connection has been established (see Owner's Manual), the user opens a web browser (e.g. Chrome or Firefox) and enters the Mockingbird IP address (e.g. 192.168.1.100), which will result in the display of the Mockingbird User Interface. The Module Menu on the left side of the interface provides user access to the installed modules.

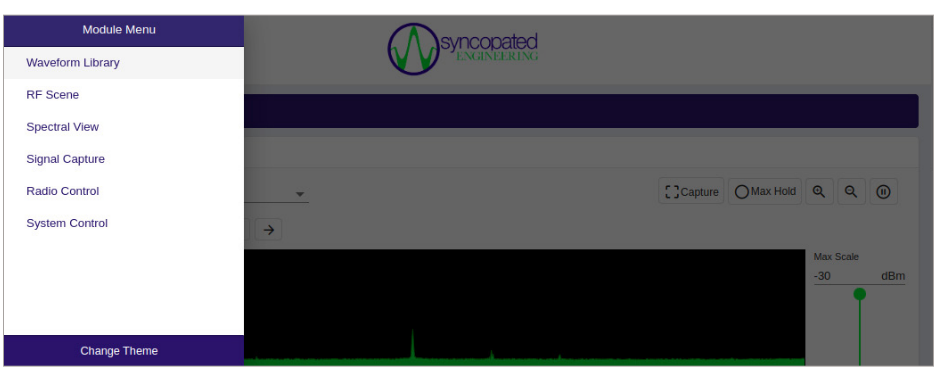


Figure 1: Module Menu

4.1. Overview of Mockingbird Software Modules

Table 3: Mockingbird Software Modules

Module	Description
Waveform Library	Create and configure waveforms and traffic patterns Import baseband I/Q files
RF Scene	Create and configure RF scenes Access stored RF scenes Import / Export RF scenes Configure Waveform Workspace Create Transmission Schedule Transmit RF Scene Monitor RF Scene Metrics
Spectral View	Conduct spectrum monitoring and analysis Capture signal
Signal Capture	Configure signal capture Capture signal View and export signal capture files
Radio Control	Manually tune the radio Create and execute frequency scans View transmitter and receiver settings
System Control	Access system information Configure system and network Update software Monitor system
Change User Theme	Select LIGHT or DARK theme

5. How to Manage the System

5.1. View System Information

The user wants to view system information to include the system version information and the installed software modules. The user selects System Control from the Module Menu. System information is displayed, including version and licensing information.

5.2. Configure System

5.2.1. View and Configure Network Settings

The user wants to view and configure the system network settings including the ability to define a new static IP address. The user selects System Control from the Module Menu and then expands the System Configuration section. The current network configuration is displayed. The user selects the edit icon and modifies the network settings. The user saves the settings.

Note: Once the IP address is changed, you will need to enter the new IP address to launch the application. Therefore, write down the new IP address and save in a secure place since this IP address is required to re-connect to the system. The system can always be reconfigured to the default factory settings, which allows connection via the default IP address, but this also deletes any stored user data (see Owner's Manual for additional details)

5.3. Display System Status

The user wants to display system status to include the system GPS information and system temperature. The user selects System Control from the Module Menu and then expands the System Monitor section. The system temperature at various points within the system is displayed. The system GPS positional information including the status of the GPS fix is displayed.

5.4. Update Firmware

The user wants to upgrade the system firmware. The user selects System Control from the Module Menu and expands the System Information section. The user adds a firmware image by uploading a firmware image distributed by Syncopated Engineering. The user installs and validates the firmware upgrade.

5.5. Change the User Interface Theme

The user wants to change the color theme for the user interface. The user selects the “Change Theme” on the Module Menu to toggle between the LIGHT and DARK themes.

6. How to Configure the Radio

6.1. Configure Radio Transmitter Settings

Note: Most transmitter settings are controlled via the Waveform Configuration Parameters.

6.1.1. Enable / Disable Radio Transmitter

The user wants to enable/disable the ability for the system to transmit based on a specific test scenario. The user selects Radio Control from the Module Menu and expands the Transmitter Settings section to reveal the Tx Enable toggle button. The user can toggle between Tx enabled (Tx Enable light ON) and Tx disabled (Tx Enable light OFF).

Note: The default is Tx enabled (Tx Enable ON) and these settings are not persisted across system power cycles. This feature is provided as a user directed safety mechanism enabling the user to disable the transmitter whenever it is required.

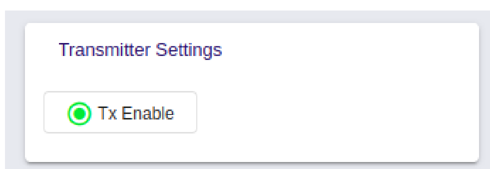


Figure 2: Tx Enable / Disable

6.2. Configure Radio Receiver Settings

6.2.1. Manually Tune the Receiver

The user wants to tune the receiver to a specific center frequency and gain. The user selects Radio Control from the Module Menu. The manual tune form is available under Receiver Settings. The user enters the center frequency, gain and various spectral analysis parameters (e.g. FFT size and time resolution). The user can choose to tune the radio with a defined bandwidth and derived sample rate or with a defined sample rate and derived bandwidth. The user submits to change the current receiver settings and the derived radio settings are displayed for the user. A user notification is displayed indicating the new settings are active and the user can view the resulting spectral display by selecting Spectral View from the Module Menu.

Note: Manual tuning will disable any active scans in the frequency scan list.

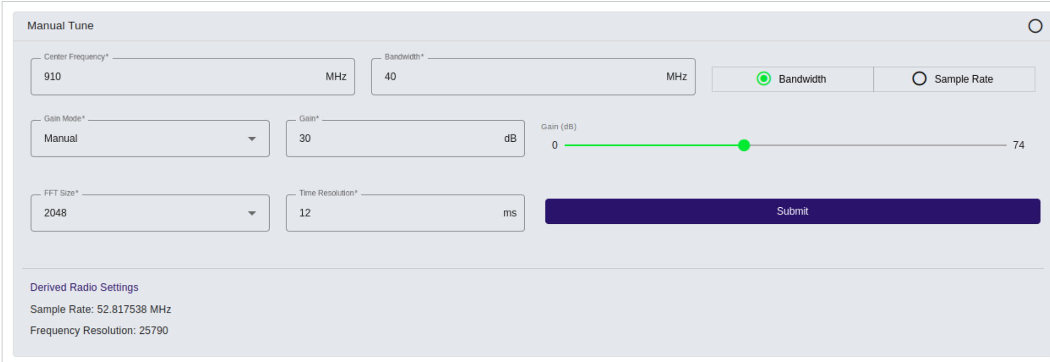


Figure 3: Manual Tune

6.2.2. Create New Frequency Scan

Frequency scans enable the user to monitor spectral bands that are greater than the instantaneous bandwidth of the system (40 MHz) as well as monitor disjoint spectral bands (e.g. 915 MHz and 2.4 GHz bands). Frequency scans implement a “Step and Dwell” approach, where the full frequency range is broken up into smaller subbands, and the spectral analysis process steps through each subband, acquires spectral data over the dwell period and stiches the results over the full frequency range. The user should match the dwell period to the expected time varying nature of the spectrum. For slowly time-varying spectrum, the dwell period can be higher. For rapid time-varying spectrum, the dwell period should be lower.

The user wants to scan a frequency range based on known frequency bands or signal characteristics. The user selects Radio Control from the Module Menu. The Frequency Scan Bands table is available under Receiver Settings. The user has the ability to create a new frequency scan by selecting the add icon and configuring the scan parameters such as start and stop frequency, gain, dwell, and various spectral analysis parameters. The user enters the scan parameters and submits to add the new scan to the Frequency Scan List. The Frequency Scan List persists across system power cycles.

6.2.3. Edit Frequency Scan

The user wants to edit an existing frequency scan. The user selects the edit icon next to the desired frequency scan entry in the Frequency Scan List. The user refines the scan parameters and saves the changes. The updated scan parameters are reflected in the Frequency Scan List.

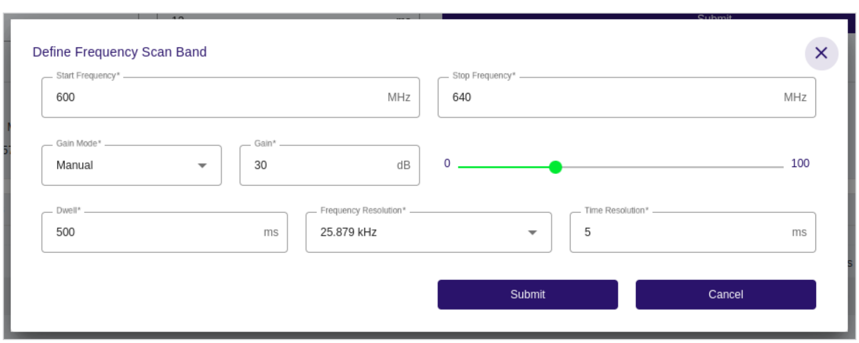


Figure 4: Define Frequency Scan Dialog

6.2.4. Execute Frequency Scan

The user wants to conduct a frequency scan based on one or more stored frequency scans in the Frequency Scan List. The user toggles the activate toggle under “Actions” for the desired frequency scans in the Frequency Scan Bands table. The active column reflects that the selected scan is now active (Note: this action overrides an active manual tuning configuration). The user can activate multiple scans from the list, resulting in a “Step and Dwell” scenario, where each scan is executed for the given dwell time and then steps to the next active scan. Typically for disjoint frequency band scans, the user will specify the same dwell period for all active scans to enable uniform monitoring performance.

Frequency Scan Bands

Active	Start Freq	Stop Freq	Gain	Dwell	Freq Resolution	Time Resolution	Actions
◉	600 MHz	640 MHz	30 dB	500 ms	25.879 kHz	5 ms	
	900 MHz	940 MHz	50 dB	500 ms	25.879 kHz	5 ms	
	1500 MHz	1600 MHz	59 dB	500 ms	25.879 kHz	5 ms	

Figure 5: Frequency Scan Bands

7. How to Operate the System

7.1. RF Signal Emulation

Note: This use case is a radio transmitter use case. The user should ensure that there is an antenna connected to the transmitter antenna port (Tx). The receiver is disabled during radio transmit operations.

7.1.1. Create Waveform

The user wants to emulate a specific waveform. The user navigates to the Waveform Library via the Module Menu. The user creates a new waveform by first defining the waveform parameters which include selecting one of the available waveform generators (e.g. Tone, Frequency Hopper, OFDM, etc.), and annotating the waveform with descriptive fields such as name, description, and RF system concept (e.g. handheld, SATCOM, radar). The user then proceeds within the Create Waveform wizard to configure the initial set of generator specific signal parameters (e.g. modulation, transmit frequency and power). The user also defines an initial traffic pattern (specification of the transmitter ON and OFF times), which is used to generate the transmitted randomized traffic pattern or communications battle rhythm. The user submits the waveform and it is added to the Waveform Library.

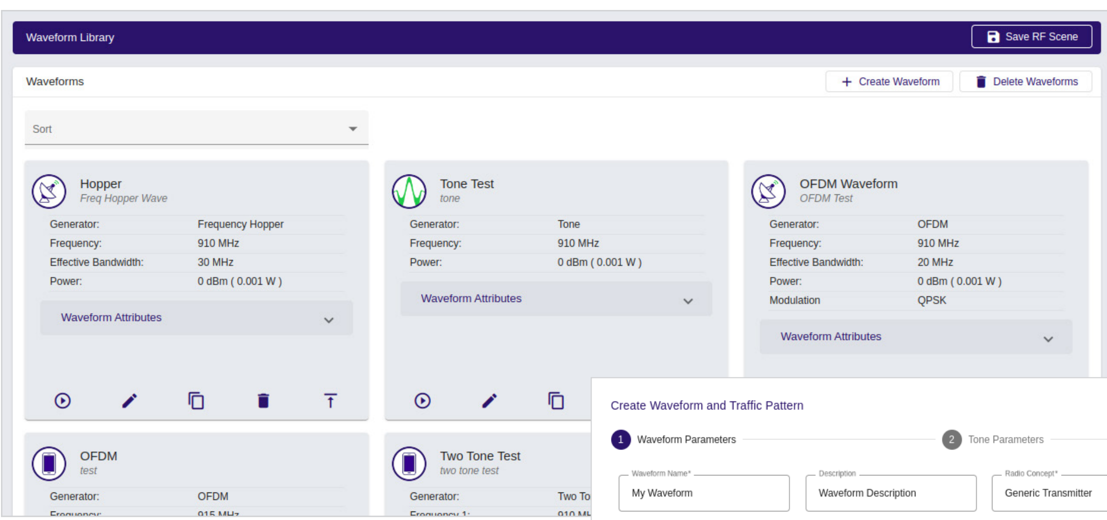


Figure 6: Waveform Library

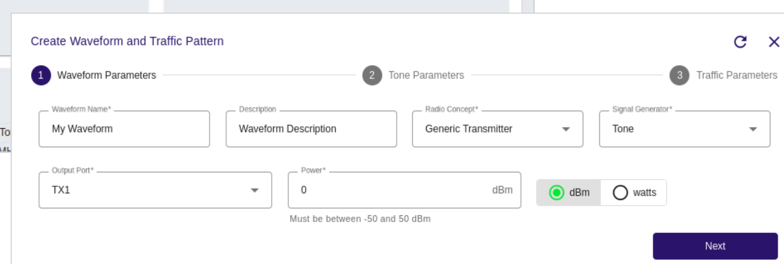


Figure 7: Create Waveform and Traffic Pattern Dialog

7.1.2. Create Waveform Use Case: Playback Complex Baseband I/Q File

The user can create a waveform from a complex baseband I/Q file, either as captured with the Signal Capture module or imported from an external file.

To import a baseband I/Q file, the user selects Import from the Baseband I/Q repository on the Waveform Library page. The user browses for and then selects the desired file from the host file system. The user identifies the input file type and sample rate, and selects the desired output signal scaling factor, then selects Import. The imported file is saved as a COMPLEX INT16 signal stored as complex <I, Q> pairs and scaled based on the user selection.

The import process supports the following input file types:

- Complex or Real Signals
- INT16, INT32 or FLOAT32
- Big or Little Endian

Note: If the input file does not represent the data in the input file, the import process will not create the desired baseband signal.

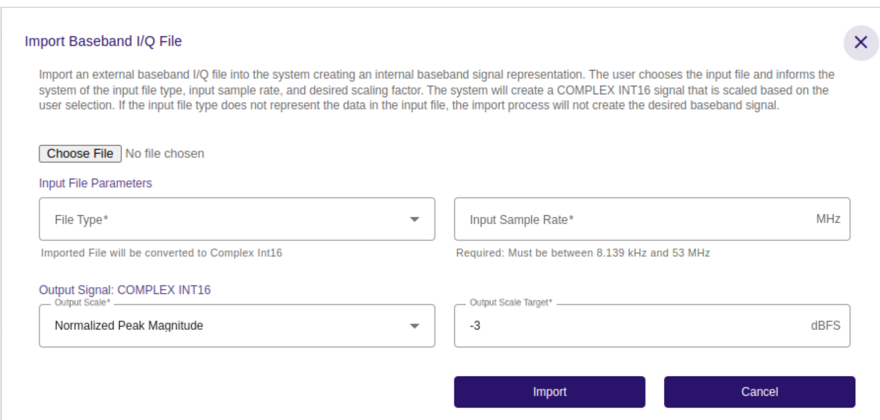


Figure 8: Import Baseband I/Q File

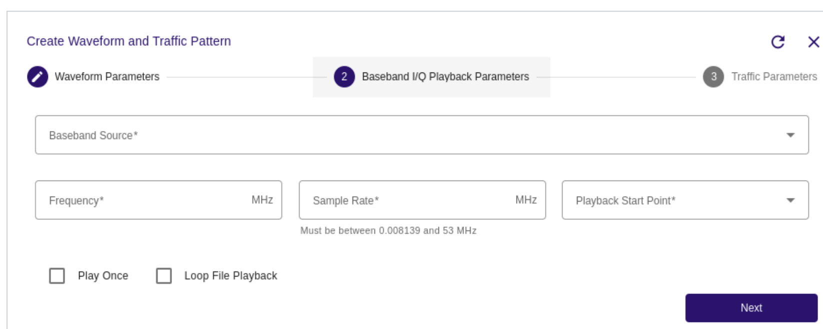


Figure 9: Create Baseband I/Q Playback Waveform

To create a waveform from a baseband I/Q file, the user follows the same procedure as creating a waveform from a built-in generator but selects "Baseband I/Q" as the waveform generator type. The user continues within the Create Waveform wizard to select the desired baseband I/Q file and configure the playback options and the initial set of generator specific signal parameters. At this point the user also has the ability to define the baseband I/Q waveform as a "Play Once" baseband I/Q waveform. If "Play Once" is selected during the waveform creation, an initial non-editable traffic pattern (specification of the transmitter ON and OFF time) will be auto generated with an ON time duration equal to the baseband I/Q file duration and an unlimited off time - forcing the traffic pattern to only play once. If "Play Once" is not selected during the waveform creation, the user can define an initial traffic pattern, which is used to generate the randomized traffic pattern or a communications battle rhythm.

7.1.3. Configure Waveform

The user wants to modify an existing waveform to refine the signal parameters and traffic patterns or add a new traffic pattern. The user edits an existing waveform in the waveform library by selecting the edit icon of the desired waveform. The user can also edit existing traffic patterns by selecting the edit icon of the desired traffic pattern under the “Waveform Attributes” section of that waveform, and add new traffic patterns which enables the user to transmit the waveform with a variety of traffic patterns.

7.1.4. Manage Waveform Library

The user wants to manage waveforms in the Waveform Library, including copying or deleting an existing waveform, and exporting/importing individual waveforms or the Waveform Library as a whole as a file on external storage (i.e. host computer storage).

The user wants to verify an existing waveform. The user initiates transmission for a specific waveform and traffic pattern, and system transmits the signal until the user turns transmit off.

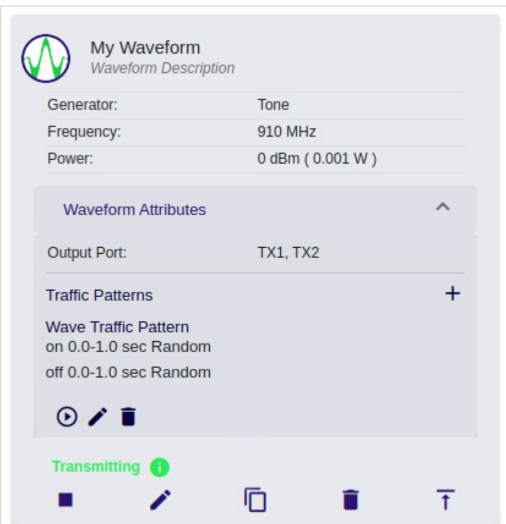


Figure 10: Waveform Card

Icon	Definition
	Stop Transmit
	Start Transmit
	Edit Waveform
	Copy Waveform
	Delete Waveform
	Export Waveform

Figure 11: Icon Definitions

7.1.5. Create / Edit RF Scene

The user wants to create a mission specific RF scene that includes a variety of waveforms populated on a transmission schedule. The user navigates to the RF Scene via the Module Menu. The user creates a new RF Scene, which includes descriptive metadata (e.g. mission name/label and description), schedule information (e.g. startup and completion) and schedule duration (2 hours).The user adds waveform traffic pattern pairs to the Waveform Workspace to use in the RF Scene Transmission Schedule. The selected waveform traffic pattern pairs will appear in the Waveform Workspace and also in the Transmission Schedule.

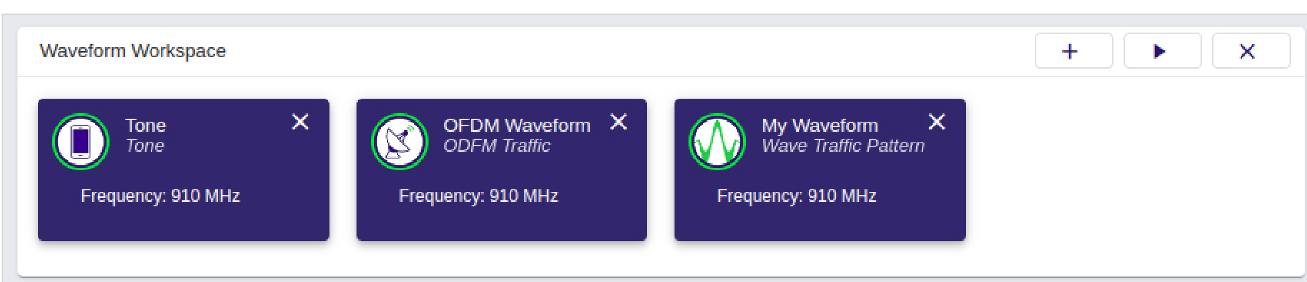


Figure 12: Waveform Workspace

The user creates a Transmission Schedule by adding transmission events to the schedule for each of the waveform traffic pattern pairs added in the Waveform Workspace. To add a transmission event the user selects the desired waveform traffic pattern pair displayed in the Transmission Schedule and defines the event attributes. The user can define either a singular transmission event or a recurring event (e.g. shift changes, comms checks). The user has the ability to verify the transmission schedule by executing (running) the RF Scene.

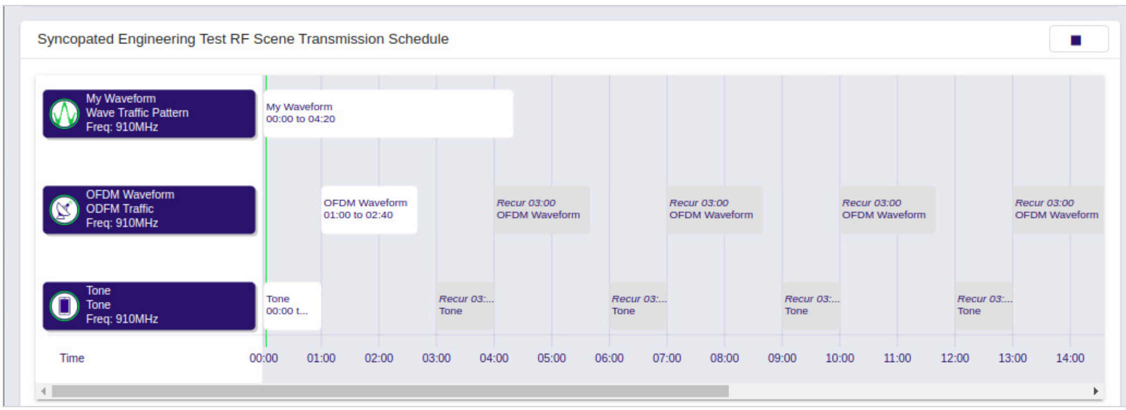


Figure 13: Tranmission Schedule

7.1.6. Monitor RF Scene Metrics

The user has curated an RF Scene using the Transmission Schedule to manage the scheduling of transmission events according to the waveform traffic pattern pair's specified ON and OFF times. The user is alerted to a transmission event collision, when the current event is transmitting and the next event is scheduled to start but is forced into additional wait time until the current event's transmission is complete, by an alert message on the Transmission Schedule detailing either a critical or warning message.

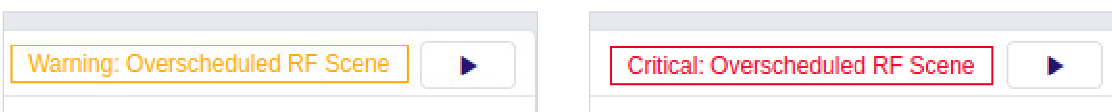


Figure 14: RF Scene Metrics Warning Labels

The user wants to monitor the RF Scene's Transmission Schedule for periods of traffic intensity that can potentially result in an overscheduled RF Scene and loss of new transmission events. The user can view each period of traffic activity on the RF Scene Metrics table, which details the level of traffic intensity (Normal, Warning, and Critical) and other metrics including average arrival time, average on time, minimum wait time, and average wait time. The user can then adjust the schedule's transmission events in order to avoid periods of high traffic intensity and an overscheduled RF Scene and ultimately achieve the desired RF Scene.

RF Scene Metrics

Traffic Intensity	Start Time	Stop Time	Avg Arrival Time	Avg On Time	Min Wait Time	Avg Wait Time
🔴	00:00:00	00:00:30	1.00000 events per sec	4.42235 sec	8.84469 sec	39.11429 sec
🔴	00:00:30	00:10:30	2.00000 events per sec	3.11490 sec	9.34469 sec	58.21552 sec
🔴	00:10:30	00:15:01	1.00000 events per sec	4.42235 sec	8.84469 sec	39.11429 sec
🟢	00:15:01	00:30:00	0.00000 events per sec	8.34469 sec	8.34469 sec	8.34469 sec
🔴	00:30:00	00:43:20	1.00000 events per sec	4.42235 sec	8.84469 sec	39.11429 sec
🟢	00:43:20	00:45:01	1.00000 events per sec	0.50000 sec	0.50000 sec	0.50000 sec
🟢	01:00:00	01:06:00	2.00000 events per sec	0.50000 sec	1.00000 sec	1.00000 sec
🟢	01:06:00	01:15:01	1.00000 events per sec	0.50000 sec	0.50000 sec	0.50000 sec
🟢	01:30:00	01:45:01	1.00000 events per sec	0.50000 sec	0.50000 sec	0.50000 sec

Figure 15: RF Scene Metrics

7.1.7. Manage RF Scenes

The user also has the ability to select a stored RF Scene previously created or import a previously exported RF Scene. Loading or importing an RF Scene will result in loading and overwriting the users current Waveform Library, Waveform Workspace, and Transmission Schedule.

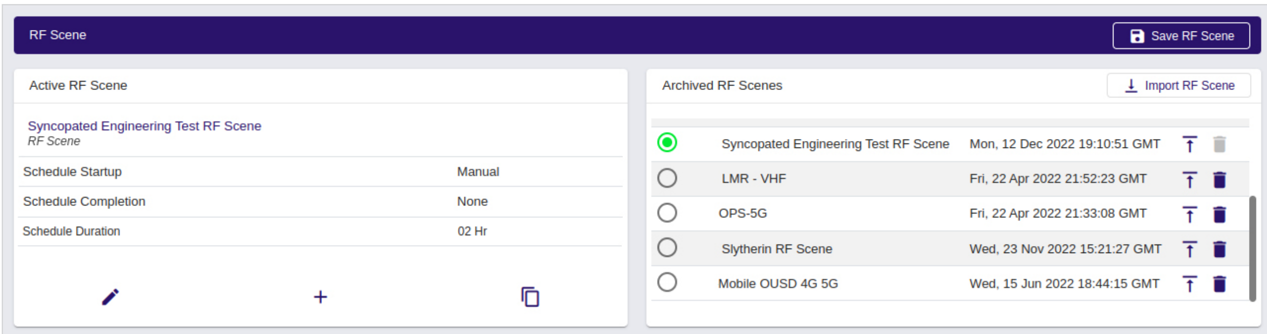
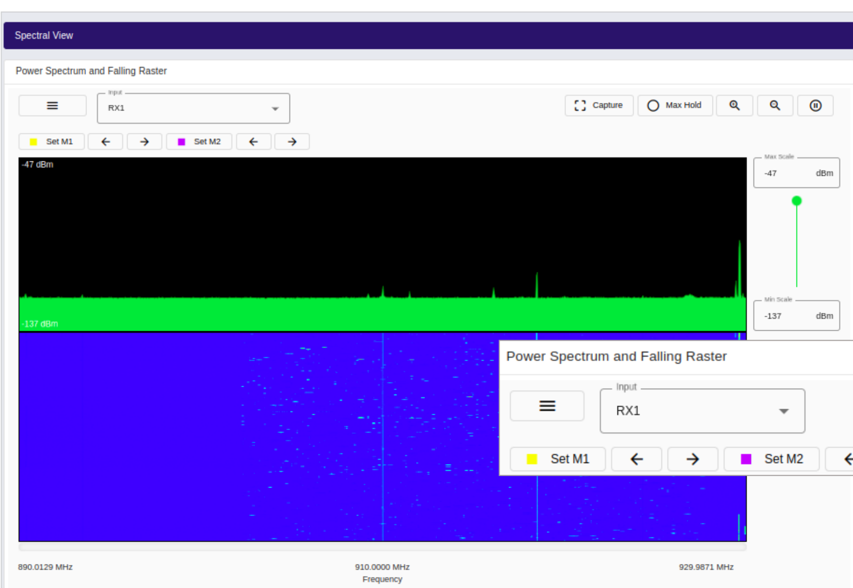


Figure 16: Active RF Scene & Archived RF Scenes

7.2. RF Spectrum Monitoring and Analysis

Note: The transmitter is disabled during spectrum monitoring and analysis to reduce interference.

The user wants to monitor the RF spectrum. The user configures the receiver by manually tuning the receiver or selecting frequency scans from the Frequency Scan List (see Radio Control section). The user selects Spectral View from the Module Menu to view the frequency power spectrum and time-frequency falling raster. The user has the access to common spectral analysis functions like max hold and zoom. The user also has access to the Spectral View Settings menu which includes Manual Tune (provides access to the same manual tuning form as the Radio Control view), Marker Settings, Capture Settings, and Spectrum Preferences. The user can adjust the scale of the display with the slider on the right side of the PSD plot.



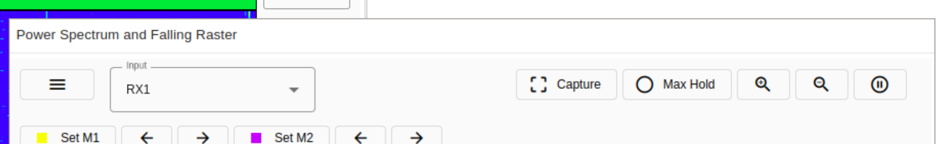


Figure 18: Spectral View Graph Controls

Figure 17: Spectral View

7.2.1. Manual Tune

Select Manual Tune from the Spectral View Settings menu and configure as described in the Radio Control Manual Tune section.

7.2.2. Spectral Markers

Select Spectral Markers from the Spectral View Settings menu. The user can set and adjust markers, which display frequency and power, as well as find the peak on the PSD spectrum. Marker controls also available on the toolbar above the PSD spectrum.

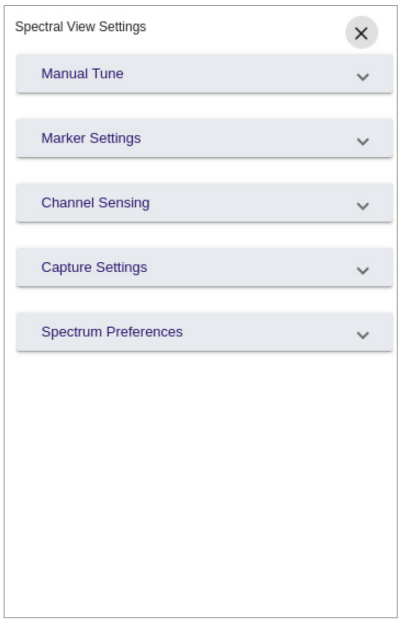


Figure 19: Spectral View Setting

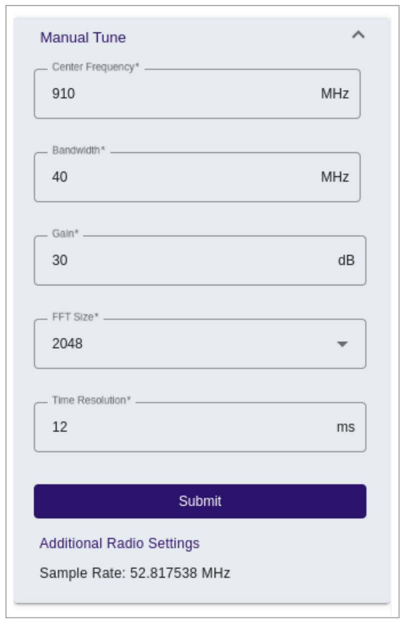


Figure 20: Manual Tune

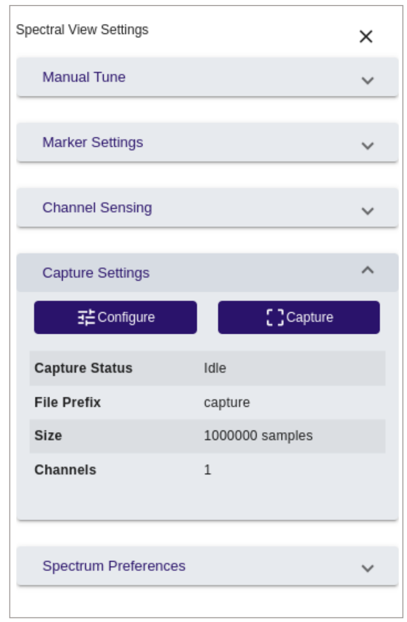


Figure 21: Capture Settings

7.2.3. Signal Capture

Select Signal Capture from the Spectral View Settings menu and configure as described in the Signal Capture section.

From the Spectral View, select Signal Capture button to execute a signal capture. Signal capture files are stored in the Baseband I/Q Library accessible on the Signal Capture view.

7.2.4. Set Spectral View Preferences

Open the Spectrum Preferences sidebar from the Spectral View Settings and configure preference such as PSD spectrum fill, and PSD power units.

7.3. RF Signal Capture

RF signal capture feature allows a user to capture a signal typically as they monitor the signal spectrum via the spectrum view.

Note: The transmitter is disabled during spectrum monitoring and analysis to reduce interference.

7.3.1. Configure Signal Capture

The user wants to configure a signal capture. The user navigates to the Signal Capture view via the Module Menu. The user opens the Configure Baseband I/Q Capture form and defines capture parameters such as file prefix and capture size, as well as the channel selection (up to 4 channels based on system configuration). The user submits the configuration and can now capture signals configured with the defined parameters.

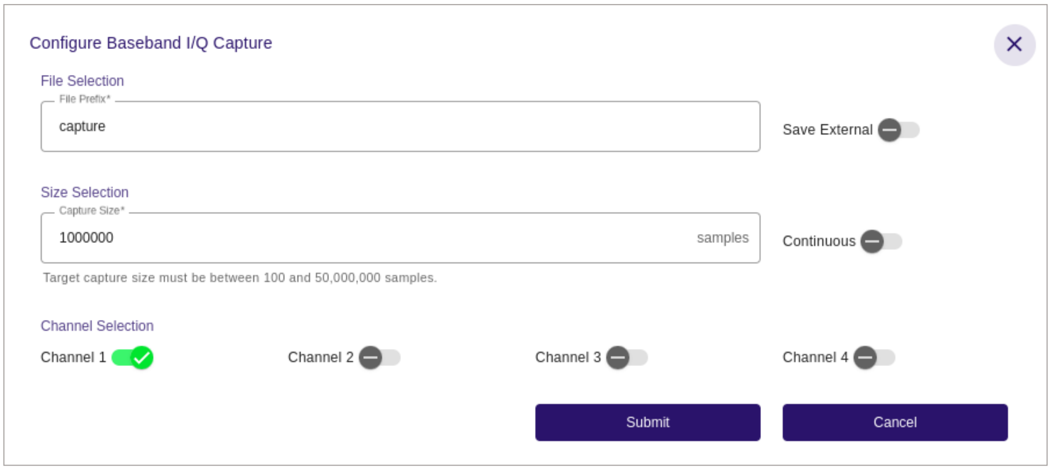


Figure 22: Configure Baseband Signal Capture

The user can also configure a baseband I/Q capture while viewing the power spectrum and falling raster on the Spectral View by navigating to the Capture Settings within the Spectral View Settings menu. (See Section 7.2.3.)

7.3.2. Execute Signal Capture

The user wants to execute a signal capture. The user typically captures a baseband I/Q capture while viewing the power spectrum and falling raster on the Spectral View by navigating to the Capture Settings within the Spectral View Settings menu. Feedback information is also available within the Capture Settings of the Spectral View Settings.

The user can also capture a signal via the Signal Capture module. The user navigates to the Signal Capture via the Module Menu. The user can execute a signal capture by clicking the "Capture" button on the Signal Capture view. Feedback on the capture such as status, duration, and progress are displayed for the user.

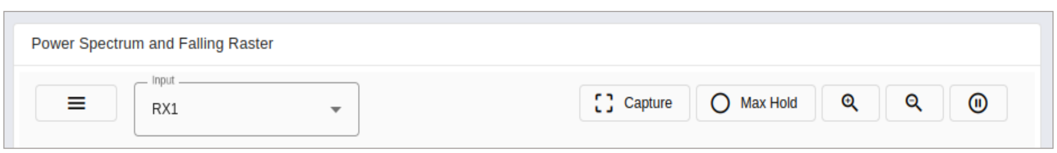


Figure 23: Capture Signal on Spectral View

7.3.3. Export Signal Capture

The user wants to execute a signal capture. The user typically captures a baseband I/Q capture while viewing the power spectrum and falling raster on the Spectral View by navigating to the Capture Settings within the Spectral View Settings menu. Feedback information is also available withing the Capture Settings of the Spectral View Settings.

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About Syncopated

Syncopated is a creative provider of custom products and solutions for Cognitive Radio and Edge Analytic hardware acceleration. Our solutions enable you to start further down the development path, reducing time-to-market and allowing you to focus on your innovative solution. Unlike many vendors, customization of our products for your specific needs is embraced not discouraged.

For Sales, please contact: Sales@SyncopatedProducts.com

For Support, please contact: Info@SyncopatedProducts.com

FCC Compliance

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the user guide and owners manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at his own expense.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: this device may not cause harmful interference, and this device must accept any interference received, including interference that may cause undesired operation.