RFXpress Advanced RF/IF/IQ Waveform Creation and Editing Software for Tektronix Arbitrary Waveform Generators

Technical Brief

RF Signal Generation

RFXpress is a powerful and easy-to-use set of software packages to synthesize digitally modulated base band, IF and RF signals that are generated by arbitrary waveform generators (AWGs). RFXpress runs as an integral part of the Tektronix AWG7000/AWG7000B and AWG5000/AWG5000B Series arbitrary waveform generators, or from an external PC.

RFXpress enables you to create the exact waveforms required for extensive, thorough and repeatable design validation, and margin and conformance testing. It considerably cuts the time you need for signal creation and simulations, thus reducing overall development and test time.

RFXpress[1] is a scalable solution, allowing you to add capabilities as needed. The modules are:

- RFXpress for General Purpose IQ, IF and RF signal creation
- RFXpress plug-in for UWB-WiMedia IQ, IF and RF conformance signal creation
- RFXpress plug-in for UWB-WiMedia IQ, IF and RF custom signal creation
- RFXpress plug-in for Radar, IQ, IF, and RF signal creation

[1] For ordering information, please refer to the data sheet at: www.tektronix.com/signal_generators

Tektronix®

RFXpress allows for replicating the waveforms of Tektronix oscilloscopes as well as IQ waveforms of real-time spectrum analyzers. To thoroughly test a design, these can then be modified by adding impairments, multipath, distortion or interferences.

Auto Mode allows automatic calculation of waveform length (in samples or symbols) and oversampling (sampling rate) required to generate the desired frequency from the arbitrary waveform generator.

UWB–WiMedia signal creation, is a plug-in for RFXpress, that has the capability to digitally synthesize and directly generate RF signals in all BandGroup of the UWB spectrum. As per the latest WiMedia specification, signals will band hop in real time over a 1.5 GHz modulation bandwidth and include all the different preamble synchronization sequences, cover sequences, TFCs and band groups. All six band groups (BG1 – BG6) can be generated with band hopping in either. The conformance mode enables you to generate all signals that conform to WiMedia specifications, while the custom mode allows you to adjust the signals for stress and margin testing.

Features and Benefits

Radar signal creation, a software module for RFXpress gives you the ultimate flexibility in creating Pulsed Radar waveforms. It gives you the ability to build your own Radar pulse suite starting from pulse to pulse trains to pulse groups. It supports a variety of Modulation schemes including LFM, Barker and Poly phase Codes, User - defined codes, Step FM, Non-Linear FM, User - Defined Step FM and Custom modulation. It also has the ability to generate pulse trains with staggered PRI to resolve Range and Doppler ambiguity, Frequency hopping for Electronic Counter Counter Measures (ECCM) and Pulse - to - Pulse Amplitude variation to simulate Swerling target models.

General Purpose IQ, IF and RF Signal Creation

- **Base band data generation** - Define base band I and Q signals using a variety of predefined modulation schemes, or by defining your own modulation using symbol maps

- **Multi-carrier setup** - Create single or multi-carrier signals where each carrier can be independently defined with parameters such as carrier frequency, symbol rate, modulation type, base band filtering, data source, and others

- **IQ impairment control** - Apply impairments which include quadrature error, quadrature imbalance, non-linear impairments (AM-AM, PM-PM) and IQ skew

- **Noise / Multipth / Interference addition** - Add noise, multipath, or interferences during waveform creation

- **Create Hopping signals**

- **Visually confirm setup** - Confirm setup in time and frequency domain: FFT, constellation, I vs. time, Q vs. time, CCDF, eye diagram and pulse shape

- **Wrap around** - RFXpress takes care of all the details to completely eliminate all the wrap-around effects found in arbitrary waveform generators, providing seamless signals that can be played back continuously without any discontinuity or glitch in the time, frequency, modulation, and channel coding domains

- **Replicate captured waveforms** - Captured IQ waveform files from oscilloscopes and real-time spectrum analyzers can be replicated either directly, or after modifications to the waveform in RFXpress

- **Connectivity between an AWG, oscilloscope and PSG**®[2] - The ability to identify and connect from an AWG, to an oscilloscope and to a PSG®, and configure their setups remotely.

[2] PSG® is a registered trademark of Agilent Technologies

UWB-WiMedia (Plug-in)

- Direct RF generation of waveforms

- Ability to generate waveforms for all BandGroups including band hopping

- User defined IF frequency including TFC pattern

- Application and standard support for MB-OFDM UWB (WiMedia)

- Comprehensive WiMedia signal generation support for MAC and PHY layers

- Ability to create UWB-WiMedia Correction files which can be automatically applied as compensation to the RF/IF signals generated

- Use of the Gated Noise feature to define noise profiles, which can be individually set for each section of the UWB packet. (Pre-amble, PPDU Header & PSDU)

- Create Tone-nulling with intermediate amplitude values (- 40 dB to +10 dB) and phase values (-180 degrees to +180 degrees) for OFDM carriers mapping

- Real-time impairments

RADAR (Plug-in)

- Create single or multiple pulse groups to form a pulse train

- Define each pulse group independently

- Define inter and intra pulse hopping patterns in both frequency and amplitude

- Define radar pulse patterns and view them graphically and in a spectrogram view

- Define all pulse parameters including Start Time, Rise Time, Off Time, Fall Time, Pulse Width, Droop, Overshoot and Ripple

- Define a staggered PRI with ramp and user defined profiles

- Create a user defined pulse sequence and use the AWG sequence mode to optimize the memory and to create large number of pulses[3]

- Support for a variety of intra-modulation types including FM chirp, FM step, Barker Codes, Polyphase Codes, user defined Step FM and Codes and Custom Modulation
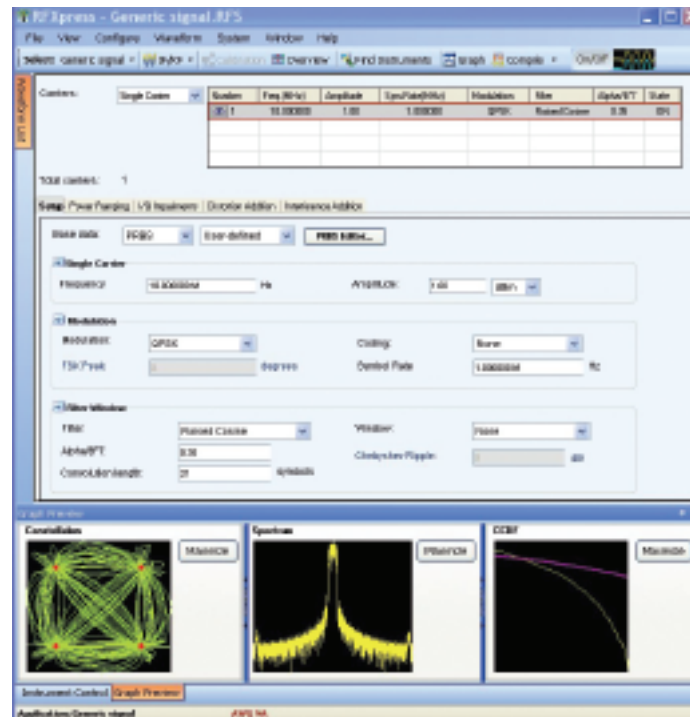
Figure 1. A single carrier QPSK signal is generated using the generic signal application in RFXpress.

RF Signal Generation Made Easy

In the new digital RF world, signals are becoming more and more complex. And it is necessary to have a tool that accurately synthesizes these signals. RFXpress takes IQ, IF and RF signal generation to the next level and fully exploits the wideband signal generation capabilities of AWG7000/B and AWG5000/B Series arbitrary waveform generators. With AWG sample rates as high as 24 GS/s, RFXpress enables you to create signals up to 9.6 GHz (4 samples / cycle) in a single instrument with ease.

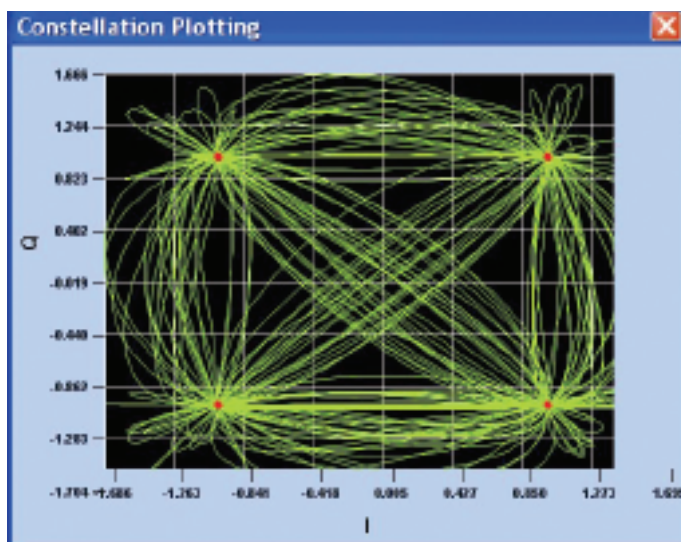[3] Need Option 08 for Tektronix AWG7000B or AWG5000B series AWG

Figure 2. Expanded view of a QPSK constellation.

Figure 3. Instrument control panel in RFXpress.

Define Your Own Modulation

RFXpress supports a variety of modulations required for wide band signal generation, from basic modulations like BPSK and QPSK to more complex modulations such as 256QAM, GMSK and others. Symbol map functions can be used to define custom modulations and "No modulation" can be used to generate signals in single-tone in single-carrier mode as well as multi-tone in multi-carrier mode.
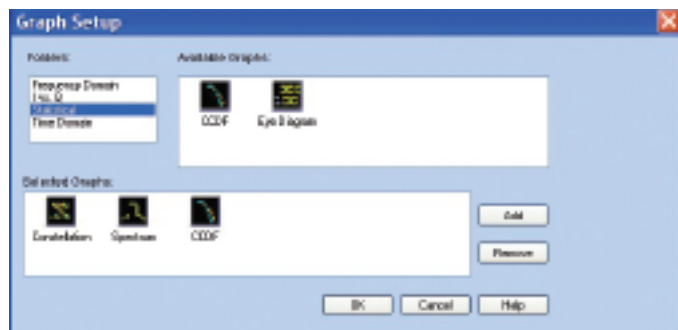

Figure 4. Graph selection setup.

Multi-carrier

Single carrier signals as well as multi-carrier signals with configurable parameters including the number of carriers, carrier spacing, modulation schemes and other parameters can easily be created.

Connect, Capture, Replicate

RFXpress automatically detects connected oscilloscopes and allows capturing waveforms at a simple push of a button. If required, captured waveforms from oscilloscopes or IQ waveform files from a real time spectrum analyzer can also be modified by adding impairments, distortion or interferences. Never before has stress and margin testing been easier.

Visual Confirmation of All the Setups and Overview Window

To visually confirm the results of your signal creation, signals can be visualized by using various graphical display options. This substantially reduces the need to use an external analyzer to verify the integrity of the signal. Up to three graphs at a time for simultaneous viewing can be selected.
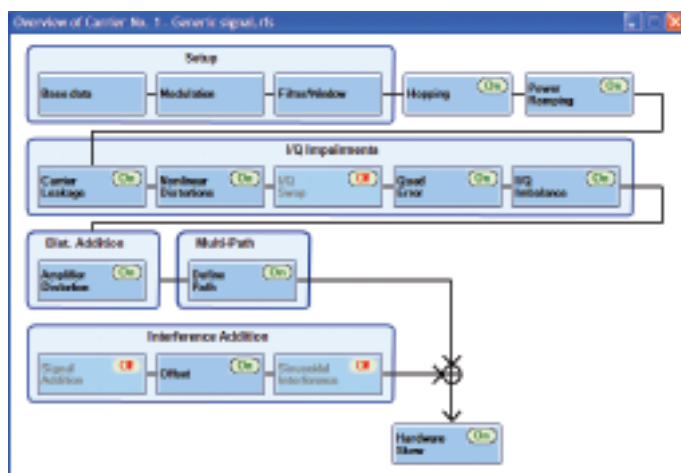
Figure 5. Overview window of WiMedia application.

The entire signal flow can also be seen from the overview window. Individual blocks like IQ Power ramping, impairments, distortion and interference can be controlled from the overview window. The individual blocks can also be switched on or off, and corresponding effects to the waveform can be observed.

Hopping

Hopping allows you to add frequency and amplitude hopping for a selected carrier. The Figure 6 shows an example of frequency hopping of carrier around center frequency of 2GHz simulated along with a Spectrogram display. You can enter the start symbol, end symbol, relative amplitude in dB, and frequency offset in Hz for the selected carrier.
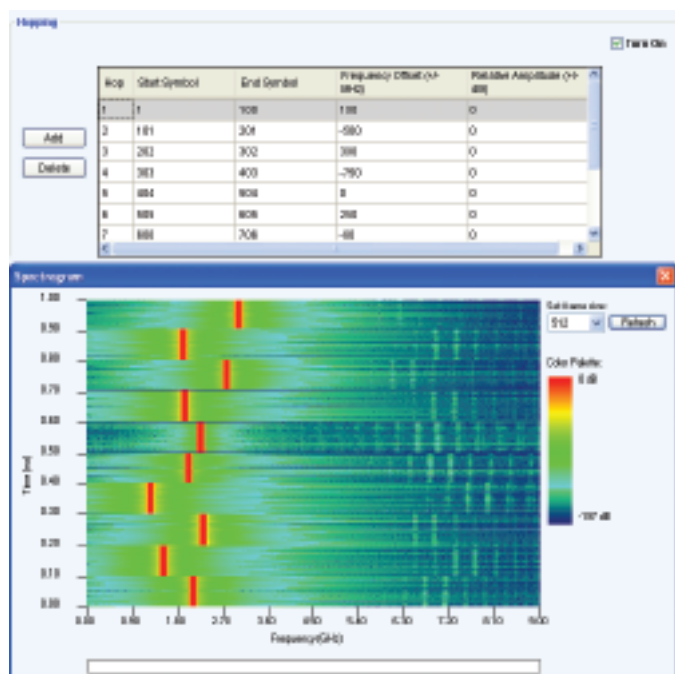

Figure 6.

Generic Signal Calibration

The RFXpress calibration feature pre-distorts the signal to provide flat frequency and linear phase response out of the AWG. Addtionally you also have a provision to calibrate the image between fs/2 and fs thus providing a flat response for the undersampled signals.

Figure 7. UWB-WiMedia signal generation in RFXpress conformance mode.

Figure 8. UWB-WiMedia signal generation in RFXpress custom mode.

UWB-WiMedia Signal Creation

Generate IQ, IF and RF UWB-WiMedia Signals

UWB-WiMedia signal creation plug-Ins for RFXpress have the capability to digitally synthesize and directly generate RF signals in all BandGroups of the UWB spectrum. As per the latest WiMedia specification, signals will band hop in real time over a 1.5 GHz modulation bandwidth and include all the different preamble synchronization sequences, cover sequences, TFCs and band groups. All six band groups (BG1 – BG6) can be generated with band hopping in either RF/IF or IQ. The conformance mode enables you to generate all signals that conform to WiMedia specifications, while the custom mode allows you to adjust the signals for stress and margin testing.

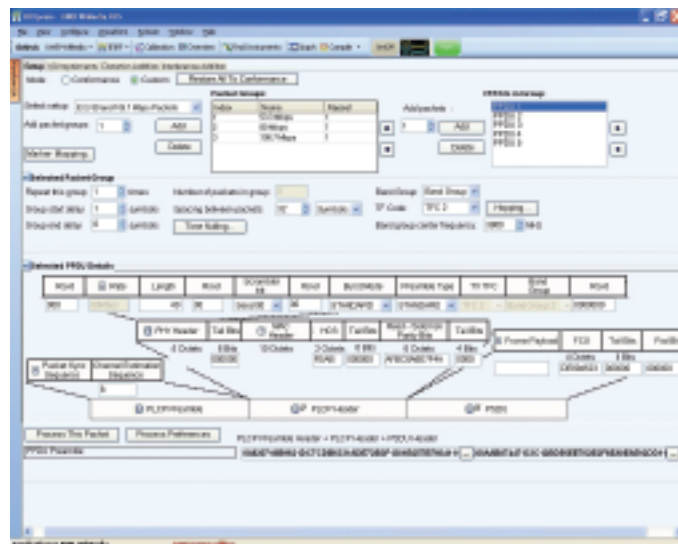Two WiMedia software plug-ins are available: conformance and custom.

The conformance plug-in allows the creation of all signals that conform to WiMedia's specification, while in the custom mode the software allows you to adjust the signals to help you characterize, stress and limit test your DUT and simulate ideal, distorted or real-world test conditions.

Calibration

It is well known that RF measurements are susceptible and sensitive to variations and changes from the environment such as temperature, system configuration and individual devices. It is recommended to calibrate the system. When compared to traditional RF signal generators, AWGs are less susceptible to these parameters. Correction files can be automatically applied during RF/IF signal generation as compensation to the signals generated.

Real-World Interference

Ready to use "Real-World Interference" like WiFi (802.11a and MIMO), WiMAX and Radar to the WiMedia waveform to test your receivers against these interferences.
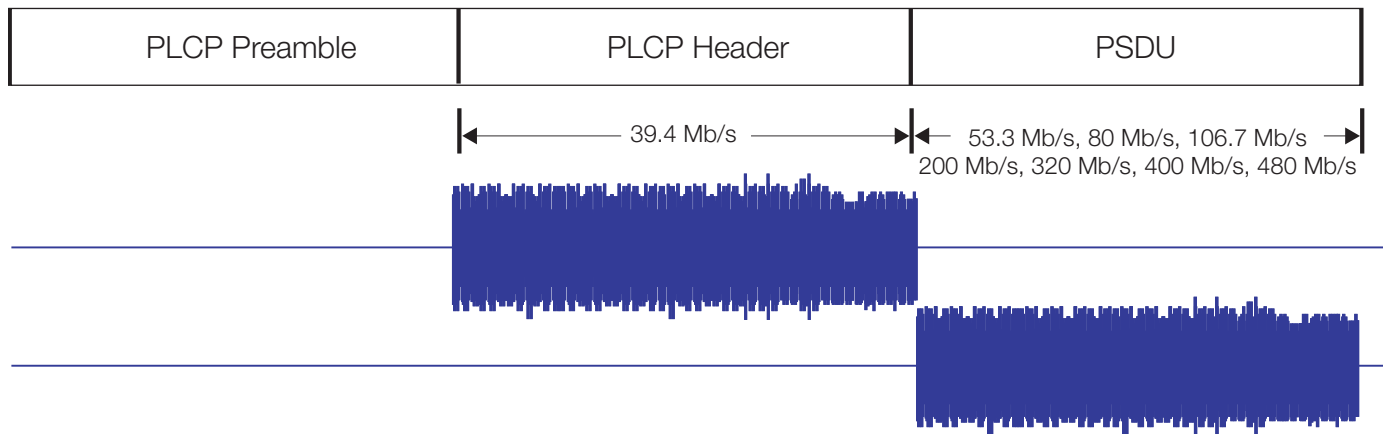
PLCP Preamble	PLCP Header	PSDU

39.4 Mb/s → 53.3 Mb/s, 80 Mb/s, 106.7 Mb/s
200 Mb/s, 320 Mb/s, 400 Mb/s, 480 Mb/s

Figure 9. A symbolic representation of Gatred Noise.
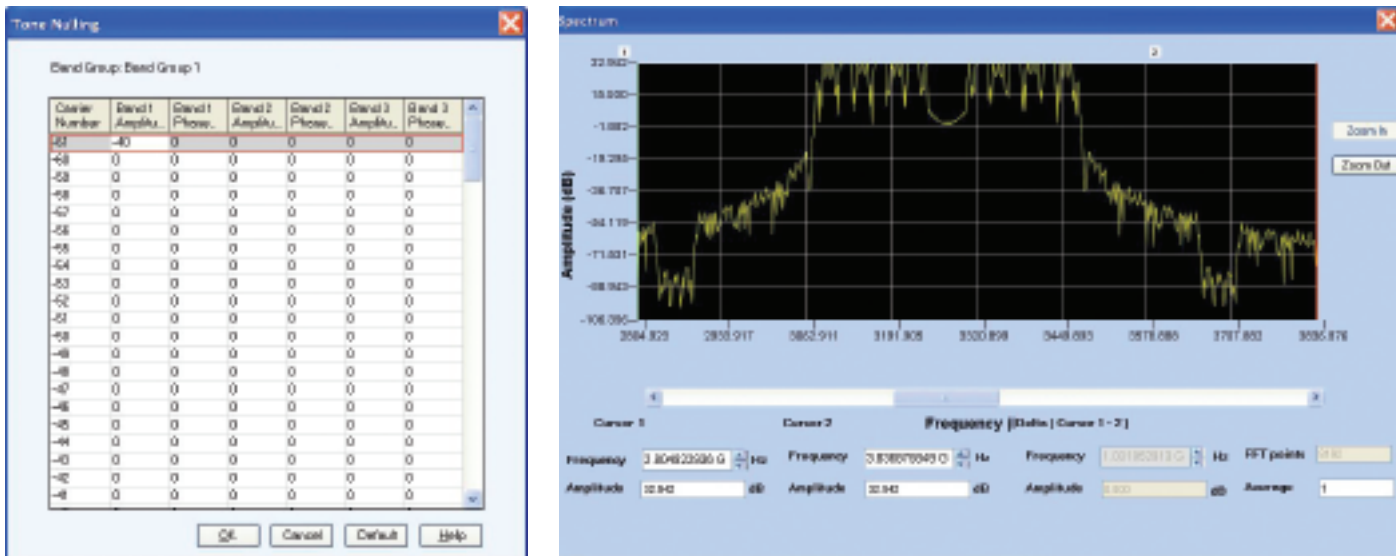
Gated Noise

RFXpress also includes a Gated Noise feature which is used to define noise profiles. For each section of the UWB packet (Pre-amble, PPDU Header and PSDU) noise profiles can be defined individually.

Other RFXpress UWB-WiMedia Features:

■ Direct RF Generation of all the WiMedia Band groups (BG1 to BG6) Including Band Hopping

■ Generate all 6 band groups for IQ and IF signals

■ Visually confirm all setups (graphical representation)

■ Remotely control and configure Tektronix oscilloscopes and PSGs®

■ Replay captured waveform files from oscilloscope, real time spectrum analyzer AWG .txt and MATLAB .mat files

■ Export all the settings to a file

■ Save and recall setups

■ Gain benefit from automatic wrap around correction with an option to disable

■ Normalize the waveforms in auto and manual modes

UWB-WiMedia Conformance Mode Allows You To:

■ Select user-defined IF frequencies

■ Define all UWB parameters for a Packet Group
  - Ability to have many packets with different data and data rate
  - Easy creation of multiple packets with minimum settings

■ Visually indicate selected hopping patterns

■ Select all standard data rates / TFCs

■ Accept spacing between packets in Symbols / MIFS / SIFS

■ Create Tone nulling with intermediate amplitude values (-40 dB to +10 dB) and phase values (-180 degrees to +180 degrees) for OFDM carriers mapping

■ Support user-defined MAC Header

■ Support file input for Payload

■ Automatically display channel number on selection of BG and TFC

■ Support Marker mapping with delay for external RF hopping control

■ Add both in-band and out-of-band interferers

■ Support for distortion / interference and IQ Impairment addition

■ Apply Ready to Use "Real-World Interference" like WiFi (802.11a and MIMO), WiMAX, Radar and Captured Baseband Waveforms as Interferer to the WiMedia Waveform

Figure 10. Tone nulling of some of the OFDM tones in Band 1 and its graphical representation.

UWB-WiMedia Custom Mode UI Delivers:

- Graphical representation of PPDU structure

- All settings defined at a Packet level

- Graphically configurable custom TFCs

- PLCP preamble and / or Preamble+Header signal generation

- User defined preamble

- HEX display of PLCP header and PSDU

- User defined TFC

- User defined cover sequence for preamble

Signals are becoming more complex in the new digital RF world. In this increasing complexity, RFXpress provides the solution that enables you to accurately synthesize these complex signals. RFXpress fully takes advantage of the wideband signal capabilities of the AWG5000/ AWG5000B and AWG7000/AWG7000B Series of arbitrary waveform generators. With AWG sample rates as high as 24 GS/s, RFXpress enables you to create signals up to 9.6 GHz in a single instrument with ease.

AWG Support for RFXpress UWB-WiMedia Plug-in

RFXpress Option	Instrument Model	Direct RF	IF	IQ	Calibration[1]
UWB Custom / Conformance	AWG7122B - Opt 06	Yes All BGs (BG1 to BG6)	Yes	Yes	Yes
	AWG7122B - Opt 02	Yes (BG1, BG2)	Yes	Yes	Yes
	AWG7122B - Standard	Yes (BG1)	Yes	Yes	Yes
	AWG7121 - Opt 02	Yes (BG1, BG2)	Yes	No	Yes
	AWG7121 - Standard	Yes (BG1)	Yes	No	Yes
	AWG7062B	No	Yes	Yes	Yes
	AWG7061B	No	Yes	No	Yes
	AWG5014B	No	No	Yes[2]	No
	AWG5012B	No	No	Yes[2]	No
	AWG5004B	No	No	No	No
	AWG5002B	No	No	No	No

[1] Supports RF/IF calibration

[2] Supports non-band hopping IQ signals

RADAR Signal Creation

RFXpress RADAR plug-in supports basic pulse generation of different shapes and modulation types.

Coherent Carrier

RFXpress allows you to define the carrier as Coherent or Non-Coherent. A coherent carrier is a continuous wave signal, the frequency and phase of which have a fixed relationship to the frequency and phase of the reference signal.

Staggered PRI

Use Staggered PRI to create multiple PRIs and define pulse-to-pulse staggering in the Staggered PRI tab. PRI staggering can be defined in two types, Ramp and User defined.

Target velocities that correspond to multiple integers of the PRF are referred to as blind speeds. It's called blind speed because an MTI filter response is equal to zero at these values. Blind speeds can pose serious problem on the performance of MTI radars and their ability to perform adequate target detection. Using PRF agility by changing the pulse repetition interval between consecutive pulses can extend the first blind speed to tolerable values

Modulation

The Pulse Modulation tab allows you to provide the different modulation schemes that can be applied to the pulse width for a selected pulse. The available modulation schemes are: No Modulation, Linear Frequency Modulation (LFM), Biphase Coded pulse-Barker, Polyphase Codes, User Defined Codes, Step Frequency Modulation, Non Linear FM, User Defined Step FM, and Custom Modulation.

Custom modulation allows you import a user defined modulation from MATLAB® (.mat formats) in to RFXpress and then add IQ impairments, pulse impairments and Interference addition.
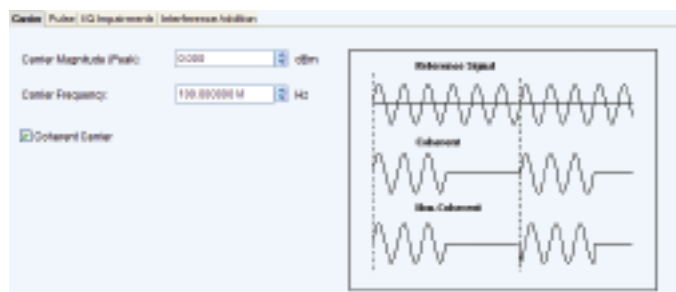
Figure 11. An example of defining a 100 MHx coherent carrier.

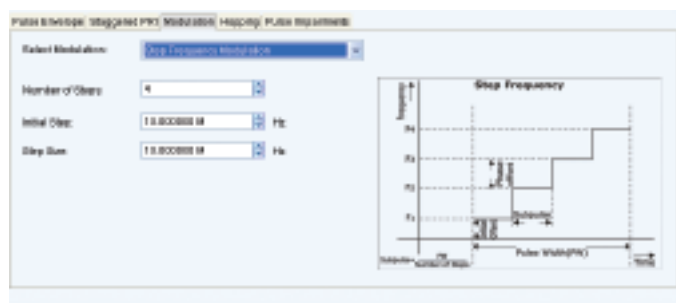**Figure 12.** A staggered PRI with Ramp type.

Figure 13. An illustration of Step Frequency Modulation.

Spectrogram and CPI Plot

You can the visually confirm the set up in various frequency and time domains including Spectrum, Spectrogram and CPI Plots.

Spectrogram is a 3-dimensional plot with Frequency along the X axis, Time along the Y axis, and the Amplitude of the point shown by the brightness of the color. The points with the highest amplitude are plotted in red and the points with lowest amplitude are plotted in blue. The color palette containing the color grading is shown on the right of the plot. The palette also shows the highest amplitude values present in the spectrogram.

CPI Plot (Coherent Pulse Interval) is a 3-dimensional plot with Frequency on X axis, Time on Y axis, and Amplitude on Z axis. This plot gives a 3-dimensional representation of a radar pulse.
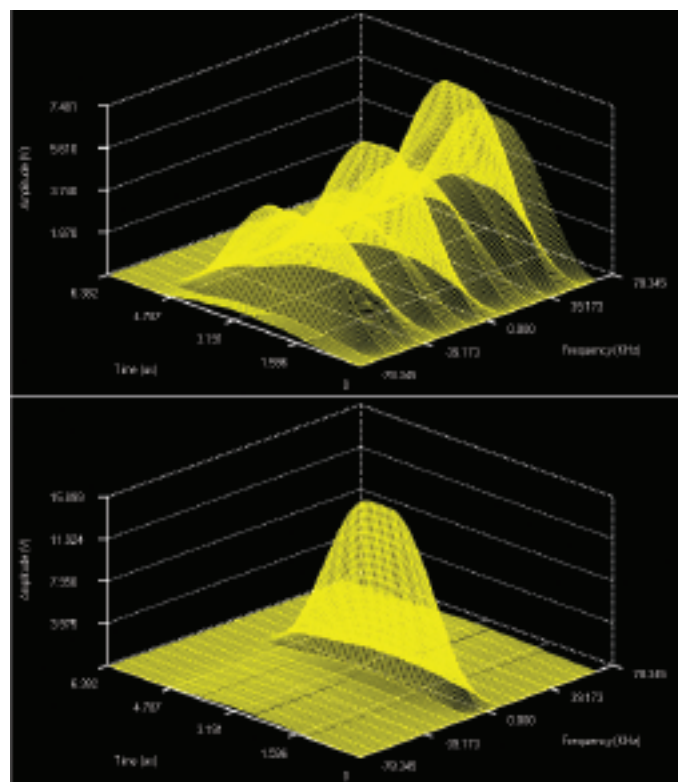
Figure 14. The Top CPI plot shows the behavior of a Non-coherent Carrier and Bottom CPI Plot show Coherent Carrier.

For Further Information

Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

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Enabling Innovation