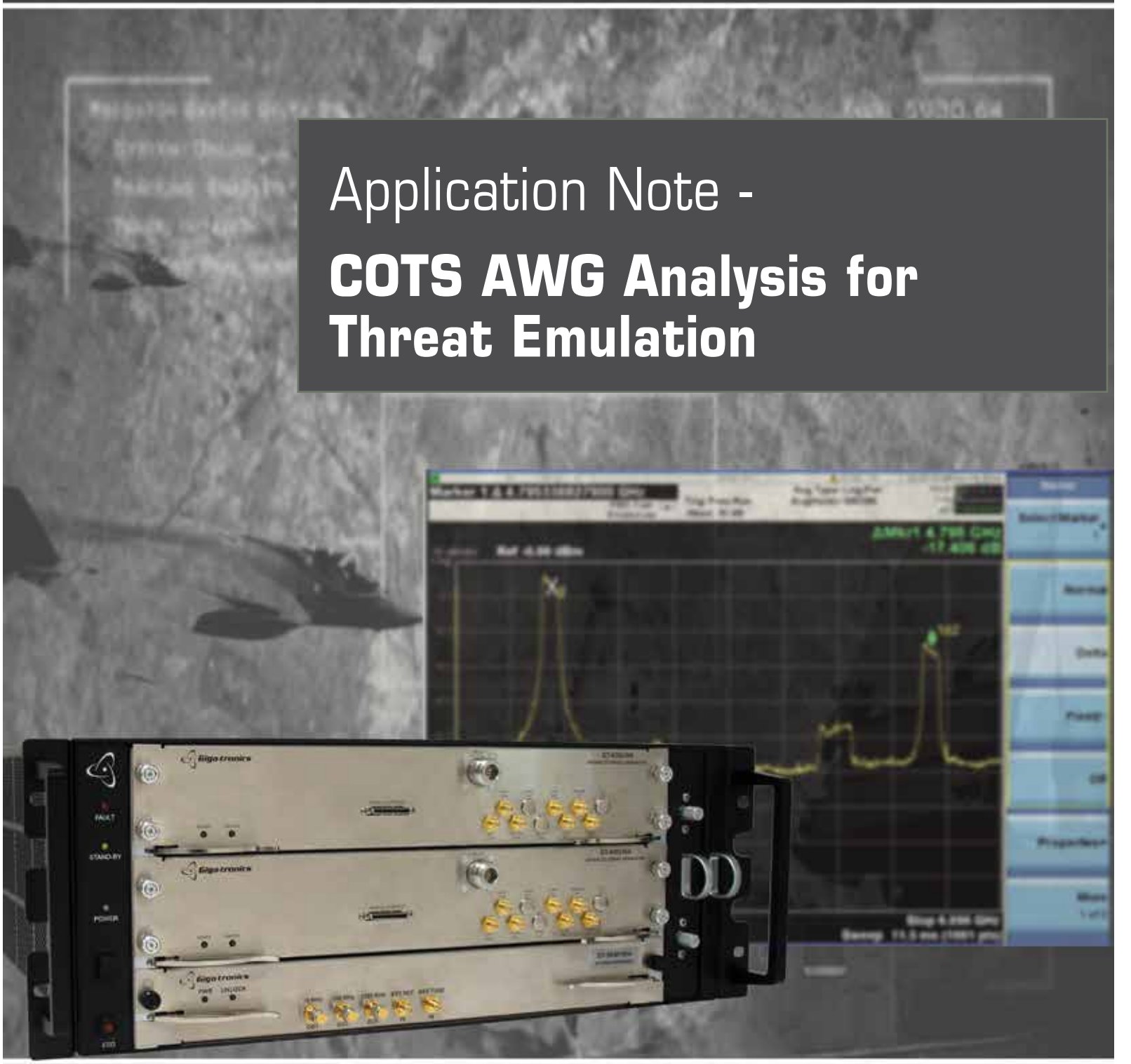
Application Note -

COTS AWG Analysis for Threat Emulation



Author: Mark Elo, VP of Marketing
Published: March 12, 2015
Revision: A

Giga-tronics

Advanced Microwave Signal Generation and Acquisition

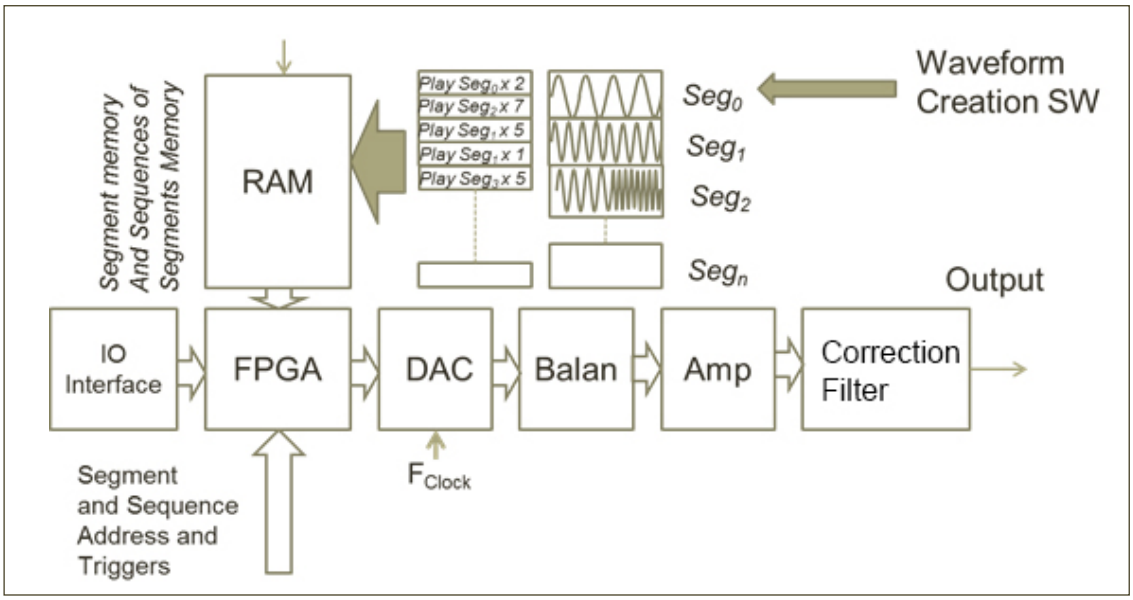
Introduction

An arbitrary waveform generator (AWG) is a piece of electronic test equipment used to generate electrical waveforms. These waveforms can continuous/repetitive or single-shot (once only) in which case some kind of triggering source is required (internal or external).

For the threat emulation application it is assumed that waveforms will be single shot and will represent different types of radar PRI's associated with different threats. Each Radar waveform can also have a number of modes such as search and track.

AWG Architecture

The following block diagram is typical of a COTS AWG.



Waveform creation software is used to create various radar waveforms. These waveforms are loaded into the instrument through an IO interface such as LAN or PCIe. In some cases such as the Tektronix 70000 AWG, the waveform generation software is internal to the instrument. In other cases a separate PC software program is used such as MatLab by the MathWorks or Signal Studio for Pulse Building by Keysight Technologies.

Memory: Waveforms can be stored in Memory Segment memory and groups of segments can be played out as Sequences. For example, a scan pattern could be stored in segment memory zero, and sequence zero would play segment zero 2 times then stop.

There are two types of memory employed in COTS AWGs: Static RAM and Dynamic RAM. Static RAM can be accessed much faster than Dynamic RAM, however the overall storage capacity of static RAM is small compared to that of Dynamic RAM.

Type	Memory	Size	Approx. Access Time
Tabor Electronics WX series	Static	32 MB	< 0.5 µs
Tektronix 70000 AWG	Dynamic	16 GB	7 to 8 µs
Keysight M8190A	Dynamic	2 GB	~ 1 µs

Dynamic Memory Access: Segments and Sequences can be played out on demand by using Dynamic or Pattern Jump interfaces that address a particular waveform then initiate play out utilizing a trigger or a strobe line. Some AWGs have an 8 bit parallel interface allowing for 256 Segment addresses while others such as the Keysight M8190A have 19 bits allowing for 524 k segment addresses.

Type	Connector	Bits	Waveforms
Tabor Electronics WX series	D Sub Female	8 Bits	256
Tektronix 70000 AWG	D Sub Female	8 Bits	256
Keysight M8190A	20 Pin Mini D	19 Bits	524 k[1]

Digital to Analog Converter: The DACs vary in sample rates depending on the AWG's overall frequency range. The sampling rate, and oversample added will affect the Spur Free Dynamic Range (SFDR) of the instrument.

Type	Max Sample Rate	Max Output Frequency	Worst Case SFDR
Tabor Electronics WX series	1.25 GS/s	50 MHz	30 dBc
Tektronix 70000 AWG	50 GS/s	< 20 GHz	42 dBc
Keysight M8190A	12 GS/s	< 6 GHz	70 dBc

Amplifier: The choice of amplifier in the output stage will determine the level of harmonics. When using an up-converter in conjunction with an AWG the harmonics will often be out of the IF band. Or if the AWG is generating signals direct to microwave the harmonics are often out of the band of the system under test. In some bases though, especially when generating wideband chirp signals, the harmonics will be in band.

Type	1st Harmonic
Tabor Electronics WX series	-40 dBc
Tektronix 70000 AWG	-50 dBc
Keysight M8190A	-40 dBc to -50 dBc

1 Two operation are required for 524 k, a single operation is 4 k waveforms

Output filtering: Waveform generators don't have a robust output filtering scheme, therefore images, spurs and other spectral anomalies can occurs. The example below shows a 6 GHz sweep on a spectrum analyzer. The intended wide bandwidth chirp is at 1.2 GHz, the other displayed signals are all anomalies of the signal creation method. All AWGs exhibit similar behavior.

Threat Signal Creation

The following needs to be taken into account when generating threats:

1. The ability to add attenuation pulse-to-pulse to emulate antenna patterns, azimuth and elevation characteristics.
2. The ability to add Doppler pulse to pulse.
3. Deterministic playback of waveforms that emulate a radar frame or mode.
4. Ability to change waveforms quickly.
5. Digital modulated real time FSK waveforms for data links.
6. SFDR > 60 dBc

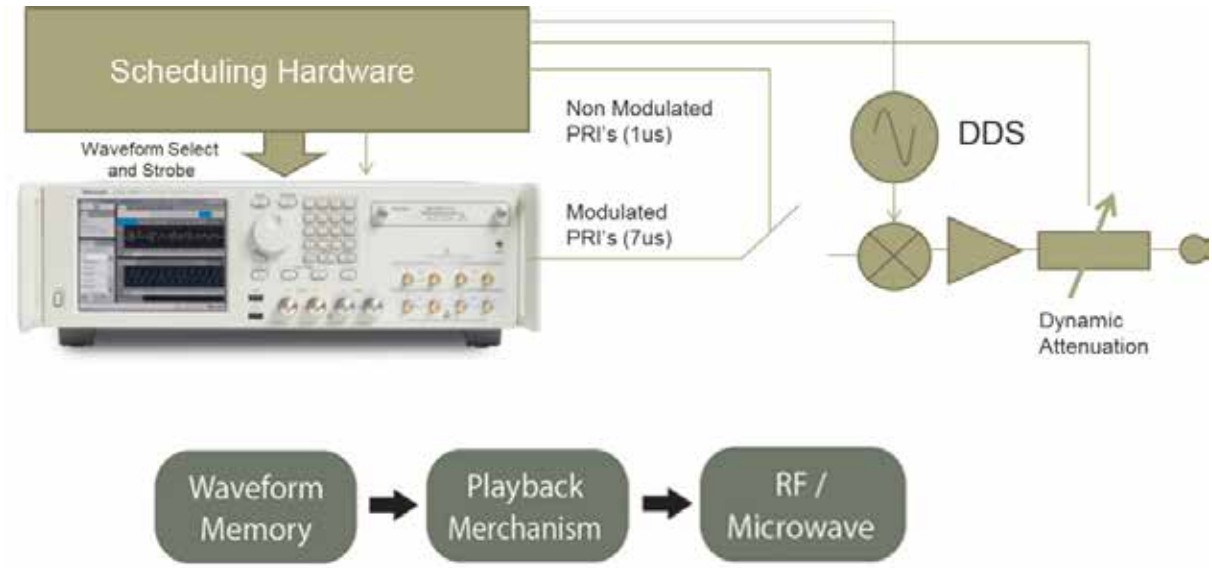
Direct to Microwave

High sample rate AWG's such as the Keysight M8190A/M8195A and the Tektronix 70000 AWG can generate directly to RF or microwave frequencies. They both have waveform creation software that allow you to generate sets of PRI's that can contain a scan pattern from a fixed location. More memory can be used to create infinite sets of waveforms that contain all movement changes in amplitude, phase and frequency, however this quickly becomes an overwhelming data set and requires the ability of addressing 1000's of waveforms. While the Keysight unit can dynamically select 524k waveforms, making this approach possible in theory, the Tektronix 70000 AWG is not capable with only 256 of selectable waveforms.

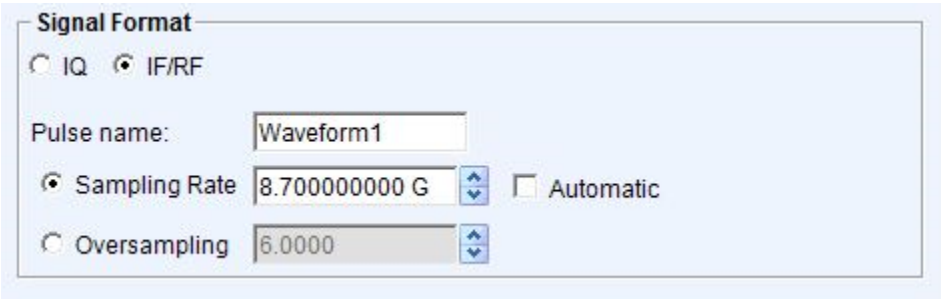
All COTS AWG have no provision for dynamic amplitude changes to the waveform. While the M8190A has a NCO (Numerically Controlled Oscillator) feature that can be used for adding phase or frequency, it cannot be controlled deterministically on a pulse to pulse basis.

A scheme outlined below would have to be used to with a direct-to-microwave generation system. Scheduling hardware would need to be contracted to a third party, along with a fine tune DDS for digital modulation and Doppler a pulse modulator and a dynamic attenuator. (If dynamic waveform play-out is not required, the whole scenario can be modeled in a single AWG file and no changes to the play out order would be required and only the AWG would be required).

When a modulated pulse is not required the scheduling hardware can set the AWG to play out a sine wave of the desired frequency and switch the modulator on and off for the desired pulse duration. The DDS can be set to add Doppler pulse-to-pulse and the attenuator would be used to emulate skin return, azimuth and elevation and the appropriate antenna pattern.



All changes in this set up will be in 7 µs increments as that is the time it takes from strobe to play out. The time can vary a little depending on sample rate, so a fixed sample rate would be recommended to keep the waveform's absolute timing.



Certain combinations of sample rates vs waveform frequency and length will lower the SFDR. If the sample rate changes, the time to waveform play out will change, so when creating waveforms it is important to keep the sample rate fixed, but if that sample rate causes a worse case SFDR as shown in the table, then a more optimal sample rate must be chosen and the strobe timing adjusted to keep the system timing accurate.

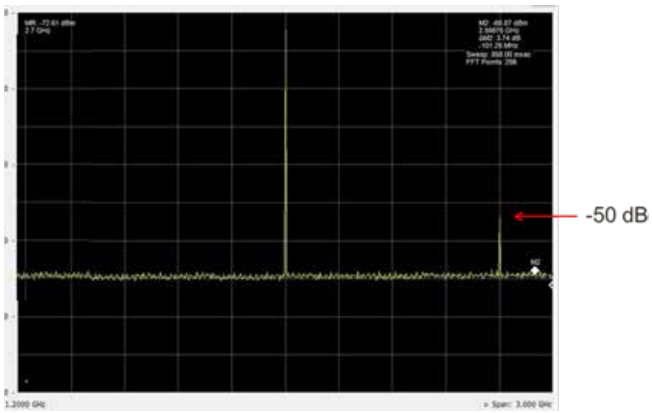
The table below shows worse case SFDR for the Tektronix 70000 AWG when playing out direct to microwave. C band is 45 dBc and X band is 50 dBc. These values are marginal. Ideally, we would like to stimulate the SUT with a SFDR range of over 60 dBc.

	In Band SFDR Performance		Adjacent Band SFDR Performance	
	Measured Across	Specification (typical)	Measured Across	Specification (typical)
100 MHz	DC to 1 GHz	-80 dBc	DC to 10 GHz	-72 dBc
DC to 500 MHz	DC to 500 MHz	-70 dBc	DC to 1.5 GHz	-66 dBc
DC to 1 GHz	DC to 1 GHz	-63 dBc	DC to 3 GHz	-63 dBc
DC to 2 GHz	DC to 2 GHz	-62 dBc	DC to 6 GHz	-60 dBc
DC to 3 GHz	DC to 3 GHz	-60 dBc	DC to 6 GHz	-52 dBc
DC to 5 GHz	DC to 5 GHz	-52 dBc	DC to 6 GHz	-52 dBc
5 GHz to 6 GHz	5 GHz to 6 GHz	-52 dBc	3 GHz to 9 GHz	-40 dBc
6 GHz to 7 GHz	6 GHz to 7 GHz	-42 dBc	4 GHz to 10 GHz	-42 dBc
7 GHz to 8 GHz	7 GHz to 8 GHz	-60 dBc	6 GHz to 12.5 GHz	-52 dBc
8 GHz to 10 GHz	8 GHz to 10 GHz	-50 dBc	6 GHz to 12.5 GHz	-52 dBc
10 GHz to 12 GHz	10 GHz to 12 GHz	-53 dBc	6 GHz to 12.5 GHz	-50 dBc
12 GHz to 13 GHz	12 GHz to 13 GHz	-22 dBc	10 GHz to 15 Ghz	-22 dBc
13 GHz to 14 GHz	13 GHz to 14 GHz	-54 dBc	11 GHz to 16 GHz	-20 dBc
14 GHz to 16 GHz	14 GHz to 16 GHz	-46 dBc	13 GHz to 18 GHz	-38 dBc
16 GHz to 18.5 GHz	16 GHz to 18.5 GHz	-42 dBc	14 GHz to 20 GHz	-30 dBc
18.5 GHz to 20 GHz	18.5 GHz to 20 GHz	-28 dBc	16 GHz to 20 GHz	-24 dBc

The Keysight M8195A direct-to-microwave AWG has similar SFDR with SFDR ranging from 42 dBc to 53 dBc across the main microwave radar bands.

Direct to IF

Another approach is to use a COTS up-converter such as the Giga-tronics GT-ASGM18A. This allows the AWG's to generate to an IF at a lower frequency, ensuring the SFDR will be in excess of 60 dBc. Also the IF input is banded within +/-500 MHz so if an appropriate sample rate is chosen, IF SFDR can be greater than 80 dBC for both the Tektronix 70000 AWG and the Keysight M8190A. See example:

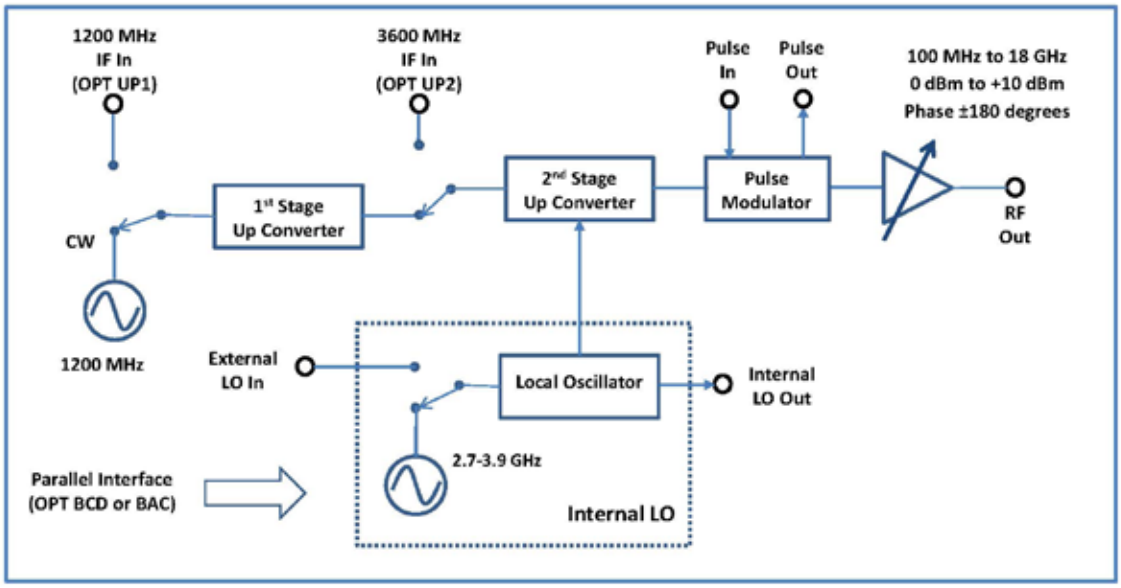


The Tektronix 70000 AWG centered at 1.2 GHz IF. The Keysight M8190A, has similar SFDR performance, but the harmonic is 40 dBc.

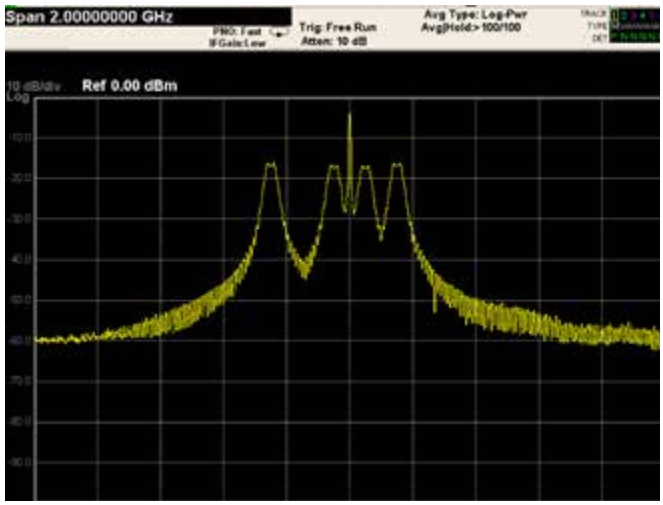
Consider the Giga-tronics GT-ASGM18A block Diagram. The AWG can be used to generate an IF signal at 1.2 GHz or 3.6 GHz. If modulation-on-pulse is not required the GT-ASGM18A can either be fed by a CW from the waveform generator or a higher fidelity 1200 MHz CW signal can be switch in. The pulse modulator can be directly controlled and frequency and amplitude switching can be achieved in less than a microsecond.

The Giga-tronics GT-ASGM18A also has a DDS that can be configured to generate on-demand modulated data pulse.

GT-ASGM18A Simplified Block Diagram

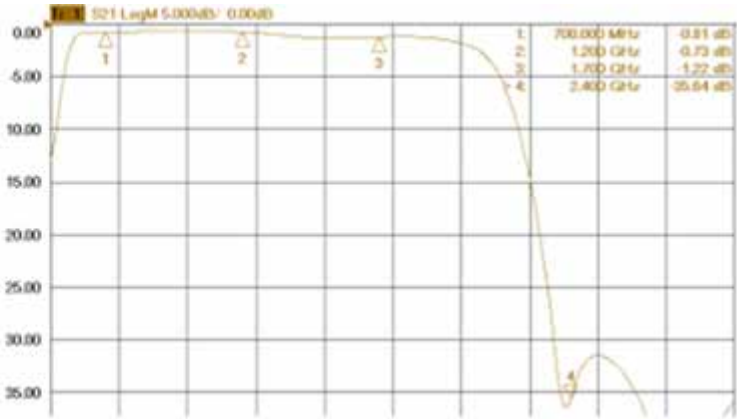


The following plot shows two PRI's both centered at 1.2 GHz. The first group of pulses is modulated and hop within the IF of the up-converter, the second group is a staggered CW PRI.



An optional 90 dB attenuator can be added to the Giga-tronics GT-ASGM18A allowing amplitude changes in 0.25 dB increments. The GT-ASGM18A also has a COTS AWG compatible control, eliminating the need for a waveform scheduler.

The output fidelity of the AWG can also be improved using readily available COTS filters from Mini-circuits, and other vendors.



Conclusions

Summary of system specifications

Specifications	Direct to IF (ASG + AWG)	Direct to RF
Non-MOP frequency and pulse switching	< 1 µs	< 1 µs to 7 µs (depending on AWG choice)
MOP Switching	< 1 µs to 7 µs (depending on AWG choice)	< 1 µs to 7 µs (depending on AWG choice)
Frequency Range	< 18 GHz	< 18 GHz
Power Flatness	< ± 0.5 dB	< ± 2 dB
IF Dynamic Range	> 60 dB	42 to 53 dBc
RF Dynamic Range (Attenuation Range)	90 dB (0.25 dB steps)	42 to 53 dBc

Direct to Microwave
- Requires a (non-COTS) custom waveform scheduling system.
- Requires a custom (non-COTS) connectorized RFIU system with DDS, Mixer, Attenuators and a Pulse Modulator.
- Direct to microwave increases the likelihood of false targets with marginal SFDR in the 45 dBc to 50 dBc range.

Direct to IF
- Simplified control model using the Giga-tronics GT-ASGM18A.
- Improved spectral purity with SFDR being better than 60 dBc.
- Built in DDS, pulse mod and attenuators.
- Simple filtering using COTS filters.

AWG Choice
- Tektronix 70000 AWG has 6 µs waveform switching speed, Keysight Technologies and Tabor Electronics are less than 1 µs.
- Tektronix and Tabor Electronics have only 8 bits of dynamic waveform selection, Keysight Technologies has 19 bits.
- Keysight Technologies M8190A has shown improved phase noise when used in a Giga-tronics chassis.

go-asg.gigatronics.com
Phone: +1 925.328.4650
Email: asg-info@gigatronics.com