RTSA Version 3
Demo Board
User Manual

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Tektronix

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www.tektronix.com
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- Worldwide, visit *www.tektronix.com* to find contacts in your area.

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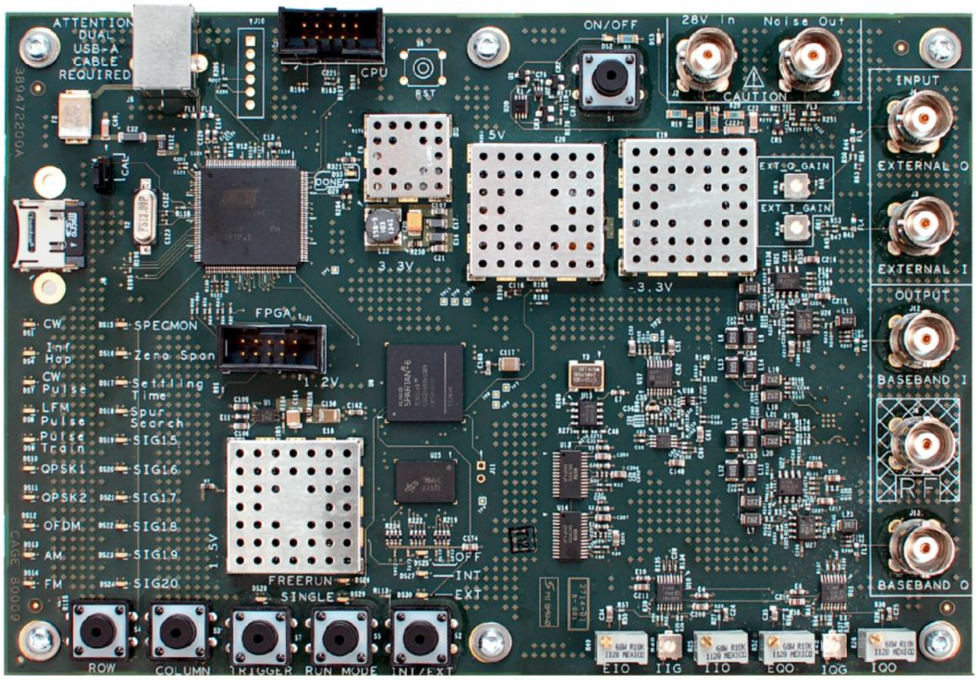
Preface

The Tektronix RTSA Version 3 demo board provides signals that you can use to demonstrate key features of Tektronix series spectrum analyzers.

The RTSA Version 3 demo board supersedes earlier versions of RTSA demo boards and is significantly different from the version 1 and version 2 boards.



This board was designed to:

- Make some of the waveforms more useful when demonstrating RSA features.
- Add more waveforms to use for demonstrating newer measurements on the RSA.
  - LFM pulses, for IPR demonstrations.
  - AM and FM waveforms for demonstrating audio analysis.
  - A basic OFDM signal that could be used “out of the box”.
  - Waveform(s) for demonstrating DPX zero span and DPXOgram displays.
  - Settling time demonstration waveform(s).

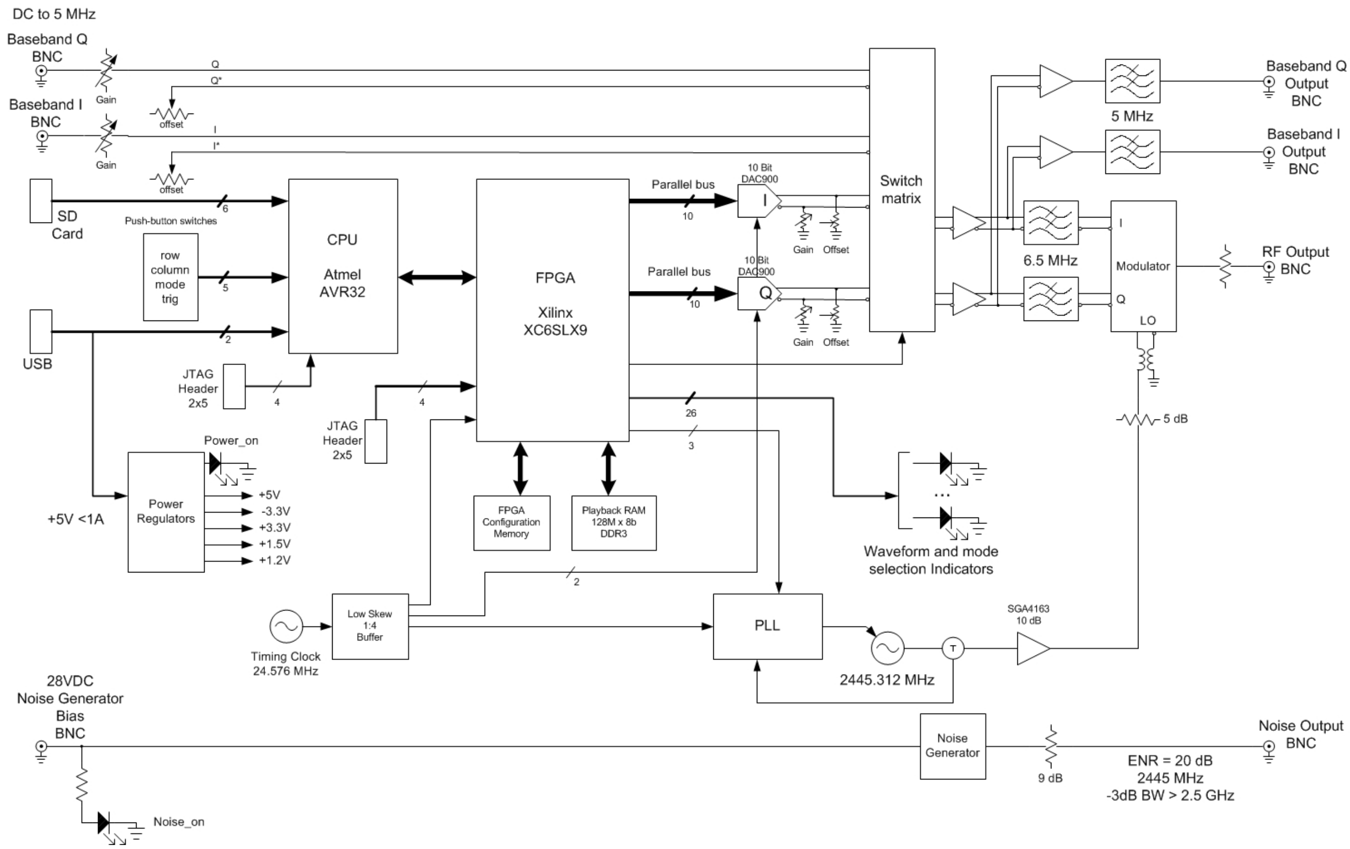
- Add a noise source that can be used directly with the RSA for noise figure testing demonstrations.
- Allow for future enhancements, additional waveforms.
  - Extra waveform slots – create your own waveforms.
  - External I/Q modulation inputs.
  - Ability to modify built-in waveforms without sending the unit back.

Preventing electrostatic damage

Electrostatic discharge (ESD) can damage components on the demo board. To prevent ESD:

- Do not touch exposed components or connector pins unless you are using ESD protective measures, such as wearing an antistatic wrist strap.
- Handle the demo board as little as possible.
- Do not slide the demo board over any surface.
- Transport and store the demo board in a static-protected bag or container.

Board description



User interface

The version 3 demo board uses 5 push button switches to select the operating mode and the waveforms. LEDs are used to indicate the selected waveform and operating mode.

Waveform generation

The previous RSA demo boards used an FPGA to algorithmically create I and Q signals fed to the modulator. Since modifying the waveforms always required a “return to the factory”, adding new signals or changing signals was problematic. The version 3 demo board implements the most useful signals (except CW, Inf. Hop, and RF Pulse) found on the version 2 demo board as I and Q samples, which are then “played back” through DACs to the modulator. In other words, the board is a “mini-AWG” with RF modulation capability.

The CW, Inf. Hop, and RF Pulse signals are implemented in an FPGA, to simplify certain aspects of those signals.

Waveform storage

All waveforms are stored in binary files on a microSD card to make the waveforms easy to modify without turning the board into a USB memory device (prohibited in some secure areas). Modifying the waveforms is as simple as removing the microSD card, copying new waveforms onto the card via PC and USB adapter, and re-installing the microSD card.

Waveforms which are stored as part of the FPGA algorithms (CW, Inf. Hop, RF Pulse) do not have I and Q waveform files on the microSD card. However, the waveforms can be modified by adding waveforms to the microSD Card with appropriate filenames.

Internal waveform memory

Waveforms on the microSD card are packed in a binary format, which is then copied directly to SDRAM when a new waveform is selected. A waveform is made up of 1 to 64 segments, each of which can be repeated up to 4 billion times. This allows for very long waveforms to be created without requiring immense amounts of SDRAM.

Baseband I and Q capabilities

In addition to the I and Q input ports on the Version 1 and 2 demo boards, the version 3 board also has I and Q outputs. Each of these outputs can also be used for baseband LF signals (such as audio tones).

Excessive LO leakage was seen on some version 1 and version 2 demo boards. To correct this, I & Q gain and I & Q offset adjustments are including in the version 3 board. Refer to the Adjustment section for details on how to minimize LO leakage through the modulator.

Sample clock division

The basic sample rate for both I and Q sample streams is 24.576 MHz. For each waveform this sample rate can be divided by two up to 10 times (24.576 MHz / 2^10 = 24 kHz). Since the board does not have a variable-bandwidth reconstruction filter, this means that copies (alias signals) are present at the output for all but the base 24.576 MHz sample rate. This should not be a problem, since the demonstration procedure for the various waveforms reduces the acquisition bandwidth (“Spans down on the signal”) providing the necessary reconstruction filtering within the RSA itself.

An easy way to think about this is that the demo board always outputs a signal with 10 MHz bandwidth, but in cases where the sample clock is divided only part of that bandwidth is the “good” part of the signal.

USB power source

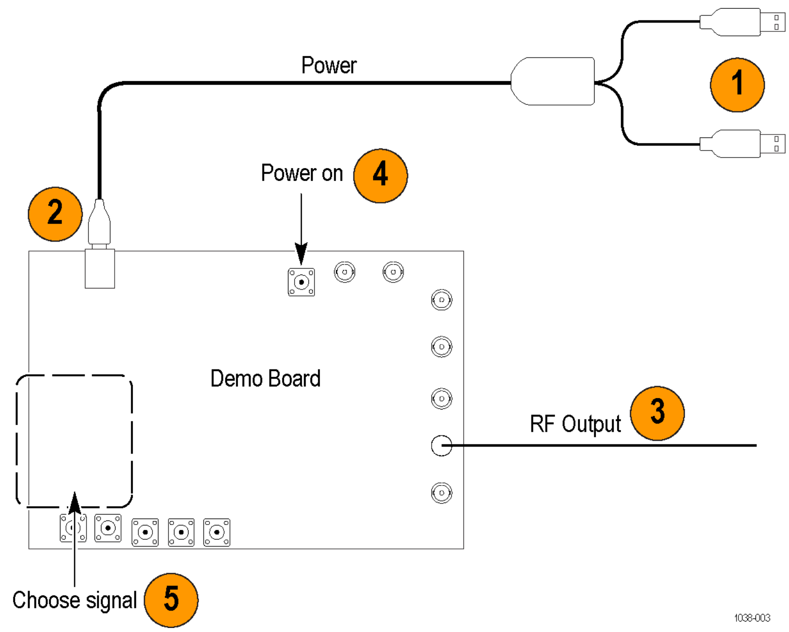
The version 3 demo board requires power from two USB 2.0 ports (total of ~750 mA at 5 Volts). The Y-cable provided must have both USB-A plugs to be connected to powered USB 2.0 ports before connecting the USB-B plug to the demo board and powering on. USB ports may become disabled when excessive power is drawn from the port, depending on the system implementation.

And, of course, the demo board may also be powered by an external 5 V supply capable of delivering at least 750 mA. A USB wall-charger for phones is a good substitute.

Specifications

Characteristic			Description
Inputs	I and Q baseband input		0-5 MHz, 1 V_{p-p}, 50 Ω
	Noise source bias input		0V (disable) or +28V (enable), 17 mA nominal
	USB-B power input		800 mA minimum
Outputs	RF output	Amplitude	-5 dBm ±1 dBm into 50 Ω
		Frequency	2.445312 GHz nominal
		Frequency Accuracy	±100 ppm (-10 °C to +55 °C), ± 20 ppm nominal at 20 °C
		Modulation BW	10 MHz nominal
	Noise output		20 dB ENR (10 MHz to 3 GHz), 50 Ω
	I and Q baseband outputs		DC – 5 MHz, 3 dB bandwidth ±100 mV nominal (-10 dBm) into 50 Ω Output levels are dependent on EXT I/Q INPUT levels when EXT is selected.
Waveform Storage			20 waveforms 1 to 64 repeatable segments per waveform Maximum 32 Msamples per waveform, not including segment repetitions

Installation



1. Plug the dual USB A connectors from one end of the “Y” USB cable into two USB ports of the RSA or your PC. Make this connection before plugging the other end of the cable in to the USB B connector on the Demo board.
2. Plug the single USB B connector into the B-connector on the Demo board.
3. Use a 50 Ω BNC cable to connect the RF OUT of the Demo board to the RF IN connector on your RSA Signal Analyzer.

NOTE. *This connection may require an N-to-BNC adapter (103-0045-XX).*

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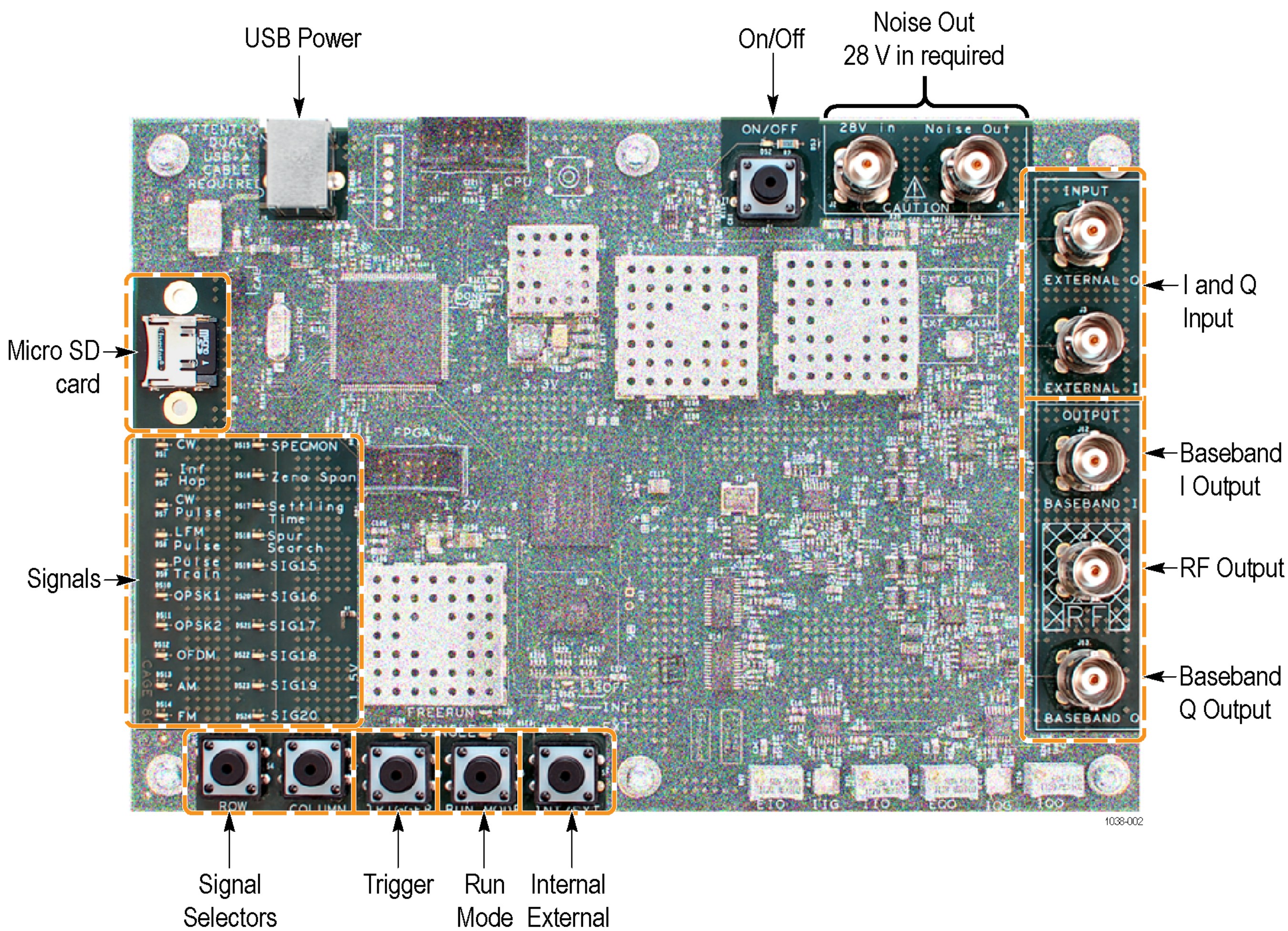
4. Press the ON/OFF button on the demo board. The red LED near this button will light.

NOTE. *If you turn on the demo board, and just one of the two USB A connectors is attached to the RSA or PC, you may cause an over-current limit (>500 mA) condition. This can generate an error message on the PC, and requires a system reboot to clear.*

Operation



USB Power
On/Off
Noise Out
28 V in required
Micro SD card
Signals
I and Q Input
Baseband I Output
RF Output
Baseband Q Output
Signal Selectors
Trigger
Run Mode
Internal External
1038-002

Signal indicators

Upon initial power-on, the top four Signal LEDs in each column alternately show the FPGA version and FW version (coded in Hex format). The left column is MS nibble, row 1 is LSB, row 4 is MSB.

After ~4 seconds, a single LED indicates the selected waveform.

Controls

ON/OFF

Power Switch (LED is Red when power is ON). Controls power to the board.

ROW/COLUMN

Selects desired signal, as indicated by the LEDs in the SIGNALS section.

- ROW – pressing this button repetitively cycles through waveform selection rows 1-10, moving one row per button press.
- COLUMN – pressing this button alternates the selected column.

Waveform loading begins ~2 seconds after selection. The signal selection LED blinks at a rate of about 1 Hz while the waveform is loading from the MicroSD card into RAM.

Signal output at RF Out initiates as soon at waveform loading is complete. (The selected signal LED will be constant ON.)

INT / EXT

Selects the modulation source.

- INT – Selects internal signals / modulation (internal waveforms).
- EXT – Selects EXTERNAL I/Q modulation inputs.
- OFF – Output is switched OFF.

RUN MODE

Selects how the waveforms are output.

- FREERUN – Waveforms are continuously output.
- SINGLE – Provides a single instance / pulse output of the waveform. The TRIGGER control generates the single instance.

  When in SINGLE mode, the TRIGGER LED blinks at about a 1 Hz rate to indicate it's waiting for a trigger event.

TRIGGER

Pressing this button generates a single waveform instance of the selected waveform at the RF output when the Run Mode is set to SINGLE.

Inputs - Outputs

USB Power (USB B Connector)

Connect the supplied USB “Y” cable to two USB A ports on an RSA, PC, or USB HUB.

This is compatible with USB 1.x, 2.x, and 3.0.

Used for power only (and future remote control capabilities).

28V IN / NOISE OUT

This is for use with the RSA5100 Series or RSA6100 Series instruments with Option 14 (Gain and Noise Figure Measurements).

Connect the 28V IN to the 28 V Output BNC located on the rear panel of an RSA5100 Series or RSA6100 Series instrument (draws ~17 mA). The LED lights BLUE when the 28V source is enabled from the RSA instrument.

Connect the NOISE OUT to the DUT. Refer to specification section (in this document) for the output level. Refer to the RSA instrument’s documentation for noise source usage.

EXTERNAL I / Q INPUT

Use these inputs when you want to create your own modulation at the RF OUT port.

These baseband I/Q inputs drive the RF modulator directly when EXT is selected, providing the modulation on the 2.4453GHz carrier.

The INT / EXT control button must be set to EXT.

Refer to specification section (in this document) for the input requirements.

BASEBAND I / Q OUTPUT

Provides I and Q output and is always enabled, regardless of the INT/EXT setting. Refer to specification section (in this document) for the output specifications.

RF OUT

Provides the RF signal output. Refer to specification section (in this document).

Connect this BNC to your RSA analyzer input using a 50 Ω cable.

Modulation and waveforms

The Demo board waveforms have two groups, External and Internal modulations.

- External modulations
  - The user provides the baseband modulation via cables to the EXTERNAL I/Q inputs.
  - The DACS are set for zero output and are not changed.
  - Modulation switches are switched to external.
- Internal modulations

  These are the Standard Waveforms. *Standard waveforms* on page 11

  - FPGA-based

    These are coded in the FPGA
  - ARB memory
    - These waveforms are stored in MicroSD card memory in proprietary binary format.
    - Stored waveforms are loaded from SD card to RAM, then playback commences.
    - Waveforms may be changed / overwritten on the MicroSD card, but must conform to the proprietary file standard. Contact your Tektronix AE for details.

Standard waveforms

The list below indicates the standard waveforms by signal number. Waveforms 1, 2, 3, and 13 are generated by the FPGA.

NOTE. *Waveforms 1, 2, 3, and 13 can be overridden by the presence of the relevant bin file on the Micro SD Card (e.g. 01.bin, 02.bin, 03.bin, and/or 13.bin)*

Waveforms 1-13 are general-purpose, and are intended to match the waveforms expected in the demo guides. Waveforms 15-20 are expansion slots used primarily for standards-based waveforms. At the time of initial board release waveforms 15 and 16 are allocated to P25 demo waveforms. Waveform 8 was originally designed to be an OFDM signal independent of standard, but 802.11p was chosen for the description of this waveform.

Refer to the RSA306 demo guide (071-3330-xx) for details on how to use these signals in demonstrations of RSA306 features and capabilities.

Table 1: List of signals

WFM #	Signal Name		
1	CW	11	SPECMON
2	Infrequent Hop	12	Zero Span
3	CW Pulse	13	Settling Time
4	LFM Pulse	14	Spur Search
5	Pulse Train	15	Waveform 15 (P25 C4FM)
6	QPSK1	16	Waveform 16 (P25 HCPM)
7	QPSK2	17	Waveform 17
8	OFDM (802.11p)	18	Waveform 18
9	AM	19	Waveform 19
10	FM	20	Waveform 20

Waveforms are selected by pressing the ROW and COLUMN buttons respectively.

Waveform details

This section provides details about each signal available on the Demo board.

CW (Waveform 1)

- Continuous 2445.312 MHz sine wave output, -5 dBm
- Q DAC is fixed at zero volts.

INFREQUENT HOP (Waveform 2)

This waveform is a -5 dBm CW signal centered at 2445.312 MHz.

Every 1.28 seconds, the frequency will hop to 2458.2 MHz for approximately 155 µs.

Use this signal to demonstrate DPX (vs. spectrum “Max Hold”), Spectrogram, frequency vs. time, and Frequency Mask Trigger.

- Starting frequency: 2445.312 MHz
- Hop frequency: 2458.2 MHz (+12.9 MHz approximate)
- Overshoot peak deviation: 2.83 MHz (approximate)

NOTE. *The damped waveform should peak at 2460.4 MHz positive, 2442.3 MHz negative.*

- Overshoot damping time constant: ~15 µs
- Hop duration: ~155 µs
- Cycle period: 1.28 sec.

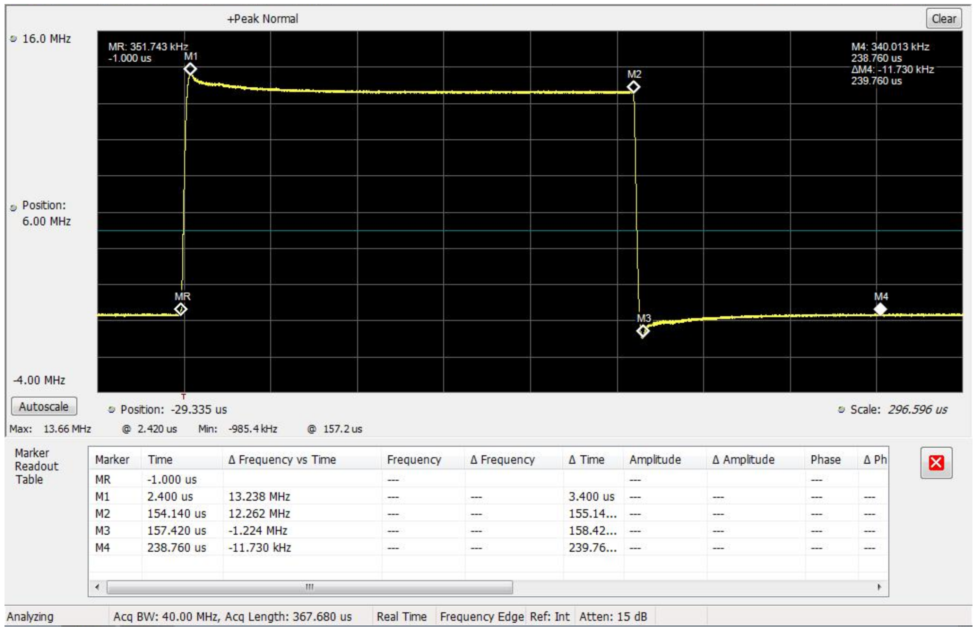


Figure 1: INF HOP Frequency vs. Time Display with markers

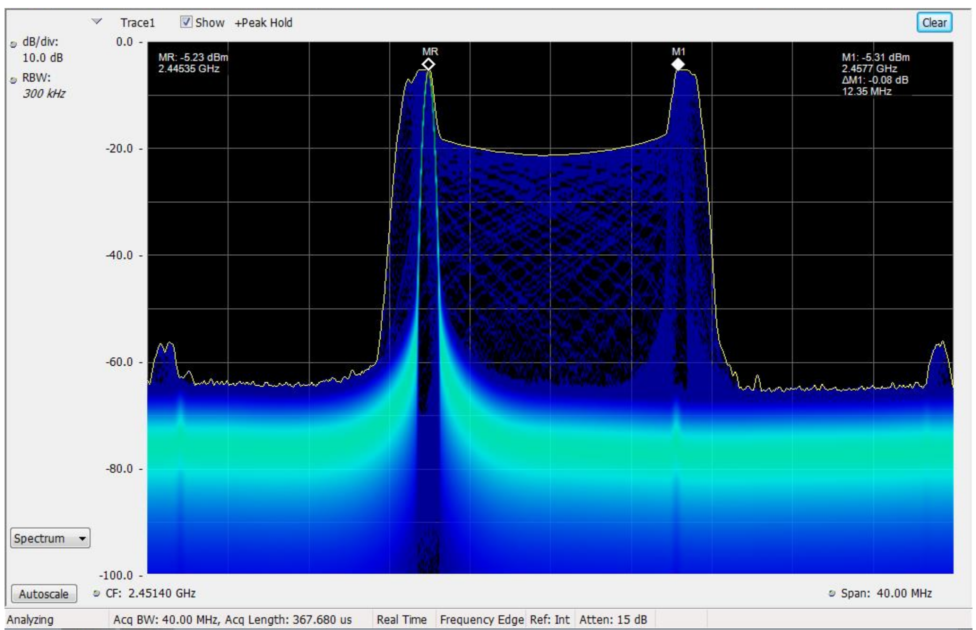


Figure 2: INF HOP signal DPX display

CW PULSE (Waveform 3)

This waveform is a pulsed CW signal, centered at 2445.312 MHz.

PRI is 100 µs - Pulse ON duration is 10 µs, OFF duration is 90 µs.

Use this waveform to demonstrate RF power trigger, Pulse measurements (option 20).

- Carrier Wave: 2445.312 MHz
- Pulse on width: 10 µs
- Pulse off width: 90 µs
- Pulse ON power: -5 dBm
- On/OFF ratio: >40 dB
- Risetime, falltime: 60 ns

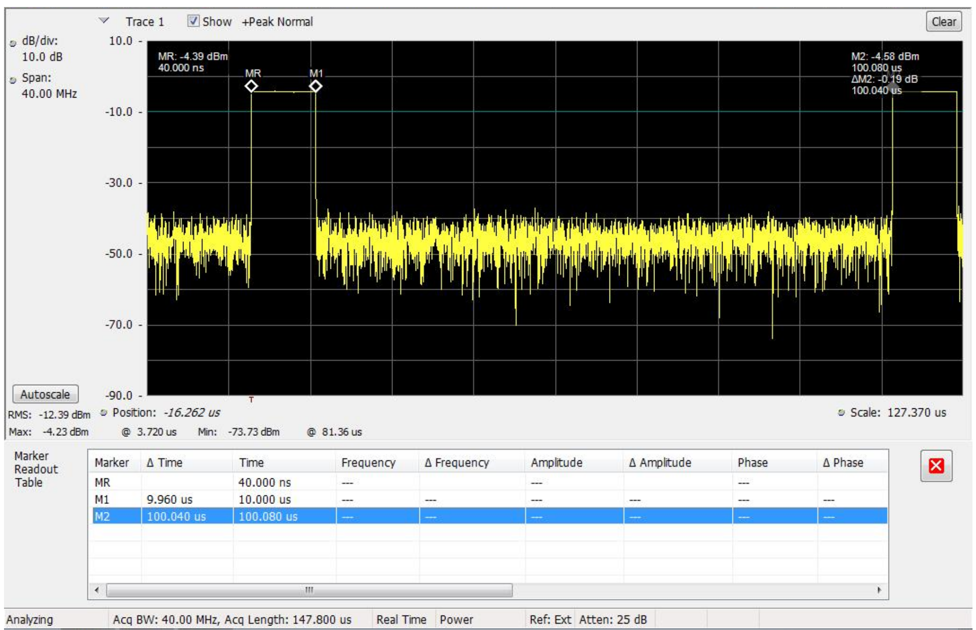


Figure 3: CW Pulse waveform

LFM PULSE (Waveform 4)

This waveform is a Linear Frequency Modulated RF Pulse waveform, centered at 2445.312 MHz.

PRI is 250 µs -Pulse on duration is 25 µs, off duration is 225 µs.

While the pulse is ON, the frequency of the signal is varied linearly from 2440.312 MHz to 2450.312 MHz.

Use this waveform to demonstrate RF power trigger, Frequency Mask trigger, Frequency vs. Time measurement, Pulse measurements (option 20)

- Carrier Wave: 2445.312 MHz
- Linear chirp: 10 MHz sweep
- PRI: 250 µs
- Pulse on width: 25 µs duty cycle is 10%

- Pulse off width: 225 µs
- Pulse ON power: -5 dBm
- On/OFF ratio: > 40 dB
- On/OFF ratio: > 40 dB
- Frequency deviation: ±5 MHz about 2445.312 MHz

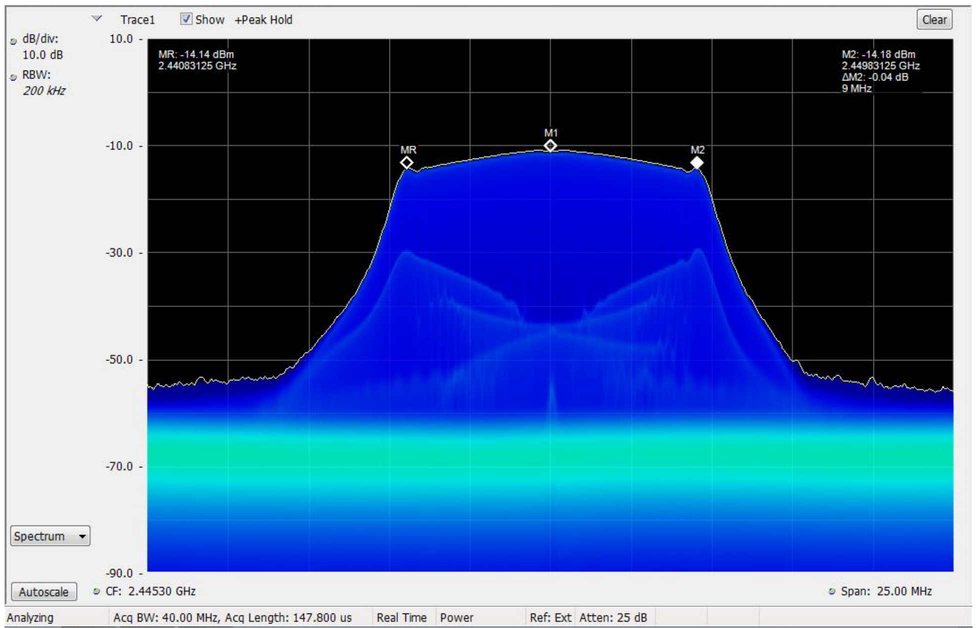


Figure 4: LFM Pulse spectrum

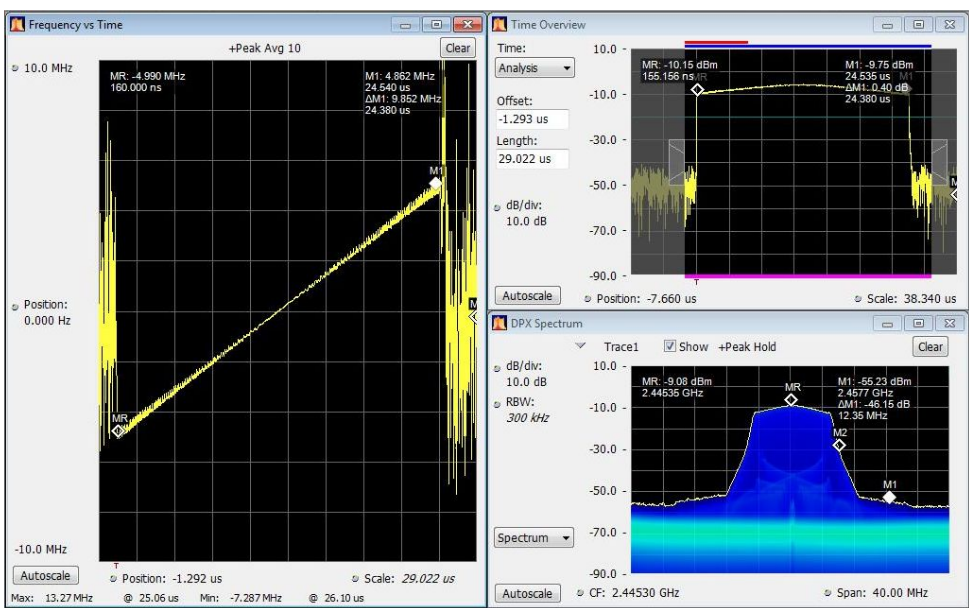


Figure 5: LFM frequency vs. time plot

PULSE TRAIN (Waveform 5)

Two 100-pulse patterns separated by 5 ms and repeated once every second. Each pulse train consists of 100 CW pulses with a full amplitude I DAC output.

Pulse Pattern #1: 100 1 µs pulses at a fixed PRI of 100 µs. 51st pulse is -20 dB down (i.e. a runt).

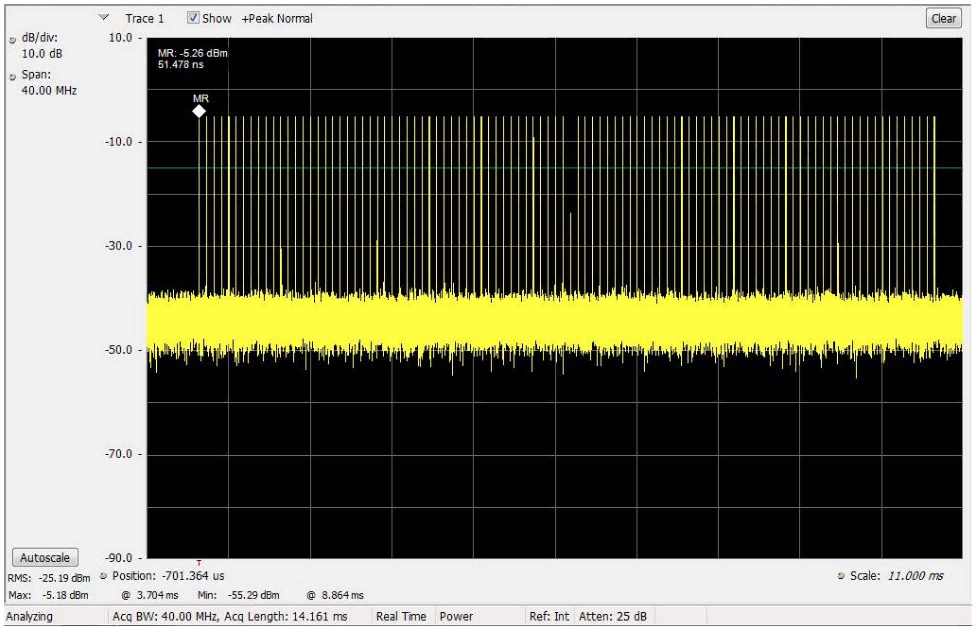


Figure 6: Pulse pattern #1

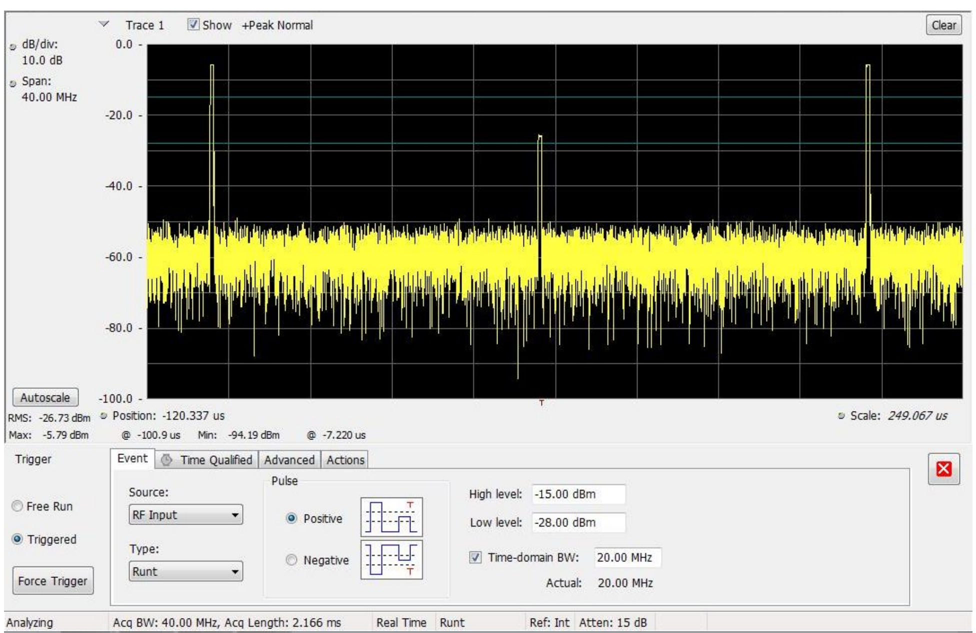


Figure 7: Close up of the "runt" pulse in the middle of pulse pattern #1

Pulse Pattern #2: First pulse is 20 µs wide and the remaining 99 pulses are 1 µs wide. PRI ramps from 96 µs to 103 µs and then back down to 96 µs.

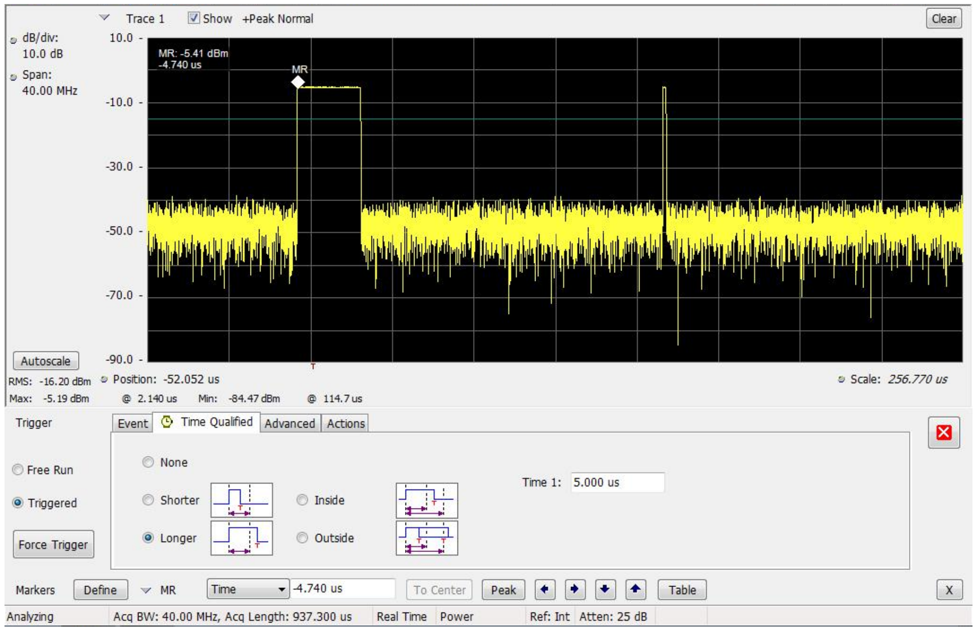


Figure 8: Pulse pattern #2, long pulse

Use this waveform to demonstrate runt trigger, time qualified triggers, Pulse measurements (option 14).

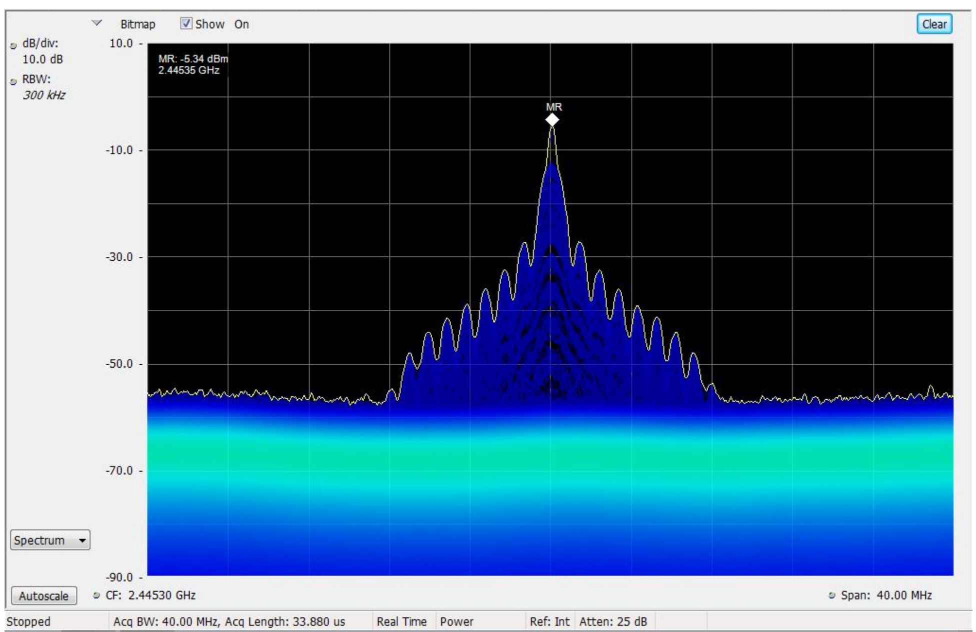


Figure 9: Pulse pattern spectrum

QPSK1 (Waveform 6)

Pre-programmed QPSK waveform (QPSK1).

- Carrier Wave: 2445.312 MHz
- Symbol rate: 3.072 MS/S
- Pattern: PRBS9
- Filter: RRC, alpha=0.33
- EVM: < 5%

Noise bandwidth used for EVM calculation: 1 kHz to 1.5 MHz.

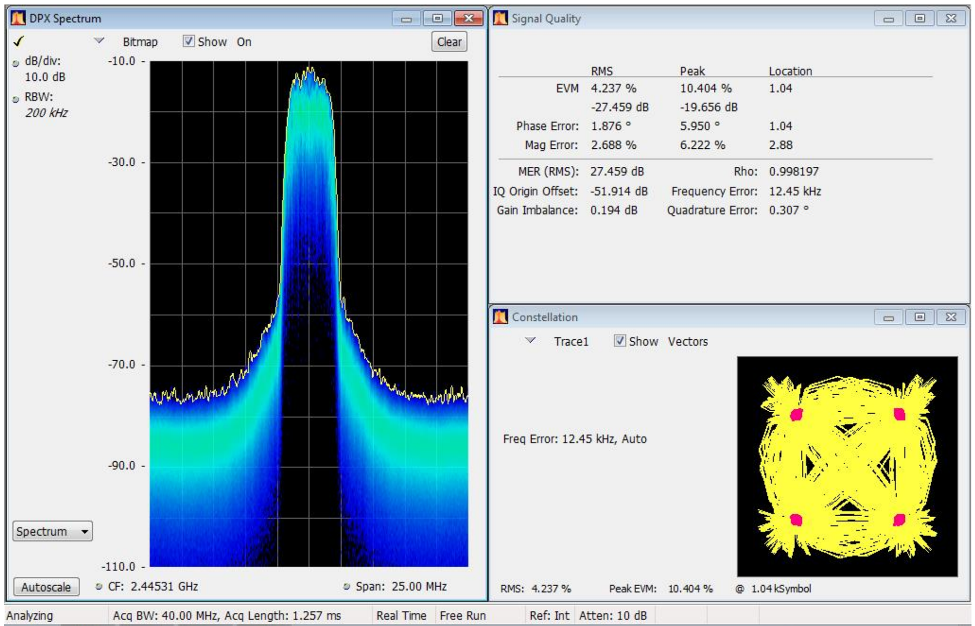


Figure 10: QPSK1 waveform

QPSK2 (Waveform 7)

Pre-programmed QPSK waveform (QPSK2).

- Carrier Wave: 2445.312 MHz
- Symbol rate: 3.84 MS/S
- Pattern: PRBS11
- Filter: RRC, alpha=0.22
- EVM: < 5%

Noise bandwidth used for EVM calculation: 1 kHz to 2 MHz.

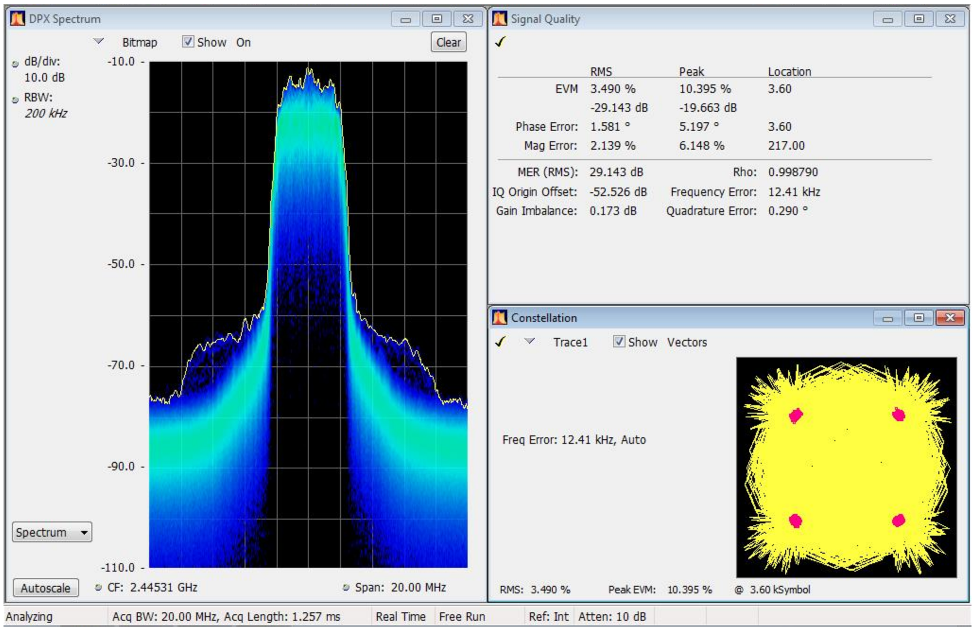


Figure 11: QPSK2 signal

OFDM (Waveform 8)

802.11p standard 10 MHz wide OFDM packet that repeats every 2 ms.

- Carrier Wave: 2445.312 MHz
- OFDM EVM, RMS all: better than -23 dB

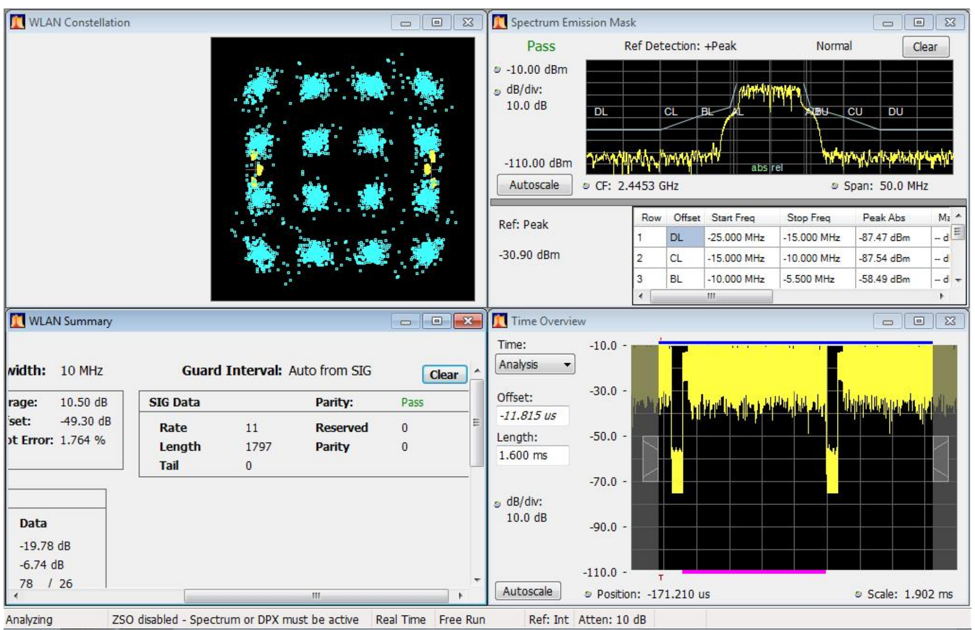
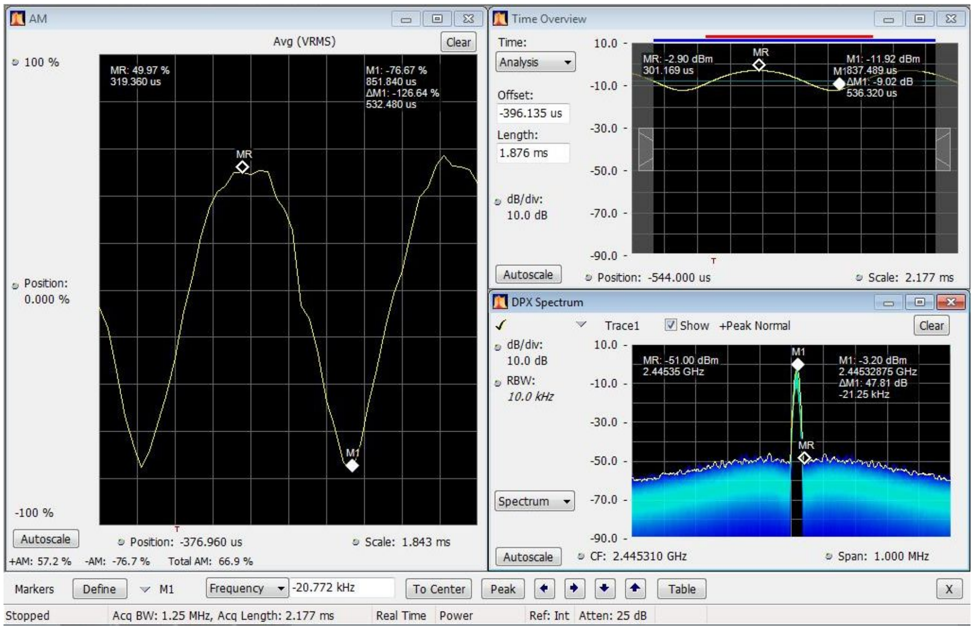


Figure 12: OFDM 802.11p waveform

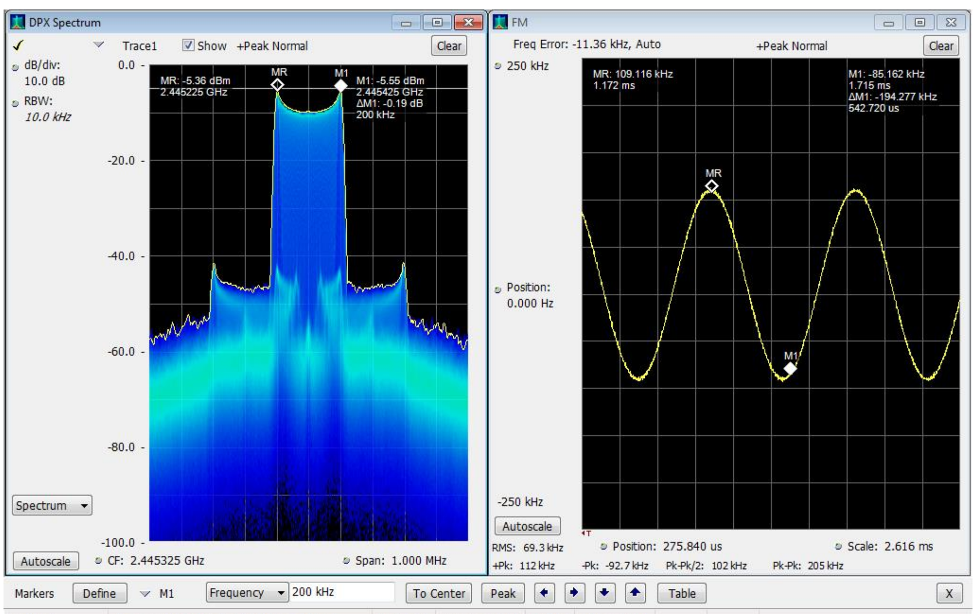
AM (Waveform 9)

- Carrier Wave: 2445.312 MHz
- Modulation rate: 1.00 kHz
- Depth-of-modulation: 50 %



FM (Waveform 10)

- Carrier Wave: 2445.312 MHz
- Modulation rate: 1.00 kHz
- Deviation: 100 kHz



SPECMON - INTERFERENCE (Waveform 11)

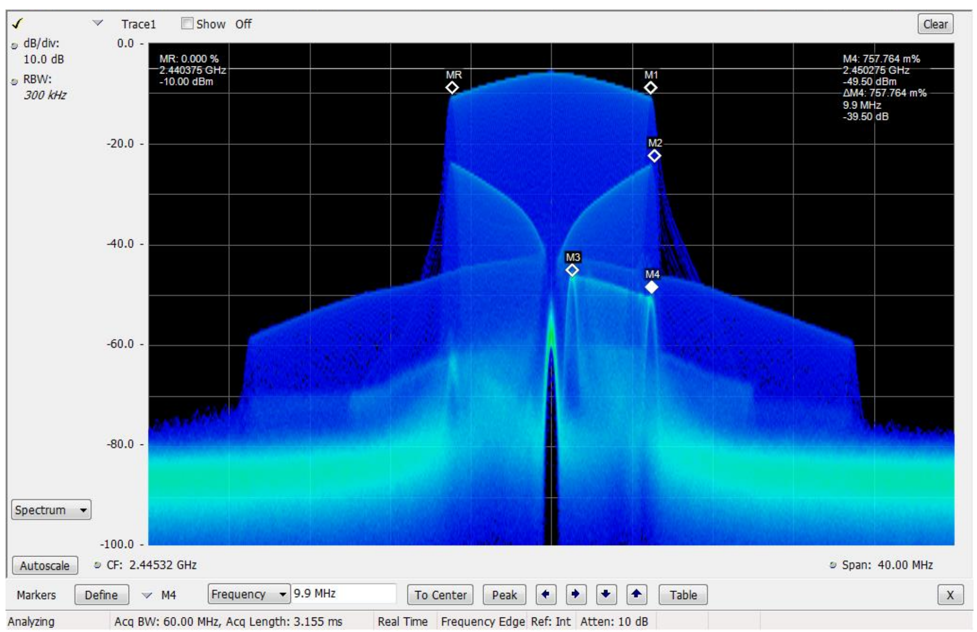
Continuous 10 MHz LFM Pulse superimposed with a FM signal -40 dB down.

LFM Pulse Description:

- Carrier Wave: 2445.312 MHz
- Linear chirp: 10 MHz sweep
- Chirp on width: 1 ms
- Chirp off width: ~0
- On/OFF ratio: > 40 dB
- Frequency deviation: ± 5 MHz about 2445.312 MHz

FM Description:

- Carrier Wave: 2445.312 MHz
- Frequency Offset: 3 MHz
- Modulation rate: 1.00 kHz
- Deviation: 2 MHz



ZERO SPAN (Waveform 12)

Zero Span cycles through four waveforms approximately every 125 µs. Each waveform is played for roughly 25 µs. Resulting PRI is about 150 µs. The waveforms in order are a 10 MHz wide LFM pulse, a 10 MHz QPSK PRBS9 waveform, an AM modulated waveform with a 1 MHz modulating frequency at 10% depth, and a FM waveform with a 1 MHz modulating frequency and a 50% modulation index.

LFM Pulse Description:

- Carrier Wave: 2445.312 MHz
- Linear chirp: 10 MHz sweep
- Chirp on width: 25 µs
- Frequency deviation: ± 5 MHz about 2445.312 MHz

QPSK Waveform Description:

- Carrier Wave: 2445.312 MHz
- Symbol rate: 3.072 MS/S
- Pattern: PRBS9
- Filter: RRC, alpha=0.33
- EVM: < 3%

AM Waveform Description:

- Carrier Wave: 2445.312 MHz
- Modulation rate: 1.00 MHz
- Depth-of-modulation: 10 %

FM Waveform Description:

- Carrier Wave: 2445.312 MHz
- Modulation rate: 1.00 MHz
- Deviation: 500 kHz

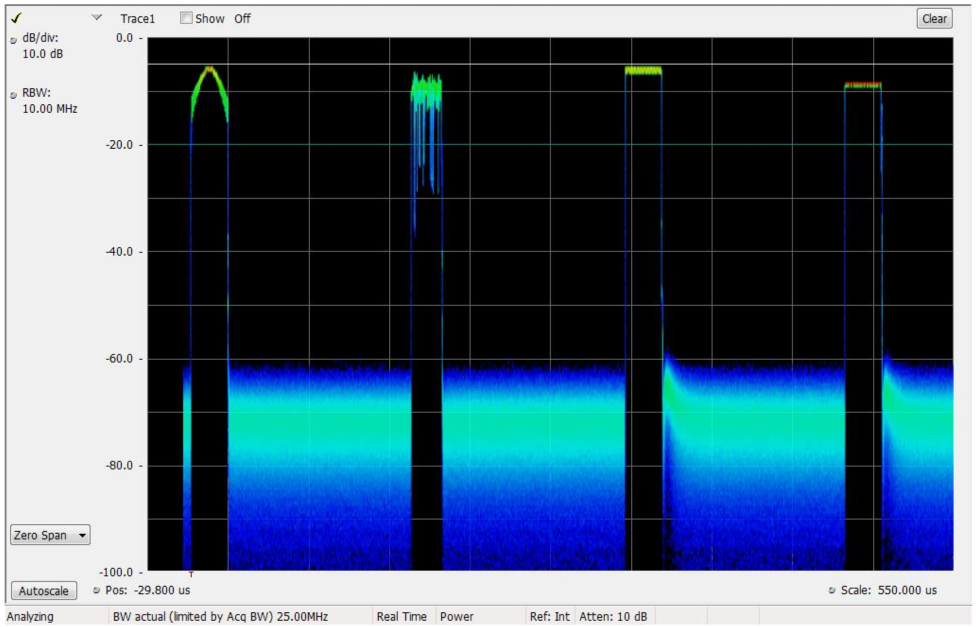


Figure 13: Zerospan waveform

SETTLING TIME (Waveform 13)

This signal is the same as Infrequent Hop (Waveform 2) signal described above.

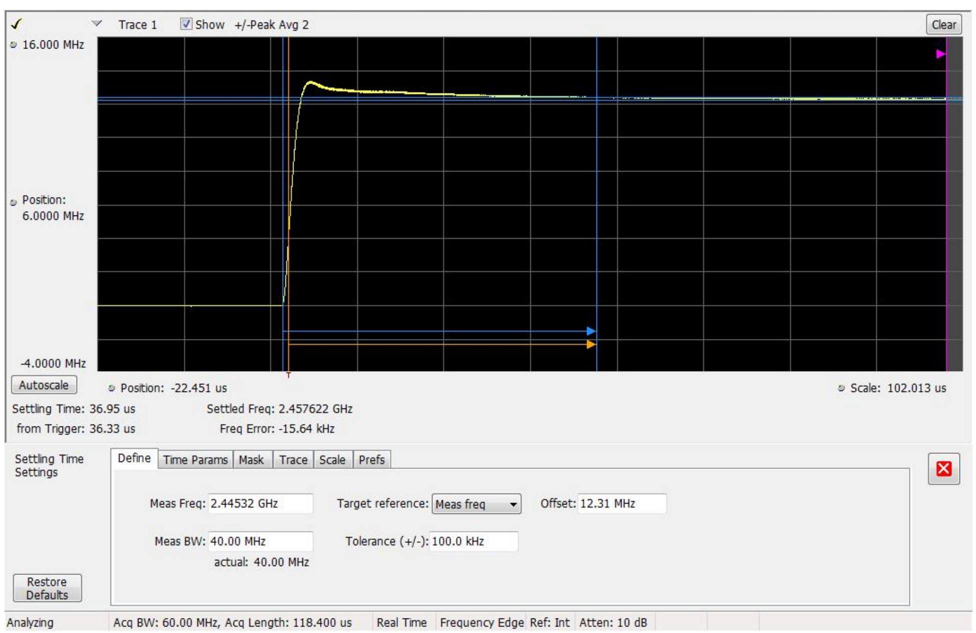


Figure 14: Settling time

SPUR SEARCH (Waveform 14)

Two-tone waveform with tones at +1 MHz and +4 MHz relative to the center frequency of 2445.312 MHz

- 4 MHz tone is -50 dB down relative to 1 MHz tone.

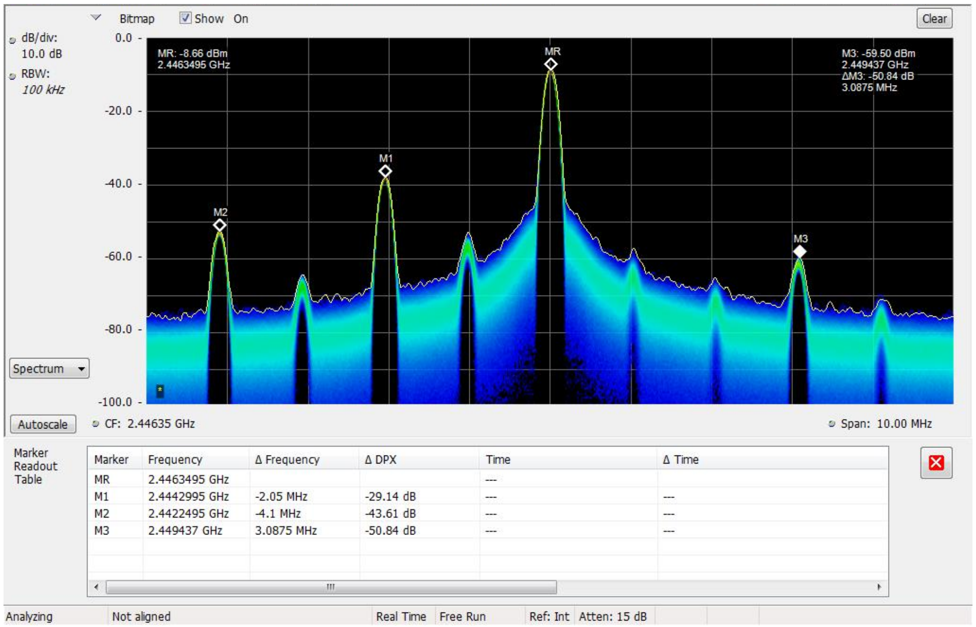


Figure 15: SPUR search

P25 C4FM (Waveform 15)

P25 standard continuous C4FM signal with a bandwidth of 12.5 kHz.

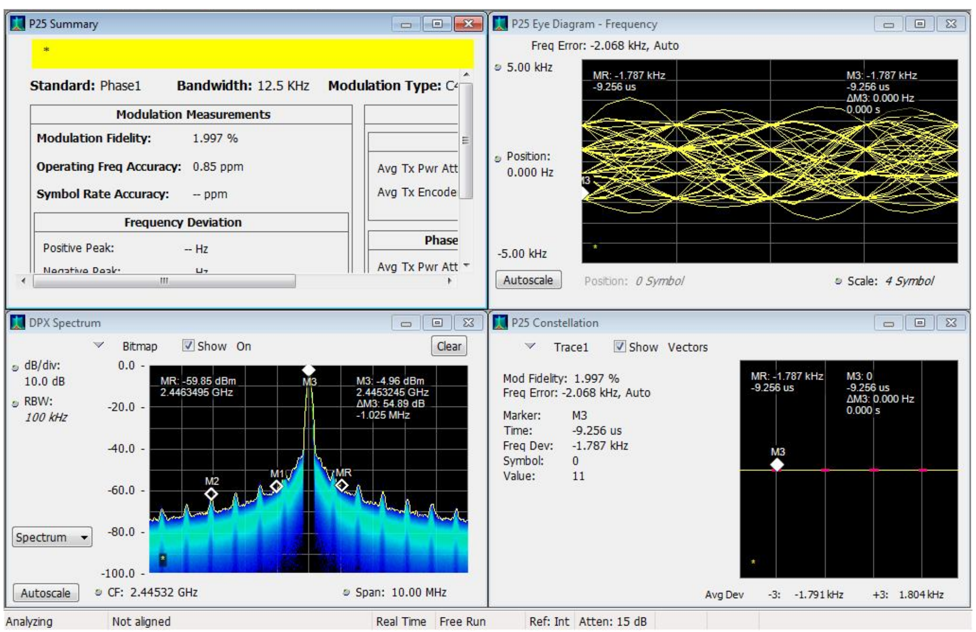


Figure 16: P25 C4FM waveform

P25 HPCM (Waveform 16)

P25 standard continuous HCPM (Inbound) signal with a bandwidth of 12.5 kHz

- Symbol rate is 4800 Symbols/sec.
- Modulation fidelity for P25 HPCM ~24%

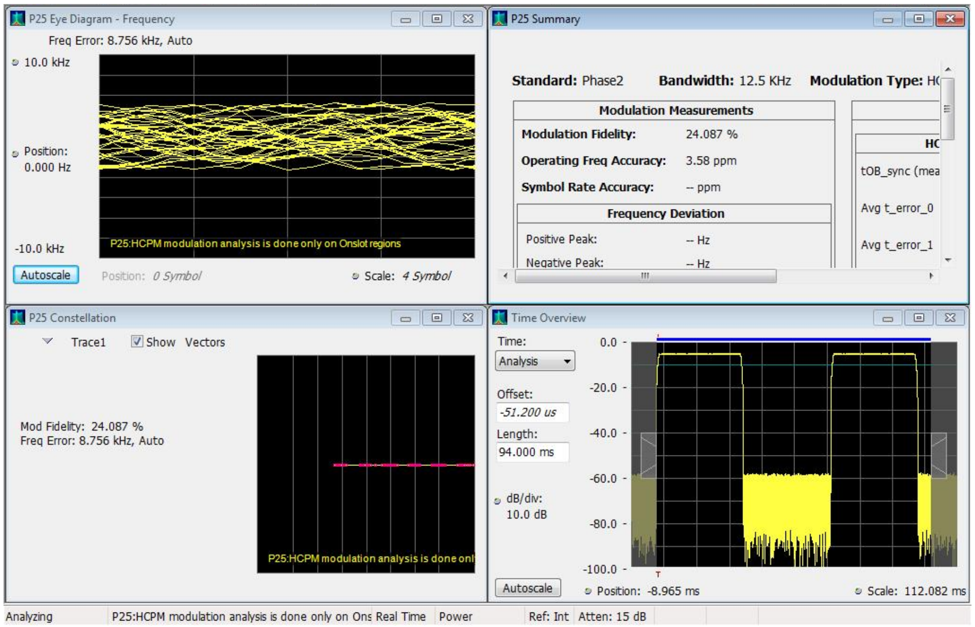


Figure 17: P25 HPCM waveform

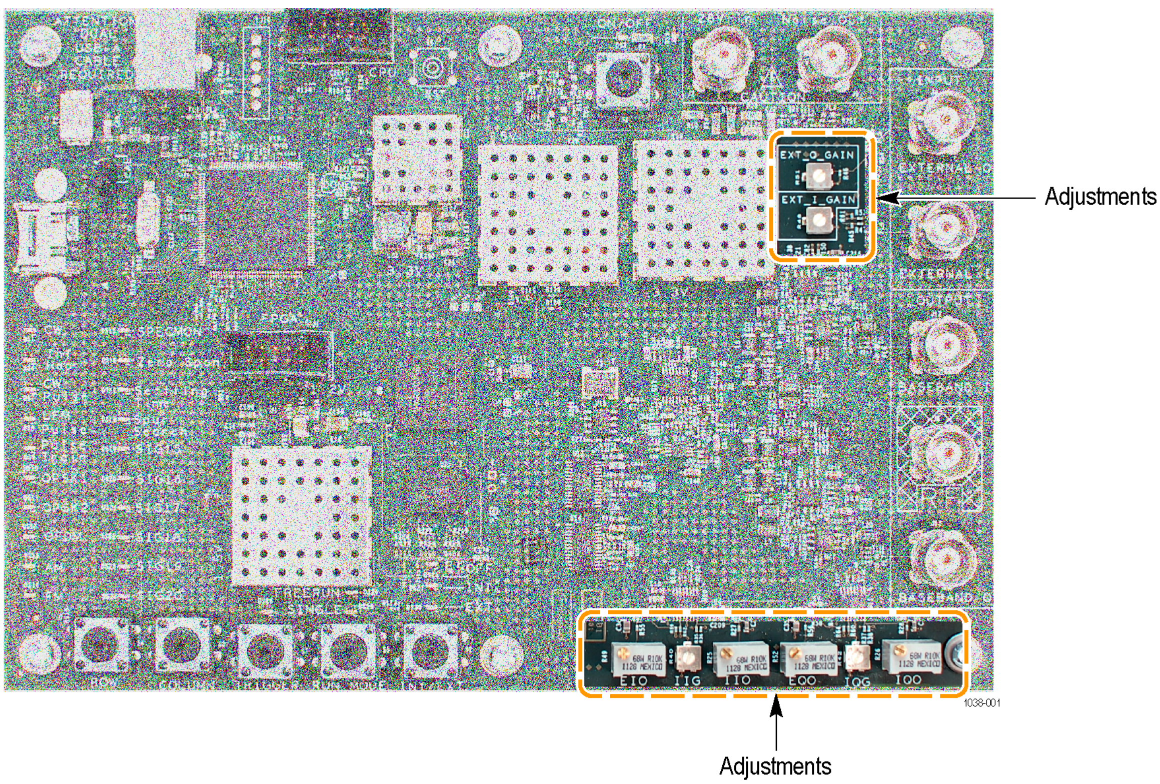
Waveform 17 - 20 (undefined)

Waveforms 17 through 20 are currently unused waveform slots that default to carrier wave signals at 2445.312 MHz.

Adjustments

There are eight adjustments to be made to adjust the offset/gain into the I/Q modulator, and minimize the carrier feedthrough. These are divided into two groups: Internal I/Q and External I/Q.

The Internal I/Q adjustments have been made at the factory. The External I/Q adjustments should be made if you're using External I/Q modulation inputs.



Potentiometer descriptions

- Internal I Gain, Internal Q Gain

  Varies amplitudes ±0.6 dB via potentiometer Initial setting nulls LO feedthrough at the modulator when internal input is selected and DAC=3FF.

- Internal I offset, Internal Q Offset

  Varies "DC" offset voltage ±2% of full scale via 20-turn potentiometer Initial setting nulls LO feedthrough at the modulator when internal input is selected and DAC=0.

- External I Gain, External Q Gain

  Varies amplitudes ±0.6 dB via potentiometer Initial setting nulls LO feedthrough at the modulator when external input is selected and input V=0.5 VDC.

- External I offset, External Q Offset

  Varies "DC" offset voltage ±2% of full scale via 20-turn potentiometer Initial setting nulls LO feedthrough at the modulator when external input is selected and DAC=0.

Calibration mode signals

When the calibration-mode jumper is added, waveforms 00, 01, 02, and 03 are output.

These waveforms are scrolled normally using the waveform Row toggle switch.

Table 2: Calibration mode signals

Location	Name	Description
00	OFF	Used to null carrier leakage through the modulator
01	Full-scale I, Q is off	Used to check I-channel magnitude
02	Full-scale Q, I is off	Used to check Q-channel magnitude
03	Full-scale I plus full-scale Q	Used to verify full scale output amplitude Same as Waveform 1, CW.

Internal I-Q offset and gain adjustment

1. Set up INTERNAL cal mode, internal CW signal OFF.
   - Select “INTERNAL” mode via push-button switch.
   - Select “Calibration” mode by moving jumper J14 to the CAL position.
   - Select calibration waveform 00 (CW = signal OFF) using the ROW button.
   - Connect the RF output BNC to the RSA input.
   - Set the RSA CF to 2.4453GHz, Ref Level -10 dBm.
   - Add a marker to the residual signal at 2.4453 GHz (press PEAK to add marker).
2. Adjust INTERNAL I Gain & Offset.
   - Adjust R40, INTERNAL_I_GAIN_ADJUST (labelled IIG), so that the 2445.3 MHz carrier residual output is minimized.
   - Adjust R25, INTERNAL_I_OFFSET (labelled IIO) to minimize the residual carrier – this is a 20-turn pot, so be patient to see the effect.
3. Adjust INTERNAL Q Gain & Offset.
   - Adjust R42, INTERNAL_Q_GAIN_ADJUST (labelled IQG), so that the 2445.3 MHz residual carrier output is minimized.
   - Adjust R26, INTERNAL_Q_OFFSET (labelled IQO) to minimize the residual carrier – this is a 20-turn pot, so be patient to see the effect.
4. Re-check INTERNAL I/Q Gain and Offset.
   - Adjusting the I & Q gain and offset are interactive will alter the output residual level slightly.
   - Steps 1 & 2 should be repeated at this point for the final offset null.

External I-Q offset and gain adjustment

1. Adjust External I Gain and offset.
   - Terminate EXTERNAL_I and EXTERNAL_Q BNC inputs with 50 Ω BNC terminations.
   - Select EXT (external) mode via the INT/EXT push-button switch.

- Monitor the 2445.3 MHz output on a spectrum analyzer.
- Adjust R49, EXTERNAL I OFFSET ADJUST (labelled EIO), and R48, EXTERNAL_I_GAIN_ADJUST (labelled EXT_I_GAIN), so that the 2445 MHz output is minimized.

2. Adjust EXTERNAL Q Gain and offset.

- Select EXT (external) mode via the INT/EXT push-button switch.
- Adjust R51, EXTERNAL_Q_GAIN_ADJUST (labelled EXT_Q_GAIN), and R52 EXTERNAL_Q_OFFSET_ADJUST (labelled EQO) to minimize the 2445 MHz output.

3. Re-check EXTERNAL I/Q DC offset.

- Adjusting the gain will alter the offset slightly.
- Steps 1 & 2 should be repeated at this point for the final offset null.