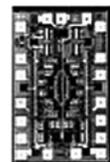
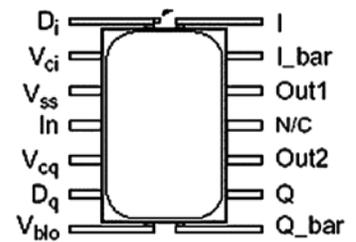


# Agilent E4438C ESG Vector Signal Generator Differential I/Q outputs

Product Note



Agilent Technologies

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## Introduction

Many I/Q modulators and ASICs have balanced inputs. The ESG offers balanced outputs expressly for testing such devices. The I and Q outputs on the ESG have corresponding  $\bar{I}$  and  $\bar{Q}$ , which are equal in magnitude, but opposite in polarity.

Manufacturers create balanced components to improve the noise rejection of the differential input device. If the source only has a single-ended output (no corresponding  $\bar{I}$  and  $\bar{Q}$ ), users have to build external circuits to create differential outputs.

### What are baseband I/Q signals?

In transmitters, the term baseband I/Q refers to signals that are the fundamental products of individual I/Q modulators, before the I and Q component signals are combined, and before up conversion to IF or RF frequencies.

### Why create signals at baseband?

DSP and baseband engineers may need to test the decoding algorithm of the format-specific demodulation measurements (e.g. CDMA, GSM, W-CDMA) in receivers.

Comparisons of measurements made at baseband and measurements of the same device at RF frequencies are especially revealing. Once signal integrity is verified at baseband, impairments can be traced to specific stages of up conversion, amplification, or filtering by RF analysis.

The E4438C ESG comes standard with four 50  $\Omega$  BNC baseband I/Q outputs located on the rear panel, see Figure 1. The upper two connectors labeled “I” and “Q” are the “unbalanced” outputs.

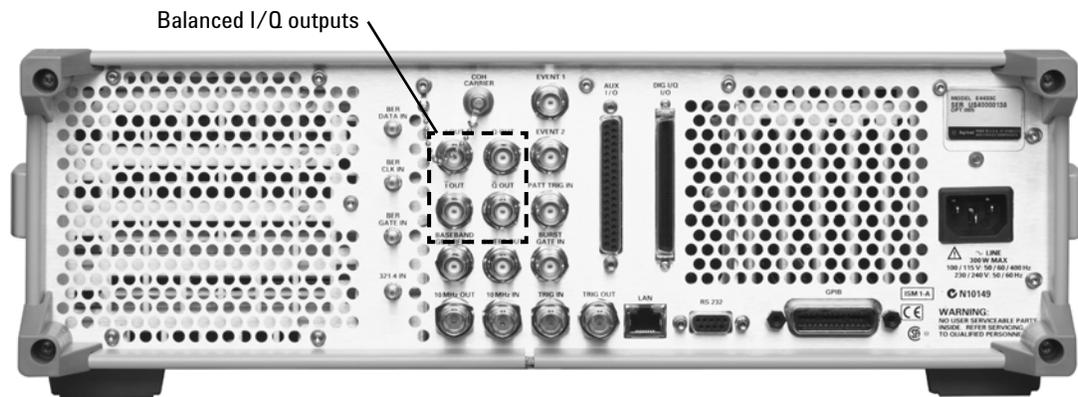


Figure 1. Back panel of E4438C ESG showing the balanced I/Q outputs

An unbalanced or “single ended” baseband I or Q signal is available out of the I or Q connector of the ESG. Baseband I/Q test signals may be generated with the “unbalanced” outputs of either two connectors (I and Q), or with the “balanced” outputs using four connectors (I, Q,  $\bar{I}$  and  $\bar{Q}$ ).

## Block Diagram of IQ Adjustments on ESG

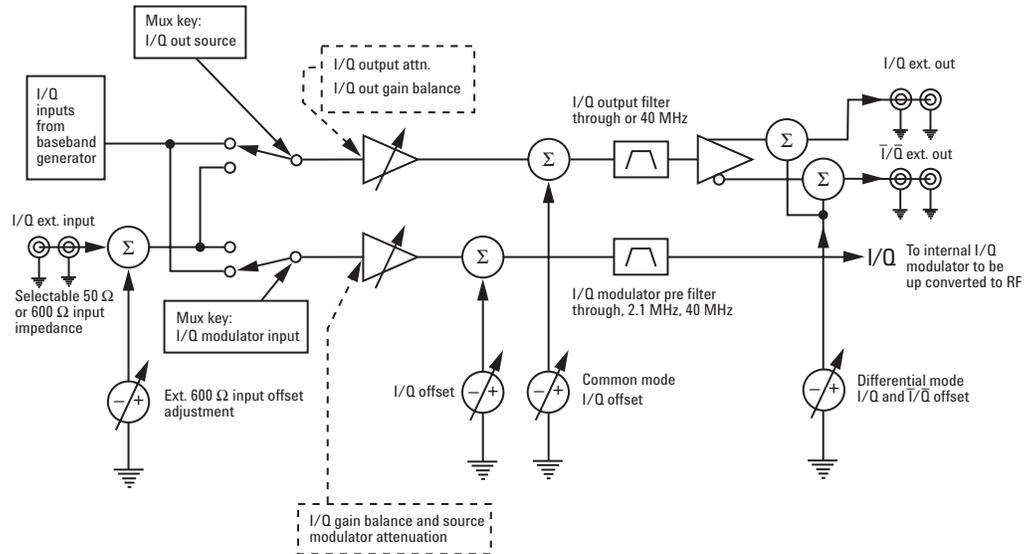


Figure 2. Block diagram of IQ adjustments. Note: the I/Q offsets are independently adjustable

### Explanation of Block Diagram

There are two I/Q paths in the ESG. One goes from the multiplexer (MUX) to the external I/Q outputs; this is the upper path in Fig. 2. The second path goes from the MUX to the internal I/Q adjustments, controlled by similar menus. The controls for the upper path are found under the "I/Q Output Menu", while the controls for the lower path are found under the "I/Q Adjustments Menu". Both menus may be found under the I/Q hardkey.

The MUX redirects the possible input sources (baseband generator, or external I/Q inputs) onto the desired path. One source may feed both paths, or each path may be an independent source.

## Demo

On the following pages is a self-guided demo. The demo will familiarize you with the menu placement of each of the adjustments, as well as their physical function. If the equipment is not available, use what equipment you do have to “dry lab” the experiments. They are sufficiently straight forward that this can still be an effective learning tool.

### Configuration of demo

In the instrument instruction tables, keystrokes that are surrounded by [ ] indicate hard keys located on the front panel, while keystrokes surrounded by { } indicate soft keys located on the display.

Measurements were made of the various I/Q features to illustrate the functionality. The equipment used is listed in Table 2 and set-up is shown in Figure 3.

| Product type                | Model number | Required options   |
|-----------------------------|--------------|--|
| ESG Vector Signal Generator | E4438C       | 001 or 002 – Baseband generator operating in CUSTOM mode |
| Infinium Oscilloscope       | 54800 Series | (with attached mouse)                                    |

Table 2: Equipment list and set-up for I/Q measurements on the E4438C ESG

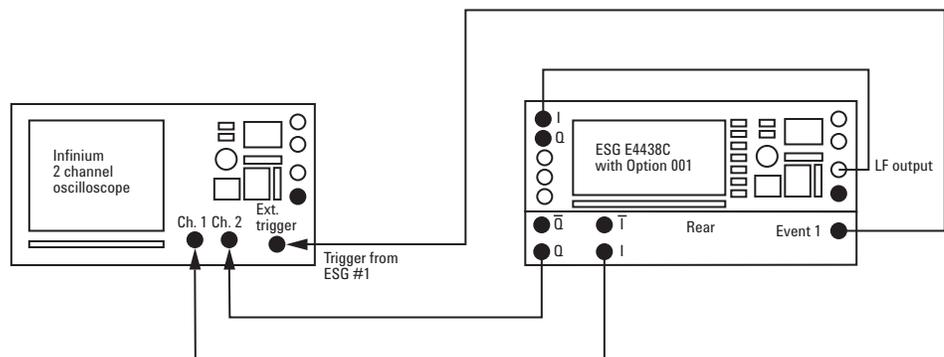


Figure 3. Equipment setup for measurements made in this document

## Generate 4-QAM Signal on ESG

Generate 4-QAM Signal on ESG      [Preset] [Mode] {Custom}  
   {Real-Time I/Q Baseband} {Data} {PN9} {Filter}  
   {Select} {Gaussian} [Return] {Symbol Rate}  
   [250] {ksps} [Return] {Modulation Type} {Select}  
   {QAM} {4 QAM} [Return] {Custom ON}



Figure 4. ESG Menu set-up to create a 4 QAM Signal

## ESG instructions

|                           |                                       |
|---------------------------|---------------------------------------|
| Go to the I/Q Menu        | [I/Q]                                 |
| Go to the I/Q Output Menu | {I/Q Output Control}                  |
| Turn I/Q adjustments on   | {I/Q Adjustments <u>ON</u> } [Return] |

Notice that I-bar is the same magnitude as I and is 180° out of phase with respect to I.

## Explore I/Q output Control Menu



Figure 5. I/Q menu on the E4438C ESG

### Description of each feature on the I/Q output adjustments menu

This menu controls the upper branch of Figure 2.

#### ① I/Q output attenuation

The I/Q output attenuation can be adjusted from 0 to 40 dB.

#### ② I/Q gain balance

This key adjusts the I and Q gain balance. Adding gain (+x dB) to the signal decreases the Q component's magnitude, while the I component stays constant. Decreasing the gain (-x dB) of the signal, decreases the I component's magnitude, while the Q component stays constant.

The range of gain adjustment allowed is -4 dB to +4 dB. Change the gain balance to adjust out imperfections in I and Q or to introduce calibrated impairments.

#### ③ Common mode I/Q offset

This key adjusts the DC offset of both I and Q signals simultaneously. The common mode offset ranges from -4 to +4 Volts.

#### ④ Differential mode I offset

This key adjusts the DC offset level of the I and I-bar output signal. I and I-bar cannot be adjusted independently. The differential mode offset ranges from -4 to +4 Volts.

#### ⑤ Differential mode Q offset

This key adjusts the DC offset level of the Q and Q-bar output signal. Q and Q-bar cannot be adjusted independently. The differential mode offset ranges from -4 to +4 Volts.

#### ⑥ IQ output filter

The default setting turns on the 40 MHz I/Q output filter. This may be bypassed by selecting {Through}. In most cases, this setting need not be changed.

## Test the features of the I/Q output control menu

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### I/Q gain balance measurement

## Infiniium oscilloscope

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Autoscale the instrument

Set up Oscilloscope: trigger off Event 1 of the ESG  
Change input impedance for all signals to 50  $\Omega$

Display I on channel 1 and Q on channel 2  
Change the trigger level to 500 mV

---

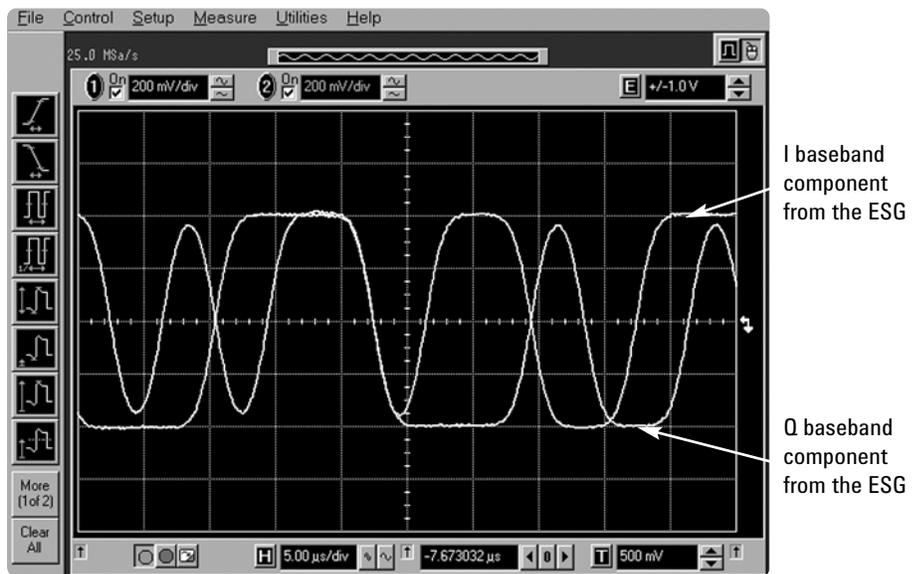


Figure 6. Infiniium oscilloscope display of I and Q of ESG 4 QAM signal

### ESG instructions

Use the RPG Knob to vary the {I/Q Out Gain Balance} [-4 to 4] dB  
I/Q Out Gain Balance and observe how  
the I and Q waveforms change in magnitude.

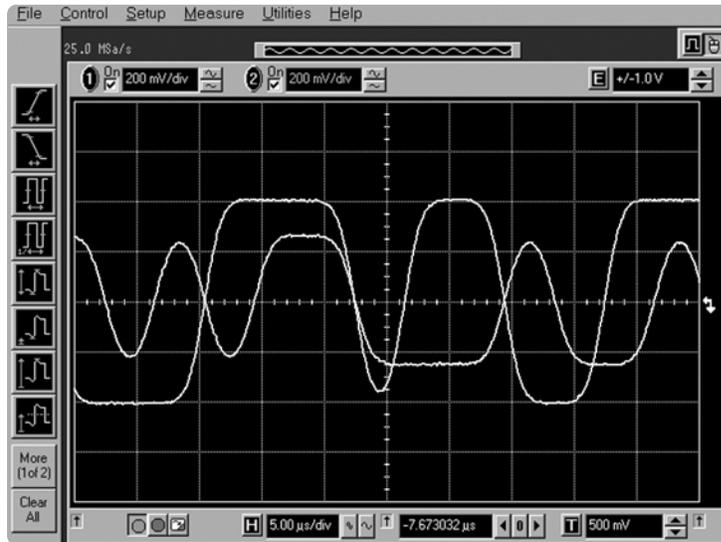


Figure 7. ESG I/Q out gain balance set to +4 dB

### Infiniium scope instructions

After viewing the waveforms in normal time domain mode, switch to XY mode, and observe the effect on the shape of the constellation. This requires using a mouse with the oscilloscope. {Measure} {Math/FFT} {verses} {display ON}. Use the hard keys to turn Channel 1 and Channel 2 voltage display OFF.

### ESG instructions

Vary the I/Q Out Gain Balance control on the ESG to see the effect.

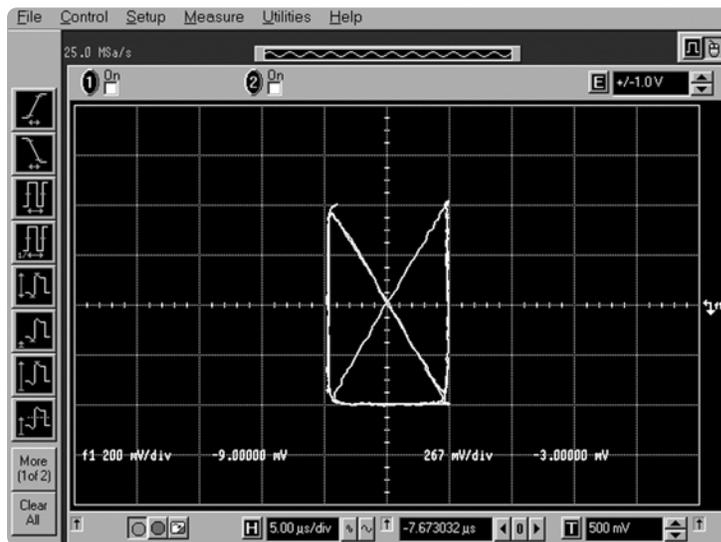


Figure 8. ESG I/Q out gain balance set to +4 dB

## Common mode I/Q offset measurement

### Infiniium scope instructions

Return to normal time domain mode by unchecking the Math Function display box. Reactivate the Channel 1 and Channel 2 voltage displays using the hard keys.

### ESG instructions

Return the I/Q Out Gain Balance to 0 dB. Press the {common mode I/Q offset} key. Use the RPG knob to vary the common mode offset. Observe the effect on the oscilloscope.

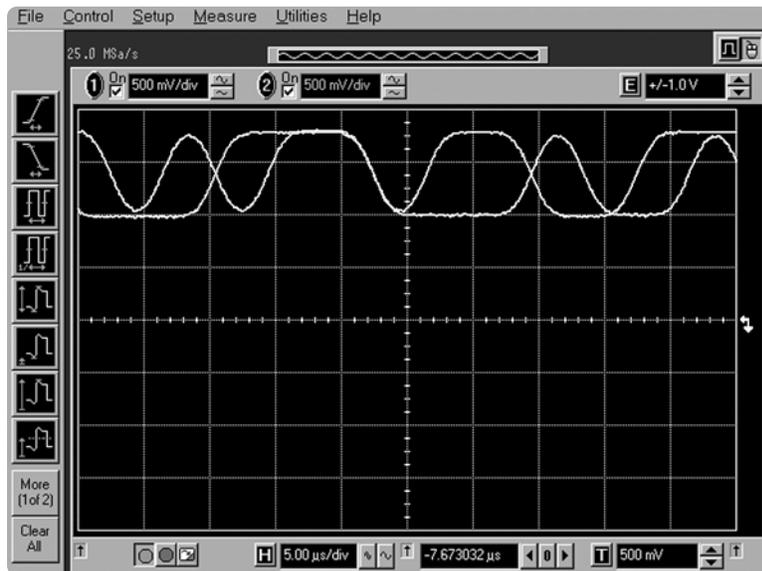


Figure 9. Display on Infiniium of ESG common mode I/Q offset set to +1.3 V

## Differential mode offset measurement

### ESG instructions

Return the Common Mode Offset to 0.00 V.

Use the RPG Knob to vary the differential mode offset on the Oscilloscope. {Differential Mode I Offset } [-4 to 4] Volts  
{Differential Mode Q Offset } [-4 to 4] Volts

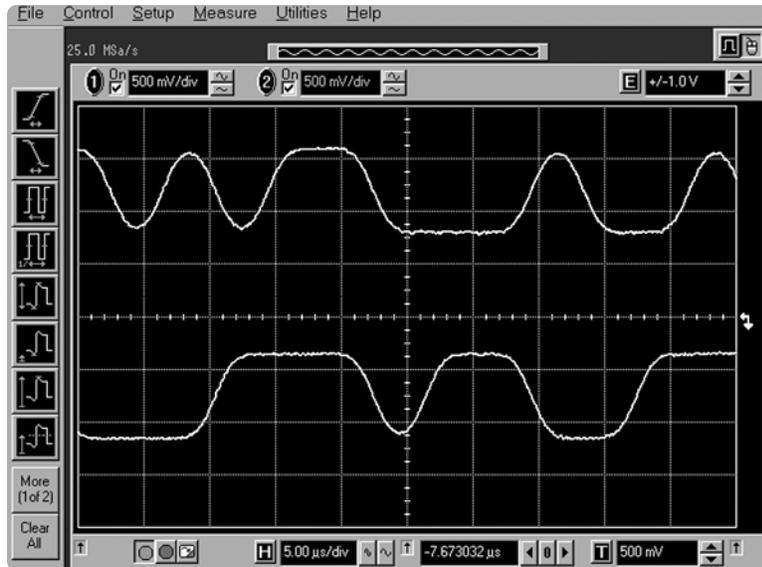


Figure 10. Oscilloscope display of ESG Diff. Mode I Offset set to +1.2 V

### Infiniium scope instructions

Place the scope back into XY mode, and repeat the differential offset adjustment.

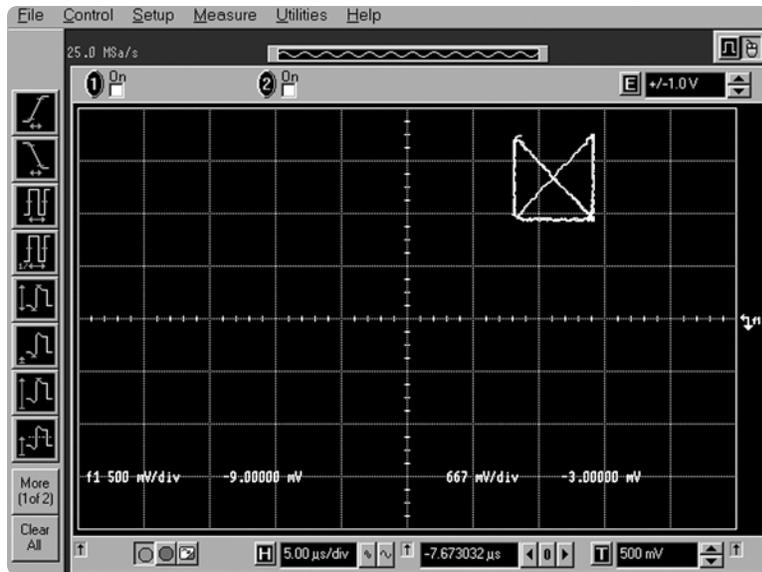


Figure 11. Display of ESG differential mode I offset set to +1.2 V

When finished, return all differential and common mode adjustments to zero on the ESG.

## Explore the Mux menu

## Mux control feature description

### ESG instructions

Go to the Mux Menu [Mux]

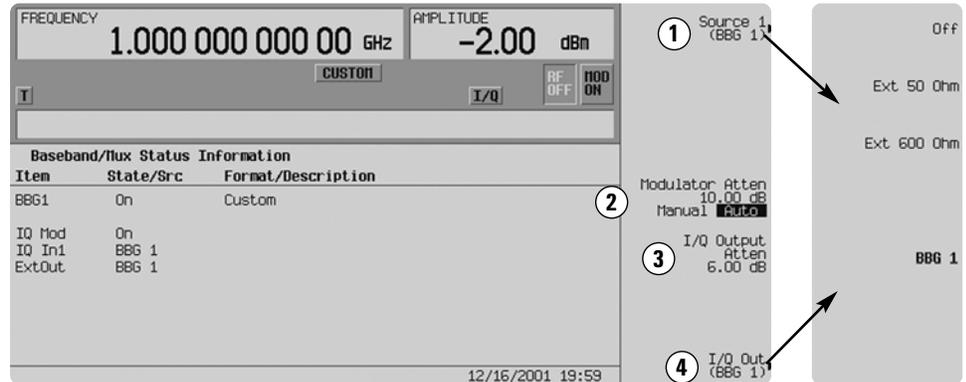


Figure 12. Mux menu on the E4438C ESG

#### ① Source 1

4 different options for the source to be sent to the IQ modulator and out the RF Output port are available:

- Off - sends no signal to the modulator
- Ext 50 Ohm (input through the I/Q inputs on the front panel of the ESG)
- Ext 600 Ohm (input through the I/Q inputs on the front panel of the ESG)
- BBG 1 (internal baseband generator from the ESG. Options 001 or 002)

#### ② Modulator atten

The user may adjust the attenuation of the signal before it goes into the I/Q modulator. There are two settings for this key: Auto and manual. Auto defaults to a preset value, depending upon the active personality. Manual is user adjustable. The range is 0 to 40 dB.

#### ③ I/Q output atten

The output attenuation may be set. The range is 0 to 40 dB. This is really a component of the upper path in figure 2, but is repeated in this menu for convenience.

#### ④ I/Q out

This sets which signal is being sent to the IQ Output ports. The following are available:

- OFF - no signal sent to the I/Q outputs
- 50  $\Omega$  - From externally supplied I and Q inputs to the ESG. The output signal is unbalanced outputs (just I and Q)
- 600  $\Omega$  - From externally supplied I and Q inputs to the ESG. The output signal is balanced outputs (I and Q and I-bar and Q-bar).
- BBG1 (default) - From the ESG's baseband generator. The output signal is balanced outputs (I and Q and I-bar and Q-bar).

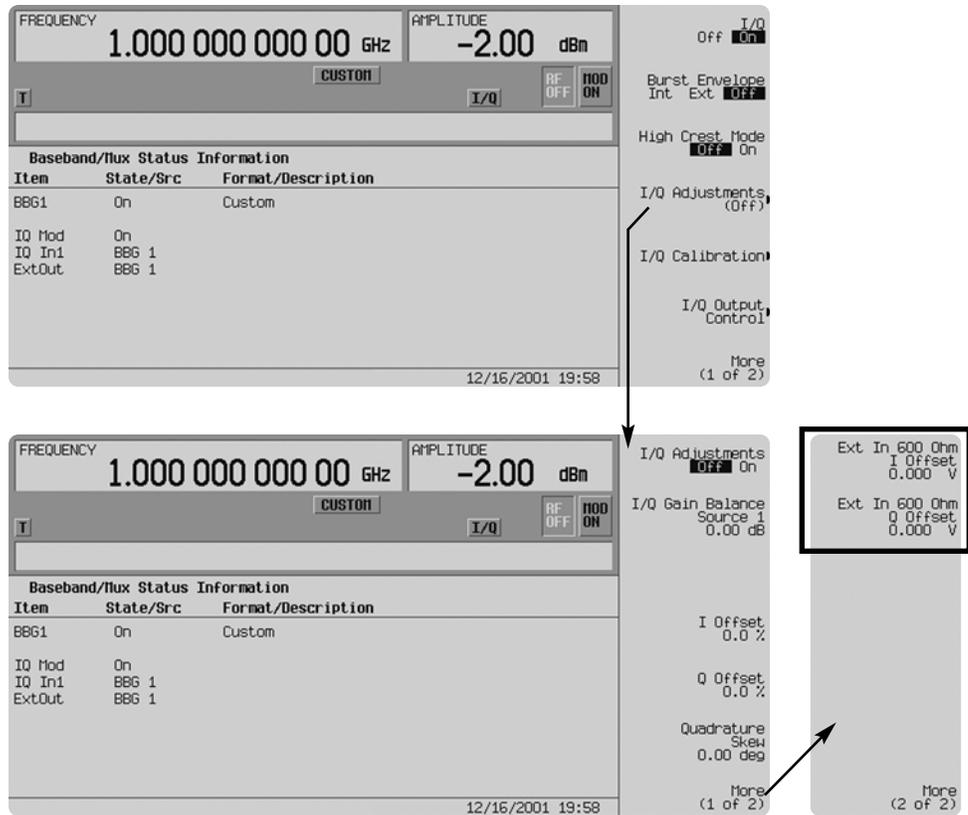


Figure 13. I/Q external In 600 Ohm offset adjustments

## Explore the I/Q adjustment menu

### IQ adjustments feature description

The ESG has a separate I/Q adjustments menu that is distinct from the I/Q output control menu. The I/Q adjustments menu controls the lower path in figure 2, going to the I/Q modulator and RF output. Many of the same adjustments that have been described previously are available, but there are two additional adjustments on this menu: External Input impedance, and Quadrature Skew.

The E4438C also gives the user the ability to adjust the externally supplied I and Q signal offsets when the selected impedance is 600  $\Omega$ . The menu structure is shown in Figure 13.

#### External In 600 Ohm I and Q offset

Configures the I and Q input offsets. The differential mode offset ranges from  $-5$  to  $+5$  Volts. (This feature is intended to balance out large DC offsets that may be present in some devices.)

#### Quadrature skew

Adjusts the phase angle between the I and Q vectors. When the quadrature skew is zero, the phase angle is 90 degrees. Positive skew increases the angle from 90 degrees while negative skew decreases the angle from 90 degrees. The range of values allowed is  $\pm 10$  degrees with a minimum increment of 0.1 degrees.

Skew adjustments are made in the I/Q modulator, and can not be made on signals delivered to the baseband I/Q outputs.

## Test the features of the I/Q adjustment menu

### ESG instructions

From the Mux menu, change the I/Q output to Ext 600  $\Omega$  {I/Q Out} {Ext 600 Ohm}

### Infiniium oscilloscope

Set the oscilloscope back to normal time base mode.  
Trigger on channel 1, adjust trigger level if necessary.

### LF Function Generator

Set the LF function generator to produce a 10 kHz sine wave, 0.5 Vp. Connect it to the I input on the front panel of the ESG.

[LF Out]  
{LF Source} {Function Generator}  
{LF Frequency} {10 kHz}  
{LF Amplitude} {0.5 Vp}  
{LF Out} {ON}

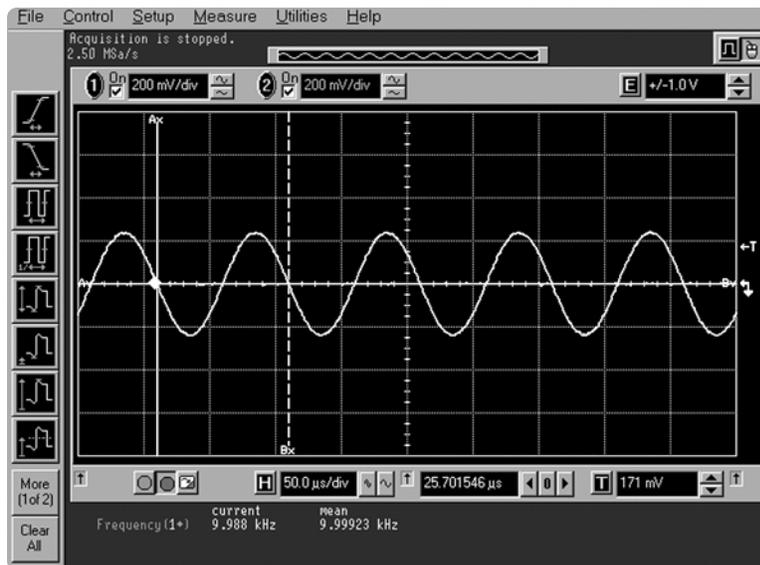


Figure 14. Sine wave signal on Infiniium Oscilloscope.

Notice that the waveform is being generated by the LF function generator, even though CUSTOM is still on and active. This signal is passing through the upper I/Q path in figure 2.

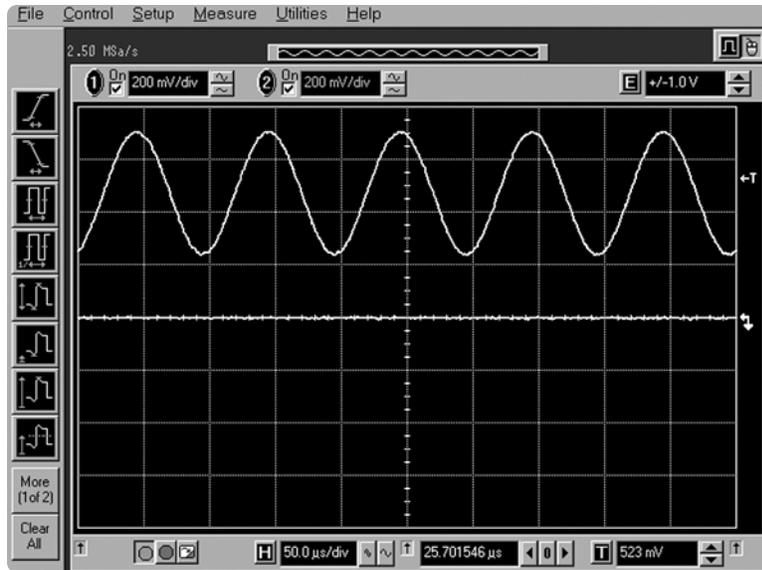


Figure 15. Sine wave output offset by Input Offset adjustment

#### ESG instructions

From the IQ menu vary the 600  $\Omega$  [I/Q] {I/Q Adjustments} {More (1 of 2)}  
input offsets of the I component. {Ext In 600 Ohm I Offset}

#### Oscilloscope instructions

Adjust the trigger level on the oscilloscope as necessary.

#### Conclusion

Preset the ESG, when finished, to restore all functions to their default values.

## Ranges of I/Q adjustments and baseband outputs

### I/Q adjustments

| Source               | Parameter             | Range                 |
|----------------------|-----------------------|-----------------------|
| I/Q baseband inputs  | Impedance             | 50 or 600 $\Omega$    |
|                      | I offset [600 .only]  | $\pm 5$ V             |
|                      | Q offset [600 .only]  | $\pm 5$ V             |
| I/Q baseband outputs | I/Q offset adjustment | $\pm 3$ V             |
|                      | I/Q offset resolution | 1 mV                  |
|                      | I/Q gain balance      | $\pm 4$ dB            |
|                      | I/Q attenuation       | 0 to 40 dB            |
|                      | I/Q low pass filter   | 40 MHz, thru          |
| RF output            | I/Q offset adjustment | $\pm 50\%$            |
|                      | I/Q gain balance      | $\pm 4$ dB            |
|                      | I/Q attenuation       | 0 to 40 dB            |
|                      | I/Q quad skew         |                       |
|                      | [< 3.3 GHz]           | $\pm 10^\circ$        |
|                      | [> 3.3 GHz]           | $\pm 5^\circ$         |
|                      | I/Q low pass filter   | 2.1 MHz, 40 MHz, thru |

### I/Q baseband outputs<sup>1</sup>

|                                 |                              |
|---------------------------------|------------------------------|
| Differential outputs            | I, $\bar{I}$ , Q, $\bar{Q}$  |
| Single ended                    | I, Q                         |
| Frequency range                 | DC to 40 MHz [with sinewave] |
| Output voltage into 50 $\Omega$ | (1.5 V P-P) [with sinewave]  |
| Output impedance                | 50 $\Omega$ nominal          |

## **Ordering information**

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The differential IQ outputs come standard on the Agilent E4438C ESG Vector Signal Generator. Contact information can be found at <http://www.agilent.com/find/assist>.

## Related literature

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### **E4438C ESG Vector Signal Generator: [www.agilent.com/find/esg](http://www.agilent.com/find/esg)**

#### **Brochure**

Agilent E4438C ESG Vector Signal Generator 5988-3935EN

#### **Data Sheet**

Agilent E4438C ESG Vector Signal Generator 5988-4039EN

#### **Configuration Guide**

Agilent E4438C ESG Vector Signal Generator 5988-4085EN

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### **Infiniium 54800 Series Oscilloscopes: [www.agilent.com](http://www.agilent.com)**

#### **Brochure**

Infiniium 54800 Series Oscilloscopes

#### **Product Overview**

Infiniium 54800 Series Oscilloscopes Product Overview 5980-2397EN

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