Agilent ESA-E Series Spectrum Analyzer Modulation Analysis Measurement Personality Self-Guided Demonstration

Product Note

This demonstration guide is a tool to help you gain familiarity with the basic functions and features of the Agilent ESA-E series (E4402B, E4404B, E4405B, and E4407B) spectrum analyzers. Among the uses of the modulation analysis personality, this guide walks you through procedures that facilitate the identification and troubleshooting of common I/Q impairments from measurement performed at the antenna port.

Almost all of the exercises utilize the Agilent E4433B or E4437B ESG series RF signal generator, and three four-foot BNC cables. Key names surrounded by [ ] indicate *hard* keys located on the front panel of the ESA spectrum analyzer, while key names surrounded by {} indicate the soft keys located on the right edge of the display. Optional settings are in smaller *italic* font.

You may notice slight differences in the soft key menu on your unit's display versus those shown in this document's figures. This is due to differences in firmware. Please consult the technical support area of the Agilent's web site, **www.agilent.com/find/esa**, for the latest firmware.

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Part 1. Demonstration preparation

To conduct the exercises in this guide, you will need the following equipment:

- An ESA-G series signal generator
  - An ESA-E series spectrum analyzer with
  - Option 229: Modulation analysis measurement personality
  - Option B7D: Digital signal processing (DSP) and fast ADC
  - Option B7E: RF communications hardware
  - Option 1D5: High stability frequency reference
  - Firmware revision A.07.03 or later
- A second ESG-D is need for Measurement 4

The configuration of the ESA with modulation analysis includes a high stability frequency reference. This means that accurate measurements can also be made using the ESA as the primary frequency reference. With the ESA, you have total flexibility in using an external or internal frequency reference.

Connect the hardware as follows. (Measure 4 will instruct you on how to connect the second ESG-D.)

1. Using an RF cable with an impedance of 50 Ω, connect the **RF Output** 50 Ω port on the ESG-D series signal generator to the **RF Input** 50 Ω port on the ESA-E series spectrum analyzer as shown.

2. Using a second RF cable with an impedance of 50 Ω, connect the **10 MHz out** on the ESG-D series signal generator to the **EXT REF in** on the ESA-E series spectrum analyzer tester as shown.

3. Using a third short RF cable with an impedance of 50 Ω, connect the **10 MHz ref out** jack on the digital demod board to the **10 MHz in** on the RF deck.

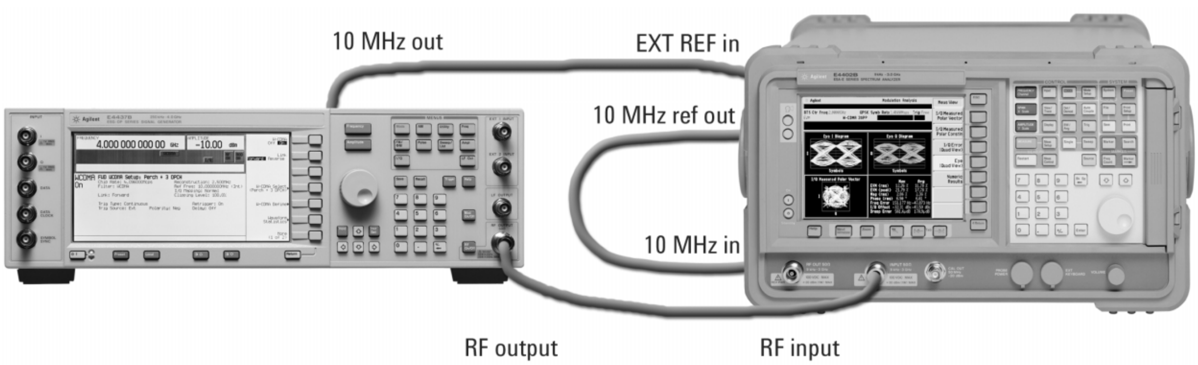

Figure 1. Proper hardware configuration for exercises outlined in this guide

Part 2. The basics: mode, measure, mode setup, view, and print

Most measurements on the ESA-E series with modulation analysis can be performed using the simple four-step procedure outlined in the table below. Most measurements are made using minimal keystrokes, using primary keys in conjunction with setup keys if necessary.

Step	Primary key	Setup keys	Related keys
1. Select and setup mode	MODE	Mode Setup	System
2. Select and setup measurement	MEASURE	Meas Setup, Restore Meas Defaults FREQUENCY Channel	Meas Control, Restart
3. Select and setup view	View/Trace	Span X scale, Amplitude Y scale, Display	Marker, Search
4. Save and print results	File Print	Print Setup	Save

Part 3. Making a W-CDMA measurement

To obtain W-CDMA measurements, configure the ESG-D series signal generator as follows:

Instructions	Keystrokes
Preset the instrument	Press [Preset]
Activate mode menu	Press [Mode] Press [Return] to return to previous menu
Go to W-CDMA mode *W-CDMA is a predefined signal in the Arb Waveform Generator.*	For predefined signal: Press {Arb Waveform Generator}{CDMA Formats}
Generate a W-CDMA signal with 1 DPCH	Press {W-CDMA (3GPP 3.4 12-00)} {W-CDMA Select}{1 DPCH}
Verify that the signal is a down link signal *This is the default*	The {Link (Down Up)} softkey should have "down" highlighted; if not press {Link}
Set frequency to 2 GHz	Press [Frequency][2]{GHz}
Set amplitude to 0 dBm	Press [Amplitude][0]{dBm}
Activate W-CDMA format	Press {W-CDMA Off On} The "On" should be highlighted
Turn on RF	Press [RF On/Off]. The display should read "RF ON"
Turn on MOD	The display should read "MOD ON"; if not, press [MOD On/Off]

Configure the ESA-E series analyzer as follows:

Instructions	Keystrokes
Preset the ESA-E	Press [Preset]
Activate mode menu	Press [Mode]
Choose modulation analysis mode	Press {Modulation Analysis}
Set frequency Note: At first power on, the default frequency upon entering the modulation analysis mode is 1 GHz. Upon subsequent returns to the modulation analysis mode, the recall mode functionality of the ESA defaults to the last-used settings and screen display.	Press [FREQUENCY][2]{GHz}

Part 4. Multi-format support

There are two ways to configure the analyzer for digital demodulation measurements.

- Manually enter values for all demodulation parameters, or
- Specify the standard of the digital communications system and let the analyzer automatically set the parameters.

The modulation analysis personality will support baseband modulation analysis for several industry standards, and you may switch between these formats. When switching to a format, the analyzer automatically sets the parameters. This flexibility is illustrated by using the ESA-E series spectrum analyzer as follows:

Instructions	Keystrokes
Activate multi-format menu	Press [Mode Setup]{Radio Std} {W-CDMA (3GPP)}
Select the correct device *The default setup is the base-station mode; if this is not the case, follow the keystrokes.*	Press {Device; (BTS MS)} The "BTS" should be underlined

Measurement 1: Monitor spectrum

When first switching into the modulation analysis mode, after power up, the default measurement is monitor spectrum. This measurement puts the instrument into a frequency sweep screen to allow the viewing of the channel in the frequency domain prior to performing an EVM measurement on the signal. This is essentially a "check and see" screen to ensure that a signal is present for measuring. The measurement is performed by setting the ESA-E series spectrum analyzer as noted below.

Instructions	Keystrokes
Access measure menu	Press [Measure]
Monitor the spectrum	This is the default view. If for any reason this is not so, then press {Monitor Spectrum}

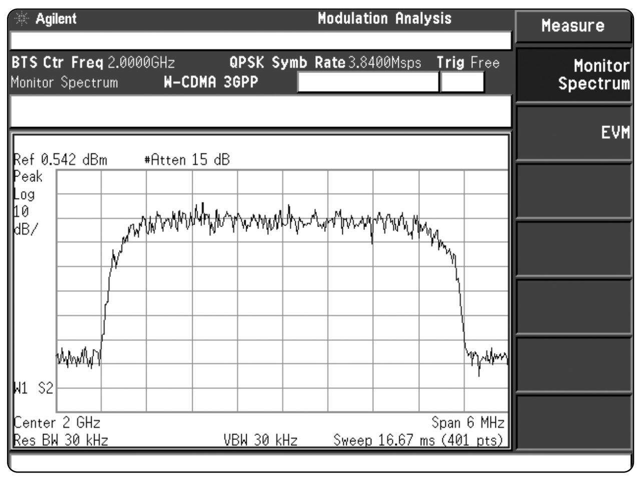

Figure 2. Monitor spectrum view

Measurement 2: Error vector magnitude (EVM)

When an EVM measurement is performed, the analyzer samples the transmitter output to capture the actual signal trajectory. This operation can be performed using the instructions below. The signal is demodulated and, given knowledge of such functions as symbol clock timing, and baseband filtering parameters, a corresponding ideal or reference signal is derived mathematically. The error vector is the vector difference at a given time between the ideal reference signal and the measured signal. It is a complex quantity that contains a magnitude and phase component. EVM is the root-mean-square (rms) value of the error vector over time at the instants of the symbol clock transitions. It is an acutely sensitive measure of modulation quality.

Instructions	Keystrokes
Measure EVM	Press [Measure]{EVM}

An I/Q polar vector display of the signal should appear on the analyzer's screen, similar to that shown in figure 3. This is one of the many views of the modulation analysis personality. Important related metrics are listed in a table to the left of the vector display.

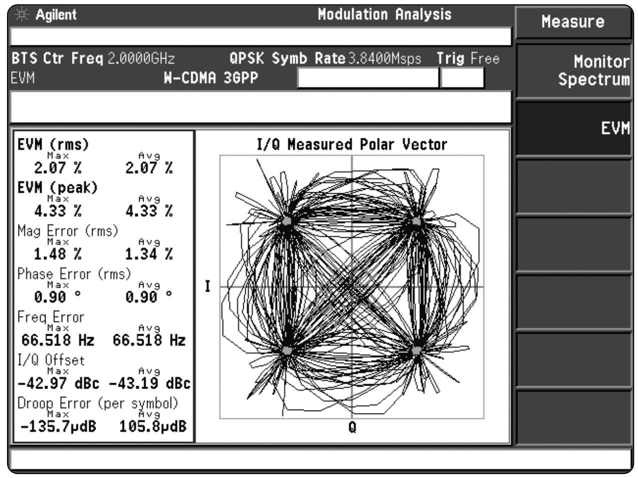

Figure 3. Polar vector view of EVM measurement

Tie instruments' frequency references together:

Instructions	Keystrokes
Access demodulation format menu	Press {Det/demod} Press {More 1 or 2}
Select ext frequency reference	Press {Opt Freq Ref}
The 10 MHz out (on/off key) should now be selectable. The "On" should be underlined. If not, follow the instructions. On your screen should be part of the instructions outlined in Part 1. Demo Preparation.	Press {Opt 10MHz out}[Esc]
You could turn averaging on to see how the average frequency error drops	Press [Meas Setup] {Avg Number} [25] {Enter} The "On" should be underlined
For the purposes of the rest of the lab, turn averaging back off	Press {Avg Number} The "Off" should be underlined

The ESA allows you the flexibility of using the internal frequency reference or connecting to an external reference. For the purposes of this guide, the averaging feature is turned off.

Part 5. Digital demodulation analysis troubleshooting I/Q impairments

The power of the modulation analysis personality option is its ability to characterize the radio signal for transmitter troubleshooting. This section illustrates how to interpret the data to identify symptoms of problems in radio signals.

The following radio signals errors are investigated in this section

- Symbol rate errors
- In-channel phase modulation (PM) interference
- In-channel amplitude modulating (AM) interference
- In-channel spurious interference
- Base band filtering errors
- Measuring a custom QPSK format signal
- I/Q gain imbalance
- I/Q quadrature skew
- I/Q offset and frequency errors

Measurement 1: Symbol rate errors

Small deviations in the symbol clock can result in significant modulation errors. Even these small errors cause a significant spread of the constellation clouds and a large increase in peak EVM. This gives you an idea of what a typical receiver will have to deal with in its attempt to demodulate the incoming signal.

The effect of symbol rate errors on the different measurements depends on the size of the error. If the symbol rate error is too large, the instrument cannot demodulate the signal, let alone make an EVM measurement. Consequently, the modulation analysis option is most useful in troubleshooting small symbol rate errors. To troubleshoot circuits with a large symbol rate error, look at the signal's channel bandwidth.

To perform this operation, use the instructions below to set the ESG-D for W-CDMA base-station signal generation with a symbol rate of 3.8415 Mcps. This is a symbol rate error of 0.0015 Mcps over the predefined symbol rate.

Instructions	Keystrokes
Access the W-CDMA define menu for the current link	Press {W-CDMA define}
Access the menu to edit the W-CDMA channel setup menu	Press {Edit Channel Setup}
Change the W-CDMA symbol rate from 3.84 to 3.8415 Mcps	Press {More 1 of 2}{Chip Rate}[3.8415]{Mcps}
Turn the symbol rate impairment on	Press [Return] [Return]{Apply Channel Setup}

Measurement 1: Symbol rate errors (continued)

The ESA has many display formats. Change to the polar constellation display, noted in figure 4, to first identify an I/Q impairment exists. To change the view to polar constellation, set the ESA-E series spectrum analyzer as follows:

Instructions	Keystrokes
Access measurement view menu for the current measurement	Press [View/Trace] "Polar Vector" should be highlighted as the default
Change to the constellation view	Press {I/Q Measured Polar Constln}

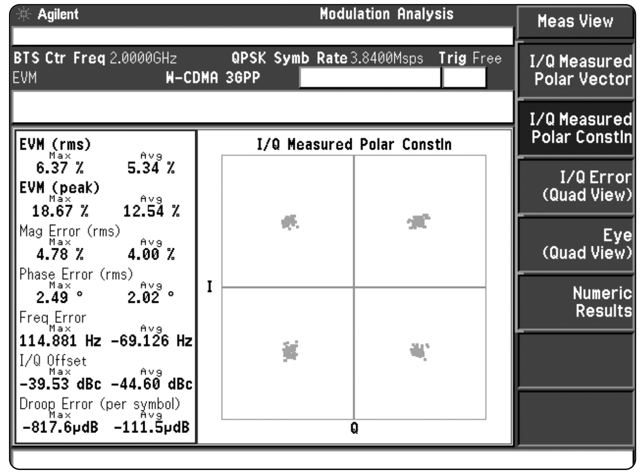

Figure 4. Polar constellation view of W-CDMA signal with a symbol rate error

Notice the spreading of the symbol decision points and the large values of EVM for a symbol rate error of only 0.0015 Msps.

Measurement 1: Symbol rate errors (continued)

To switch to the I/Q error (Quad View) of the modulation analysis personality, as shown in figure 5, set the ESA as noted below. Note that in the bottom left of the trace, the EVM versus time graph shows a "V" shape.

Instructions	Keystrokes
Access quad view menu	Press {I/Q Error (Quad View)}

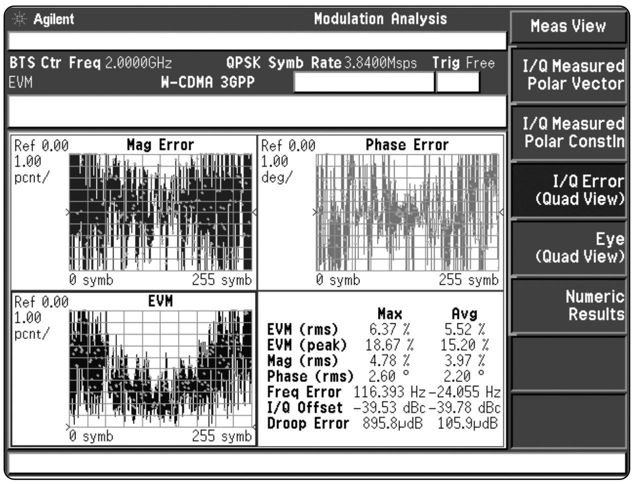

Figure 5. I/Q (Quad View) showing a symbol rate error

To view just the EVM versus Symbol display, follow these steps:

Instructions	Keystrokes
Zoom in on the EVM vs symbol plot	The "EVM" vs symbol quadrant should be highlighted by default. If not, cycle through the windows as noted below.
There are four traces in this view. This allows the identification of the potential error	Press [Next Window]
To exclusively access the EVM vs Symbol display, zoom in on it	Press [Zoom]

The figure below shows a "V" shape in the EVM versus time trace. This characteristic is caused by the demodulator aligning the expected symbol clock rate with the clock rate of the signal, for best fit at the mid-point of the trace. The differences in the two clocks show increasing "slip" or deviation further from the center of the trace. To phrase it another way, at one arbitrary reference sample, the signal will be sampled correctly. Since the symbol rate is skewed, any other sample in the positive or negative direction will be slightly off in time causing an error that grows linearly in time.

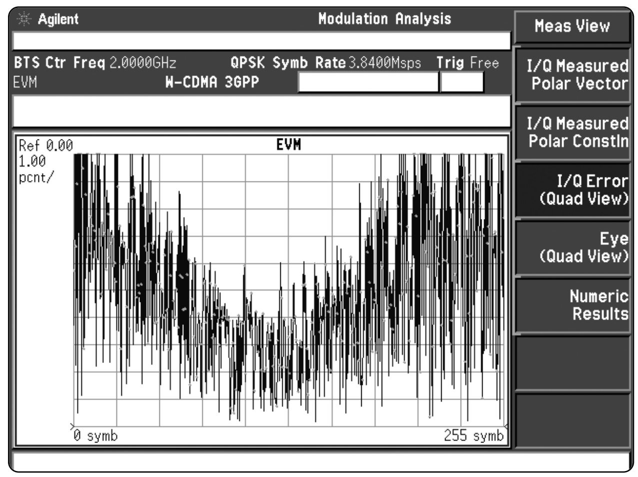

Figure 6. Zoomed EVM vs symbol display showing a symbol rate error

The ESA is an ideal troubleshooting tool for determining symbol rate errors. It can be used to

- Tweak a circuit until the symbol rate matches the correct rate. (This would be indicated by the V-shape disappearing.)
- Rotate the dial on the ESA-E series until the V-shape starts to flatten out. Proceed until an "equilibrium" point is reached where the V-shape is at a "minimum." This allows for the identification of the erroneous symbol rate that the circuit is transmitting.

Measurement 2: In-channel phase modulating (PM) interference

When integrating a communications system, many signals (digital, baseband, IF, and RF) are present. The close proximity of the components is an invitation to cross-talk and can lead to unwanted signals in the signal output. This spurious signal is usually too small to be seen in the frequency domain. However, the modulation analysis personality has the capability to easily highlight the presence of such interference. The interfering signal causes the amplitude or phase of the transmitted signal to be different each time the signal passes through the same state. PM interference causes a variation of the phase around the ideal symbol reference point.

In this section, set the ESG to generate a phase modulating interfering signal at 45 kHz and deviation of 0.03 π radians or 5.5 degrees as follows:

Instructions	Keystrokes
Restore symbol rate to default Access the menu to edit the W-CDMA channel setup menu	Press {Edit Channel Setup}
Change the W-CDMA symbol rate from 3.8415 to 3.84 Mcps	Press {More 1 of 2}{Chip Rate} [3.84]{Mcps}
Turn the symbol rate impairment on	Press [Return] [Return]{Apply Channel Setup}
Go to Frequency and phase modulation menu	Press [FM/ϕM]
Toggle to the phase modulation menu	Press {FM ϕM} The ϕM term should be highlighted
Set the frequency of the internally-generated phase modulating signal to 45 kHz	Press {ϕM Rate}[45]{kHz}
Set the phase modulation deviation to 0.03 π radians or approximately 5.5 degrees	Press {ϕM Dev}[0.03]{π rad}
Turn on the phase modulation	Press ϕM [Off On] The “On” should be highlighted

The I/Q polar constellation should be the first step in identifying the in-channel PM problem. To view this on the ESA analyzer, as shown in figure 7, follow these steps:

Instructions	Keystrokes
Access the measurement view menu for the current measurement	Press [View/Trace]
Change to the constellation view	Press {I/Q Measured Polar Constln}

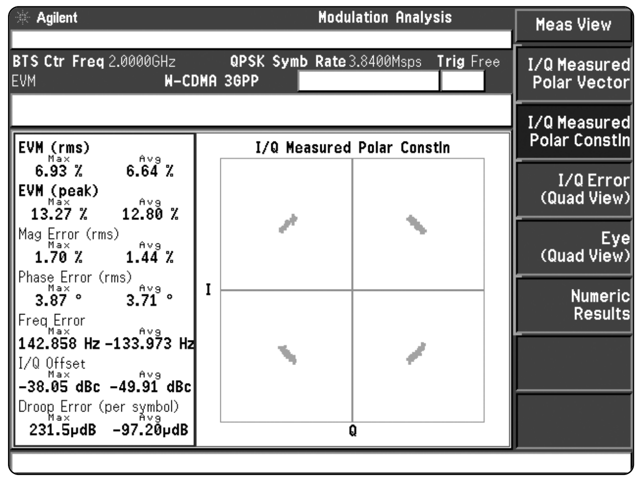

Figure 7. Polar constellation view of W-CDMA signal with a phase modulating interference of 45 kHz

Note the variation of the phase around the ideal symbol reference point. This variation is due to the measured symbols preserving the right amplitude but varying in phase. Also note that the average phase error is larger than the magnitude error. With the interference identified as a PM interference, the next step is to identify the frequency and peak deviation of this PM signal.

Measurement 2: In-channel phase modulating (PM) interference (continued)

To identify the frequency of phase-modulating signal, turn on phase error versus time display on the ESA analyzer. This is done as follows:

Instructions	Keystrokes
Access the measurement view menu	Press [View/Trace]
Access the quad view menu Note the "regular" modulating waveform of the interfering PM signal in the phase error versus time plot. *If the plot is random it indicates phase noise.*	Press {I/Q Error (Quad View)}

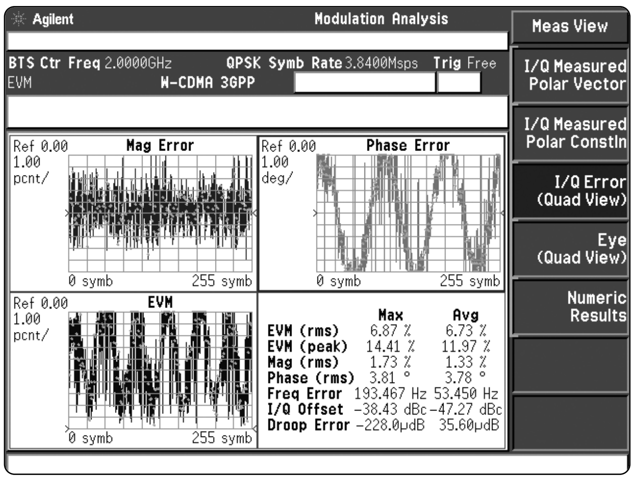

Figure 8. Quad view display with a phase modulating signal of 45 kHz

For further analysis, it is useful to zoom in on the phase error (refer to figure 9.) This is done as follows:

Instructions	Keystrokes
Turn on the phase error versus symbol plot There are four traces in this view. This allows for the easy identification of the potential error.	Press [Next window] until the phase error vs symbol display is highlighted
To exclusively access the phase error vs symbol display, zoom in on it	Press [Zoom]

If the number of cycles can be accurately determined, the frequency of the phase modulating signal can be determined. (Refer to table 1.) To do this, it could be useful to adjust the scaling using the span and amplitude keys if necessary. It may also be helpful to pause the measurement to easier determine the number of cycles. Use the Meas Control key to pause the measurement:

Instructions	Keystrokes
Access menu to pause or restart the measurement.	Press [Meas Control]
Pause the measurement	Press {Pause}
Restart the measurement	Press {Resume}

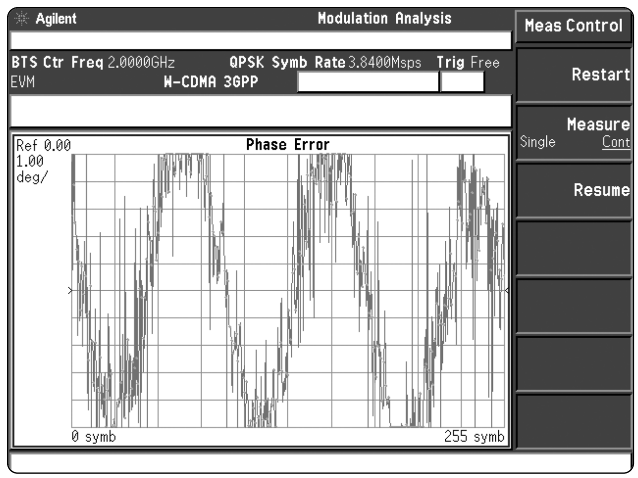

Figure 9. Zoomed in display of a phase modulating interference of frequency 45 kHz

Table 1. Calculating the PM interference

Frequency of PM interference = (cycles/second)
$$\left(\frac{\text{No. of Cycles}}{\text{symbol}}\right)\left(\frac{\text{No. of Symbols}}{\text{second}}\right)$$

In this case
Frequency of PM interference =
$$\left(\frac{3\ \text{cycles}}{256\ \text{symbol}}\right)\left(\frac{3.84 \times 10^6\ \text{symbols}}{1\ \text{second}}\right)$$

= 45 kHz

The peak deviation is easily determined by looking at the amplitude scale. There are about five divisions of peak phase modulation at one degree per division. These both correspond to the interference generated with the ESG signal generator.

Measurement 3: In-channel amplitude modulating (AM) interference

When integrating a communications system, many signals (digital, baseband, IF, and RF) are present. The close proximity of the components is an invitation to cross-talk and can lead to unwanted signals in the signal output. This spurious signal is usually too small to be seen in the frequency domain. However, the modulation analysis personality has the capability to identify at a glance the presence of such interference. The interfering signal causes the amplitude or phase of the transmitted signal to be different each time the signal passes through the same state. AM interference causes a variation of the amplitude around the ideal symbol reference point. In this section, set the ESG to generate an amplitude modulating interfering signal at 45 kHz and depth of ten percent.

Instructions	Keystrokes
Go to the amplitude modulation menu	Press [AM]
Set the frequency of the internally generated amplitude modulating signal to 45 kHz	Press {AM Rate} Key in [45] Press {kHz}
Set the amplitude modulation depth to 10%	Press {AM Depth} Key in [10] {%}
Turn on the amplitude modulation	Press {AM Off On} The "On" should be highlighted

This type of error can also be identified using the polar constellation view of the signal on the ESA-E analyzer as follows:

Instructions	Keystrokes
Access the measurement view menu for the current measurement	Press [View/Trace]
Change this to the constellation view	Press {I/Q Measured Polar Constln}

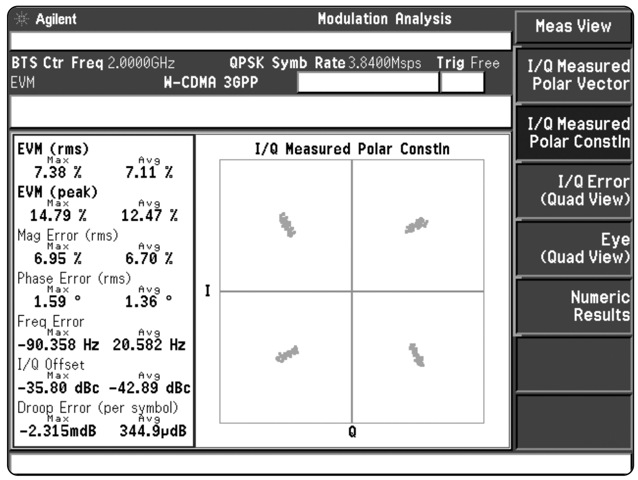

Figure 10. Polar constellation view of W-CDMA signal with an amplitude modulating interference of 45 kHz

Measurement 3: In-channel amplitude modulating (AM) interference (continued)

First note the order of magnitude difference in the magnitude and phase error. This indicates that some sort of unwanted amplitude modulation is the dominant error mode. The way the analyzer's algorithm calculates the amplitude error means that for a digitally modulated signal using the QPSK format, the percentage AM is shown by the IQ error (magnitude). Also note the amplitude around the ideal symbol reference point.

With the interference identified as an AM interference, the next step is to identify the frequency and depth of this AM signal. This can be done by

- Turning on the amplitude error vs time display.
- Repeating the process outlined above to identify the frequency of the AM signal.

View the amplitude error versus time display on the ESA analyzer (shown in figure 11) as follows:

Instructions	Keystrokes
Access measurement view menu	Press [View/Trace]
Access quad view menu	Press {I/Q Error (Quad View)}
Turn on the amplitude error versus symbol plot There are four traces in this view. This allows the potential error to be easily identified	Press [Next Window] Until the amplitude error versus symbol display is highlighted
To exclusively access the amplitude error versus symbol display, zoom in on it	Press [Zoom]
Adjust the amplitude scale	Press [AMPLITUDE]{Scale/Div}[5]{%}

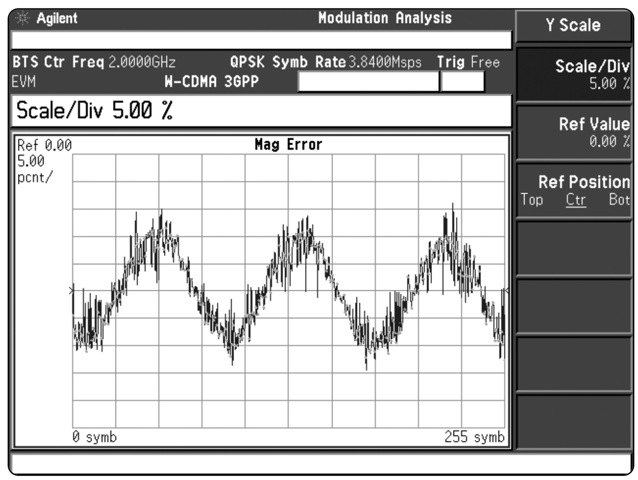

Figure 11. Zoomed in and scaled display of amplitude modulating interference of 45 kHz and depth of 10%

Measurement 4: In-channel spurious interference

Note: A second ESG signal generator is needed for this section. A spur from the second ESG is to be used to corrupt the signal from the first ESG.

Instructions	Keystrokes
Set frequency to 100 kHz above carrier of first ESG, or at 2.0001 GHz	Press [Frequency][2.0001]{GHz}
Set amplitude of spur to 15 dB below carrier frequency of modulated signal (-15 dBm)	Press [Amplitude][+/-][15]{dBm}
Turn on RF	Press [RF On/Off]. The display should read "RF ON"
Turn on MOD	The display should read "MOD ON" if not, Press [MOD On/Off]

A tone or spur generated anywhere in the transmitter can interfere with the transmitted signal if it falls in the signal's bandwidth. (Refer to figure 12.) If the interfering tone falls outside of the signal's bandwidth, then it can cause interference with other channels or systems. These tones or spurious signals will show up on a spectrum analyzer if the dynamic range is sufficient.

In-channel interfering tones, however, are usually masked by the signal in the frequency domain. The spurious or interfering tones combine with the modulated signal and interact in a manner dependent on their relative phase relationships. Even though the spur is invisible in the frequency domain, it may be identified in the modulation domain. The ESA-E series, with its constellation display, allows the identification of in channel spurious signals.

Set the first ESG-D series signal generator as follows:

Instructions	Keystrokes
Go to the amplitude modulation menu	Press [AM]
Turn the AM impairment off	Press {AM Off On} "Off" should be highlighted

Set the ESA-E series spectrum analyzer as follows:

Instructions	Keystrokes
Access the measure menu	Press [Measure]
Monitor the spectrum	Press {Monitor Spectrum}
Turn on averaging	Press {Meas Setup}{Avg Number}[100]{Enter} The "On" should be underlined

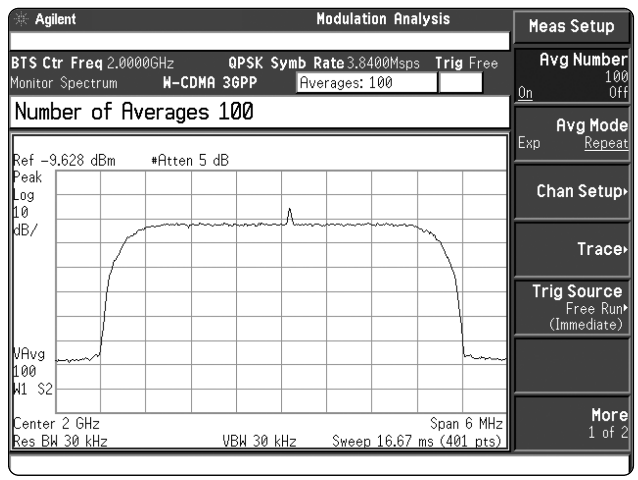

Figure 12. Spectrum of W-CDMA signal with an interfering spur 100 kHz away from carrier

Measurement 4: In-channel spurious interference (continued)

An interfering signal as substantial as this is barely visible in the spectrum view, even with a healthy amount of averaging on. A signal of amplitude any less than this will basically disappear into the "random-noise" like spectrum of the digitally modulated signal.

Fortunately there is another way to identify if an interfering spur exists. Since the spur modulates both the amplitude and phase of both the I and Q signals, it forms circles around the decision region of the constellation diagrams (as shown in figure 13.)
To see this view on the ESA analyzer, use the following steps:

Instructions	Keystrokes
Access the measure menu	Press [Measure]
Measure the EVM	Press {EVM}
Access the measurement view menu for the current measurement	Press [View/Trace]
Change this to the constellation view	Press {I/Q Measured Polar Constln}

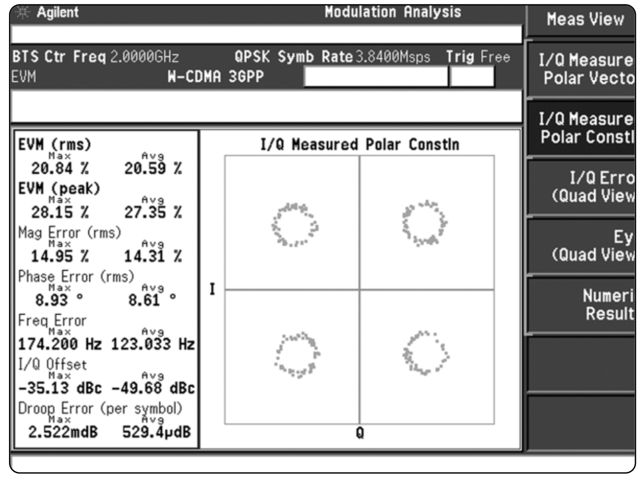

Figure 13. Constellation diagram of a W-CDMA signal with an interfering spur 100 kHz away from carrier

Using the following instructions, turn off the ESG sending the corrupting signal:

Instructions	Keystrokes
Turn on the RF	Press [RF On/Off] The display should read "RF OFF"

Measurement 5: Baseband filtering errors

Filtering errors are among the most common problems in digital communication design. Typical errors can be due to errors in filter alpha, wrong filter shape, or such problems as incorrect filter coefficients and incorrect windowing. In all cases, these errors result in increased inter-symbol interference and overshoot of the baseband signal.

Alpha defines the sharpness of the filter. In fact, the lower the alpha, the sharper the filter is in the frequency domain and the higher the overshoot in the time domain. Conversely, the larger the alpha, the smaller the overshoot is in the time domain.

In many communication systems, when using Nyquist baseband filtering, the filter response is shared between the transmitter and the receiver. The filters must be compatible and correctly implemented in each.

The constellation diagram provides the first indication of baseband filtering errors. The smaller overshoots due to an increased alpha is shown by the trajectories between the symbol points. This reduces the required peak power and reduces the power requirements of the transmitter.

Note: A lower peak overshoot can also be caused by signal compression like that in an overdriven amplifier stage.

To illustrate this error, set the ESA analyzer with an incorrect filter alpha as follows. The analyzer will display the screen shown in figure 14a.

Instructions	Keystrokes
Change view to polar vector view	Press {View/Trace} {I/Q Polar Vector}
Access demodulation format menu	Press {Det/demod}
Enter the wrong alpha of one (1) This lowers the overshoot.	Press {Alpha/BT}[1][Enter]

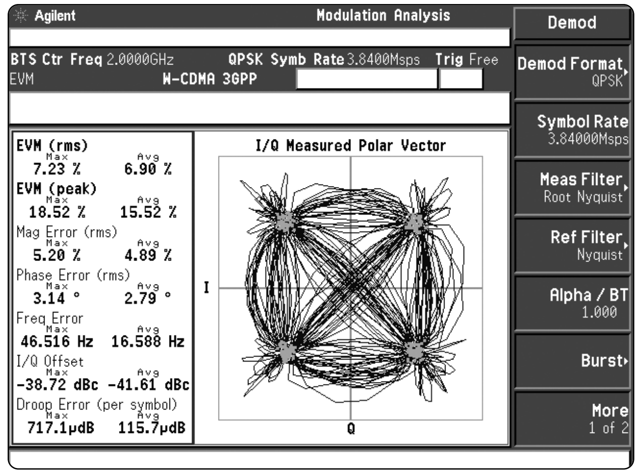

Figure 14a. Polar vector diagram of a W-CDMA signal with incorrect alpha

Next, set a correct alpha using the following instructions. This setup will create the screen shown in figure 14b.

INSTRUCTIONS	KEYSTROKES
Access demodulation format menu	Press {Det/demod}
Enter in the correct alpha of 0.22	Press {Alpha/BT}[0.22][Enter]

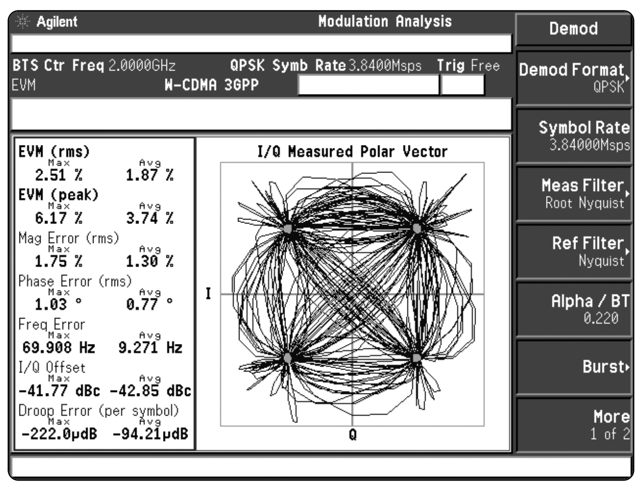

Figure 14b. Polar vector diagram of a W-CDMA signal with correct alpha

Measurement 5: Baseband filtering errors (continued)

Another useful way to identify baseband filtering errors is by looking at the EVM versus symbol (time) display. This can be done by setting the ESA-E series spectrum analyzer back with the wrong filter alpha as follows:

Instructions	Keystrokes
Change view to EVM versus symbol view	Press {View/Trace}{I/Q Error (Quad View)}
Zoom in on the EVM versus symbol display	Press [Zoom]
The peaks of the EVM signal will go off the vertical scale once an incorrect filter alpha is entered again, so increase the Y-axis scaling.	Press [Amplitude]{Scale/Div}{6}{%}
To view the trend of EVM when moving between symbols, zoom in on the X-axis scale as well. The symbol dot feature is "on" to identify the symbol locations.	Press [SPAN]{Scale/Div}[1]{Sym}
Toggle this on and off to view the differences	Press [Display]{Symbol Dots (Quad View) On Off}
Access the demodulation format menu	Press {Det/demod}
Enter in the wrong alpha of one (1) again. (If the I/Q points/symbol is not >1, this phenomena will not be seen since no inter-symbol data is shown.)	Press {Alpha/BT}[1][Enter]

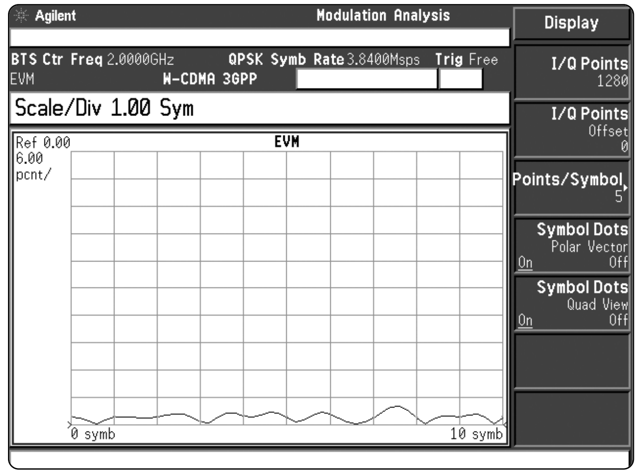

Figure 15a. Magnitude of error vector versus time of a W-CDMA signal with correct alpha

Looking at Figure 15b, the mismatch of alphas between the transmitter and receiver is seen. Although the difference would not unduly affect the symbol locations, it would cause incorrect transitions. As a result, the error vector would be large between symbol points and relatively small at the symbol locations.

Incorrect alphas also show up markedly in CCDF curves.

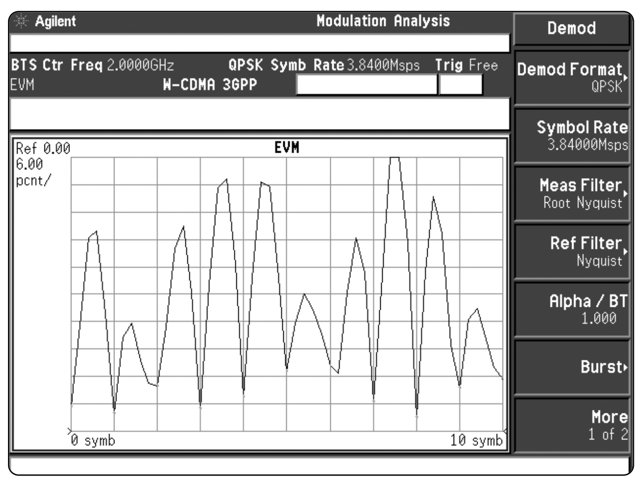

Figure 15b. Magnitude of error vector versus time of a W-CDMA signal with incorrect alpha

Measurement 5: Baseband filtering errors (continued)

Another way to visually identify baseband filtering errors is with the eye diagram view. Eye diagrams are commonly used in troubleshooting digital communication systems and can help identify problems such as ISI (inter-symbol interference) and jitter.

To display an eye diagram on the ESA-E analyzer, follow the steps outlined below:

Instructions	Keystrokes
Change view to eye diagram view	Press {View/Trace}{Eye}
Notice how compact the symbol transitions are without a lot of filtering	Press [Next Window] until the Eye diagram is highlighted
Zoom in on the eye diagram display	Press [Zoom]

An eye diagram is simply the display of the I (real) or Q (imaginary) signal magnitude versus time that is triggered by the symbol clock. The eye diagram is a superimposed display. For example, the analyzer draws the first trace, then overlays the second trace, the third trace, and so on until the number of symbols specified by [Measure Interval] is displayed. The second trace is a continuation of the first trace, the third trace is a continuation of the second trace, and so forth. Refer to figure 16.

In other words, the analyzer draws one trace to the end of the display, and then wraps it back to the beginning of the display to start the next trace. To create a complete eye diagram, the I or Q signal must alternate between all states.

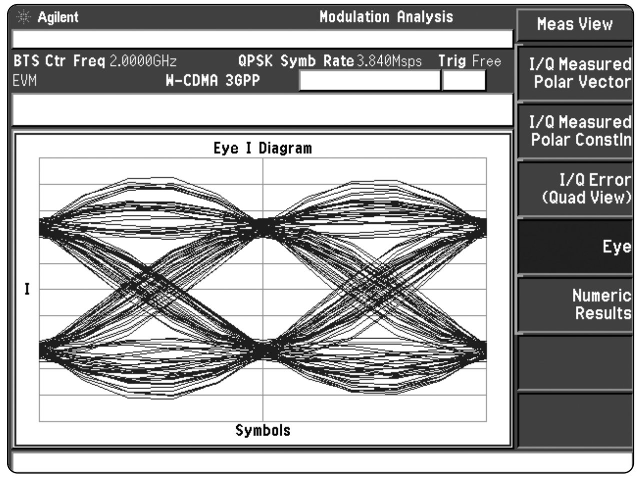

Figure 16. Eye diagram of W-CDMA signal with an incorrect alpha of 1

Measurement 5: Baseband filtering errors (continued)

Even though the symbol transitions are very compact, the spectral occupancy of the signal is large. The price one pays for little filtering, hence little overshoot, is the large occupied bandwidth.

Instructions	Keystrokes
Change the filter alpha back to 0.22	Press {Det/Demod}[0.22]{ Enter}
Notice how the eye transitions spread out	No key strokes

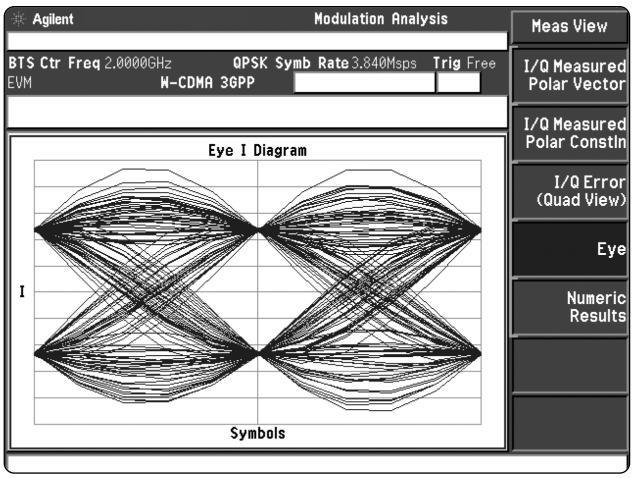

Figure 17. Eye diagram of W-CDMA signal with the correct (0.22) alpha

The eye diagram illustrated in figure 17 has a full opening at the midpoint of the eye. Now since the midpoint of the eye represents the sampling instants of each pulse, where the pulse amplitude is a maximum without interference from any other pulse, this implies that ISI is at a minimum. ISI and channel noise will cause deviation of the pulse amplitude values from their full-scale by differing amounts during each trace. This will in turn cause blurring at the decision points since the traces are superimposed. The decision threshold as to which symbol, 1 or 0, is transmitted is the midpoint of the eye.† This means that for zero ISI, the system can tolerate noise up to one-half the vertical opening of the eye. Because the ISI reduces the eye opening, it clearly reduces noise tolerance. This is a useful tool, not only for determining the presence of noise, but also for determining the robustness of the system.

† This is true for two-level decision. For a three-level decision, there will be two thresholds.

Measurement 6: Measuring a custom QPSK format signal

Set the ESG for QPSK signal generation using the following parameters:

Symbol rate	3.46 Msymbols/sec
Measurement filter	root-raised cosine
Reference filter	raised cosine
Alpha	0.35

Impair signal with an I/Q gain imbalance of 2 dB using the ESG-D signal generator as follows:

Instructions	Keystrokes
Activate the mode menu	Press [Mode] Press [Return] to return to previous menu
Go to custom mode Custom is a mode in the built-in real time I/Q baseband waveform generator that allows the construction of customized signals	For customized signal: Press {Real Time I/Q Baseband}{Custom}
Generate a QPSK signal with parameters described above	Press {Modulation Type}{Select}{PSK (π/4 DQPSK}{QPSK and OQPSK}{QPSK}
Return to the previous screen	Press [Return]
Set the symbol rate to 3.46 Msps	Press {Symbol rate}[3.46]{Msps}[Return]
Setup filter format	Press {Filter} By default the filter format should be root Nyquist. If not, Press {Select}{Root Nyquist} By default the filter alpha should be 0.35. If not, Press {Filter Alpha}[0.35]{Enter}
Optimize filter for EVM measurements	Press {Optimize FIR for EVM ACP} "EVM" should be underlined
Turn the custom signal on	Press [Return]{Custom Off On} "On" should be highlighted

Set the ESA to demodulate custom signal.
The ESA-E series with modulation analysis does not require external filtering or coherent carrier signals. The filters and symbol rates defined by the communication standards are built in. The settings can be altered if the signal being analyzed differs from a defined radio standard. The ESA is a flexible tool that allows the demodulation of any signal with a modulation formats such as QPSK. The demodulation parameters can be set up as follows:

Instructions	Keystrokes
Access demodulation format menu	Press {Det/demod}
Enter the right alpha	Press {Alpha/BT}[0.35]{Enter}
Enter the right symbol rate In W-CDMA mode 3.46 Msps should be the default. If not follow these keystrokes:	Press {Symbol rate}[3.46]{Msps}
Enter the right demodulation format In W-CDMA mode, QPSK should be the default. If not follow these keystrokes:	Press {Demod Format}{QPSK}

Change the view on the ESA-E analyzer to the polar constellation view as follows:

Instructions	Keystrokes
Access measurement view menu for the current measurement	Press [View/Trace]
Change this to the constellation view The classic four symmetric decision regions (symbol points) of a QPSK constellation should be visible	Press {I/Q Measured Polar Constln}

Measurement 7: I/Q gain imbalance

Since I and Q are two separate signals, each one is created and amplified independently. Inequality of the gain between the I and Q paths results in an incorrect positioning of each symbol in the constellation, causing errors in the recovered data. Gain imbalance can be caused by matching problems due to component differences (filters, DACs, etc.), between the I side and Q side of a network. To illustrate this, set the ESG-D generator as follows:

Instructions	Keystrokes
Go to I/Q modulation menu	Press [I/Q]
Access the I/Q impairments menu	Press {I/Q adjustments}
Add 2 dB of I/Q gain imbalance	Press {I/Q Gain}[2]{dB}
Turn the I/Q impairment on	Press {I/Q adjustments Off On} "On" should be highlighted

This signal has a 2 dB gain difference between its I and Q channels. This makes the QPSK constellation a rectangle instead of the ideal square. It is not easy to see from this constellation diagram that the gain in the Q (horizontal) axis is less that that of the I (vertical) axis. This is because these errors may appear to jump around or rotate around the axes.

However, it is easy to see that there is an I/Q gain imbalance. The reason for this is that the ESA computes a new carrier phase reference for each new time record. The ESA acts as an asynchronous receiver. There is no way to be able to work out exactly what the "right" carrier phase reference is, so it arbitrarily assigns the demodulated symbols to the I and Q channels. Try pausing the analyzer to view a single time record. As shown in figure 18b, you can also see the gain imbalance in the eye diagram display.

Pause the measurement on the ESA-E series spectrum analyzer as follows:

Instructions	Keystrokes
Access menu to allow the pausing or restarting of the measurement	Press [Meas Control]
Pause measurement	Press {Pause}
Restart measurement	Press {Resume}

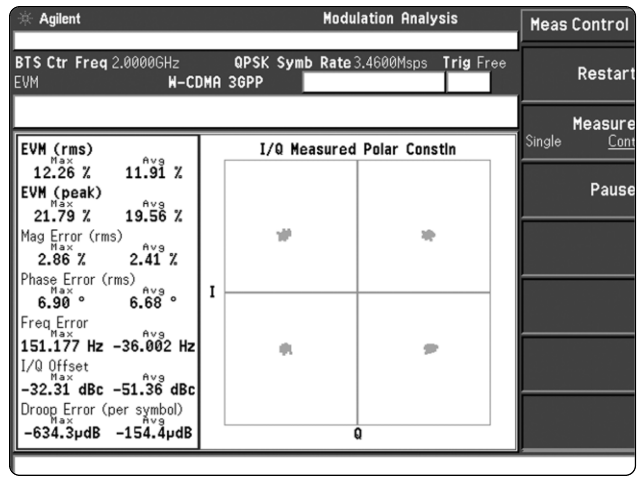

Figure 18a. Constellation display with an I/Q gain imbalance of 2 dB. Note the characteristic rectangular shape

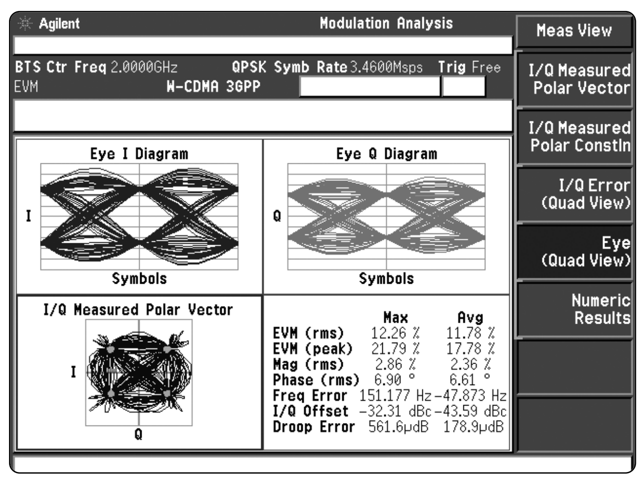

Figure 18b. Eye display with an I/Q gain imbalance of 2dB. Note that vertical axis, which corresponds to the signal magnitude, is larger on one eye than the other

Measurement 8: I/Q quadrature skew

Quadrature error occurs when the local oscillator signal at either the RF or IF mixes with the I and Q channels of a transmitter and are not operating precisely at 90 degrees to each other. This error manifests itself as a distortion of the constellation. This can cause a misinterpretation of the recovered signals. To generate a signal with an I/Q quadrature skew of 10 degrees, set the ESD-G as follows:

Instructions	Keystrokes
Go to I/Q modulation menu	Press [I/Q]
Access the I/Q impairments menu	Press {I/Q adjustments}
Turn off 2 dB of I/Q gain imbalance	Press {I/Q Gain}[0]{dB}
Turn on 10 degrees of I/Q quadrature skew This means that the angle between the I and Q paths is now 100 deg	Press {Quadrature Skew}[10]{deg }
Turn on the I/Q impairment	Press {I/Q adjustments Off On} The "On" should be highlighted

Pause the measurement on the ESA-E series spectrum analyzer as follows:

Instructions	Keystrokes
Access menu to allow the pausing or restarting of the measurement	Press [Meas Control]
Pause measurement	Press {Pause}
Restart measurement	Press {Resume}

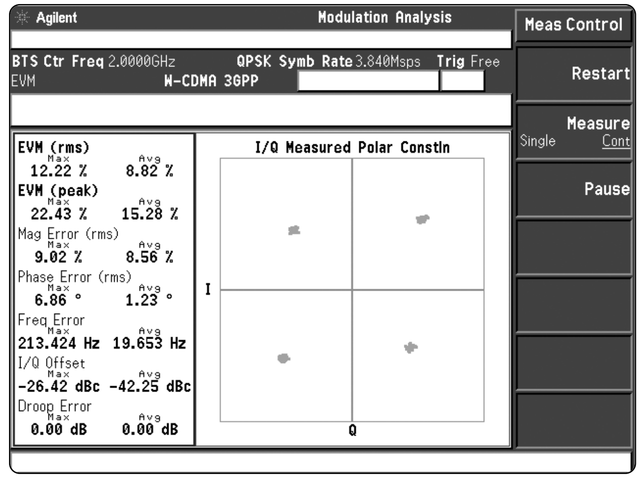

Figure 19. Constellation display of a custom QPSK signal with an I/Q quadrature skew of 10 degrees. Note the characteristic parallelogram shape.

Measurement 9: I/Q Offset and frequency errors

DC offsets may be introduced in the I and Q paths. This error mechanism is a primary indicator of LO feed-through in a transmission system. This in turn can point to potential problems such as an imbalance in the "balanced modulator." The DC offsets may also be a result of DC terms being added in components like the amplifier in the I and Q paths. Ideally, an error like this shows up in a displaced constellation from the origin of the I/Q plane. However, during the demodulation process in the ESA, certain errors like carrier frequency error and IQ offset (also known as IQ origin offset) are measured and removed. These errors are then reported in the error summary/symbol table.

To illustrate DC offset, set the ESG as follows:

Instructions	Keystrokes
Go to I/Q modulation menu	Press [I/Q]
Access the I/Q impairments menu	Press {I/Q adjustments}
Turn off 10 degrees of I/Q quadrature skew	Press {Quadrature Skew}[0]{deg}
Turn on some DC offset	Press {I Offset}[10]{%}
Turn on the I/Q impairment	Press {I/Q adjustments Off On}, The "On" should be highlighted

The constellation diagram should remain the same, indicating that the IQ origin offset error has been measured and removed by the ESA. The error is reported in the results window as an I/Q offset. This is reported as a dBc (decibel with respect to the carrier) value and explains why the figure is a negative value. This number should jump with an increase in DC offset. The residual I/Q offset of the ESA is nominally around –56 dBc.

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