Agilent
PSA Series Spectrum Analyzers Flexible Digital Modulation Analysis Measurement Personality

Technical Overview with Self-Guided Demonstration, Option 241

The PSA Series is Agilent Technologies' highest performing spectrum analyzer family. From millimeter wave and phase noise measurements to spur searches and cellular communications conformance tests - the PSA Series offers a leading-edge combination of speed, accuracy and dynamic range. R&D and manufacturing engineers in cellular, commercial and emerging wireless communications, aerospace or defense can now easily, quickly and accurately perform flexible modulation analysis on digitally modulated signals with Agilent's new measurement personality.

Agilent Technologies

Flexible Digital Modulation Analysis Inside Agilent PSA Series Spectrum Analyzers

A single analyzer for spectrum and modulation analysis

The Agilent PSA Series spectrum analyzers with the flexible digital modulation analysis measurement personality (Option 241), provide the flexibility of general-purpose spectrum analysis combined with the ability to analyze signal modulation quality. This powerful troubleshooting combination enables you to quickly identify and quantify impairments on digitally modulated signals for all major modulation formats. Now you can perform spectrum and vector measurements using one comprehensive measurement tool. By adding this option you can reduce the need for additional equipment, help increase measurement accuracy, and minimize development time.

Flexible modulation formats

Option 241 supports a wide variety of digital modulation formats including industry standard formats such as: IS-95 (cdmaOne), cdma2000, W-CDMA, EDGE/GSM, NADC, PDC, PHS, TETRA, *Bluetooth™*, ZigBee, APCO25 (phase1) and VDL mode3. If customized formats from existing cellular standards are developed, you can easily configure the digital format, filter, symbol rate and measurement interval to meet your needs. Otherwise you can set up your own custom modulation formats (MSK, PSK, FSK, QAM, DVBQAM, etc.) and parameters to suit your application.

Available measurement results

The flexible digital modulation analysis measurement personality allows you to measure error vector magnitude (EVM), the most widely used modulation quality metric in digital communications systems. EVM related metrics includes: I/Q magnitude, I/Q phase, I/Q frequency and I/Q offset (carrier feed-through).

Various traces include: I/Q polar vector and constellation, I and Q eye diagrams, magnitude error versus symbol, phase error versus symbol, and EVM versus symbol. For more in-depth analysis, use the following new PSA capabilities: demodulated bits, error vector spectrum, and EQ channel response (frequency and phase).

For an even more extensive and flexible set of digital modulation analysis measurements, consider combining a PSA Series spectrum analyzer with the Agilent 89600 Series vector signal analysis software.

Key features

- Analyze and visualize I/Q modulation with confidence and simplicity.
- Detect the most common errors with the help of intuitive measurement displays and symbol dot feature.
- Expedite troubleshooting and easily define errors with the various quantitative RMS and peak measurements available in the comprehensive results table.
- Increase productivity and reduce user error with one-button setups.
- Minimize training with easy-to-use display tools (eye, constellation, and vector diagrams).
- Distinguish between linear and non-linear sources of error by using the built-in adaptive equalizer function.
- Increase measurement confidence with guaranteed specifications below 3 GHz.
- Perform flexible digital modulation analysis on millimeter-wave signals up to 50 GHz by adding Option 241 to the PSA E4448A.
- Select from three modulation bandwidths: 10 MHz standard PSA, 40 MHz (PSA E4440A/43A/45A with Option 140), or 80 MHz (PSA E4440A/43A/45A with Option 122). Option 123 preselector bypass is recommended to add to Option 140 and 122 for higher performance over 3 GHz.

This technical overview includes:
- Measurement capabilities
- Demonstrations and explanations
- Key specifications
- Ordering information
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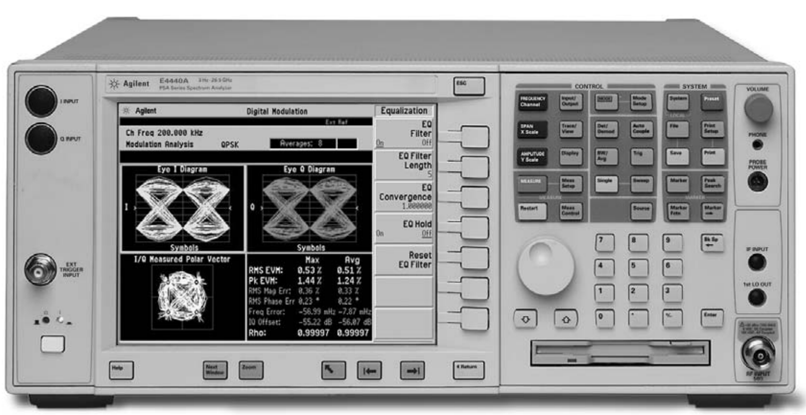

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Measurement Capabilities

Modulation formats	Predefined standards	Results, displays and analysis tools
MSK	GSM	I/Q vector & constellation
EDGE	EDGE	EVM (RMS/peak)
BPSK, QPSK, OQPSK, DQPSK	W-CDMA	Magnitude error RMS
π/4 DQPSK	cdma2000	Phase error RMS
8PSK, D8PSK, 3π/8 8PSK	*Bluetooth*	Frequency error
FSK (2, 4, 8)	NADC	I/Q origin offset
QAM (16, 32, 64, 128, 256)	PDC	Rho
DVBQAM (16, 32, 64, 128, 256)	PHS	Mean power
	IS-95	Eye diagram
	TETRA	Mag error vs. time
	ZigBee 2450 MHz	Phase error vs. time
	APCO25 phase 1	EVM vs. time
	VDL mode3	Equalization filter ON/OFF
		EQ channel response (frequency and phase)
		Error vector spectrum
		RF spectrum
		Demodulated bits

Demonstrations and Explanations

Demonstration preparation

The following options are required for the ESG and the PSA Series in order to perform this demonstration.

Product type	Model number	Required options
ESG vector signal generator	E4438C	503, 504, or 506 – frequency range up to at least 3 GHz 601 or 602 – baseband generator
PSA Series spectrum analyzer	E4440A/E4443A/E4445A/ E4446A/E4447A/E4448A	122 or 140 wide bandwidth digitizer (Not mandatory for this demo. If these options are installed on the PSA, use Option 123 as well.) 241 – flexible digital modulation analysis measurement personality

All demonstrations use the PSA Series and the E4438C ESG vector signal generator. Key strokes surrounded by [ ] indicate hard keys located on the front panel, while key names surrounded by { } indicate soft keys on the right edge of the display.

To configure these instruments, connect the ESG's 50 Ω RF output to the PSA Series' 50 Ω RF input with a 50 Ω RF cable. Turn on the power in both instruments.

Now set up the ESG to generate a QPSK signal.

Instructions	Keystrokes
On the ESG:	
Set the carrier frequency to 1 GHz.	[Preset] [Frequency] [1] {GHz}
Set amplitude to –20 dBm.	[Amplitude] [–20] {dBm}
Select custom mode.	[Mode] {Custom} {Real Time I/Q Baseband}
Set modulation parameters.	{Data} {PN Sequence} {PN23} {Filter} {Select Root Nyquist} {Filter Alpha} [0.22] {Enter} {Return} {Symbol Rate} [3.84] {Msps} [Return] {Modulation Type} {Select} {PSK} {QPSK} [Return]
Turn on the signal.	{Custom On}
Turn on RF output.	[RF On]

Instructions	Keystrokes
On the PSA Series:	
Enter digital modulation analysis mode in the analyzer.	[Preset] [Mode] {Digital Modulation}
Set center frequency to 1 GHz.	[FREQUENCY] [1] {GHz}
Change the span to see the measured spectrum.	[Span] [10] {MHz}

Demonstration start

Error vector magnitude (EVM)

An effective way to quantify modulation accuracy is to compare the signal being measured to an ideal signal. Figure 1 defines the error vector, a measure of the amplitude and phase differences between the ideal modulated signal and the actual modulated signal. EVM can be calculated and reported as RMS and peak values, and can be measured at multiple points during each symbol time, or at symbol times only. This is the error vector magnitude (EVM). EVM is a common modulation quality metric widely used in digital communications.

CDMA-based formats, which rely on correlation as part of their operation, use another parameter called rho (ρ). Rho is a measure of the correlated power to the total power. The correlated power is computed by removing frequency, phase, and time offsets and performing a cross correlation between the corrected measured signal and the ideal reference. Rho is important because uncorrelated power appears as interference to a receiver.

Measurement

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.

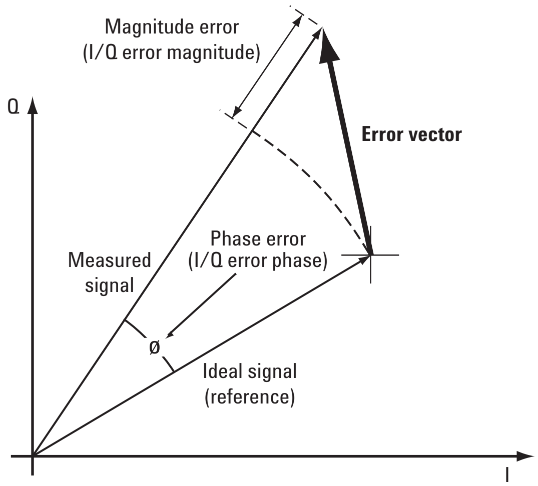

Figure 1. The error vector

Instructions	Keystrokes
On the PSA Series:	
Access to EVM measurement (Figure 2).	[Measure] {Modulation Analysis}

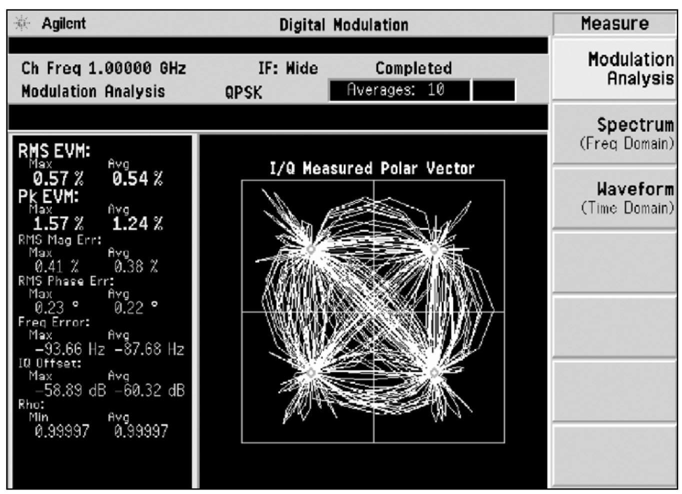

Figure 2. Polar vector view of EVM measurement

Reported 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 quality.

An I/Q polar vector display of the signal should appear on the analyzer screen, similar to that shown in Figure 2. 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.

Digital modulation analysis troubleshooting I/Q impairments

The following radio signal errors are investigated in this section:
- Symbol rate errors
- In-channel phase modulation (PM) interference
- Baseband filter errors

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 points 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 on this page to set the ESG-C for a QPSK signal with a symbol rate of 3.8415 Msps. This is a symbol rate error of 0.0015 Msps over the predefined symbol rate.

This exercise demonstrates the symbol error impact on EVM of signal modulated in QPSK with changing display.

The power of the flexible digital modulation analysis measurement personality 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 with the Agilent PSA Series with Option 241.

Instructions	Keystrokes
On the ESG:	
Change the symbol rate from 3.84 to 3.8415 Msps.	{Symbol Rate} [3.8415] {Msps}

Instructions	Keystrokes
On the PSA Series:	
Change the view menu from vector & constellation to the constellation only (Figure 3).	[Display] {I/Q Polar Type} {Constellation}

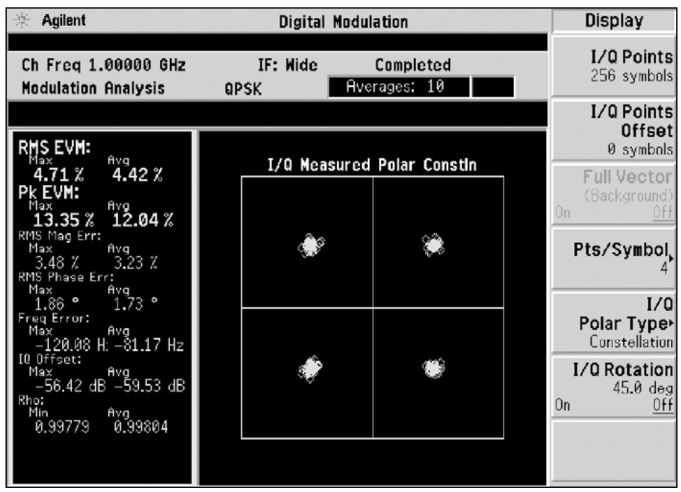

Figure 3. Polar constellation view of QPSK signal with a symbol rate error

Notice the spreading of symbol decision points and the large value of EVM for a symbol rate error of only 0.0015 Msps (.04%).

In-channel phase modulation (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. These spurious signals are 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 shown:

> This exercise demonstrates the PM interference on EVM of QPSK signal with changing view/trace.

The I/Q polar constellation should be the first step in identifying the in-channel PM problem. To view this on the PSA Series spectrum analyzer, as shown in Figure 4, follow these steps:

Instructions	Keystrokes
On the ESG:	
Change the symbol rate from 3.8415 to 3.84 Msps.	{Symbol Rate} [3.84] {Msps}
Go to frequency and phase modulation menu and select phase modulation.	[FM/ϕM], toggle {ϕM} highlighted
Set frequency of the internally generated phase modulation signal to 45 kHz.	{ϕM Rate} [45] {kHz}
Set phase modulation deviation to 0.03 π radians or approximately 5.5 degrees.	{ϕM Dev} [0.03] {pi rad}
Turn on the phase modulation.	Select ϕM {On}

Instructions	Keystrokes
On the PSA Series:	
Check the signal with constellation only display (Figure 4).	[Display] {I/Q Polar Type} {Constellation}

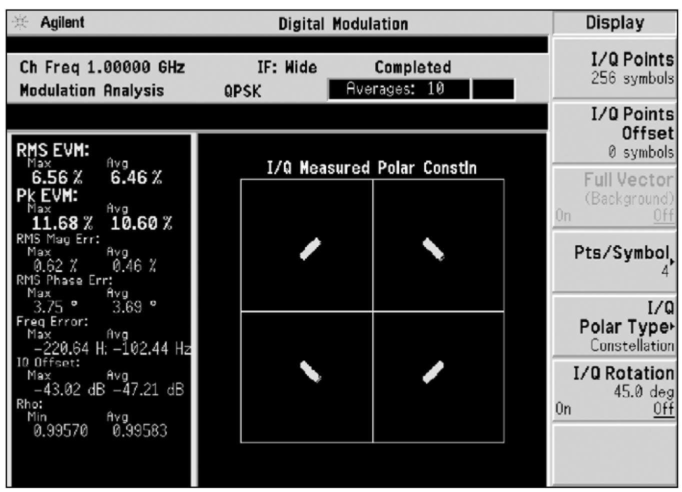

Figure 4. Polar constellation view of QPSK signal with a phase modulation interference of 45 kHz at 0.03 π radians

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.

In-channel phase modulation (PM) interference (cont'd)

To identify the frequency of the phase-modulating signal, turn on the phase error versus time display on the PSA Series spectrum analyzer.

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
On the PSA Series:	
Change the measurement view menu.	[View/Trace] {I/Q Error (Quad View)}
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*.	
Move selected windows in quad view.	[Next window] below PSA display
Select phase error versus symbol window and zoom on.	[Zoom]
Change the Y scale to see the detail on phase error trace (Figure 5).	[Y Scale Amplitude] {Scale/Div} [3] {Symbols}

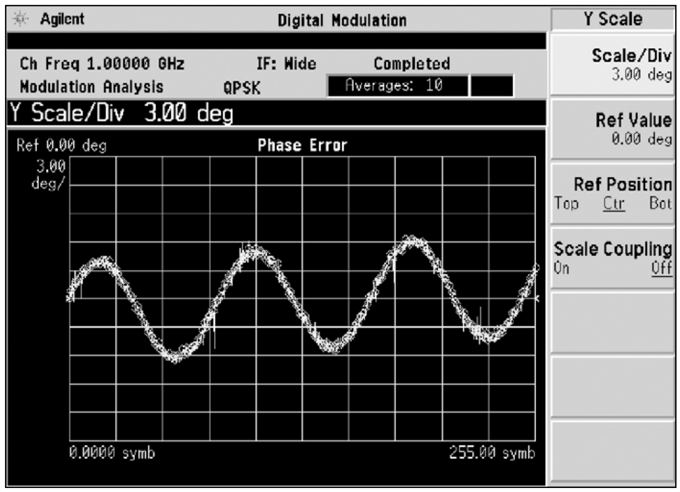

Figure 5. Zoomed phase error trace with phase modulation interference of 45 kHz at 0.03 π radians

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 $= \left(\frac{\text{3 cycles}}{\text{256 symbol}}\right)\left(\frac{3.84 \times 10^6 \text{ symbols}}{\text{1 second}}\right)$

$= 45$ 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.

Baseband filtering errors

Filtering errors are among the most common problems in digital communication design. Typical filtering errors can be due to errors in filter alpha, wrong filter shape, or problems such as incorrect filter coefficients and incorrect windowing. In all cases, these errors result in increased inter-symbol interference and overshoot or undershoot 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 PSA Series spectrum analyzer with an incorrect filter alpha as follows. The analyzer will display the screen shown in Figure 6.

Another useful way to identify baseband filtering errors is by looking at the EVM versus symbol (time) display. Set the filter alpha value to a larger value to demonstrate what baseband filtering errors look like in the EVM versus symbol (time) display.

Instructions	Keystrokes
On the ESG:	
Turn off phase modulation of the current signal.	[FM/ϕM], select {ϕM Off}
On the PSA Series:	
Change the measurement view to I/Q measured polar graph.	[View/Trace] {I/Q Measured Polar Graph}
Change from constellation only to polar vector display.	[Display] {I/Q Polar Type} {Vec & Constellation}
Enter the wrong filter alpha to lower the overshoot (Figure 6).	[Meas Setup] {Demod} {Alpha/BT} [1] [Enter]

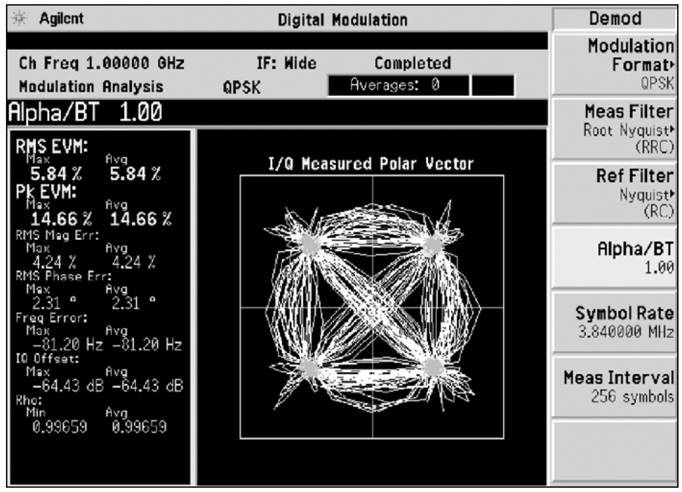

Figure 6. Polar vector diagram of a QPSK signal with incorrect filter alpha

Instructions	Keystrokes
On the PSA:	
Change view to EVM versus symbol window and zoom in.	[View/Trace] {I/Q Error (Quad View)} [Next window] [Zoom]
To see the wrong filter alpha impact on EVM between symbols, zoom in on the X-axis scale.	[Span] {Scale/Div} [1] {Symbol}
Increase the Y-axis scaling to see the peaks of the EVM signal going off the vertical scale with incorrect filter alpha (Figure 7).	[Amplitude] {Scale/Div} [5] {%}

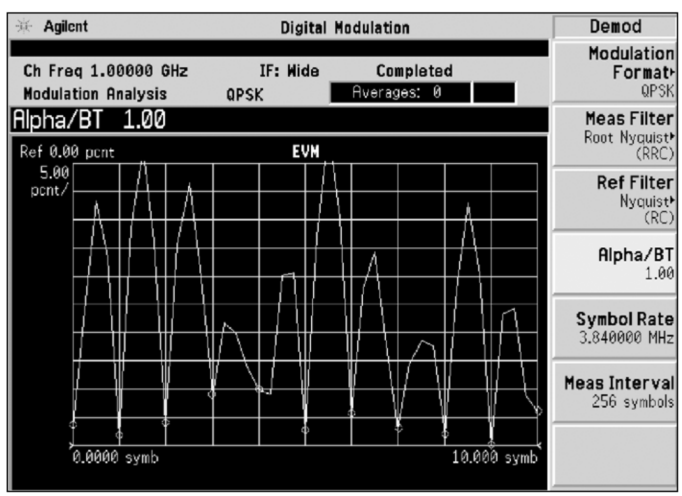

Figure 7. EVM versus time (symbols) of a QPSK signal with incorrect filter alpha

Incorrect alphas also show up markedly in CCDF curves.

Baseband filtering errors (cont'd)

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.

An eye diagram is the display of the I (real) or Q (imaginary) signal magnitude versus time that is triggered by the symbol clock. To build the eye diagram, 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.

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.

Instructions	Keystrokes
On the PSA:	
Switch view to eye diagram and zoom out (Figure 8).	[View/Trace] {Eye} [Zoom]
Change the filter alpha back to 0.22.	[Meas Setup] {Demod} {Alpha/BT} [0.22] [Enter]
Restart measurements and compare the differences on eye diagram (Figure 9).	[Restart]

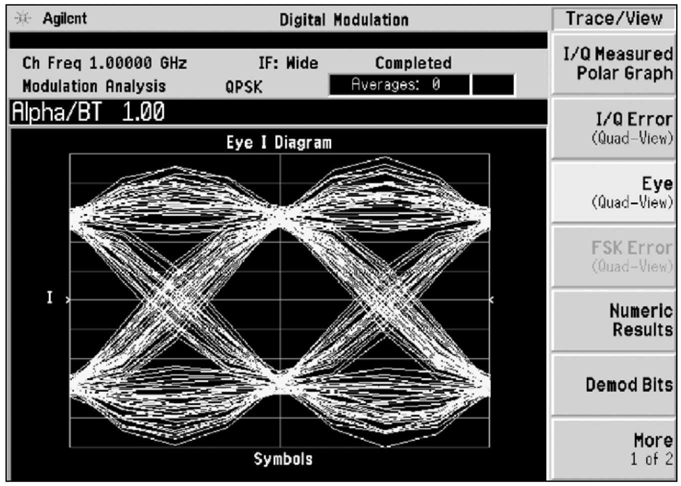

Figure 8. EVM versus time (symbols) of a QPSK signal with incorrect filter alpha

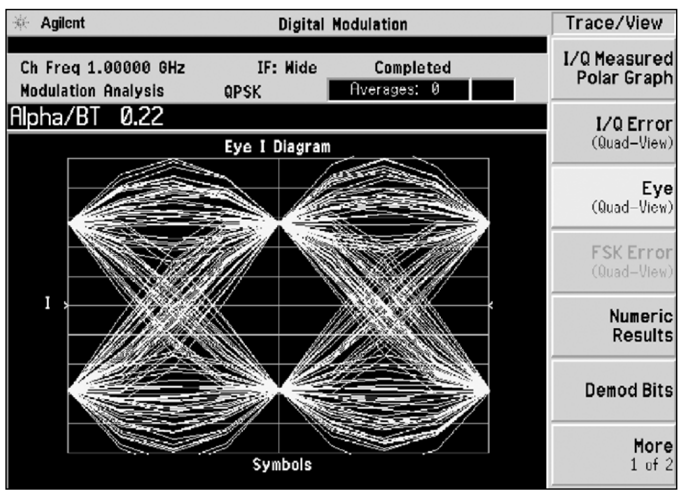

Figure 9. EVM versus time (symbols) of a QPSK signal with correct filter alpha

The eye diagram illustrated in Figure 9 has a full opening at the midpoint of the eye. 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, 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 causes 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.[1] 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 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.

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

Configuring modulation analysis parameters

We've already seen the importance of modulation parameters for correct modulation analysis. To configure and check the complicated parameters the PSA Series provides user friendly "form" for easier setup.

This exercise shows how to configure parameters in the setup "form".

Instructions	Keystrokes
On the PSA Series:	
Select "form" to check the current signal configurations (Figure 10).	[Meas Setup] {Meas Setup...}
Move selected item from "modulation format" to other parameters.	Use [<=] and [=>] keys below PSA display

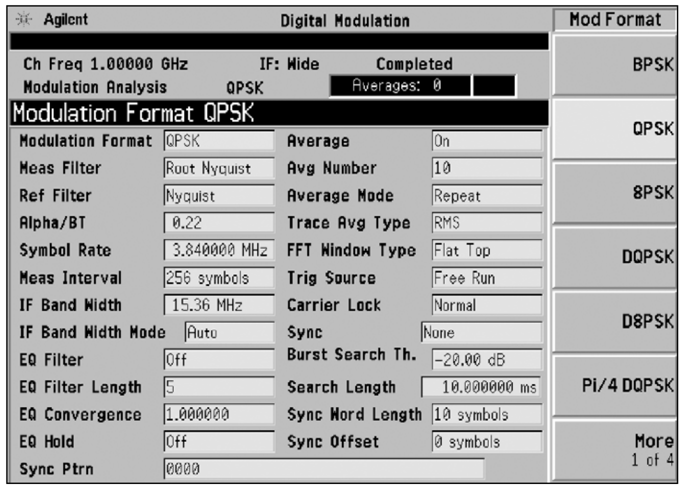

Figure 10. Convenient format to configure modulation parameters for the target signals

Using the equalization filter

Instructions	Keystrokes
On the ESG:	
Change the signal frequency from 1 GHz to 200 kHz.	[Frequency] [200] {kHz}
Modify the symbol rate from 3.84 Msps to 50 ksps.	[Mode] {Custom} {Real Time I/Q Baseband} {Symbol Rate} [50] {ksps} [Return]

This exercise shows how to eliminate linear error component in baseband filter with equalization filter function. Switching the equalization function on and off allows post-equalization and pre-equalization error measurements to be compared.

Instructions	Keystrokes
On the PSA Series:	
Change the symbol rate to the captured signal.	[Meas Setup] {Demod} {Symbol Rate} [50] {kHz}
Adjust the center frequency to 200 kHz.	[Frequency] [200] {kHz}
Switch view to I/Q polar vector to check the EVM. (Figure 11).	[View/Trace] {I/Q Measured Polar Graph} [Display] {I/Q Polar Type} {Vec & Constellation}
Change screen view to I/Q error quad view for more detail information.	[View/Trace] {I/Q Error (Quad View)}
Move selected window from mag error vs. time to EVM vs. time to zoom in.	[Next Window] [Zoom]
Change X scale to see EVM trace of 20 symbols in detail (Figure 12).	[Span X Scale] {Scale/Div} [2] [Enter]

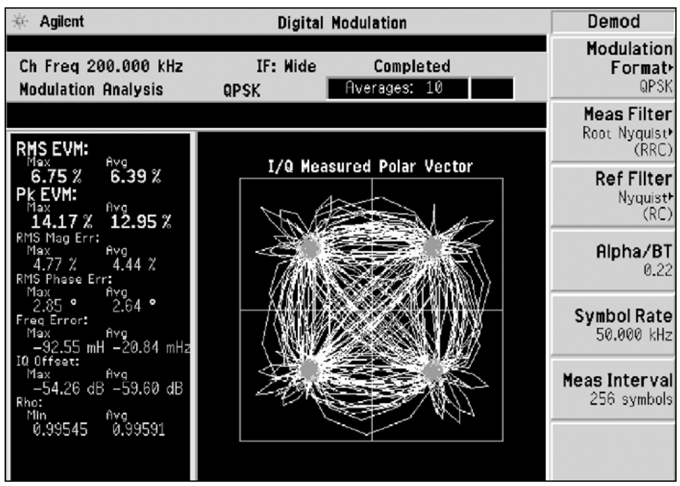

Figure 11. I/Q polar vector at center frequency 200 kHz

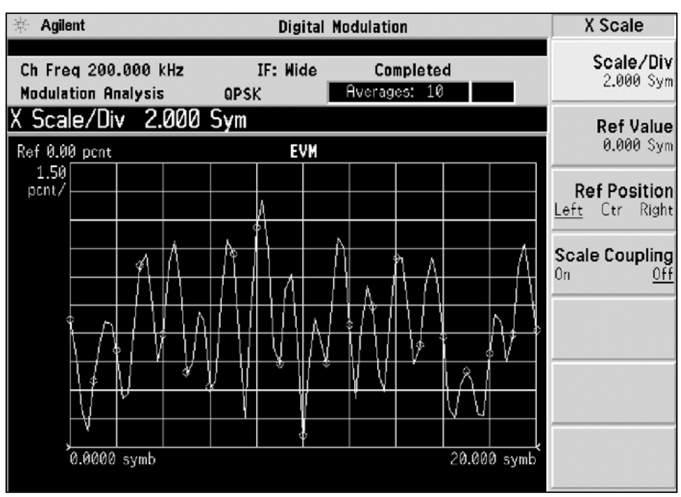

Figure 12. EVM versus time (symbols) trace of 20 symbols

Using the equalization filter (cont'd)

Adaptive equalization

Adaptive equalization identifies and removes linear errors from I/Q modulated signals by dynamically creating and applying a compensating filter. These errors include group delay distortion, frequency response errors, and reflections or multipath distortion. You can also uncover DSP errors such as miscoded bits, or incorrect filter coefficients.

Equalization is a tool that designers can use to identify and correct linear errors. Pre-distorting a signal to correct linear errors can be simpler, faster, and cheaper than modifying hardware to make corrections. Furthermore, some wideband signals are almost impossible to measure without adaptive equalization.

Instructions	Keystrokes
On the PSA Series:	
Turn equalization on (Figure 13).	[Meas Setup] {More} {Equalization} {EQ Filter On}
Check the EVM result improvement with EQ filter in numeric result table.	[Next Window]
Switch view to eye diagram.	[View/Trace] {Eye}
Turn EQ filter off and on to find the differences of eye diagram shape (Figure 14).	[Meas Setup] {More} {Equalization} {EQ Filter Off} and {On}

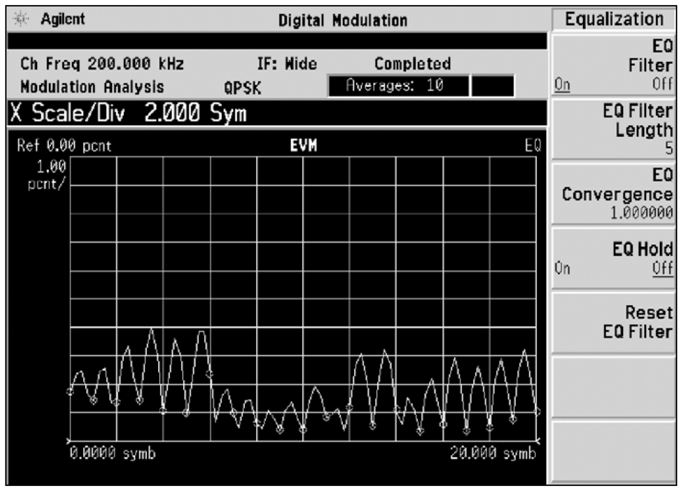

Figure 13. EVM versus time (symbols) trace of 20 symbols with EQ filter ON

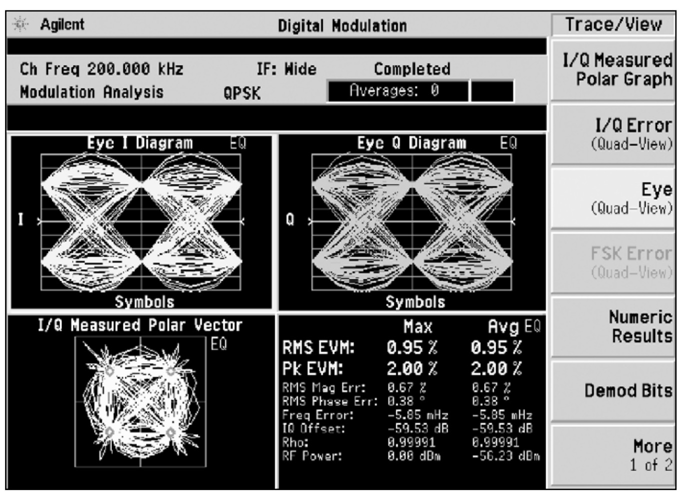

Figure 14. Eye diagram with EQ filter ON

Note:
The cause of the poor EVM at 200 kHz is the low frequency cut-off filter in the ESG signal generator. This filter removes low frequency signals and noise, and thus the ESG is not specified below 250 kHz. The adaptive equalization filter is able to compensate for the tilt (low-frequency rolloff) of this filter and dramatically improve the modulation quality.

Using the equalization filter (cont'd)

Instructions	Keystrokes
On the PSA:	
Switch the view from eye diagram to EQ filter (Figure 15). Note: When the EQ filter is turned Off, the trace cannot be seen in the equalizer quad.	[Trace/View] {Equalizer (quad view)}
Go to error vector spectrum view with EQ filter ON.	[Trace/View] {Error Vector Spectrum (quad view)}
Turn off the EQ filter to see the difference between IQ measured polar vector and IQ reference polar vector trace (Figure 16).	[Meas Setup] {Equalizer} {EQ Filter Off}

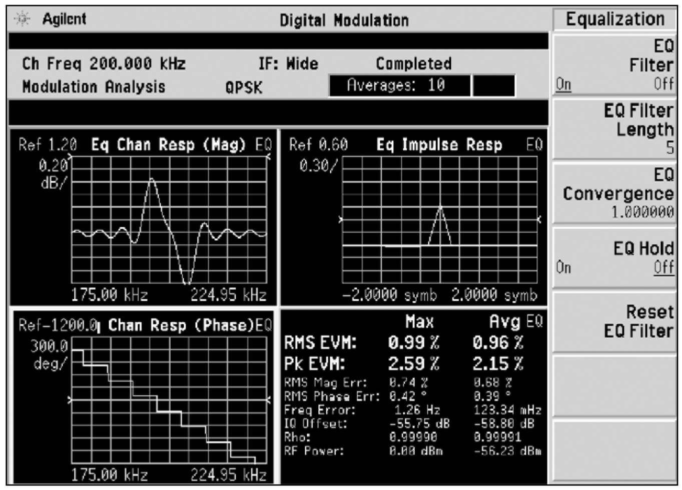

Figure 15. Equalizer view with channel frequency response, channel phase response, and impulse response with EQ filter ON

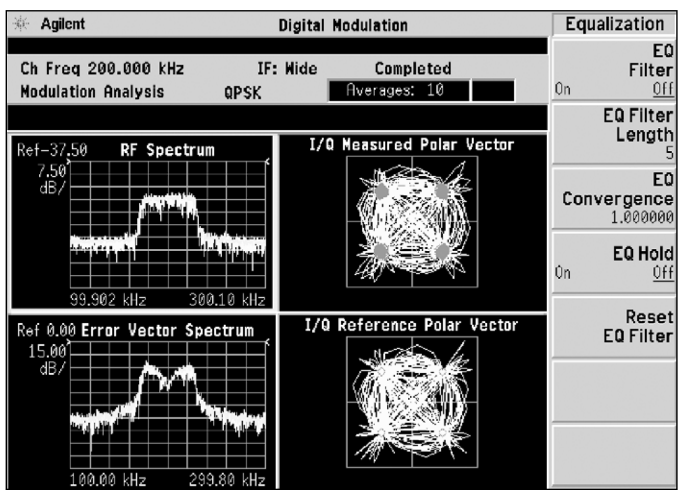

Figure 16. Error vector spectrum view with EQ filter OFF

More Useful Displays

Instructions	Keystrokes
On the PSA:	
Find the statistic result table in Result Metrics (Figure 17).	[Trace/View] {Numeric Results}
Access to the demodulated bits stream (Figure 18).	[Trace/View] {Demod Bits}

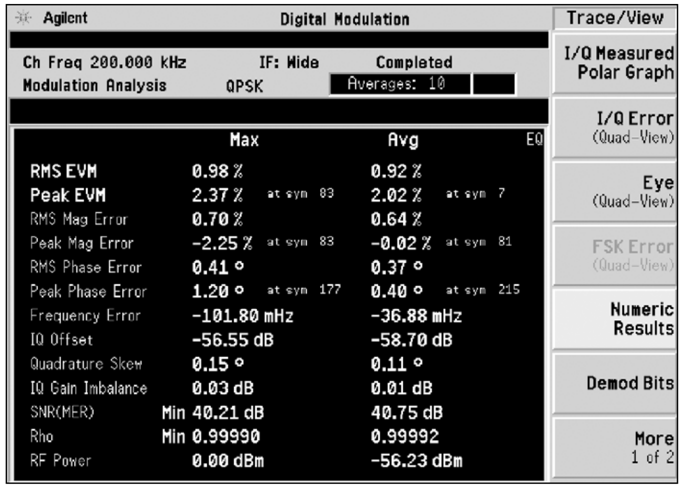

Figure 17. Numeric result table calculated for maximum and averaged values

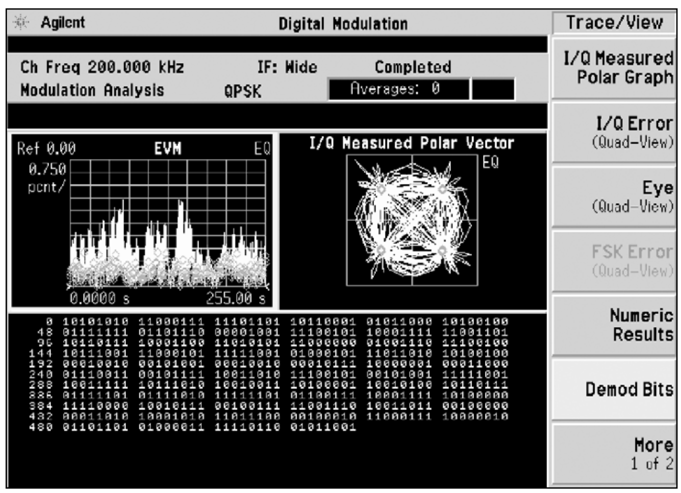

Figure 18. Demodulated bits stream with EVM versus time trace and IQ measured polar vector

PSA Series Key Specifications[1]

Flexible digital modulation analysis measurement personality

Description	Specifications	Supplemental information
Signal acquisition		
Frequency range[2]		
Specified range	10 MHz to 3 GHz	
Operational range	3 Hz to 50 GHz	Maximum frequency for each PSA model
Analysis bandwidth		
Without E444xA-122/123[3]		
Range (IFBW)	1 kHz to 10 MHz	Flat top
IF frequency response, IFBW = 10 MHz		±0.12 dB (nominal)
Phase linearity, IFBW = 6.4 MHz		1º peak-to-peak (nominal)
With E444xA-140/123[3]		
Range (IFBW)	1 kHz to 40 MHz	Flat top
IF frequency response		Supplemental information: Please refer to the IF frequency response specifications in the 80/40 MHz BW digitizer chapter of *PSA* the *Specification Guide*
Data block length	10 to 20000 symbols	Variable, based on samples per symbol
Samples per symbol	1, 2, 4, 5 or 10[4]	
Symbol clock	Internally generated	
Carrier lock	Internally generated	
Lock range (wide)[5]		± (Symbol rate or 1.5MHz smaller of) (nominal) for BPSK, QPSK, OQPSK, DQPSK, 16QAM, 64QAM, 256QAM ± (Symbol rate/2 or 750 kHz smaller of) (nominal) for 8PSK, D8PSK
Lock range (narrow)[6]		± (Symbol rate/7) (nominal) for BPSK ± (Symbol rate/12.5) (nominal) for QPSK, DQPSK, π/4 DQPSK ± (Symbol rate/200) (nominal) for OQPSK ± (Symbol rate/25) (nominal) for 8PSK ± (Symbol rate/46) (nominal) for D8PSK ± (Symbol rate/40) (nominal) for 16QAM, 32QAM ± (Symbol rate/56) (nominal) for 64QAM ± (Symbol rate/125) (nominal) for 128QAM ± (Symbol rate/360) (nominal) for 256QAM

1. See PSA Series spectrum analyzer data sheet for more details (literature number 5980-1284E).
2. Specified range is the frequency range of all specifications applying. Operational range is the frequency range of the personality being operated on each PSA model.
3. For wideband modulation analysis up to 80 MHz, E444xA-123 is necessary to get maximum performance out of Option 122 at frequencies above 3.05 GHz.
4. 2, 4 or 10 when modulation format is set to OQPSK.
5. Clean signal with random data sequence, carrier lock is set to wide. When the EVM of the signal is not good, the automatic carrier lock may find the false spectrum for the carrier frequency. In that case, the automatic carrier lock works better with the carrier lock set to normal with narrower locking range. The entire spectrum including the frequency offset must fit inside of instrument analysis bandwidth (center frequency ± (res BW/2)). The automatic carrier lock does not adjust the center frequency.
6. Clean signal with random data sequence, carrier lock is set to normal. The entire spectrum including the frequency offset must fit inside of instrument analysis bandwidth (center frequency ± (Res BW/2)).

Description	Specifications	Supplemental information
Trigger		
Source	Free run (immediate), video (IF envelope), RF burst (IF wideband), ext front, ext rear, frame	
Trigger delay		For video, RF burst, ext front,
Range	–100 ms to +500 ms	ext rear
Repeatability	±33 ns	
Trigger slope	Positive, negative	
Trigger holdoff		
Range	0 to 500 ms	
Resolution	1 μs	
Auto trigger	On, Off	
Time interval range		0 to 10 s (nominal) Does an immediate trigger if no trigger occurs before the set time interval
RF burst trigger		IF wideband for repetitive burst
Peak carrier power		signals
range at RF Input	+27 dBm to –40 dBm	
Trigger level range	0 to –25 dB	Relative to signal peak
Bandwidth		> 15 MHz (nominal)
Video (IF envelope) trigger		
Range	+30 dBm to noise floor	
Measurement control	Single, continuous, restart, pause, resume	
Data synchronization		User-selected synchronization words
Supported data formats		
Carrier types	Continuous, pulsed (burst, such as TDMA)	
Modulation formats	FSK (2, 4, 8) MSK (type 1, type 2) BPSK QPSK 8PSK OQPSK DQPSK D8PSK π/4 DQPSK 3π/8 8PSK (EDGE) QAM (16, 32, 64, 128, 256) DVBQAM (16, 32, 64, 128, 256)	
Single button pre-sets Mode for BTS and MS	W-CDMA cdmaOne cdma2000 NADC EDGE GSM PDC PHS TETRA *Bluetooth* ZigBee 2450MHz VDL Mode3 APCO25 Phase1	Single-carrier, single code channel only

Description	Specifications	Supplemental information

Filtering

Description	Specifications	Supplemental information
Measurement filter types	Nyquist (raised cosine), root nyquist (square-root raised cosine), IS-95 compatible, gaussian, EMF (EDGE) rectangle, none	
Reference filter types	Nyquist (raised cosine), root nyquist (square-root raised cosine), IS-95 compatible, gaussian, EDGE rectangle, half sine	
User-selectable alpha/BT		
Range	0.01 to 1.0	
Resolution	0.01	

Symbol rate

Description	Specifications	Supplemental information
Range		
IFBW = Narrow		1 kHz to 10 MHz[1] (nominal)
IFBW = Wide, with E444xA-122/123		10 kHz to 80 MHz[1] (nominal)
IFBW = Wide, with E444xA-140/123		10 kHz to 40 MHz[1] (nominal)
Maximum symbol rate		IFBW / (1 + α)[2]

Accuracy[3]

BPSK, QPSK, 8PSK, DQPSK, D8PSK, π/4 DQPSK[4]

Symbol rate ≥ 1kHz

Residual errors	$\alpha \geq 0.3$	$0.2 \leq \alpha < 0.3$	$\alpha \geq 0.3$ (typical)	$0.2 \leq \alpha < 0.3$ (typical)
Error vector magnitude (EVM)				
Symbol rate < 10 kHz	0.8% rms	0.9% rms	0.7% rms	0.7% rms
Symbol rate < 100 kHz	0.7% rms	0.7% rms	0.6% rms	0.6% rms
Symbol rate < 1 MHz	0.9% rms	0.9% rms	0.6% rms	0.7% rms
Symbol rate < 6 MHz	2.1% rms	2.1% rms	1.2% rms	1.2% rms
Magnitude error				
Symbol rate < 10 kHz	0.4% rms	0.5% rms	0.4% rms	0.5% rms
Symbol rate < 100 kHz	0.4% rms	0.5% rms	0.4% rms	0.5% rms
Symbol rate < 1 MHz	0.5% rms	0.6% rms	0.4% rms	0.5% rms
Symbol rate < 6 MHz	1.5% rms	1.5% rms	0.8% rms	0.8% rms
Phase error[5]				
Symbol rate < 10 kHz	0.5° rms	0.5° rms	0.4° rms	0.4° rms
Symbol rate < 100 kHz	0.4° rms	0.4° rms	0.3° rms	0.3° rms
Symbol rate < 1 MHz	0.5° rms	0.5° rms	0.3° rms	0.3° rms
Symbol rate < 6 MHz	1.2° rms	1.2° rms	0.7° rms	0.7° rms
Frequency error			± Symbol rate / 500,000 + tfa[6] (nominal)	
I-Q origin offset			–60 dB (nominal)	

16QAM, 32QAM, 64QAM, 128QAM, 256QAM[7]

Symbol rate ≥ 10 kHz

Residual errors	$0.2 \leq \alpha \leq 0.3$	$0.1 \leq \alpha < 0.2$	$0.2 \leq \alpha \leq 0.3$ (typical)	$0.1 \leq \alpha < 0.2$ (typical)

1. Meaningful operational range is limited by the maximum symbol rate. For best EVM results, the spectrum must be inside of the instrument analysis bandwidth (venter frequency ± (Res BW/2)).
2. Determined by the IFBW and the excess bandwidth factor (a) of the input signal. The entire signal must fit within the selected IFBW.
3. These specifications apply to the signal without an input overload message, (RF input power – input atten) ≥ –25 dBm, random data sequence, and temperature 20 to 30 °C.
4. Meas filter = root nyquist, ref filter = nyquist, results length = 150 symbols.
5. For modulation formats with equal symbol amplitudes.
6. tfa = transmitter frequency x frequency reference accuracy
7. Meas filter = root nyquist, ref filter = nyquist, results length = 800 symbols.

Description	Specifications		Supplemental information	
Error vector magnitude (EVM)				
Symbol rate < 100 kHz	0.7% rms	0.9% rms	0.6% rms	0.8% rms
Symbol rate < 1 MHz	0.8% rms	1.0% rms	0.6% rms	0.9% rms
Symbol rate < 6 MHz	2.1% rms	2.7% rms	1.2% rms	1.3% rms
Magnitude error				
Symbol rate < 100 kHz	0.3% rms	0.5% rms	0.2% rms	0.5% rms
Symbol rate < 1 MHz	0.5% rms	0.7% rms	0.4% rms	0.6% rms
Symbol rate < 6 MHz	1.5% rms	2.0% rms	0.9% rms	0.9% rms
Phase error				
Symbol rate < 100 kHz	0.4° rms	0.6° rms	0.3° rms	0.6° rms
Symbol rate < 1 MHz	0.6° rms	0.7° rms	0.4° rms	0.6° rms
Symbol rate < 6 MHz	1.5° rms	1.8° rms	0.9° rms	0.9° rms
Frequency error			± Symbol rate / 500,000 + tfa[1] (nominal)	
I-Q origin offset			–60 dB (nominal)	
MSK[2]				
Symbol rate = 200 to 300 kHz BT = 0.3				
Residual errors				
Phase error	0.3° rms			
Frequency error	±5 Hz + tfa[1]			
I-Q origin offset			–60 dB (nominal)	
16, 32, 64, 128, 256DVBQAM				
Symbol rate = 6.9 MHz				
Alpha = 0.15				
Residual errors				
Error vector magnitude (EVM)			0.7 % rms (nominal)	
Frequency = 1.0 GHz				
QPSK[3] Symbol rate = 5 MHz			Operated with E4440A-122 or 140 (IF path = wide) and 123 (preselector = OFF)	
Residual errors			α = 0.22 (nominal)	
Error vector magnitude (EVM)				
Frequency = 5.0 GHz			0.4% rms	
Frequency = 10.0 GHz			0.4% rms	
Frequency = 15.0 GHz			0.6% rms	
Frequency = 20.0 GHz			0.8% rms	
QPSK[3] Symbol rate = 15 MHz			Operated with E4440A-122 or 140 (IF path = wide) and 123 (preselector = OFF)	
Residual errors			α = 0.22 (nominal)	
Error vector magnitude (EVM)				
Frequency = 5.0 GHz			0.6% rms	
Frequency = 10.0 GHz			0.7% rms	
Frequency = 15.0 GHz			0.8% rms	
Frequency = 20.0 GHz			1.2% rms	
QPSK[3] Symbol rate = 30 MHz			Operated with E4440A-122 or 140 (IF path = wide) and 123 (preselector = OFF)	
Residual errors			α = 0.22 (nominal)	
Error vector magnitude (EVM)				
Frequency = 5.0 GHz			1.4% rms	
Frequency = 10.0 GHz			1.3% rms	
Frequency = 15.0 GHz			1.6% rms	
Frequency = 20.0 GHz			1.9% rms	

1. tfa = transmitter frequency x frequency reference accuracy
2. Meas filter = none, ref filter = Gaussian, results length = 148 symbols.
3. Meas filter = root Nyquist, ref filter = Nyquist, results length = 150 symbols.

Ordering Information

PSA Series spectrum analyzer

E4443A	3 Hz to 6.7 GHz
E4445A	3 Hz to 13.2 GHz
E4440A	3 Hz to 26.5 GHz
E4447A	3 Hz to 42.98 GHz
E4446A	3 Hz to 44 GHz
E4448A	3 Hz to 50 GHz

Options

To add options to a product, use the following ordering scheme:

Model	E444xA (x = 0, 3, 5, 6 or 8)
Example options	E4440A-B7J E4448A-1DS

Digital demodulation hardware

E444xA-B7J	Digital demodulation hardware (required for cellular communication measurement personalities)

Wireless communication measurements

E444xA-BAF	W-CDMA measurement personality (requires B7J)
E444xA-210	HSDPA measurement personality (requires B7J and BAF)
E444xA-202	GSM w/ EDGE measurement personality (requires B7J)
E444xA-B78	cdma2000 measurement personality (requires B7J)
E444xA-214	1xEV-DV measurement personality (requires B7J and B78)
E444xA-204	1xEV-DO measurement personality (requires B7J)
E444xA-BAC	cdmaOne measurement personality (requires B7J)
E444xA-BAE	NADC, PDC measurement personality (requires B7J)
E444xA-211	TD-SCDMA measurement personality
E444xA-217	WLAN measurement personality (requires 140 or 122, 123)

General purpose measurements

E444xA-226	Phase noise measurement personality
E444xA-219	Noise figure measurement personality (requires 1DS)
E444xA-241	Flexible digital modulation analysis measurement personality
E444xA-266	Programming code compatibility suite
E444xA-215	External source control

Hardware

E444xA-1DS	100 kHz to 3 GHz built-in preamplifier
E444xA-B7J	Digital demodulation hardware
E4440A-122	80 MHz bandwidth digitizer (E4440A only, excludes H70)
E444xA-140	40 MHz bandwidth digitizer (E4440A/43A/45A only, excludes 122, H70)
E444xA-123	Switchable MW preselector bypass (E4440A/43A/45A only, excludes AYZ)
E444xA-124	Y-axis video output
E444xA-AYZ	External mixing (E4440A/46A/47A/48A only, excludes 123)
E4440A-BAB	Replaces type-N input connector APC 3.5 connector

Amplifiers

E444xA-1DS	100 kHz to 3 GHz built-in preamplifier

Inputs and outputs

E444xA-H70	70 MHz IF output (excludes 122, 140)
E444xA-H26	Highband preamplifier (requires 1DS)

Connectivity software

E444xA-230	BenchLink Web remote control software
E444xA-233	N5530S measuring receiver software and license
E4440A-235	Wide bandwidth digitizer calibration wizard

Accessories

E444xA-1CM	Rack mount kit
E444xA-1CN	Front handle kit
E444xA-1CP	Rack mount with handles
E444xA-1CR	Rack slide kit
E444xA-015	6 GHz return loss measurement accessory kit
E444xA-045	Millimeter wave accessory kit
E444xA-0B1	Extra manual set including CD ROM
E444xA-0B0	Delete manual set

Warranty and service

Standard warranty is 36 months.

R-51B	Return-to-Agilent warranty and service plan

Calibration[1]

R-50C-011-3	Inclusive calibration plan, 3-year coverage
R-50C-013-3	Inclusive calibration plan and cal data, 3-year coverage
E444xA-0BW	Service manual, assembly level
E444xA-UK6	Commercial calibration certificate with test data
N7810A	PSA Series calibration application software

1. Options not available in all countries.

Product Literature

PSA in general

- *Selecting the Right Signal Analyzer for Your Needs, Selection Guide,* literature number 5968-3413E
- *PSA Series, Brochure,* literature number 5980-1283E
- *PSA Series, Data Sheet,* literature number 5980-1284E
- *PSA Series, Configuration Guide,* literature number 5989-2773EN
- Self-Guided Demonstration for *Spectrum Analysis, Product Note,* literature number 5988-0735EN

Wide bandwidth and vector signal analysis

- *40/80 MHz Bandwidth Digitizer, Technical Overview,* literature number 5989-1115EN
- *Vector Signal Analysis Basics, Application Note 150-15,* literature number 5989-1121EN
- *Using Extended Calibration Software for Wide Bandwidth Measurements, PSA Option 122 & 89600 VSA, Application Note 1443,* literature number 5988-7814EN
- *PSA Series Spectrum Analyzer Performance Guide Using 89601A Vector Signal Analysis Software, Product Note,* literature number 5988-5015EN
- *89650S Wideband VSA System with High Performance Spectrum Analysis, Technical Overview,* literature number 5989-0871EN

Measurement personalities and applications

- *Phase Noise Measurement Personality, Technical Overview,* literature number 5988-3698EN
- *Noise Figure Measurement Personality, Technical Overview,* literature number 5988-7884EN
- *External Source Measurement Personality, Technical Overview,* literature number 5989-2240EN
- *Flexible Modulation Analysis Measurement Personality, Technical Overview,* literature number 5989-1119EN
- *W-CDMA and HSDPA Measurement Personalities, Technical Overview,* literature number 5988-2388EN
- *GSM with EDGE Measurement Personality, Technical Overview,* literature number 5988-2389EN
- *cdma2000 and 1xEV-DV Measurement Personalities, Technical Overview,* literature number 5988-3694EN
- *1xEV-DO Measurement Personality, Technical Overview,* literature number 5988-4828EN
- *cdmaOne Measurement Personality, Technical Overview,* literature number 5988-3695EN
- *WLAN Measurement Personality, Technical Overview,* literature number 5989-2781EN
- *NADC/PDC Measurement Personality, Technical Overview,* literature number 5988-3697EN
- *TD-SDCMA Measurement Personality, Technical Overview,* literature number 5989-0056EN
- *Agilent N5530S Measuring Receiver System, Technical Overview,* literature number 5989-1113EN
- *BenchLink Web Remote Control Software, Product Overview,* literature number 5988-2610EN
- *IntuiLink Software, Data Sheet,* literature number 5980-3115EN
- *Programming Code Compatibility Suite, Technical Overview* literature number 5989-1111EN

Options

- *PSA Series Spectrum Analyzers Video Output (Option 124), Technical Overview,* literature number 5989-1118EN
- *PSA Series Spectrum Analyzers, Option H70, 70 MHz IF Output, Product Overview,* literature number 5988-5261EN

Back to basics

- *Optimizing Dynamic Range for Distortion Measurements, Product Note,* literature number 5980-3079EN
- *PSA Series Amplitude Accuracy, Product Note,* literature number 5980-3080EN
- *PSA Series Swept and FFT Analysis, Product Note,* literature number 5980-3081EN
- *PSA Series Measurement Innovations and Benefits, Product Note,* literature number 5980-3082EN
- *Spectrum Analysis Basics, Application Note 150,* literature number 5952-0292
- *8 Hints for Millimeter Wave Spectrum Measurements, Application Note,* literature number 5988-5680EN
- *Spectrum Analyzer Measurements to 325 GHz with the Use of External Mixers, Application Note 1453,* literature number 5988-9414EN
- *EMI, Application Note 150-10,* literature number 5968-3661E

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