HP 89441A
dc to 2.65 GHz
Vector Signal Analyzer

Technical Data

Specifications describe warranted performance over the temperature range of 0° to 55°C (except where noted) and include a 30-minute warm-up from ambient conditions, automatic calibrations enabled, auto-zero on, time domain calibration off, and anti-alias filter in, unless noted otherwise. Supplemental characteristics identified as "typical" or "characteristic," provide useful information by giving non-warranted performance parameters. Typical performance is applicable from 20° to 30°C.

When enabled, automatic calibrations are periodically performed to compensate for the effects of temperature and time sensitivities. During the calibration, no signals >0 dBm should be connected to the front panel inputs.

Definitions

Baseband = dc to 10 MHz measurements.

Baseband time = Time-domain measurements selected by setting start frequency to exactly 0 Hz or choosing full span in 0 to 10 MHz measurements.

dBc = dB relative to input signal level.

dBfs = dB relative to full scale amplitude range setting. Full scale is approximately 2 dB below ADC overload.

Analog demodulation mode = Measurements with AM, PM, and FM demodulation capabilities.

FS or fs = Full scale; synonymous with amplitude range or input range.

RBW = Resolution bandwidth.

RF = 2 MHz to 2.65 GHz measurements.

Scalar mode = Measurements with only frequency-domain analysis available. Frequency spans up to 2648 MHz.

SNR = Signal to noise ratio.

Vector mode = Measurements with frequency- and time-domain capabilities. Frequency spans up to 10 MHz in baseband, and 7 MHz for RF analysis (8 MHz with option AYH).

Zoom time = Time-domain measurements selected by setting frequency parameters using center frequency and span values.

Standard Features

Frequency
dc to 2.650 GHz
51 to 3201 points
Center frequency signal-tracking

Instrument modes
Scalar (frequency-domain only)
Vector (amplitude and phase information in frequency- and time-domain and also time-gating)
Analog demodulation (AM/FM/PM)

Sweep types
Continuous
Manual
Single

Triggering
Free run
External
Input channel
External arm
IF channel
Programmable polarity and level
Internal source
HP-IB
Pre and post delay
Trigger holdoff

Averaging
Video
Peak hold
Video exponential
Simultaneous display of instantaneous and average spectrum
Time
Time exponential

Source types
CW
Periodic chirp
Random noise
Arbitrary (up to 8192 points)

Input
One channel
Second 10 MHz input channel (optional)
Auto-ranging (baseband only)
Overload indicators
50/75/1M Ω BNC (dc to 10 MHz)
50 Ω Type-N, 75 Ω with minimum-loss pad (2 MHz to 2650 MHz)

Resolution/window shapes
1-3-10 bandwidth steps
Arbitrary RBW
Windows: Flat-top (high amplitude accuracy), Gaussian-top (high dynamic range), Hanning (high frequency resolution), Uniform
Detectors: normal, positive peak, sample

Measurement data
Spectrum
Time capture
PSD
Frequency response, coherence, cross spectrum, and cross correlation (with second 10 MHz input channel)
Main time
Gate time
Math function
Data register
Auto correlation
Instantaneous spectrum

Data format
Log magnitude
Imaginary part
Linear magnitude
Group delay
Phase (wrap or unwrap)
Log/linear x-axis
Real part

Trace math

Display
1, 2, or 4 grids
1 to 4 traces displayed (single or overlay)
Auto-scaling
Color (user definable)
User trace title and information
Graticule on/off
Data label blanking
X-axis scaling
Instrument/Measurement state displays
External monitor

Markers
Marker search: Peak, next peak, next peak right, next peak left, minimum
Marker to: Center frequency, reference level, start frequency, stop frequency
Offset markers
Couple markers between traces
Marker functions: Peak track, frequency counter, band power (frequency, time, or demodulation results), peak/average statistics

Memory and data-storage
Disk devices
Nonvolatile RAM disk (100 Kbyte)
Volatile RAM disk (up to 1 Mbyte)
90 mm (3.5-inch) 1.44 Mbyte flexible disk (HP LIF or MS-DOS® formats)
External HP-IB disk
Disk format and file delete, rename, and copy
Nonvolatile clock with time/date
Save/recall of: Trace data, instrument states, trace math functions, HP Instrument BASIC programs, time-capture buffers

Online help

Hard copy output
HP-IB/HPGL plotters
HP-IB/RS-232/parallel printers
Plot to file
Time stamp
Single-plot spooling

Interfaces
HP-IB (IEEE 488.1 and 488.2)
External reference in/out
External PC-style keyboard
Active probe power
RS-232 (one port)
Centronics
LAN and second HP-IB (optional)

Standard data format utilities

Optional features
HP Instrument BASIC (option 1C2)
Vector modulation analysis (option AYA)
Digital video modulation analysis (option AYH)
Waterfall and spectrogram (option AYB)
Extended RAM and additional I/O (option UFG)
Advanced LAN support (option UG7)
Adaptive Equalization (option AYH or AYJ)

RF

RF specifications apply with the receiver mode set to "RF section (2-2650 MHz)."

Frequency

Frequency tuning

Frequency range	2 MHz to 2650 MHz
Frequency span	
Scalar mode	1 Hz to 2648 MHz
Vector mode	1 Hz to 7 MHz (8 MHz with option AYH)
Center frequency tuning resolution	0.001 Hz
Number of frequency points/span	51 to 3201

Signal track (when enabled) keeps the largest measured signal at the center frequency.

Frequency accuracy (with standard high-precision frequency reference)

Frequency accuracy is the sum of initial accuracy, aging, and temperature drift.

Initial accuracy	± 0.1 ppm
Aging	± 0.015 ppm/month
Temperature drift	± 0.005 ppm (0° to 55°C)

Frequency counter

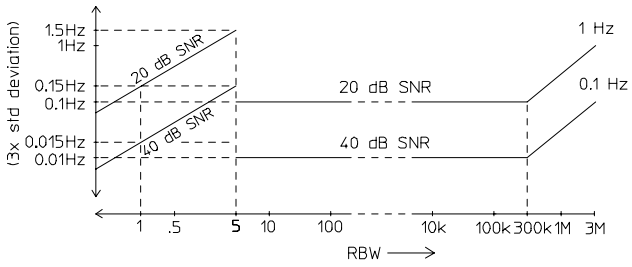
The frequency counter operates in scalar or vector mode.

Frequency counter accuracy

Total accuracy is the sum of the frequency counter's basic accuracy and the instrument's frequency accuracy.

Conditions/Exceptions:

Signal-to-noise ratio within resolution bandwidth, 20 dB minimum
Marker within 1/2 resolution bandwidth of peak
Unspecified for uniform window and resolution bandwidth < 5 Hz



Frequency counter basic accuracy

Stability (spectral purity) (with standard high-precision frequency reference or equivalent with ≥ 5 dBm level)

Phase noise (absolute and residual)

F_{in} ≤ 200 MHz

100 Hz offset	<– 103 dBc/Hz
1 kHz offset	<– 112 dBc/Hz
≥ 10 kHz offset	<– 116 dBc/Hz

200 MHz ≤ F_{in} ≤ 1 GHz

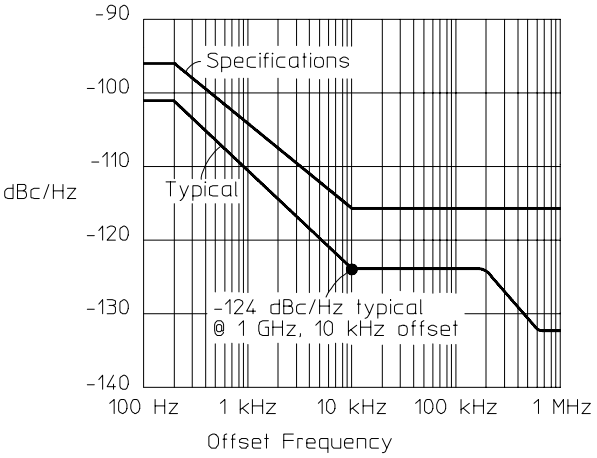
100 Hz offset	<– 96 dBc/Hz
1 kHz offset	<– 104 dBc/Hz
≥ 10 kHz offset	<– 116 dBc/Hz

1 GHz ≤ F_{in} ≤ 2650 MHz

100 Hz offset	<– 87 dBc/Hz
1 kHz offset	<– 97 dBc/Hz
≥ 10 kHz offset	<– 116 dBc/Hz

LO spurious sidebands

Offset > 1 kHz	<– 75 dBc
Offset ≤ 1 kHz	
f_{in} ≤ 2 GHz	<– 70 dBc
f_{in} > 2 GHz	<– 68 dBc



Spectral purity at 1 GHz

Resolution bandwidth

Range	312.5 µHz to 3 MHz in 1, 3, 10 sequence or arbitrary user-definable bandwidth

Note: In scalar mode, the minimum resolution bandwidth is 312.5 µHz and the maximum resolution bandwidth is a function of span. In vector mode, the minimum resolution bandwidth is a function of span and the number of frequency points, and the maximum resolution bandwidth is a function of span only.

Window	Selectivity†	Passband flatness	Sideband level
Flat-top	2.45:1	+ 0, – 0.01 dB	– 95 dBc
Gaussian-top	4.0:1	+ 0, – 0.68 dB	– 125 dBc
Hanning	9.1:1	+ 0, – 1.5 dB	– 32 dBc
Uniform	716:1	+ 0, – 4 dB	– 13 dBc

† Shape factor or ratio of – 60 dB to – 3 dB bandwidths.

Amplitude

Input range	– 50 dBm to + 25 dBm (5 dB steps)
Maximum safe input power	
Average continuous power	+ 25 dBm (300 mW)
DC voltage	25 V
A/D overload level (typical)	> 1.5 dB above range

Input port

Input channels	1
VSWR	
Range ≥– 20 dBm	1.6:1 (12.7 dB return loss)
Range ≤– 25 dBm	1.8:1 (11 dB return loss)
Impedance	50 Ω (75 Ω with minimum-loss pad option 1D7)
Connector	Type-N

Amplitude accuracy

Accuracy specifications apply with flat-top window selected.
Amplitude accuracy is the sum of absolute full-scale accuracy and amplitude linearity.

Absolute full-scale accuracy (with signal level equal to range)

	20° - 30°C	0° - 55°C
≥– 25 dBm range	± 1 dB (0.5 dB typical)	± 2 dB
≤– 30 dBm range	± 1.5 dB (0.5 dB typical)	± 3 dB

Amplitude linearity

0 to – 30 dBfs	< 0.10 dB
– 30 to – 50 dBfs	< 0.15 dB
– 50 to – 70 dBfs	< 0.20 dB

In vector mode, relative level accuracy within a single span is the sum of vector mode frequency response and amplitude linearity.

Vector mode frequency response (relative to the center frequency)	± 0.4 dB

Dynamic range

Dynamic range indicates the amplitude range that is free of erroneous signals within the measurement bandwidth.

Harmonic distortion (with a single full scale signal at the input)

≥– 25 dBm range	<– 75 dBc
≤– 30 dBm range	<– 54 dBc

Third-order intermodulation distortion (with two input tones at 6 dB below full scale and ≥ 10 MHz) <– 75 dBc

General spurious (with input signal level equal to range and input frequency ≤ 2650 MHz)

For spans ≤ 1.5 MHz and for offset frequencies ≤ 1.5 MHz from input signal	<– 75 dBc
For all spans and offsets	<– 70 dBc †

Residual responses (50 Ω input) <– 80 dBfs

Input noise density (50 Ω input, vector mode or scalar mode with sample detector) ‡

	20° - 30°C	0° - 55°C
≥– 25 dBm range	<– 115 dBfs/Hz	<– 112 dBfs/Hz
≤– 30 dBm range	<– 110 dBfs/Hz	<– 109 dBfs/Hz

Sensitivity‡

– 50 dBm range	<– 160 dBm/Hz	<– 159 dBm/Hz

† <- 60 dBc for RF (2-2650 MHz)-wide (option AYH)
‡ Add 4 dB for RF (2-2650 MHz)-wide (option AYH)

Phase (vector mode)

Phase specifications apply with flat-top window selected.

Deviation from linear phase (relative to best fit line with peak signal level within 6 dB of full scale) ± 5 deg

Time (vector mode)

Time-sample resolution = 1/(k*span(Hz)) [second]; where k = 1.28 for zoom time.

Main time length = (number of frequency points – 1) ÷ span (Hz) [second]; for resolution bandwidth in arbitrary and auto-coupled mode.

Amplitude accuracy (for a sine wave in the measurement passband, time-domain calibrations on, range ≥– 25 dBm)

20° - 30°C	± 12% full scale (± 6% typical)
0° - 55°C	± 26% full scale

Sample error rate for zoom time (typical)

Error threshold: 5% full scale 10^{-8} times/sample

Sample error rate reflects the probability of an error greater than the error threshold occuring in one time sample.

Analog demodulation

Demodulation specifications apply with demodulation mode selected and time-domain calibration on.

AM, PM, or FM demodulation. Auto carrier locking is available with PM or FM demodulators and the carrier value determined is a displayable marker function.

Demodulator bandwidth (determined by selected measurement span)

Maximum bandwidth	7 MHz (typical)

AM demodulation (typical performance)

Accuracy	± 1%
Dynamic range	60 dB (100%) for a pure AM signal
Cross demodulation	< 0.3% AM on an FM signal with 10 kHz modulation, 200 kHz deviation

PM demodulation (typical performance)

Accuracy	± 3 degrees
Dynamic range	60 dB (rad) for a pure PM signal
Cross demodulation	< 1 degree PM on an AM signal with 80% modulation

FM demodulation (typical performance)

Accuracy	± 1% of span
Dynamic range	60 dB (Hz) for a pure FM signal
Cross demodulation	< 0.5% of span FM on an AM signal with 80% modulation

Trigger

Trigger types

Scalar mode	Free run, internal source, HP-IB, external (each measurement step requires a separate trigger)
Vector mode	Free run, IF channel, internal source, HP-IB, external

Pre-trigger delay range (see time specifications for sample resolution)

One channel	64 Ksamples (1 Msample with extended time capture, option AY9)
Two channels (requires second 10 MHz input, option AY7)	32 Ksamples (0.5 Msample with extended time capture, option AY9)

Post-trigger delay range (see time specifications for sample resolution)	2 Gsample

Trigger holdoff

When enabled, each measurement requires two trigger events. The first event starts a holdoff timer. After the specified holdoff time, a subsequent trigger event will initiate a measurement.

Holdoff resolution	2.5 µs
Holdoff range	2.5 µs to 41 s

IF trigger (characteristics only)

Used to trigger only on in-band energy, where the trigger bandwidth is determined by the measurement span (rounded to the next higher $10^7/2^n$[Hz]).

Amplitude resolution	< 1 dB
Amplitude ranges	+1 to – 70 dBfs. Useable range will become limited by the total integrated noise in the measurement span.
IF trigger hysterysis	< 4 dB

External trigger (positive and negative slope)

Level accuracy	± 0.5 V
Range	± 5 V
Input impedance	10 kΩ (typical)

External arm

Level accuracy	± 0.5 V
Range	± 5 V
Input impedance	10 kΩ (typical)

Source (requires internal RF source option AY8)

Source types † (vector mode)	CW (fixed sine), random noise, periodic chirp, arbitrary

Frequency

Range	2 MHz to 2650 MHz
Maximum offset from center frequency	3.5 MHz

Amplitude (fixed sine source type)

Amplitude range	–40 dBm to +13 dBm	
Typical maximum amplitude (overdrive is available using direct numeric entry)	+17 dBm	
Amplitude resolution	0.1 dB	
Amplitude accuracy (source level ≤ 13 dBm)		
Source amplitude accuracy is the sum of absolute accuracy at the center frequency (zero offset frequency) and the IF flatness.		
	20° - 30°C	0° - 55°C
Absolute accuracy at the center frequency	± 1.2 dB	± 3.5 dB
IF flatness (relative to center frequency)	± 1 dB	± 1.5 dB
IF Flatness with |offset frequency| ≤ 500 kHz		± 0.3 dB
Dynamic range (source level ≤ 0 dBm)		
Harmonic distortion	<– 40 dBc	
Non-harmonic spurious (within measurement bandwidth)	<– 40 dBc	
Average noise level (for offsets > 1 MHz from the carrier and carrier frequency > 100 MHz. For offsets < 1 MHz, add the LO phase noise.)	<– 120 dBc/Hz	
Crosstalk (source-to-receiver, source level ≤ 0 dBm)	– 80 dBfs	

† See Baseband section for random noise, periodic chirp, and arbitrary source characteristics.

Source port

VSWR	
Level ≤ – 10 dBm	1.8:1 (11 dB return loss)
Impedance	50 Ω (75 Ω with optional minimum-loss pad)
Connector	Type-N

Baseband

Baseband specifications apply with the receiver mode set to "IF section (0-10 MHz)" or "RF section (0-10 MHz)" unless noted otherwise. Specifications noted as "IF section only" apply with the receiver mode set to "IF section (0-10 MHz)" and the input signal connected directly to the IF section's channel 1 or channel 2 input.

Frequency

Frequency tuning (characteristic only)

Frequency range	dc to 10 MHz
Frequency span	1.0 Hz to 10 MHz
Center frequency tuning resolution	0.001 Hz
Number of frequency points/span	51 to 3201

Signal track (when enabled) keeps the largest measured signal at the center frequency.

Frequency accuracy

Same as the RF specifications.

Frequency counter

Same as the RF specifications.

Stability (spectral purity)

Absolute and residual phase noise, F_{in} = 10 MHz (with standard high precision frequency reference or equivalent)

100 Hz offset	<– 106 dBc/Hz
1 kHz offset	<– 110 dBc/Hz
≥10 kHz offset	<– 120 dBc/Hz

Phase noise decreases with decreasing input frequency by $20 \log_{10} \left| \frac{F_{in}}{10\ MHz} \right| dB$.

Resolution bandwidth

Same as the RF specifications.

Amplitude

Input range (characteristic only)(2 dB steps)

50 Ω input	– 30 dBm to + 24 dBm
75 Ω input	– 31.761 dBm to +22.239 dBm
1 MΩ input (referenced to 50 Ω)	– 30 dBm to + 28 dBm

Maximum safe input power

50 Ω/75 Ω input	+ 27 dBm
1 MΩ input	20 V peak

Auto-ranging (characteristic only)

Up-only, up-down, single, off

Input port

Input channels	1 (second 10 MHz input channel optional)
Return loss (IF section only)	
50 Ω input	> 25 dB
75 Ω input	> 20 dB
Coupling	dc/ac (ac coupling attenuation < 3 dB at 3 Hz)
Input Impedance (IF section only)	50/75 Ω, 1 MΩ ± 2% (< 80 pF shunt capacitance)
Connector	BNC (RF section: Type-N)

Amplitude accuracy

Accuracy specifications apply with flat-top window selected.
Amplitude accuracy is the sum of absolute full-scale accuracy and amplitude linearity.

Absolute full-scale accuracy (IF section only, with signal level equal to range)	± 0.5 dB
Amplitude linearity	
0 to – 30 dBfs	< 0.10 dB
– 30 to – 50 dBfs	< 0.15 dB
– 50 to – 70 dBfs	< 0.20 dB
Residual dc (50 Ω)	<– 25 dBfs

Dynamic range

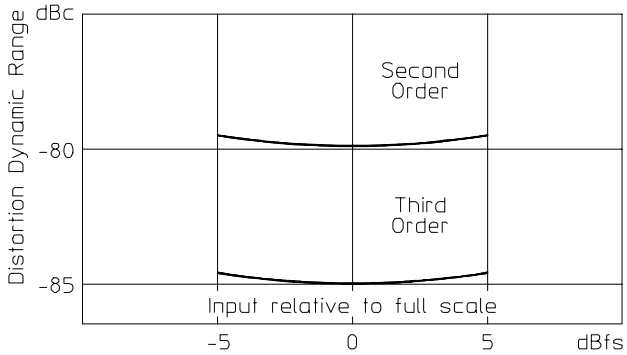
Dynamic range indicates the amplitude range that is free of erroneous signals within the measurement bandwidth.

Harmonic distortion (with a single full scale signal at the input)

2nd	<– 75 dBc (– 80 dBc typical)
3rd, 4th, 5th	<– 75 dBc (– 85 dBc typical)

Intermodulation distortion (with two input tones at 6 dB below full scale)

Second-order	<– 75 dBc (– 80 dBc typical)
Third-order	<– 75 dBc (– 85 dBc typical)



Typical harmonic and intermodulation distortion

Residual (spurious) responses (IF section only) (50 Ω input and front panel connections to RF section disconnected)

Frequencies < 1 MHz	<– 75 dBfs or <– 100 dBm whichever is greater
Frequencies ≥ 1 MHz	<– 80 dBfs
Alias responses (for a single out-of-band tone at full scale)	<– 80 dBfs

Input noise density (50 Ω input, vector mode or scalar mode with sample detector)

1 kHz to 40 kHz	<– 101 dBfs/Hz
40 kHz to 10 MHz	<– 114 dBfs/Hz (– 118 dBfs/Hz typical)

Sensitivity (– 30 dBm range, 50 Ω input, vector mode or scalar mode with sample detector)

1 kHz to 40 kHz	<– 131 dBm/Hz
40 kHz to 10 MHz	<– 144 dBm/Hz (– 148 dBm/Hz typical)
Crosstalk (source-to-input or channel-to-channel, 50 Ω terminations)	<– 85 dBfs

Phase (vector mode)

Phase specifications apply with flat-top window selected.

Deviation from linear phase (relative to best fit line with peak signal level within 6 dB of full scale)	± 5 deg

Time (vector mode)

Time-sample resolution = 1/(k*span(Hz)) [second]; where k = 1.28 for zoom time, 2.56 for baseband time measurements.

Main time length = (number of frequency points – 1) ÷ span (Hz) [second]; for resolution bandwidth in arbitrary and auto-coupled mode.

Amplitude accuracy (IF section only)(for a sine wave in the measurement passband, time-domain calibrations on)	± 5% full scale

Sample error rate for zoom time (typical)

Error threshold: 5% full scale	10^{-8} times/sample

Sample error rate reflects the probability of an error greater than the error threshold occuring in one time sample.

Analog channel-to-channel time skew (IF section only) (time-domain calibrations on, both channels on the same range)	< 1 ns

Analog demodulation

Same as RF analog demodulation specifications except as noted below.

Demodulator bandwidth (determined by selected measurement span)

Maximum bandwidth	10 MHz (typical)

Two-channel

The second 10 MHz input channel (option AY7) provides additional measurements, including frequency response, coherence, cross spectrum, and cross correlation. These measurements are made by comparing a signal on channel two to a signal on channel one or to a demodulated signal on the RF input.

Channel match ± 0.25 dB, ± 2.0 deg

(IF section only, at the center of the frequency bins, dc coupled, 16 rms averages, frequency response, full scale inputs, both inputs on the same range. Exclude the first 5 bins of the dc response.)

Trigger

Same as RF trigger specifications with the following additional specifications.

Input channel trigger (positive and negative slope)

Level accuracy	± 10% full scale
Range	± 110% full scale
Resolution	Full scale/116 (typical)

Source (with output filter on)

Source types

Scalar mode	CW (fixed sine), arbitrary
Vector mode	CW, random noise, periodic chirp, arbitrary

Random noise source % of energy in-band > 70%
(Span = 10 MHz/2^N, N = 1 to 24)

Periodic chirp source % of energy in-band > 85%

Frequency

Frequency range	dc to 10 MHz
Frequency resolution	25 μHz

Amplitude

Source level

CW and random noise	– 110 dBm to + 23.979 dBm (50 Ω), 5.0 Vpk maximum
Periodic chirp and arbitrary	– 110 dBm to + 19.542 dBm (50 Ω), 3.0 Vpk maximum
DC offset	± 3.42 V maximum (resolution and range of programmable dc offset is dependent on source amplitude)

Amplitude accuracy (50 Ω, fixed sine)
(IF section only)

– 46 dBm to + 24 dBm	± 1.0 dB
– 56 dBm to – 46 dBm	± 2.0 dB

Harmonic and other spurious products (fixed sine, 0 V dc offset)

dc to 10 kHz	<– 55 dBc
10 kHz to 5 MHz	<– 40 dBc
5 MHz to 10 MHz	<– 33 dBc

Source port

Return loss (IF section only)	> 20 dB
Source impedance	50/75 Ω

Arbitrary source characteristics

The arbitrary source repetitively outputs data stored in a data register. The data register may contain a single time record or, with option AYB, a trace buffer. The time length of the register depends on the time-sample resolution for the span entered when the data register was saved or created. See time specifications for time-sample resolution details.

Arbitrary source length

Single time record	Up to 4096 complex or 8192 real points.
Trace buffer (requires option AYB)	Up to 16,384 real or complex points. Some configurations allow up to 32,768 real or complex points (see the *Operator's Guide* for details)

General

Safety and environmental

Safety standards	CSA Certified for Electronic Test and Measurement Equipment per CSA C22.2, No. 231
This product is designed for compliance to	UL1244 and IEC348, 1978
Acoustics	LpA < 55 dB typical at 25°C ambient (Temperature controlled fan to reduce noise output)
Temperature	
Operating	0° to 55°C
Internal disk operations	4° to 40°C
Storage (no disk in drive)	– 20° to 65°C
Humidity, non-condensing	
Operating	10% to 90% at 40°C
Internal disk operations	20% to 80% at 30°C
Storage (no disk in drive)	10% to 90% at 40°C
Altitude	
Operating (above 2285 m (7,500 ft), derate operating temperature by – 3.6°C/1000 m (– 1.1°C/1000 ft))	4600 m (15,000 ft)
Storage	4600 m (15,000 ft)
Calibration interval	1 year
Warm-up time	30 minutes
Power requirements	
115 VAC operation	
IF section	90 - 140 Vrms, 47 - 440 Hz
RF section	90 - 140 Vrms, 47 - 63 Hz
230 VAC operation	198 - 264 Vrms, 47 - 63 Hz
Maximum power dissipation	
IF section	750 VA
RF section	275 VA

IEC 801-3 (Radiated Immunity) Performance degradation may occur at Severity Level 2.

Physical

Weight	IF section	25 kg (55 lb)
	RF section	25 kg (55 lb)
Dimensions		
IF section	Height	230 mm (9.1 in)
	Width	426 mm (16.7 in)
	Depth	530 mm (20.9 in)
RF section	Height	173 mm (6.8 in)
	Width	419 mm (16.5 in)
	Depth	495 mm (19.5 in)

Real time bandwidth (characteristics only)

Real-time bandwidth is the maximum frequency span that can be continually analyzed without missing any time segment of the input signal.

Frequency spans of $10^7/2^n$ Hz, arbitrary auto-coupled resolution bandwidth, markers off, one display trace with calculations off on other traces, and maximum frequency points equal to number of frequency points.

Averaging off

Single-channel vector mode (log magnitude spectrum measurement data, 1601 frequency points, channel 2 off, averaging off)	78.125 kHz, 48 updates/second
Two-channel vector mode (requires second 10 MHz input channel, option AY7) (Log magnitude frequency response measurement data, 801 frequency points, averaging off)	39.0625 kHz, 48 updates/second

Averaging

Single-channel vector mode averaging (log magnitude spectrum measurement data, 1601 frequency points, channel 2 off)

Fast average	78.125 kHz
Displayed	78.125 kHz, 48 updates/second

Two-channel vector mode averaging (requires second 10 MHz input channel, option AY7) (Log magnitude frequency response measurement data, 801 frequency points)

Fast average	39.0625 kHz
Displayed	39.0625 kHz, 48 updates/second

Demodulation

Single-channel analog demodulation mode (log magnitude spectrum measurement data, 1601 frequency points, time cal off, channel 2 off, averaging off)

AM demodulation	19.53125 kHz
FM or PM demodulation	9.765625 kHz

Measurement speed

Display update speed (vector mode with full span, one or two channels, 401 frequency points, no averaging, markers off, single trace with calculations off on other traces, log magnitude spectrum, frequency spans of $10^7/2^n$ Hz): 60/second

Averaging (characteristics only)

Number of averages	1 to 99,999
Overlap averaging	0% to 99.99%
Average types	
Scalar mode	rms (video), rms (video) exponential, peak hold
Vector mode	rms (video), rms (video) exponential, time, time exponential, peak hold

Fast averaging allows averaging a user-defined number of measurements without updating the displayed result. This provides faster averaging results for most measurements.

Gating (characteristics only)

Time-selective, frequency-domain analysis can be performed on any input or analog demodulated time-domain data. When gating is enabled, markers appear on the time data; gate length and delay can be set directly. Independent gate delays can be set for each input channel. See time specifications for main time length and time resolution details.

Gate length
Maximum: Main time length
Minimum: Approximately window shape ÷ (0.3 × span (Hz)) [seconds]; where window shape (ws) and minimum gate length for a 10 MHz zoom time span are (for 10 MHz baseband time spans subtract 39.0625 ns):

Window	ws	Minimum gate length
Flat-top	3.819	1.328125 µs
Gaussian-top	2.215	781.25 ns
Hanning	1.5	546.875 ns
Uniform	1.0	390.625 ns

Time-capture (characteristics only)

Direct capture of input waveforms can be accomplished with spans of 10 MHz/2^n Hz. See time specifications for time-sample resolution details.

Time capture memory: 64 Ksample; 1 Msample (option AY9)

Benchmarks: For a one-channel, zoom time measurement (for baseband time, halve the time), 64 Ksample captures from 5.12 ms in a 10 MHz span to over 11.9 hours in a 1.19 Hz span. The optional 1 Msample captures from 81.92 ms in a 10 MHz span to over 190 hours in a 1.19 Hz span. Memory is shared if two channels are enabled, therefore length of capture is half as long.

Band power marker (characteristics only)

Markers can be placed on any time, frequency, or demodulated trace for direct computation of band power, rms square root (of power), C/N, and C/N_o within the selected portion of the data.

Peak/Average Statistics

Peak and peak-to-average statistics can be enabled on main time, gate time, IQ measured time(AYA), IQ reference time (AYA), and math functions involving these trace types. Average power and peak statistics are computed using all samples in the active trace. Each successive trace adds additional samples to the calculations.

Displayed Results	average power peak power peak/average ratio number of samples
Peak Percent	90% – 99.99%. Setting can be changed at any time during or after the measurement.
Signal characteristics	
Peak power range	+ 13 dB relative to average power of the first time record
Average power range	± 3 dB relative to average power of the first time record.

Display (characteristic only)

Trace formats	One to four traces on one, two, or four grids or a quad display
Other displays	On-line help text, view state
Number of colors	User-definable palette
Display points/trace	401
User-definable trace titles and information	
X-axis scaling	Allows expanded views of portions of the trace information
Display blanking	Data or full display
Graticule on/off	
Center	± 5 mm referenced to bezel opening
Dimensions	
Height	105 ± 5 mm
Width	147 ± 5 mm
Diagonal	180.6 mm (7.1 in)

Status indicators

Overload, half range, external trigger, source on/off, trigger, pause, active trace, remote, talk, listen, SRQ.

External PC-style keyboard interface

Compatible with PC-style 101-key keyboard, such as the HP C1405B with HP C1405-60015 adapter.

Interfaces (characteristics only)

Active probe power	+15 Vdc, – 13 Vdc; 150 mA maximum, compatible with HP active probes
Sync out	Active low TTL level signal synchronous with source output of periodic chirps and arbitrary blocks up to 8192 samples.

External reference in/out IF section

External reference input	Locks to a 1, 2, 5, or 10 MHz (± 10 ppm) with a level > 0 dBm
External reference output	Output the same frequency as the external reference input at a level of > 0 dBm into a 50 Ω load.

External reference in/out RF section

External reference input	Locks to a 1, 2, 5, or 10 MHz (± 10 ppm) with a level > 0 dBm (use ≥ 5 dBm for optimum phase noise performance).
External reference output	Outputs 10 MHz at > 0 dBm (+6 dBm typical) into a 50 Ω load.

HP-IB

Implementation of IEEE Std 488.1 and 488.2
SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C1, C2, C3, C12, E2

Benchmark characteristics (typical transfer rate of 401 frequency-point traces)

Scalar	25 traces/second
Vector	20 traces/second
RS-232	Serial port (9-pin) for connection to printer
Centronics	Parallel port for connection to a printer

External monitor output

Format	Analog plug-compatible with 25.5 kHz multi-sync monitors
Impedance	75 Ω
Level	0 to 0.7 V
Display rate	60 Hz
Horizontal refresh rate	25.5 kHz
Horizontal lines	400

Optional interfaces

Option UFG includes the following interfaces

Second HP-IB	Implementation of IEEE Std 488.1 and 488.2
LAN	ThinLAN BNC

Peripherals

Plot/print

Direct plotting and black-and-white printing to parallel (Centronics), serial (RS-232), and HP-IB graphics printers and plotters. Printers supported include the HP LaserJet, HP PaintJet, HP ThinkJet, HP DeskJet, and HP QuietJet. Single-plot spooling allows instrument operation while printing or plotting a single display.

Memory and data storage

Disk devices	
Nonvolatile RAM disk	100 Kbyte
Volatile RAM disk	1 Mbyte that can be partitioned between measurement, HP Instrument BASIC program space and RAM. Volatile RAM also supports memory of waterfalls and spectrograms with option AYB.
Internal 90 mm (3.5-inch) flexible disk (HP LIF or MS-DOS® formats)	1.44 Mbyte
External disk	HP-IB interface

Disk format and file delete, rename and copy

Nonvolatile clock with time/date

Save/recall can be used to store trace data, instrument states, trace math functions, HP Instrument BASIC programs, and time-capture buffers.

Benchmarks (typical disk space requirements for different file types)

Trace data (401 points)	6.2 Kbyte
Instrument state	12.3 Kbyte
Trace math	2 Kbyte
Time-capture buffers (32 Ksamples)	271 Kbyte
Optional extended RAM	Option UFG includes 4 Mbyte additional RAM for expanding the volatile RAM capabilities listed earlier.

Trace math

Operands	measurement data, data register, constant, other trace math functions, jw
Operations	+, –, *, /, cross correlation, conjugate, magnitude, phase, real, imaginary, square root, FFT, inverse FFT, natural logarithm, exponential

Trace math can be used to manipulate data on each measurement. Uses include user-units correction and normalization.

Marker functions

Peak signal track, frequency counter, band power, peak/average statistics.

Standard data format utilities

Included on two 90 mm (3.5-inch) 1.44 Mbyte flexible disks and two 130 mm (5.25-inch) 1.2 Mbyte floppy disks. The utilities run in MS-DOS® 2.1 or greater on an IBM PC (AT or higher) or compatible. The utilities include conversions to standard data format (SDF), PC displays of data and instrument state information, and utilities for conversion to PC-MATLAB, $MATRIX_x$, data set 58 and ACSII formats.

Options

Vector Modulation Analysis — Option AYA

Supported modulation formats

The vector modulation analysis option supports both single modulated carriers and separate baseband I-Q signals. The optional second 10 MHz input channel is required for baseband I and Q analysis.

Carrier types	Continuous and pulsed/burst (such as TDMA)
Modulation formats	2 level FSK (including GFSK) 4 level FSK MSK (including GMSK) QAM implementations of: BPSK, QPSK, OQPSK, DQPSK, π/4DQPSK, 8PSK, 16QAM, 32QAM
Default parameter settings †	NADC, PDC (JDC), GSM, PHS, DECT, CDPD, TETRA, CDMA Base, CDMA Mobile

Filtering

All filters are computed to 20 symbols in length

Filter types	Raised cosine Square-root raised cosine IS-95 compatible Gaussian None Rectangular Low pass
User-selectable filter parameters	Alpha/BT continuously adjustable from 0.05 to 10
User-defined filters	User-defined impulse response, fixed 20 points/symbol Maximum 20 symbols in length or 401 points

Frequency and symbol rate

Receiver mode	Information bandwidth
ch1 + j*ch2	≤ 20 MHz‡
0 - 10 MHz	≤ 10 MHz
2 - 2650 MHz	≤ 7 MHz
2 - 2650 MHz - wide	≤ 8 MHz (option AYH only)
External	≤ 8 MHz (HP 89411A only)

†NADC and CDMA preset settings require option UFG.

‡ Two-channel measurements such as ch1 + j*ch2 require option AY7 second 10 MHz input channel.

Symbol Rate

Symbol Rate is limited only by the information bandwidth

$$Symbol\ Rate = \frac{Bits/Second}{Bits/Symbol}.$$

Where bits/symbol is determined by the modulation type. Example: For the raised-cosine filter

$$Max\ Symbol\ Rate \le \frac{Information\ Bandwidth}{1+\alpha}.$$

Measurement results (formats other than FSK)

Display update rate

Conditions: NADC preset, 50 kHz span, result length 150 symbols, 1 point/symbol. IQ envelope triggering and data synchronization off.

Update rate	>2 per second (characteristic only)
I-Q measured	Time, spectrum
(Filtered, carrier locked, symbol locked)	
I-Q reference	Time, spectrum
(Ideal, computed from detected symbols)	
I-Q error vs. time	Magnitude, phase
(I-Q measured vs. reference)	
Error vector	Time, spectrum
(Vector error of computed vs. reference)	
Symbol table + error summary	Error vector magnitude is computed at symbol times only

Measurement results (FSK)

FSK measured	Time, spectrum
FSK reference	Time, spectrum
Carrier error	Magnitude
FSK error	Time, spectrum

Display formats

The following trace formats are available for measured data and computed ideal reference data, with complete marker and scaling capabilities and automatic grid line adjustment to ideal symbol or constellation states.

Polar diagrams

Constellation: Samples displayed only at symbol times

Vector: Display of trajectory between symbol times with 1 to 20 points/symbol

I or Q vs time

Eye diagrams: Adjustable from 0.1 to 10 symbols
Trellis diagrams: Adjustable from 0.1 to 10 symbols

Continuous error vector magnitude vs. time

Continuous I or Q vs. time

Error summary (formats other than FSK)

Measured rms and peak values of the following:
Error vector magnitude
Magnitude error
Phase error
Frequency error (carrier offset frequency)
I-Q offset
Amplitude droop (formats other than QAM)
SNR (QAM formats)

Error summary (FSK)

Measured rms and peak values of the following:
FSK error
Magnitude error
Carrier offset frequency
Deviation

Detected bits (symbol table)

Binary bits are displayed and grouped by symbols. Multiple pages can be scrolled for viewing large data blocks.
Symbol marker (current symbol shown as inverse video) is coupled to measurement trace displays to identify states with corresponding bits.
For formats other than FSK and MSK, bits are user-definable for absolute states or differential transitions. Note: Synchronization words are required to resolve carrier phase ambiguity on non-differential modulation formats.

Accuracy (formats other than FSK and IS-95 CDMA)

Conditions: Specifications apply from 20° to 30°C, for a full-scale signal fully contained in the selected measurement span, random data sequence, instrument receiver mode of IF 0-10 MHz or RF 2-2650 MHz, range ≥– 25 dBm, start frequency ≥ 15% of span, alpha/BT ≥ 0.3 †, and symbol rate ≥1 kHz. For symbol rates less than 1 kHz, accuracy may be limited by phase noise.

Residual errors (result length = 150 symbols, averages = 10)

Error vector magnitude

Freq span ≤ 100 kHz	0.3 % rms
Freq span ≤ 1 MHz	0.5 % rms
Freq span > 1 MHz	1.0 % rms

† 0.3 ≤ alpha ≤ 0.7 for Offset QPSK

Magnitude error

Freq span ≤ 100 kHz	0.3 % rms
Freq span ≤ 1 MHz	0.5 % rms
Freq span > 1 MHz	1.0 % rms

Phase error (For modulation formats with equal symbol amplitudes.)

Freq span ≤ 100 kHz	0.17°rms
Freq span ≤ 1 MHz	0.34°rms
Freq span > 1 MHz	0.57°rms

Frequency error	Symbol rate/500,000

(Added to frequency accuracy if applicable.)

Origin/I-Q Offset	– 60 dB

Accuracy (2 FSK and 4 FSK)

Residual errors, typical

4 FSK or 2 FSK, symbol rate = 3.2 kHz, deviation = 4.8 kHz, instrument receiver mode of IF 0-10 MHz or RF 2-2650 MHz, 50 kHz span, full-scale signal, range ≥– 25 dBm, result length = 150, averages = 10, tenth-order Bessel filtering with 3 dB bandwidth = 3.9 kHz. ‡

FSK error	0.5 % rms
Magnitude error	0.3 % rms
Deviation	± 0.3 % rms (14 Hz)
Carrier frequency offset (Added to frequency accuracy if applicable)	± 0.3 % of deviation

DECT preset (2 FSK, symbol rate = 1.152 MHz, BT = 0.5) 288 kHz deviation, instrument receiver mode of IF 0-10 MHz or RF 2-2650 MHz, 4 MHz span, full-scale signal, result length = 150, averages = 10.

FSK error	1.5 % rms
Magnitude error	1.0 % rms
Deviation	± 1.0 % rms (2.88 kHz)
Carrier frequency offset (Added to frequency accuracy if applicable)	± 0.5 % of deviation

‡ Note: For error analysis, a Gaussian reference filter with BT = 1.22 is used to approximate the tenth-order Bessel filter.

Accuracy (IS-95 CDMA)

CDMA Base or CDMA Mobile preset, instrument mode of IF (0 – 10 MHz) or RF (2 – 2650 MHz), 2.6 MHz span, full scale signal, result length=200, averages=10.

Residual Errors

Error vector magnitude	1% rms
Magnitude error	1% rms
Phase error	0.57° rms
Frequency error	10 Hz
(Added to frequency accuracy if applicable.)	
Origin I/Q offset	– 60 dB

Signal Acquisition

Note: Signal acquisition does not require an external carrier or symbol clock

Data block length

Adjustable up to 1024 samples (4096 samples with extended RAM option UFG).
Examples (with option UFG):
4096 symbols at 1 point/symbol;
409 samples at 10 points/symbol.

Symbol clock	Internally generated
Carrier lock	Internally locked

Triggering

Single/continuous
External
Internal source
Pulse search (searches data block for beginning of TDMA burst, and performs analysis over selected burst length)

Data synchronization

User-selected synchronization words
Arbitrary bit patterns up to 30 symbols long, at any position in a continuous or TDMA burst and measurement result. Up to 6 words can be defined.

Arbitrary waveform source

RAM-based arbitrary waveforms

Waveform registers	Maximum 6
Waveform length	4096 Complex points each (16,384 with option AYB)

Residual accuracy, typical

Examples

π/4DQPSK, 24.3 ksymbols/second, α = 0.35	EVM ≤ 0.7% rms
GMSK, 270.833 ksymbols/second, BT= 0.30	EVM ≤ 1.0% rms

Digital Video Modulation Analysis — Option AYH (requires option AYA)

This option extends the capabilities of the vector modulation analysis option AYA by adding modulation formats used for digital video transmission. Except where noted, all of the standard capabilities of option AYA are provided for the new modulation formats.

Supported modulation formats

Additional modulation formats	8 and 16VSB 16, 32, 64 and 256QAM 16, 32, and 64QAM (differentially encoded per DVB standard)

Frequency span

The (2–2650 MHz)-wide receiver mode increases the maximum allowable vector frequency span to 8 MHz. Specifications for this mode are in the RF specification section.

Maximum symbol rate

Option AYH analyzes vector modulated signals up to a maximum symbol rate determined by the information bandwidth of the receiver mode and the excess bandwidth factor (α) of the input signal, according to:

$$Max\ Symbol\ Rate \leq \frac{Information\ Bandwidth}{1+\alpha}$$

(Note: the maximum symbol rate is doubled for VSB signals.)

Receiver mode	Information bandwidth
ch1 + j*ch2	≤ 20 MHz †
0 - 10 MHz	≤ 10 MHz
2 - 2650 MHz - normal	≤ 7 MHz
2 - 2650 MHz - wide	≤ 8 MHz
External	≤ 10 MHz †

Example: For a 64QAM signal (α = 0.15), the maximum symbol rate for the (2-2650 MHz)-wide receiver is 8 MHz/(1.15) = 6.96 Msymbols/second.

Measurement results and display formats.

Identical to option AYA measurement results and display formats except for the following changes to the error summary display:

VSB pilot level is shown, in dB relative to nominal.

For VSB formats, SNR is calculated from the real part of the error vector only.

For DVB formats, EVM is calculated without removing IQ offset.

Accuracy

Residual errors (typical)

8VSB or 16VSB, symbol rate = 10.762 MHz, α = 0.115, instrument receiver mode of IF 0-10 MHz or RF 2-2650 MHz, 7 MHz span, full-scale signal, range ≥ – 25 dBm, result length = 800, averages = 10.

Residual EVM ≤ 1.5% (SNR ≥ 36 dB)

16, 32, 64 or 256 QAM, symbol rate = 6.9 MHz, α = 0.15, instrument receiver mode of IF 0-10 MHz or RF 2-2650 MHz-wide, 8 MHz span, full-scale signal, range ≥ – 25 dBm, result length = 800, averages = 10.

Residual EVM ≤ 1.0% (SNR ≥ 40 dB)

† Downconverter dependent.

Filtering

All option AYA filter types are supported except user-defined filters for VSB analysis. Filters are calculated to 40 symbols in length.

Triggering and Synchronization

All option AYA signal acquisition features are supported except pulse and sync word search for VSB analysis.

Adaptive Equalization — Option AYH or Option AYJ

(AYJ adds adaptive equalization to option AYA)

This option equalizes the digitally-modulated signal to remove effects of linear distortion (such as unflatness and group delay) in a modulation quality measurement.

Equalizer performance is a function of the filter design (e.g., length, convergence, taps/symbol) and the quality of the signal being equalized.

Equalizer

Decision-directed, LMS, feed-forward equalization with adjustable convergence rate.

Filter length	3–99 symbols, adjustable
Filter taps	1,2,4,5,10, or 20 taps/symbol

Measurement results

Equalizer impulse response

Channel frequency response

Supported modulation formats

MSK, BPSK, QPSK, OQPSK, DQPSK, π/4DQPSK, 8 PSK, 16 QAM, 32 QAM, 64 QAM, 256 QAM, 8 VSB, 16 VSB

Waterfall and Spectrogram — Option AYB

Waterfall

Types	Vertical and skewed „ Azimuth adjustable 0 to ± 45 Normal and hidden line With or without baseline.
Adjustable parameters	Trace height Buffer depth Elevation Threshold

Spectrogram

Types	Color, normal and reversed Monochrome, normal and reversed User color maps (2 total)
Adjustable parameters	Number of colors Enhancement (color-amplitude weighting) Threshold

Trace select

When a waterfall or spectrogram measurement is paused or completed, any trace in the trace buffer can be selected by trace number or by z-axis value. The marker values and marker functions apply to the selected trace.

Z-axis value

The z-axis value is the time the trace data was acquired relative to the start of the measurement. The z-axis value of the selected trace is displayed as part of the marker readout.

Display update rate 30 to 60/second, typical

System memory (characteristic only)

Note: In standard configuration, the analyzer has approximately 1-2 Mbytes of free memory for these displays. Option UFG adds 4 Mbytes of free memory.

Memory required (characteristic only)

Displays occupy memory at the rate of 175 traces/Mbyte (for traces of 401 frequency points).
A full screen of 307 traces will require 2.25 Mbytes of free memory.
With option UFG, the analyzer will typically accommodate more than 1000 traces in memory.

4 Mbytes Extended RAM and Additional I/O — Option UFG

Extended RAM

Extended memory type: 4 Mbytes dynamic RAM

Available memory with option UFG installed: Approximately 6 Mbytes, user-allocatable to measurement memory, RAM disk and IBASIC program space.

LAN I/O

LAN support: Ethernet (IEEE 802.3) TCP/IP

LAN interface: ThinLAN (BNC connector) or AUI

Recommended MAU: HP 28685B (10base-T) or HP 28683A (FDDI)

Program interface: Send and receive HP-IB programming codes, status bytes and measurement results in ASCII and/or binary format.

HP-IB I/O

Secondary HP-IB port: Per IEEE Std 488.1 and 488.2

Functions: Controller-only; accessible from IBASIC program or front panel commands.

Note: Option UFG is strongly recommended for use with option AYA Vector Modulation Analysis and option AYB Waterfall and Spectrogram.

Advanced LAN Support — Option UG7

Remote X11 display (characteristic only)

Update rate: > 20 per second, depending on workstation performance and LAN activity.

X11 R4 compatible

X-terminals, UNIX workstations, PC with X-server software

Display: 640 × 480 pixel minimum resolution required; 1024 × 768 recommended.

FTP data (characteristic only)

Traces A, B, C, D
Data registers D1-D6
Time capture buffer
Disk files (RAM, NVRAM, floppy disk)
Analyzer display plot/print

Note: Option UG7 requires option UFG.