Spectrum Analysis
Back to Basics

Agilent Technologies
Agenda

Introduction

Overview:

• What is Spectrum and Signal Analysis?
• What Measurements are available?

Theory of Operation

Specifications

Modern Signal Analyzer Designs & Capabilities

• Wide Bandwidth Vector Measurements

Wrap-up

Appendix
Analyzer Definitions

Spectrum Analyzer

– “A spectrum analyzer measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals.”

Vector Signal Analyzer

– “A vector signal analyzer measures the magnitude and phase of an input signal at a single frequency within the IF bandwidth of the instrument. The primary use is to make in-channel measurements, such as error vector magnitude, code domain power, and spectral flatness, on known signals.”

Signal Analyzer

– “A signal analyzer provides the functions of a spectrum analyzer and a vector signal analyzer.”
**Overview**

**What is Spectrum Analysis?**

- Display and measure amplitude versus frequency for RF & MW signals
- Separate or demodulate complex signals into their base components (sine waves)

**Spectrum Analysis**
Agilent Technologies’ Signal Analysis Portfolio

**N9320B**
- Basic performance
- 9 kHz to 3 GHz

**N9922C BSA**
- 9 kHz to 7 GHz

**CXA**
- Low-cost
- 10 Hz to 26, 32, 44 GHz

**EXA**
- X-Series
- Economy-class
- 10 Hz to 26.5 GHz

**MXA**
- X-Series
- Mid-performance
- 10 Hz to 26.5 GHz

**PSA**
- Market leading performance
- 3 Hz to 50 GHz

**8560EC**
- Mid-performance

**PXA**
- X-Series
- High-performance
- 3 Hz to 26.5 GHz
- 3 Hz to 43/44/50 GHz

**CSA**
- Low cost portable
- 100 Hz to 26 GHz

**N9935/36/37/38A**
- 5 kHz to 9/14/18/26.5 GHz
- Handhelds

**N9340B/42/43/44C**
- 100 kHz to 3/7/13.6/20 GHz
- Handhelds

**X-Series Code Compatibility**
- ✓ Backward CC with legacy
- ✓ Inherent X-Series CC
Overview

Frequency versus Time Domain

Amplitude (power)

time

frequency

Time domain Measurements
(Oscilloscope)

Frequency Domain Measurements
(Spectrum Analyzer)
Overview

Types of Measurements Available

Frequency, power, modulation, distortion & noise

- Spectrum monitoring
- Spurious emissions
- Scalar network analysis
- Noise figure & phase noise
- Harmonic & intermodulation distortion
- Analog, digital, burst & pulsed RF Modulation
- Wide bandwidth vector analysis
- Electromagnetic interference

- Measurement range (-172 dBm to +30 dBm)
- Frequency range (3 Hz to >>325 GHz)
Overview
Different Types of Analyzers

FFT Analyzer

Parallel filters measured simultaneously

LCD shows full spectral display

A

f₁ f₂ f
Overview
Different Types of Analyzers

Swept Analyzer

Filter 'sweeps' over range of interest

LCD shows full spectral display

A

\( f_1 \quad f_2 \quad f \)
Agenda

Introduction
Overview

Theory of Operation:
  • Swept Spectrum Analyzer Hardware

Specifications
Modern spectrum analyzer designs & capabilities
  – Wide Bandwidth Vector Measurements

Wrap-up
Appendix
Theory of Operation
Swept Spectrum Analyzer Block Diagram

- Input signal
- RF input attenuator
- Pre-Selector
- Or Low Pass Input Filter
- local oscillator
- Crystal Reference Oscillator
- mixer
- IF gain
- IF filter (RBW)
- envelope detector
- Log Amp
- video filter
- sweep generator
- ADC, Display & Video Processing
Theory of Operation
Display terminology

![Spectrum Analyzer Image]

- **Freq. Span**: The frequency span covered by the sweep.
- **Stop Freq.**: The higher frequency limit of the sweep.
- **Center Freq.**: The frequency at the center of the sweep.
- **Reference Level**: The reference level for the display, shown as -20.00 dBm.
- **Amplitude**: The vertical scale showing the amplitude of the signal.
- **Start Freq.**: The lower frequency limit of the sweep.

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Theory of Operation
Mixer

\[ f_{\text{sig}} \rightarrow 1.5 \text{ GHz} \rightarrow \text{RF} \rightarrow \text{MIXER} \rightarrow f_{\text{LO}} \rightarrow 3.6 \text{ GHz} \rightarrow \text{IF} \rightarrow f_{\text{LO}} - f_{\text{sig}} \rightarrow 6.5 \text{ GHz} \rightarrow f_{\text{LO}} + f_{\text{sig}} \]
Theory of Operation

IF Filter (Resolution Bandwidth – RBW)

IF Filter

Input Spectrum

IF Bandwidth (RBW)

Display

A
B
C
Theory of Operation

Envelope Detector

Before detector

Envelope Detector

After detector
Theory of Operation

Envelope Detector and Detection Types

- Negative detection: smallest value in bin displayed
- Positive detection: largest value in bin displayed
- Sample detection: middle value in bin displayed

Other Detectors: Normal (Rosenfell), Average (RMS Power)

Digitally Implemented Detection Types

- Positive detection: largest value in bin displayed
- Negative detection: smallest value in bin displayed
- Sample detection: middle value in bin displayed

Other Detectors: Normal (Rosenfell), Average (RMS Power)
Power Average Detection (rms) = Square root of the sum of the squares of ALL of the voltage data values in the bin /50Ω
Theory of Operation

Video Filter (Video Bandwidth – VBW)
Theory of Operation

Video Filter vs. Trace/Video averaging

- **Video Filter** operates as the sweep progresses, sweep time may be required to slow down by the transient response of the VBW filter.

- **Trace/Video Average** takes multiple sweeps, sweep time for each sweep is not affected.

- Many signals give the same results with either video filtering or trace averaging.

---

**Trace averaging** for 1, 5, 20, and 100 sweeps, top to bottom (trace position offset for each set of sweeps)
Theory of Operation
Other Components

RF INPUT
ATTENUATOR

IF GAIN
Theory of Operation
How it All Works Together - 3 GHz spectrum analyzer

Signal Range
LO Range

input
mixer

sweep generator
LO

detector

LCD display

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Agenda

Overview

Theory of Operation

Specifications:
  • Which are important and why?

Modern spectrum analyzer designs & capabilities
  – Wide Bandwidth Vector Measurements

Wrap-up

Appendix
Key Specifications

- Safe spectrum analysis
- Frequency Range
- Accuracy: Frequency & Amplitude
- Resolution
- Sensitivity
- Distortion
- Dynamic Range
Specifications?  
A Definition

Specifications describe the performance of parameters covered by the product warranty (temperature = 0 to 55°C, unless otherwise noted).

Typical values describe additional product performance information that is not covered by the product warranty. It is performance beyond specification that 80% of the units exhibit with a 95% confidence level over the temperature range 20 to 30°C. Typical performance does not include measurement uncertainty.

Nominal values indicate expected performance, or describe product performance that is useful in the application of the product, but is not covered by the product warranty.
Specifications

Practicing safe spectrum analysis - Safe Hookups to RF Input

• Use best practices to eliminate static discharge to the RF input!
• Do not exceed the Damage Level on the RF Input!
• Do not input signals with DC bias exceeding what the analyzer can tolerate while DC coupled!

0 V DC MAX
+30dBm (1W) MAX
### Specifications

#### Frequency Range

<table>
<thead>
<tr>
<th>Description</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Mixing</td>
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<tr>
<td>Bands</td>
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<tr>
<td>0</td>
<td>3 Hz to 3.6 GHz</td>
</tr>
<tr>
<td>1</td>
<td>3.5 to 8.4 GHz</td>
</tr>
<tr>
<td>2</td>
<td>8.3 to 13.6 GHz</td>
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<tr>
<td>3</td>
<td>13.5 to 17.1 GHz</td>
</tr>
<tr>
<td>4</td>
<td>17 to 26.5 GHz</td>
</tr>
<tr>
<td>5</td>
<td>26.4 to 34.5 GHz</td>
</tr>
<tr>
<td>6</td>
<td>34.4 to 50 GHz</td>
</tr>
</tbody>
</table>
Unprecedented signal insight

- Unmatched sensitivity to 50 GHz
- Highest third-order dynamic range
- Superior close-in phase noise performance
- The industry’s most accurate analyzer

Ideally suited for aerospace/defense

- Advanced radar
- Satellite communications
- Surveillance
- Military communications
Extend Unmatched Performance with External Mixing

- Extend to 325 GHz and beyond
  - Supported measurements
    - Spectrum analysis
    - PowerSuite one-button power measurements
    - N9068A phase noise measurement application
    - 89600A VSA
  - Supported external mixers
    - 11970 Series
    - OML Inc.
    - VDI
    - And other third-party external mixers

Better close-in phase noise performance than internally-mixed 67 GHz analyzers!
Specifications

Accuracy: Frequency & amplitude

Components which contribute to uncertainty are:

- Input mismatch (VSWR)
- RF Input attenuator (Atten. switching uncertainty)
- Mixer and input filter (frequency response)
- IF gain/attenuation (reference level accuracy)
- RBW filters (RBW switching uncertainty)
- Log amp (display scale fidelity)
- Reference oscillator (frequency accuracy)
- Calibrator (amplitude accuracy)
Specifications

Absolute and Relative Accuracy: Frequency & Amplitude

Note: Absolute accuracy is also “relative” to the calibrator reference point
Specifications

Accuracy: Frequency Readout Accuracy

• From the PXA Data Sheet:

\[ \pm (\text{marker frequency} \times \text{freq reference accuracy} + 0.1\% \times \text{span} + 5\% \text{ of RBW} + 2\text{Hz} + 0.5 \times \text{Horiz. Res.}^*) \]

*Horizontal resolution is span/(sweep points – 1)
Specifications
Accuracy: Frequency Readout Accuracy Example

Frequency: 1 GHz
Span: 400 kHz
RBW: 3 kHz
Sweep points: 1000

Calculation:

\[
\begin{align*}
\text{Frequency: } & 1 \times 10^9 \text{ Hz} \\
\text{Span: } & 400 \text{ kHz } \times 0.1\% \\
\text{RBW: } & 3 \text{ kHz } \times 5\% \\
2 \text{ Hz } + 0.5 \times & 400 \text{ kHz } / (1000-1)
\end{align*}
\]

\[= (1 \times 10^9 \text{ Hz}) \times (\pm 1.55 \times 10^{-7} / \text{Year ref. Error}) = 155 \text{ Hz}\]
\[= 400 \text{ Hz} = 150 \text{ Hz} = 202 \text{ Hz} = \pm 907 \text{ Hz}\]

*Utilizing internal frequency counter improves accuracy to \pm 155Hz

** The Maximum # of sweep points for the X-Series is 40,001 which helps to achieve the best frequency readout accuracy.
## Specifications
### Accuracy: Key Amplitude Uncertainty Contributions

<table>
<thead>
<tr>
<th>Relative and absolute:</th>
<th>PXA Uncertainties</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Input impedance mismatch</td>
<td>(±0.13 dB)</td>
</tr>
<tr>
<td>• Input attenuator switching uncertainty</td>
<td>(±0.14 dB)</td>
</tr>
<tr>
<td>• Frequency response</td>
<td>(±0.35 dB)</td>
</tr>
<tr>
<td>• Reference level accuracy</td>
<td>(0 dB)</td>
</tr>
<tr>
<td>• RBW switching uncertainty</td>
<td>(±0.03 dB)</td>
</tr>
<tr>
<td>• Display scale fidelity</td>
<td>(±0.07 dB)</td>
</tr>
</tbody>
</table>

### Absolute only:

- • Calibrator accuracy                        | (±0.24 dB)
Specifications
Accuracy: Frequency Response

Signals in the Same Harmonic Band

Absolute amplitude accuracy — Specification: ± 1 dB
Relative amplitude accuracy — Specification: ± 2 dB
Specifications

Accuracy: Display Fidelity

Display Fidelity includes:
- Log Amp Fidelity
- Envelope Detector Linearity
- Digitizing Circuit Linearity

Display fidelity error applies when signals are not at the same reference level amplitude when measured.

In the past, technique for best accuracy was to move each measured signal to the reference line, eliminating display fidelity error.

Display Scale Fidelity of analyzers with digital IF are superior to those with analog IF i.e. X-series analyzers have +/- 0.1 db vs. ESA, 856xEC +/- 1.0 db.
Specifications

Amplitude Accuracy: Reference Level Switching

Uncertainty applies when changing the Ref. Level

Also called IF Gain Uncertainty

Decision: Do I change the reference level or live with the display fidelity uncertainty in my measurements?

However with today’s X-series analyzers, provided the attenuation remains unchanged, the signal no longer needs to be at the reference level for the most accurate measurement.
Specifications
Amplitude Accuracy - Summary

Optimize measurement setup & techniques for best accuracy

- **Minimize changes to uncertainty contributors**
  - Or change contributor with least error impact
  - Or stay within the optimum accuracy envelope parameters that modern auto-alignment calibration techniques provide

- **Traditionally, one technique for best accuracy was to move each measured signal to the reference line**, eliminating display fidelity error. However, in today’s designs, display fidelity has improved to the point where there is generally less error just to leave the signals where they occur on the display.

- **Except for freq. response**, uncertainty contributors that impact both signals equally in a relative measurement can be ignored.

- In the absence of specified relative freq. response, the relative response uncertainty is assumed to be 2x specified absolute error.
What Determines Resolution?

Resolution Bandwidth

RBW Type and Selectivity

Noise Sidebands
Specifications

Resolution: Resolution Bandwidth

Input Spectrum

Mixer

3 dB BW

3 dB

IF Filter/
Resolution Bandwidth Filter (RBW)

Envelope Detector

LO

Sweep

RBW

Display

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Specifications

Resolution: Resolution BW

Determines resolvability of **equal** amplitude signals
Specifications
Resolution BW Selectivity or Shape Factor

Selectivity = \frac{60 \text{ dB BW}}{3 \text{ dB BW}}

Determines resolvability of unequal amplitude signals
Specifications
Resolution BW Selectivity or Shape Factor

RBW = 1 kHz
Selectivity 15:1

RBW = 10 kHz
distortion products

3 dB
60 dB

7.5 kHz
60 dB BW = 15 kHz

10 kHz 10 kHz

60 dB BW = 15 kHz
Specifications
Resolution: RBW Type and Selectivity

Typical Selectivity
- Analog: 15:1
- Digital: ≤5:1

* The X-series RBW shape factor is 4.1:1
Specifications

Resolution: Noise Sidebands

Noise Sidebands can prevent resolution of unequal signals
Specifications
Resolution: RBW Determines Sweep Time

Penalty For Sweeping Too Fast Is An Uncalibrated Display
Specifications

Resolution: RBW Type Determines Sweep Time

8563E Analog RBW

PXA Swept RBW

PXA FFT RBW

280 sec

134 sec

10.7 sec
A Spectrum Analyzer Generates and Amplifies Noise Just Like Any Active Circuit
Specifications

Sensitivity/DANL

Sensitivity is the Smallest Signal That Can Be Measured

Signal Equals Noise

~ 2.2 dB
Specifications
Sensitivity/DANL

Effective Level of Displayed Noise is a Function of RF Input Attenuation

Signal To Noise Ratio Decreases as RF Input Attenuation is Increased

Attenuation = 10 dB

Attenuation = 20 dB
Specifications
Sensitivity/DANL: IF Filter (RBW)

Display Noise is a Function of IF Filter Bandwidth

Decreased BW = Decreased Noise
Specifications

Sensitivity/DANL: Video BW filter (or Trace Averaging)

Video BW or Trace Averaging Smoothes Noise for Easier Identification of Low Level Signals
Specifications

Sensitivity/DANL:

Signal-to-Noise Ratio Can Be Graphed

Displayed Noise in a 1 kHz RBW

Displayed Noise in a 100 Hz RBW

POWER AT MIXER = INPUT - ATTENUATOR SETTING dBm
Standard feature that improves DANL for the PXA
Noise Floor Extension

• The PXA combines real-time measurement processing with an unprecedented characterization of the analyzer’s own noise to allow that noise to be accurately removed from measurements.

• The improvement from *noise floor extension* varies from RF to millimeter wave. At RF, from about 3.5 dB for CW and pulsed signals to approximately 8 dB for noise-like signals, and up to 12 dB or more in some applications.

• DANL at 2 GHz is –161 dBm without a preamp and –172 dBm with the preamp.
Hardware Option that improves DANL for the PXA

**LOW NOISE PATH (LNP)**

- At microwave frequencies any sort of signal routing or switching results in signal path loss.
- Preamplifiers can compensate for this loss and improve signal/noise for small signals, but they can cause distortion in the presence of larger signals.
- LNP allows the “lossy” elements normally found in the RF input chain to be completely bypassed for highest sensitivity without a preamplifier.
- LNP allows measurements of small spurs w/o speed penalty imposed by narrow RBW that would otherwise be needed for adequate noise level.
Specifications
Sensitivity/DANL: Summary

For Best Sensitivity Use:

- Narrowest Resolution BW
- Minimum RF Input Attenuation
- Sufficient Averaging (video or trace)
- Using the Preamp also improves sensitivity
- Low Noise Path (PXA only)
- Noise Floor Extension (PXA only)
Specifications
Distortion

Mixers Generate Distortion

Signal To Be Measured

Frequency Translated Signals

Mixer Generated Distortion

Resultant
Most Influential Distortion is the Second and Third Order

Two-Tone Intermod

Harmonic Distortion
Specifications
Distortion

Distortion Products Increase as a Function of Fundamental's Power

Two-Tone Intermod

Second Order: $\Delta 2 \text{ dB/dB of Fundamental}$
Third Order: $\Delta 3 \text{ dB/dB of Fundamental}$

Harmonic Distortion

Second-order distortion
Third-order distortion

Power in dB

$2f_1 - f_2$
$f_1$
$f_2$
$2f_2 - f_1$
Specifications
Distortion

Distortion is a Function of Mixer Level

POWER AT MIXER = INPUT - ATTENUATOR SETTING dBm

DISTORTION, dBc

-100 -80 -60 -40 -20 0

-60 -30 0 +30

TOI SHI

Second Order
Third Order
Specifications
Distortion – Internal or External?

**Attenuator Test:**
Change power to the mixer

1. Change input attenuator by 10 dB
2. Watch distortion amplitude on screen

*No change in amplitude:* distortion is part of input signal (external)

*Change in amplitude:* at least some of the distortion is being generated inside the analyzer (internal)
Specifications

Spectrum Analyzer Dynamic Range

The ratio, expressed in dB, of the largest to the smallest signals simultaneously present at the input of the spectrum analyzer that allows measurement of the smaller signal to a given degree of uncertainty.
Specifications

Dynamic Range

Dynamic Range Can Be Presented Graphically

Maximum 2nd Order Dynamic Range

Maximum 3rd Order Dynamic Range

Optimum Mixer Levels

POWER AT MIXER = INPUT - ATTENUATOR SETTING dBm

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Dynamic Range for Spur Search Depends on Closeness to Carrier
Dynamic Range is actually:

Maximum dynamic range calculation

Calculated from distortion products and sensitivity/DANL

bounded by

-dBc/Hz Phase Noise sidebands @ close-in offset frequencies

Determined by the phase noise specifications of the SA
Specifications
Dynamic Range vs. Measurement Range

Maximum Power Level
+30 dBm

Mixer Compression
+3 dBm

Third-Order Distortion
-40 dBm

Second-Order Distortion
-50 dBm

Noise Sidebands
0 dBc

Minimum Noise Floor (DANL)

Display Range
100 dB @ 10 dB/Div
(200 dB @ 20dB/Div)

Measurement Range
195 dB

Signal/Noise
158 dB

Signal/3rd Order Distortion
115 dB range

Signal/2nd Order Distortion
105 dB range

Signal/Noise Sidebands
-129 dBc @ 10kHz Offset

Increasing RBW or Attenuation

-155 dBm (1 Hz BW & 0 dB Attenuation)
-165 dBm with preamp
Specifications

Summary: Optimizing Dynamic Range

• What settings provide the best sensitivity?
  • Narrowest resolution bandwidth
  • Minimal input attenuation
  • Sufficient averaging

• How do you test for analyzer distortion?
  • Increase the input attenuation and look for signal amplitude changes
  • Then set the attenuator at the lowest setting without amplitude change

• What determines dynamic range?
  • Analyzer distortion, noise level, and sideband/phase noise
Agenda

Introduction
Overview
Theory of Operation
Specifications
Modern spectrum analyzer designs & capabilities
  • Wide Analysis Bandwidth Measurements
Wrap-up
Appendix
Modern Spectrum Analyzer Block Diagram

- Pre-amp
- Attenuation
- YIG
- Analog IF Filter
- ADC
- Digital IF Filter
- Swept vs. FFT
- Digital Log Amp
- Digital Detectors
- FFT
- Replaced by Back to Basics Training
Modern Spectrum Analyzer Block Diagram

**Auto Alignment**
- Temp & time calibration

**3 to 50 GHz Pre-amp**
- Improve 1 GHz
- DANL -155dBm to -165dBm

**Analog Pre-Filter**
- (Single Pole)

**Attenuation**
- 2 dB step to 50 GHz

**Digitally Synthesized LO**
- Fast tuning
- Close-in phase noise
- Far-out phase noise

**16 bit ADC**
- Wider dynamic range with autoranging
- Dither on/off

**Digital IF Filters**
- 160 RBW filters
- 1 Hz to 8 MHz
- ±0.03 dB switching error

**Digital Log Amp**
- ±0.07 dB Scale Fidelity
- >100 dB Dynamic range
- ±0.0 dB reference level error

**Digital Detectors**
- Normal
- Peak
- Min
- Sample

**Digital Video Filters**
- Power, voltage, log filtering

**FFT vs Swept RBW**
- Faster Sweep w/Max DR

**Digital Log Amp**
- ±0.07 dB Scale Fidelity
- >100 dB Dynamic range
- ±0.0 dB reference level error

**Frequency Counter**
- Fast (0.1s)
- High resolution (mHz)

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Modern Spectrum Analyzer - Specifications

Digital IF provides improved accuracy

<table>
<thead>
<tr>
<th>Specification</th>
<th>PXA</th>
<th>Traditional</th>
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</thead>
<tbody>
<tr>
<td>Input impedance mismatch</td>
<td>±0.13</td>
<td>±0.29 dB</td>
</tr>
<tr>
<td>Input attenuator switching uncertainty</td>
<td>±0.14</td>
<td>±0.6 dB</td>
</tr>
<tr>
<td>Frequency response</td>
<td>±0.35</td>
<td>±1.8 dB</td>
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<tr>
<td>Reference level accuracy</td>
<td>±0.0</td>
<td>±1.0 dB</td>
</tr>
<tr>
<td>RBW switching uncertainty</td>
<td>±0.03</td>
<td>±0.5 dB</td>
</tr>
<tr>
<td>Display scale fidelity</td>
<td>±0.07</td>
<td>±0.35 dB</td>
</tr>
<tr>
<td>Calibrator accuracy</td>
<td>±0.24</td>
<td>±0.34 dB</td>
</tr>
</tbody>
</table>

Total accuracy (up to 3 GHz) 95% Confidence

±0.59 dB vs. ±1.8 dB
±0.19 dB
Modern Spectrum Analyzer Features
Built-in One-Button Power Measurements

Power Measurements:
- Occupied Bandwidth
- Channel Power
- ACP
- Multi-carrier ACP
- CCDF
- Harmonic Distortion
- Burst Power
- TOI
- Spurious Emissions
- Spectral Emissions Mask

Format Setups include:

<table>
<thead>
<tr>
<th>Format</th>
<th>Standard</th>
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<tr>
<td>cdma2000 1x</td>
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<td>NADC</td>
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<td>PDC</td>
<td>IS-97D/98D</td>
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<td>GSM/EDGE</td>
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<td>TETRA</td>
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<td></td>
<td>S-DMB System E</td>
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<td>UWB Indoor</td>
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</table>

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Modern Spectrum Analyzer Features

Application Focused Internal Software (one-button measurements)

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<th>Flexible digital modulation analysis</th>
<th>Power &amp; digital modulation measurements for wireless comms formats</th>
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<td>ACPR, Multi-carrier Power</td>
<td>ACPR</td>
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<td>Ext. source control</td>
<td>Occupied Bandwidth (OBW)</td>
<td>SEM</td>
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<td>Noise figure</td>
<td>Spectral Emissions Mask</td>
<td>EVM</td>
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<td>Code compatibility suite</td>
<td>Phase and Freq. (PFER)</td>
<td>ORFS (GSM/EDGE)</td>
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<td>EMI pre-compliance</td>
<td>Mod Accuracy (Rho)</td>
<td>Spurious Emissions</td>
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<td>Analog demod</td>
<td>Code Domain Power</td>
<td>Power vs Time</td>
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<tr>
<td>Flexible demod</td>
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<td>Channel power</td>
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<tr>
<td>LTE FDD, TDD</td>
<td></td>
<td>IM distortion</td>
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<tr>
<td>W-CDMA/HSPA/HSPA+</td>
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<td>CCDF</td>
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<tr>
<td>GSM/EDGE/EDGE Evo</td>
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<td>ORFS (GSM/EDGE)</td>
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<td>cdma2000 &amp; 1xEV-DO</td>
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<td>Spurious Emissions</td>
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<tr>
<td>cdmaOne</td>
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<td>Power vs Time</td>
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<td>DVB-T/H/C/T2</td>
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<td>Channel power</td>
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<td>TD-SCDMA/HSPA</td>
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<td>WLAN (802.11a/b/g/p/j)</td>
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<td>802.16 OFDMA</td>
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<td>Bluetooth</td>
<td></td>
<td>Spurious Emissions</td>
</tr>
</tbody>
</table>

*SEM = Spectral Emissions Mask*
Features/Option EDP – Enhanced Display Package

- Spectrogram
- Trace zoom
- Zone span

Enhances Swept SA measurements and complements N6141A for EMI users
SPECTROGRAM

• Allows you to see time history in bottom window
• Amplitude displayed using color
• Great for finding intermittent signals
**Trace Zoom**

- Allows you to zoom in on your trace data
- Same trace in both screens but bottom screen shows “close up” view with fewer points
- Great to look more closely at high-density traces
Zone Span (legacy feature from 859x and ESA)

- Allows you to take a reference sweep in the top window and then re-sweep in a narrower span in the bottom
- Two different sweeps in the two windows
- So bottom window can have different settings, can even go to zero-span
**X-Series Signal Analyzer Security Features**

**Comparisons**

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**Non-volatile data**
- OS + Instrument SW
- Alignment files
- Analyzer states, setups, limit lines, amp cor files
- Measurement results, traces, screen shots, etc.

**Sensitive user data**
- Secured Area
- Non-Volatile data
- Non-Classified Removable SDD

**Non-secured Area**
- Removing Analyzer from a secured area
- Returning Analyzer to a secured area

**Removable SSD**
- Always kept in secured area!
- For use in non-secured area
Premier frequency, time & modulation analysis for Wireless R&D

Supports > 70 signal formats
- GSM to WiFi, WiMAX & LTE
- 2FSK to 1024QAM
- AM/FM/PM
- SISO and MIMO (4x4)
- Custom OFDM

High resolution (409K line) FFT based spectrum

High quality time measurements

SCPI Programming
Agilent Vector Signal Analysis Software

89600B VSA Software

- FFT-based spectrum, time-domain & bit-level modulation analysis
- Support for more than 70 signal standards and modulation types
- Unlimited trace/marker capability and arbitrary window arrangement
- Digital persistence and cumulative history displays

- Wireless networking: 802.11a/b/g/n, 802.16 OFDMA, WiMAX, 802.11ac
- Cellular: LTE (FDD/TDD), W-CDMA HSPA+, LTE Advanced
- Custom OFDM modulation analysis for proprietary signals

- Links to over 30 hardware platforms including: X-series signal analyzers, 16800 logic analyzers, 90000 X-series scopes, Infiniium scopes, VXI, N7109A Multi Channel Signal Analyzer
- Runs on external PC linked to hardware or embedded operation on instruments with Windows OS
Who needs wide analysis BW?

Modern designs demand more bandwidth for capturing high data rate signals and analyzing the quality of digitally modulated bandwidths

Aerospace and Defense

- **Radar** – Chirp errors & modulation quality
- **Satellite** – Capture 36/72 MHz BW’s w/high data rates
- **Military communications** – Capture high data rate digital comms & measure EVM

Emerging communications

- **W-LAN, 802.16 (wireless last mile), mesh networks**
  - Measure EVM on broadband, high data rate signals

Cellular Communications

- **W-CDMA ACPR & Multi-carrier Pre-Distortion**
  - High dynamic range over 60 MHz BW to see low level 3\textsuperscript{rd} order distortion for 4 carrier pre-distortion algorithms
PXA Wideband analysis

PXA Simplified Block Diagram (160 MHz BW)

160 MHz Path
- ADC Nominal bits: 14
- ADC Effective bits: 11.2
- SFDR: up to 75 dBC

160 MHz (option B1X)
- 160 MHz
- ADC
- FPGA
- ASIC

40 MHz (option B40)
- 40 MHz
- ADC
- FPGA
- ASIC

40 MHz BW (option B40)
- 40 MHz
- ADC
- FPGA
- ASIC

Switched filters,
- F₀=300 MHz
- 2Gbyte SDRAM
- ASIC

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- F₀=322.5 MHz
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Swept IF,
- 10 MHz & 25 MHz BW (option B25)
- FPGA
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Electronic Preamp, e-attenuator and calibrator switches

0-3.6 GHz low band

RF converter

4.8 GHz LO, 140 MHz

2nd converter

Linearity Corrections

1 dB-step electronic attenuator

RF preamp

1-2-6 GHz

Cal input

4 GHz

Electronic Preamp, e-attenuator and calibrator switches

3 Hz-50 GHz Input

3.5-50 GHz high band

Cal input

4 GHz

Electronic Preamp, e-attenuator and calibrator switches

1 dB-step electronic attenuator

RF preamp

1-2-6 GHz

Front End

ADC Nominal bits: 14
ADC Effective bits: 11.2
SFDR: up to 75 dBC

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Swept IF,
Measurement of Analog IQ Signals

Oscilloscope for baseband has some limitations

RF

Analog Baseband

89600B VSA
Software in both domains

X-Series Spectrum Analyzer

PXA/MXA BBIQ

Oscilloscope for baseband has some limitations
Analog BB inputs

- Probe Interface
- 1 MΩ / 50 Ω Z Select
- Single ended/Differential Select
- Switched Gain amplifier
- Real-time IQ corrections
- Re-sampling/Decimation
- 500 MSa Capture Memory

16-bit ADC, 100 MS/s

Baseband to 40 MHz (for 1ch/2ch)
- 10, 25 or 40 MHz BW
- 500 MSa memory

Baseband Calibrator Out
PXA 900MHz Wideband IF Output

- This capability is useful for customers looking to make **wideband radar and communication measurements** of bandwidths less than 900 MHz.
- The IF bandwidth tends to be much greater than currently-available downconverters.
- This utilizes options “MPB” (microwave preselector bypass) and “CR3” (connector rear, 2^{nd} IF output).
- See PXA configuration guide for information on retrofitting option MPB
- Wideband IF output is achieved by bypassing the microwave preselector and moving the first microwave IF higher depending on the desired bandwidth.
Configuring the PXA for 900 MHz of IF output
Creating the proper frequency offset

\[ f_{\text{offset}} = f_{\text{normal IF}} - f_{\text{desired IF}} \]

- In our case, \( f_{\text{normal IF}} \) is always 322.5 MHz
- Agilent recommends an desired IF of no greater than 700 MHz for a maximum IF bandwidth of 1 GHz.
- If the required IF bandwidth is 500 MHz or less, we recommend using the standard 322.5 MHz IF with no frequency offset.
- In our example, we’re using an offset of -377.5 MHz, (322.5 – 700 MHz), for an IF center frequency of 700 MHz and an IF bandwidth of 900 MHz.
Configuring the PXA for 900 MHz of IF output

1. FREQ Channel
   - Center Freq: 10.000000000 GHz
   - Freq Offset: -377.500000 MHz

2. SPAN X Scale
   - Zero Span

3. AMPTD Y Scale
   - More 1 of 2
   - μW Path Ctrl
     - μW Preselector Bypass
   - μW Preselector Bypass

4. Input/Output
   - More 1 of 2
   - Output Config
     - Aux IF Out
     - Second IF [322.5 MHz]

5. System
   - Alignments
   - Auto Align [Off, RF]
   - Off

6. Single
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Agilent Technologies’ Signal Analysis Portfolio

N9320B
Basic performance
9 kHz to 3 GHz
N9922C BSA
9 kHz to 7 GHz

CXA
Low-cost
10 Hz to 26, 32, 44 GHz

EXA
X-Series
Economy-class
10 Hz to 26.5 GHz

MXA
X-Series
Mid-performance
10 Hz to 26.5 GHz

PXA
X-Series
High-performance
3 Hz to 26.5 GHz
3 Hz to 43/44/50 GHz

PSA
Market leading performance
3 Hz to 50 GHz

8560EC
Mid-performance

ESA
World’s most popular
3 Hz to 50 GHz

CSA
Low cost portable
100 Hz to 7 GHz

N9935/36/37/38A
5 kHz to 9/14/18/26.5 GHz
Handhelds

N9340B, N9342/43/44C
100 kHz to 3/7/13.6/20 GHz
Handhelds

X-Series Code Compatibility
✓ Backward CC with legacy
✓ Inherent X-Series CC
Agilent Spectrum Analyzer Families (X-Series)

**PXA Series**
- **Highest** Performance SA -- 3 Hz to 3.6, 8.4, 13.6, 26.5, 43, 44 or 50 GHz
- All digital IF -- 160 RBW settings FFT or swept
- 10/25/40/160 MHz analysis BW
- Internal preamplifier options from 3.6 to 50 GHz
- External Source control
- Over 25 measurement applications including LTE, GSM, TD-SCDMA
- Programming remote language compatibility w/ PSA and other X-Series
- 89600 VSA software runs inside PXA with more than 75 signal formats
- Connectivity: GPIB, USB 2.0, LAN (1000Base-T), LXI class-C compliant
- Extend frequency to 325 GHz and beyond with external mixing

**MXA Series**
- **Mid**-Performance SA -- 10 Hz to 3.6, 8.4, 13.6, 26.5 GHz
- All digital IF -- 160 RBW settings FFT or swept
- 25 MHz std/40 MHz optional analysis BW
- Internal preamplifier options from 3.6 to 26.5 GHz
- Analog baseband IQ inputs with 40 MHz baseband analysis bandwidth
- External Source control
- Over 25 measurement applications including WiMax, GSM, W-CDMA
- Programming remote language compatibility w/ PSA and other X-Series
- 89600 VSA software runs inside MXA with more than 75 signal formats
- Connectivity: GPIB, USB 2.0, LAN (1000Base-T), LXI class-C compliant
Agilent Spectrum Analyzer Families (X-Series)

**EXA Series**
- **Economy-Class SA** -- 10 Hz to 3.6, 7.0, 13.6, 26.5, 32, 44 GHz
- Internal preamplifier options up to 44 GHz
- All digital IF -- 160 RBW settings FFT or swept
- 25 MHz std /40 MHz Optional analysis BW
- External Source control
- Over 25 measurement applications including WiMAX, LTE, W-CDMA
- 89600 VSA software runs inside EXA with more than 75 signal formats
- Connectivity: GPIB, USB 2.0, LAN (1000Base-T), LXI class-C compliant
- Extend frequency to 325 GHz and beyond with external mixing (32, 44 GHz models only)
- Programming remote language compatibility w/ ESA and other X-Series

**CXA Series**
- **Low-Cost SA** -- 9 kHz to 3.0, 7.5. 13.6, 26.5 GHz
- Reduce cost and improve throughput in manufacturing test
- All digital IF -- 160 RBW settings FFT or swept
- 10/25 MHz analysis BW
- Tracking Generator 3 or 6 GHz
- External Source control
- Over 25 measurement applications
- 89600 VSA software runs inside PXA with more than 75 signal formats
- Connectivity: GPIB, USB 2.0, LAN (1000Base-T), LXI class-C compliant
- Programming remote language compatibility w/ ESA and other X-Series
**Agilent Spectrum Analyzer Families (Basic)**

**N9320B Basic Performance Bench Top**
- 9 kHz to 3 GHz
- Minimum non-zero span sweep time: < 10 ms
- Resolving power RBW: 10 Hz to 1 MHz
- Sensitivity DANL: -130 dBm, -148 dBm with preamp on
- Overall amplitude accuracy: ±0.5 dB

**N9322C Basic Performance Bench Top**
- 9 kHz - 7 GHz frequency range
- Sensitivity: Typical –160dBm DANL (preamp on)
- ±0.4 dB absolute amplitude accuracy
- 7 GHz tracking generator, with built in VSWR bridge
- AM/FM, ASK/FSK demodulation; Task planner for automation
- 7.6 kg weight, 132x320x400 (mm) dimension, 3U height
New mixer family
• M1970V Option 001 (50 to 75 GHz)
• M1970V Option 002 band (50 to 80 GHz)
• M1970E (60 to 90 GHz)
• M1970W (75 to 110 GHz)

Mixer smart features
• Automatic amplitude correction and transfer of conversion loss data through USB plug and play features
• Automatic LO amplitude adjustment to compensate the cable loss (up to 3 m or 10 dB loss)
• Auto detect mixer model/serial number when used with;
  • N9030A PXA
  • N9010A EXA (options 532,544)
• Automatic setting of default frequency range and LO harmonic numbers
• Automatic LO alignment at start up
• Automatic run calibration when time and temperature changes

Improved DANL and TOI
• Excellent conversion loss of 25 dB maximum and excellent amplitude calibration accuracy of 2.2 dB

Go smart with harmonic mixing!
Agilent Spectrum Analyzer Families (Handhelds)

**N9935A, N9936A Handheld Spectrum Analyzer**
- **Handheld** SA -- 5 kHz to 9, 14 GHz
- –155 dBm displayed average noise level (DANL) pre amp on
- +15 dBm third order intercept (TOI)
- Phase noise -111 dBc at 10 kHz offset
- Full-band tracking generator
- Independent signal source
- Interference analyzer
- Built-in high accuracy power meter
- Built-in GPS receiver
- Built-in variable DC voltage source

**N9936A, N9938A Handheld Spectrum Analyzer**
- **Handheld** SA -- 5 kHz to 18, 26.5 GHz
- –155 dBm displayed average noise level (DANL) pre amp on
- +15 dBm third order intercept (TOI)
- Phase noise -111 dBc at 10 kHz offset
- Full-band tracking generator
- Independent signal source
- Interference analyzer
- Built-in high accuracy power meter
- Built-in GPS receiver
- Built-in variable DC voltage source
N9344C Handheld Spectrum Analyzer
- **Handheld** SA -- 100 kHz to 20 GHz
- Fastest sweep – minimum sweep time < 2ms
- –144 dBm displayed average noise level (DANL) typical
- +15 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life

N9343C Handheld Spectrum Analyzer
- **Handheld** SA -- 100 kHz to 13.6 GHz
- 10 ms non-zero span sweep time
- –144 dBm displayed average noise level (DANL) with pre-amplifier
- +15 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life
Agilent Spectrum Analyzer Families (Handhelds)

**N9342C Handheld Spectrum Analyzer**
- **Handheld SA** -- 100 kHz to 7.0 GHz
- Fastest sweep -- minimum sweep time < 2ms
- –152 dBm displayed average noise level (DANL) typical
- +10 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life

**N9340B Handheld Spectrum Analyzer**
- **Handheld SA** -- 100 kHz to 3.0 GHz
- 10 ms non-zero span sweep time
- –144 dBm displayed average noise level (DANL) with pre-amplifier
- +10 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life
Agilent Spectrum Analyzer Families (Legacy)

**PSA Series**
- **High** performance SA -- 3 Hz to 6.7, 13.2, 26.5, 44, 50 / 325 GHz
- All digital IF -- 160 RBW settings FFT or swept
- 40/80 MHz analysis BW with >75 dB dynamic range
- 2G/3.5 G digital demodulation
- 15 Optional measurement personalities

**ESA-E Series**
- **Mid-Performance** SA – 30 Hz to 1.5, 3, 6.7, 13.2, 26.5 / 325 GHz
- Rugged/Portable with color LCD display
- Fast & Accurate with 5 minute warm-up
- Express analyzers for fast & easy delivery

**CSA**
- Low priced, **basic** performance SA – 100 kHz to 3, 6 GHz
- Lightweight portable, optional internal battery
- General purpose for Mfg., bench-top and service environments
- Cable fault, return and insertion loss, built-in TG and VSWR bridge

**856X- EC Series**
- **Mid-Performance** SA – 30 Hz to 2.9, 13.2, 26.5, 40, 50 / 325 GHz
- Rugged/Portable
- Color LCD Display
- Low Phase Noise
- Digital 1 Hz RBW
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Basic Spectrum Analyzer Application & Product Notes

A.N. 150 – Spectrum Analysis Basics: #5952-0292EN
A.N. 150-15 - Vector Signal Analysis Basics: #5989-1121EN

Spectrum Analyzer & Signal Analyzer Selection Guide: #5968-3413E

N9030A PXA Brochure: 5990-3951EN
N9020A MXA Brochure: 5989-5047EN
N9010A EXA Brochure: 5989-6527EN
N9000A CXA Brochure: 5990-3927EN
89600B VSA Brochure: 5990-6553EN
N9342,43,44C Brochure: 5990-8024EN
N9935,36,37,38A Brochure: 5990-9779EN

www.agilent.com/find/sa
THANK YOU!