Jeff Thomas
Tom Holmes
Terri Hightower

Learn RF Spectrum Analysis Basics

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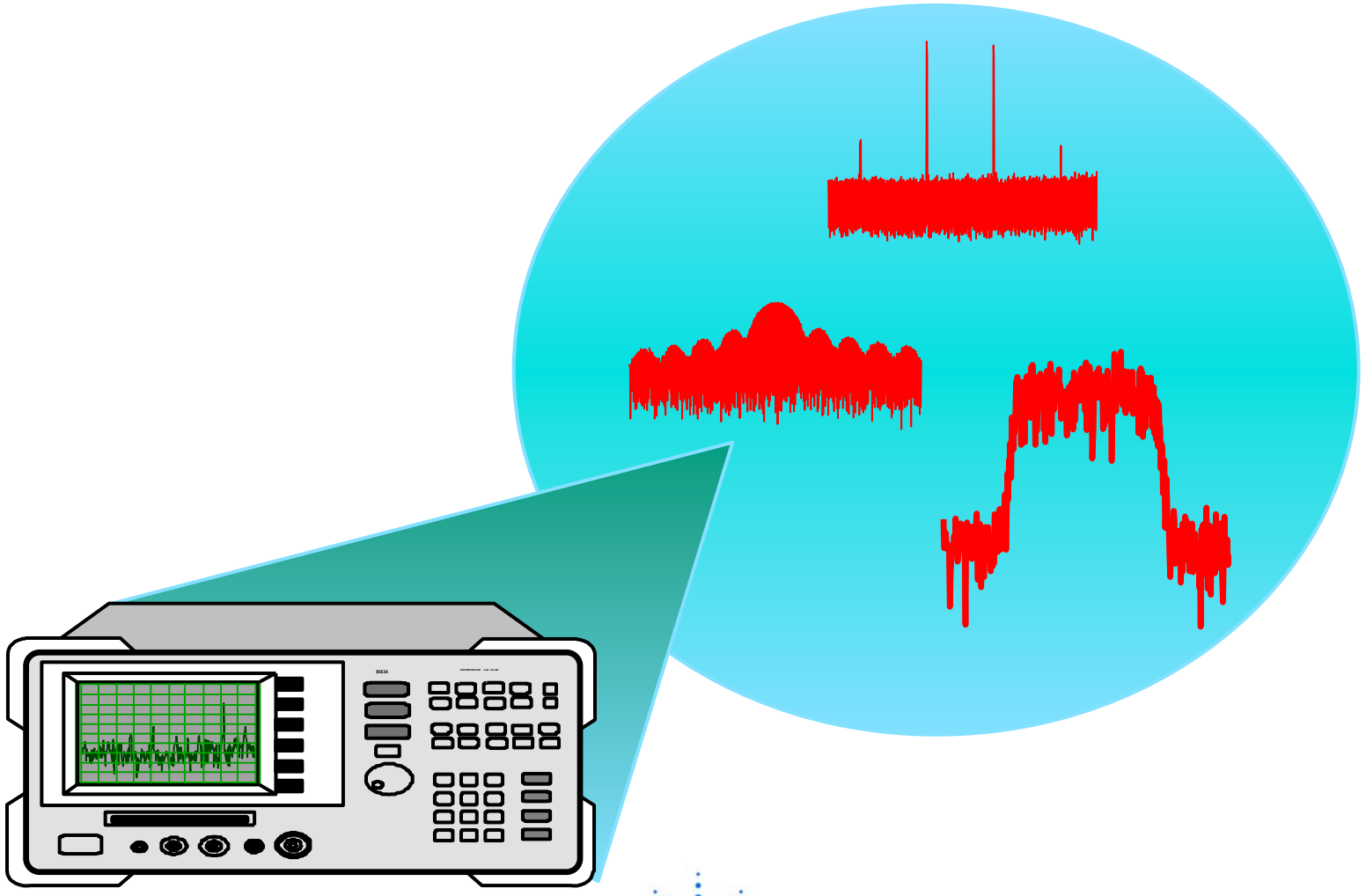
Agenda

- Overview: Spectrum analysis and its measurements
- Theory of Operation: Spectrum analyzer hardware
- Frequency Specifications
- Questions and Answers break
- Amplitude Specifications
- Summary
- Questions and Answers break

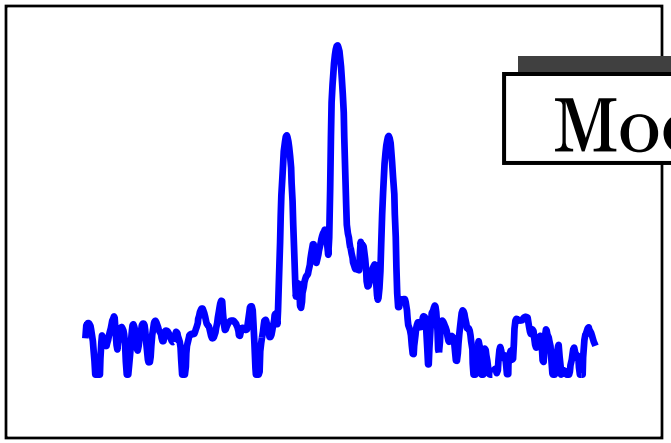
Learning Objectives

- Name the major measurement strengths of a swept-tuned spectrum analyzer
- Explain the importance of frequency resolution, sensitivity, and dynamic range in making analyzer measurements
- Outline the procedure making accurate distortion measurements

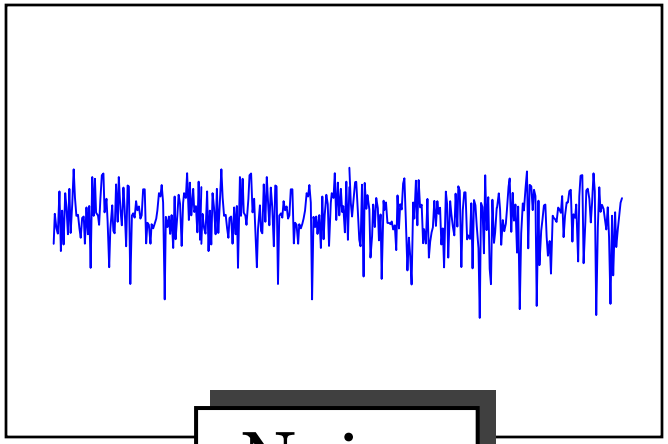
Overview: What is Spectrum Analysis?



Types of Tests Made

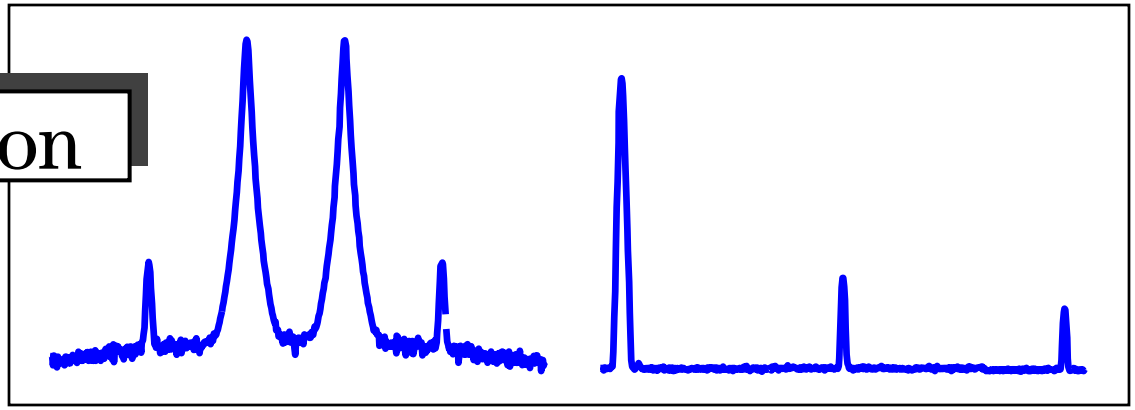


Modulation

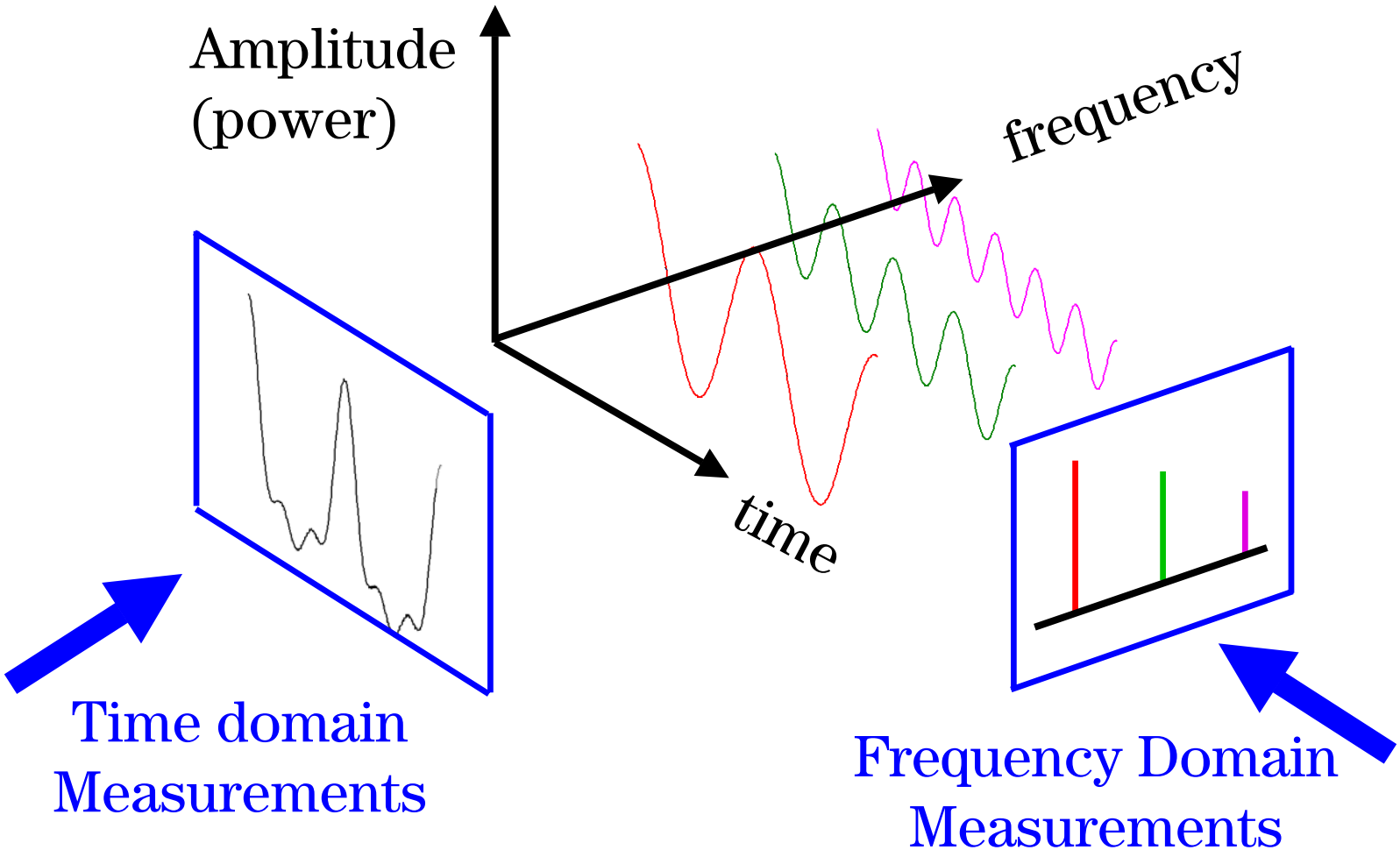


Noise

Distortion



Frequency Versus Time Domain



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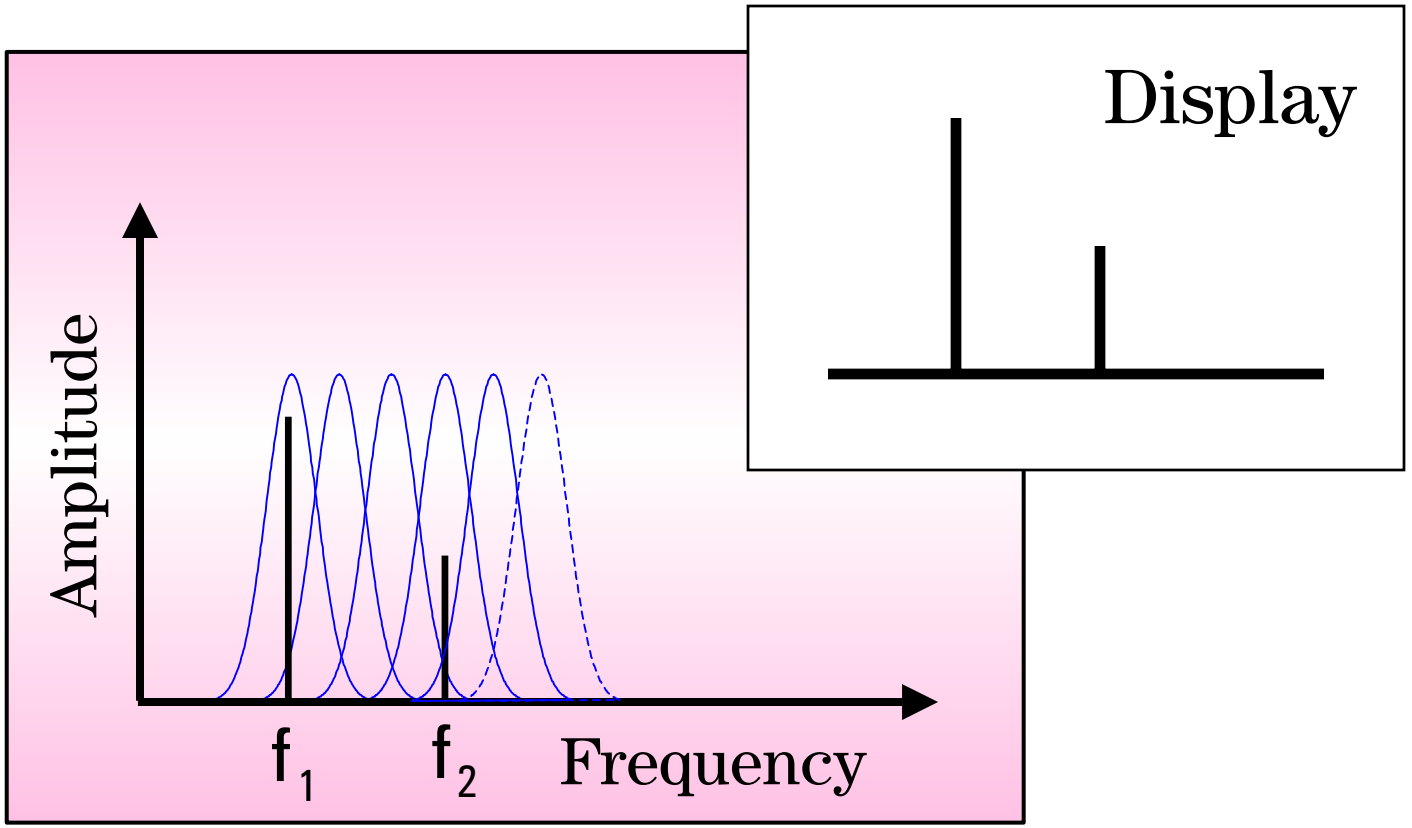
Fourier Spectrum Analyzer

Fourier analyzer transforms a signal over time into a frequency spectrum



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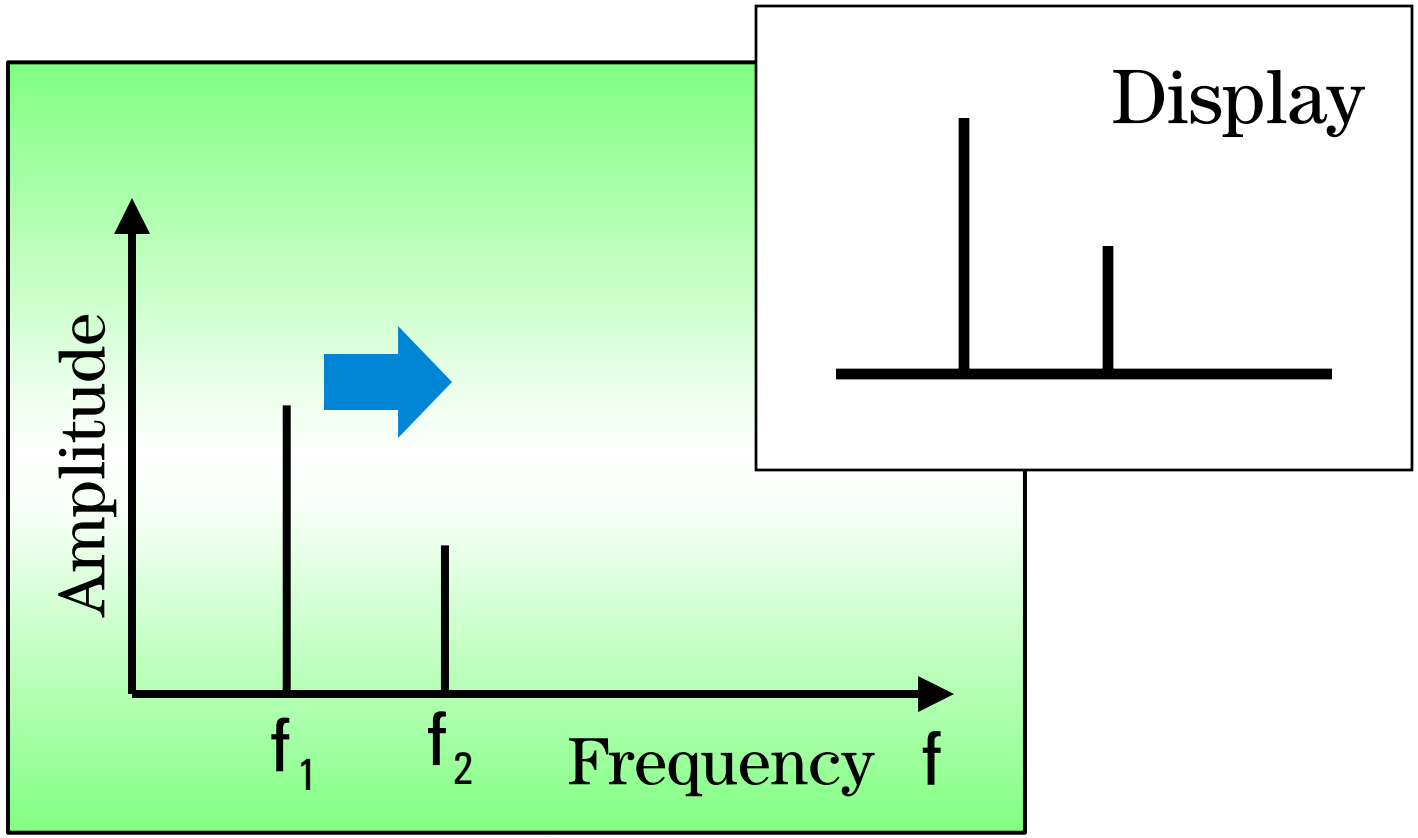
Swept-Tuned Spectrum Analyzer

Filter “sweeps” over a frequency range



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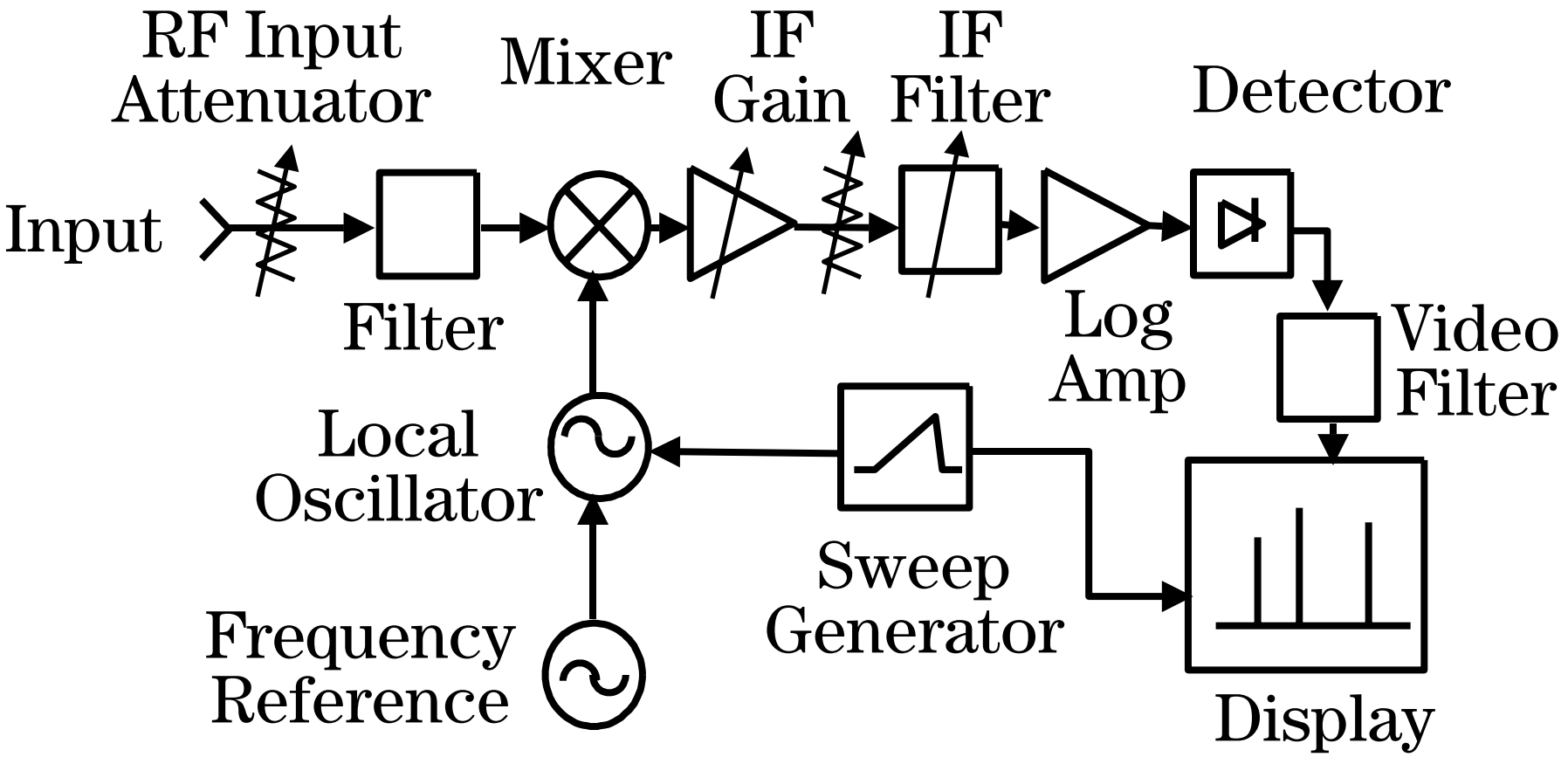
Spectrum Analyzer Block Diagram



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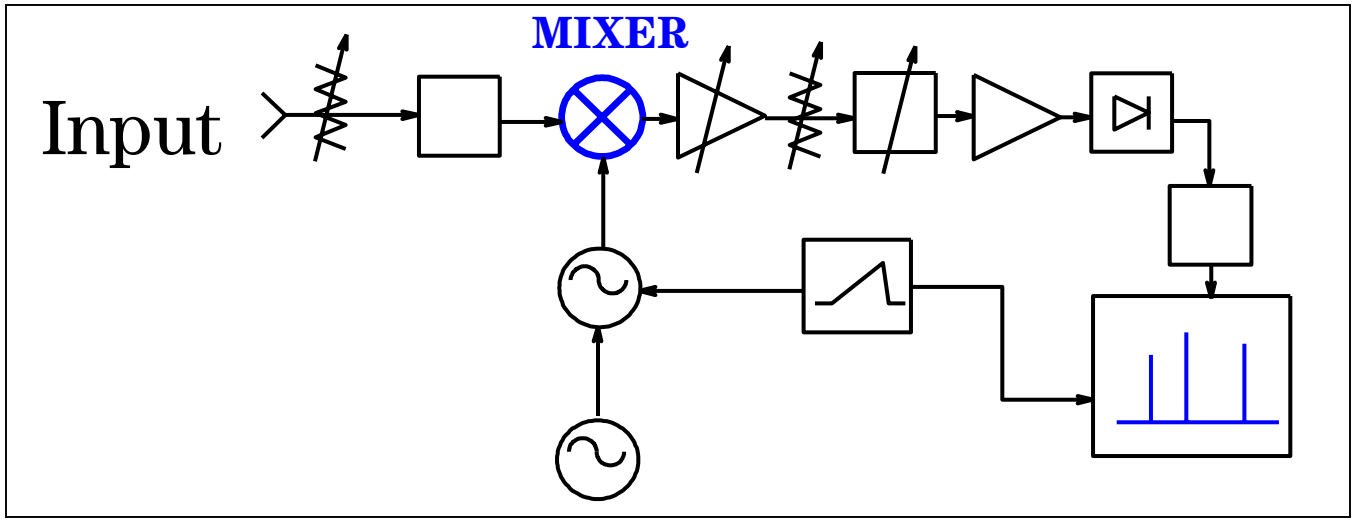
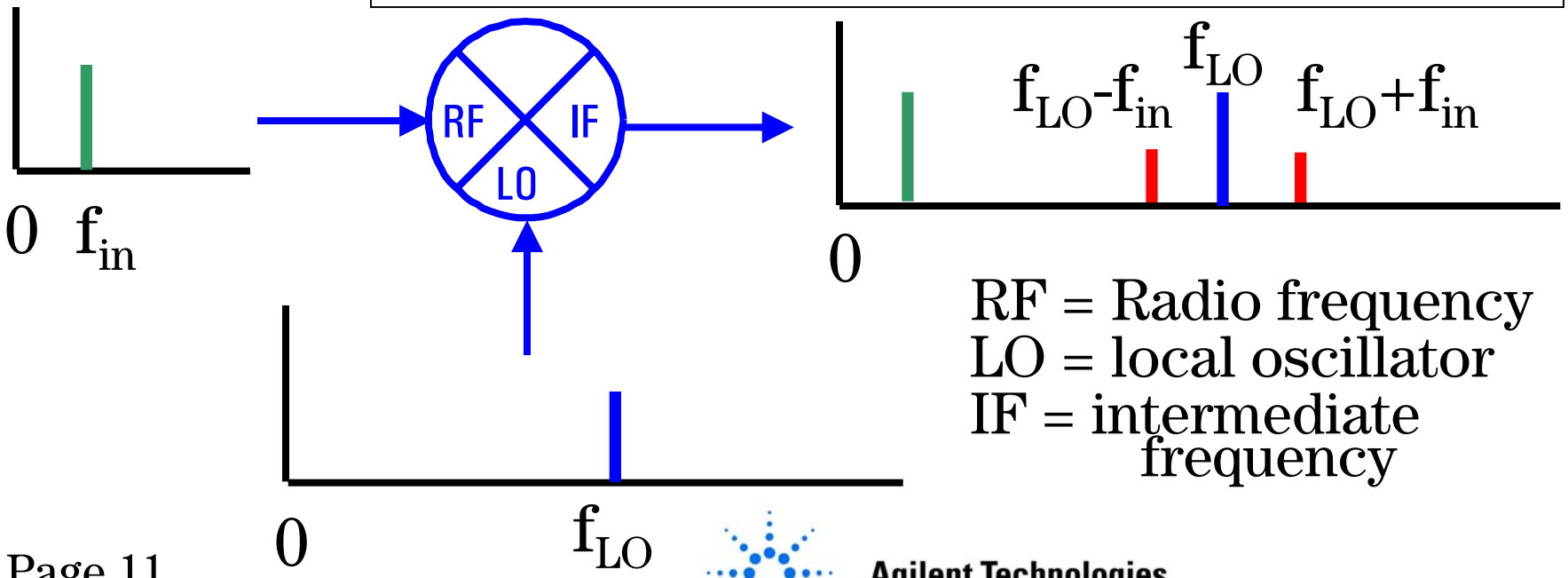
The Mixer: Key to a Wide Frequency Range





RF = Radio frequency
LO = local oscillator
IF = intermediate frequency

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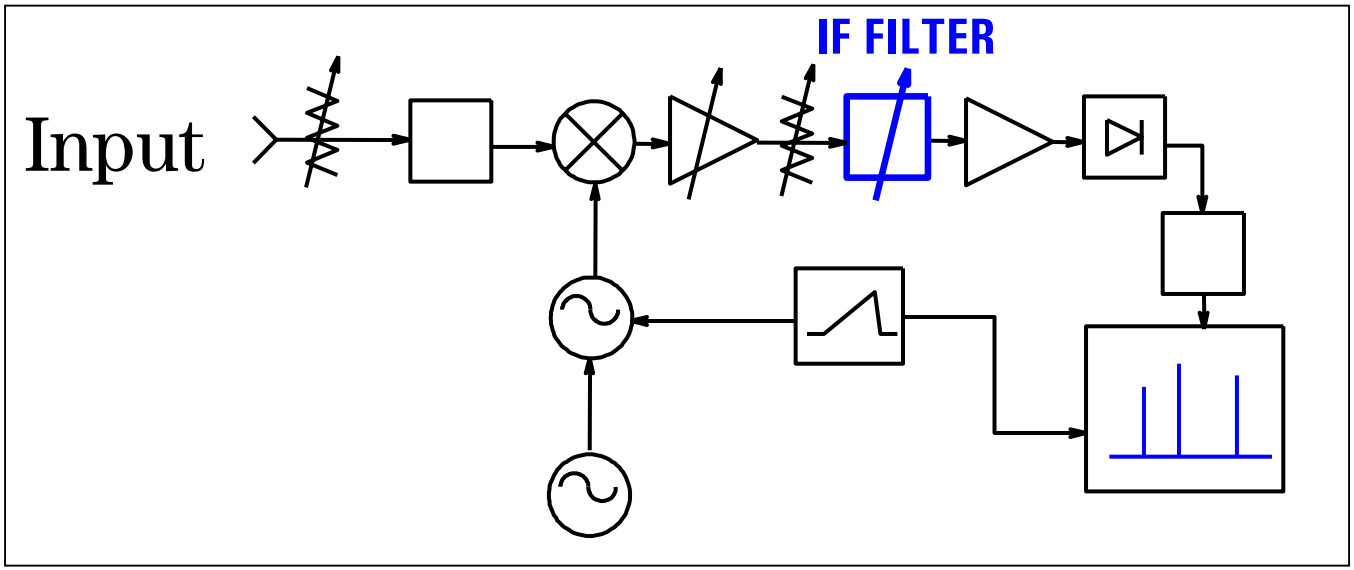
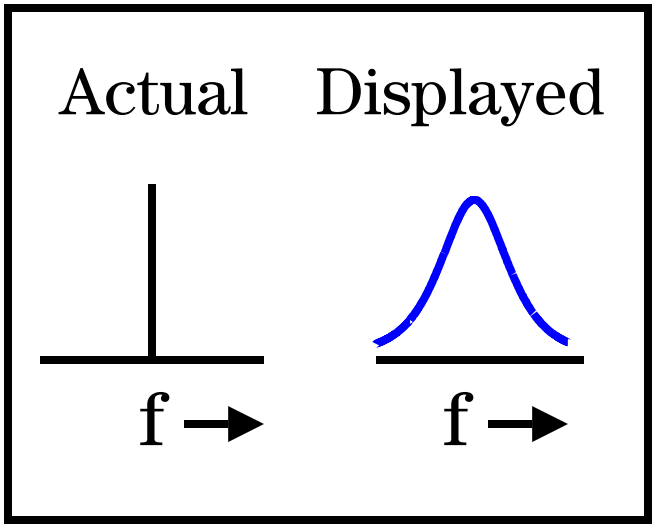
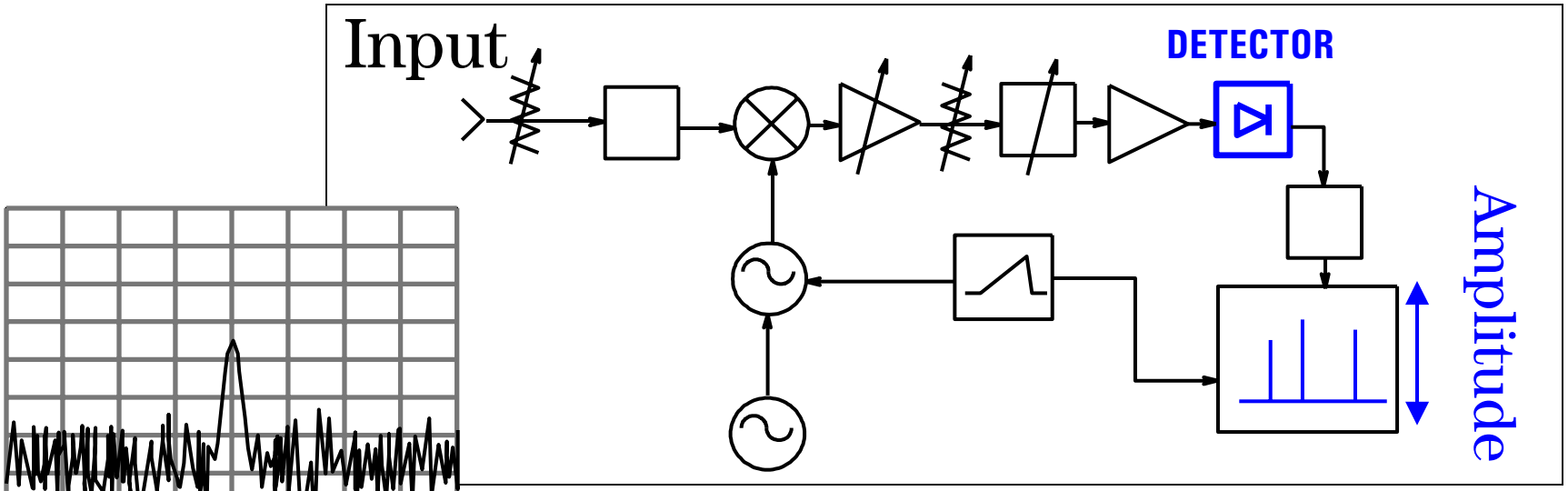
Intermediate Frequency (IF) Filter

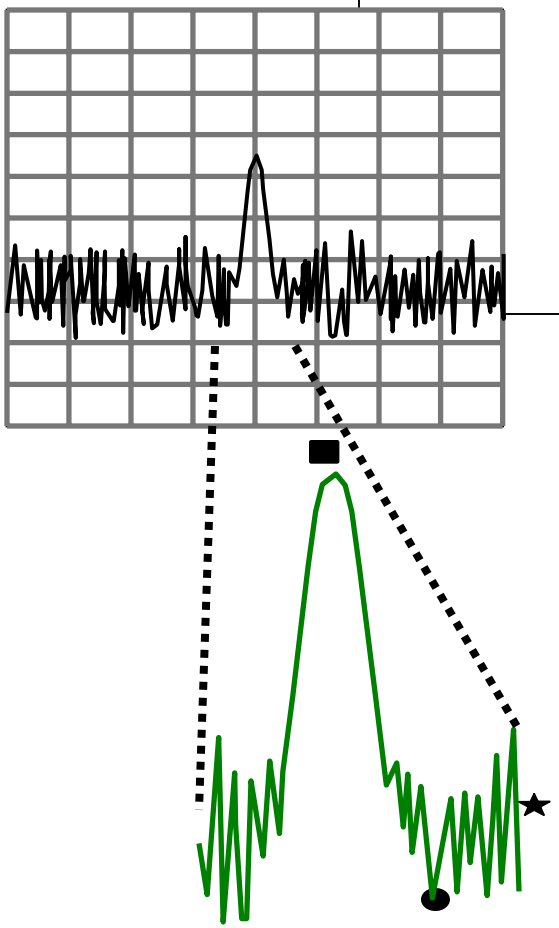


- IF Bandwidth: also known as resolution bandwidth and RBW
- Provides shape of frequency domain signal



Detector





Values Displayed

- ■ Positive detection: largest
- ● Negative detection: smallest
- ★ Sample detection: last

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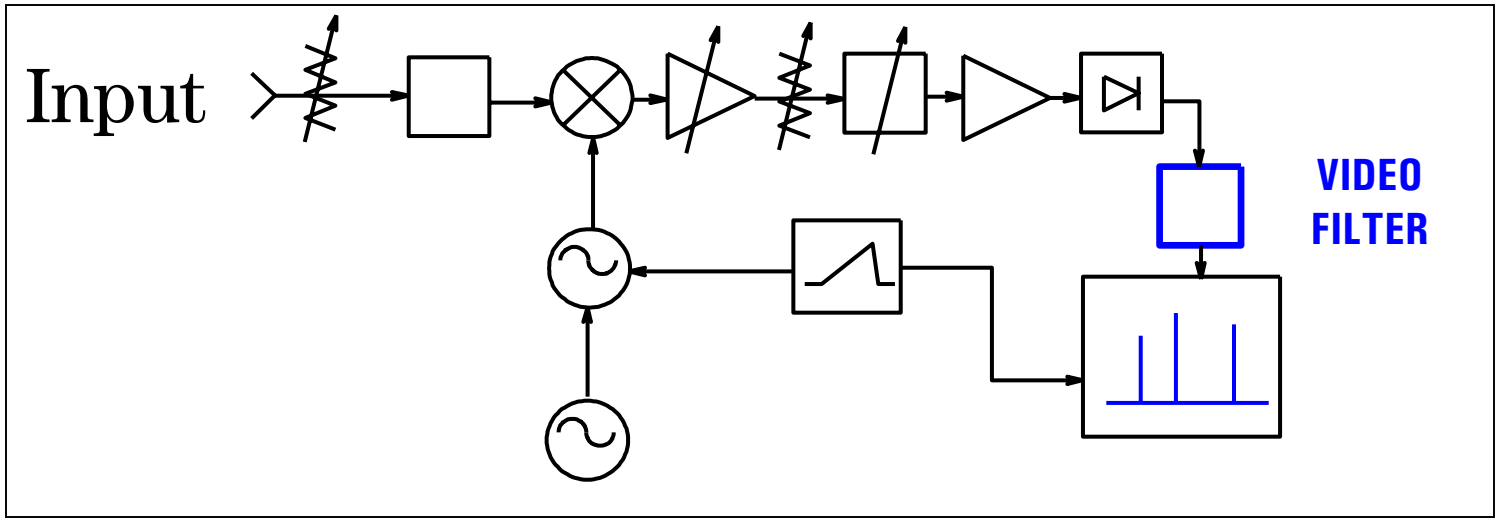
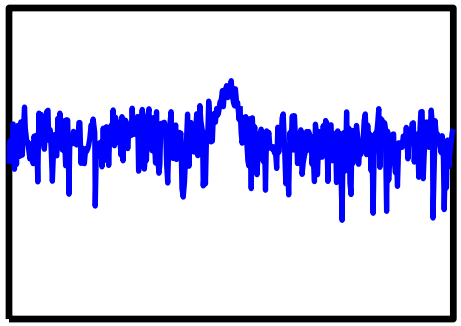
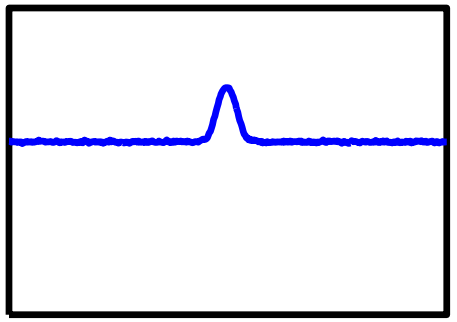
Video Filter



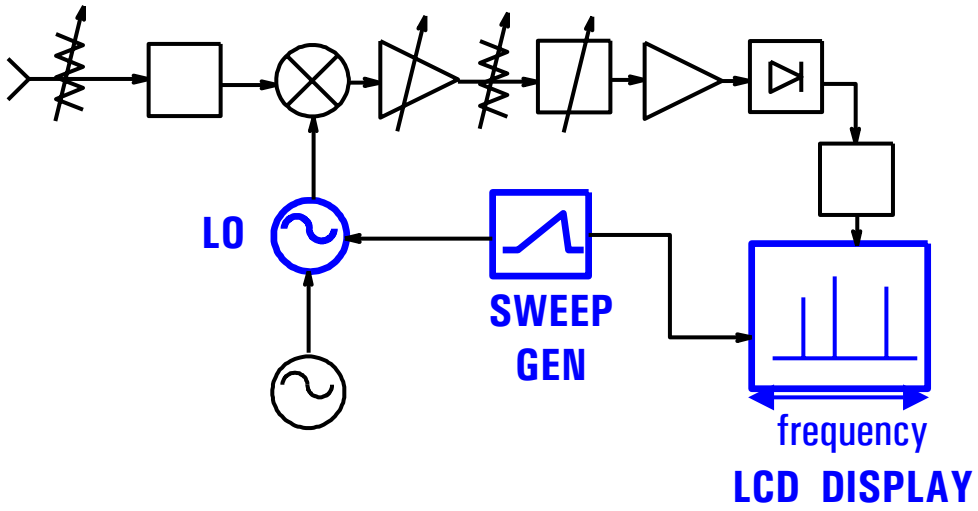


Without video filtering



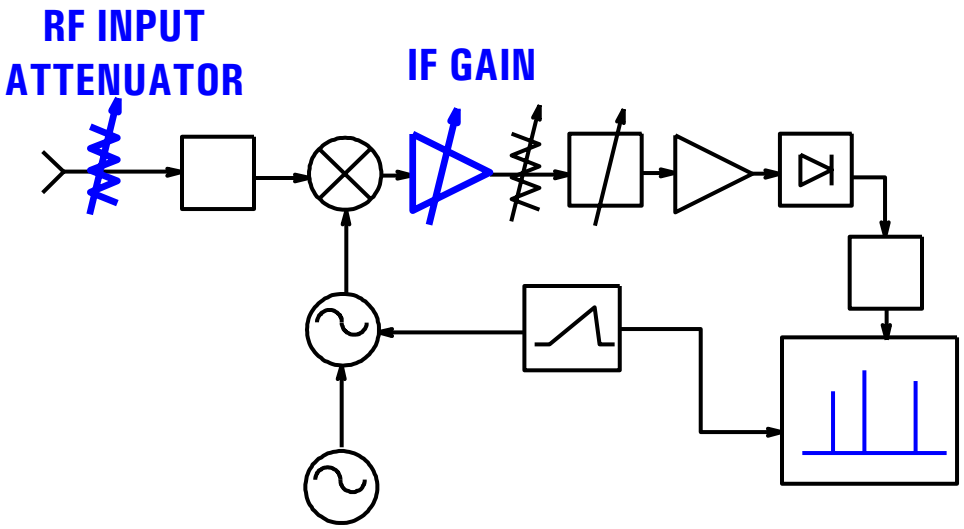
With video filtering

Local Oscillator and Sweep Generator



- Provides swept display

Input Attenuator and IF Gain Circuits



- Protects input circuits
- Calibrates signal amplitude
- Keeps signal display position constant

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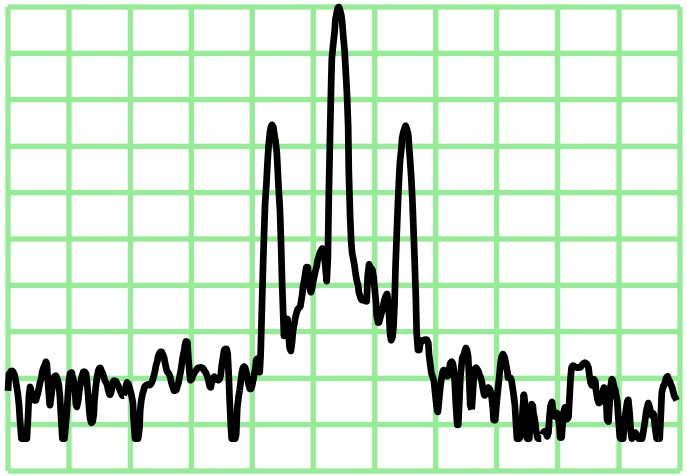
What Spectrum Analyzer Specifications are Important?

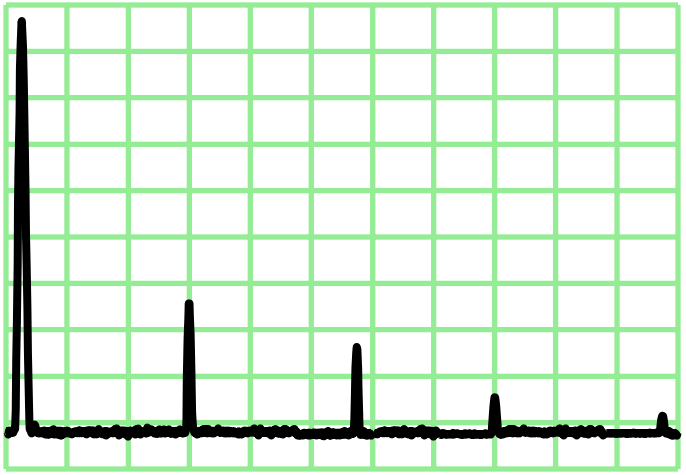
- Frequency Range
- Frequency and Amplitude Accuracy
- Frequency Resolution
- Sensitivity
- Distortion
- Dynamic Range

Frequency Range

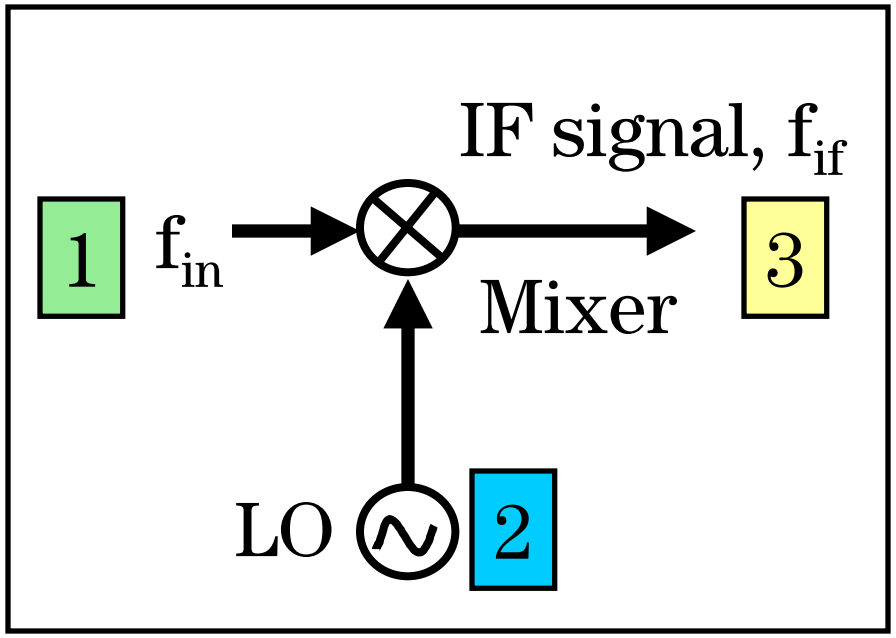
Low frequencies for baseband and IF



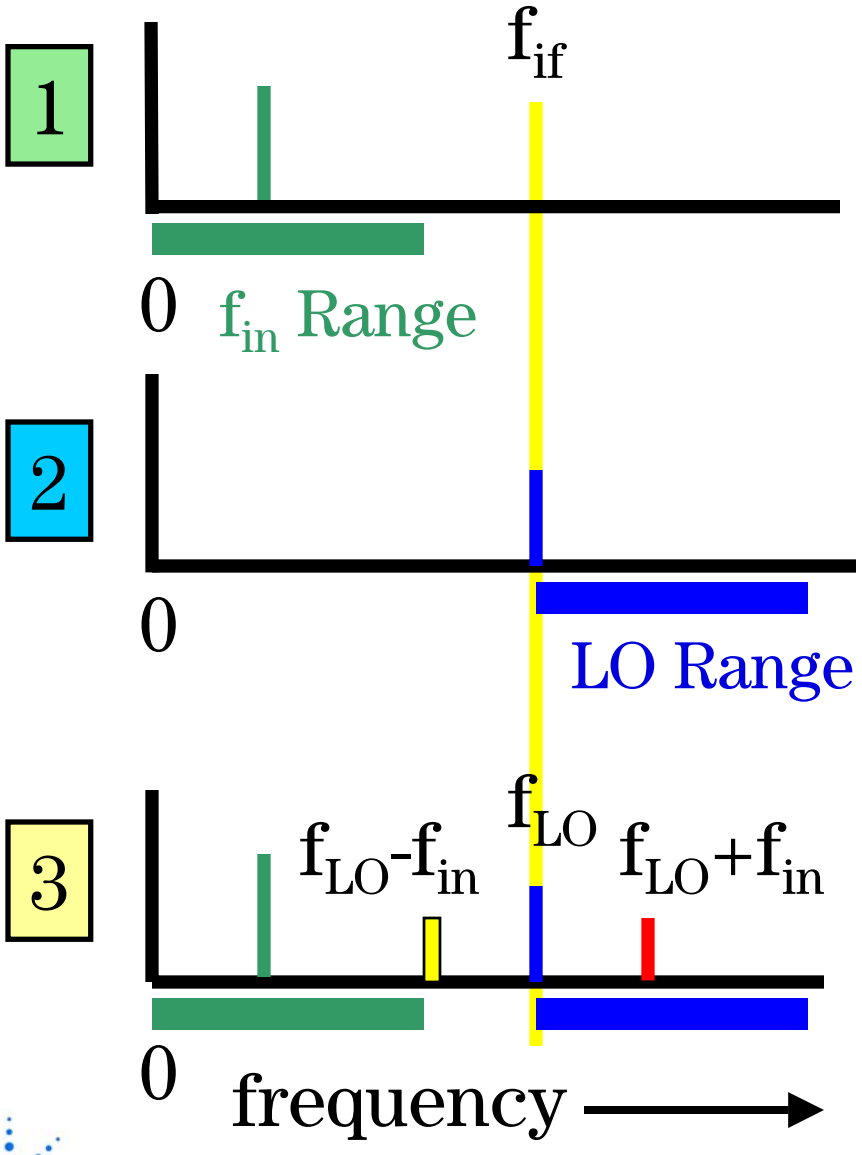
High frequencies for harmonics and beyond



Getting the Frequency Range You Need



The input signal is displayed when
$f_{LO} - f_{in} = f_{IF}$



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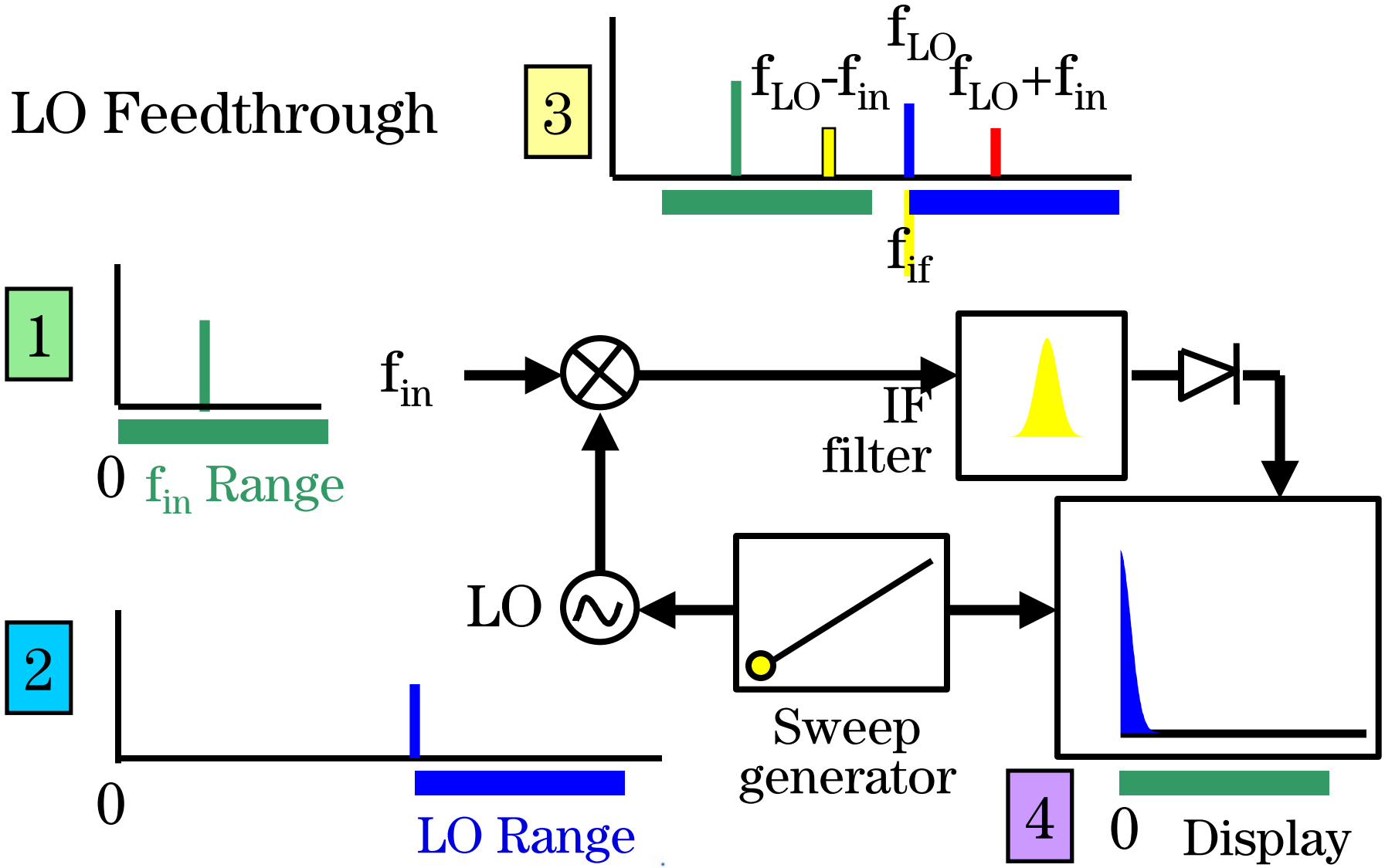
Getting the Frequency Range You Need



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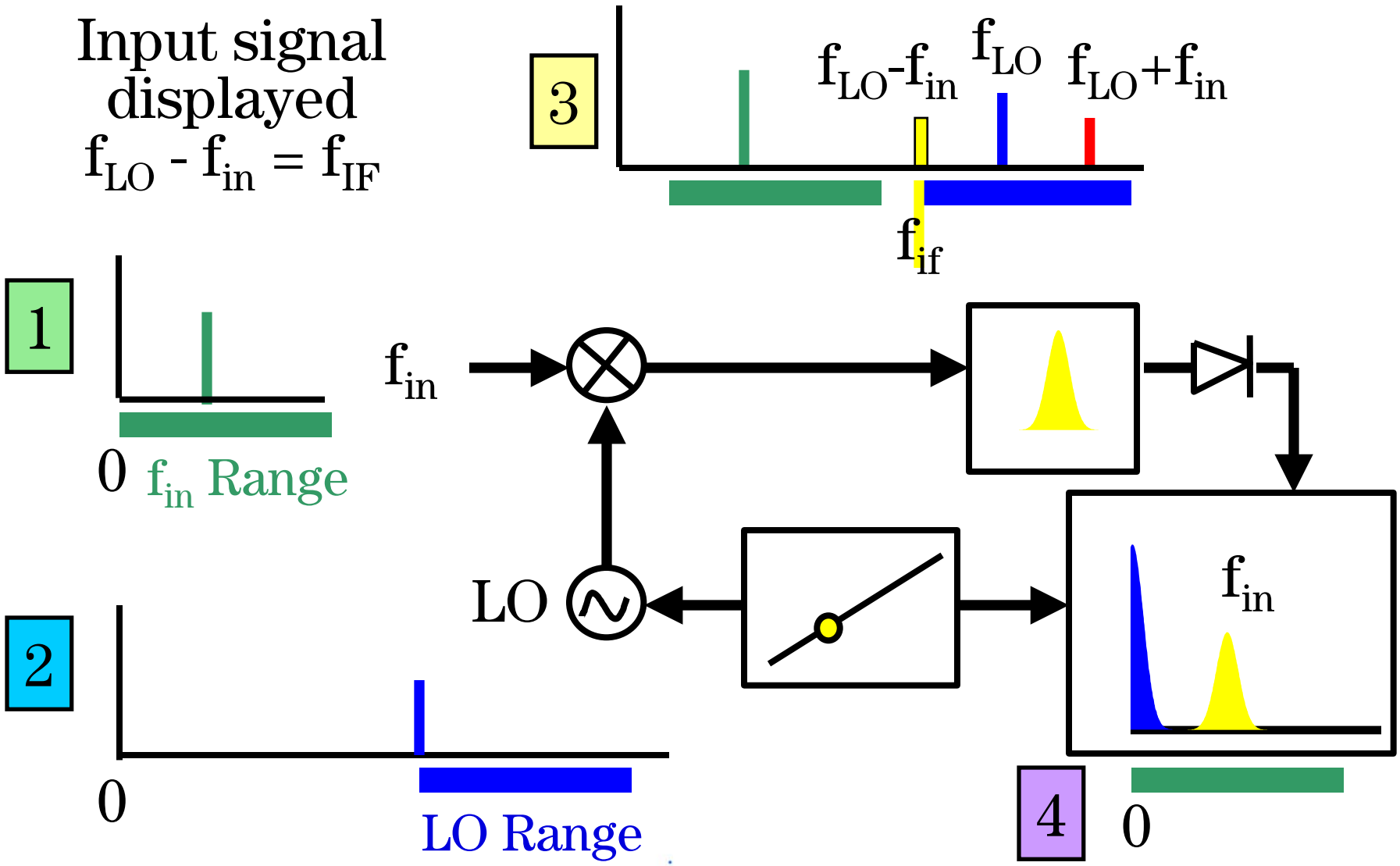
Getting the Frequency Range You Need



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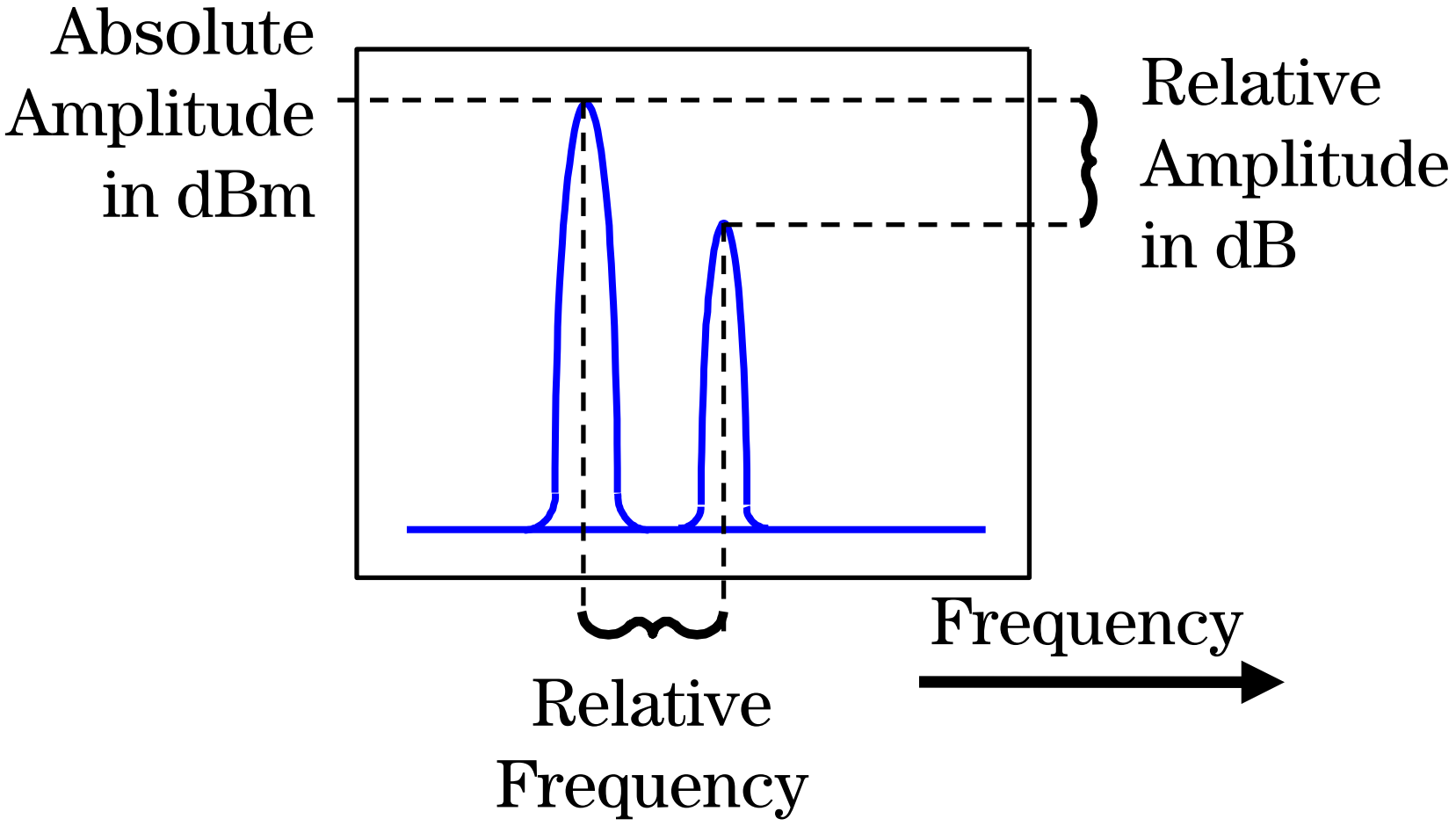
Getting the Frequency Range You Need

- Lower frequency limited by LO feedthrough
- Upper frequency limited by LO range and IF frequency
- Microwave frequency measurement uses harmonic mixing

Frequency and Amplitude Accuracy



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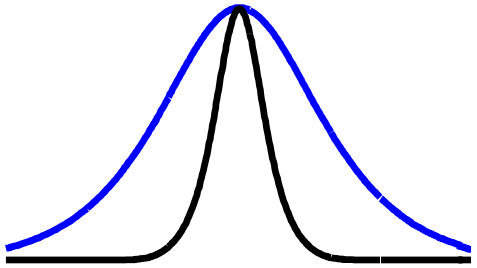
Frequency and Amplitude Accuracy

- Frequency accuracy:
  - –Internal/external frequency reference
  - –Use of internal counter
- Amplitude accuracy:
  - –Not as good as a power meter
  - –Dependent upon measurement procedure
  - –Excellent relative measurements

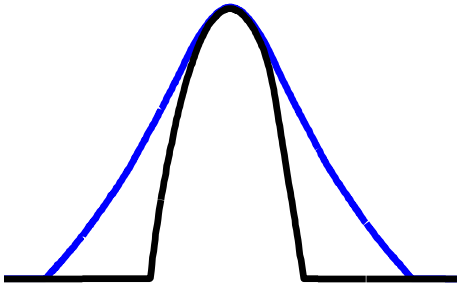
Signal Resolution

What Determines Resolution?

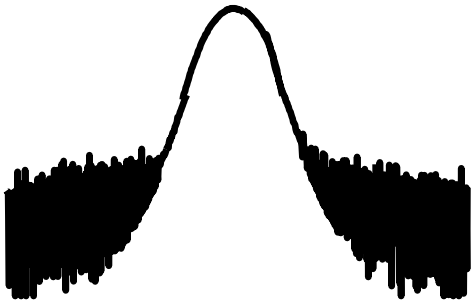


Resolution Bandwidth

Residual FM

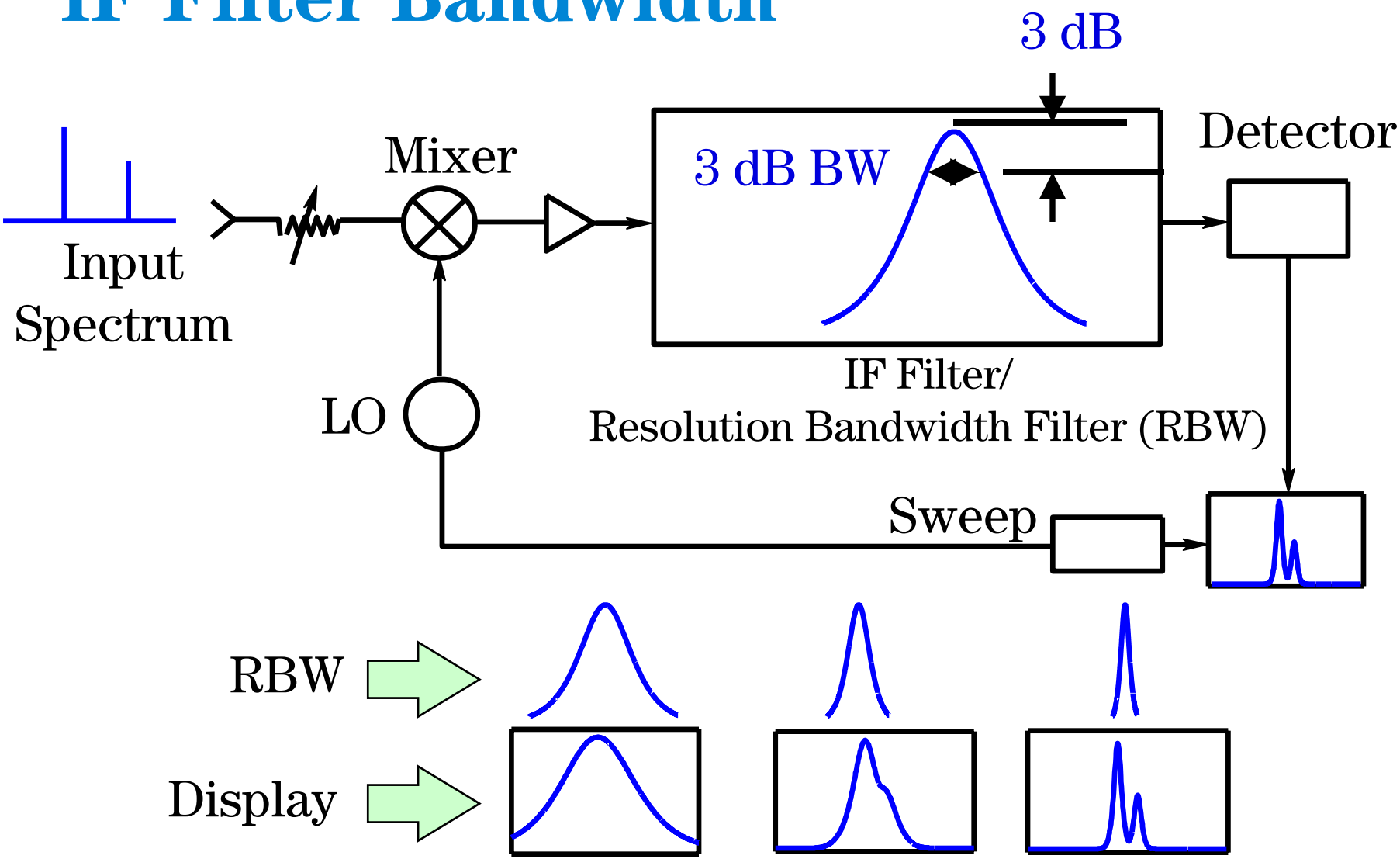


RBW Type and Selectivity



Noise Sidebands

IF Filter Bandwidth



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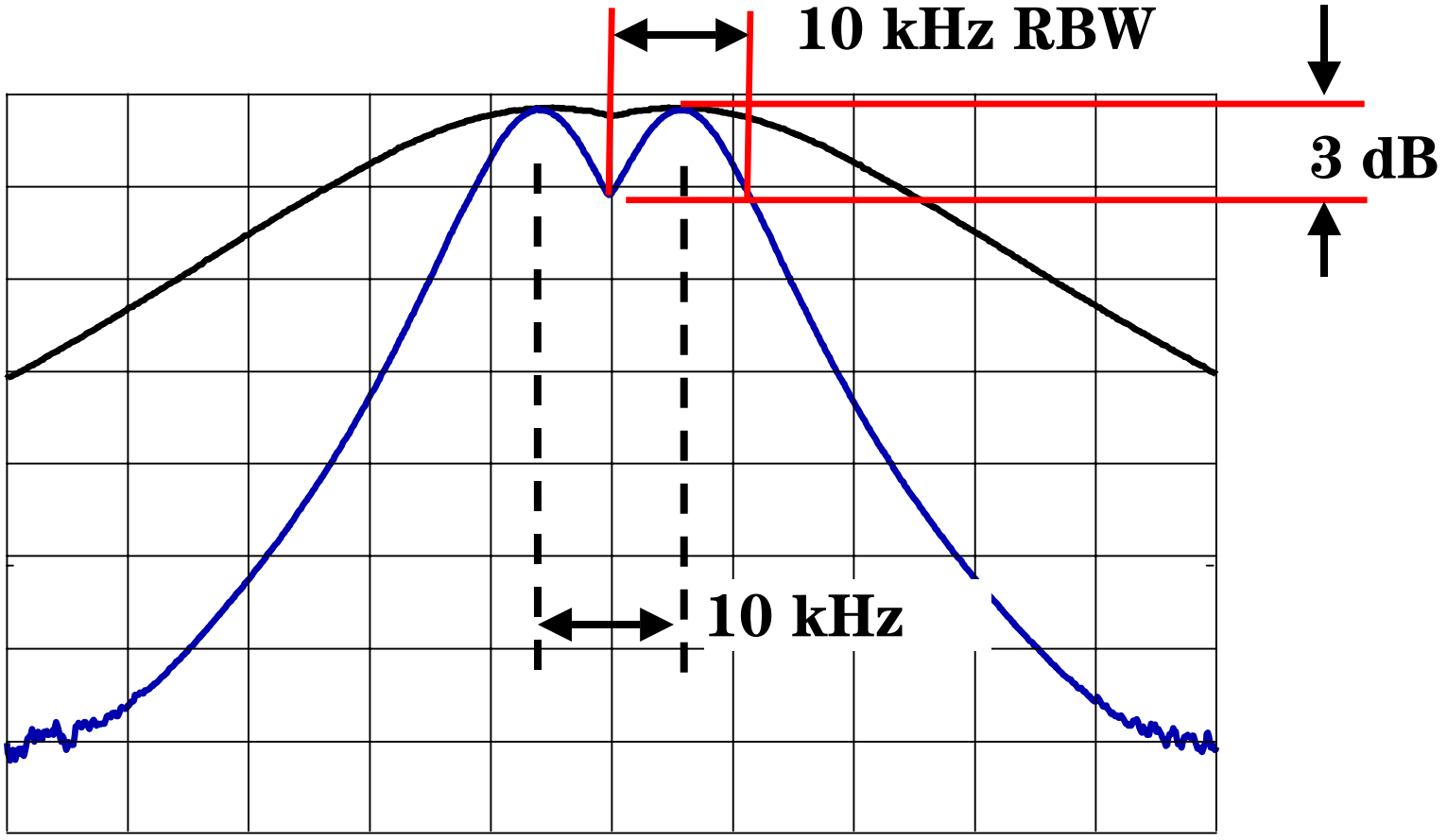
Resolving Two Equal-level Signals



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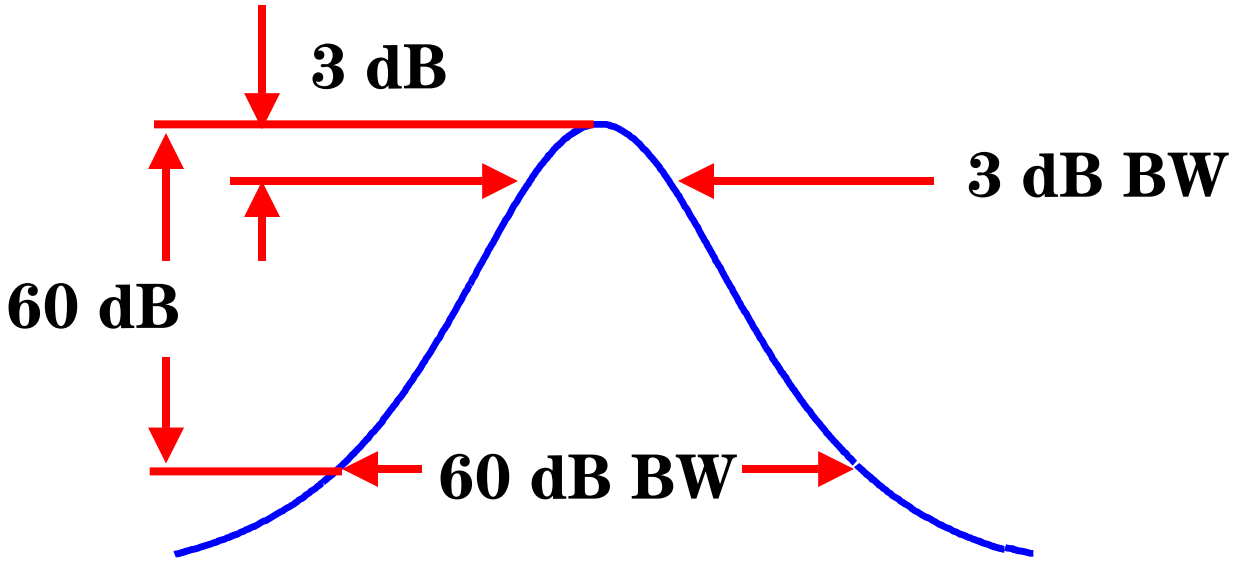
Resolving Two Unequal-level Signals

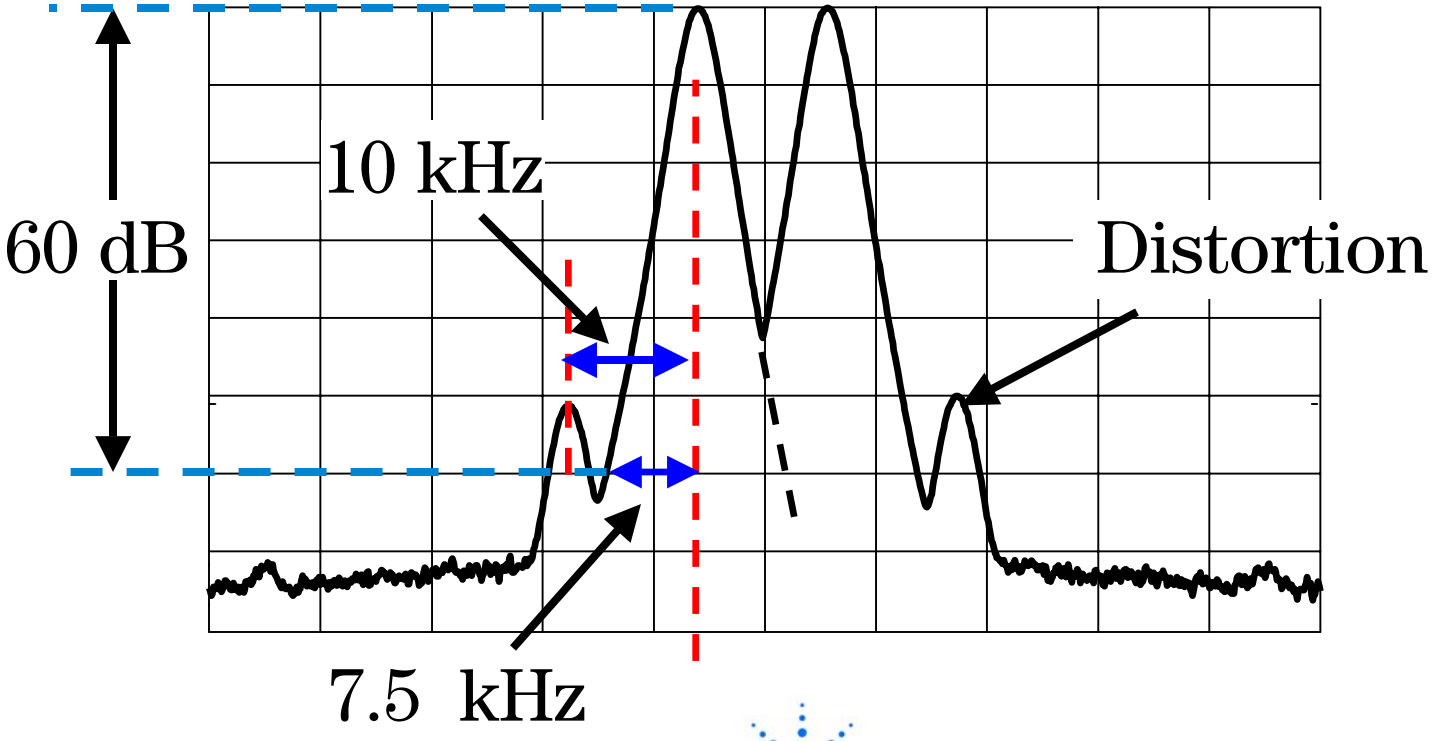
- 3 dB bandwidth
- Selectivity (filter shape)



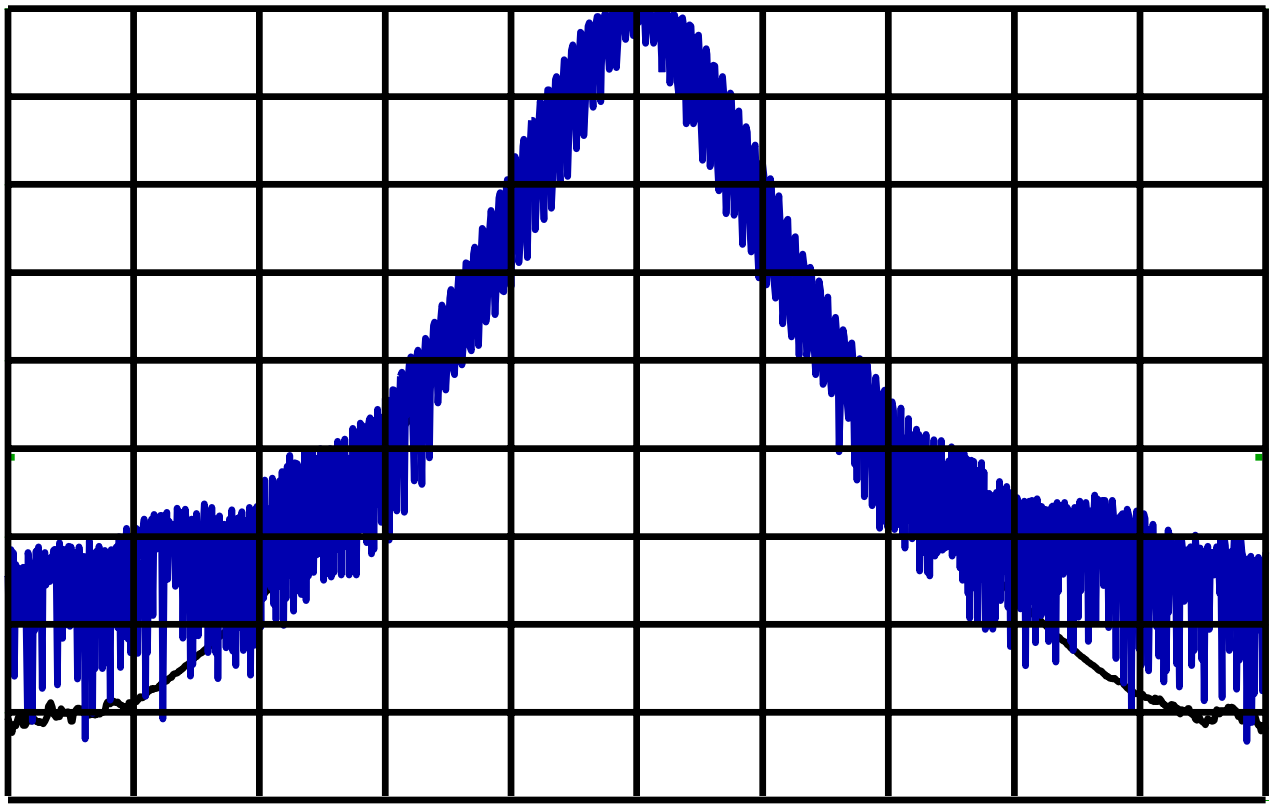
$$\text{Selectivity} = \frac{\text{3 dB BW}}{\text{60 dB BW}}$$

Resolving Two Unequal-level Signals

- For a RBW of 1 kHz and a selectivity of 15:1, the 60 dB bandwidth is 15 x 1 kHz = 15 kHz...
- ...so the filter skirt is 7.5 kHz away from the filter's center frequency

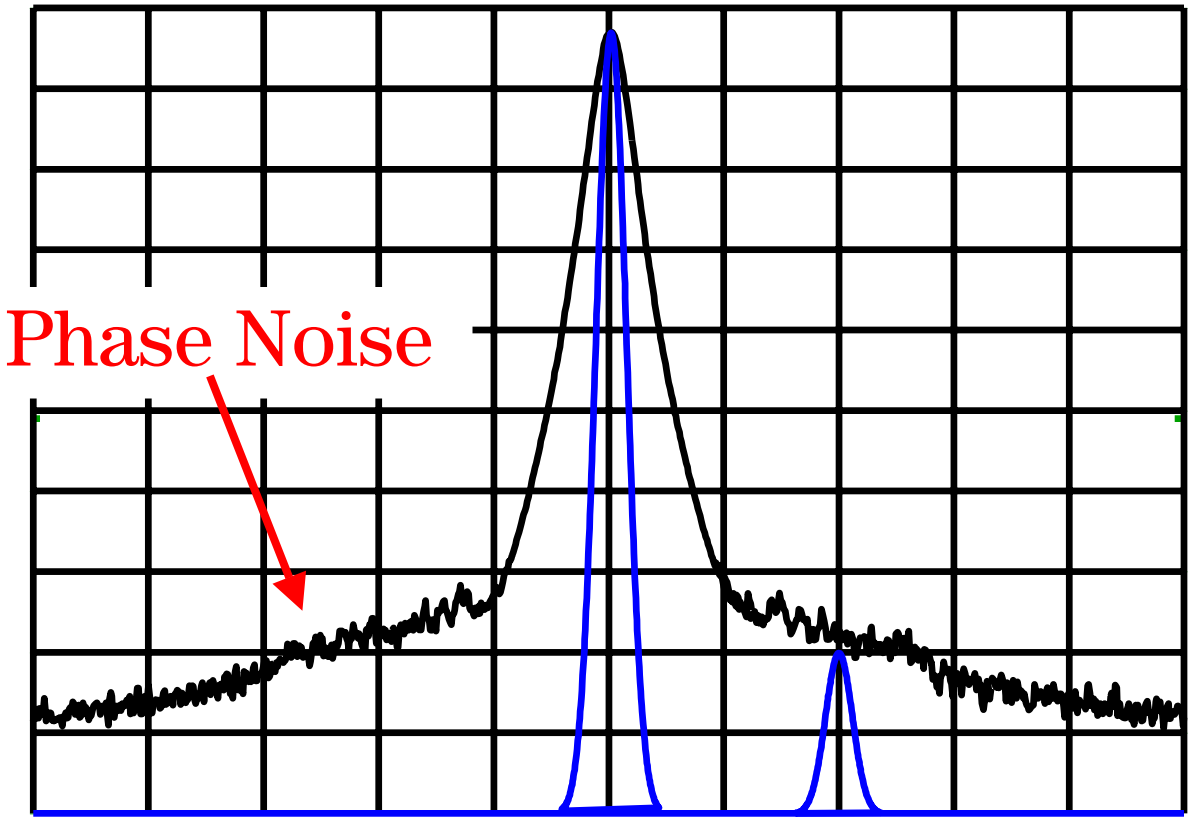


Residual FM



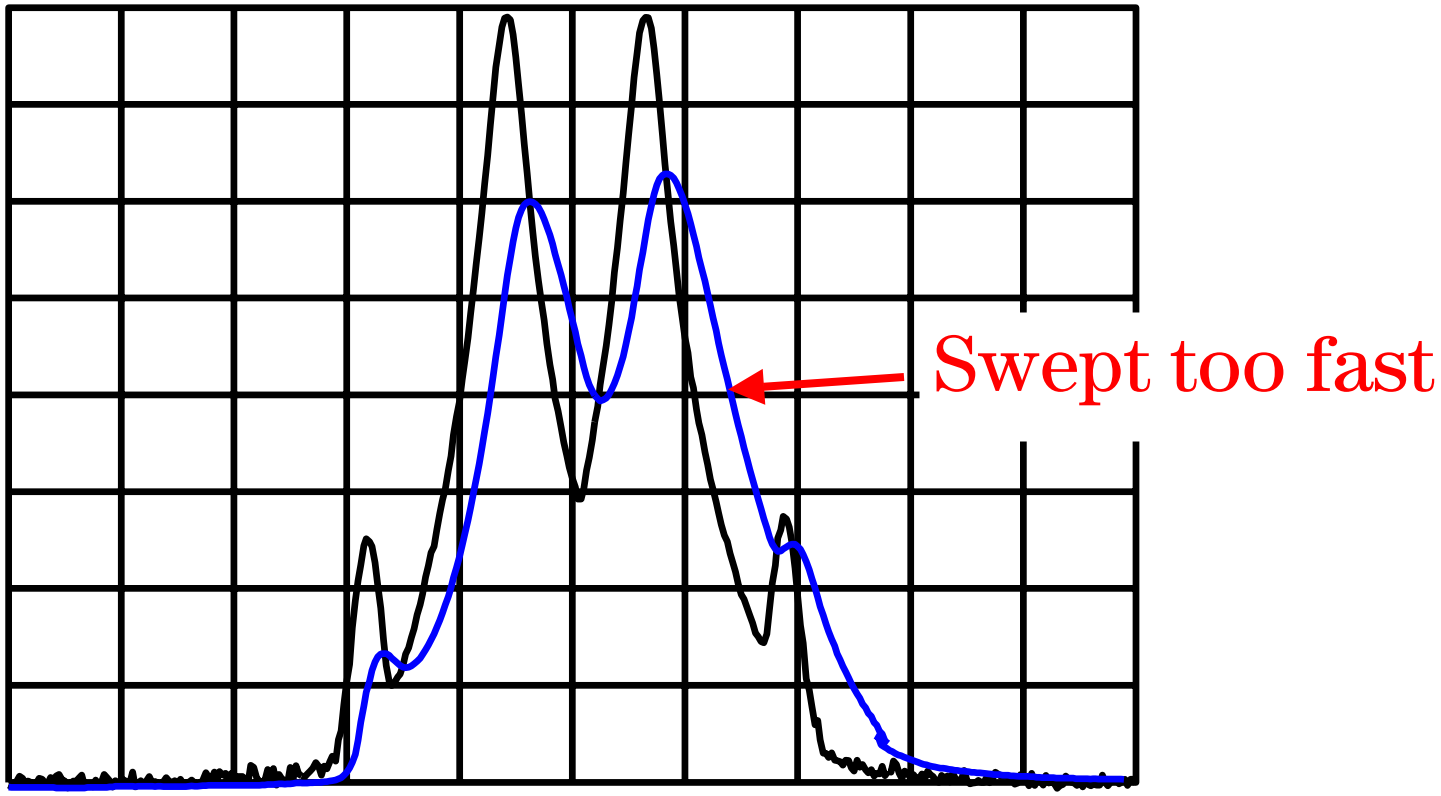
Residual FM
"Smears" the Signal

Noise Sidebands (Phase Noise)



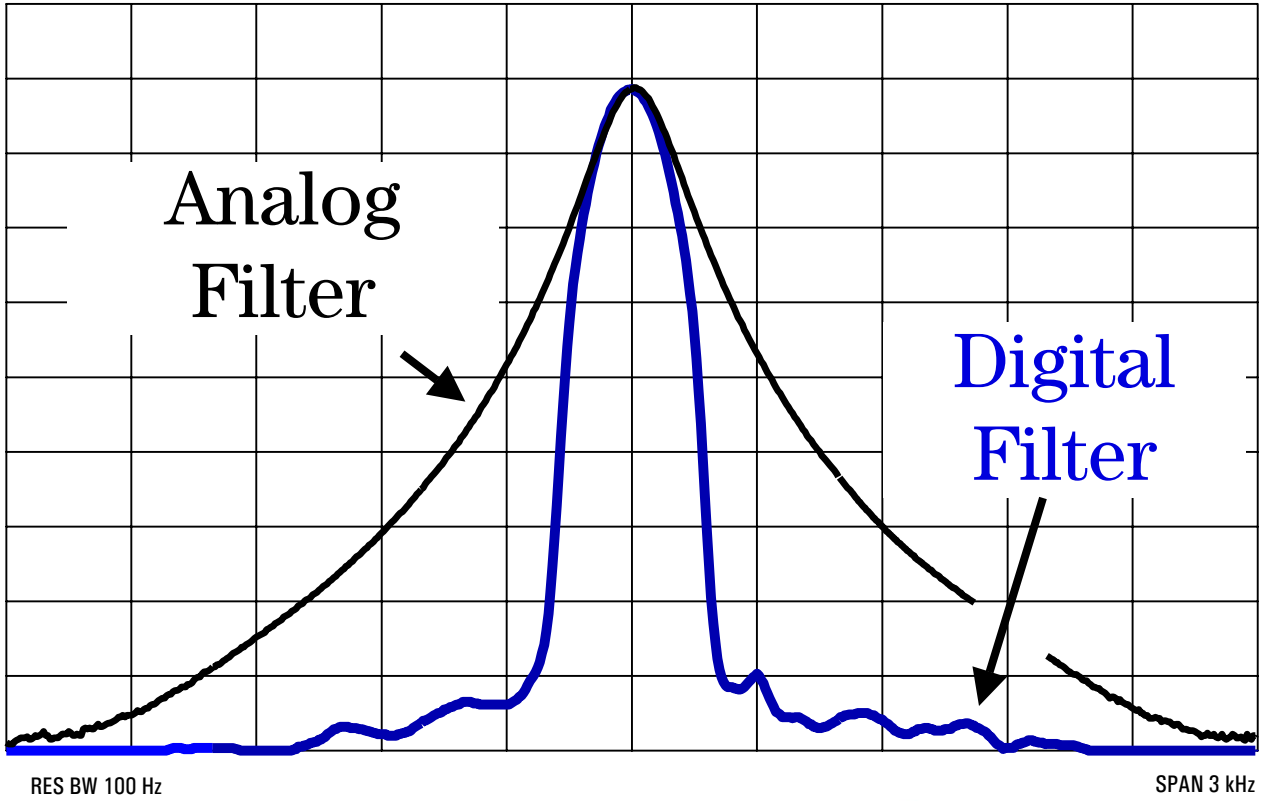
Noise Sidebands can prevent resolution of unequal signals

Sweep Rate



Penalty For Sweeping Too Fast
Is An Uncalibrated Display

Analog versus Digital Resolution Bandwidths



Typical Selectivity

Analog 15:1

Digital 5:1

Rules to Analyze By:

Use the Analyzer's Automatic Settings Whenever Possible

- When using the analyzer in its preset mode, most measurements will be easy, fast, and accurate
- Automatic selection of resolution bandwidth, video bandwidth, sweep time and input attenuation
- When manually changing the analyzer parameters, check for "uncal" messages

Are There Any Questions?

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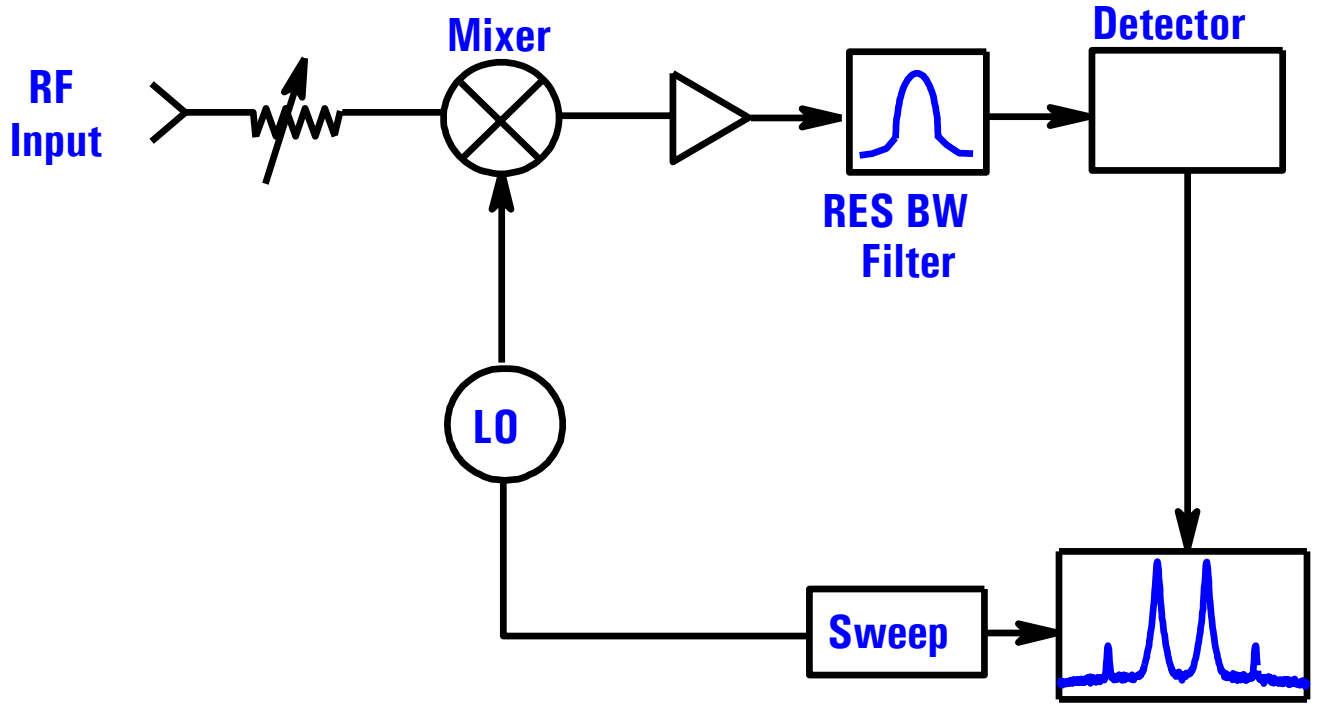
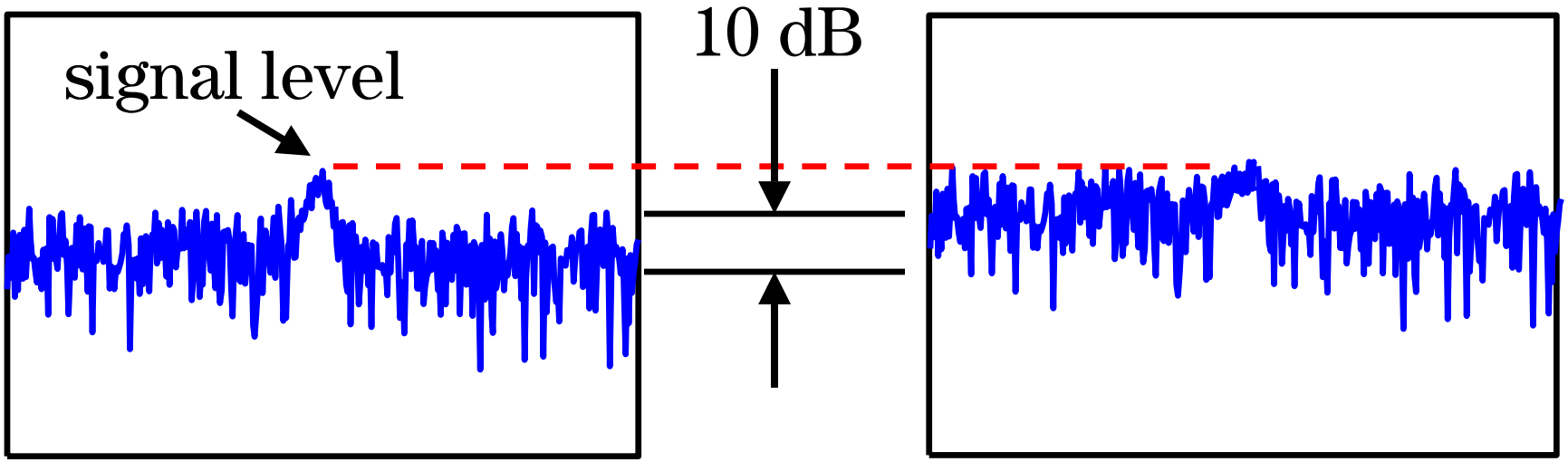
Sensitivity and Displayed Average Noise Level



A spectrum analyzer generates and amplifies noise just like any active circuit.

RF Input Attenuator Effects

Displayed noise is a function of RF input attenuation

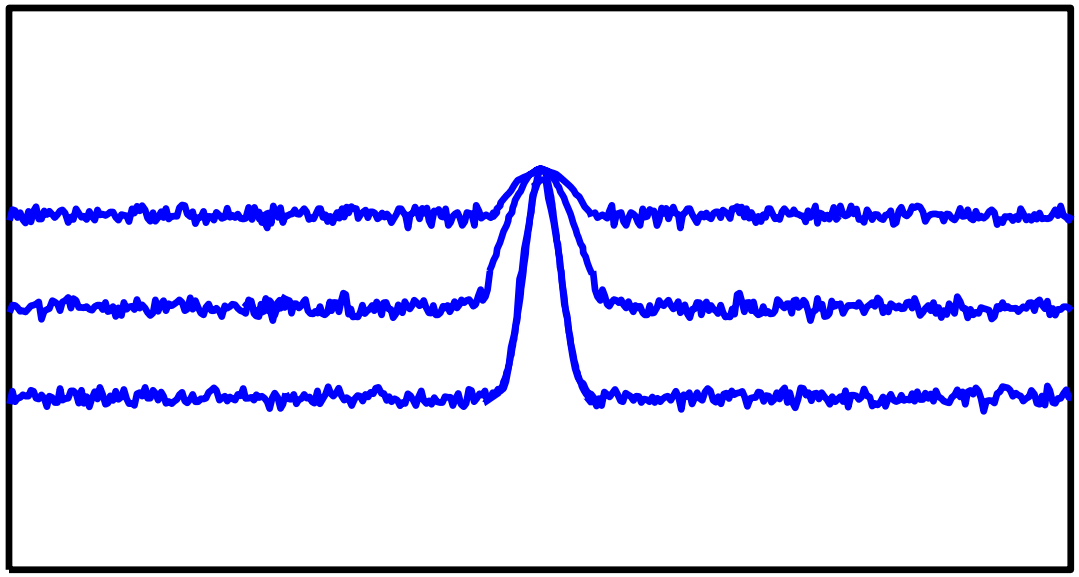


Signal-to-noise ratio decreases as RF input attenuation is increased

IF Filter (Resolution Bandwidth) Effects

Displayed noise is a function of IF filter bandwidth

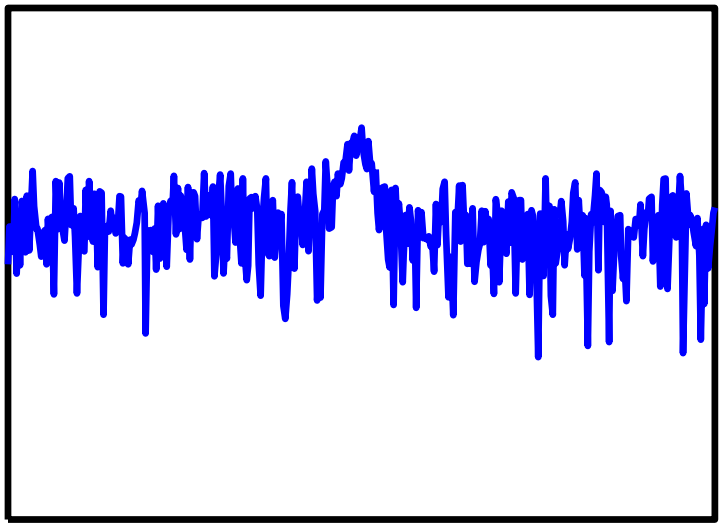
Decreased BW = Decreased Noise

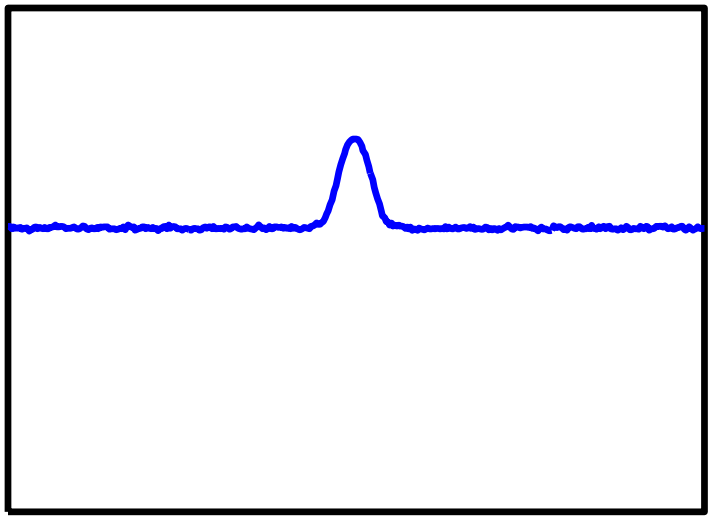


Best sensitivity = narrowest RBW

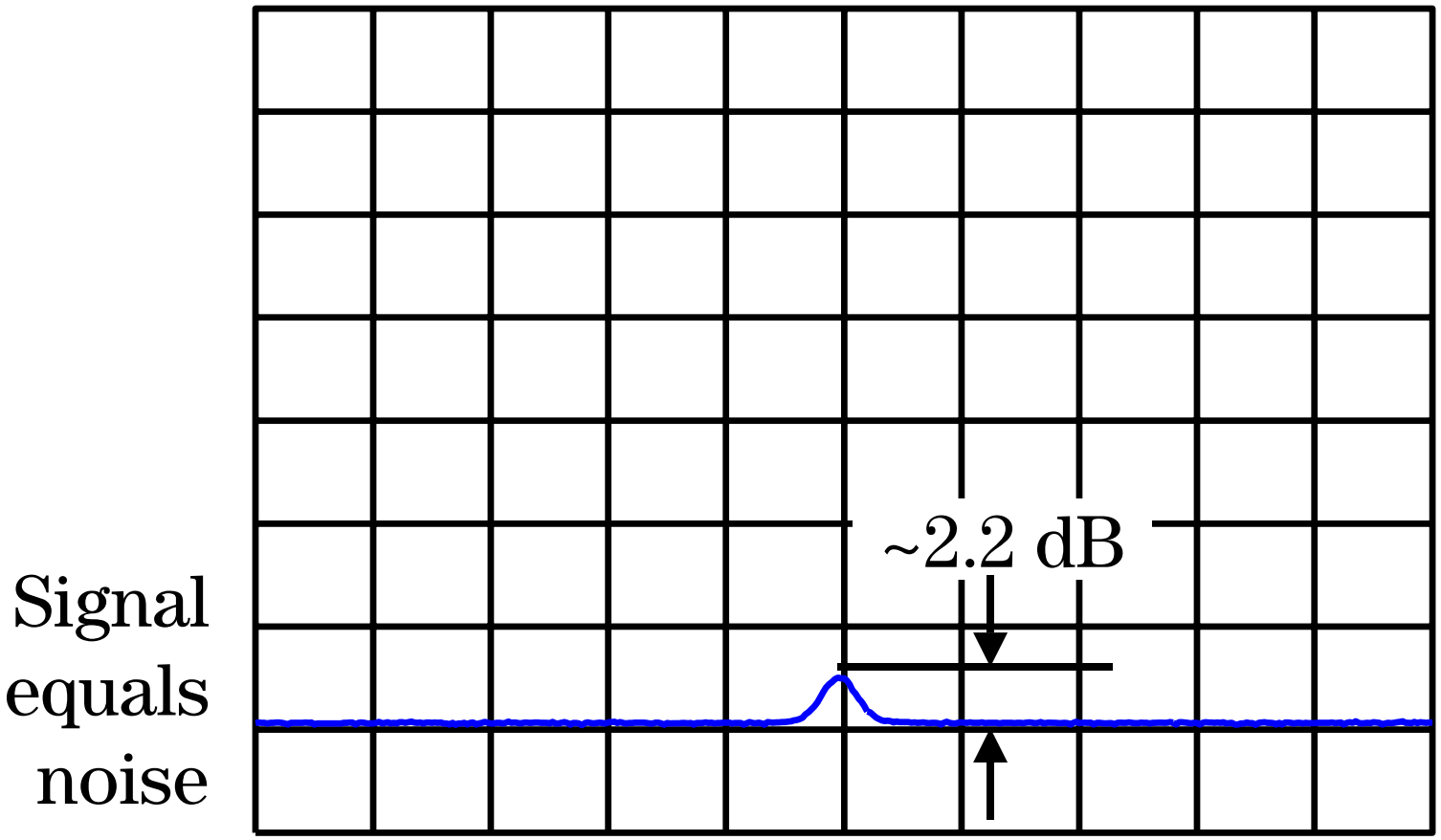
Video Bandwidth Effects

Video BW smoothes noise for easier identification and measurement of low-level signals





Sensitivity - the smallest signal that can be measured



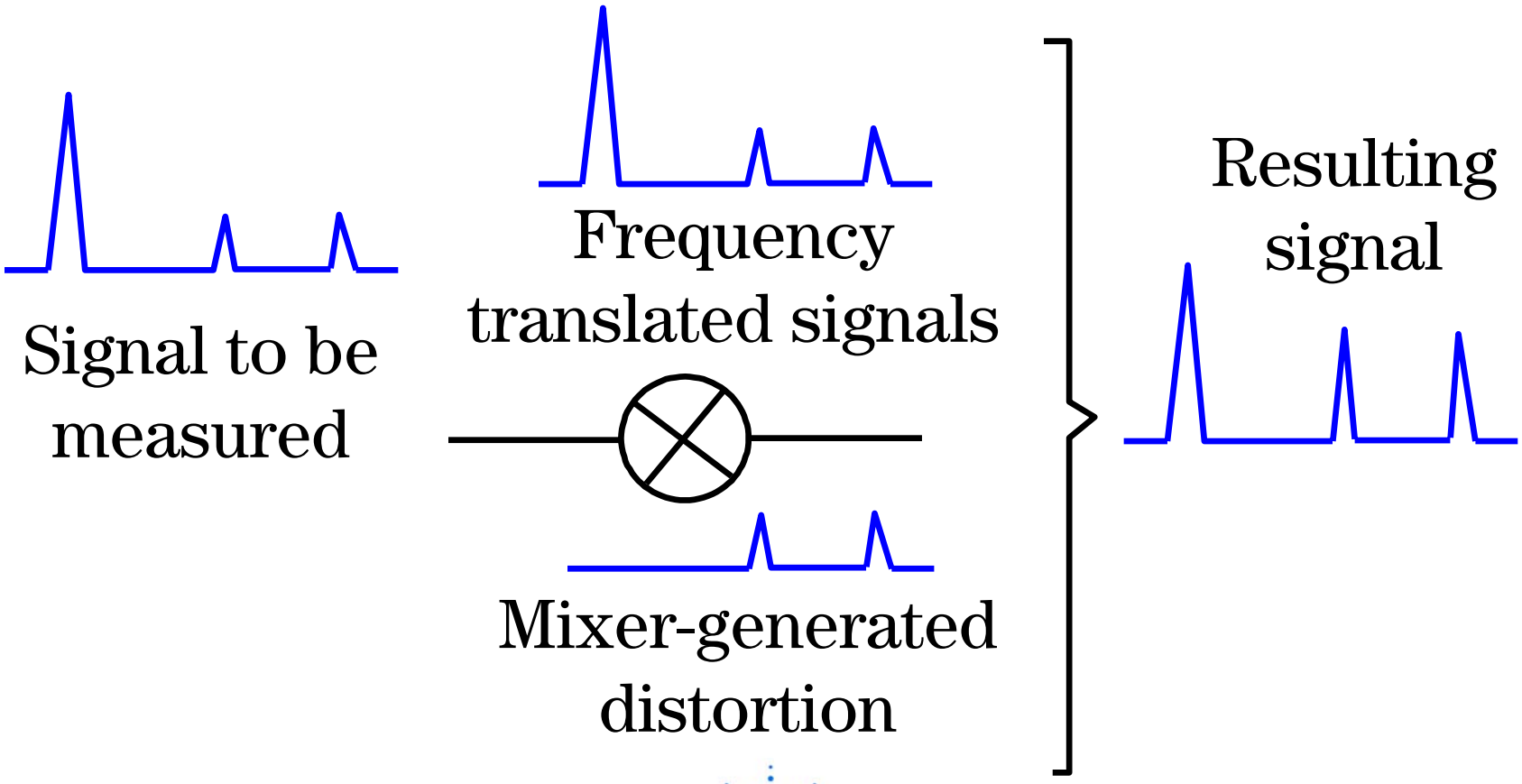
Rules to Analyze By:

Getting the Best Sensitivity Requires Three Settings

- Narrowest resolution bandwidth
- Minimum RF attenuation
- Sufficient video filter to smooth noise (VBW < 0.01 Resolution BW)

Where is Distortion Generated?

Mixers Generate Distortion



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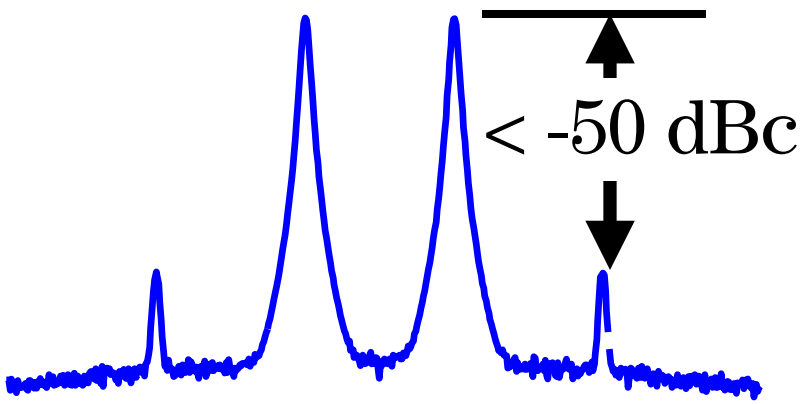
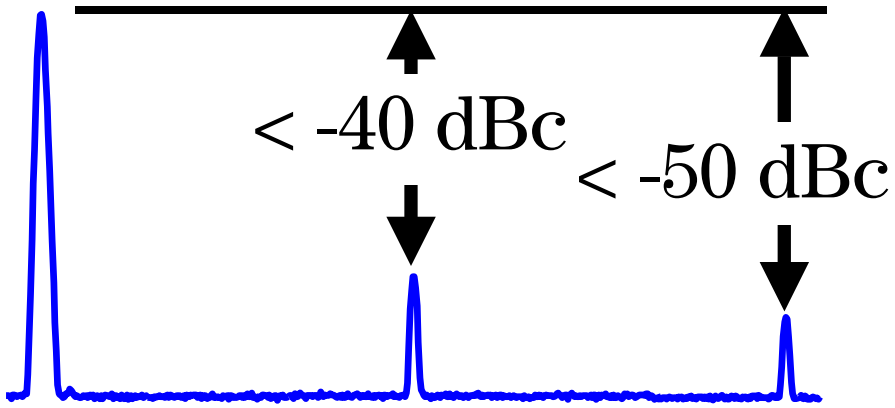
Most Influential Distortion is the Second and Third Order

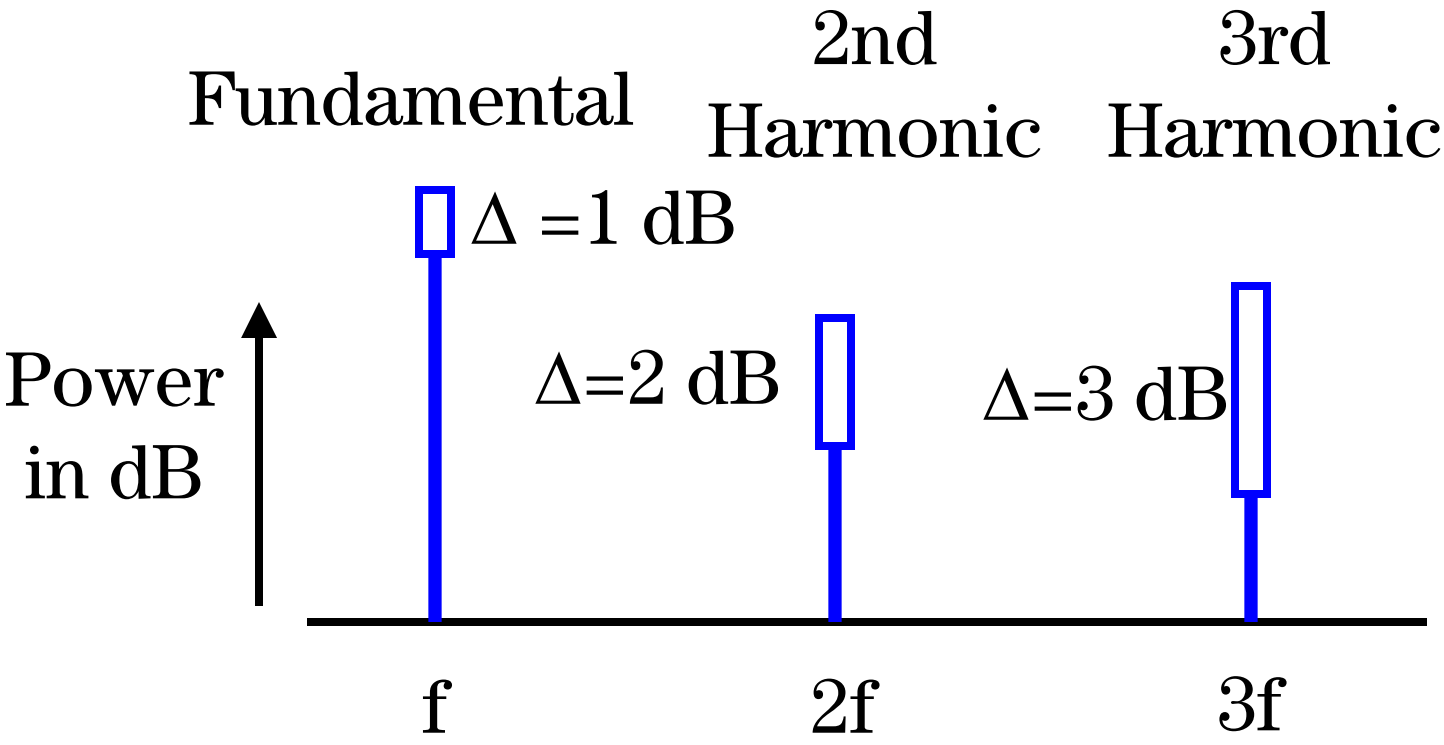


Two-Toned Intermod



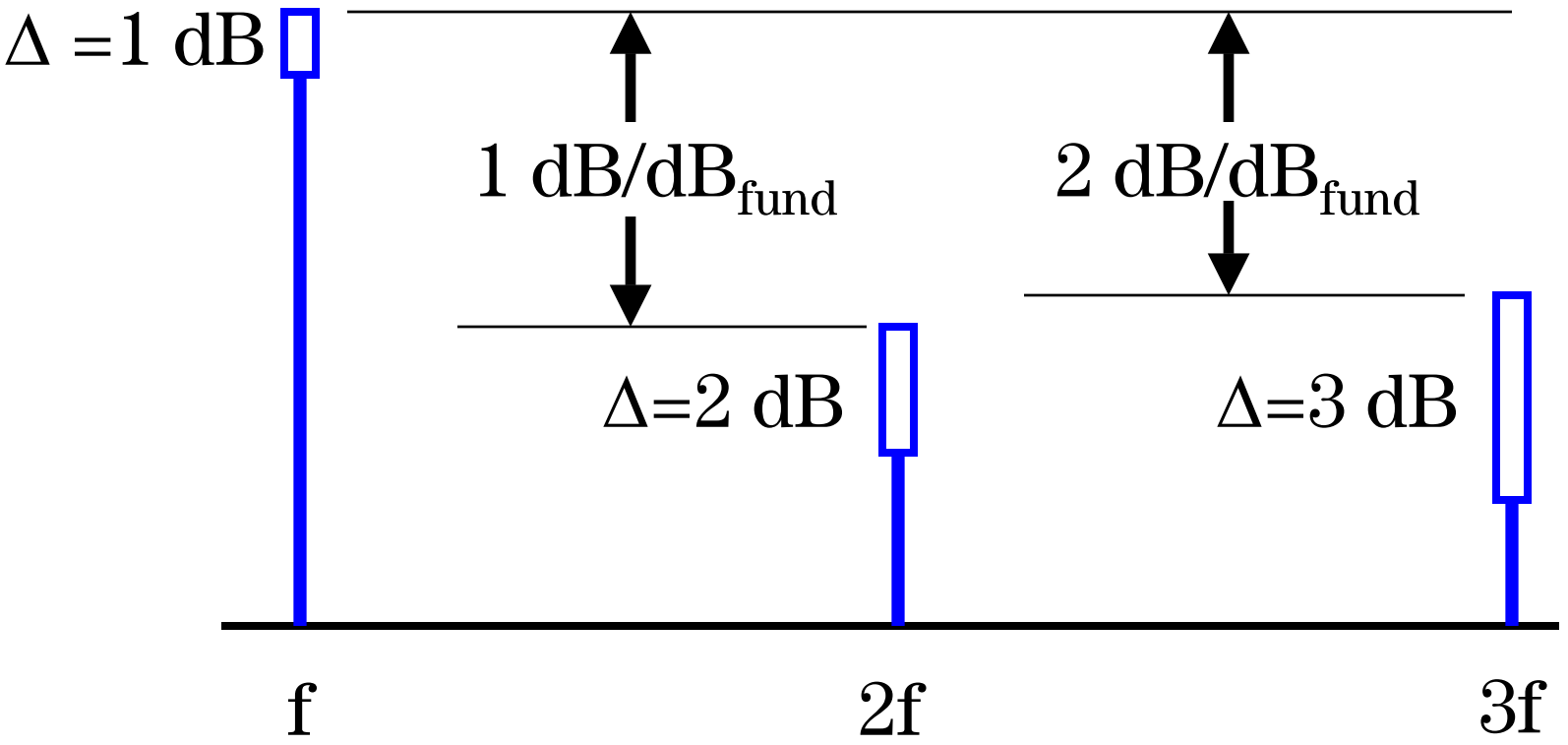
Harmonic Distortion

Distortion Increases as a Function of the Fundamental's Power



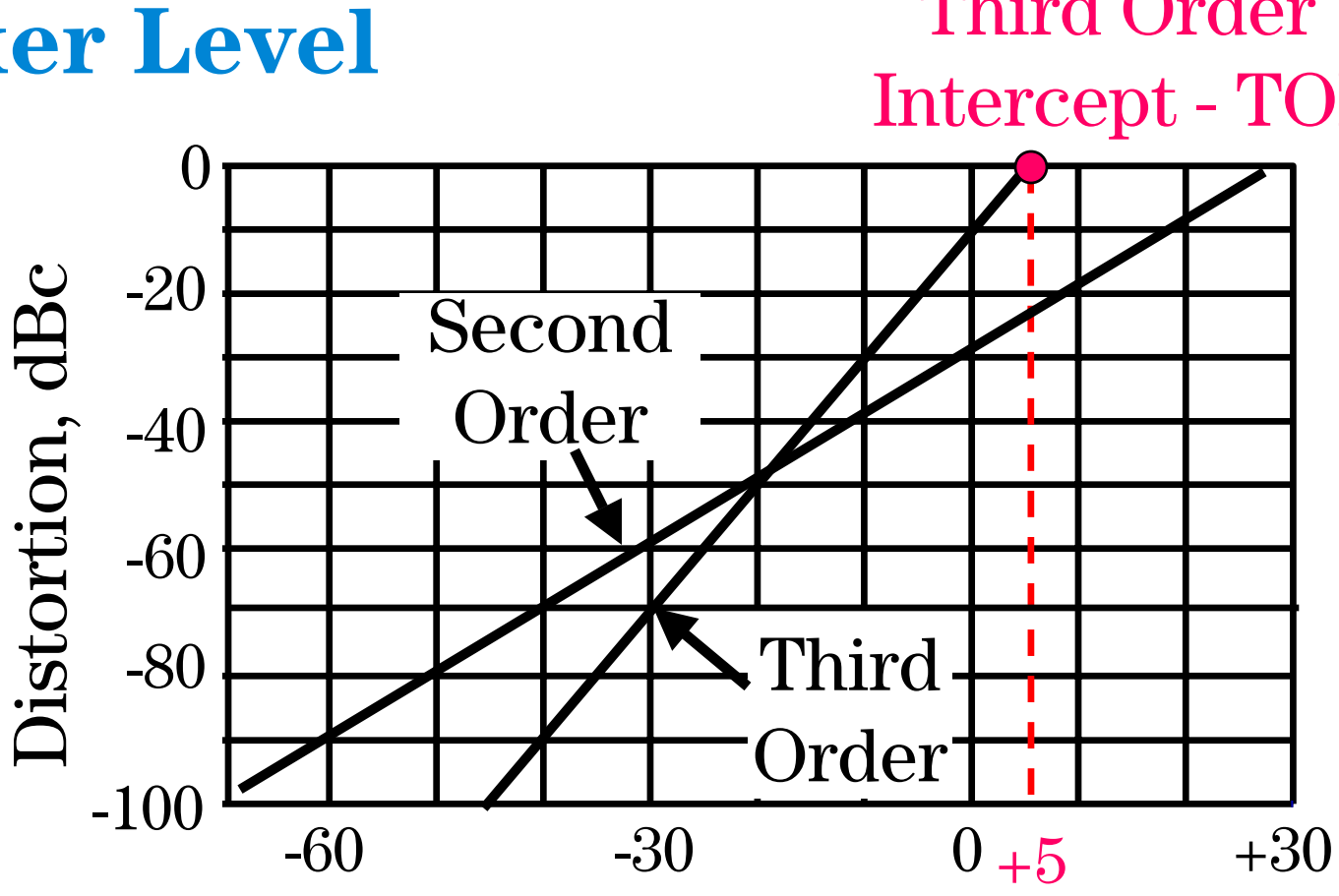
For every dB fundamental level change,
the 2nd changes 2 dB and the 3rd changes 3 dB.

How Distortion Amplitudes Change



Since distortion changes relative to the fundamental, a graphical solution is practical.

Plotting Distortion as a Function of Mixer Level



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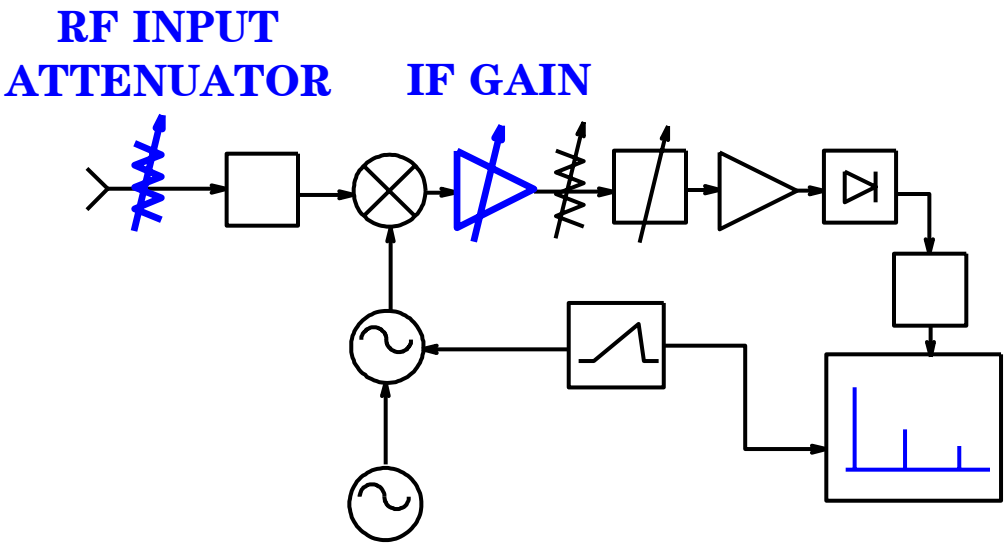
Rules to Analyze by:
A Simple Distortion Test

Is the distortion from the signal or from the analyzer?

1. Change Input Attenuation by 10 dB

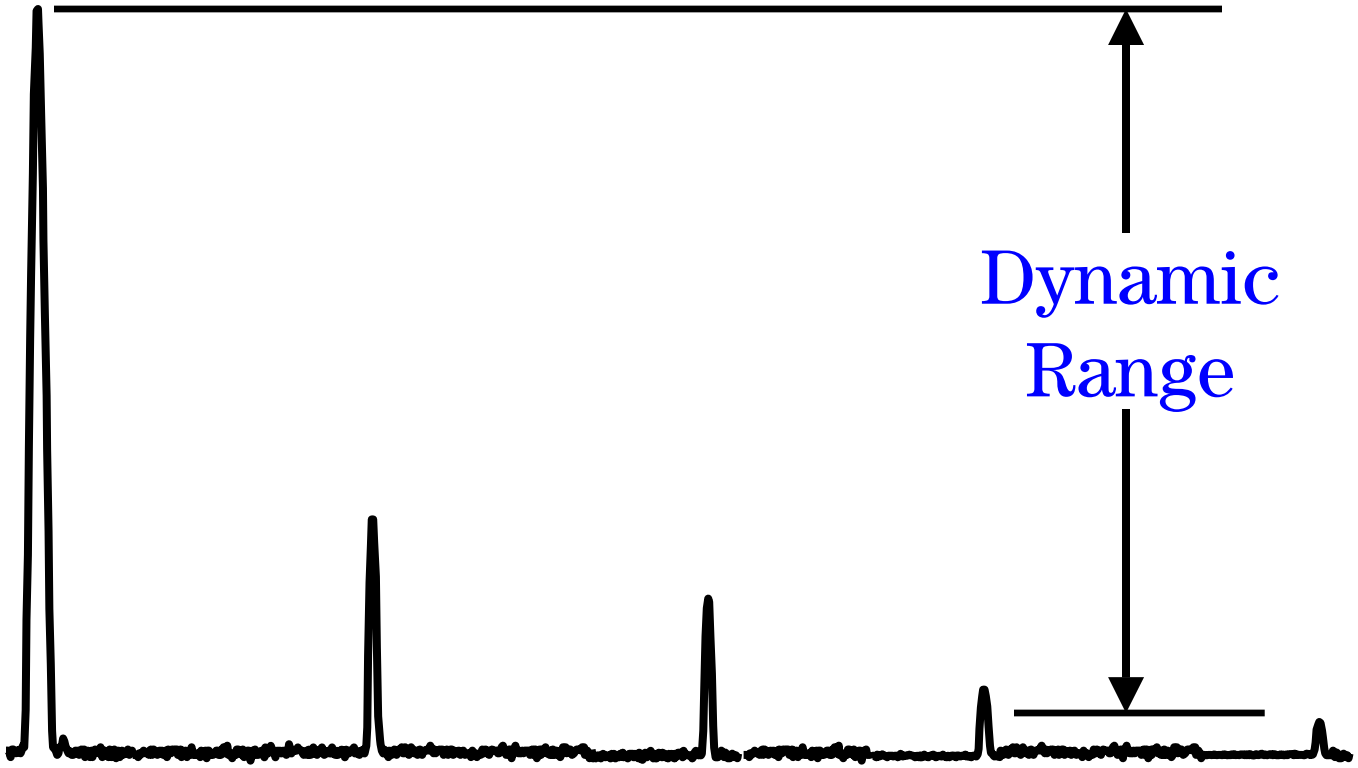
2. Watch Signal on Screen:



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)

Dynamic Range - Optimum Amplitude Difference Between Large and Small Signals



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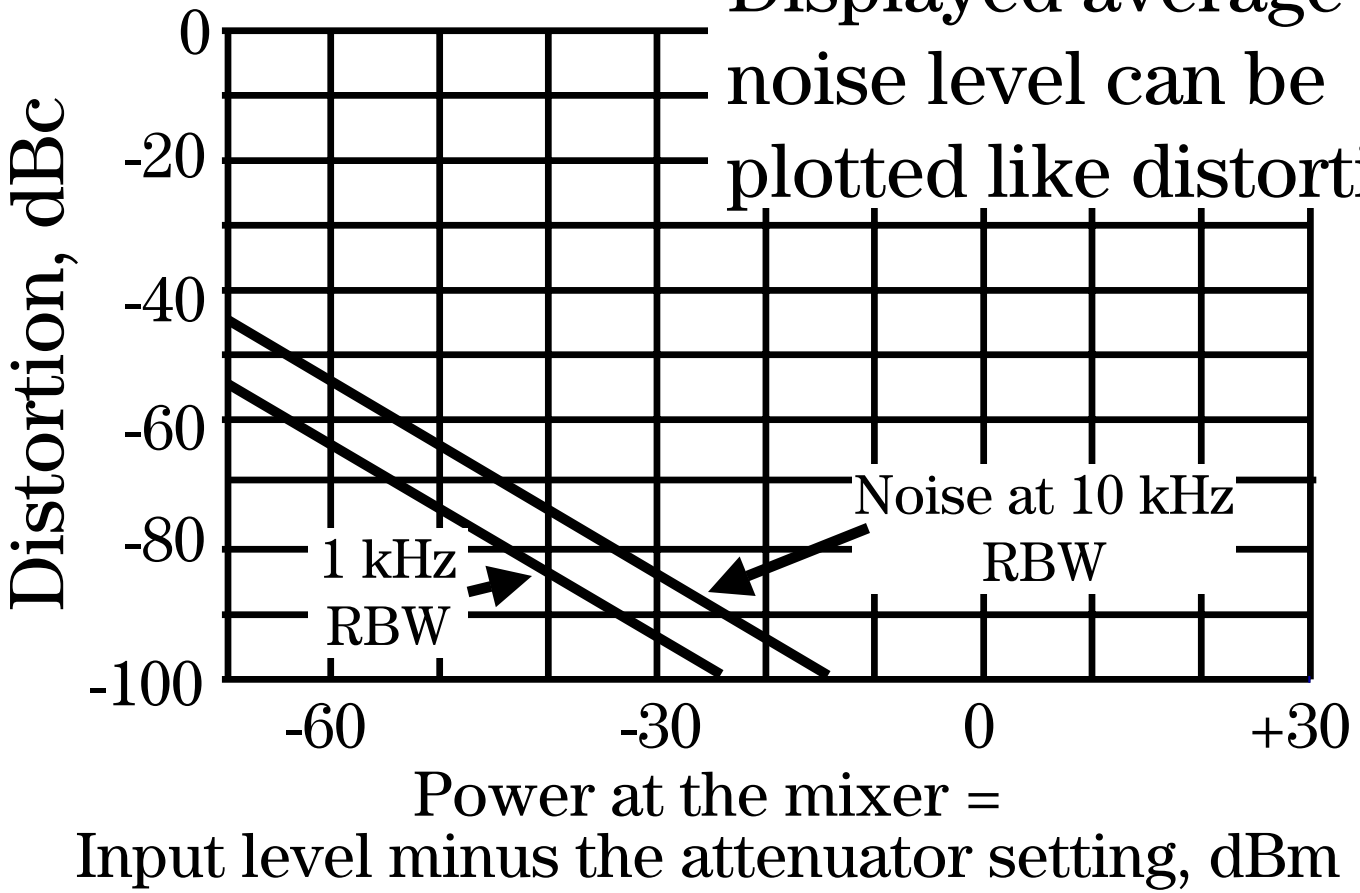
Displayed Noise Limits Dynamic Range

Displayed average noise level can be plotted like distortion.



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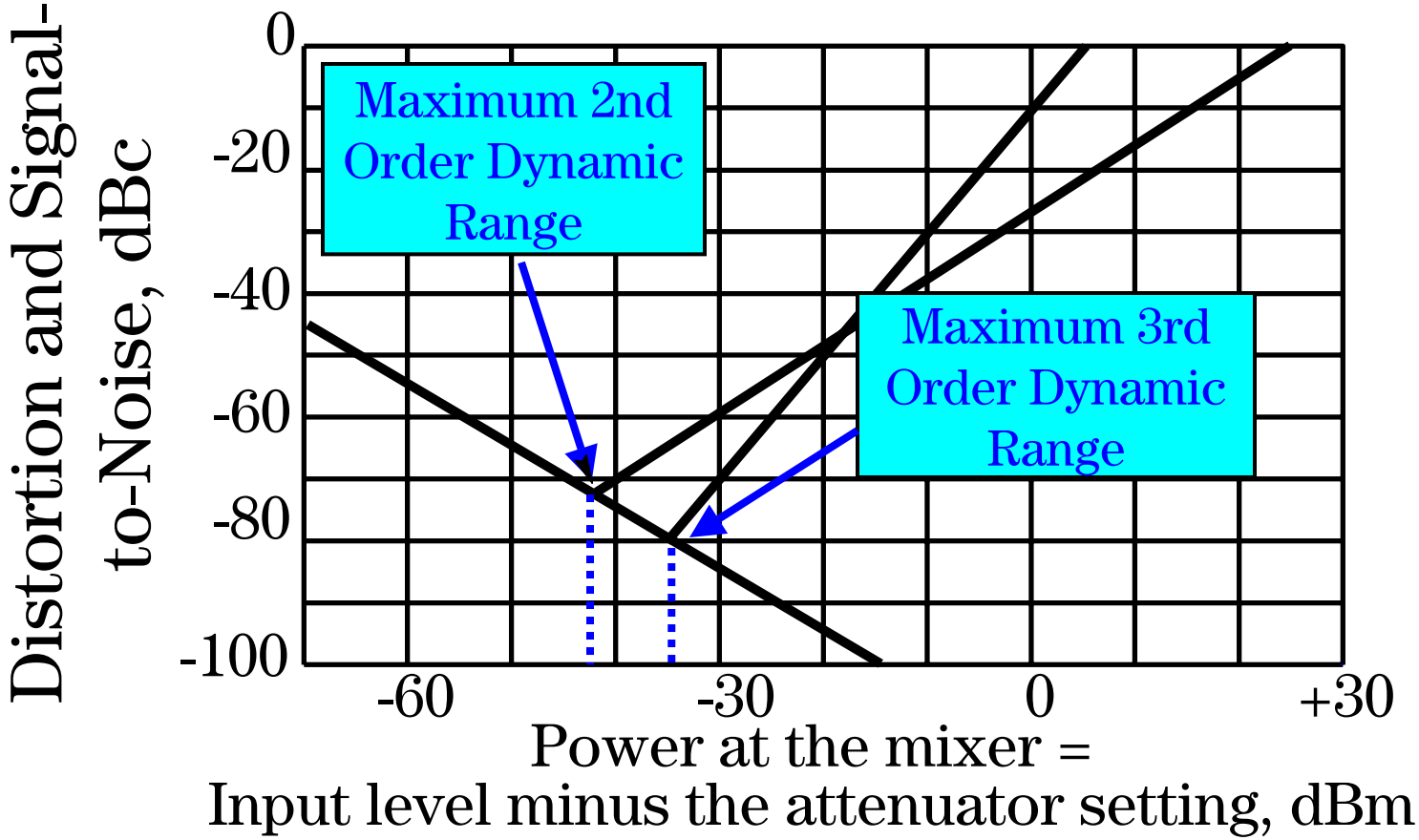
Dynamic Range as a Function of Distortion and Noise Level



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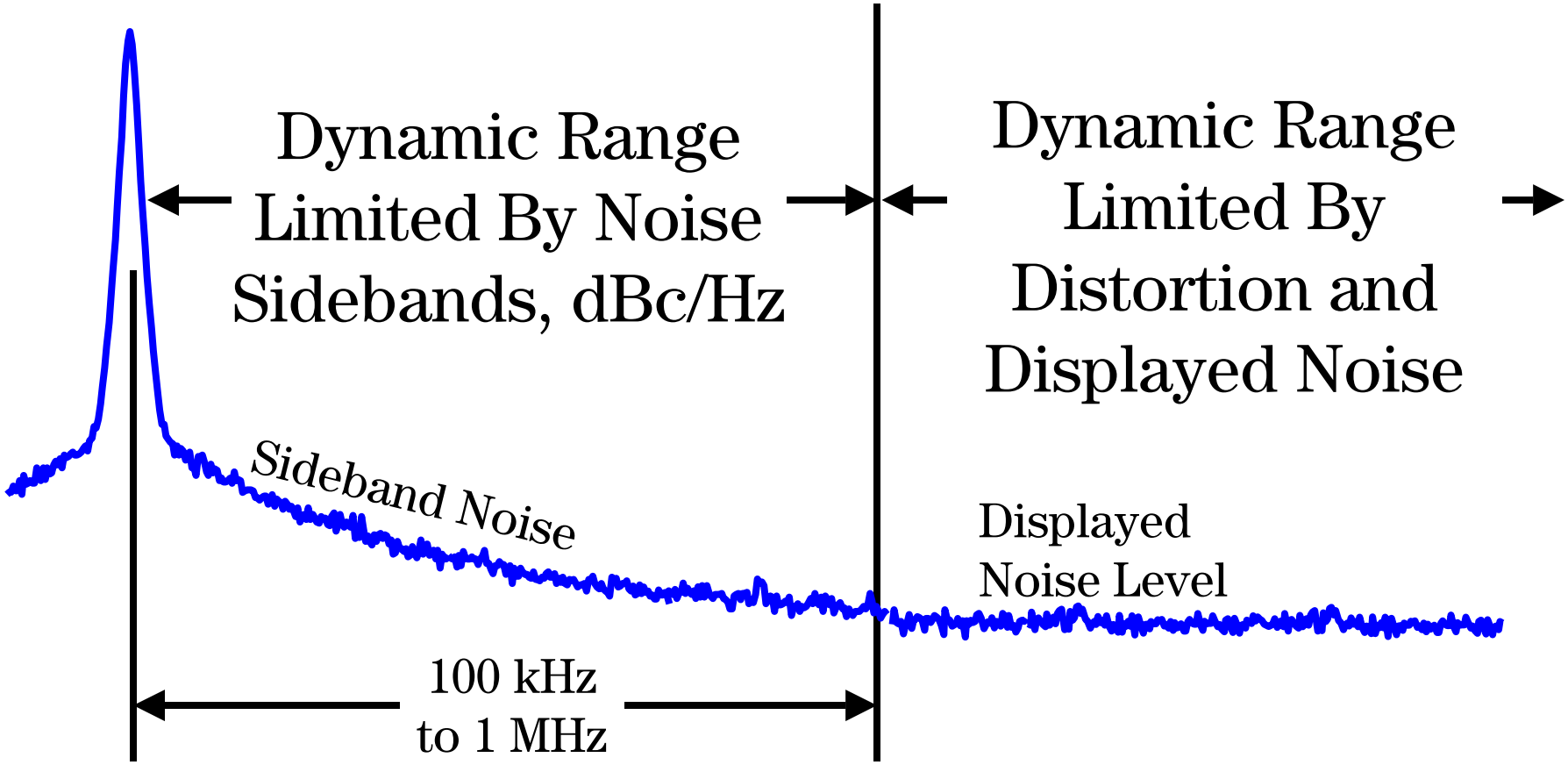
Close-in Dynamic Range Limited by Noise Sidebands



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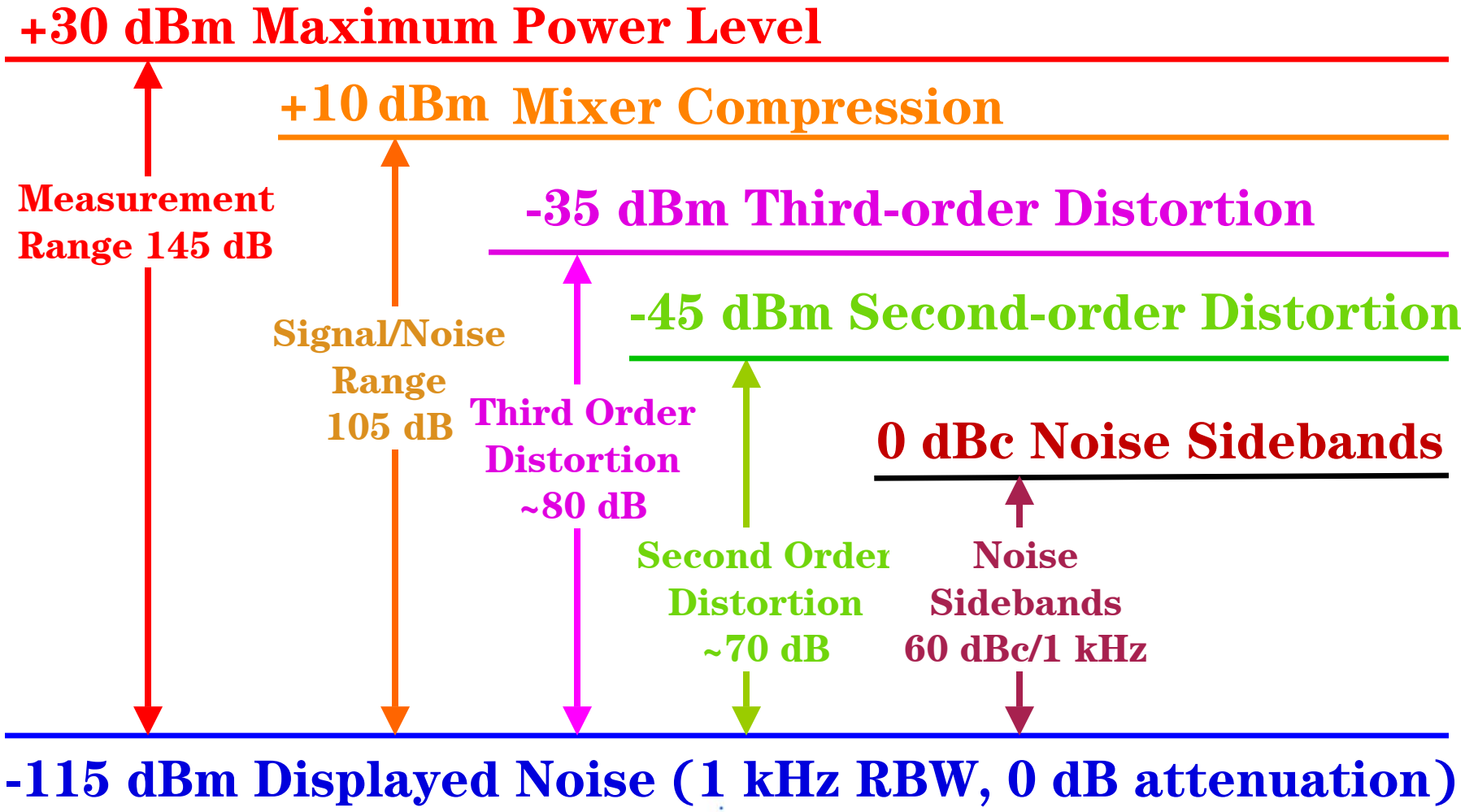
Rules to Analyze by:

Determining Dynamic Range

Your spectrum analyzer's dynamic range is dependent upon:

- Internal second and/or third order distortion
- Displayed noise level
- Noise sidebands when close to large signals

Dynamic Range is Defined by Your Application



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Summary

- The RF spectrum analyzer is a heterodyne receiver
- Offers a narrow resolution capability over a wide frequency range
- Measures small signals in presence of large signals
- Remember to:
  - —Adjust the measurement procedure for specific application
  - —Test for internal distortion
  - —Take sideband noise into account

Agilent Spectrum Analyzer Product Families - Swept Tuned

PSA Series

- Highest performance SA!
- 3 Hz to 50 GHz
- Pre-selection to 50 GHz
- Worlds best accuracy (**0.24dB**)
- 160 RBW settings
- Phase noise optimization
- FFT or swept at any RBW
- Complete set of detectors
- Fastest spur search
- Vector signal analysis.

ESA-E Series

- Mid-Performance
- 30 Hz to 26.5 / 325 GHz
- Rugged/Portable
- Fast & Accurate
- Unparalled range of performance and application options.
- Remote WEB interface

856X- EC Series

- Super Mid-Performance
- 30 Hz to 50 / 325 GHz
- Rugged/Portable
- Pre-selection to 50 GHz
- Color LCD Display
- Low Phase Noise
- Digital 1 Hz RBW

ESA-L Series

- Low cost
- 9 kHz up to 26.5 GHz
- General Purpose
- Rugged/Portable
- Fully synthesized

Agilent Vector Signal Analyzer Product Families

E4406A

- Multi-Format wireless capabilities
- 7 MHz - 4 GHz
- Fast & Accurate
- Simple User Interface
- Base-band IQ inputs

89400 Series

- Flexible Signal Analysis
- DC to 2.65 GHz
- 10 MHz Signal Bandwidth
- Block Digital demodulation
- Integral Signal Source
- Spectrum & Time waveform Analysis
- Complex time varying signals
- Color LCD Display

89600 Series

- Multi-Format & Flexible vector signal analysis
- DC – 6.0 GHz
- Bandwidth: 36 MHz RF, 40 MHz Baseband
- RF and modulation quality of digital communications signals including WLAN.
- Spectrum & Time (FFT) Analysis
- OFDM Analysis (802.11a)
- Links to design software (ADS)
- PC Based for the Ultimate in Connectivity
- Analysis software links to PSA, ESA, E4406A signal analyzers.

89600 Ultra-wide bandwidth

- 500+ MHz Signal Bandwidth!
- 89600 Analysis Capability
- Low Cost Oscilloscope Front-end for "RF Scope" measurements

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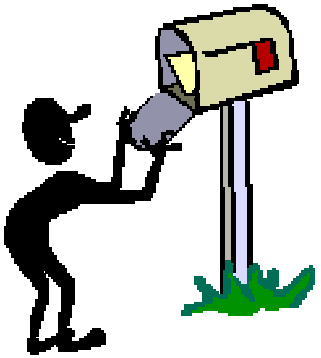

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