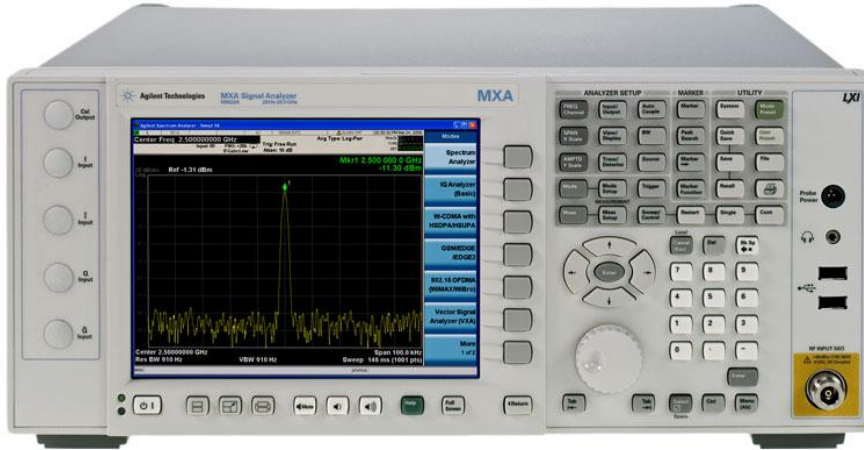


Spectrum Analyzer Basics



Adolfo Del Solar

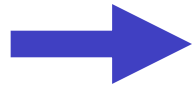
Application Engineer

adolfo_del-solar@agilent.com



Agilent Technologies

Agenda



- Overview

What is spectrum analysis?

- Theory of Operation

Simplified block diagram

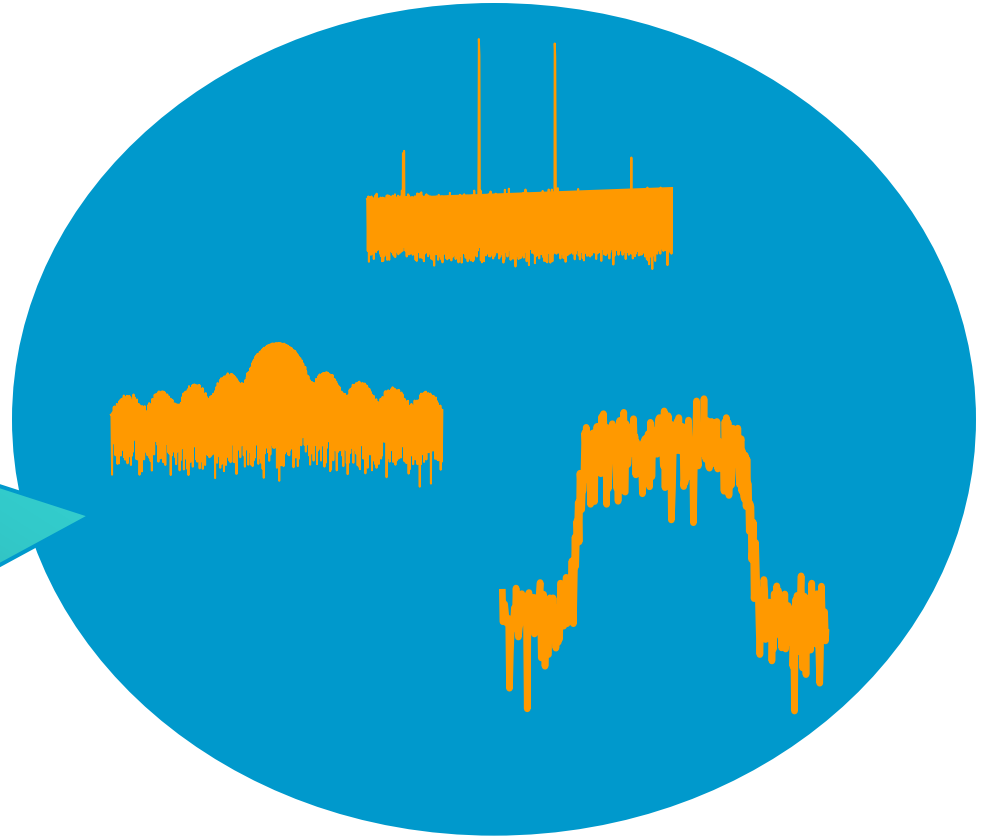
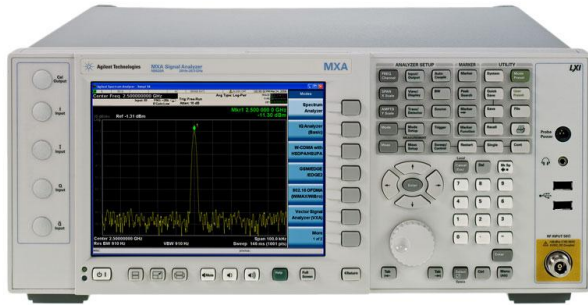
- Specifications

Which are important and why?



Overview

What is Spectrum Analysis?



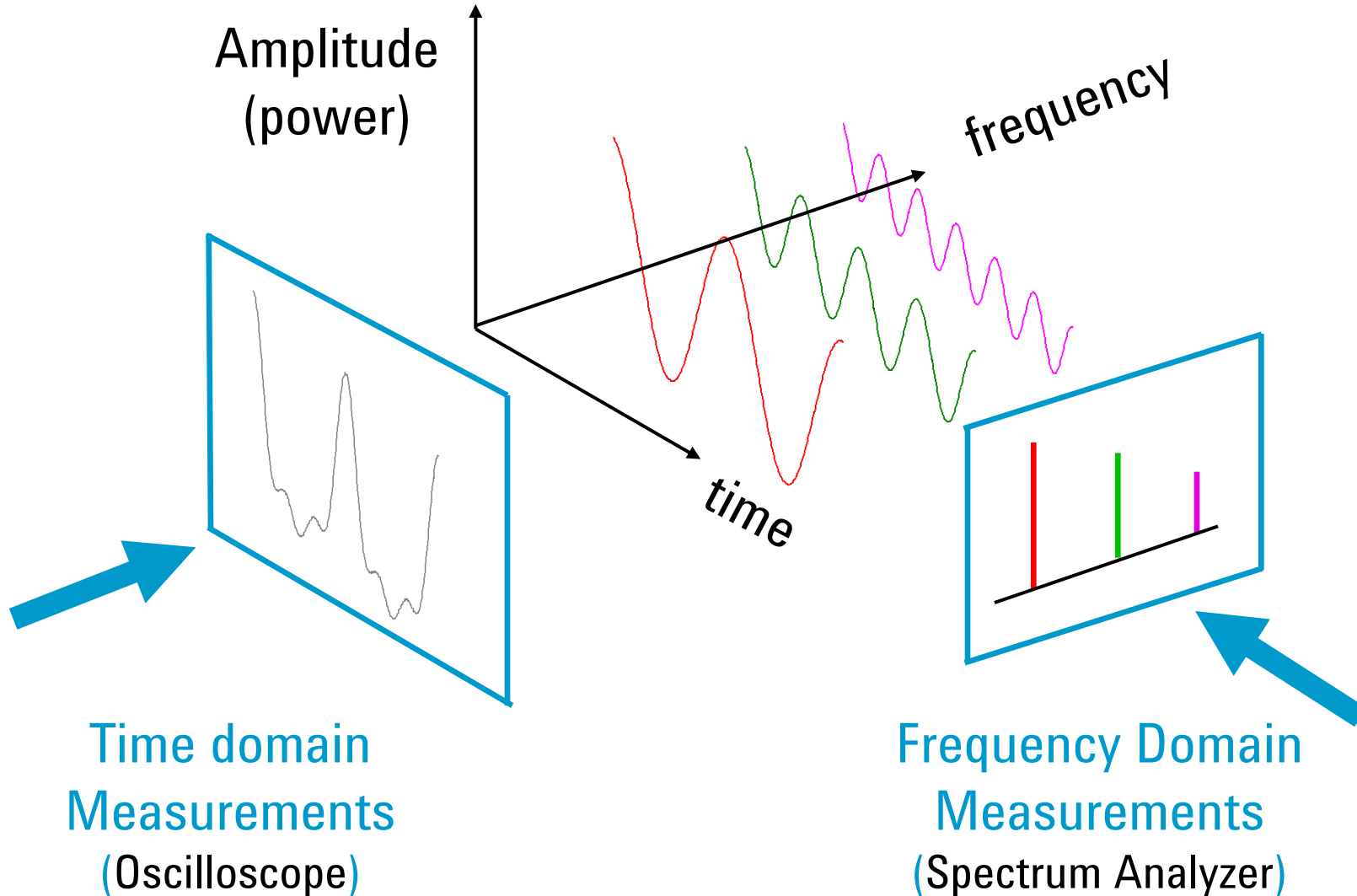
Spectrum Analysis

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



Overview

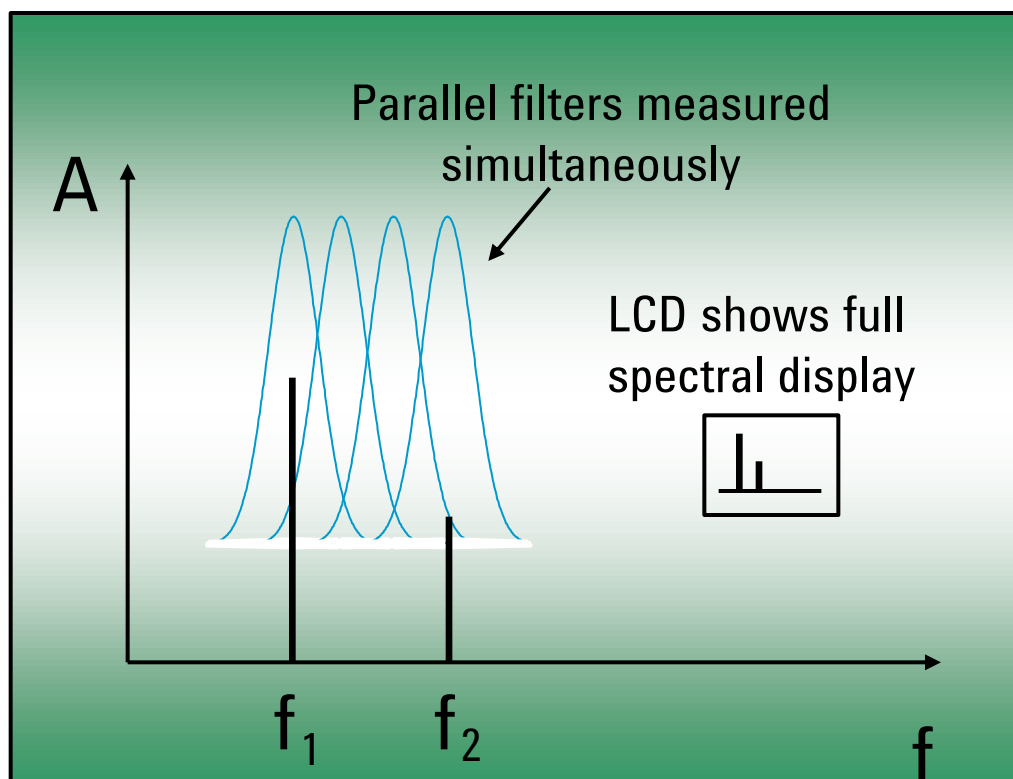
Frequency versus Time Domain



Overview

Different Types of Analyzers

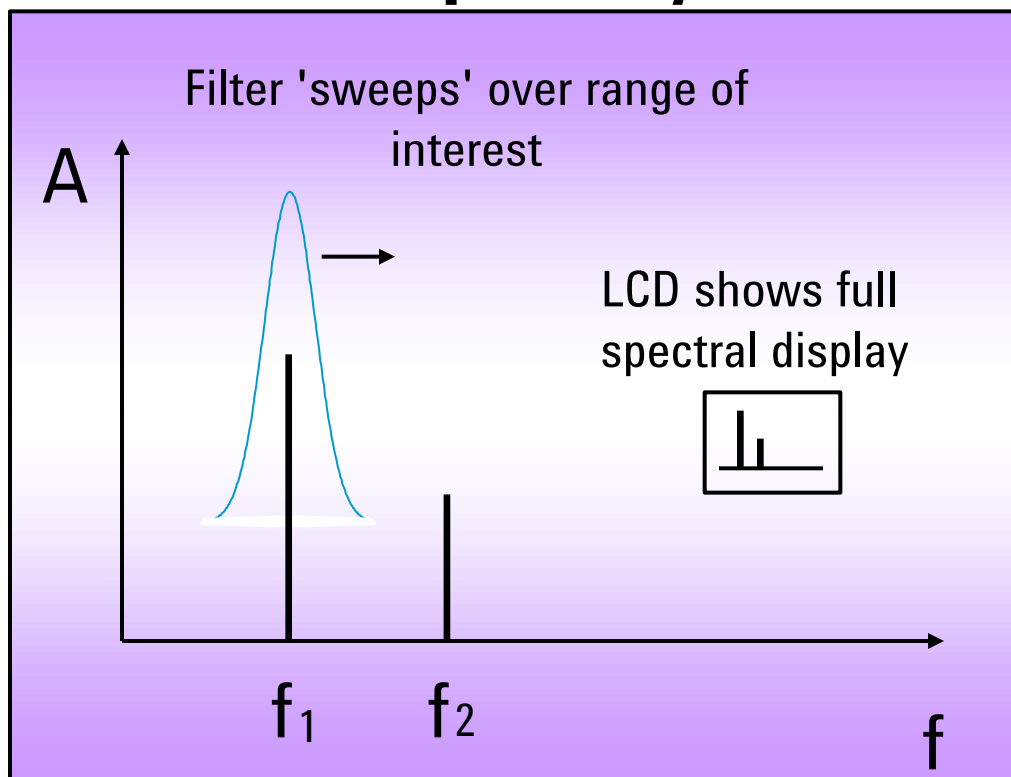
FFT Analyzer



Overview

Different Types of Analyzers

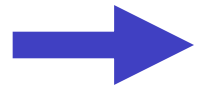
Swept Analyzer



Agenda

- Overview

What is spectrum analysis?



- Theory of Operation

Simplified block diagram

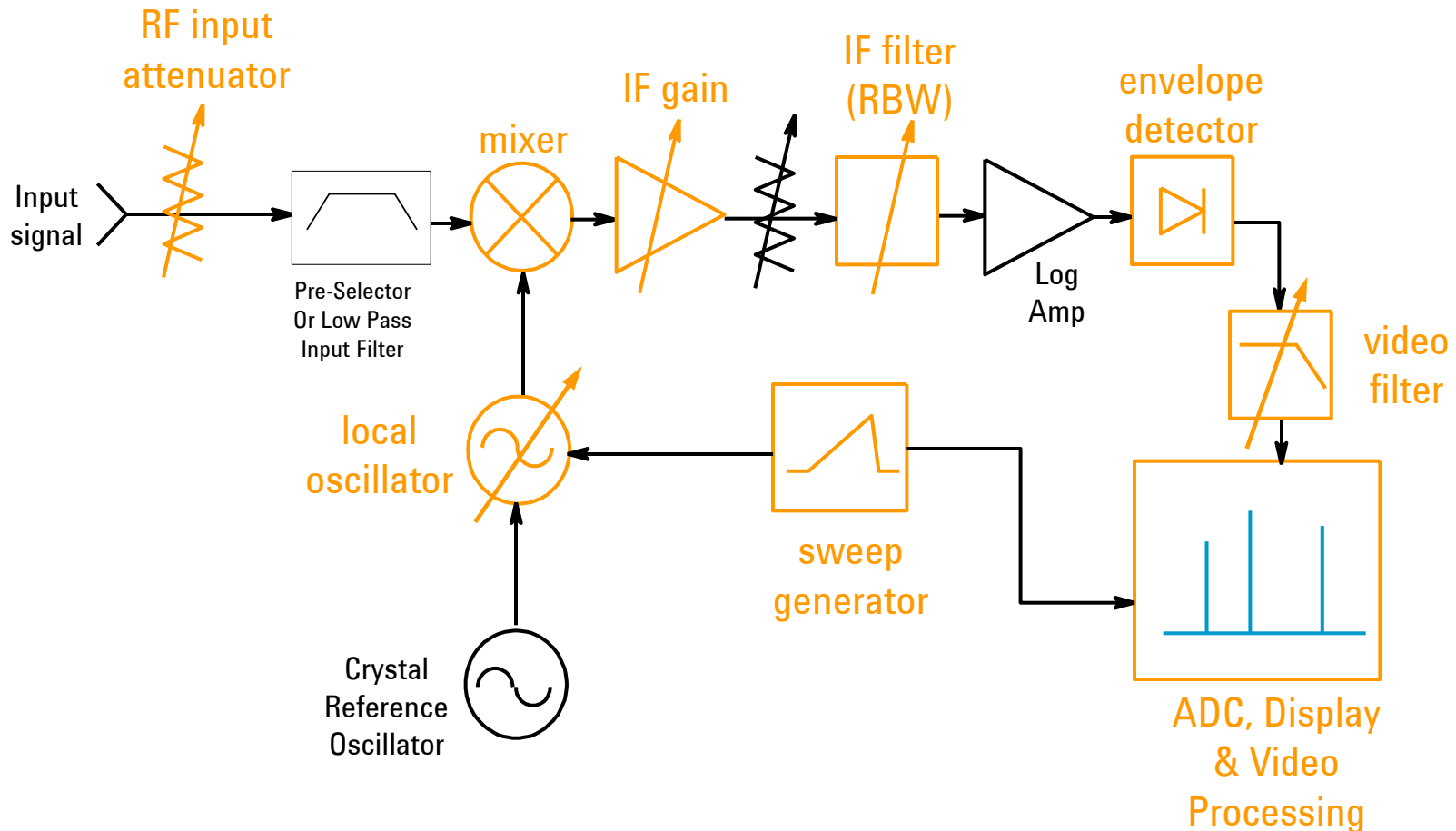
- Specifications

Which are important and why?



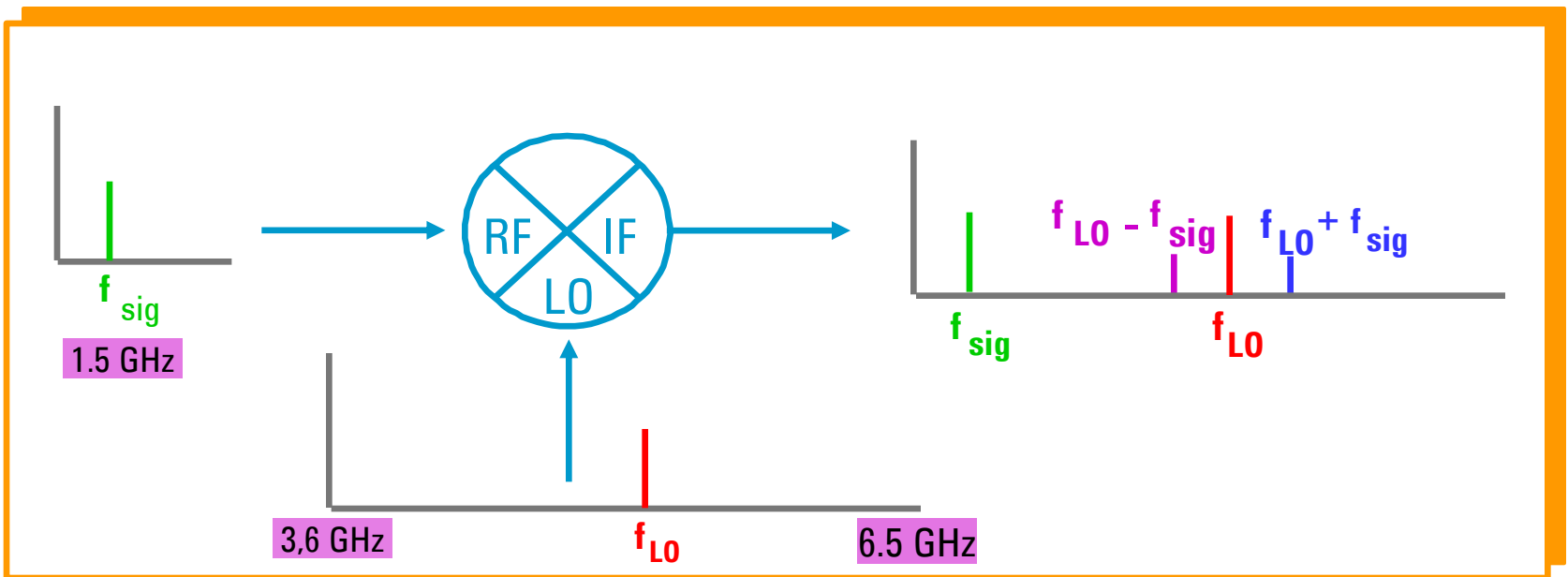
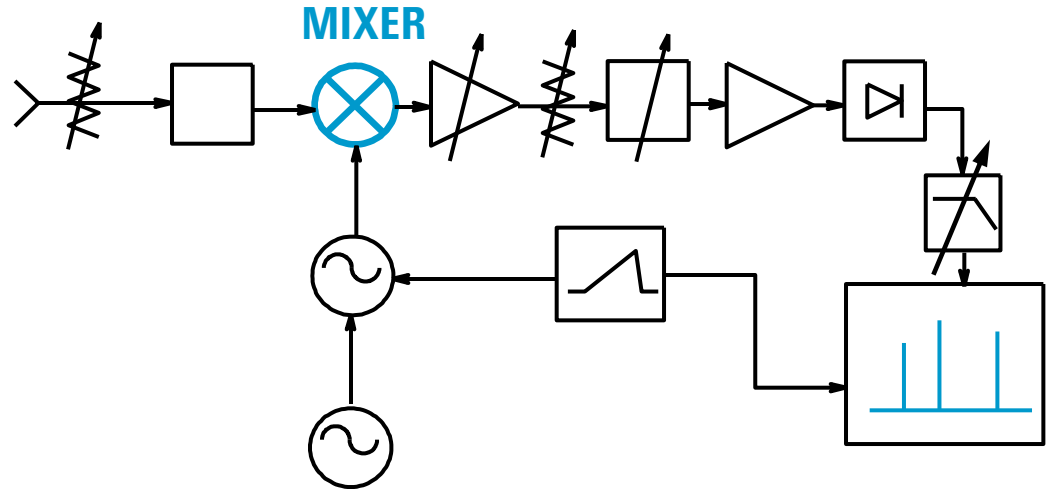
Theory of Operation

Swept Spectrum Analyzer Block Diagram



Theory of Operation

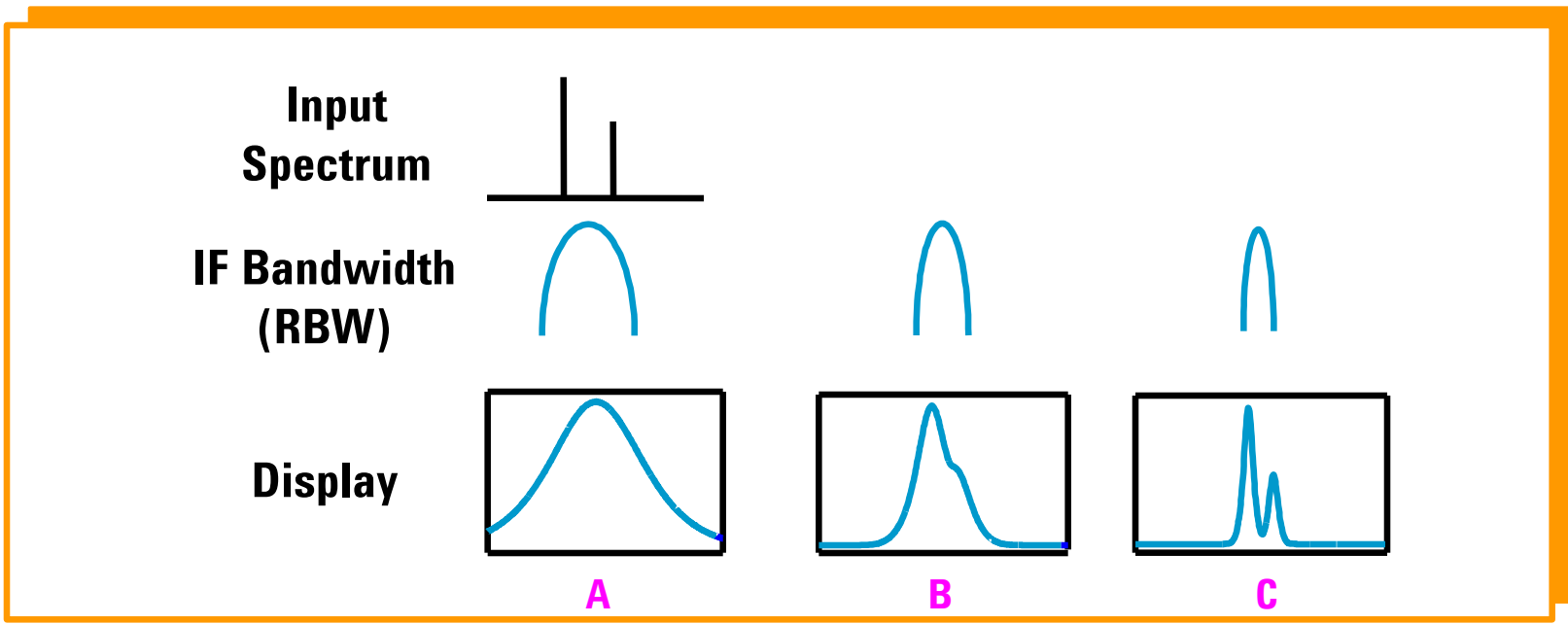
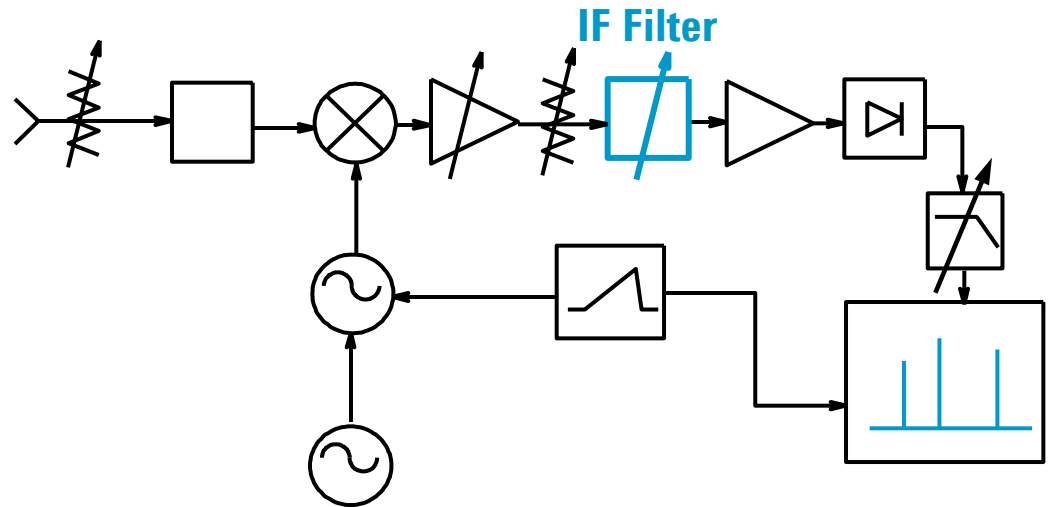
Mixer



Theory of Operation

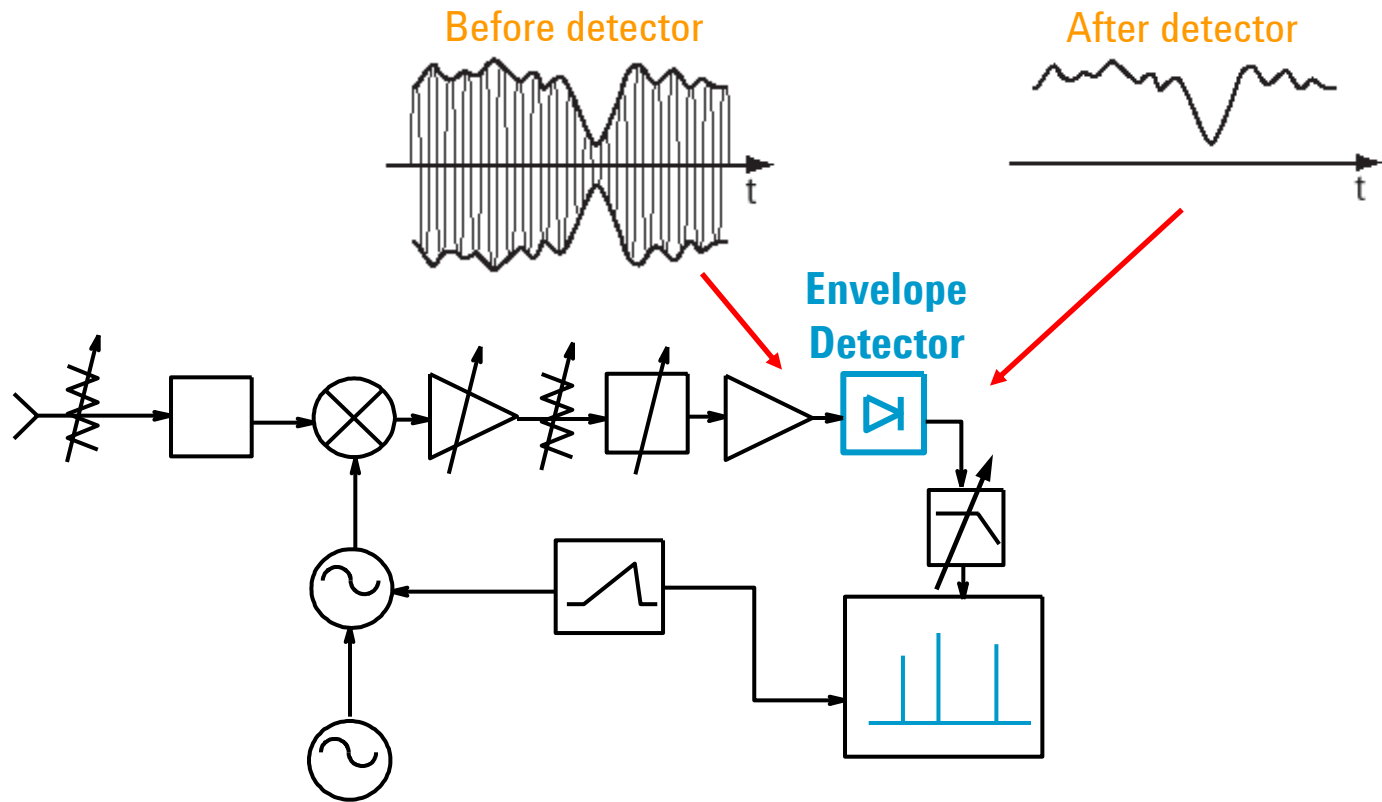
IF Filter

(Resolution Bandwidth – RBW)



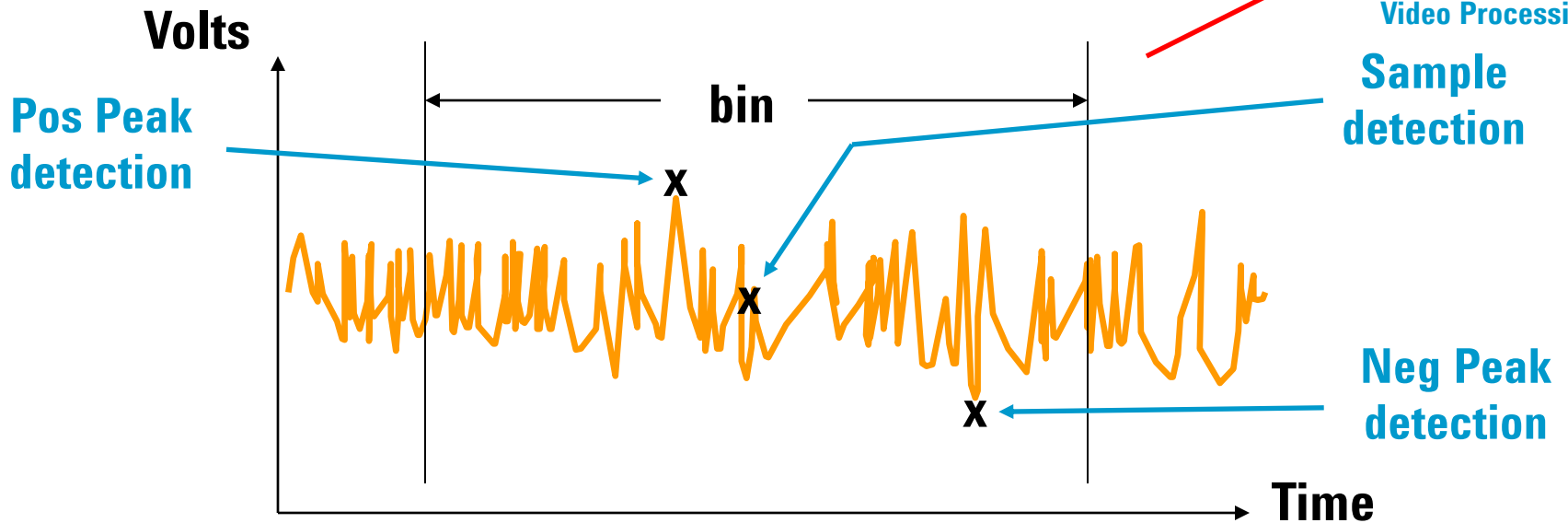
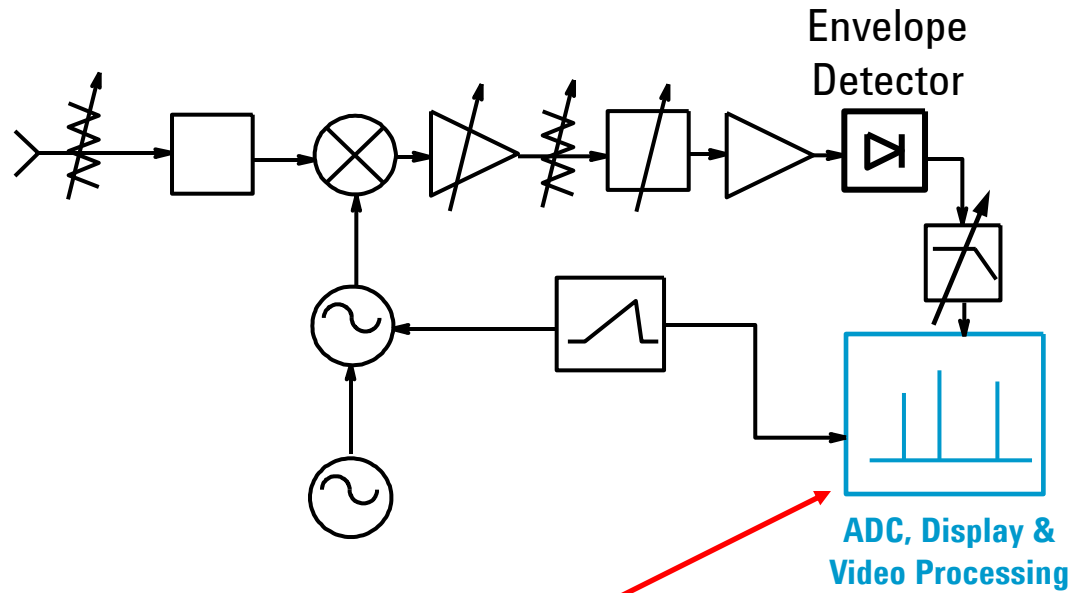
Theory of Operation

Envelope Detector



Theory of Operation

Average Detector Type

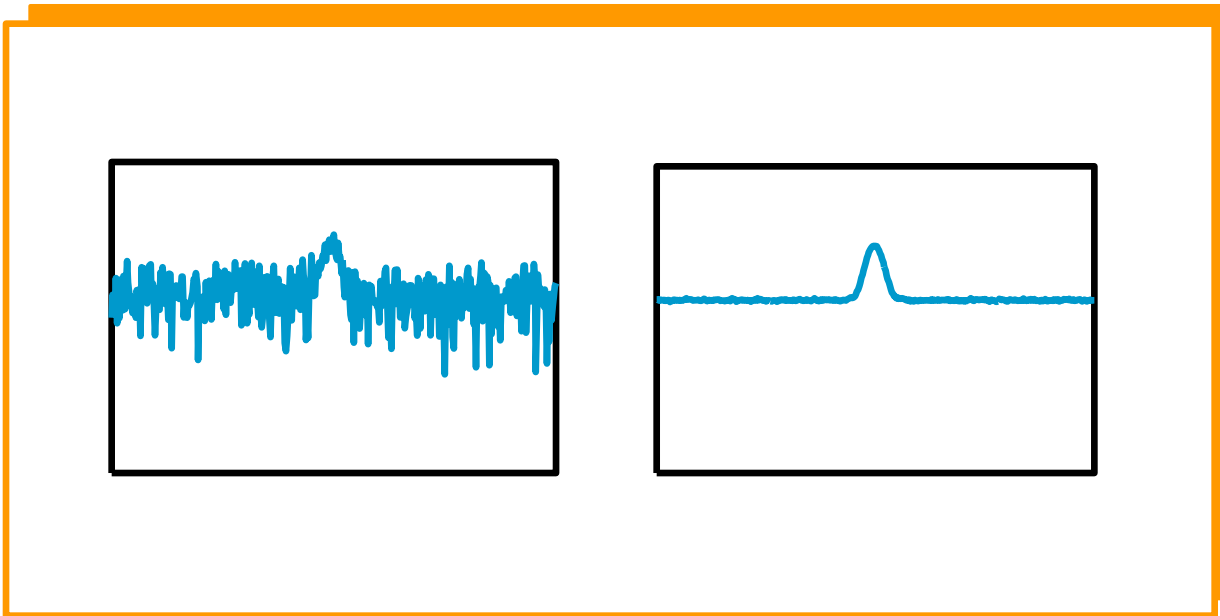
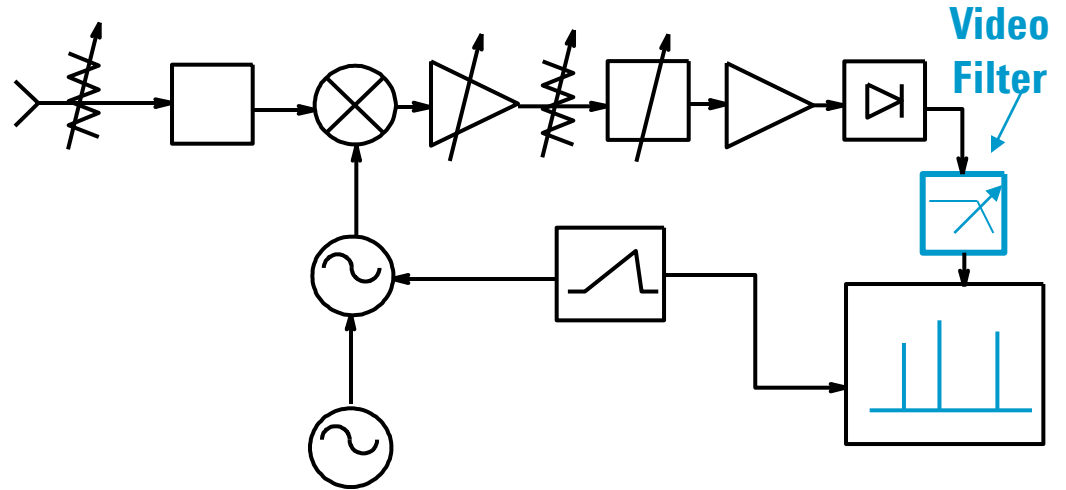


Power Average Detection (rms) = Square root of the sum of the squares of ALL of the voltage data values in the bin / 50Ω



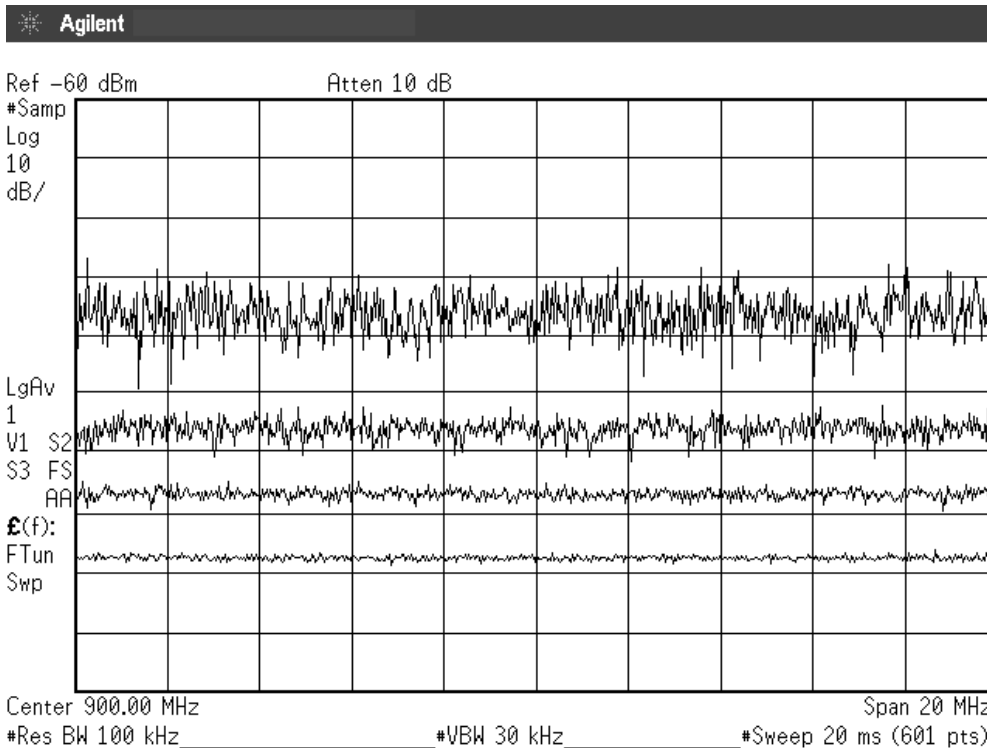
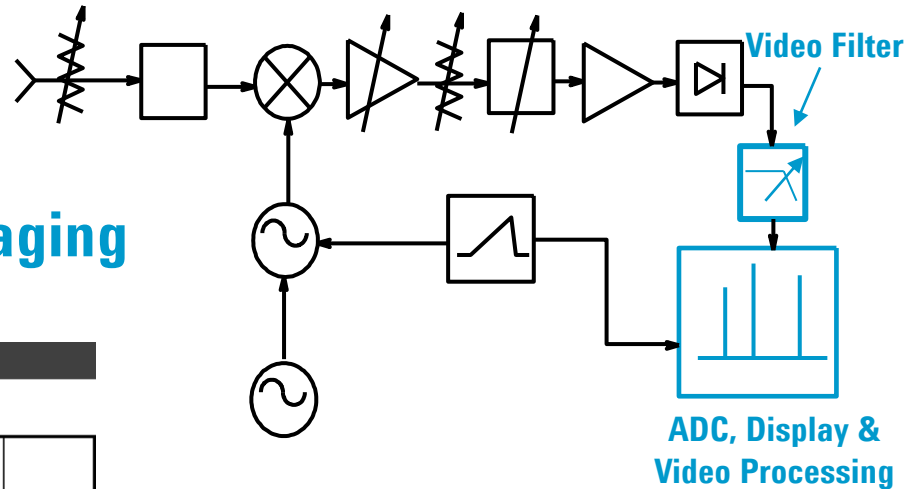
Theory of Operation

Video Filter
(Video Bandwidth – VBW)



Theory of Operation

Video Filter vs. Trace/Video averaging



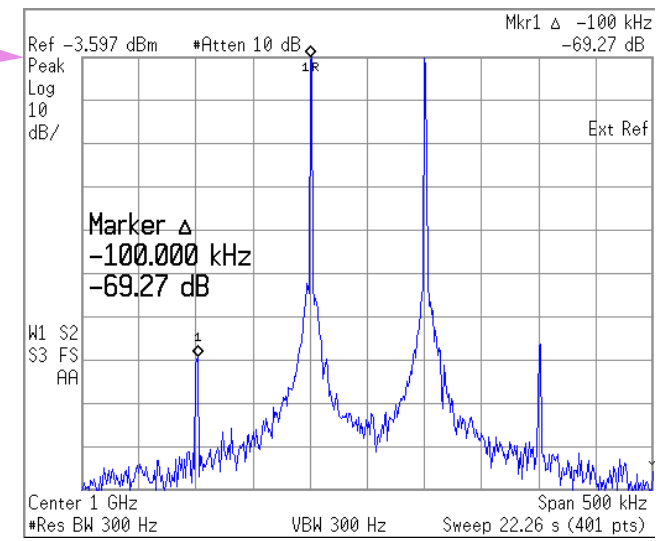
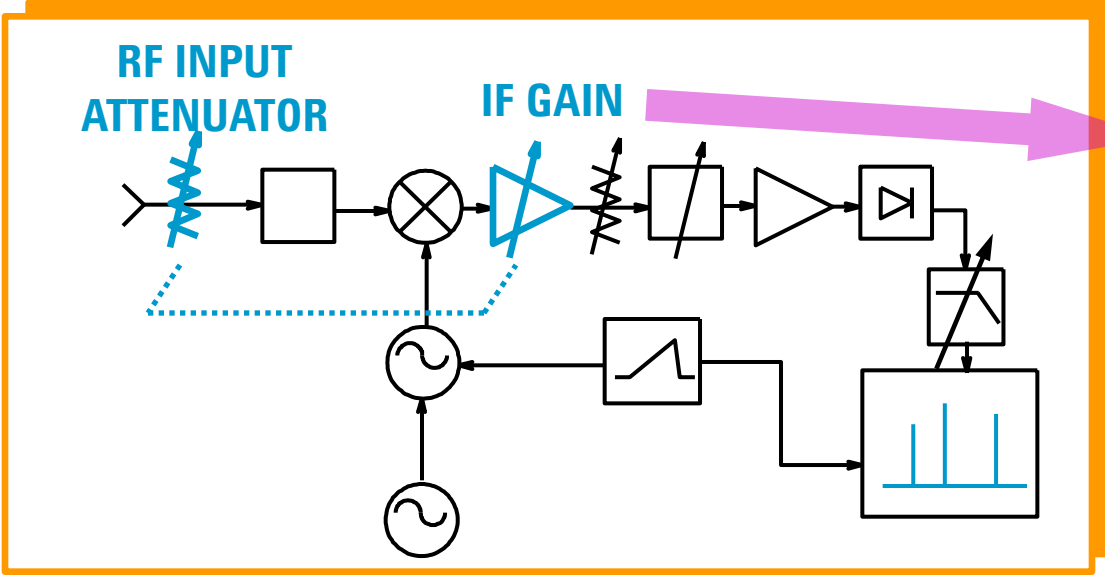
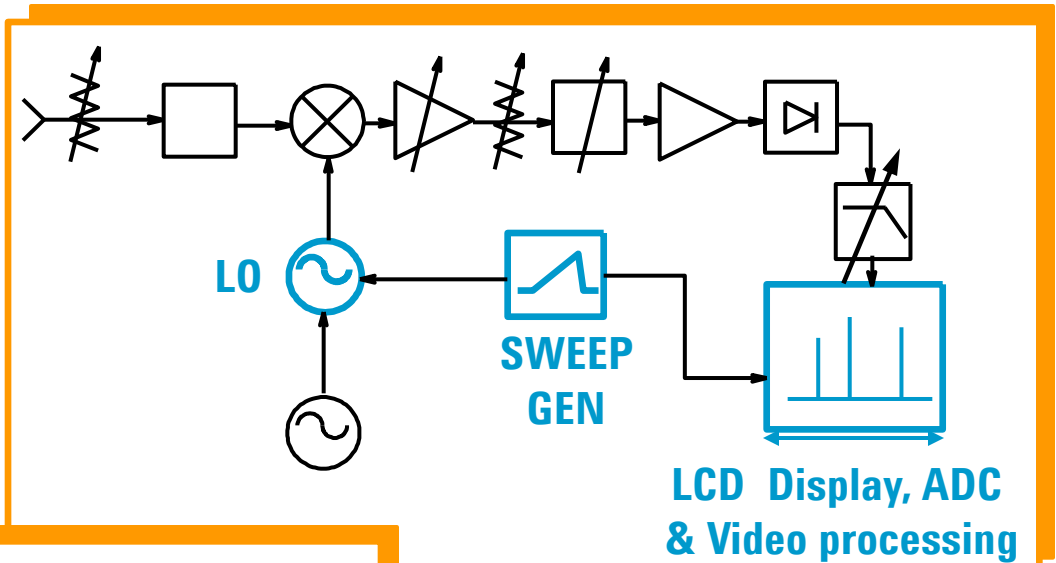
Trace averaging for 1, 5, 20, and 100 sweeps, top to bottom (trace position offset for each set of sweeps)

- 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



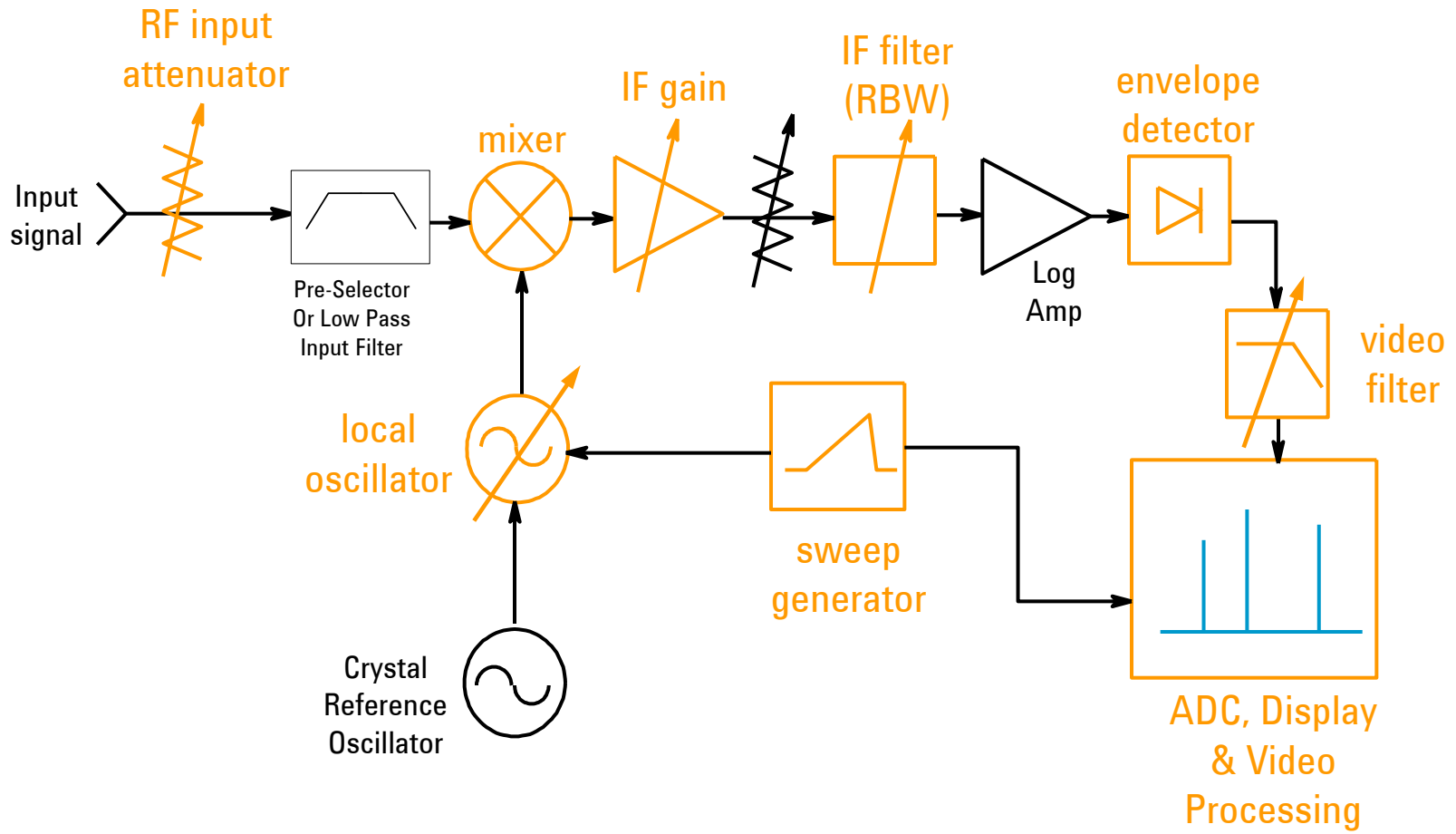
Theory of Operation

Other Components



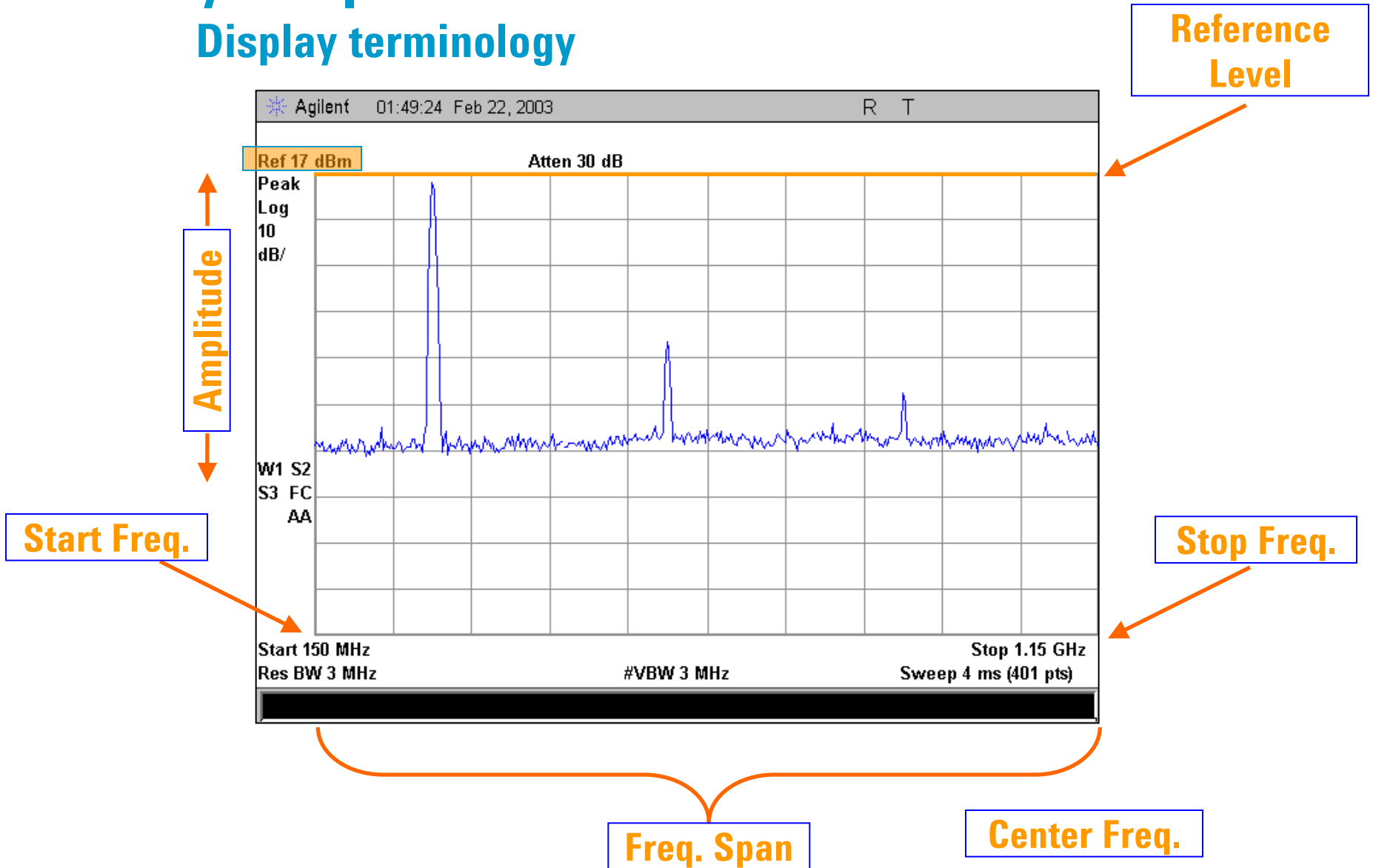
Theory of Operation

How it All Works Together

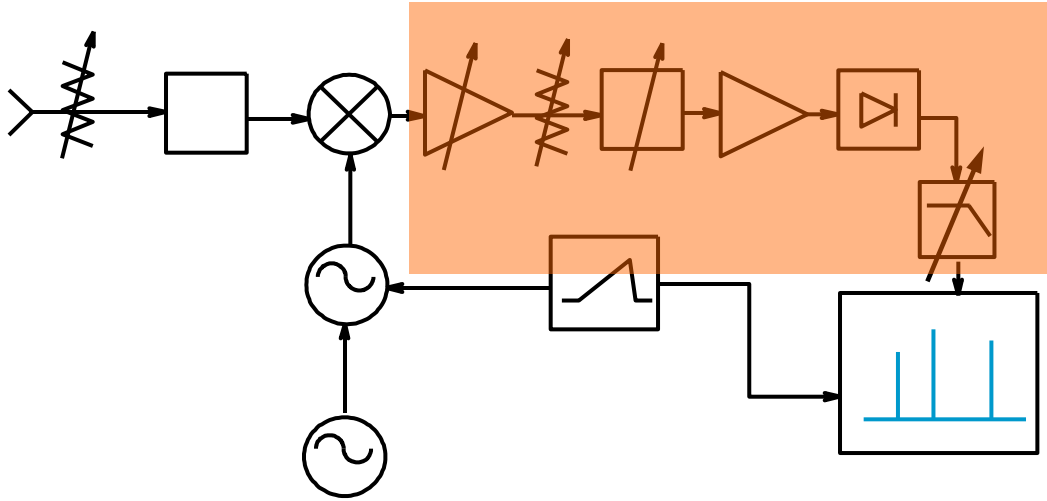
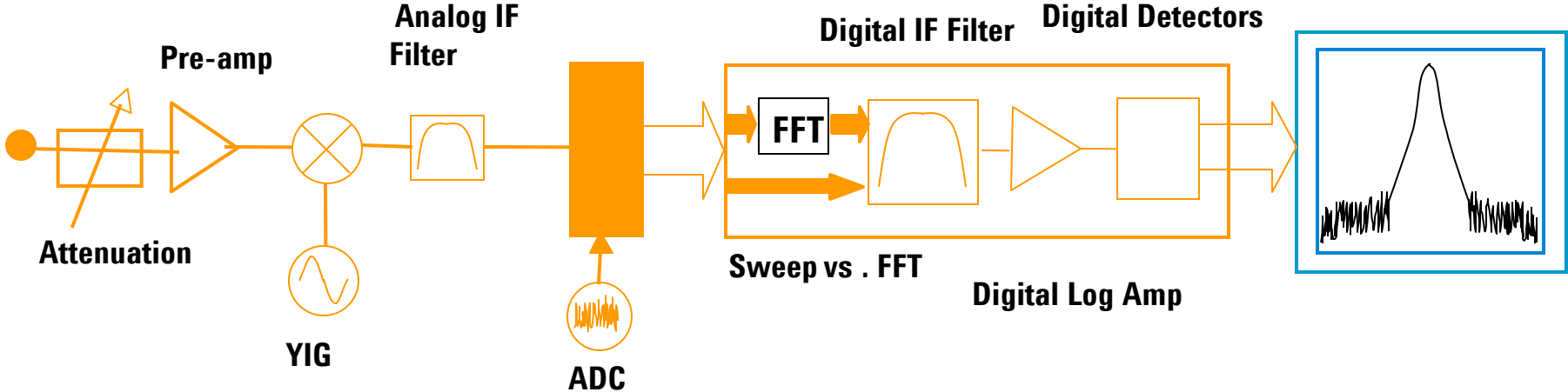


Theory of Operation

Display terminology



Modern Spectrum Analyzer Block Diagram



Agenda

- Overview

What is spectrum analysis?

- Theory of Operation

Simplified block diagram



- Specifications

Which are important and why?



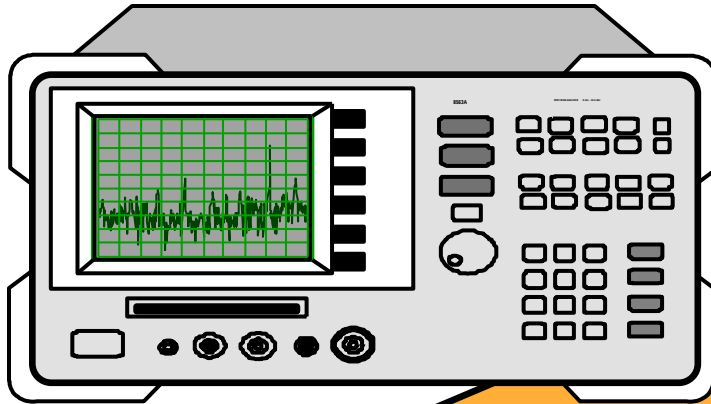
Specifications?

A Definition

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



Key Specifications



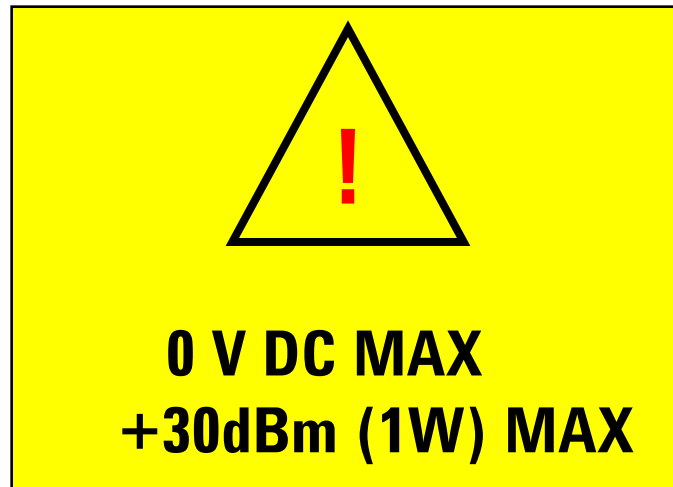
- Safe power levels
- Frequency Range
- Resolution
- Sensitivity
- Distortion
- Dynamic Range



Specifications

Safe power levels - Safe Hookups to RF Input

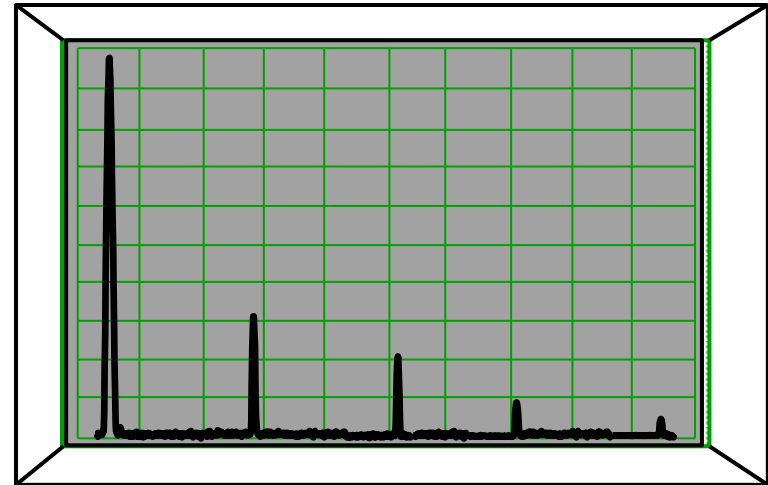
- **Use best practices to eliminate static discharge to the RF input!**
- **Do not exceed the Damage Level on the RF Input!**
- **Do not input signals with DC bias!**



Specifications

Frequency Range

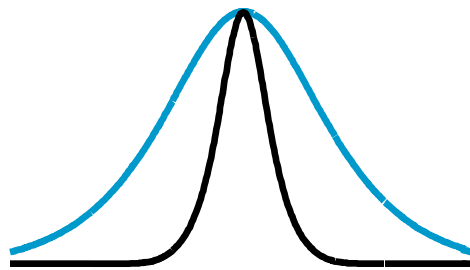
<u>Description</u>	<u>Specifications</u>
Internal Mixing Bands	
0	3 Hz to 3.0 GHz
1	2.85 to 6.6 GHz
2	6.2 to 13.2 GHz
3	12.8 to 19.2 GHz
4	18.7 to 26.8 GHz
5	26.4 to 31.15 GHz
6	31.0 to 50.0 GHz
External Mixing	18 to 325 GHz



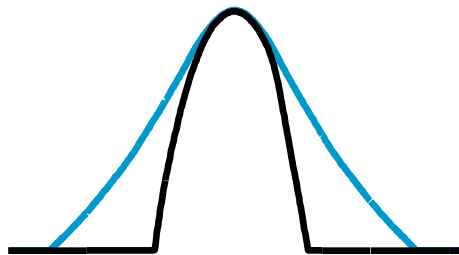
Specifications

Resolution

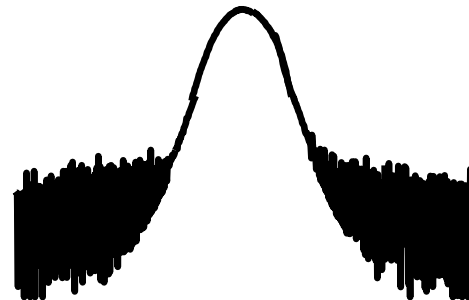
What Determines Resolution?



Resolution Bandwidth



RBW Type and Selectivity

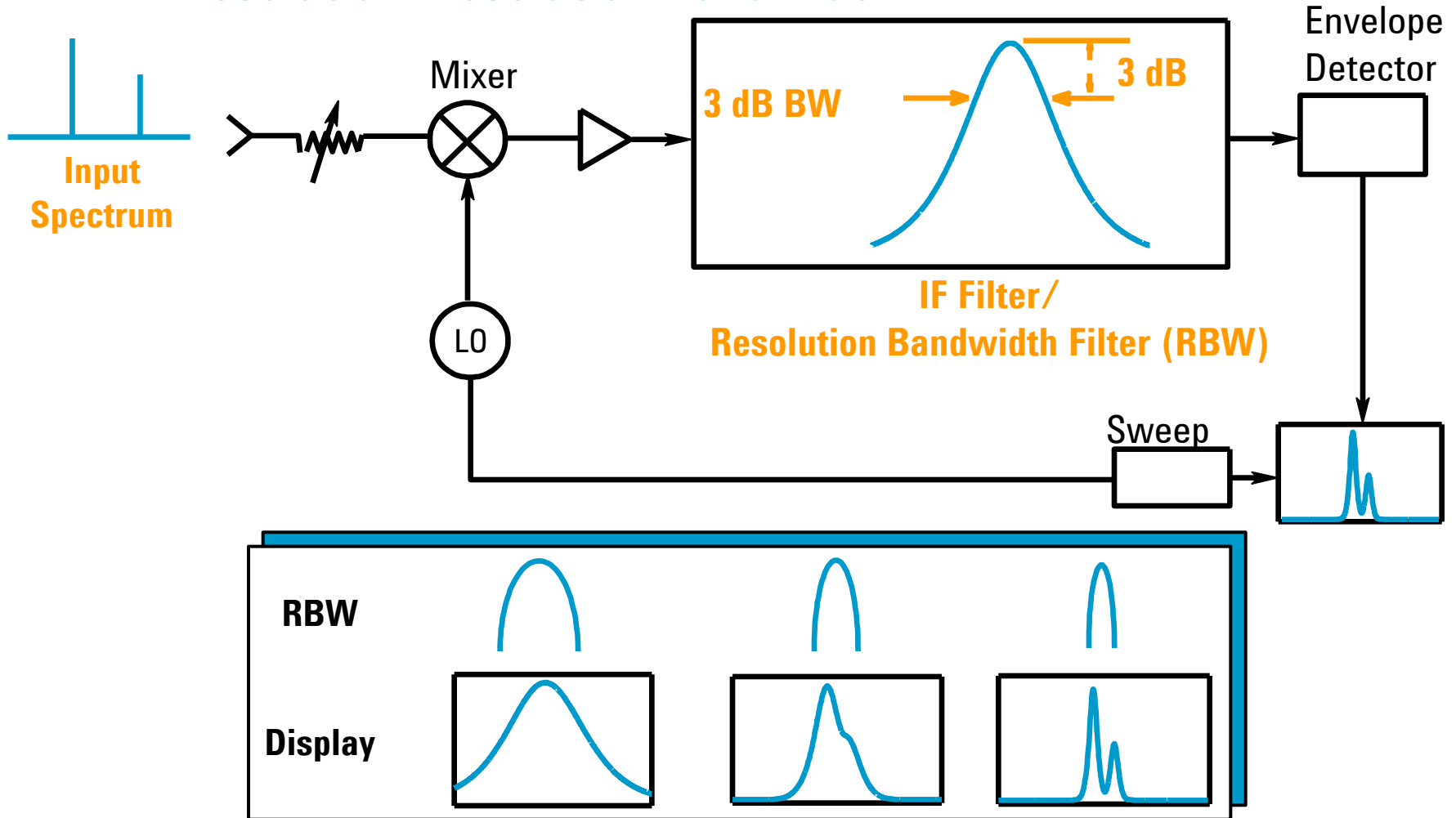


Noise Sidebands



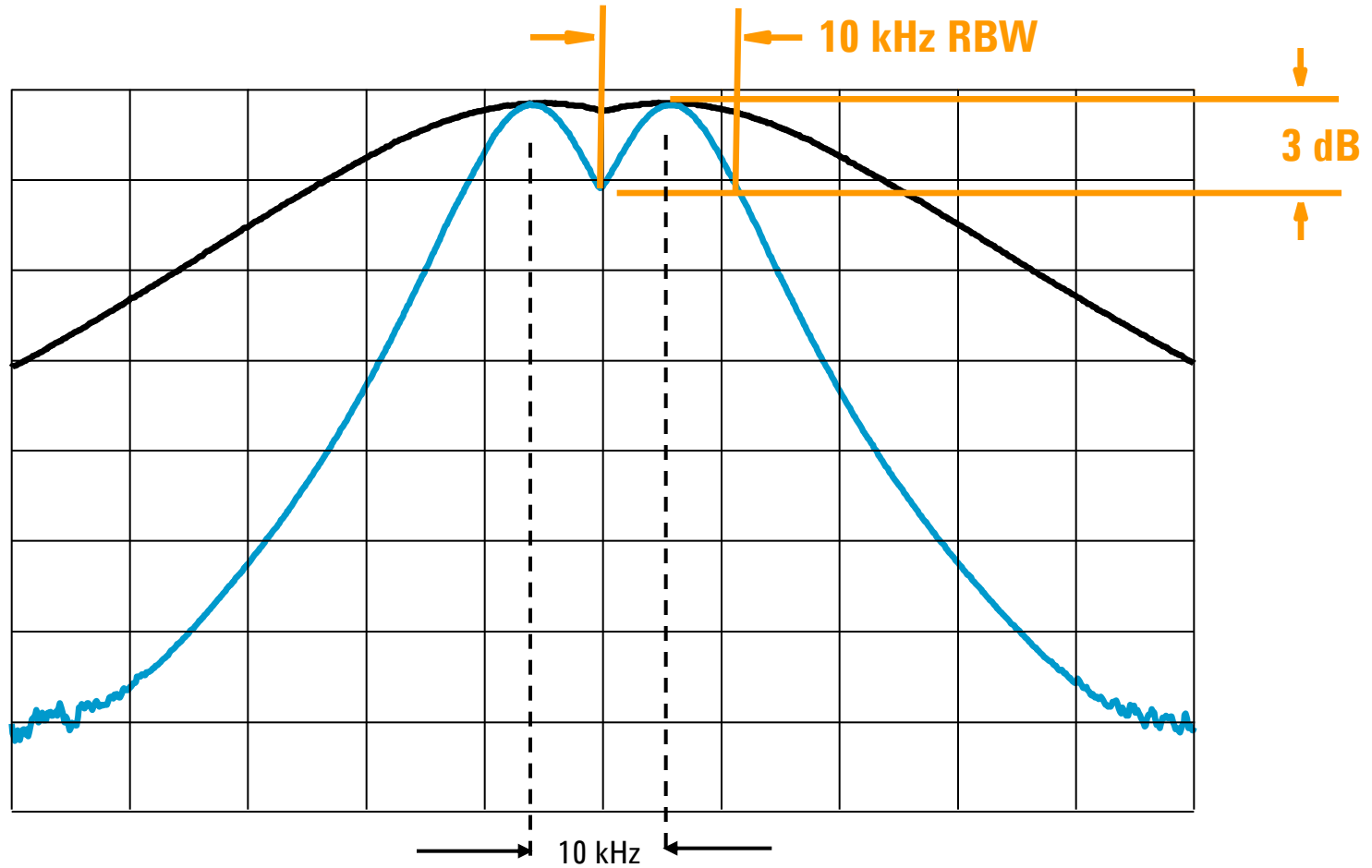
Specifications

Resolution: Resolution Bandwidth



Specifications

Resolution: Resolution BW

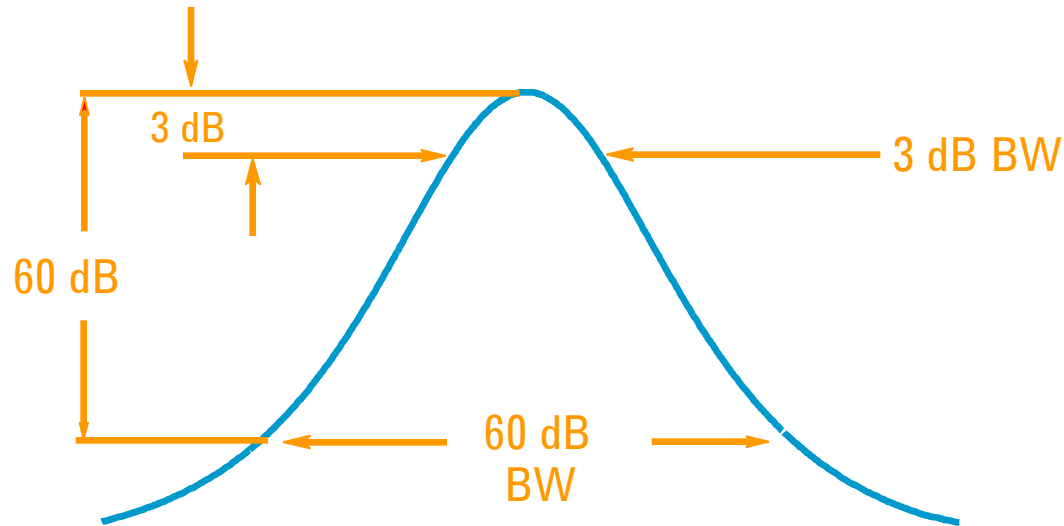


Determines resolvability of **equal** amplitude signals



Specifications

Resolution BW Selectivity or Shape Factor



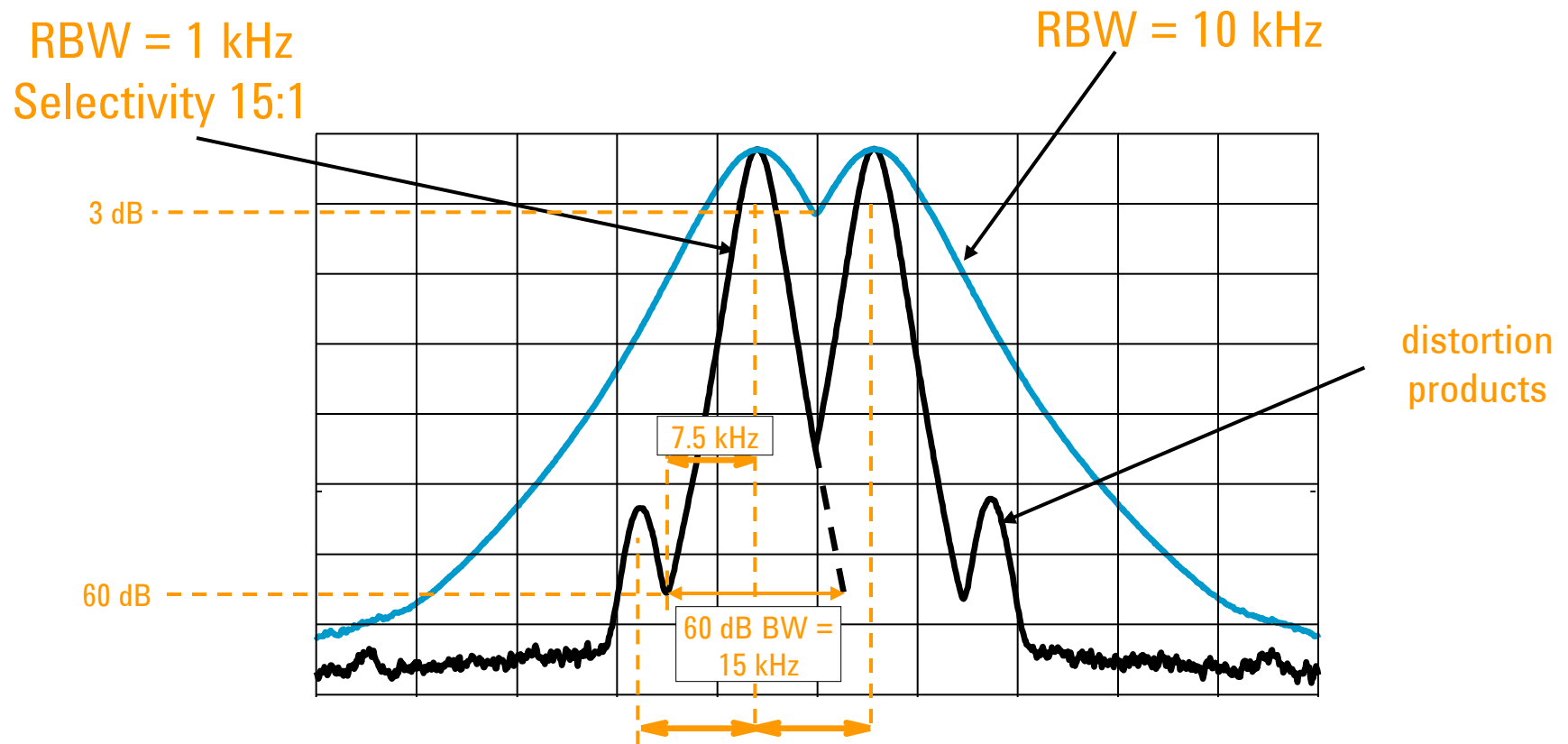
$$\text{Selectivity} = \frac{60 \text{ dB BW}}{3 \text{ dB BW}}$$

Determines resolvability of **unequal** amplitude signals



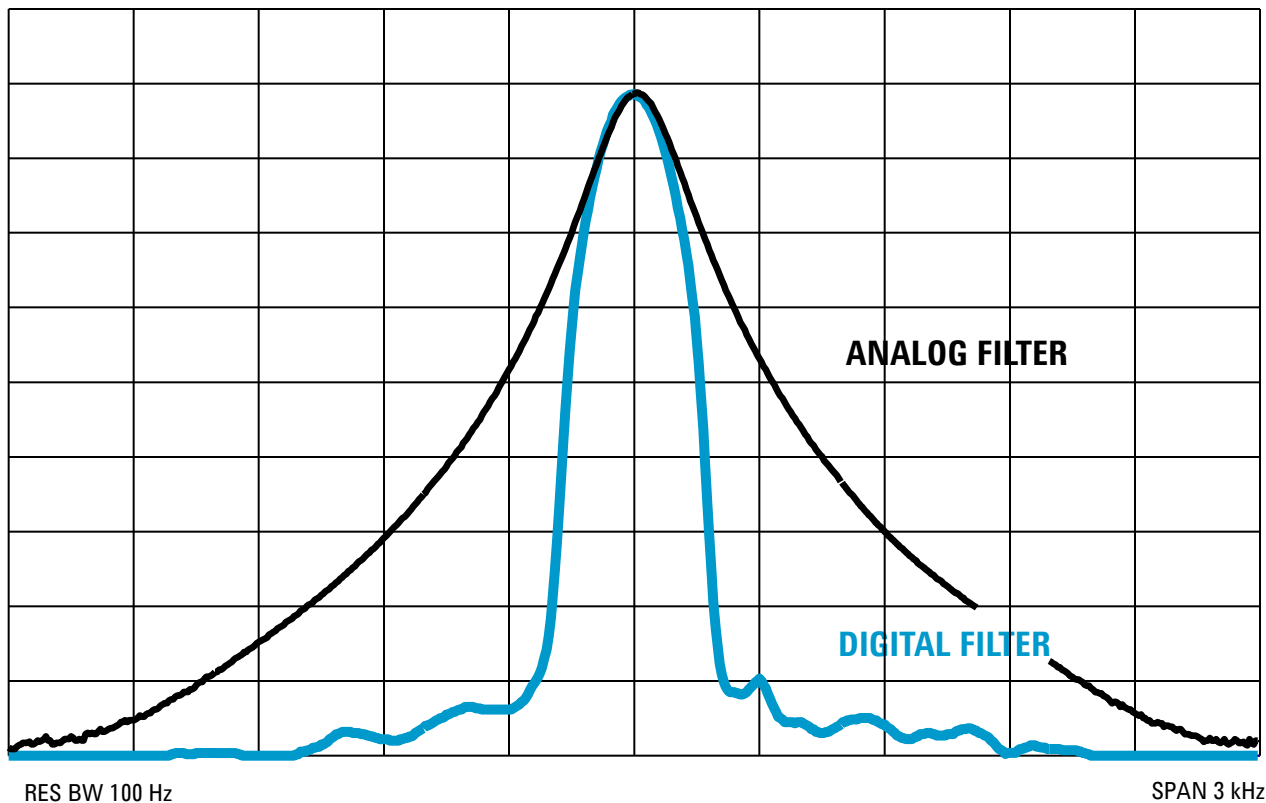
Specifications

Resolution BW Selectivity or Shape Factor



Specifications

Resolution: RBW Type and Selectivity



Typical Selectivity

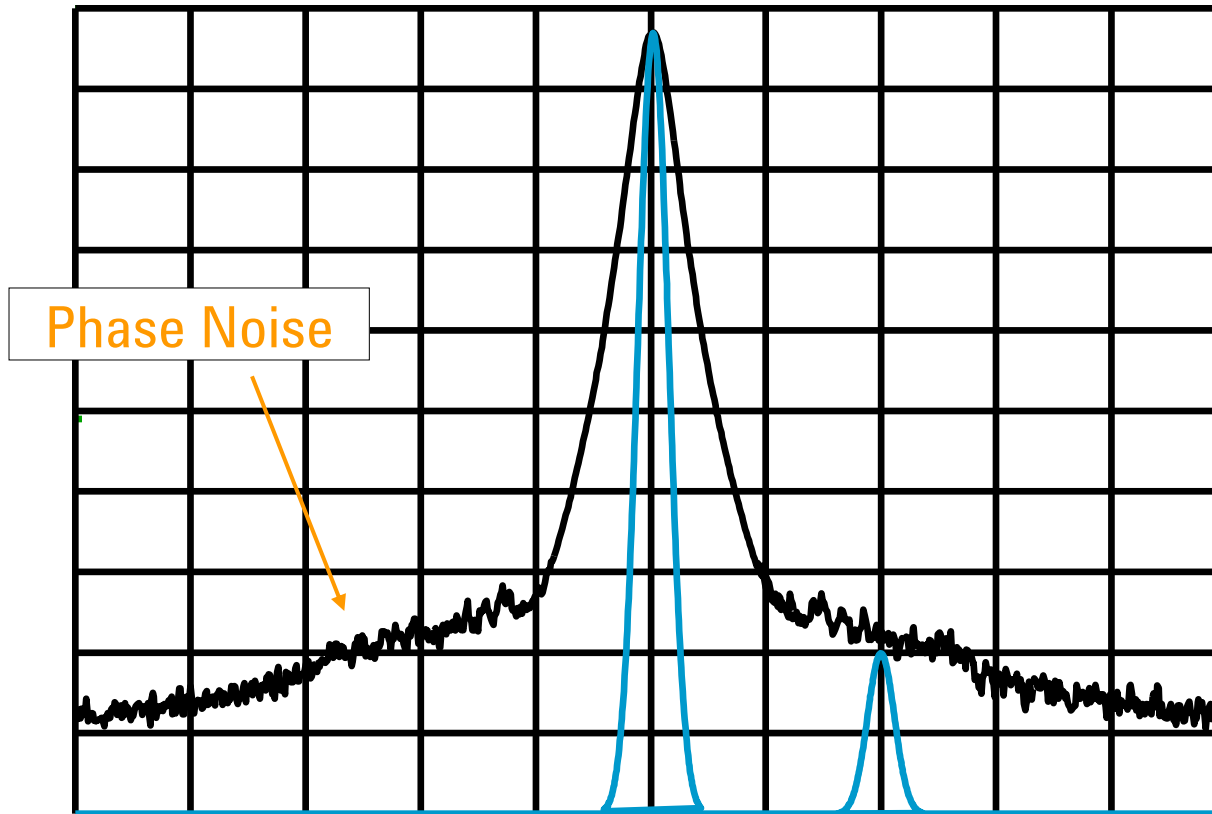
Analog 15:1

Digital $\leq 5:1$



Specifications

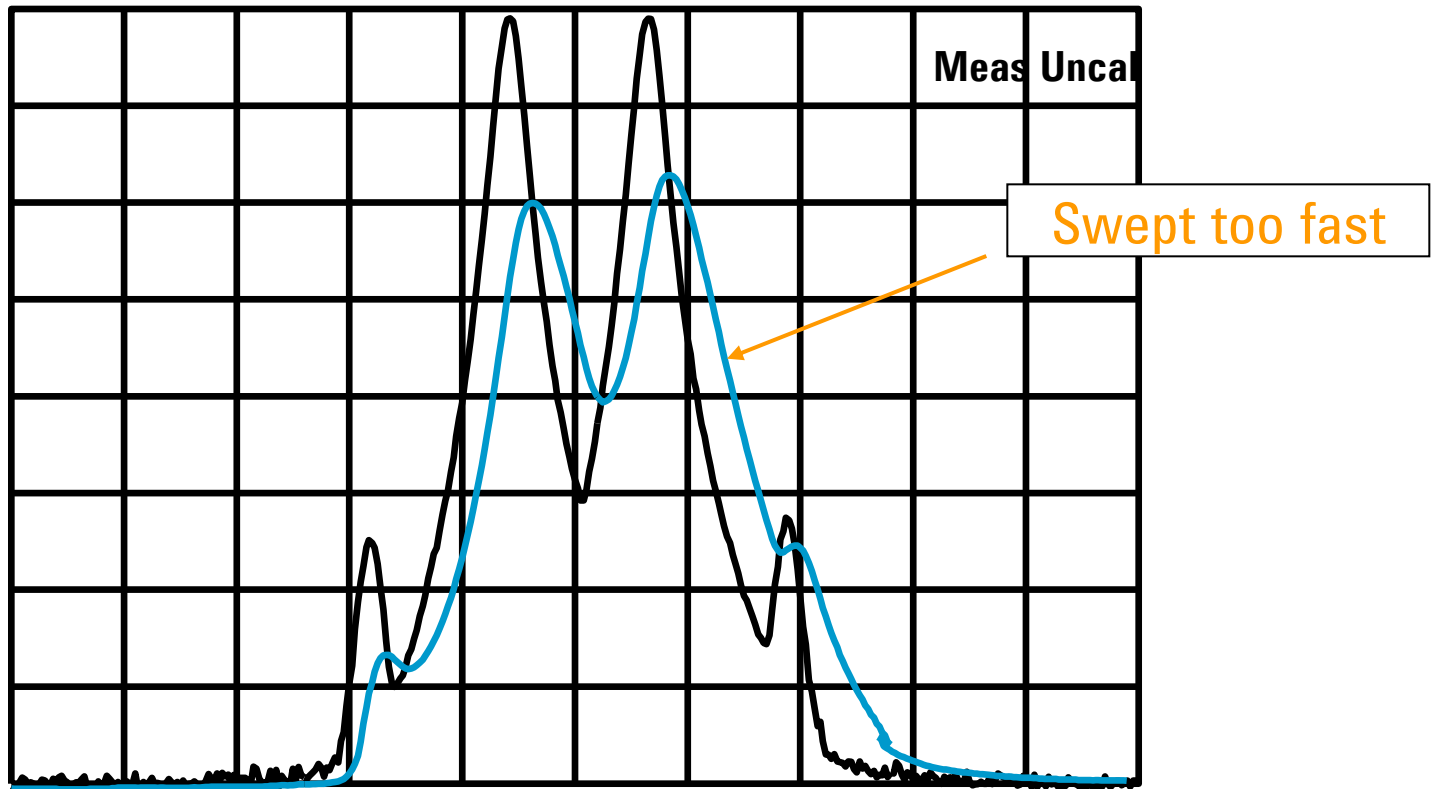
Resolution: Noise Sidebands



Noise Sidebands can prevent resolution of unequal signals

Specifications

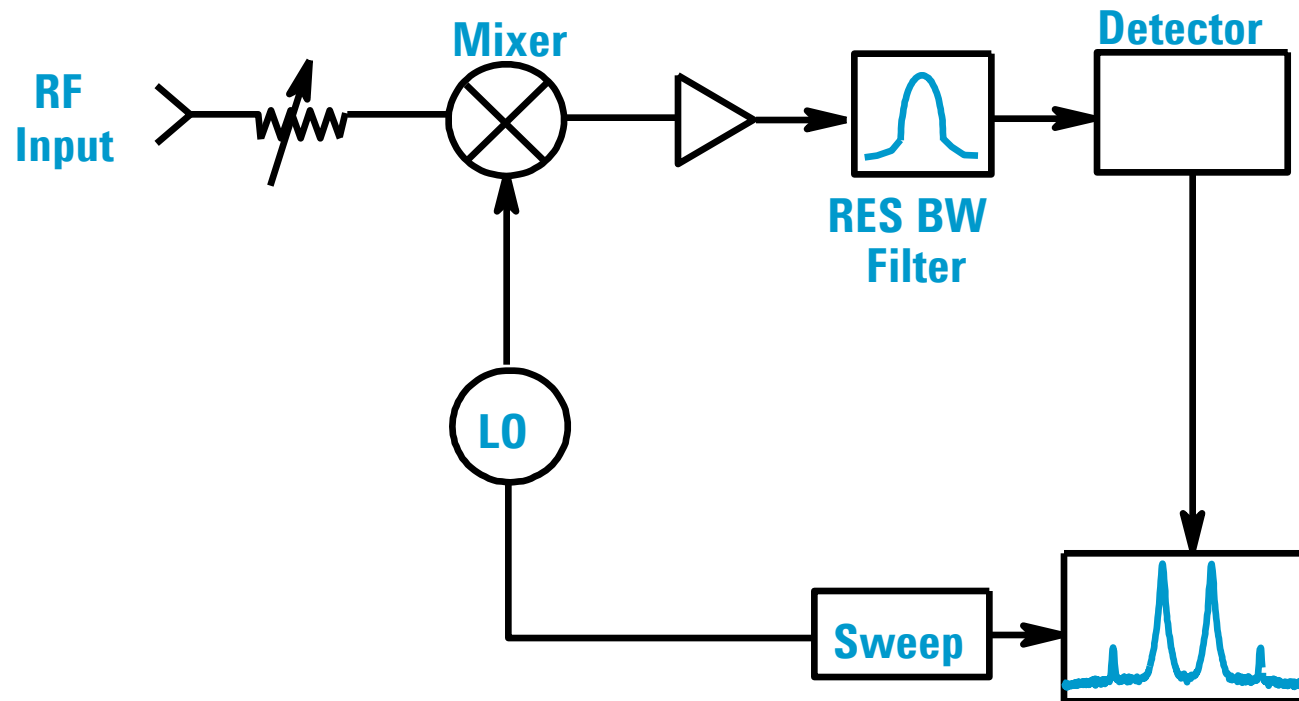
Resolution: RBW Determines Sweep Time



**Penalty For Sweeping Too Fast
Is An Uncalibrated Display**

Specifications

Sensitivity/DANL

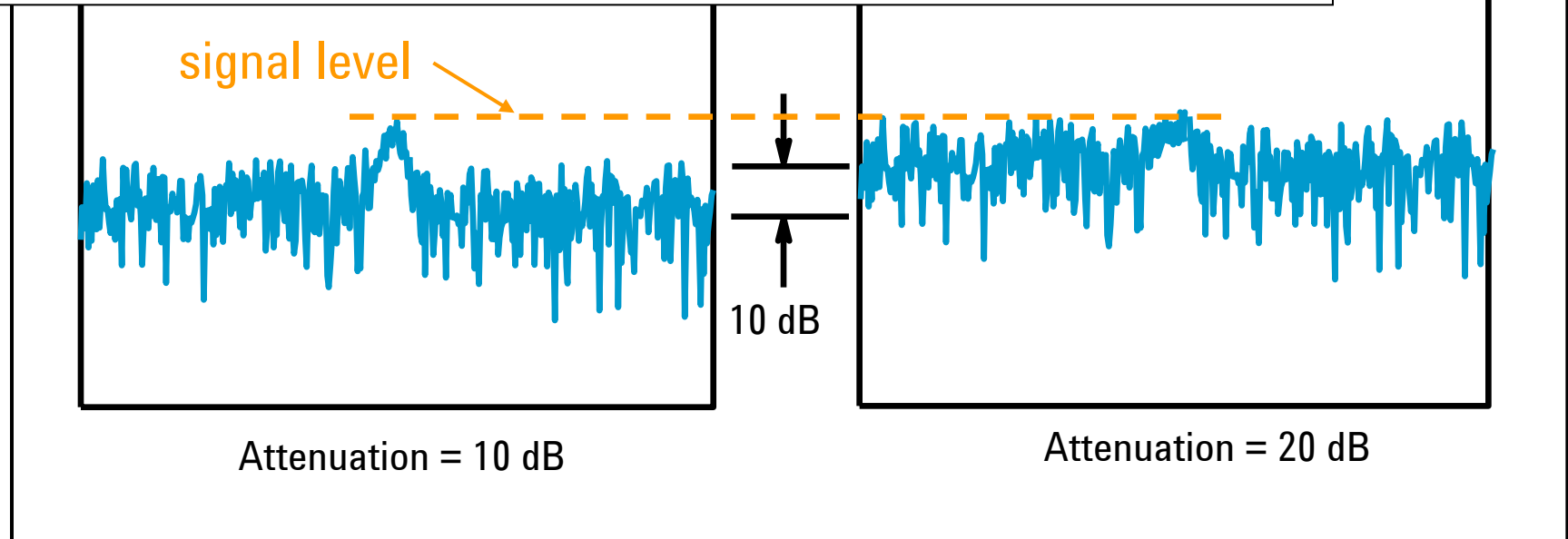


A Spectrum Analyzer Generates and Amplifies Noise Just Like Any Active Circuit

Specifications

Sensitivity/DANL

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



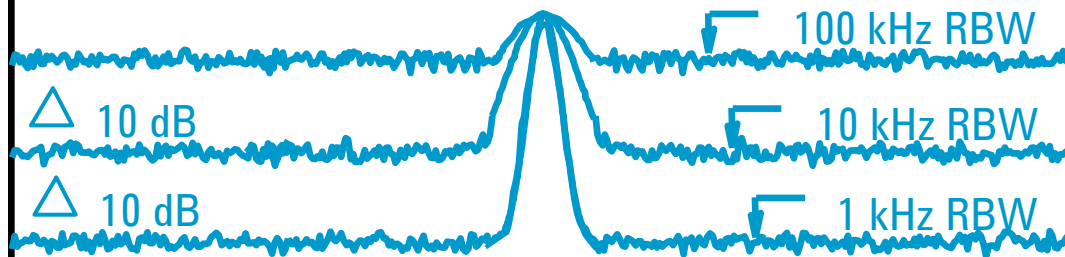
Signal To Noise Ratio Decreases as RF Input Attenuation is Increased



Specifications

Sensitivity/DANL: IF Filter(RBW)

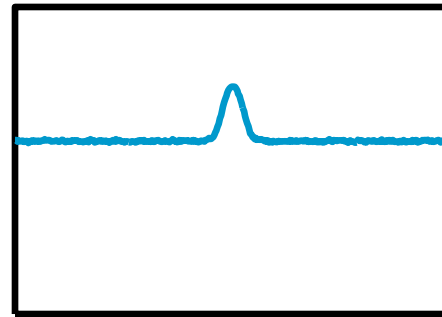
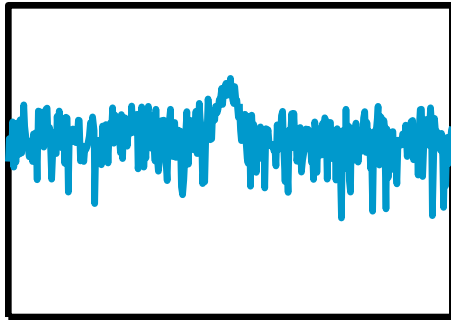
Displayed Noise is a Function of IF Filter Bandwidth



Specifications

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

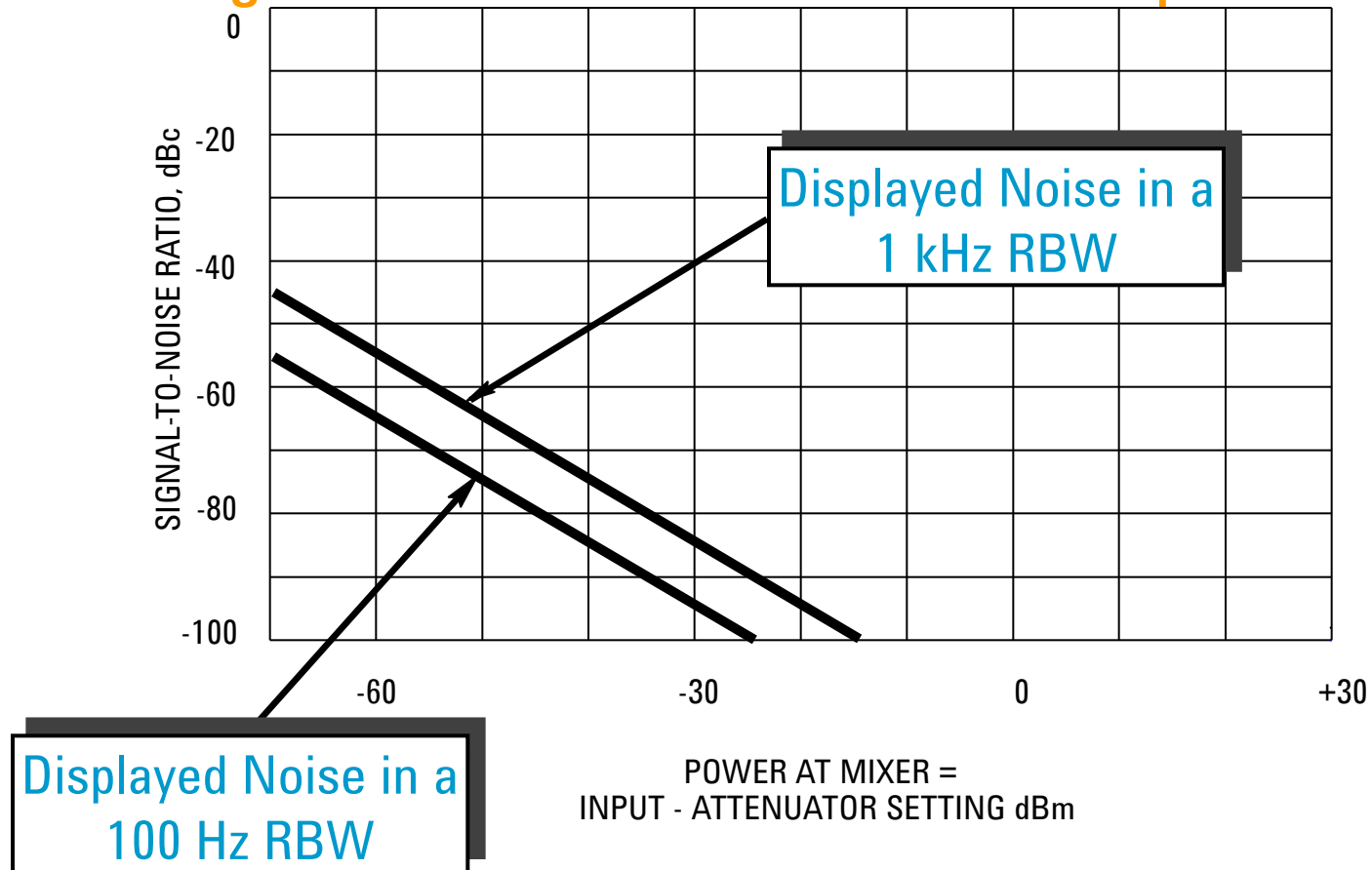
Video BW or Trace Averaging Smooths Noise
for Easier Identification of Low Level Signals



Specifications

Sensitivity/DANL:

Signal-to-Noise Ratio Can Be Graphed



Specifications

Sensitivity/DANL: Summary

For Best Sensitivity Use:

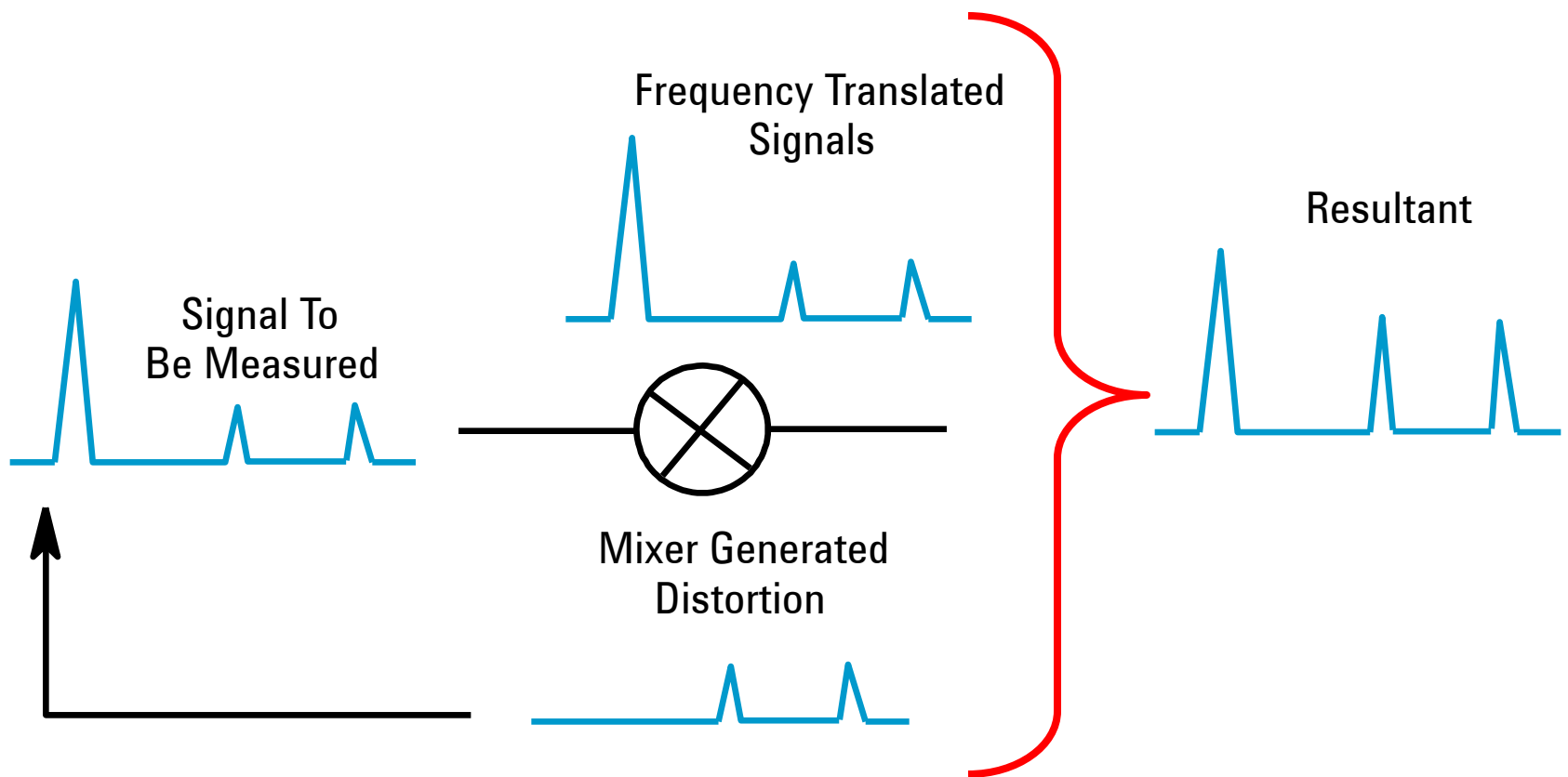
- **Narrowest Resolution BW**
- **Minimum RF Input Attenuation**
- **Sufficient Averaging (video or trace)**



Specifications

Distortion

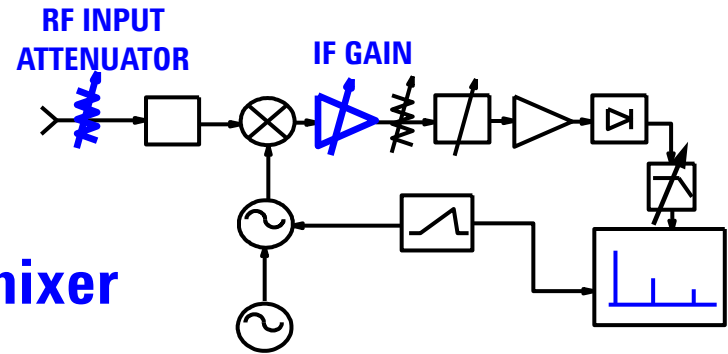
Mixers Generate Distortion



Specifications

Distortion – Internal or External?

Attenuator Test: Change power to the mixer



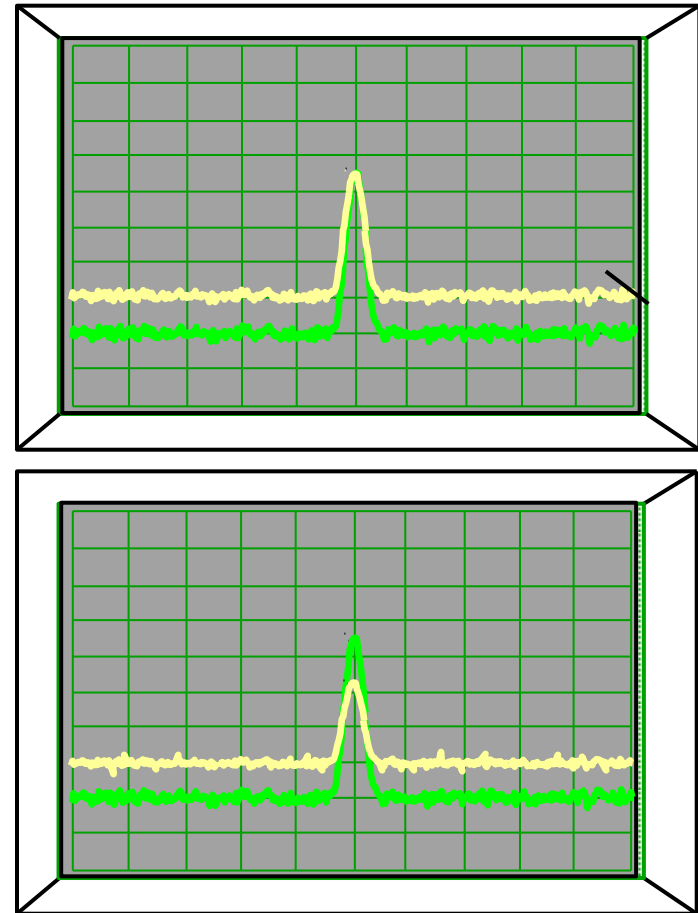
- 1 Change input attenuator by 10 dB
- 2 Watch distortion amplitude on screen

No change in amplitude:

distortion is part of input signal (external)

Change in amplitude:

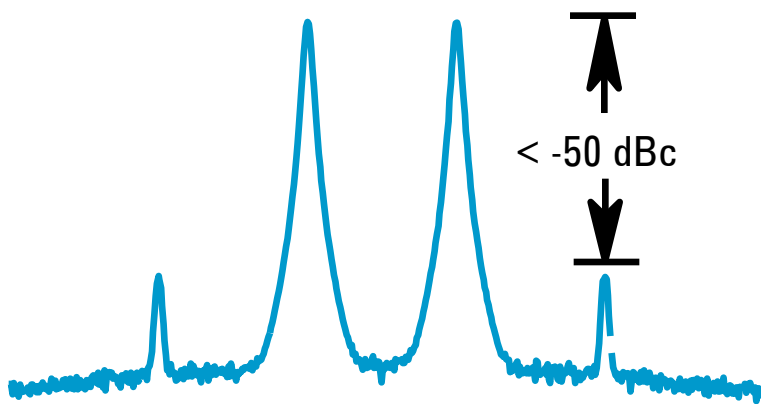
at least some of the distortion is being generated inside the analyzer (internal)



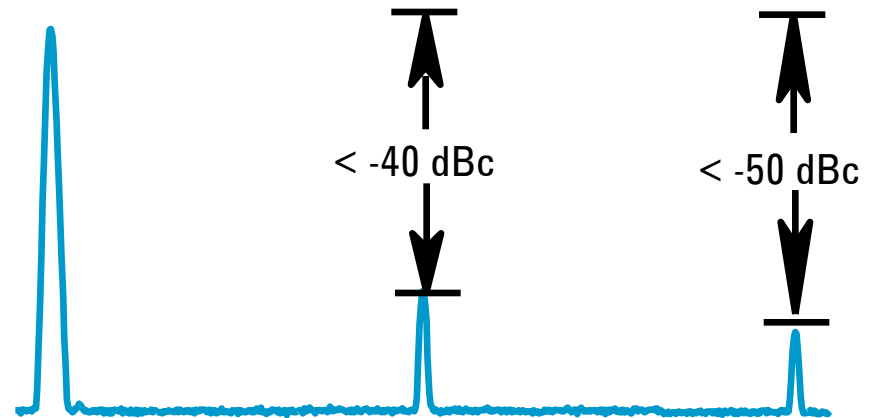
Specifications

Distortion

Most Influential Distortion is the Second and Third Order



Two-Tone Intermod



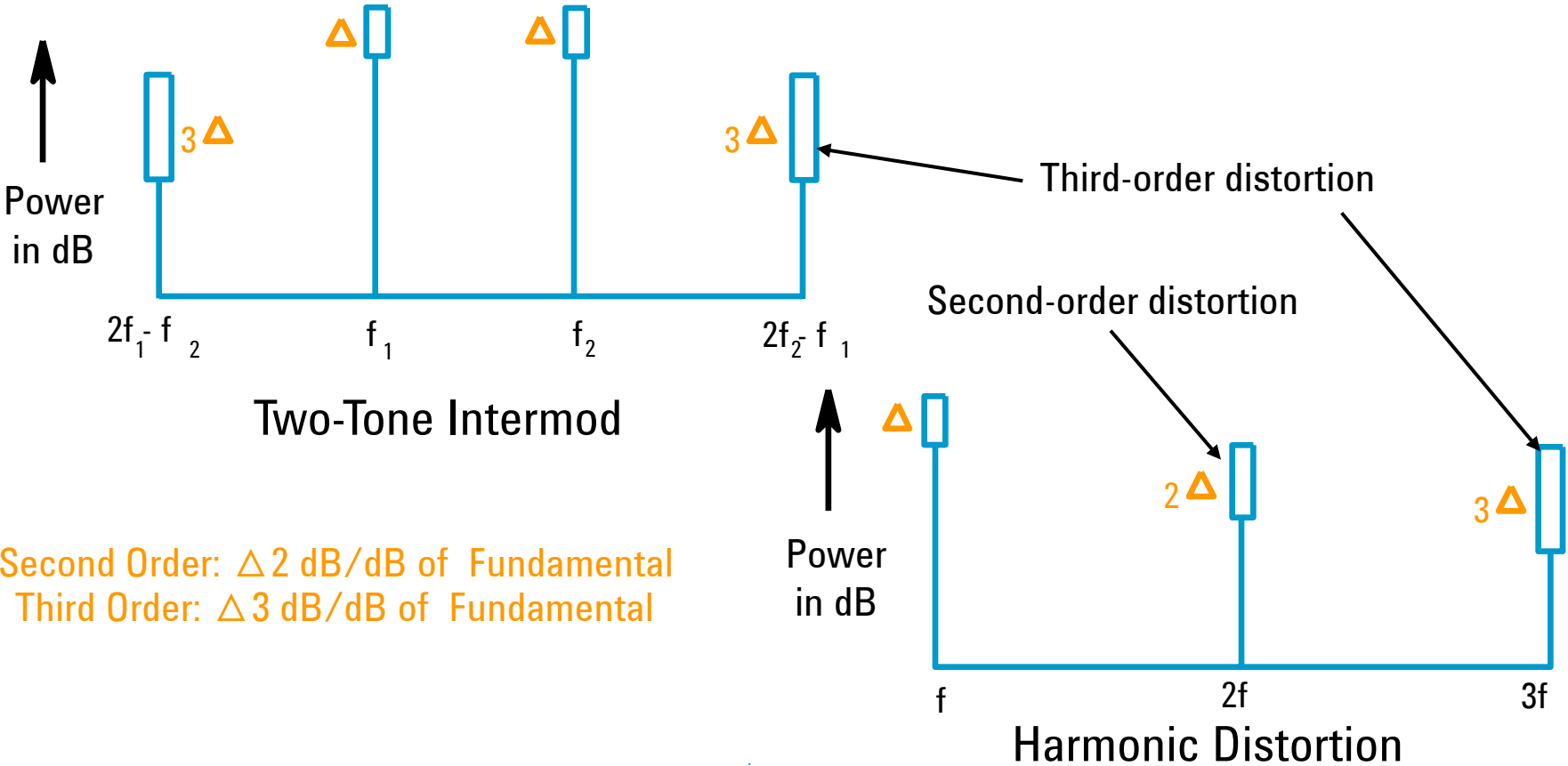
Harmonic Distortion



Specifications

Distortion

Distortion Products Increase as a Function of Fundamental's Power

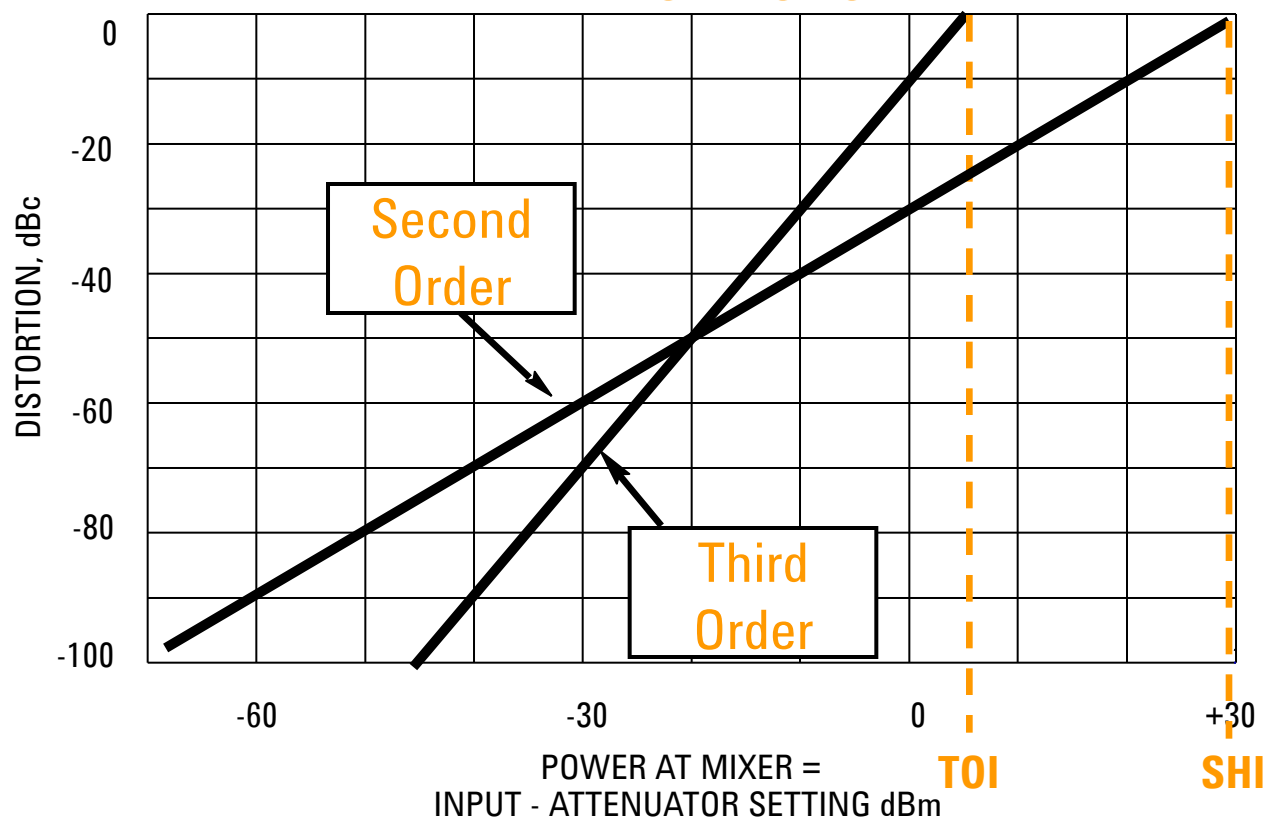


Second Order: $\Delta 2$ dB/dB of Fundamental
Third Order: $\Delta 3$ dB/dB of Fundamental

Specifications

Distortion

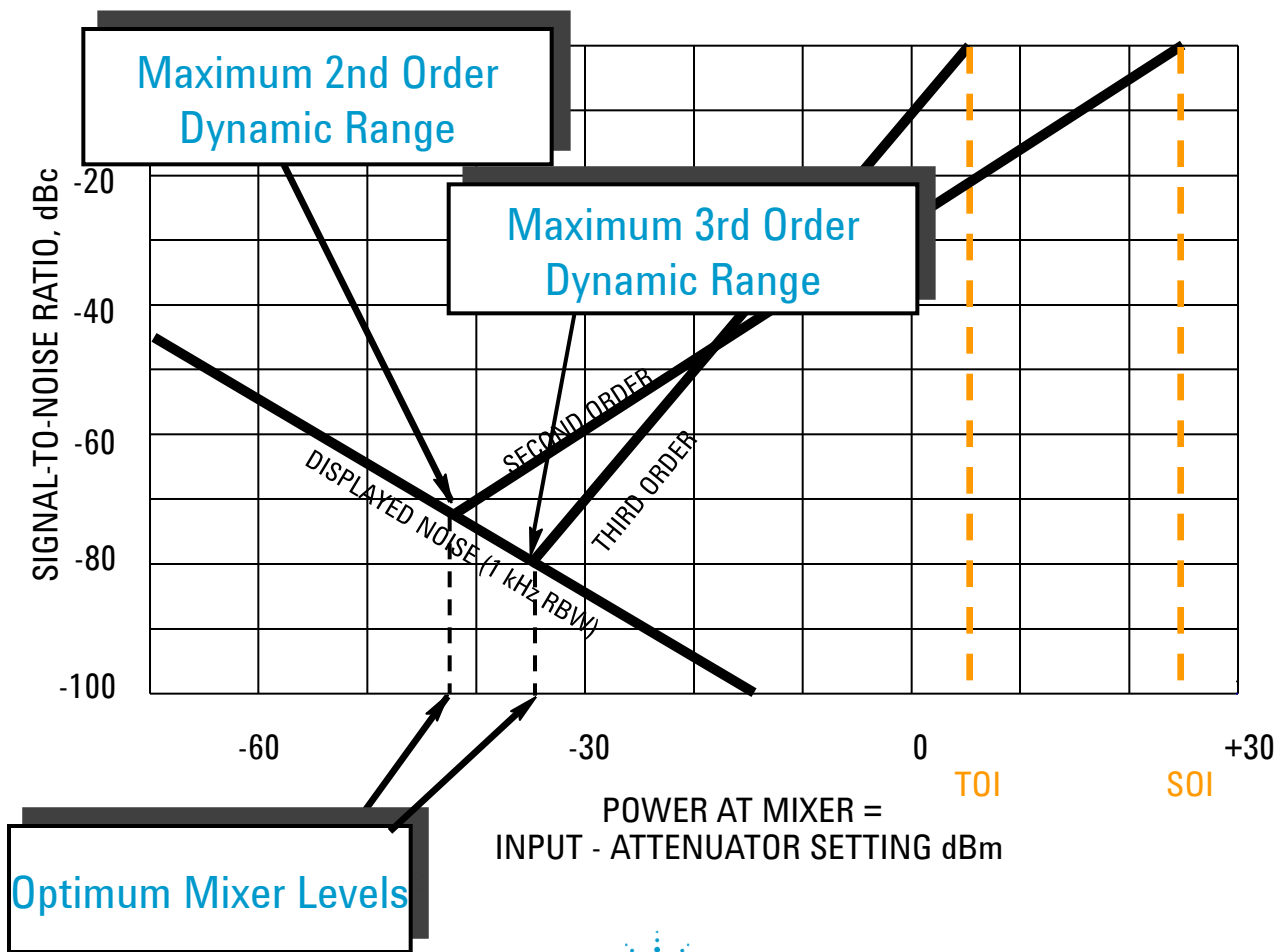
Distortion is a Function of Mixer Level



Specifications

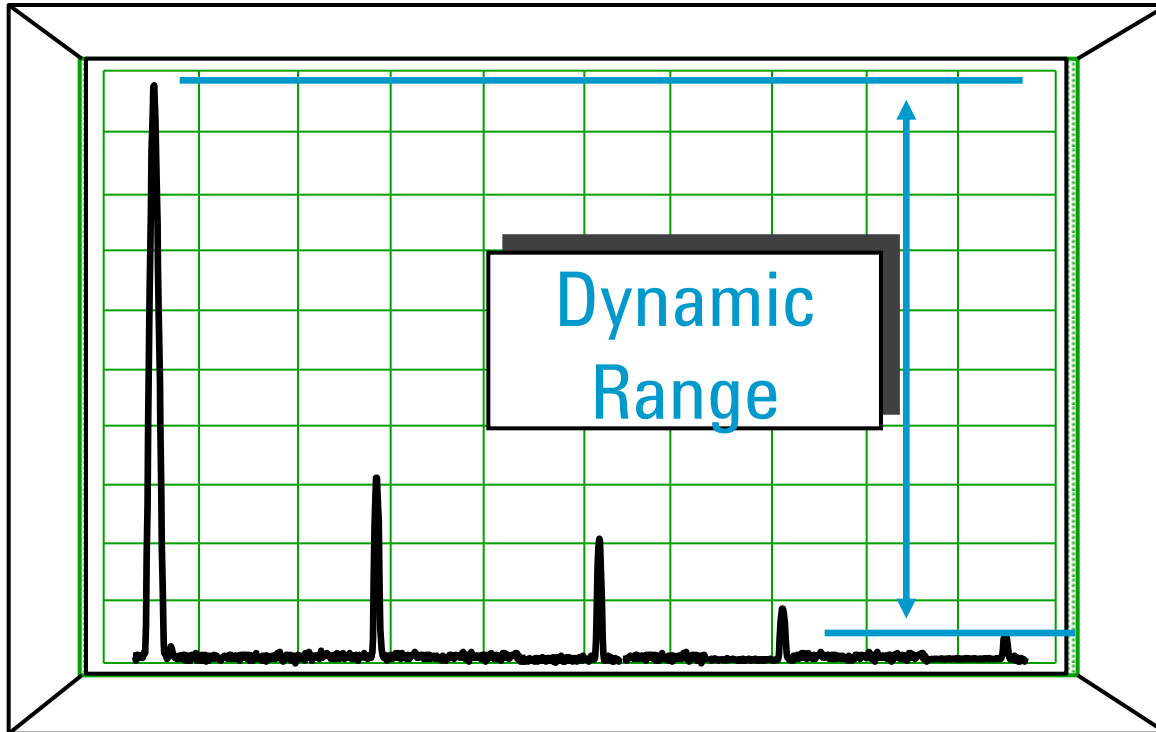
Dynamic Range

Dynamic Range Can Be Presented Graphically



Specifications

Spectrum Analyzer Dynamic Range



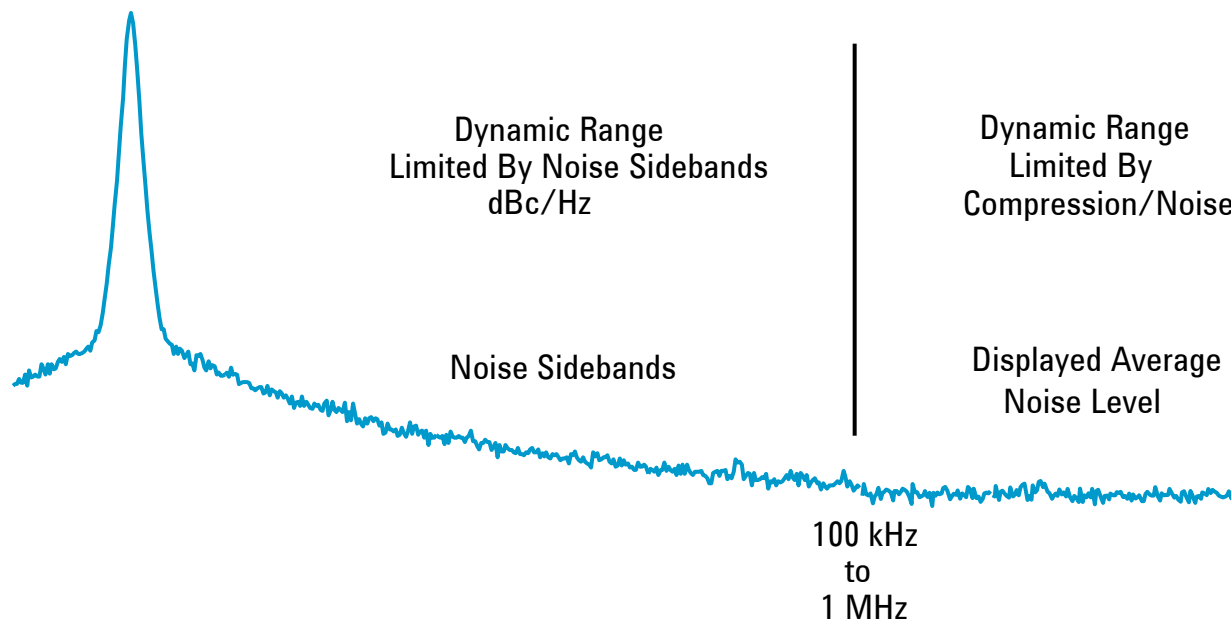
The ratio, expressed in dB, of the largest to the smallest signals simultaneously present at the input of the spectrum analyzer that allows measurement of the smaller signal to a given degree of uncertainty.



Specifications

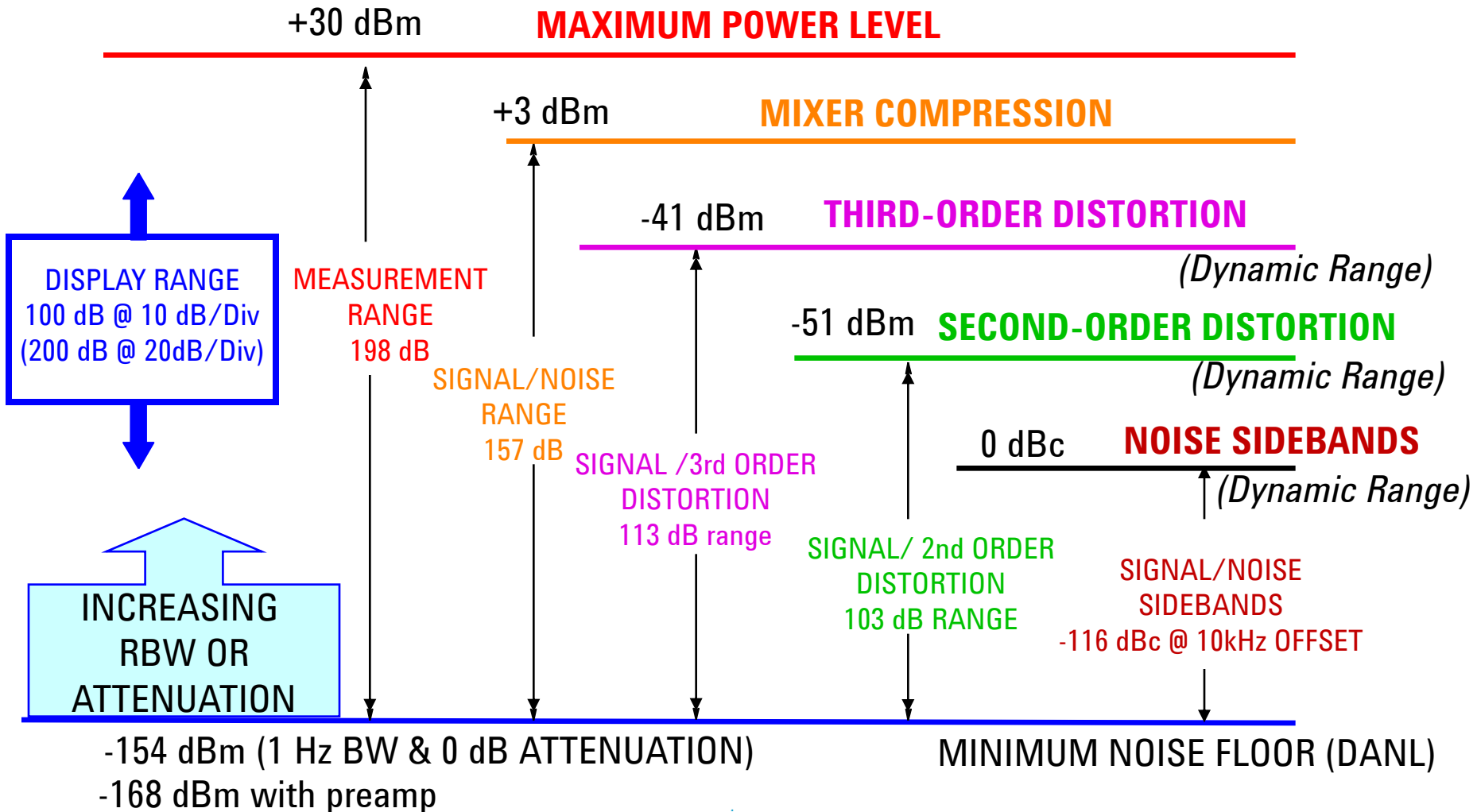
Dynamic Range

Dynamic Range for Spur Search Depends on Closeness to Carrier



Specifications

Dynamic Range vs. Measurement Range



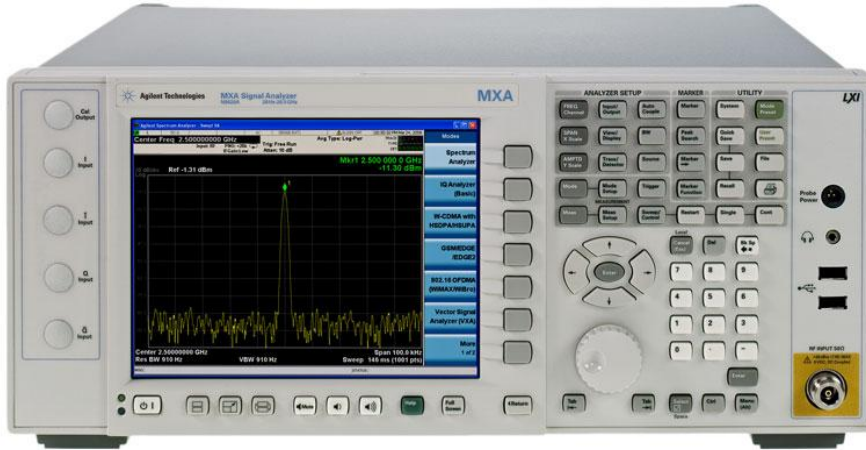
Specifications

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 change**
- **What determines dynamic range?**
 - **Analyzer distortion, noise level, and sideband/phase noise**



Thank you!



Adolfo Del Solar

Application Engineer

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Agilent Technologies