Signal Analysis Fundamentals

是德科技資深專案經理

蘇千翔

Engineers Never Stop Learning

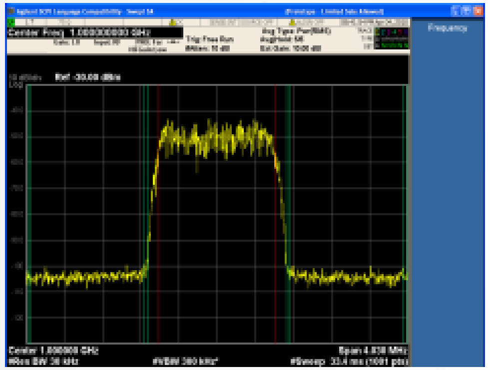
SIGNAL ANALYSIS FUNDAMENTALS

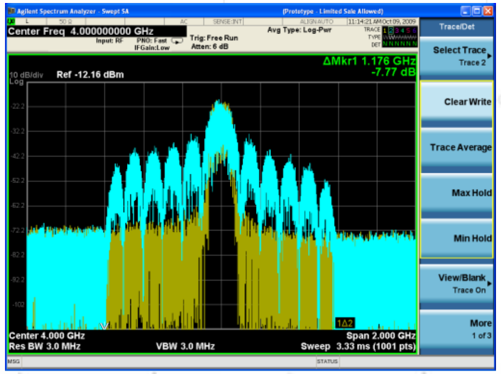
- Overview
- Theory of Operation
  - Traditional Spectrum Analyzers
  - Modern Signal Analyzers
- Specifications
- Features
- Wrap-up

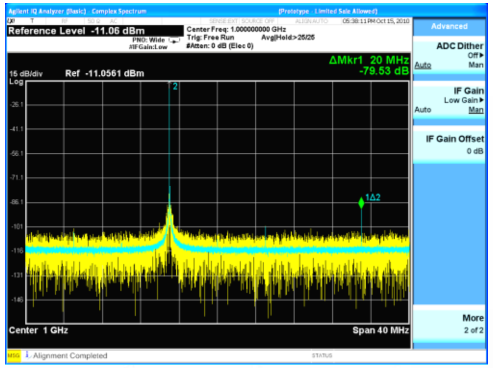
Overview

What is Spectrum Analysis

- Passive Receiver
- Display and measure amplitude versus frequency
- Separate and resolve complex signals into their base components (sine waves)

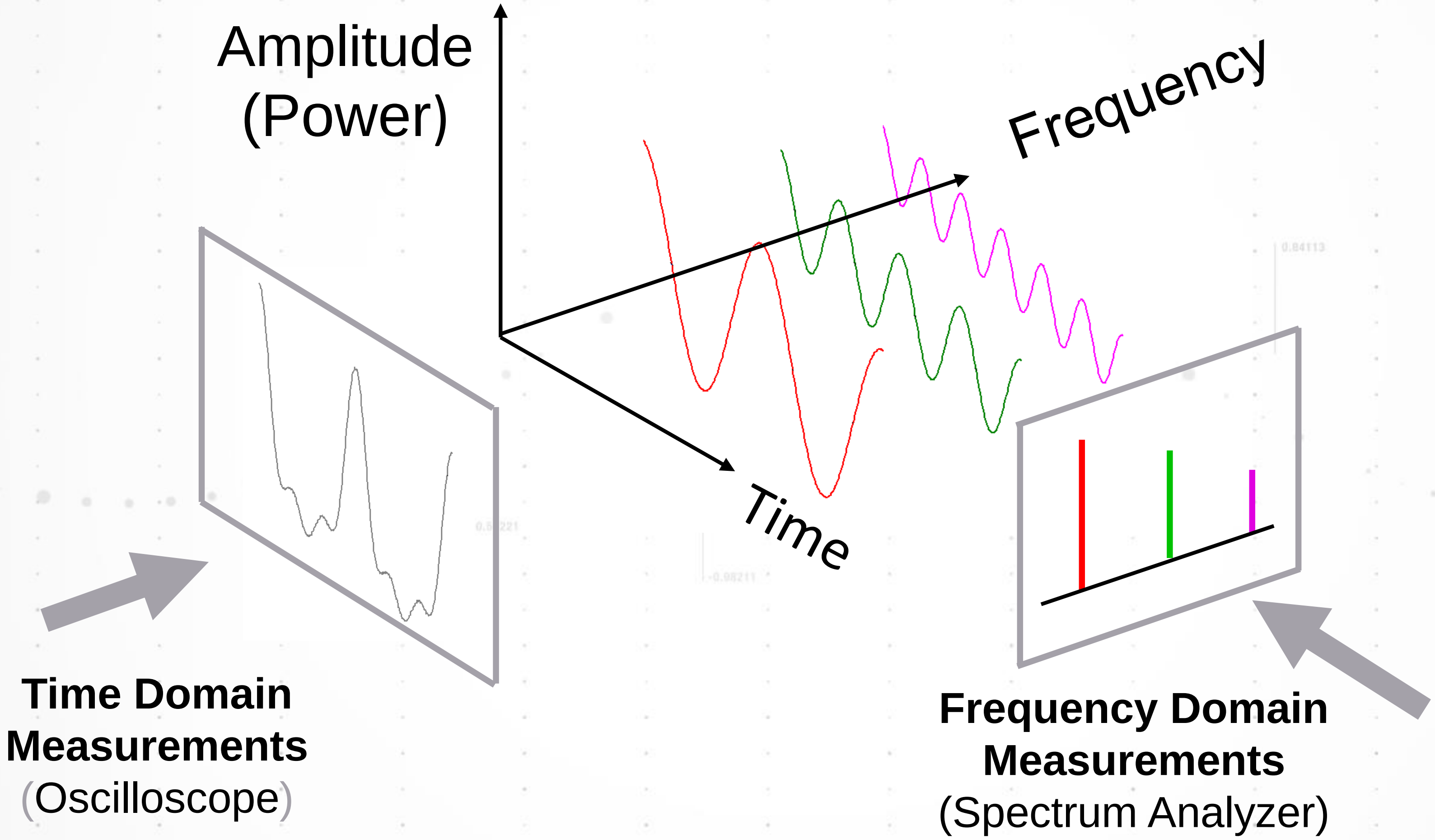






Overview

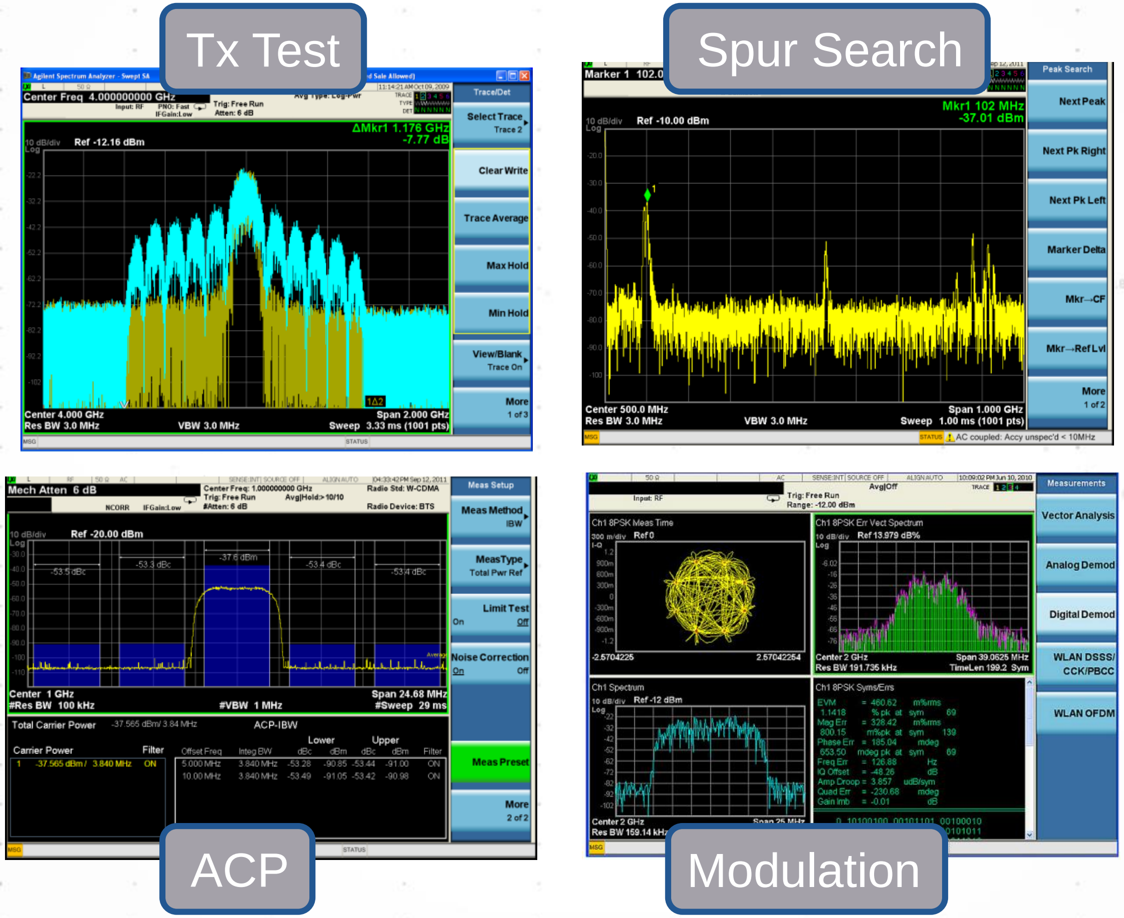
Time-Domain vs Frequency-Domain



Overview

Many Measurements

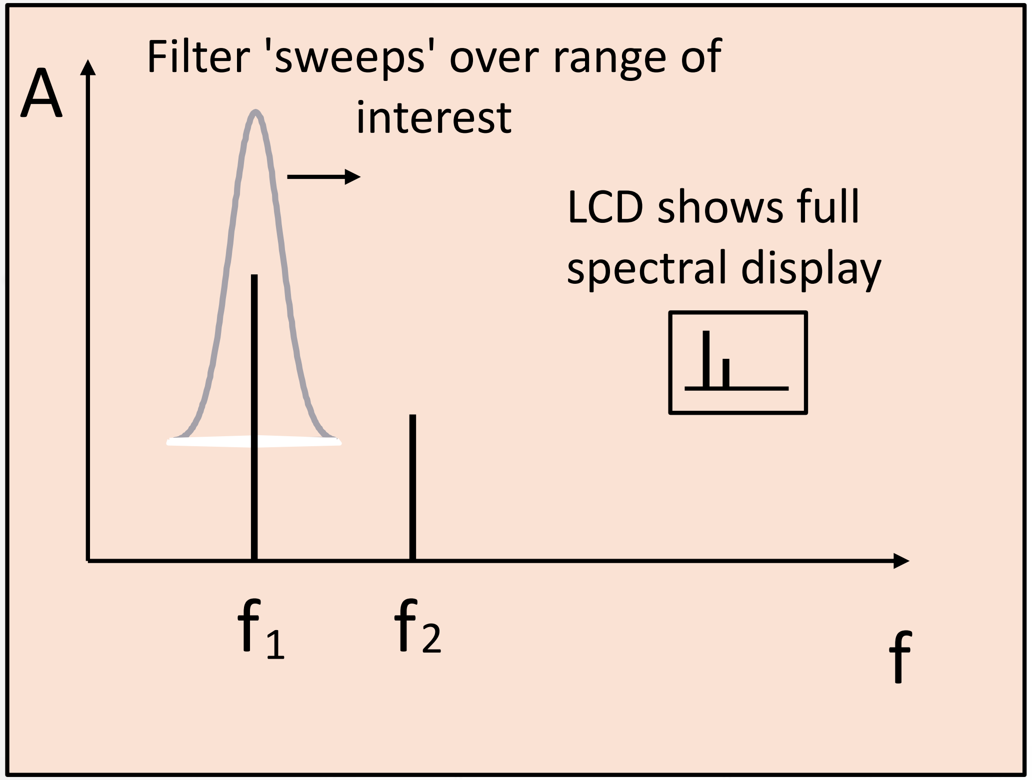
- **Frequency, power, modulation, distortion, and noise**
  - Transmitter test
  - Spectrum monitoring
  - Spurious emissions
  - Harmonic & intermodulation distortion
  - Noise figure & phase noise
  - Electromagnetic interference
  - Analog, digital, burst, & pulsed RF modulation
  - Wide bandwidth vector analysis
- **Measurement range:** -172 dBm to +30 dBm
- **Frequency range:** 3 Hz to 1.1 THz



Overview

Different Types of Analyzers

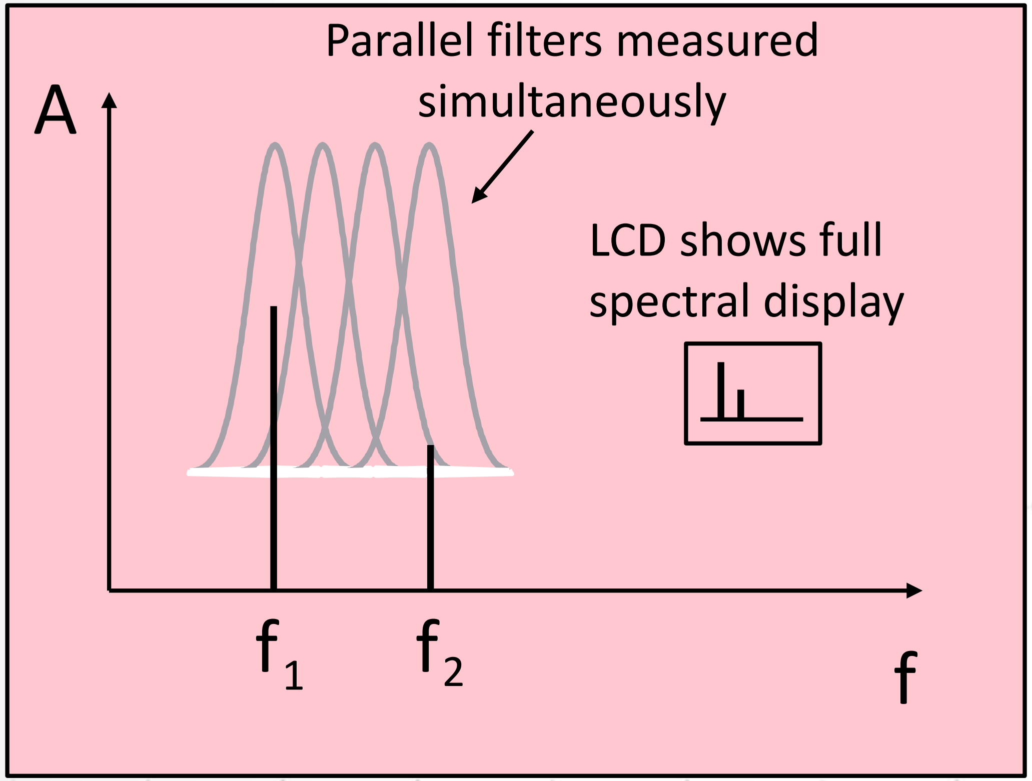
Swept Analyzer



Overview

Different Types of Analyzers

FFT Analyzer



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 display and measure Amplitude vs. Frequency of known and unknown RF and Microwave signals.

Analyzer Definitions

- **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.

Analyzer Definitions

- **Signal Analyzer:** A signal analyzer provides the functions of a spectrum analyzer and a vector signal analyzer.

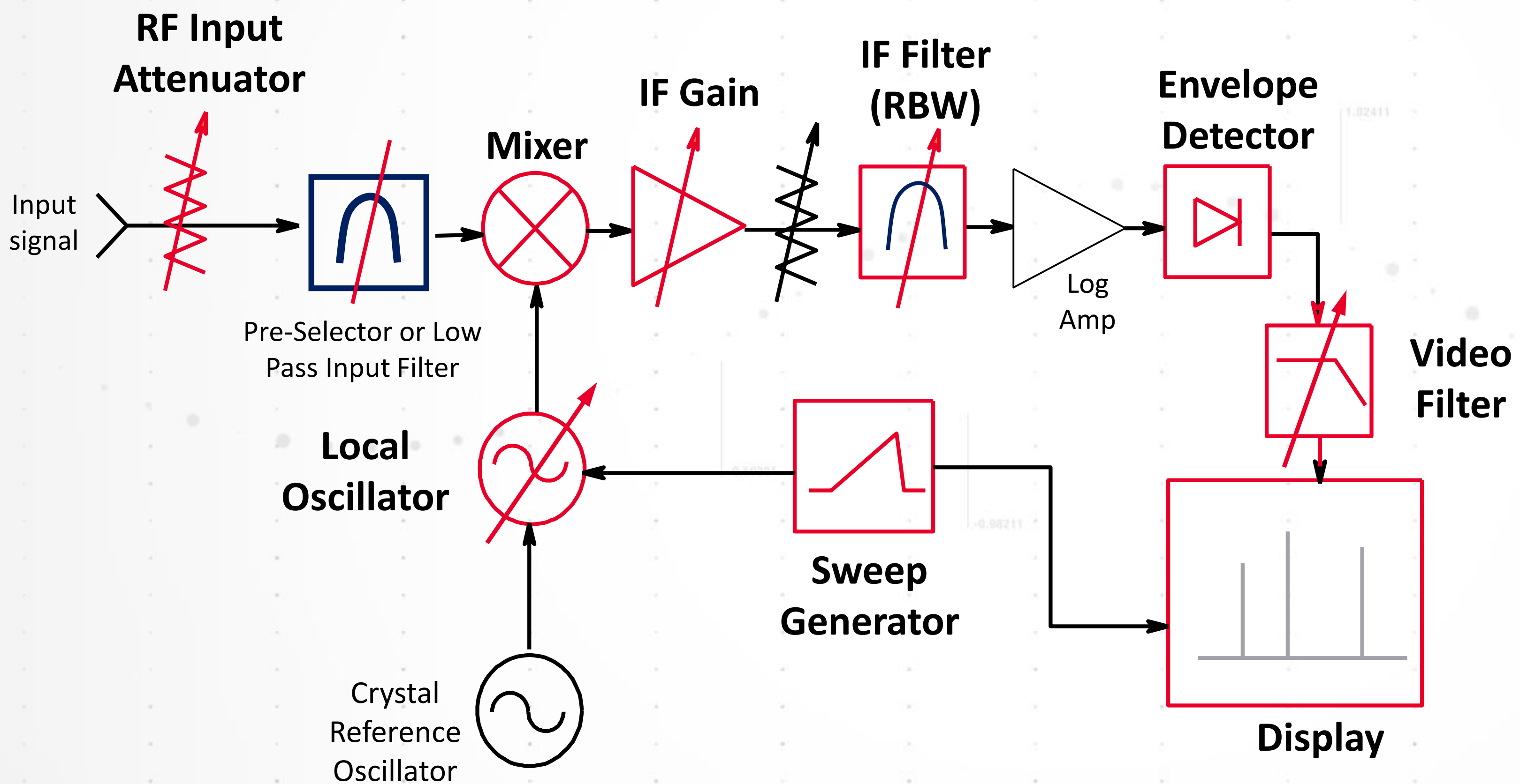
Engineers Never Stop Learning

SIGNAL ANALYSIS FUNDAMENTALS

- Overview
- Theory of Operation
  - Traditional Spectrum Analyzers
  - Modern Signal Analyzers
- Specifications
- Features
- Wrap-up

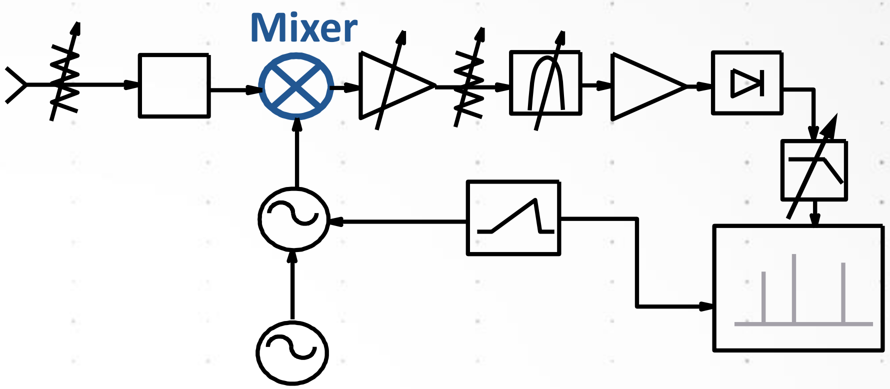
Theory of Operation

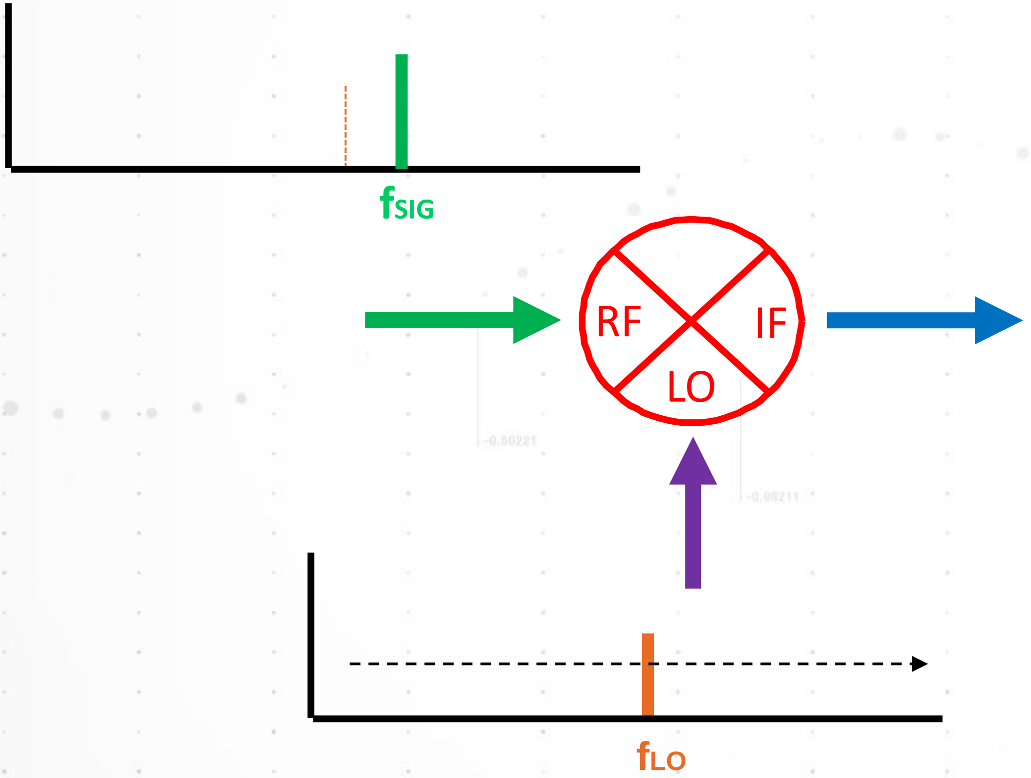
SWEPT SPECTRUM ANALYZER BLOCK DIAGRAM

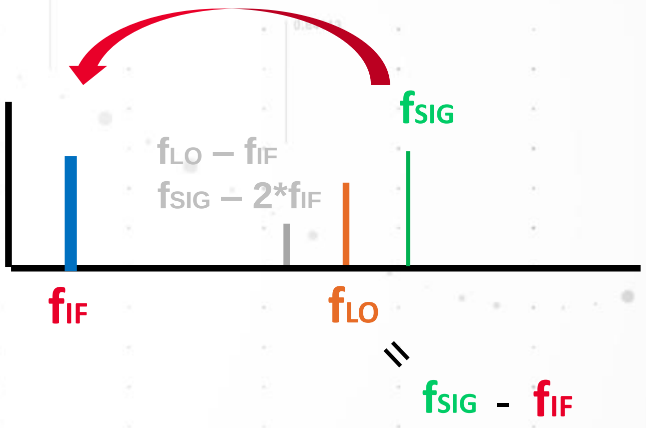


Theory of Operation

Mixer



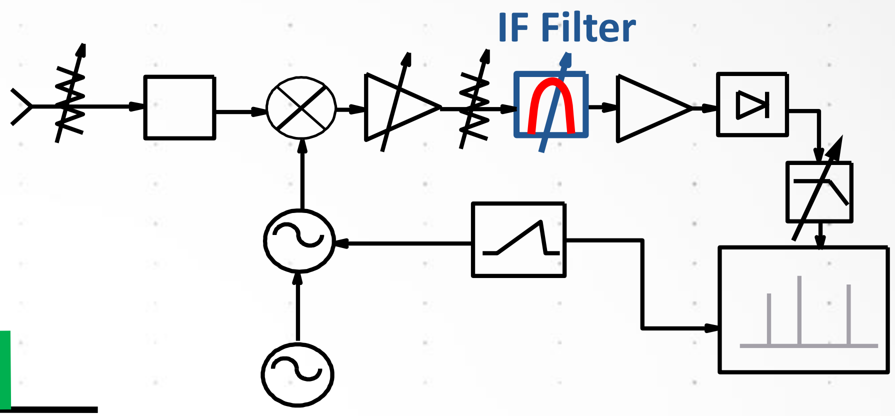


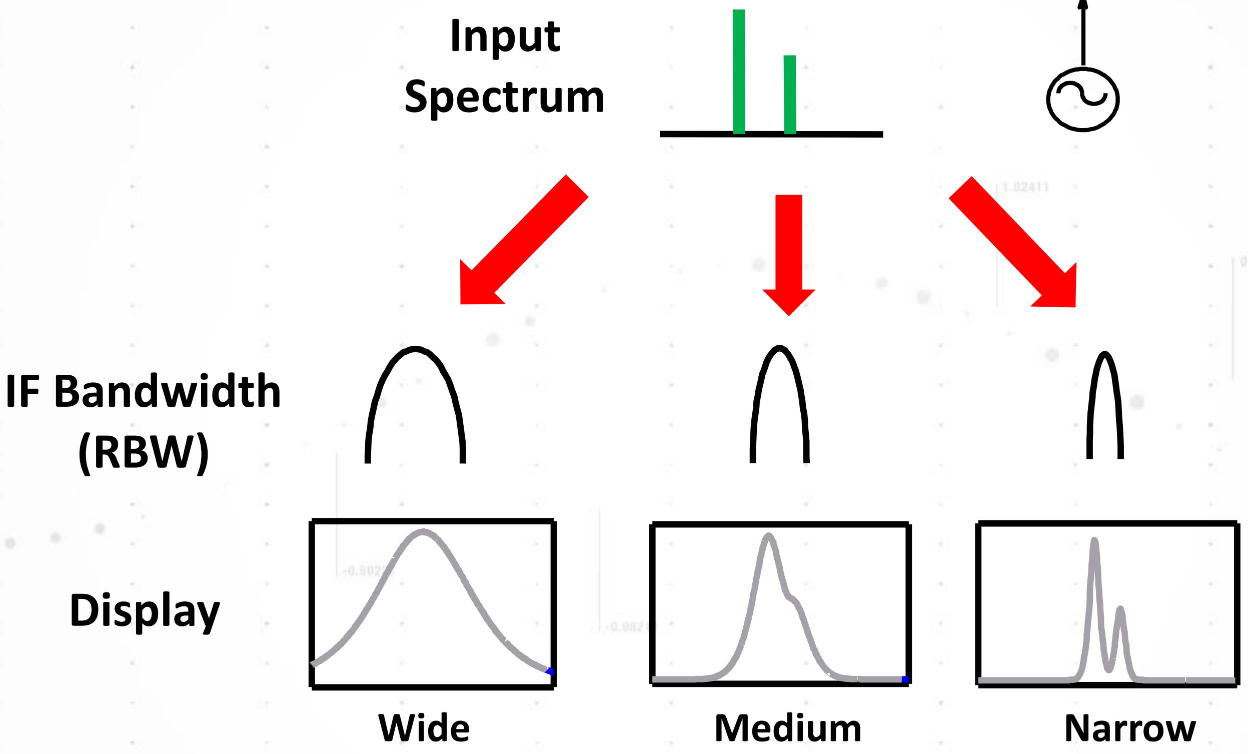


Sometimes use ***<u>other</u>*** mix product
Some use ***<u>2</u>*** mixers
Some mix ***<u>up</u>*** in frequency

Theory of Operation

Resolution Bandwidth (RBW)



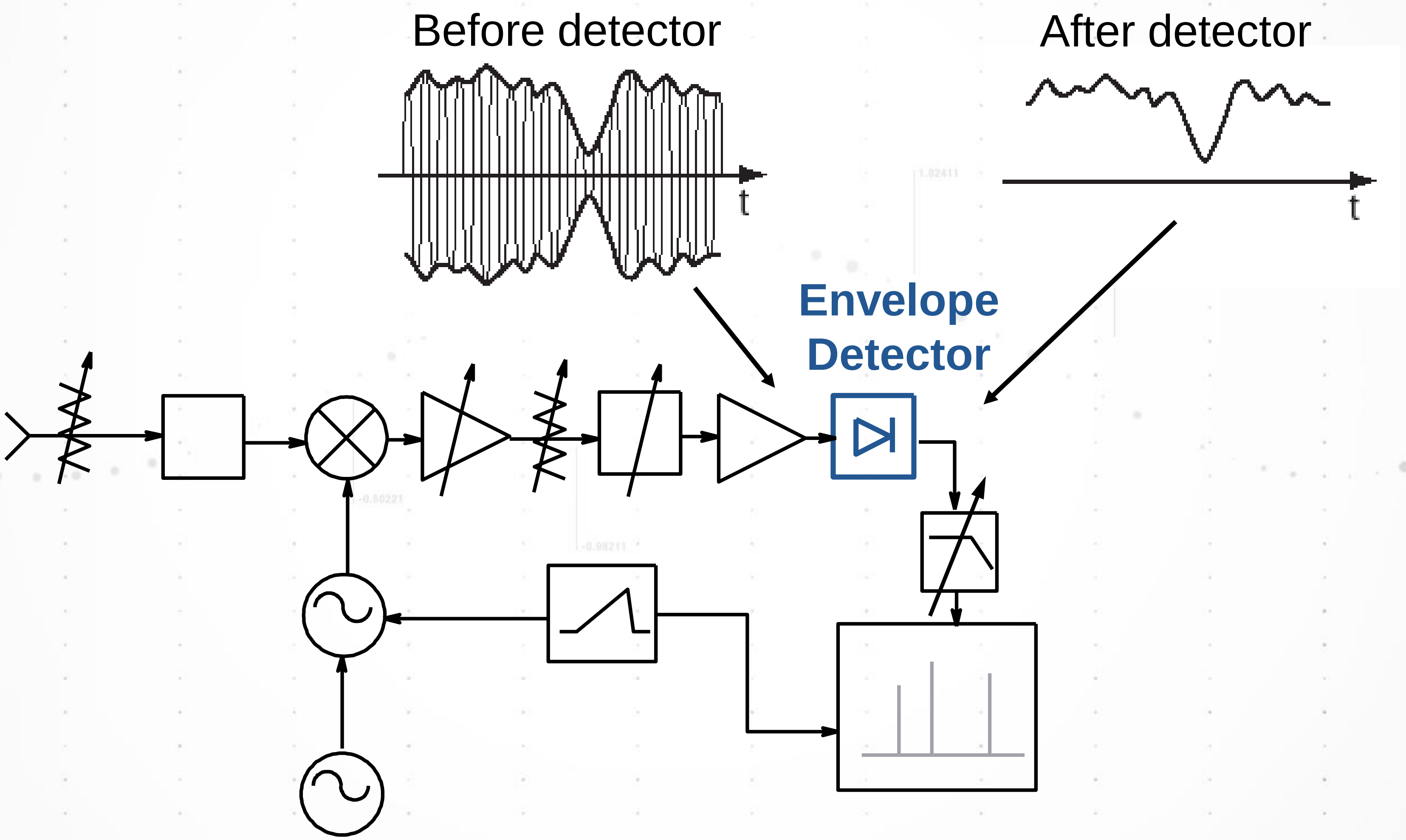


Faster
See Wide Freq

Resolve in Freq
Reduce Noise Floor

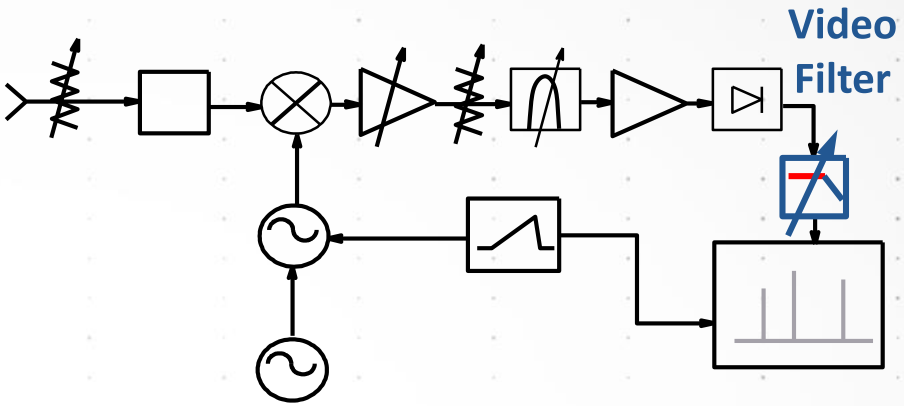
Theory of Operation

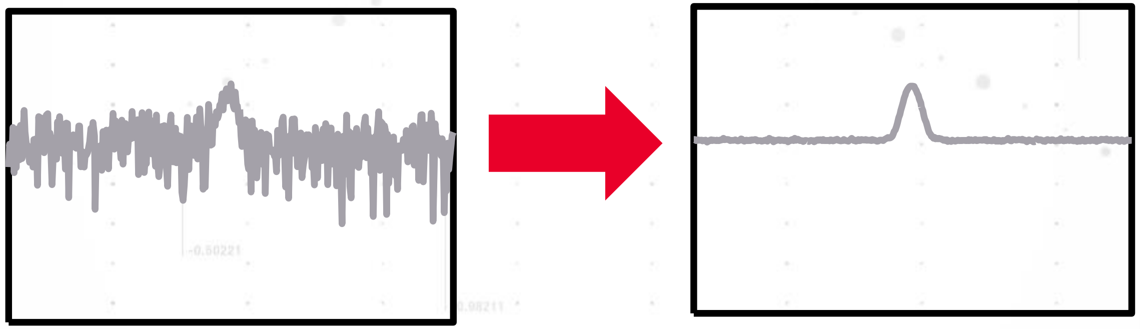
Detector



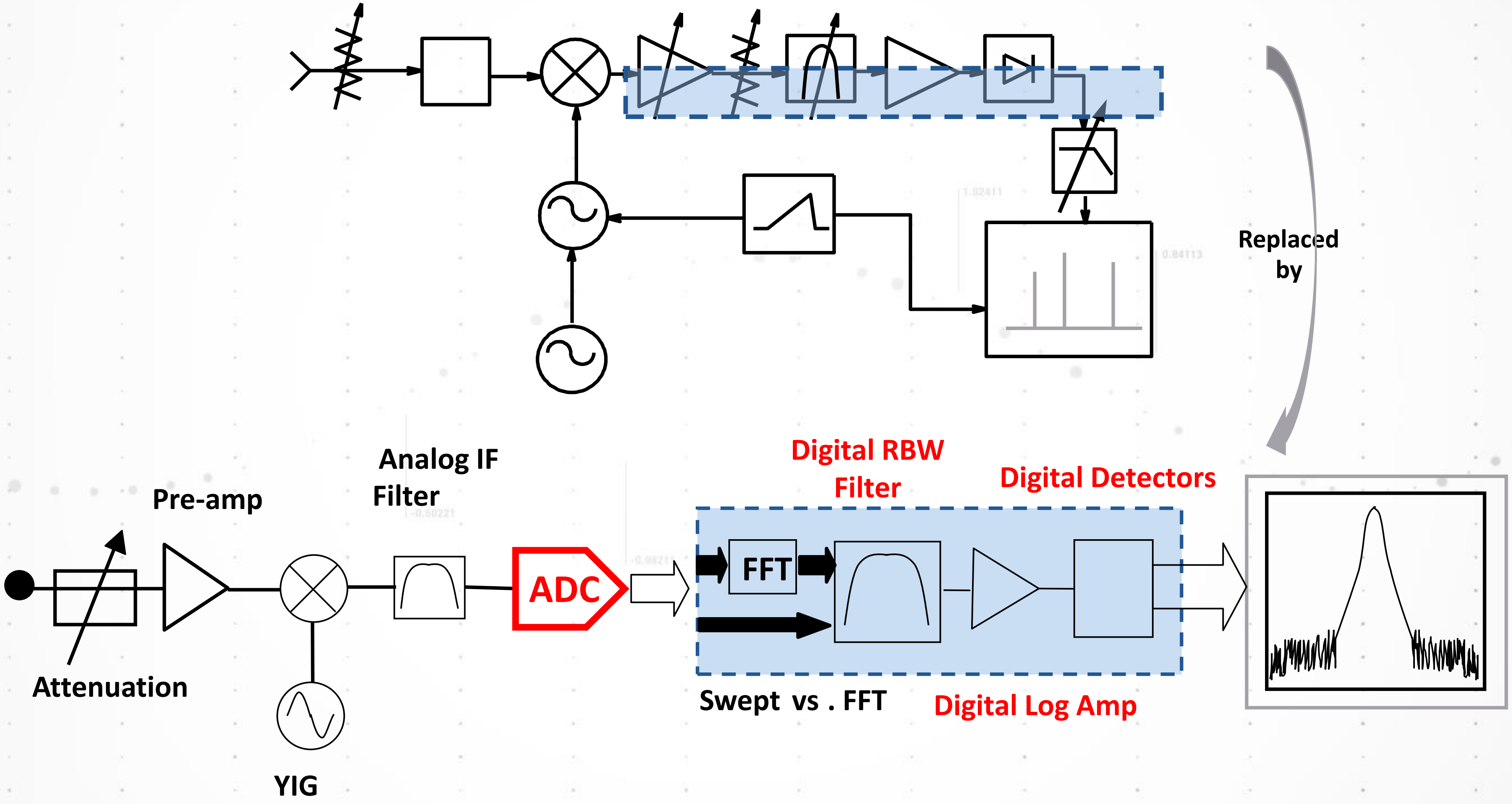
Theory of Operation

Video Bandwidth (VBW)



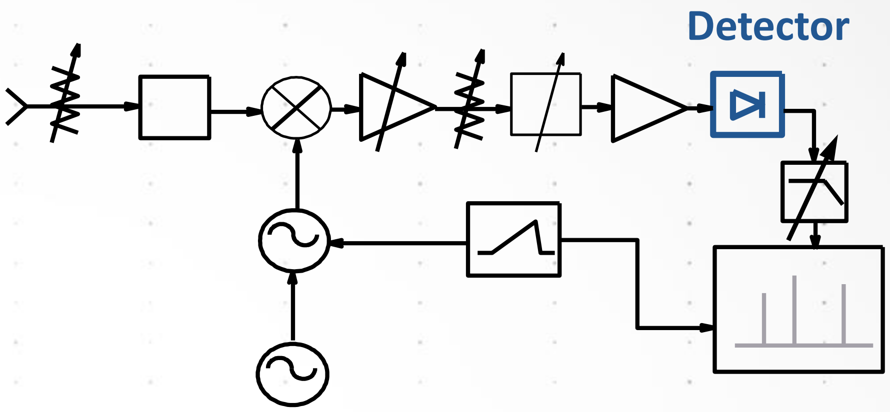


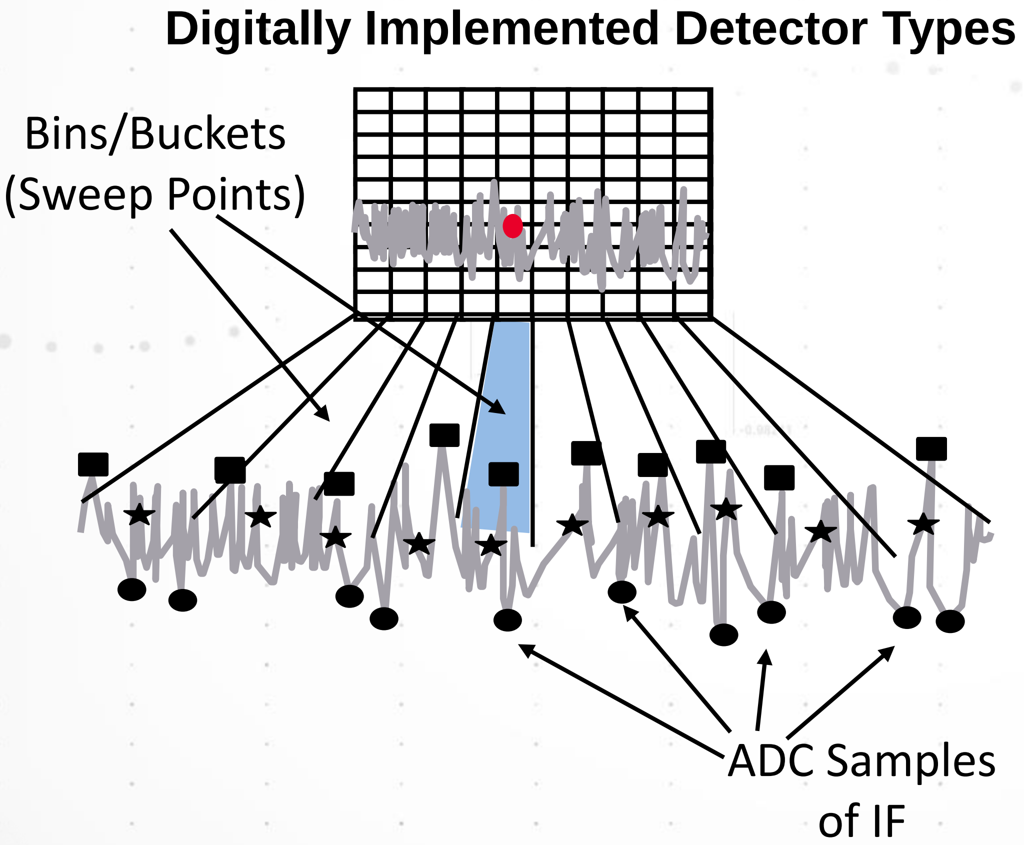
Modern Digital IF



Modern Digital IF

Detection Types





■ **Positive:** largest sample in bin displayed

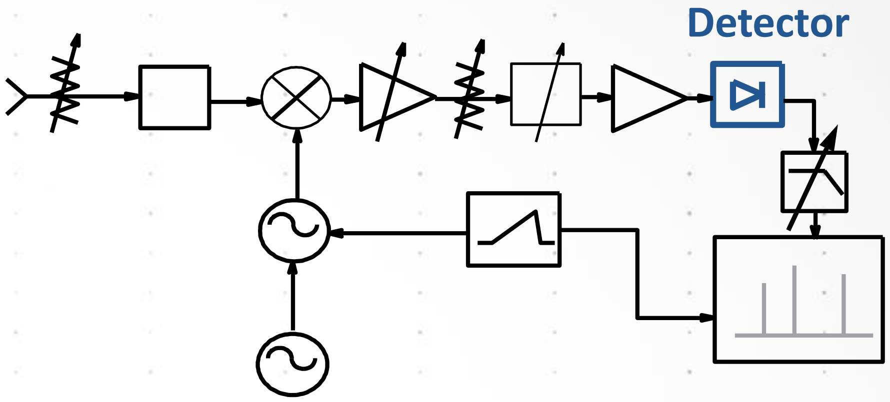
● **Negative:** smallest sample in bin displayed

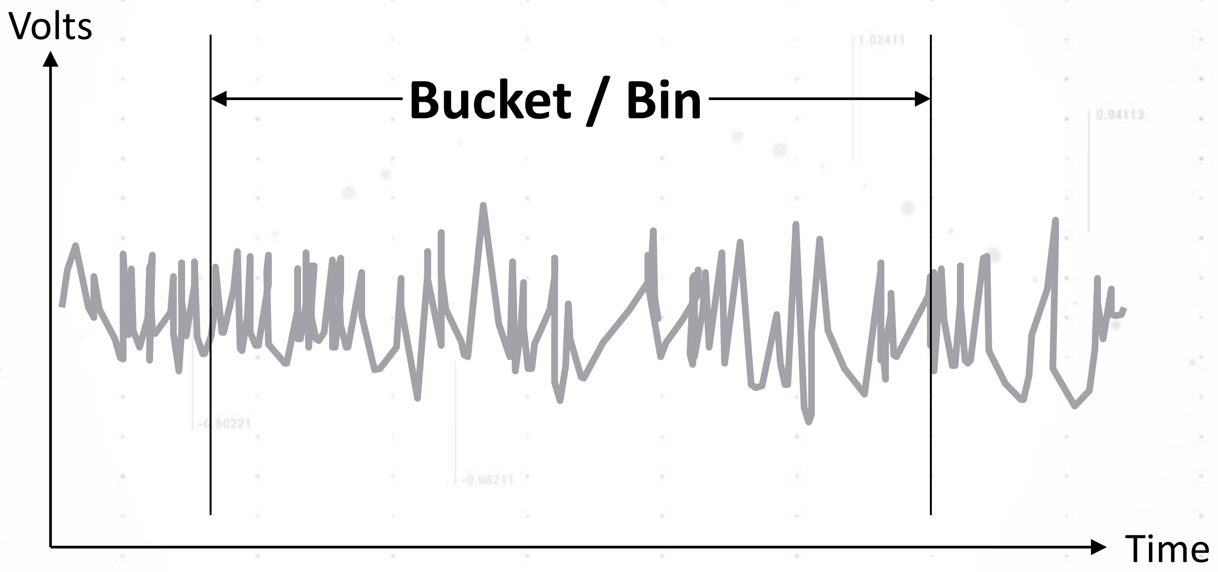
★ **Sample:** middle sample in bin displayed

Normal ("Rosenfell"): selects sample to display using algorithm that treats noise and signals differently

Modern Digital IF

Average Detector Type

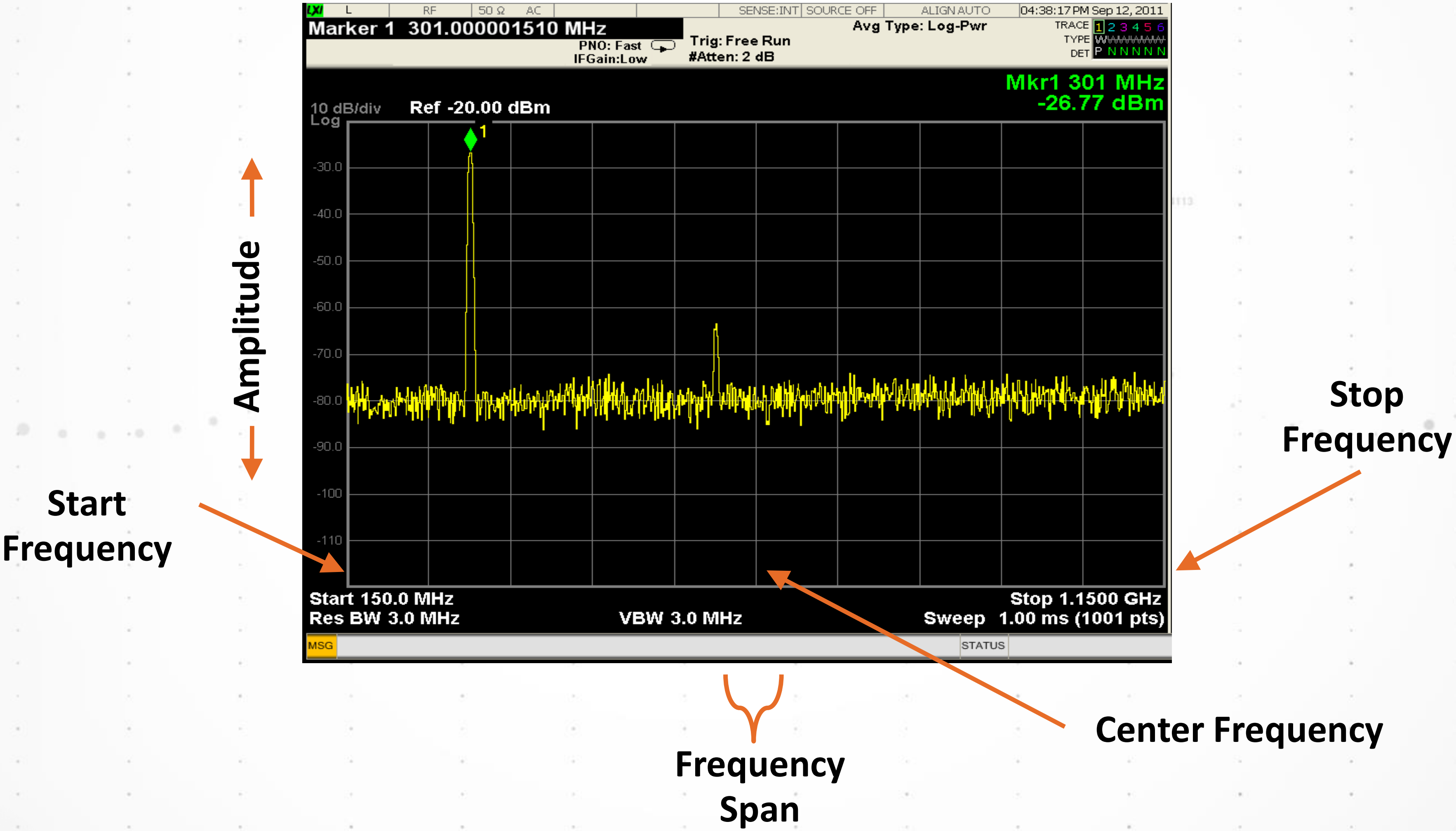




Power Average Detector (RMS): Square-root of the sum of the squares of ALL samples in the bin, expressed as power in 50Ω

Theory of Operation

Display Terminology



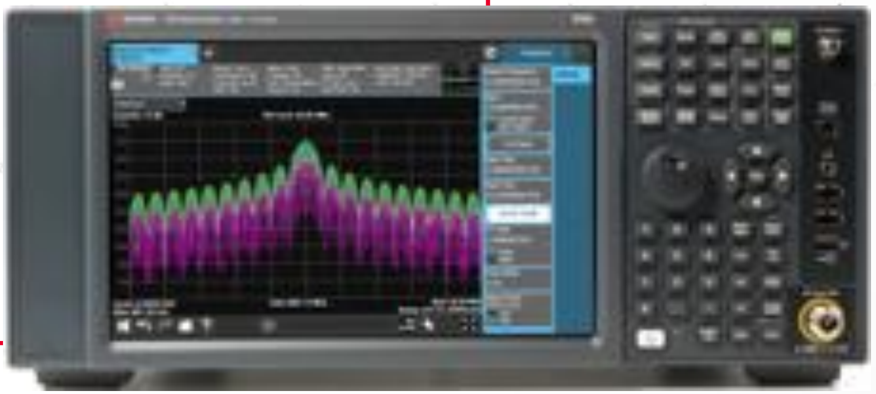
Engineers Never Stop Learning

SIGNAL ANALYSIS FUNDAMENTALS

- Overview
- Theory of Operation
  - Traditional Spectrum Analyzers
  - Modern Signal Analyzers
- Specifications
- Features
- Wrap-up

Key Specifications

- Safe spectrum analysis
- Frequency Range
- Accuracy: Frequency & Amplitude
- Resolution
- Sensitivity
- Distortion
- Dynamic Range



Specifications

Accuracy: Frequency Readout Accuracy

Frequency Readout Accuracy =

± [(Marker Frequency x Frequency Reference Accuracy) + (0.1% x Span) + (5% x RBW) + 2Hz + (0.5 x Horizontal Resolution)]

Frequency Reference Accuracy = ± [(time since last adjustment **x** aging rate) + temperature stability + calibration accuracy] = **1.55 x 10^{-7}/ year**

Horizontal Resolution = span / (sweep points – 1)

Example: 1 GHz Marker Frequency, 400 kHz Span, 3 kHz RBW, 1000 Sweep Points

Calculation: (1×10^9Hz) x ($\pm 1.55 \times 10^{-7}$/Year) = 155 Hz

400kHz Span x 0.1% = 400 Hz

3kHz RBW x 5% = 150 Hz

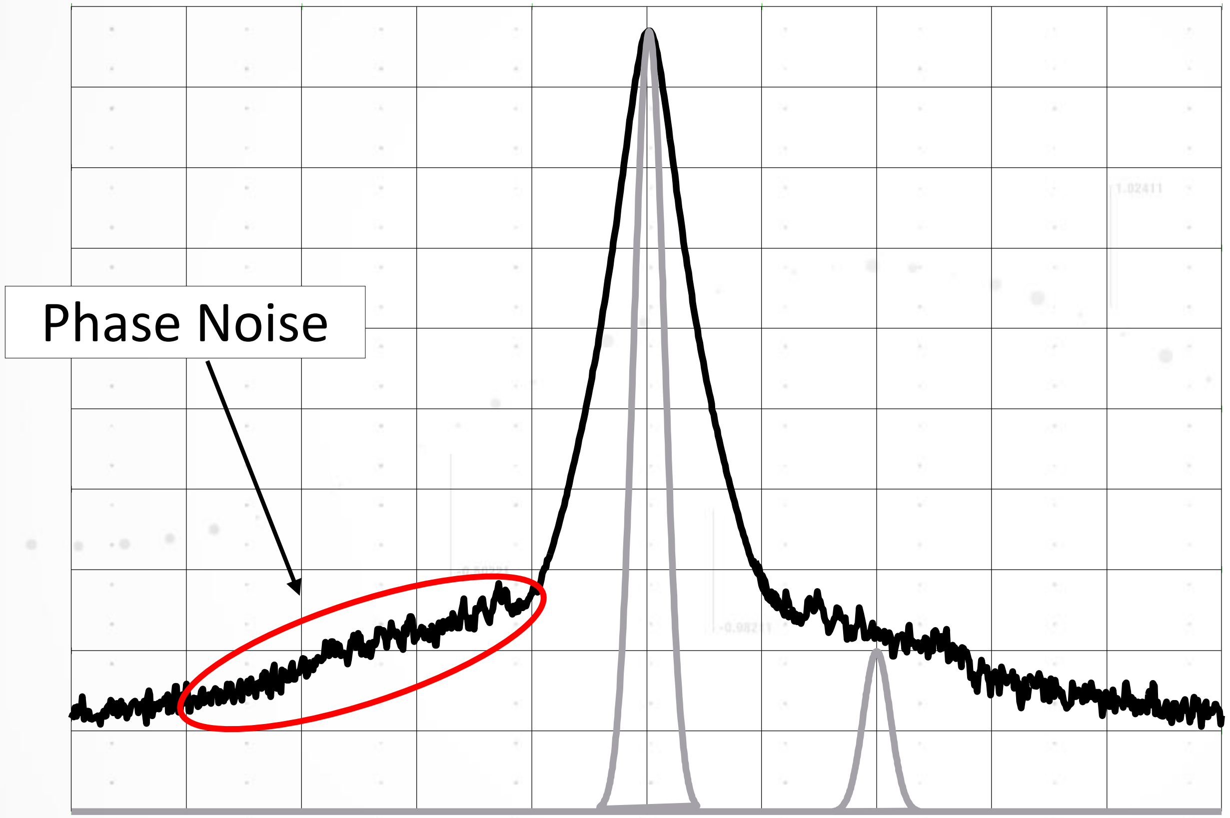
2Hz + 0.5 x 400kHz/(1000-1) = 202 Hz

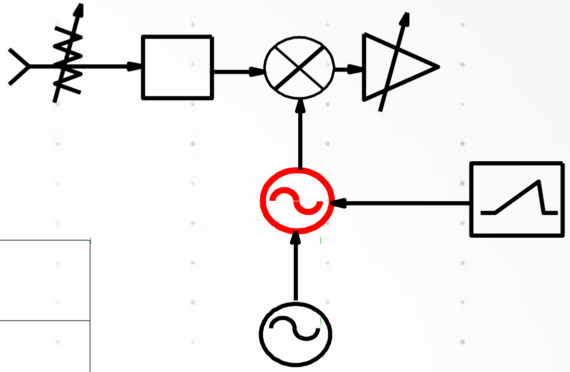
Total uncertainty = ±907 Hz

- Utilizing internal frequency counter improves accuracy to ±155 Hz
- The maximum number of sweep points for the X-Series Analyzers is 40,001 which helps to achieve the best frequency readout accuracy

Specifications

Phase Noise or Noise Sidebands

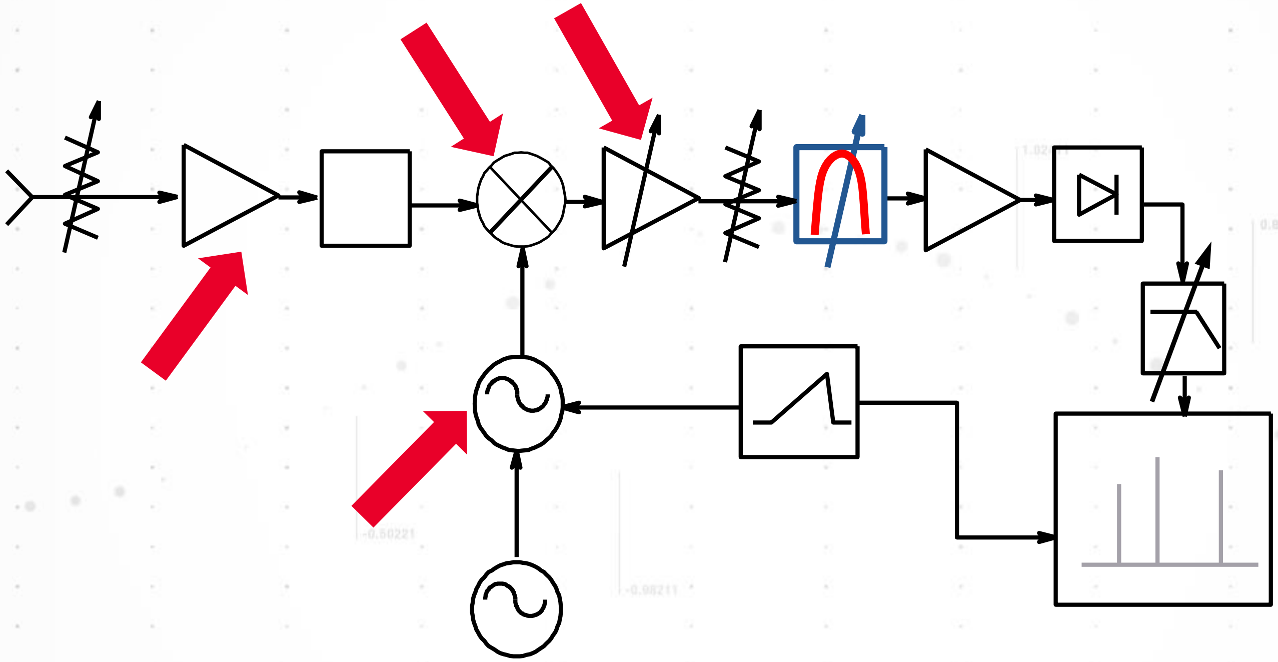




Noise sidebands can prevent resolution of unequal signals.

Specifications

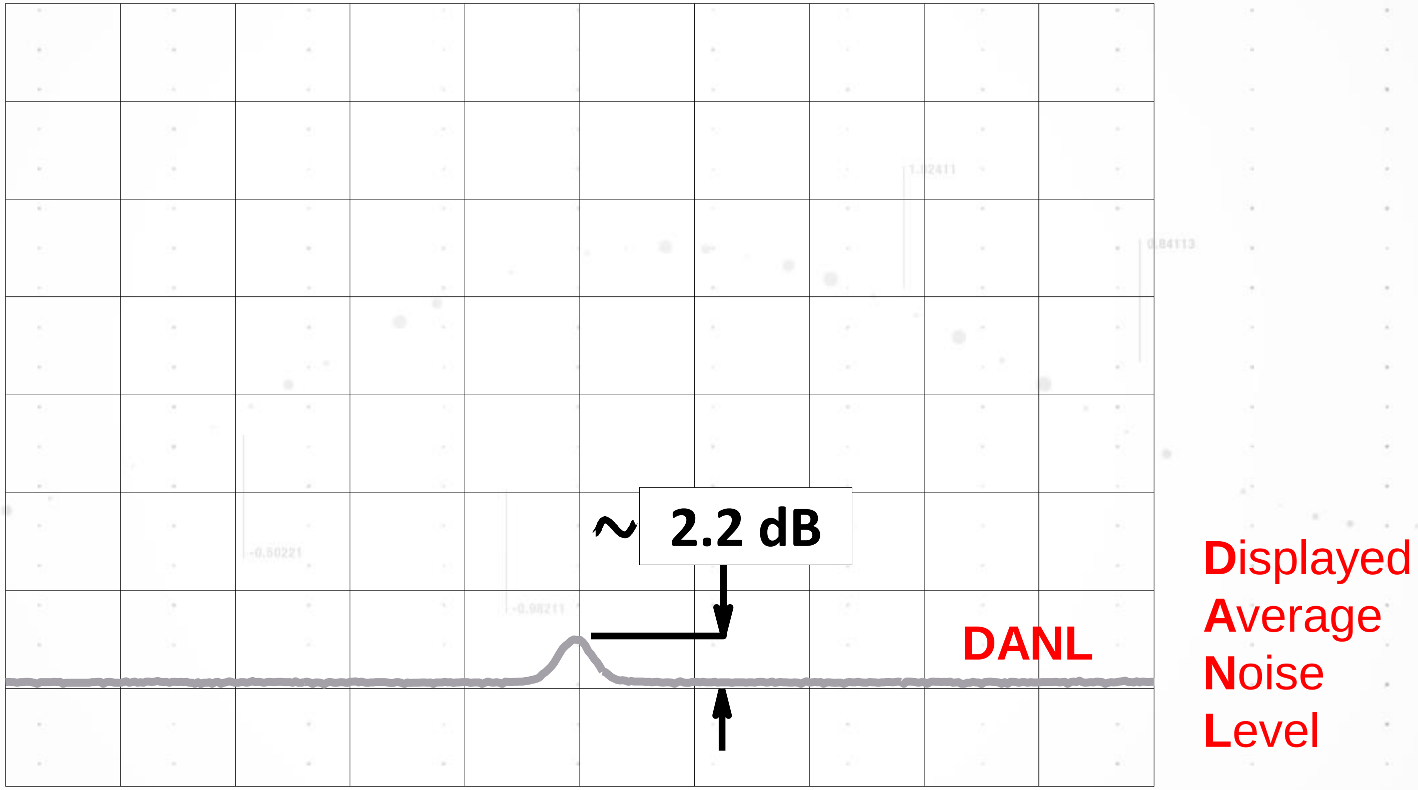
Sensitivity



All active electronic circuits generate noise – including spectrum analyzers.

Specifications

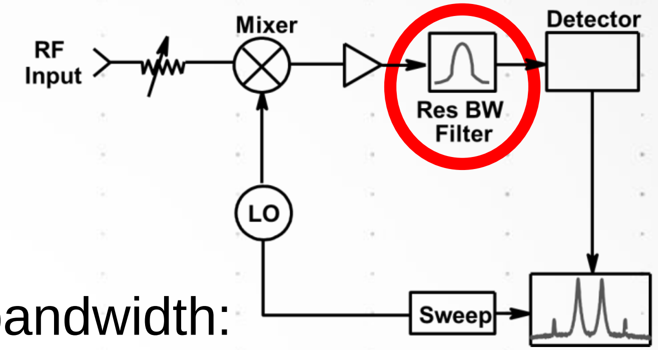
Sensitivity



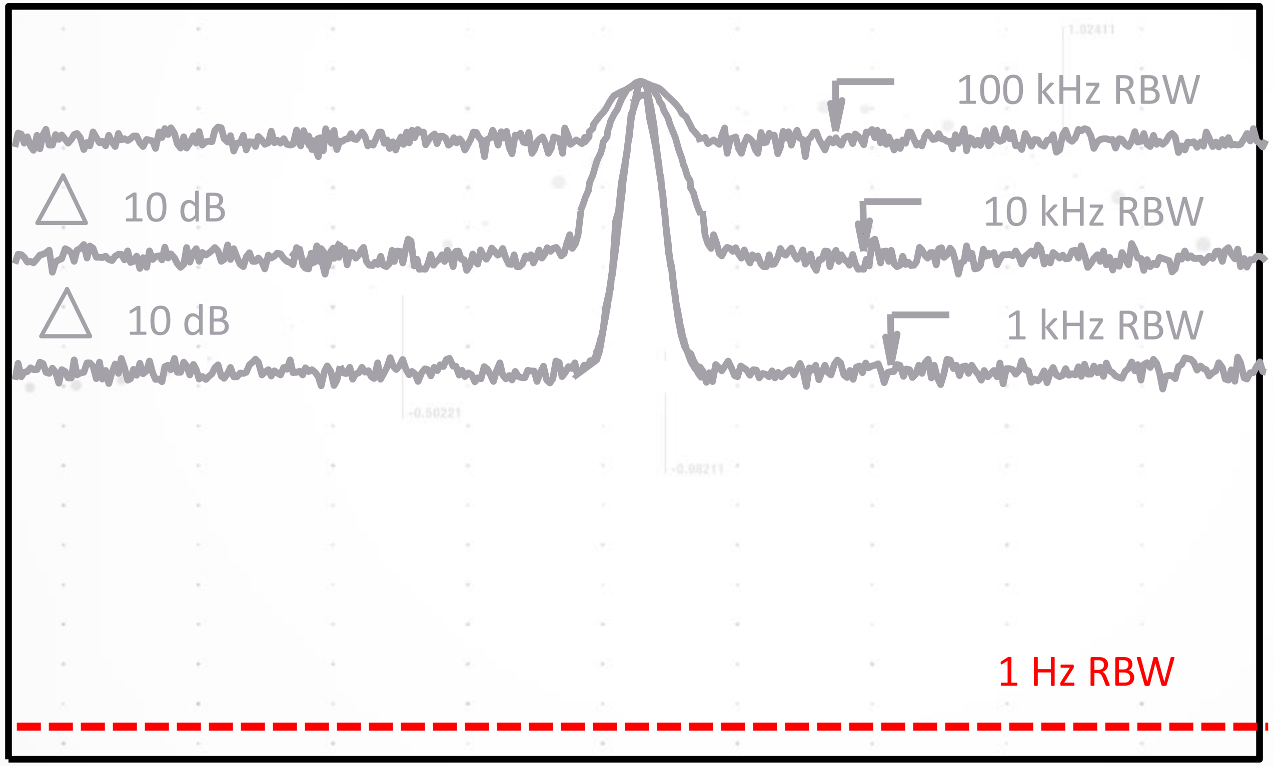
Sensitivity is the smallest signal that can be measured.

Specifications

Sensitivity/DANL: RBW Filter



Displayed noise is a function of RBW filter bandwidth: noise decreases as bandwidth decreases.

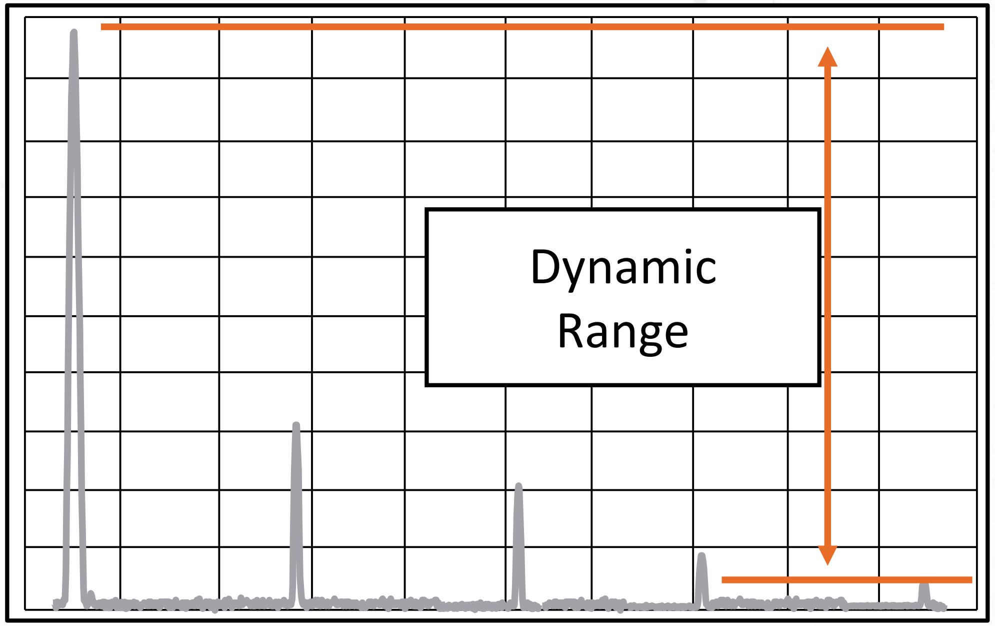


DANL spec'ed in 1 Hz RBW

Specifications

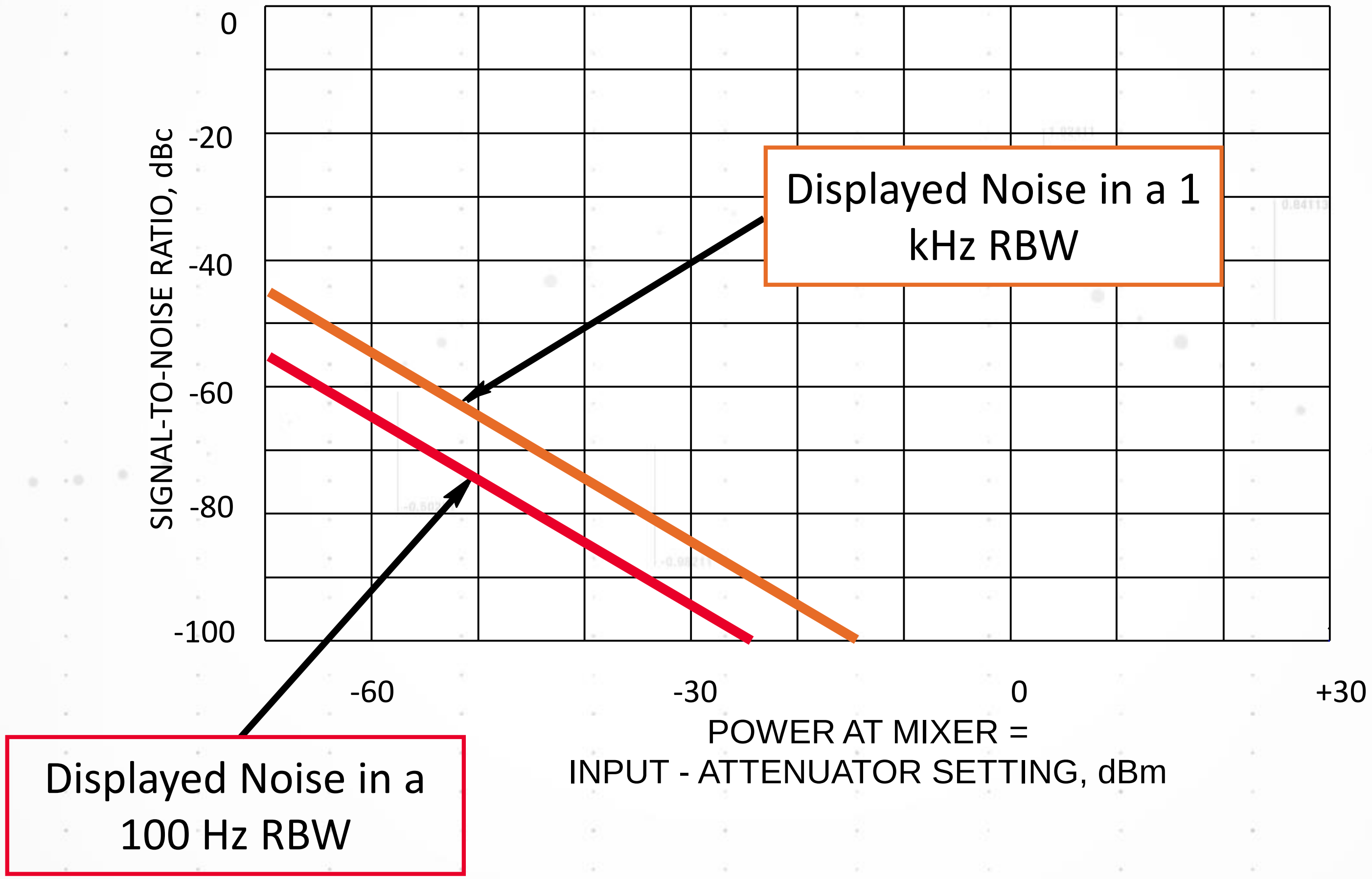
Dynamic Range

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.



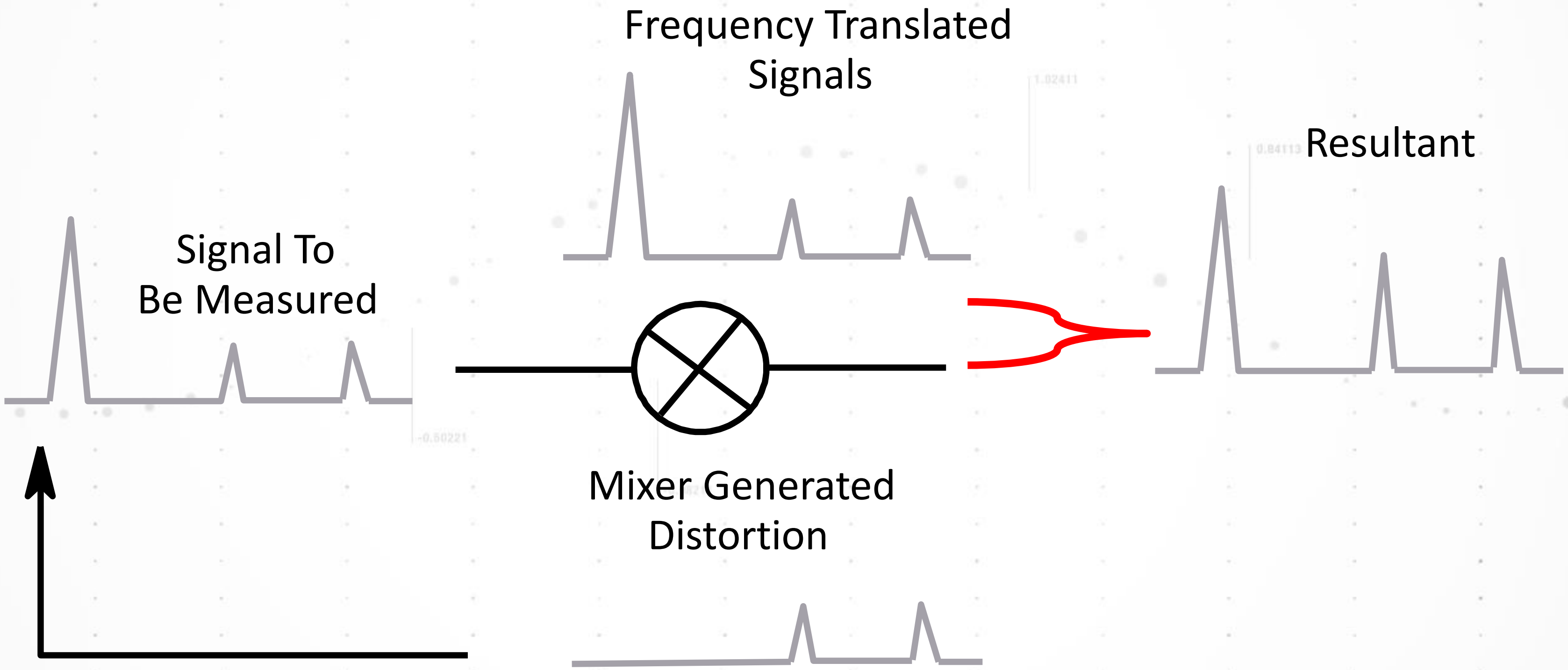
Specifications

Displayed DANL per RBW and Mixer Input Power



Specifications

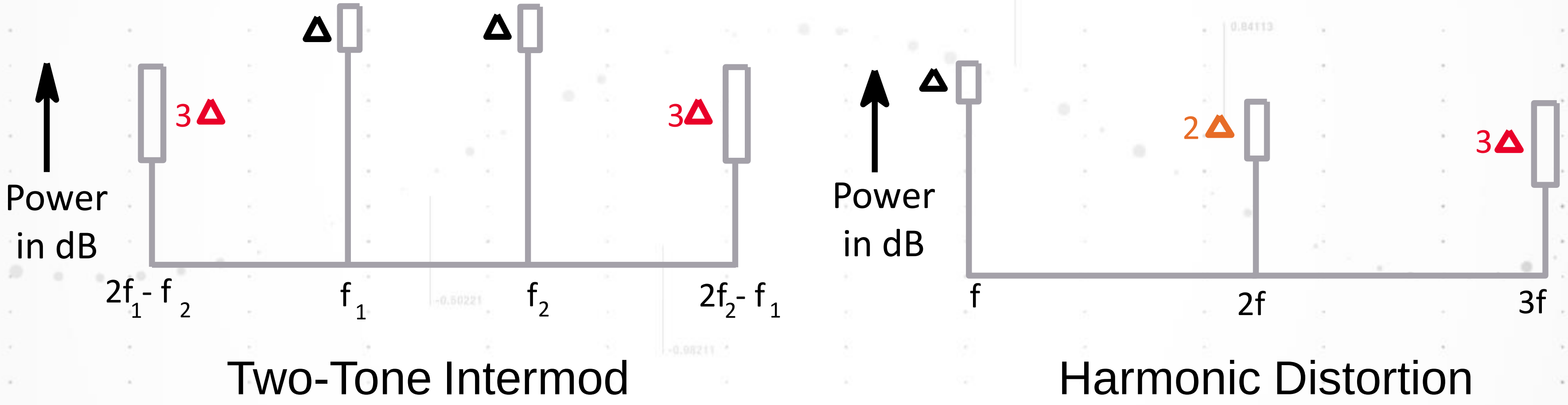
Distortion: Mixers



Specifications

Distortion: Second and Third Order

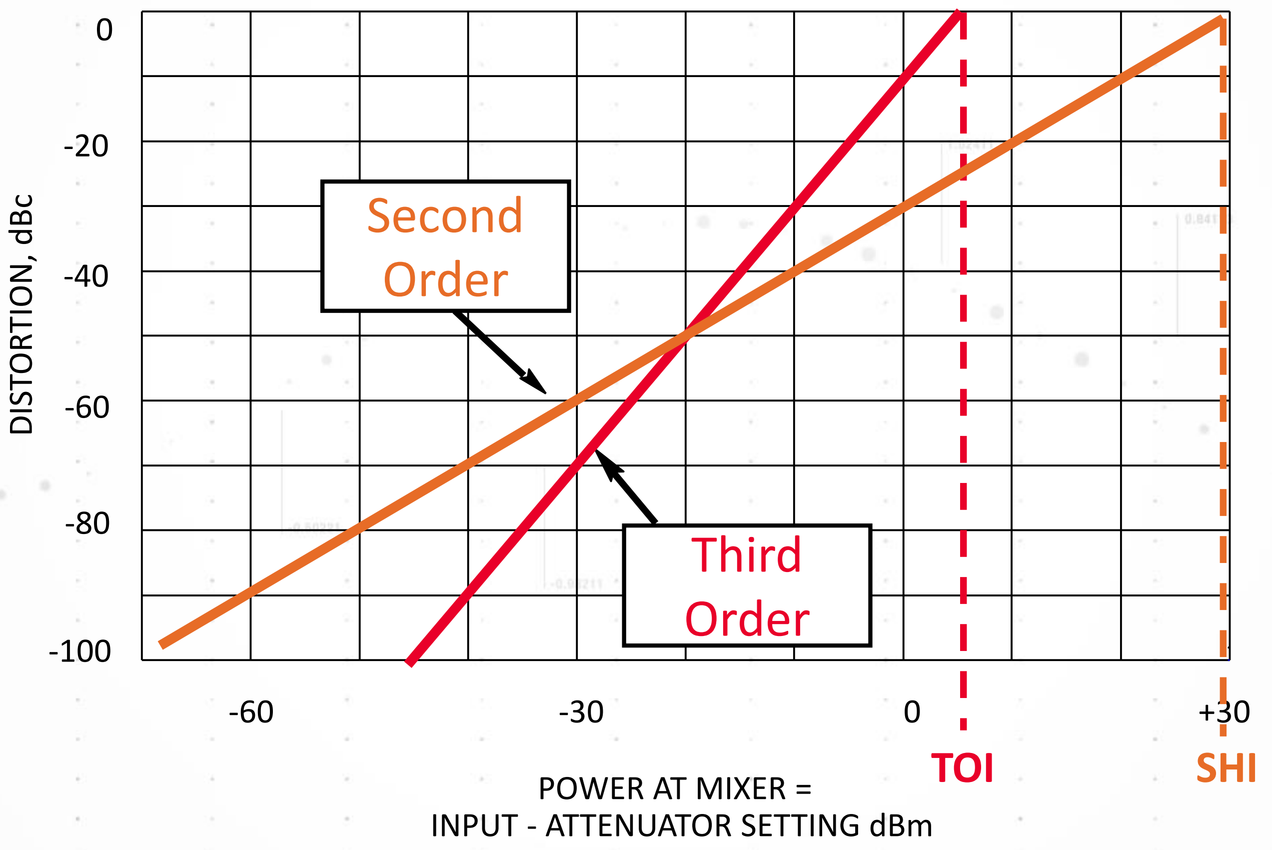
Distortion products increase as a function of fundamental's power.



Third Order: △3 dB/dB of Fundamental
Second Order: △2 dB/dB of Fundamental

Specifications

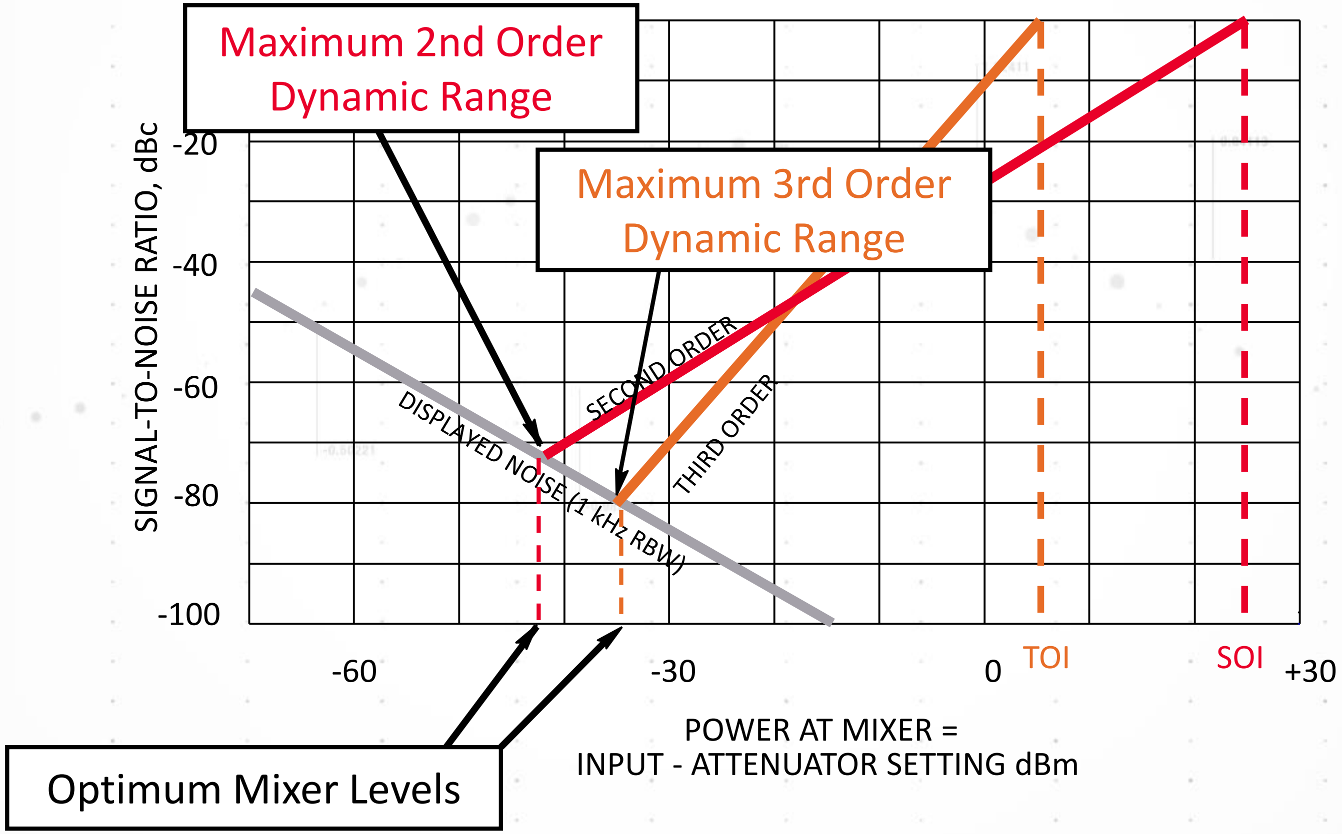
Distortion: A Function of Mixer Level



Specifications

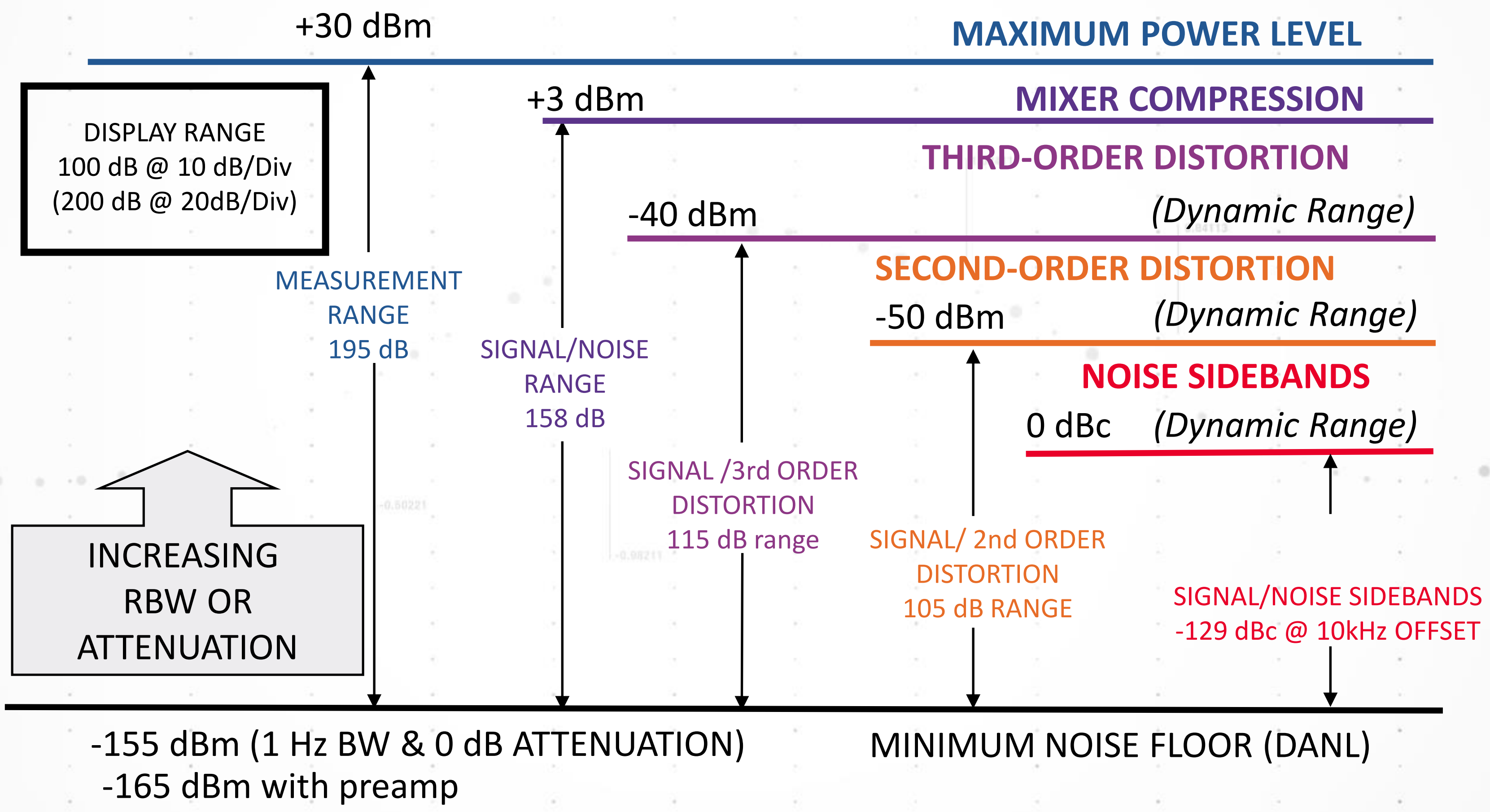
Dynamic Range (DANL, RBW, Distortion)

Dynamic range can be presented graphically.



Specifications

Dynamic Range vs Measurement Range



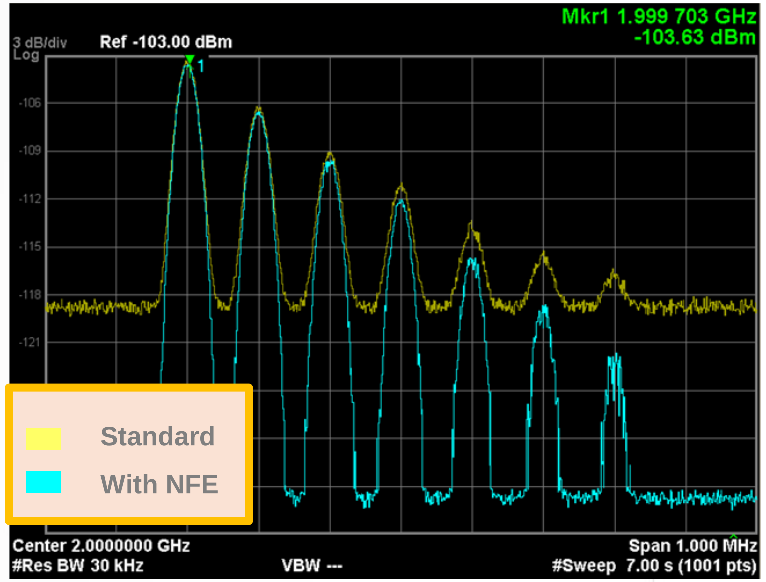
Engineers Never Stop Learning

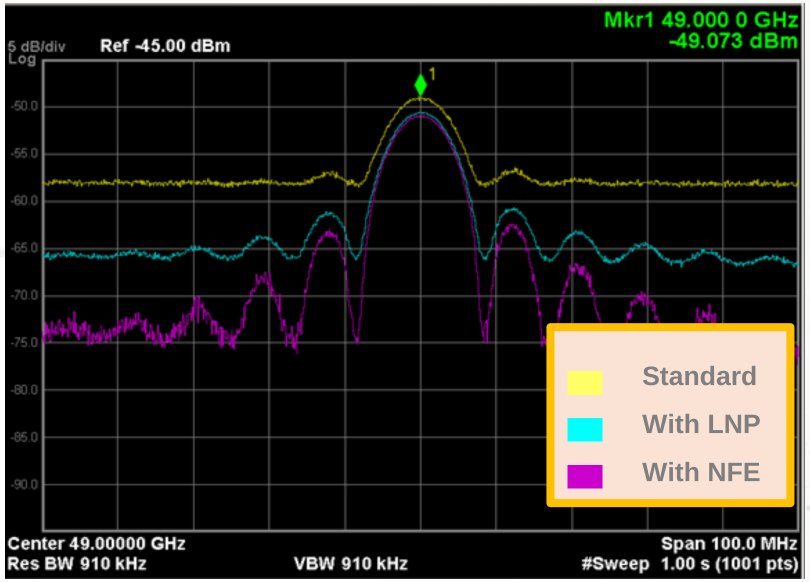
SIGNAL ANALYSIS FUNDAMENTALS

- Overview
- Theory of Operation
  - Traditional Spectrum Analyzers
  - Modern Signal Analyzers
- Specifications
- Features
- Wrap-up

Features

Noise Floor Extension





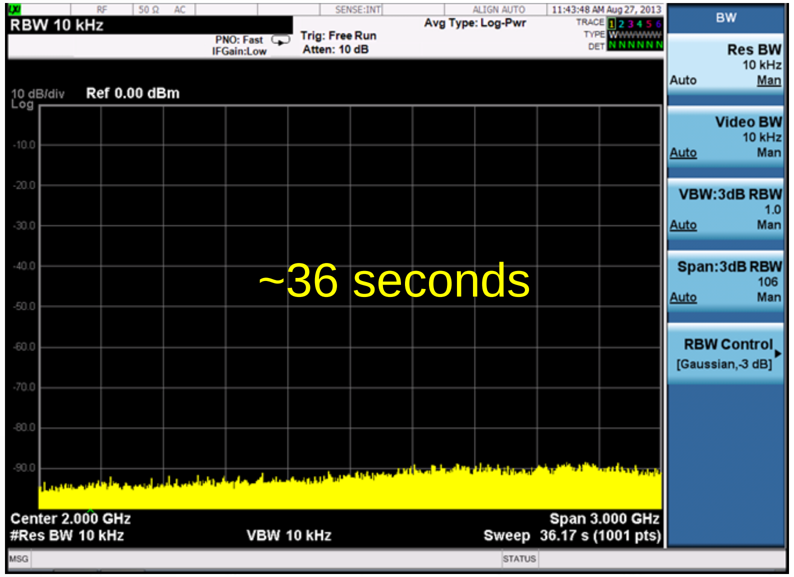
- **NFE** lowers the noise floor (DANL) of the SA, by measuring its own noise (no input), and subtracting that noise power. This only works with high averaging (low variance). The improvement can be up to 8-12 dB, depending on nature of signal near noise.
- **NF2** is “adaptive” NFE. It applies noise subtraction gradually, in proportion to averaging and reduced variance. The trace appears less chaotic while gathering averages.

Features

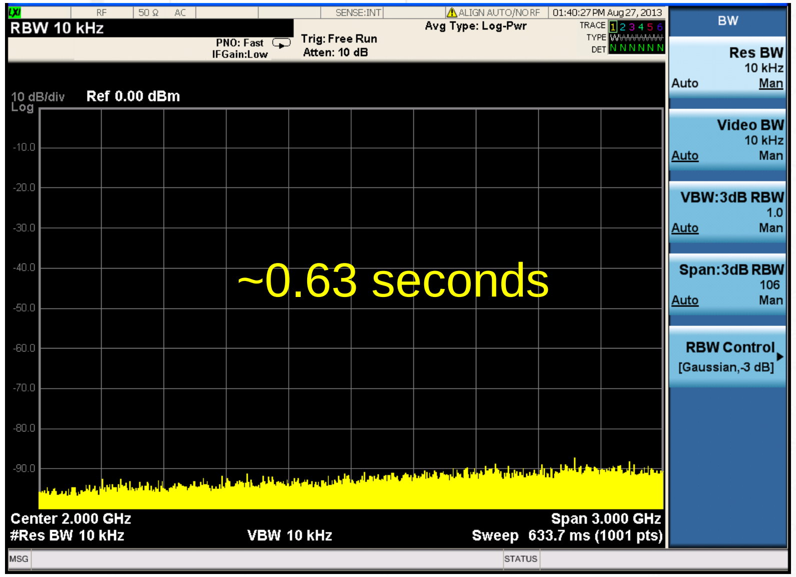
Fast Sweep Processing

RBW filter can be "over-swept": too fast to fully respond.

But in digital filters, this error is well-known, and can be corrected.



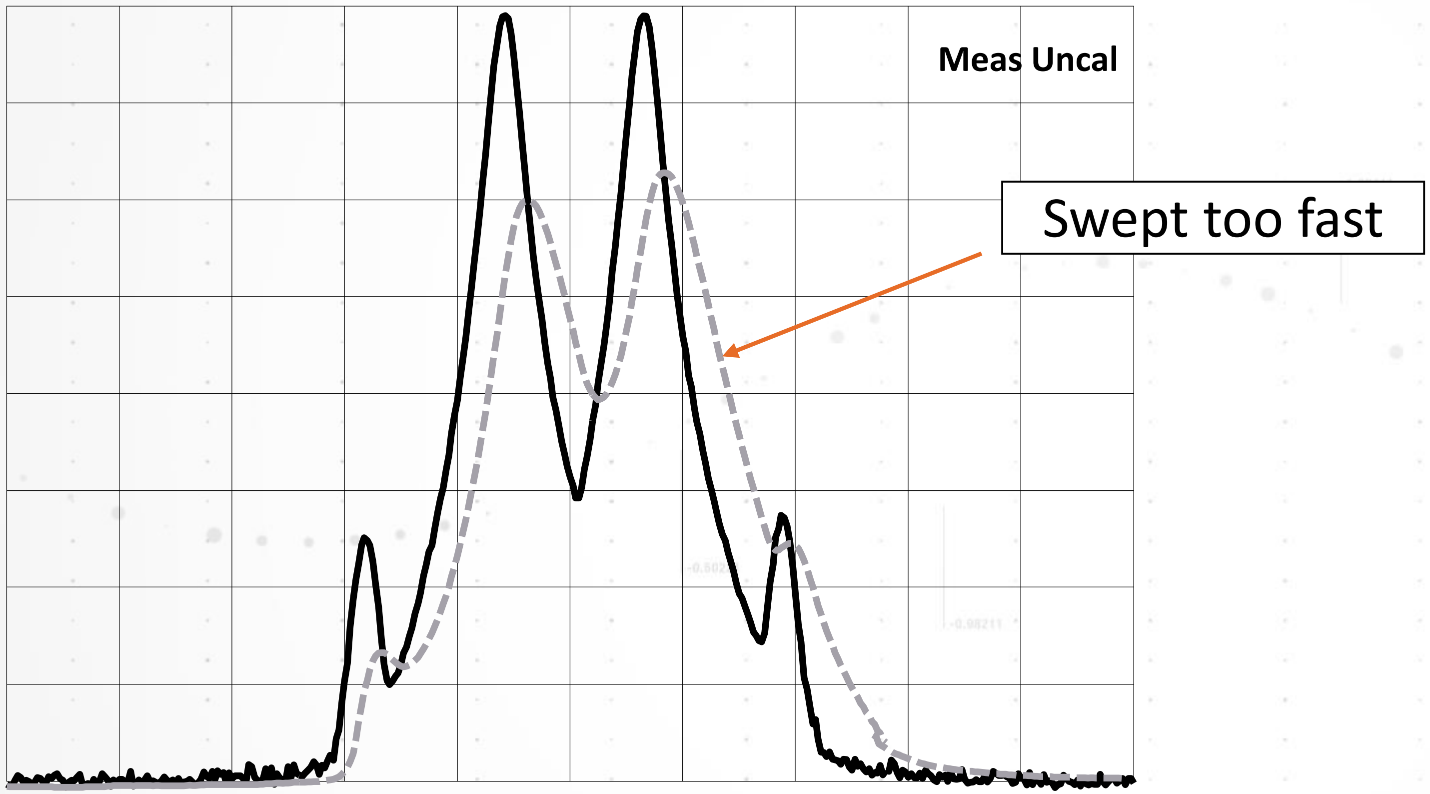
Sweep without fast sweep enabled



Sweep with fast sweep enabled

Specifications

Resolution: RBW Determines Sweep Time

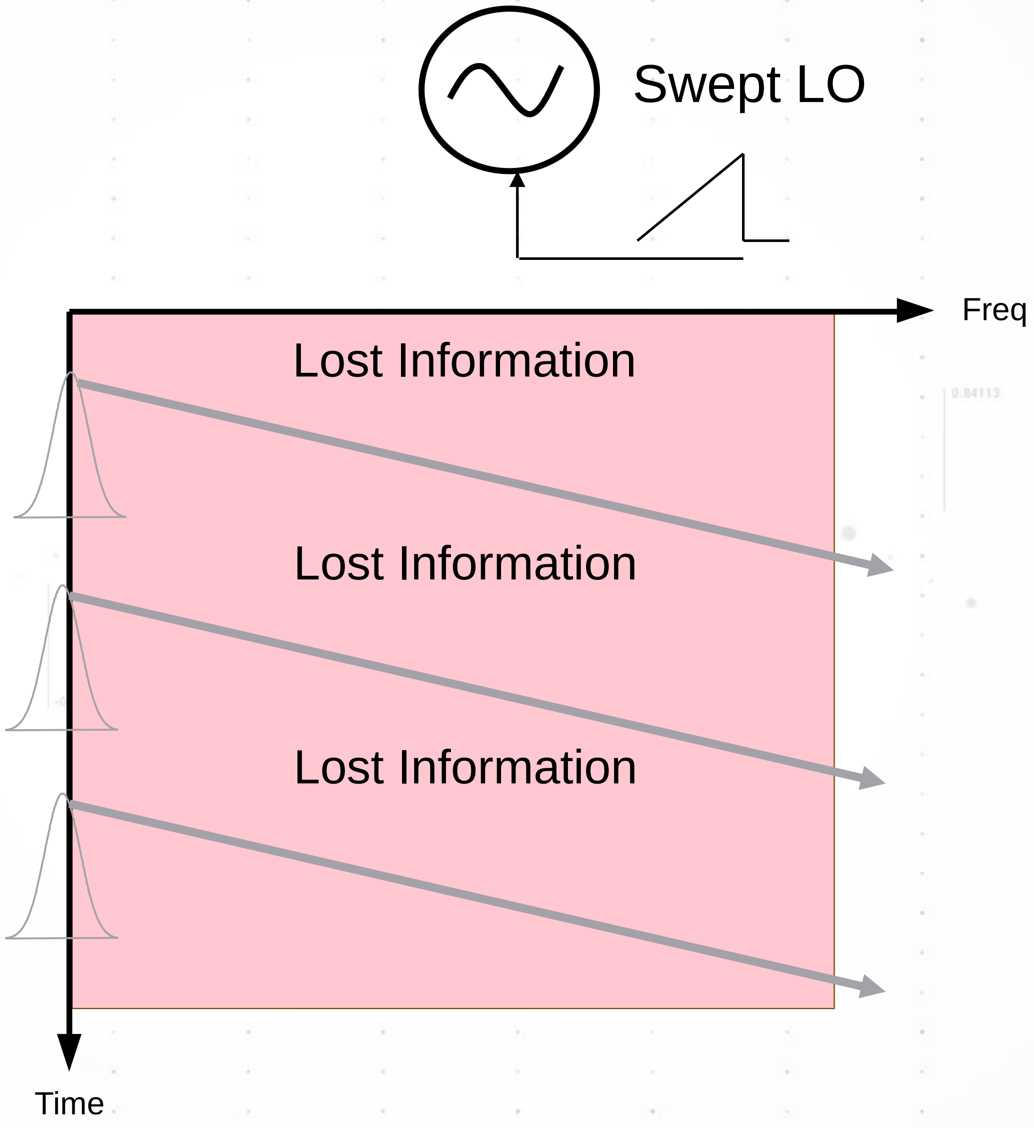


The penalty for sweeping too fast is an uncalibrated display.

Data Acquisition and Processing

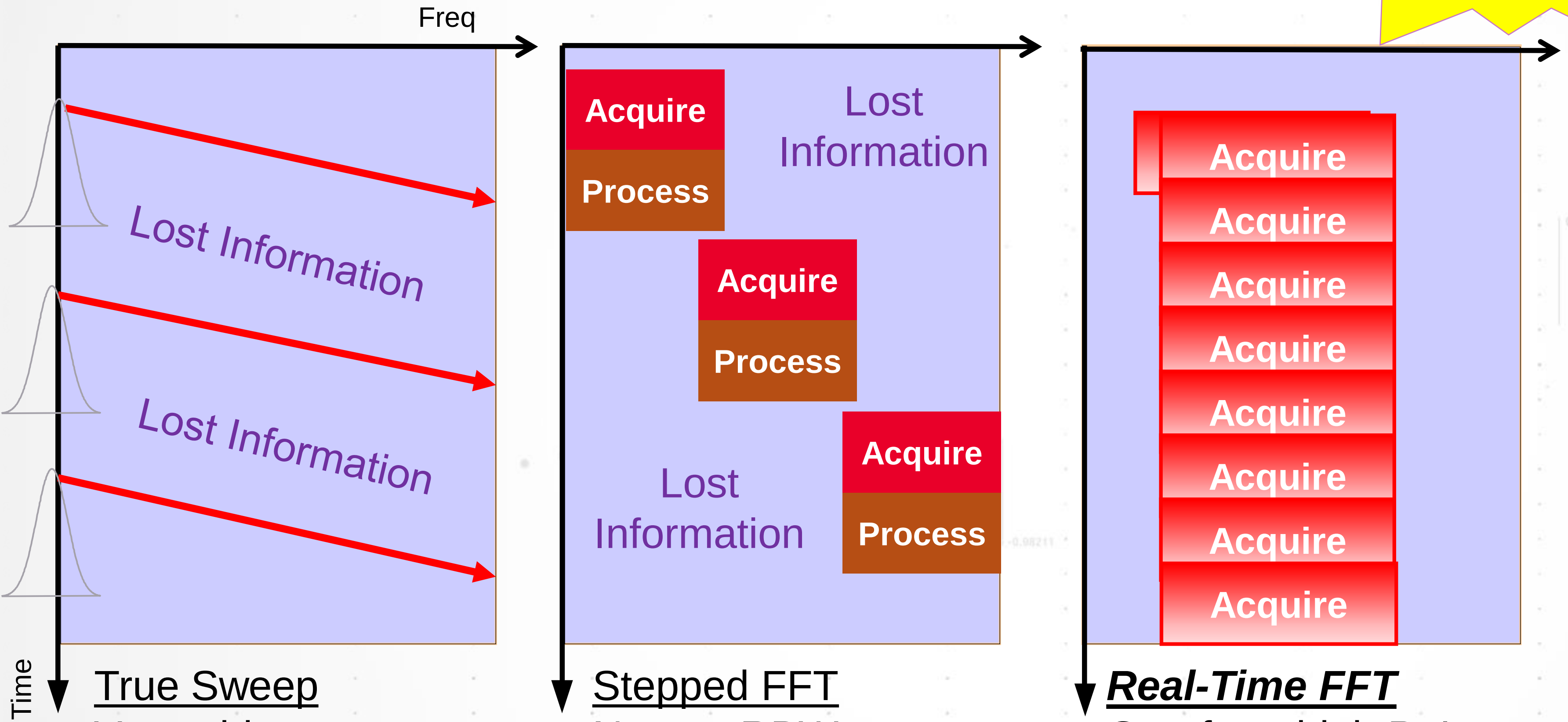
Swept Mode

- A swept LO w/ an assigned RBW.
- Covers much wider span.
- Good for events that are stable in the frequency domain.
- Magnitude ONLY, no phase information (scalar info).
- Captures only events that occur at right time and right frequency point.
- Data (info) loss when LO is “not there”.



Real-Time Spectrum Analysis

Acquisition is continuous and *gap-free*! FFT Process runs fast *during* Acquisition!



True Sweep
Very wide spans
Stationary, repetitive

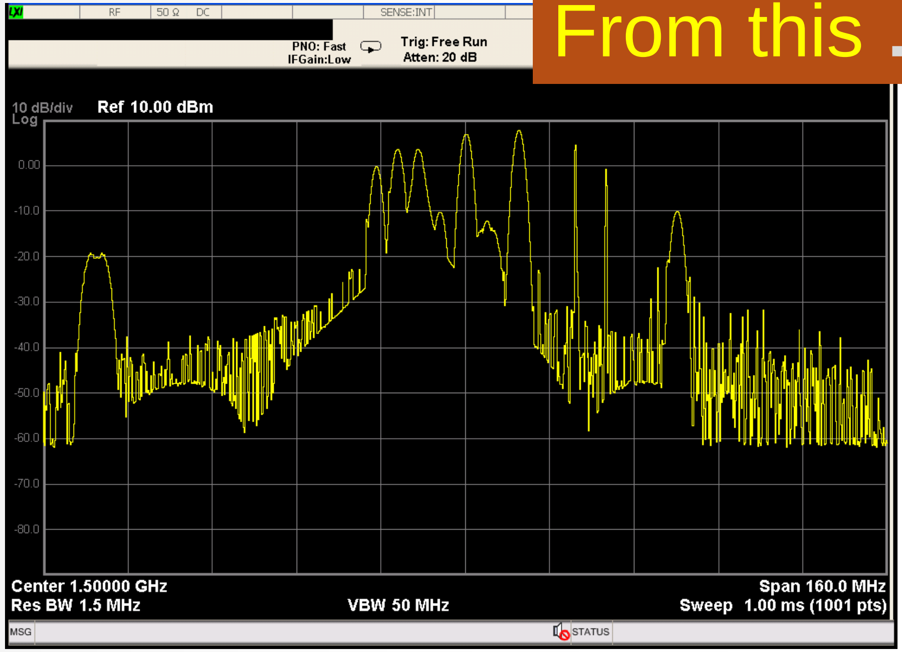
Stepped FFT
Narrow RBW

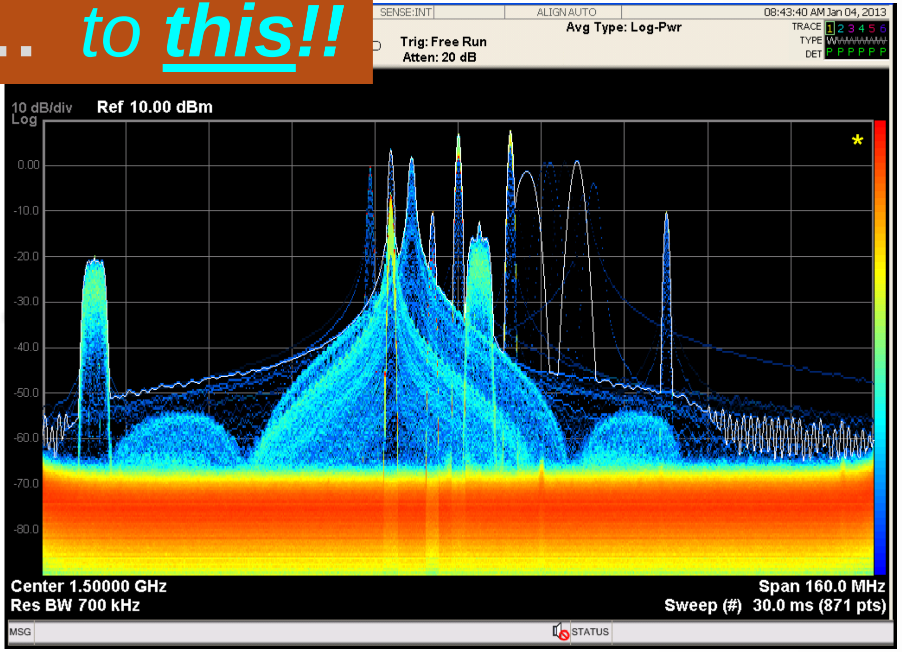
Real-Time FFT
Gap-free, high PoI
Span of Digitizer

Real-Time Spectrum Analysis

Swept vs RTSA

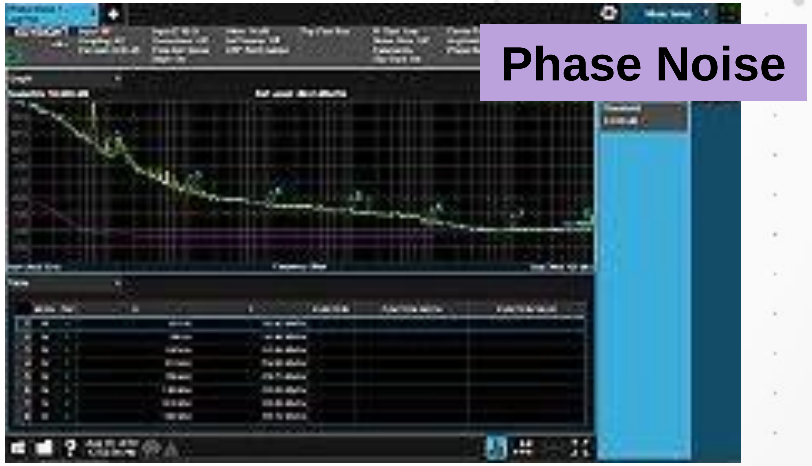
From this … *to this!!*





Detect signals as brief as 3.5 us
Density (histogram) color-map display
Persistence: brief events stay visible
Capture rare events with FMT trigger

Get More from Your Analyzer



Extend Frequencies to 110 GHz and Beyond

- **N9041B** “flagship” covers 3 Hz to 110 GHz
- DANL ~150 dBm at 60 GHz
- 1 GHz BW internal, 5-8 GHz via IF Out to external digitizer/oscilloscope

- M1971V/E/W “Smart” External Mixers to 110 GHz, waveguide, dual-conversion, wide BW out
- Legacy: M1970V/E/W and 11970 Series
- 3rd party mixers & converters, to 1.1 THz
  - OML Inc.
  - VDI

Vector Demodulation, Wide Bandwidth

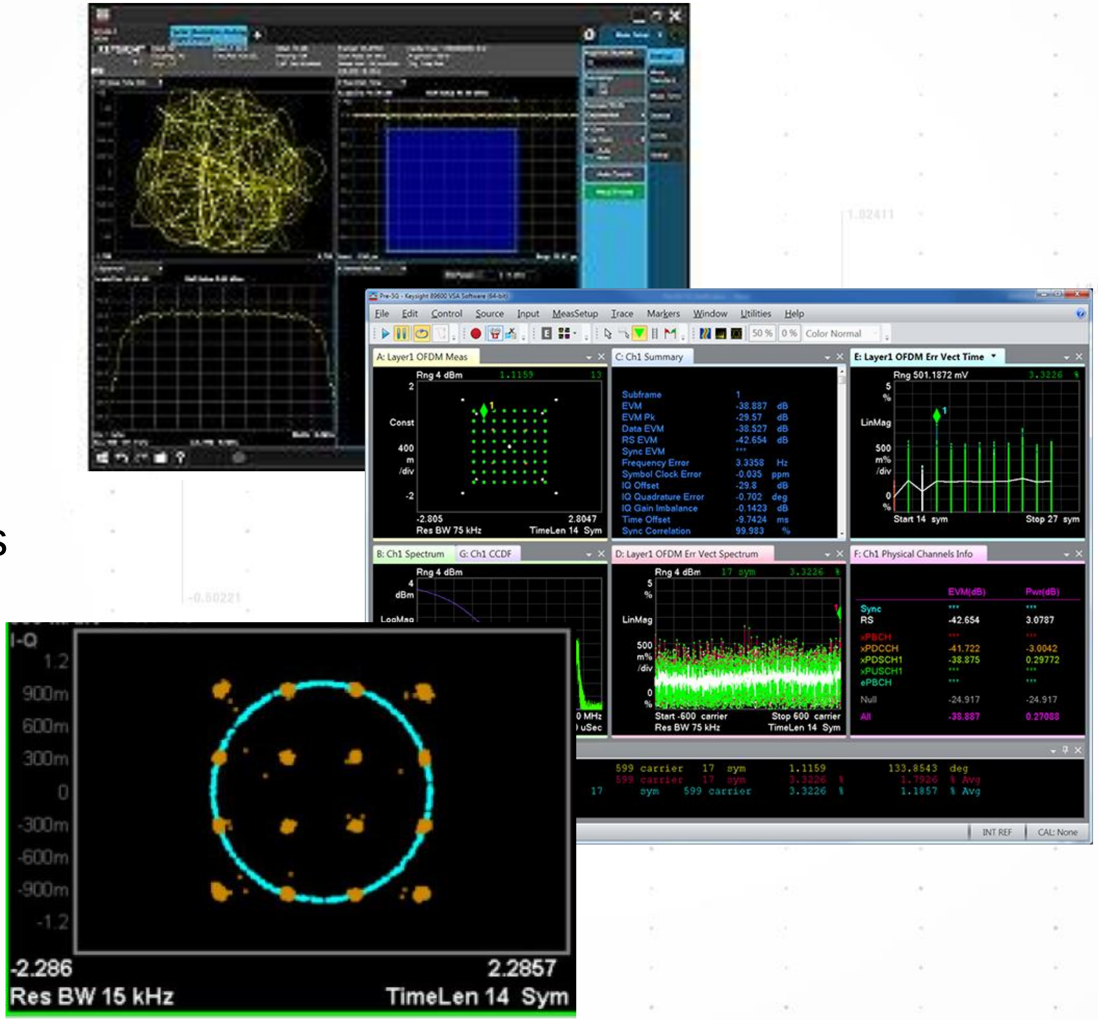
- Assess modulation quality (EVM) with in-channel vector demodulation
- Wide range of wireless formats

  WCDMA, LTE, 5G, 802.11, Bluetooth, etc.

  and basic constellations

  BPSK, QPSK, QAM, etc.

- Bandwidths from 40 MHz to 1 GHz, and beyond



Signal Analyzer Measurement Resources

- Keysight RF and Digital Monthly Webcast Series
  www.keysight.com/find/webcastseries
  - Live and On Demand Viewing
  - Register for Future Webcasts

- Keysight RF Learning Center www.keysight.com/find/klc
  - Webcast Recordings
  - Application Notes
    - AN 150 – Spectrum Analysis Basics
    - 8 Hints for Better Spectrum Analysis
    - 10 Hints for Making Better Noise Figure Measurements
  - Seminar Vide

KEYSIGHT
TECHNOLOGIES

频谱分析典型应用分享

Speaker Title / Company Name

Speaker Name

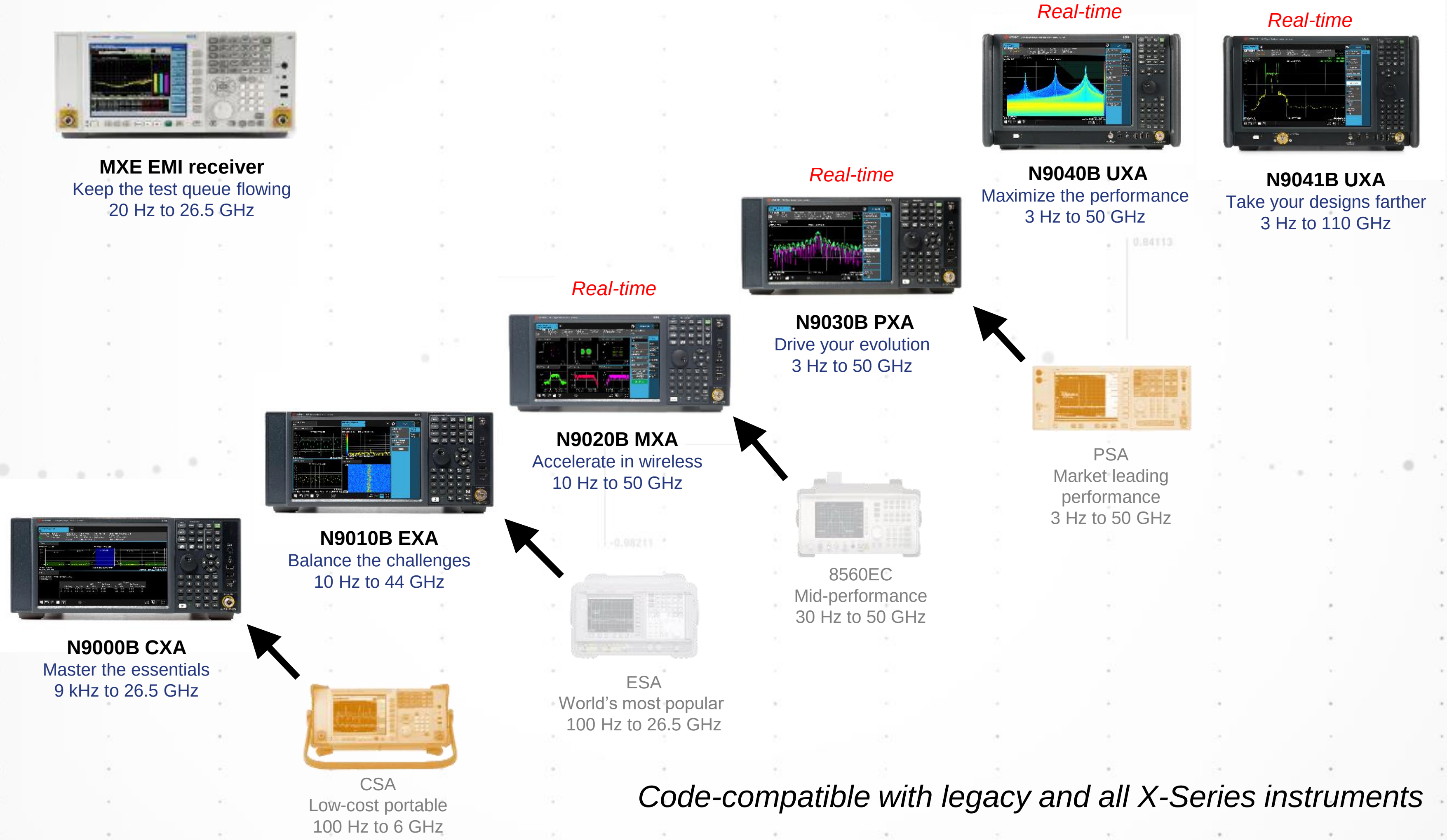
Engineers Never Stop Learning

频谱分析仪典型应用分享

- 是德科技频谱分析仪家族简介
- 5G信号的频谱测试和解调测试
- 脉冲雷达信号的测试方法
- 时变的跳频信号的捕捉和参数测试

Keysight X-Series Signal Analysis Portfolio

SAME MULTI-TOUCH GUI, SAME SCPI



Code-compatible with legacy and all X-Series instruments

Engineers Never Stop Learning

频谱分析仪典型应用分享

- 是德科技频谱分析仪家族简介
- 5G信号的频谱测试和解调测试
- 脉冲雷达信号的测试方法
- 时变的跳频信号的捕捉和参数测试

Engineers Never Stop Learning

频谱分析仪典型应用分享

- 是德科技频谱分析仪家族简介
- 5G信号的频谱测试和解调测试
- 脉冲雷达信号的测试方法
- 时变的跳频信号的捕捉和参数测试

Engineers Never Stop Learning

频谱分析仪典型应用分享

- 是德科技频谱分析仪家族简介
- 5G信号的频谱测试和解调测试
- 脉冲雷达信号的测试方法
- 时变的跳频信号的捕捉和参数测试