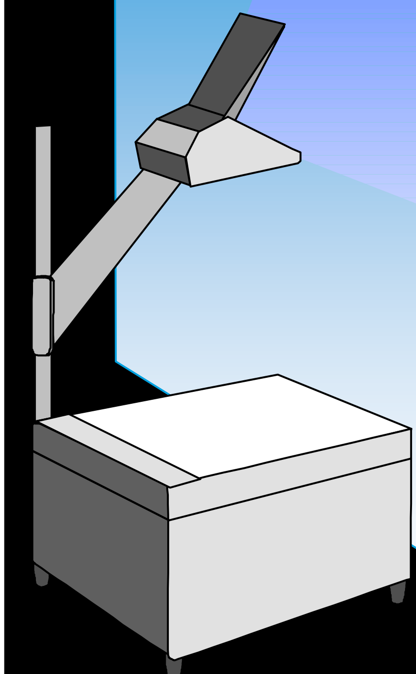
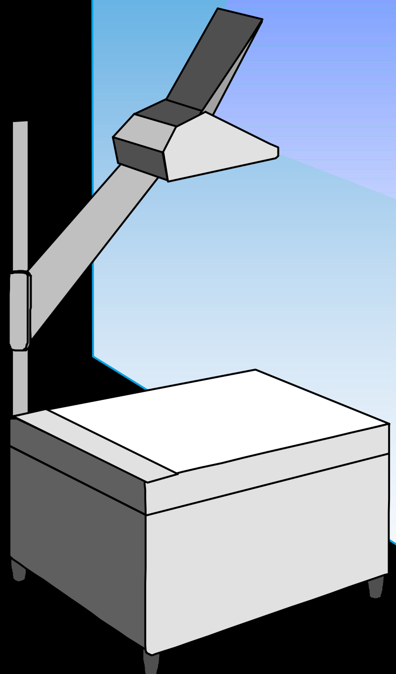
Agenda



- Overview:
  - What is spectrum analysis?
  - What measurements do we make?
- Theory of Operation:
  - Spectrum analyzer hardware
- Specifications:
  - Which are important and why?
- Features
  - Making the analyzer more effective
- Summary
- Appendix

Agilent Technologies

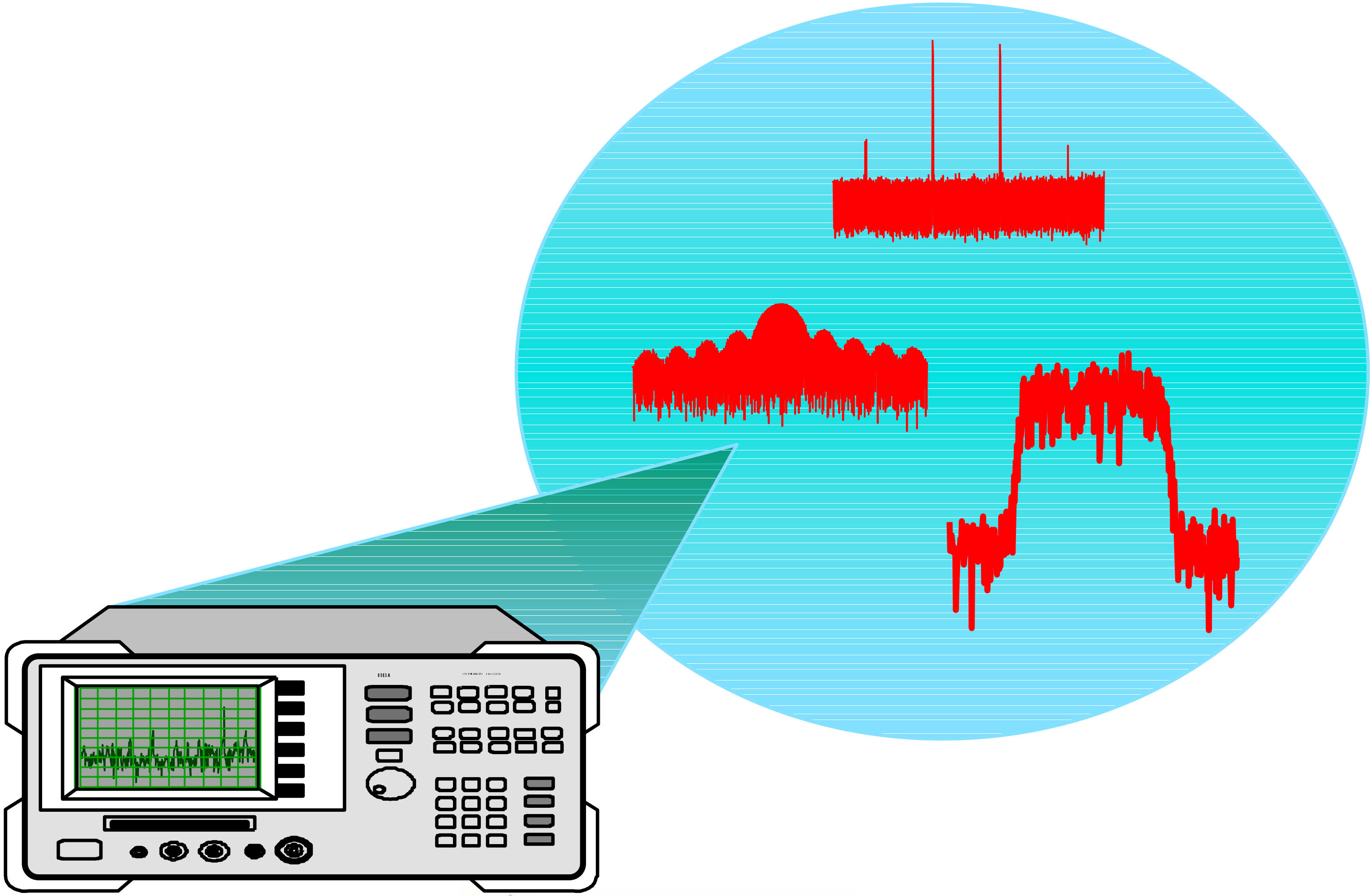
Agenda



- Overview
- Theory of Operation
- Specifications
- Features
- Summary
- Appendix

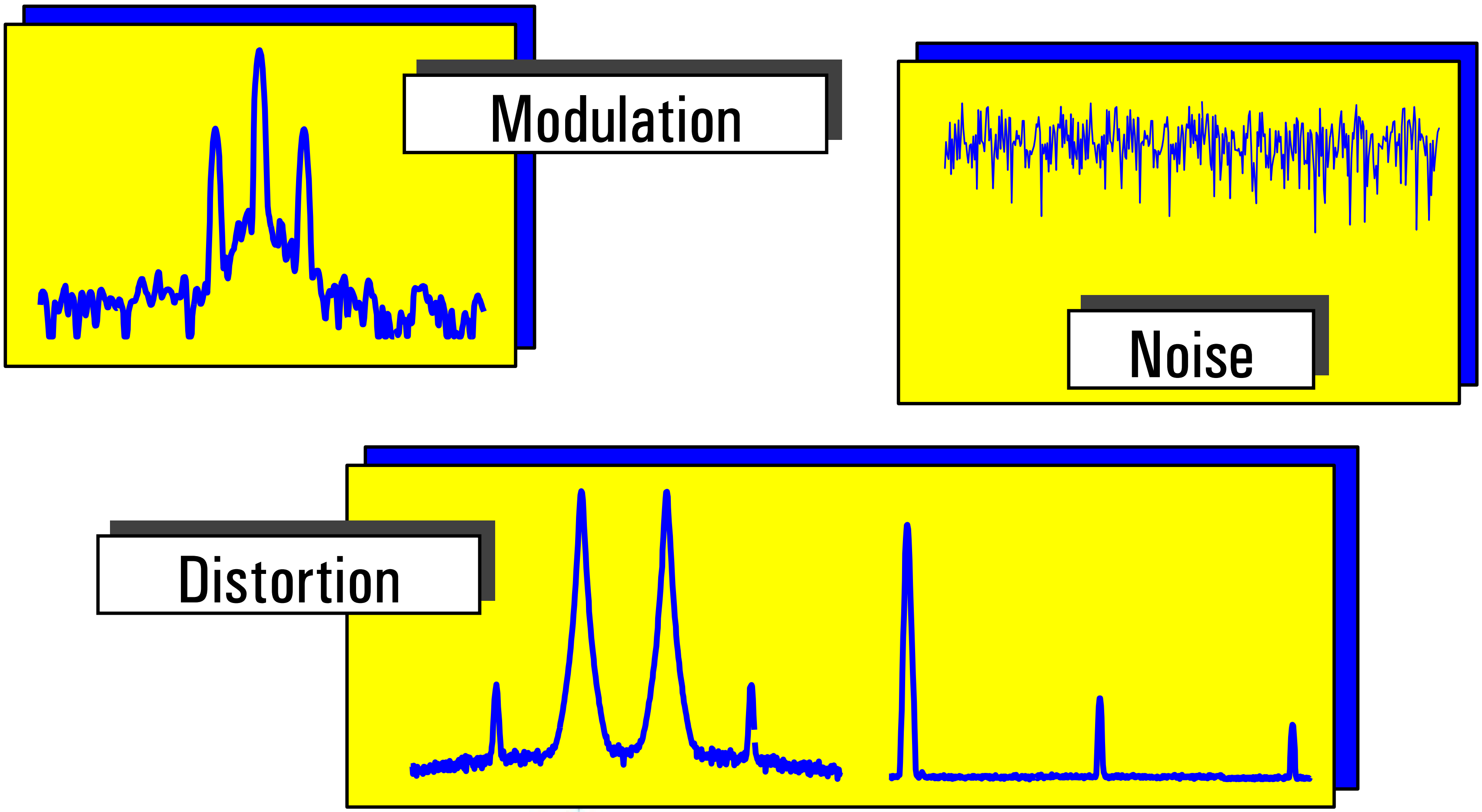
Overview

What is Spectrum Analysis?



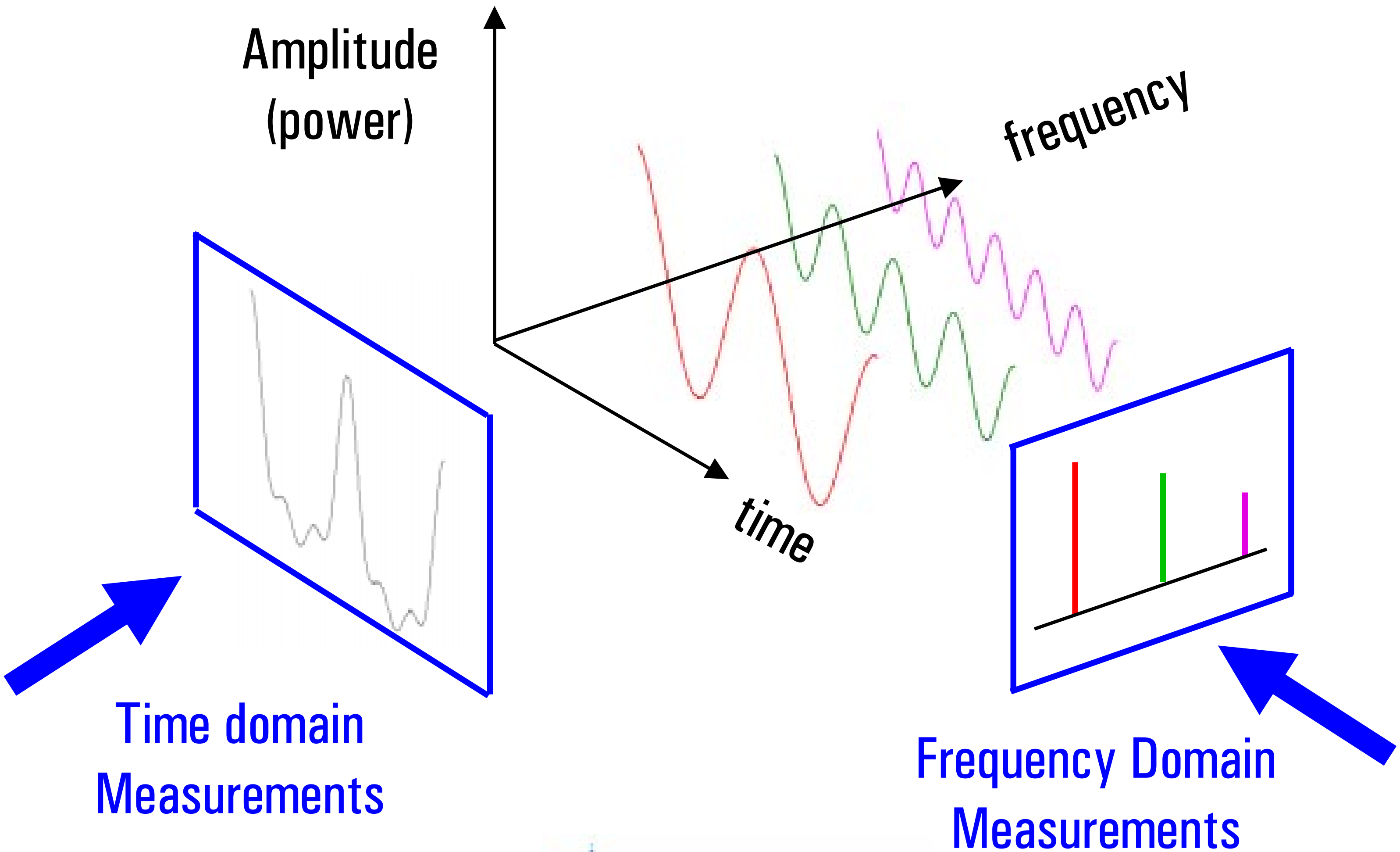
Overview

Types of Tests Made



Overview

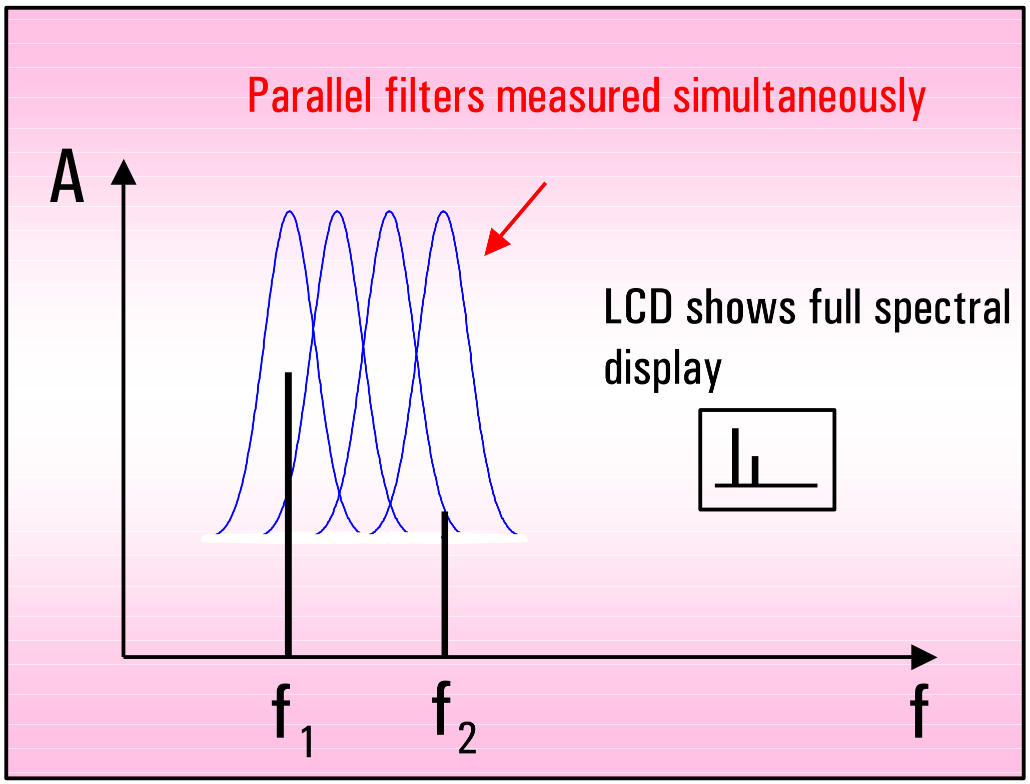
Frequency versus Time Domain



Overview

Different Types of Analyzers

Fourier Analyzer



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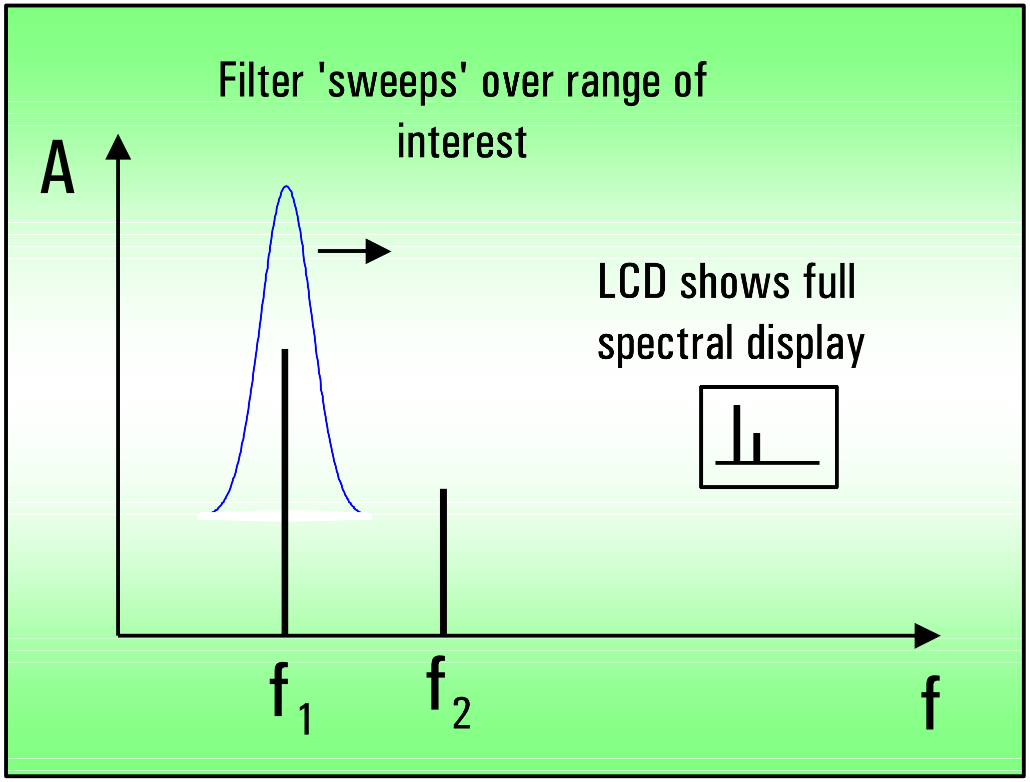
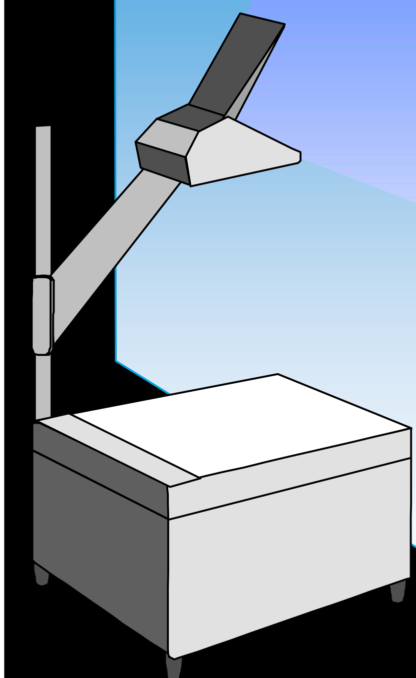
Overview

Different Types of Analyzers

Swept Analyzer



Agenda



- Overview
- Theory of Operation
- Specifications
- Features
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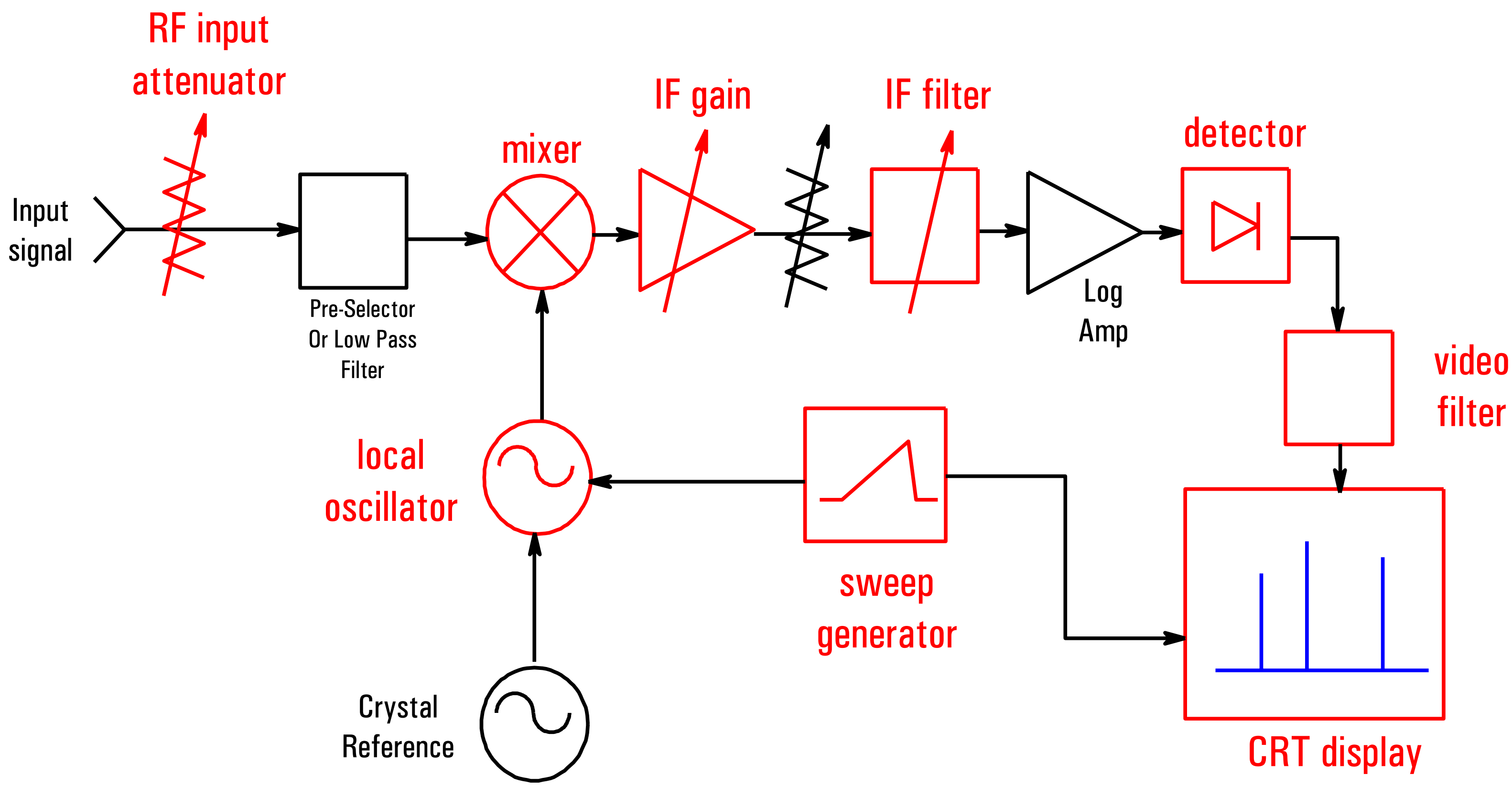
- Appendix

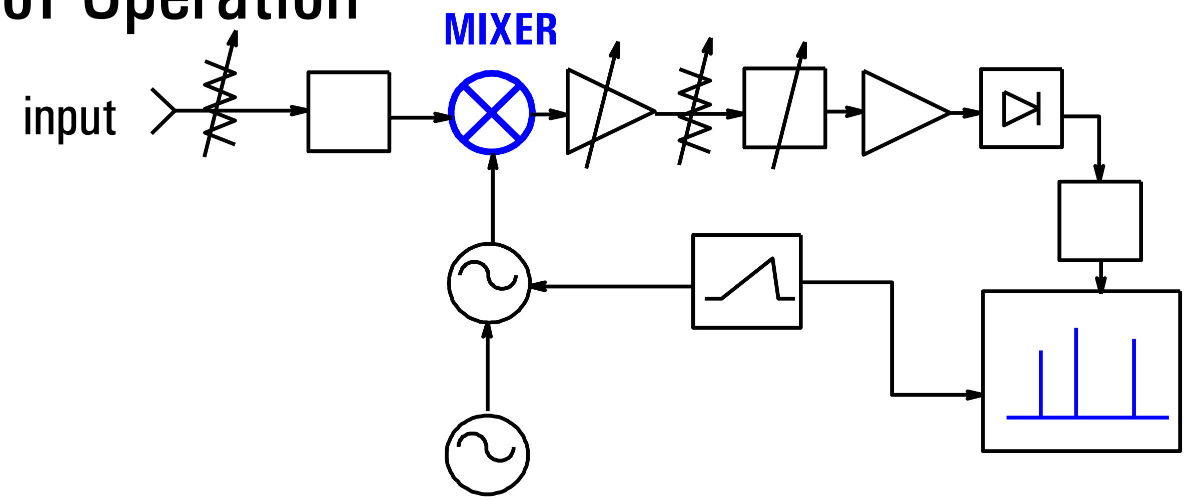
Theory of Operation

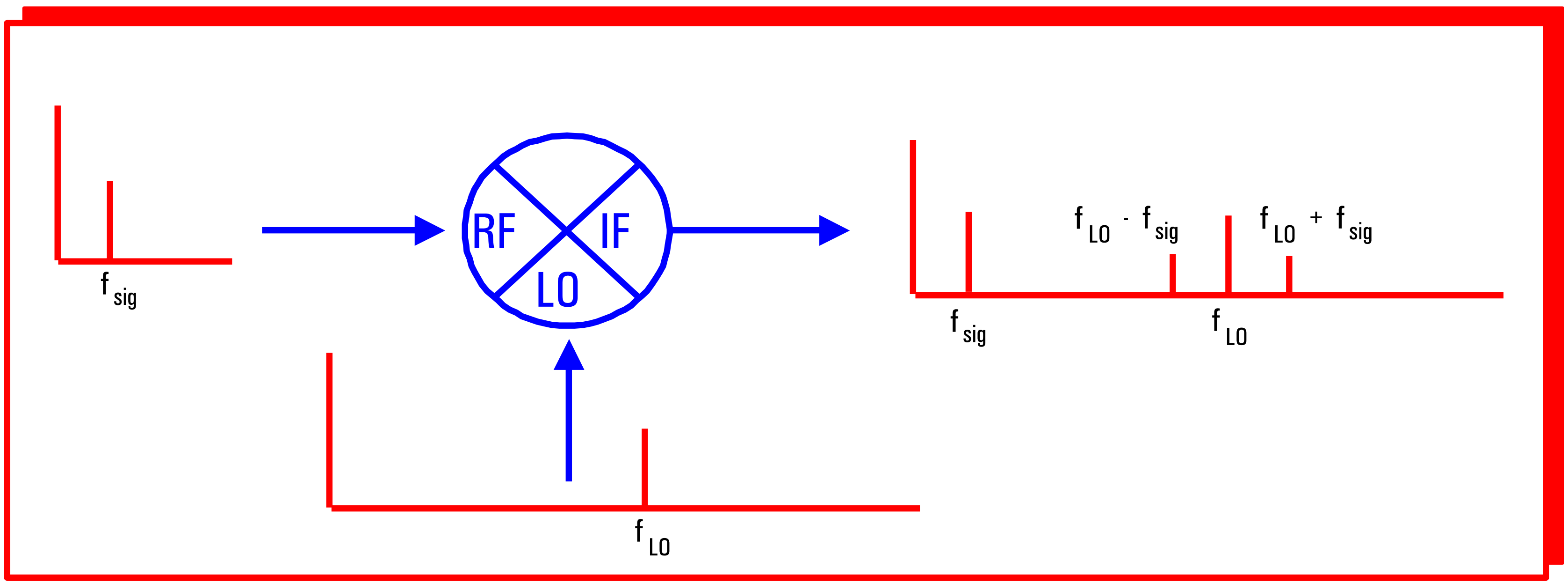
Spectrum Analyzer Block Diagram



Theory of Operation

Mixer





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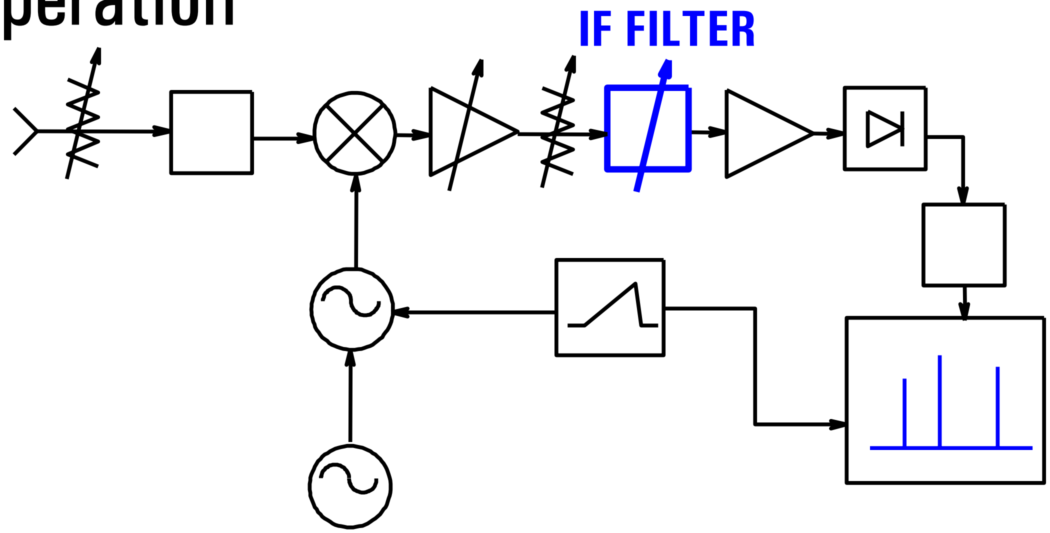
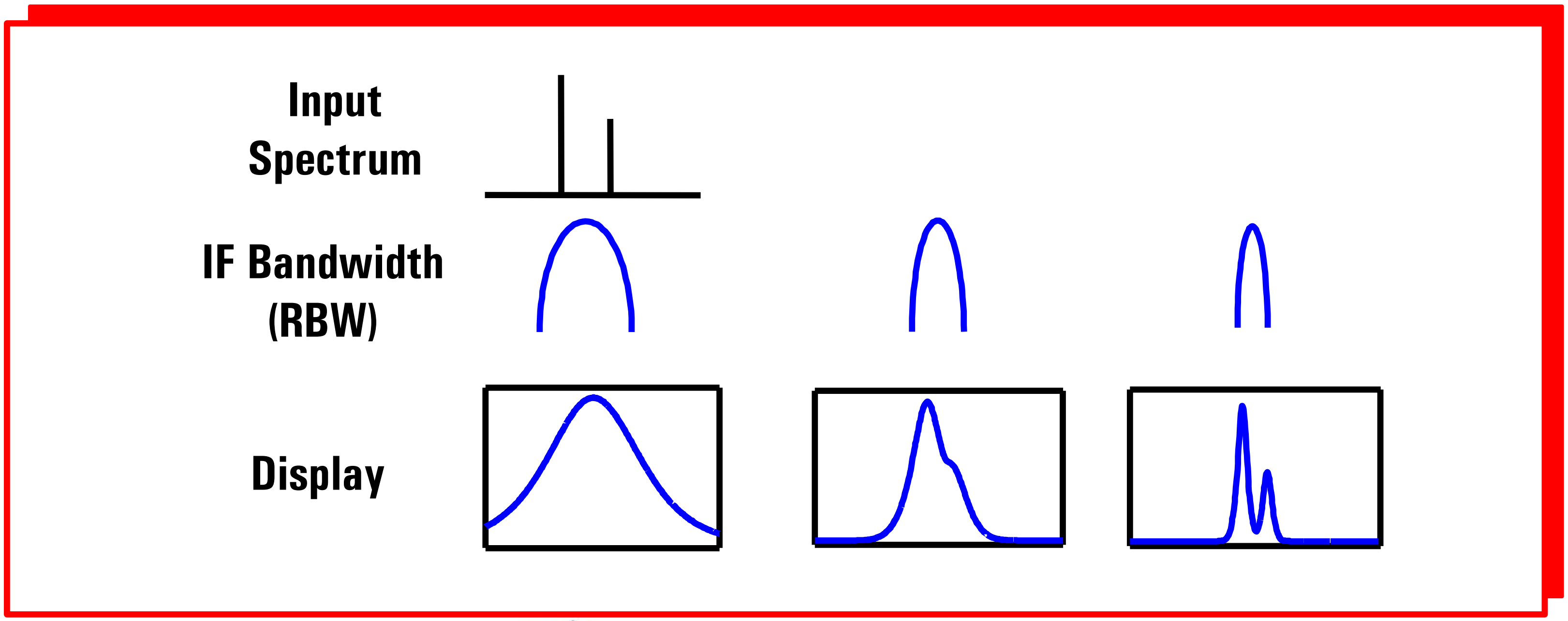
Theory of Operation

IF Filter

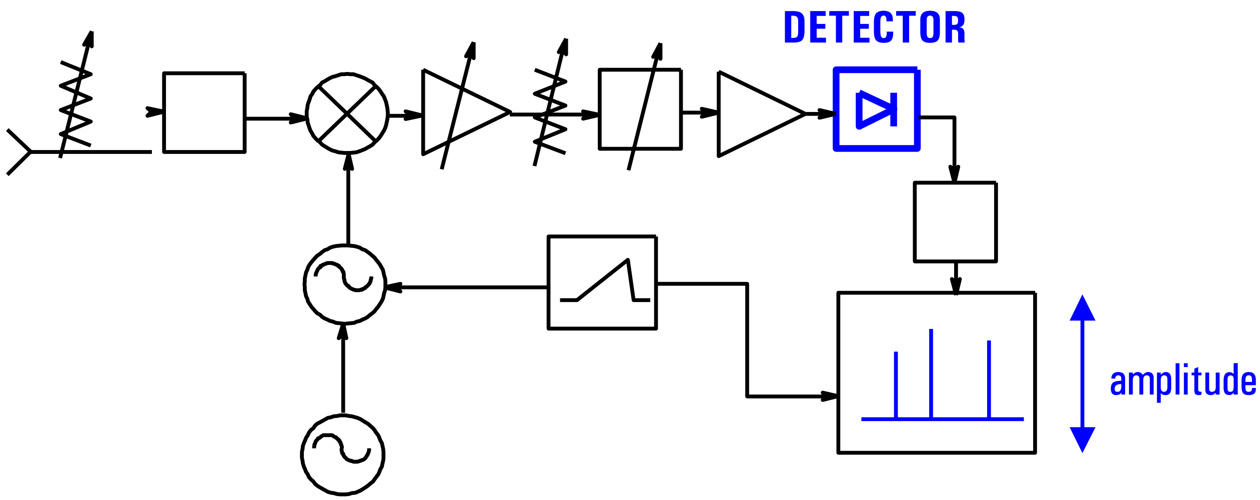


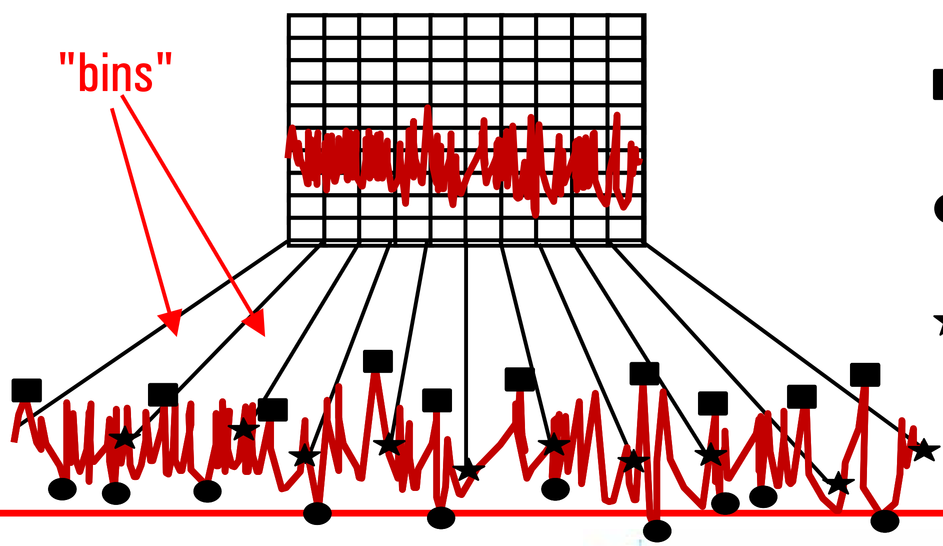


Agilent Technologies

Theory of Operation

Detector





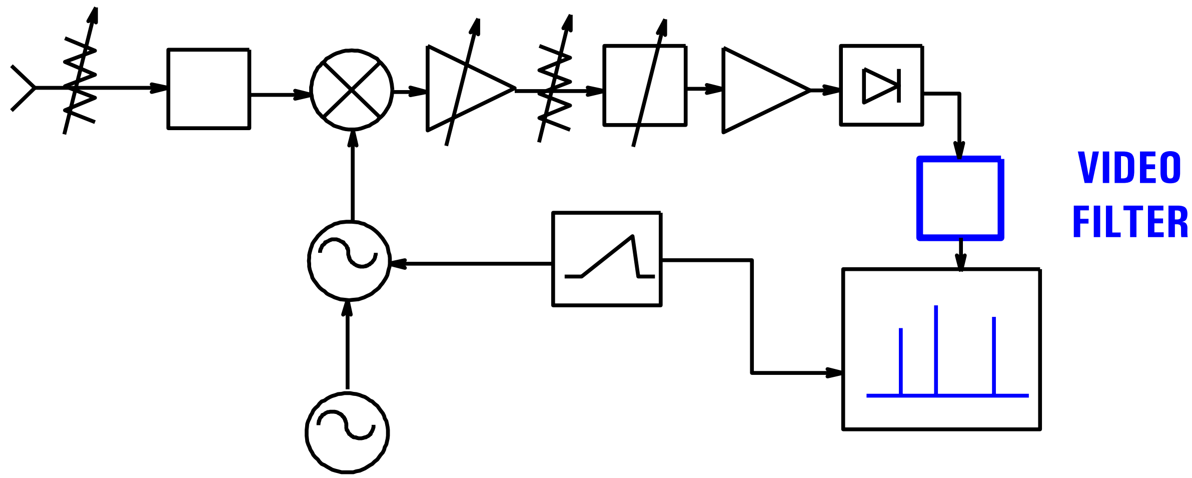
■ Positive detection: largest value in bin displayed

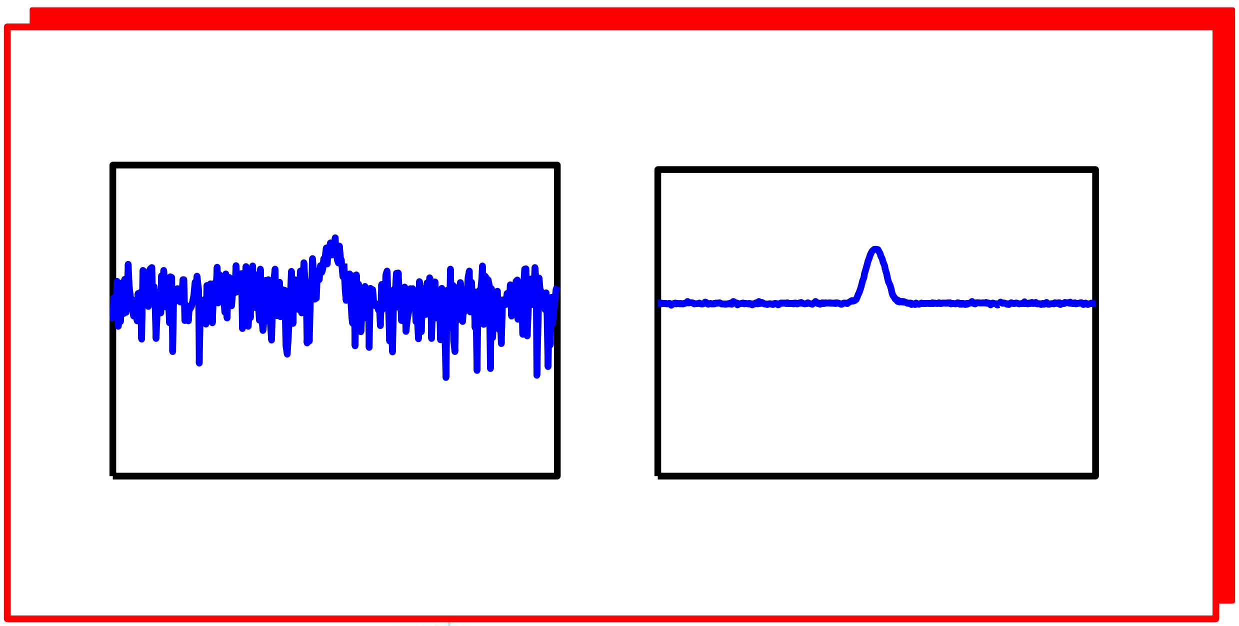
● Negative detection: smallest value in bin displayed

★ Sample detection: last value in bin displayed

Theory of Operation

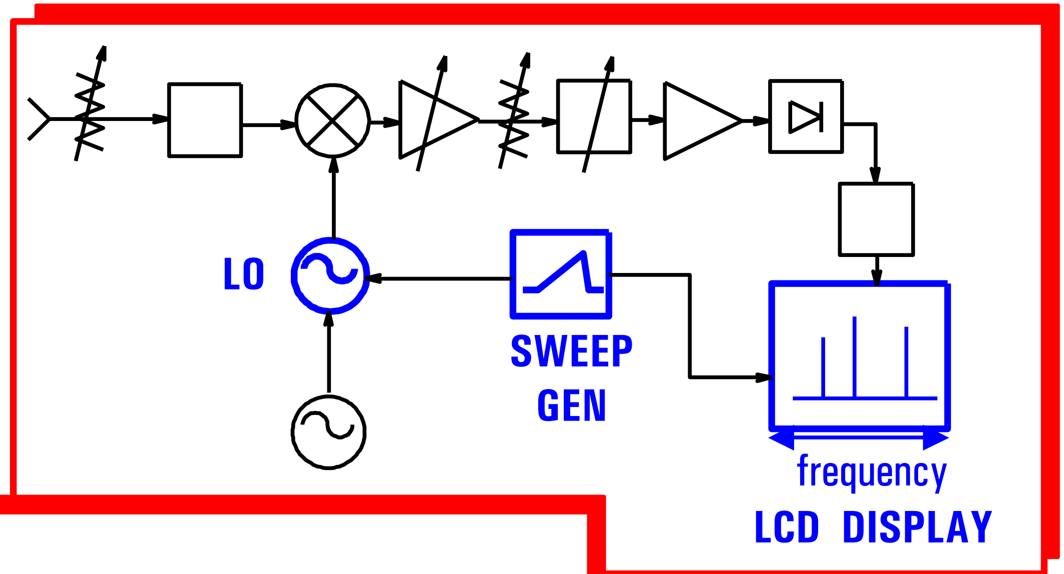
Video Filter

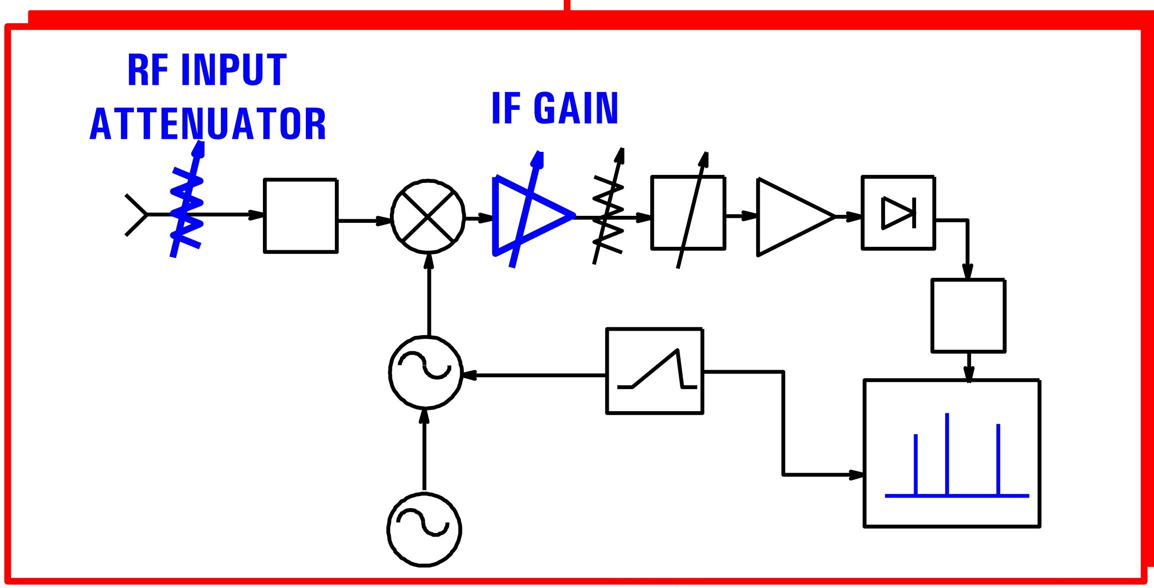




Theory of Operation

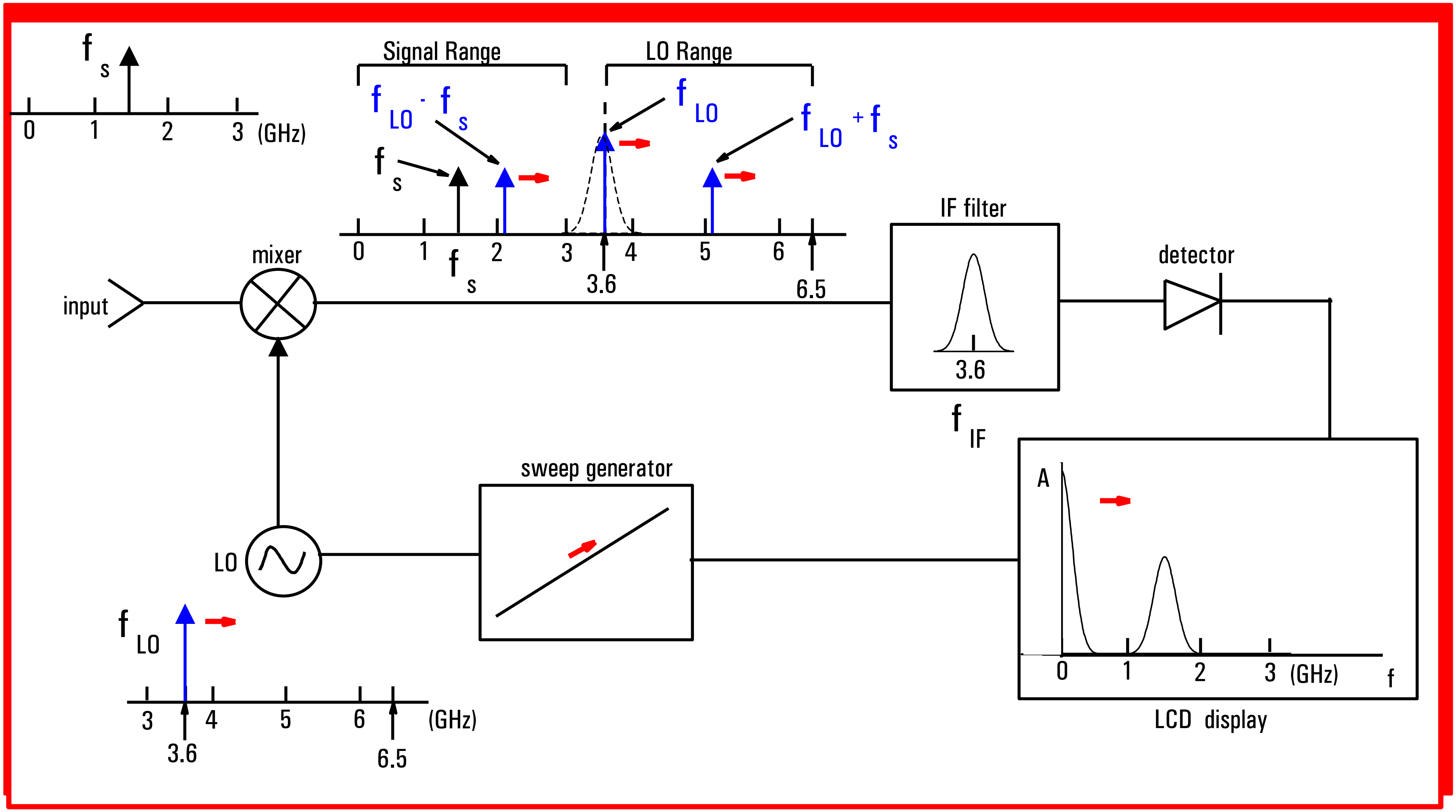
Other Components





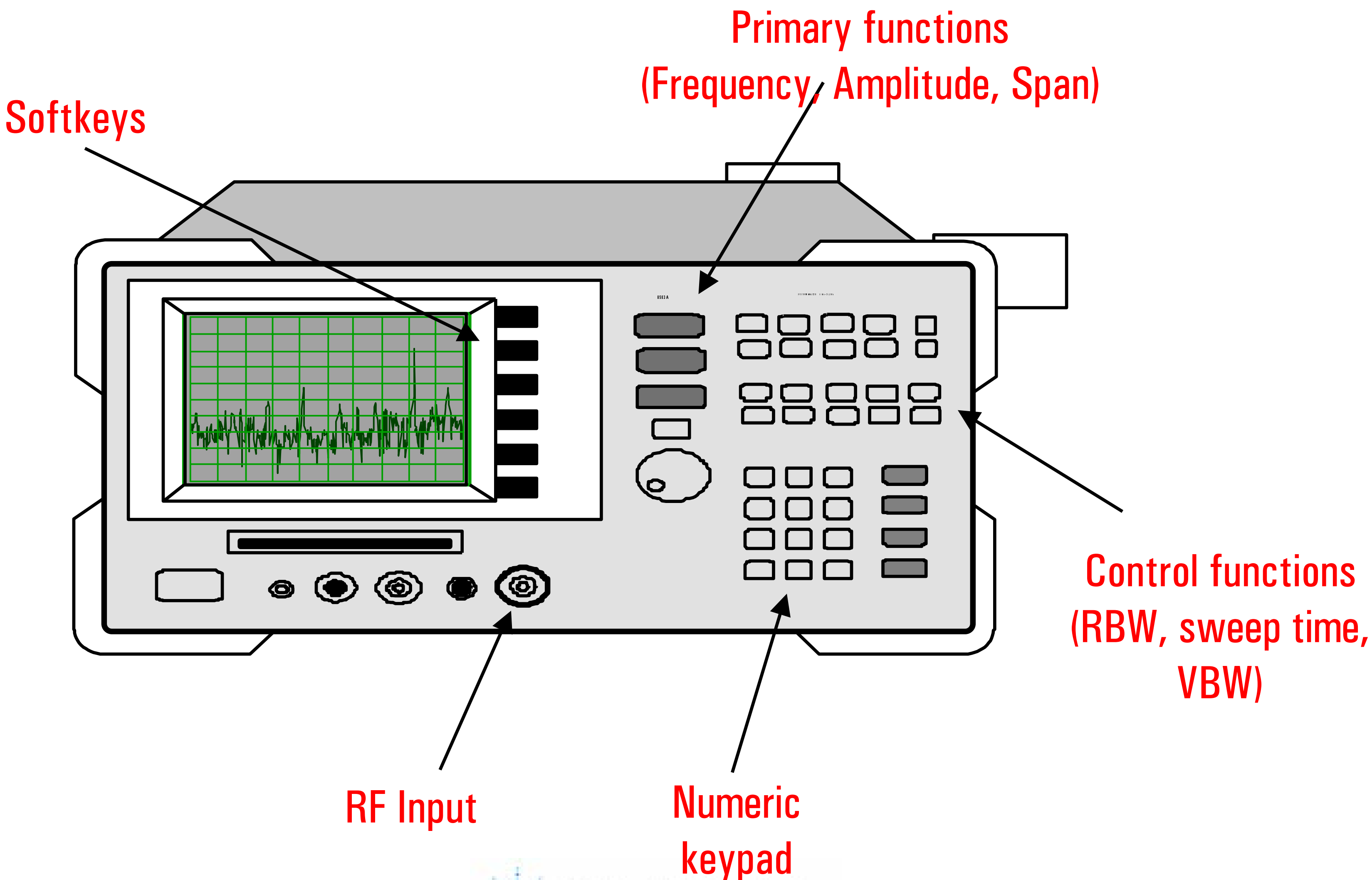
Theory of Operation

How it all works together

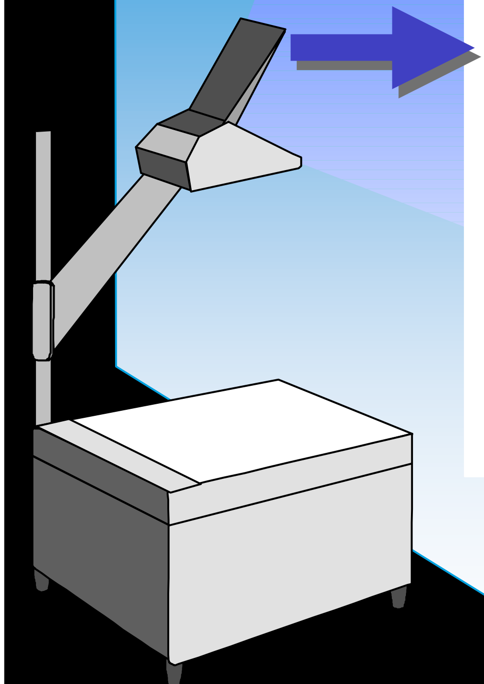


Theory of Operation

Front Panel Operation

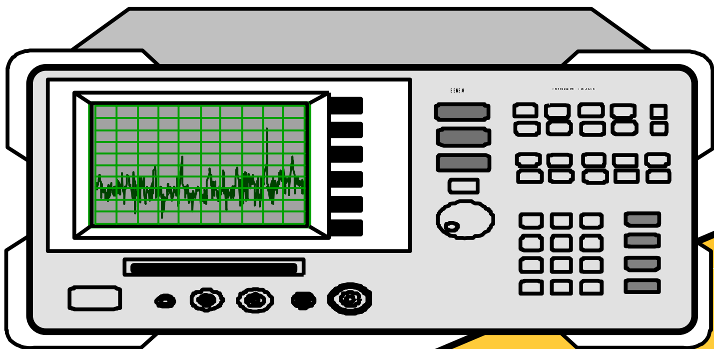


Agenda



- Overview
- Theory of Operation
- Specifications
- Features
- Summary
- Appendix

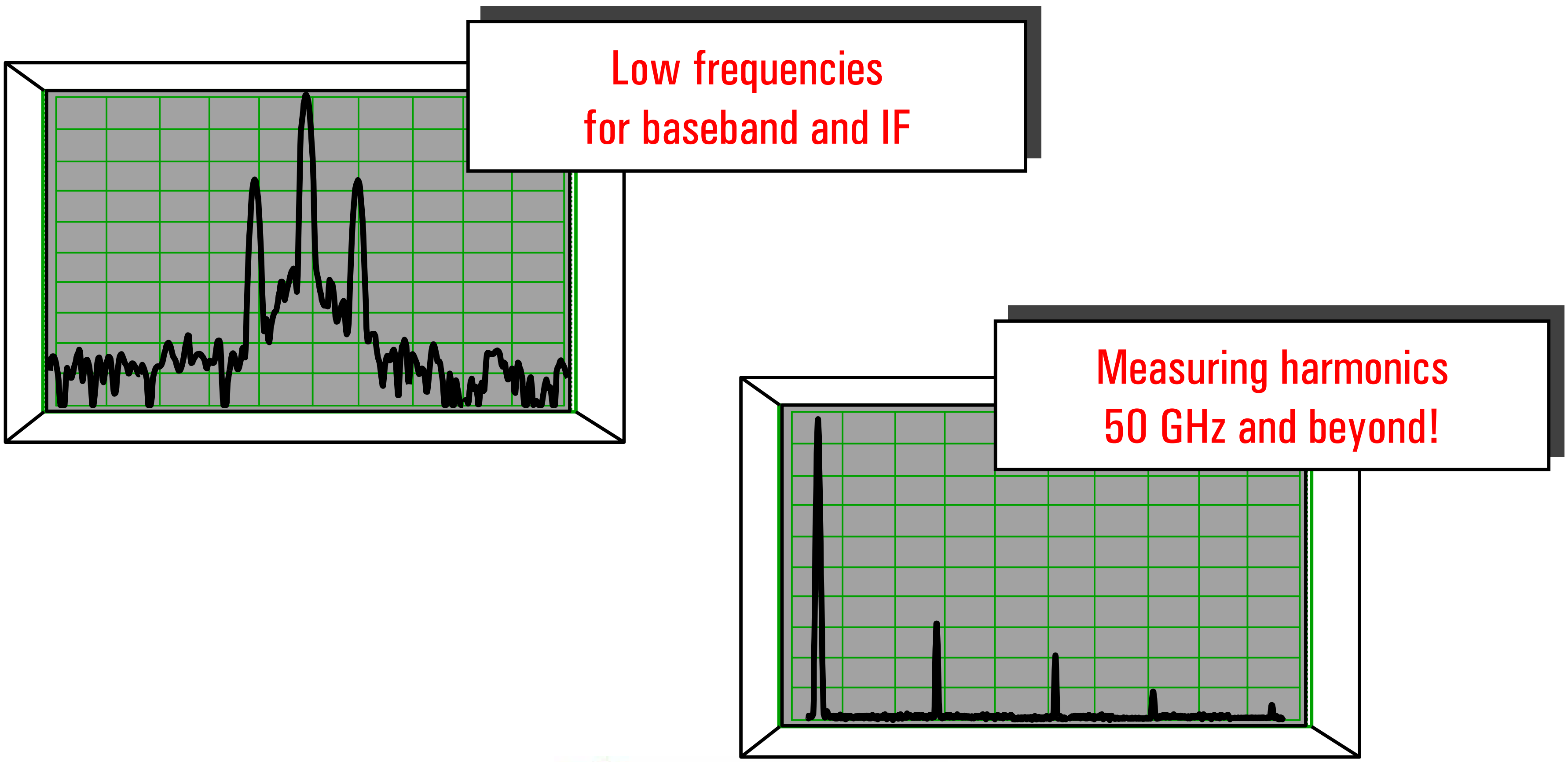
Specifications



- ➤ Frequency Range
- ➤ Accuracy: Frequency & Amplitude
- ➤ Resolution
- ➤ Sensitivity
- ➤ Distortion
- ➤ Dynamic Range

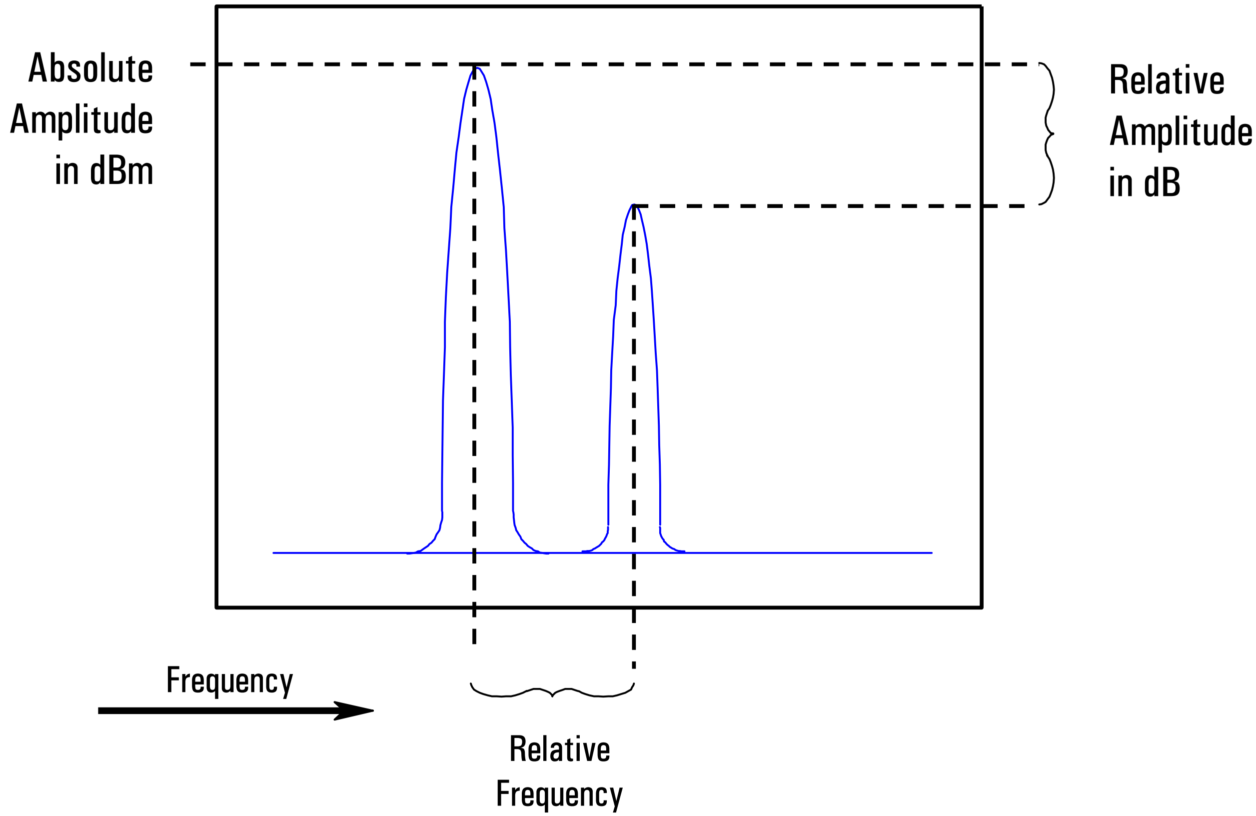
Specifications

Frequency Range



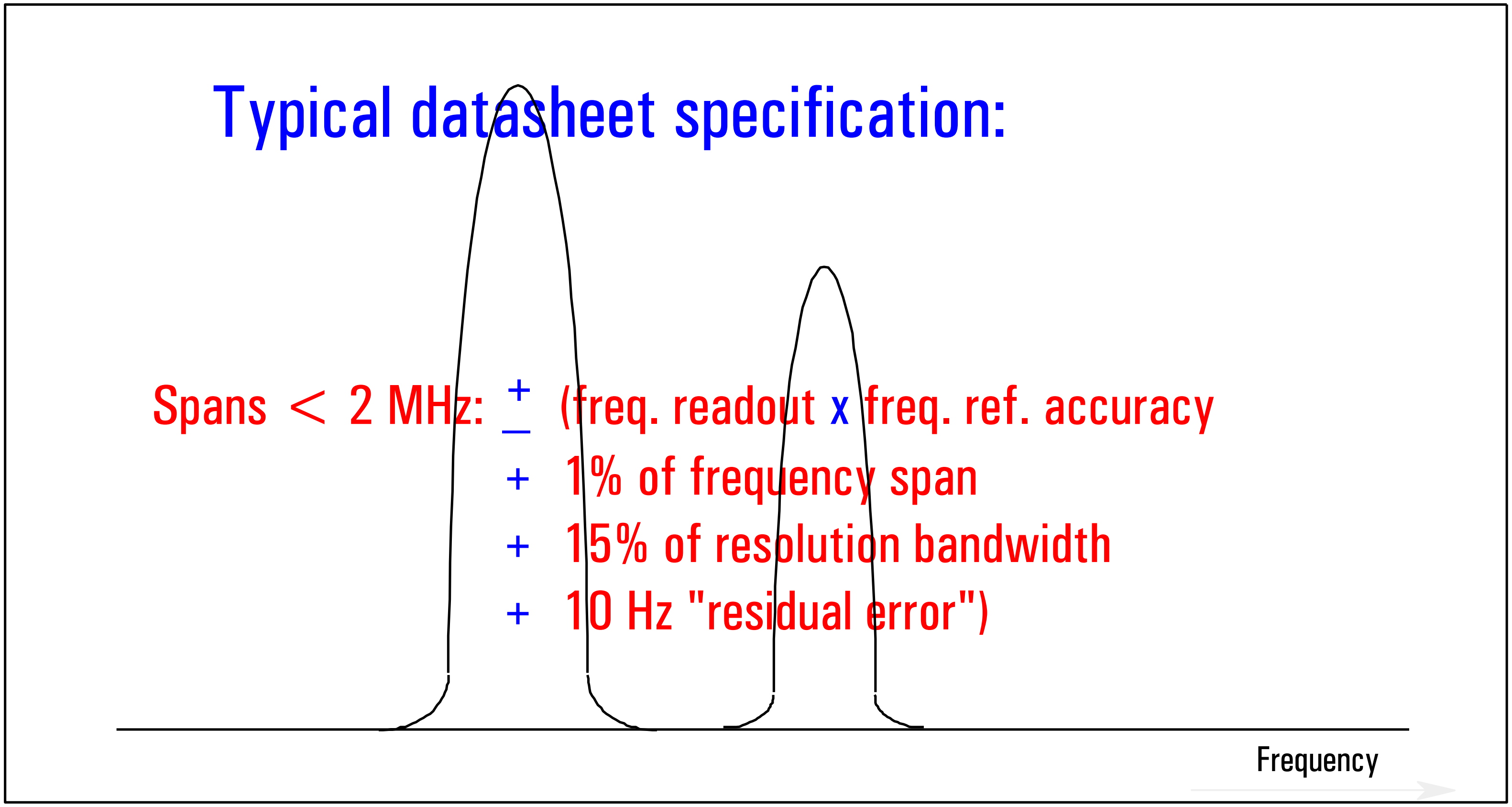
Specifications

Accuracy



Specifications

Accuracy: Frequency Readout Accuracy



Typical datasheet specification:

Spans < 2 MHz: ± (freq. readout x freq. ref. accuracy
+ 1% of frequency span
+ 15% of resolution bandwidth
+ 10 Hz "residual error")

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Specifications

Accuracy: Frequency Readout Accuracy Example

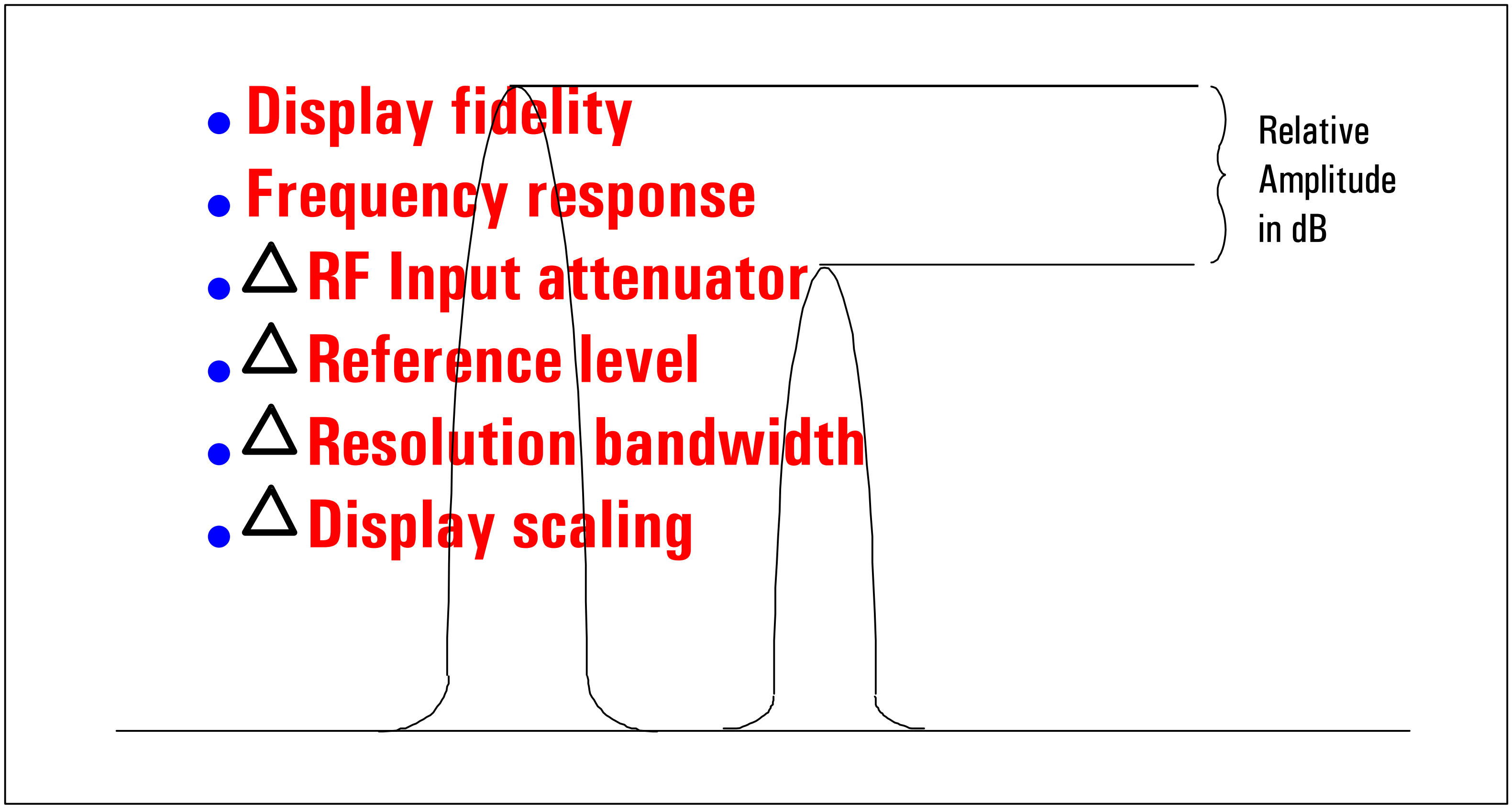
Single Marker Example:

2 GHz
400 kHz span
3 kHz RBW

Calculation:	$(2 \times 10^{9}\,\mathrm{Hz}) \times (1.3 \times 10^{-7}$/yr.ref.error)	=	260 Hz
	1% of 400 kHz span	=	4000 Hz
	15% of 3 kHz RBW	=	450 Hz
	10 Hz residual error	=	10 Hz
	Total =	$\pm$	4720 Hz

Specifications

Accuracy: Relative Amplitude Accuracy



- Display fidelity
- Frequency response
- Δ RF Input attenuator
- Δ Reference level
- Δ Resolution bandwidth
- Δ Display scaling

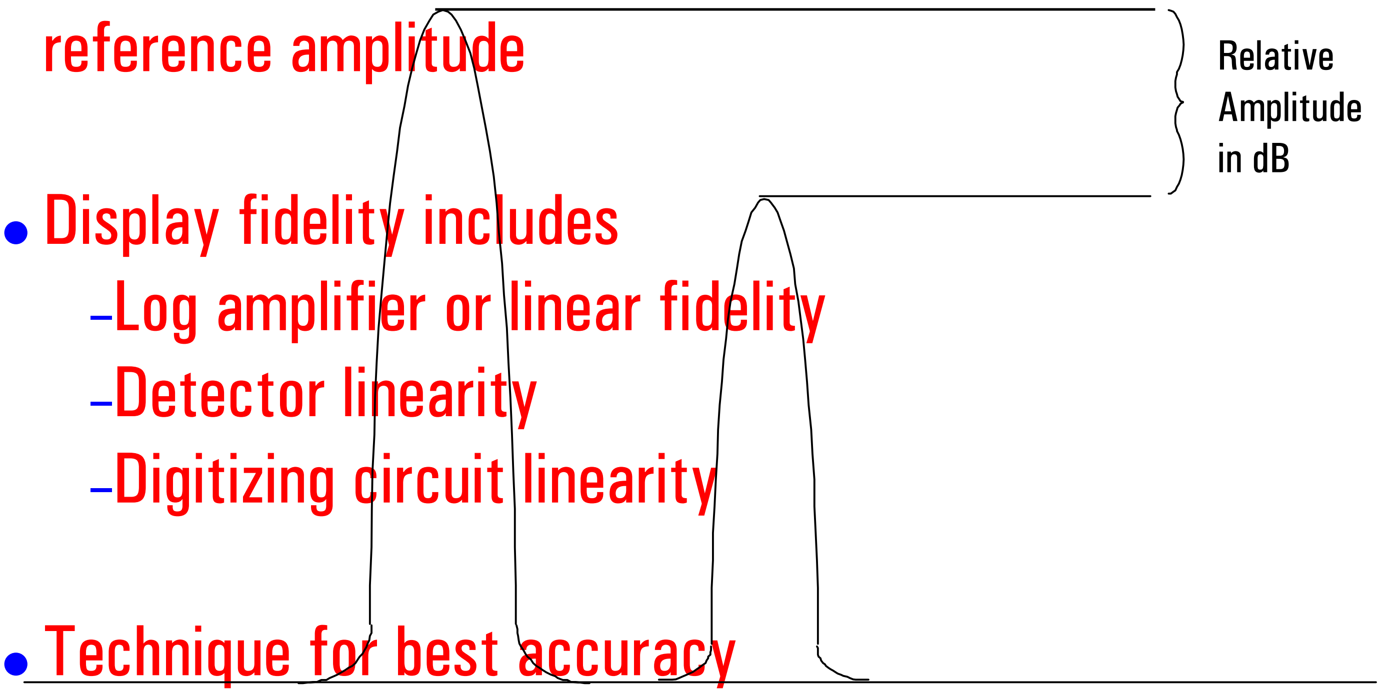
Specifications

Accuracy: Relative Amplitude Accuracy - Display Fidelity

- Applies when signals are not placed at the same reference amplitude

- Display fidelity includes
  - Log amplifier or linear fidelity
  - Detector linearity
  - Digitizing circuit linearity

- Technique for best accuracy



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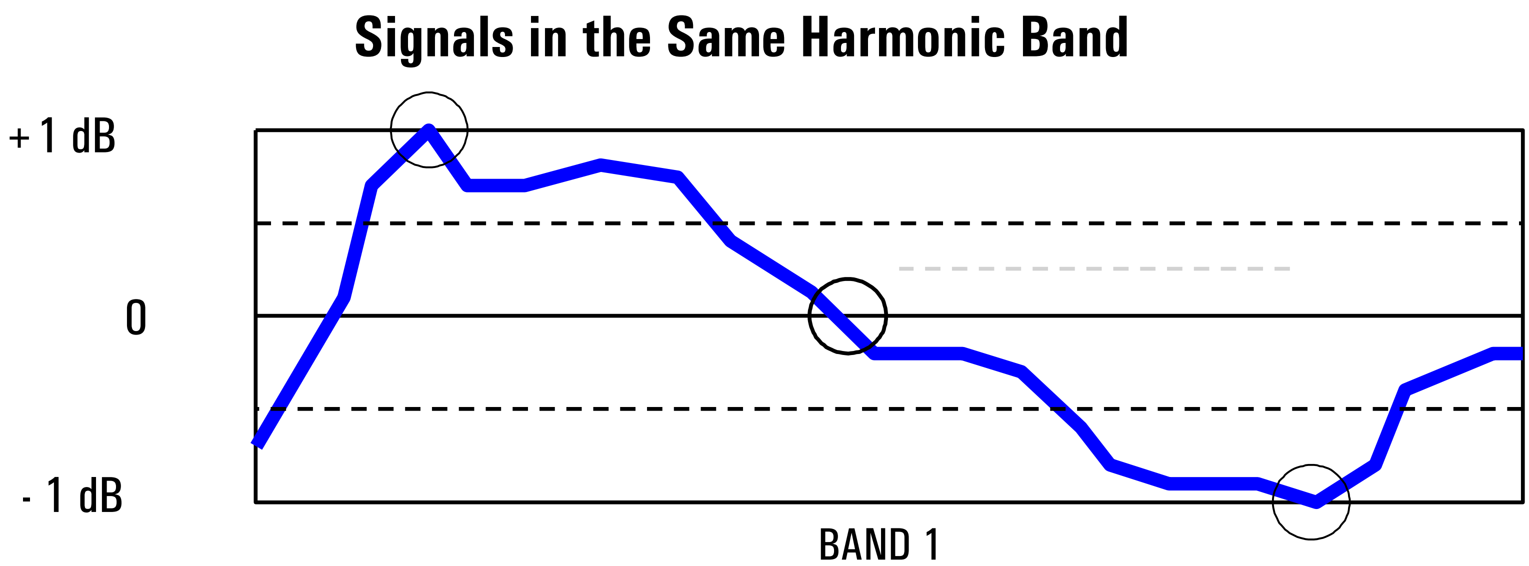
Specifications

Accuracy: Relative Amplitude Accuracy - Freq. Response



Specification: ± 1 dB

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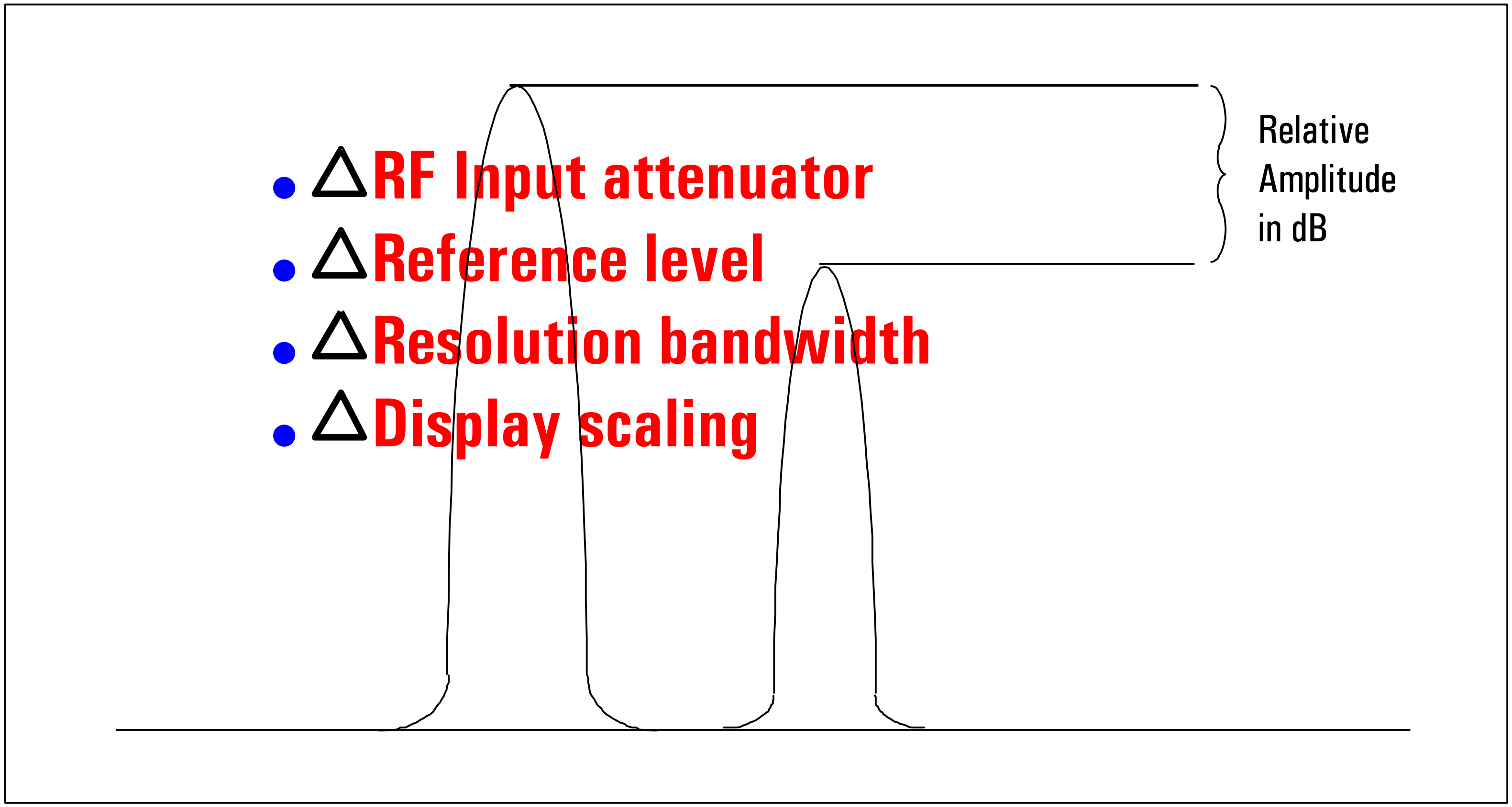
Specifications

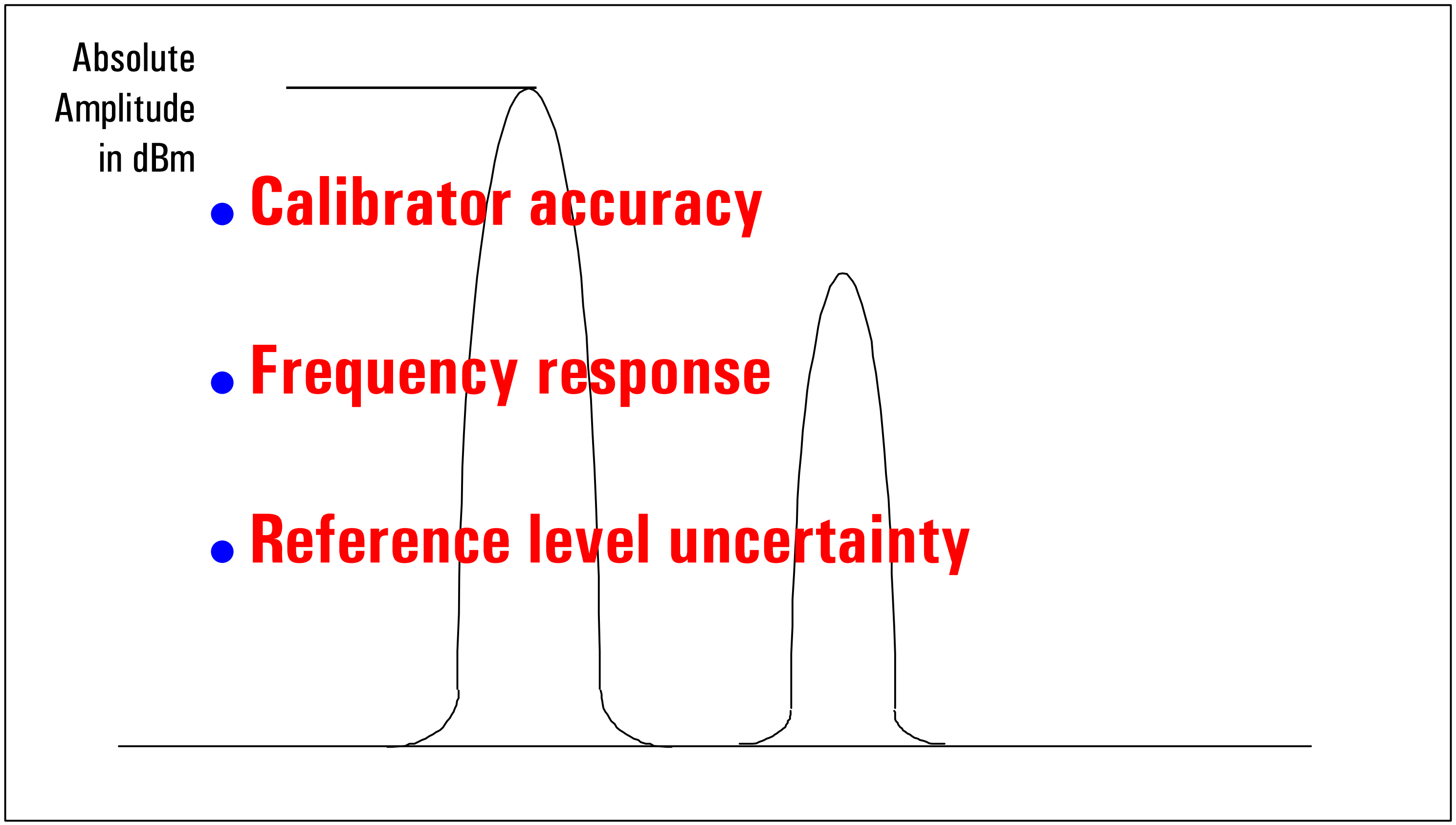
Accuracy: Relative Amplitude Accuracy

- Δ RF Input attenuator
- Δ Reference level
- Δ Resolution bandwidth
- Δ Display scaling



Specifications

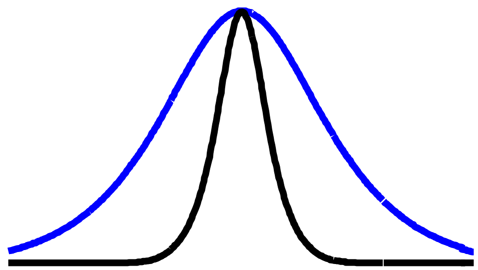
Accuracy: Absolute Amplitude Accuracy



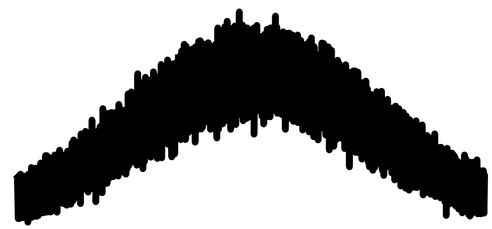
- Calibrator accuracy
- Frequency response
- Reference level uncertainty

Specifications
Resolution

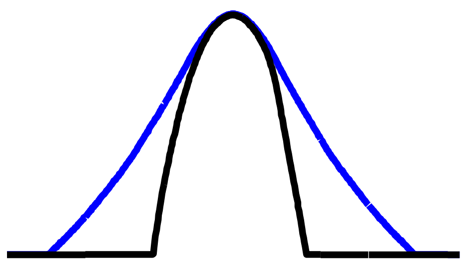
What Determines Resolution?



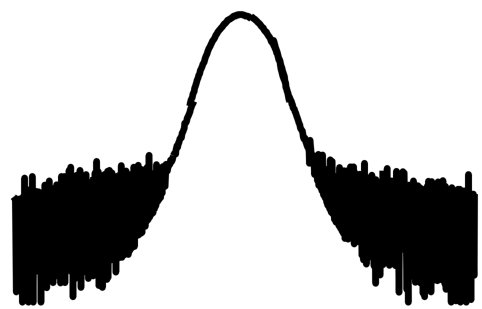
Resolution Bandwidth



Residual FM



RBW Type and Selectivity



Noise Sidebands

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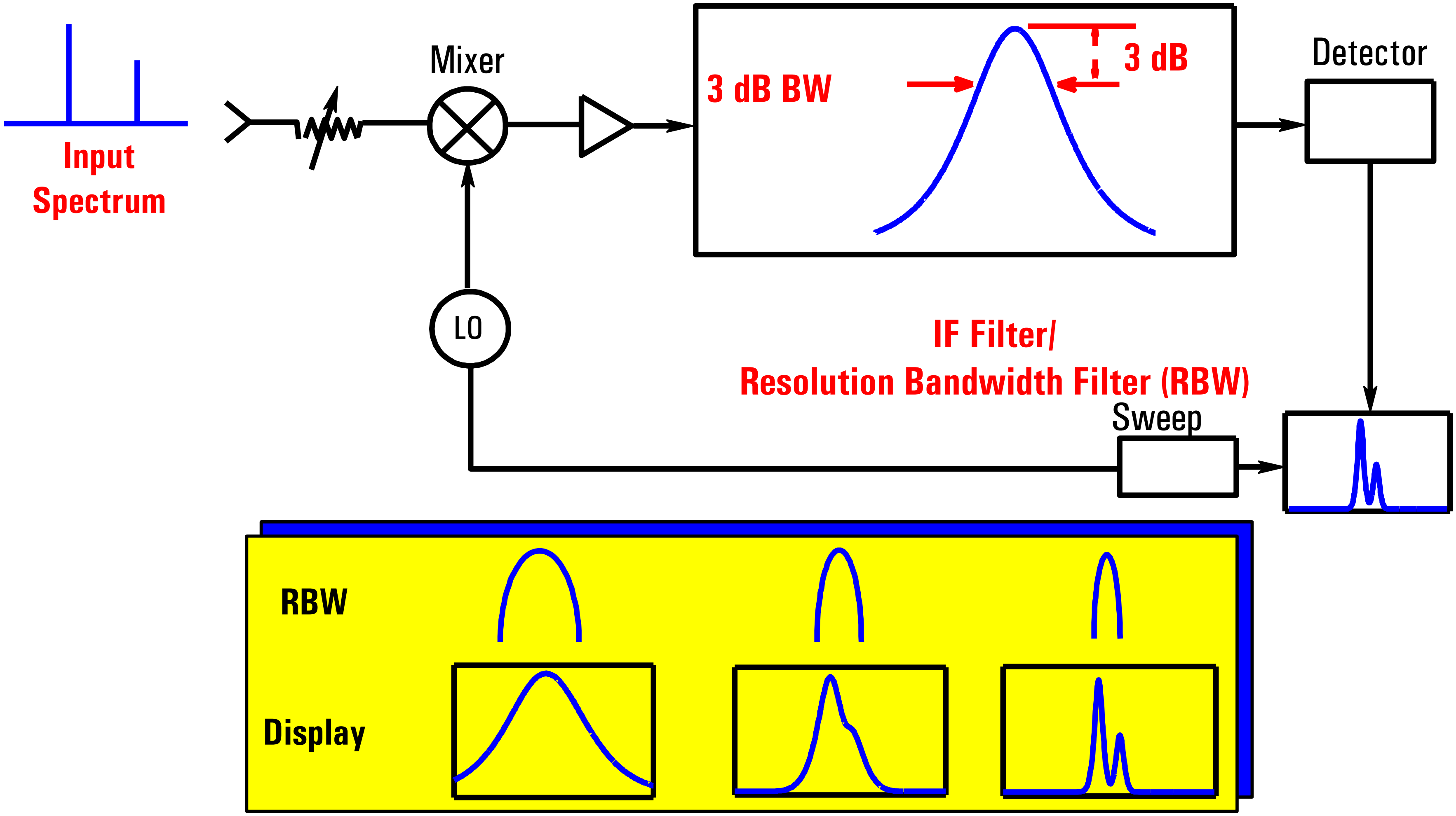
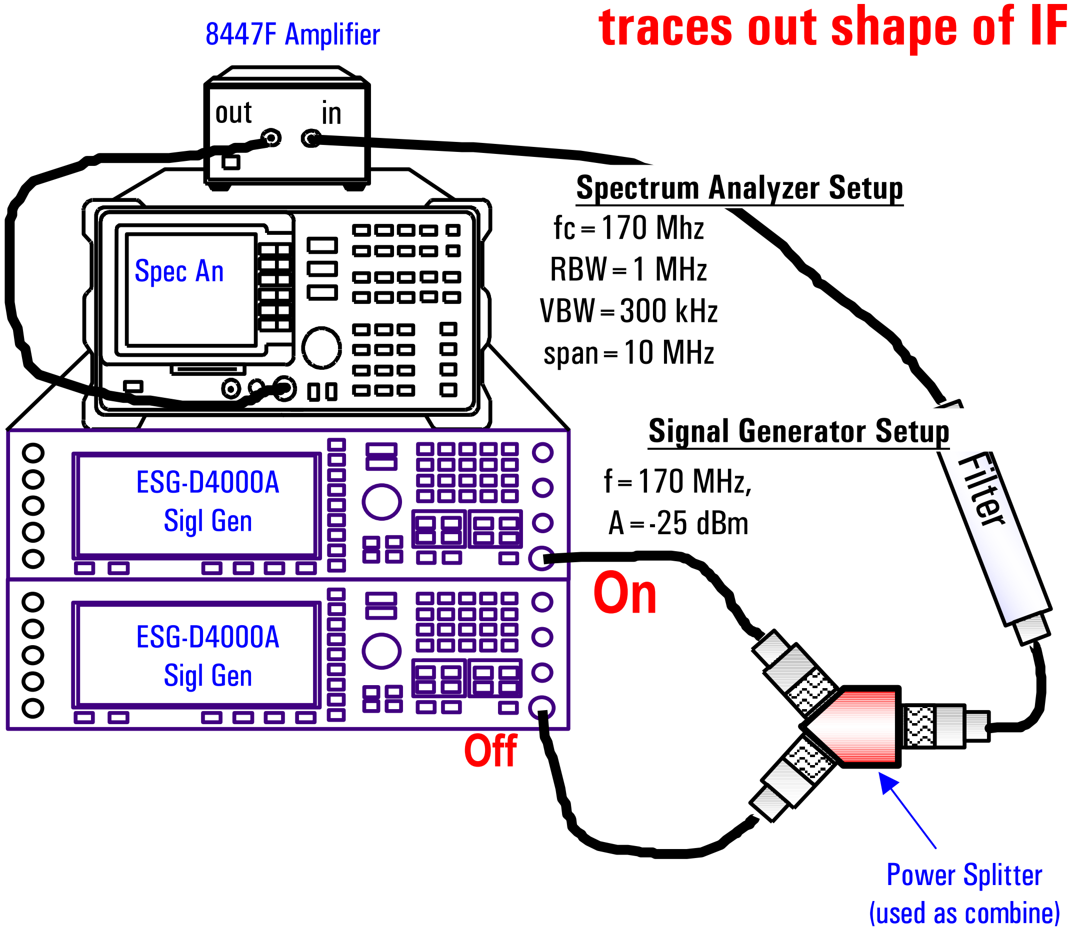
Specifications

Resolution: Resolution Bandwidth



Demo - Theory: IF filter

One signal - change RBW to see how display traces out shape of IF filter



Bandpass filter
(center frequency = 170 MHz)

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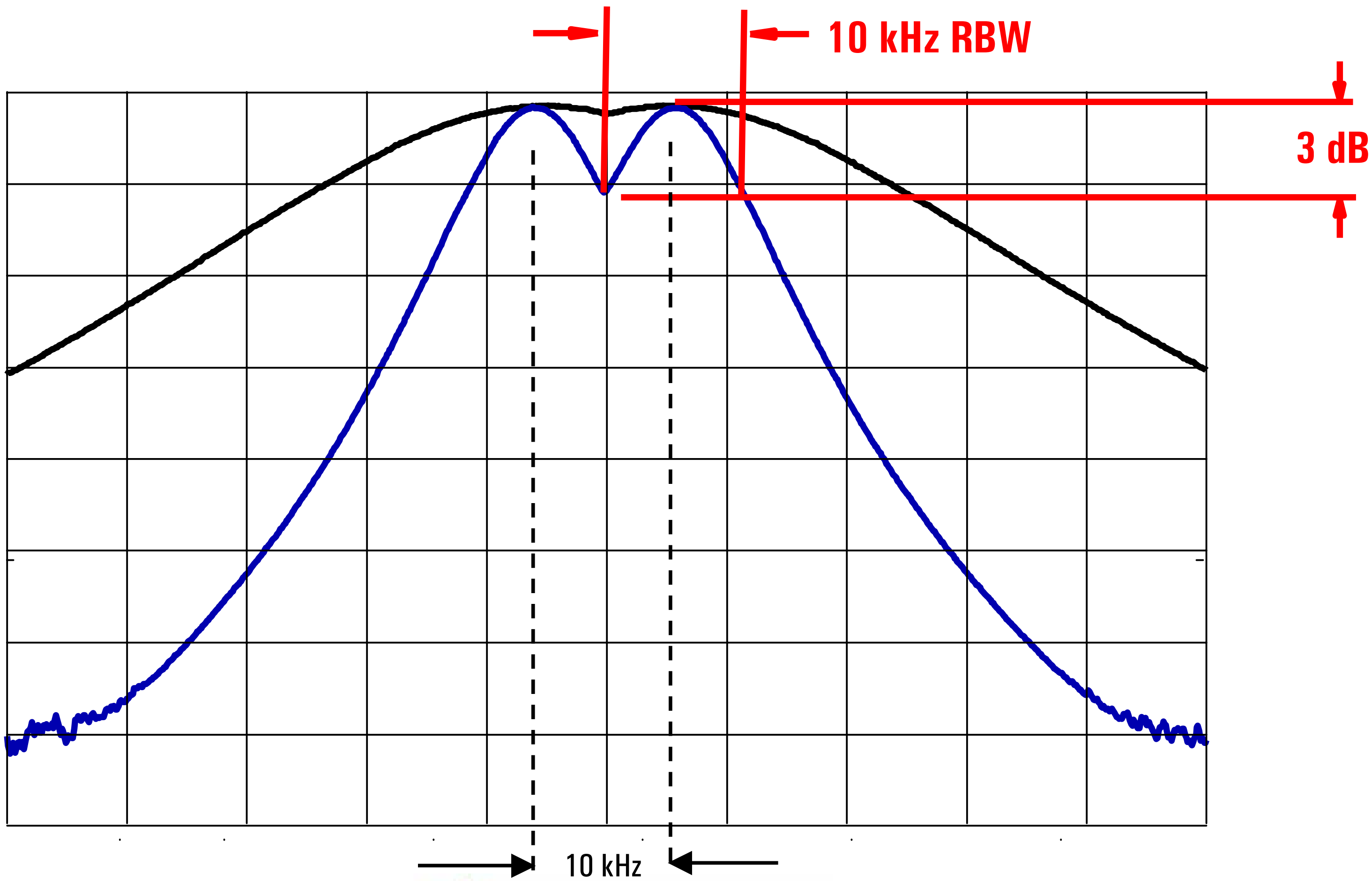
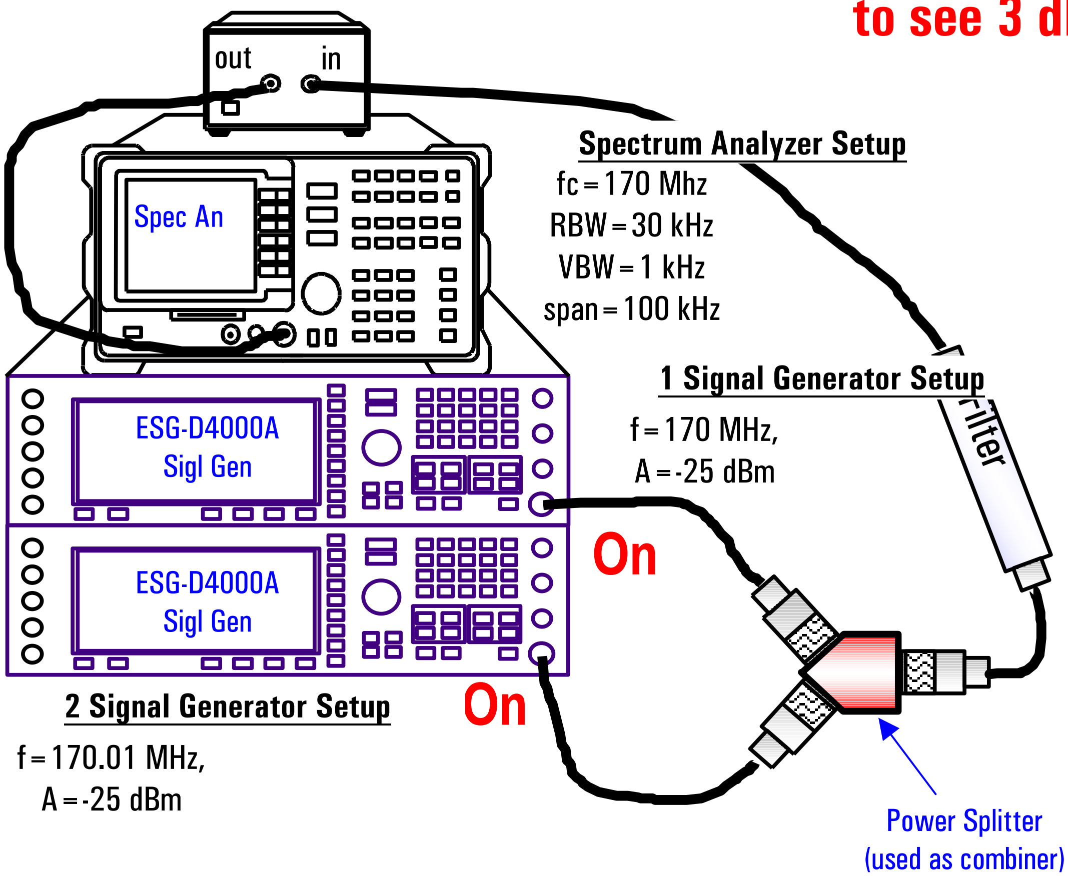
Specifications

Resolution: Resolution Bandwidth



Demo #4 - Resolution: RBW

Two equal-amplitude signals spaced 10 kHz apart - change RBW to 10 kHz to see 3 dB 'dip'



Spectrum Analyzer Setup

fc = 170 Mhz
RBW = 30 kHz
VBW = 1 kHz
span = 100 kHz

1 Signal Generator Setup

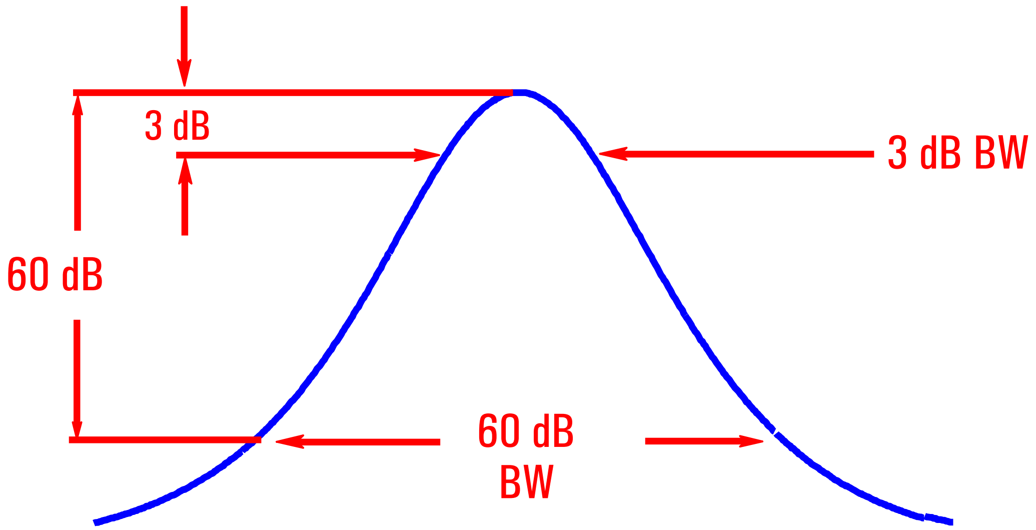
f = 170 MHz,
A = -25 dBm

2 Signal Generator Setup

f = 170.01 MHz,
A = -25 dBm

Specifications

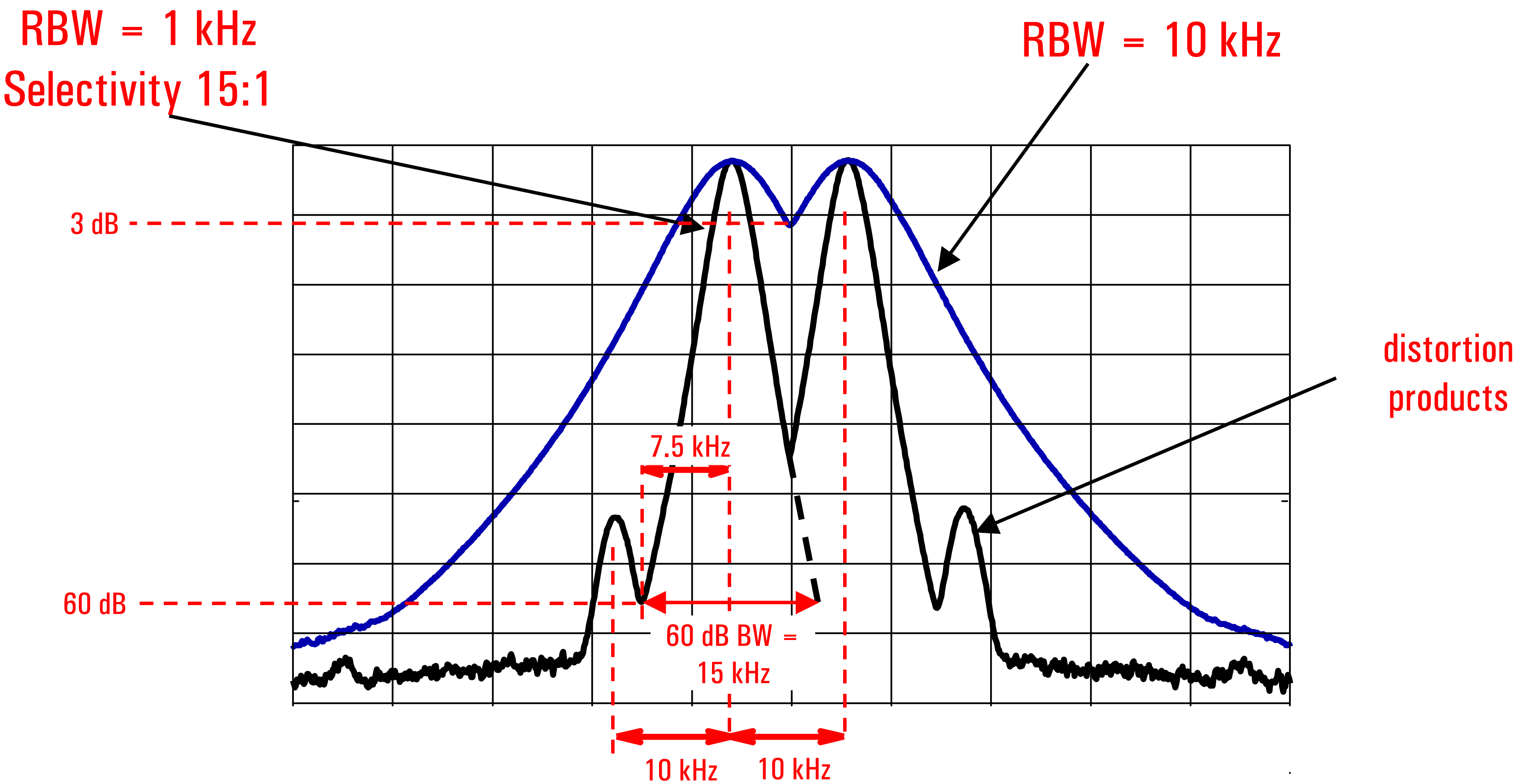
Resolution: RBW Type and Selectivity



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

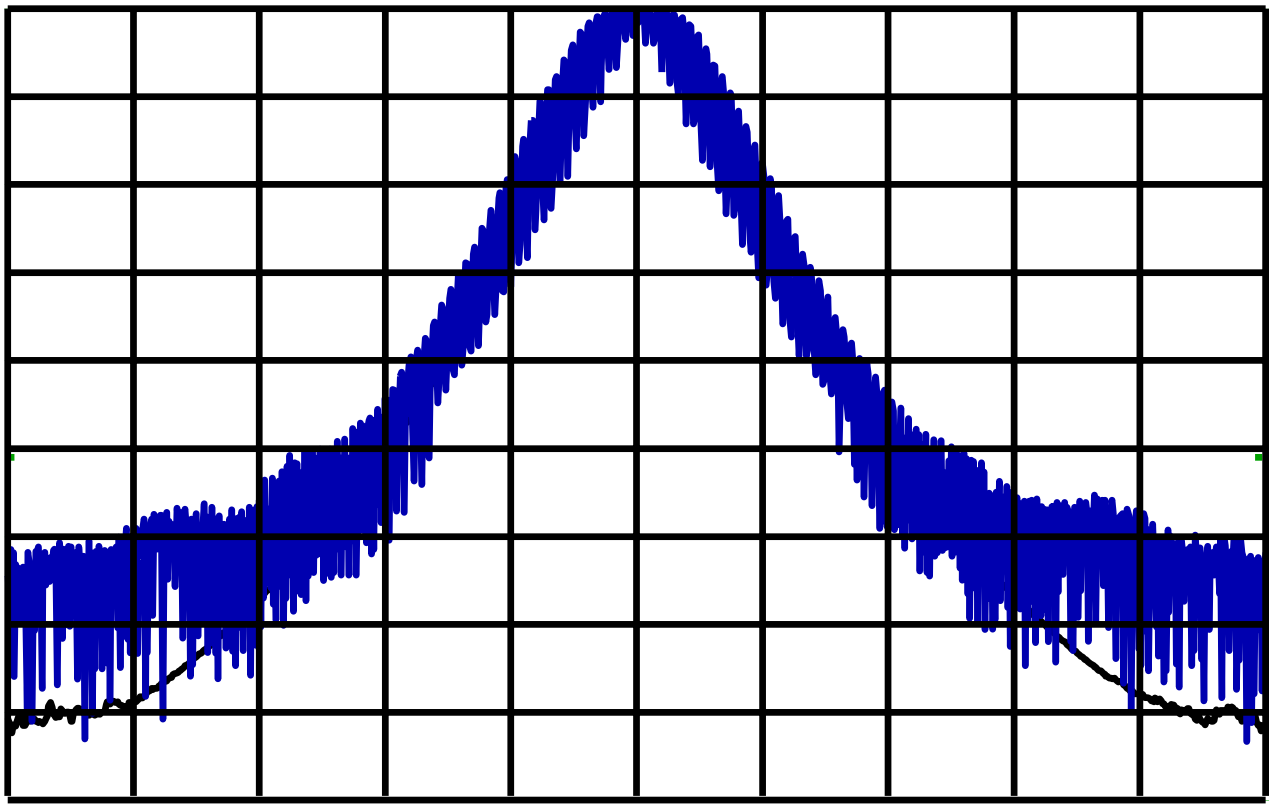
Specifications

Resolution: RBW Type and Selectivity



Specifications

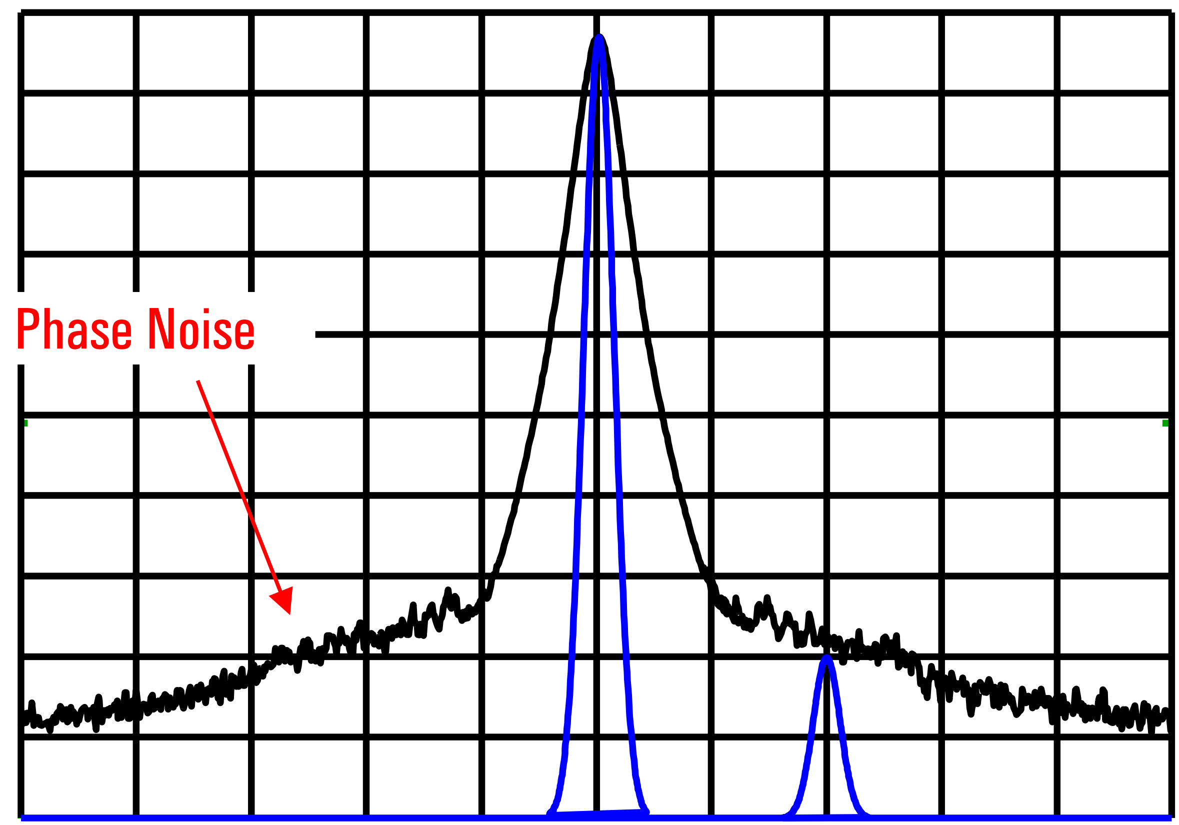
Resolution: Residual FM



Residual FM

"Smears" the Signal

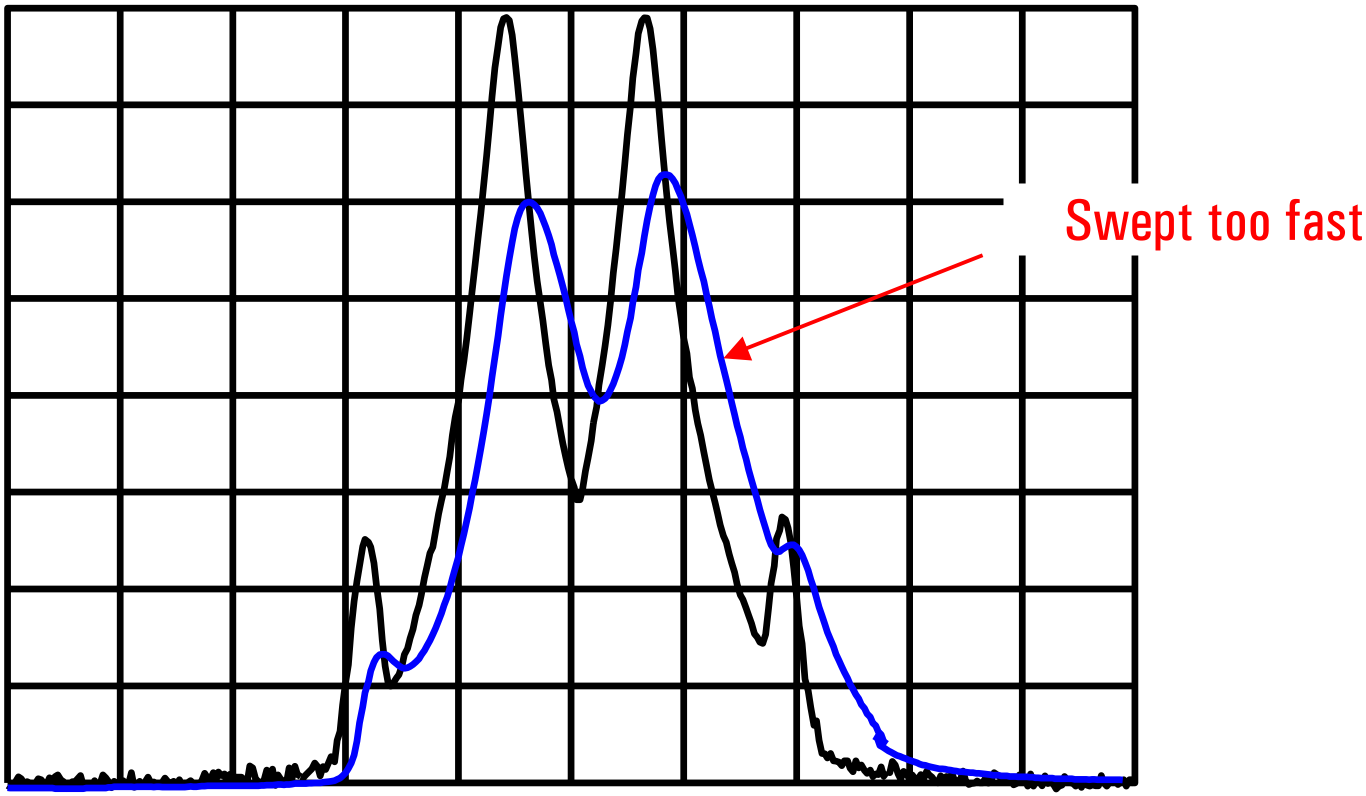
Specifications
Resolution: Noise Sidebands



Noise Sidebands can prevent resolution of unequal signals

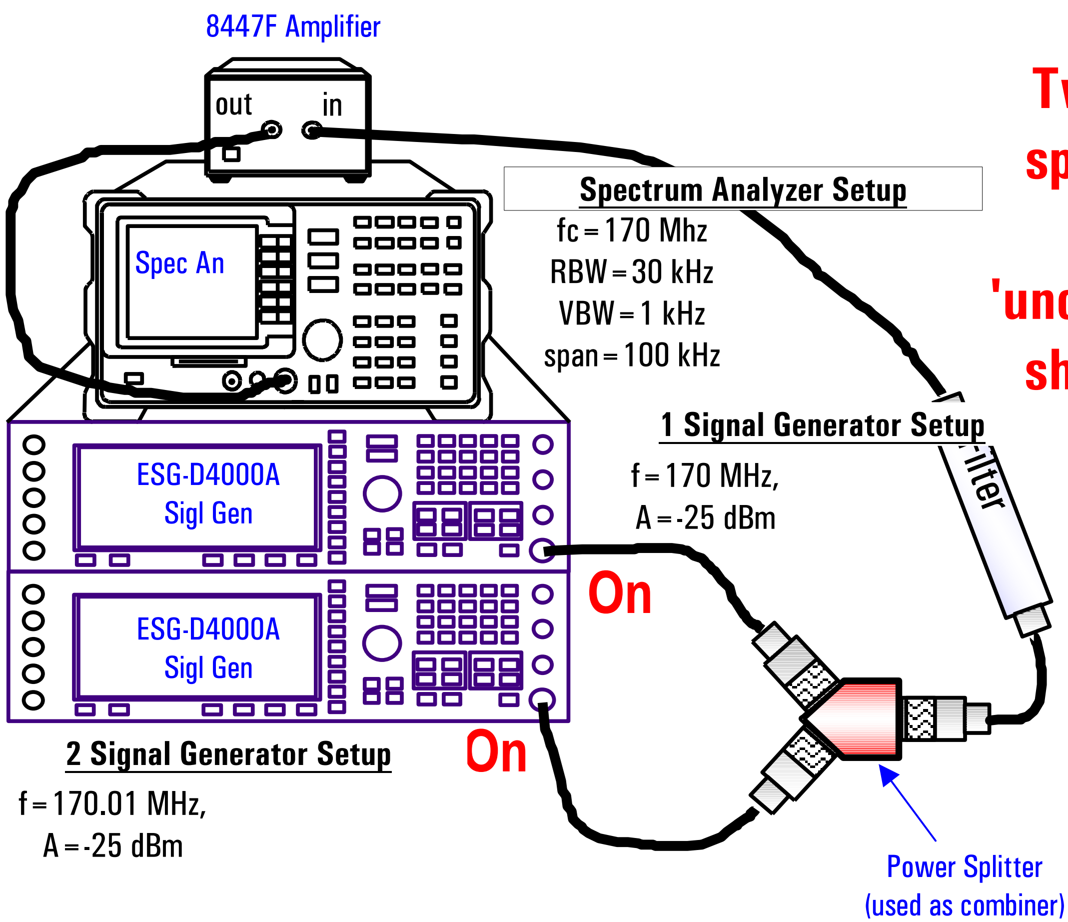
Specifications

Resolution: RBW Determines Measurement Time



Penalty For Sweeping Too Fast
Is An Uncalibrated Display

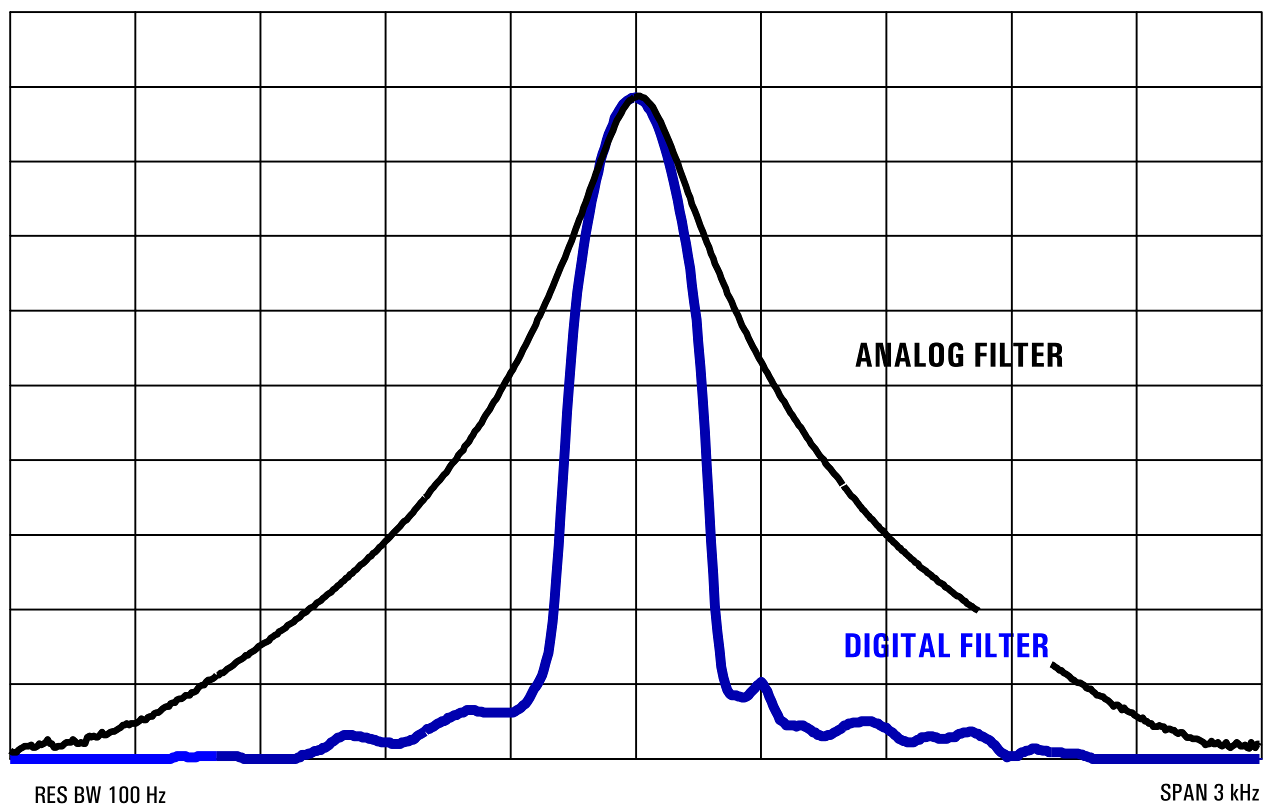
Demo - Specs: Resolution: RBW Determines Measurement Time



Two equal-amplitude signals spaced 10 kHz apart - change sweep time to show 'uncalibrated' message, & signal shifted down and to the right

Specifications

Resolution: Digital Resolution Bandwidths



Typical Selectivity

Analog 15:1

Digital 5:1

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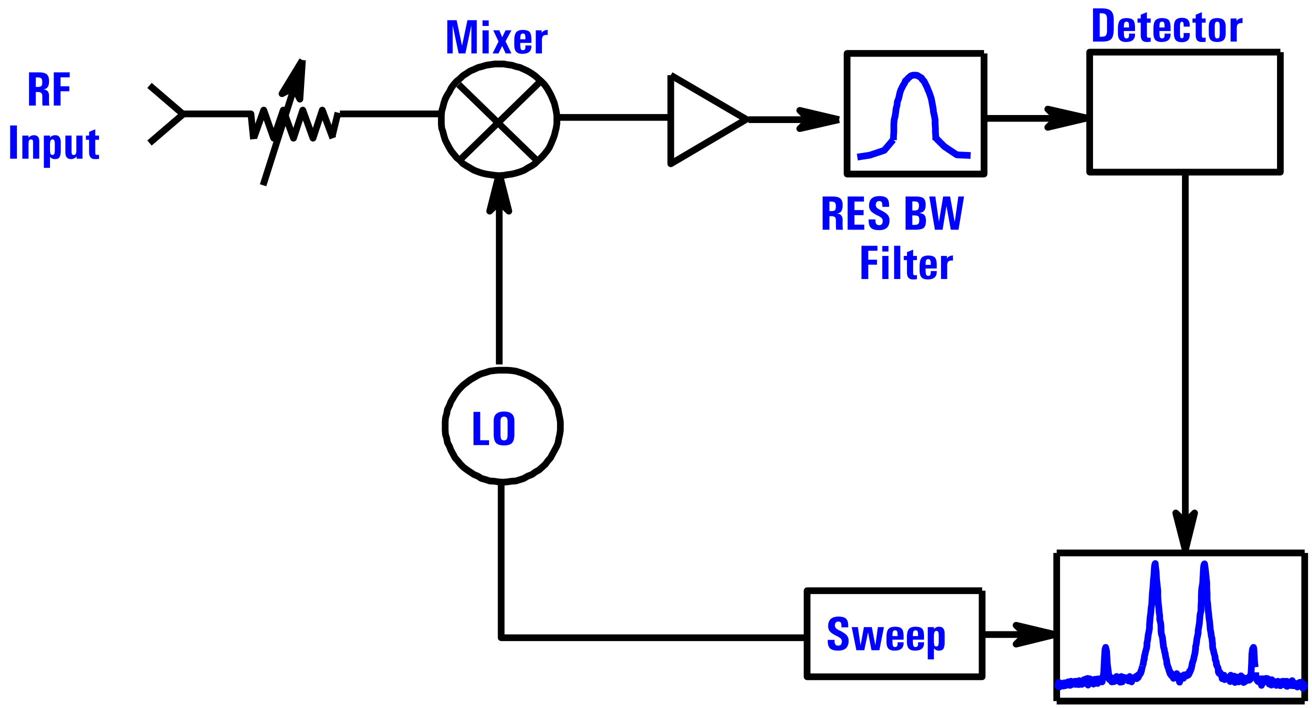
Specifications

Sensitivity/DANL

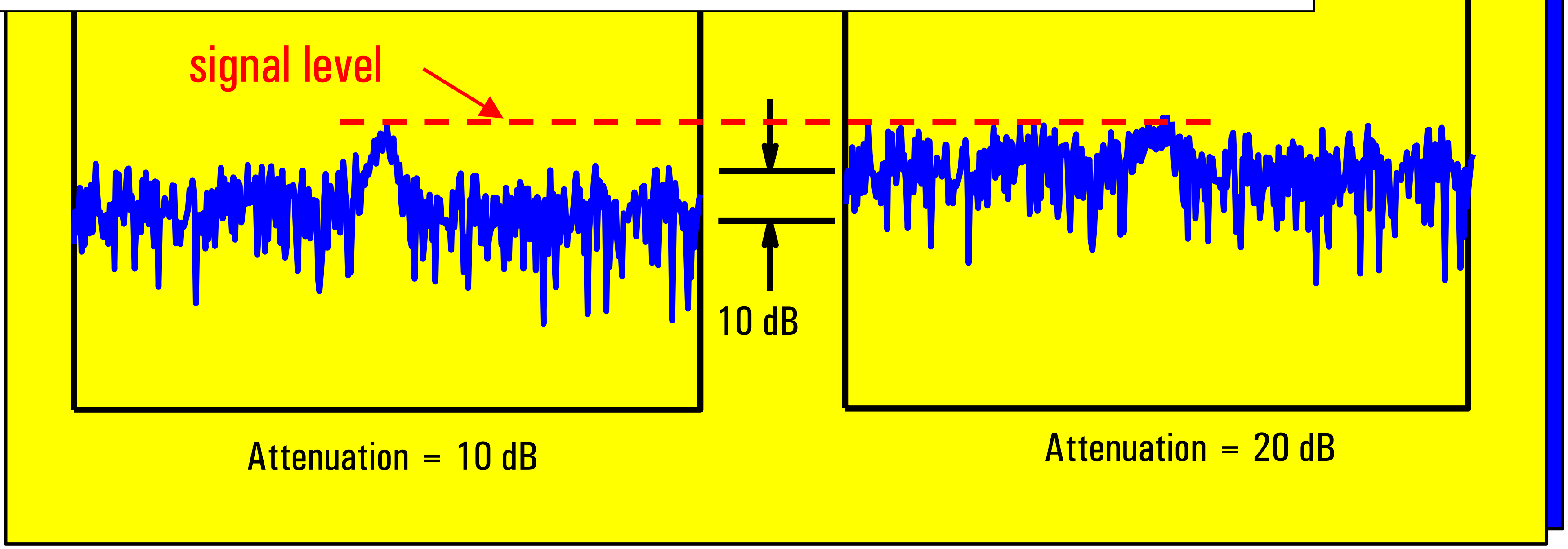


A Spectrum Analyzer Generates and Amplifies Noise Just Like Any Active Circuit

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

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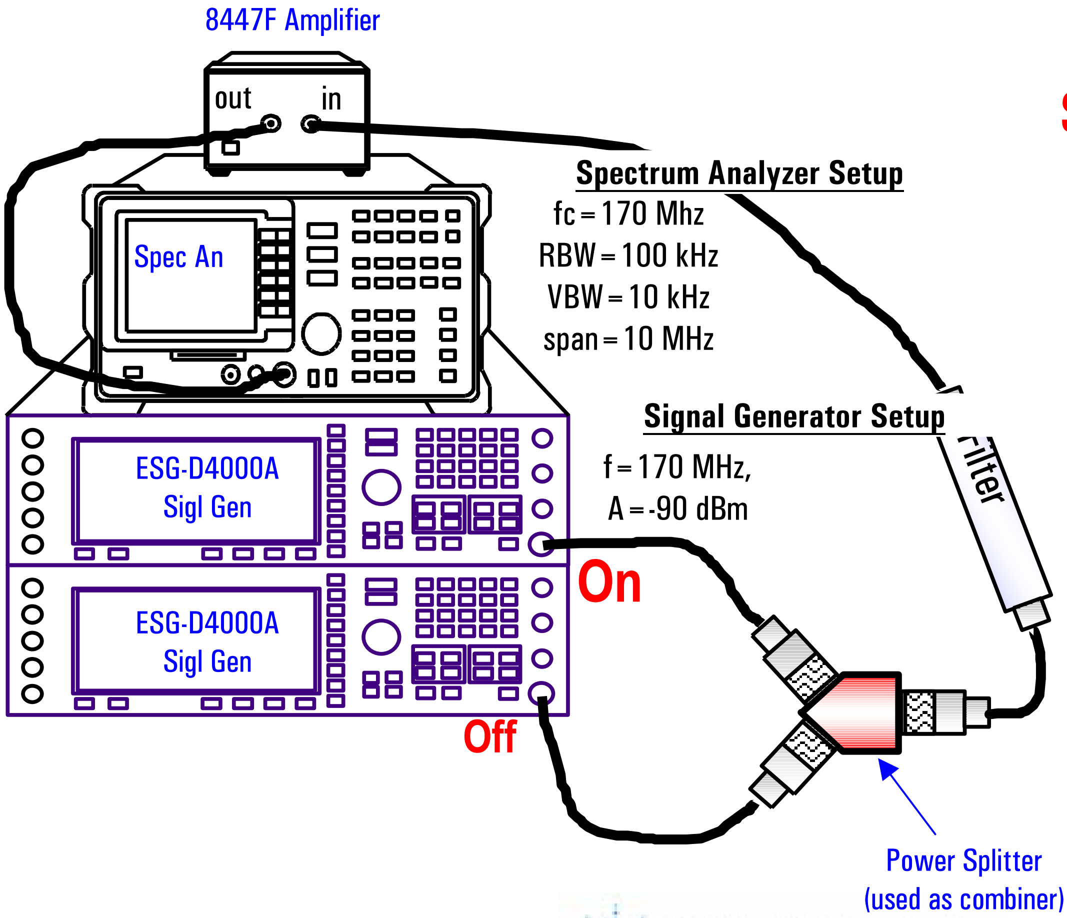
Demo #6 - Sensitivity/DANL - SNR decreases as RF input attn increases

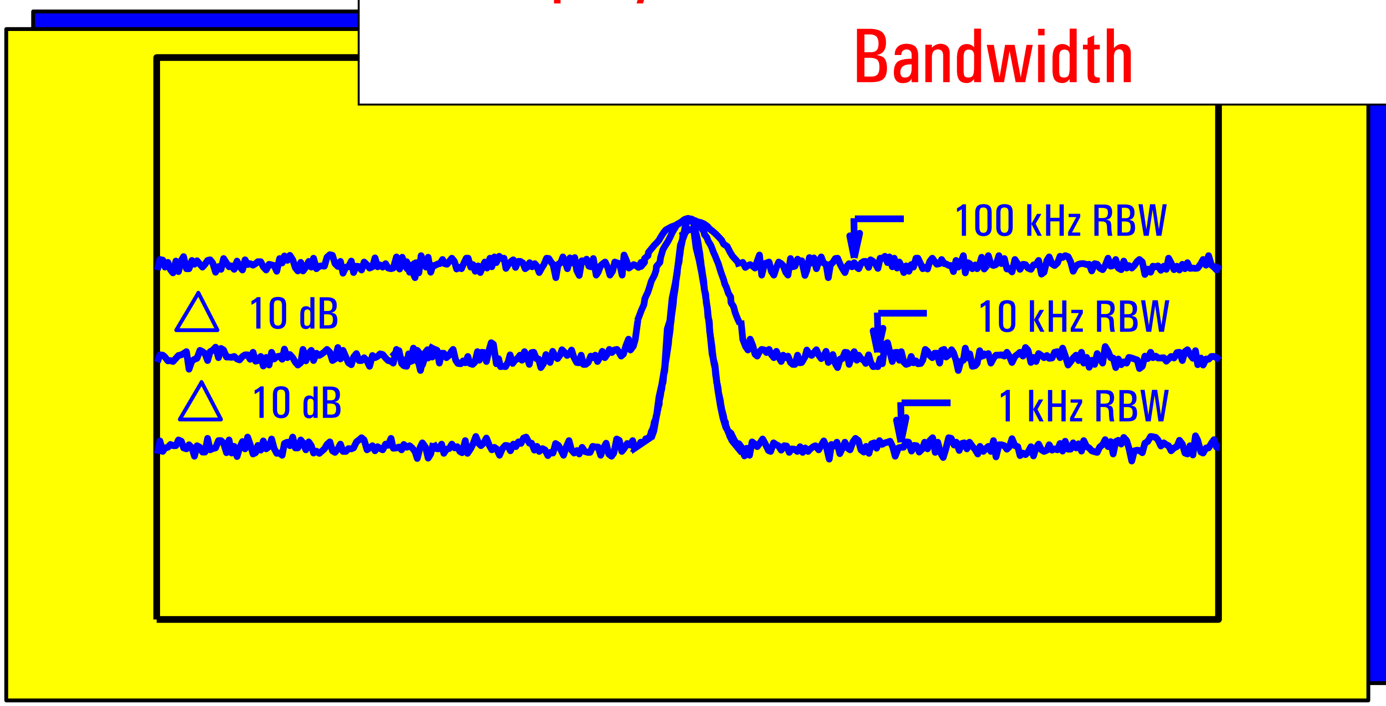


Small signal - change Input attenuation to see SNR decrease

Specifications

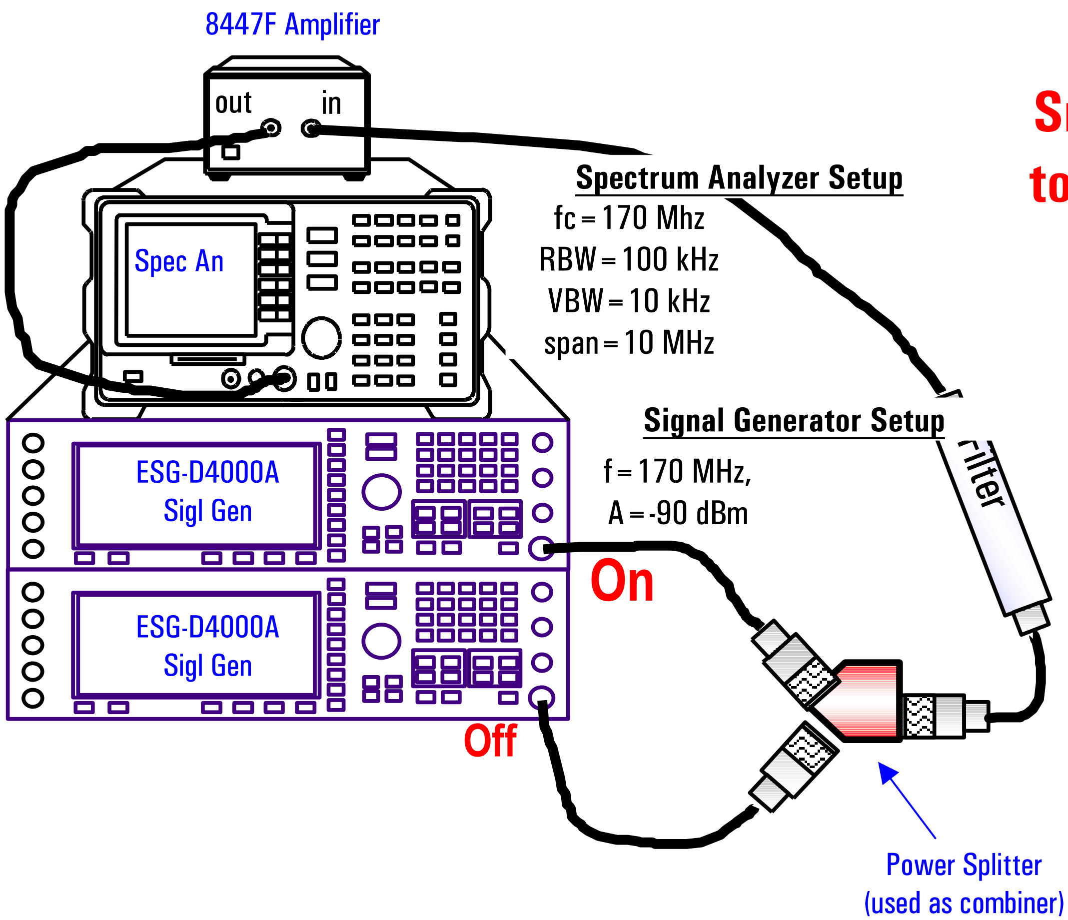
Sensitivity/DANL: IF Filter (RBW)

Displayed Noise is a Function of IF Filter Bandwidth



Decreased BW = Decreased Noise

Demo - Specs: Sensitivity/DANL: IF Filter



Spectrum Analyzer Setup

fc = 170 Mhz
RBW = 100 kHz
VBW = 10 kHz
span = 10 MHz

Signal Generator Setup

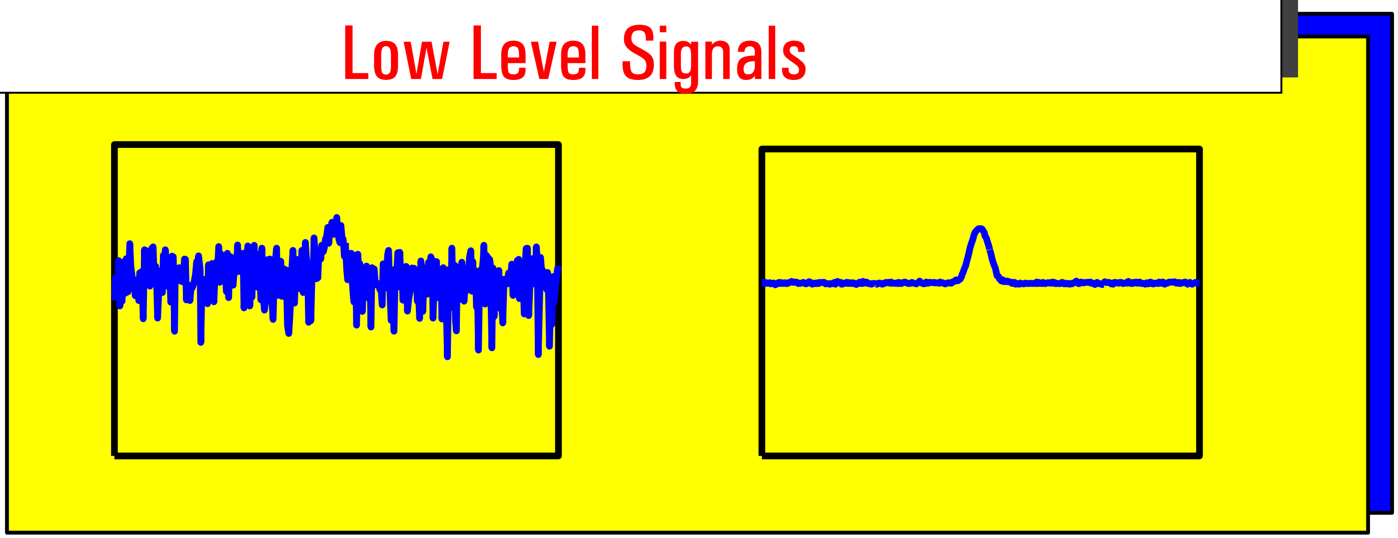
f = 170 MHz,
A = -90 dBm

Small signal - change RBW to see Noise level decrease

Specifications

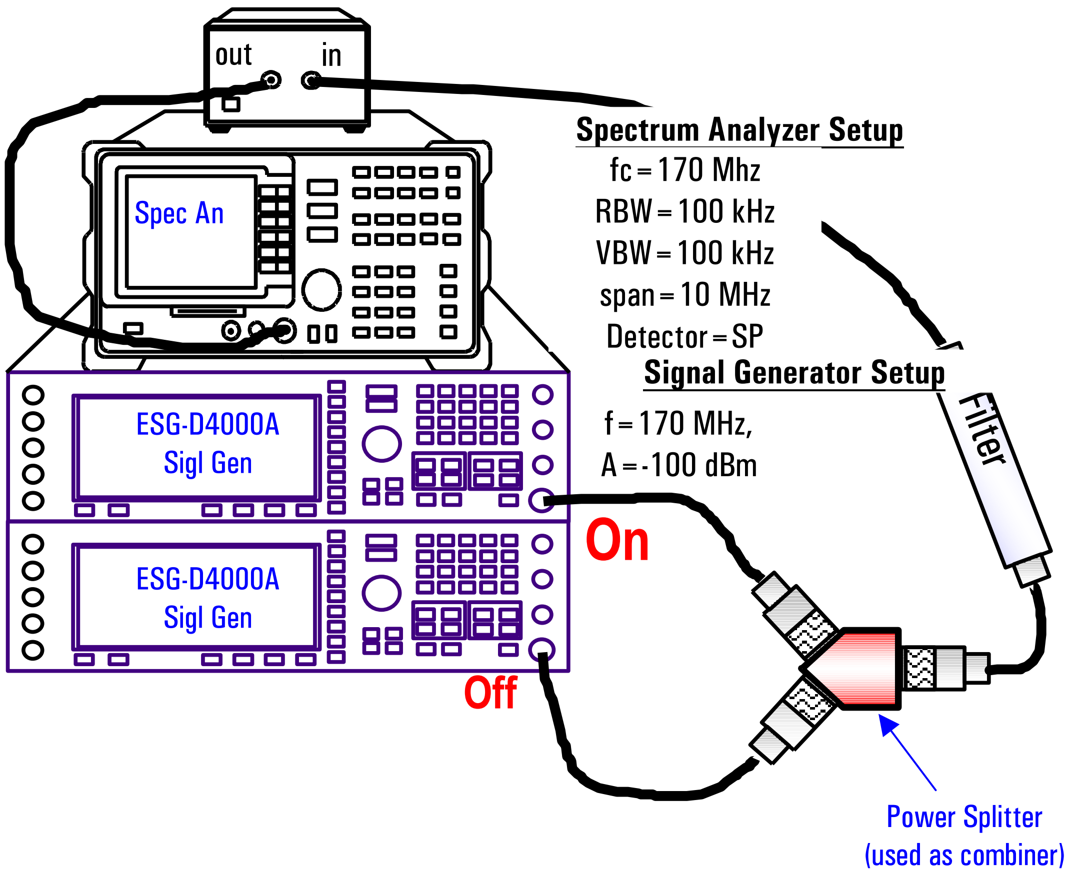
Sensitivity/DANL: VBW

Video BW Smoothes Noise for Easier Identification of Low Level Signals



Demo - Theory: Video Filter

Small signal in noise - change VBW to see smooth out



Spectrum Analyzer Setup

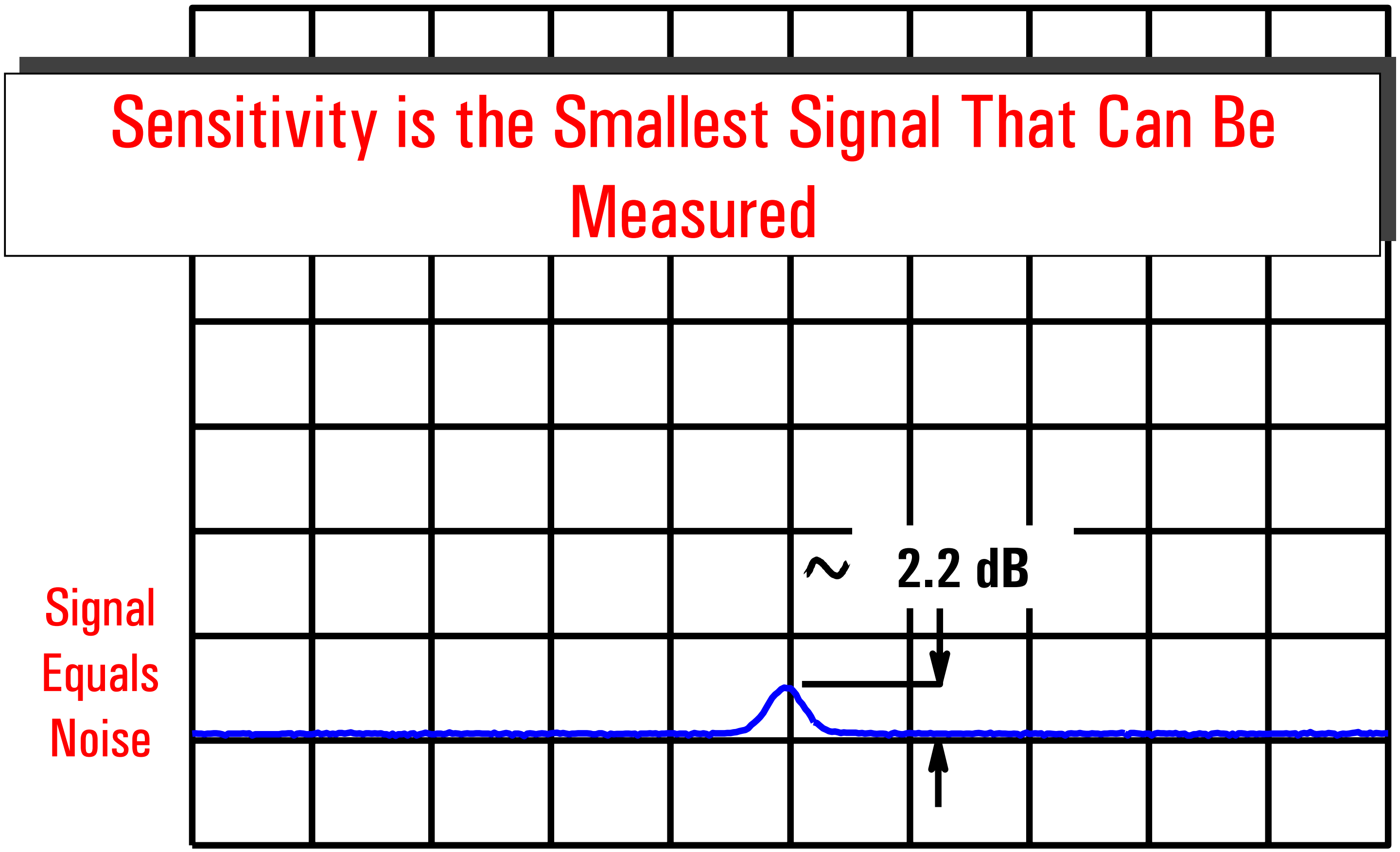
fc = 170 Mhz
RBW = 100 kHz
VBW = 100 kHz
span = 10 MHz
Detector = SP

Signal Generator Setup

f = 170 MHz,
A = -100 dBm

Specifications

Sensitivity/DANL



Specifications

Sensitivity/DANL

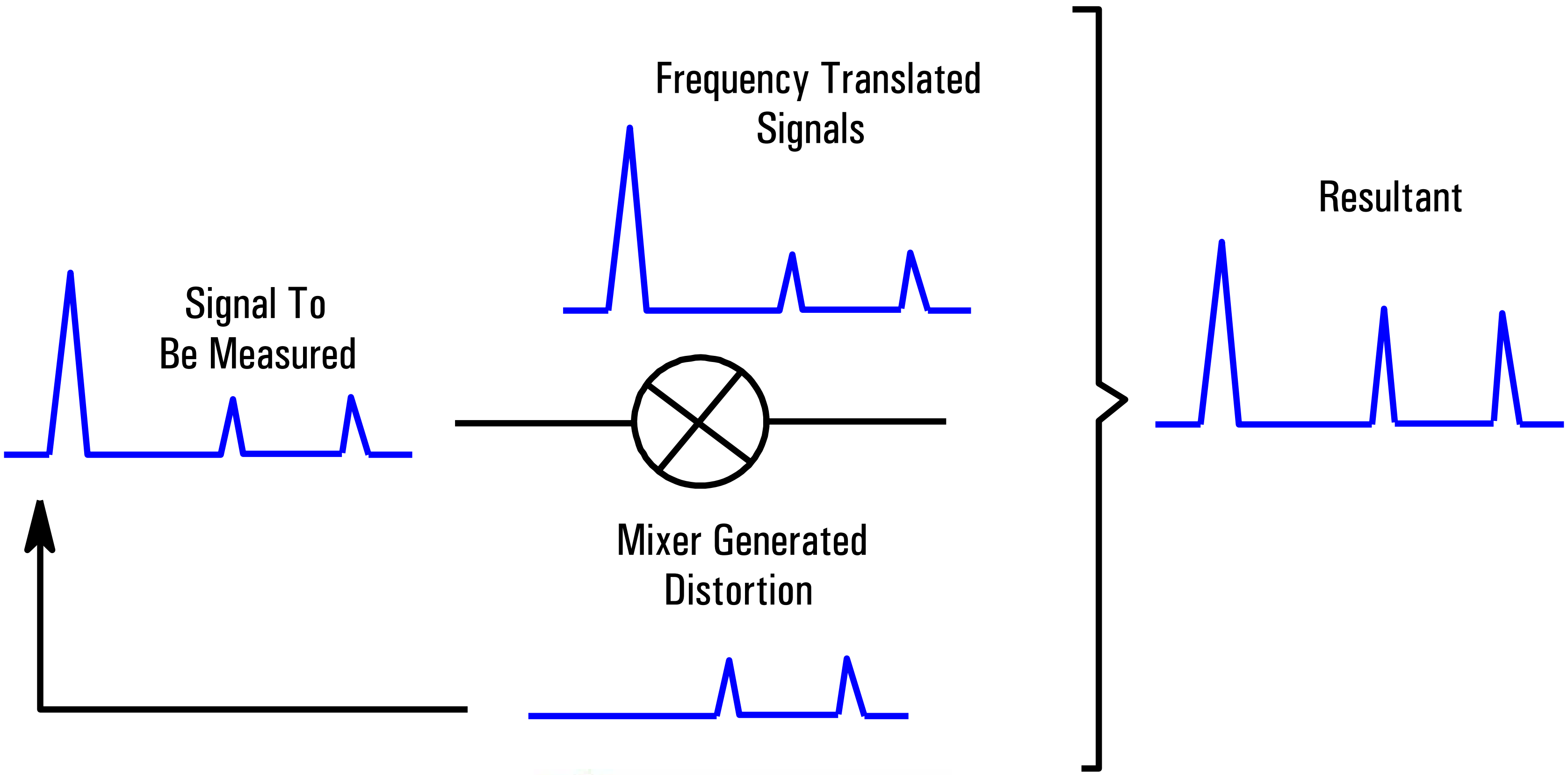
For Best Sensitivity Use:

- ★ **Narrowest Resolution BW**
- ★ **Minimum RF Input Attenuation**
- ★ **Sufficient Video Filtering**
  (Video BW < .01 Res BW)

Specifications

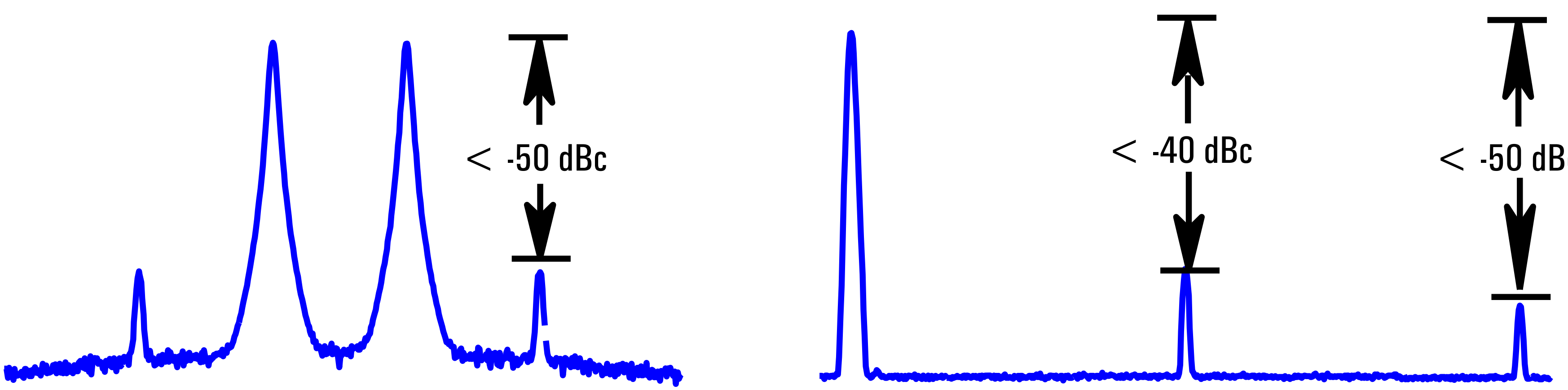
Distortion

Mixers Generate Distortion



Specifications
Distortion

Most Influential Distortion is the Second and Third Order



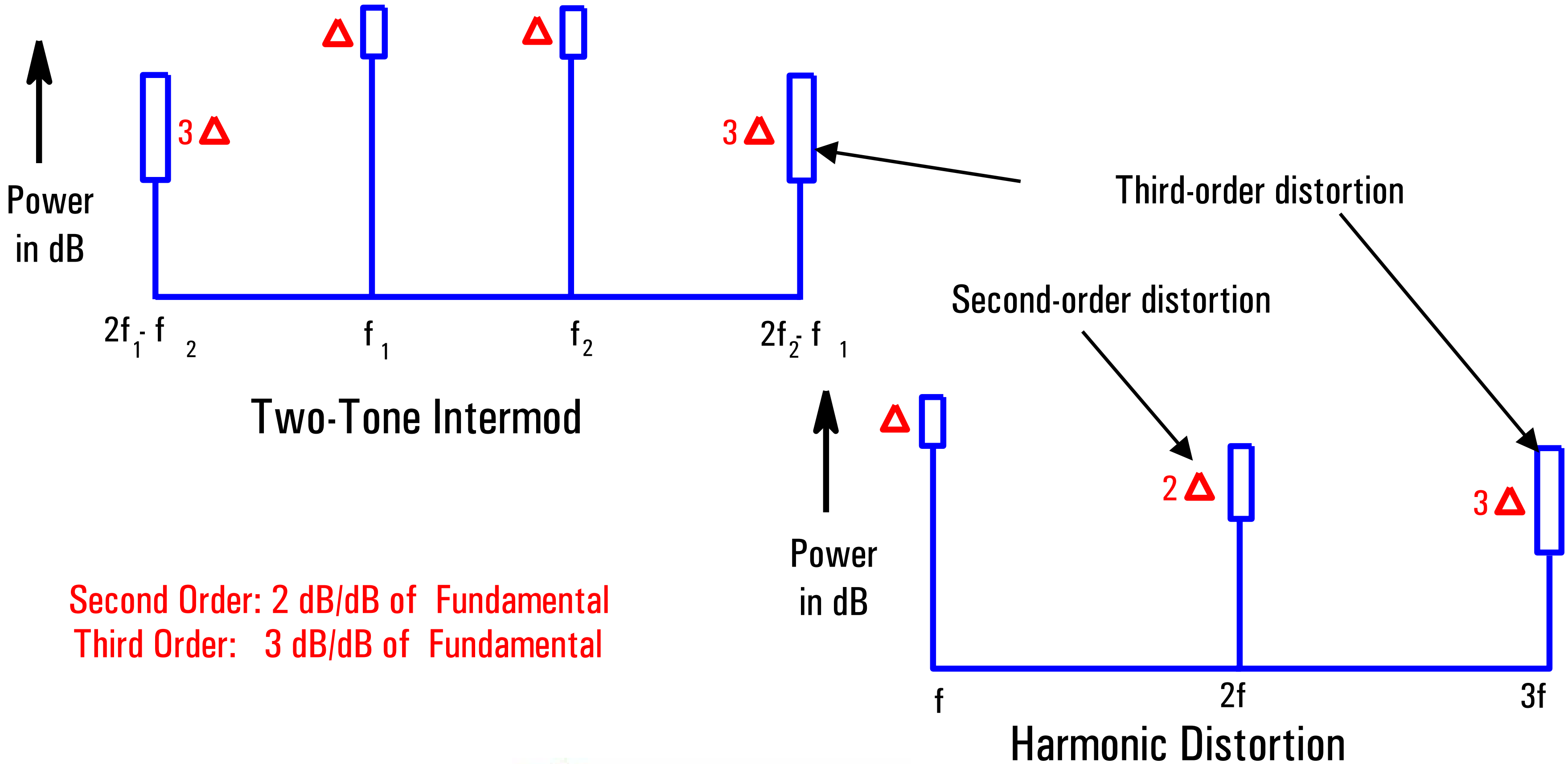
Two-Tone Intermod

Harmonic Distortion

Specifications

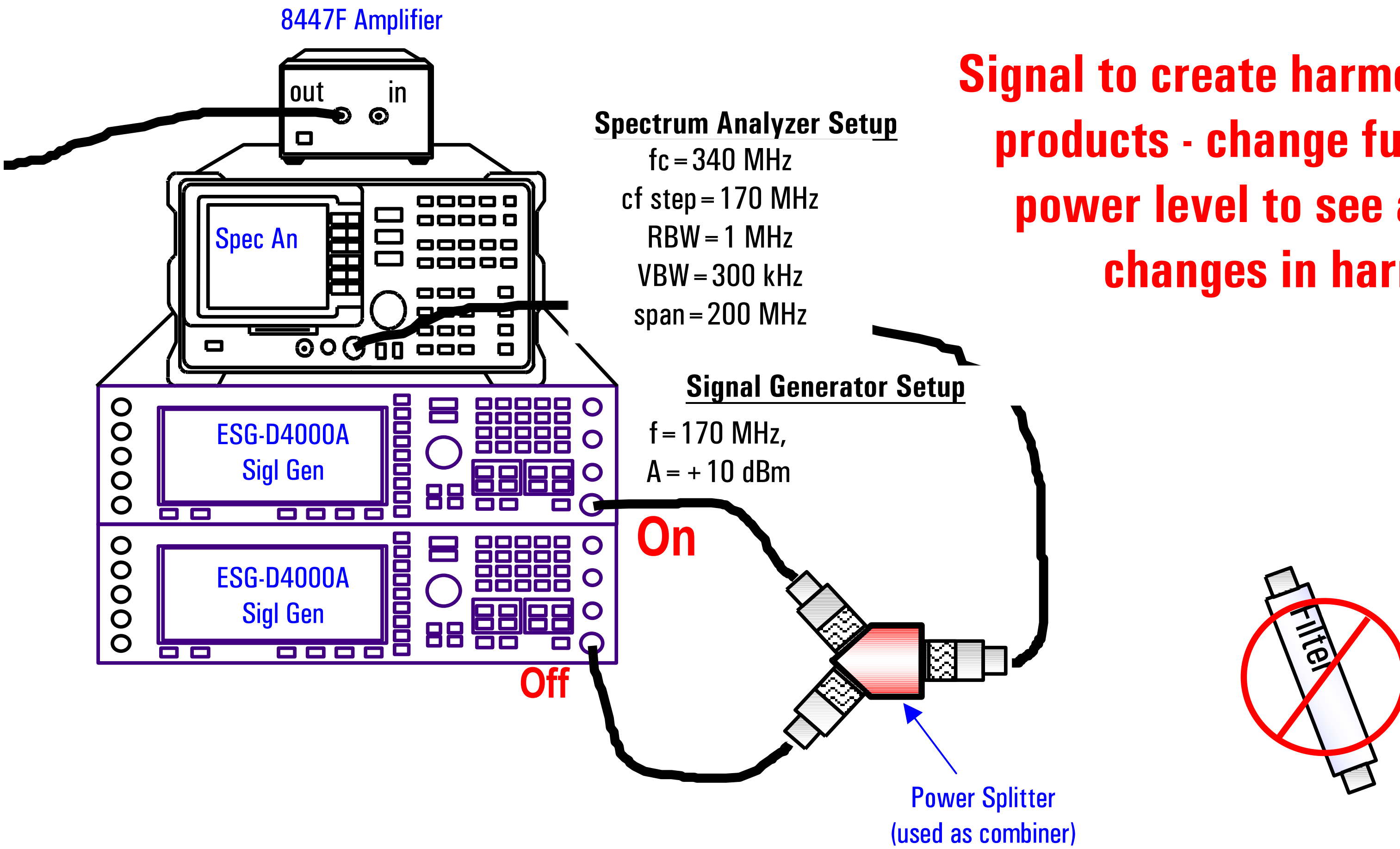
Distortion

Distortion Products Increase as a Function of Fundamental's Power



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

Demo - Specs: Distortion - Distortion products increase as a function of fundamental's power



Spectrum Analyzer Setup

fc = 340 MHz
cf step = 170 MHz
RBW = 1 MHz
VBW = 300 kHz
span = 200 MHz

Signal Generator Setup

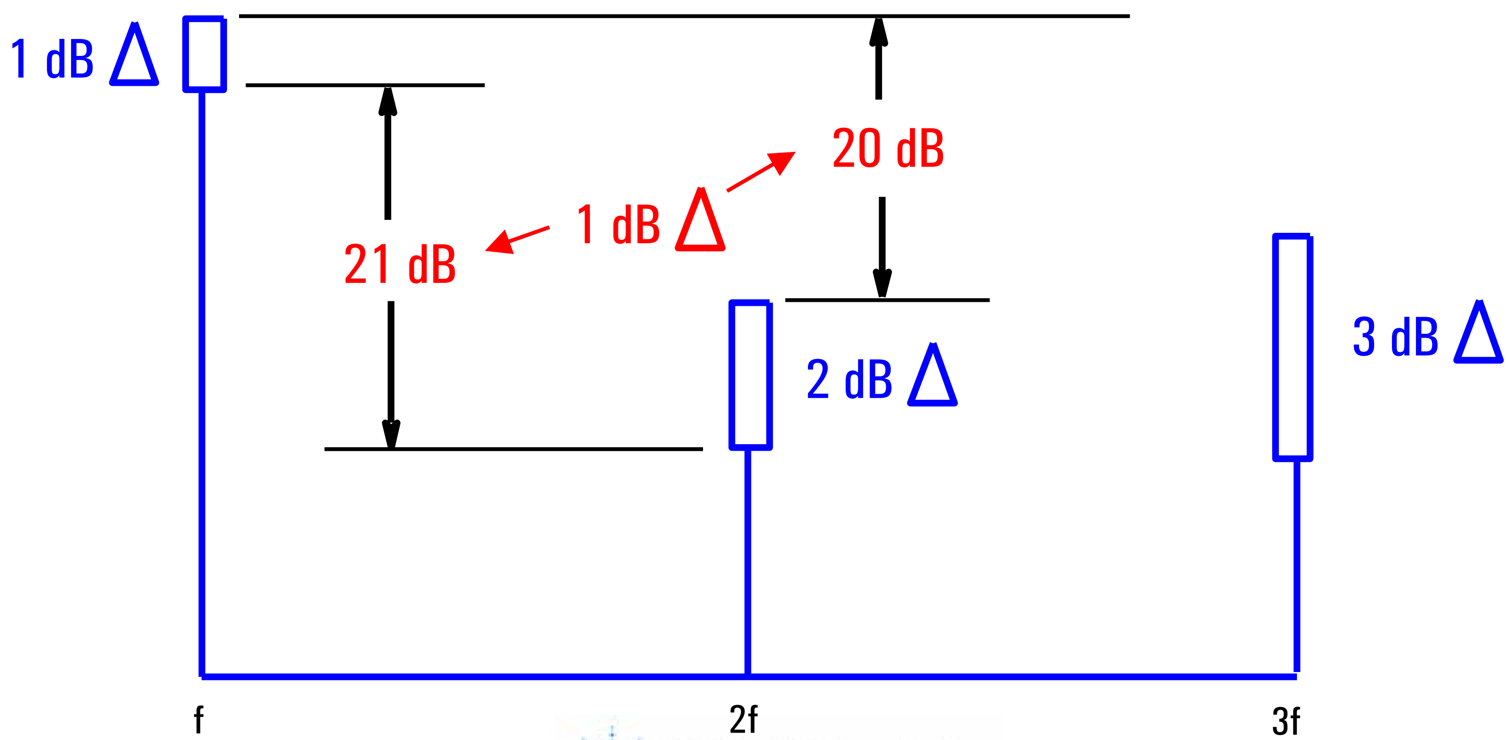
f = 170 MHz,
A = + 10 dBm

Signal to create harmonic distortion products - change fundamental's power level to see appropriate changes in harmonics

Specifications

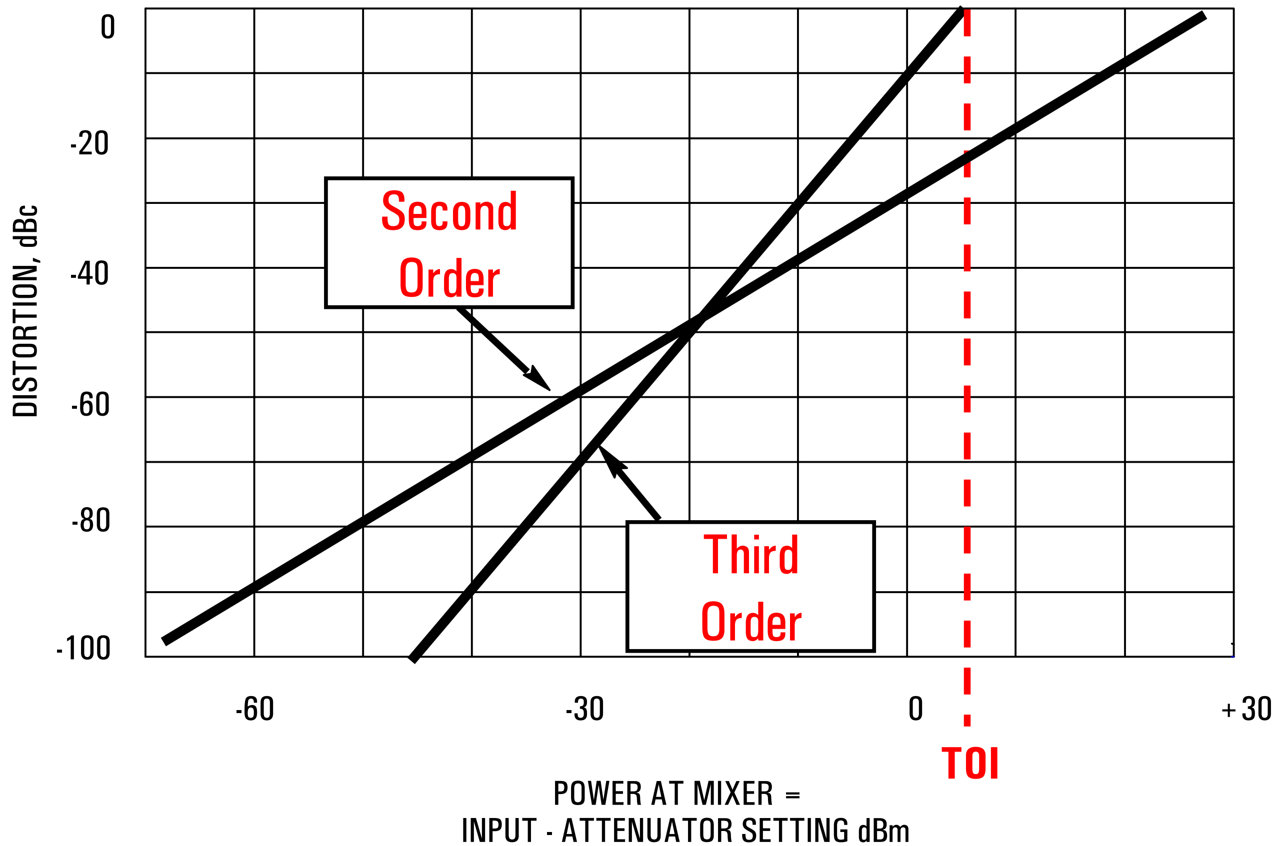
Distortion

Relative Amplitude Distortion Changes with Input Power Level



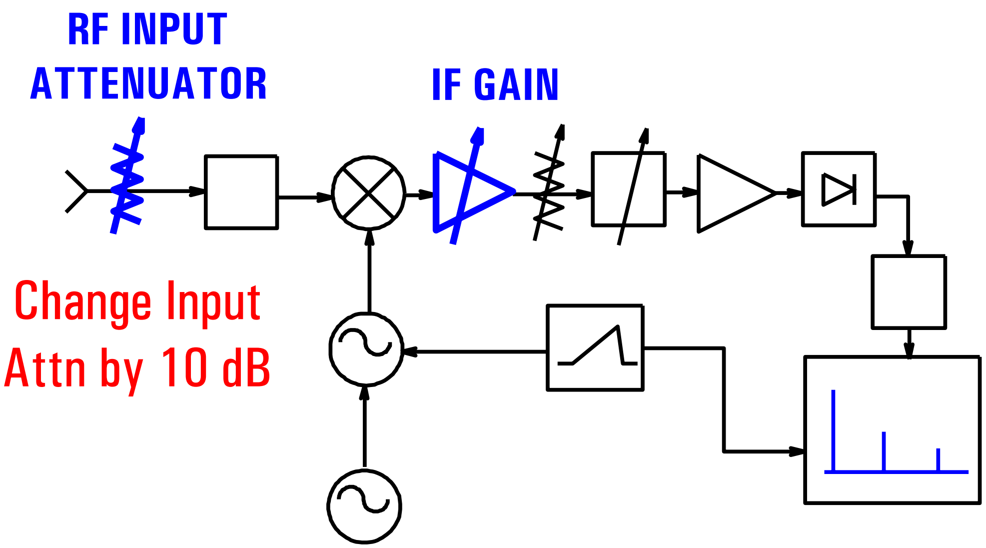
Specifications
Distortion

Distortion is a Function of Mixer Level



Specifications
Distortion

Distortion Test:
Is it Internally or Externally Generated?



1 Change Input Attn by 10 dB

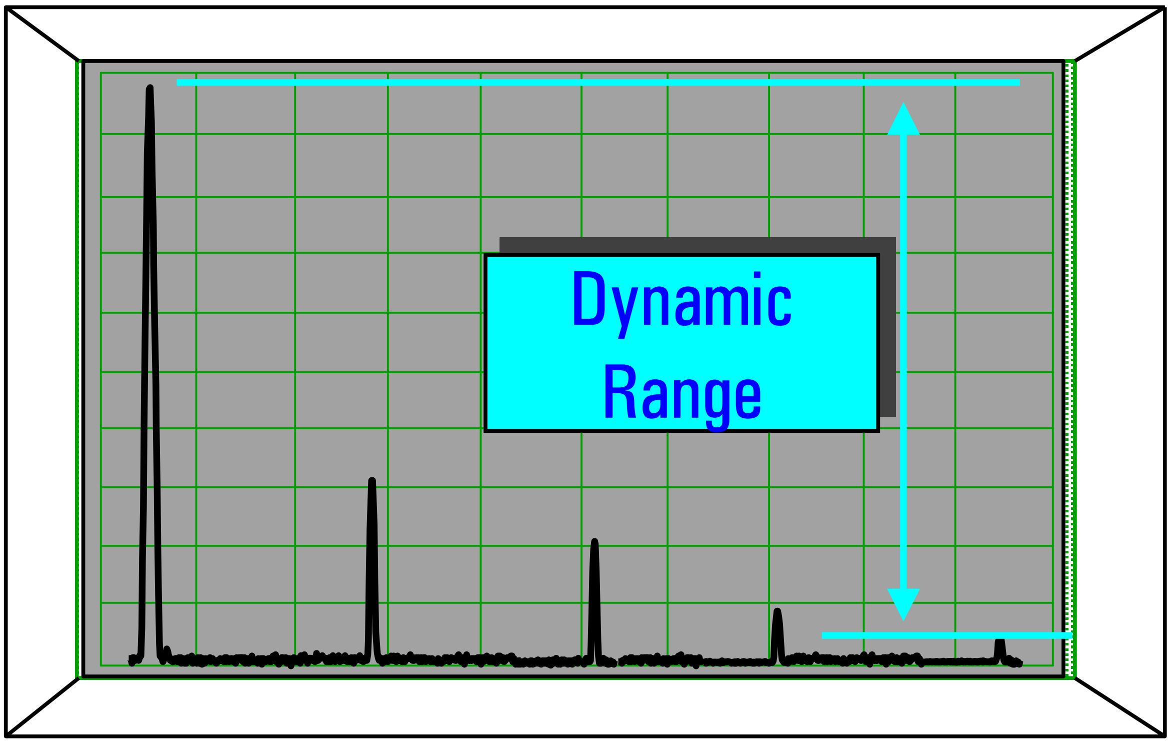
2 Watch Signal on Screen:

- 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)

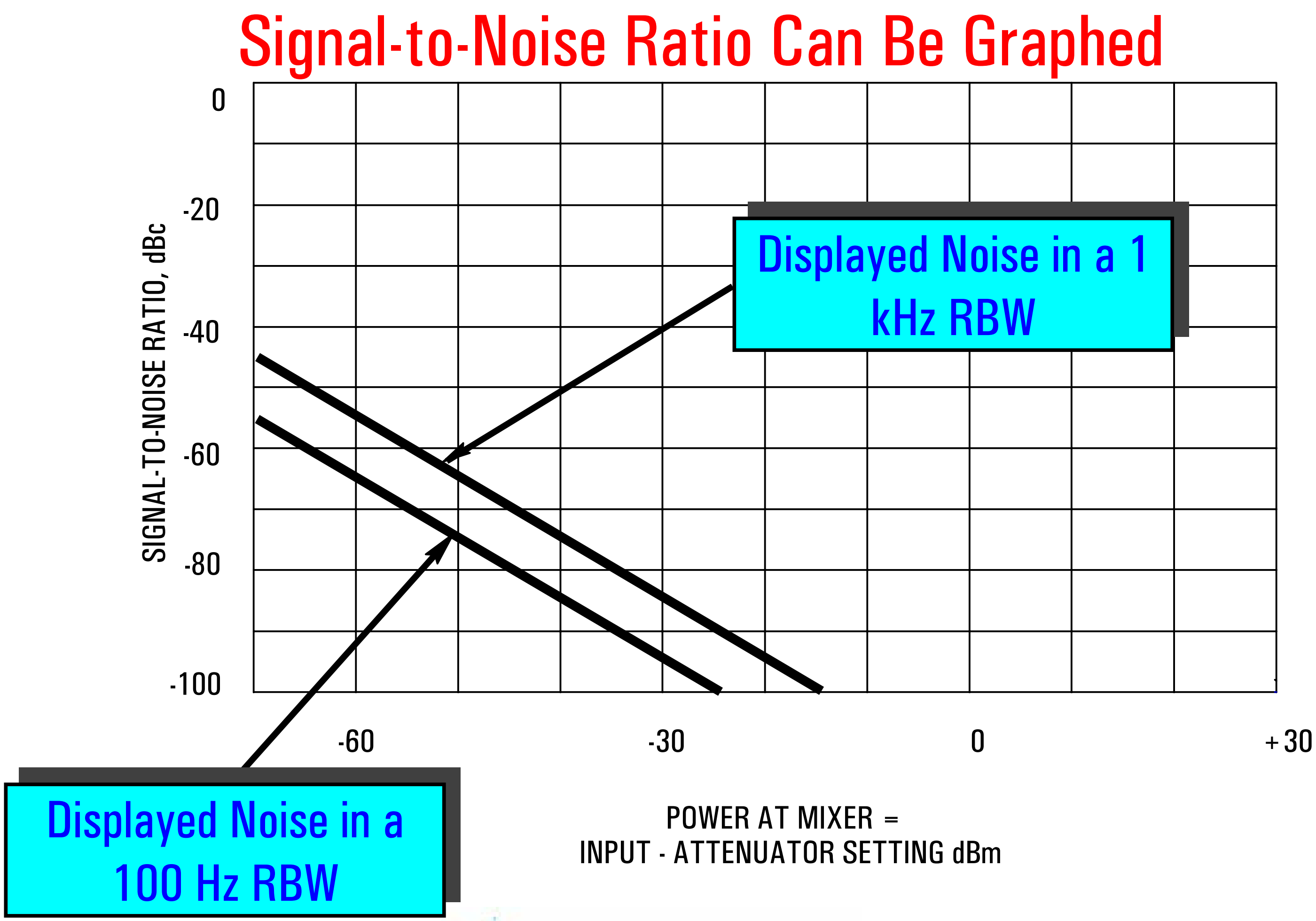
Specifications

Dynamic Range



Specifications

Dynamic Range



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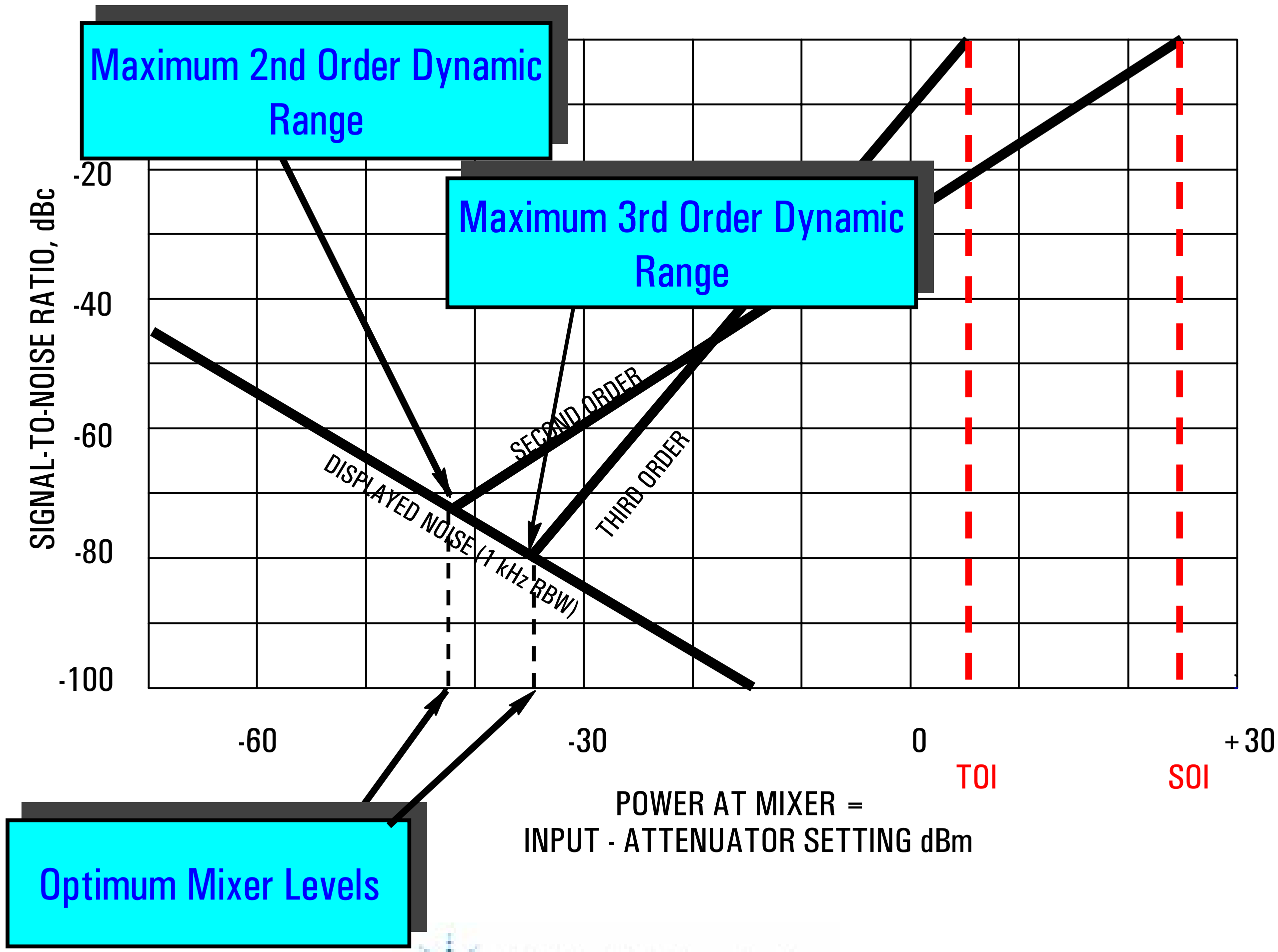
Specifications
Dynamic Range

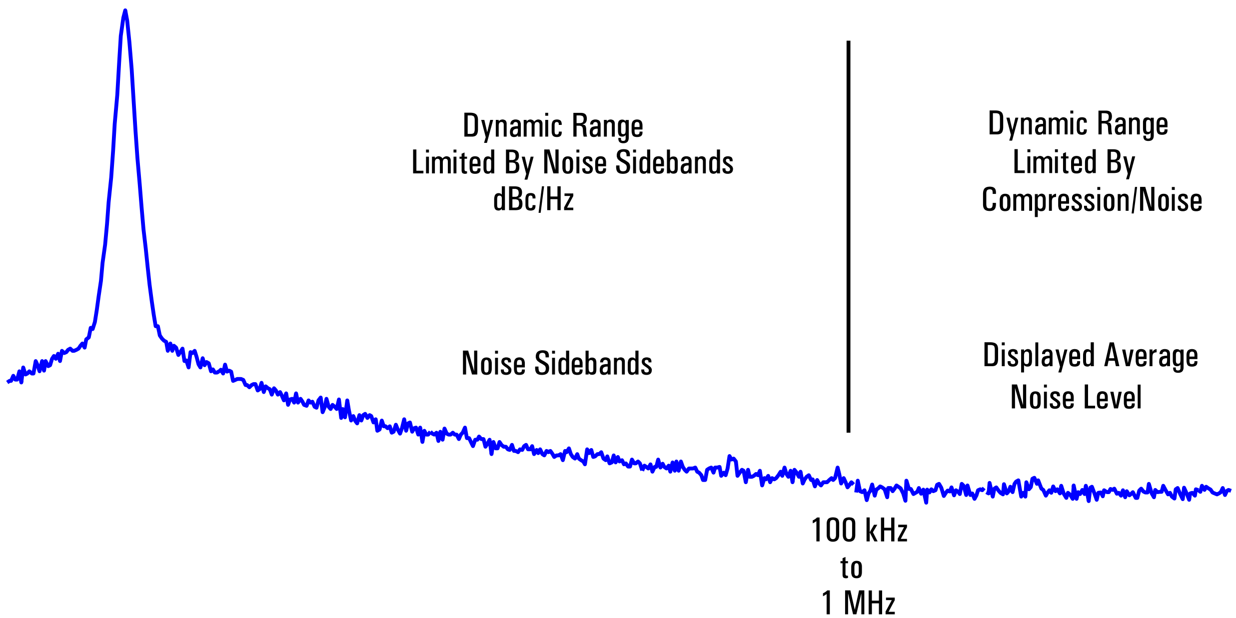
Dynamic Range Can Be Presented Graphically



Specifications

Dynamic Range

Dynamic Range for Spur Search Depends on Closeness to Carrier



Specifications

Dynamic Range

Actual Dynamic Range is the Minimum of:

Maximum dynamic range calculation

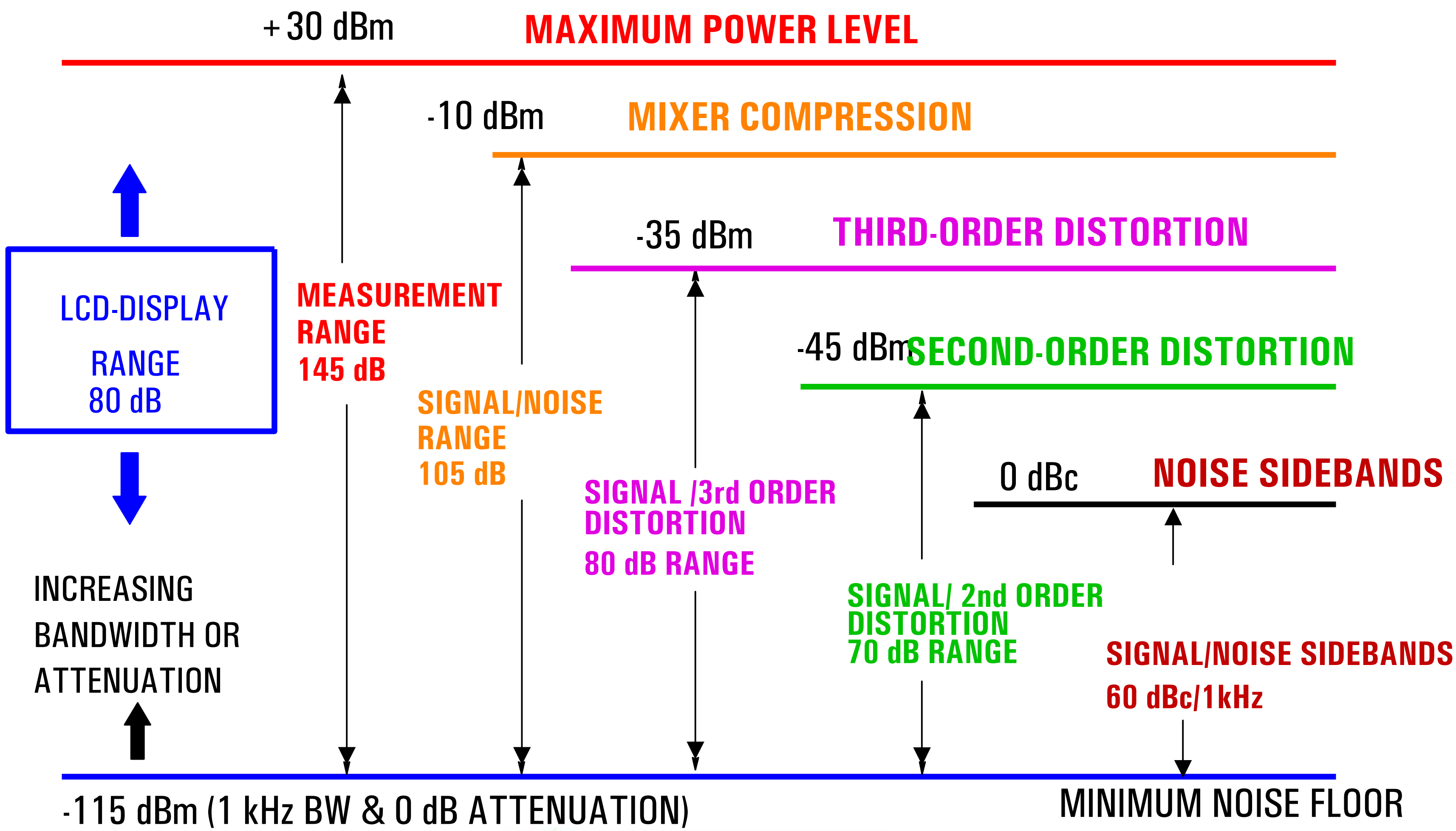
Calculated from:

- → distortion
- → sensitivity

Noise sidebands at the offset frequency

Specifications

Dynamic Range



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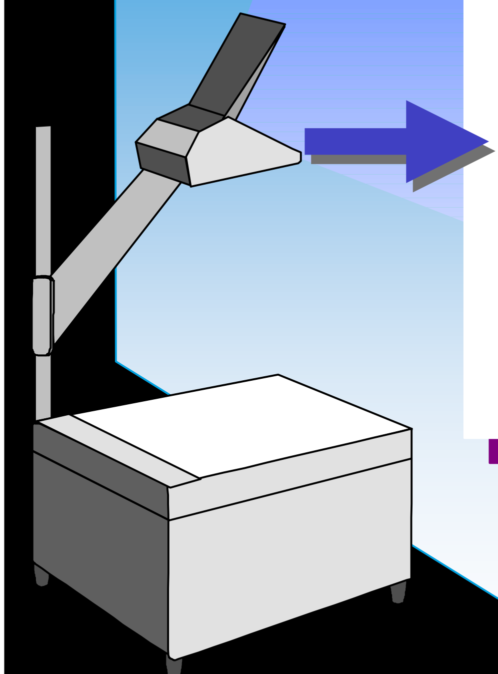
Agenda



- Overview
- Theory of Operation
- Specifications
- Features
- Summary
- Appendix

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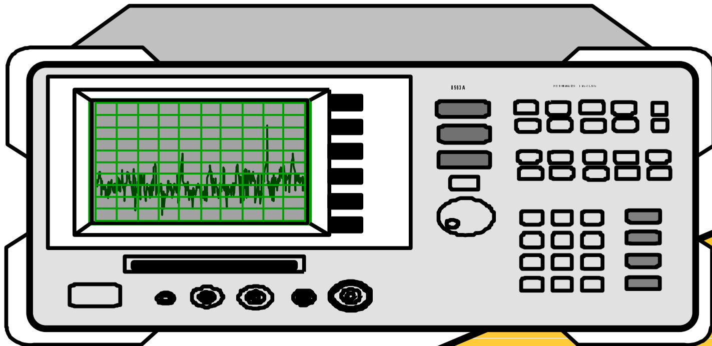
Features



➤ Basic Operation

- ✓ remote operation
- ✓ markers
- ✓ limit lines

➤ Modulation Measurements

- ✓ time domain
- ✓ FFT
- ✓ AM/FM detector
- ✓ time-gating

➤ Noise Measurements

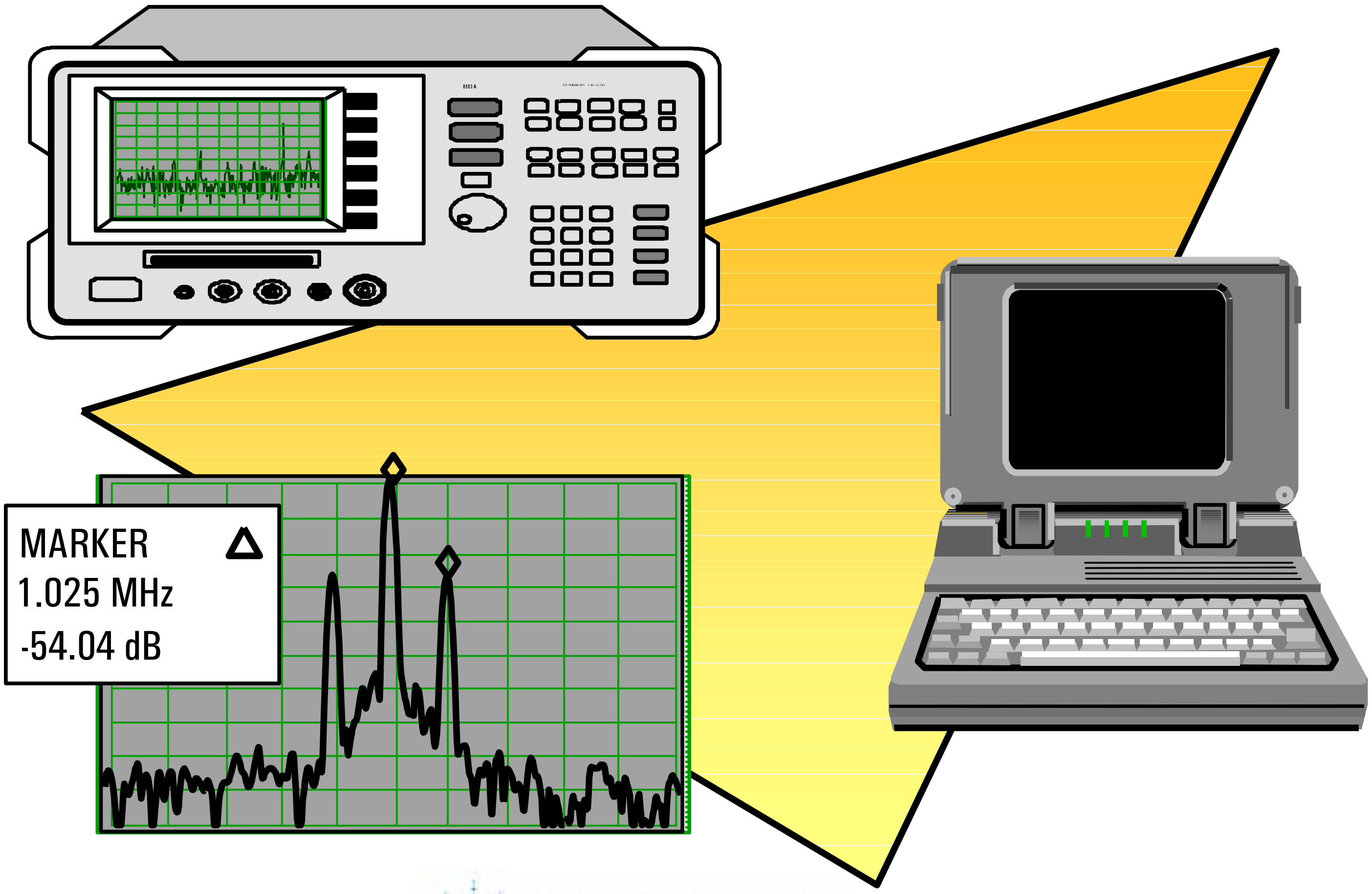
- ✓ noise marker
- ✓ averaging

➤ Stimulus Response Measurements

- ✓ tracking generator

Features

Basic Operation: Remote Operation, Markers & Limit Lines



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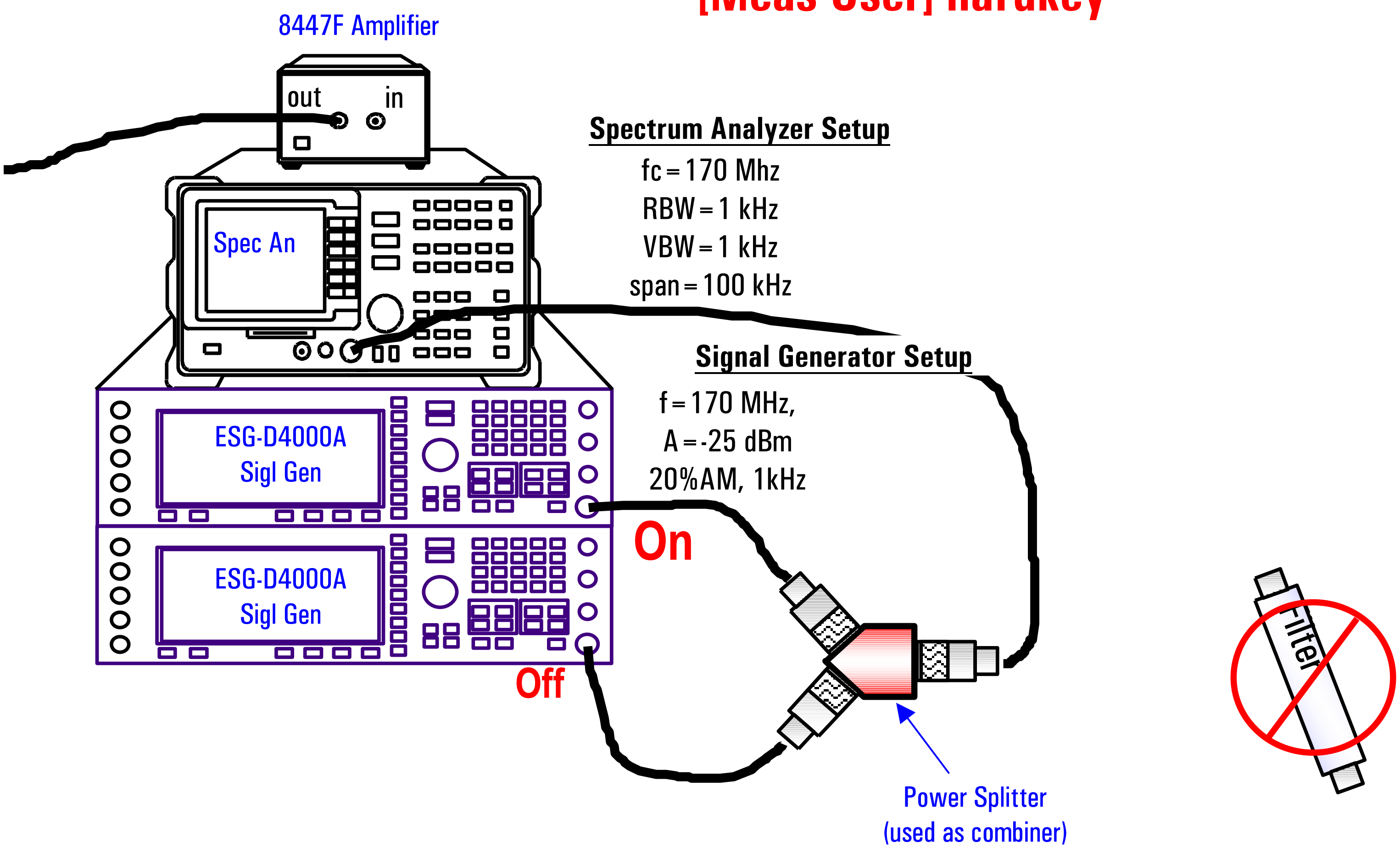
Demo #9 - Features: Basic Operation

Show use of %AM markers under [Meas User] hardkey



Spectrum Analyzer Setup

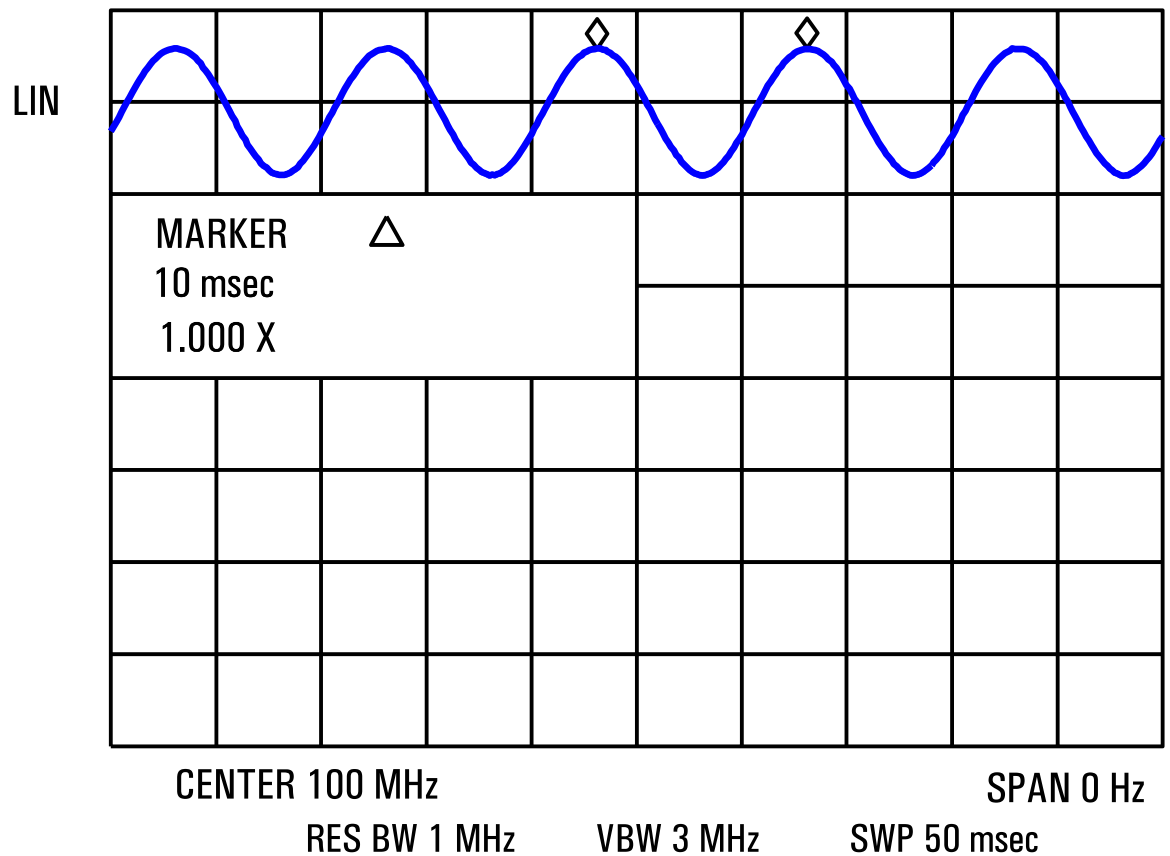
fc = 170 Mhz
RBW = 1 kHz
VBW = 1 kHz
span = 100 kHz

Signal Generator Setup

f = 170 MHz,
A = -25 dBm
20%AM, 1kHz

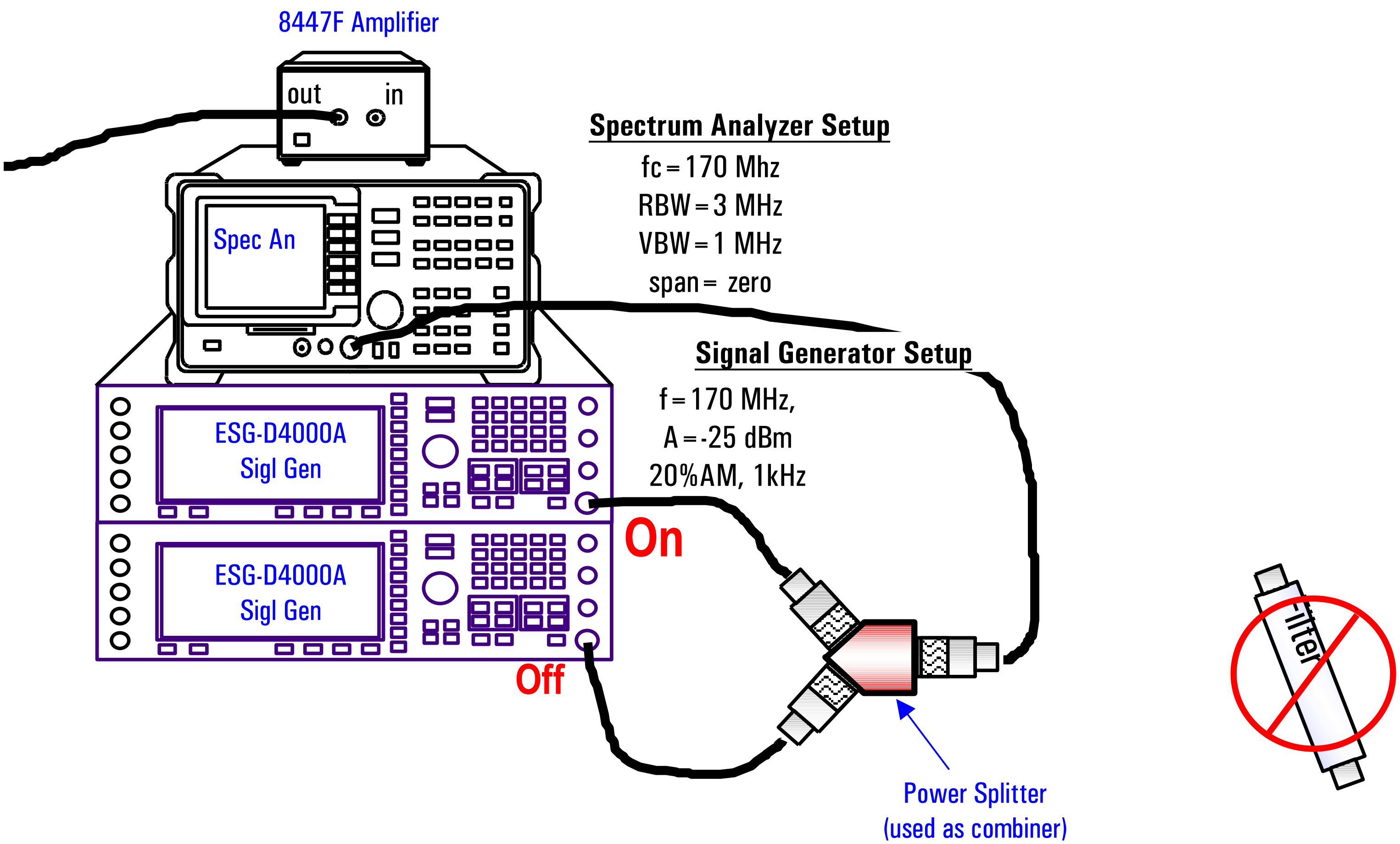
Features

Modulation Measurements: Time Domain



Demo #10 - Features: Mod Meas'ts: Time Domain

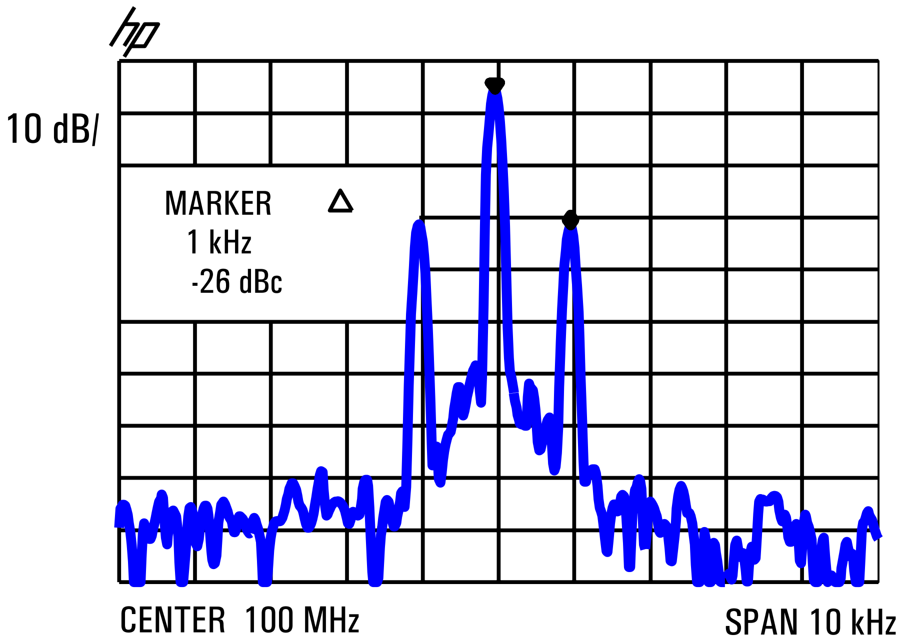
AM signal - look at in zero-span



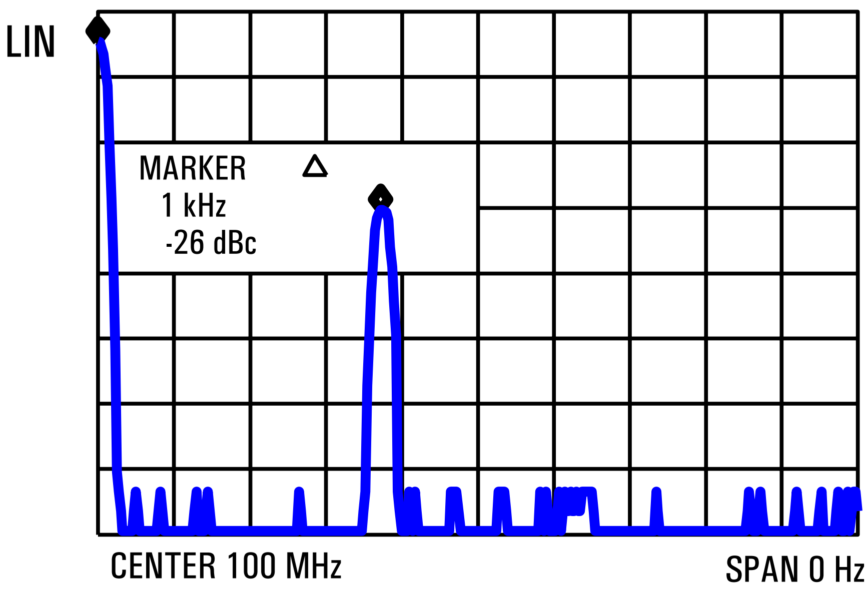
Features

Modulation Measurements: FFT

Swept Frequency Domain

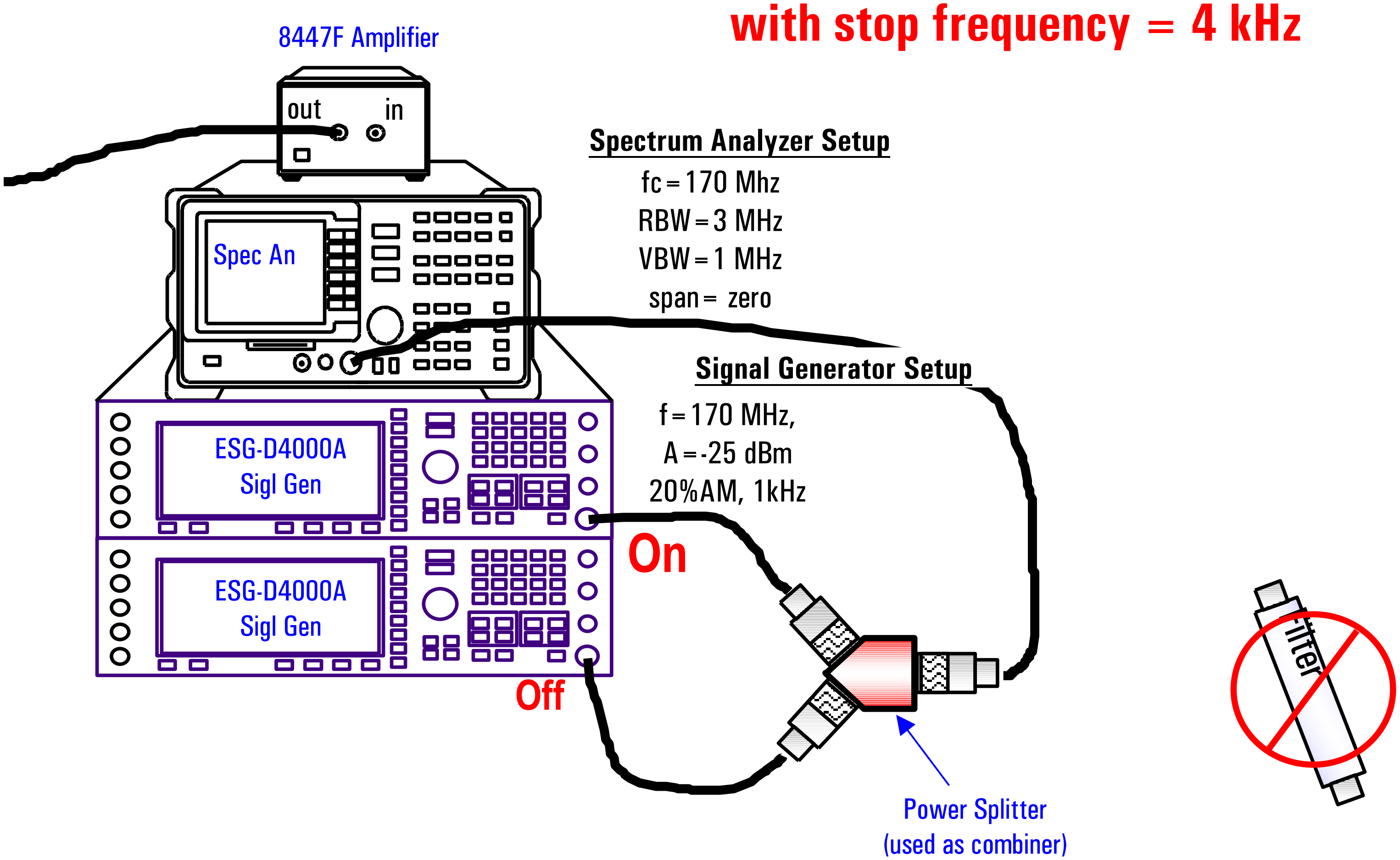


FFT Frequency Domain



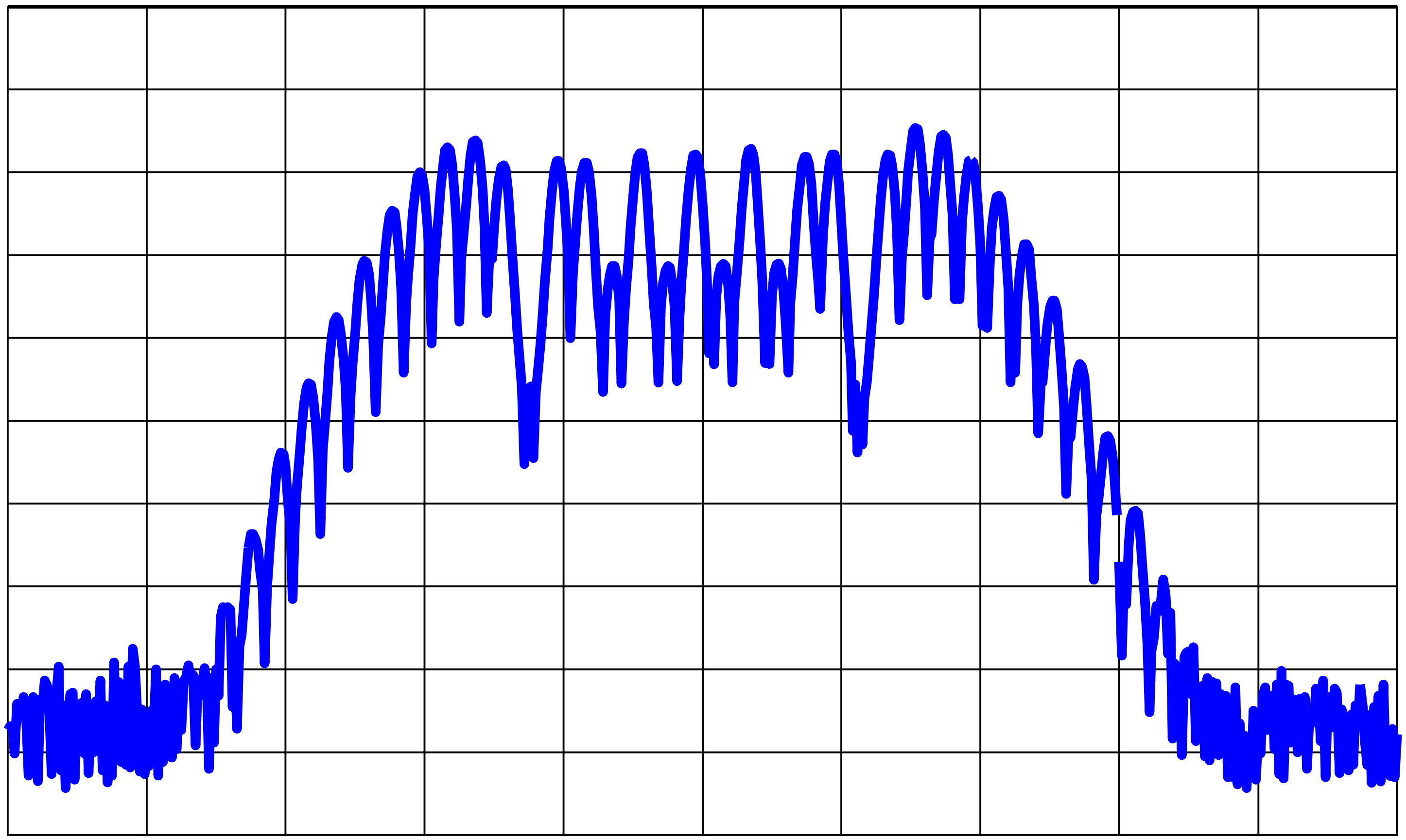
Demo #11 - Features: Mod meas: FFT

AM signal - look at in zero-span, turn on FFT with stop frequency = 4 kHz



Features

Modulation Measurements: FFT



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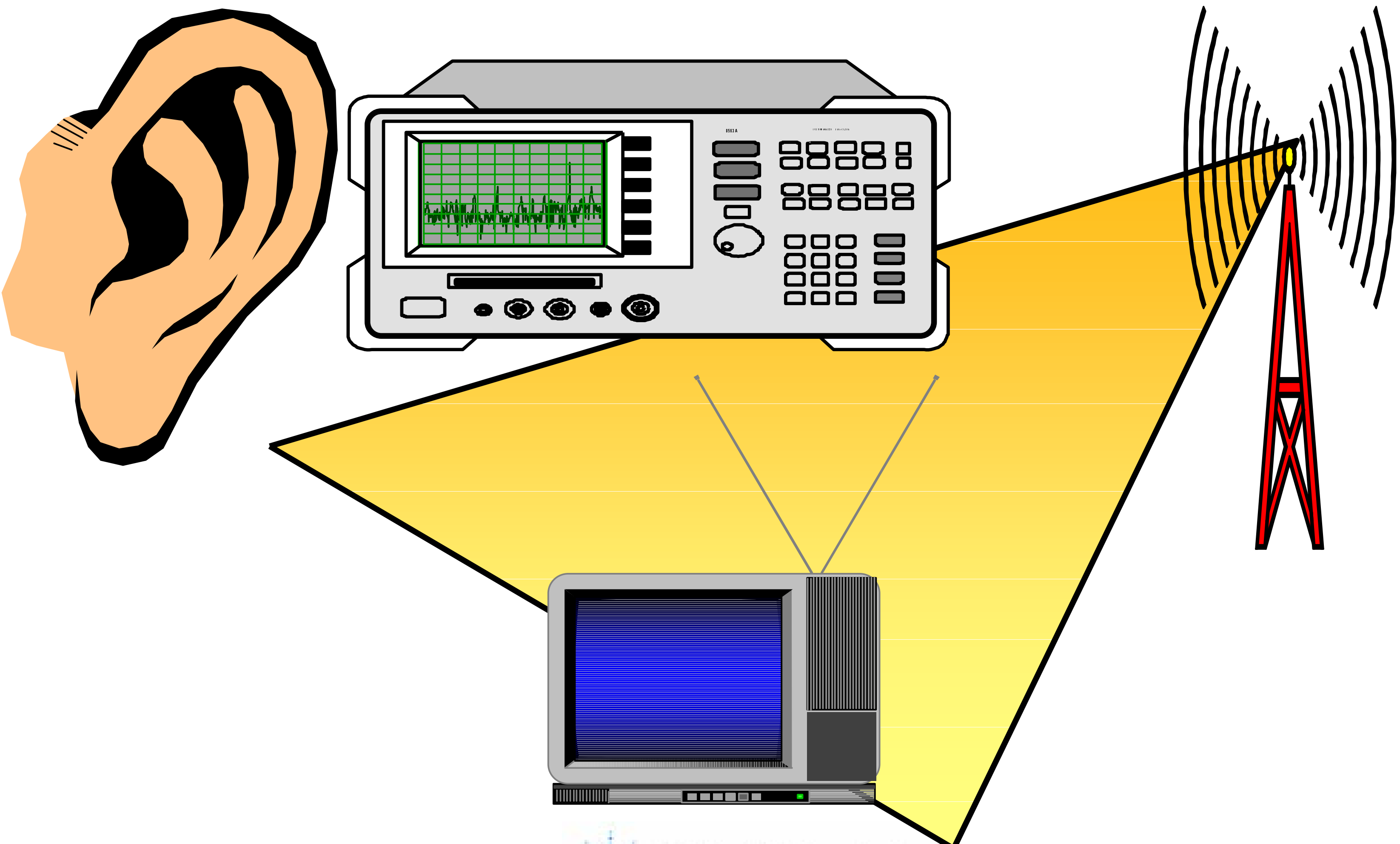
Features

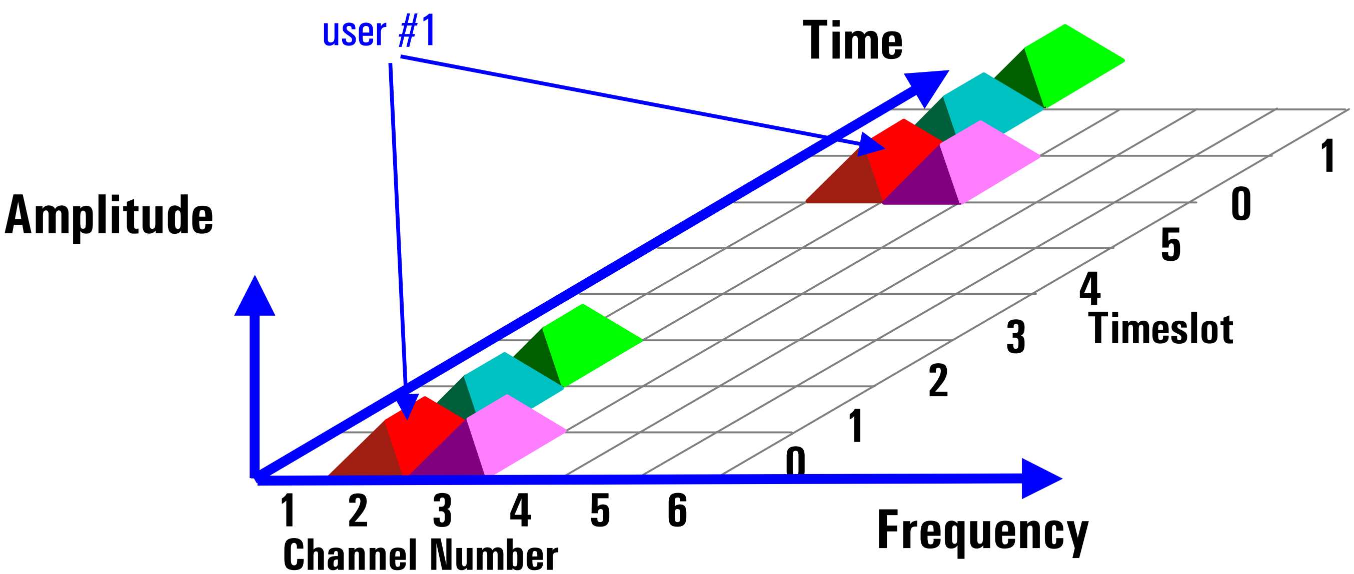
Modulation Measurements: AM/FM Detector with Speakers



Features

Modulation Measurements: Time-Gating

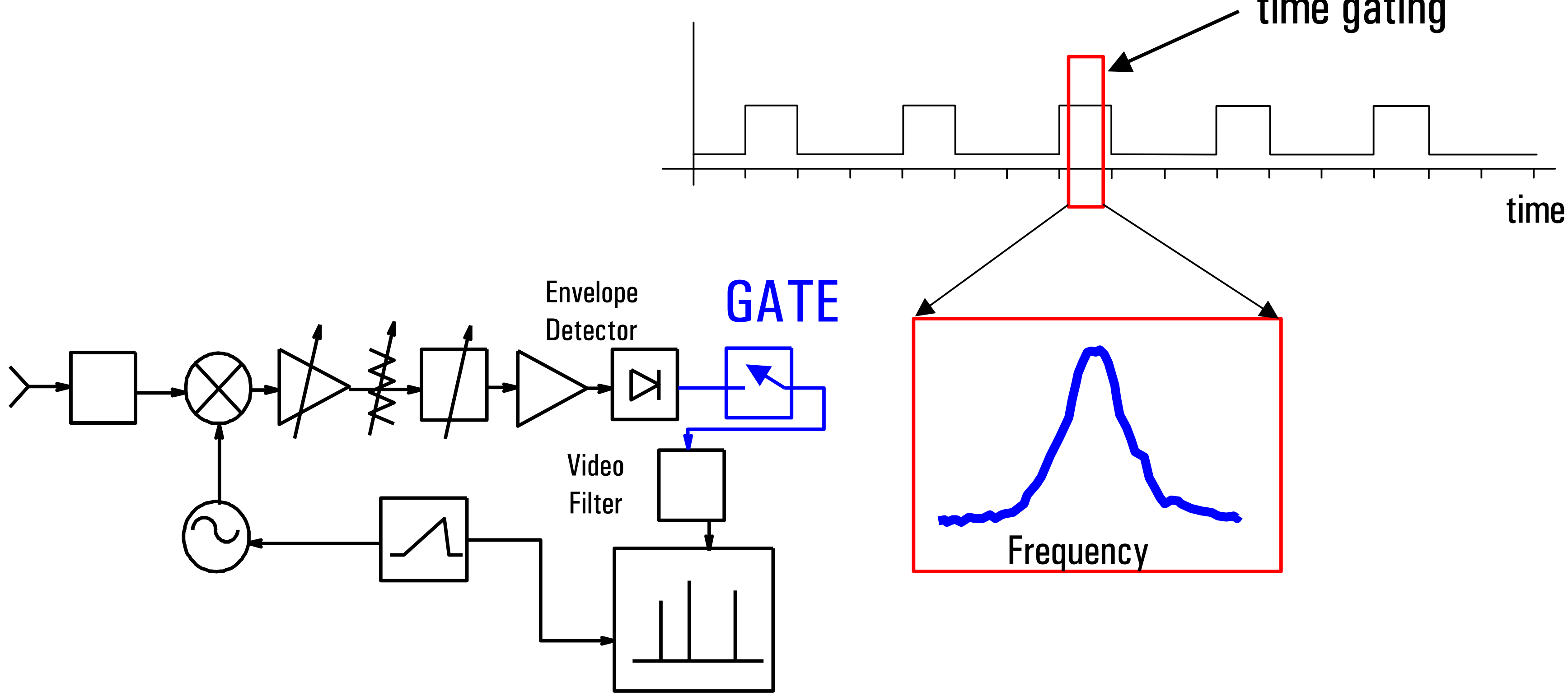
Time Division Multiple Access (TDMA)



Features

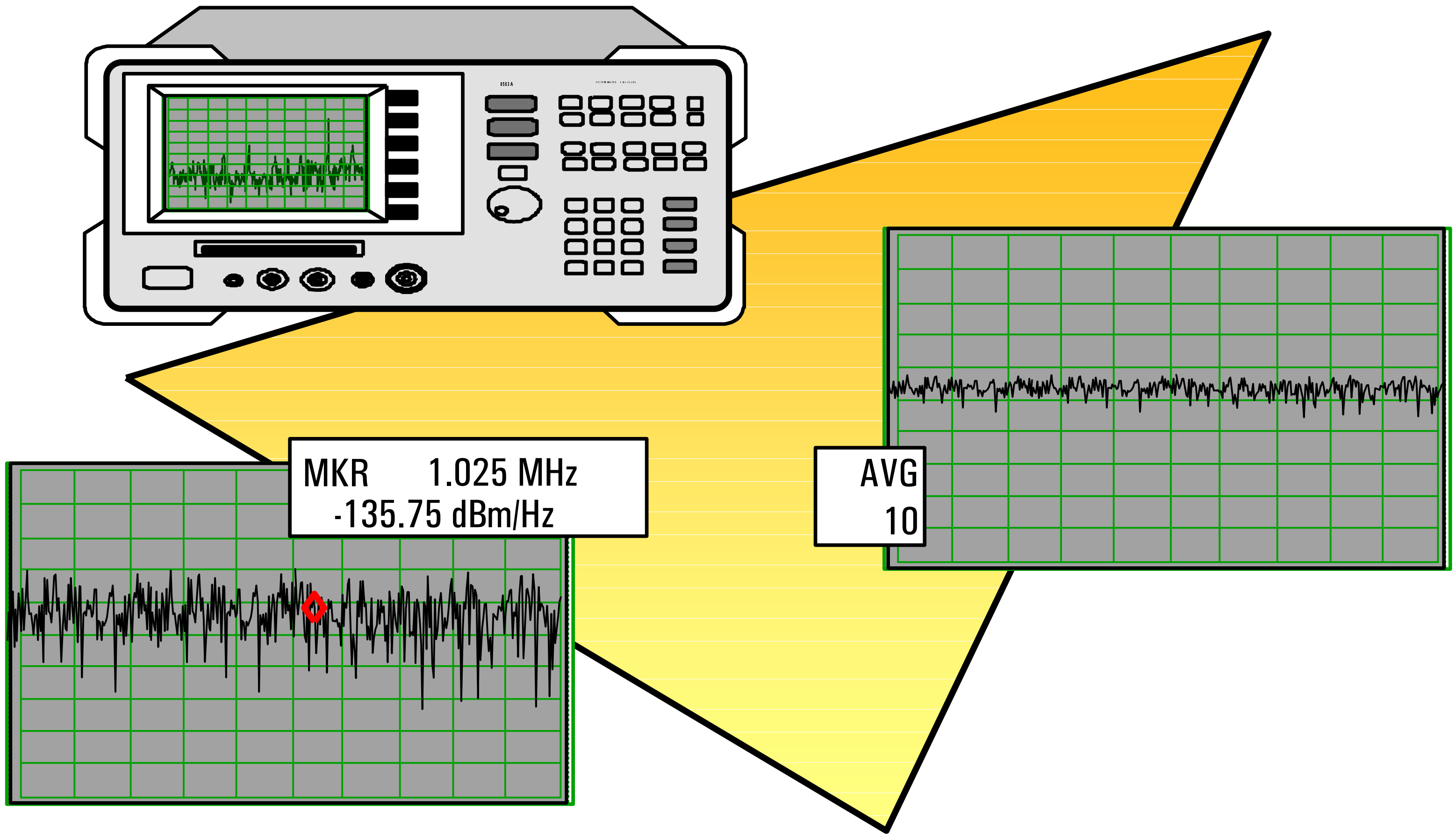
Modulation Measurements: Time-Gating

Time-Gated Measurements in the Frequency Domain



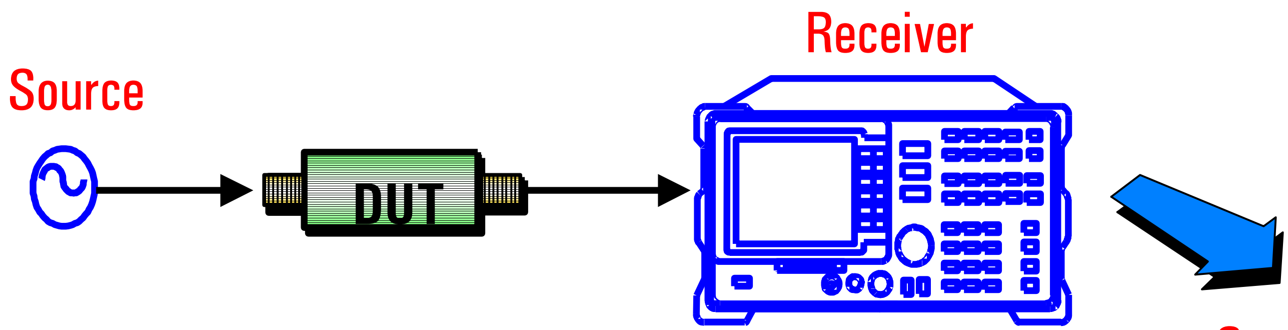
Features

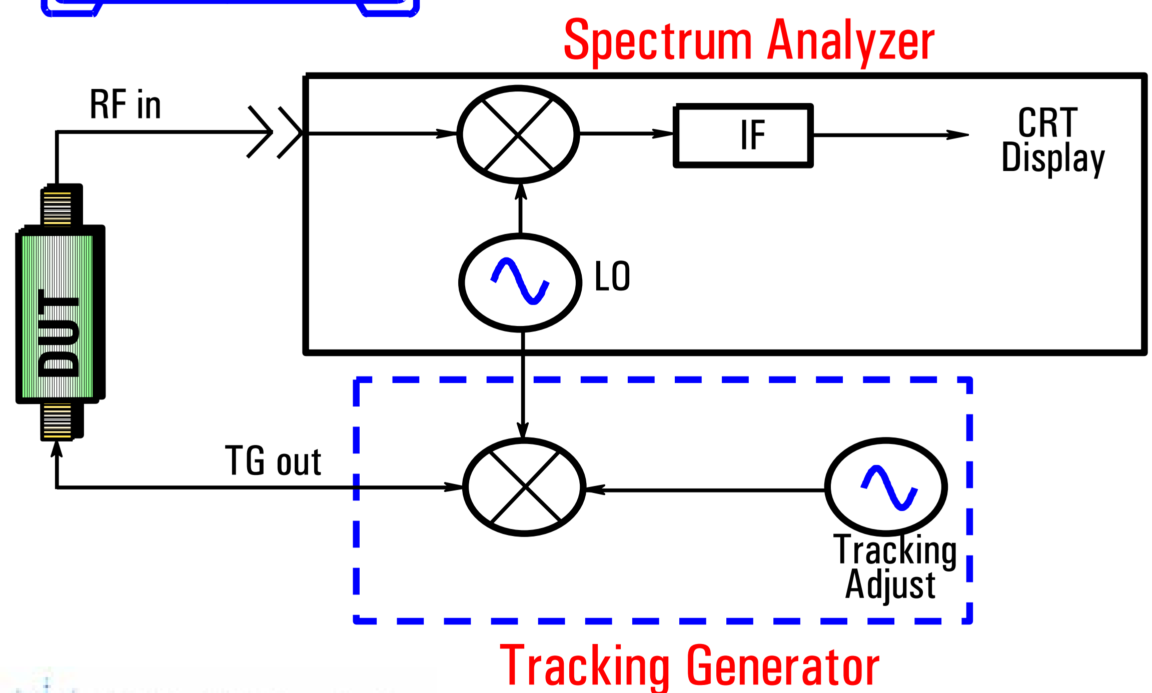
Noise Measurements: Noise Marker & Video Averaging



Features

Stimulus Response: Tracking Generator

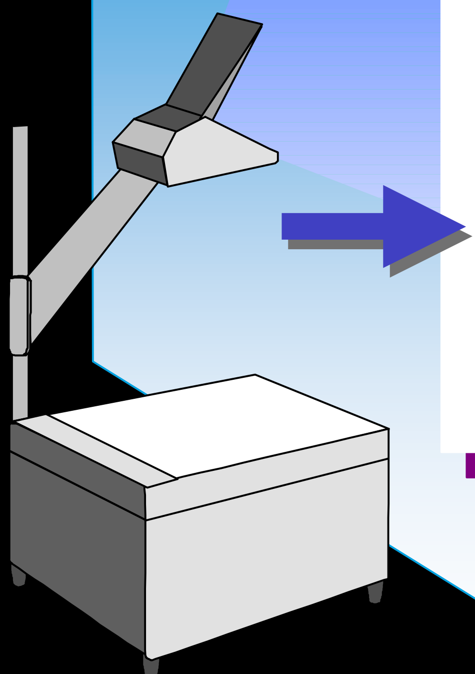




Agilent Technologies

Agenda

- Overview
- Theory of Operation
- Specifications
- Features
- Summary
- Appendix



Agilent Spectrum Analyzer Product Families

ESA-E Series
- 30 Hz to 26.5 GHz
- MID-Performance
- Flexible Platform
- Application Focused Solutions
- Color Display
- Fast and Accurate

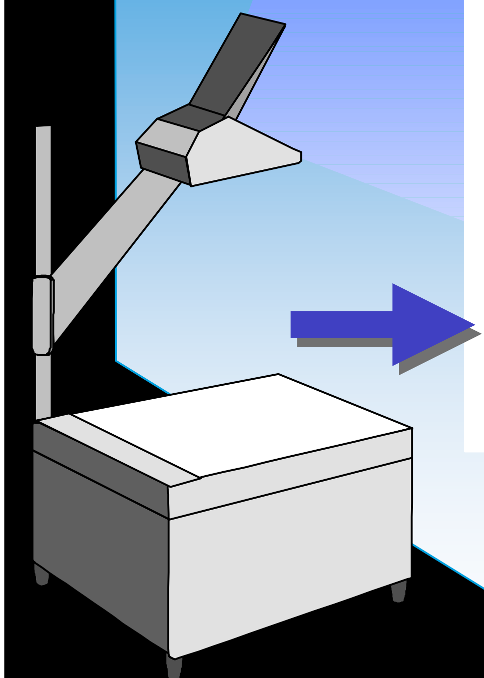
856XEC family
- 30 Hz up to 50 GHz
- high performance
- color display
- W-CDMA test set
- fast, digital 1 Hz RBW

ESA-L series
- 9 kHz up to 26 GHz
- low cost
- general purpose
- fully synthesized
- rugged

HP 89441A vector signal analyzer, dc to 2.65 GHz

89400 family
- DC to 2.65 GHz
- vector signal analyzers
- digital modulation
- complex, time-varying signals
- spectrum and time waveform analysis

Agenda

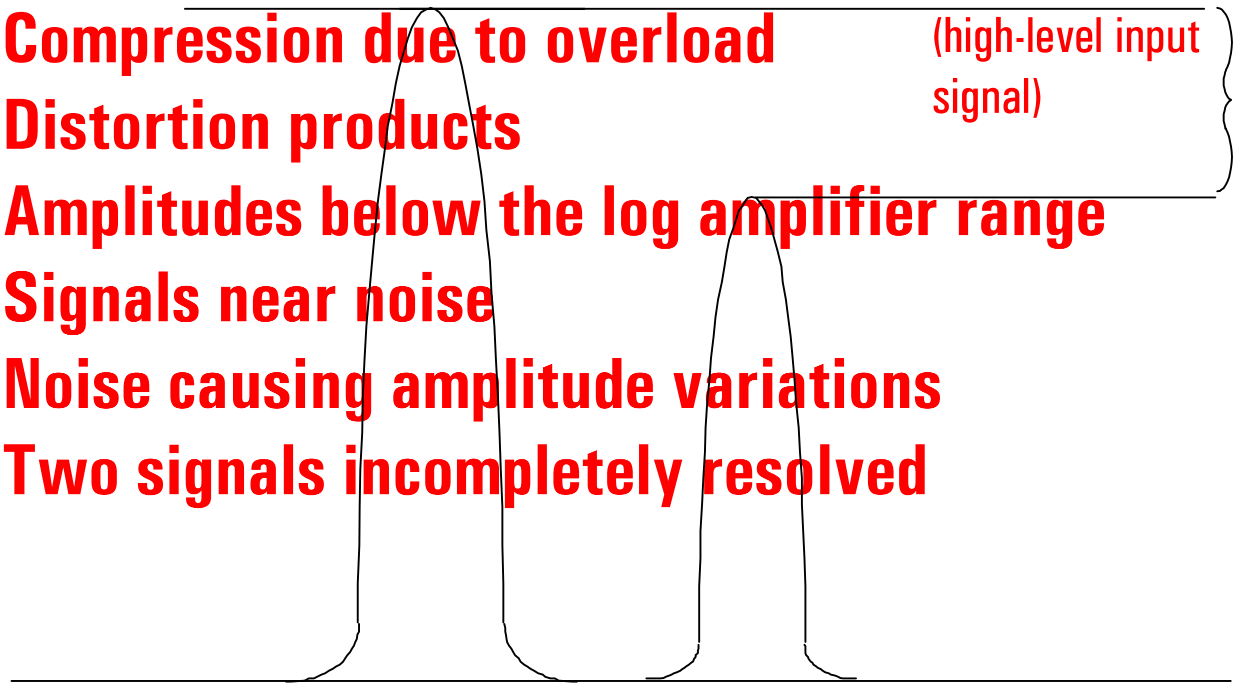


- Overview
- Theory of Operation
- Specifications
- Features
- Summary
- **Appendix**

Specifications

Accuracy: Other Sources of Uncertainty

- **Mismatch** (RF input port not exactly 50 ohms)
- **Compression due to overload**
- **Distortion products**
- **Amplitudes below the log amplifier range**
- **Signals near noise**
- **Noise causing amplitude variations**
- **Two signals incompletely resolved**



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Specifications

Dynamic Range

Calculated Maximum Dynamic Range

$$MDR_3 = 2/3\,(DANL - TOI)$$

$$MDR_2 = 1/2\,(DANL - SOI)$$

Where TOI = Mixer Level - dBc/2

SOI = Mixer Level - dBc

Optimum Mixer Level = DANL - MDR

Attenuation = Signal - Optimum Mixer Level

Specifications

Dynamic Range

Example Calculation

$$MDR_3 = 2/3\,[(-115) - (+5)]$$
$$= -80 \text{ dBc (1 kHz RBW)}$$

Where TOI $= (-30) - (-70)/2$

$= +5$ dBm

Optimum Mixer Level $= (-115) - (-80)$

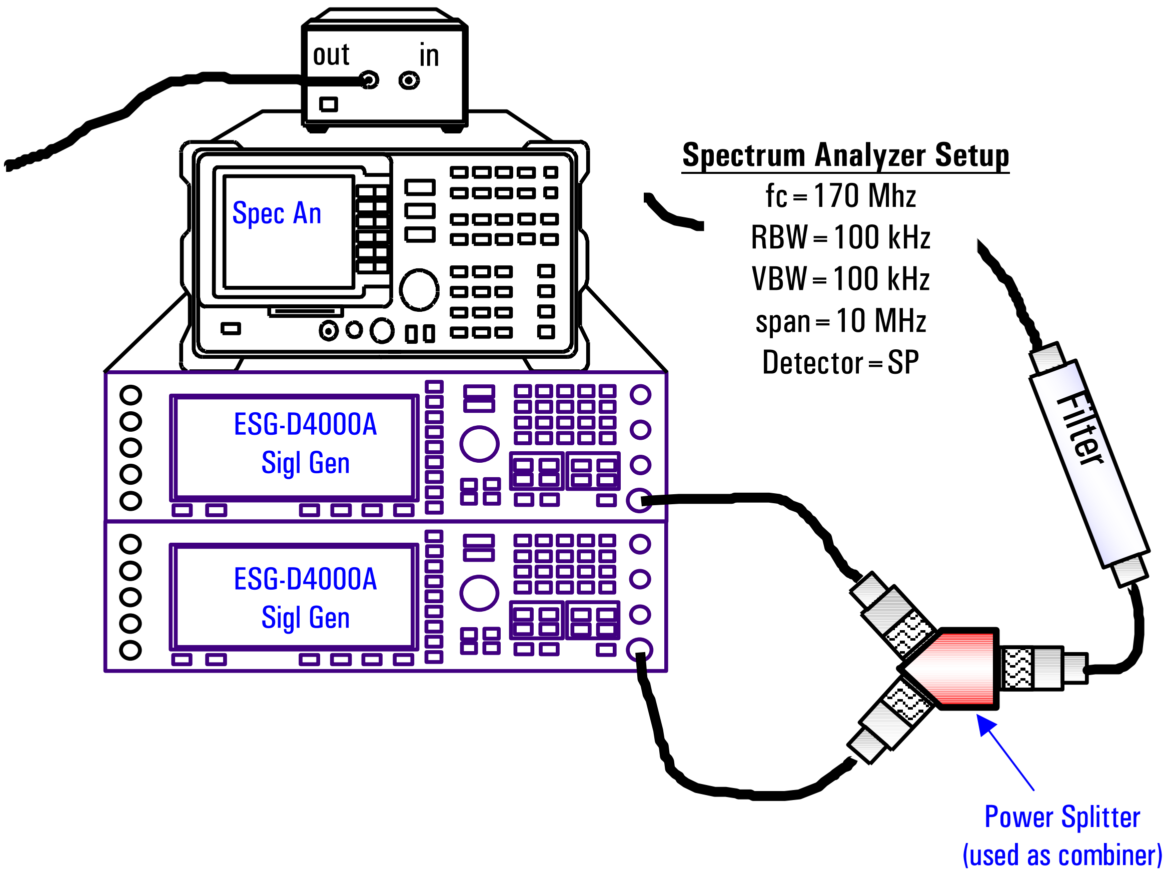
$= -35$ dBm

Attenuation $= (0) - (-35)$

$= +35$ dBm

Demo - Theory: Detector

No signal (just noise) - change detector modes to see difference



Spectrum Analyzer Setup

fc = 170 Mhz
RBW = 100 kHz
VBW = 100 kHz
span = 10 MHz
Detector = SP

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