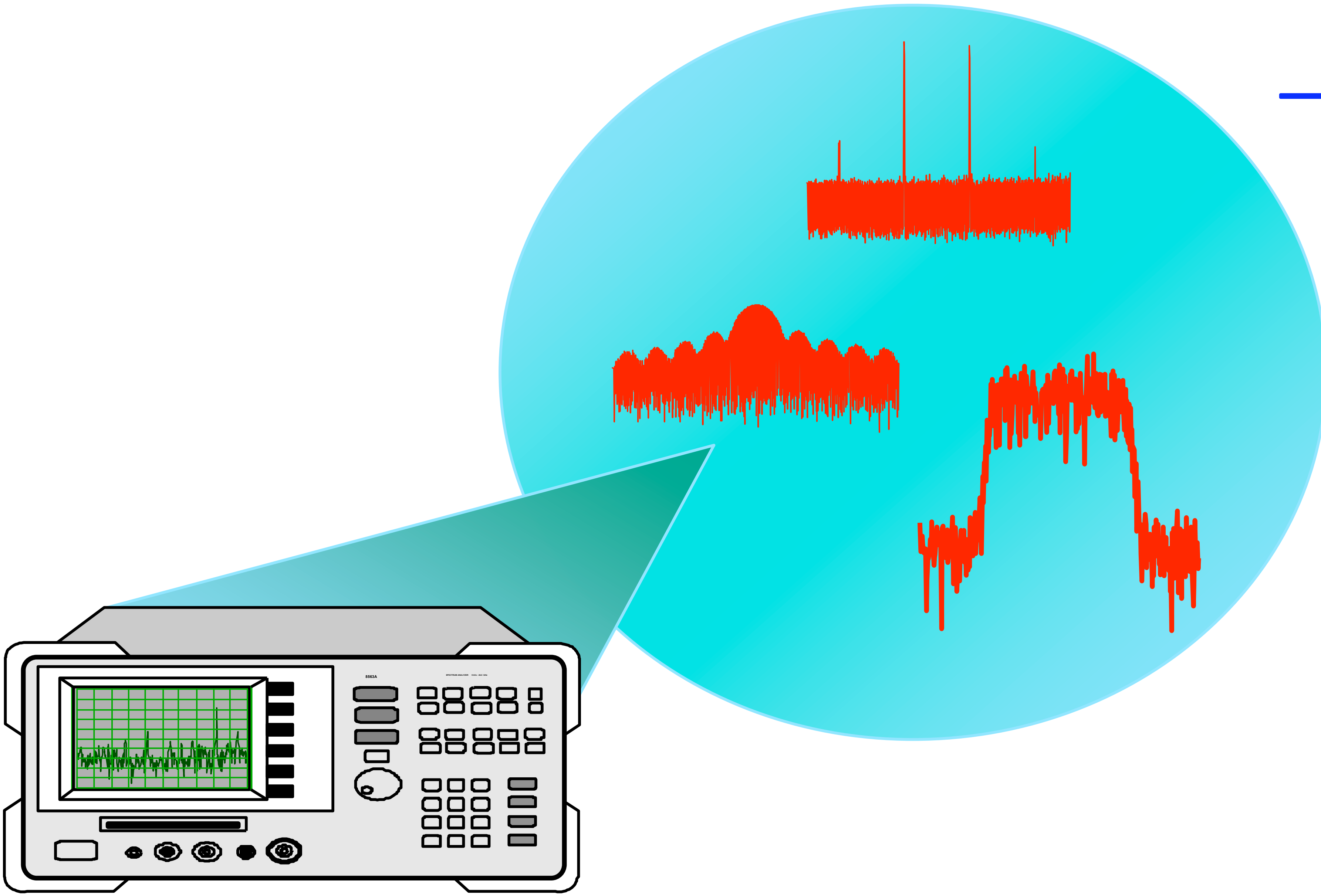
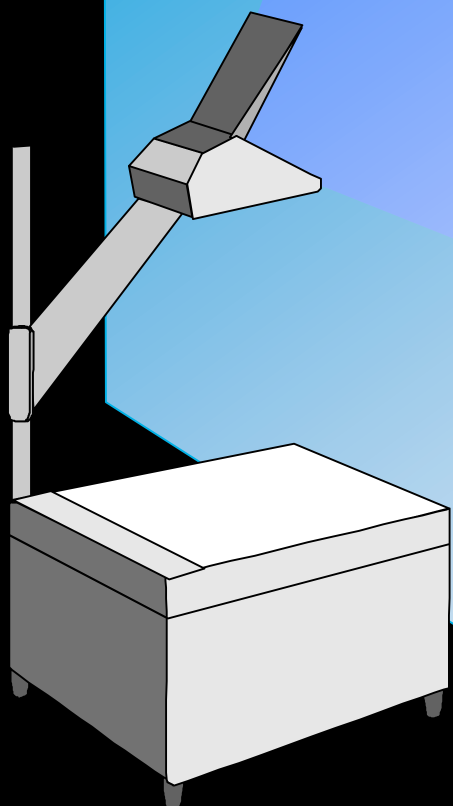


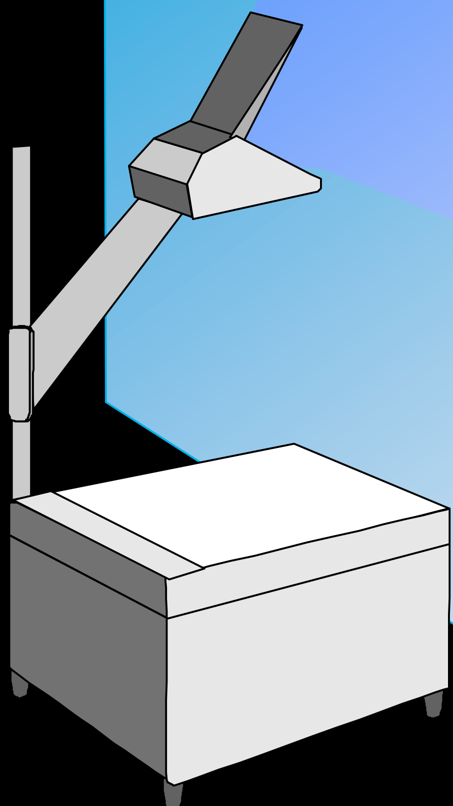
Agenda



- 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

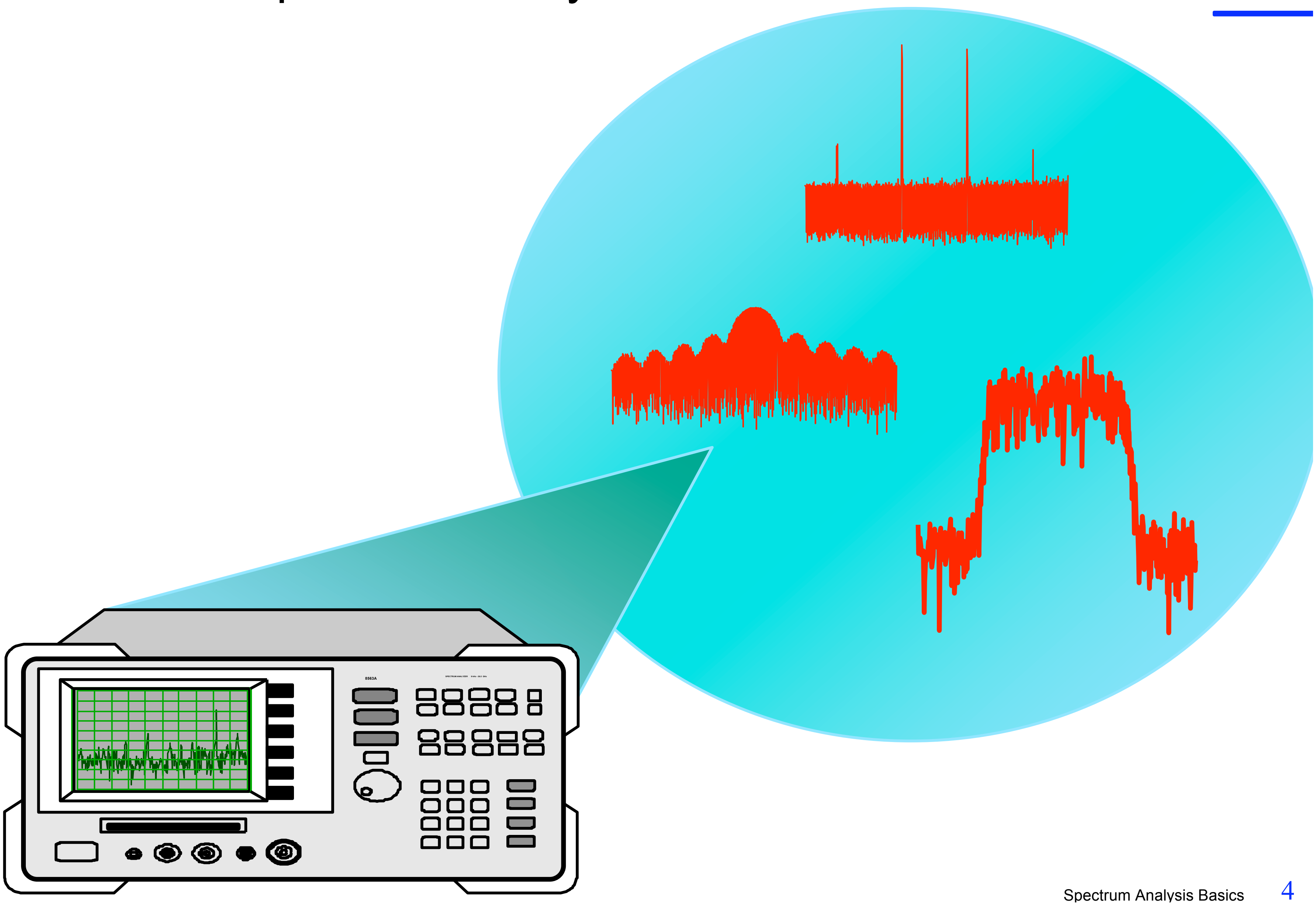
Agenda

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



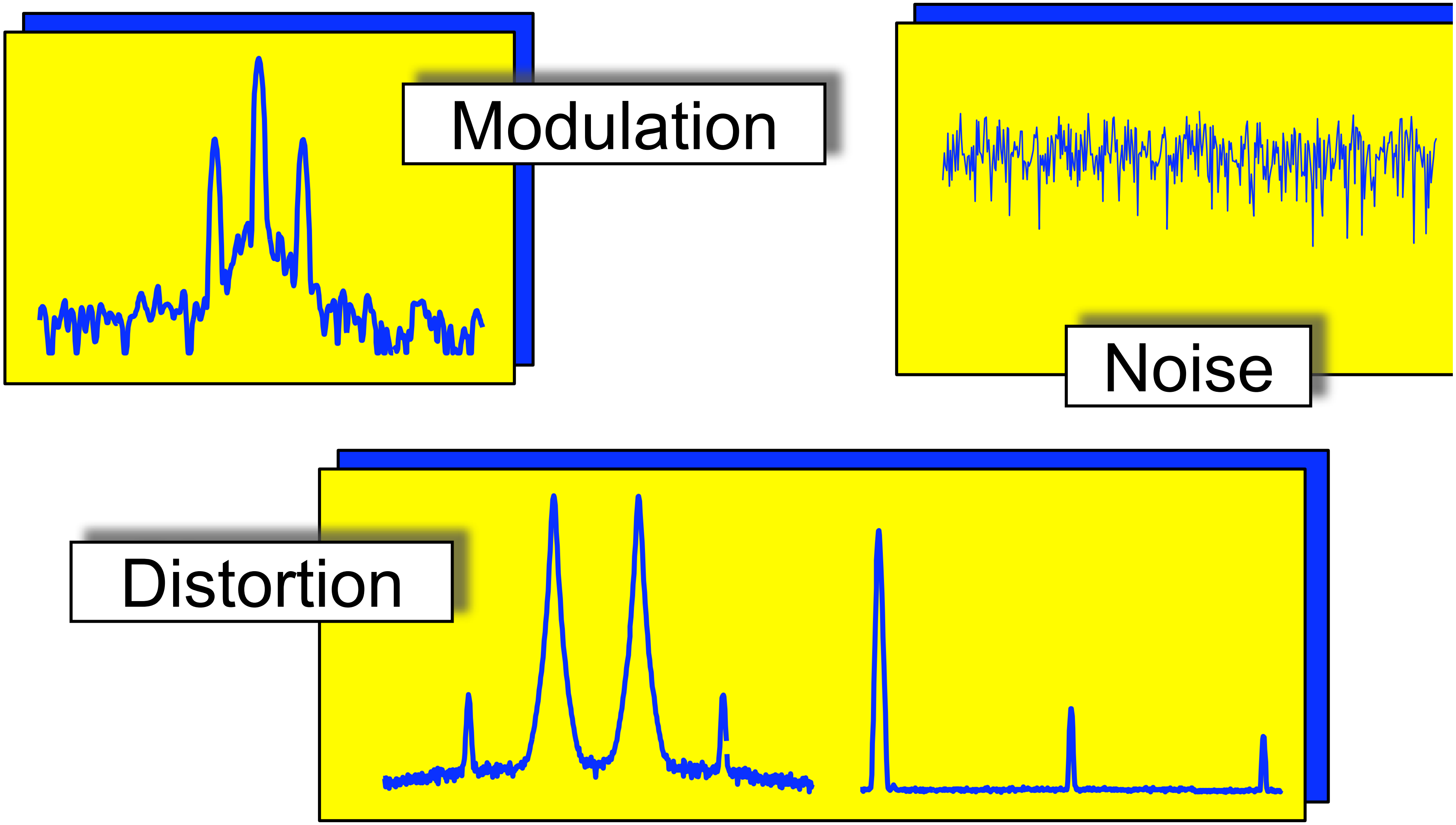
Overview

What is Spectrum Analysis?



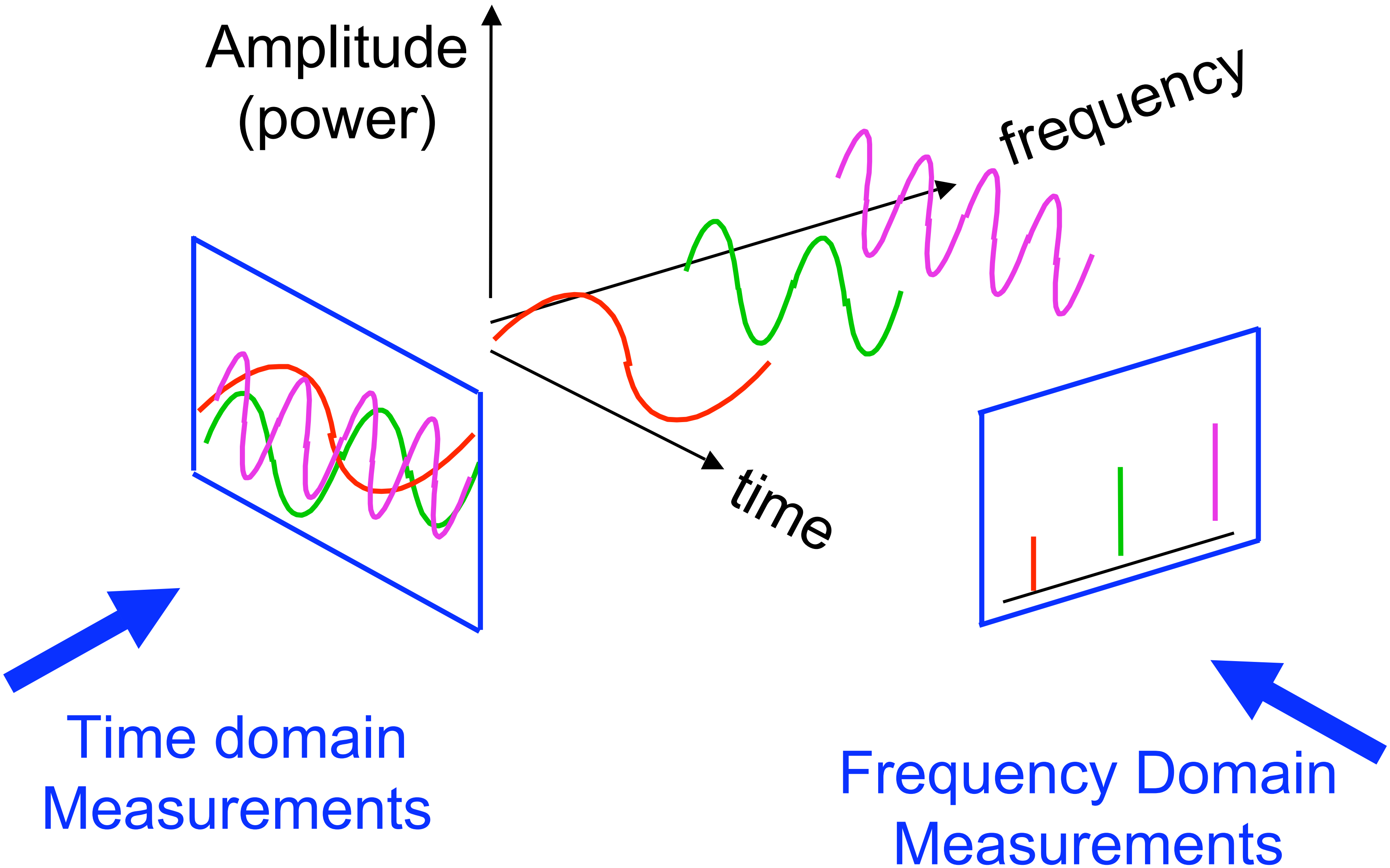
Overview

Types of Tests Made



Overview

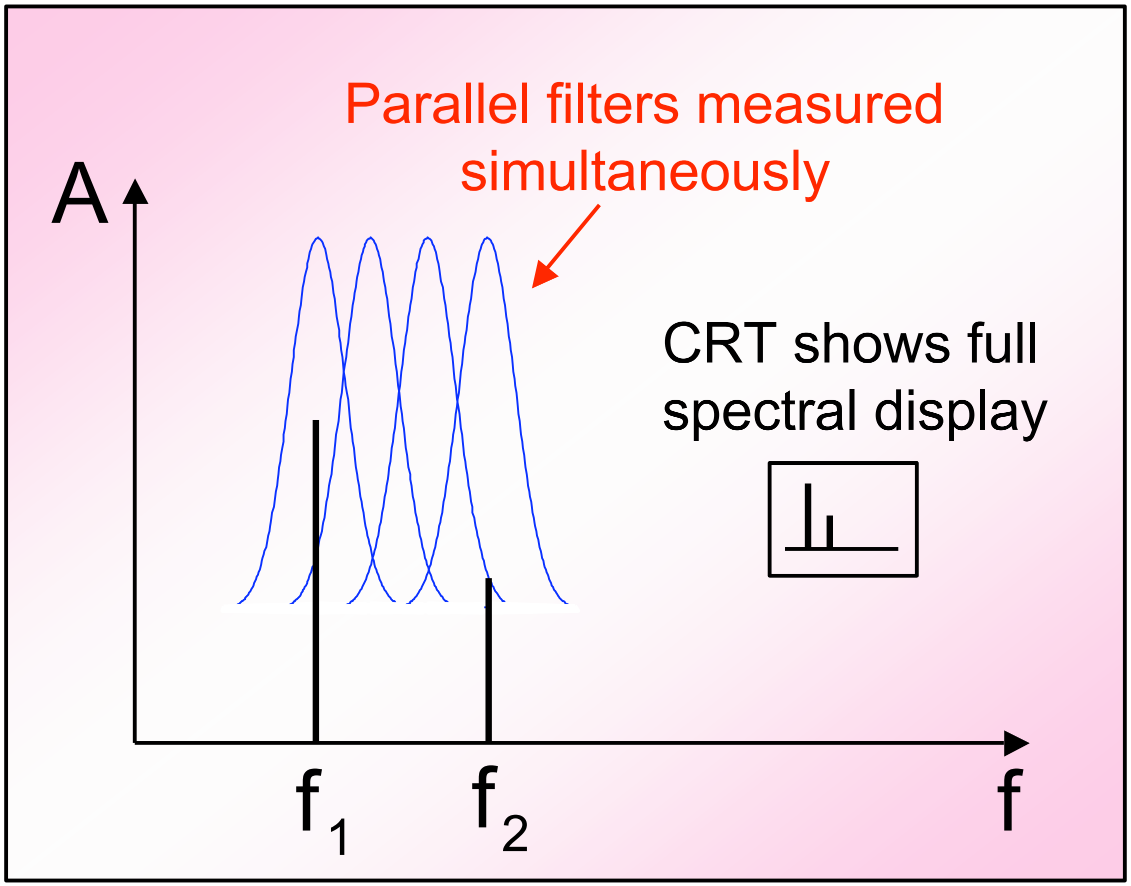
Frequency versus Time Domain



Overview

Different Types of Analyzers

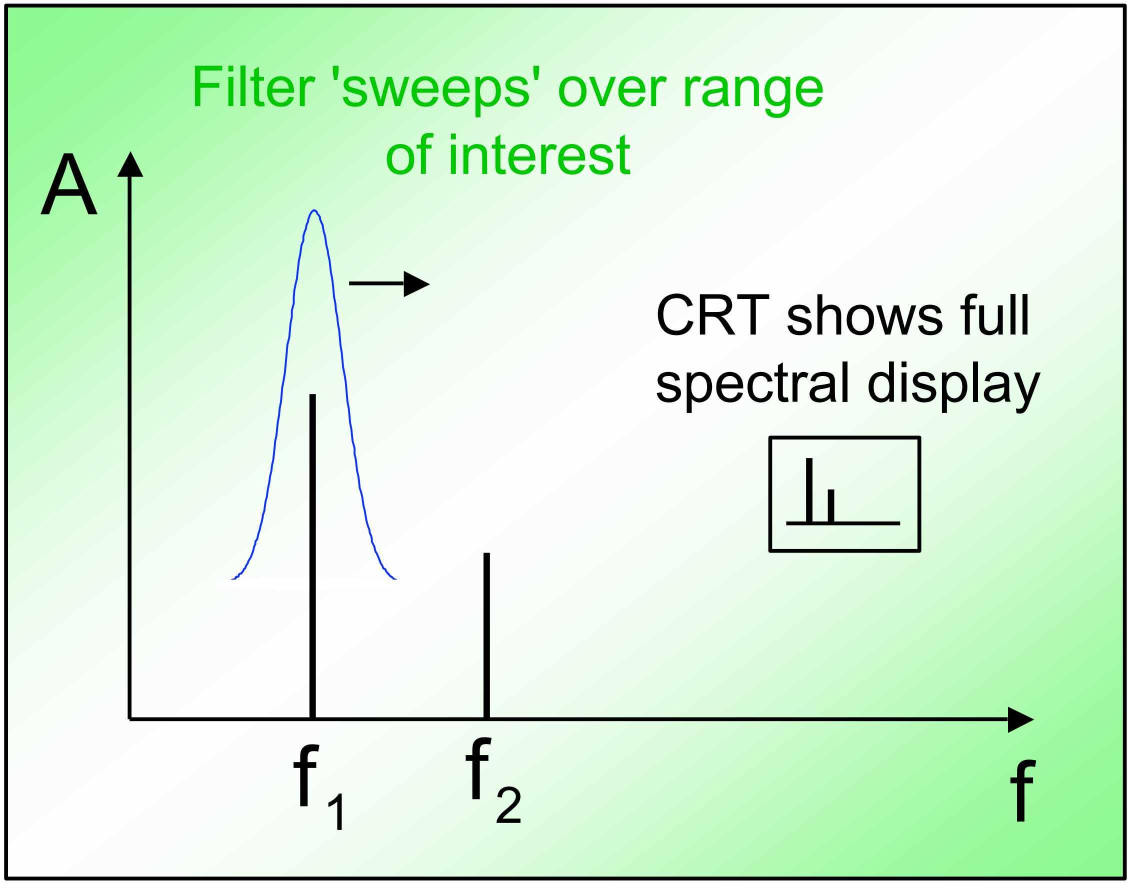
Fourier Analyzer



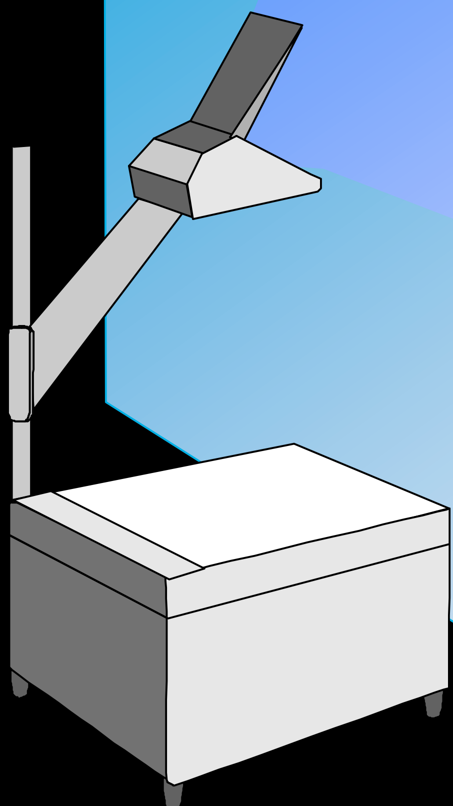
Overview

Different Types of Analyzers

Swept Analyzer



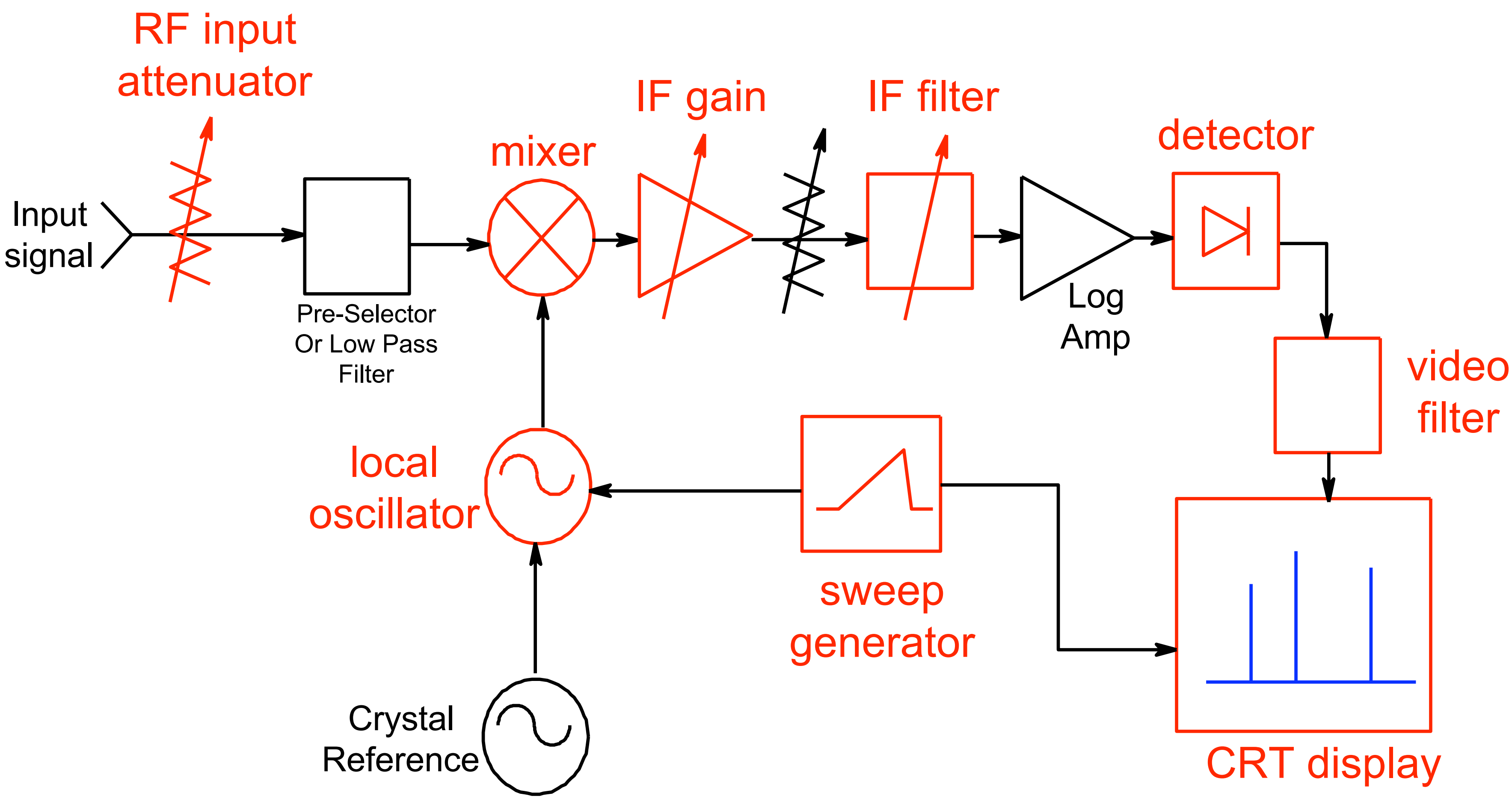
Agenda



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

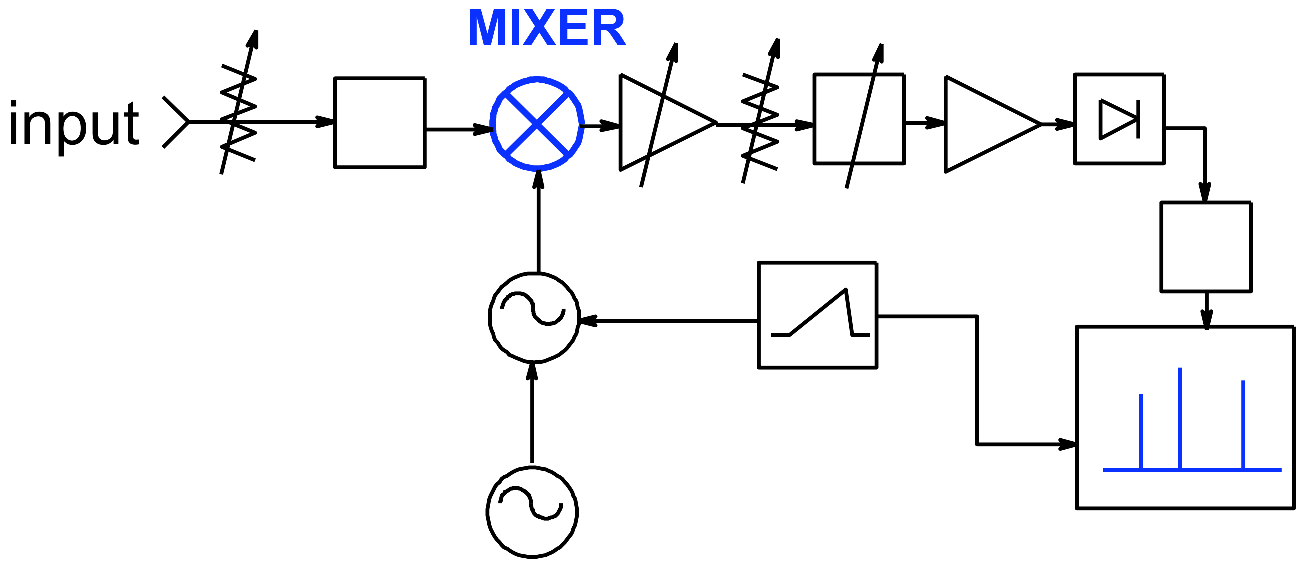
Theory of Operation

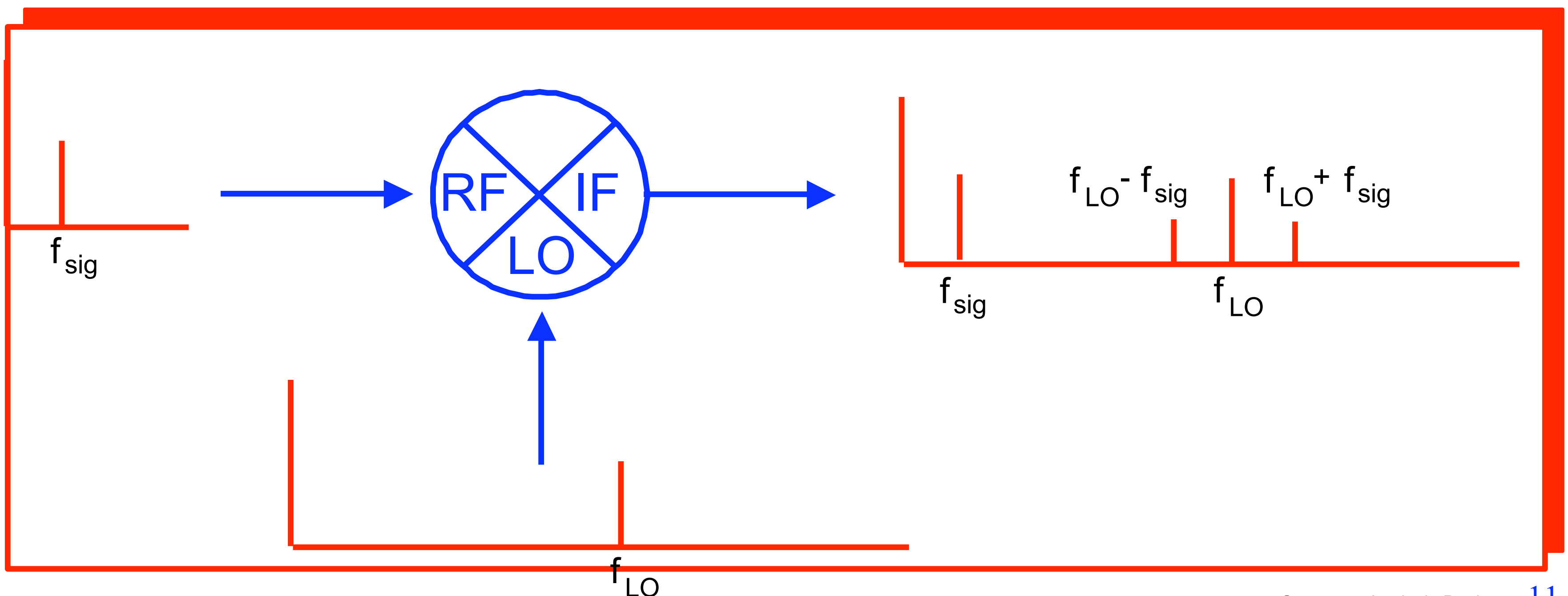
Spectrum Analyzer Block Diagram



Theory of Operation

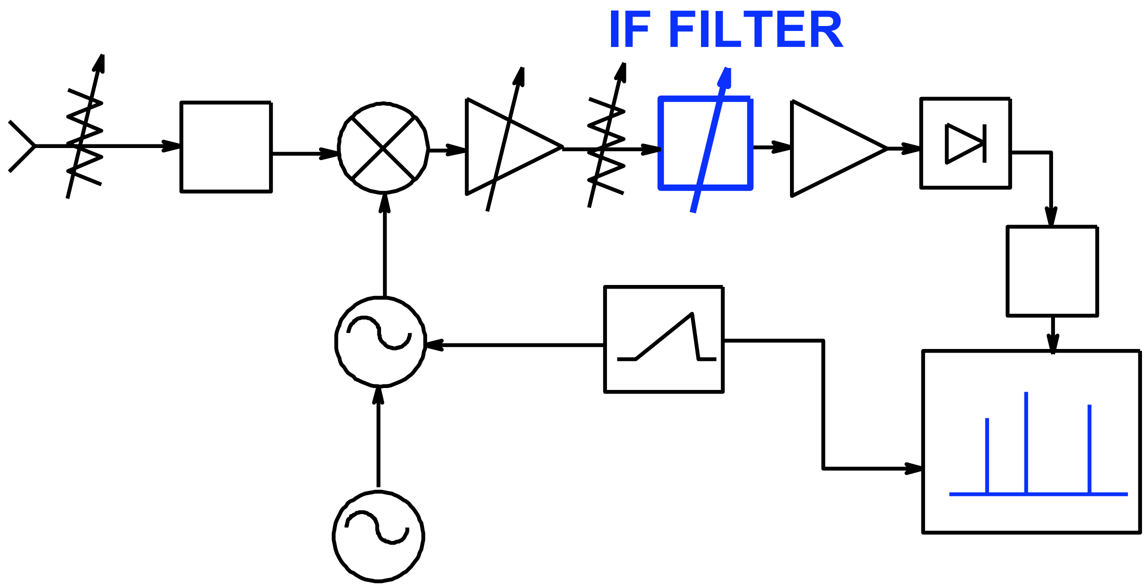
Mixer

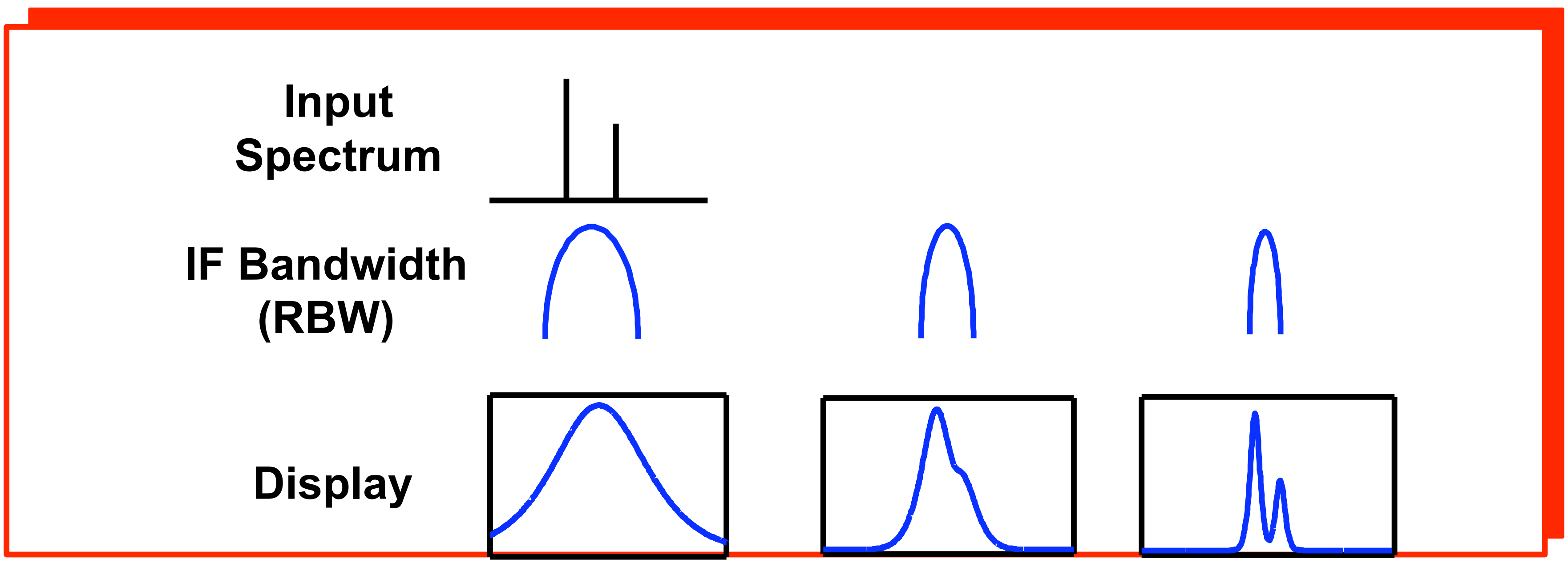




Theory of Operation

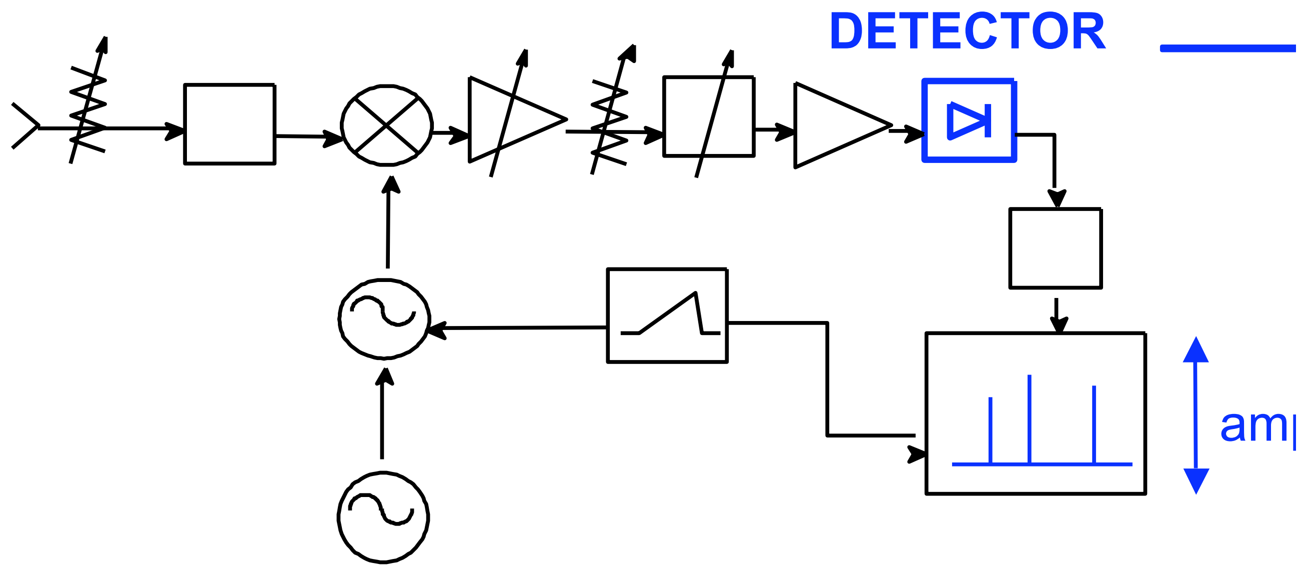
IF Filter

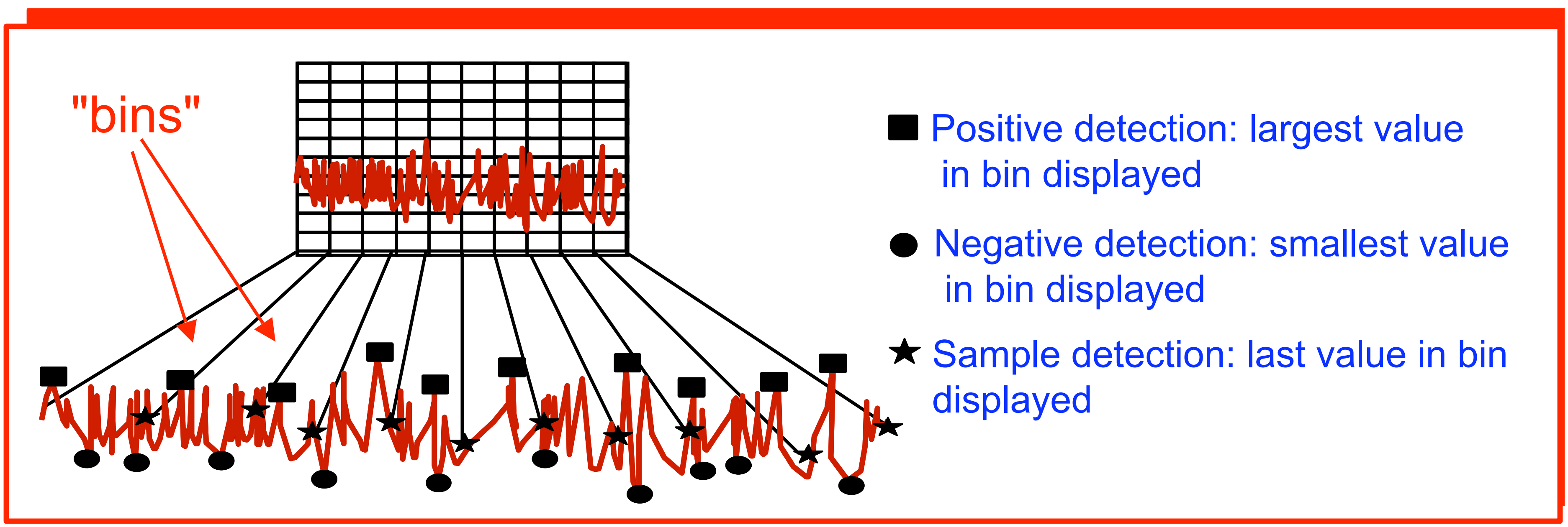




Theory of Operation

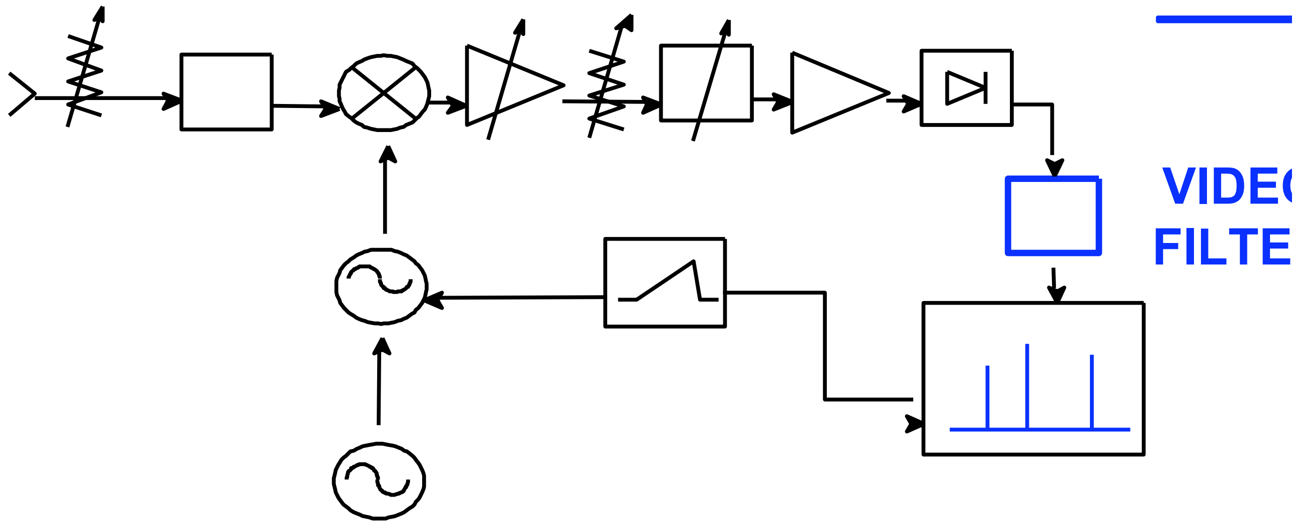
Detector

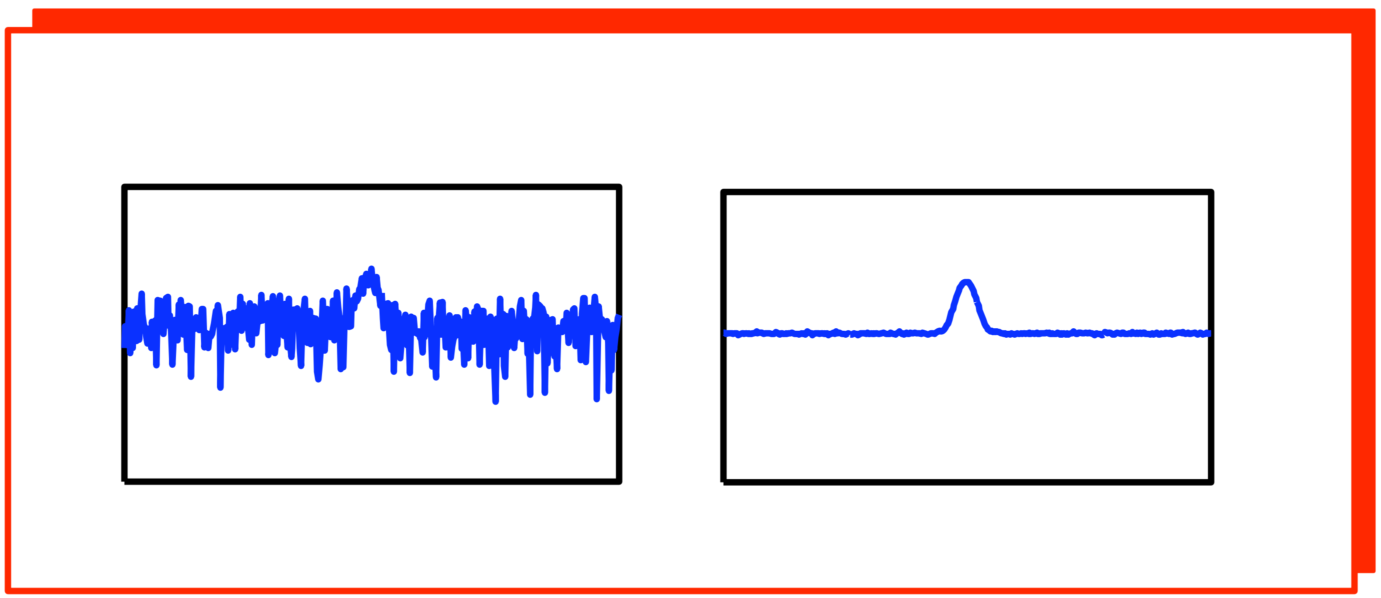




Theory of Operation

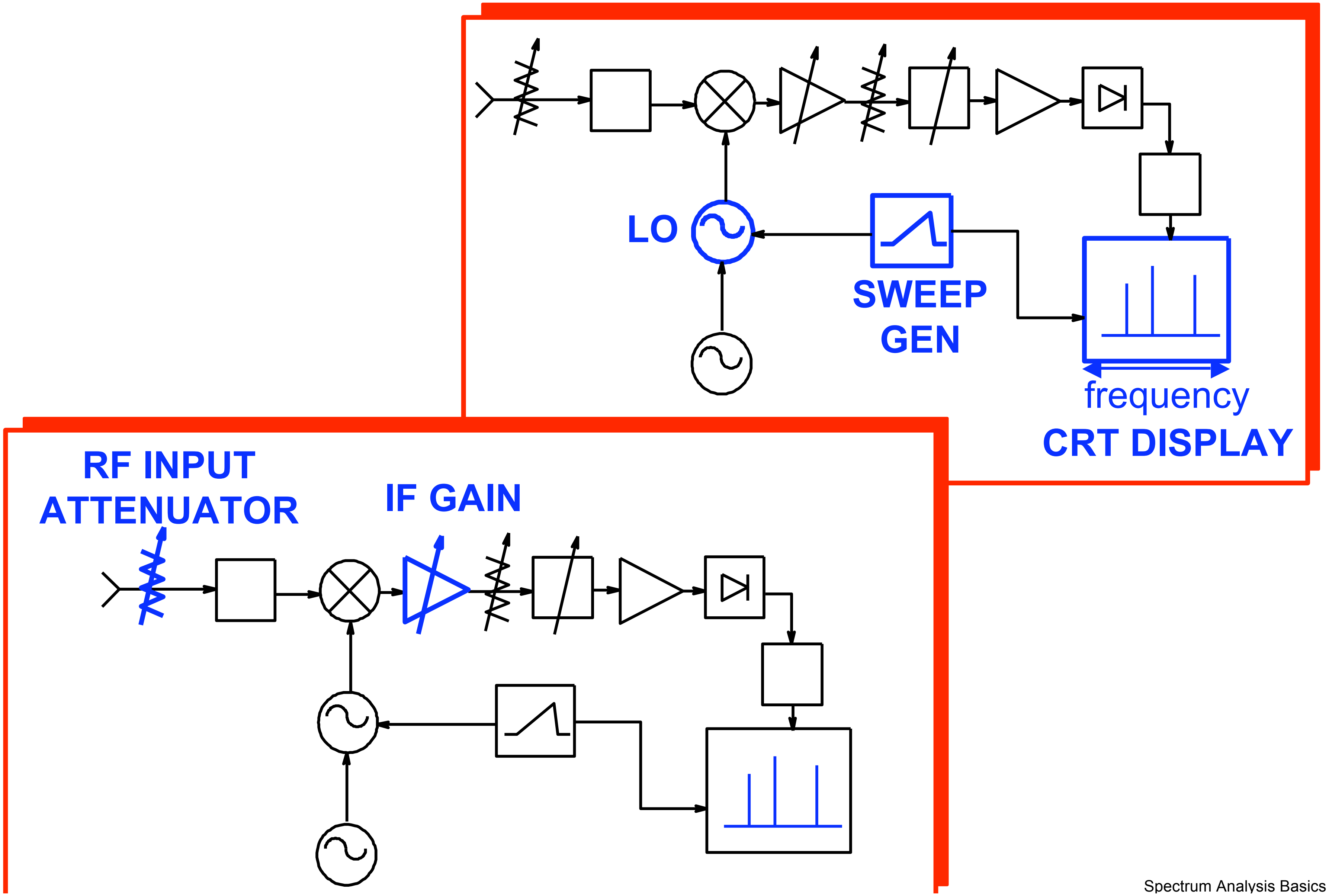
Video Filter





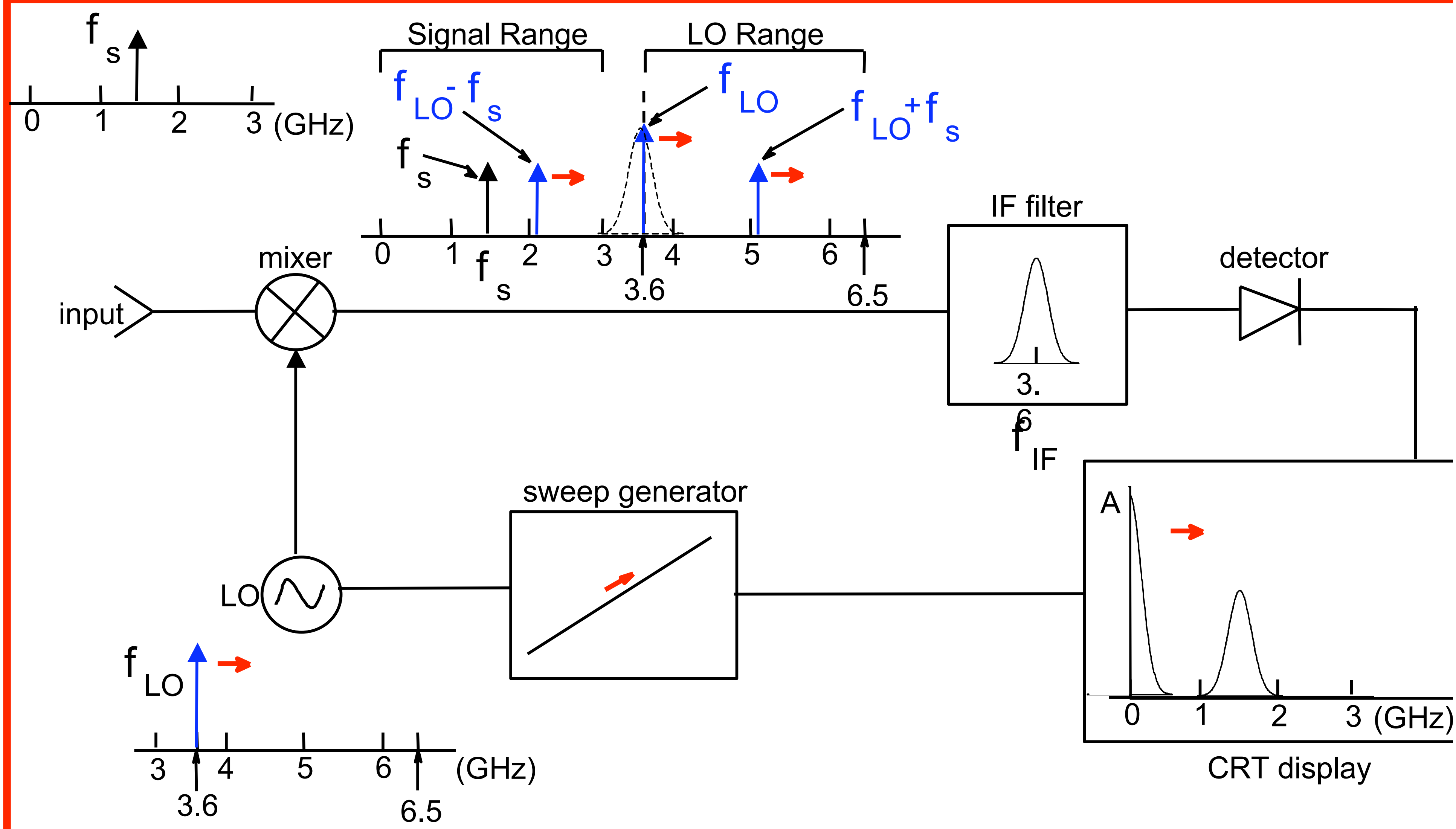
Theory of Operation

Other Components



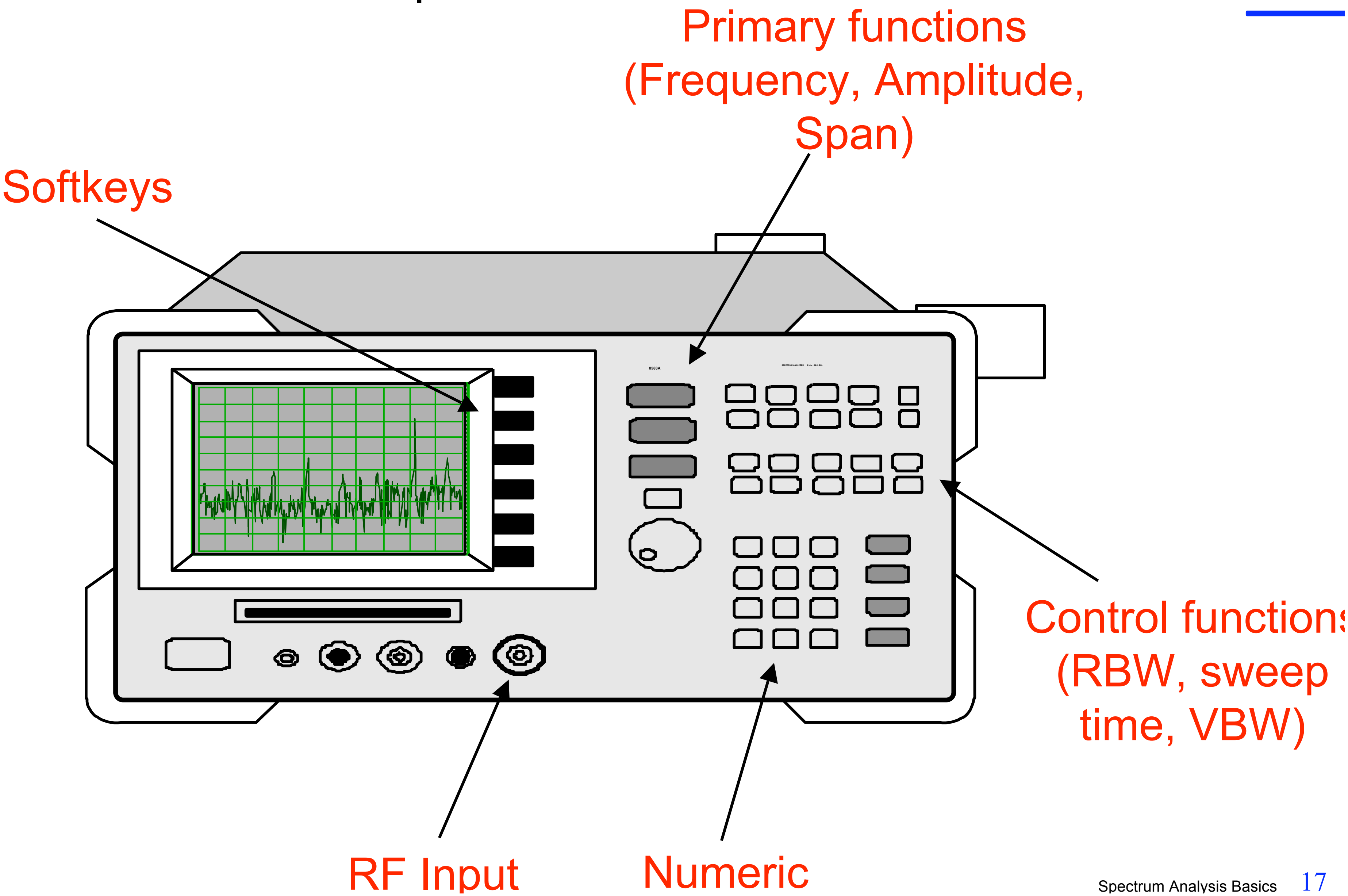
Theory of Operation

How it all works together

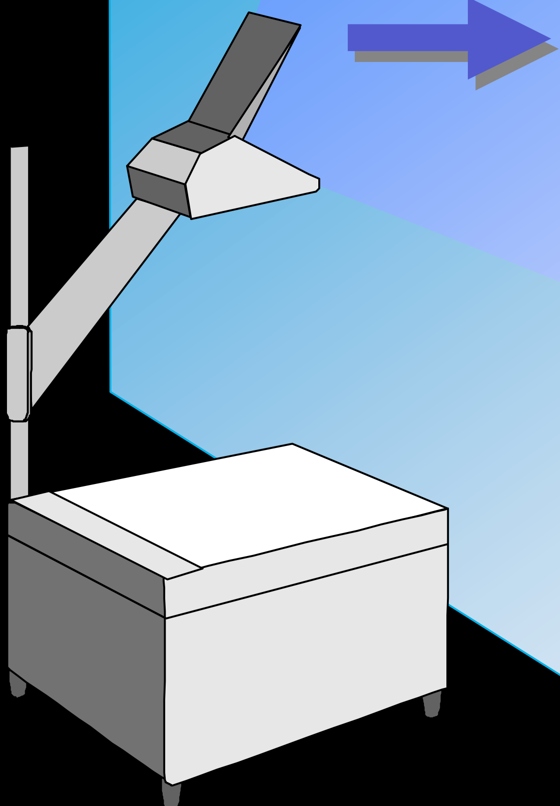


Theory of Operation

Front Panel Operation

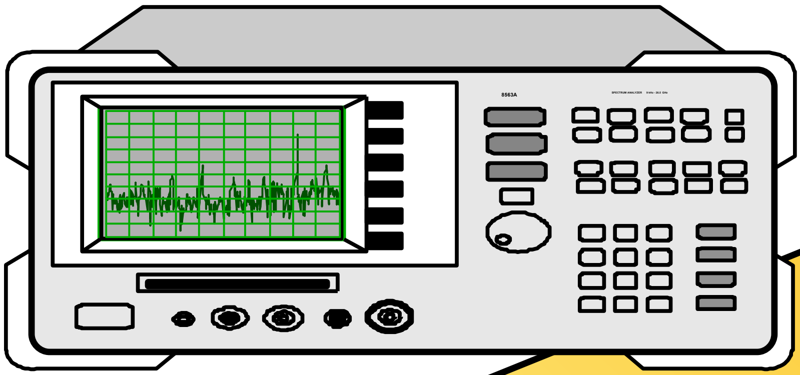


Agenda



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

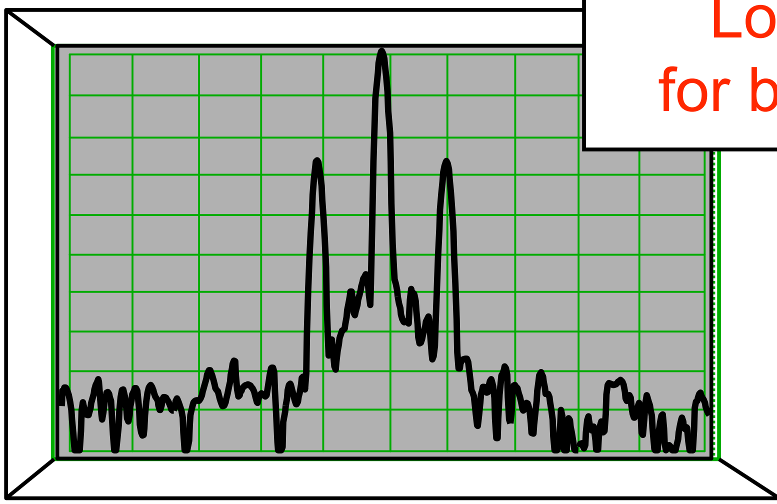
Specifications



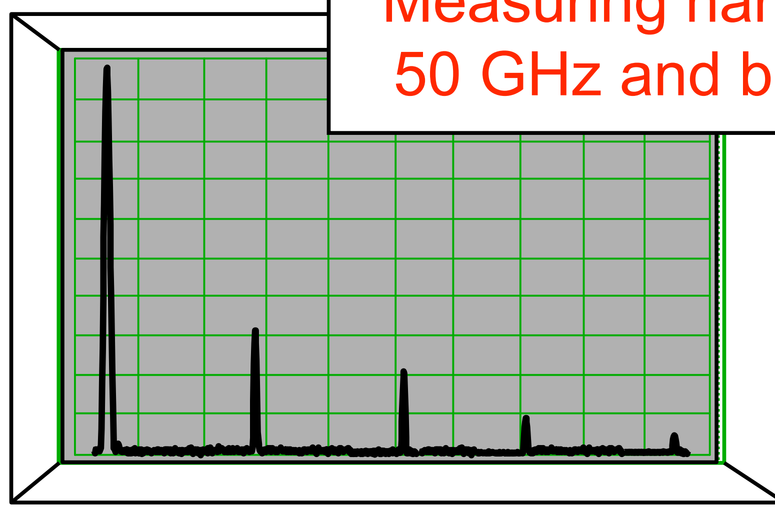
- Frequency Range
- Accuracy, Frequency & Amplitude
- Resolution
- Sensitivity
- Distortion
- Dynamic Range

Specifications

Frequency Range



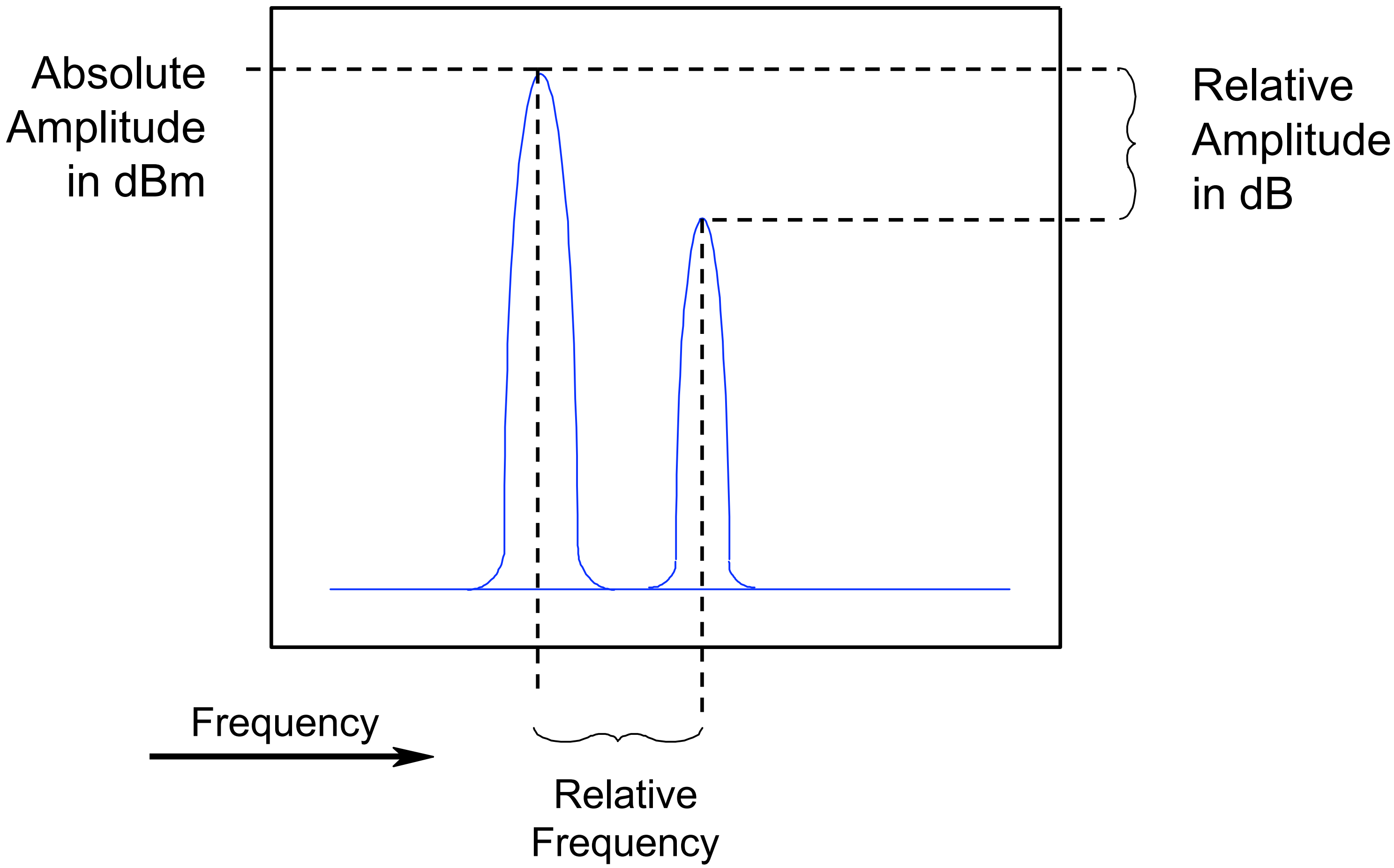
Low frequencies
for baseband and IF



Measuring harmon
50 GHz and beyon

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")

Specifications

Accuracy: Frequency Readout Accuracy Example

Single Marker Example:

2 GHz
400 kHz span
3 kHz RBW

Calculation: $(2\times10^{9}\,\text{Hz}) \times (1.3\times10^{-7}/\text{yr.ref.error})$ = 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**
- **△ RF Input attenuator**
- **△ Reference level**
- **△ Resolution bandwidth**
- **△ CRT scaling**

Specifications

Accuracy: Relative Amplitude Accuracy - Display Fidelity

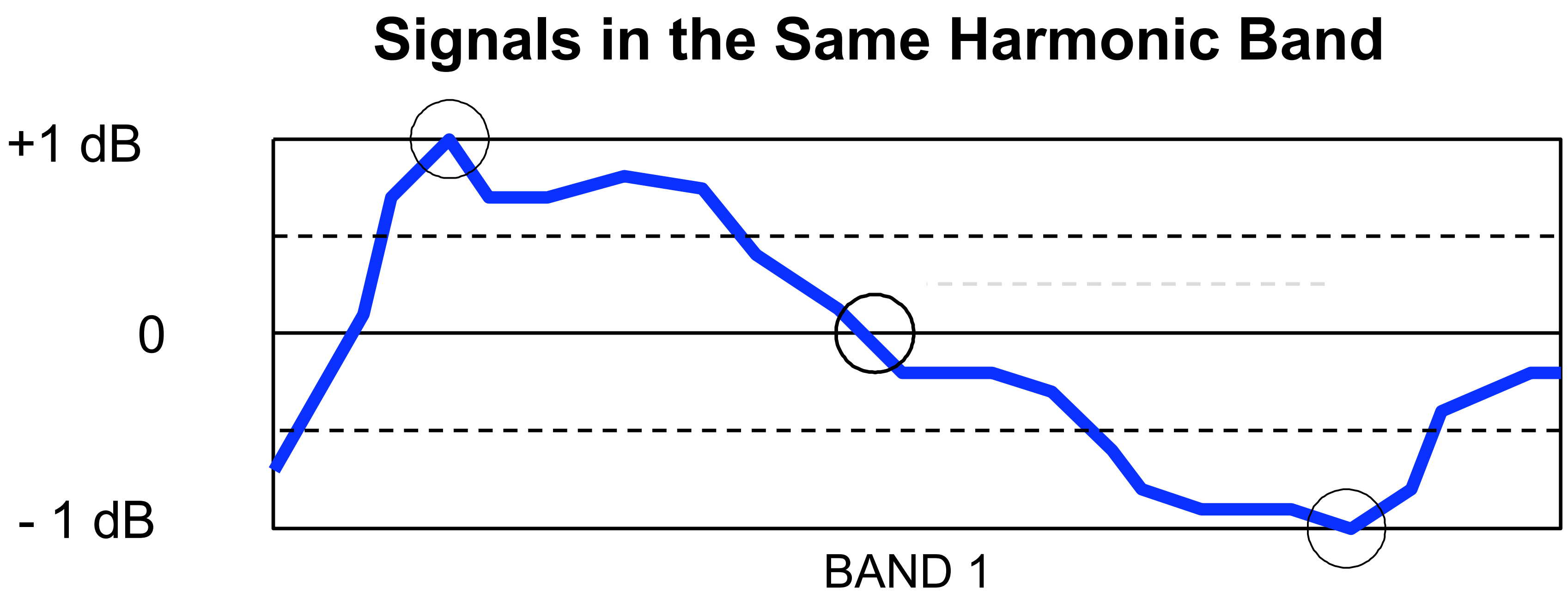
- Applies when signals are not placed at the same reference amplitude

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

- Technique for best accuracy

Specifications

Accuracy: Relative Amplitude Accuracy - Freq. Response



Specification: ± 1 dB

Specifications

Accuracy: Relative Amplitude Accuracy

- △ **RF Input attenuator**
- △ **Reference level**
- △ **Resolution bandwidth**
- △ **CRT scaling**

Specifications

Accuracy: Absolute Amplitude Accuracy

- **Calibrator accuracy**
- **Frequency response**
- **Reference level uncertainty**

Specifications

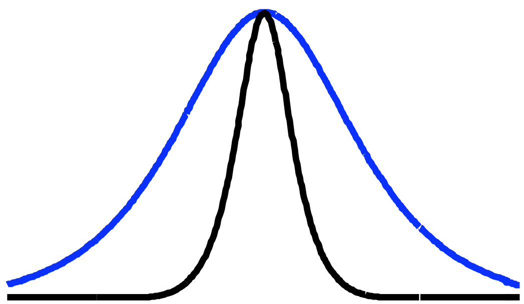
Accuracy: Other Sources of Uncertainty

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

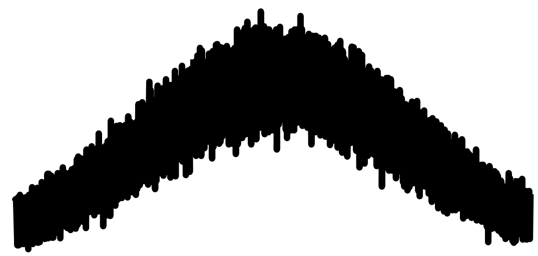
Specifications

Resolution

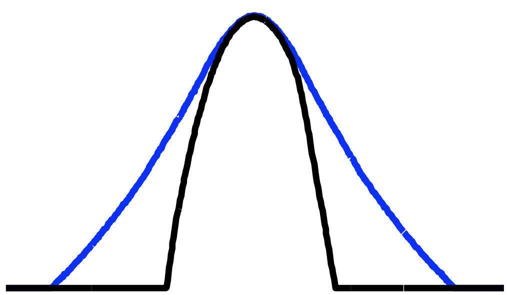
What Determines Resolution?



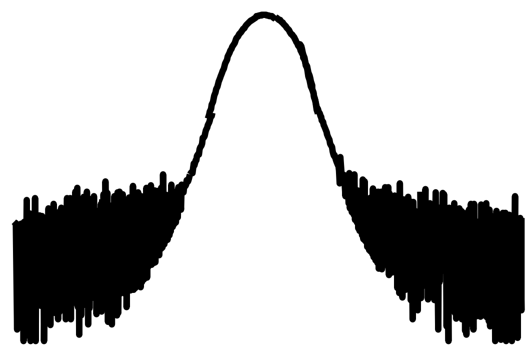
Resolution Bandwidth



Residual FM



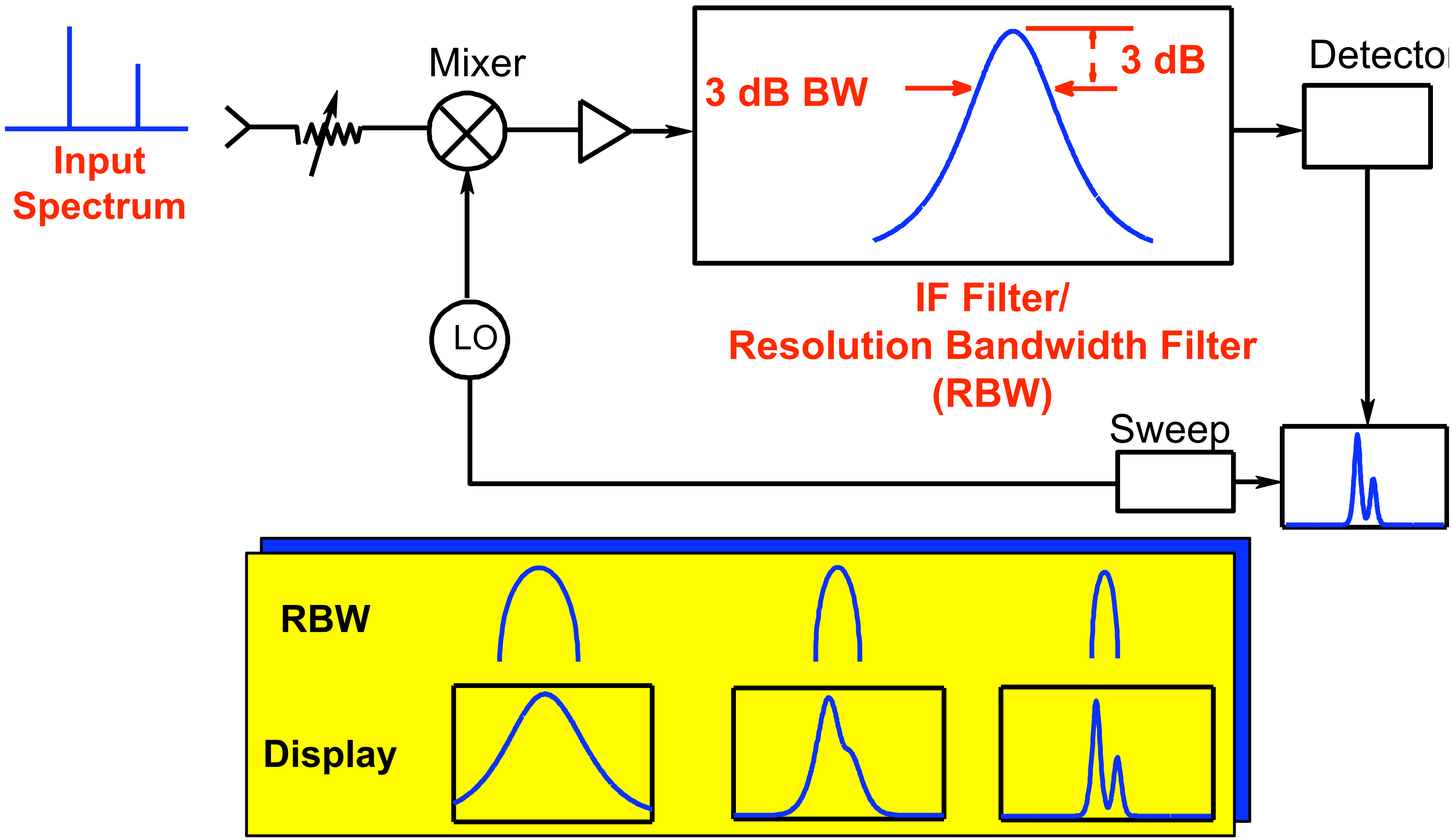
RBW Type and Selectivity



Noise Sidebands

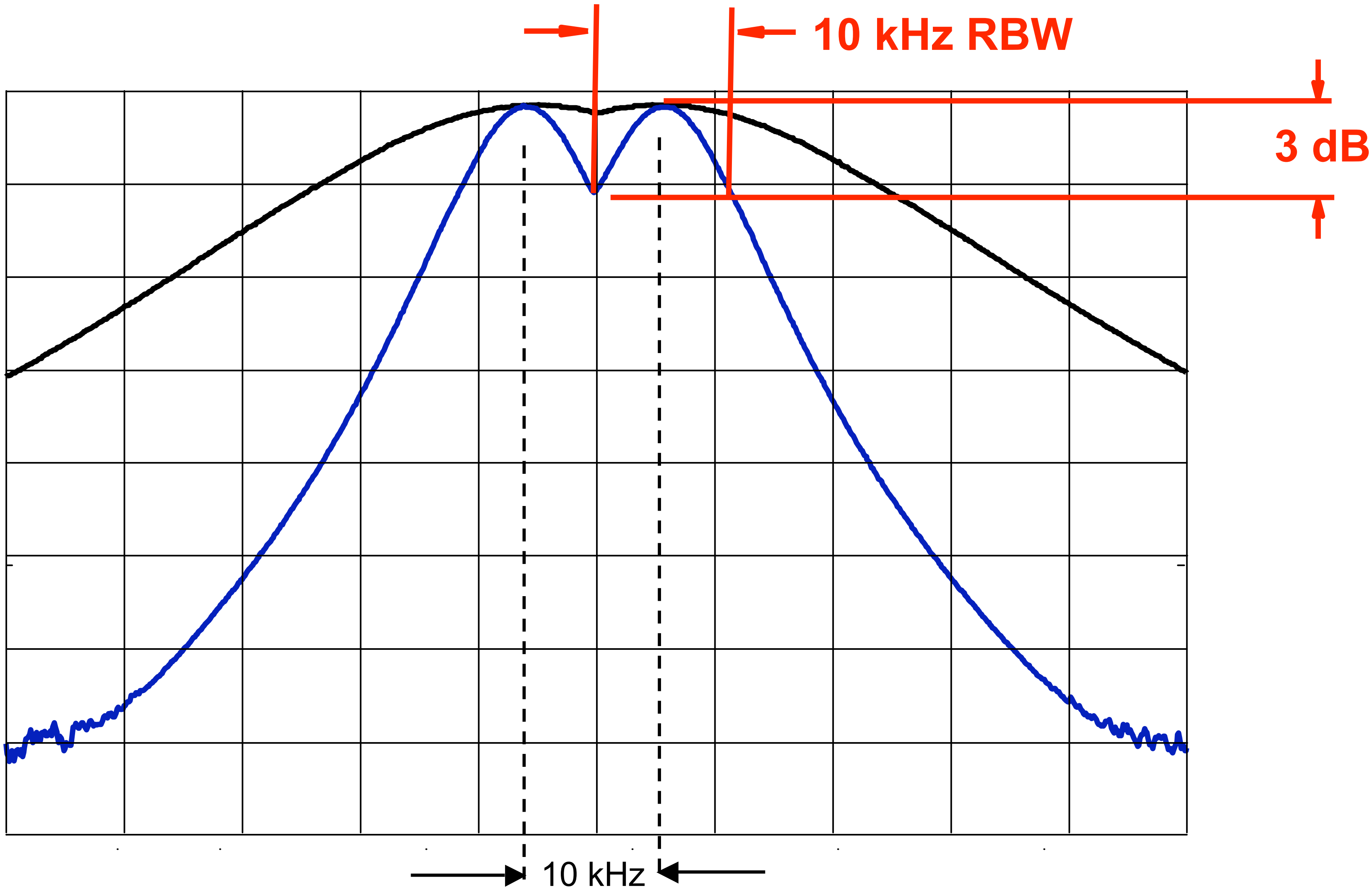
Specifications

Resolution: Resolution Bandwidth



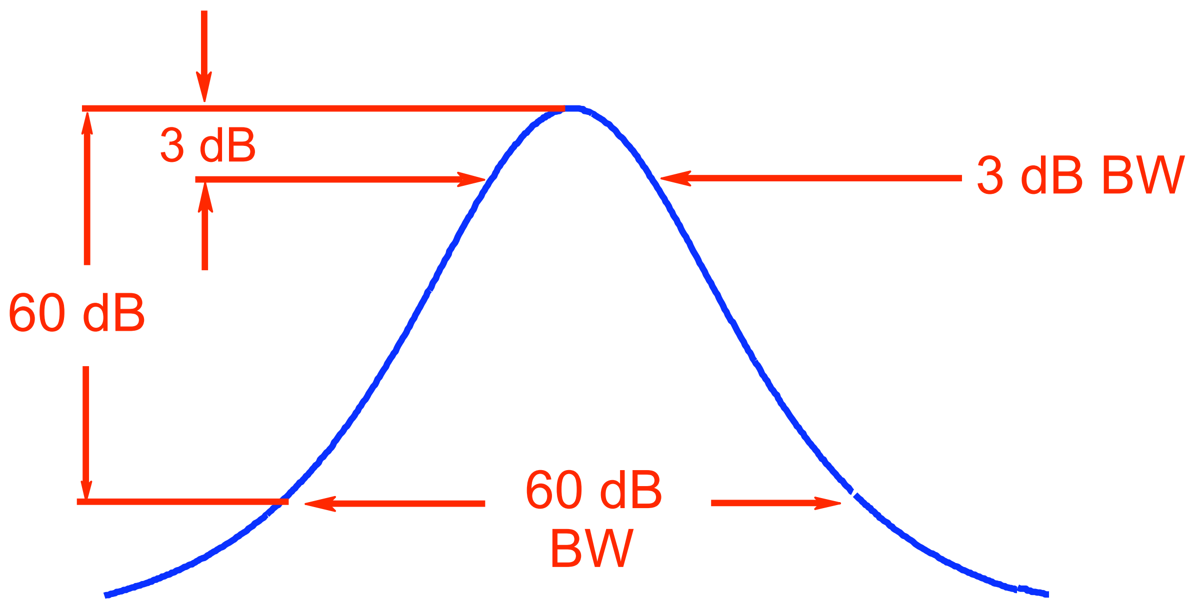
Specifications

Resolution: Resolution Bandwidth



Specifications

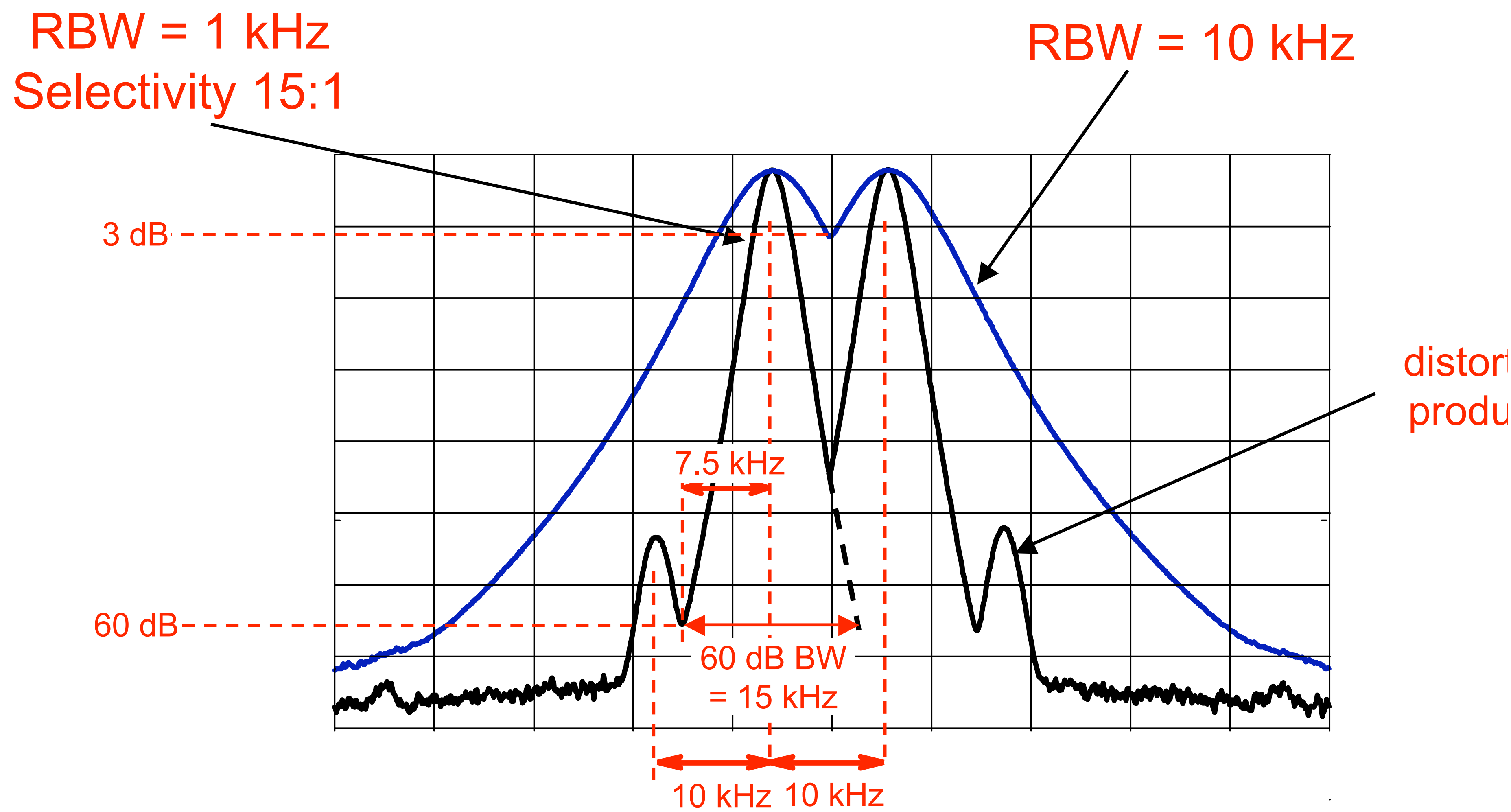
Resolution: RBW Type and Selectivity



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

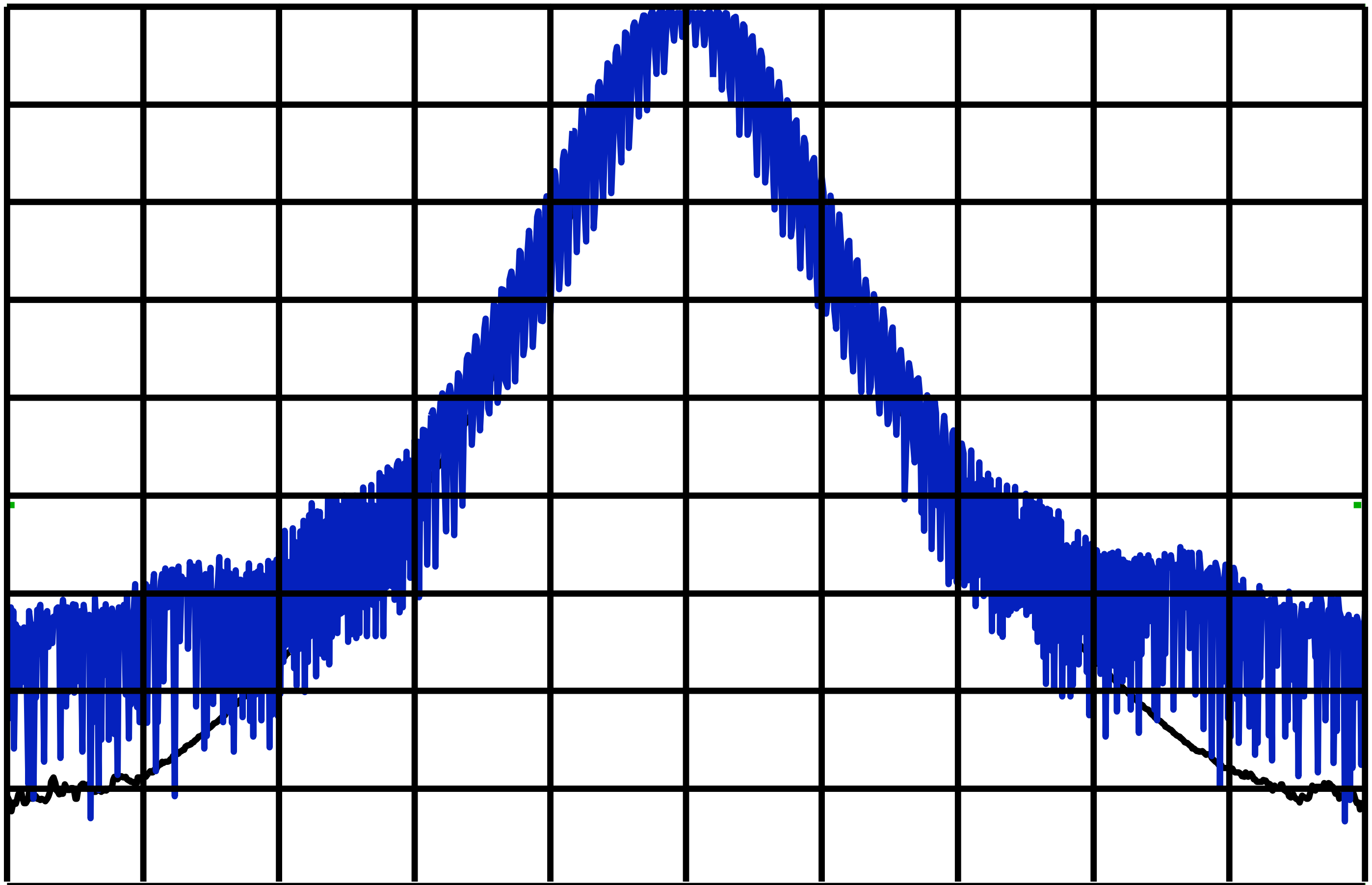
Specifications

Resolution: RBW Type and Selectivity



Specifications

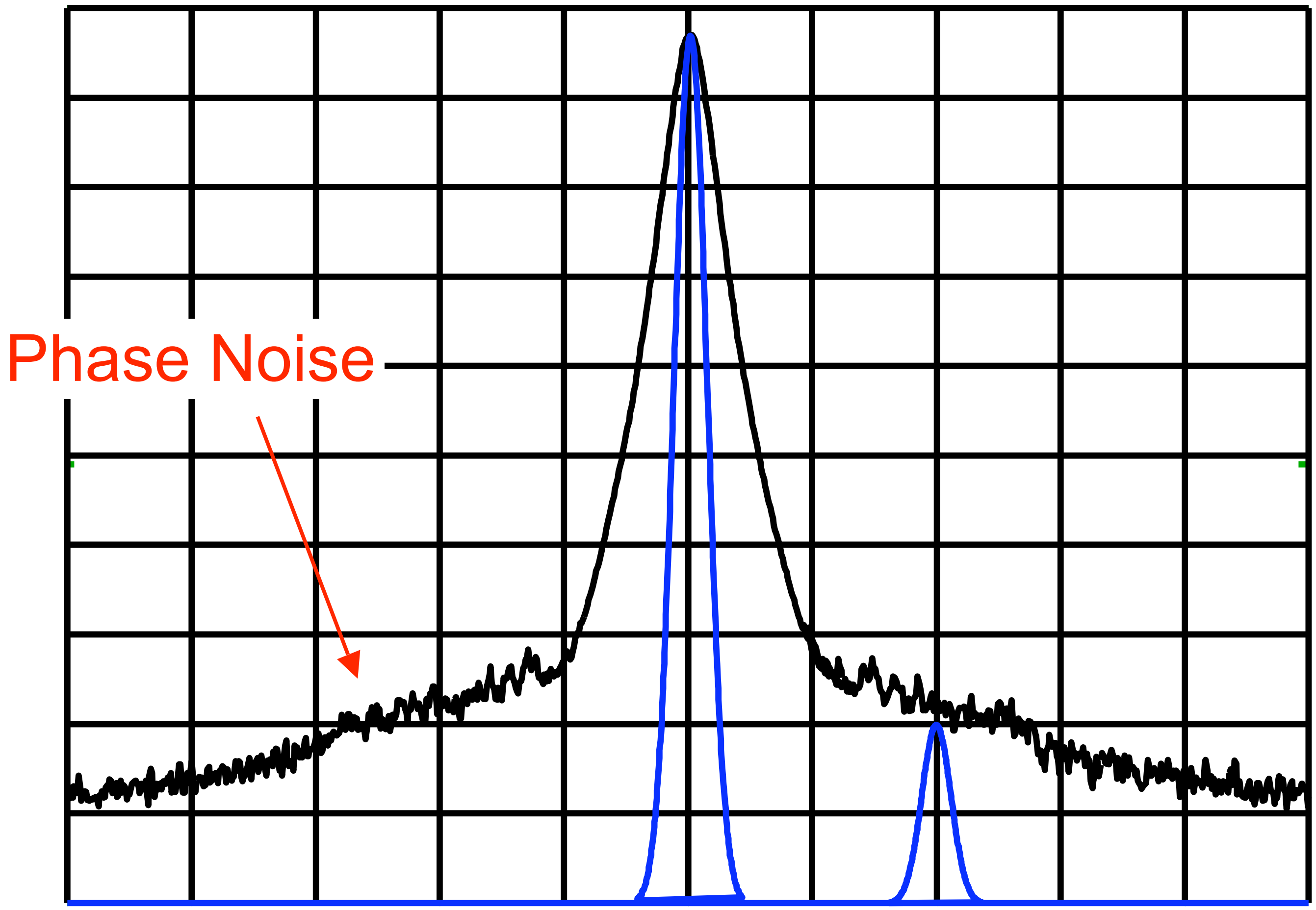
Resolution: Residual FM



Residual FM
"Smears" the Signal

Specifications

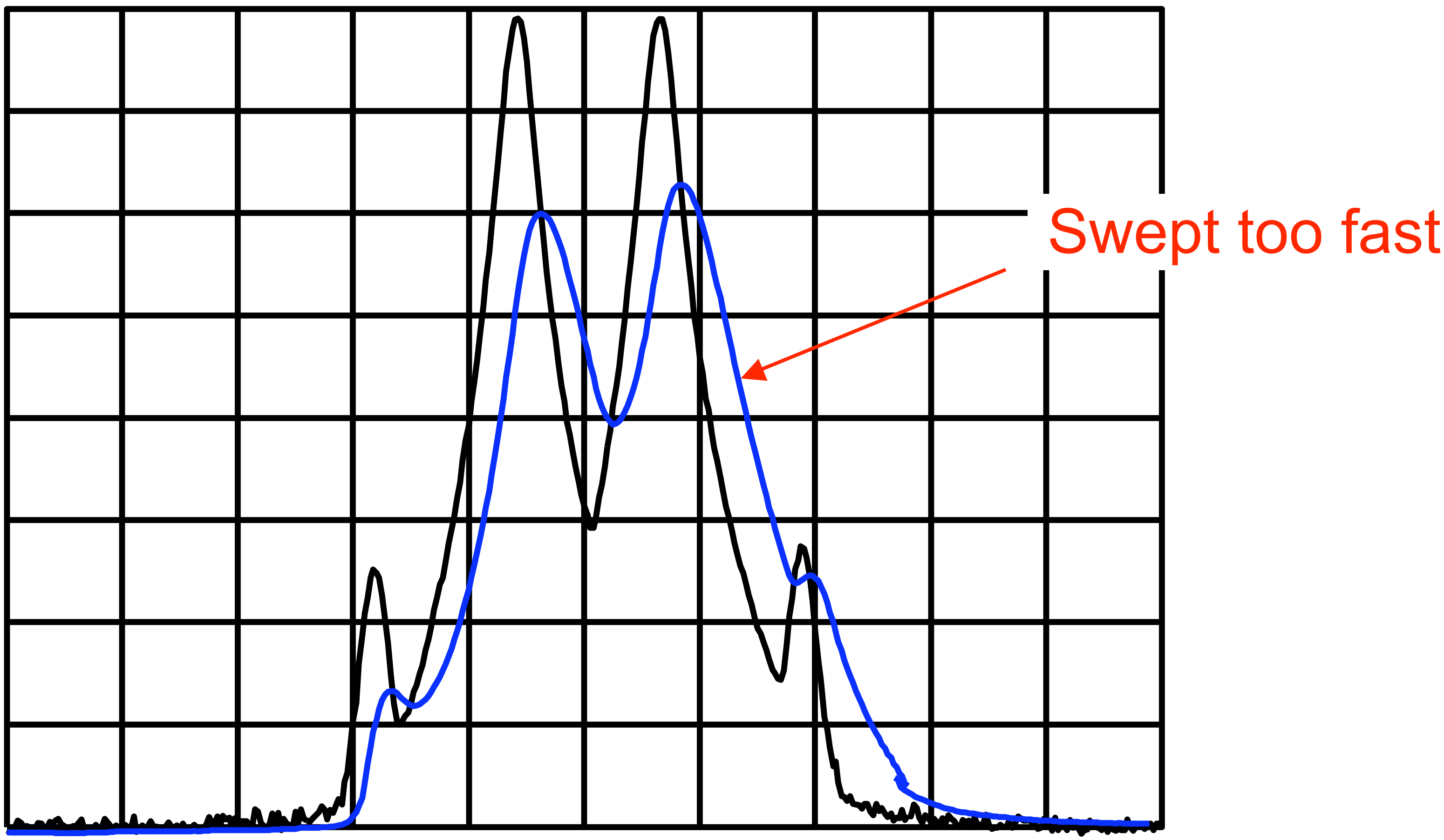
Resolution: Noise Sidebands



Noise Sidebands can prevent resolution of unequal signals

Specifications

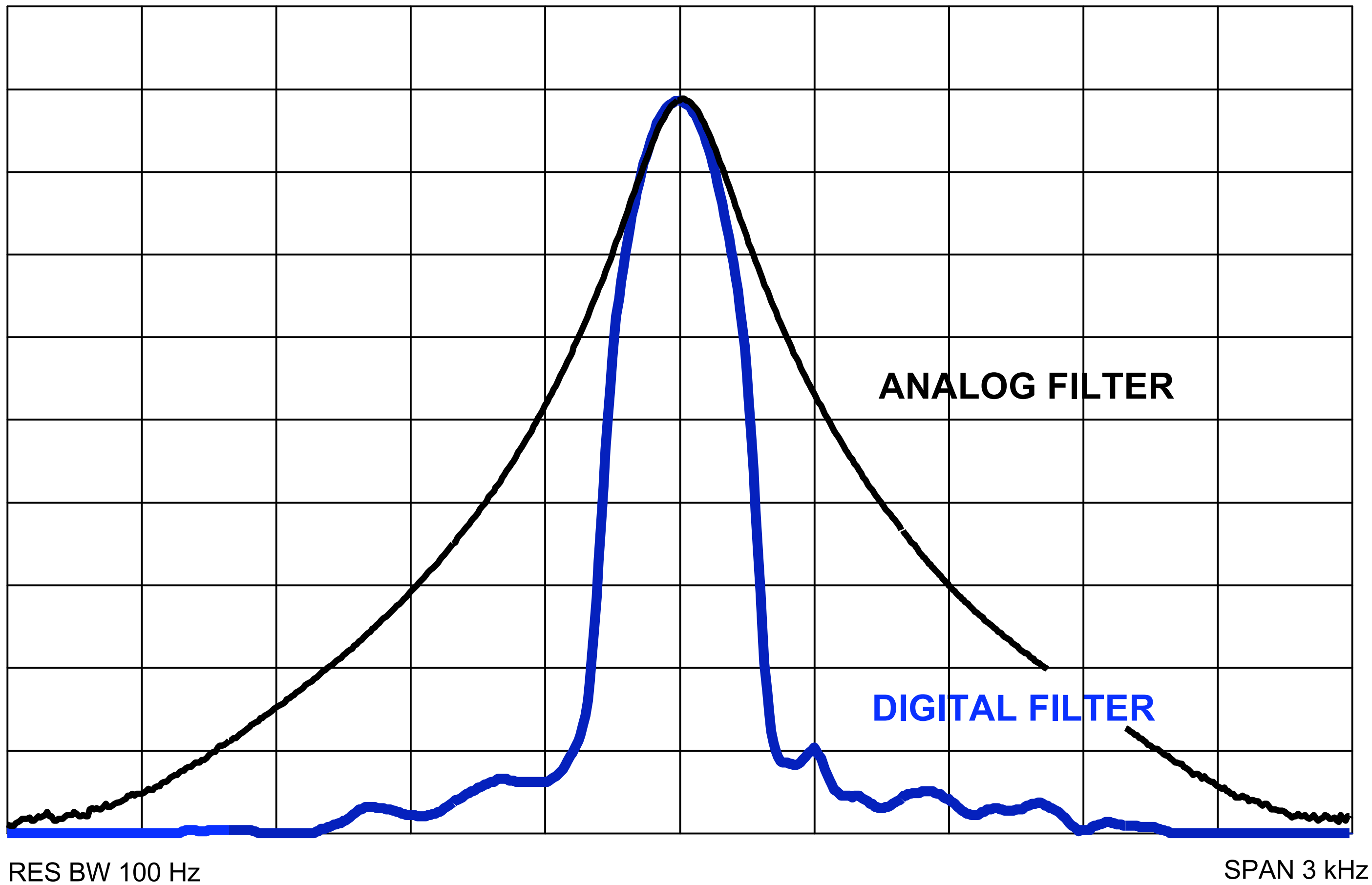
Resolution: RBW Determines Measurement Time



Penalty For Sweeping Too Fast
Is An Uncalibrated Display

Specifications

Resolution: Digital Resolution Bandwidths



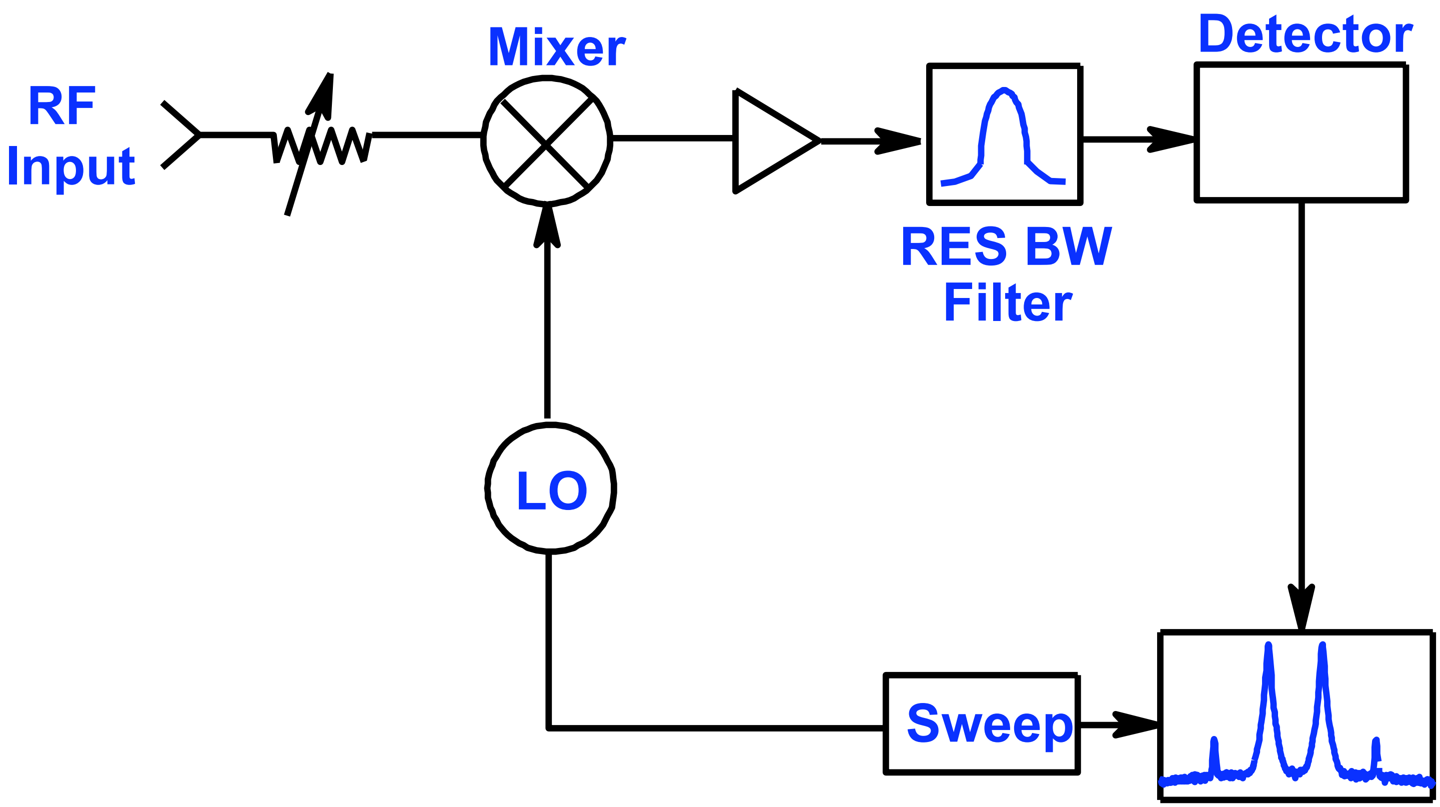
Typical Selectiv

Analog 15:

Digital 5:

Specifications

Sensitivity/DANL

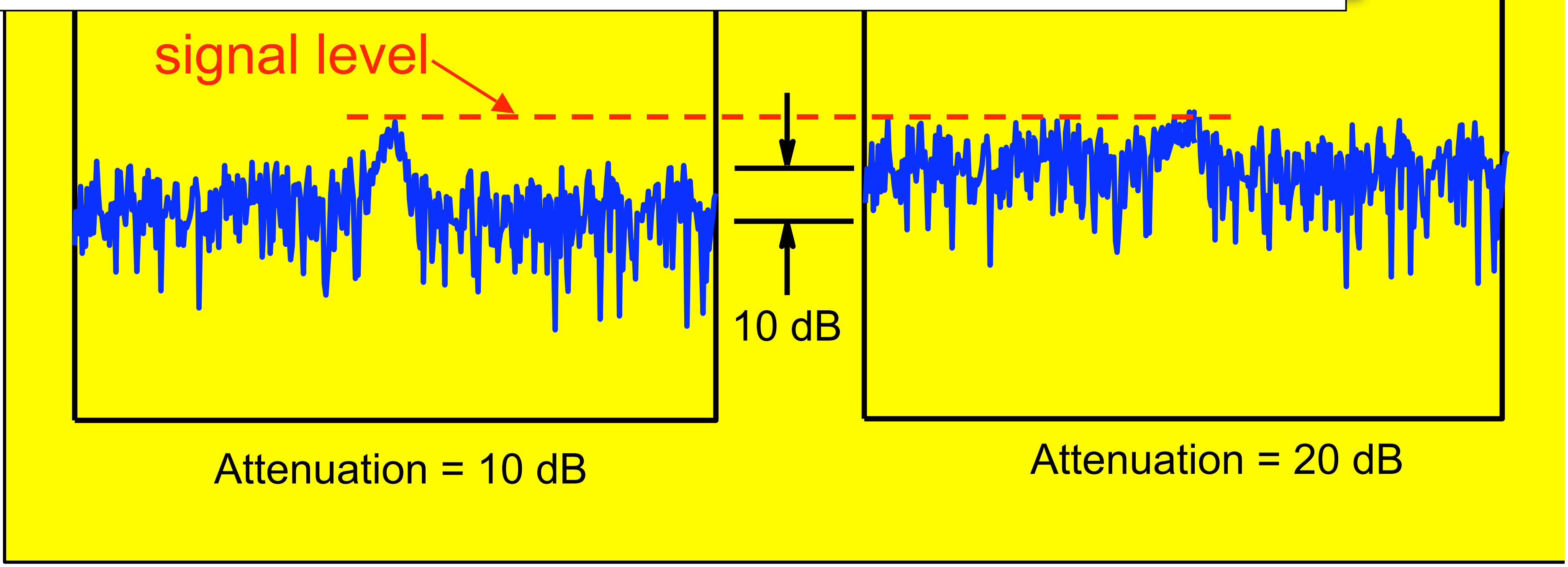


A Spectrum Analyzer Generates and Amplifies Noi
Just Like Any Active Circuit

Specifications

Sensitivity/DANL

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

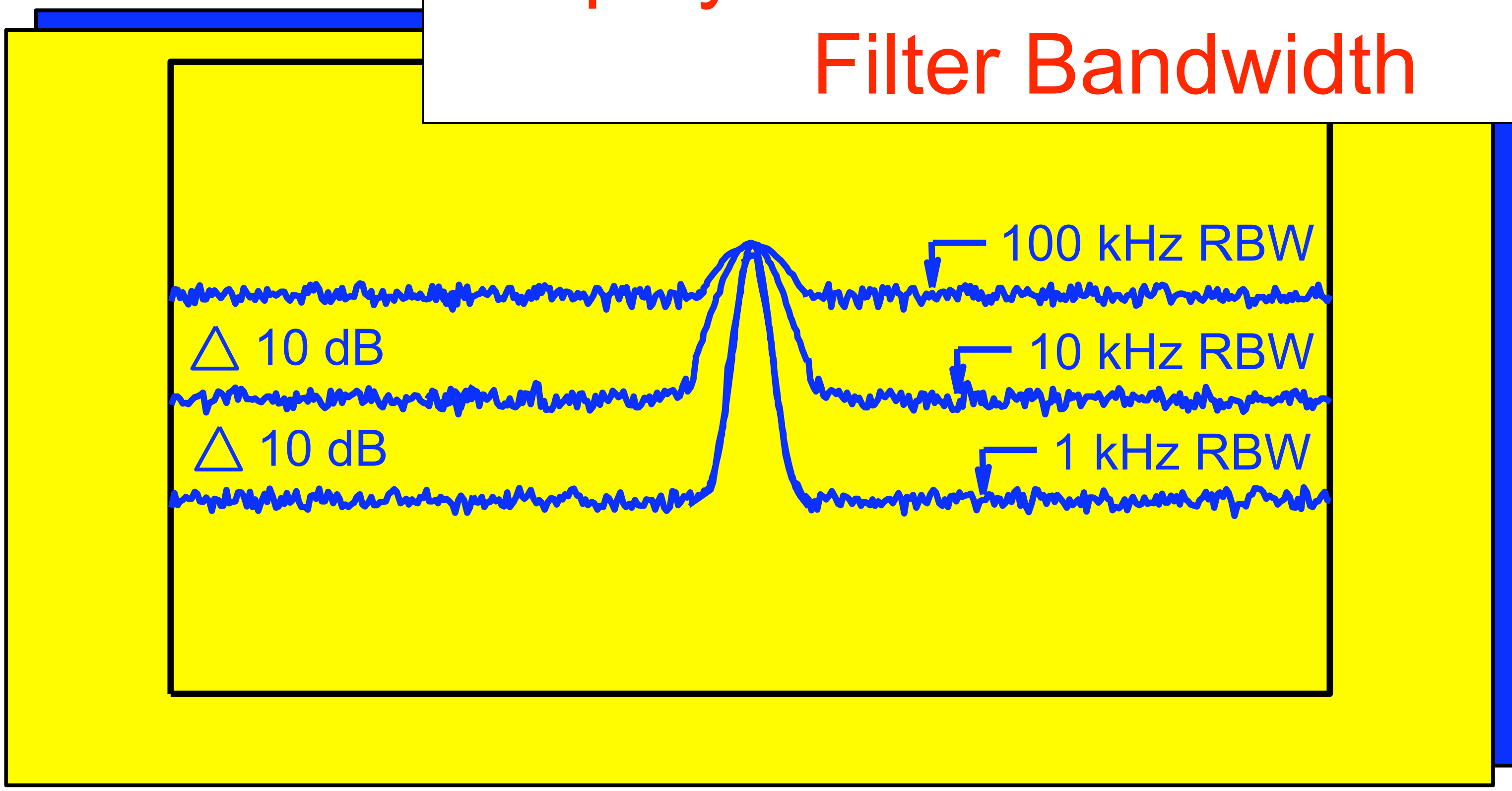


Signal-To-Noise Ratio Decreases as RF Input Attenuation is Increased

Specifications

Sensitivity/DANL: IF Filter (RBW)

Displayed Noise is a Function of I
Filter Bandwidth

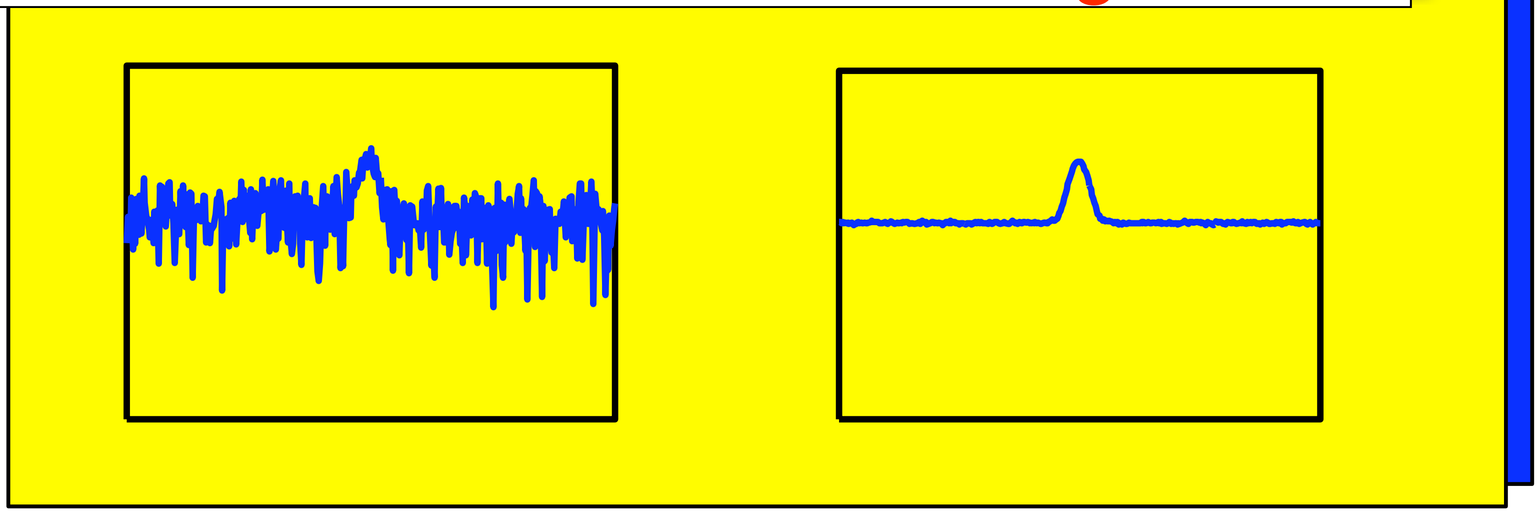


Decreased BW = Decreased Noise

Specifications

Sensitivity/DANL: VBW

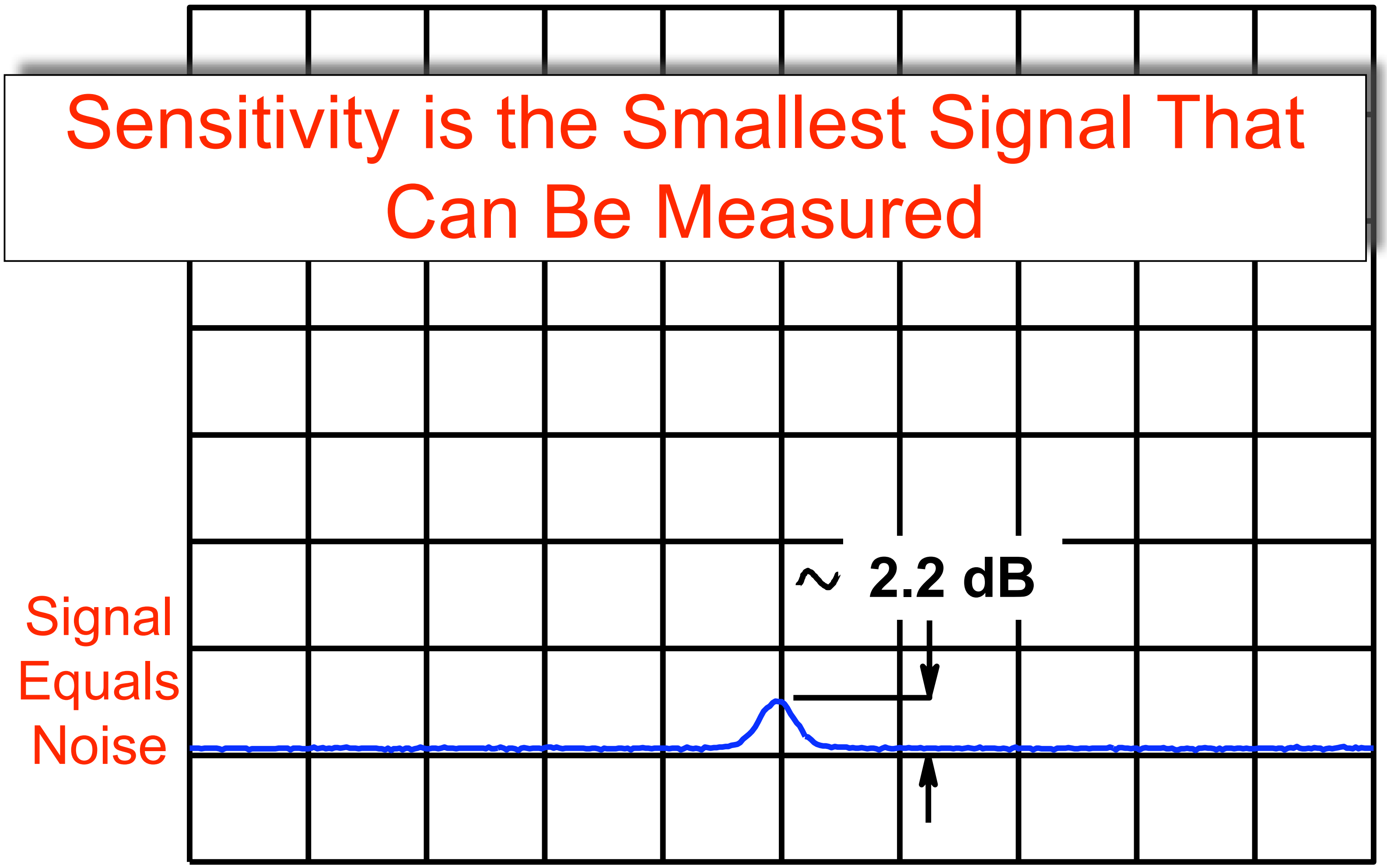
Video BW Smoothes Noise for Easier Identification of Low Level Signals



Specifications

Sensitivity/DANL

Sensitivity is the Smallest Signal That Can Be Measured



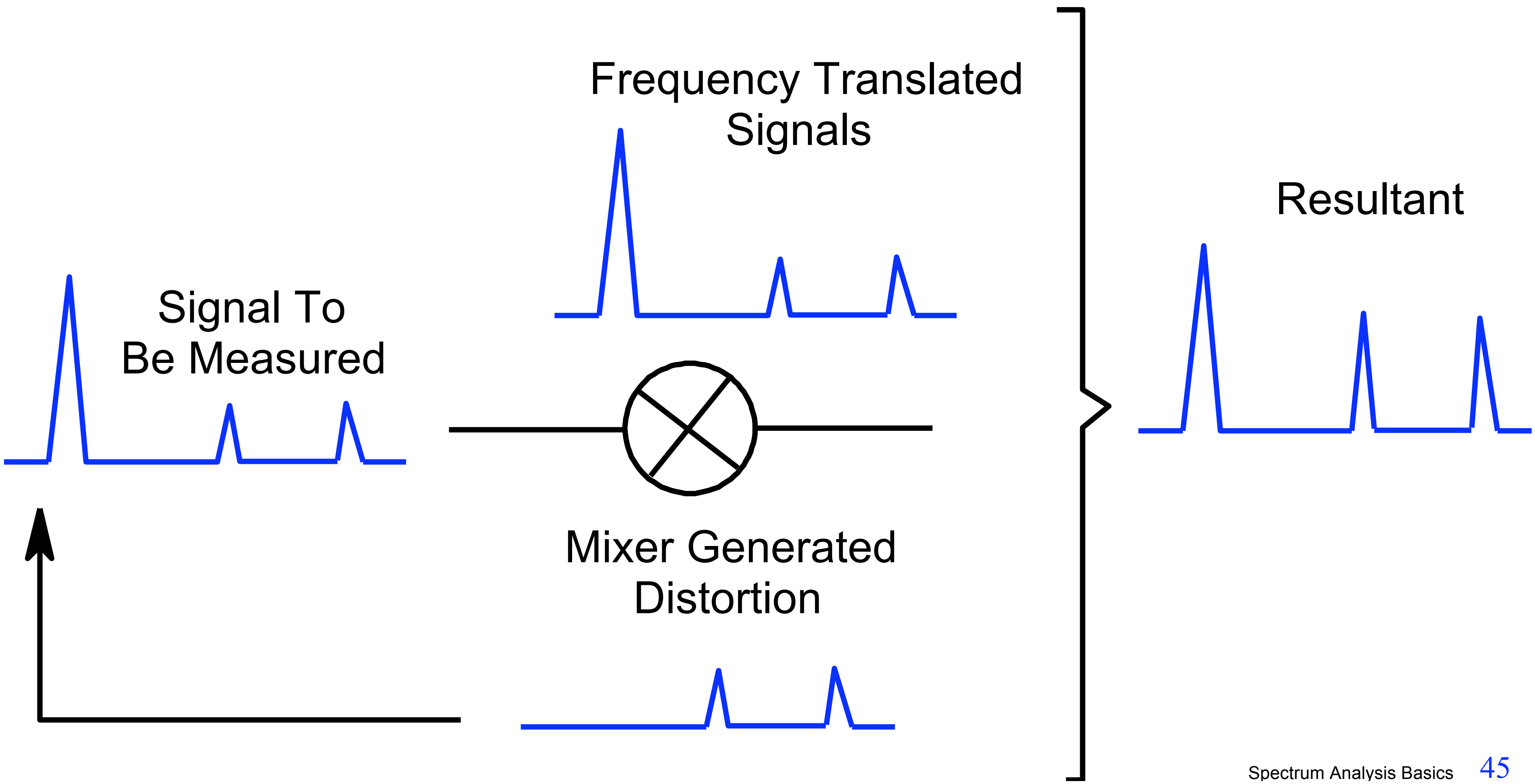
Specifications

Sensitivity/DANL

For Best Sensitivity Use:

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

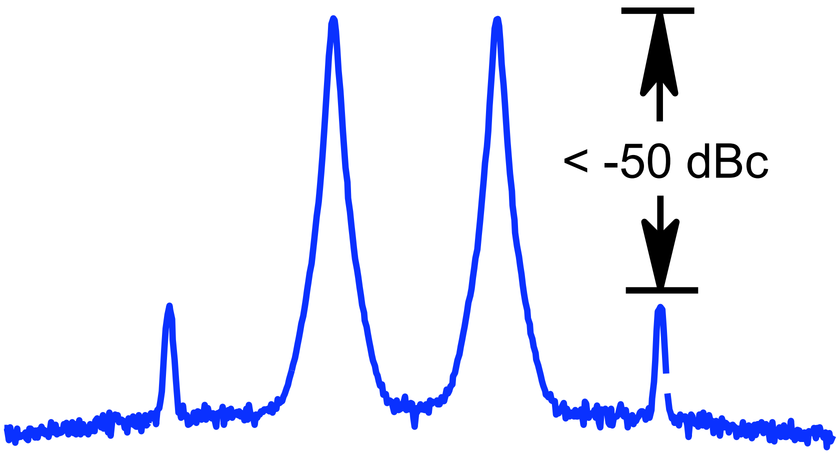
Mixers Generate Distortion



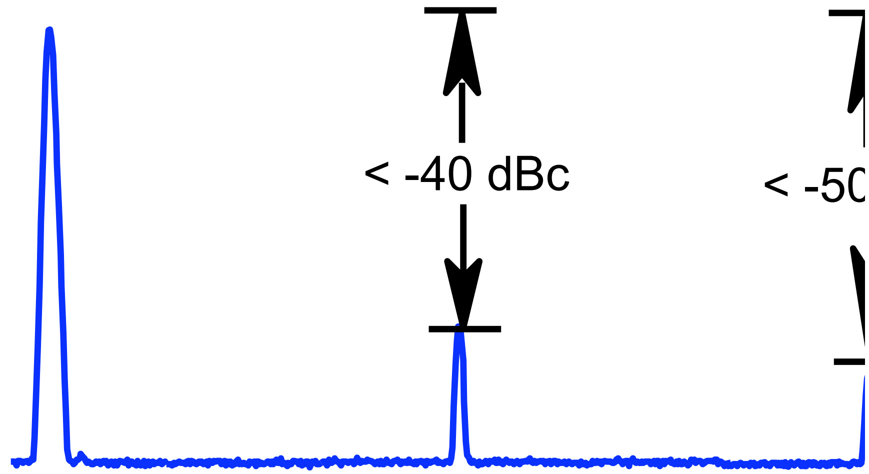
Specifications

Distortion

Most Influential Distortion is the Second and Third Order



Two-Toned Intermod

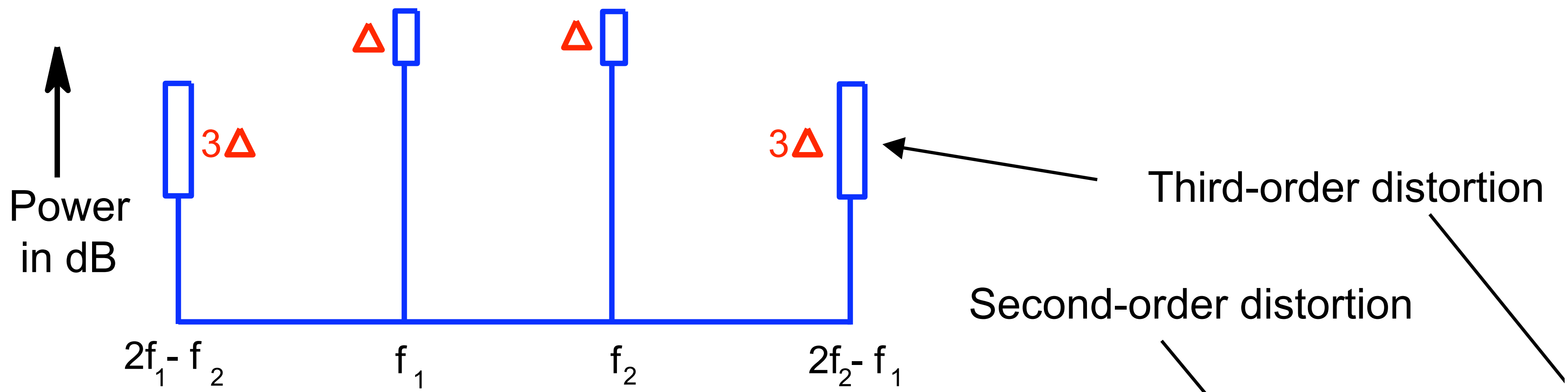


Harmonic Distortion

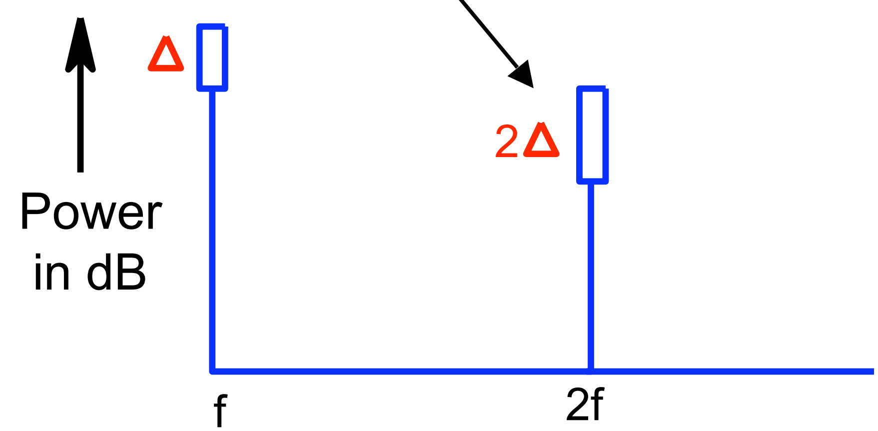
Specifications

Distortion

Distortion Products Increase as a Function of Fundamental's Power



Two-Toned Intermod



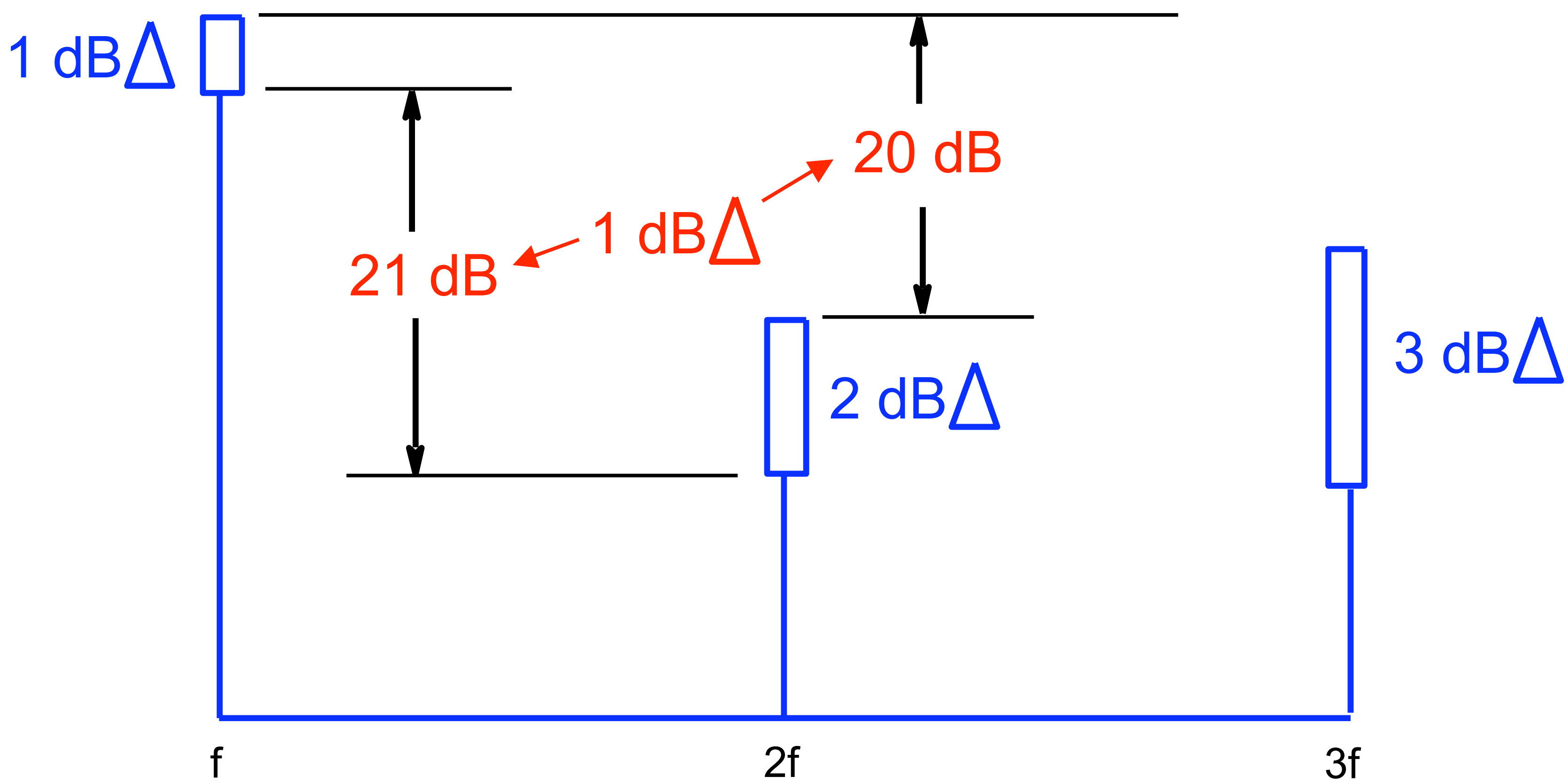
Harmonic Distortion

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

Specifications

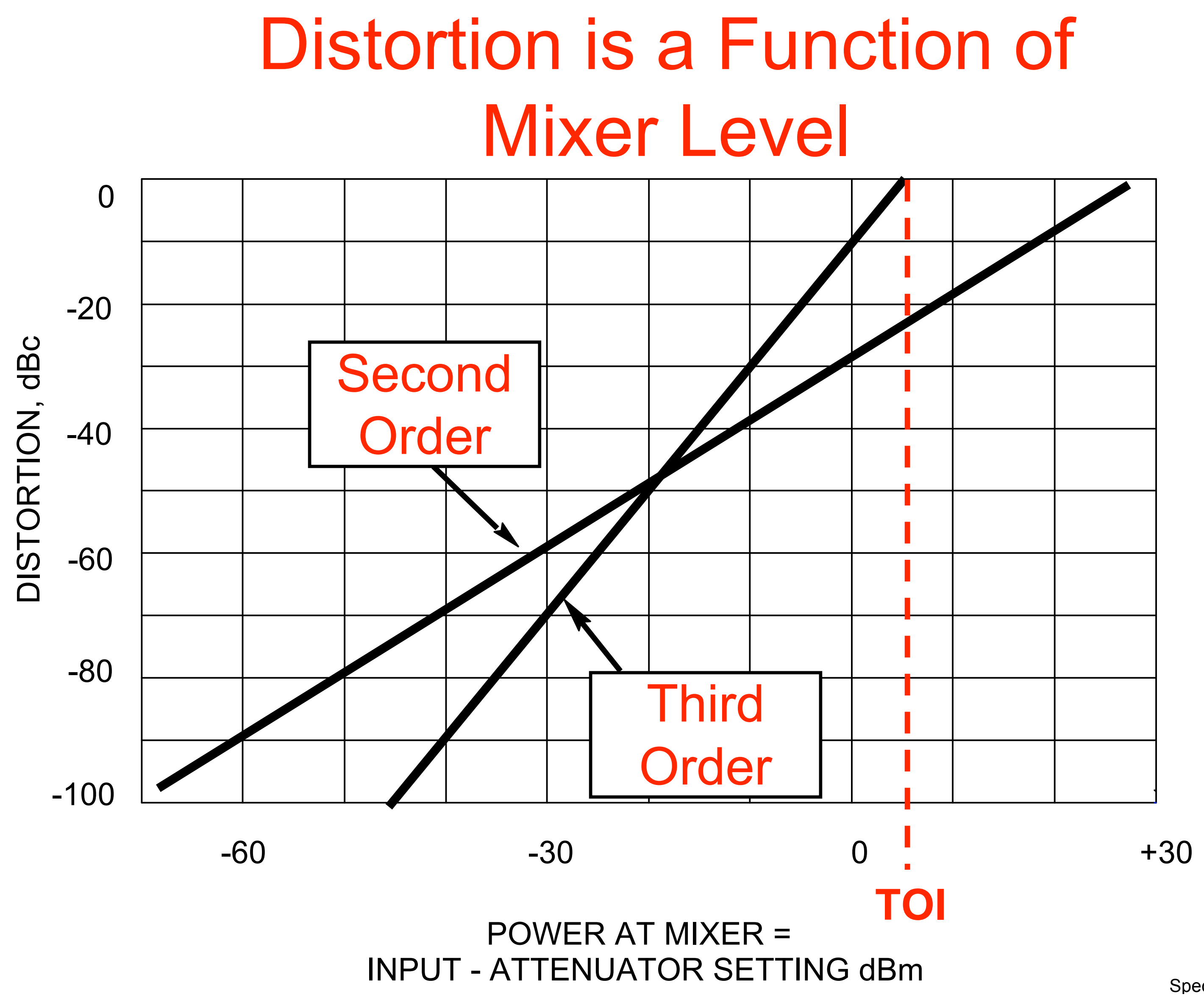
Distortion

Relative Amplitude Distortion Changes with Input Power Level



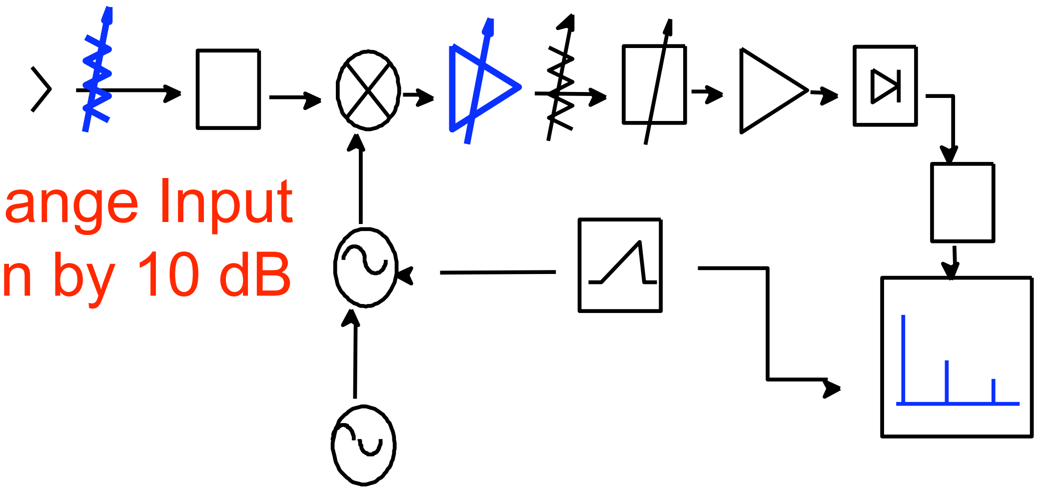
Specifications

Distortion



Specifications
Distortion

Distortion Test:
Is it Internally or Externally Generated?



① Change Input Attn by 10 dB

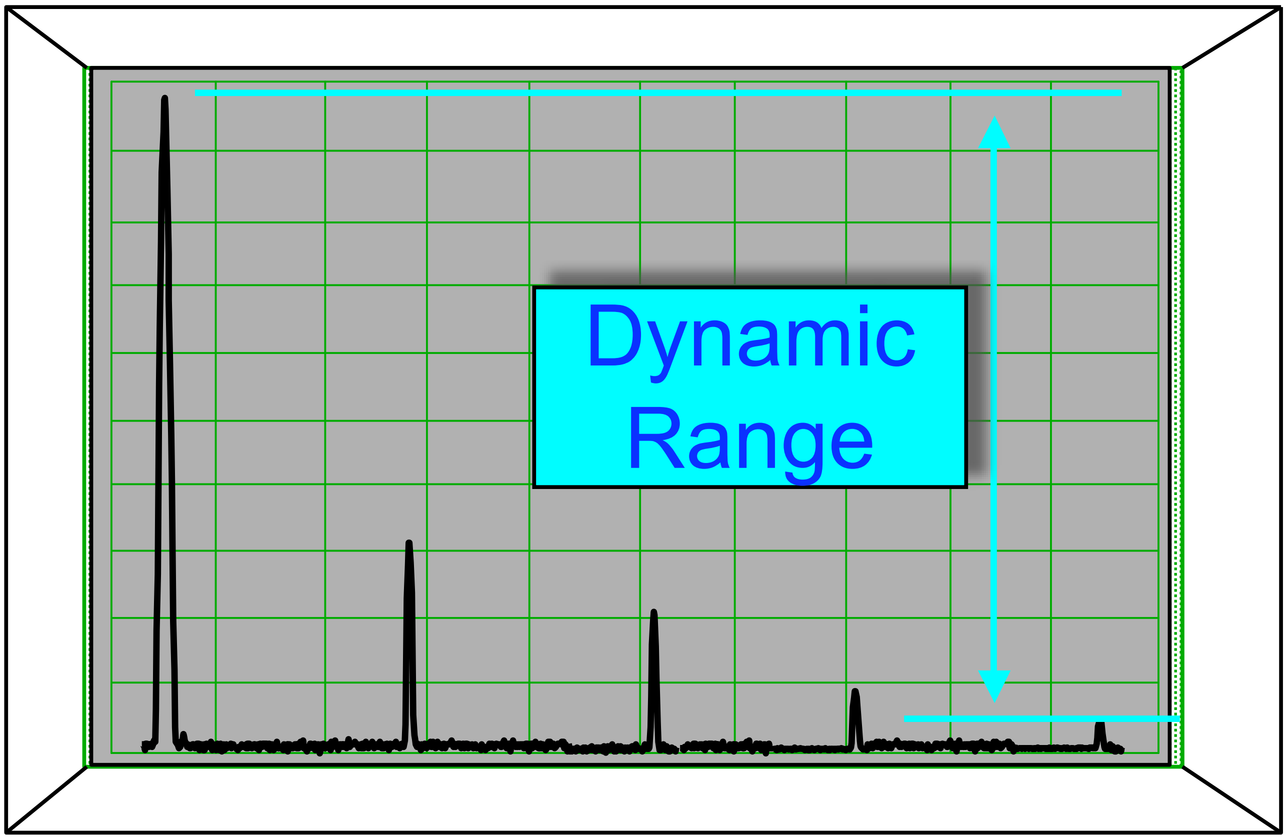
② Watch Signal on Screen:

- No change in amplitu = distortion is part of input signal (external

- Change in amplitude = at least some of the distortion is being generated inside

Specifications

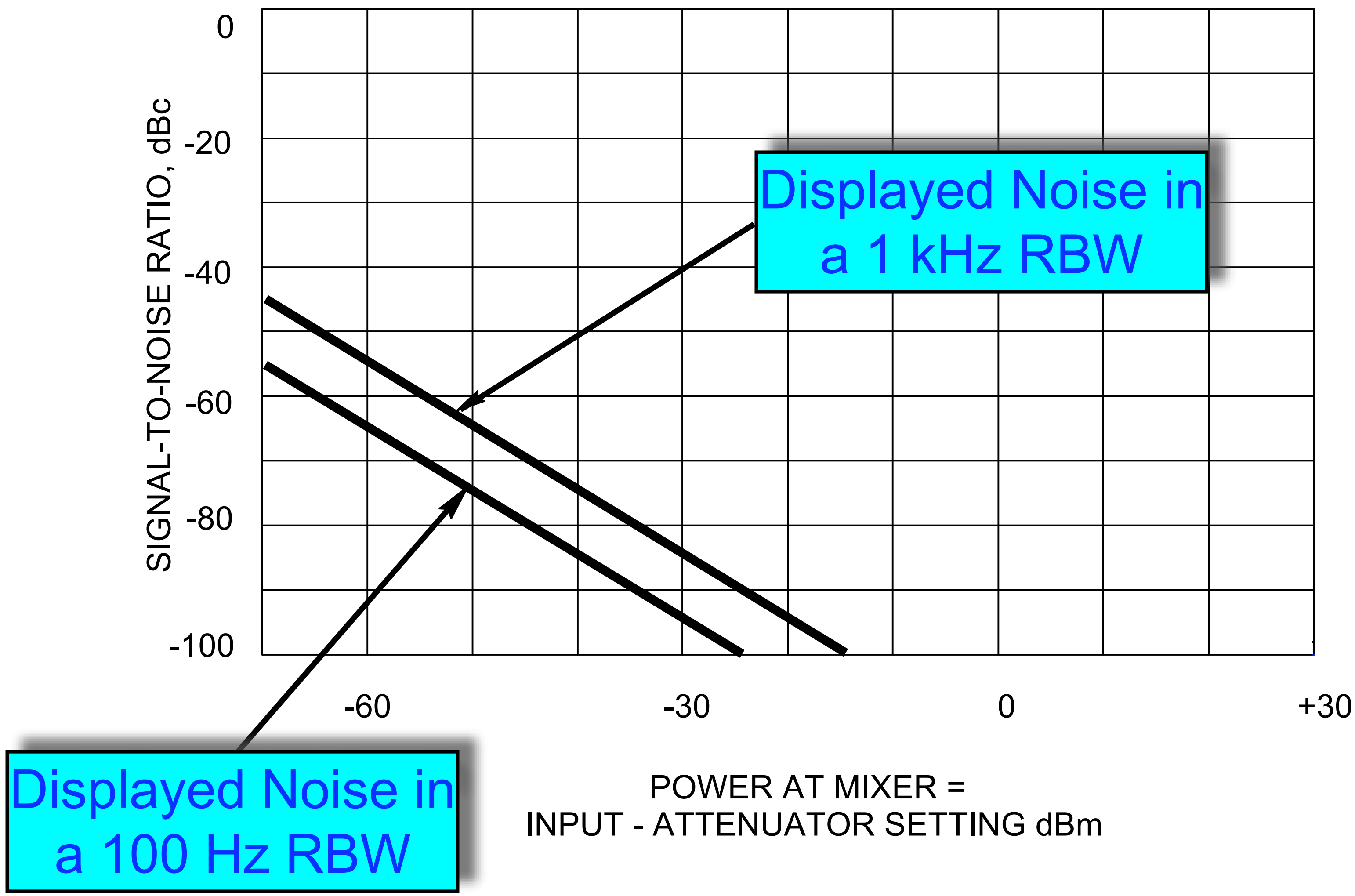
Dynamic Range



Specifications

Dynamic Range

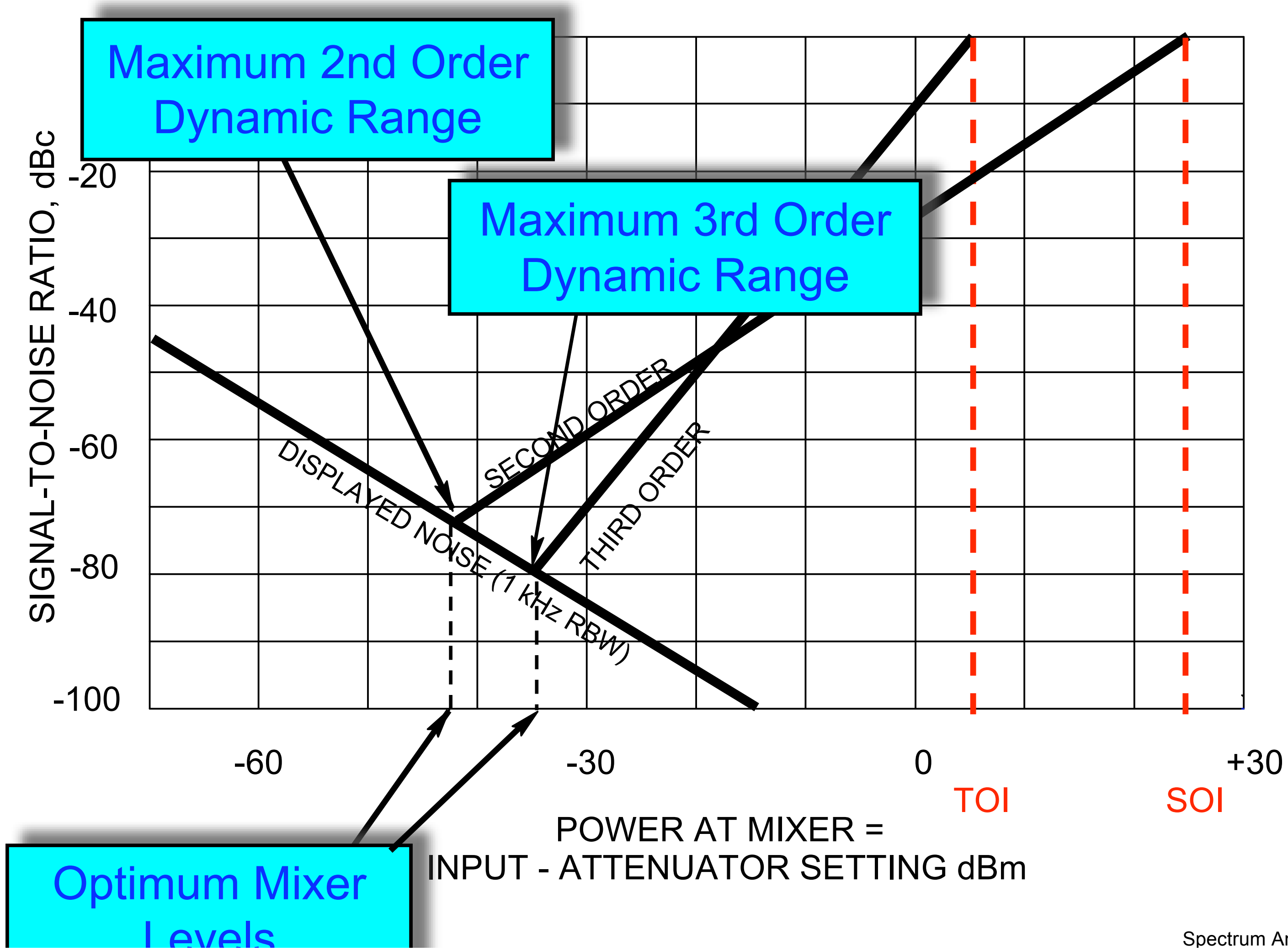
Signal-to-Noise Ratio Can Be Graphed



Specifications

Dynamic Range

Dynamic Range Can Be Presented Graphically



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 dBc (1 kHz RBW)

Where TOI = (-30) - (-70)/2
= + 5 dBm

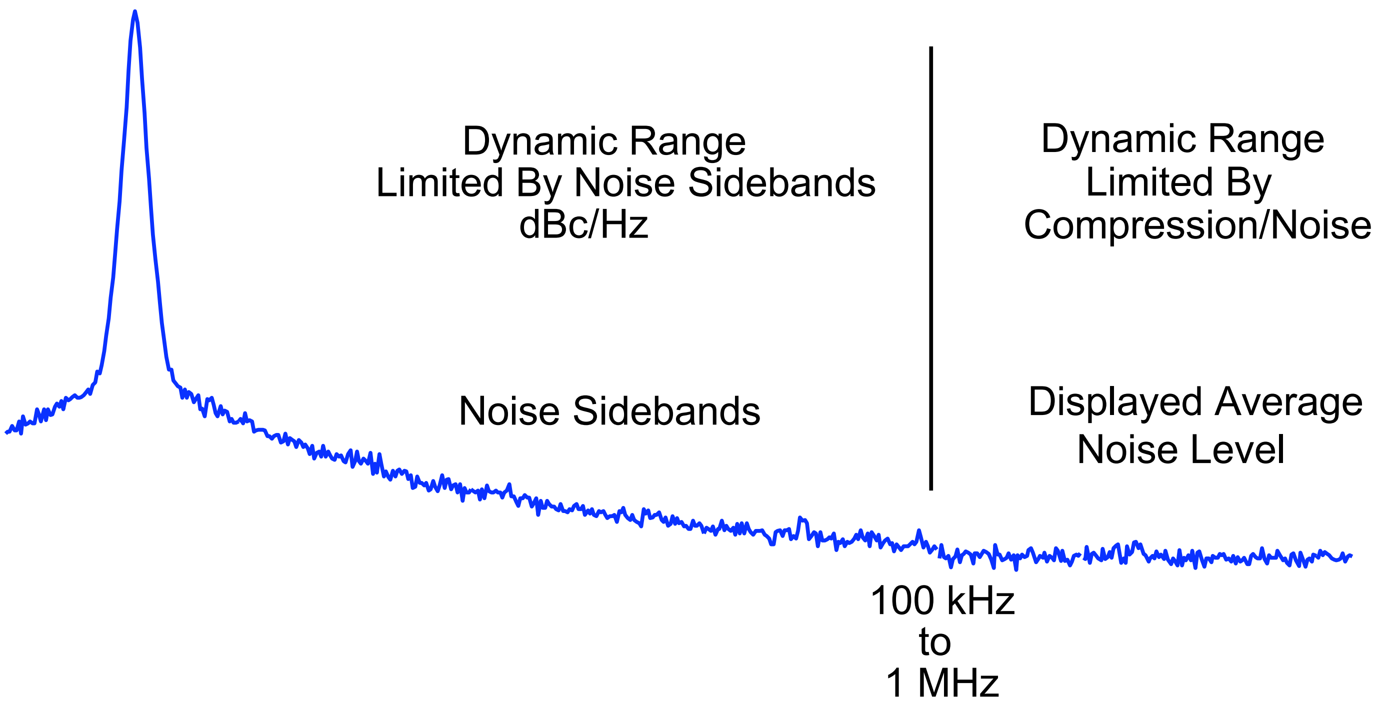
Optimum Mixer Level = (-115) - (-80)
= -35 dBm

Attenuation = (0) - (-35)
= +35 dBm

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

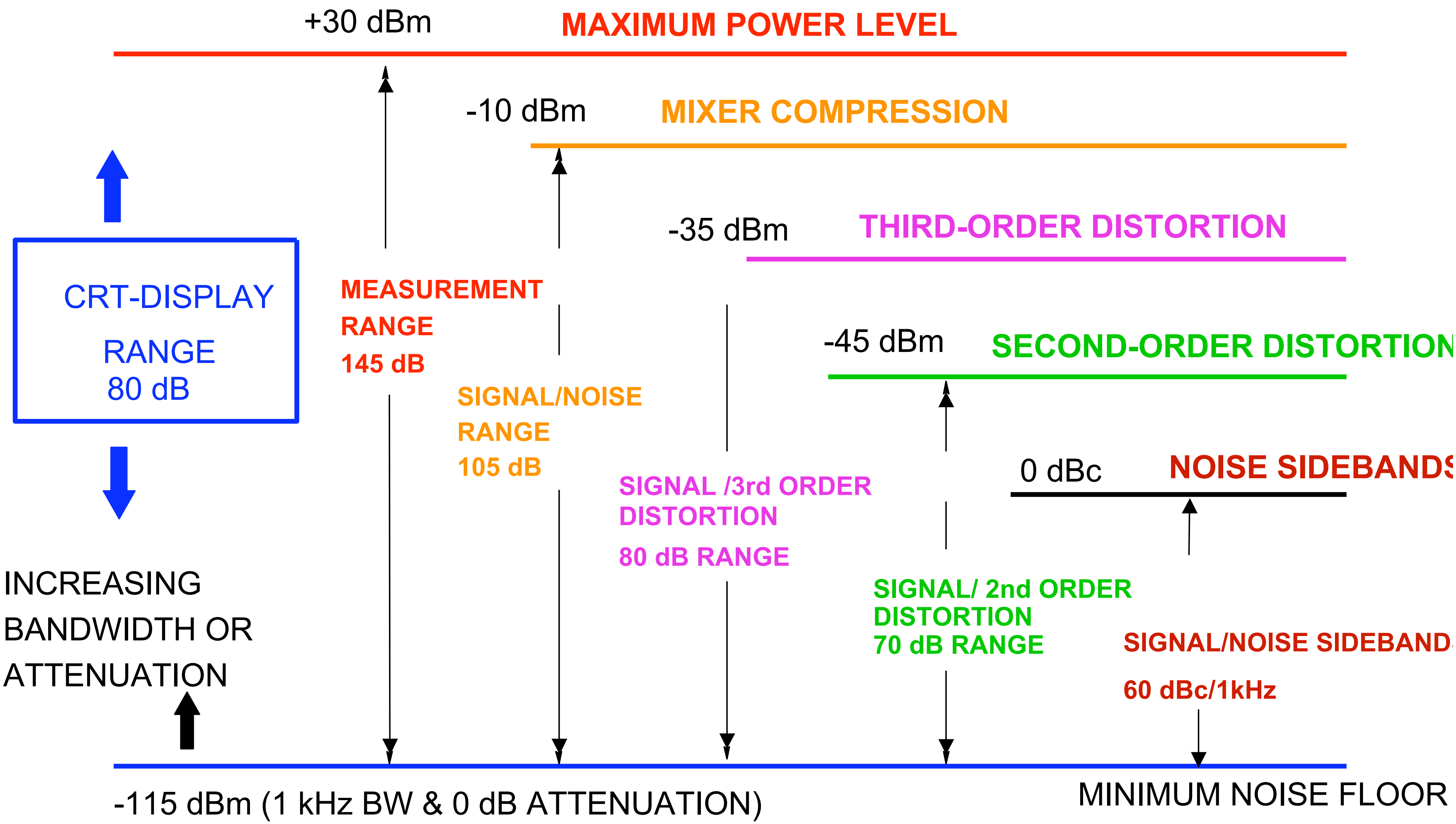
Calculated from:

- distortion
- sensitivity

Noise sidebands at the offset frequency

Specifications

Dynamic Range



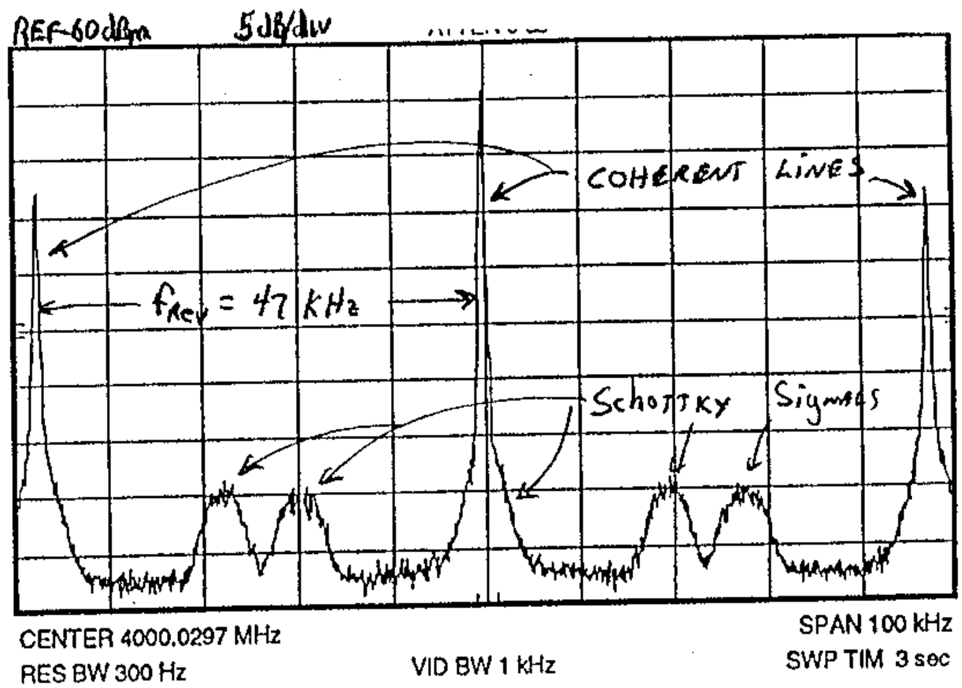
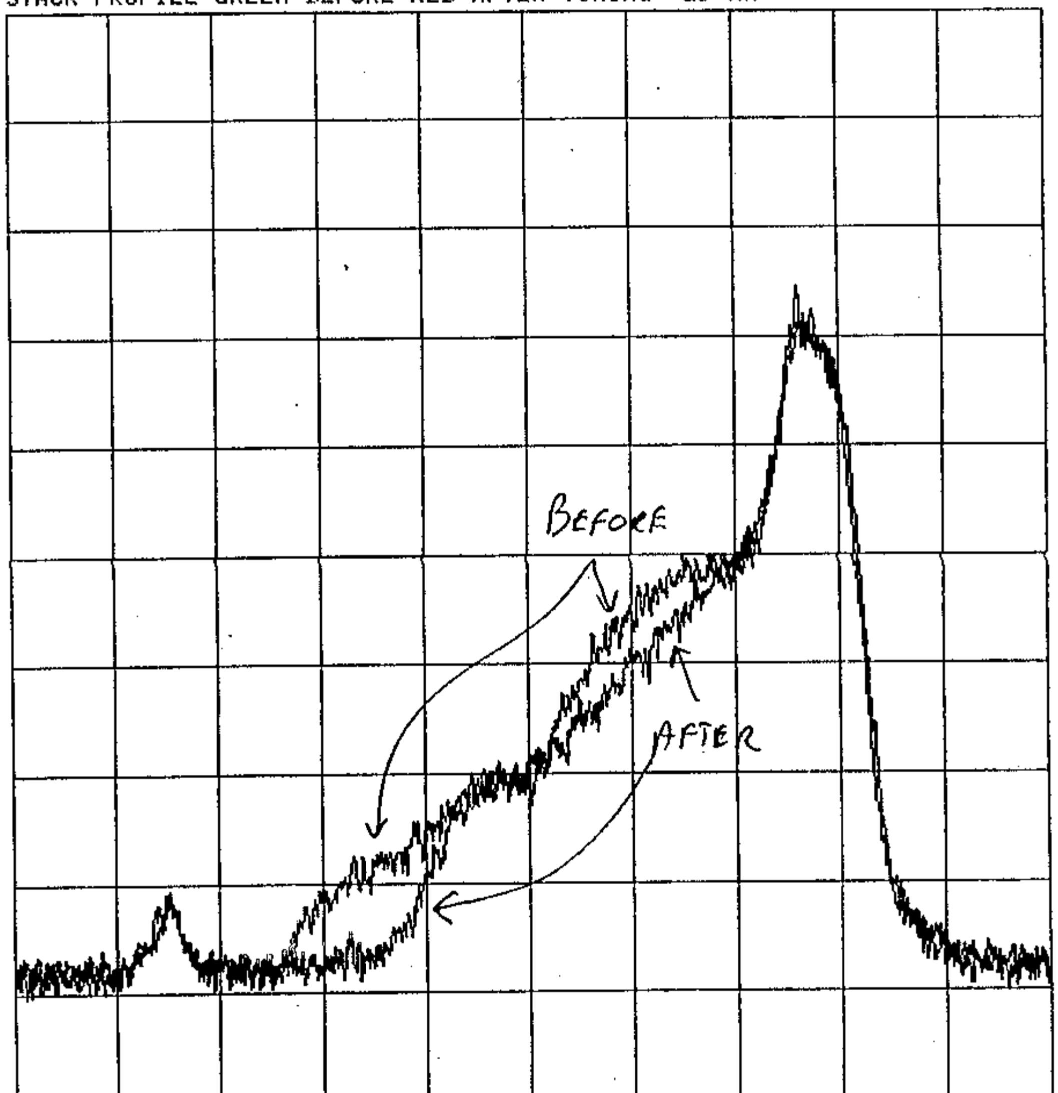


Figure 5. Typical Tevatron vertical bunched beam spectrum at 4 GHz as measured by the vertical proton pickup.

Console Location 3, 22-MAR-1995 13:21
Pbar SA Plot

STACK PROFILE GREEN BEFORE RED AFTER TUNING 29 MA



03/22/95 1306

Scale 10 dB/div

Atten 0 dB

Swp 1 sec

Vid BW 300 Hz

Res BW 300 Hz

Ref Lvl -30 dB

VID AVG

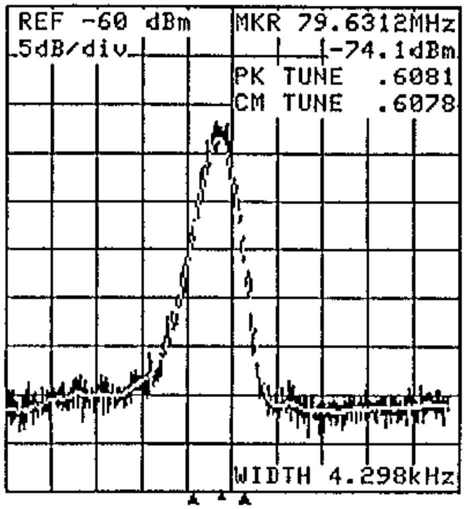
Start Freq 79.21000001 MHz

Stop Freq 79.26000001 MHz

Console Location 1,
Emittance Measurement / Traces

10-DEC-1994 23:46

"Lower" HORIZONTAL SIDEBAND



CENTER 79.632MHz SPAN 37.7kHz

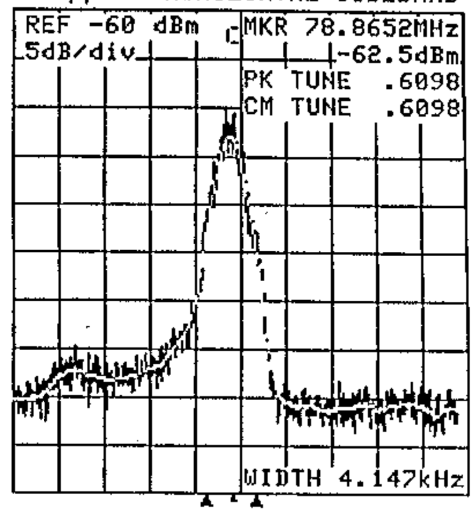
ACCUMULATOR

12/10/94 2343

BEAM CURRENT	66.36 mA
STACKING RATE	6.117 mA/h
HARMONIC NUMBER	126
REV FREQUENCY	628958 Hz
DELTAP/P	.1951 %
HORIZONTAL TUNE	.6088
VERTICAL TUNE	.6072
HORZ CHROMATICITY	-.0607
VERT CHROMATICITY	-.1879

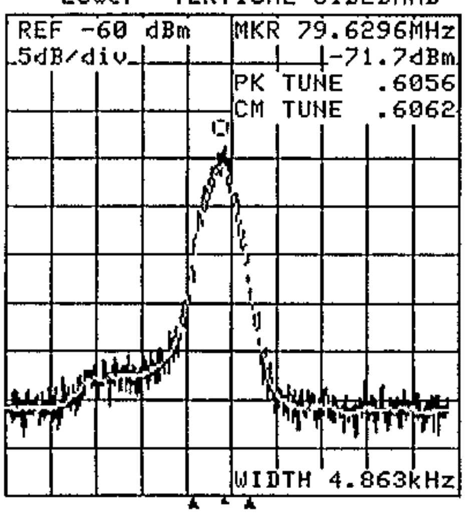
Correct Chromaticity
CALCULATION 10/06/92

"Upper" HORIZONTAL SIDEBAND



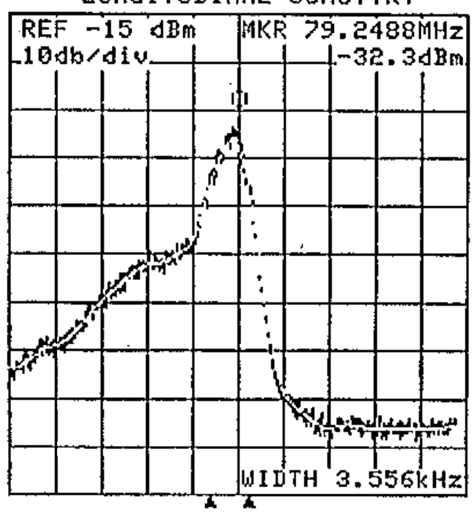
CENTER 78.866MHz SPAN 37.7kHz

"Lower" VERTICAL SIDEBAND



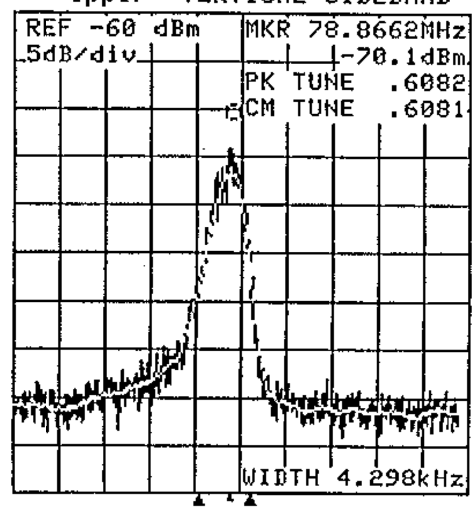
CENTER 79.631MHz SPAN 37.7kHz

LONGITUDINAL SCHOTTKY



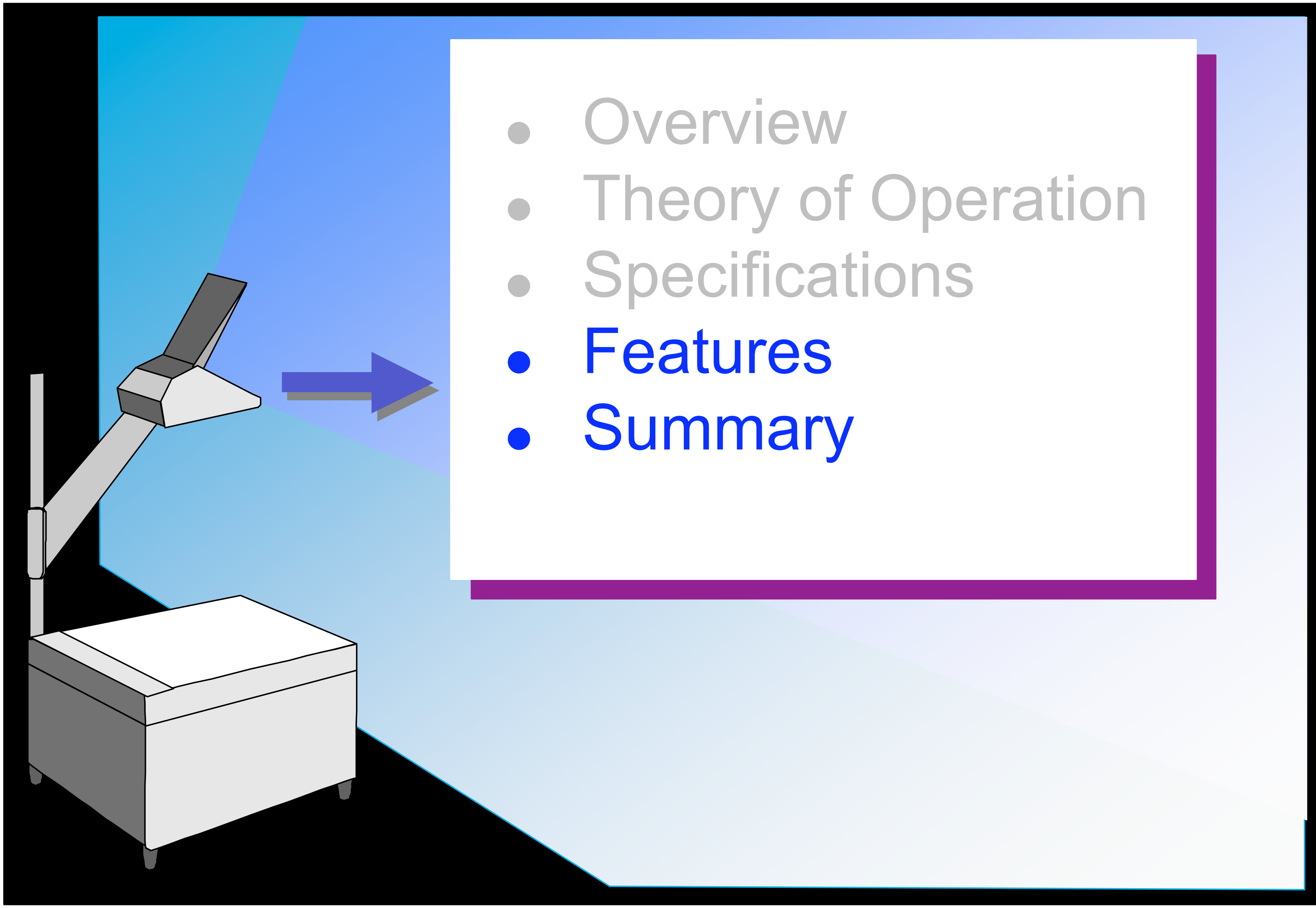
CENTER 79.249MHz SPAN 40 kHz

"Upper" VERTICAL SIDEBAND



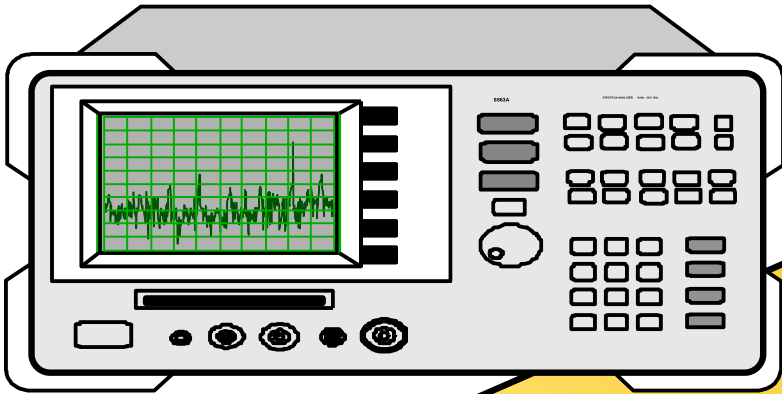
CENTER 78.867MHz SPAN 37.7kHz

Agenda



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

Features



➢ Basic Operation
- ✓ remote operation
- ✓ markers
- ✓ limit lines

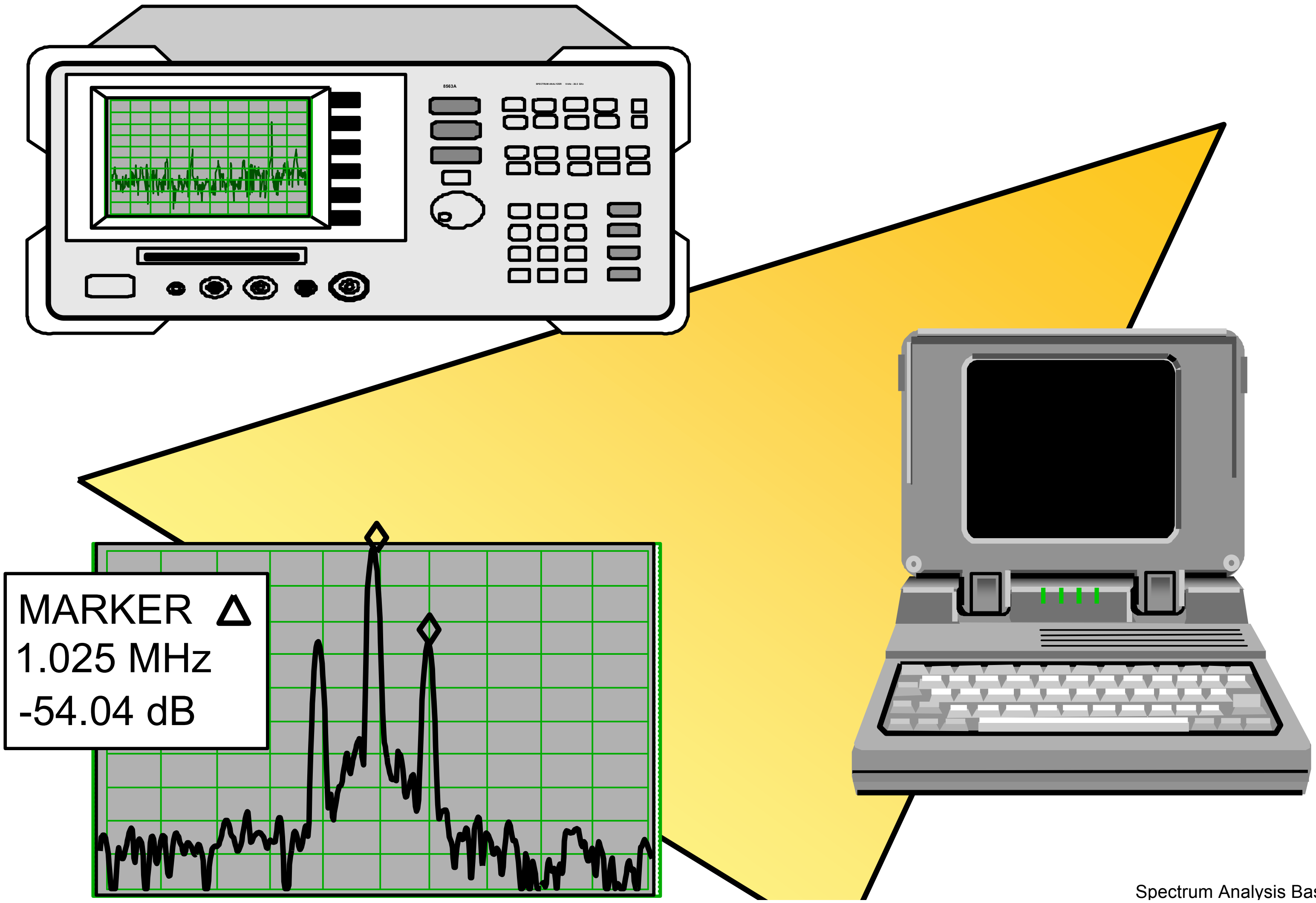
➢ Modulation Measurements
- ✓ time domain
- ✓ FFT
- ✓ AM/FM detector
- ✓ time-gating

➢ Noise Measuremer
- ✓ noise marker
- ✓ averaging

➢ Stimulus Response Measurements
- ✓ tracking generator

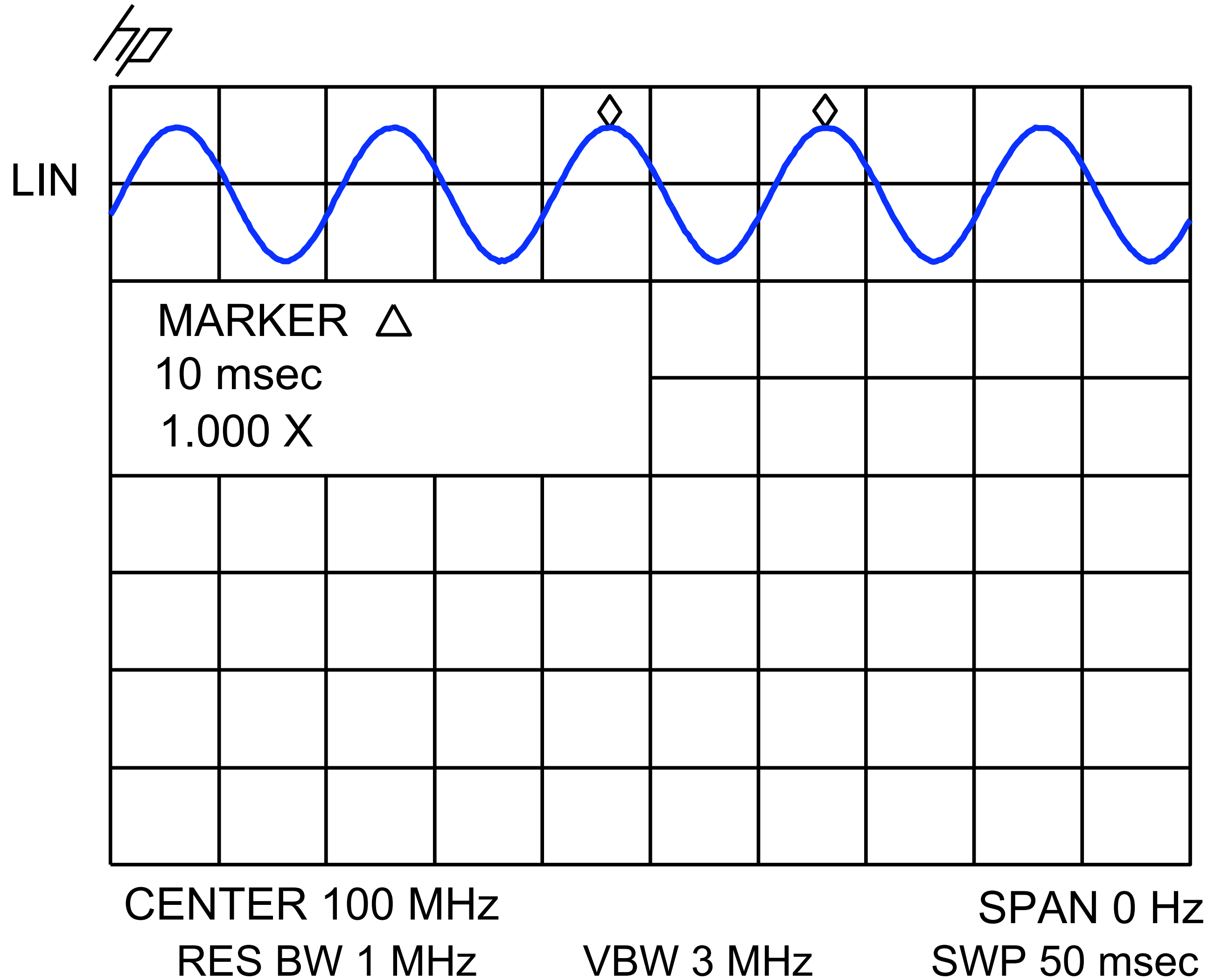
Features

Basic Operation: Remote Operation, Markers & Limit Lines



Features

Modulation Measurements: Time Domain

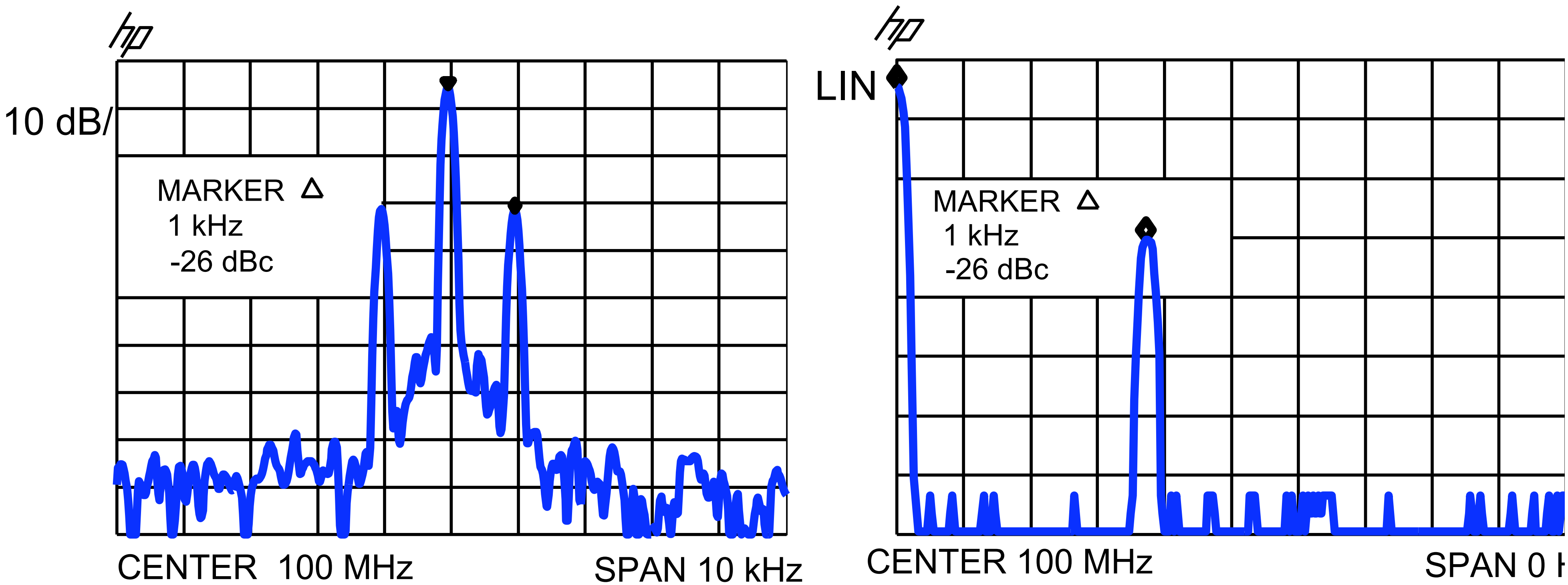


Features

Modulation Measurements: FFT

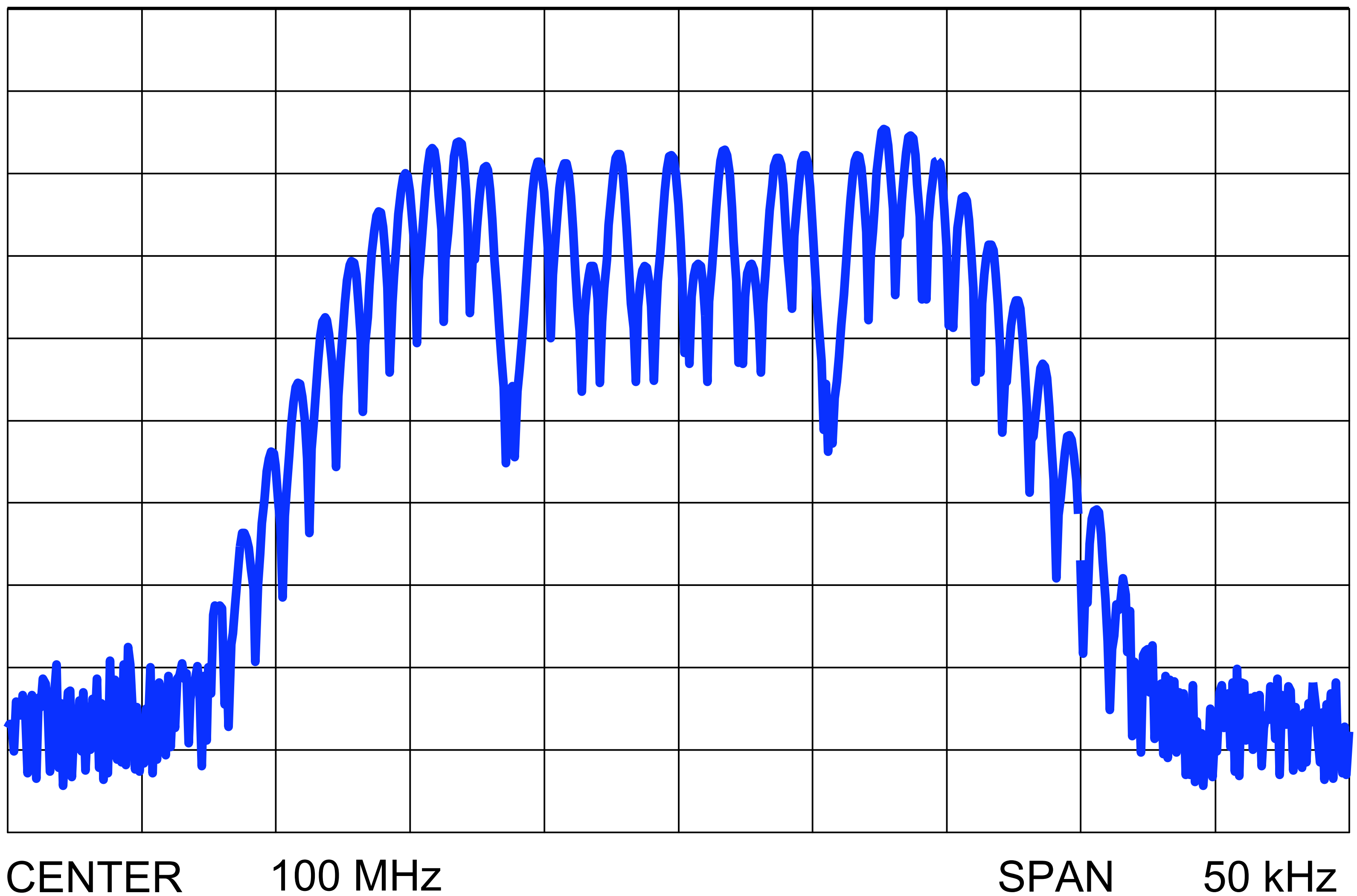
Swept Frequency Domain

FFT Frequency Domain



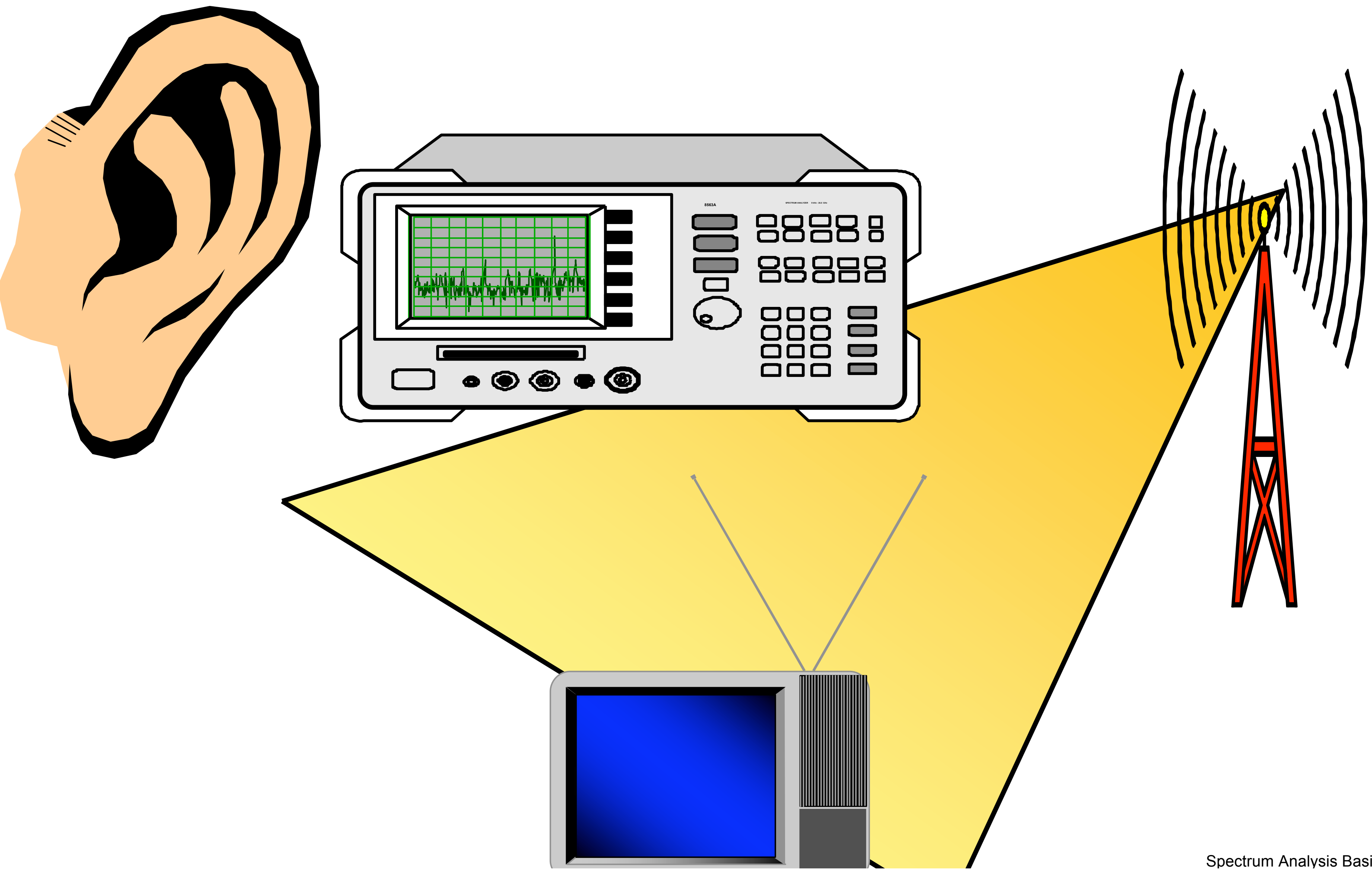
Features

Modulation Measurements: FFT



Features

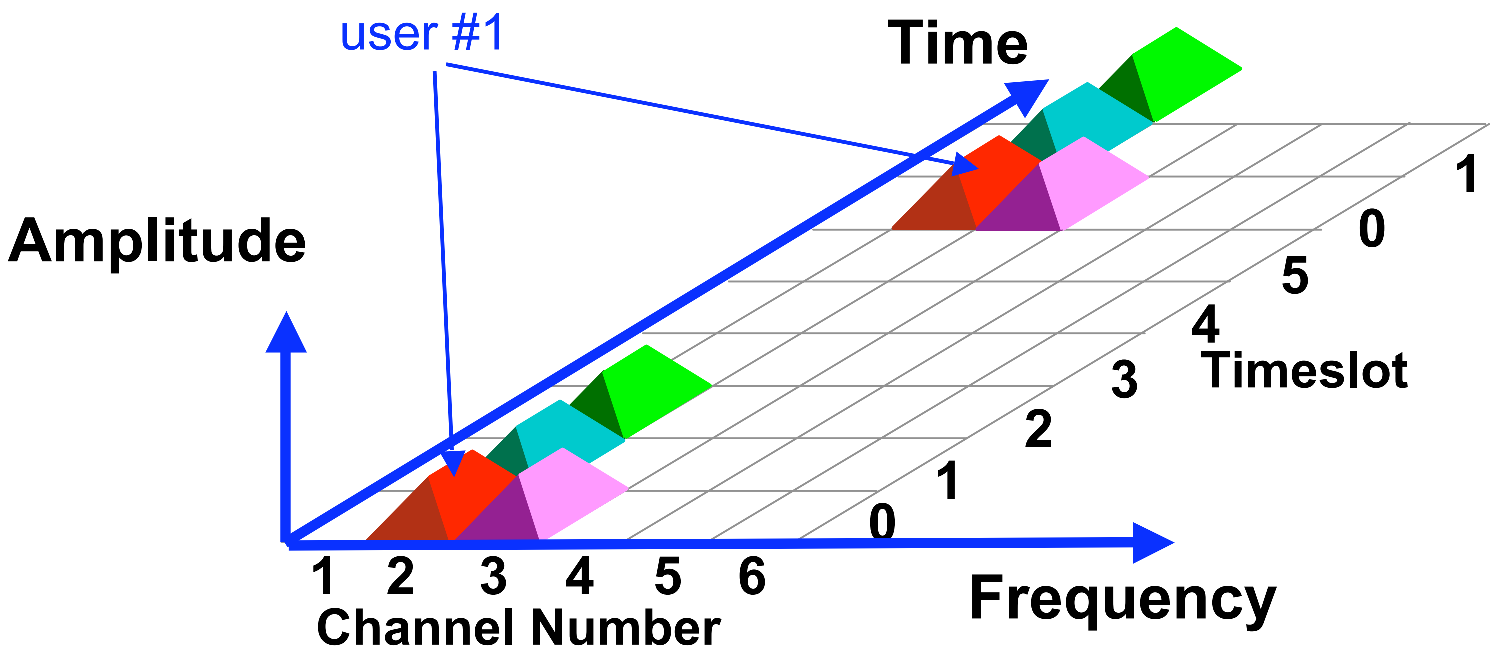
Modulation Measurements: AM/FM Detector with Speaker



Features

Modulation Measurements: Time-Gating

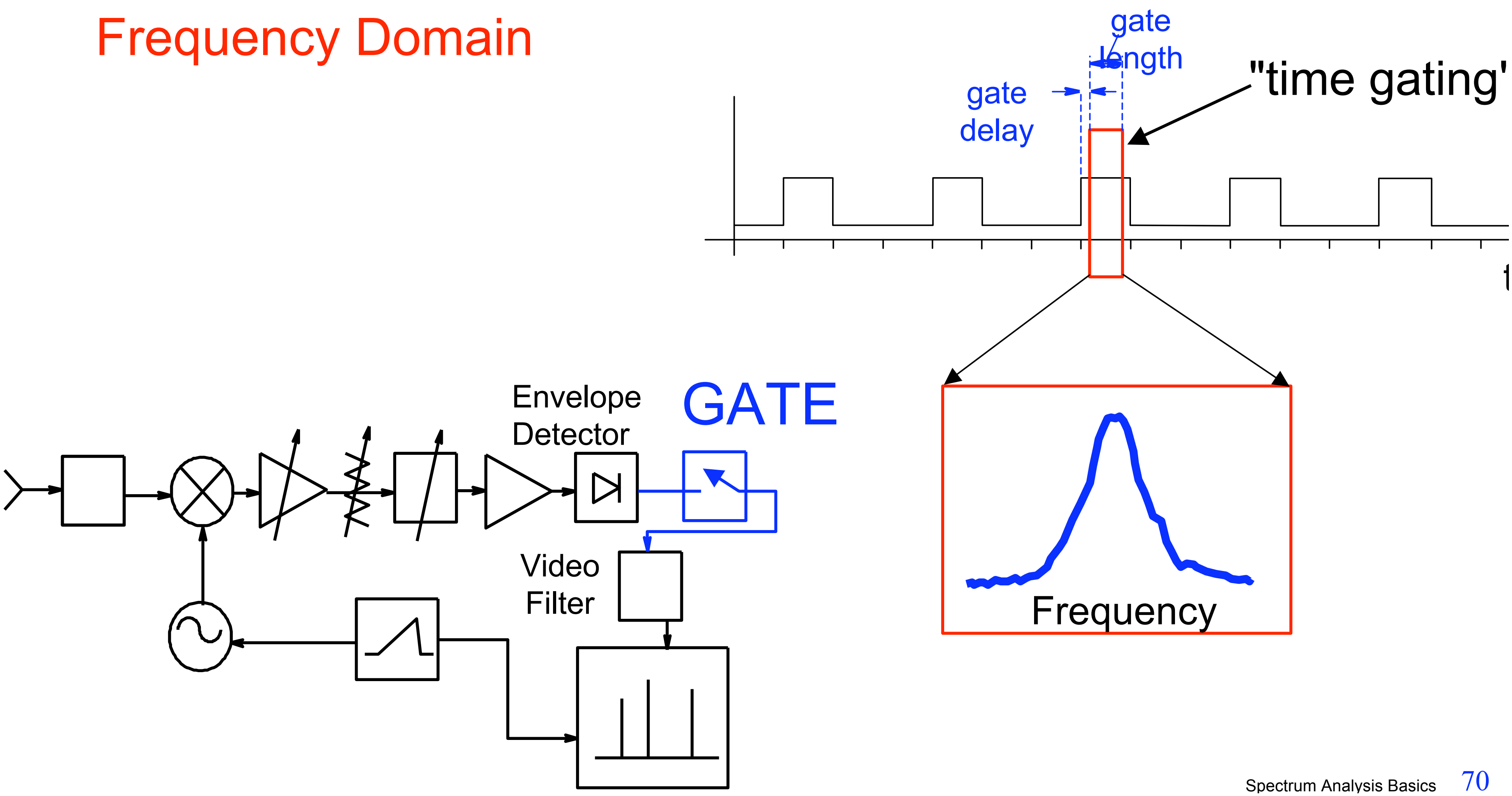
Time Division Multiple Access (TDMA)



Features

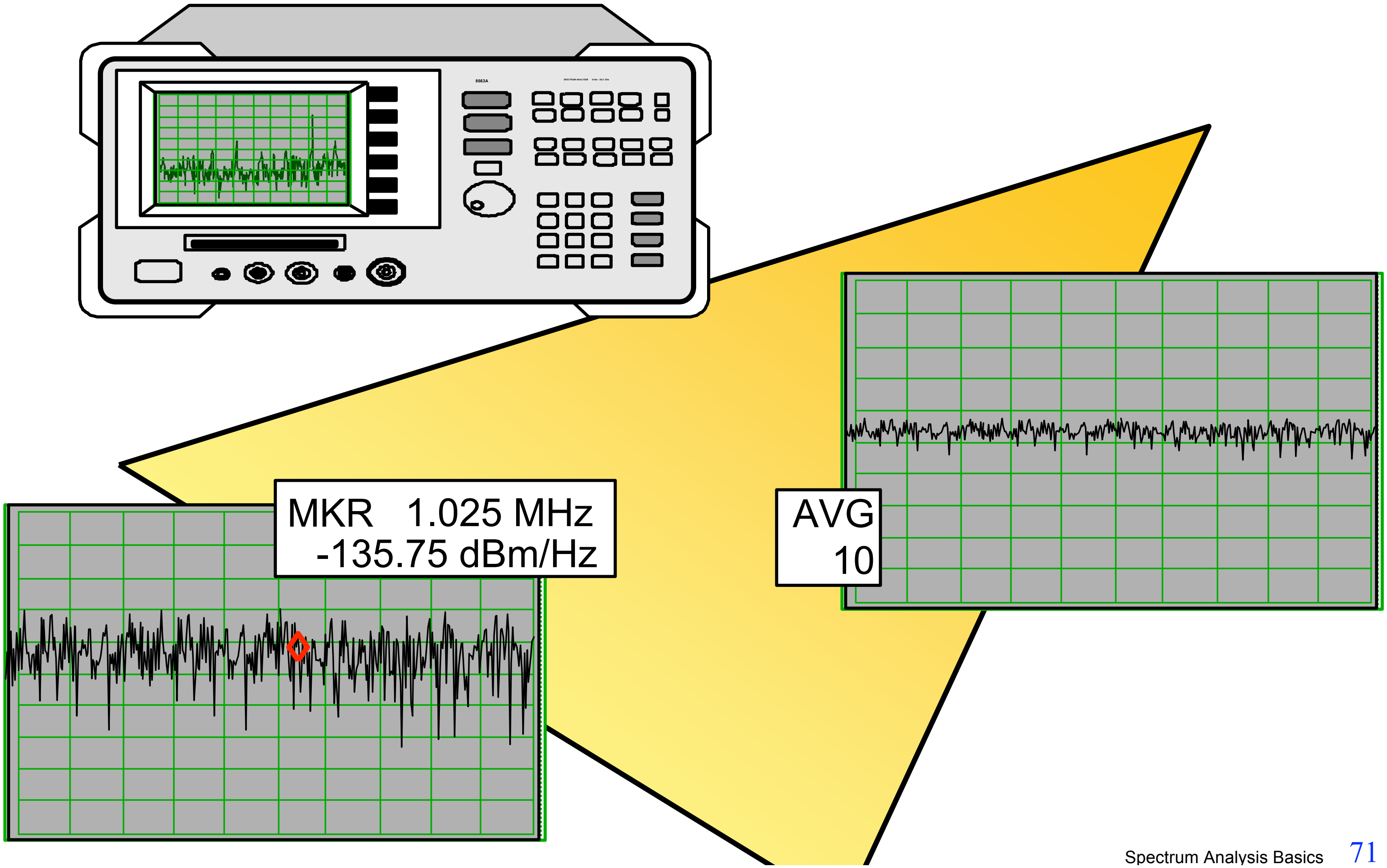
Modulation Measurements: Time-Gating

Time-Gated Measurements in the Frequency Domain



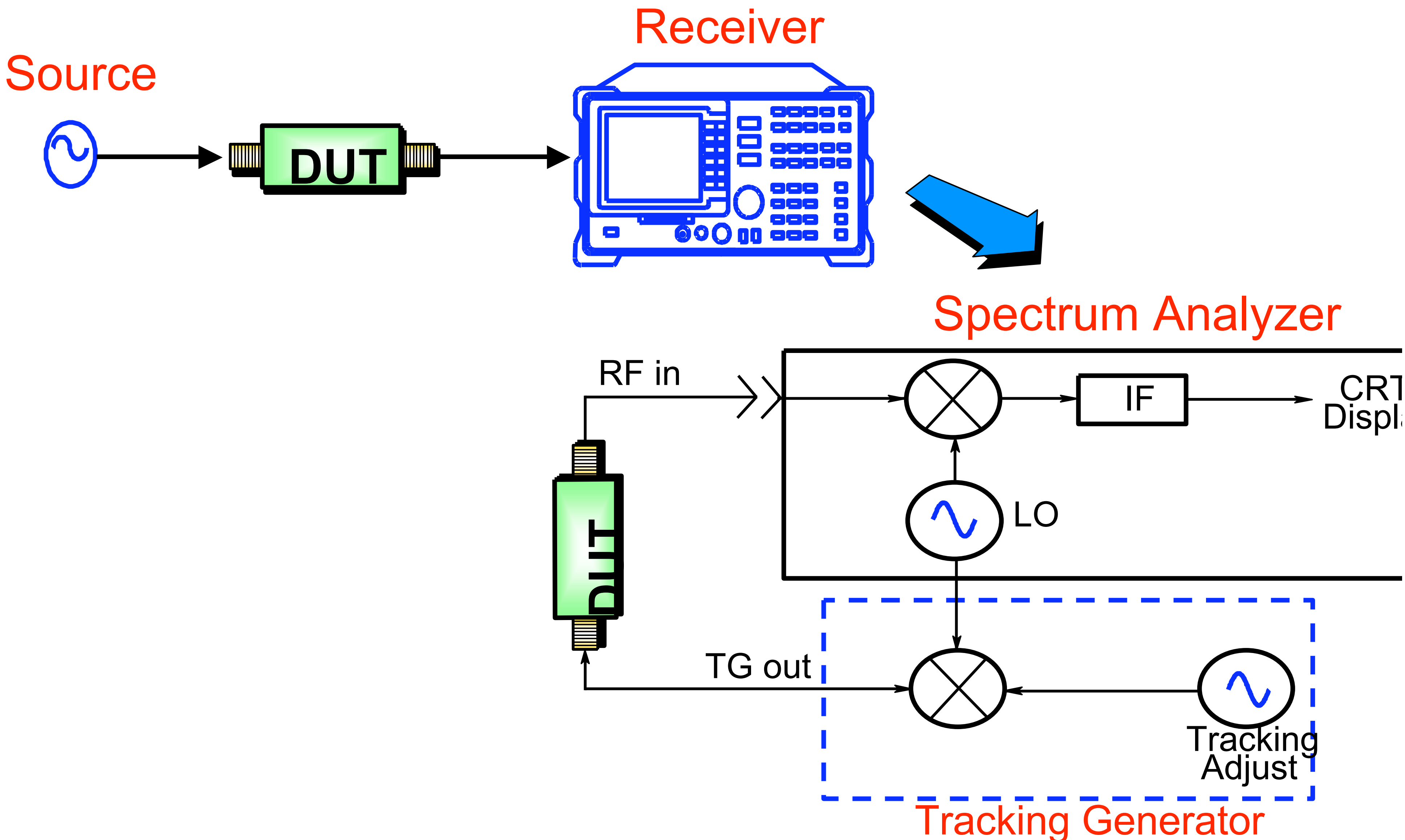
Features

Noise Measurements: Noise Marker & Video Averaging

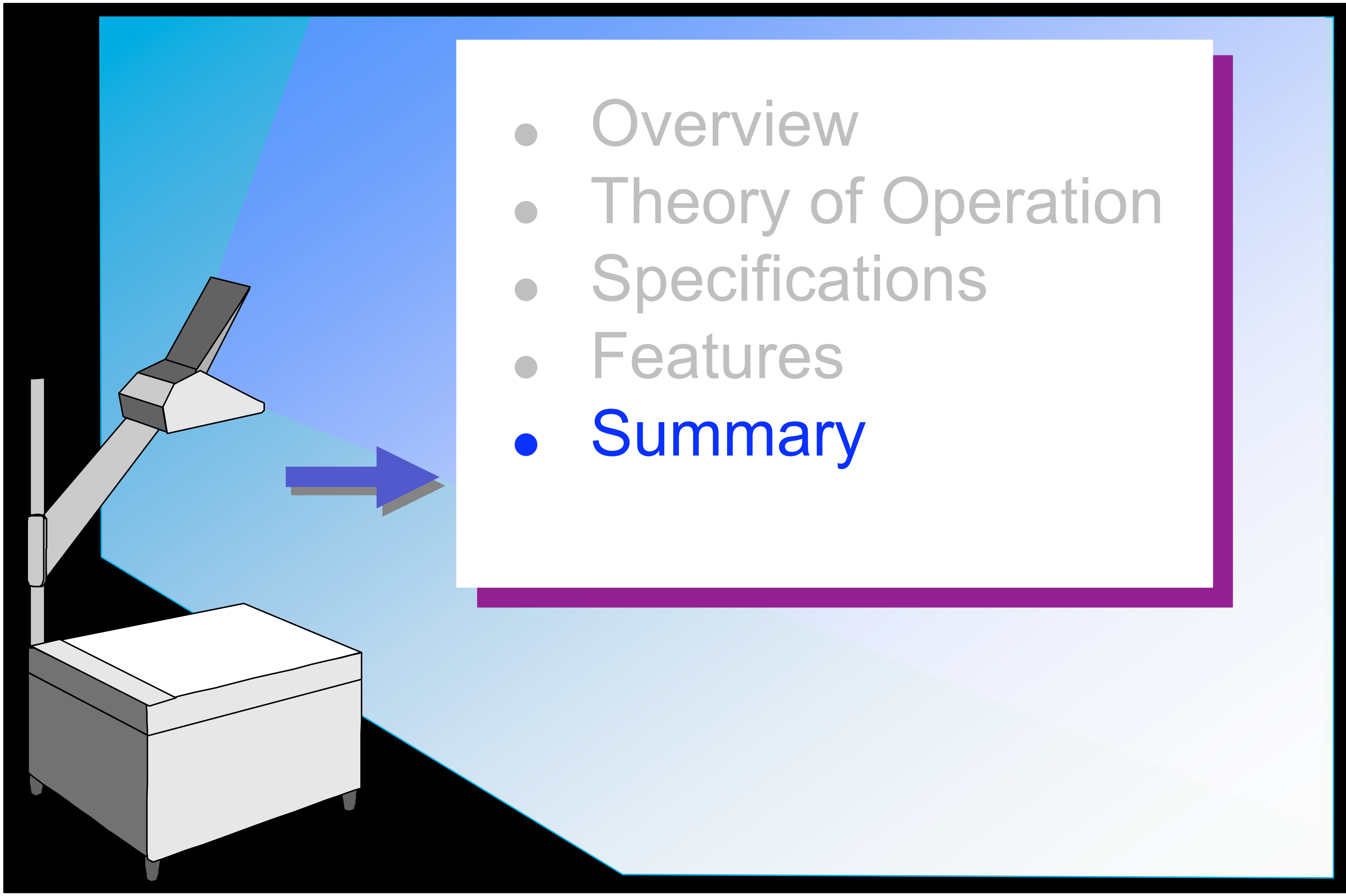


Features

Stimulus Response: Tracking Generator



Agenda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