KEYSIGHT

RF Signal Generation and Analysis

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Agenda

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  - Analog Modulation
  - Demo
  - Digital Modulation
  - Demo

Agenda

- Spectrum Analyzers
  - Block Diagram
  - Internal Mixing
  - Demo
  - Resolution Bandwidth
  - Demo
  - Amplification and Attenuation
  - Video Filter
  - Detector Type
  - Demo
  - Sensitivity
  - Demo
  - Phase Noise
  - Realtime spectrum Analyzer
  - Demo

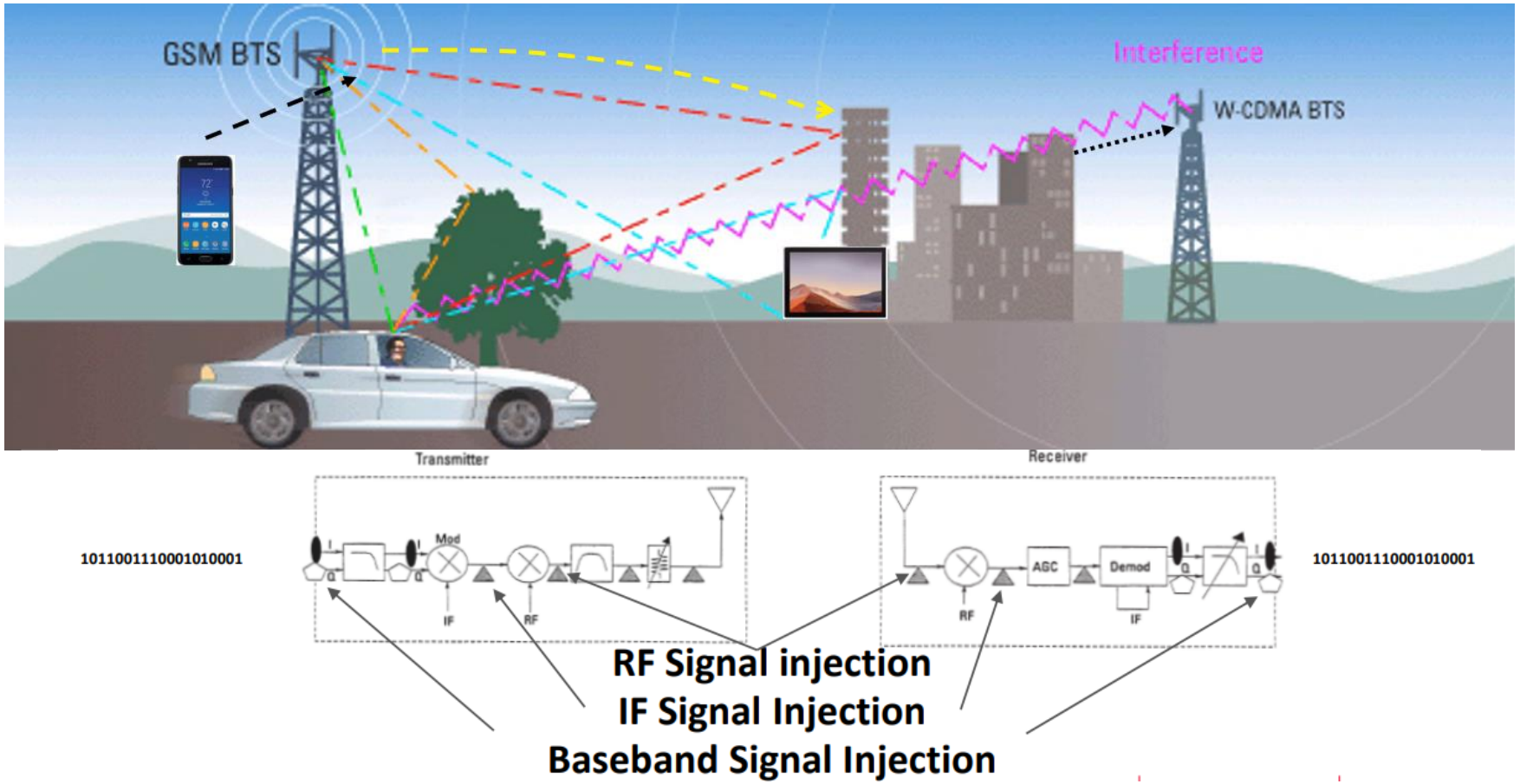
KEYSIGHT

Signal Sources

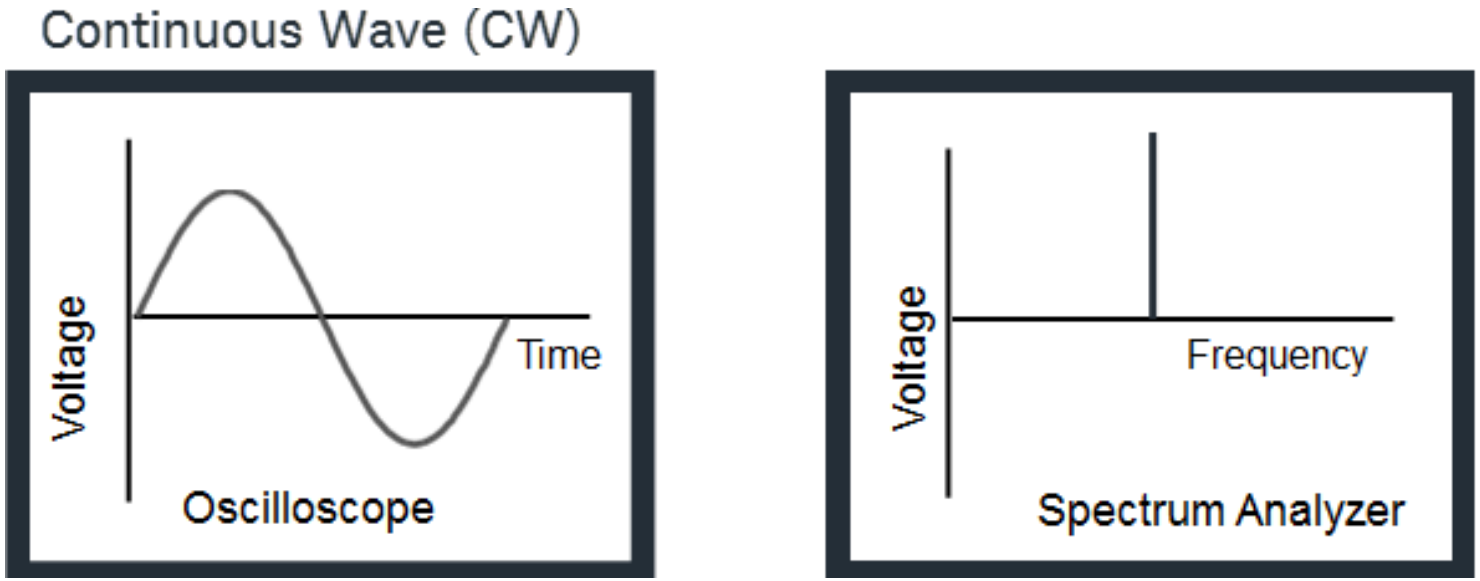
What is a signal source?

- A signal source is any component, IC, circuit, or module that oscillates and generates a sinusoidal CW (continuous wave) signal.

The Need for a Signal Generator

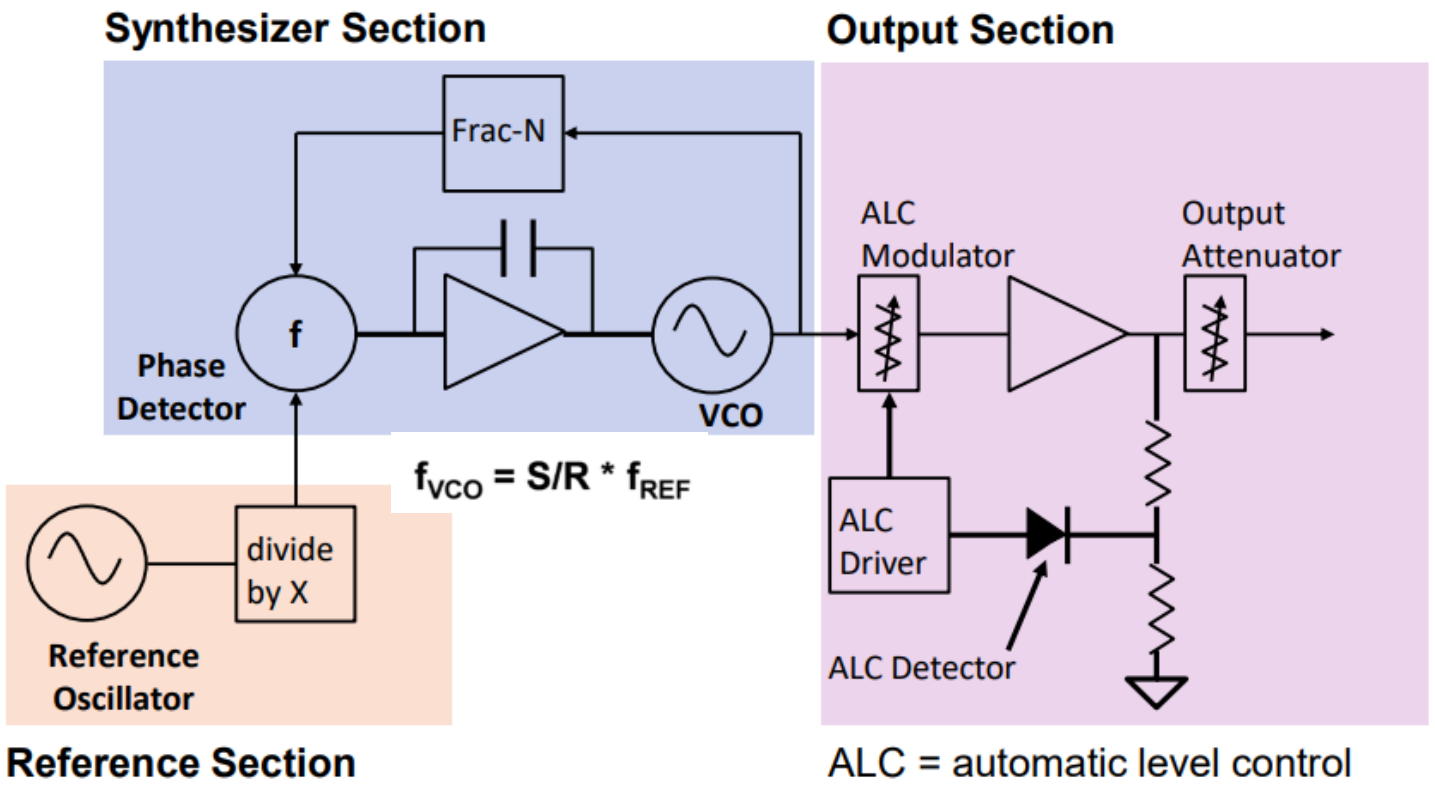


Generating Signals



Signal Generator Block Diagram

CW signal

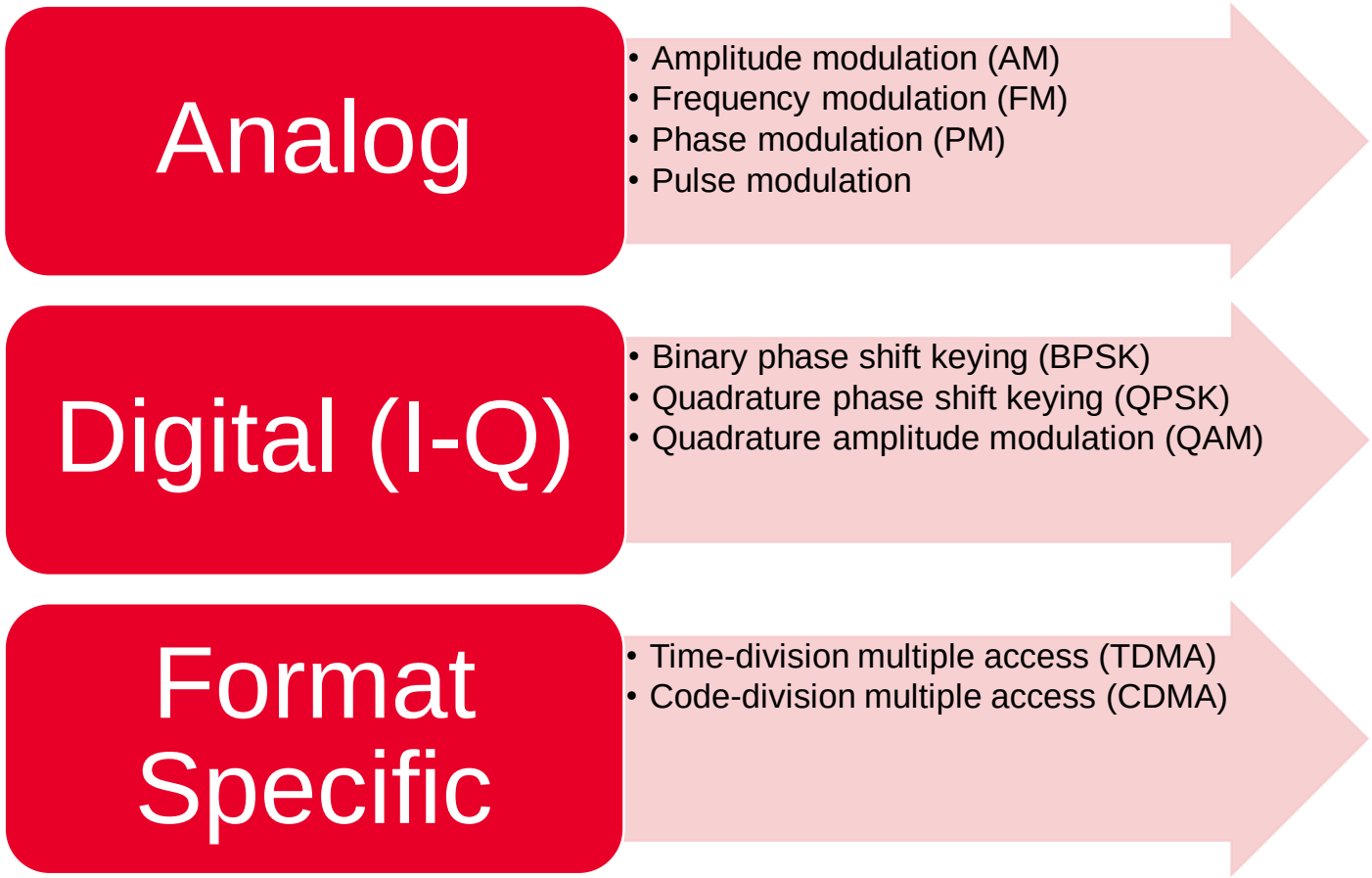


Why is modulation used?

Why not send the information directly?

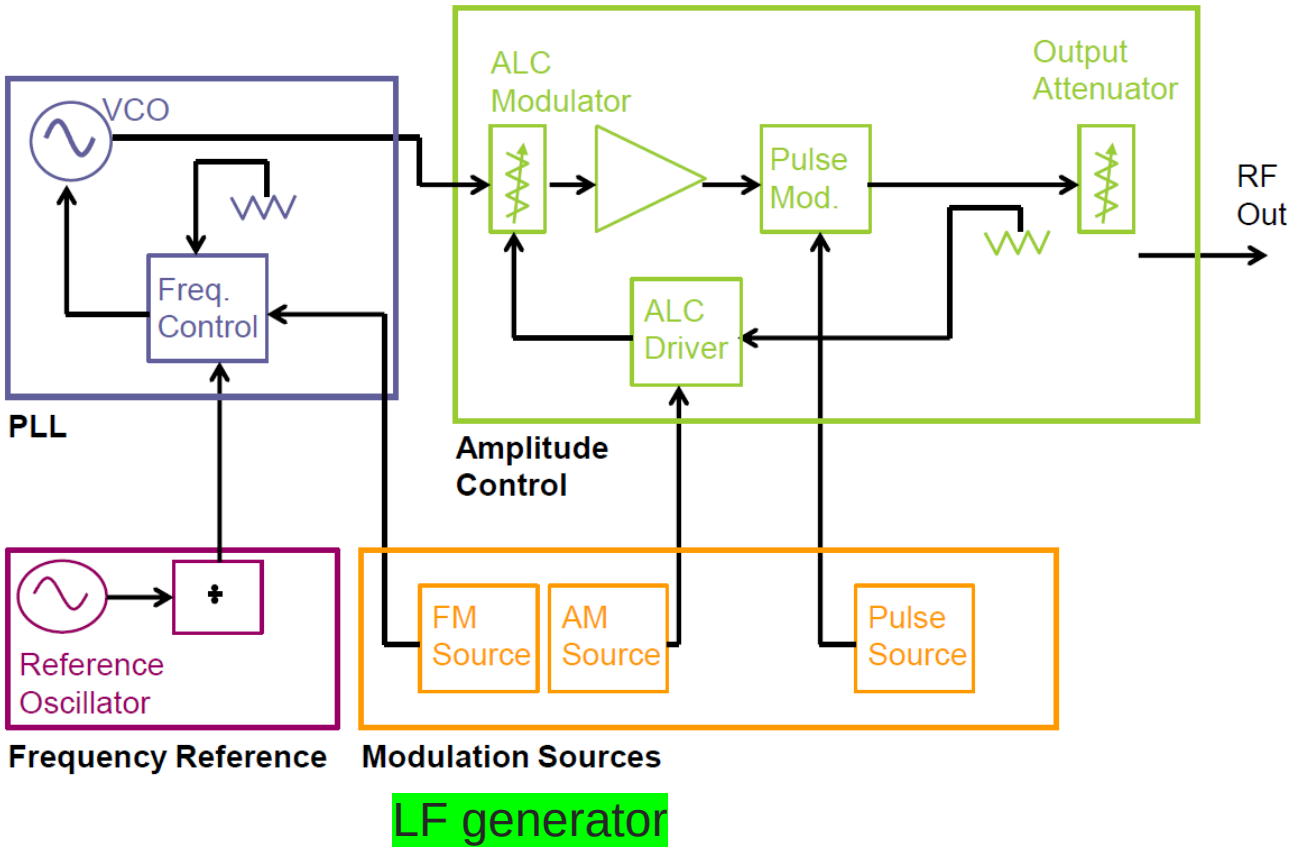
- More available space in the higher frequency spectrum
- Using multiple carriers at different frequencies
- Greater efficiency and smaller size of higher-frequency antennas

Modulation Types

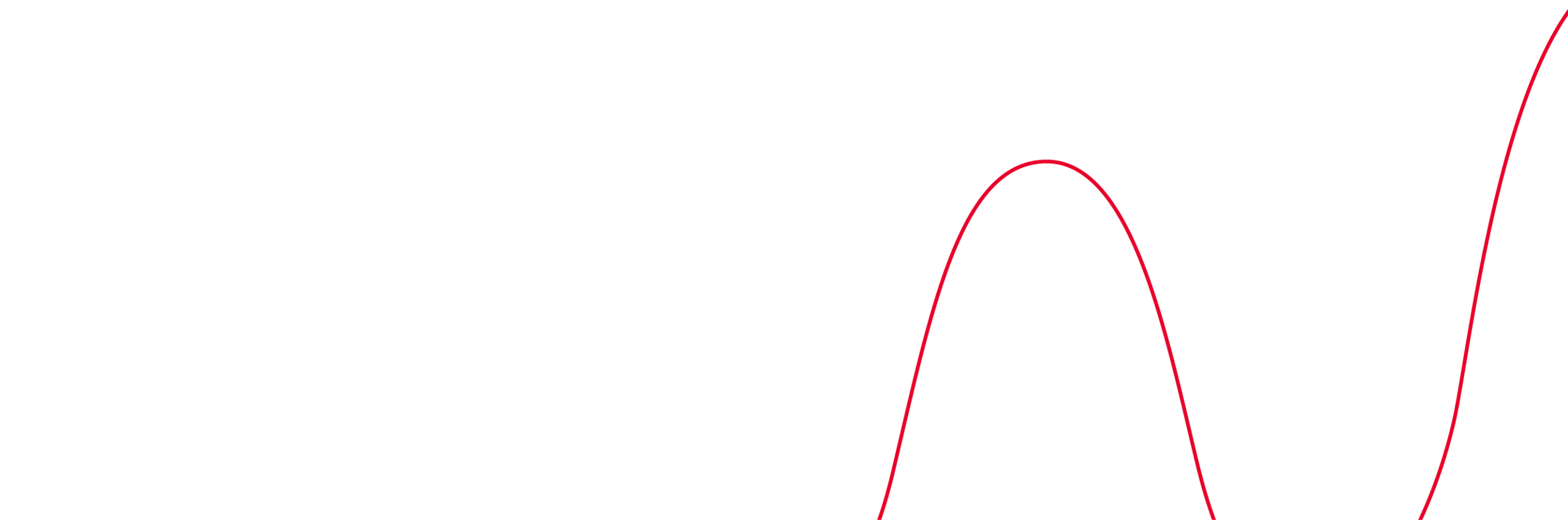


Signal Generator Block Diagram

With Modulation

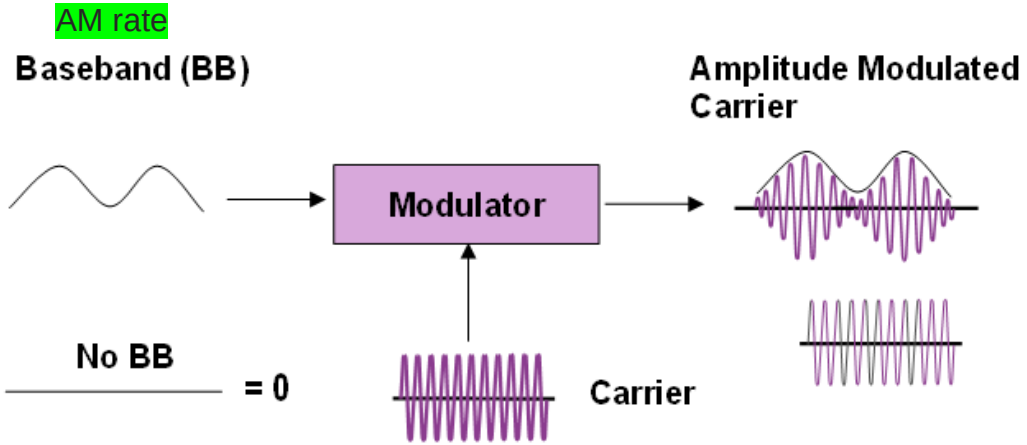


Analog Modulation

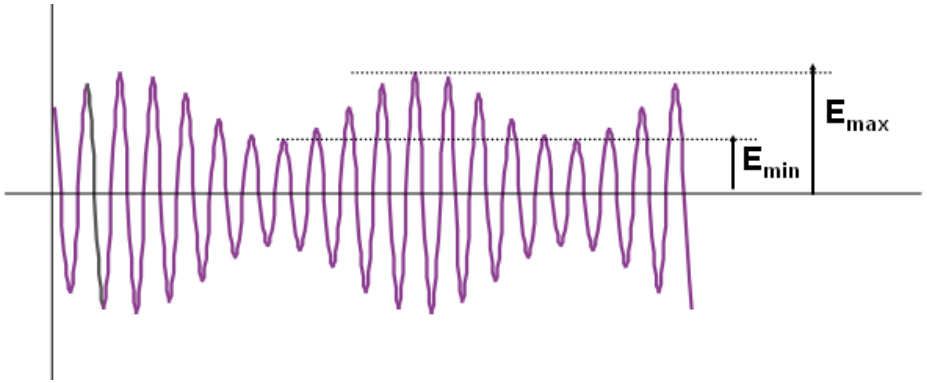


Amplitude modulation

Key parameters



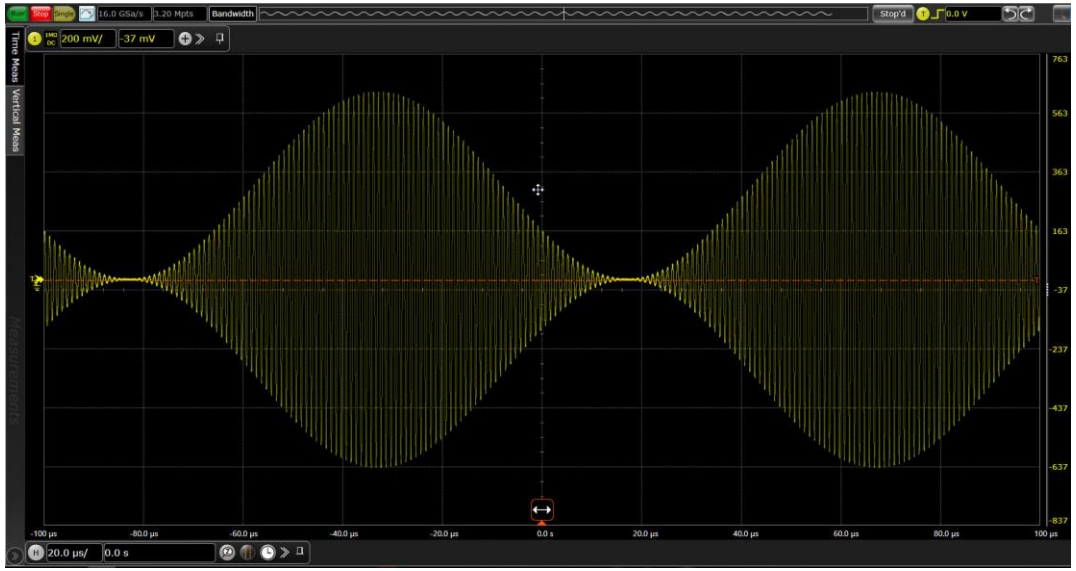
$$\text{modulation index} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} = m$$

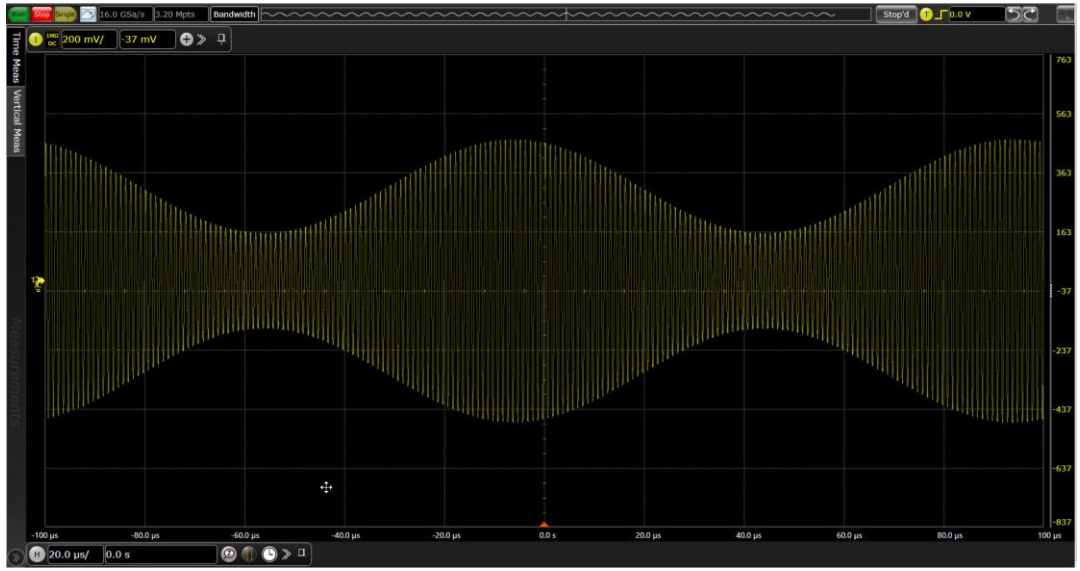


Amplitude modulation

Modulation index change

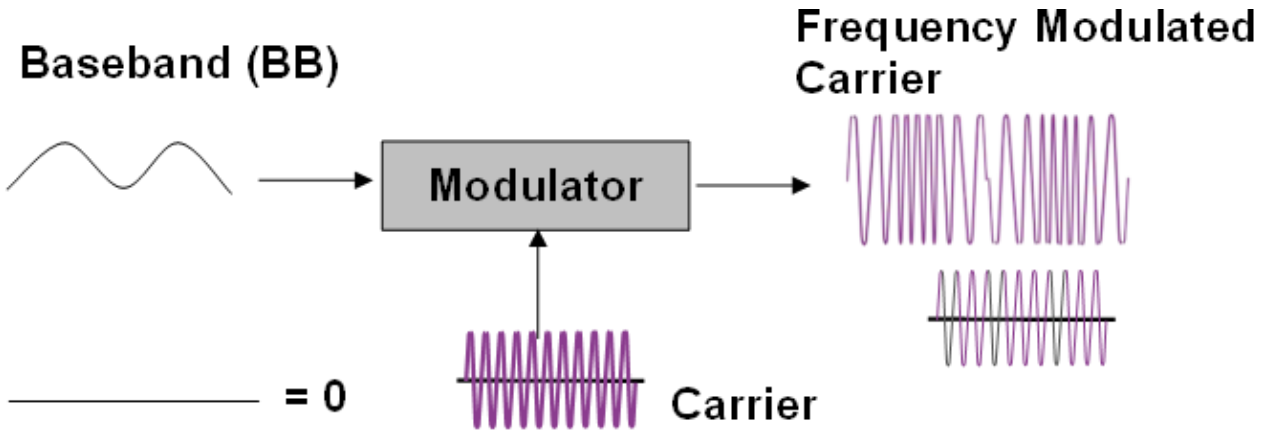
- 100% and 50%





Frequency Modulation

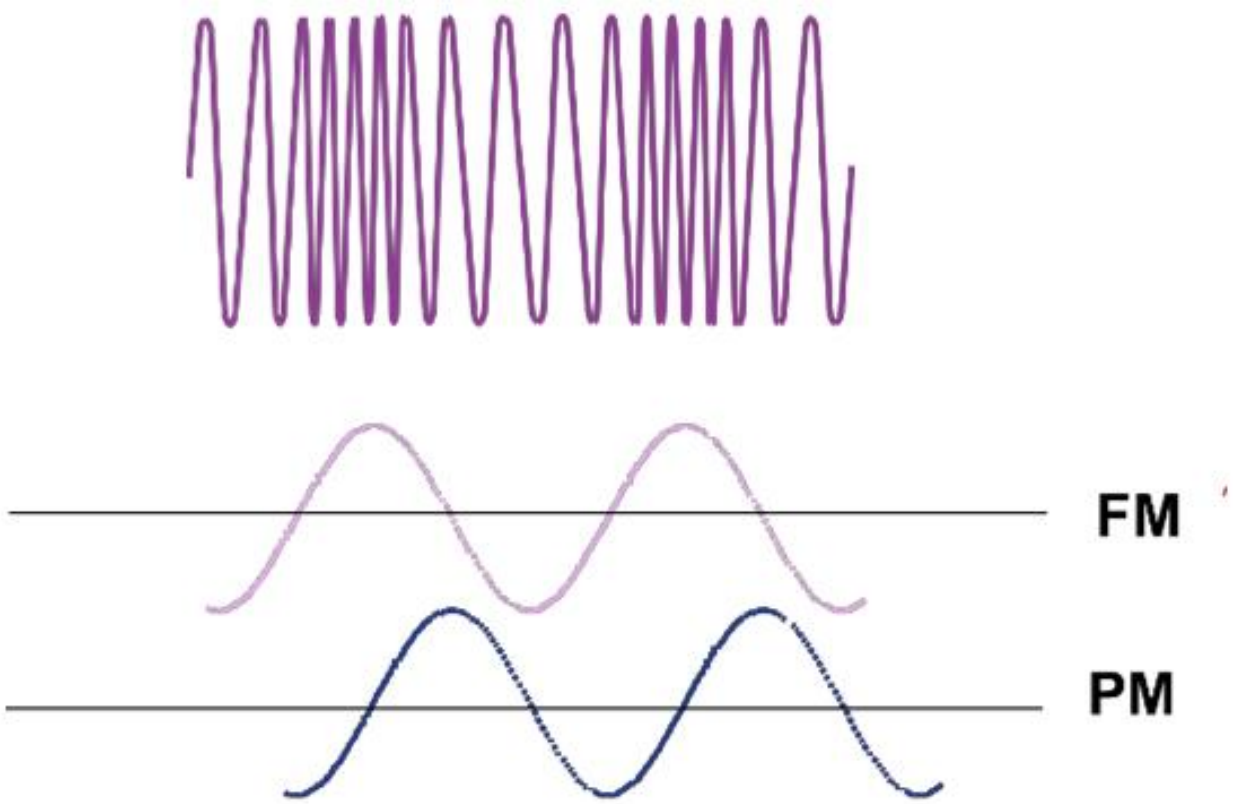
Key parameters



Frequency Deviation: How far the deviated center frequency goes (Δf)

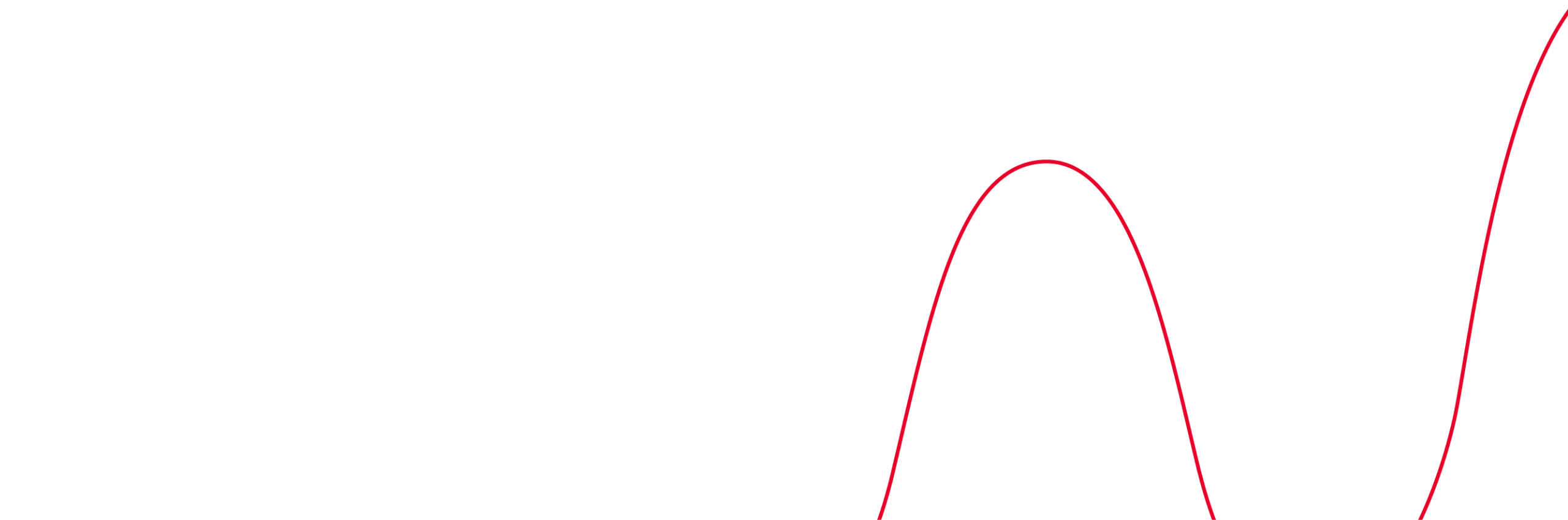
Phase Modulation

Key parameters

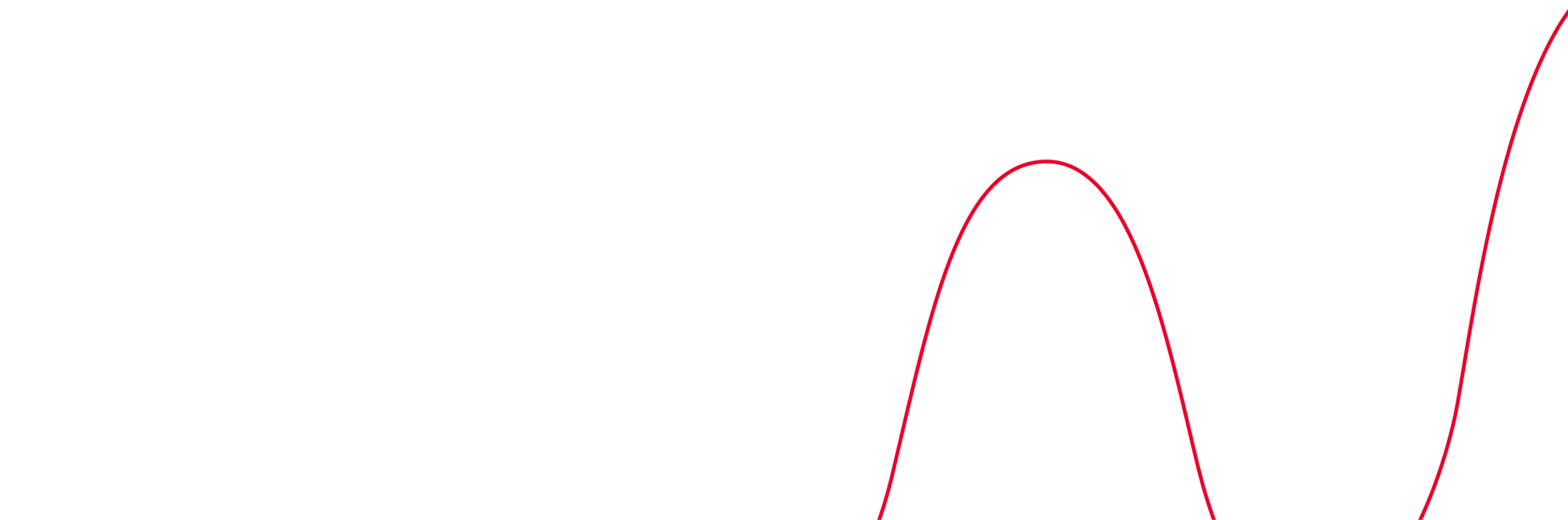


Demo

- Analog Modulation



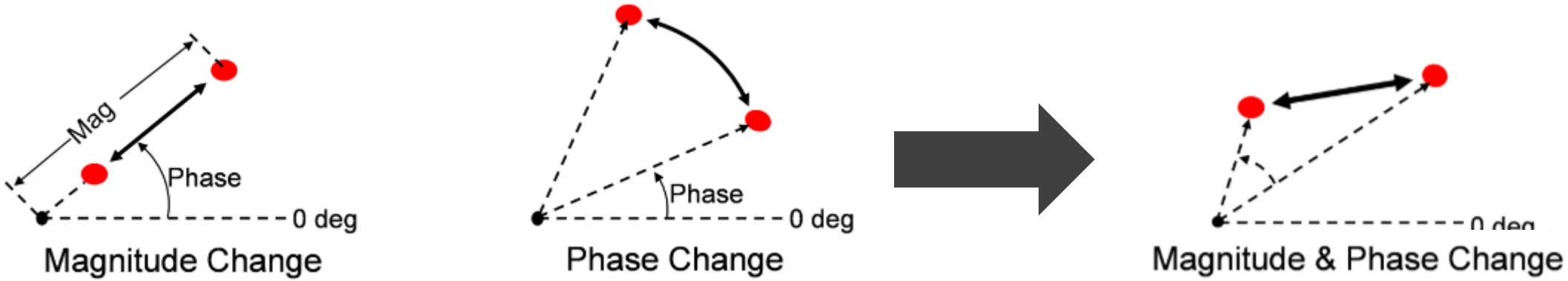
Digital Modulation



What is digital modulation?

- Simultaneous modulation of two modulation type.

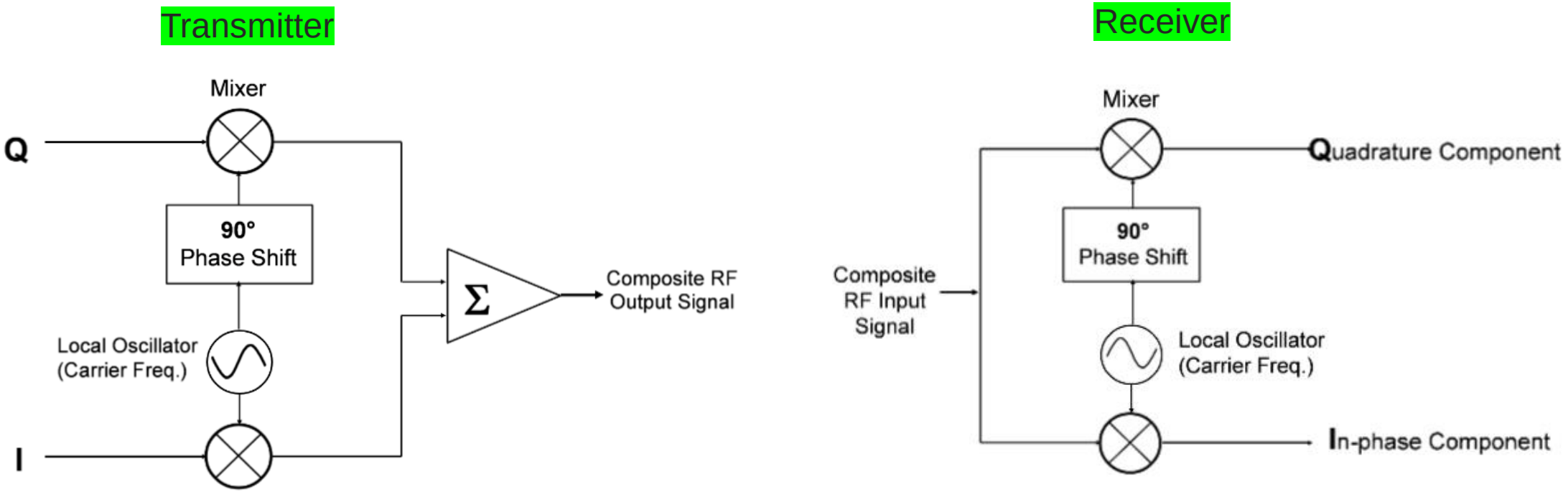
Digital Modulation



Why use digital modulation?

- More information in the same bandwidth
- Miniaturization
- Lower power consumption
- Compatibility with digital data services
- Higher data security

I/Q Modulation in a Transmitter/Receiver

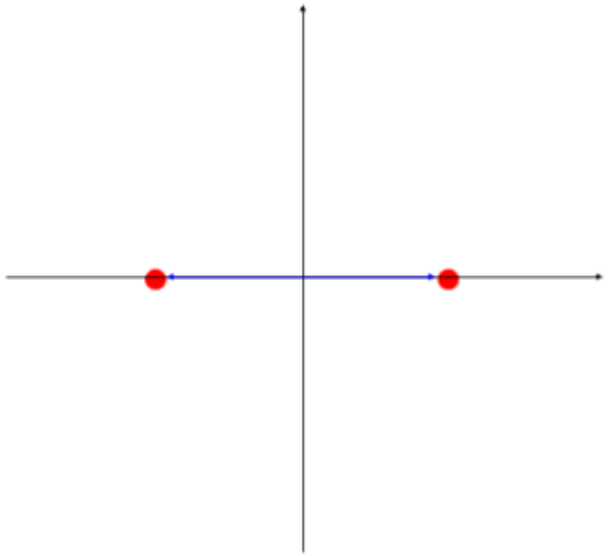


Bit Rate and Symbol Rate

- **Bit rate:** the frequency of a system's bit stream (bit/s)
- What is the basic bit rate of a radio with an 8-bit sampler sampling at 10 kHz?
- 80 kilobit/s.
- **The symbol rate (baud rate):** the bit rate divided by the number of bits that can be transmitted with each symbol.

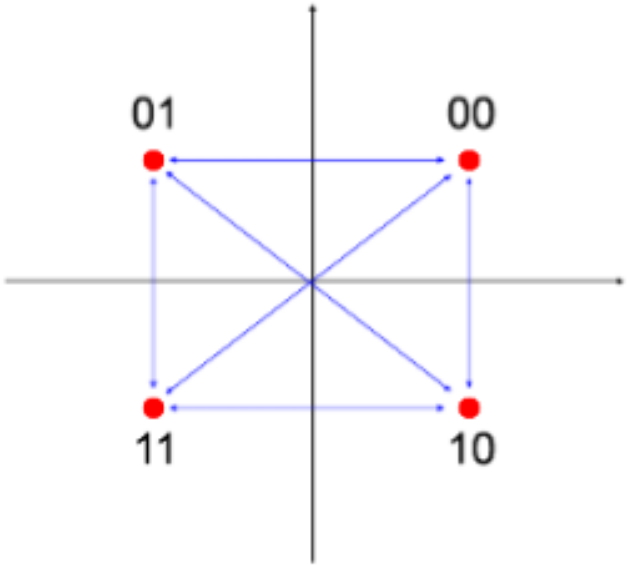
Binary Phase shift Keying (BPSK)

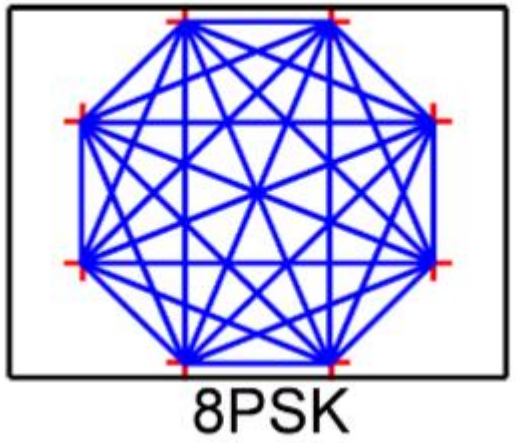
- The phase of a constant-amplitude carrier moves between two states, zero and 180 degrees.
- Symbol rate= bit rate



Quadrature Phase Shift Keying (QPSK)

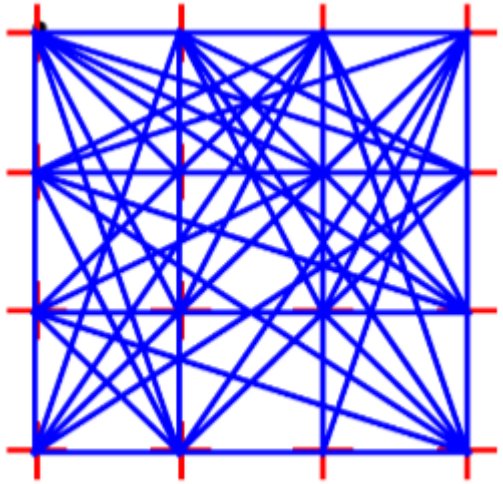
- The signal shifts between four phase states 90 degrees apart.
- Symbol rate= 0,5*bit rate



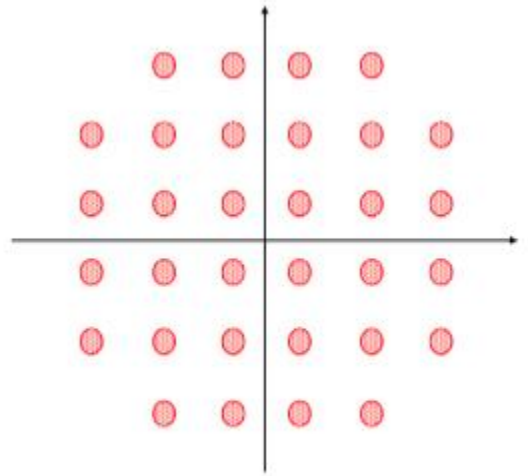


Quadrature amplitude modulation (QAM)

- Independent amplitude and phase modulation.



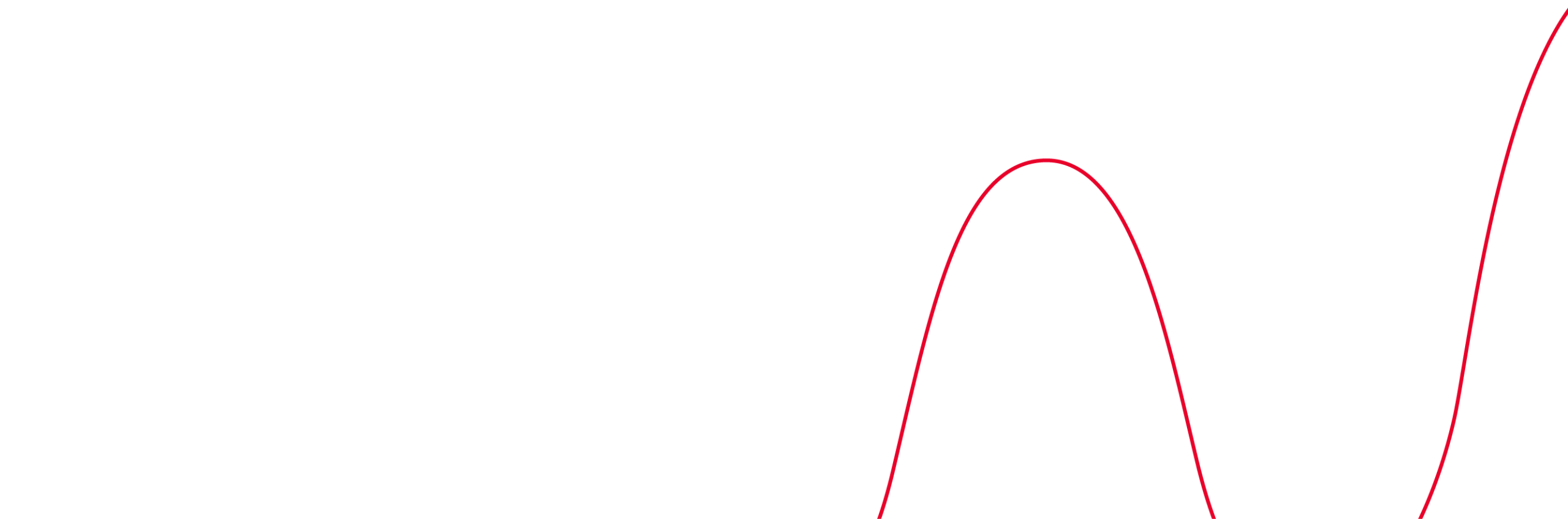
16QAM



32QAM

Demo

- Digital Modulation



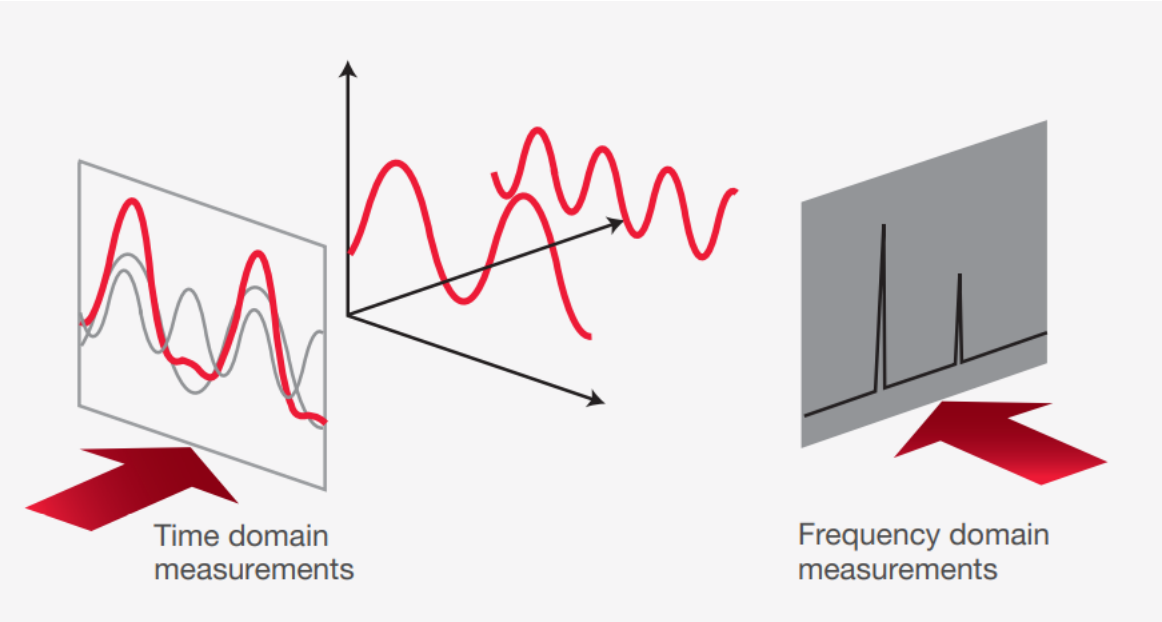
KEYSIGHT

Spectrum Analyzers

Frequency versus Time domain

How do we see the spectrum?

- Time domain: Amplitude vs time
- Frequency domain: Amplitude vs frequency
  - FFT analyzer
  - Swept-tuned superheterodyne analyzer

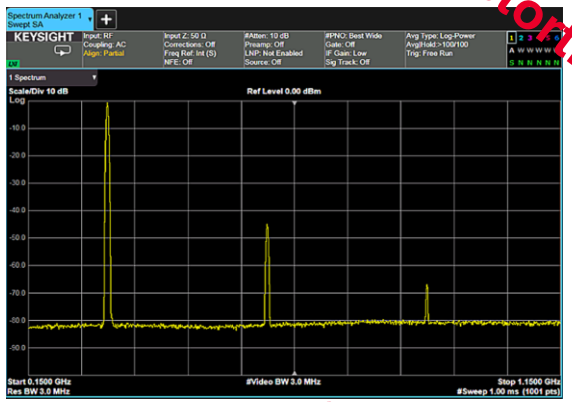


Why we use spectrum analyzer?

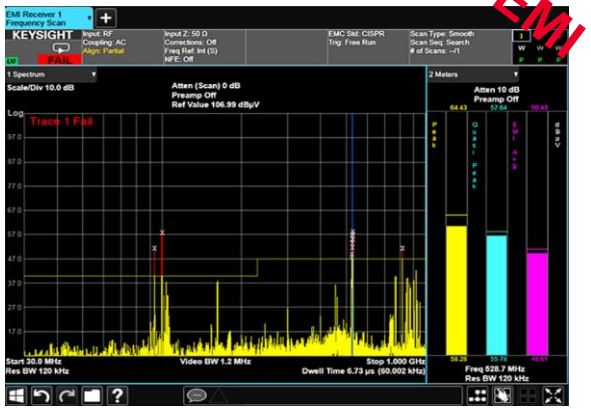
Example of spectrum analyzer measurements

Modulation

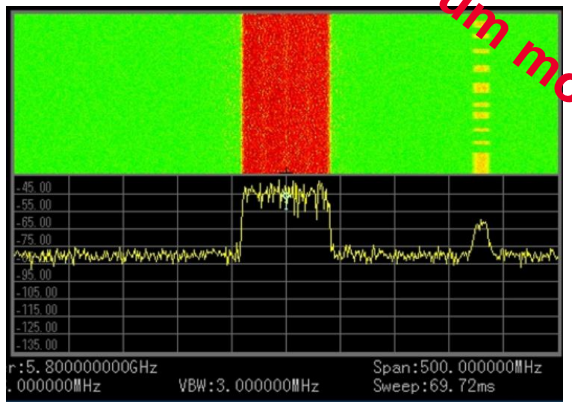
Distortions



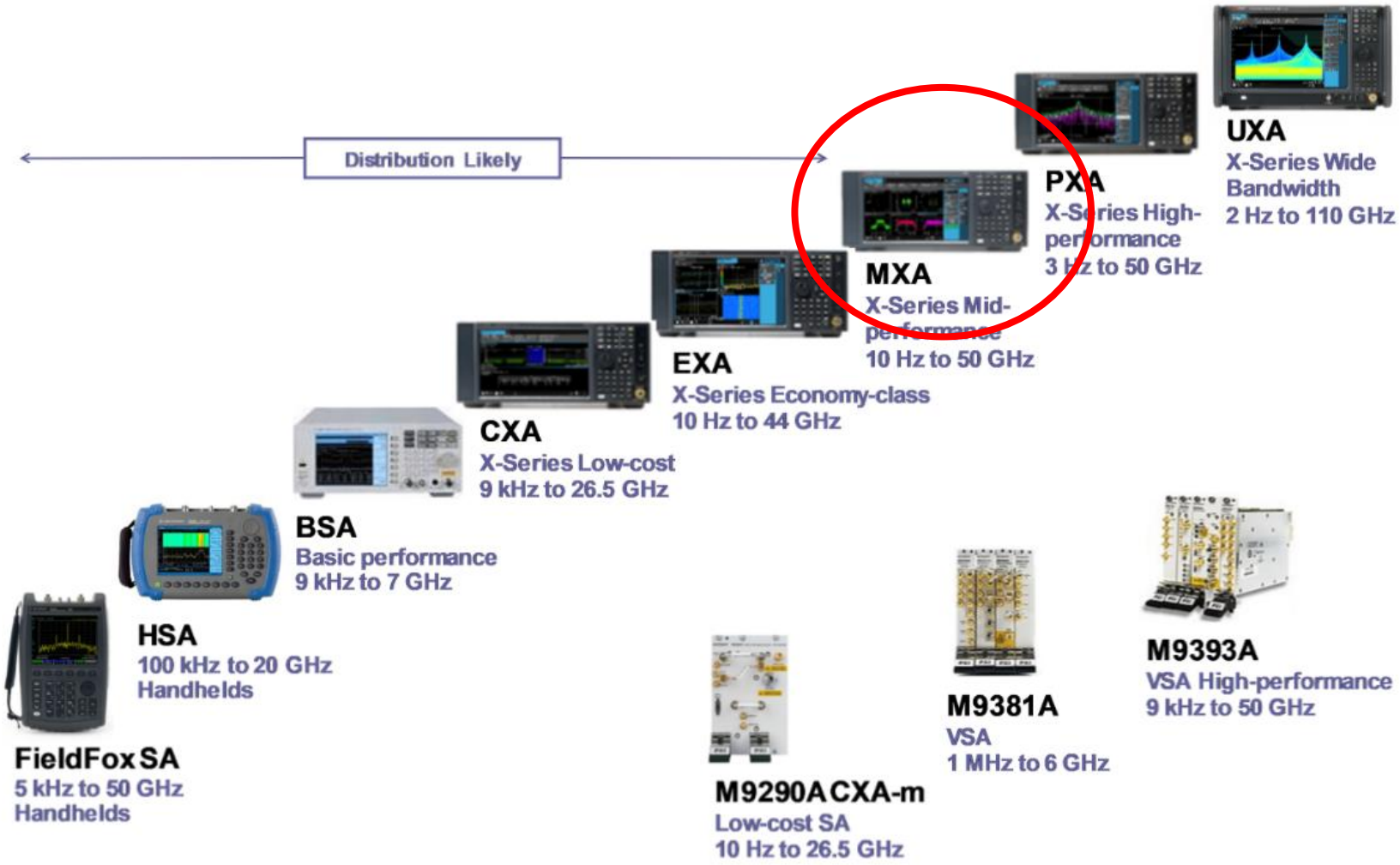
EMI



Spectrum monitoring



Spectrum Analyzer Portfolio

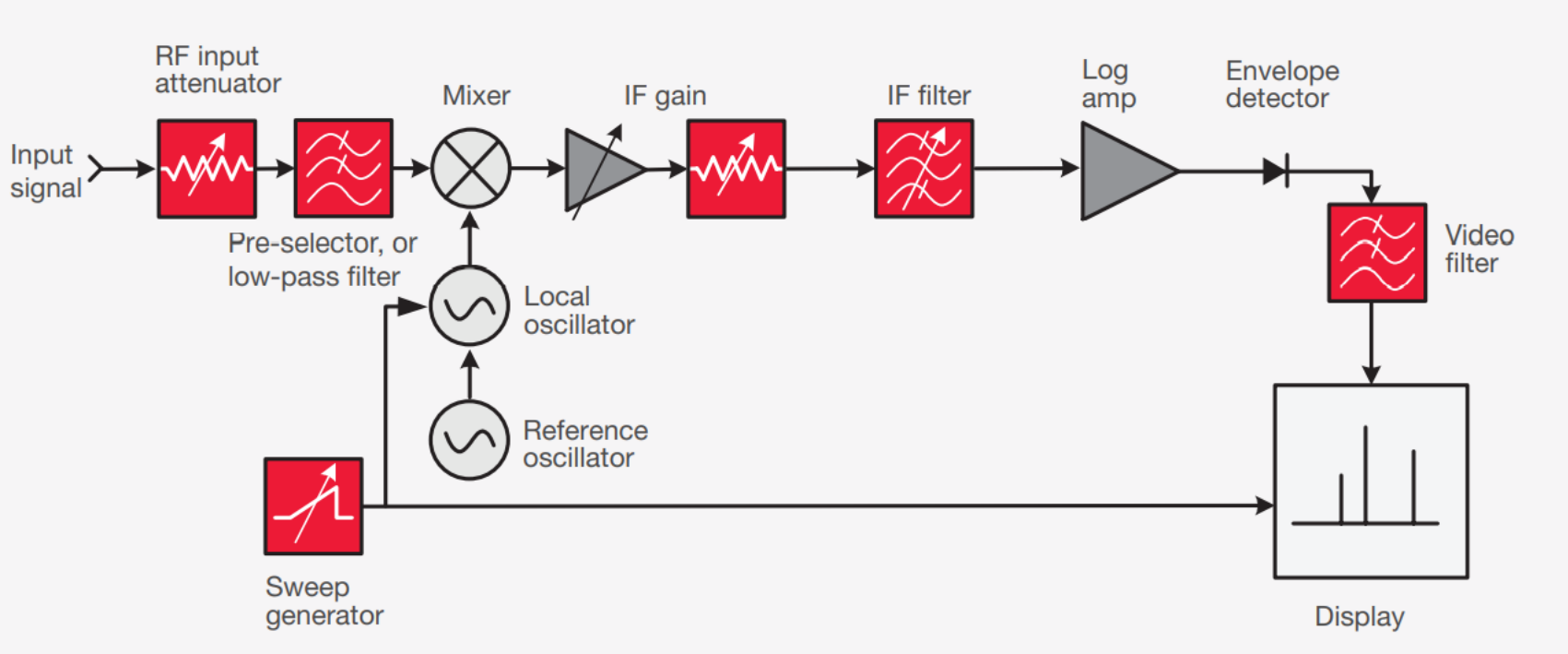


What are the main components of a spectrum analyzer?

Spectrum Analyzer Block Diagram

Swept-tuned Superheterodyne spectrum analyzer

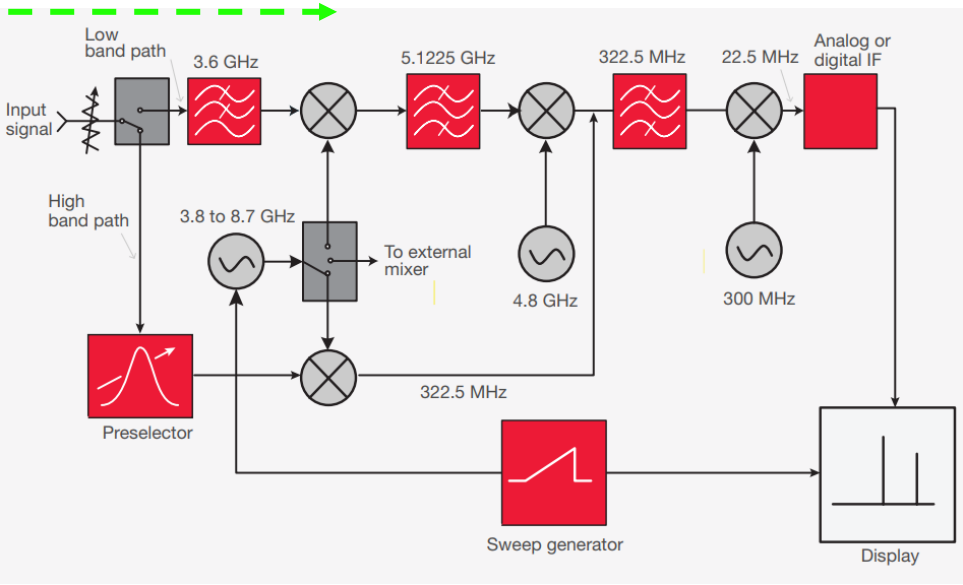
- The most used analyzers are the swept tuned superheterodyne ones

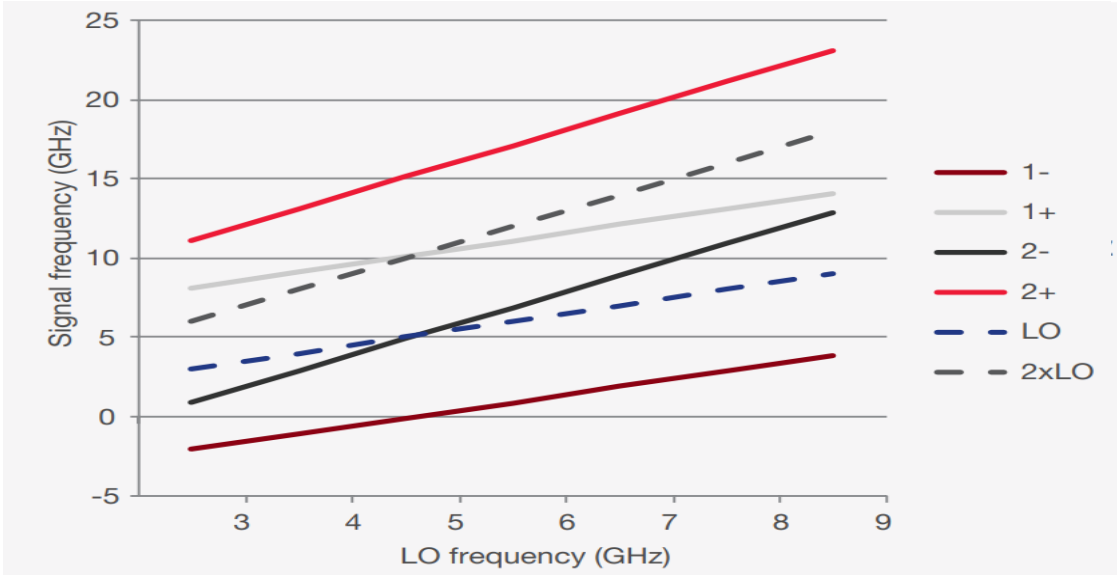


Internal Mixing

Fundamental mixing in the low band, high IF case

- $f_{IF} = 5.1225\ GHz$, $f_{sig} = nf_{LO} \pm f_{IF}$

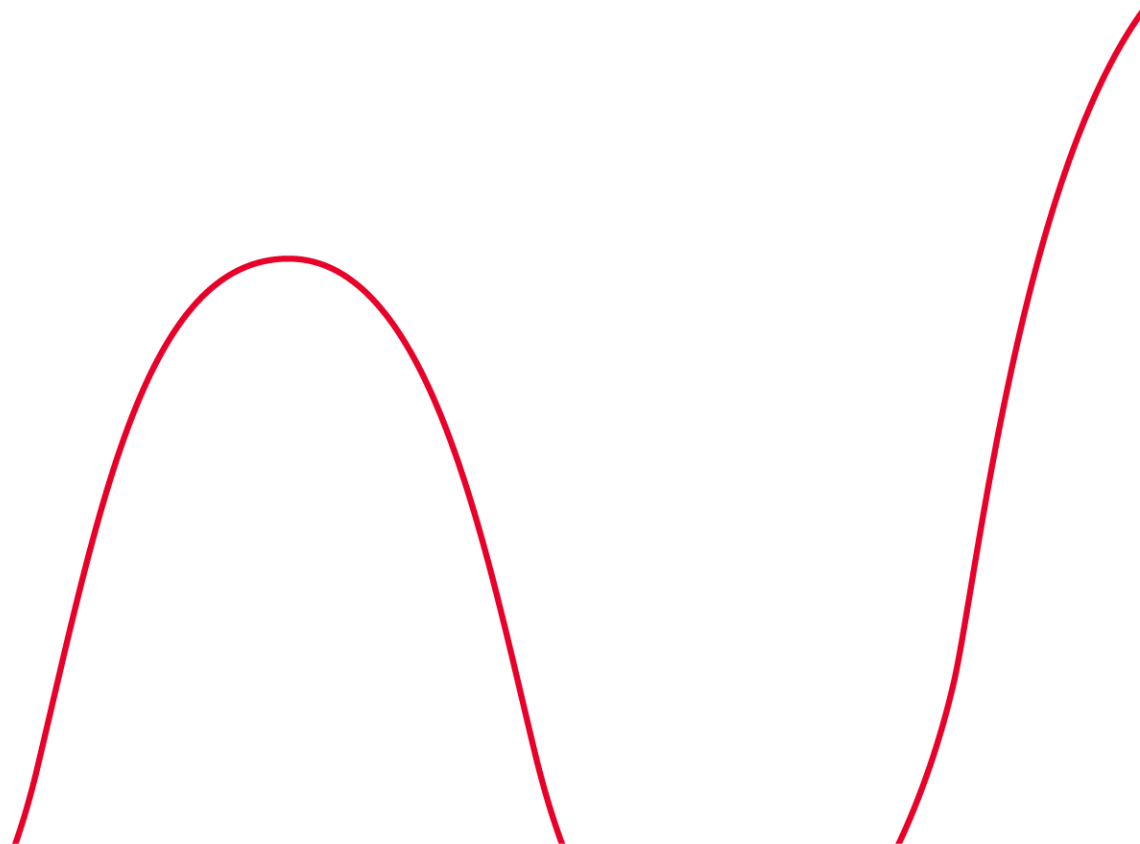




Demo

- Finding a signal

812 MHz, 0dBm
Span=100MHz

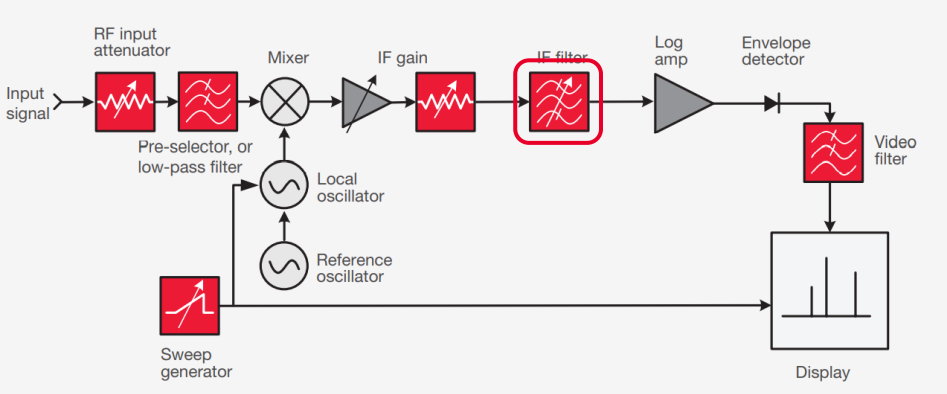


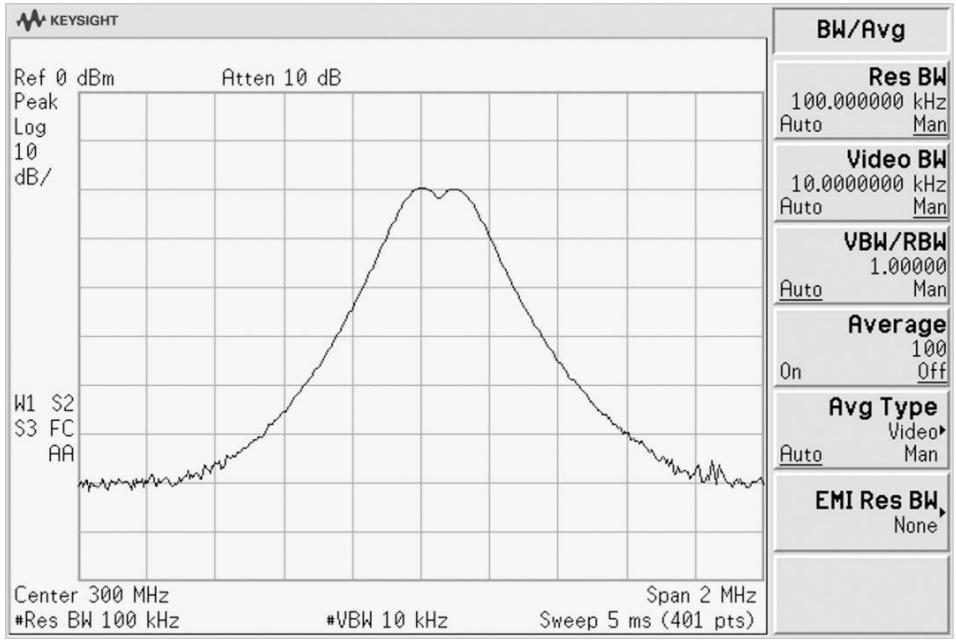
IF Filter and resolution bandwidth

3dB-BW of two equal amplitude signals

- Determines the ability of the analyzer resolving equal amplitude signals

- Two signals with same amplitude must be separated 3dB-BW with the selected RBW



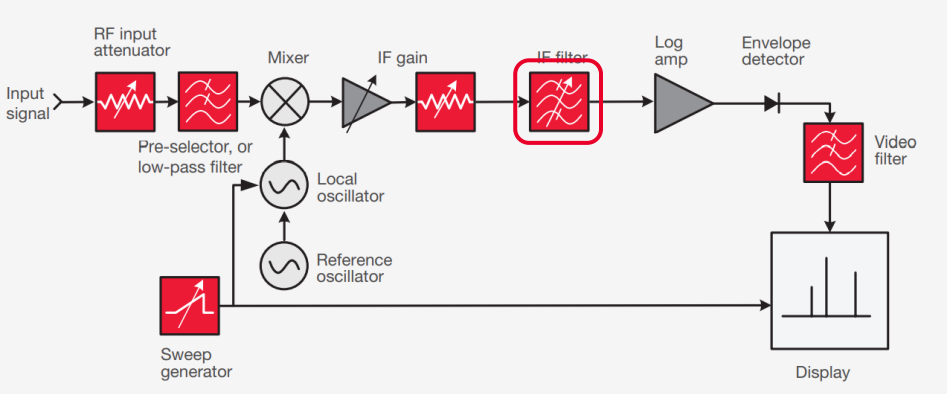


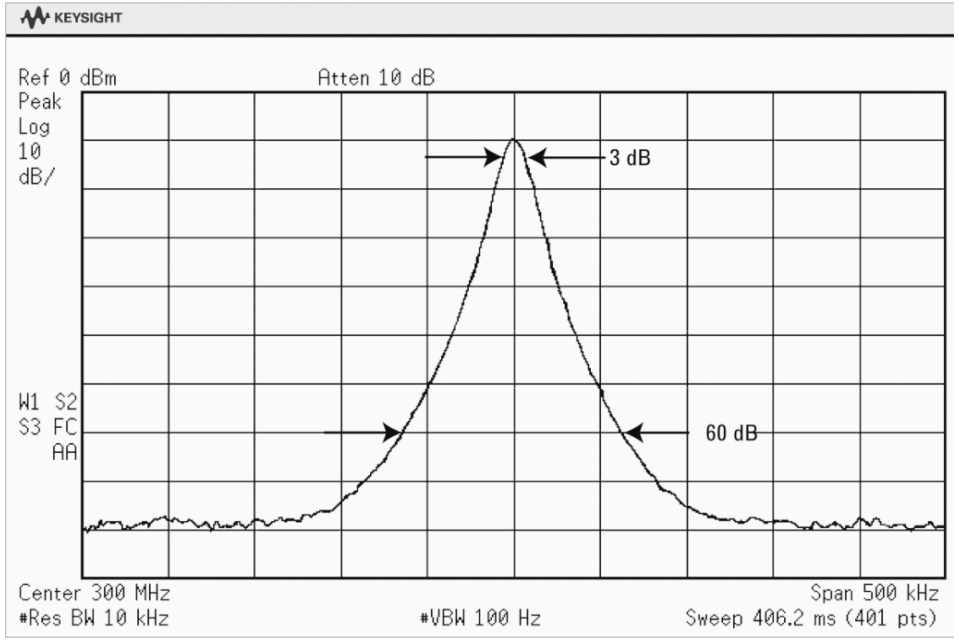
IF Filter and resolution bandwidth

Selectivity: 60-dB bandwidth to the 3-dB bandwidth

- Determines the ability of the analyzer resolving unequal amplitude signals.

- Bandwidth selectivity tells how steep the filter skirts are.





Demo

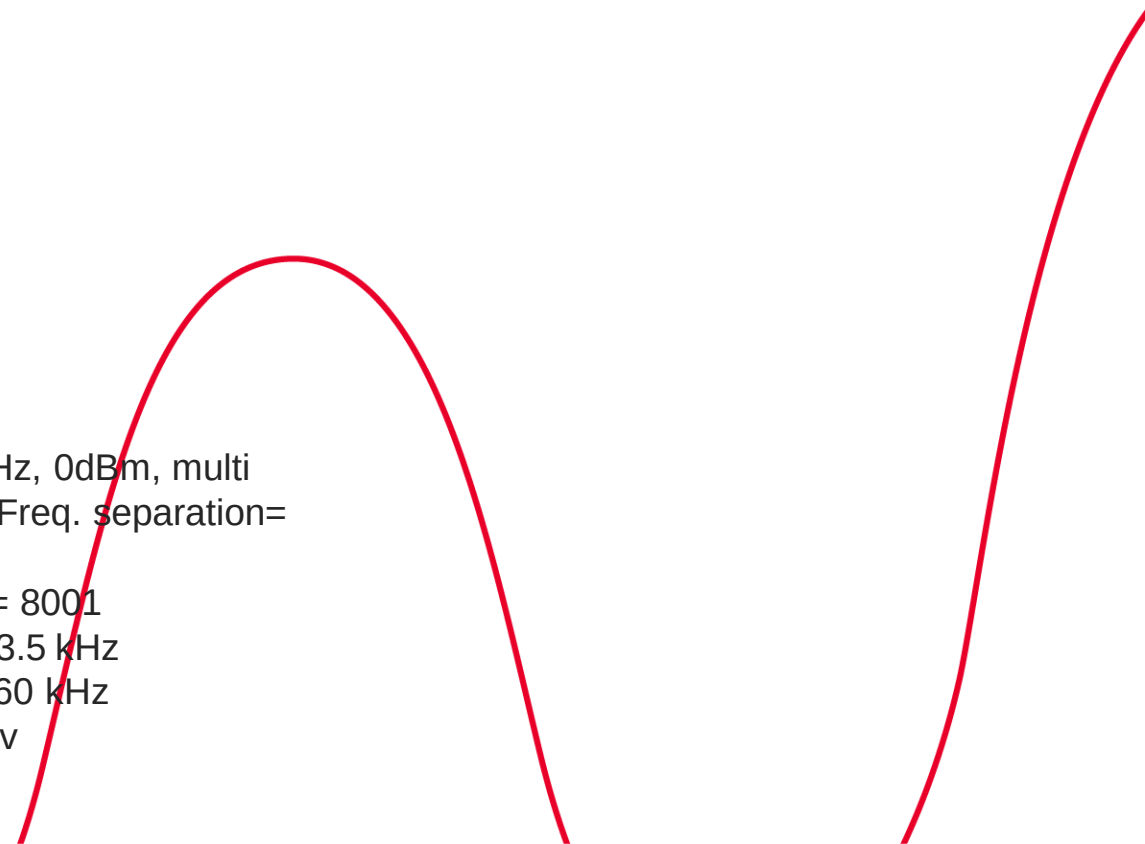
- Determine the bandwidth of the filter
- Two equal amplitude signals and smoothing
- Selectivity (shape factor) of the filter
- Two unequal amplitude signals and smoothing

812 MHz, 0dBm
RBW=10 kHz
Span=15 kHz
1 dB/div

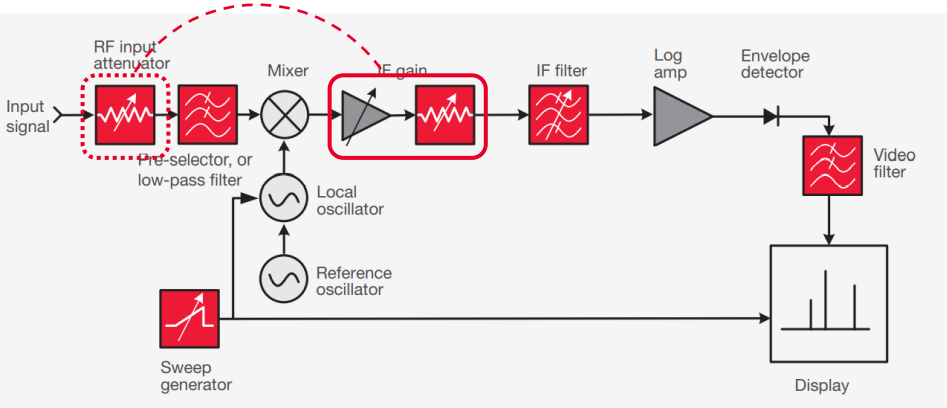
812 MHz, 0dBm, two tones,
Freq. separation= 10 kHz
RBW=10 kHz
Span=20 kHz
1 dB/div
Sweep time= 300 ms

812 MHz, 0dBm
Points= 8001
RBW=10 kHz
Span=60 kHz
7 dB/div

812 MHz, 0dBm, multi tones, Freq. separation= 20 kHz
Points= 8001
RBW=3.5 kHz
Span=60 kHz
7 dB/div



IF Gain and attenuation



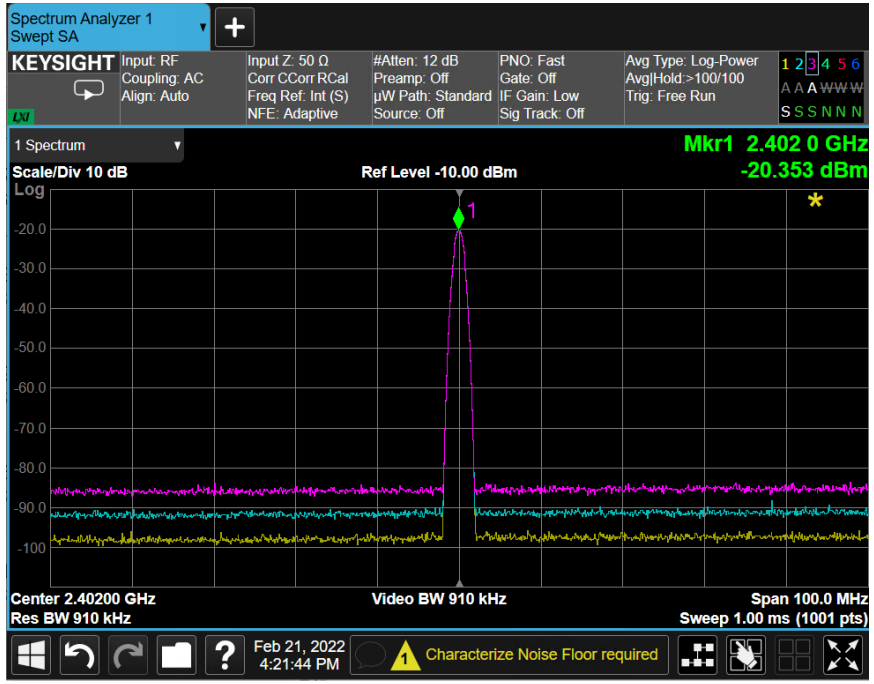
- Combination of IF gain and attenuator adjusts the IF signal level

- Change in RF input attenuator → change in IF gain → Keep constant IF signal level
  - The input signals are attenuated by a factor and then amplified by the same factor
  - Signal level remains the same. However, noise floor level increases

IF Gain and attenuation

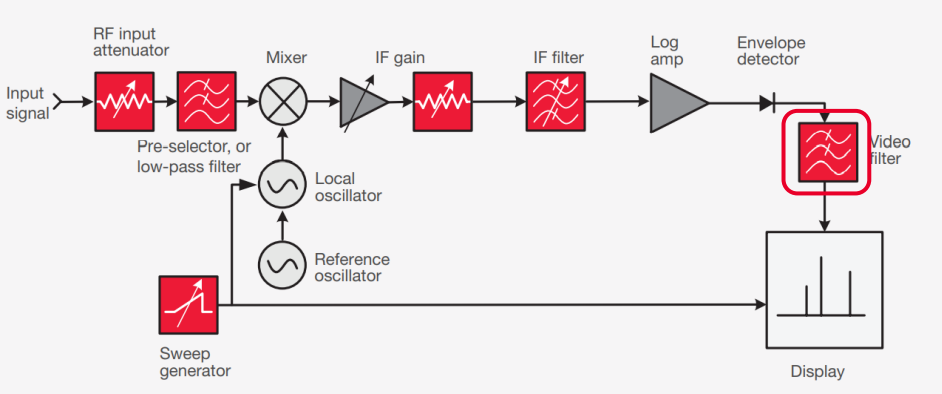
Influence of RF input attenuation on noise floor

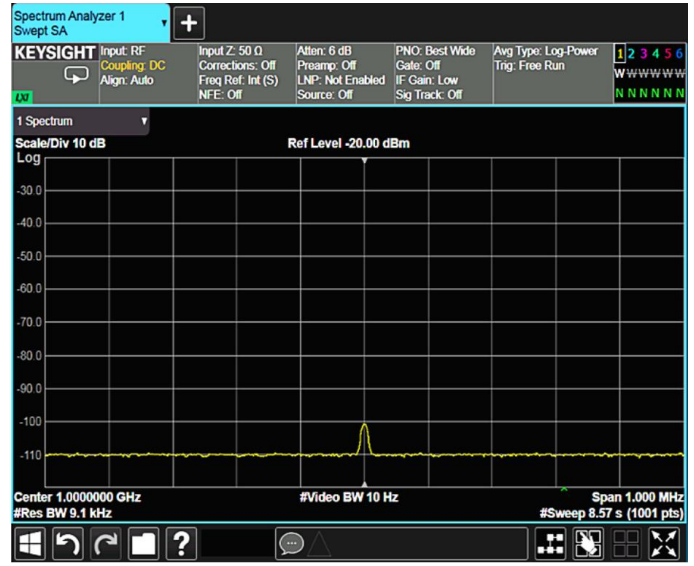
- Different input attenuations are applied
  - Trace 1: 0 dB attenuation
  - Trace 2: 6 dB attenuation
  - Trace 3: 12 dB attenuation
- Same signal level for all traces
  - Signal level not exactly -20 dBm → Cable losses (.353 dB)
- Different noise floor levels
  - Noise level increases with the increase of input attenuation



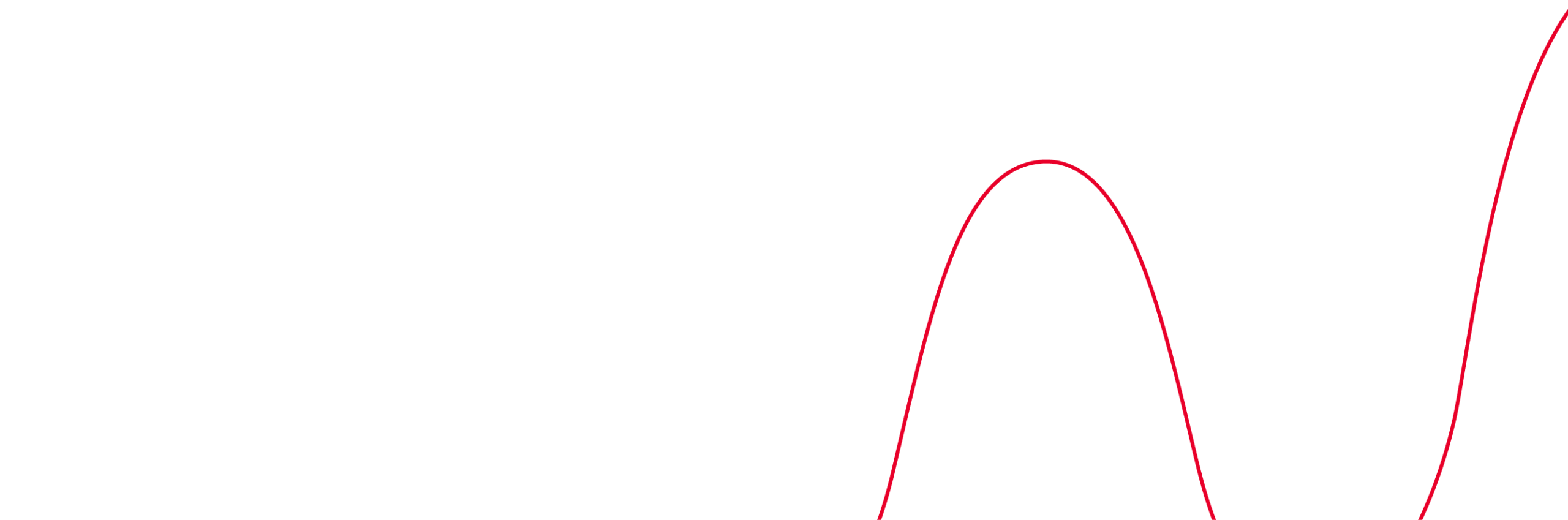
Video Filter

- VBW smoothers the displayed signal





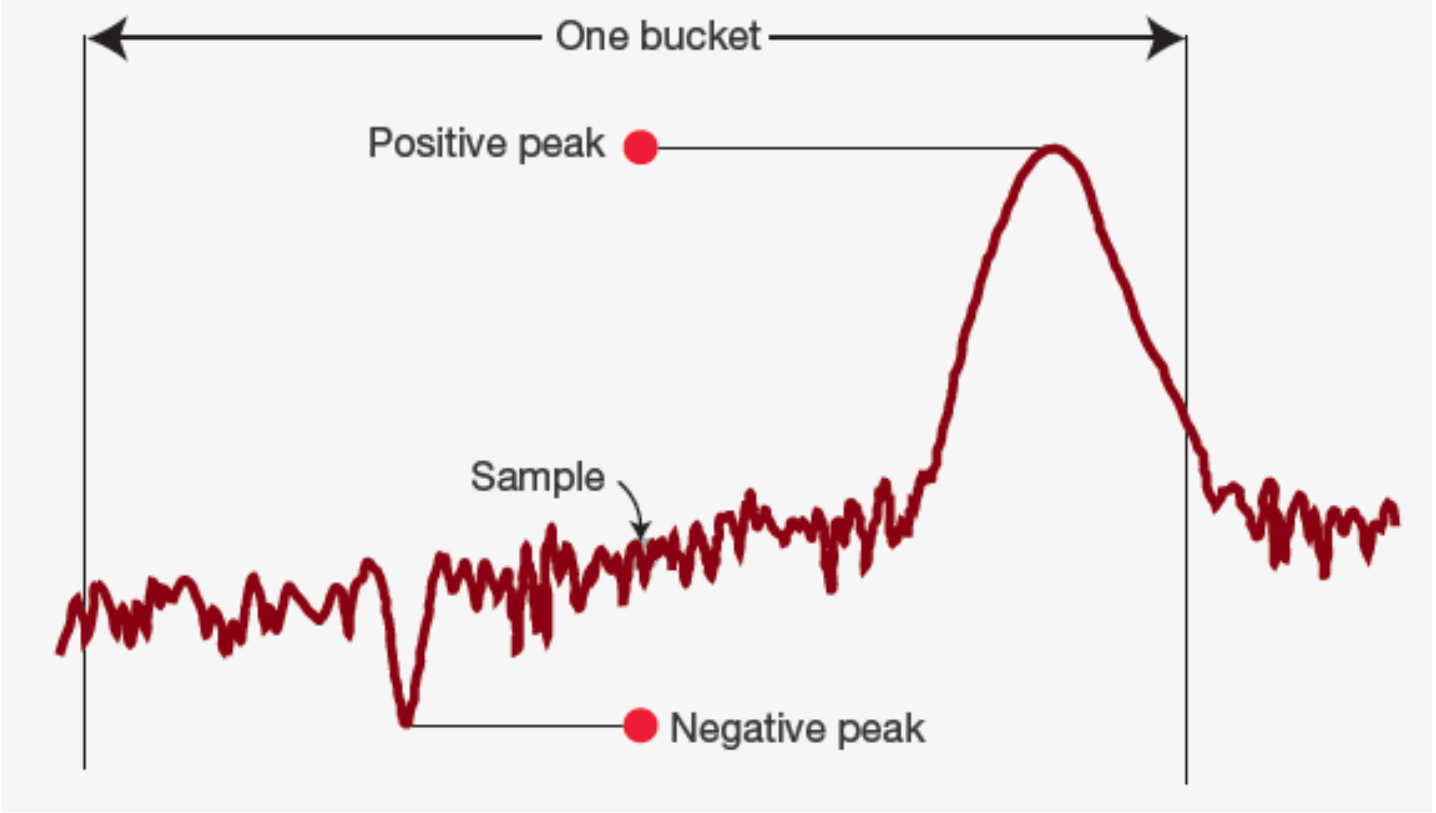
Detector Types



Detector Types

Sample Detection

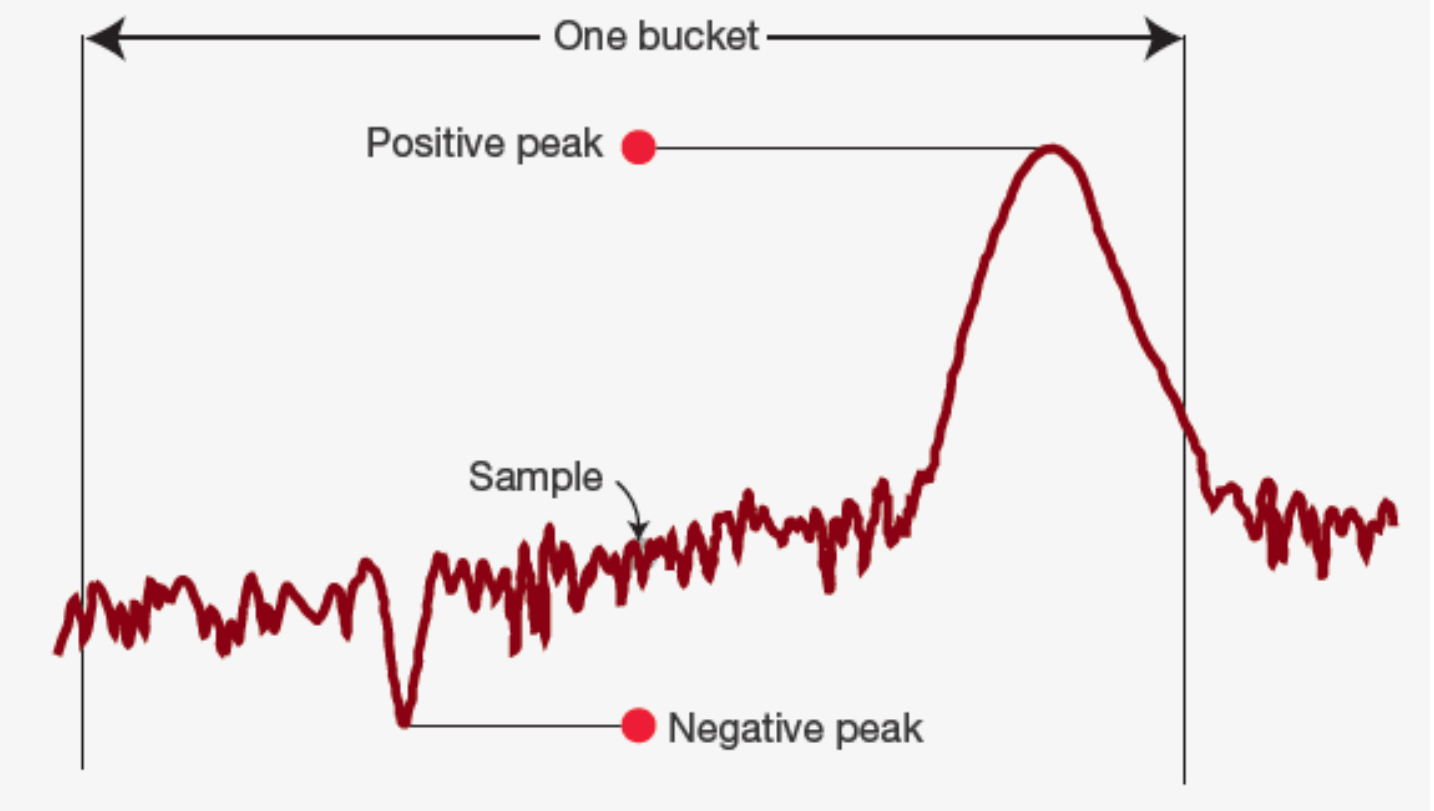
- Chooses the middle sample in each bucket
- Good job at detecting noise
- Not good at detecting sinusoids



Detector Types

Positive Peak Detection

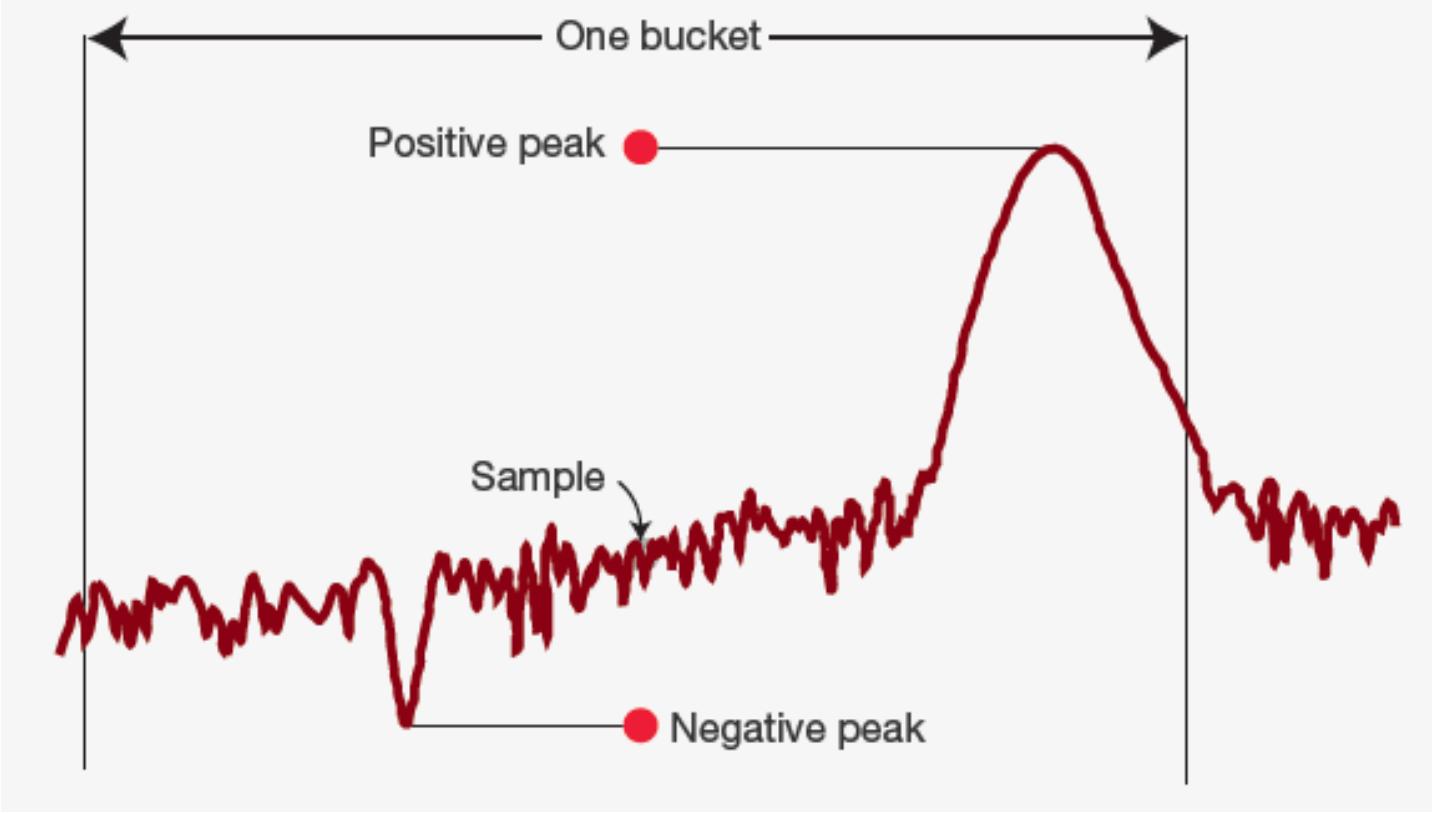
- Displays maximum value in each bucket
- Good for sinusoids
- Not a good representation of random noise



Detector Types

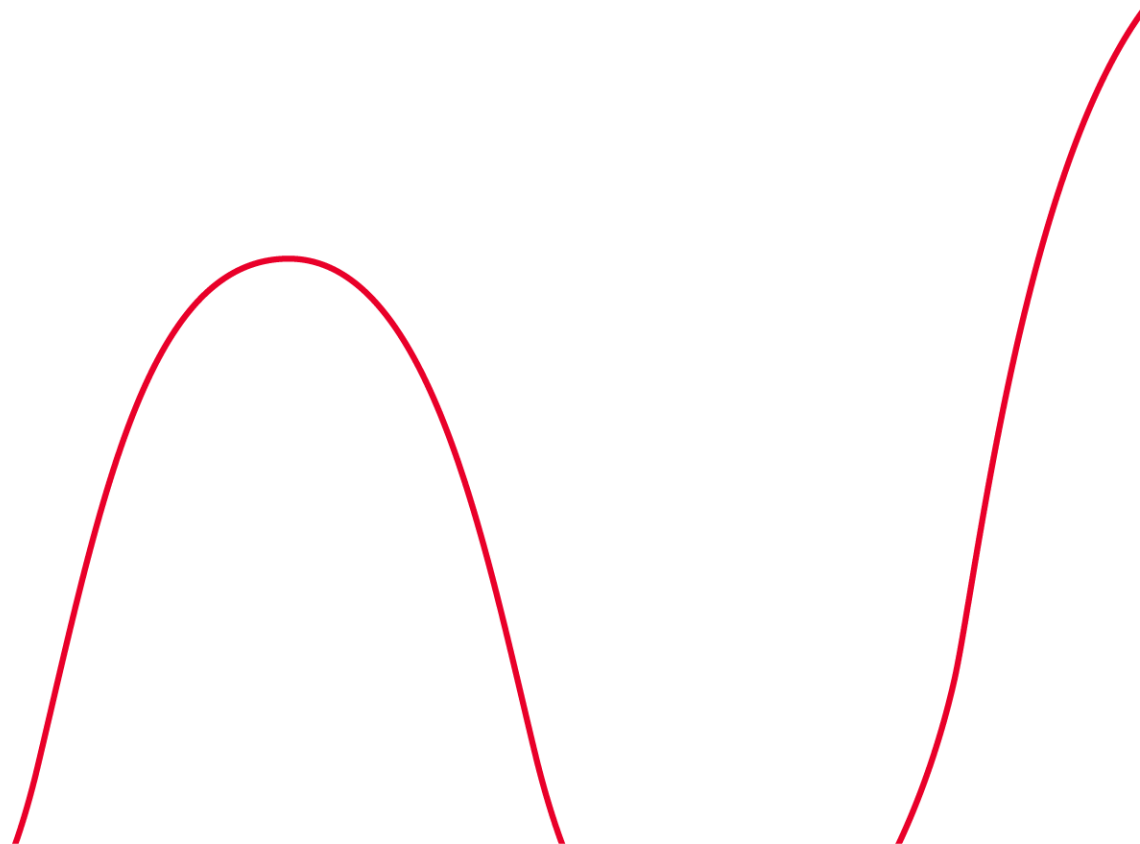
Negative Peak Detection

- Displays minimum value in each bucket
- Good for EMC testing

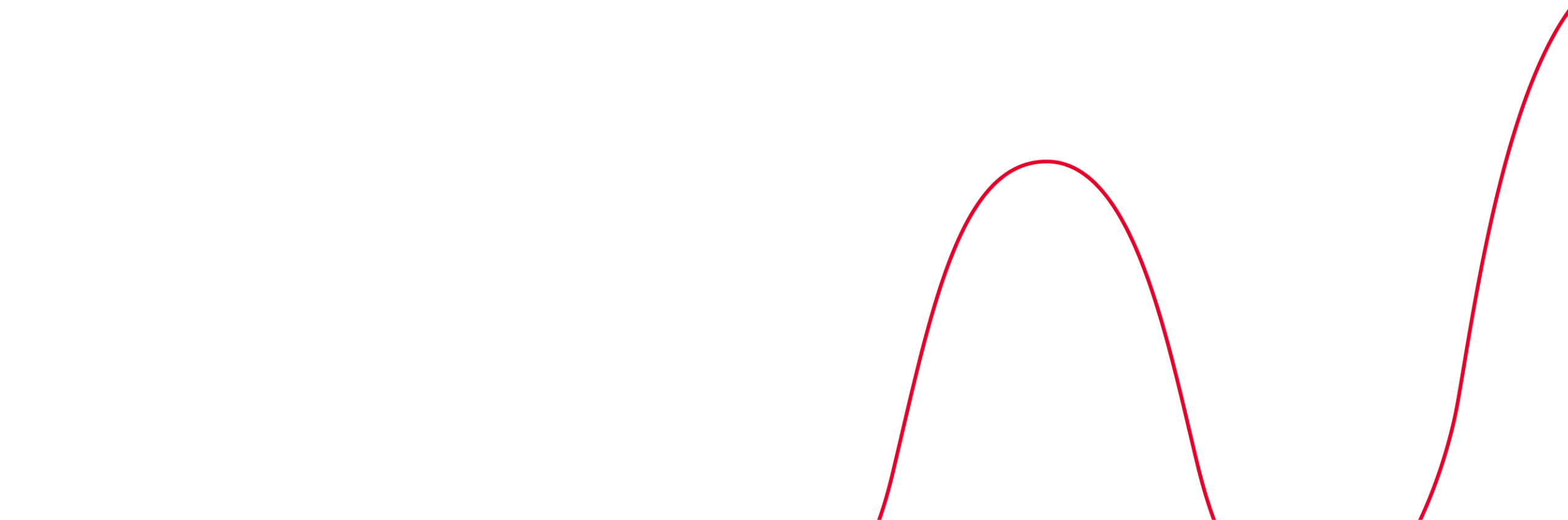


Demo

- Smoothing and averaging
- Video filter
- IF gain and attenuation



Displayed Average Noise Level Sensitivity



What is Sensitivity?

- The smallest signal that can be measured.

Displayed Average Noise Level (DANL)

- The DANL specifies all the internal noise of the spectrum analyzer [dBm/Hz].

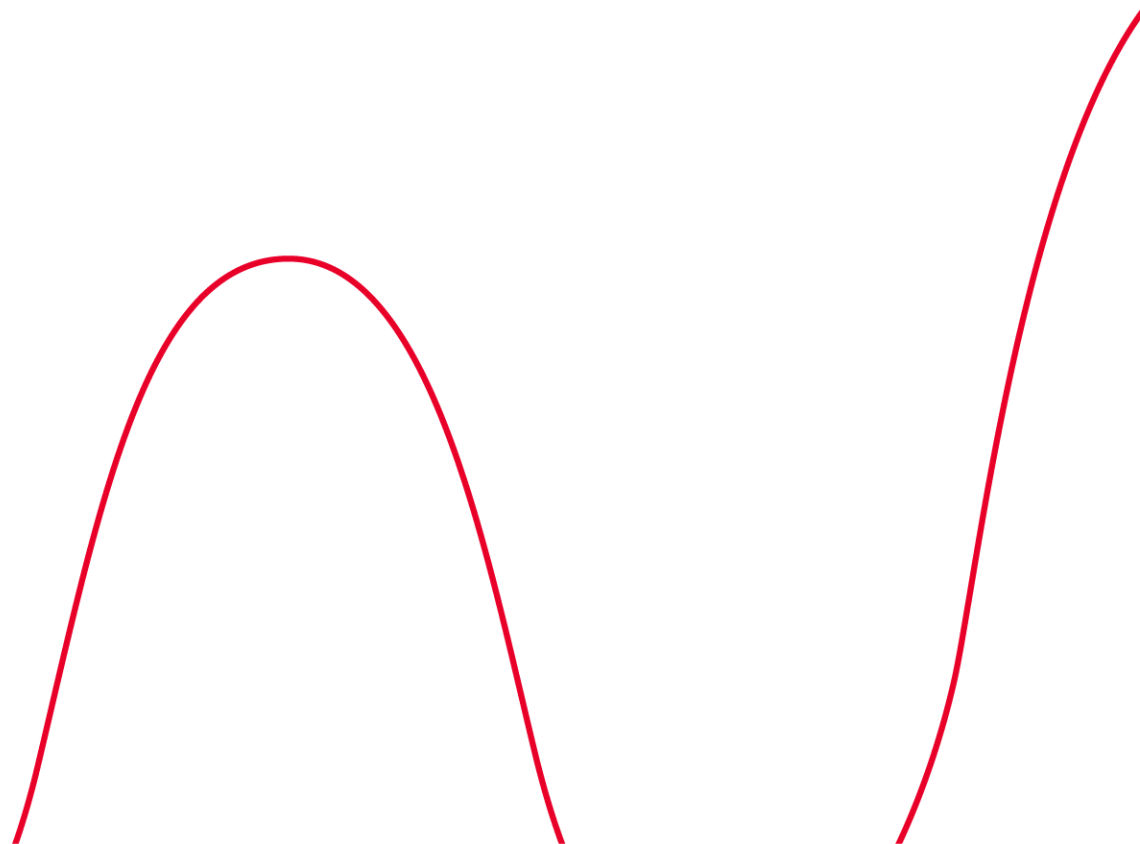
$$\propto Thermal\ Noise\ Floor = (k \cdot T \cdot B),$$

$$k = Boltzman\ constant\ [J/K]$$
$$T = Temperature\ [K]$$
$$B = Bandwidth\ [Hz]$$

- Frequency and bandwidth (RBW) dependent;
- Input signals below this level are not measured;
- Theoretical thermal noise at room temperature: $-174\,\frac{dBm}{Hz}$

Demo

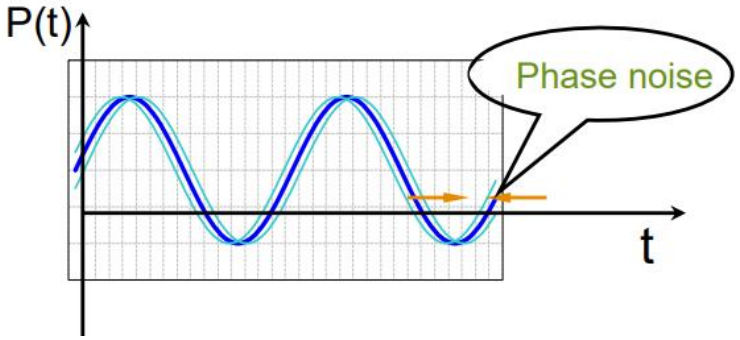
- RBW vs sensitivity
- Attenuation vs sensitivity
- Preamplifier vs sensitivity

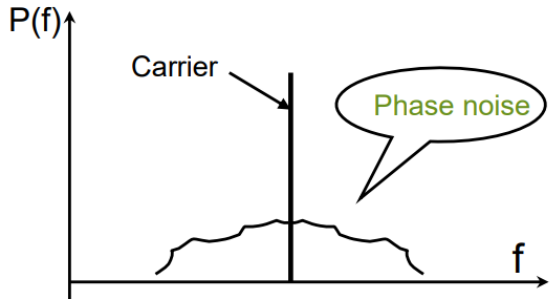


Phase noise

Noise Sidebands

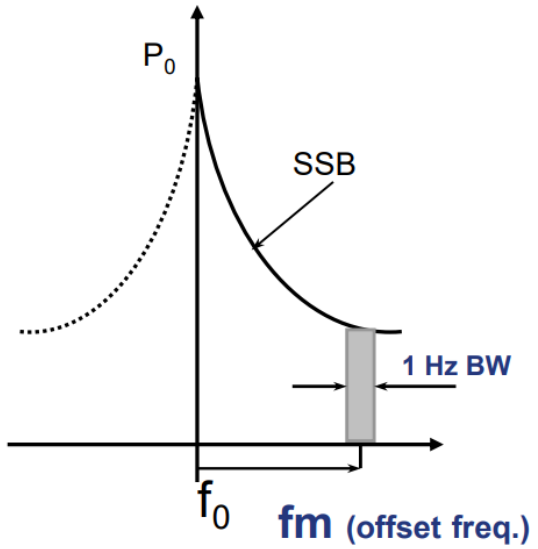
- A random, side band noise in Frequency domain.
- Jitter in time domain.
- Caused by phase fluctuations of an oscillator
- Why is it important to measure?
- Because it interferes with close in signals!



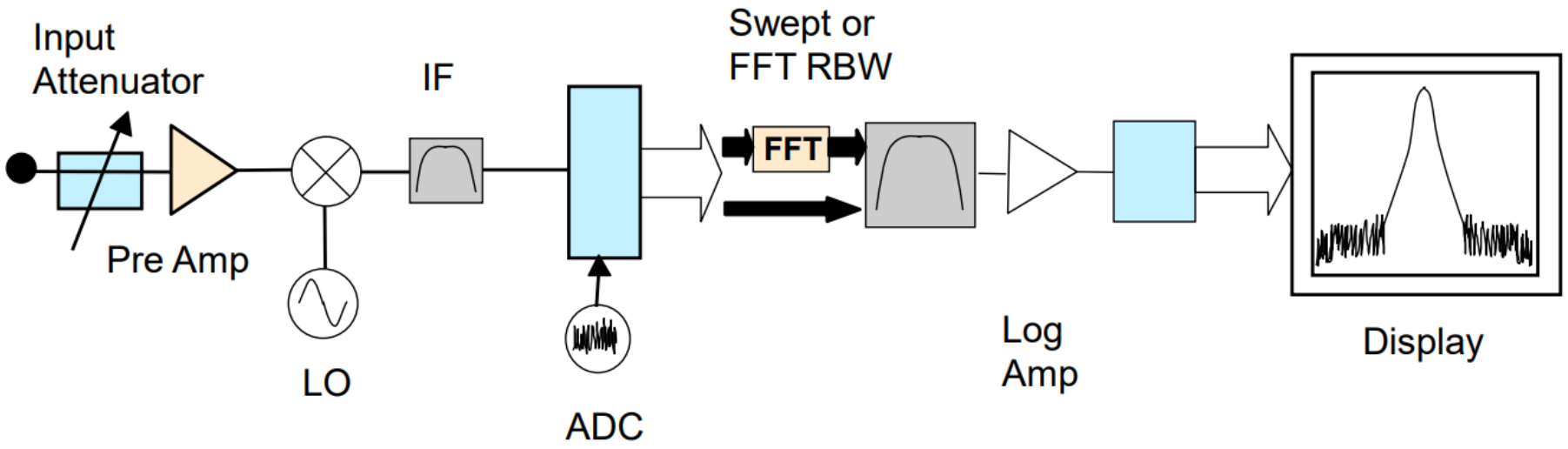


How to Define Phase Noise?

- Offset freq. from Carrier Freq.
- Power Spectral Density (in 1 Hz BW).
- Relative to carrier power in dBc.
- dBc/Hz @ offset frequency fm

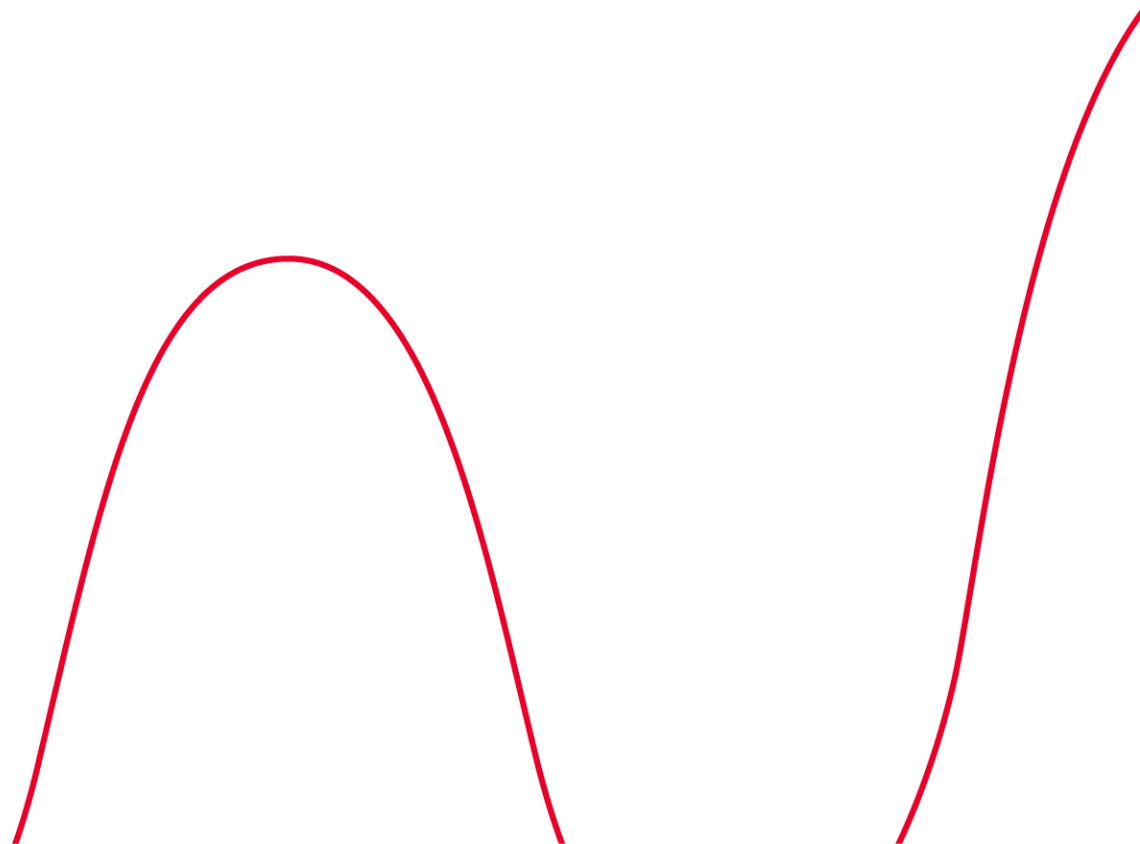


Real-Time Spectrum Analysis



Demo

- Phase Noise
- Real Time Analyzer
- 5G NR
- VSA Software



KEYSIGHT

Thank you