Spectrum Analyzer Basics

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What is a Spectrum Analyzer

- A measuring instrument that displays an electrical signal according to its frequency.
- Each frequency component contained in the input signal is displayed as a signal level corresponding to that frequency.
- (i.e. The X axis is Frequency and the Y axis is power)

What Instrument for which measurement?

• Spectrum	Spectrum analyzer

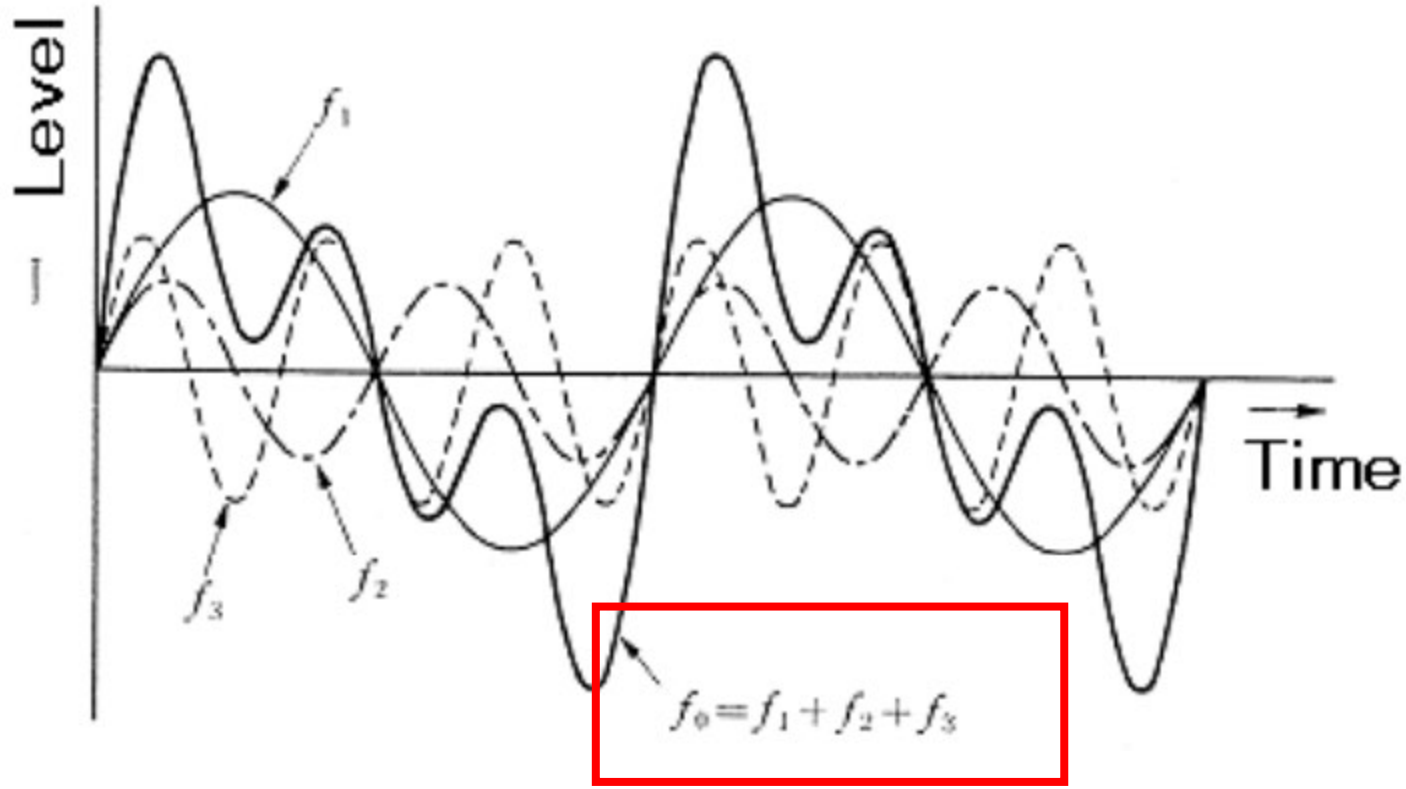
Other measurements can use other instruments:

• Power (Level)	Power meter
• Frequency	Frequency counter
• Transmission/Refection	Network analyzer
• Time characteristics	Oscilloscope
• Modulation characteristics	Modulation analyzer

Describing Electrical Signals

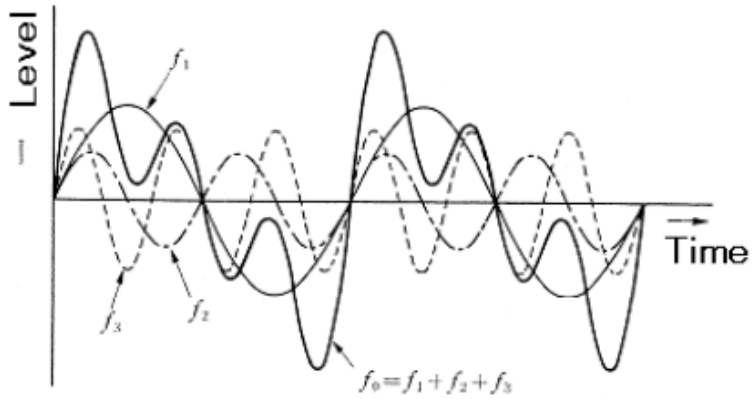
F_0= 0.11mW (-9.6dBm) signal with distortion

Oscilloscope waveforms



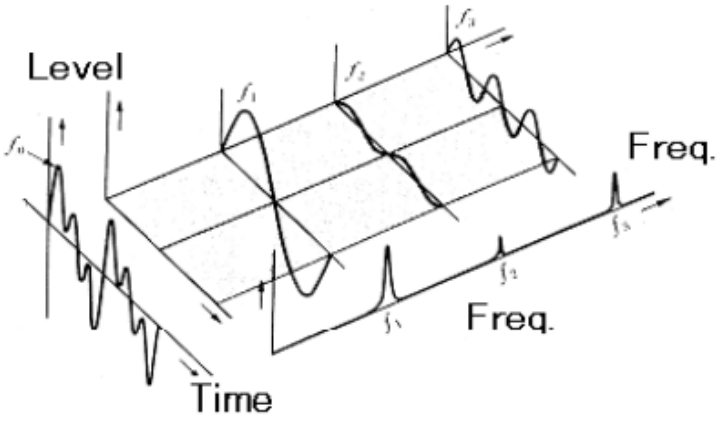
Describing Electrical Signals

Oscilloscope waveforms



Power 0.11mW (-9.6dBm)

Spectrum analyzer waveforms



Frequency	Power (dBm)	(W)
f_0	-10dBm	0.1mW
$2f_0$	-20dBm	0.01mw
$3f_0$	-54dBm	4.0nW
(Sum)		0.11mW

Analysis of Electrical Signals

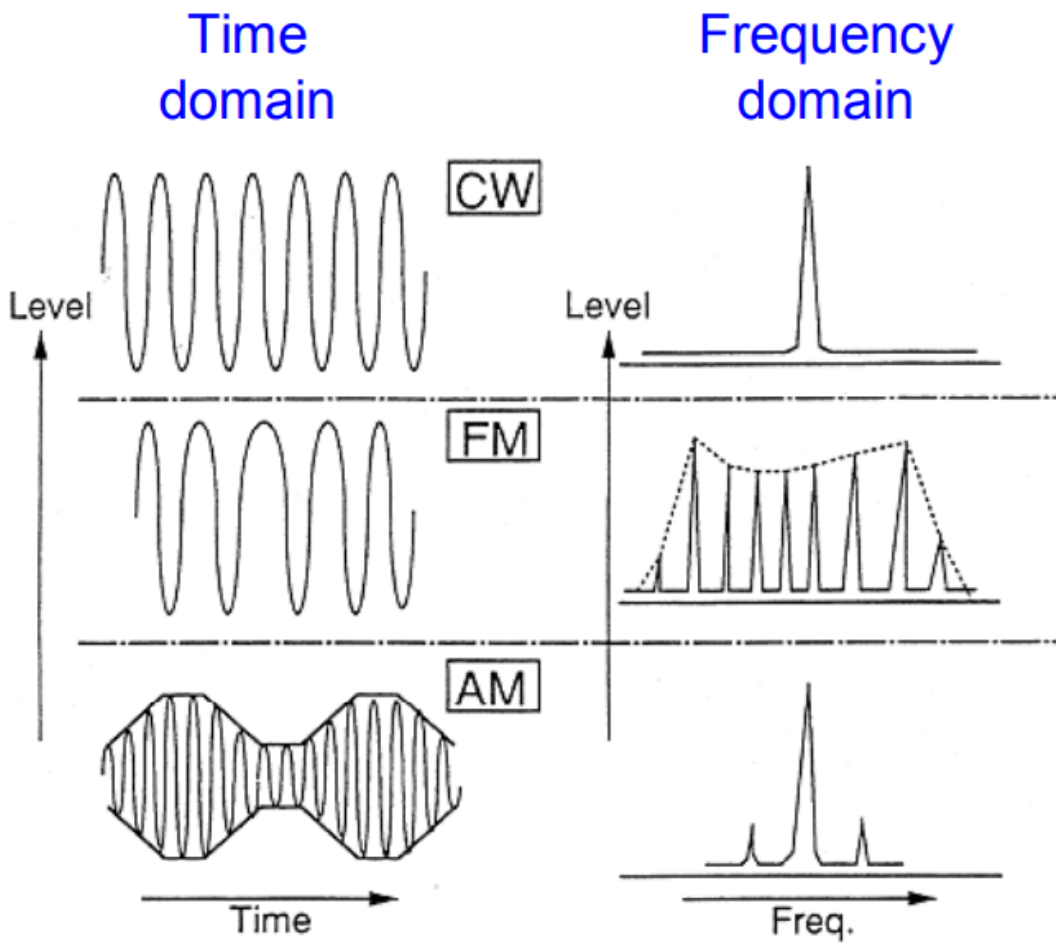
Time Domain

- Changes in time can be seen.
- If a signal has many frequency elements, the analysis is difficult.

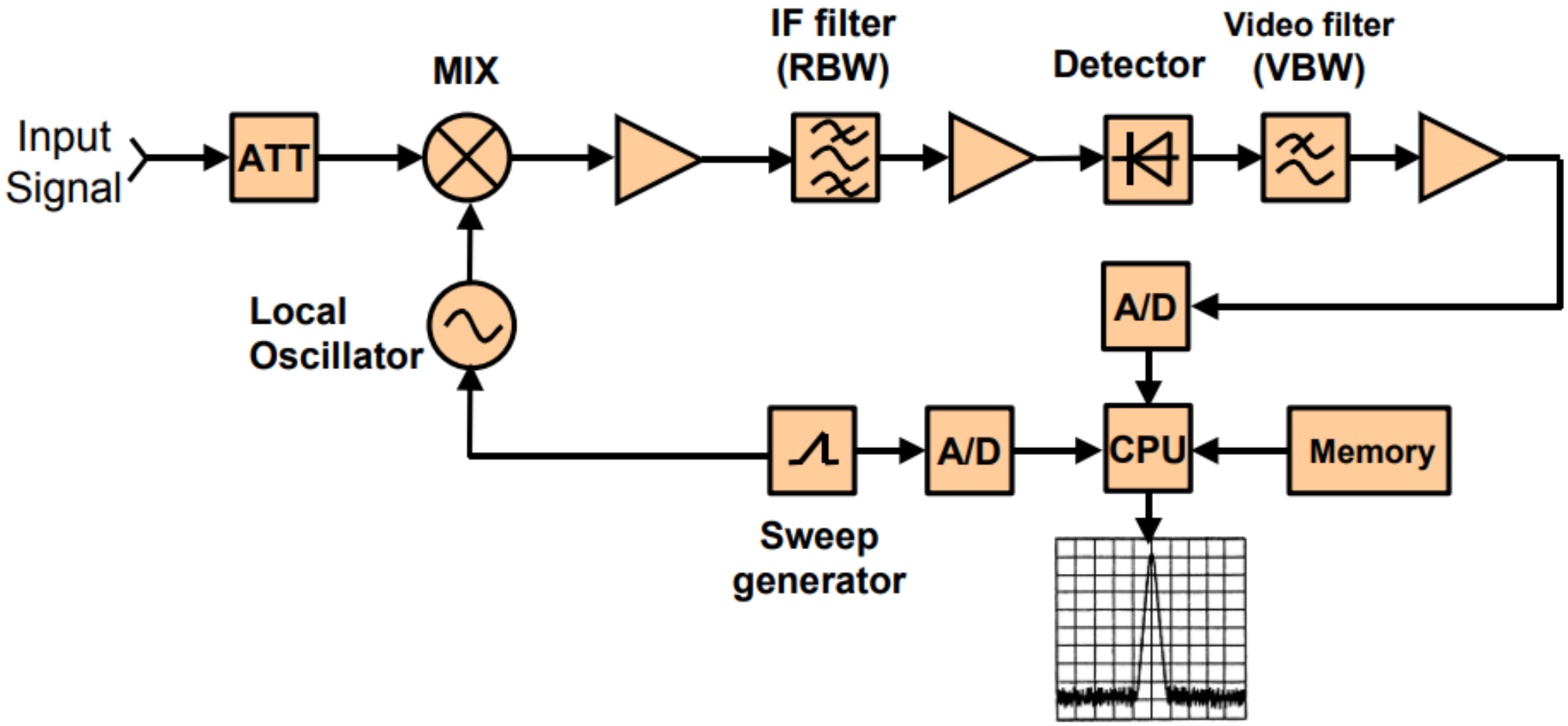
Frequency Domain

- Each element of a complex signal can be separated easily.
- Low-level distortion signals can be detected.
- Spurious elements can be measured.

Comparing Domains



Block Diagram of Super Heterodyne Spectrum Analyzer



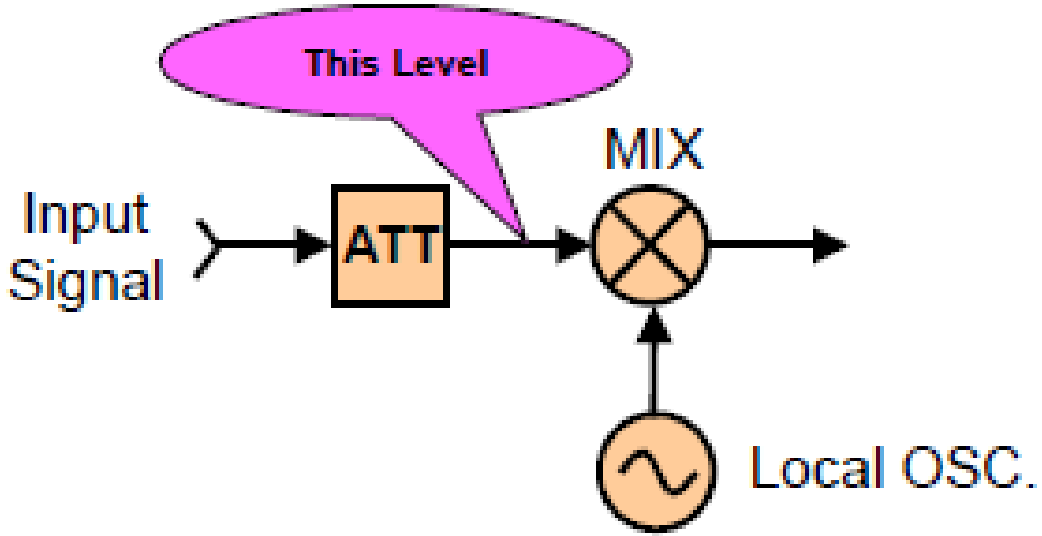
Key specs for a Spectrum Analyzer

- Suitable Input Level
- Maximum Input Level
- Measurement Frequency Range
- Sideband Noise (phase noise)
- Resolution bandwidth (RBW)
- RBW and Sweep Time
- Detection methods
- Video filter (VBW)
- Dynamic Range (Average Noise Level, Residual response, Distortion)

Suitable Input Level

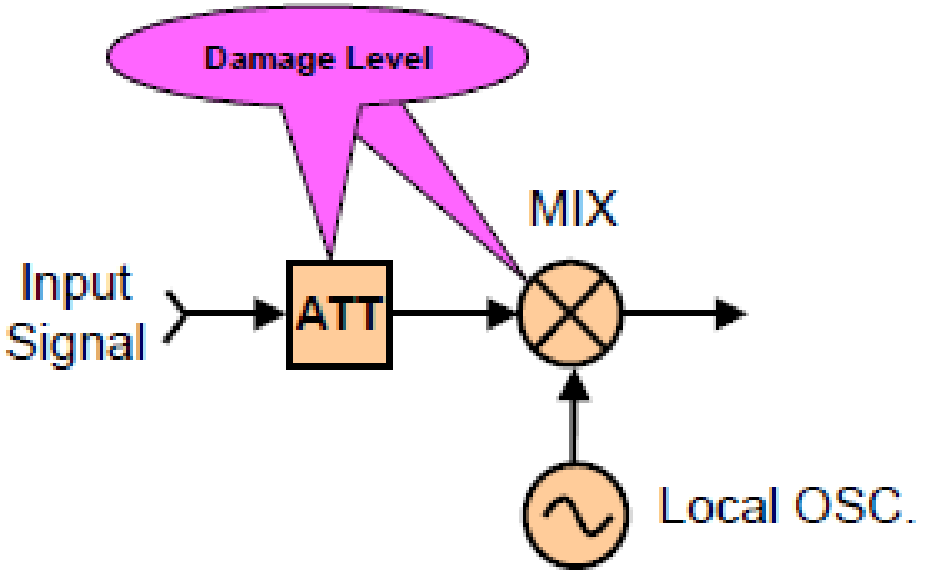
When the signal and local oscillator are added at the mixer input, the suitable input level is the distortion level specification that doesn't influence the measurement. The level relationship between the input signal and the distortion is specified at the mixer input level, not at the input connector.

Therefore, the RF attenuator attenuates the input signal to a suitable mixer input level.



Maximum Input Level

The maximum input level prevents damage to the input circuit. It is based on the input levels to the Attenuator and Mixer.



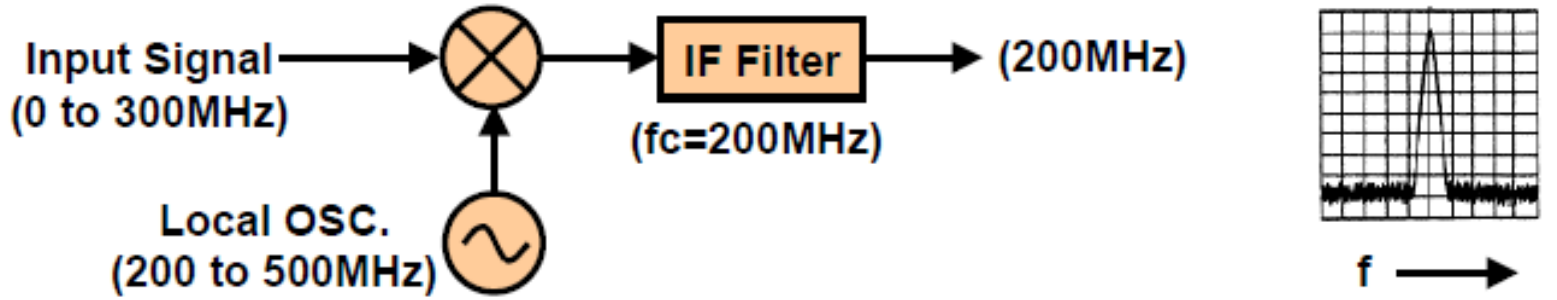
Measurement Frequency Range

The measurement frequency range is determined by the center frequency of the IF filter and the local oscillator frequency range.

Input Signal Freq. = Local Osc Freq. – IF Freq.

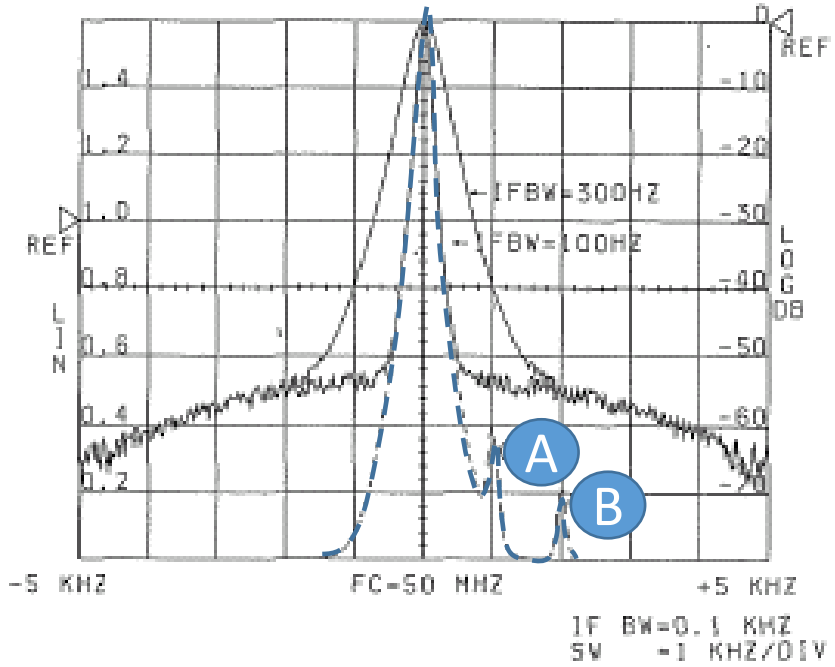
The input signal and the local osc are mixed by the mixer.

The mixer output is filtered by the IF filter with center frequency f_c and displayed on the screen.



Sideband Noise (phase noise)

It appears in the base of the spectrum because of noise in the internal local signal source. Sideband noise shows the signal purity, and the performance of nearby signal analysis is determined by this characteristic. It is specified by how many dB down from the center at an offset of 10kHz (or 100kHz) when the resolution bandwidth (RBW) is narrow enough, and a high purity signal is input.



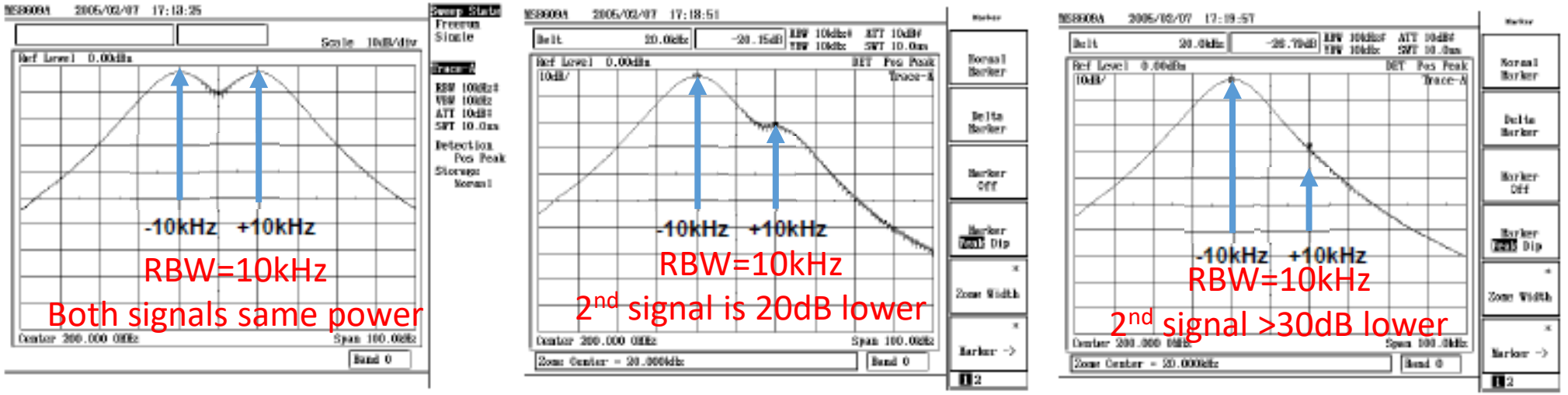
For the local signal source, the dotted line spectrum is the ideal. However, it actually has sideband noise like the solid line. Masking occurs by the sideband noise when there is a nearby A or B signal and it is not possible to detect it.

Resolution bandwidth (RBW)

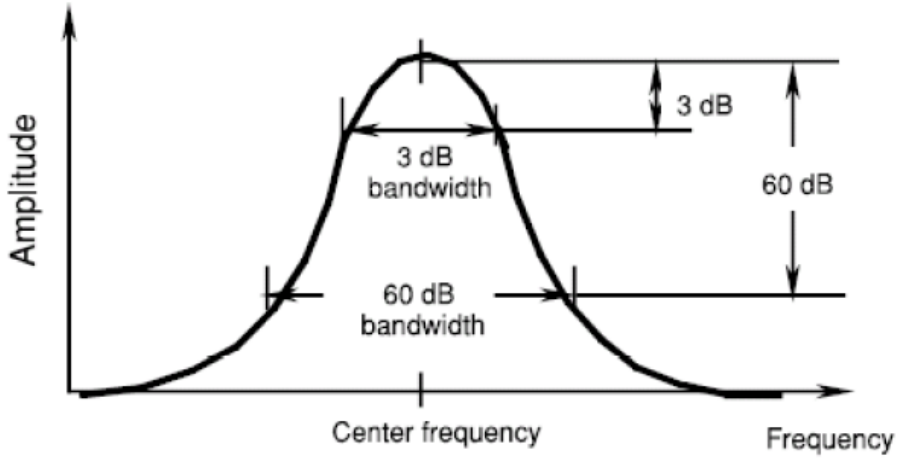
Two input signals can be seen as two spectrum waveforms only if they exceed the 3dB bandwidth of the IF filter.

The 3dB bandwidth of this IF filter is called the resolution bandwidth (RBW).

f1=199,990MHz, f2=200,0010MHz at RBW 10KHz



Resolution bandwidth (RBW)- selectivity



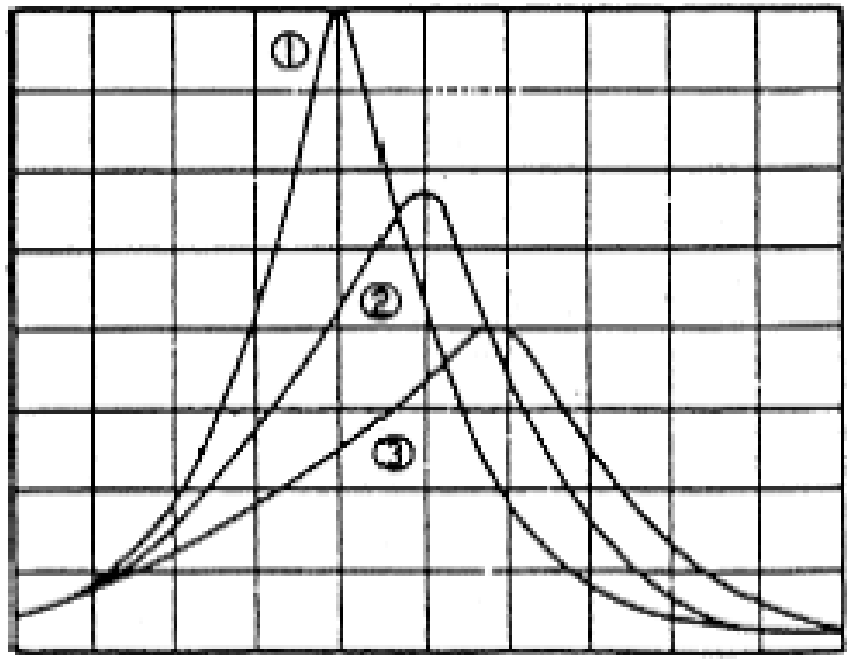
$$\text{Selectivity} = \frac{\text{60dB BW}}{\text{3dB BW}}$$

Selectivity is a measure of how narrow the IF filter is.

When a narrow RBW is selected, the 3dB bandwidth and

60dB bandwidth become small, the frequency resolution is greater, the average noise level falls, and you can see low level signals.

RBW and Sweep Time



A signal displayed with the proper sweep time is shown in the 1st wave.

The amplitude in the display decreases in the 2nd and 3rd waves when the sweep is made too early, and the frequency shifts.

When the sweep speed is not proper, UNCAL is displayed in the screen.

$$\text{Proper sweep time} = K \times \frac{\text{Frequency Span}}{\text{RBW} \times \text{VBW}}$$

(RBW ≥ VBW)

For older analyzers K=3, newer analyzers have lower K

Detection methods

Normal: Displays both the maximum level and the minimum level present between the current sample point and the next sample point.

Pos Peak: Displays the maximum level present between the current sample point and the next sample point. Pos Peak is used to measure the peak value of signals near the noise level.

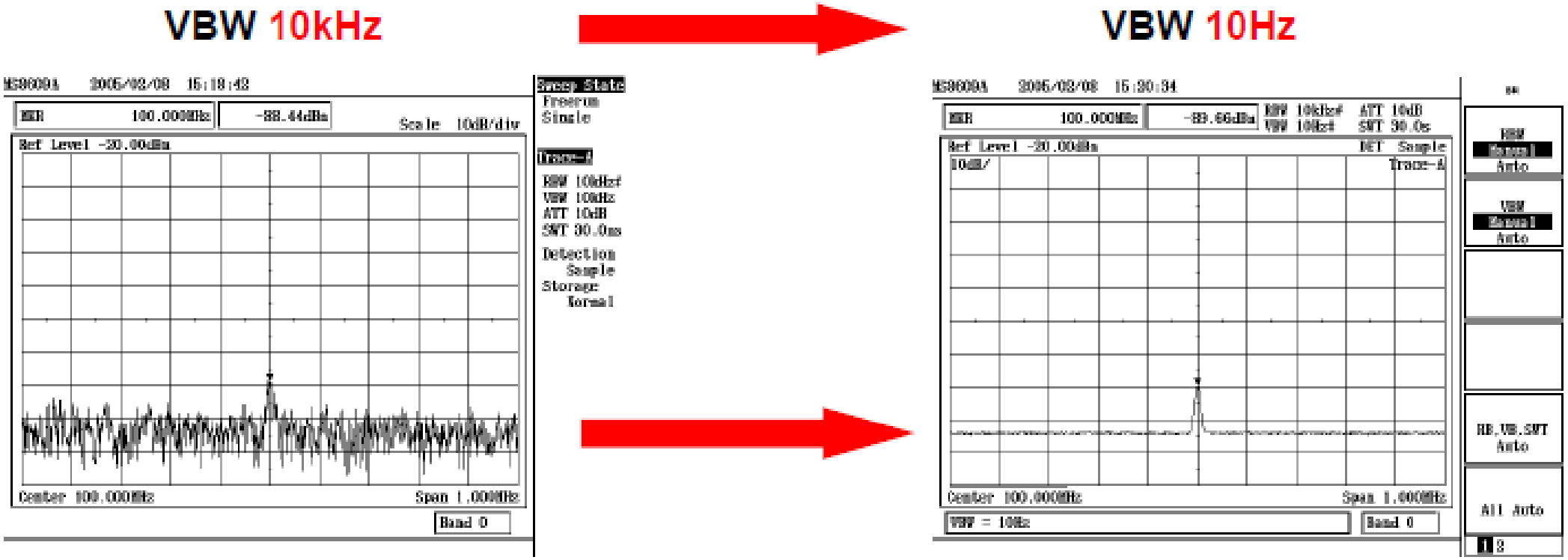
Sample: Displays the instantaneous signal level at each sample point. Sample is used for noise level measurement and time domain measurement.

Neg Peak: Displays the minimum level present between the current sample point and the next sample point.

RMS: Displays the root-mean-square (effective) value of the signal input between the current sample point and the next sample point.

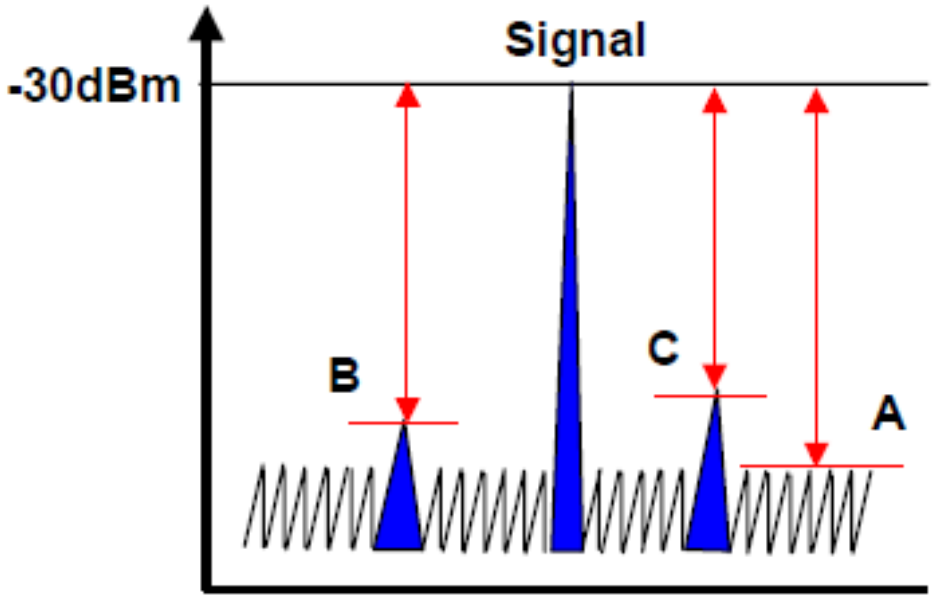
Video filter (VBW)

The VBW filter is a way to average noise in a signal.



Dynamic Range

Dynamic Range is the range that can be measured without making the signal suffer in the noise level, residual (or spurious) responses, and distortion.



Dynamic Range is the power range that a signal can be accurately measured. It is limited on the high end by the front end distortion, and on the low end by either the noise floor or the unwanted spurious signals that are internally generated in the analyzer.

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