Spectrum Analyzer 101+

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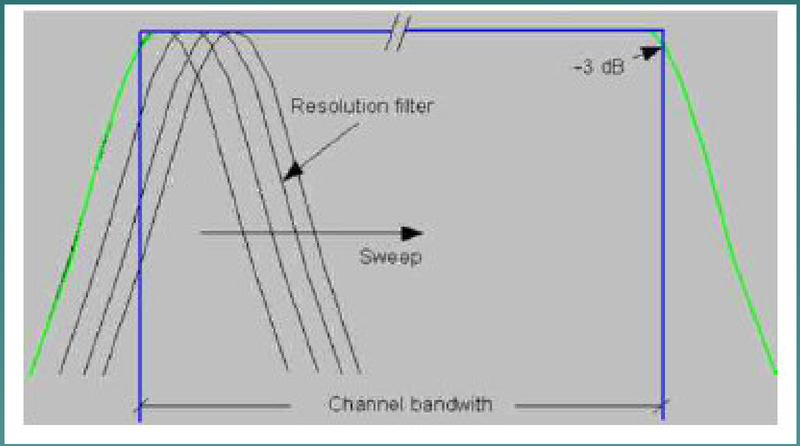
Spectrum Analyzer 101

- Spectrum Analyzer Background and Reference Material
- Block Diagram
- Key specifications
- Controls and Settings
- Hands-on measurements—Analog and Digital signals
- Hints and Kinks
- Questions and next installment

Spectrum Analyzer 101

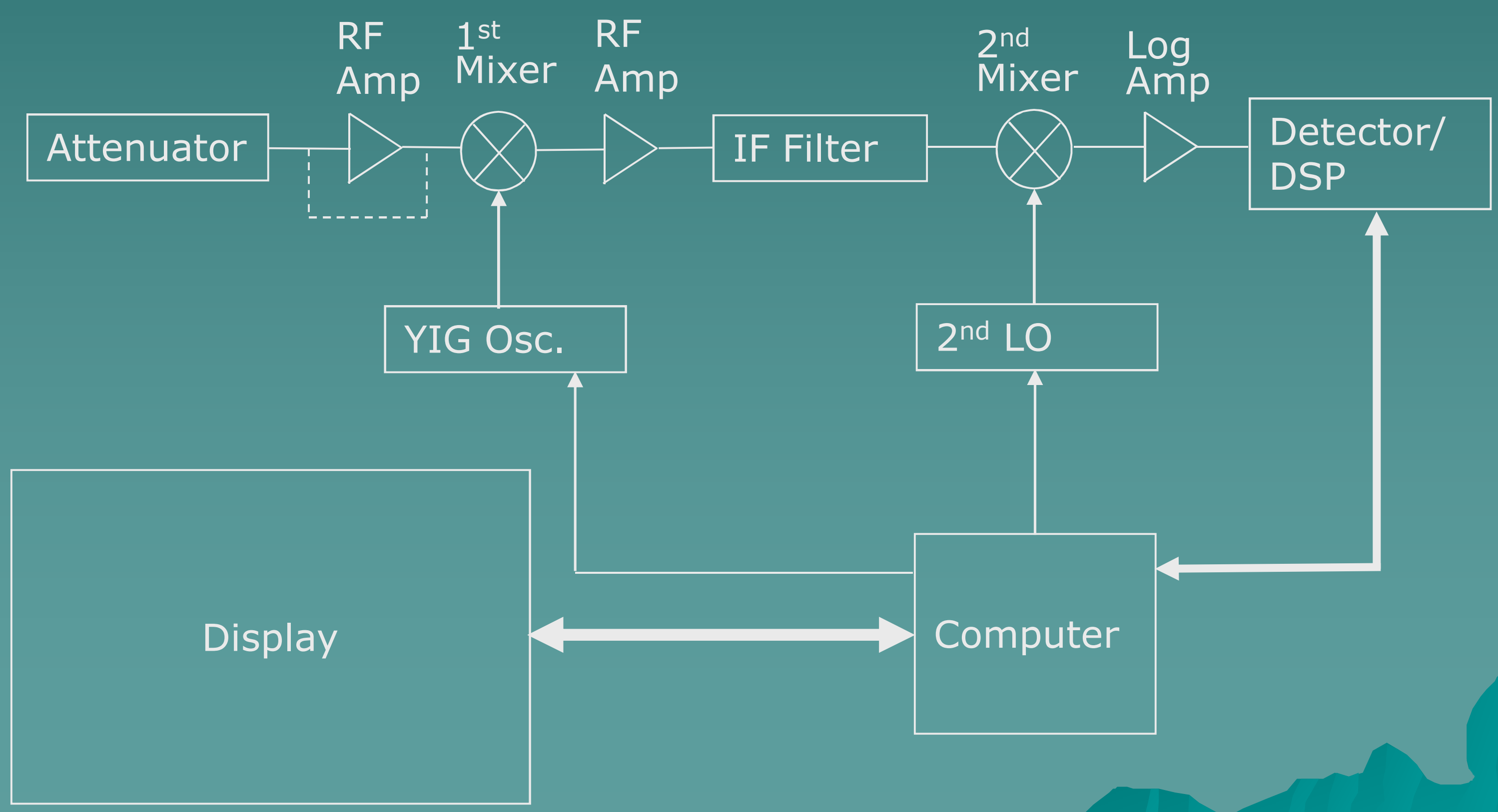
– A spectrum analyzer is a swept-frequency receiver.



– Receivers have at least 3 basic components
  - Frequency converter and amplifier
  - Selectivity for the desired signal
  - Detector to demodulate the signal

Spectrum Analyzer 101

– Typical Block Diagram



Spectrum Analyzer 101 Reference Material

HP Application Notes

– http://www.hpmemory.org/ressources/resrc_an_01.htm

- App Note 63 for Fundamentals
- App Note 134 for Intermediate Subjects
- App Note 1298 for Advanced Topics-Digital Communications
- App Note 1303 for Advanced Topics-Noise-Like Signals
- App Note 1316 for Advanced Topics-Amplitude Accuracy

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– Key Controls
  - Center Frequency
  - Span—Zero span equals fixed frequency
  - Amplitude—Attenuator value and ref level
  - Sweep Speed
  - Resolution Bandwidth
  - Video Bandwidth
  - Detector Setting

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- Secondary Controls
  - Attenuator range, log or linear, and reference level offsets or position
  - Sweep Points
  - Trigger
  - Averaging
  - Markers

Spectrum Analyzer 101

- Spectrum Analyzer Features
  - Tracking Generator
  - Channel Power Measurement Mode
  - Markers
  - Averaging
  - Trace Math
  - Frequency Counters
  - Signal Analyzers
  - High Stability
  - Remote Control
  - Etc.

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- Key Specifications
- Frequency Range
- Noise figure
  - DANL
- Dynamic Range (Spurious Free)
  - 3rd Order Intercept Point (aka TOI)
  - 2nd Order Intercept Point
- Selectivity
- Filter Shape Factor
- Attenuator or Maximum input signal

Spectrum Analyzer 101
Hints and Kinks

- Great Tool for
  - Amplitude Comparison between frequencies
  - Occupied Bandwidth/Emission mask compliance
  - Frequency Measurements

- Not a Great Tool for
  - Power Measurement
  - Signal Quality (SNR)

Spectrum Analyzer 101
Spurious Free Dynamic Range

- Ability to see a very small signal in the presence of a very large signal.

- Spectrum Analyzer must use minimum attenuation in order to see a small signal but large attenuation in order to prevent spurious signals from being generated.

- Typical comparison is TOI-3rd Order Intercept

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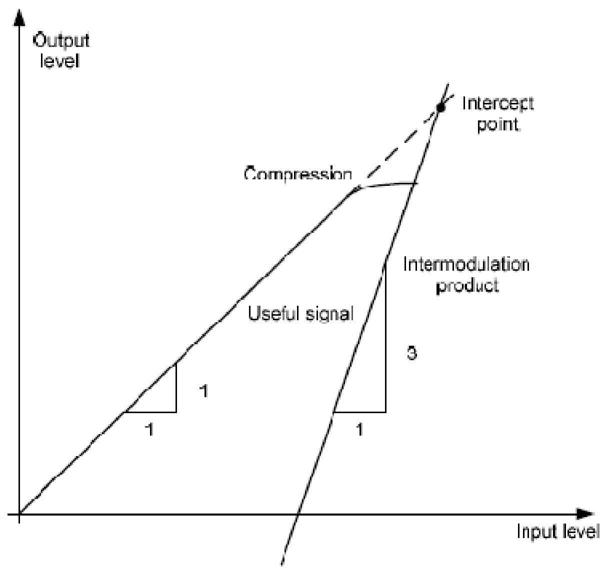
Dependence of intermodulation level on useful signal level



The useful signals at the two–port output increase proportionally with the input level as long as the two port is in the linear range. A level change of 1 dB at the input causes a level change of 1 dB at the output. Beyond a certain input level, the two–port goes into compression and the output level stops increasing. The intermodulation products of the third order increase three times as much as the useful signals. The intercept point is the fictitious level where the two lines intersect. It cannot be measured directly since the useful level is previously limited by the maximum two–port output power.
It can be calculated from the known line slopes and the measured spacing a_{D3} at a given level according to the following formula.

$$IP3 = \frac{a_{D3}}{2} + P_N \quad (3)$$

Courtesy Rohde and Schwarz

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– Example TOI Calculation
  - Input Level = Pn = -20 dBm
  - IMD measured = Ad3 = 60 dB
  - TOI = (60/2)+ (-20) = 10 dBm
  - Pn = Input level into Mixer

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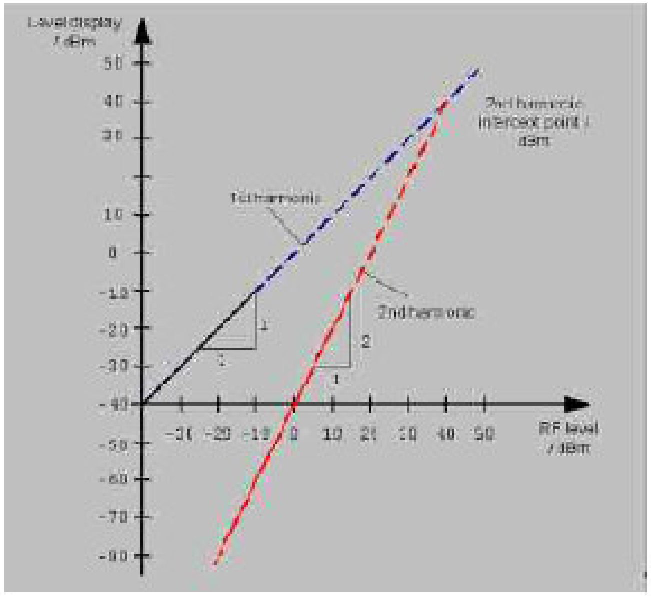
Extrapolation of the 1st and 2nd harmonics to the 2nd harmonic intercept at 40 dBm



The following formula for the obtainable harmonic distortion d_2 in dB is derived from the straight–line equations and the given intercept point:

$d_2 = S.H.I - P_I$ (1)

d2	=	harmonic distortion
P_I	=	mixer level/dBm
S.H.I.	=	second harmonic intercept

Courtesy Rohde and Schwarz

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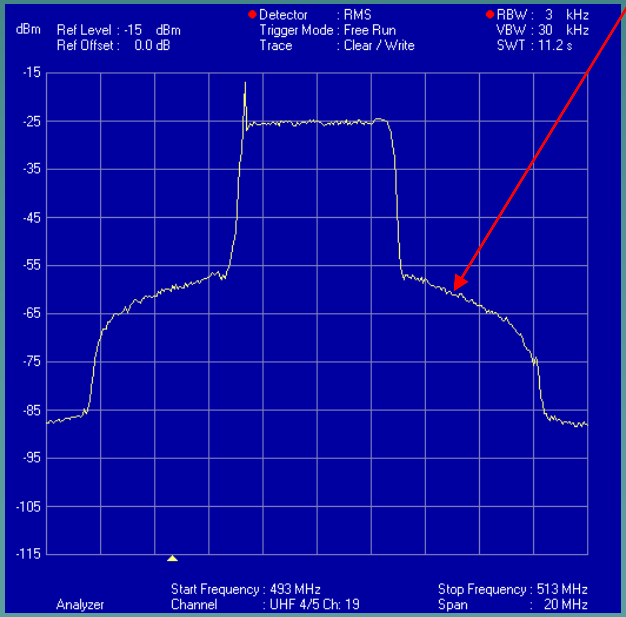
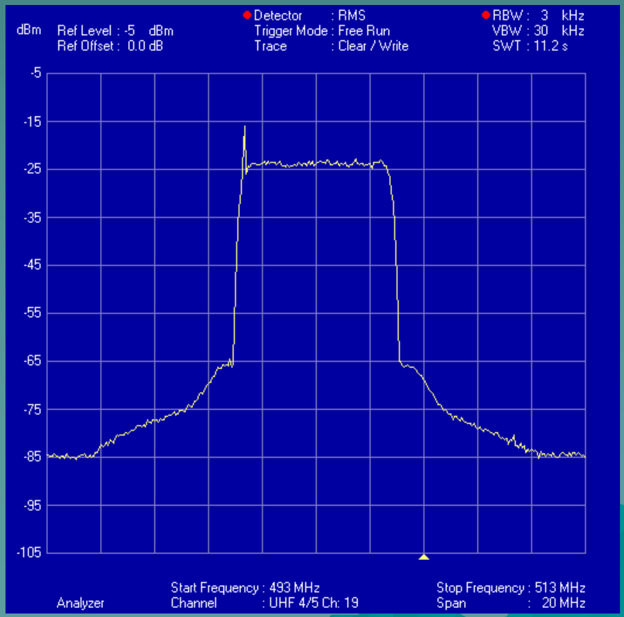
Is the signal distortion transmitter or measurement instrument related

SA Internally generated IMD





Spectrum Analyzer 101
DANL

- DANL or Noise Figure
  - Displayed Average Noise Level
  - How sensitive is the Spectrum Analyzer
  - Noise Figure = F1 +(F2-1)/G1
    - In S.A. with no preamp G1 < 1
  - Next slide shows how important DANL is

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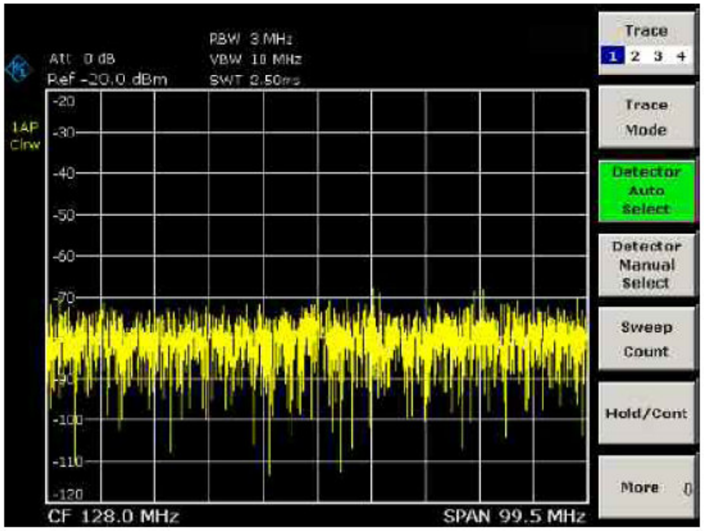
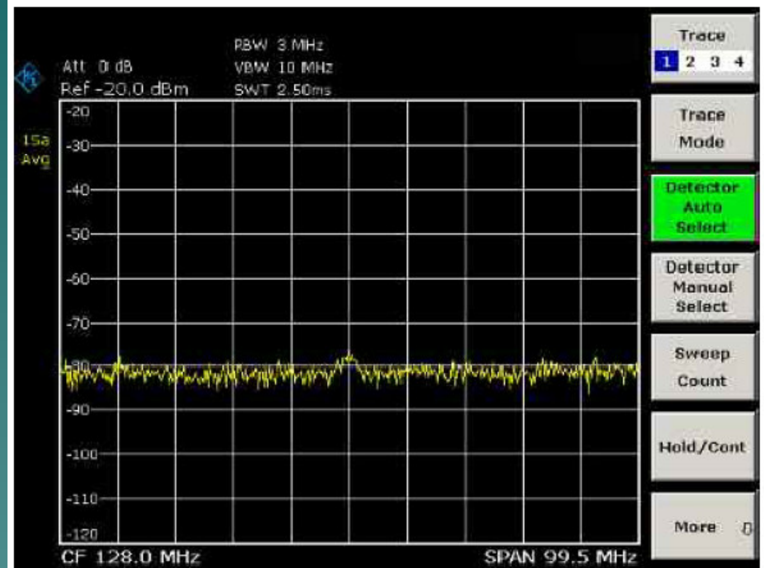
Low SNR Measurements

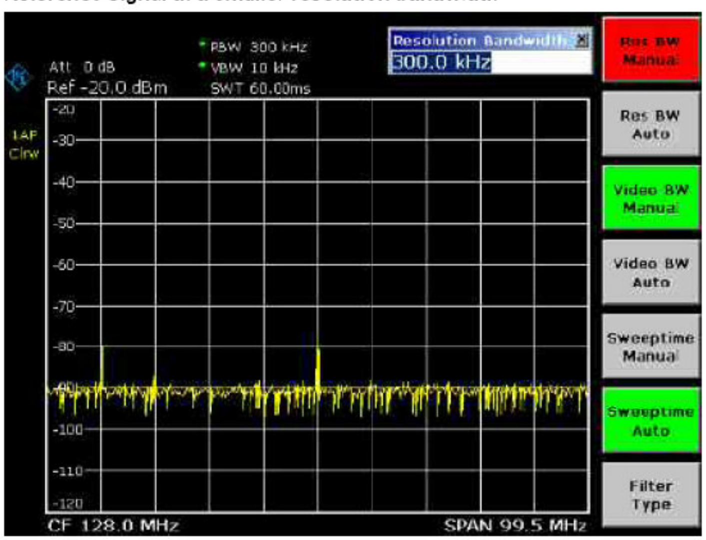
Sinewave signal with low S/N ratio. The signal is measured with the auto peak detector and is completely hidden in the intrinsic noise of the instrument



RF sinewave signal with low S/N ratio if the trace is averaged



Reference signal at a smaller resolution bandwidth



Courtesy Rohde and Schwarz

Spectrum Analyzer 101
Selectivity

- Nearly all selectivity is accomplished in the IF portion of the Spectrum Analyzer.
- Filters set by RBW Control
- Large Bandwidth—L & C filters
- Medium Bandwidth—Crystal Filters
- Small Bandwidth—DSP filters
- RBW vs VBW
  - RBW filter actual signals
  - VBW filters after detection occurs

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Selectivity

– LC Filters drift and require more alignment.
– How do they make filters have exactly the same performance from unit to unit?
– Self alignment process trims the LO's
– DSP—Most stable & less correction needed
– Shape Factor—10:1 or 2:1?
  - Ratio of 60 dB to 6 dB
  - In general the lower the better and especially for sharp transition bandwidth signals like DTV or IBOC

Spectrum Analyzer 102
Analog and Digital Measurements

- We think of Analog signals as sine waves with narrowband modulation.
- Sine waves use very small bandwidth (relative to Spectrum Analyzer RBW filters) so almost no matter what RBW is selected, the spectrum measured does not change.
- Digital signals are combinations of sine waves but have large spectrums and are generally randomized to prevent propagation from affecting the signal.

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8-VSB and IBOC signals are noise-like signals and thus the Spectrum Analyzer displays them as such.

Therefore, the total signal amplitude is dependent on RBW used for the measurement instrument.

$$P_{dBm_{500\,kHz}} = P_{dBm_{10\,kHz}} + 10\log\left(\frac{500\text{kHz}}{10\text{kHz}}\right) = P_{dBm_{10kHz}} + 17.0\text{dB}$$

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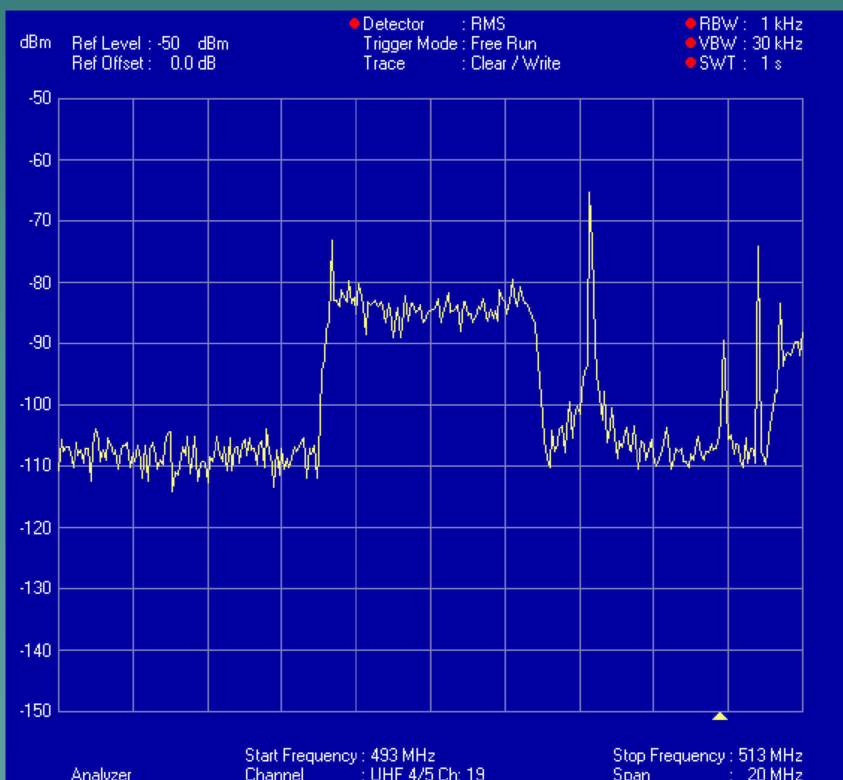
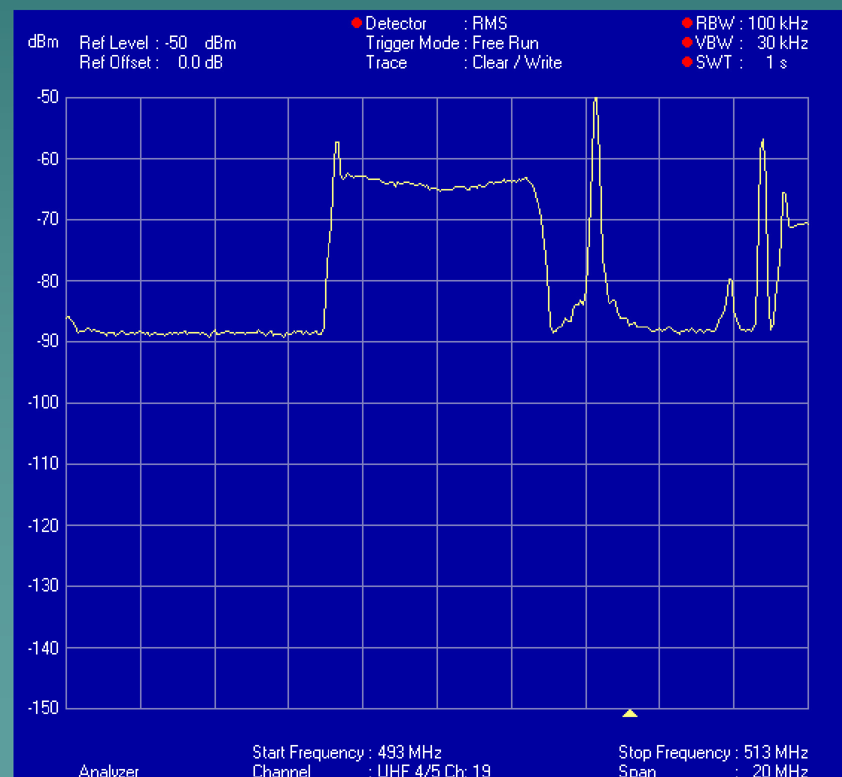
Displayed Signal changes with RBW

RBW =1 kHz



RBW =100kHz



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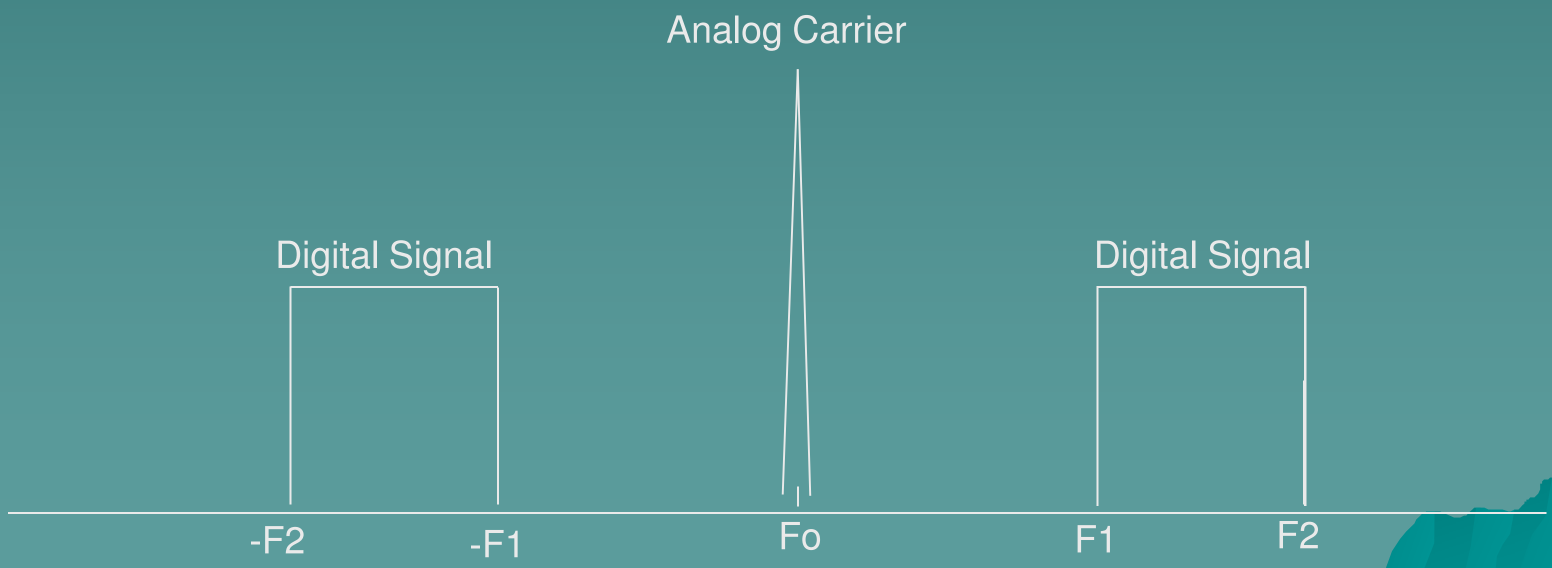
Hybrid analog and digital spectrum



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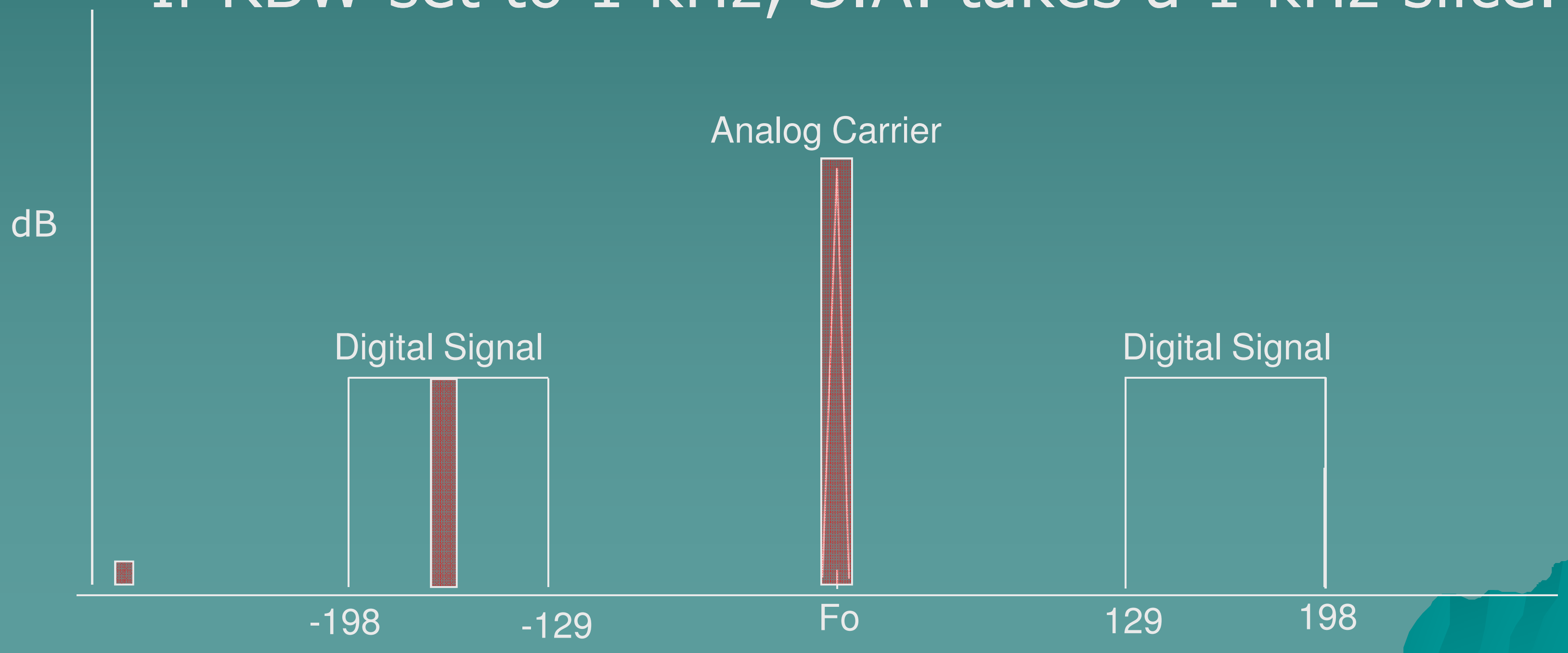
Spectrum analyzer measures the signal in the RBW of the instrument setting.

If RBW set to 1 kHz, S.A. takes a 1 kHz slice.



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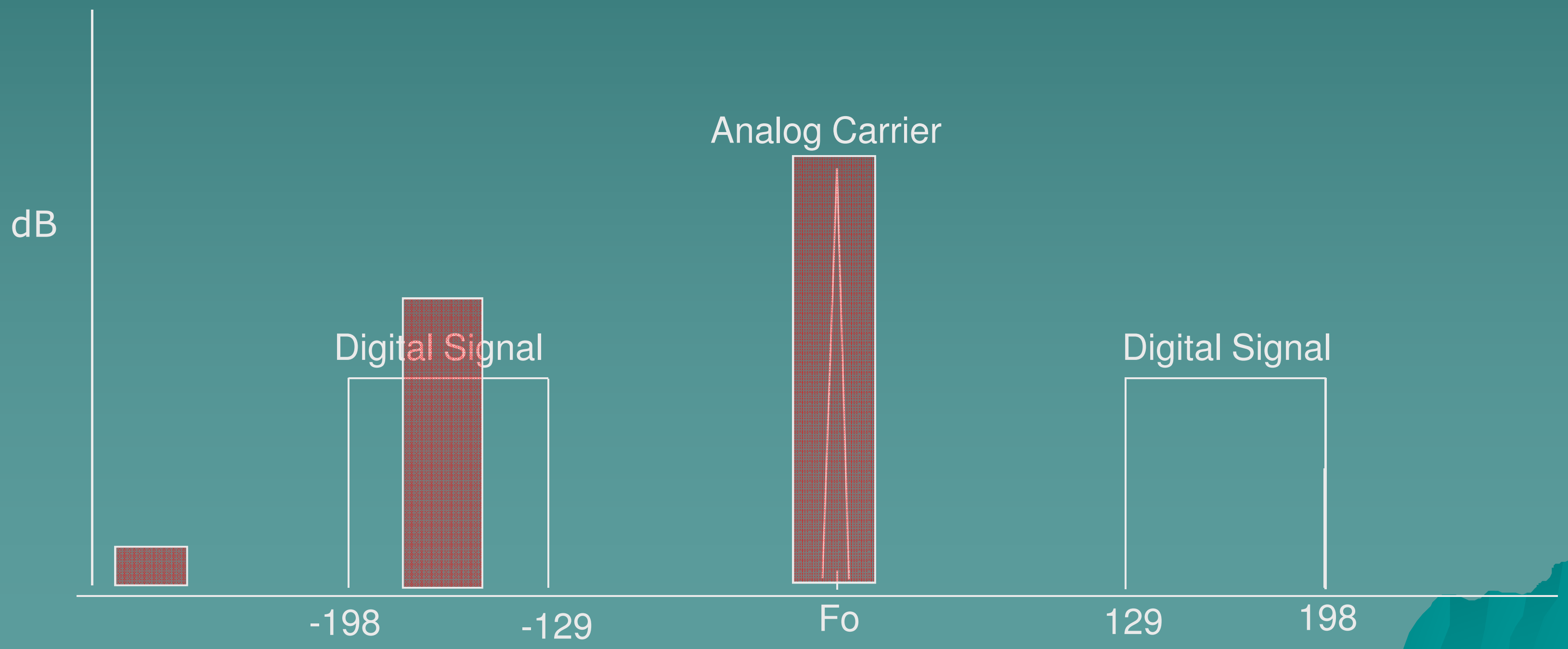
Now the same spectrum using a 10 kHz RBW
If RBW set to 10 kHz, S.A. takes a 10 kHz slice.



Spectrum Analyzer 102
Hints and Kinks

- Most errors result from detector settings.
  - 2.5 dB error between peak detector and RMS detectors
- Frequency counters on Spectrum Analyzers very handy for digital signals.
- Before you apply the signal estimate the amplitude and start with more attenuation than you need

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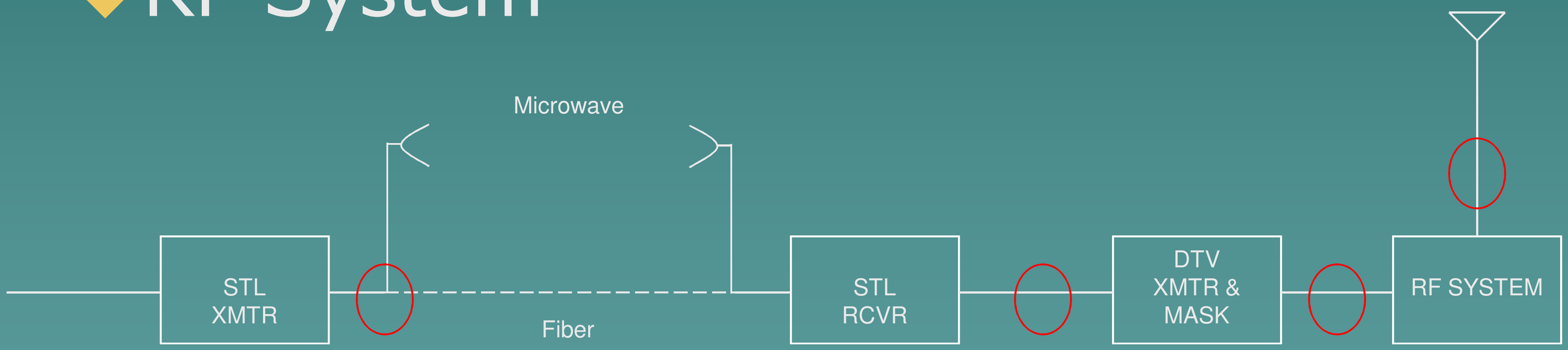
Transmitter Measurements

- STL
- Main Transmitter
- RF System



Spectrum Analyzer 102
Hands on Measurements

- FM IBOC Emission Mask Compliance
- Harmonics
- DTV Shoulders
- DTV SNR
- Frequency Tolerance

Spectrum Analyzer 102 Summary and Conclusion

- One Commandment

- "Know thy measurement instrument"
  - Spectrum analyzer strong and weak points
  - Don't assume default settings are fine
  - Instrument characteristics & settings—determines resultant accuracy
    - Attenuator setting determines mixer level & IMD
    - RBW—Use the same for all measurements if possible
    - Normally use VBW as 10X the RBW
    - Detector setting depends on type of measurement

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Questions???