Antenna Lab – Report#1

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Report #1

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Summary: How a Spectrum Analyzer Works

Definition and Purpose

A Spectrum Analyzer is a device, **that receives RF signals**, **measured** their **magnitude versus frequency**, and **processes** the **signal according to display settings we have set**, in order to **display it appropriately** based on how we want to observe the signal.

What does it simply do?

The main job of a Spectrum Analyzer, as its clear according to its name, is to **compute the Fourier Transform** of a **received RF signal** and **display** it within the **frequency range** we want.

Test types using a Spectrum Analyzer: 1. Modulation, 2. Noise, 3. Distortion

Spectrum Analyzer Specifications (Amp, Freq. Domain)

1. Frequency Range:

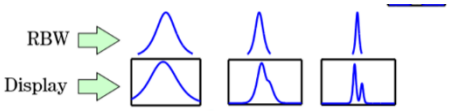
- The frequency range of a spectrum analyzer should **cover the entire spectrum of RF signals we want to observe** and examine.
- Furthermore, it needs **both wide/narrow spans** when needed, **wide span** for when we want to **observe signal harmonics** and **narrow span** for **frequency selective details** around a monotone.
- Usually the span, should **cover a noise band around the subject area**, so that noise levels are clearly separated from weak signal amplitudes

2. Accuracy (Both in Amp. & Freq. domains):

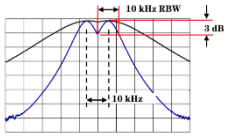
- All the **confidence** we have in **interpreting** our **results**, relies on the amplitude and frequency acc. we have.
- A **low amplitude accuracy** may **cause noise/signal confusion.**
- A **low frequency accuracy** may cause **non-accurate modulation** and **display** and **therefore non-reliable deductions**

3. Resolution Bandwidth (RBW):

- RBW is **the 3dB bandwidth** of the input signal to the IF filter.
- RBW should be **large enough to separate close frequencies** and **small enough to not lag behind real time fast frequency oscillations**. Thus, there's a **trade-off** between the **resolution (frequency separation)** and the **processing delay** we expect from an **IF filter**.



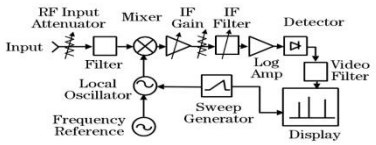
- Ex: RBW should be many times larger than 10kHz for a signal containing two monotones separated 10kHz apart. For instance, it should be 40, 50 kHz:



4. Amplitude Specifications:

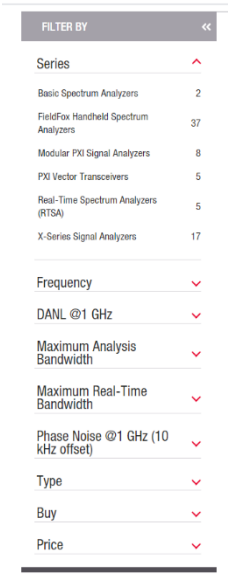
- Measuring **strong signals needs attenuation** to **prevent damage**. (Ex: 50dB attenuation for a 100W signal)
- **No Attenuation** should be done for **weak signals** due to **signal/noise confusion**.
- **Sensitivity** is a very important factor as it determines the **minimum signal amplitude** that can be **separated from noise.**
- **Dynamic Range:** The range between the maximum and minimum sensible amplitudes.

Main Components of a Spectrum Analyzer



Component	Purpose	How it works	Main Parameter	Important tips		Neighbor Components
Attenuator	Prevent system damage caused by strong signals	Reduces power of the signal based on a resistance division circuit	Attenuation level (Gain)	Gain should be set to 0 for weak input signals due to noise confusion	Flat frequency response to avoid distortion!	Input, BP filter
Main BP filter	Freq. Range Selection	-	f_{stop} , f_{start}	Flat response required to avoid distortion		Attenuator, Mixer
Mixer (Modulator)	Shift RF frequencies to IF range	Modulating filtered input and LO signals to construct proper IF signal	-	Can be done in 2 steps (via Super-heterodyne receiver) or in 1 step		LO, BP filter
IF Amplifier	Amplifying attenuated signal	-	Gain	Attenuation and Gain should cancel out each other in all frequencies		Mixer, IF filter
IF filter	Noise Control	Separate signal/noise according to RBW level	RBW	$RBW \uparrow \leftrightarrow Noise\ level \downarrow \leftrightarrow Process\ Delay \uparrow$ High RBW shouldn't be used for signals with fast frequency variations		IF amplifier, Detector
LO (Local Oscillator)	Producing needed frequencies for IF modulation	Connected to a sweep generator	Reference Freq., Operation BW	Should be capable of shifting and sweeping, wide operation BW due to wide RF range input		Mixer, Sweep generator, Frequency reference
Detector	Envelope Detection, Signal Power Measurement	-	Sensitivity, Mode: (Positive, Negative, Sample (RMS))	High sensitivity needed to separate weak signals from noise		IF filter, Video Filter
Video Filter	Averaging Signal to prevent deviations	LPF smoothing undesirable oscillation	f_{stop}	-		Detector, Display monitor

Bonus Part: Brief Comparison - Keysight Spectrum Analyzers



- Specifications and Parameters to compare:

After entering the main website of the company, and going to the Spectrum Analyzer part, we can see a panel on the left, which is used to **filter different products according to various aspects** such as:

- **Series**: (Basic, Field-fox handheld, Modular PXI, PXI vector transceiver, RTSA (Real-time Spectrum Analyzer), X-series)
- **Type**: (Benchtop, Handheld, Modular, Real-Time, Vector)
- **Operation Frequency**: (Total range: 1Hz – 50GHz)
- **DANL** (Displayed Average Noise Level): (Total Range: from -145dBm/Hz, to -174dBm/Hz)

It's a measure used to **define the sensitivity of a spectrum analyzer**. The DANL specifies **all the internal noise** of the spectrum analyzer **referenced to 1 Hz** and **represented in dBm/Hz**. The DANL is **frequency dependent** and it **increases** with frequency. Spectrum analyzers use **preamplifiers** to **reduce DANL**. The instrument is unable to measure any input signal that is below this level.

- **Maximum Analysis BW**: (ABW) (Total Range: 1.5 MHz – 11Ghz)
  The analysis bandwidth defines **the maximum bandwidth** that can **be recorded simultaneously with** the analog-to-digital converter (**ADC**) used by the spectrum analyzer. **The signal's bandwidth must be smaller or equal to the ABW**.

What's it's difference with RBW (Resolution Bandwidth)?
RBW limits the bandwidth of a signal **before it is digitized and displayed on the screen**

- **Maximum Realtime BW:** (Total Range: 10 MHz – 510MHz)

This is the widest **bandwidth** over which the RSA can capture/record signals over **time**. It is also **the widest Span** that the device's display can present "**live**" without sweeping, for **real-time** analysis

- **Phase Noise:** (Referenced in 1Ghz, 10kHz offset):
  Phase noise is the **frequency-domain representation** of the **random fluctuations** in the **phase** of a waveform, due to **time-domain deviations from perfect periodicity**(**jitter**). **RF engineers** should consider **Phase Noise of an Oscillator**, whereas **Digital System Engineers** should consider **jitters of a clock**

- **Price:** (8970 – 59531 U.S $)

As there are a lot of spectrum analyzers in the website, I have chosen 5 of them from the **X-series spectrum analyzers** to compare:

- Comparison Table:

Product Model	Operation Frequency	DANL @ 1GHz(dBm)	Maximum ABW	Maximum RT-BW	Phase Noise (dBc/Hz)
N9042B 	N/A	-174	11 GHz	N/A	N/A
N9021B 	N/A	-172	510 MHz	N/A	-130
N9042B 	2Hz – 110GHz	-174	1 GHz	255MHz	-135
N9000B 	9kHz – 26.5 GHz	-163	25 MHz	N/A	-110
N9030B 	N/A	-174	510 MHz	510 MHz	-136

For example, if we want to compare N9030B with N9042B, the N9030B has a better real time performance due to higher RT-BW, but weaker ABW(RBW), resulting in less separation of close monotones. Both have similar Average Noise level at 1GHz (reference frequency) and similar Phase Noise levels.

References

1. https://www.keysight.com/us/en/catalog/key-34567/spectrum-analyzers-signal-analyzers.html
2. https://www.everythingrf.com/community/what-is-danl#:~:text=DANL%20or%20displayed%20average%20noise,and%20it%20increases%20with%20frequency.
3. https://www.tek.com/blog/real-time-acquisition-and-measurement-bandwidth#:~:text=Real%20Time%20Bandwidth%3A%20This%20generally,%2C%20for%20real%2Dtime%20analysis
4.