University of Puerto Rico

Electrical and Computer Engineering

Radio Frequency Spectrum Management Workshop

Presented at the UPR/RUM Radio Frequency Spectrum Management Workshop

Spectrum Monitoring and Measurements

ITU EM1 – SMM

May 25, 2015

James S. Avilés

Senior RF Spectrum Engineer

Workshop Briefing Outline

- ITU Spectrum Management Training Program (SMTP)
- ITU SMTP Reference Model for RF Workshop – OM3/EM1
- The Spectrum Analyzer
- Spectrum Analyzer Resolution Bandwidth
- Spectrum Measurements Accuracy
- Spectrum Analyzer Sensitivity
- Spectrum Analyzer Distortion
- Real Time Spectrum Analysis
- Spectrum Analyzer Costs
- Very Low Cost SDR Alternatives

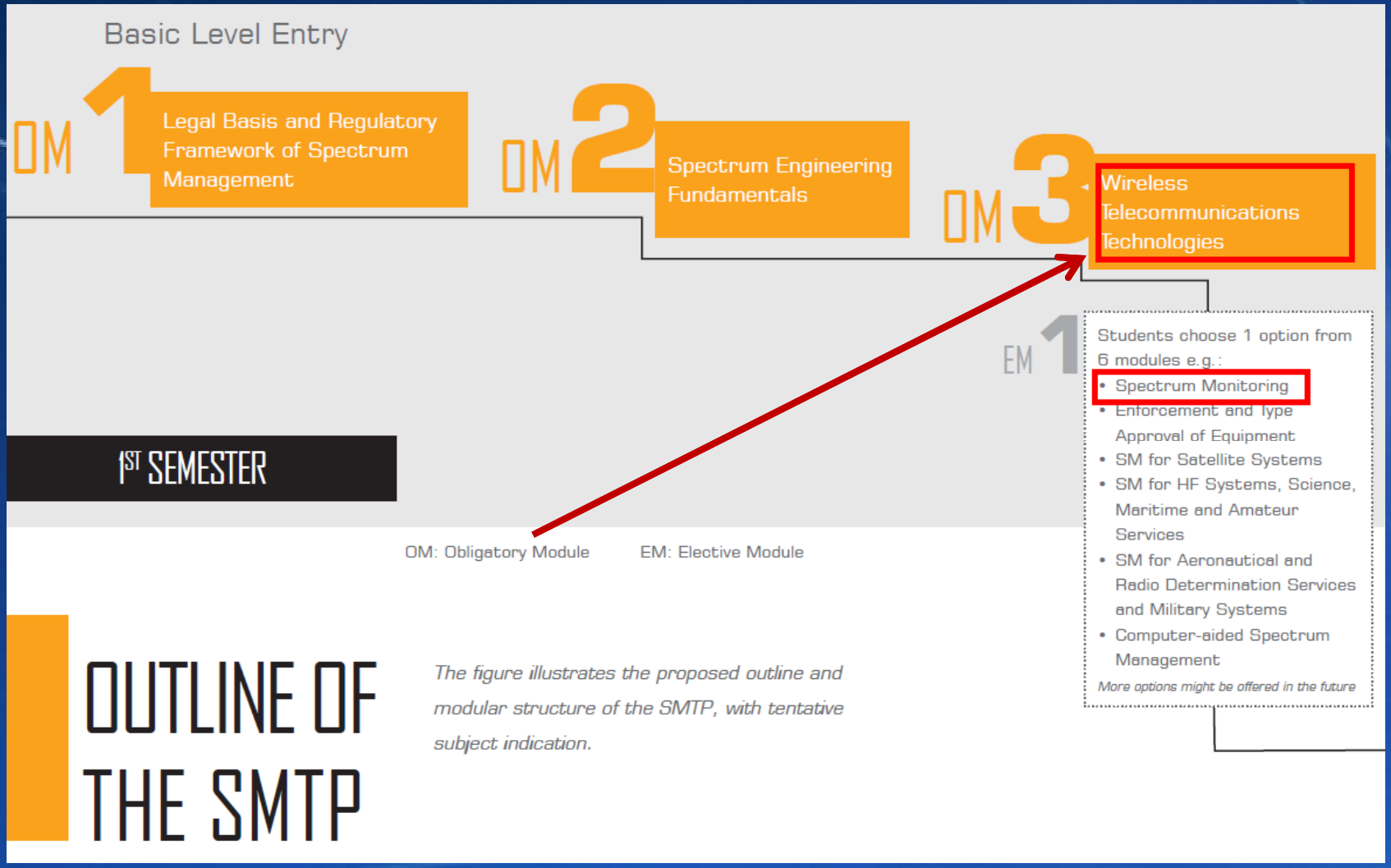
RF Workshop Reference Model

ITU Academy
empowering minds

International Telecommunications Union Initiative for:

Spectrum Management Training Program

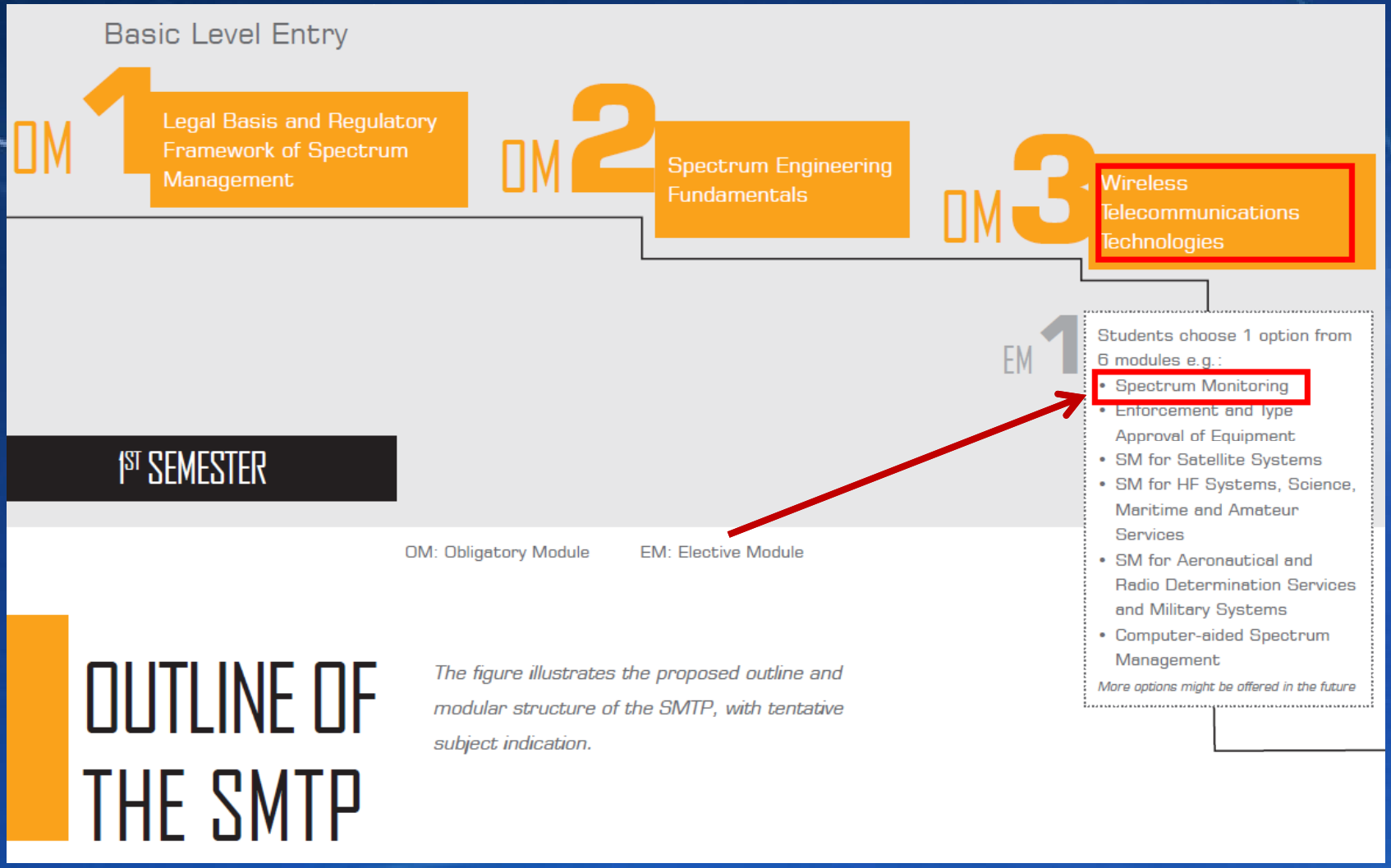
Obligatory Module OM3 – WTT



OUTLINE OF THE SMTP

The figure illustrates the proposed outline and modular structure of the SMTP, with tentative subject indication.

Elective Module EM1 – SMM



OUTLINE OF THE SMTP

The figure illustrates the proposed outline and modular structure of the SMTP, with tentative subject indication.

Other SMTP Modules

Advanced Level

2ND SEMESTER

OM 4 Economic and Market Tools of Spectrum Management

OM 5 Strategic Planning and Policies for Wireless Innovation

EM 2

Students choose 2 options from 4 modules:

- Advanced Spectrum Authorization Regimes
- Terrestrial TV Broadcasting Planning and Digital Transition
- Socio-economic Impact of Spectrum Regulation; Competition and Consumer Protection
- Opportunistic Spectrum Access and Cognitive Radio

More options might be offered in the future

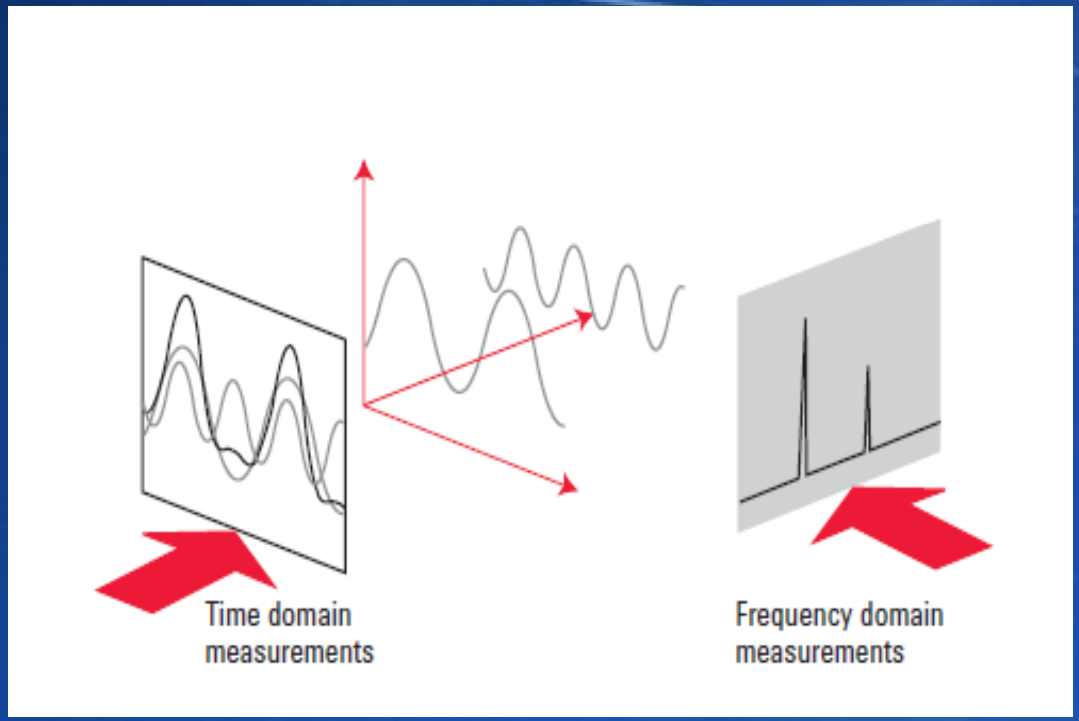
Optional Master Thesis in case of pursuing MSc academic diploma

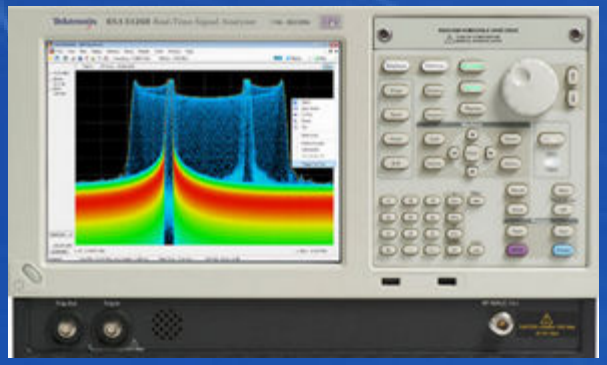
3RD SEMESTER

Possibility of Advanced entry point subject to test

The Spectrum Analyzer

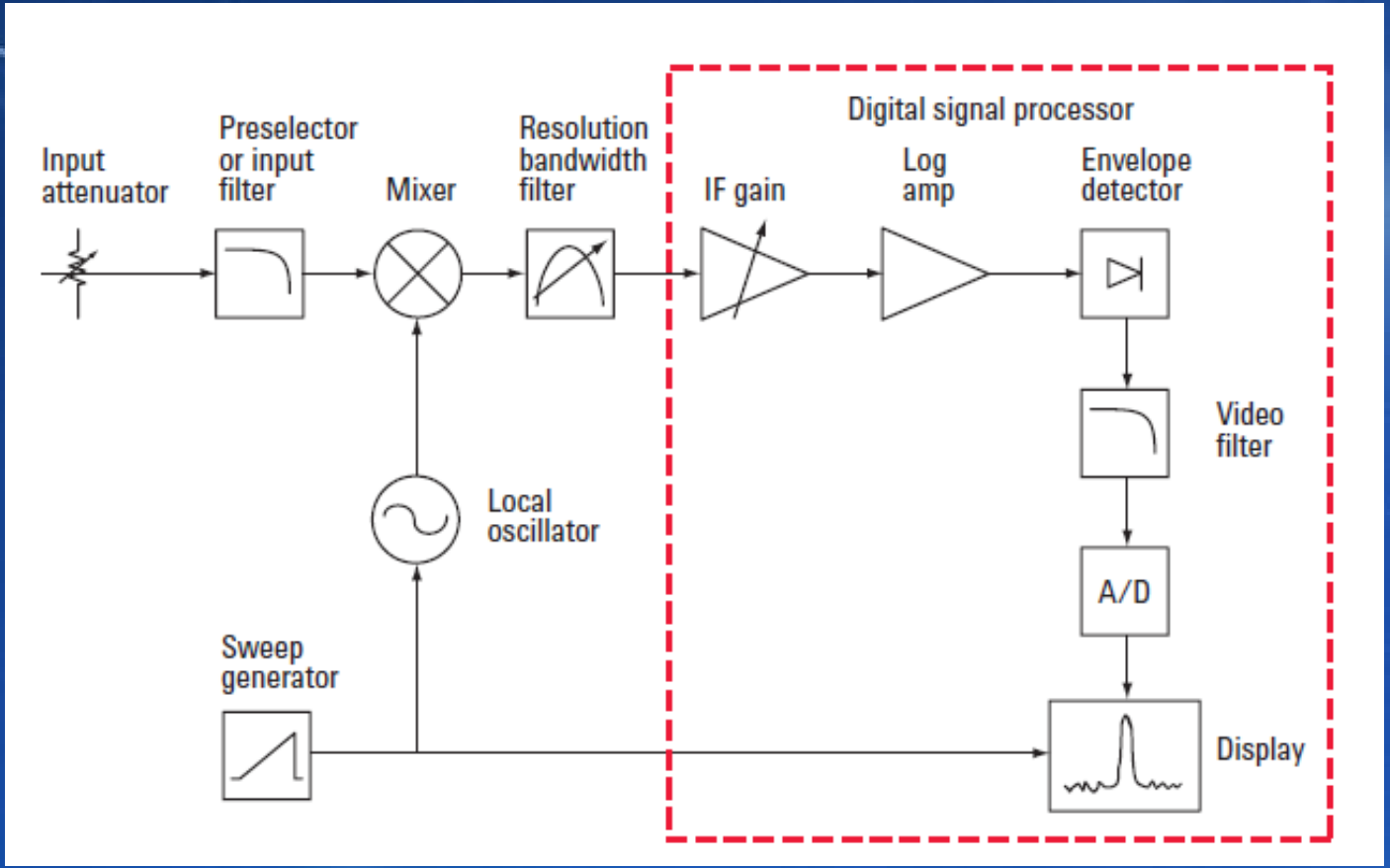
- The spectrum analyzer is the essential tool used for measuring electromagnetic signals in the Frequency Domain. The well known oscilloscope provides a window to measuring signal in the time domain.





Spectrum Analyzer Block Diagram

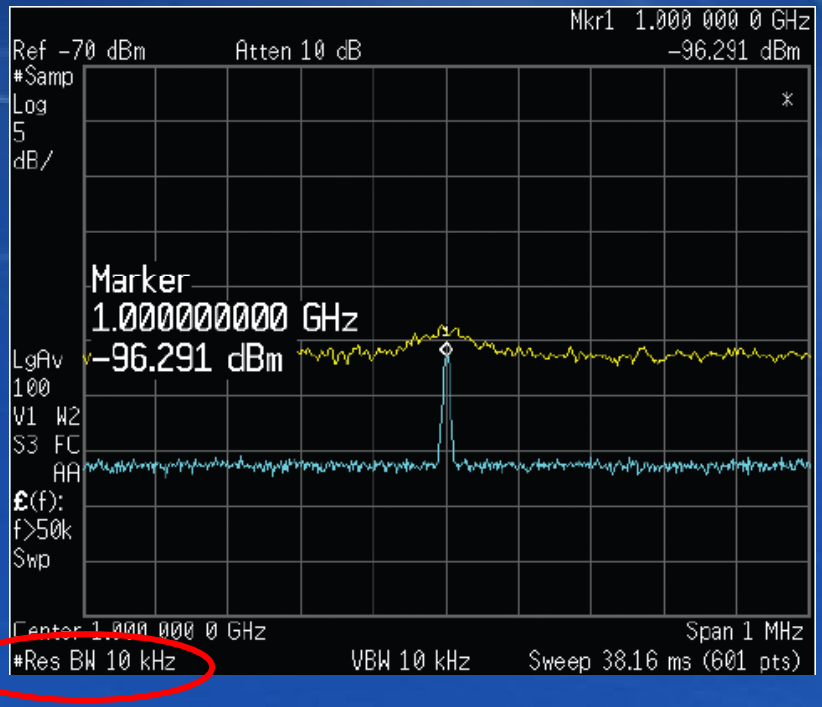
When digital technology first became viable, it was used to digitize the input signal. As digital technology has advanced, the spectrum analyzer has evolved to incorporate Digital Signal Processing (DSP).



Selecting the Best RBW

- Resolution Bandwidth (RBW) must be considered when separating spectral components, setting an appropriate noise floor and demodulating a signal.

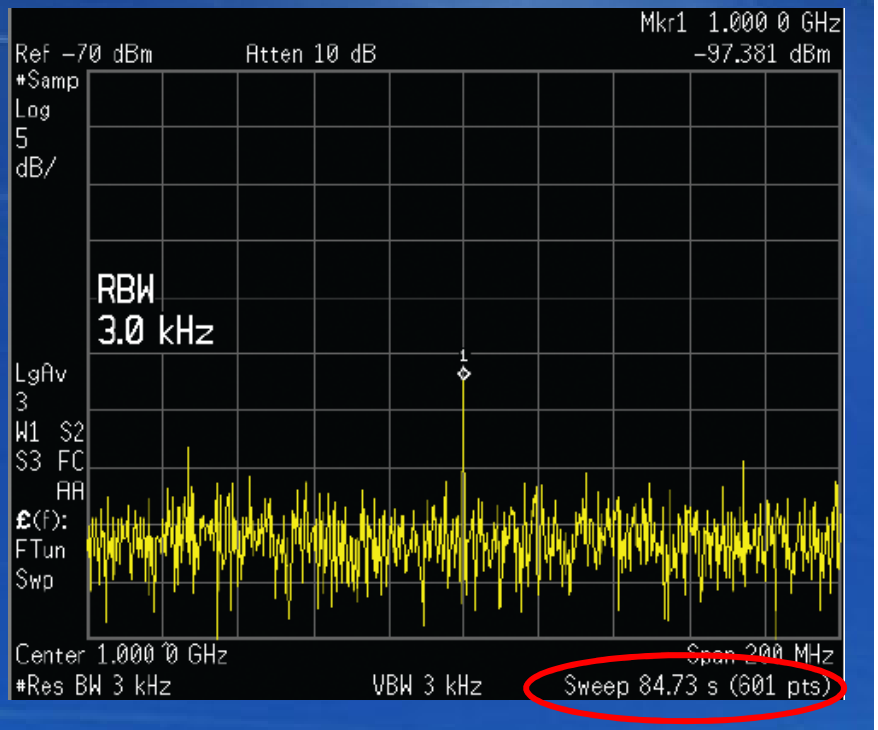
- Using a narrow RBW is best when making Accurate Measurements of low-level signals. When using a narrow RBW, the displayed average noise level (DANL) of the spectrum analyzer is lowered, increasing the Dynamic Range and improving the sensitivity of the spectrum analyzer. A –96 dBm signal is more properly resolved by changing the RBW from 100 kHz to 10 kHz.



Measurement Accuracy

- Narrowest RBW setting is not always ideal. For modulated signals, the RBW should be set wide enough to include the sidebands of the signal. Neglecting to do so will make the measurement very Inaccurate.

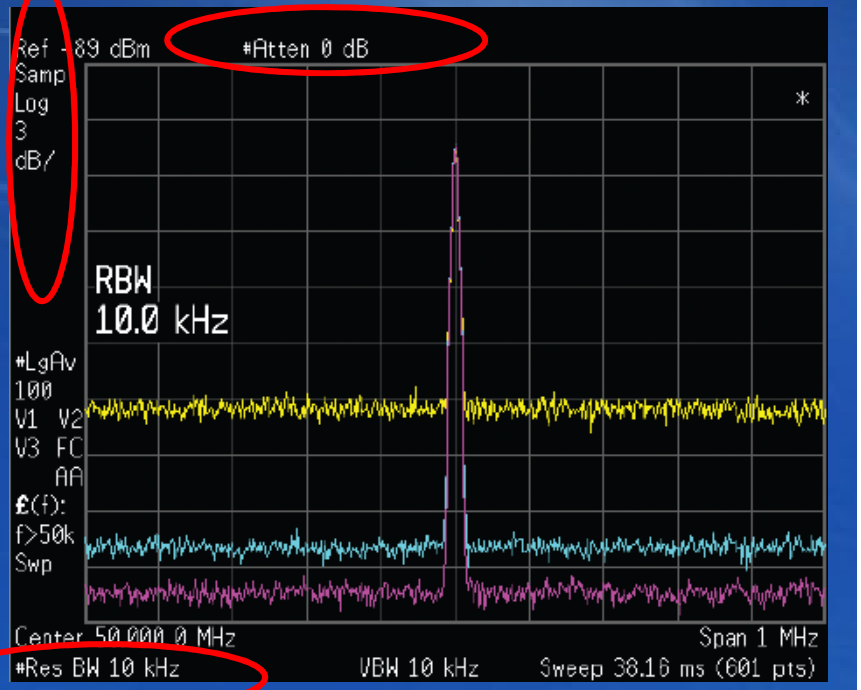
- A serious drawback of narrow RBW settings is in Sweep Speed. A wider RBW setting allows a faster sweep across a given span compared to a narrower RBW setting. A Sweep time of 84.73 seconds for 3 kHz RBW will be very long when measuring at 200 MHz span using sample detector. A sweep time of 7.626 seconds is achieved with 10 kHz RBW.



Sensitivity for Low-level Signals

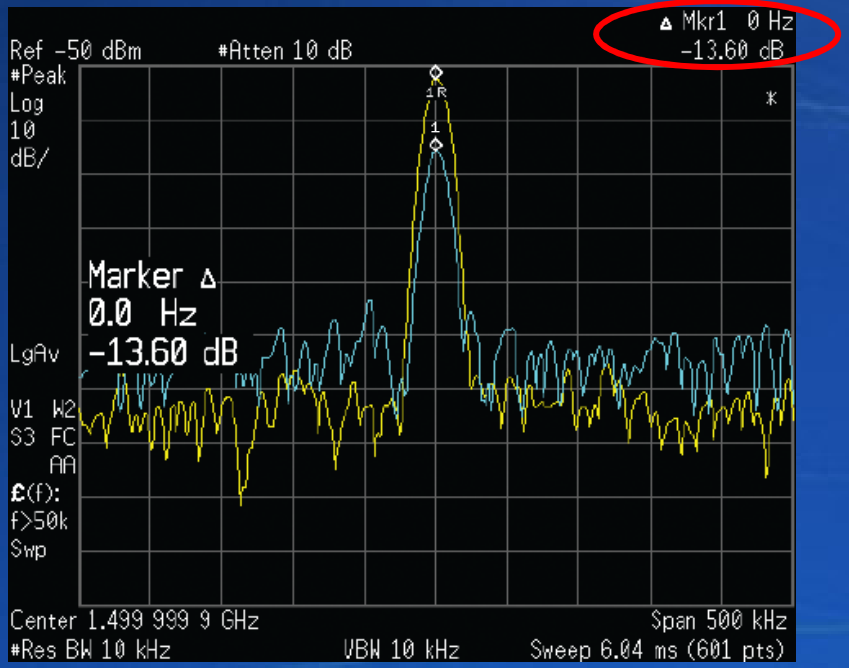
- A spectrum analyzer's ability to measure low-level signals is limited by the Noise Generated Inside the spectrum analyzer. This sensitivity to low-level signals is affected by the analyzer settings.

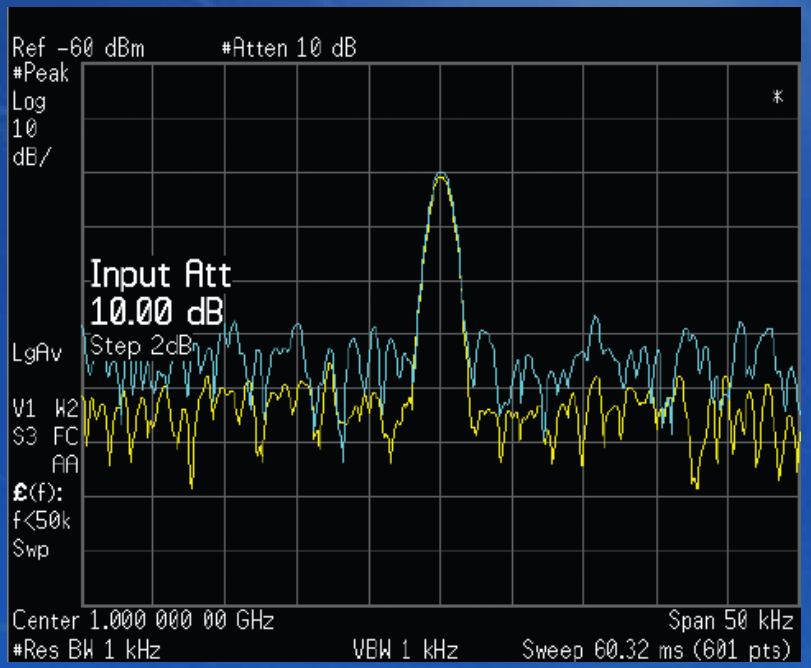
- To measure the low-level signal, the spectrum analyzer's sensitivity must be improved by minimizing the input attenuator, narrowing down the resolution bandwidth (RBW) filter, and using a preamplifier. These techniques effectively lower the displayed average noise level (DANL), revealing the low-level signal. Noise is generated after the input attenuator, the attenuator setting affects the signal to- noise ratio (SNR)



Internal Distortion High-level Signals

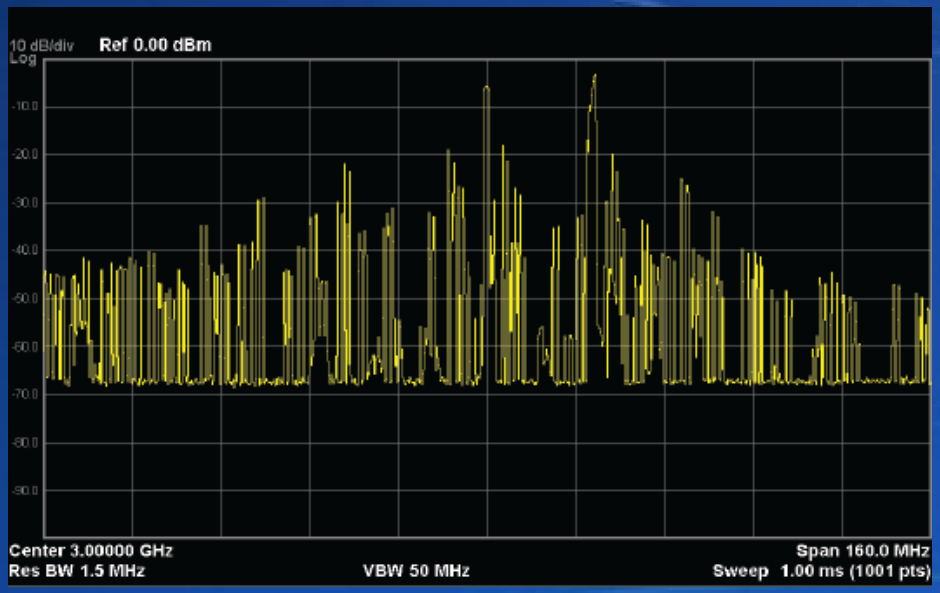
- High-level input signals may cause internal spectrum analyzer distortion products that could mask the real input signal. Using dual traces and the analyzer's RF attenuator, you can determine whether or not distortion generated within the analyzer has any effect on the measurement.

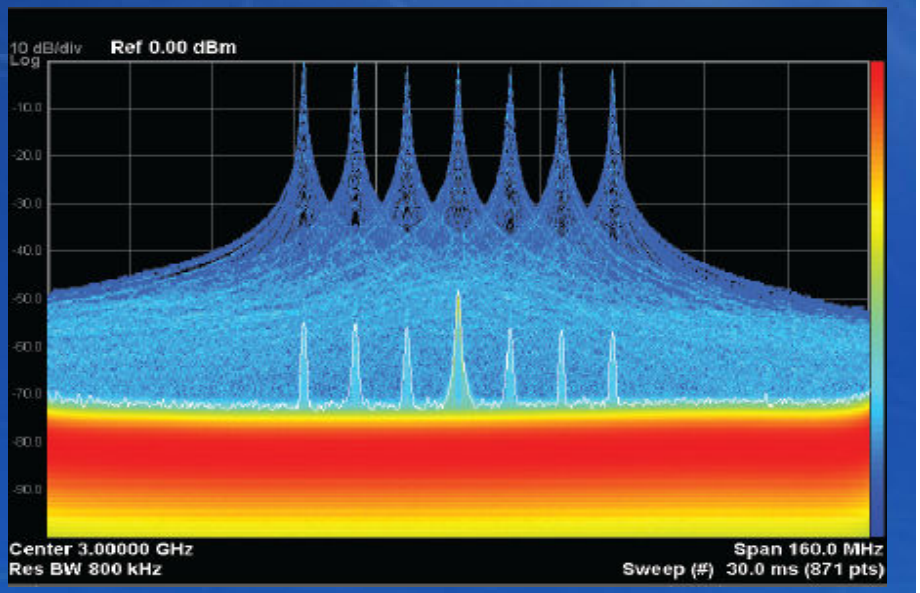




Real-Time Spectrum Analysis

- Today's Complex and Agile signals environments are proving to be challenging. To keep up with evolving Spectrum analysis needs, new types of analyzers have emerged in recent years. Analyzers now offer a combination of Swept spectrum, Real-Time signal analysis capability.





Spectrum Analyzer Costs

- Many Manufacturers of Spectrum Analyzers have developed units to meet the field Spectrum Engineers needs for handheld platforms. This handheld platform has revolutionized the ability of field engineers to perform measurements. Costs are still above or around the $5,000 threshold for used and refurbished units.

Keysight (Agilent)

$12,420.30

Rohde & Schwarz

$4,750.00 refurbished

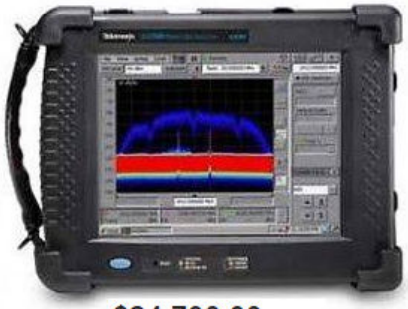
ProTek A734

$5,289.95

Anritsu MS2721B

$5,995.00 refurbished

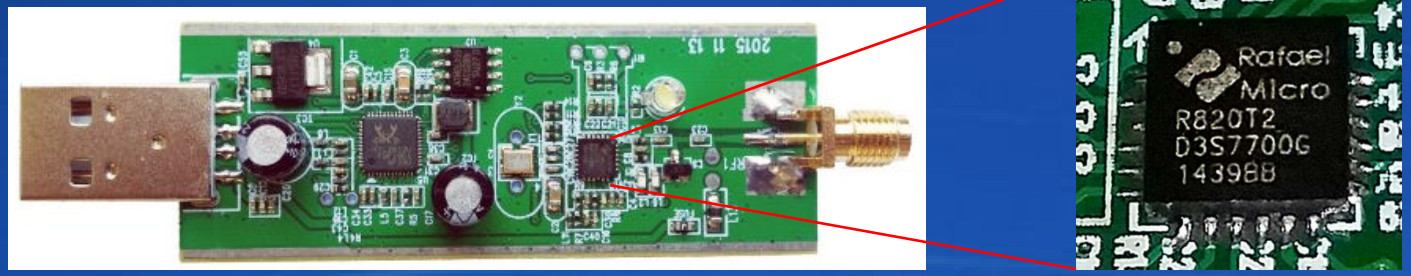
Tektronix H500



$24,700.00 used

RTL2832U DVB-T SDR Alternative

- **A very low cost software defined radio that uses a DVB-T TV tuner dongle based on the Realtek RTL2832U chipset:**
  - **The chipset signal I/Q data can be accessed directly, allowing it to be converted into a wideband software defined radio (SDR) with the use of a personal computer and software drivers.**
  - **Radio components such as modulators, demodulators, amplifiers are traditionally implemented in hardware. Modern computers allows most of these traditionally hardware based components to be implemented into software instead.**



What is the Cost?

- SDRs are showing up every few months. This list of some available SDRs compare their cost, frequency range, Analog-to-Digital Converter resolution, maximum instantaneous bandwidth, if it can transmit (TX) and if it has any pre-selectors built in.
  - Frequency Range: The range of frequencies the SDR can tune to.
  - ADC Resolution: Higher resolution means more dynamic range, less signal imaging, a lower noise floor, more sensitivity when strong signals are present and better ability to discern weak signals. Some SDR's give their resolution in ENOB which stands for Effective Number of Bits.
  - Instantaneous Bandwidth: The size of the Real Time RF available.
  - RX/TX: Can the radio receive and/or transmit.
  - Preselectors: Analogue filters on the front end to help reduce out of band interference and imaging.

Round-Up of Low-Cost SDRs

- **R820T RTL2832U – RTL-SDR**
  - Cost: $10 to $24 USD
  - Freq. Range: 24 to 1766 MHz
  - ADC Resolution: 8 Bits
  - Max BW: 3.2 MHz
  - TX/RX: RX Only
  - Preselector: None

- **SDRPlay RSP**
  - Cost: $150 USD
  - Freq. Range: 100 kHz to 2000 MHz
  - ADC Resolution: 12 Bits
  - Max BW: 8 MHz
  - TX/RX: RX Only
  - Preselector: Yes 8 Switched Filters

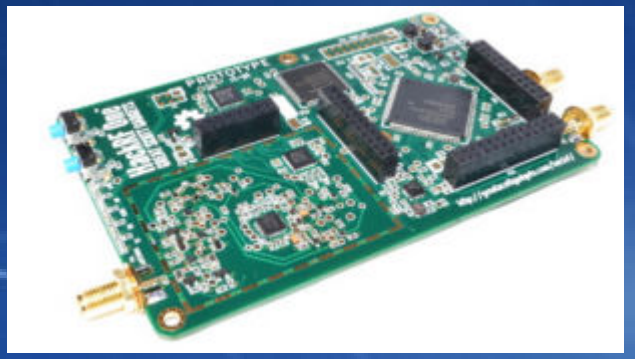
More Low-Cost SDRs

- **AirSpy**
  - Cost: $199 USD
  - Freq. Range: 24 to 1750 MHz
  - ADC Resolution: 12 Bits
  - Max BW: 10 MHz
  - TX/RX: RX Only
  - Preselector: Yes, Tracking RF Filters

- **FunCube Dongle Pro+**
  - Cost: $210 USD
  - Freq. Range-1: 150 kHz to 260 MHz
  - Freq. Range-2: 410 MHz to 2050 MHz
  - ADC Resolution: 16 Bits
  - Max BW: 192 kHz
  - TX/RX: RX Only
  - Preselector: Yes 11 Switched SAW Filters

Even More Low-Cost SDRs

- **HackRF One**
  - Cost: $299 USD
  - Freq. Range: 10 to 6000 MHz
  - ADC Resolution: 8 Bits
  - Max BW: 20 MHz
  - TX/RX: TX and RX (Half Duplex)
  - Preselector: None

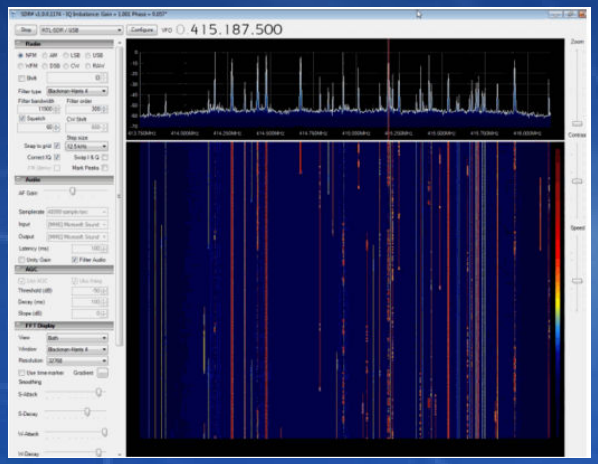


- **Myriad RF**
  - Cost: $299 USD
  - Freq. Range: 300 to 3800 MHz
  - ADC Resolution: 12 Bits
  - Max BW: 28 MHz
  - TX/RX: TX and RX (Full Duplex)
  - Preselector: None

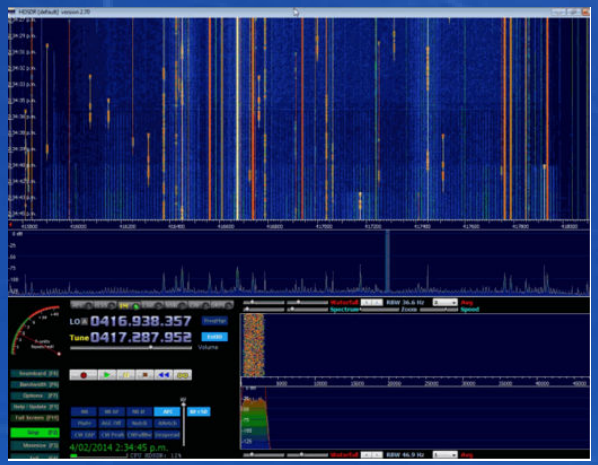
Do They Work ?

- **There are now dozens of FREE Software Defined Radio packages that support these Low-Cost SDRs:**

- **SDR# (Windows) (Free):** The most popular free SDR compatible software in use at the moment. It is relatively simple to use compared to other SDR software and has a simple modular set up procedure.



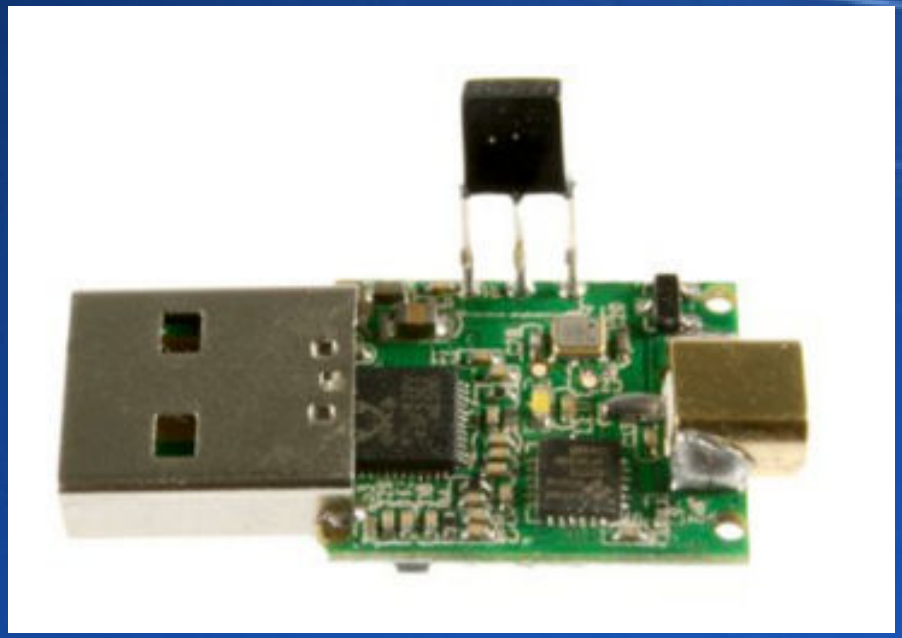
- **HDSDR (Windows) (Free):** Along with an FFT display and waterfall, HDSDR has some extra advanced features. Users will also find an Audio FFT and waterfall display on the bottom of the screen.



Let's Try One and See – Demo

NooElec NESDR Nano 2+ Tiny Black RTL-SDR USB Set (RTL2832U + R820T2) with Ultra-Low Phase Noise 0.5PPM TCXO, MCX Antenna & Remote Control; Software Defined Radio, DVB-T and ADS-B Compatible, ESD Safe

Sale: $27.95 & FREE Shipping



UPR RFSMW Committee Again – Thank You

Dr. Rafael Medina-Sánchez

Assistant Professor

Dr. Leyda León

Assistant Professor

Dr. Sandra Cruz-Pol

Professor

References

[1] Keysight-5992-1480EN

[2] Keysight-5992-1516EN

[3] Keysight-Spectrum-Analyzer-Basics-AN.

[4] Keysight-Spectrum-Analyzer-Tips-AN.

[5] Keysight-Wireless-Site-Survey-Spectrum-Monitoring-Interference-Analysis.

[6] http://en.wikipedia.org/wiki/Software-defined_radio

[7] http://rtlsdr.org/softwarewindows

[8] http://wiki.spench.net/wiki/USRP_Interfaces