EECE 411 – Antennas and Propagation

Module 1B
RF Test & Measurement

Introduction to Spectrum Analyzers

Why Measure the Spectrum of a Signal?

- to characterize noise and interference
- to measure distortion (both intermodulation and harmonic)
- to characterize amplitude, phase, frequency or pulse modulated signals
- to estimate spectrum usage and occupancy

How to Measure the Frequency Content of a Signal?

- Fourier theory works well when applied to mathematical abstractions.
- What about physical signals?
- Options:
  - analog filter bank
  - analog-to-digital conversion followed by a discrete Fourier transform
  - tunable bandpass filter
  - swept frequency spectrum analyzer
- Each approach has particular strengths and weaknesses!

Analog Filter Bank or *Fourier Analyzer*

- The first widely used technique to estimate frequency spectra, analog filter banks of various types have been used for over a century.
- They can be implemented by mechanical, electromechanical, and electronic means.
- *Strengths*: simplicity, low cost
- *Weaknesses*: poor resolution, inflexible configuration, poor performance at low frequencies.
- *Example*: spectrum displays of the sort often found in audio systems.

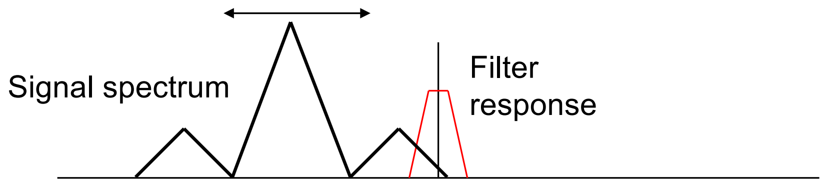
Digital Fourier Analyzer or *Vector Signal Analyzer*

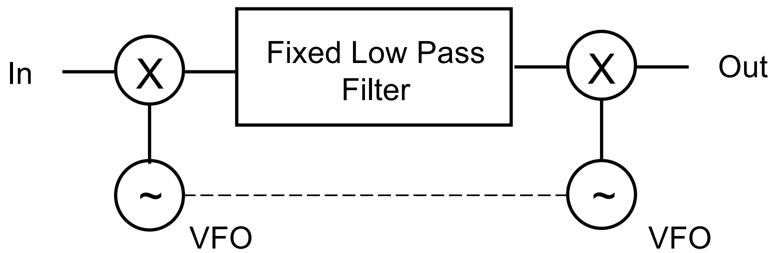
- Digital techniques became practical almost forty years ago with the introduction of the minicomputer and the fast Fourier transform.
- First major application: vibration analysis and biomedical signal processing.
- Initially limited to relatively low frequencies due to hardware limitations, but modern VSA's work up to 10 GHz and beyond.
- *Strengths*: flexibility, stability, recovers both amplitude and phase spectra, recovers all frequencies simultaneously, suitable for measuring transient signals.
- *Weaknesses*: Relatively poor dynamic range (limitation of ADC), and low frequency span (limitations of sampling rate), and high cost (particularly at high frequencies).

Tunable or Frequency Agile Bandpass Filter

- One possibility is to apply the signal of interest to a tunable bandpass filter then sweep the filter through the frequency range of interest while observing the output
- This effectively overcomes the most serious limitation of analog filter banks but implicitly assumes that the spectrum is either time invariant or at least changing much more slowly than the sweep rate.
- The biggest problem: How to build such a filter?
  – Tunable SAW or crystal filters are out of the question. Tunable LC or RC filters are also difficult.
  – One possibility is to use an LO and mixer at the input and another at the output to translate the signal spectrum past a fixed lowpass filter.

Tunable or Frequency Agile Bandpass Filter - 2





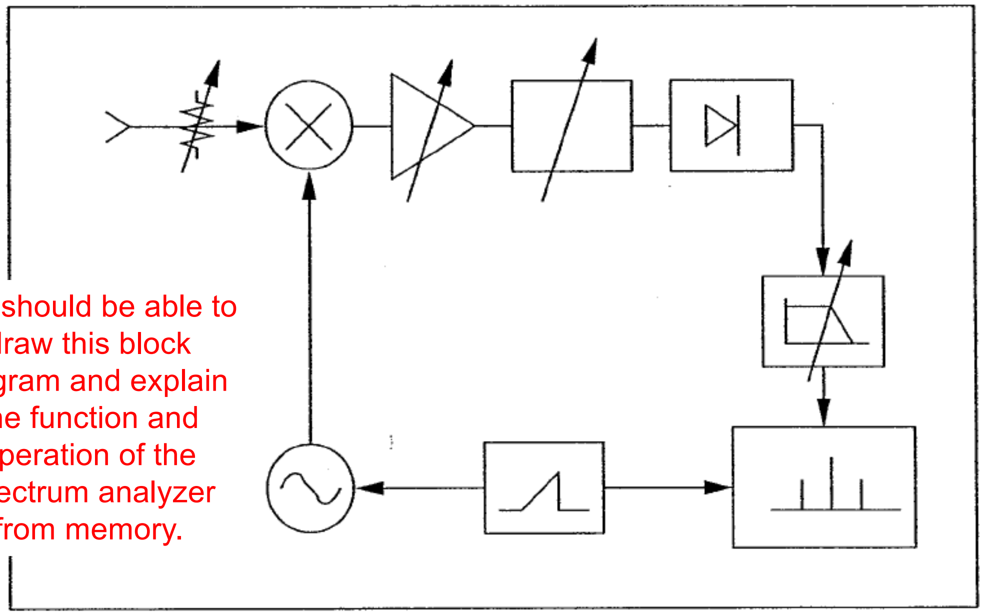
Although one appears to be shifting the corner frequency of the filter, one is actually translating the spectrum of the signal!

- for the details, see Oppenheim & Willsky, pp. 325-6

Swept-tuned Spectrum Analyzer

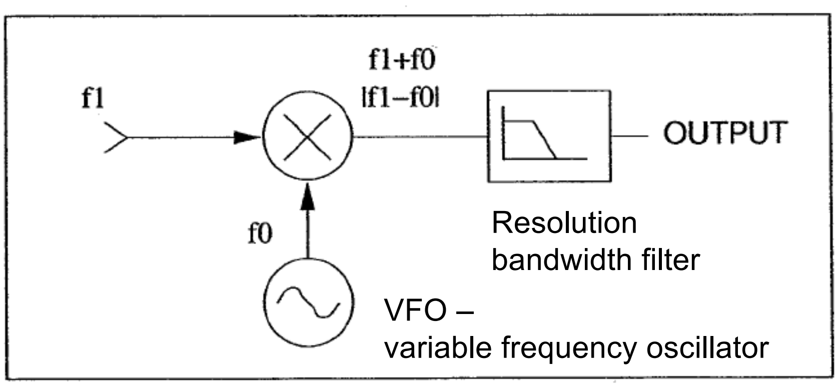
- Swept-tuned spectrum analyzers were introduced during the Second World War as a method for measuring the characteristics of pulsed radar signals.
- They have since become the standard method for measuring the frequency content of RF and microwave signals.
- Used in conjunction with a tracking generator, they can be used to characterize the frequency response of two-port devices.
- *Strengths*: Good dynamic range, broad frequency span, relatively low cost.
- *Weaknesses*: Recovers only the power spectrum, scans the frequency spectrum sequentially, are less suitable for measuring time variant spectra or transient signals.

Inside the Swept-Tuned Spectrum Analyzer



You should be able to draw this block diagram and explain the function and operation of the spectrum analyzer from memory.

The Fundamental Principle of Swept-Tuned Spectrum Analysis



As the f_0 increases, the spectrum of the input signal is translated past the centre frequency of the resolution bandwidth filter. For practical reasons, we normally must employ a bandpass filter rather than the low pass filter shown.

Key Differences between Fourier Theory and Spectrum Analyzer Measurements

	Fourier Theory	Spectrum Analyzer
Spectrum	Two-Sided	One-Sided
Amplitude Spectrum	Yes	Yes
Phase Spectrum	Yes	No
Noise	No	Yes
Spectral Lines	Delta functions	Finite Width

Configuring a Spectrum Analyzer

1. Ensure signal is $<<$ 30 dBm; connect to spectrum analyzer input, possibly through a 20 dB attenuator
2. Set center frequency and frequency span *or* start and stop frequencies
3. Set reference level and dB/division
4. Set resolution bandwidth (video bandwidth and sweep time will be set automatically unless manual mode is chosen)
5. Adjust settings as required to obtain best view of the frequency content of the signal
6. Activate markers and use readout to precisely measure signal amplitudes

Supplementary Materials

- "Spectrum Analyzer Basics," AN-150, Agilent Technologies, 2005.
  - Available from: http://courses.ece.ubc.ca/411/priv/AN150.pdf

- Spectrum Analyzer Multimedia Tutorial for Windows, Agilent Technologies, 2000.
  - Available from: http://courses.ece.ubc.ca/411/priv/Spectrum.zip
  - Installed on the PCs in MCLD 306

- "dB or not dB? - Everything you ever wanted to know about decibels but were afraid to ask," AN-1MA98, Rohde & Schwarz, 2005.
  - Available from http://courses.ece.ubc.ca/411/priv/R&S-dB.pdf