Modulation and Demodulation of Signals

Contributed to the ACAS 2016 School

John D. Fox

Applied Physics Department
Stanford University
Stanford Linear Accelerator Center
Work supported by the DOE under contract # DE-AC02-76SF00515 and the DOE LHC Accelerator Research Program LARP

January 2016

Outline

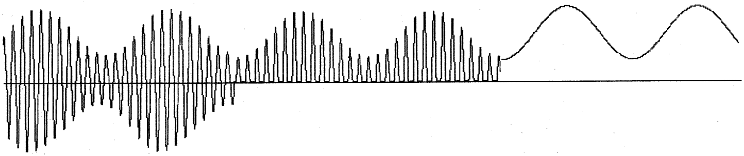
Modulation, Demodulation

- A signal is often represented as a modulation on a carrier
  - AM (Amplitude Modulation)
  - FM (Frequency Modulation)
  - PM (Phase Modulation)
- The signal itself and information is often called the baseband information
- To process and recover the baseband signal, a receiver often heterodynes a modulated signal with local oscillator to translate the information to processing IF (intermediate Frequency)
  - Local Oscillator
  - Mixer
  - Detection method (Diodes? PLL? Slope detector?

Receiving AM and simple detection

Receiving Amplitude Modulated Signals:

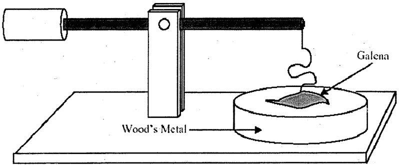
Carrier Frequency: 530-1600 KHz
Modulating Frequency: 20Hz-20KHz

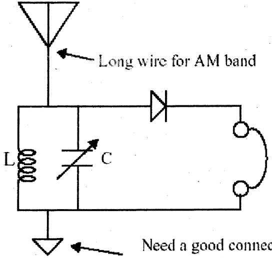


Modulated Waveform Rectified Waveform Demodulated Audio Waveform

Diode Detection

Old Fashioned Radio:





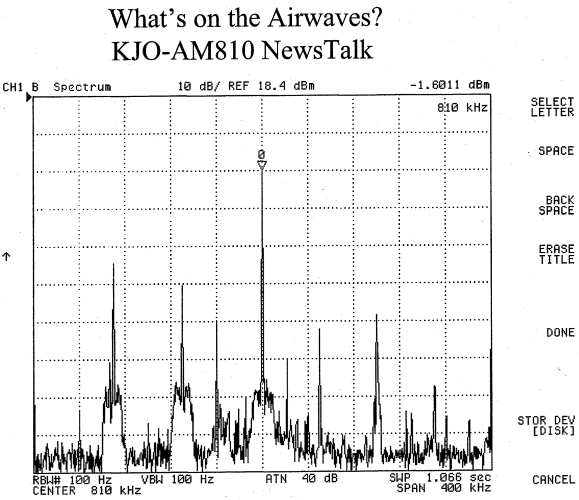
L: Approx. 250µH

C: Approx. 40-400pF to tune AM band

Headphones need to be high-Z (> a few kΩ)

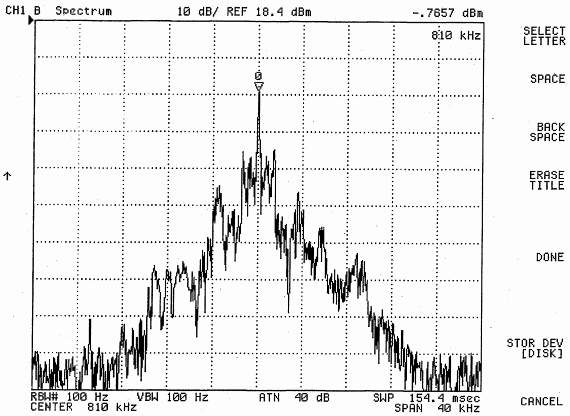
Need a good connection to earth ground for best results (The ground terminal of an AC power outlet often works okay, but be sure to hook things up right, or there could be some measure of unpleasantness)

Selecting a Station



AM modulation sidebands around the Carrier

What do you think of Sammy Sosa's corked bat, Jeff?



Spectra for FM and PM modulation

Frequency Modulation

$$A cos(\omega' t + \Phi)$$
$$\omega' = \omega_c(1 + k cos(\omega_m t)) \quad (1)$$

k is modulation index

Φ Modulation

$$A cos(\omega_c t + \Phi\prime)$$
$$\Phi' = \Phi_0(1 + k cos(\omega_m t)) \quad (2)$$

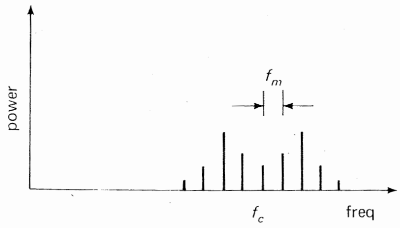


Figure 13.44. Wideband FM spectrum.

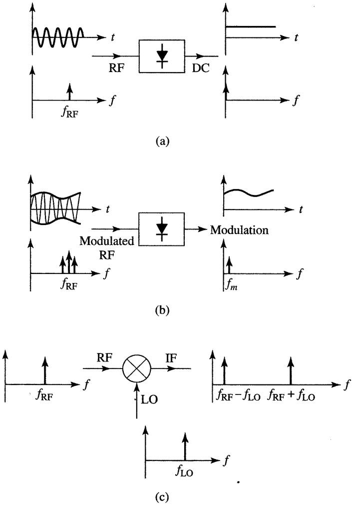
Bessel Functions describe amplitudes of sidebands

For small modulation, only $\pm\omega_m$ sidebands

Demodulation and Detection

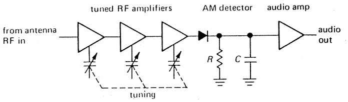
- AM Detection
  - Baseband Diode Detector
  - Synchronous (Homodyne) detection
- FM and PM detection
  - Slope Detection (tune circuit off frequency, FM to AM converter)
  - PLL (Phase Locked Loop)
  - Foster-Seely Detector

Diodes as Detectors and as a Mixer



Basic operations of rectification, detection, and mixing. (a) Diode rectifier. (b) Diode detector. (c) Mixer.

AM receivers beyond the Crystal radio



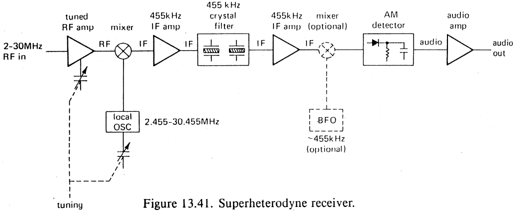


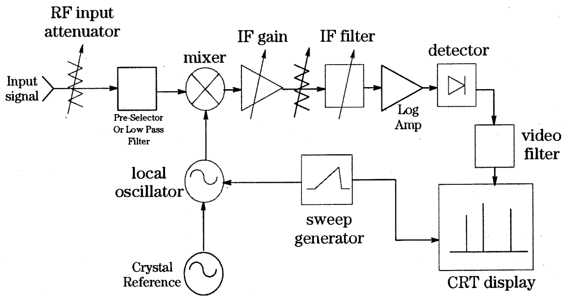
Figure 13.41. Superheterodyne receiver.

- What is the advantage of the Heterodyned receiver?
- How do you choose the IF Frequency and bandwidth??

Spectrum Analyzer as a Tuned Receiver

Theory of Operation

Spectrum Analyzer Block Diagram



- how do you set the instrument to be a tuned receiver?
- How do you choose the IF filter, video filter bandwidths?

SLAC NATIONAL ACCELERATOR LABORATORY

A real multi-stage Spectrum Analyzer

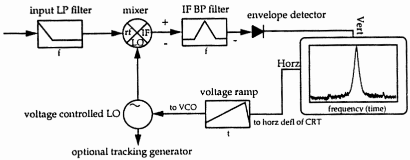


Figure 1: Simplified schematic of a superheterodyne spectrum analyzer.

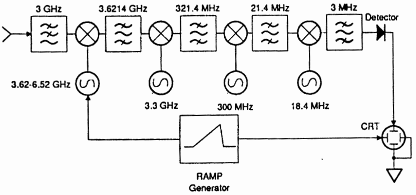
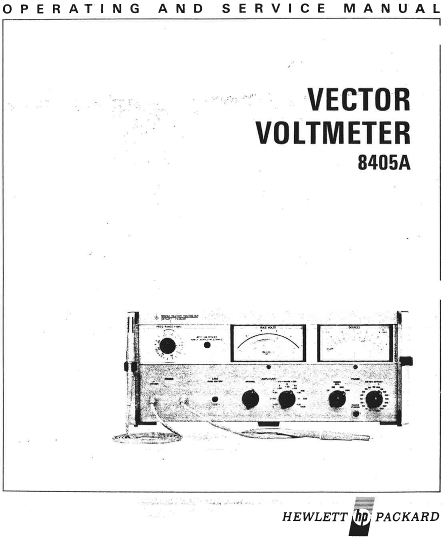
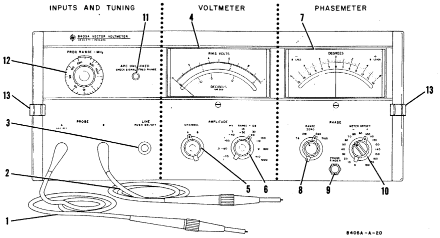


Figure 2: Schematic of a multiple IF stage SPA.

- how do you set the instrument to be a tuned receiver?
- How do you choose the IF filter, video filter bandwidths?

Vector Voltmeter - measures magnitude and phase





1. Probe A. Input to channel A. The Voltmeter and Phasemeter tune to probe A input frequency.
2. Probe B. Input to channel B. A signal at probe A is required for phase measurement and for channel B amplitude measurement.
3. LINE. Depress to turn on 8405A; lamp lights. Pushbutton retainer unscrews for lamp replacement.
4. AMPLITUDE METER. Reads amplitude of fundamental component of signal applied to probe A or probe B.
5. AMPLITUDE CHANNEL. Selects channel to be measured on voltmeter.
6. AMPLITUDE RANGE. Sets AMPLITUDE meter scale.
7. Phase Meter. Reads phase angle between the fundamental components of signals applied to probes.
8. PHASE RANGE. Set phase meter scale. Red ZERO control has at least ±10° range.
9. PHASE FINDER. Overrides PHASE RANGE and PHASE METER OFFSET to select the ±180 phase range and zero offset. Used to find phase angle without changing settings of controls.
10. PHASE METER OFFSET. Used to reduce input phase angle and allow use of expanded PHASE RANGE scales. Not usable unless a definite input angle exists.
11. APC UNLOCKED. Lamp lights to indicate 8405A not tuned. Amplitude is too low and/or FREQ RANGE - MHZ selector is not set to the range which includes fundamental frequency of probe A input.
12. FREQ RANGE - MHz. Coarse tuning control to put input signals within capture range of automatic fine tuning. Selected range must include fundamental frequency of signal applied to probe A.
13. Probe Holder.

Vector Voltmeter - is a Sampling (heterodyning) instrument

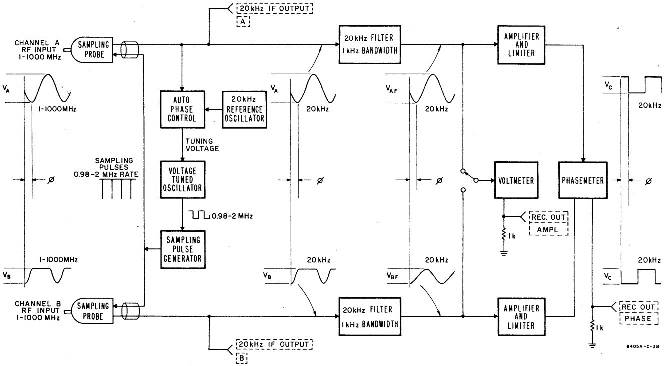
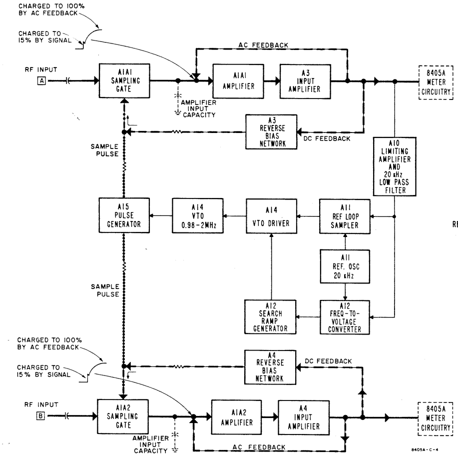


Figure 4-1. Simplified Overall Block Diagram

- Why are there TWO probe leads??
- Sampling pulses are VERY narrow(1 ns or less)
- What is in the sampling probe? a sample and hold circuit

Vector Voltmeter - Detailed system



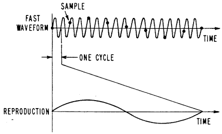


Figure 4-3. Fast Waveform Reproduced on Slower Time Base by Sampling

4-3

- How is sampling related to heterodyning?
- How is the phase at the RF frequency related to the phase at the IF frequency?