

Applications for Radio Frequency Signals

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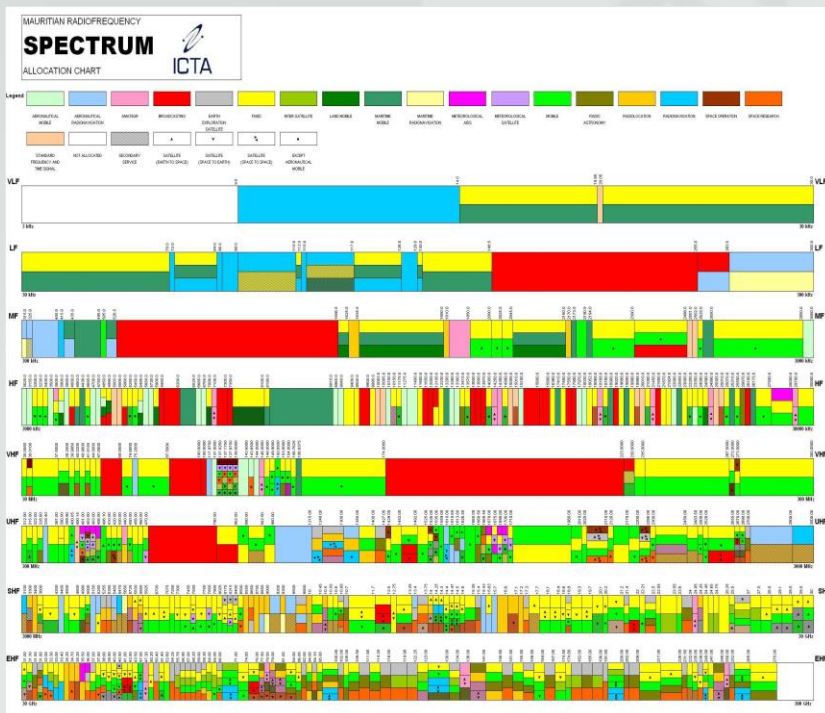
Sponsor:

MSU ECE Department

Overview

- Overview of Radio Frequency (RF)
- Software Defined Radio
- Sizing, antenna(s), gain plots
- Phase & Application
- Modulation

Frequency Spectrum



- This is a graphical representation of the frequency spectrum.
- The FCC is responsible for maintaining the integrity of the of the frequency spectrum.
- As you can see, its getting quite full.

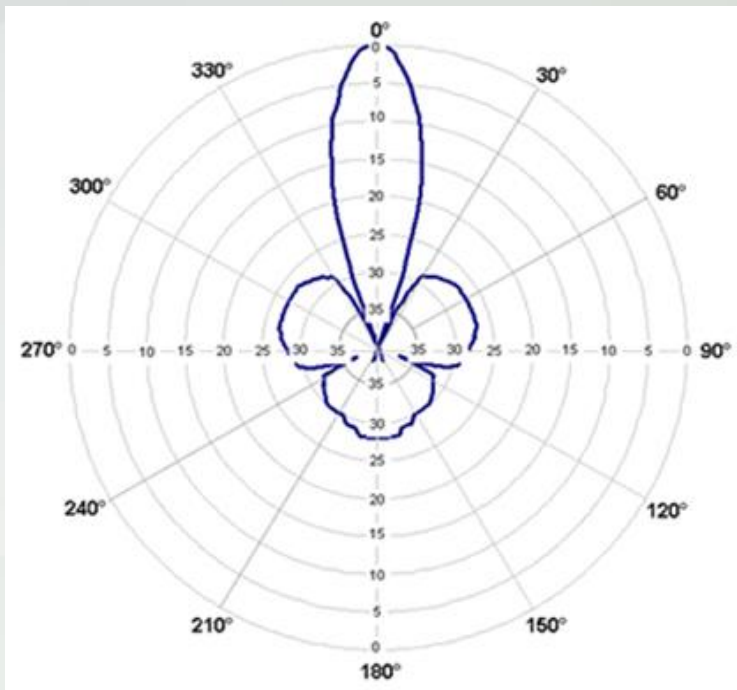
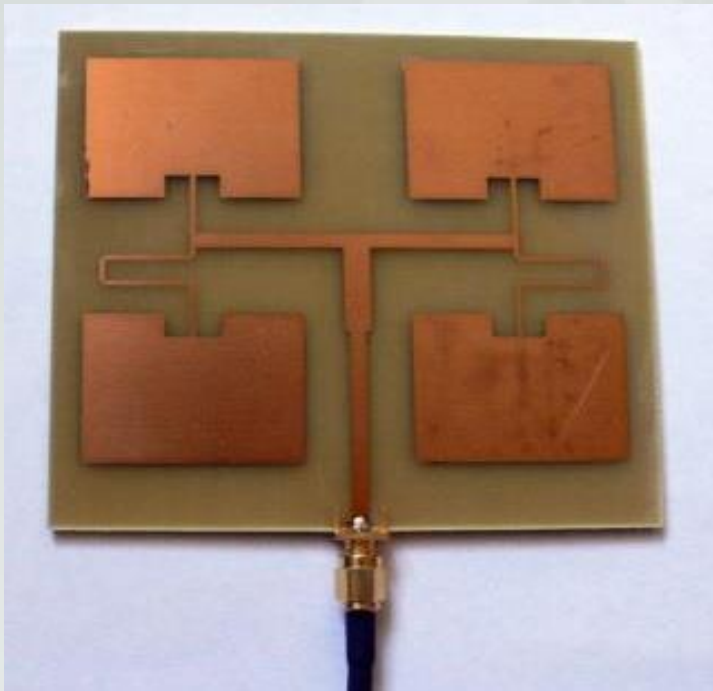
Cognitive Radio

Cognitive radio is a “smart” radio that automatically detects available frequencies in wireless spectrum, then changes its transmission or reception parameters accordingly.

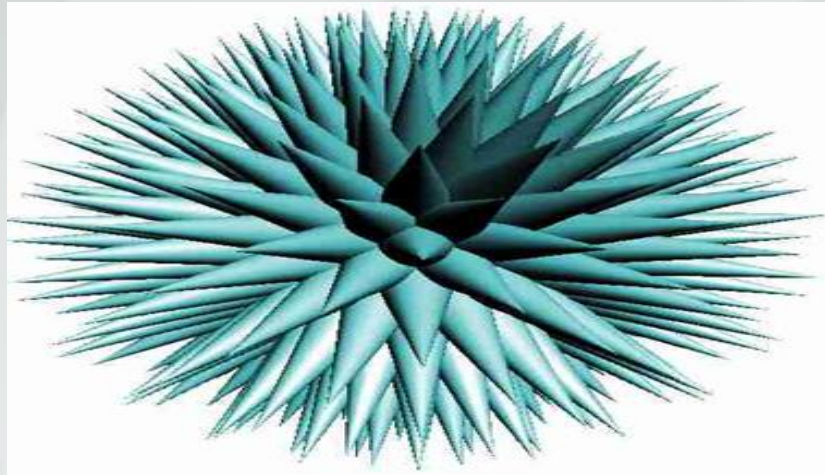
This goes hand in hand with directional antenna and could help us solve the spacial frequency problem.

Directional Antenna

Patch antenna array 2x2



Improve Cell Phone Reception

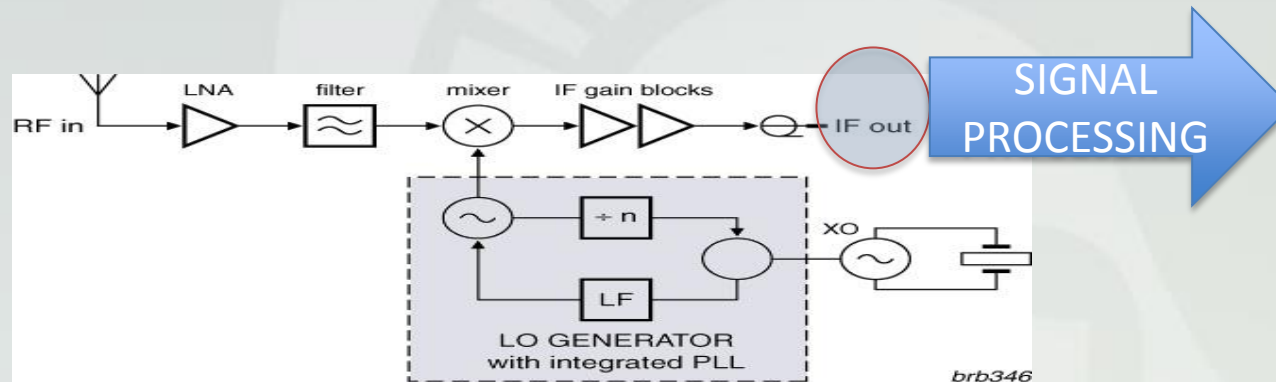


Software Defined Radio – Joe Godby



What makes Software Defined Radios (SDR) unique from other radios that are available?

- Software *controlled* radios are nothing new...

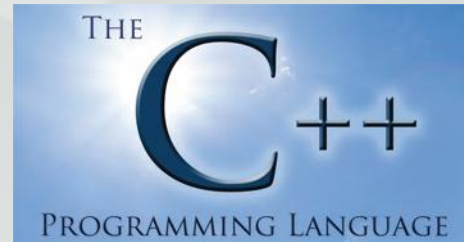


- Software *defined* radios are relatively new
- Used for research and education because of their flexibility. Not used in commercial products

GNU Radio Software



Script Control



Imports from GNU Radio Library

FILTER.h

MATH.h

SIGNAL
SOURCE.h

MANY
OTHER
BLOCKS...

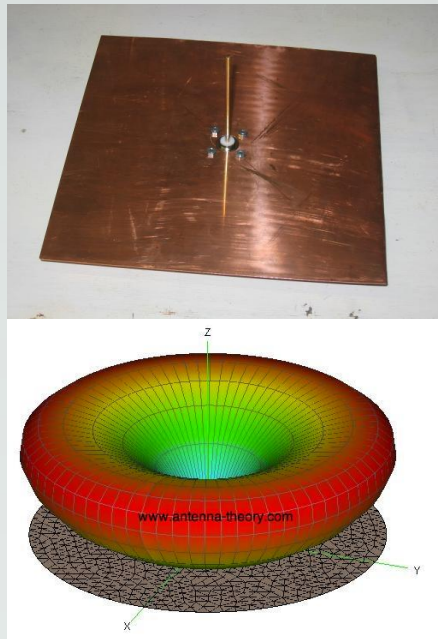
Python
glue

Python
glue

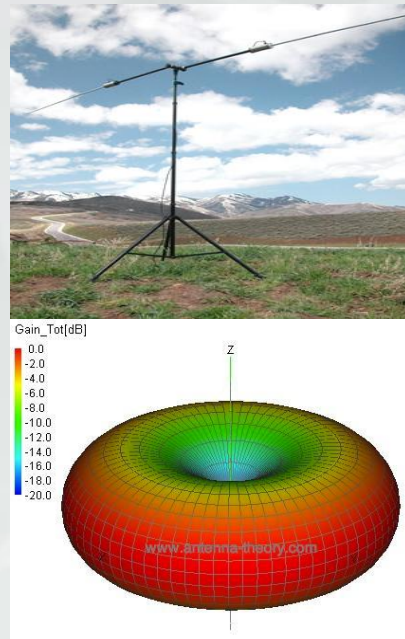


Types of Antennas

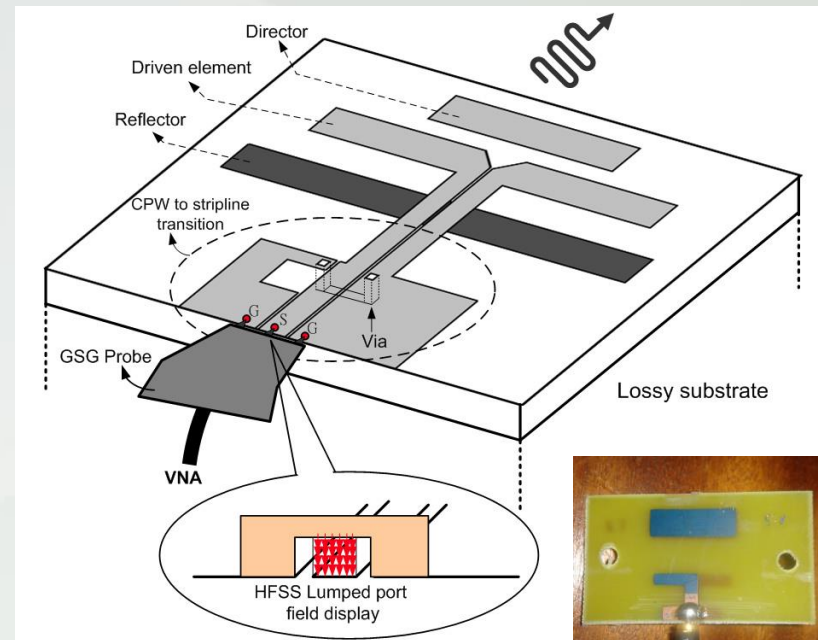
- There are about 27 types of antennas used in RF applications today
- When considering an antenna for your design, the radiation plot does the best job of depicting which one you're looking for



Monopole Antenna



Dipole Antenna



Aspects to always consider

- Shape (as discussed in previous slide)
- Near/Far-Field
- Wavelength

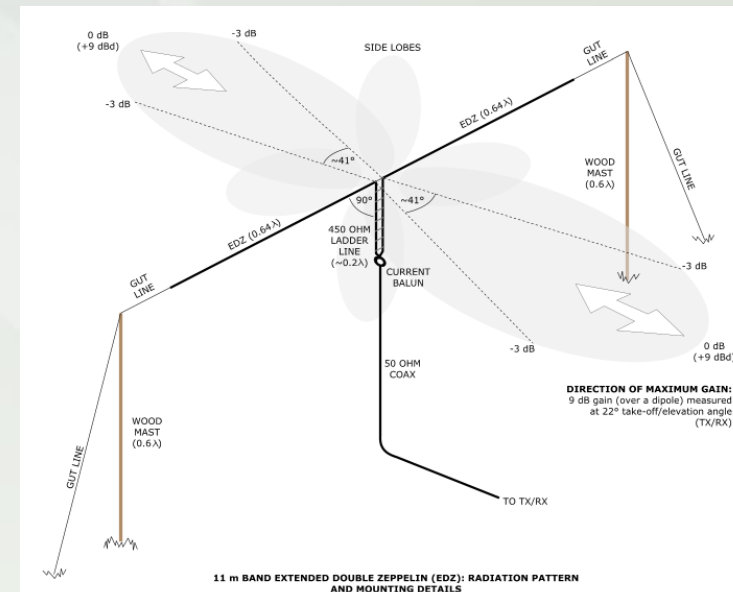
- $\lambda = \frac{c}{f}$

“c” is different in real world applications! (e.g. $c \approx 2 \times 10^8$ in coaxial cable)

- Impedence matching

- VSWR used to scale effectiveness

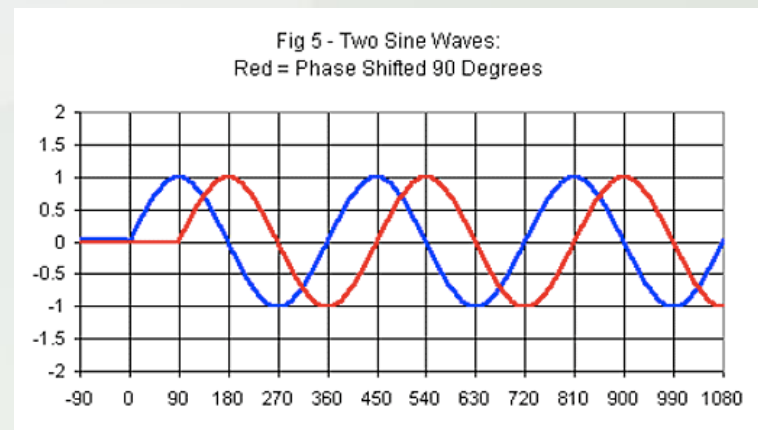
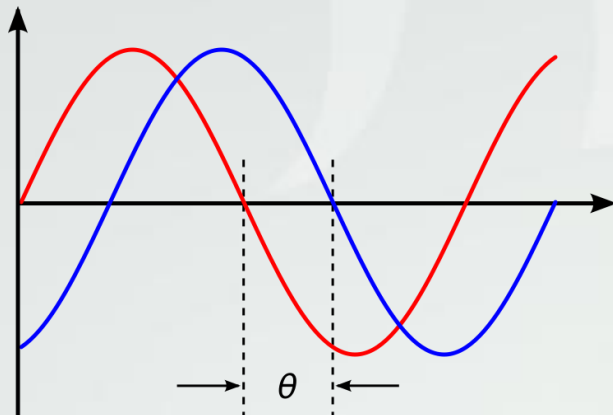
- $\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$ $VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$



Phase & Application

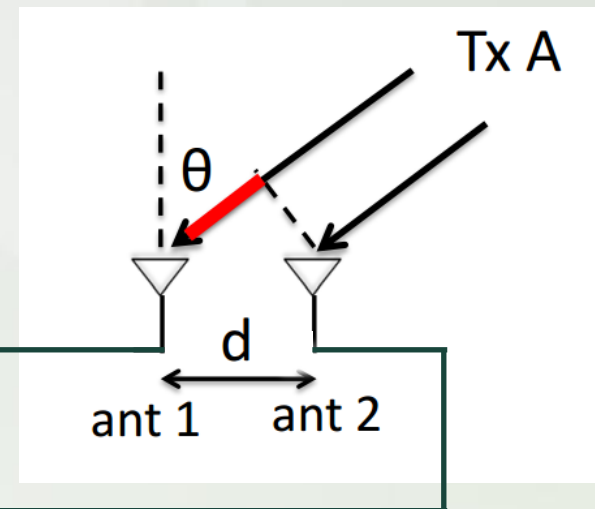
■ Phase Difference

- Difference between two waves having the same frequency and referenced to the same point in time.
- Same frequency, but different phases have a phase difference. (Out of Phase)
- Expressed in degrees or radians.



Phase & Application

- Phase-Interferometry (Angle of Arrival)
 - Used in radar and direction finding applications
 - Accurately estimate the direction of arrival of source signal
 - Phase difference of signal on 2+ separated antennas



Phase & Application

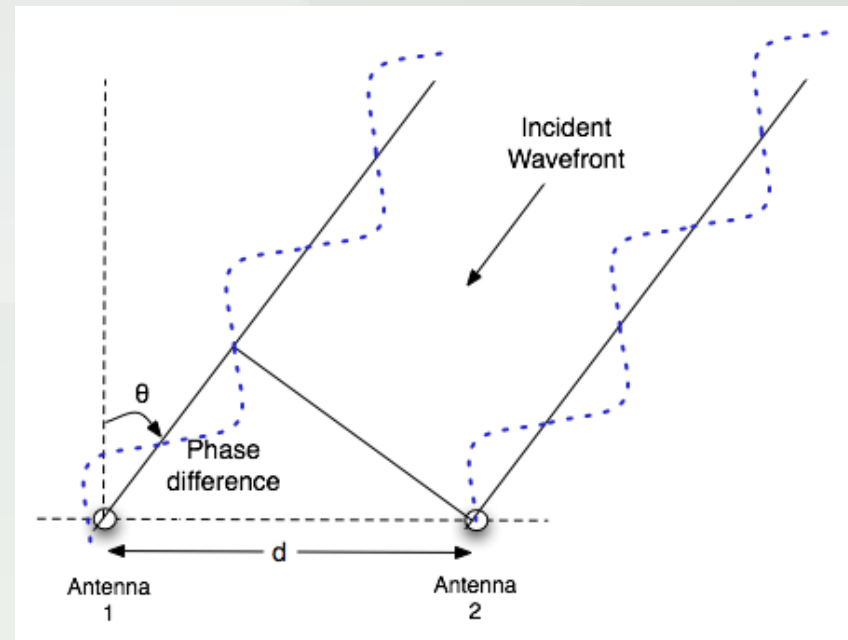
■ Phase-Interferometry (Angle of Arrival)

- $\theta = \sin^{-1}\left(\frac{\lambda \Delta\phi}{2\pi d}\right)$

- d – distance between two antennas
- λ – signal wavelength
- $\Delta\phi$ – phase difference

■ Antennas

- Spaced half a wavelength or less apart.



Phase & Application

- Phase-Interferometry (Angle of Arrival)
 - Signal-to-noise ratio (SNR)
 - Level of desired signal to the level of background noise
 - SNR directly affects measurement of phase
 - Accuracy of AoA dependent upon SNR
- Real World Application
 - Locating jamming source / illegal transmission
 - Distress signal

Modulation

- What is it?
 - Modulation is the process of manipulating various properties of a periodic waveform to convey information.

What are the components?

- Modulating Signal
 - Signal containing the information.
 - $V_m(t)$
- Carrier Signal
 - Simple periodic waveform that is “modulated” by the modulation signal
 - $V_{C-PP} \sin(2\pi f_c + \phi_c)$

Why not just send the modulating signal?

- You can use multiple carrier frequencies to carry the same information without the two interfering.
- Optimal antenna lengths depend on the received signal's frequency. You can send low frequency information using a high frequency carrier so that your antenna unreasonably long.

How is the carrier “modulated”

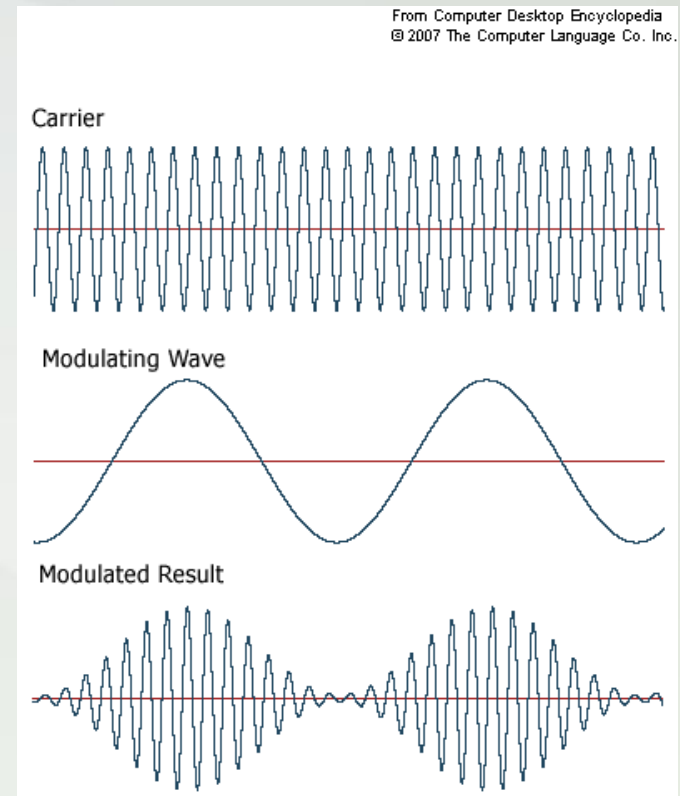
- Amplitude Modulation
- Frequency Modulation
- Phase Modulation

Amplitude Modulation

- Amplitude of the carrier signal is adjusted by the modulating signal

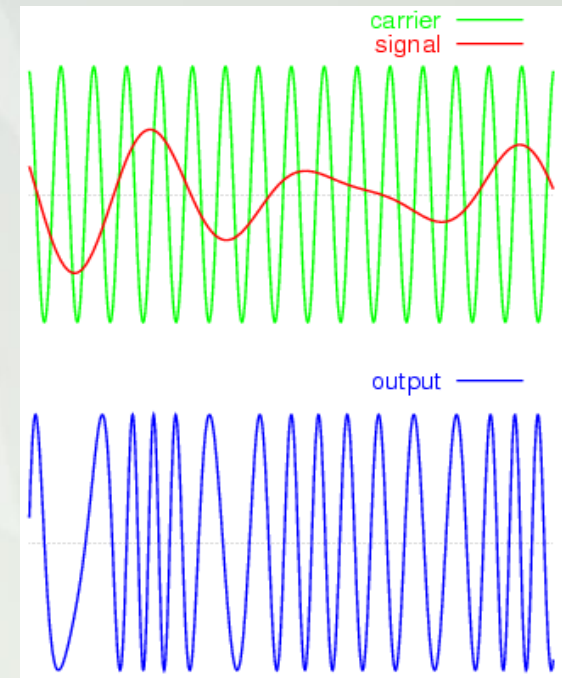
- $VAM = |VAM| \sin(2\pi f_c t + \phi_c)$

- $|VAM| = \{V_{c-PP} + V_m(t)\}$



Frequency Modulation

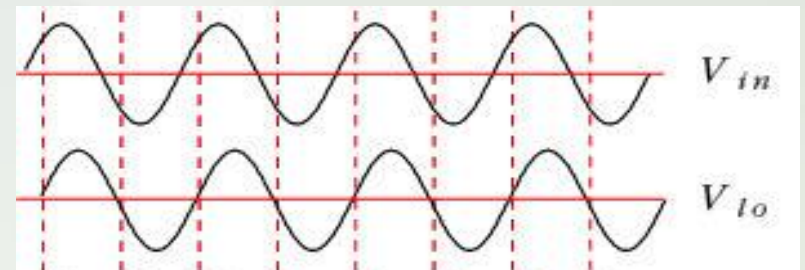
- Frequency of the carrier signal is adjusted by the modulating signal
- $V_{FM} = V_c - PPS \sin(2\pi f_{FM} + \phi_c)$
- $f_{FM} = f_c + (\Delta f_{max} / V_{m-max}) V_m(t)$



Phase Modulation

- Phase of the carrier signal is adjusted by the modulating signal
- $V_{PM} = V_c - PPS \sin(2\pi f_c + \phi_{PM})$
- $\phi_{PM} = \phi_c + (\Delta\phi_{max}/V_{m-max})V_m(t)$

Figure shows a constant phase shift. This would occur when $V_m(t)$ is constant.

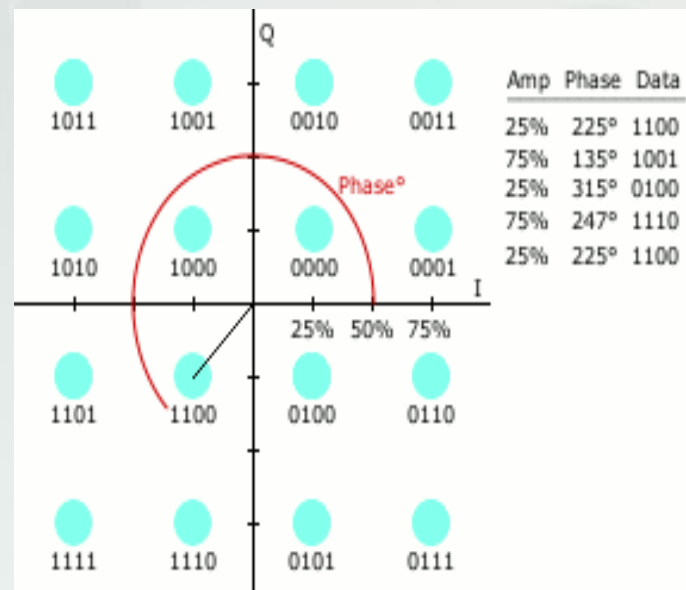


What about digital?

- Much like analog-digital conversion, digital modulation use “constellations” to map binary information to waveform property values.

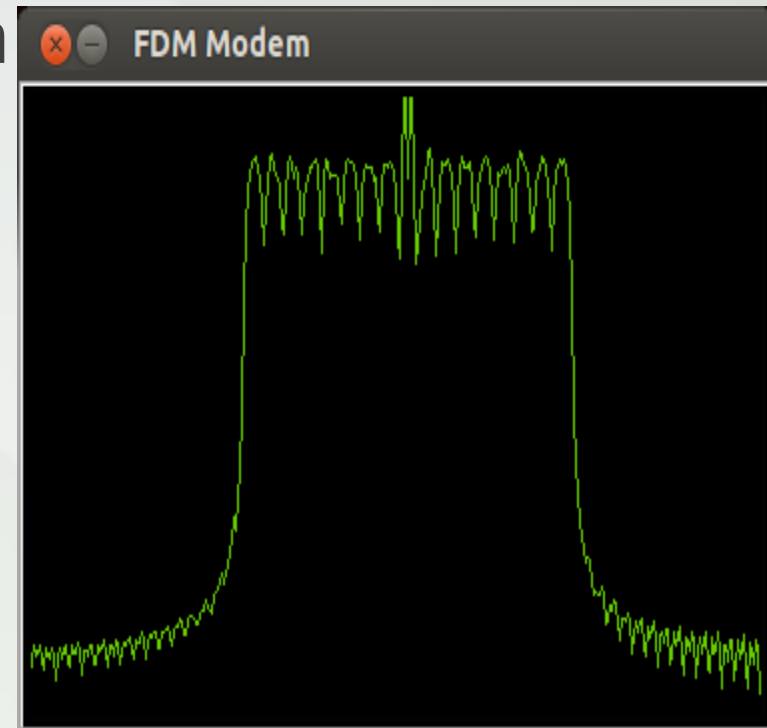
Digital Example Using QAM

- Quadrature Amplitude Modulation
- Uses two modulating and carrier signals.



Complex Modulations Build On These and Other Modulation Techniques

- Quadrature Amplitude Modulation
- Space Modulation
- Single-Sideband Modulation
- Trellis Coded Modulation
- ...and many more





Questions