

# HY-330

fall semester 2021

## Introduction to telecommunication systems theory

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# Modulation

- ✦ Why?
- ✦ Time domain - Frequency domain
- ✦ Analog - Continuous Wave (CW)
- ✦ Digital...



# Modulation Example

$$A_c \cos(2\pi f_c t)$$

$$s(t) = \begin{cases} A_c \cos(2\pi f_c t) \\ -A_c \cos(2\pi f_c t) \end{cases}$$



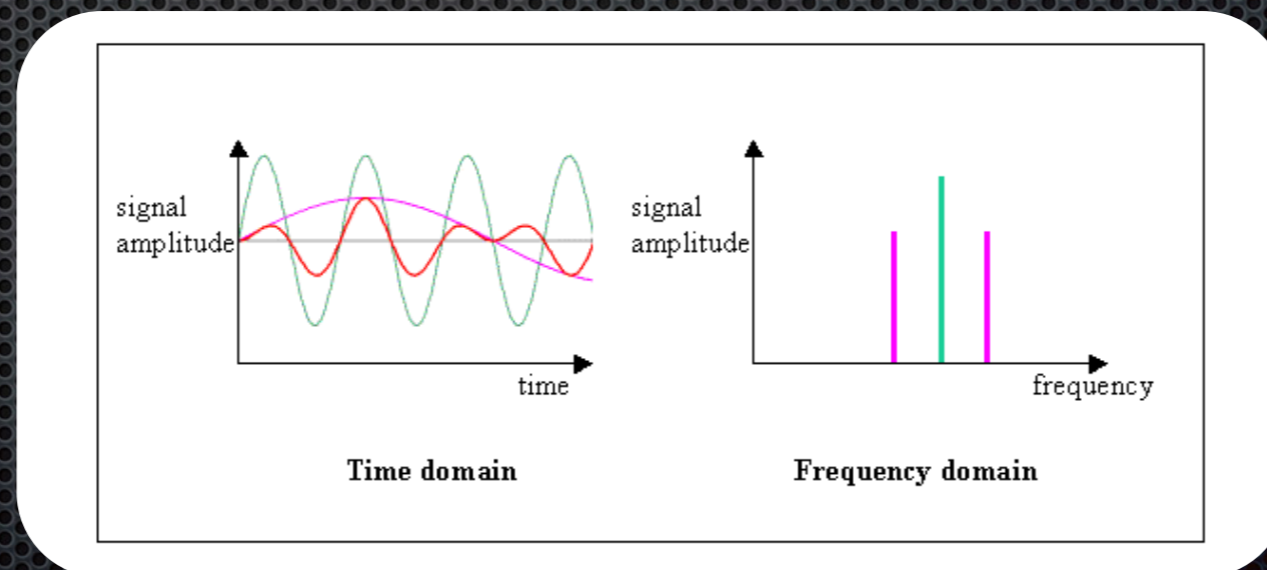
# Baseband Signal

- ✦ “Low frequencies” - raw unmodulated signal
- ✦ Typically:
  - ✦ nowadays up to few MHz
  - ✦ “audio” band 20 - 20000 Hz
- ✦ Low pass filtered



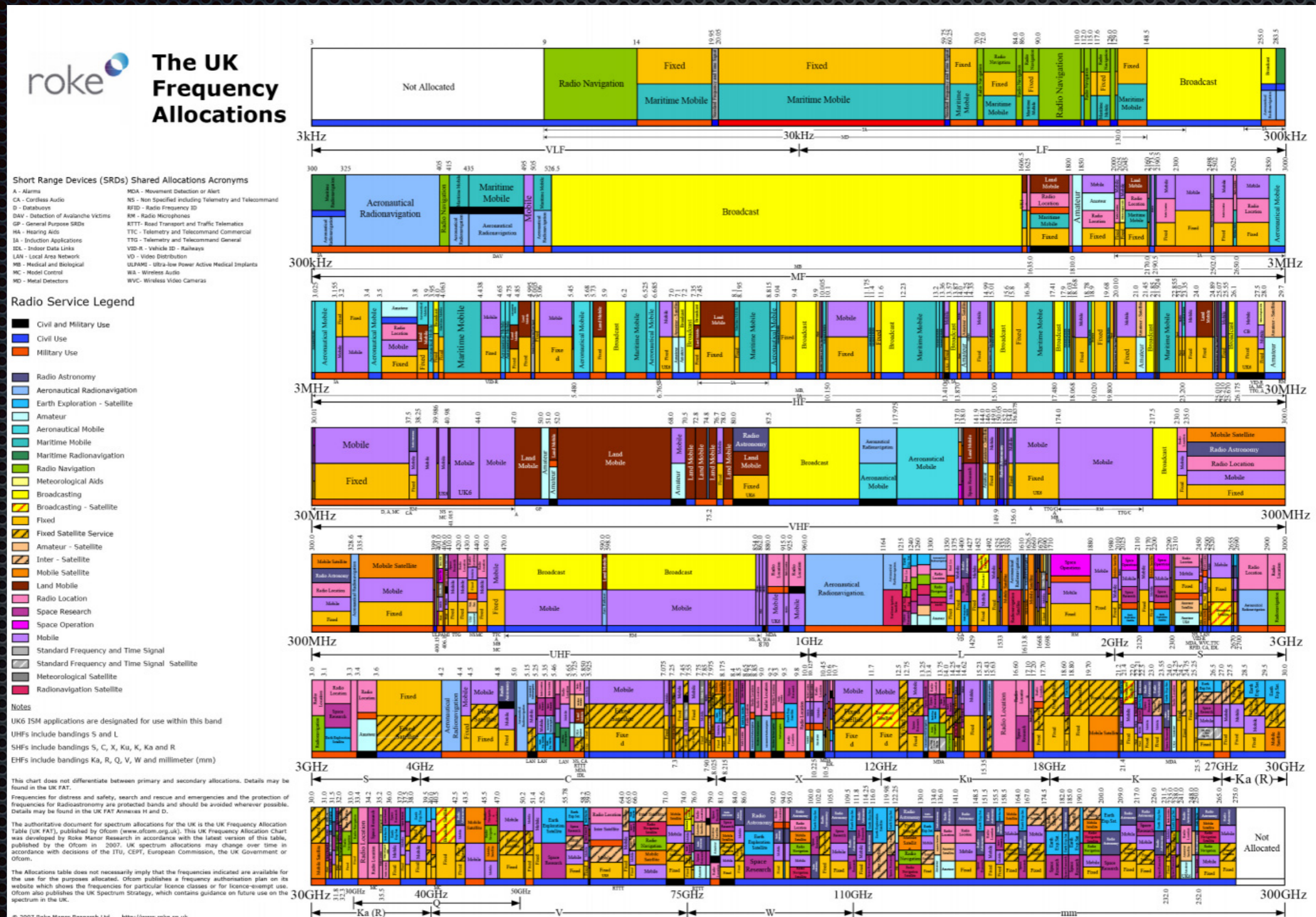
# Time vs. Frequency Domain

- Analog signals are manipulated in time domain
- Filters are used to restrict signals in frequency domain
- We may go from one domain to the other using (Inverse) Fourier Transform
- The frequency domain representation reveals the bandwidth requirements





# Spectrum Availability



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# Carrier

- Cosine/Sine signal
- $f_c \gg \gg f_m$
- Incorporates no info

$$c(t) = A_c \cos(2\pi f_c t)$$



# Modulating Signal

- ✦ Consisted by multiple cosines

$$m(t) = M \cos(2\pi f_m t + \phi)$$

- ✦ Should make sure no over-modulation occurs
- ✦ Follows the information source



# Amplitude Modulation

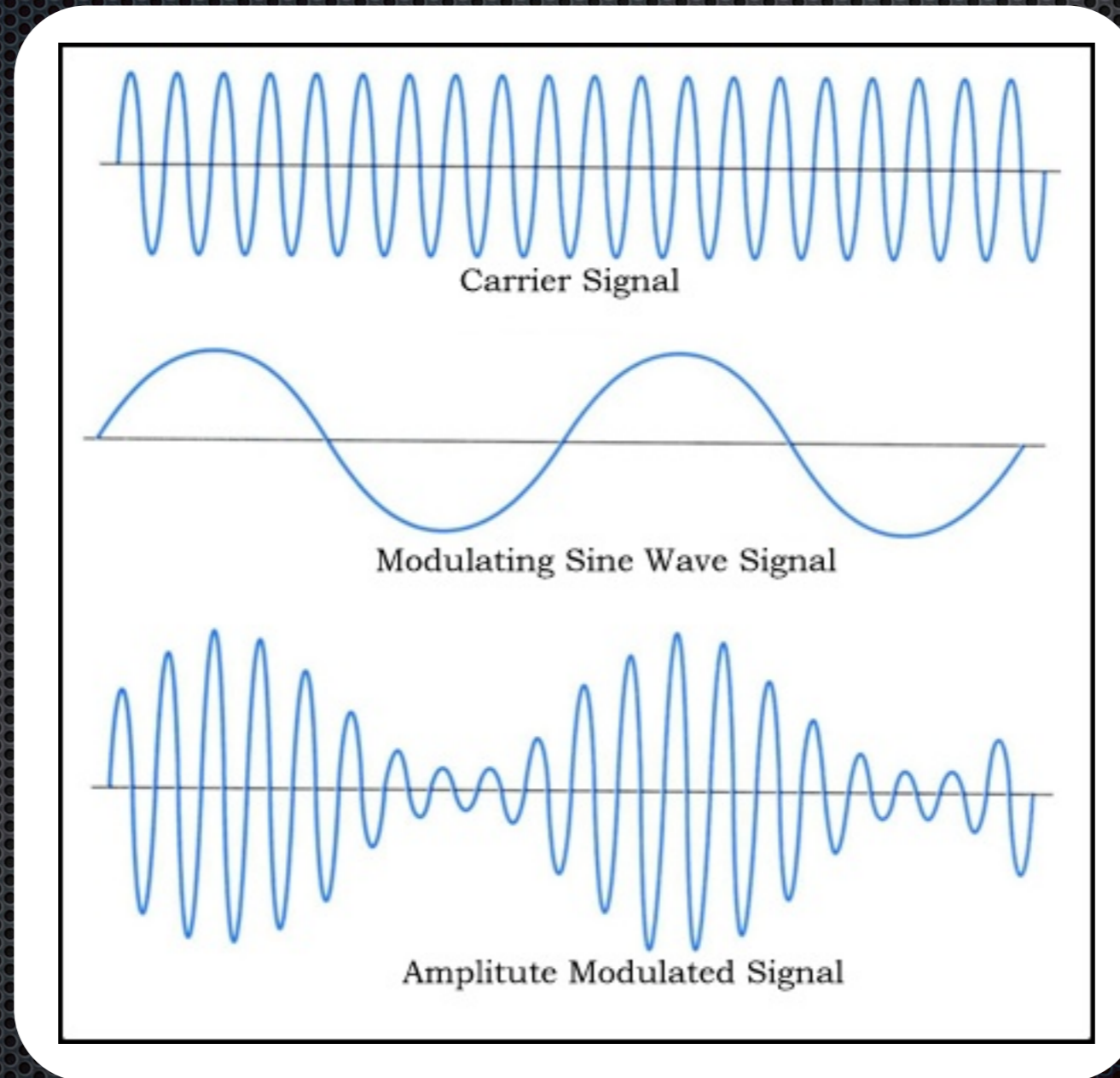
$$M < 1 \Rightarrow [1 + m(t)] > 0$$

$$\begin{aligned} s(t) &= [1 + m(t)] \cdot c(t) \\ &= [1 + M \cos(2\pi f_m t + \phi)] \cdot A_c \cos(2\pi f_c t) \end{aligned}$$

$$s(t) = A_c \cos(2\pi f_c t) + \frac{MA_c}{2} \cos(2\pi(f_c + f_m)t + \phi) + \frac{MA_c}{2} \cos(2\pi(f_c - f_m)t - \phi)$$

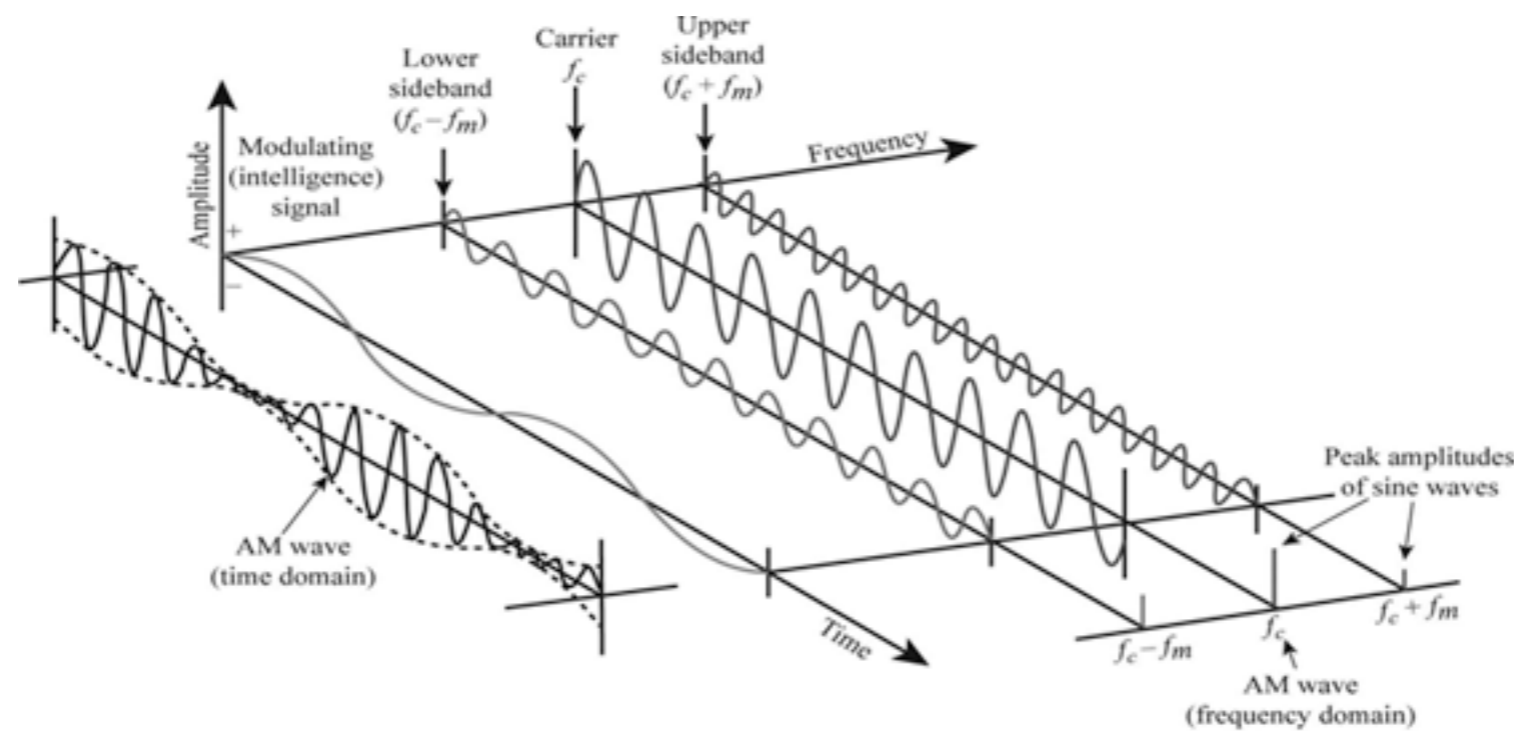


# Amplitude Modulation





# Amplitude Modulation





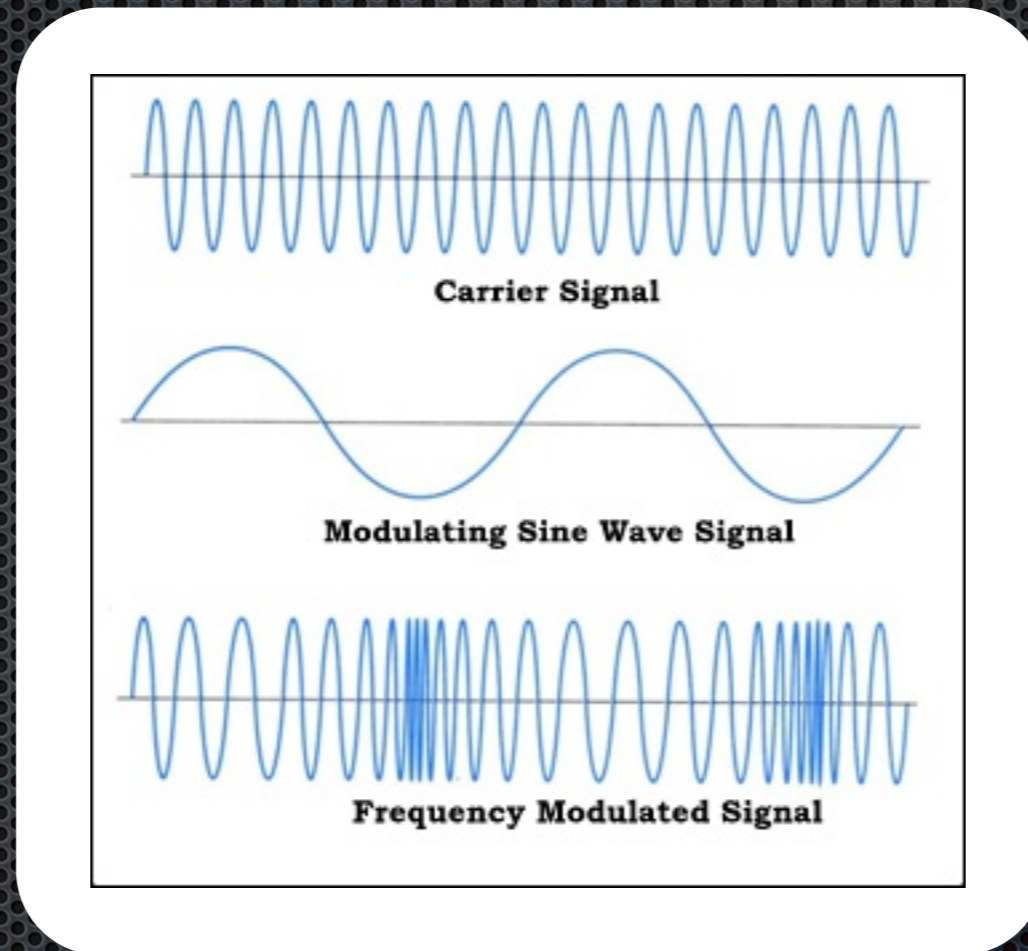
# Frequency Modulation

$$f_{\Delta} = k_f M$$

$$s(t) = A_c \cos \left( 2\pi f_c t - \frac{f_{\Delta}}{f_m} \cos(2\pi f_m t) \right)$$



# Frequency Modulation





# AM vs FM

