HY-330

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Introduction to telecommunication systems theory

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Modulation

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

Modulation Example

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

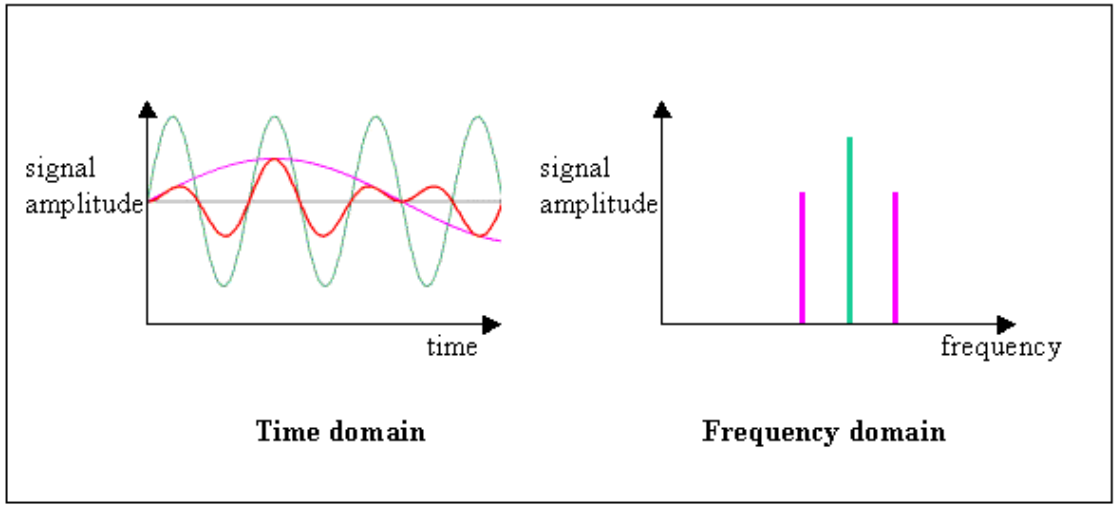
$$s(t) = \begin{cases} A_c \cos\left(2\pi f_c t\right) \\ -A_c \cos\left(2\pi f_c t\right) \end{cases}$$

Baseband Signal

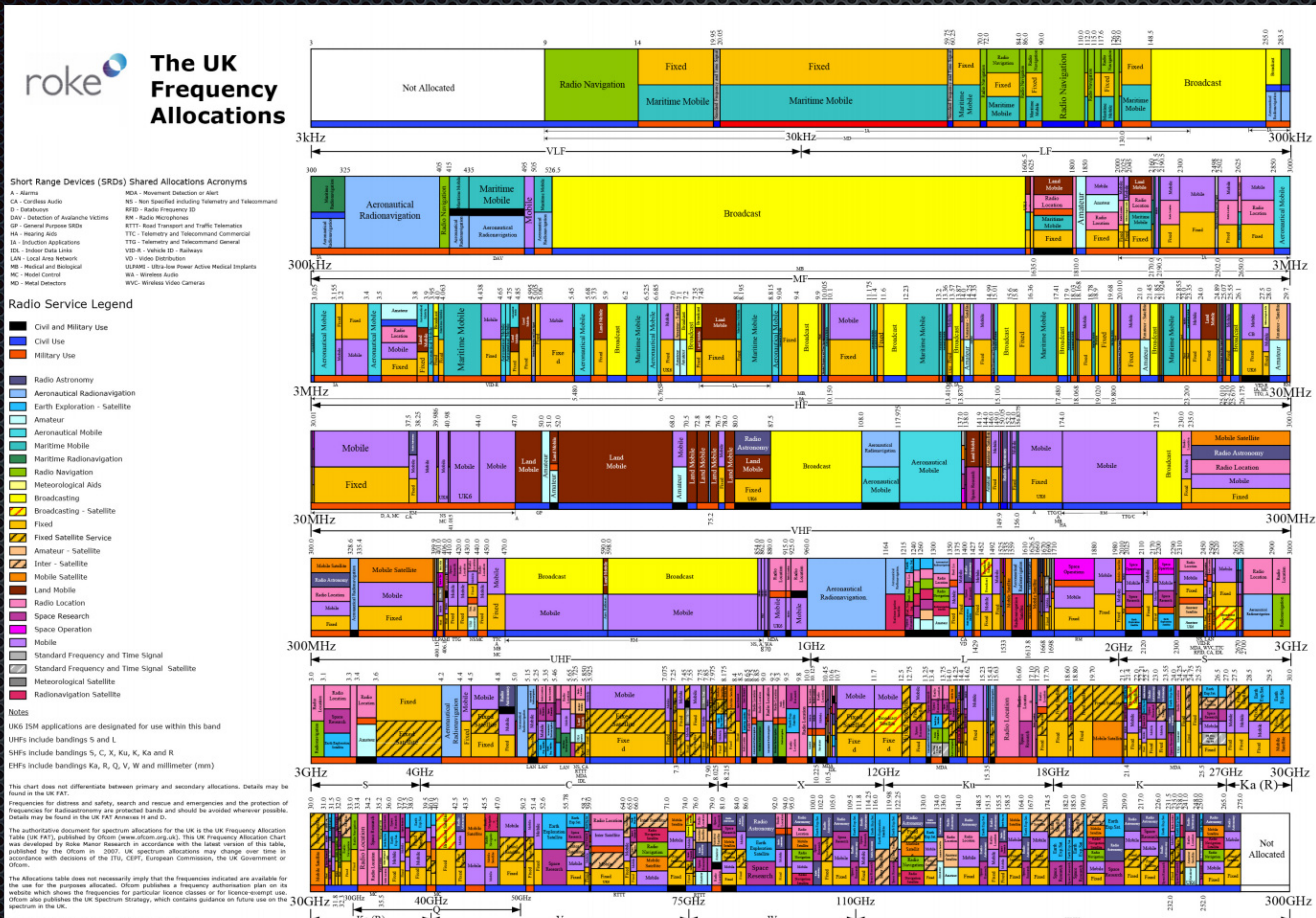
- “Low frequencies” - raw unmodulated signal
- Typically:
  - “audio” band 20 - 20000 Hz
  - nowadays up to few MHz
- Low pass filtered

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



Carrier

- Cosine/Sine signal
- $f_c >> f_m$
- Incorporates no info

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

Modulating Signal

- Consisted by multiple cosines $m(t) = M \cos\left(2\pi f_m t + \phi\right)$
- Should make sure no over-modulation occurs
- Follows the information source

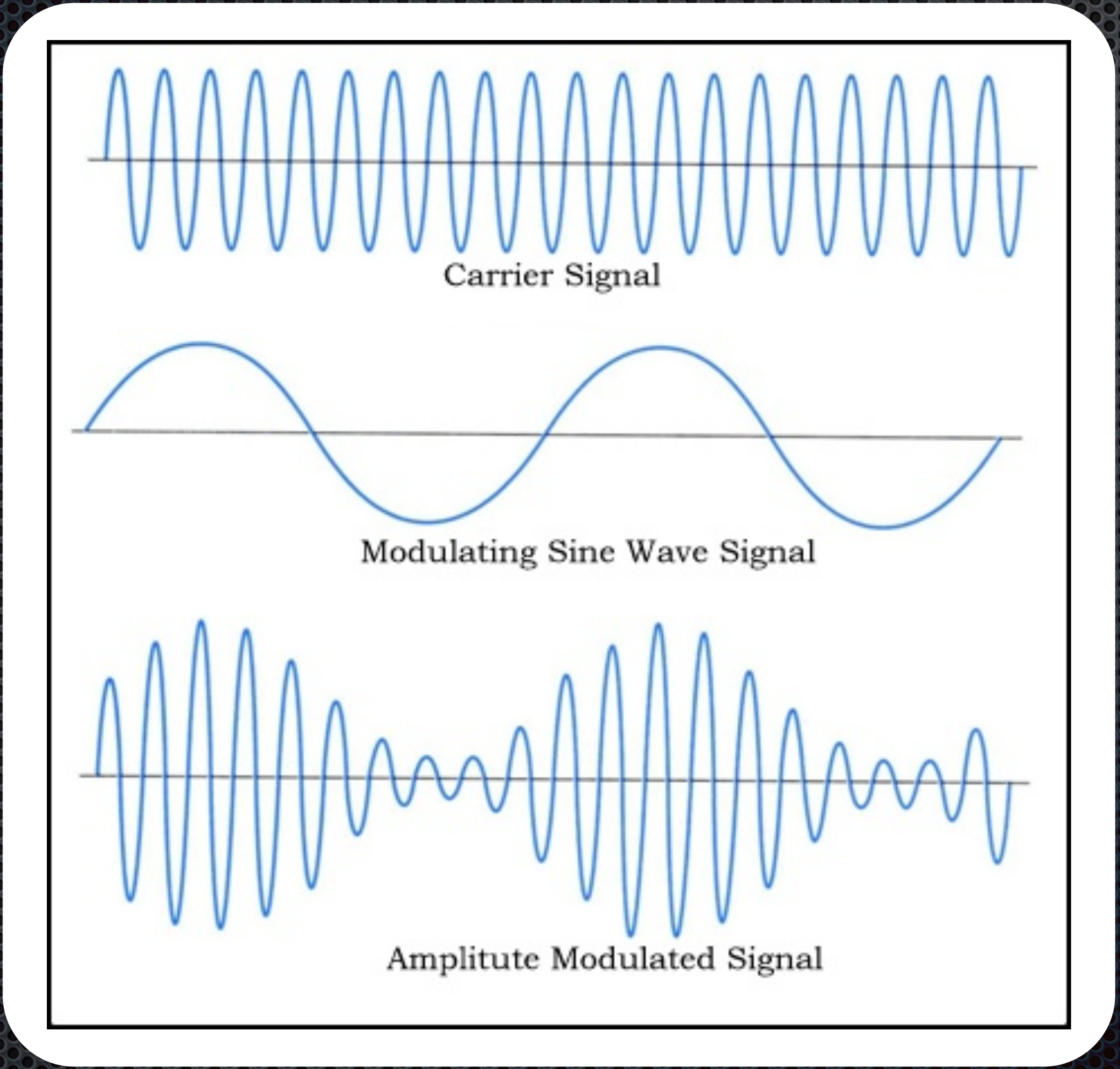
Amplitude Modulation

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

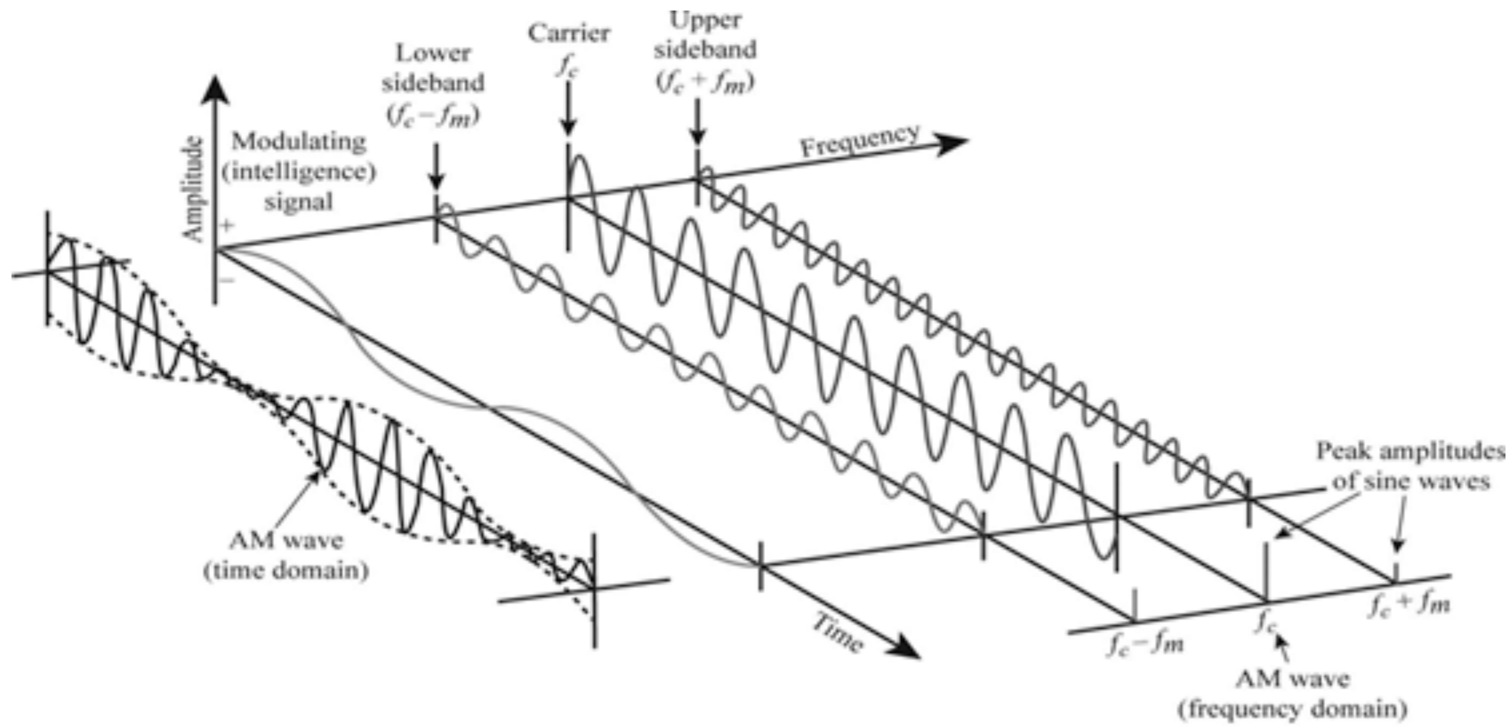
$$\begin{aligned} s(t) &= [1 + m(t)] \cdot c(t) \\ &= [1 + M\cos(2\pi f_m t + \phi)] \cdot A_c \cos(2\pi f_c t) \end{aligned}$$

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

Amplitude Modulation



Amplitude Modulation

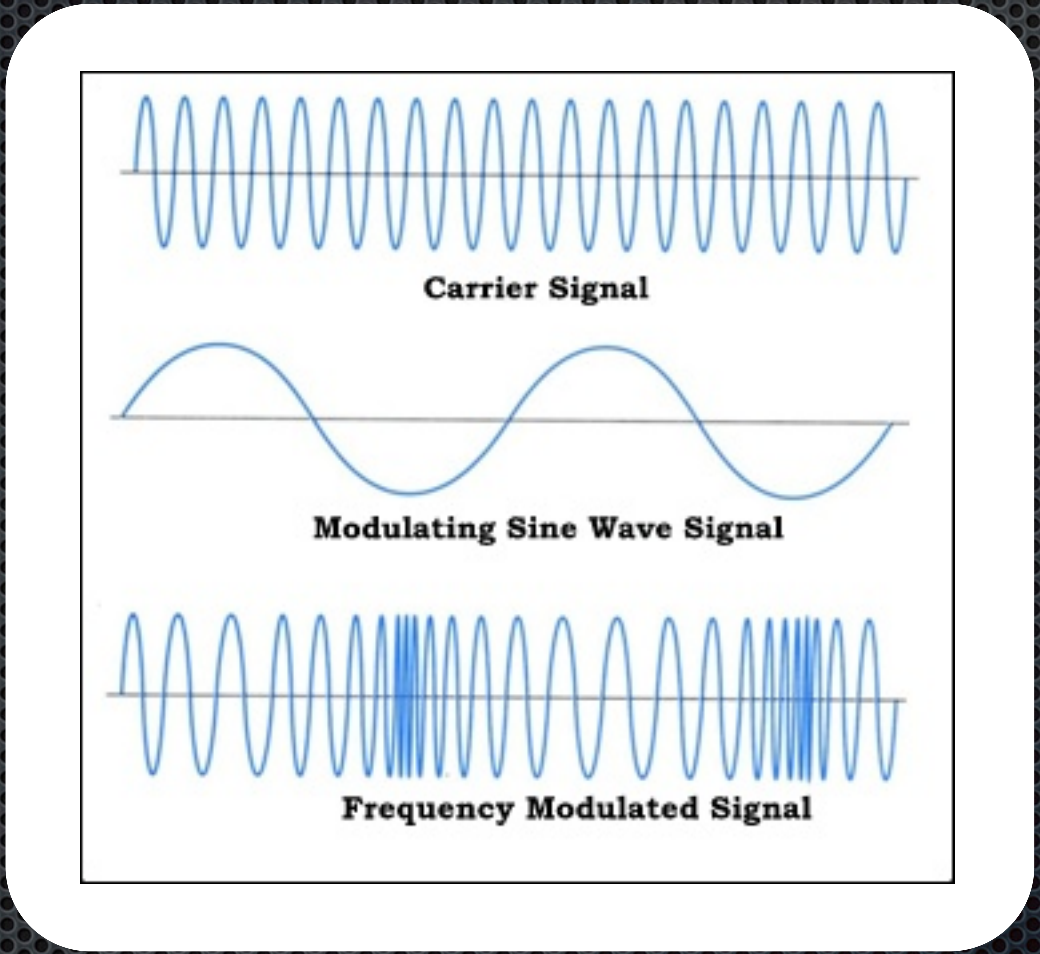


Frequency Modulation

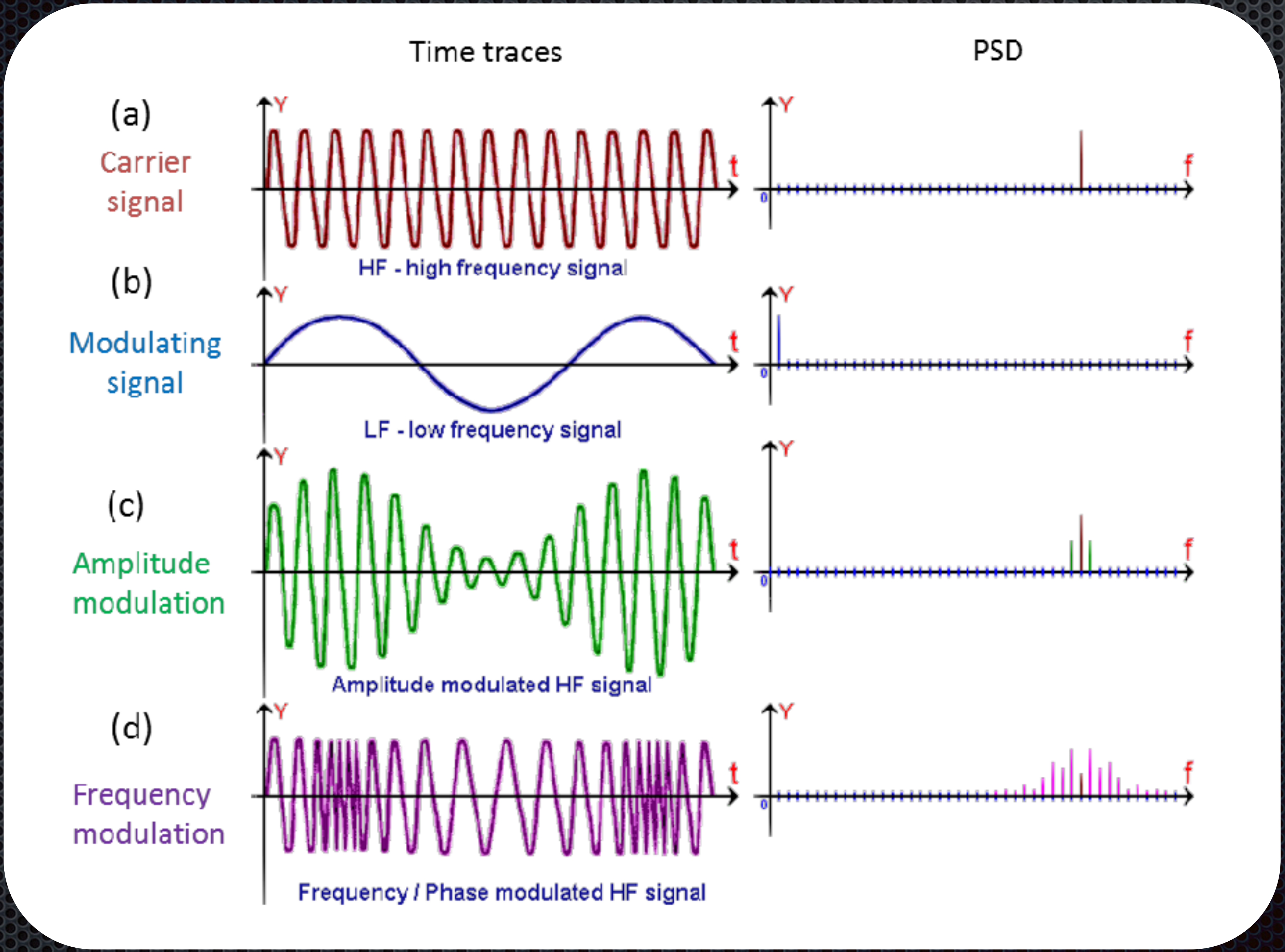
$$f_\Delta = k_f M$$

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

Frequency Modulation



AM vs FM


Time traces
PSD
(a)
Carrier signal
HF - high frequency signal
(b)
Modulating signal
LF - low frequency signal
(c)
Amplitude modulation
Amplitude modulated HF signal
(d)
Frequency modulation
Frequency / Phase modulated HF signal
Y
t
f
0

frequency mixer