Experiment 3
Angle Modulation-Part 1

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FM MODULATION

- Angle Modulation: is a modulation technique where the amplitude of the carrier signal is held constant while either the phase or the time derivative of the phase is varied linearly with the message signal m(t).
- An FM signal is expressed as:

$$s(t) = A_c \cos\left(\omega_c t + 2\pi k_f \int_{-\infty}^{t} m(\alpha)d\alpha\right)$$

- Kf: sensitivity of the FM modulator in Hz/V
- Ac: The amplitude of the carrier.

FM MODULATION

- The instantaneous frequency of s(t) is:

$$f_i(t) = f_c + k_f m(t)$$

- Note that this frequency is linearly proportional to the message signal m(t).
- The characteristic of the modulator can be obtained by allowing m(t) to change and measuring fi for each value of m(t). **To be done in the lab**
- The peak frequency deviation is defined as the maximum Deviation from the unmodulated carrier fc. **To be measured in the lab**
- The FM modulation index is defined as the peak frequency deviation divided by the message bandwidth.

$$\beta = \frac{\Delta f}{f_m}$$

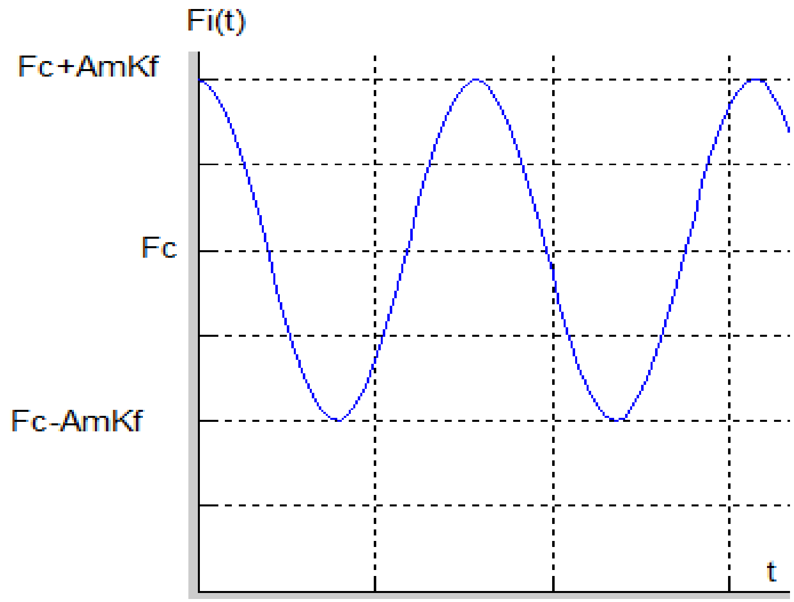
FM MODULATION

- When $m(t) = A_m \cos \omega_m t$

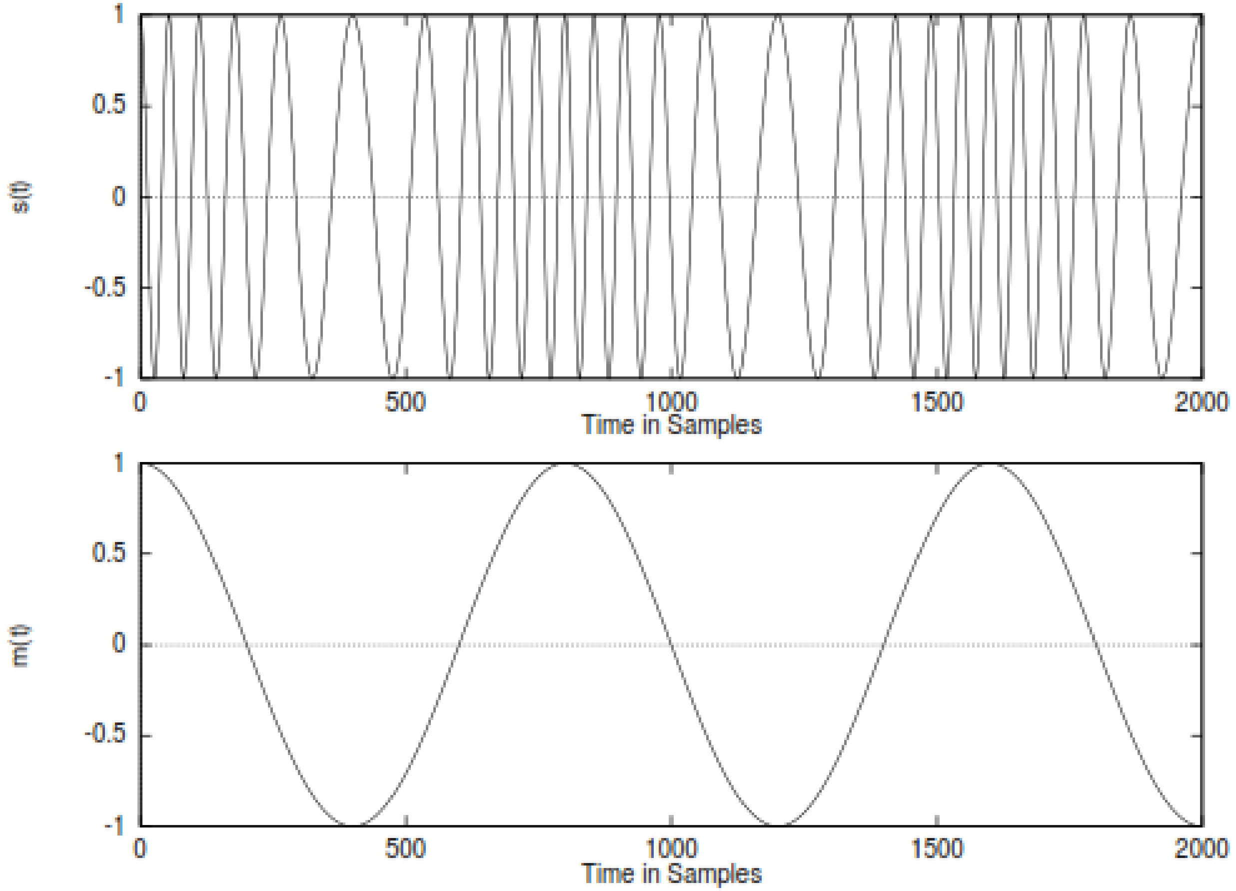
$$s(t) = A_c \cos\ (\omega_c t + \beta \sin 2\pi f_m t).$$

$$f_i(t) = f_c + A_m k_f \cos 2\pi f_m t$$

$$\beta = \frac{\Delta f}{f_m} = \frac{k_f A_m}{f_m}$$



FM MODULATION



fc=1 KHz, fm = 100 Hz.

You should observe a similar display in the lab.

Single tone FM Spectrum

- Let m(t) be a single tone signal. The FM signal is

$$s(t) = A_c \cos\ (\omega_c t + \beta \sin 2\pi f_m t).$$

- This signal can be expanded in a Fourier series as:

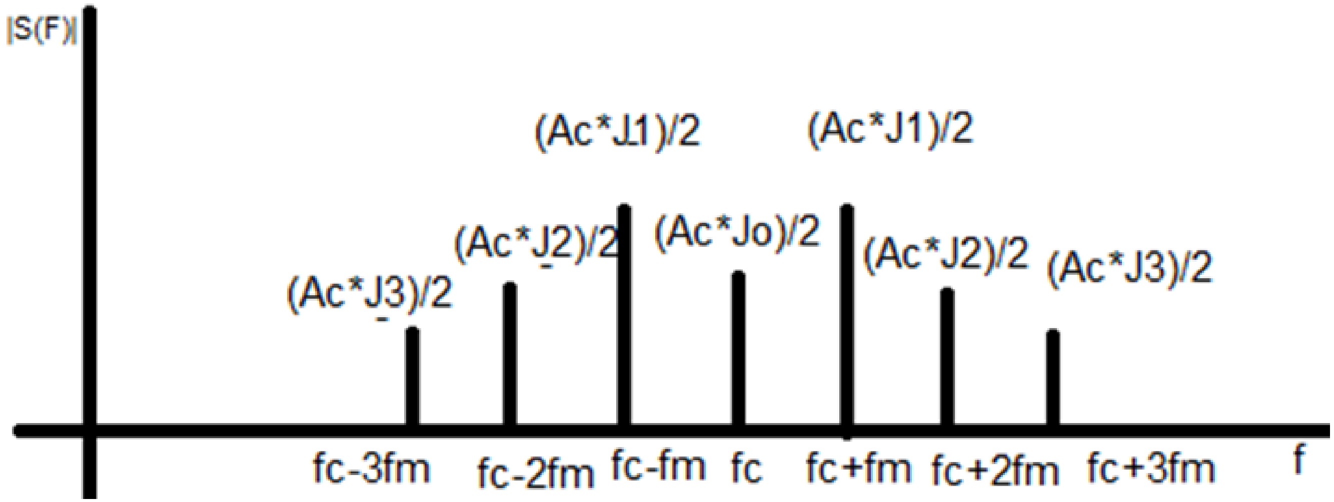
$$s(t) = A_c \sum_{-\infty}^{\infty} J_n(\beta) \times \cos(2\pi(f_c + n f_m)t)$$

Jn is the Bessel function of the first type of order n.

- The spectrum consists, theoretically, of an infinite number of sinusoidal terms centered at fc.
- Carson’s rule: determines the FM signal bandwidth

$$B_T = 2(\beta + 1) f_m$$

Single tone FM Spectrum



$$s(t) = A_c \sum_{-\infty} J_n(\beta) \times \cos(2\pi(f_c + nf_m)t)$$

$$\beta = \frac{\Delta f}{f_m} = \frac{k_f A_m}{f_m}$$

The spacing between spectral lines equals fm

You should observe this spectrum in the experiment

Single tone FM Spectrum

- Note from the figure that

$$\beta = \frac{\Delta f}{f_m} = \frac{k_f A_m}{f_m}$$

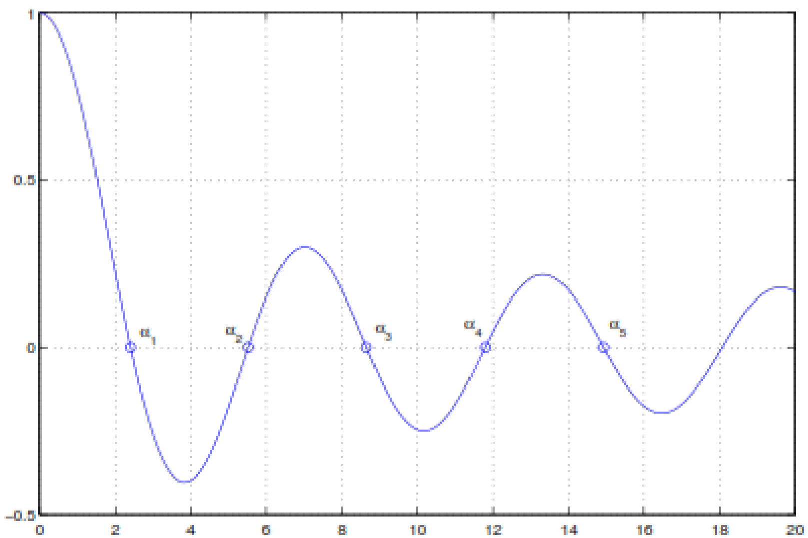
- The term at the carrier is :

$$A_c J_0(\beta)$$

- This term can be made zero when

$$J_0(\beta) = 0$$

The Bessel Function



- The first few roots of the Bessel function occurs at beta= 2.4048, 5.5200, 8.6537 Here, J0(beta)=0.
- The component at the carrier becomes zero when beta=2.4048, 5.5200, 8.6537
- This condition will be explored in the lab first by holding Am constant and changing fm, and then changing Am while holding fm constant