

Frequency Modulation (FM)

Prof. Hyunggon Park

Lecture Note

1 Key Terms

- frequency, analogue, modulation, demodulation

2 Frequency Modulation

- Recall - Analog and Digital Modulations
 - Analog modulation - applied continuously in response to the analog information signal
 - * AM (Amplitude Modulation): amplitude of carrier signal is varied in accordance to instantaneous amplitude of modulating signal
 - * Angle modulation:
 - Frequency modulation (FM): frequency of carrier signal is varied in accordance to instantaneous value of modulating signal
 - Digital modulation - analog carrier signal is modulated by a digital bit stream.

- Details:

- Message signal: $x_m(t)$
- Carrier: $x_c(t) = A_c \cos(2\pi f_c t)$
- So that,

$$\begin{aligned} y(t) &= A_c \cos \left(2\pi \int_0^t f(\tau) d\tau \right) \\ &= A_c \cos \left(2\pi \int_0^t [f_c + f_\Delta x_m(\tau)] d\tau \right) \\ &= A_c \cos \left(2\pi f_c t + 2\pi f_\Delta \int_0^t x_m(\tau) d\tau \right) \end{aligned}$$

- difference between instantaneous and base frequency of the carrier is directly proportional to instantaneous value of input signal amplitude.

- Modulation index for FM

- For sinusoidal message signal,

$$\int_0^t x_m(t) dt = \frac{A_m \cos(2\pi f_m t)}{2\pi f_m}$$

- The corresponding FM signal:

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

- We define modulation index for FM:

$$h = \frac{\text{Peak frequency deviation}}{\text{Highest frequency component in } x_m(t)} = \frac{f_\Delta}{f_m} = \frac{f_\Delta |x_m(t)|}{f_m}$$

* if $h \ll 1$, narrow band FM, BW≈

* if $h \gg 1$, wideband FM, BW≈

3 FM Demodulation

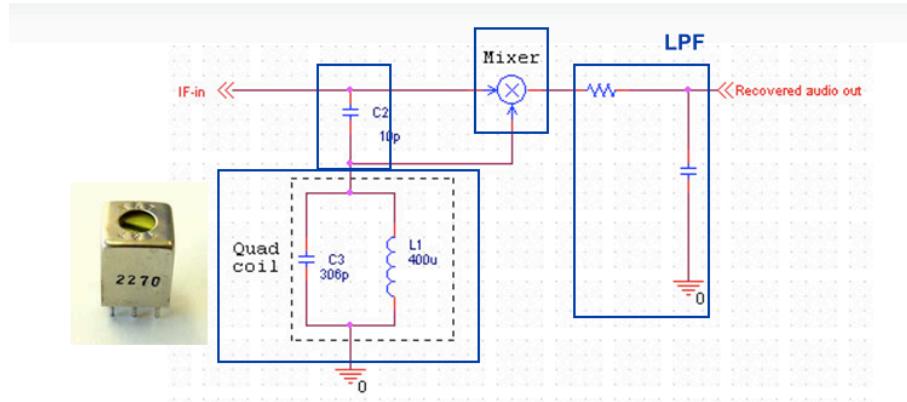
- AM demodulators:

- cannot be used due to the constant amplitude of FM signals

- FM dedicated demodulator

- Phase detector
- The Foster-Seeley discriminator
- Ratio detector
- Quadrature detector
- etc.

- Quadrature detector

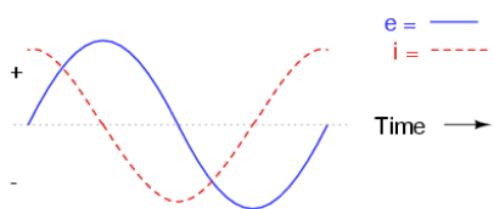
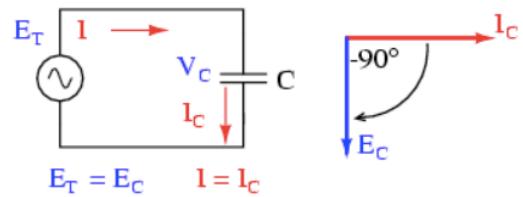


- High-reactance capacitor (C2): produce two signals with _____ degree phase difference
- Phase-shifted signal is then applied to LC-tuned resonant at carrier frequency (L1 and C3)
- Frequency changes will then produce an additional leading or lagging phase shift into the mixer

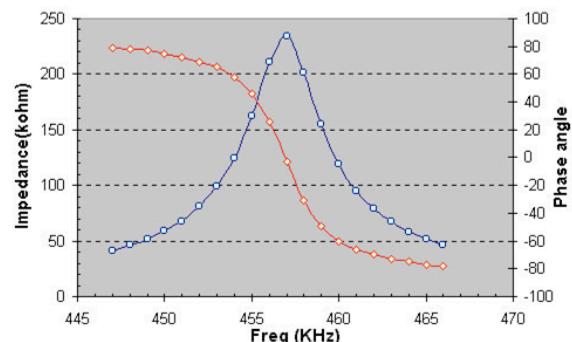
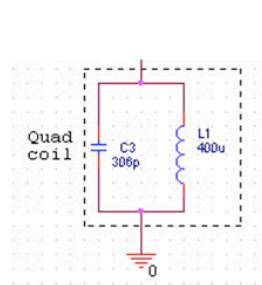
- Recall - Capacitor and Phase

- Flow of electrons through capacitor is directly proportional to rate of change of voltage across capacitor.
- More detail,

$$i = C \frac{dV}{dt}$$



- Impedance and Phase of LC tuned Circuit



- Facts:
 - * Phase (red curve): _____ at resonance
 - * Frequency lower than 457KHz: _____ phase
 - * Frequency higher than 457KHz: _____ phase
- In conclusion: If frequency changes, phase will also vary and output voltage (audio signal) too

- Property: multiplication of two periodic signals with same frequency produces DC voltage that is directly proportional to signal phase difference

- * Example:

$$\sin(x) \sin(90^\circ + x + \theta) =$$

- Finally, we can recover signal that is proportion to frequency changes!

4 Lab Experiment

