ET368 HOMEWORK #6 KEY

MILLER CHAPTER 5 PROBLEMS 1-3,5,6,9-24,27,28,35,37,40,42

27 POINTS TOTAL (1 PER QUESTION). ALL WORK MUST BE SHOWN.

1. **ANGLE MODULATION** is defined as modulation where the angle of a sine-wave carrier is varied from its reference value.

   TWO SUBCATEGORIES are **FREQUENCY** and **PHASE** modulation.

2. The key difference is that in PM, the amount of phase change (shift) is proportional to the information amplitude, while in FM, the frequency change is proportional to the information amplitude.

3. Two reasons why PM is important in the study of FM:

   1. PM can be used to generate FM "with a trick" – by integrating the information signal. (Many older FM transmitters use this technique.)

   2. Understanding PM helps in the analysis of FM noise immunity.

5. A **condenser microphone** can be used to generate FM by coupling it to the tank circuit of an oscillator. As sound strikes the mic, its plates will vibrate back and forth, changing its total capacitance and thereby frequency-modulating the oscillator.

6. The **deviation constant** is the same as the **modulator sensitivity** for an FM exciter. It is in units of Hz/Volt (kHz/Volt in the text), and predicts how much frequency change (deviation) will be produced per Volt of information signal.

9. Given: Fmin = 89.999 MHz, Fmax = 90.001 MHz, dev_rate = 1000 Hz, Vm=3V.

   (a) The carrier frequency = (Fmin+Fmax)/2 = <u>90.000 MHz</u>

   (b) Fm = dev_rate = <u>1 KHz</u>

   (b) Vm' = Vm * (dev' / dev) = 3 V * (1.5 K / 1 K) = <u>4.5 V</u>

10. The **FREQUENCY OF THE INFORMATION** determines the **rate** of frequency swing in an FM transmitter.

11. One way of expressing the **instantaneous output frequency** *f* would be:

$f = f_c + K_0 V_m(t)$, where: F = The instantaneous carrier frequency,
K0= The modulator sensitivity, in Hz/Volt,
Vm(t) = The information signal, in volts.

There are **many** correct ways to express this relationship; this is just one!

12. The modulation index m_f is the **peak or maximum phase shift** induced on the carrier.

13. Only the AMPLITUDE of the audio tone determines the percent modulation of an FM transmitter.

14. As mf goes from 0 to 15, the carrier frequency component (CFC) goes through a cyclical change. For $0<mf<2.4$, the CFC is decreasing as sideband power is accumulated, and at mf=2.4, the CFC has approximately zero amplitude. For $2.4<mf<5.6$, the carrier again increases (never again regaining full amplitude), then again becomes zero at 5.6. This pattern continues.

15. GIVEN: Deviation = 15 KHz, Fm=3 KHz
Deviation = same, Fm = 2.5 and 5 KHz.

FIND: The bandwidth using a Bessel table.

(a) mf = $\frac{\delta}{fm}$ = 15 K / 3 K = 5.0

BW = 16 * 3 K = 48 KHz

(b) mf = 15 K / 2.5 K = 6.0

BW = 18 * 2.5 K = 45 KHz

(c) mf = 15 K / 5K = 3.0

BW = 12 * 5K = 60 KHz

16. **GUARD BANDS** are extra frequency space between broadcast stations to help prevent interference.

An FM broadcast channel is 200 KHz wide (150 KHz operating region, 50 KHz guard bands.)

17. 75 KHz deviation is defined as 100% modulation in FM broadcast.

18. **CENTER FREQUENCY** is the same thing as AVERAGE or CARRIER FREQUENCY. It is the frequency that the transmitter produces at rest.

19. **FREQUENCY SWING** refers to DEVIATION or FREQUENCY CHANGE.

20. An FM transmitter modulated 60% produces a swing or deviation of:

DEVIATION = 0.6 (75 KHz) = 45 KHz.

21. GIVEN: 40 % Modulation, FM broadcast, Fm=5 KHz.
FIND: What is the deviation when percentage of modulation is doubled?

DEVIATION = 2 * 0.4 (75 KHz) = 60 KHz.

22. GIVEN: 50 % Modulation, FM broadcast, Fm=7 KHz.
FIND: Deviation when Fm is changed to 5 KHz.

The deviation does NOT depend on Fm, therefore, it will be:

DEVIATION = 0.5 * 75 KHz = 37.5 KHz

23. GIVEN: Output current of FM transmitter is 8.5 A without modulation.
FIND: Output current when percentage of modulation is 90%.

The total power in FM is CONSTANT. Therefore, the current must also be constant.

I = 8.5 A

24. Given: *Vfm(t)=1000sin(*10^9*t + 4 sin(*10^4*t))* , RL=75 Ohms.
Find: Fc, Fm, Pt, mf, deviation, and BW.

a) $f_c = \frac{\omega_c}{2\pi} = \frac{10^9}{2\pi} = \underline{\underline{159.155 MHz}}$

b) $f_m = \frac{\omega_m}{2\pi} = \frac{10^4}{2\pi} = \underline{\underline{1.592 KHz}}$

c) $Pt = \frac{Vc^2}{RL} = \frac{\left(1000 / \sqrt{2}\right)^2}{75\Omega} = \underline{\underline{6.667 KW}}$

d) $m_f = \underline{\underline{4.0}}$ By inspection (peak phase shift)

e) By definition, $m_f = \frac{\delta}{f_m}$ so: $\delta = m_f f_m = (4.0)(1.592 KHz) = \underline{\underline{6.366 KHz}}$

f) By **Carson's Rule**, $BW \approx 2(f_m + \delta) \approx 2(1.592 KHz + 6.36 KHz) \approx \underline{\underline{15.9 KHz}}$

27. **FM RECEIVERS** do not *easily* respond to static interference.

28. The purpose of the **LIMITER** stage in an FM receiver is to remove any **amplitude** variations from the IF signal prior to detection. This rejects most noise sources, which present as amplitude disturbances.

35. **Preemphasis** is a method of improving the signal-to-noise (S/N) performance of an FM system. It works by boosting the deviation for *high* intelligence frequencies during transmit. In the USA, preemphasis is applied at and above 2122 Hz, which corresponds to an RC time-constant of 75 μS.

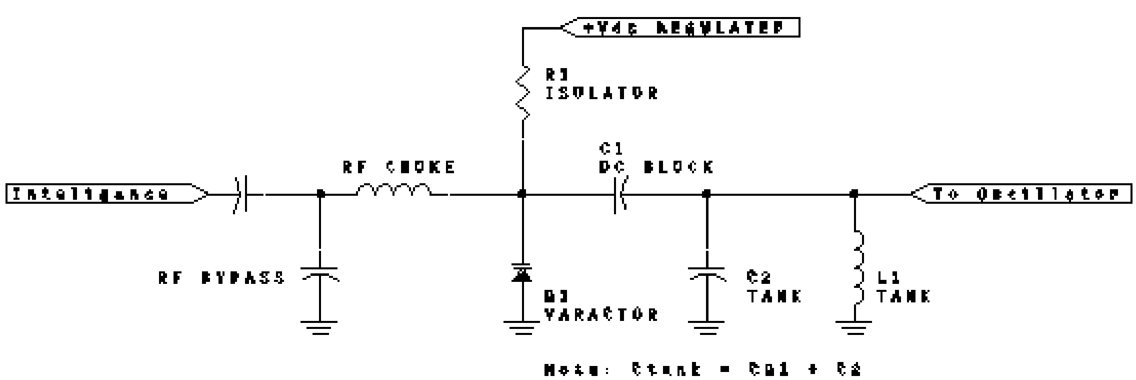
Deemphasis completes the process at the receiver by *attenuating* high intelligence frequencies in exactly the opposite manner of the preemphasis that was applied at the transmitter, thus preserving a “flat” frequency response in the signal channel. *Deemphasis helps the system noise figure by reducing the sensitivity of the receiver to high-frequency noise, which is the most objectionable to the listener.*

NOTE:

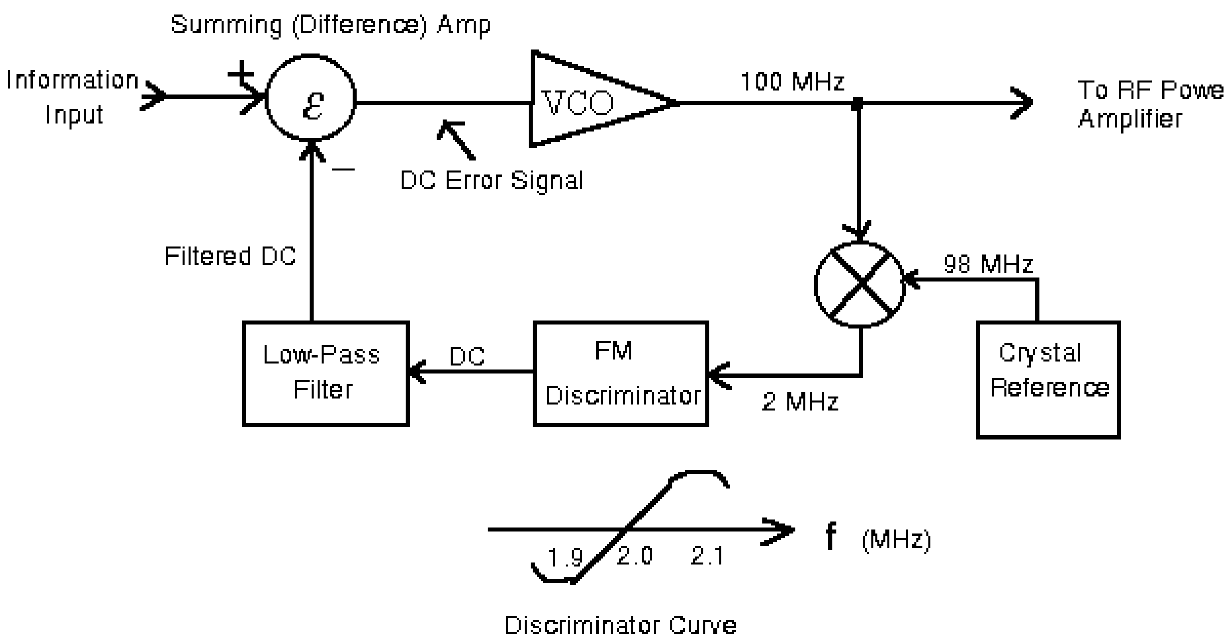
In terms of the RC time-constant (τ) the cutoff frequency of the filters for preemphasis and deemphasis can be calculated as:

$$fco = \frac{1}{2\pi\tau} = \frac{1}{2\pi * 75\mu S} = 2122Hz$$

37. A simple FM generator employing a **varactor diode** is shown below. It works by varying the DC reverse-bias on the diode in step with the information signal. This in turn changes the total diode capacitance; since the diode is part of the tank circuit, its resonant frequency changes – and thus FM is generated.



40. A **Crosby** FM modulator uses a conventional LC-controlled VCO as its frequency determining element. This allows it to produce plenty of deviation with low distortion, but unfortunately, would allow the center frequency to drift if not corrected. Therefore, a Crosby exciter also includes circuitry to compare the average transmitter frequency with a crystal-based frequency reference. Any long-term errors are sent back to the VCO as an error signal, thus cancelling most of the frequency error. Short-term errors in frequency are allowed; otherwise, it would be impossible for the VCO to be frequency-modulated! A low-pass filter with an RC time-constant of approximately 200 mS is used to force the system to ignore the short-term (modulation) errors.



42. If an FM transmitter employs one doubler, one tripler, and one quadrupler, what is the carrier frequency swing (deviation) when the original oscillator deviation is 2 KHz?

$\delta' = \delta * N = 2KHz * (2*3*4) = \underline{\underline{48KHz}}$ Where N is the total multiplication.