EECS 562

Homework 9

**1.** Determine the instantaneous phase and frequency for the following signals. Let $f_c$=100kHz

a. $\cos(2\pi f_c t+500t^2)$

b. $\cos(2\pi f_c t+500\sqrt{t})$

**2.** Given a set of information bits $b_i$ = {0, 1 ,1, 0}. Let x(t) = 0 for 1 ms for a bit = 0 and x(t) = 1 for 1ms for a bit = 1.
A modulated RF signal is $y_{RF}(t) = 10\cos(2\pi( x(t)*10000 + f_c)t)$ where $f_c$=10kHz. Plot y(t) for 0<t<4ms.

**3.** A message signal is $x(t)= \cos(2\pi f_m t)$. The transmitted RF signal is given by $y_{RF}(t) = 20\cos(2\pi f_c t + \beta\sin(2\pi f_m t))$, where $f_c$=100MHz, $\beta$=3, and $f_m$= 15kHz.

a. Is the RF modulation:

i. PM

ii. FM

iii. VSB

iv. SSB

v. DSB-LC

b. What is the instantaneous frequency?

c. What is the total power in $dB_W$?

d. What is the frequency deviation, Δf?

e. What is the RF bandwidth of $y_{RF}(t)$?

f. How much power is at 100 MHz?

g. How much power is at 100.03 MHz?

**4.** Let the RF signal be
$y_{RF}(t) = A_c\cos(\theta_i(t))$ where
$\theta_i(t) = 2\pi f_c t + \beta\sin(2\pi f_m t)$ with $x_{bb}(t) = A_m\cos(2\pi f_m t)$
Here $A_m$=2.0V and $f_c$=109MHz, $f_m$=1kHz, $A_c$=20V, $\beta$=0.25

a. Is the phase or frequency modulation?

b. What is the modulation index?

c. Find the frequency deviation.

d. Find the frequency sensitivity factor in Hz/V.

e. Plot the amplitude spectrum of $y_{RF}(t)$.
State any approximations.

f. What is the total power in $y_{RF}(t)$ in $dB_W$?

g. What is the RF bandwidth?

**5.** Let the RF signal be
$y_{RF}(t) = A_c\cos(\theta_i(t))$ where
$\theta_i(t) = 2\pi f_c t + \beta\sin(2\pi f_m t)$ with $x_{bb}(t) = A_m\cos(2\pi f_m t)$
Here $A_m$=1.0V and $f_c$=109MHz, $f_m$=1kHz, $A_c$=10V, $\beta$=5.

a. Find the frequency deviation, Δf.

b. Find the frequency sensitivity factor in Hz/V.

c. Plot the amplitude spectrum of $y_{RF}(t)$.

d. What is the RF bandwidth?

**6.** For each case below use using Carson's rule to find the bandwidth of the frequency modulated signal. The deviation constant = 0.75 Hz/volt.

a. $A_c$=1.5V, $f_m$=2 Hz, $f_c$=8 Hz, message amplitude = $A_m$=0.5V,

b. $A_c$ =1.5V, $f_m$ =2 Hz, $f_c$=8 Hz, message amplitude = $A_m$ =1.5V

c. $A_c$ =1.5V, $f_m$ =0.5 Hz, $f_c$=8 Hz, message amplitude = $A_m$ =1.5V

d. Define a bandwidth expansion factor as $B_{RF}$ $/B_{bb}$. Calculate the bandwidth expansion factor the systems defined in parts a)-c).

**7.** Let the message signal m(t) given below be the input to an FM modulator with $k_f$=20Hz/V and $f_c$=200 Hz and $A_c$=1.0. $v$ = {2.5, 5, 7.5}, the symbol time=40ms.

m(t)= $\sum_{i=1}^{3} v_i \,\text{rect}\left(\frac{t-(i-1)\,T_s-0.5\,T_s}{T_s}\right)$

a. Plot m(t).

b. Plot the RF signal, $y_{RF}$(t).

c. What frequencies are present in $y_{RF}$(t)

d. Suggest a detector architecture detect each symbol

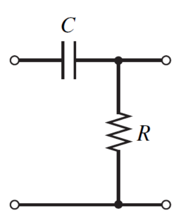
**8.** In a stream of bits each pair of bits (2 bits) is mapped into one voltage level to form the baseband signal, e.g. m(t) = $v_i$ for 20 ms, where $v_i$=0, 2.5, 7.5, 10. The message signal is input to an FM modulator with $k_f$=20Hz/V and $f_c$=2000 Hz and $A_c$=1.

a. What is the bit rate for this signal?

b. During a symbol time of 20ms are the 4 possible transmitted RF signals, are these orthogonal to each other?

**9.** A DC blocking capacitor is not needed when a balanced discriminator is used to demodulate FM signals, why?

**10.** A HPF shown below has a transfer function of H(f) = $\frac{j2\pi fRC}{1+j2\pi fRC}$, the 3dB cutoff frequency = $\frac{1}{2\,\pi RC}$; let R=800Ω, $C = 10^{-9}$ f,




a. Plot |H(f)| and find and mark the 3dB cutoff = $f_{3\,\text{dB}}$.

b. The input to H(f) is $x_{RF}(t)$ =cos(2 $\pi$f$_c$t +$\beta$sin(2 $\pi$f$_m$t)). The output $y(t) \approx H(f_i(t))$. For R=800Ω, $C = 10^{-9}$ f, $\beta$=1, $f_m$=1000Hz, and $f_c$=100kHz. Find |y(t)|; note here $f_c \ll f_{3\,\text{dB}}$ and H(f) is approximately linear.

**11.** A message signal $m(t) = A_1 \cos(2\pi f_1 t) + A_2 \cos(2\pi f_2 t)$ is input to an FM modulator with modulation index $\beta$. The transmitted FM signal can be written as

$s(t) = A_c \cos\left(2\pi f_c t + \beta\left(\frac{A_1}{2\pi f_1}\sin(2\pi f_1 t) + \frac{A_2}{2\pi f_2}\sin(2\pi f_2 t)\right)\right)$ let

$\beta_1 = \beta \frac{A_1}{2\pi f_1}$ and $\beta_2 = \beta \frac{A_2}{2\pi f_2}$ then s(t) can be expanded using Bessel functions to form

$$s(t) = A_c \sum_{k=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} J_k(\beta_1) J_n(\beta_2) \cos\left(2\pi \left(f_c + k f_1 + n f_2\right) t\right)$$

Given this knowledge is FM a linear or non-linear modulation and justify your answer.