EECS 562

Homework 9

1. Determine the instantaneous phase and frequency for the following signals. Let f_c=200kHz

a. $\cos(2\pi f_c t + 400t^2)$

b. $\cos(2\pi f_c t + 400\sqrt{t})$

2. Given a set of information bits b_i = {1, 0 ,0, 1}.
Let x(t) = 0 for 2 ms for a bit = 0 and x(t) = 2 for 2ms for a bit = 1, i.e., the bit time is 2 ms.
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 $y_{RF}(t) = 10\cos(2\pi f_c t + \beta\sin(2\pi f_m t))$, where f_c=100MHz, β=2, 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 in dB_W?

g. How much power is at 100.03 MHz in dB_W?

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, β=0.4

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, β=4.

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=1.5Vand f_m=2 Hz message amplitude = A_m=0.5V,
b. A_c =1.5V and f_m =2 Hz message amplitude = A_m =1.5V
c. A_c =1.5V and f_m =0.5 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).
e. Use Interactive: Spectrum of FM/PM Tone Modulated Signals to verify your answers to a-c and report magnitude spectrum plots for each case.

7. Let the message signal m(t) given below be the input to an FM modulator with k_f=15Hz/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=40Hz/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 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 β. 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

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

$$s(t) = A_c \sum_{k=-\infty}^{\infty}\sum_{n=-\infty}^{\infty} J_k(\beta_1)J_n(\beta_2)\cos\left(2\pi\left(f_c + kf_1 + nf_2\right)t\right)$$

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