Polytechnic University of Puerto Rico
Electrical Engineering Department
EE 4704-09: Analog Communication I
Quiz #2, Spring Quarter 2004, May 03

Apellido _____ Nombre_____#_____

Write the solutions in this sheet, However, show <u>all intermediate</u> steps in a separate piece of paper when required . In that case no credit will be given for final results only.

Problem 1. *Topic: demodulation in DSB-SC Modulation (15 points)*
What is the first step to adquire the carrier in DSB-SC modulation?

a) ☐ Use a Band Pass Filter tuned to f_c to separate the carrier from the sidebands.

b) ☐ Square the signal to obtain a $2f_c$ component from the signal.

c) ☐ Demodulate and use a Low Pass Filter to separate the information signal.

d) ☐ It can't be done, since in DSB-SC there is not carrier.

Problem 2. *Topic: PLL (15 points)*
What is the effect in the output of the VCO when the frequency of the PLL input signal increase?

a) ☐ The phase of the VCO increases.
b) ☐ The frequency of the VCO increases.
c) ☐ The error signal increases.
d) ☐ The equilibrium is reached.

Problem 3. *Topic: DSB-TC (15 points)*
What is the effect in the efficiency η if the carrier amplitude changes from 2 to 1 and we know that the sideband power is 1? (You should justify this answer in a separate piece of paper)

a) ☐ η is doubled.

b) ☐ η increases by a factor of 3.

c) ☐ η increases by a factor of 4.

d) ☐ η does not change.

Problem 4. *Topic: Upper and Lower Sidebands in DSB-TC Modulation (55 points)*
The signal $m(t) = 2\cos(200\pi t)$ is modulated by the carrier $c(t) = \cos(2000\pi t)$ using DSB-TC modulation. If the modulation index is $\mu = 1$

a) *(5 points)* Find the power of the sidebands ..
b) *(5 points)* Find the power of the carrier (after modulation). ..
c) *(5 points)* Find the efficiency using only μ ..
d) *(5 points)* Find the efficiency using the Power of the carrier and sidebands. ..
e) *(5 points)* Plot the time signal $m(t)$

f) *(5 points)* Plot the time signal, $c(t)$

g) *(5 points)* Plot the time signal $\varphi_{DSB-TCm}(t)$

h) *(5 points)* Plot the spectrum of $m(t)$ i.e. $|M(f)|$,

i) *(5 points)* Plot the spectrum of $c(t)$ i.e. $|C(f)|$

j) *(5 points)* Plot the spectrum of $\varphi_{DSB-TCm}(t)$ i.e. $|\Gamma_{DSB-TCm}(f)|$

k) *(5 points)* Mark on the drawing the upper side band frequencies of $|\Gamma_{DSB-TCm}(f)|$

Problem 1 SOLUTION. *Topic: demodulation in DSB-SC Modulation (15 points)*
What is the first step to adquire the carrier in DSB-SC modulation?

a)☐ Use a Band Pass Filter tuned to f_c to separate the carrier from the sidebands.

b)☒ Square the signal to obtain a $2f_c$ component from the signal.

c)☐ Demodulate and use a Low Pass Filter to separate the information signal.

d)☐ It can't be done, since in DSB-SC there is not carrier.

Problem 2 SOLUTION. *Topic: PLL (15 points)*
What is the effect in the output of the VCO when the frequency of the PLL input signal increase?

a)☐ The phase of the VCO increases.

b)☒ The frequency of the VCO increases.

c)☐ The error signal increases.

d)☐ The equilibrium is reached.

sideband power is 1? (You should justify this answer in a separate piece of paper)

Problem 3 SOLUTION. *Topic: DSB-TC (15 points)*
What is the effect in the efficiency η if the carrier amplitude changes from 2 to 1 and we know that the sideband power is 1?

a)☒ η is doubled.

b)☐ η increases by a factor of 3.

c)☐ η increases by a factor of 4.

d)☐ η does not change.

Justification: by definition the efficiency is:

$$\eta = \frac{UsefulPower}{TotalPower} = \frac{P_s}{P_c + P_s}$$

The carrier power is defined as:

$P_c = \frac{A^2}{2} = \frac{2^2}{2} = 2$ where *A* is the carrier amplitude.

Therefore at the beginning:

$$\eta = \frac{P_s}{P_c + P_s} = \frac{1}{2+1} = 1/3$$

If the carrier amplitude changes from 2 to 1 the new carrier power is:

$P_{c2} = \frac{(1)^2}{2} = \frac{1}{2} = \frac{1}{4}P_c$. Therefore the power diminishes by 4.

The new efficiency is then:

$$\eta_2 = \frac{P_s}{P_{c2} + P_s} = \frac{1}{\frac{1}{2}+1} = \frac{2}{1+2} = \frac{2}{3}$$ Is double than before.

In general

$$\eta_2 = \frac{P_s}{P_{c2} + P_s} = \frac{P_s}{\frac{P_c}{4} + P_s} = \frac{4P_s}{P_c + 4P_s}$$

Problem 4 SOLUTION. *Topic: Upper and Lower Sidebands in DSB-TC Modulation (55 points)*
The signal $m(t) = 2\cos(200\pi t)$ is modulated by the carrier $c(t) = \cos(2000\pi t)$ using DSB-TC modulation. If the modulation index is $\mu = 1$

a) *(5 points)* Find the power of the sidebands.

The Power of the sidebands is half the power of $m(t)$

The Power of $m(t)$ is $P_m = \frac{m^2{}_p}{2} = \frac{2^2}{2} = 2$

Therefore the Power of the sideband is

$$P_s = \frac{1}{2} P_m = 1$$

b) *(5 points)* Find the power of the carrier (after modulation).
After modulation the carrier has amplitude *A*.

$$A = \mu m_p = 1 * 2$$

The power is then $P_c = \frac{A^2}{2} = \frac{2^2}{2} = 2$

c) *(5 points)* Find the efficiency using only μ

By the formula for tone modulation

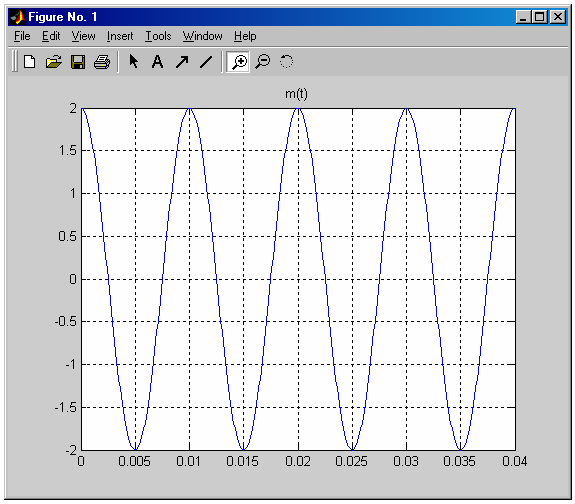
$$\eta = \frac{\mu^2}{2 + \mu^2} * 100\% = \frac{1^2}{2 + 1^2} * 100\% = 33.3\%$$

d) *(5 points)* Find the efficiency using the Power of the carrier and sidebands.

$$\eta = \frac{P_s}{P_c + P_s} 100\% = \frac{1}{2 + 1} 100\% = 1/3 * 100\% = 33.3\%$$

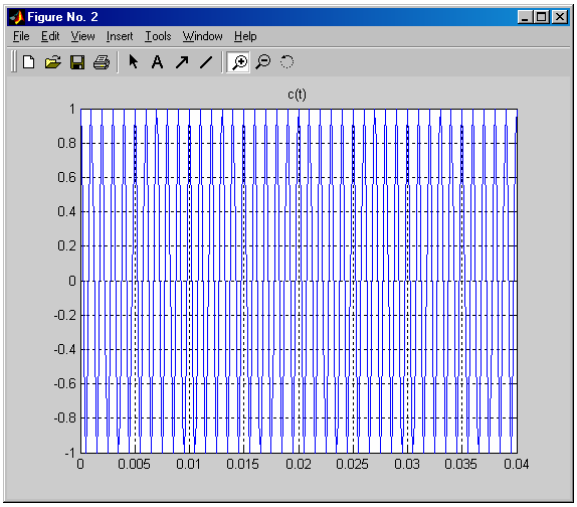
e) *(5 points)* Plot the time signal $m(t)$

$$m(t) = 2\cos(200\pi t)$$



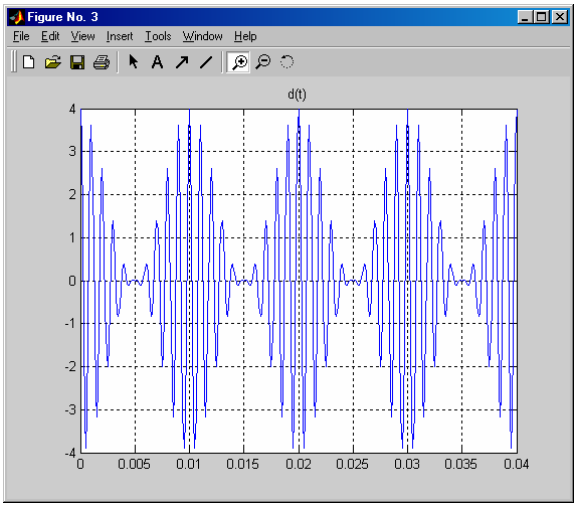
f) *(5 points)* Plot the time signal, $c(t)$

$$c(t) = \cos(2000\pi t)$$

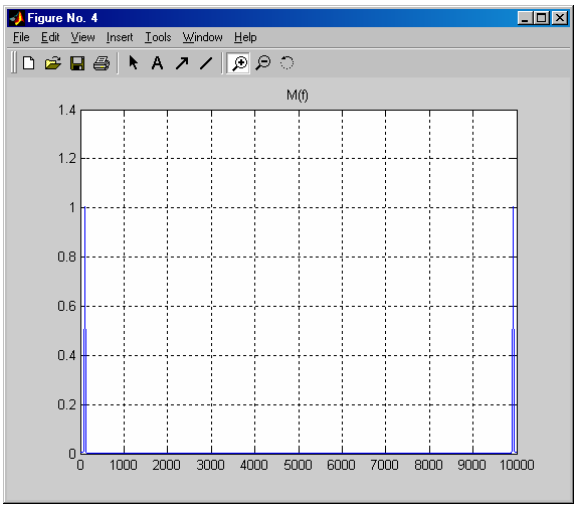


g) *(5 points)* Plot the time signal $\varphi_{DSB-TCm}(t)$

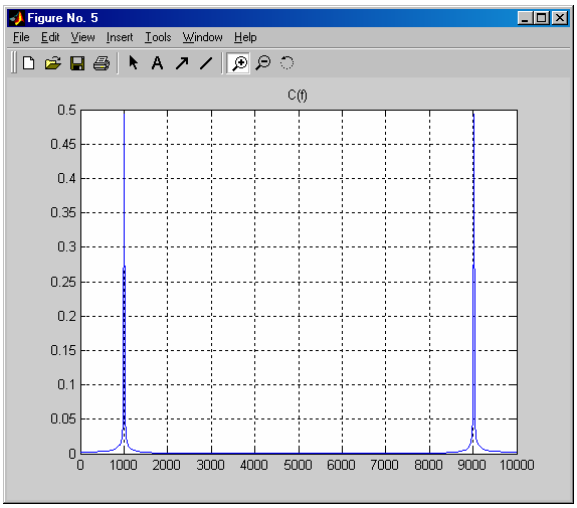
$$\varphi_{DSB-TCm}(t) = (A + m(t))c(t) = (2 + 2\cos(200\pi t))\cos(2000\pi t)$$



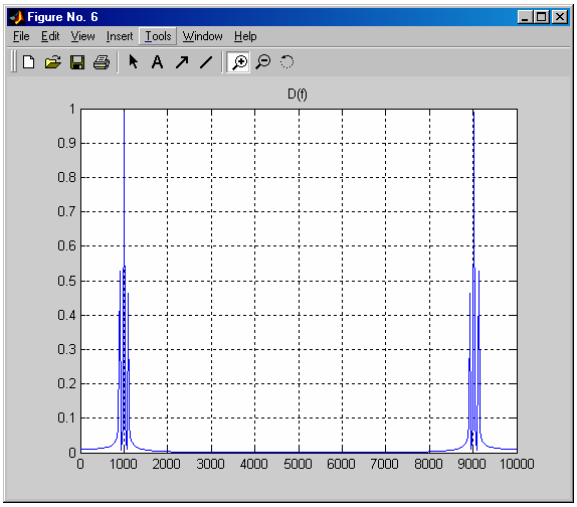
h) *(5 points)* Plot the spectrum of $m(t)$ i.e. $|M(f)|$,



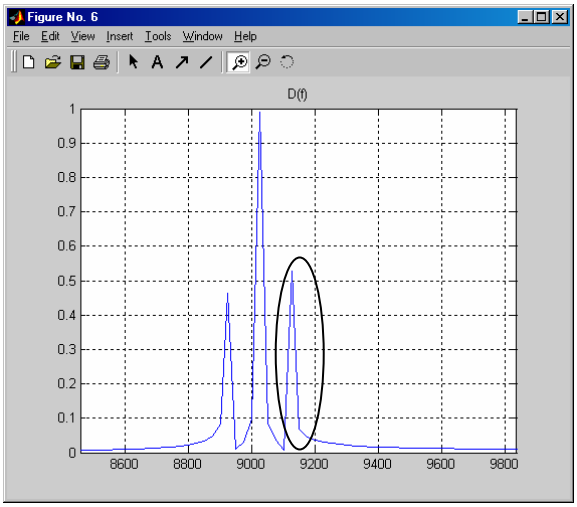
i) *(5 points)* Plot the spectrum of $c(t)$ i.e. $|C(f)|$



j) *(5 points)* Plot the spectrum of $\varphi_{DSB-TCm}(t)$ i.e. $|\Gamma_{DSB-TCm}(f)|$



k) *(5 points)* Mark on the drawing the upper side band frequencies of $\left|\Gamma_{DSB-TCm}(f)\right|$



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