Birzeit University
Faculty of Engineering and Technology
Department of Electrical and Computer Engineering
Communication Systems ENEE 3309
Midterm Exam

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Problem 1: 25 Points

Consider the normal AM signal $s(t) = A_c\,[1 + \mu\cos(2\pi 150t)]\,cos2\pi(1500)t$.
When μ = 0.42, s(t) has a total average power of 47.3 W.

a. Find the power efficiency η
b. Find the bandwidth of s(t)
c. Calculate the average power in the carrier
d. Calculate the average power in the upper sideband.

a. $\eta = \frac{\mu^2}{2+\mu^2} = \frac{(0.42)^2}{2+(0.42)^2} = 0.081$

b. $B.W = 2f_m = 2(150) = 300\ HZ$

c. $s(t) = A_c \cos 2\pi f_c t + A_c \mu \cos 2\pi f_c t \cos 2\pi f_m t$
$= A_c \cos 2\pi f_c t + \frac{A_c \mu}{2} \cos 2\pi (f_c + f_m)t$
$+ \frac{A_c \mu}{2} \cos 2\pi (f_c - f_m)t$

$P_{av} = \frac{A_c^2}{2} + \frac{A_c^2 \mu^2}{8} + \frac{A_c^2 \mu^2}{8}$

$P_{av} = \frac{A_c^2}{2}\left(1 + \frac{1}{2}\mu^2\right) \Rightarrow 47.3 = P_c\left(1 + \frac{1}{2}(0.42)^2\right)$

$\Rightarrow \boxed{} = \frac{A_c^2}{2}$

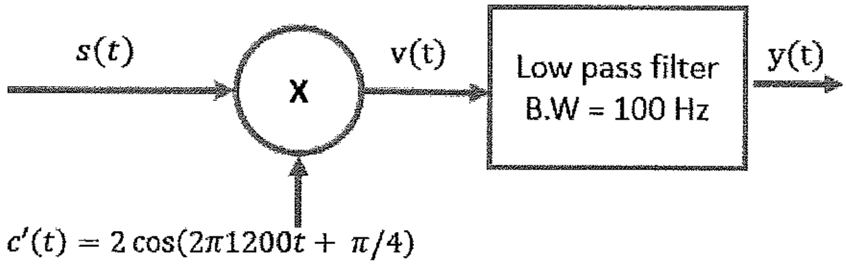
$\Rightarrow$ $47.3 = 1.088\ P_c \Rightarrow P_c = 43.46 = A^2/2$

d. upper side band $= \frac{A_c \mu}{2} \cos 2\pi (f_c + f_m)t$

Power $= \frac{A_c^2 \mu^2}{8} = \frac{A_c^2}{2} \cdot \frac{\mu^2}{4}$
$= (43.46) * \frac{(0.42)^2}{4} = 1.91$

Problem 2: 25 Points

The message signal $m(t) = 3\cos(2\pi 60t) + 6\cos(2\pi 120t)$ along with the carrier signal $c(t) = 4\cos(2\pi 1200t)$ are applied to a modulator that generates the double sideband suppressed carrier signal s(t). The demodulator is as shown in the figure below. It consists of a multiplier followed by a low pass filter, where the locally generated signal is $c'(t) = 2\cos(2\pi 1200t + \pi/4)$ and the bandwidth of the low pass filter is 100 Hz.



a. Find the bandwidth of m(t).
b. Find the time-domain expression of the modulated signal s(t).
c. Find the total average transmitted power.
d. Find the signal at the demodulator output.

a. B.W = 120 Hz

b. $s(t) = 4[\cos 2\pi(1200)t][3\cos 2\pi(60)t + 6\cos 2\pi(120)t]$

$= 12\cos 2\pi(1200)t \cos 2\pi(60)t$

$+ 24\cos 2\pi(1200)t \cos 2\pi(120)t$

$= 6\cos 2\pi(1260)t + 6\cos 2\pi(1140)t$

$+ 12\cos 2\pi(1320)t + 12\cos 2\pi(1080)t$

c. Power in $s(t) = \frac{(6)^2}{2} + \frac{(6)^2}{2} + \frac{(12)^2}{2} + \frac{(12)^2}{2}$

$= 36 + 144 = 180$ W

d. component at 120 HZ will not pass plus other high frequency terms

$y(t) = s(t) * 2\cos(2\pi 1200t + \pi/4)$

$= LP\{6\cos 2\pi(1260)t \times 2\cos(2\pi 1200t + \pi/4)\}$

$= 6\cos 2\pi(60)t \cos\frac{\pi}{4}$

$y(t) = \frac{6}{\sqrt{2}}\cos 2\pi(60)t = 4.24\cos 2\pi(60)t$

Problem 3: 25 Points

Consider the double sideband suppressed carrier signal

$$s(t) = 2\cos(2\pi 140t)\cos(2\pi 1750t)$$

An upper single sideband signal g(t) is to be generated from s(t) using the filtering method

7 a. Find g(t), assuming an ideal bandpass filter is used.
5 b. Find the best choice for the center frequency of the bandpass filter used to produce g(t)
8 c. Draw the block diagram of the receiver used to recover m(t) from g(t) without distortion identifying the details and properties of each block.
5 d. What will be the output of the diagram of part c?

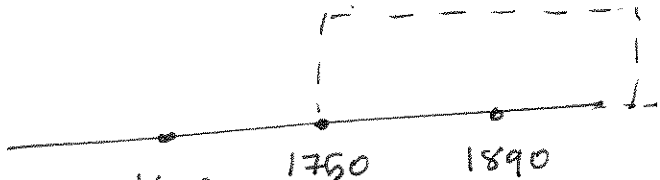
$s(t) = 2\cos 2\pi(140)t \cos 2\pi(1750)t$

$1750 - 140$

7 $= \cos 2\pi(140+1750)t + \cos 2\pi(1610)$

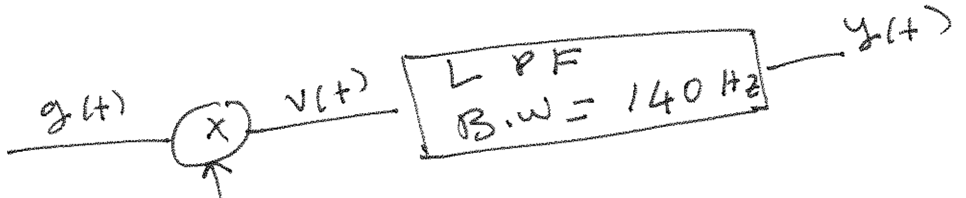
a. $s(t) = \cos 2\pi(1890)t + \cos 2\pi(1610)t$

$g(t) = \cos 2\pi(1890)t$



b. $f_0 = 1890$

c.



$A_c' \cos 2\pi(1750)t$

$v(t) = A_c' \cos 2\pi(1890)t \cos 2\pi(1750)t$

$v(t) = \frac{A_c'}{2}\cos 2\pi(3640)t + \frac{A_c'}{2}\cos 2\pi(140)t$

$y(t) = \frac{A_c'}{2}\cos 2\pi(140)t$

Problem 4: 25 Points

The audio signal $m(t) = A_m\cos(2\pi(100)t)$ frequency modulates the carrier $c(t) = \cos 2\pi(1000)t$. The resulting FM signal is

$$s(t) = \cos[2\pi(1000)t + \beta sin2\pi(100)t].$$

When $A_m = 1.8$, s(t) shows a peak frequency deviation of 320 Hz.

7 a. Find the FM modulation index

6 b. Use Casron's rule to estimate the bandwidth of s(t)

6 c. Find k_f , the sensitivity of the FM modulator in Hz/V

6 d. If A_m changes to 3.2 V, find the new frequency modulation index.

Good Luck

$s(t) = \cos(2\pi(1000)t + \beta \sin 2\pi(100)t)$

$A_m = 1.8, \quad \Delta f = 320 \text{ Hz}$

a. $\beta = \dfrac{\Delta f}{f_m} = \dfrac{320}{100} = 3.2$

b. $B.W = 2(\beta+1) f_m = 2(3.2+1) * 100$

$= 840 \text{ Hz}$

c. $\Delta f = K_f A_m$

$320 = K_f (1.8) \Rightarrow K_f = 177.77 \text{ Hz/V}$

d. $\Delta f = K_f A_m$

$= 177.77 * 3.2$

$= 568.864 \text{ Hz}.$

$\beta = \dfrac{568.4}{100} = 5.68$

TABLE A6.4 *Trigonometric Identities*

$\exp(\pm j\theta) = \cos\theta \pm j\sin\theta$

$\cos\theta = \frac{1}{2}[\exp(j\theta) + \exp(-j\theta)]$

$\sin\theta = \frac{1}{2j}[\exp(j\theta) - \exp(-j\theta)]$

$\sin^2\theta + \cos^2\theta = 1$

$\cos^2\theta - \sin^2\theta = \cos(2\theta)$

$\cos^2\theta = \frac{1}{2}[1 + \cos(2\theta)]$

$\sin^2\theta = \frac{1}{2}[1 - \cos(2\theta)]$

$2\sin\theta\cos\theta = \sin(2\theta)$

$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$

$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$

$\tan(\alpha \pm \beta) = \dfrac{\tan\alpha \pm \tan\beta}{1 \mp \tan\alpha\tan\beta}$

$\sin\alpha\sin\beta = \frac{1}{2}[\cos(\alpha - \beta) - \cos(\alpha + \beta)]$

$\cos\alpha\cos\beta = \frac{1}{2}[\cos(\alpha - \beta) + \cos(\alpha + \beta)]$

$\sin\alpha\cos\beta = \frac{1}{2}[\sin(\alpha - \beta) + \sin(\alpha + \beta)]$

TABLE A6.2 *Fourier-Transform Pairs*

Time Function	*Fourier Transform*
$\mathrm{rect}\left(\frac{t}{T}\right)$	$T\,\mathrm{sinc}\,(fT)$
$\mathrm{sinc}\,(2Wt)$	$\frac{1}{2W}\mathrm{rect}\left(\frac{f}{2W}\right)$
$\exp(-at)u(t), \quad a > 0$	$\frac{1}{a + j2\pi f}$
$\exp(-a\|t\|), \quad a > 0$	$\frac{2a}{a^2 + (2\pi f)^2}$
$\exp(-\pi t^2)$	$\exp(-\pi f^2)$
$\begin{cases} 1 - \frac{\|t\|}{T}, & \|t\| < T \\ 0, & \|t\| \geq T \end{cases}$	$T\,\mathrm{sinc}^2(fT)$
$\delta(t)$	1
1	$\delta(f)$
$\delta(t - t_0)$	$\exp(-j2\pi f t_0)$
$\exp(j2\pi f_c t)$	$\delta(f - f_c)$
$\cos(2\pi f_c t)$	$\frac{1}{2}[\delta(f - f_c) + \delta(f + f_c)]$
$\sin(2\pi f_c t)$	$\frac{1}{2j}[\delta(f - f_c) - \delta(f + f_c)]$
$\mathrm{sgn}(t)$	$\frac{1}{j\pi f}$
$\frac{1}{\pi t}$	$-j\,\mathrm{sgn}(f)$
$u(t)$	$\frac{1}{2}\delta(f) + \frac{1}{j2\pi f}$
$\sum_{i=-\infty}^{\infty} \delta(t - iT_0)$	$\frac{1}{T_0}\sum_{n=-\infty}^{\infty} \delta\left(f - \frac{n}{T_0}\right)$