EET368 HOMEWORK #3 KEY

MILLER CHAPTER 2 PROBLEMS 1-7,9-13,15-22

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

1. The result of combining a 1500 KHz carrier and a 2 KHz intelligence in a **nonlinear** device would include:

   (a) 0 Hz (DC Level)
   (b) The ORIGINAL frequencies (1500 KHz, 2 KHz)
   (c) The SUM of the frequencies (1502 KHz)
   (d) The DIFFERENCE of the frequencies (1498 KHz)

2. The AM signal (Fc=1500 KHz and Fm=2 KHz) contains:

   (a) The carrier frequency, Fc: 1500 KHz
   (b) The UPPER SIDE BAND, Fusb: 1502 KHz
   (c) The LOWER SIDE BAND, Flsb: 1498 KHz

3. The **SIDEBANDS** are created by the combination or **mixing** of the CARRIER and INTELLIGENCE frequencies in a **nonlinear** device.

4. The bandwidth of an AM emission is determined by the **HIGHEST INTELLIGENCE FREQUENCY** $F_{m(max)}$. $BW = 2\ F_{m(max)}$

5. A SIDE FREQUENCY is ONE discrete (individual) frequency produced during modulation.

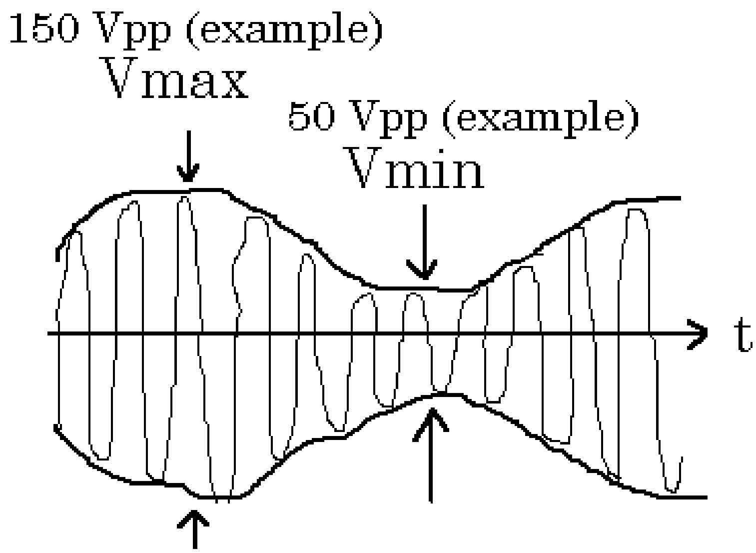
   A SIDEBAND is a RANGE of frequencies that are produced during modulation. It includes all possible **side frequencies** on one side of the carrier, either above (USB) or below (LSB).

6. At **point 6 in Fig 2-7**, the total instantaneous voltage *Vam(t)* is zero because the **total sideband voltage** and **carrier voltage** are exactly **equal** but **opposite**.

   The implication about the modulation signal, therefore, is that **its amplitude is exactly equal to the carrier voltage**, since *Vm=Vusb+Vlsb*. This signal is being 100% modulated.

7. The **phasor representation** of the components of an AM signal demonstrate the phenomenon of **interference.** The peaks and valleys of an AM waveform are created by **constructive and destructive interference** between the carrier and side frequencies. At the instant that all the voltages are in the same direction, maximum envelope magnitude results. When the voltages are maximally opposing, the trough or minimum envelope magnitude results. The frequency of the interference is the same as the frequency difference between the sidebands and carrier.

9. Draw a diagram of a carrier wave envelope when modulated 50% by a sinusoidal wave. Indicate on the diagram the dimensions from which the percentage of modulation is determined.



Vmax = 3 Vmin for 50% Modulation

THE DIMENSIONS "Vmax" AND "Vmin" SHOULD BE SHOWN ON THE WAVEFORM IN ORDER TO DETERMINE THE PERCENTAGE OF MODULATION.

THE EXAMPLE ABOVE SHOWS 50% MODULATION, WHICH MEANS THAT Vmax = 3*Vmin.

10. Some possible consequences of OVERMODULATION are:

- **Distorted sound** at the receiver.
- **Excessive bandwidth** (SPLATTERING).

11. If the UNMODULATED carrier is 300 V p-p, then the %m can be calculated for each "maximum p-p value" as follows:

By **symmetry**, we know that *Vmax* is the **same amount larger** than *Vunmod* That *Vmin* is **smaller than** *Vunmod.*

For example, Vunmod is 300 Vpp. Vmax is given as 400 Vpp, so they are 100 Vpp **different** and Vmin is therefore going to be 300 Vpp – 100 Vpp (the difference) = 200 Vpp. Therefore:

a) $m = \frac{V\max - V\min}{V\max + V\min} = \frac{400Vpp - 200Vpp}{400Vpp + 200Vpp} = 0.333 = \underline{\underline{33.3\%}}$

b) $m = \frac{V\max - V\min}{V\max + V\min} = \frac{500Vpp - 100Vpp}{400Vpp + 100Vpp} = 0.666 = \underline{\underline{66.6\%}}$

c) $m = \frac{V\max - V\min}{V\max + V\min} = \frac{600Vpp - 0Vpp}{600Vpp + 0Vpp} = 1 = \underline{\underline{100\%}}$

12. In figure 2-8, A=200V and B=60V. A is really Vmax and B is Vmin, so we get:

$$m = \frac{V\max - V\min}{V\max + V\min} = \frac{200Vpp - 60Vpp}{200Vpp + 60Vpp} = 0.5385 = \underline{\underline{53.85\%}}$$

13. Ec is the *average* of Vmax and Vmin:

Ec = (Vmax+Vmin)/2 = (100 Vpk + 30 Vpk) / 2 = 65 Vpk (45.96 Vrms)

Em is the *difference* between Vmax and Ec (or Ec and Vmin):

Em = Vmax – Ec = 100 Vpk – 65 Vpk = 35 Vpk (24.75 Vrms)

15. Given Vc=100 V, Fm=1 KHz, m=0.75 (75%) modulation, determine the side-frequency amplitudes.

Since *m = Vm/Vc,* we know that *Vm=m Vc = 0.75 (100V) = 75 V.*

Each sideband gets 50% of the information voltage, so:

Vusb = Vlsb = Vm / 2 = 75V/2 = 37.5V

16. Given Fc=1 MHz, Vc=40 V pk, Fm=5 KHz, m=0.7, RL = 50 Ohms; Calculate the power of each spectral component in the antenna.

(a) $Pc = Vc^2 / R_L = \left(40V/\sqrt{2}\right)^2 / 50\Omega = \underline{\underline{16 Watts}}$

(b) $Pusb = Plsb = \frac{1}{2} Pc\left(\frac{m^2}{2}\right) = (1/2)(16W)(0.7^2/2) = \underline{\underline{1.96 Watts}}$

Note: The term $Pc\left(\frac{m^2}{2}\right)$ gives total sideband power.

17. Find the carrier and sideband power if Pt = 500 W with the data from problem 15. (m=0.75)

$Pt = Pc(1 + m^2 / 2)$, so $Pc = Pt / (1 + m^2 / 2) = 500W/(1+0.75^2 / 2)$

Pc = $\underline{\underline{\text{390.24 Watts}}}$

Psidebands = Pt - Pc = 500W - 390.2439W = $\underline{\underline{\text{109.76 Watts}}}$

18. Find %m when Iantenna = 6.2A (Unmod) and 6.7A (modulated).

The solution may be derived by writing the **power** equation in terms of **current**: (Recall that $P = I^2 R$)

Let Itu = Unmod current = 6.2 A
Itm = Mod current = 6.7 A

$Pt = Pc(1 + m^2/ 2)$ by definition.

Then substituting the currents, we get:

$Itm^2 RL = Itu^2 RL (1 + m^2 / 2)$, since $P = I^2 R$

Solving for "m" yields:

$$m = \sqrt{2}\sqrt{\frac{Itm^2}{Itu^2} - 1} = \sqrt{2}\sqrt{\frac{6.7A^2}{6.2A^2} - 1} = 0.579295 = \underline{\underline{57.93\%}}$$

19. It is important to have a high percentage of modulation because THE POWER IN THE SIDEBANDS IS MAXIMUM AT 100% MODULATION, AND SIDEBANDS CARRY THE INFORMATION.

20. At 100% modulation, the sidebands contain the following percentage of the AVERAGE TOTAL power:

Under 100% modulation, the power of the carrier is **Pc**, a constant.

The power in the sidebands is given by the power equation:

$Pt = Pc(1 + m^2 / 2) = Pc(1) + Pc(m^2 / 2)$

Carrier Power + Sideband Power

$Psb / Pt = \text{Percentage} = Pc(m^2 / 2) / Pt = Pc(m^2 / 2) / Pc(1 + m^2 / 2)$

$= 1/3 = \underline{\underline{33.3\ \%}}$

21. Given 3 equal amplitude tones modulating a transmitter with m(effective) = 0.8, and Pc = 1 KW, calculate:

(a) The individual values for m1, m2, m3.

$$m_{eff} = \sqrt{m_1^2 + m_2^2 + m_3^2}$$

When m1=m2=m3, we can let *m* equal any of the three indices and write:

$$m_{eff} = \sqrt{3m^2}$$

Solving for ‘m’ yields:

$$m = m_{eff}\sqrt{\frac{1}{3}} = 0.8\sqrt{\frac{1}{3}} = \underline{\underline{0.462}}$$

(b) The total transmitted power Pt.

$$Pt = Pc(1 + \frac{m^2}{2}) = 1000W(1 + \frac{0.8^2}{2}) = \underline{\underline{1320 Watts}}$$

22. A 50 V RMS carrier is modulated by a square wave whose amplitude is 20 V peak (40 V p-p). What is m(effective) considering only the first 4 harmonics?

$$m_{eff} = \sqrt{m_1^2 + m_2^2 + m_3^2 + m_4^2}$$

Where m1..4 are the individual modulation indices caused by each spectral component of the information signal.

A Fourier analysis of the square wave reveals that each harmonic has an RMS voltage of:

$$Bn = \frac{4A}{n\pi\sqrt{2}}$$ (RMS Volts)

Where n = { 1,3,5,7 } for the first 4 terms of the series, and A=20Vpk (given).

Therefore, m(n) = Bn / Vc, and each spectral component is computed:

n	Bn(RMS)	m(n)	
1	18.00	0.360	(Fundamental/1st Harmonic)
3	6.00	0.120	(3rd Harmonic)
5	3.60	0.072	
7	2.57	0.0514	

$$m_{eff} = \sqrt{0.36^2 + 0.12^2 + 0.072^2 + 0.0514^2} = \underline{\underline{0.389 = 38.9\%}}$$