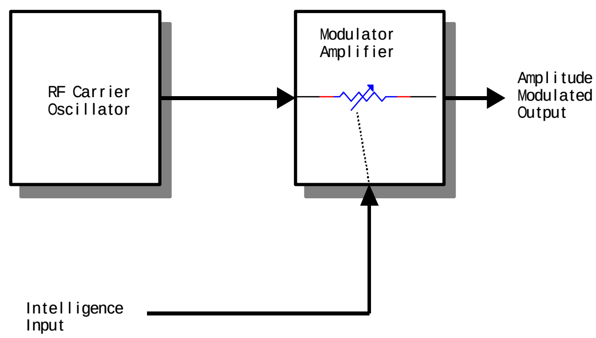
Homework #3 Solution Set

(26 points - 1 per problem)

1. *Draw a block diagram illustrating how an AM signal is generated*.



Above is figure 3-2, which shows that a variable gain element is needed in order to generate AM.

2. *What property of a modulator circuit causes AM to be generated*?

<u>Nonlinearity</u> is the property that causes AM to be generated. A nonlinear amplifier has a variable gain, which is required for generating AM.

3. *What signals are applied to the two inputs of a modulator*?

The two signals that are applied are the <u>carrier frequency</u> and the <u>intelligence frequency</u>.

4. *What is the envelope of an AM signal*?

The <u>envelope</u> is an imaginary line formed by the tips of the modulated RF waveform. There are two such lines, one on top and other on the bottom of the modulated waveform. The envelope represents the information signal.

5. *Define the modulation index of an AM signal. What is the maximum legal value*?

The <u>modulation index</u> is the ratio of intelligence voltage to carrier voltage, Vm/Vc. **Its maximum legal value is <u>1</u>.**

6. *What is the percentage of modulation for an AM signal with a modulation index of 0.3*?

An AM signal with a modulation index of 0.3 has <u>30% modulation</u>.

7. *List two consequences of overmodulation*.

Two consequences of overmodulation include <u>distortion of the information signal</u> and <u>excessive bandwidth (splatter)</u>.

8. *For the following AM signals, calculate the modulation index and percentage of modulation: a) Vmax=300 V, Vmin=100V ; b) Vmax=150 V, Vmin=0V ; c) Vmax=75 mV, Vmin=50 mV ; d) Vmax=5 V, Vmin=5V*

a) $m = \frac{V\max - V\min}{V\max + V\min} = \frac{300V - 100V}{300V + 100V} = \underline{\underline{0.5}} = \underline{\underline{50\% Modulation}}$

b) $m = \frac{V\max - V\min}{V\max + V\min} = \frac{150V - 0V}{150V + 0V} = \underline{\underline{1.0}} = \underline{\underline{100\% Modulation}}$

c) $m = \frac{V\max - V\min}{V\max + V\min} = \frac{75mV - 50mV}{75mV + 50mV} = \underline{\underline{0.2}} = \underline{\underline{20\% Modulation}}$

d) $m = \frac{V\max - V\min}{V\max + V\min} = \frac{5V - 5V}{5V + 5V} = \underline{\underline{0.0}} = \underline{\underline{0\% Modulation}}$ **(Dead-keyed)**

9. *What is the percentage of modulation of a dead-keyed transmitter***?**

A dead-keyed transmitter is unmodulated, or <u>0% modulated</u>.

10. *What is the name given to the new frequencies generated during the process of modulation***?**

The new frequencies that are generated during the process of modulation are called <u>sidebands</u>.

11. *How many sidebands are generated by each information frequency***?**

Each information frequency tone creates <u>two</u> sidebands (or <u>one pair</u>).

12. *An AM signal is being produced with the following characteristics: fc=560 KHz, Vc=1000V; fm=3 KHz, Vm=300V. Calculate the following:*
a) f_{usb} ; b) f_{lsb} ; c) m ; d) Percent Modulation ; e) V_{usb} ; f) V_{lsb} ; g) Bandwidth

a) $f_{usb} = f_c + f_m = 560KHz + 3KHz = \underline{\underline{563KHz}}$

b) $f_{lsb} = f_c - f_m = 560KHz - 3KHz = \underline{\underline{557KHz}}$

c) $m = \frac{Vm}{Vc} = \frac{300V}{1000V} = \underline{\underline{0.3}}$

d) $\%\text{mod} = 100\%(m) = 100\%(0.3) = \underline{\underline{30\%}}$

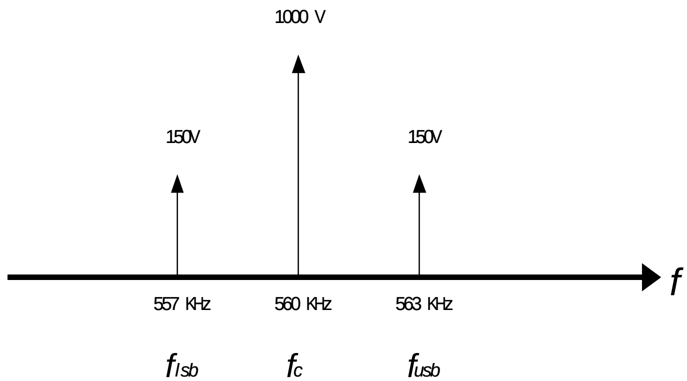
e) $V_{usb} = \frac{V_m}{2} = \frac{300V}{2} = \underline{\underline{150V}}$

f) $V_{lsb} = V_{usb} = \frac{V_m}{2} = \frac{300V}{2} = \underline{\underline{150V}}$

g) $BW = f_{usb} - f_{lsb} = 563KHz - 557KHz = \underline{\underline{6KHz}}$

13. *Draw a spectrogram of the AM signal of problem 12, showing all frequencies and voltages***.**

The figure below shows all frequencies and voltages of the resulting emission.



14. *An AM transmitter is operating on a carrier frequency of 9260 KHz with a carrier voltage of 20 V. For each of the information voltages and frequencies below, calculate f_{usb} , f_{lsb}, m, Percent Modulation, V_{usb}, V_{lsb}, and Bandwidth.*
a) Vm=10 V, fm = 2 KHz ; b) Vm=20 V, fm = 4 KHz ; c) Vm=5 V, fm = 1.5 KHz

a) $f_{usb} = f_c + f_m = 9260KHz + 2KHz = \underline{\underline{9262KHz}}$

$f_{lsb} = f_c - f_m = 9260KHz - 2KHz = \underline{\underline{9258KHz}}$

$m = \frac{Vm}{Vc} = \frac{10V}{20V} = \underline{\underline{0.5}}$

$\%\,\text{mod} = 100\%(m) = 100\%(0.5) = \underline{\underline{50\%}}$

$V_{usb} = \frac{V_m}{2} = \frac{10V}{2} = \underline{\underline{5V}}$

$V_{lsb} = V_{usb} = \underline{\underline{5V}}$

$BW = 2f_m = \underline{\underline{4KHz}}$

b) $f_{usb} = f_c + f_m = 9260KHz + 4KHz = \underline{\underline{9264KHz}}$

$f_{lsb} = f_c - f_m = 9260KHz - 4KHz = \underline{\underline{9256KHz}}$

$m = \frac{Vm}{Vc} = \frac{20V}{20V} = \underline{\underline{1.0}}$

$\%\,\text{mod} = 100\%(m) = 100\%(1.0) = \underline{\underline{100\%}}$

$V_{usb} = \frac{V_m}{2} = \frac{20V}{2} = \underline{\underline{10V}}$

$V_{lsb} = V_{usb} = \underline{\underline{10V}}$

$BW = 2f_m = \underline{\underline{8KHz}}$

c) $f_{usb} = f_c + f_m = 9260KHz + 1.5KHz = \underline{\underline{9261.5KHz}}$

$f_{lsb} = f_c - f_m = 9260KHz - 1.5KHz = \underline{\underline{9258.5KHz}}$

$m = \frac{Vm}{Vc} = \frac{5V}{20V} = \underline{\underline{0.25}}$

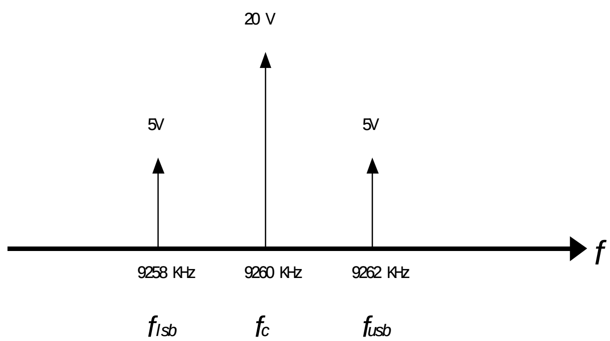
$\%\,\text{mod} = 100\%(m) = 100\%(0.25) = \underline{\underline{25\%}}$

$V_{usb} = \frac{V_m}{2} = \frac{5V}{2} = \underline{\underline{2.5V}}$

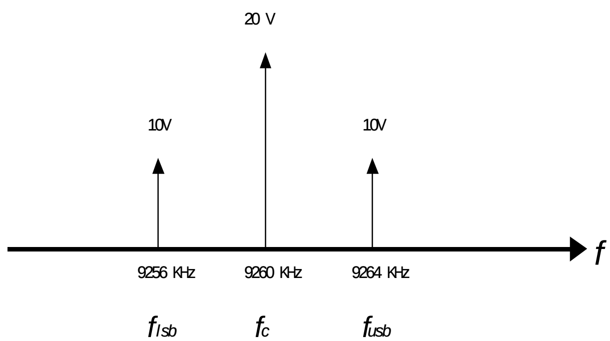
$V_{lsb} = V_{usb} = \underline{\underline{2.5V}}$

$BW = 2f_m = \underline{\underline{3KHz}}$

15. *Draw a spectrogram for each of the AM signals of problem 14, showing all frequencies and voltages*.

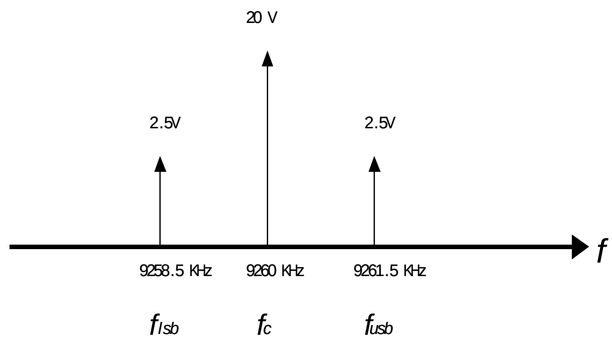


a)



b)

c)



16. *What characteristic of an information signal determines the bandwidth of an AM transmitter***?**

The frequency of the information signal determines the bandwidth. $BW=2f_m$

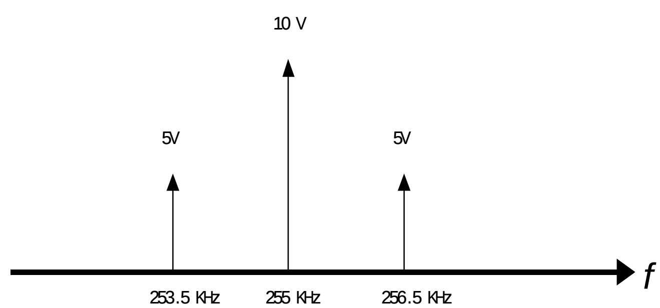
17. *In the USA, the FCC (Federal Communications Commission) regulates radio communications. In the FCC band plan for the AM broadcast band, each broadcaster is allowed to use 8 KHz of bandwidth in a 10 KHz wide "slot." What is the maximum information frequency that can modulate a broadcaster's transmitter***?**

This problem can be solved by solving equation (3-6) for f_m**:**

(3-6) $BW = 2f_m$

$$f_m = \frac{BW}{2} = \frac{8KHz}{2} = 4KHz$$

18. *What is the information frequency* f_m *and percentage of modulation for the AM signal pictured below***?**



[Figure 3-23]

The information frequency can be found by:

$$f_m = f_{usb} - f_c = 256.5KHz = 255KHz = \underline{\underline{1.5KHz}}$$

The percentage of modulation is calculated by first finding the modulation index *m*:

$$m = \frac{V_m}{V_c} = \frac{V_{lsb} + V_{usb}}{V_c} = \frac{5V + 5V}{10V} = \underline{\underline{1.0}}$$ **Which is <u>100% modulation</u>.**

19. *What is the bandwidth of the signal pictured in figure 3-23***?**

The bandwidth is calculated by:

$$BW = f_{usb} - f_{lsb} = 256.5KHz - 253.5KHz = \underline{\underline{3KHz}}$$

20. *The signal of figure 3-23 is being sent into a 50 Ohm antenna system. Calculate: a) Plsb ; b) Pc ; c) Pusb ; d) Pt*

a) $P_{lsb} = \frac{V_{lsb}^2}{R_L} = \frac{5V^2}{50\Omega} = \underline{\underline{0.5W}}$

b) $P_c = \frac{V_c^2}{R_L} = \frac{10V^2}{50\Omega} = \underline{\underline{2W}}$

c) $P_{usb} = \frac{V_{usb}^2}{R_L} = \frac{5V^2}{50\Omega} = \underline{\underline{0.5W}}$ **(Same as P_{lsb})**

d) $P_t = P_{lsb} + P_c + P_{usb} = 0.5W + 2W + 0.5W = \underline{\underline{3W}}$

21. *The AM transmitter of problem 14 is feeding a 75 Ohm antenna. For each case, calculate Plsb, Pc, Pusb, and Pt*

a) $P_{lsb} = \frac{V_{lsb}^2}{R_L} = \frac{5V^2}{75\Omega} = \underline{\underline{0.33W}}$

$P_c = \frac{V_c^2}{R_L} = \frac{20V^2}{75\Omega} = \underline{\underline{5.33W}}$

$P_{usb} = \frac{V_{usb}^2}{R_L} = \frac{5V^2}{75\Omega} = \underline{\underline{0.33W}}$ **(Same as P_{lsb})**

$P_t = P_{lsb} + P_c + P_{usb} = 0.33W + 5.33W + 0.33W = \underline{\underline{6W}}$

b) $P_{lsb} = \frac{V_{lsb}^2}{R_L} = \frac{10V^2}{75\Omega} = \underline{\underline{1.33W}}$

$P_c = \frac{V_c^2}{R_L} = \frac{20V^2}{75\Omega} = \underline{\underline{5.33W}}$

$P_{usb} = \frac{V_{usb}^2}{R_L} = \frac{10V^2}{75\Omega} = \underline{\underline{1.33W}}$ **(Same as P_{lsb})**

$P_t = P_{lsb} + P_c + P_{usb} = 1.33W + 5.33W + 1.33W = \underline{\underline{8W}}$

c) $P_{lsb} = \frac{V_{lsb}^2}{R_L} = \frac{2.5V^2}{75\Omega} = \underline{\underline{0.0833W}}$

$P_c = \frac{V_c^2}{R_L} = \frac{20V^2}{75\Omega} = \underline{\underline{5.33W}}$

$P_{usb} = \frac{V_{usb}^2}{R_L} = \frac{2.5V^2}{75\Omega} = \underline{\underline{0.0833W}}$ **(Same as P_{lsb})**

$P_t = P_{lsb} + P_c + P_{usb} = 0.0833W + 5.33W + 0.0833W = \underline{\underline{5.5W}}$

22. *What is the ratio of Pt to Pc at 100% modulation in an AM transmitter***?**

The ratio of *Pt* **to** *Pc* **is** **<u>1.5:1</u>** **at 100% modulation.**

23. *A certain AM transmitter is operating on 760 KHz, and when unmodulated, delivers 5000W to the antenna circuit. What will the total power be when it is: a) 25% modulated ; b) 50% modulated ; c) 75% modulated ; d) 100% modulated*

a) $P_t = P_c(1+\frac{m^2}{2}) = 5000W(1+\frac{0.25^2}{2}) = \underline{\underline{5156.25 Watts}}$

b) $P_t = P_c(1+\frac{m^2}{2}) = 5000W(1+\frac{0.50^2}{2}) = \underline{\underline{5625 Watts}}$

c) $P_t = P_c(1+\frac{m^2}{2}) = 5000W(1+\frac{0.75^2}{2}) = \underline{\underline{6406.25 Watts}}$

d) $P_t = P_c(1+\frac{m^2}{2}) = 5000W(1+\frac{1^2}{2}) = \underline{\underline{7500 Watts}}$

24. *Define the efficiency of a communication system***.**

The efficiency is defined as the ratio of information power to total transmitted power.

25. *Calculate the efficiency of the AM transmitter of problem 23 for each of the four conditions given***.**

a) $$h_{AM} = efficiency = \frac{P_{lsb}+P_{usb}}{P_{lsb}+P_c+P_{usb}} = \frac{P_{lsb}+P_{usb}}{P_t} = \frac{P_c\left(\frac{m^2}{2}\right)}{P_t} = \frac{5000W\left(\frac{.25^2}{2}\right)}{5156.25W} = \underline{\underline{3\%}}$$

b) $$h_{AM} = efficiency = \frac{P_{lsb}+P_{usb}}{P_{lsb}+P_c+P_{usb}} = \frac{P_{lsb}+P_{usb}}{P_t} = \frac{P_c\left(\frac{m^2}{2}\right)}{P_t} = \frac{5000W\left(\frac{.5^2}{2}\right)}{5625W} = \underline{\underline{11.1\%}}$$

c) $$h_{AM} = efficiency = \frac{P_{lsb}+P_{usb}}{P_{lsb}+P_c+P_{usb}} = \frac{P_{lsb}+P_{usb}}{P_t} = \frac{P_c\left(\frac{m^2}{2}\right)}{P_t} = \frac{5000W\left(\frac{.75^2}{2}\right)}{6406.25W} = \underline{\underline{22\%}}$$

d) $$h_{AM} = efficiency = \frac{P_{lsb}+P_{usb}}{P_{lsb}+P_c+P_{usb}} = \frac{P_{lsb}+P_{usb}}{P_t} = \frac{P_c\left(\frac{m^2}{2}\right)}{P_t} = \frac{5000W\left(\frac{1^2}{2}\right)}{7500W} = \underline{\underline{33\%}}$$

26. *Why does a radio transmitting antenna appear as a resistance in a circuit***?**

A transmitting antenna appears as a resistance because it accepts energy without returning it to the circuit (like a capacitor or inductor would do). The energy that goes into an antenna is converted into radio waves.