EE334
Amplitude Modulation #2

1. A carrier signal with an amplitude of 9 V is mixed with a modulating signal with an amplitude of 7.5 V. What is the modulation percentage (or fraction) of the resulting signal?

2. You're listening to an AM radio broadcast in the electrical engineering laboratory. You decide to hook up the output of the radio to a spectrum analyzer. A spectrum analyzer is a device that shows frequency content of a signal. You see that the frequencies coming out of the radio range between 150 and 4000 Hz. The radio is tuned to AM 700 (center frequency is 700 kHz). Sketch a frequency plot of the AM broadcast that your radio is receiving.

AM Power

- In the last set of notes you learned that a modulating sinusoid of frequency f_m that's mixed with a carrier produces a pair of sidebands. Each sideband is offset from the carrier by $\pm f_m$. Here's the corresponding equation for the AM signal's voltage:

$$v_{AM} = \frac{V_m}{2}\cos\left[2\pi(f_c - f_m)t\right] + V_c\cos\left[2\pi f_c t\right] + \frac{V_m}{2}\cos\left[2\pi(f_c + f_m)t\right]$$

- Note that there are three sinusoids (cos expressions) in the equation above. Moreover, each sinusoid is associated with a voltage. Since radio signals are both transmitted and received using antennas and antennas have resistance, power is present in the AM signal. In fact, we can associate power with both of the sidebands and the carrier:

$$P_{AM} = P_{LSB} + P_c + P_{USB}$$

- Recalling that V_m and V_c are the peak power values for the sinusoids and using the fact that

$$P = \frac{V_{\text{rms}}^2}{R} = \frac{\left(V_{pk} / \sqrt{2}\right)^2}{R} = \frac{V_{\text{pk}}^2}{2R}$$

where R is the resistance of an antenna, we can rewrite the AM power equation as

$$P_{AM} = \frac{V_m^2}{8R} + \frac{V_c^2}{2R} + \frac{V_m^2}{8R} = \frac{V_c^2}{2R} + \frac{V_m^2}{4R}$$

- We can also introduce the modulation index, $m = V_m / V_c$, into the mix and derive the following useful equations.

$$P_c = \frac{V_c^{\,2}}{2R}$$
$$P_{AM} = P_c\left(1 + \tfrac{m^2}{2}\right)$$
$$P_{LSB} = P_{USB} = P_c \tfrac{m^2}{4}$$
$$P_{SB} = 2P_{LSB} = 2P_{USB} = P_c \tfrac{m^2}{2}$$

3. An AM transmitter has carrier amplitude of 55V applied to an antenna with an impedance of 50Ω. The percentage modulation is 85%. Calculate the carrier power, total power, and the power in one sideband.

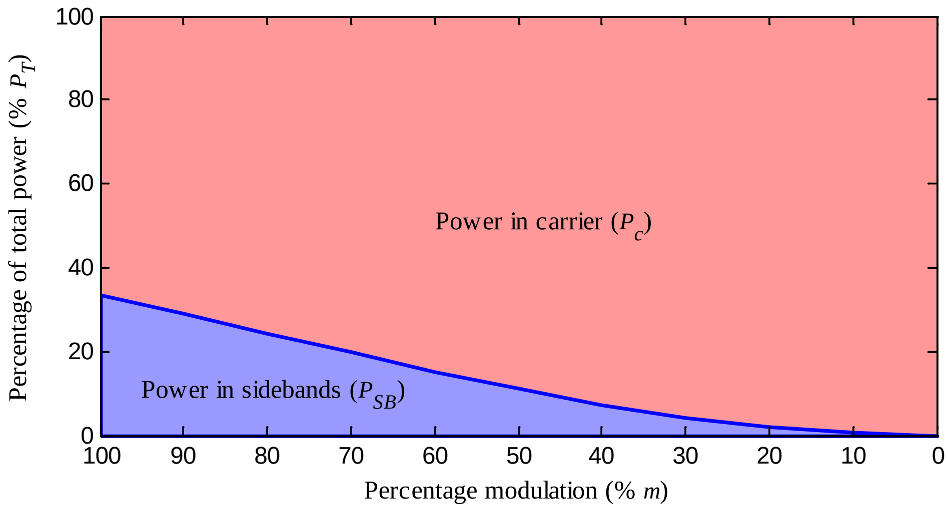
4. An AM transmitter has a carrier power of 100 W. The USB and LSB each are transmitting at a maximum of 10 W. Determine the modulation index.

5. If the modulation index goes over 1, the AM signal will be distorted. What is the percentage of power in the sidebands (both sidebands added together) when the modulation index is 1? What percent of the total AM power is in the carrier?

6. Repeat problem #5 with m = 0.5.

7. Is the useful information in an AM signal located in the carrier or in the sidebands?

8. Looking back at problems #5 and #6, which modulation index is a better use of power? Hint: more power means further transmission distances. The graph below may also be useful



9. Note that each sideband is essentially a copy of the baseband signal. Are we wasting power by having two sidebands? Can we get away with just having one sideband?

10. Say a radio station has a total rms power output of 150 W and is achieving 100% modulation. How much power is in the carrier? How much is in the sidebands? How much power is wasted (tricky)?

11. Suppose that after modulation the station filtered out the carrier and one of the sidebands and then boosted the remaining sideband to 150W. What would be the impact on your ability to receive a broadcast from the station compared to the unaltered broadcast from #10?

Improving AM

- The previous chain of problems suggest that we can:
  - Save power by reducing or eliminating the carrier and/or a sideband.
  - Increase the reception distance of an AM signal by eliminating the carrier and/or a sideband and putting that power into the remaining sideband(s).
- In fact, suppressing the carrier and/or a sideband is a common practice. Listed below are the common names and descriptions of various AM broadcast formats.
  - **DSB-LC –** "Double sideband, Large Carrier" – This is normal AM.
  - **SSB-LC –** "Single sideband, Large Carrier" – After modulation, but before being amplified for transmission, one of the sidebands is filtered out of the AM signal.
  - **DSB-SC –** "Double sideband, Suppressed Carrier" **–** The carrier is either greatly reduced in amplitude or removed altogether via filtering. Despite the great power savings DSB-SC is not commonly used because the absence of the carrier makes it hard to demodulate (recover) the signal at the receiver (would make radios expensive).
  - **SSB-SC –** "Single sideband, Suppressed Carrier"

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12. What are the advantages of SSB-LC over SSB-SC?

13. What are the advantages of SSB-LC over DSB-LC?

14. A DSB-LC AM transceiver is rated at 60 watts maximum power has a modulation index of 100%. What is the transmitted power of the USB?

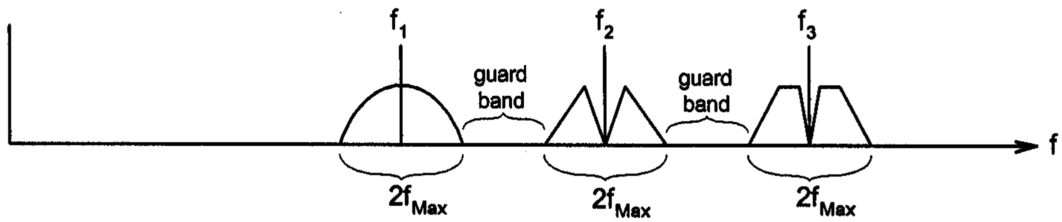
If the carrier was suppressed (DSB-SC), what would the transmitted power of the USB be?

If the LSB was suppressed (SSB-SC), what would the transmitted power of the USB be?

15. Sketch frequency plots for the four types of AM signals if f_c = 800 kHz and f_m = 5 kHz.

Frequency Division Multiplexing

- Just like a multiplex cinema can show multiple copies of the same movies at the same time by using multiple screens, we can broadcast multiple radio programs simultaneously by modulating each baseband signal to different frequencies. The illustration below demonstrates the **frequency division multiplexing** concept for three AM signals.



- Note that buffers called **guard bands** are placed between each of the signals. The guard bands prevent any accidental overlap of the AM signals.
- In the United States, commercial AM radio (audio programming) broadcasts are limited to the frequency range of 535 to 1705 kHz. Further, the modulation frequency of each broadcast must be less than 5 kHz.

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16. What are minimum and maximum carrier frequencies for commercial AM broadcasts in the USA?

17. What is the minimum distance between the center frequencies of stations in the USA?

18. Although stations are supposed to keep their baseband transmissions between 0 and 5 kHz, stations are often spaced apart at greater distances than what you found in #15. Why?

19. Is the sound quality (alternately content) of an AM station at 600 kHz fundamentally different from a station broadcasting at 1500 kHz? Why or why not?