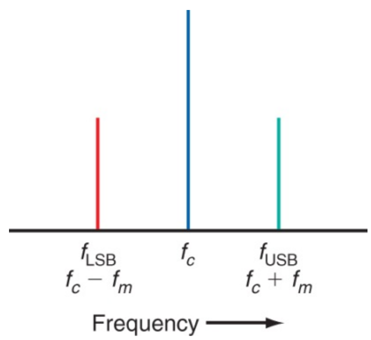
EE302 Lesson 8

Sources: (1) Course materials developed by CDR Hewitt Hymas, USN
(2) Frenzel, Principles of Electronic Communication Systems, 3rd ed., McGraw Hill, 2008

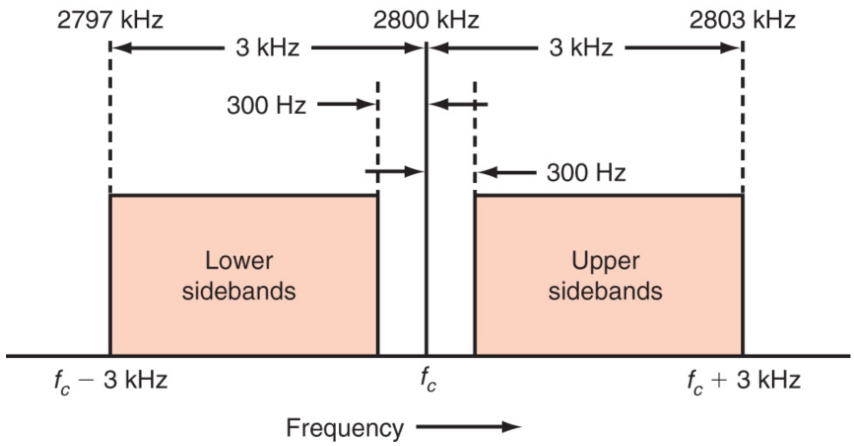
Sidebands. Recall that when we look at an AM signal in the frequency domain, we see the presence of the carrier signal (at frequency f_C), but we also see sidebands, which occur at the sum and difference of the carrier and modulating frequencies.

If a sine wave of frequency f_m modulates a carrier of frequency f_C:

- The upper sideband is at $f_C + f_m$
- The lower sideband is at $f_C - f_m$



Let's say the modulating signal is more complicated, say a voice signal that has frequencies within the range of 300 Hz to 3000 Hz. If this signal modulates a carrier of 2800 kHz, the frequency domain representation of the AM signal is:



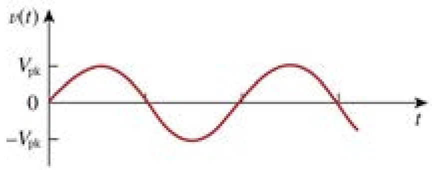
The bandwidth of the AM signal is 2803 kHz – 2797 kHz, which is 6 kHz. This is twice the highest frequency that was in the modulating signal.

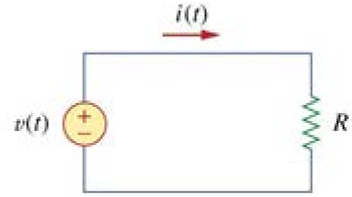
AM Power The AM signal consists of the carrier and the two sidebands, and each of these produces power. The total transmitted power P_T is the sum of the carrier power P_c and power in the two sidebands P_{LSB} and P_{USB}.

$$P_T = P_c + P_{\text{LSB}} + P_{\text{USB}}$$

Recall that the average power dissipated by resistor R with a sinusoidal source of amplitude V_{pk} is given

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





Since the v_{AM} is composed of three sinusoids

$$v_{\text{AM}} = V_c \sin 2\pi f_c t + \frac{V_m}{2} \cos 2\pi (f_c - f_m)t - \frac{V_m}{2} \cos 2\pi (f_c + f_m)t$$

the total average power dissipated by the antenna with resistance R is given as:

$$\begin{aligned} P_T &= P_c + P_{\text{LSB}} + P_{\text{USB}} \\ &= \frac{\left(V_c / \sqrt{2}\right)^2}{R} + \frac{\left(V_m / 2\sqrt{2}\right)^2}{R} + \frac{\left(V_m / 2\sqrt{2}\right)^2}{R} \\ &= \frac{V_c^2}{2R} + \frac{V_m^2}{8R} + \frac{V_m^2}{8R} \end{aligned}$$

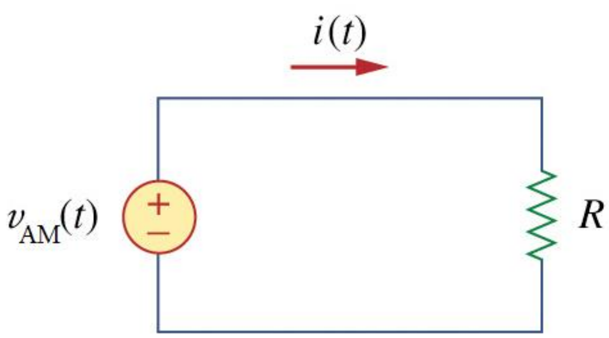
Remembering that the modulation index is $m = V_m / V_c$ we can write

$$P_T = \frac{(V_c)^2}{2R} + \frac{(mV_c)^2}{8R} + \frac{(mV_c)^2}{8R} = \frac{V_c^2}{2R}\left(1 + \frac{m^2}{4} + \frac{m^2}{4}\right)$$

The common term is just the carrier power, thus the total power can also be written

$$P_T = P_C \left(1 + \frac{m^2}{2}\right)$$

In reality it is difficult to determine AM power by measuring the output voltage. However, antenna current is easy to measure and output power can be expressed

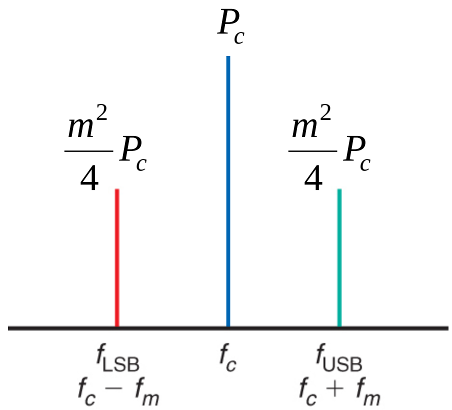


$$P_T = I_T^2 R \quad \text{where} \quad I_T = I_c \sqrt{1 + \frac{m^2}{2}}$$

AM Power Efficiency

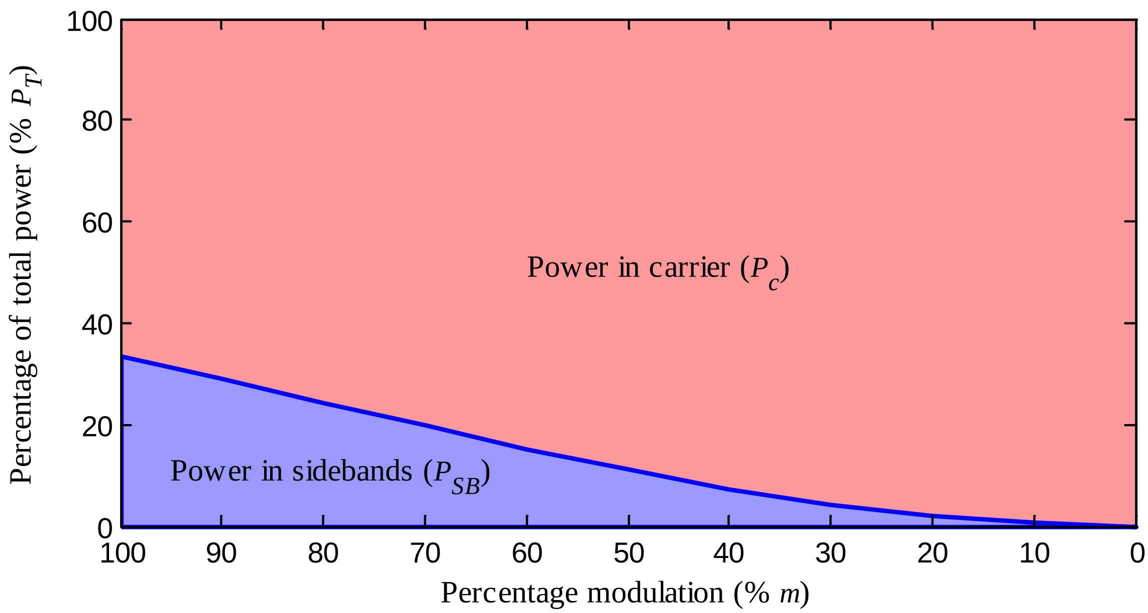
Sideband power is maximized by setting $m = 1$.

$$P_T = P_c\left(1+\frac{m^2}{2}\right)$$



For $m = 1$, what percentage of the total power is dedicated to the sidebands?

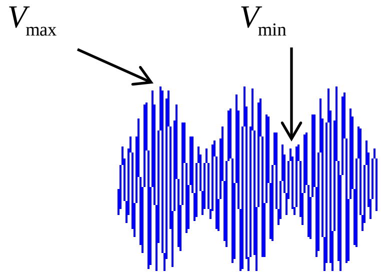
At maximum modulation, the sideband power is at most 33% of the total transmitted power.



Two-thirds of the power is wasted in the carrier. Further, 100% modulation only occurs at peaks in the modulating signal, thus the average sideband power is considerably worse than the ideal. Notwithstanding these problems, AM is still widely used because it is simple and effective.

- ☐ AM broadcast radio
- ☐ CB radio
- ☐ TV broadcasting
- ☐ Air traffic control radios
- ☐ Garage door opens, keyless remotes

Example Problem 1. In the picture shown, you measure V_{max} to be 5.9 volts and V_{min} to be 1.2 volts.



(a) Determine V_m and V_C (the amplitudes of the modulating waveform and the carrier waveform)

(b) Determine the modulation index.

Example Problem 2. A 400 Hz tone modulates a 300 kHz carrier. What are the upper and lower sideband frequencies?

Example Problem 3. The carrier of an AM transmitter is 1000 W, and it is modulated 100%. Determine:

(a) The total power of the AM signal
(b) The power in each sideband

Example Problem 4. A 70% modulated 250 Watt carrier is used. What is the power in each sideband?

Example Problem 5. An AM transmitter has a carrier power of 30 W. The percentage modulation is 85%. Calculate (a) the total power, and (b) the power in one sideband.

Example Problem 6. The unmodulated carrier current into a 50 Ω antenna is 10 A. What is the total output power if the transmitted AM signal is 85% modulated?

Example Problem 7. One way to measure percentage modulation is to measure both modulated and unmodulated antenna currents. Suppose that the current produced by the carrier alone (no modulation) is 2.2 A. If the modulated signal current is 2.6 A, what is the percentage modulation?

Example Problem 8. An AM signal is 100% modulated (modulation index = 1). The carrier power is 100 W.

(a) What is the total power in the sidebands?
(b) What is the total power of the AM signal?
(c) What is the percentage of power in the sidebands?

Example Problem 9. An AM signal has a carrier power of 500 W and a modulation index of 70%. How much power is in each sideband?

Example Problem 10. An antenna has an impedance of 40 Ω. An unmodulated AM signal produces a current of 4.8 A. The modulation is 90%. Determine:

(a) The carrier power
(b) The total power.
(c) The total power in the sidebands