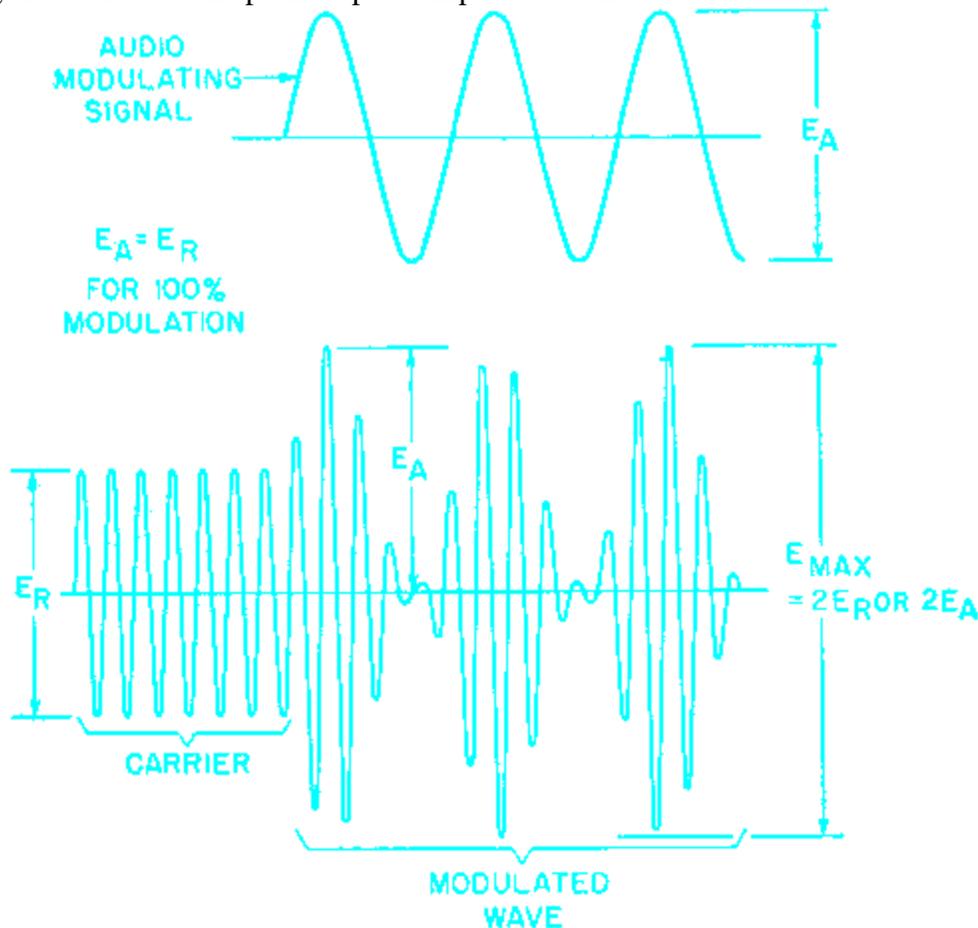


## Amplitude Modulation

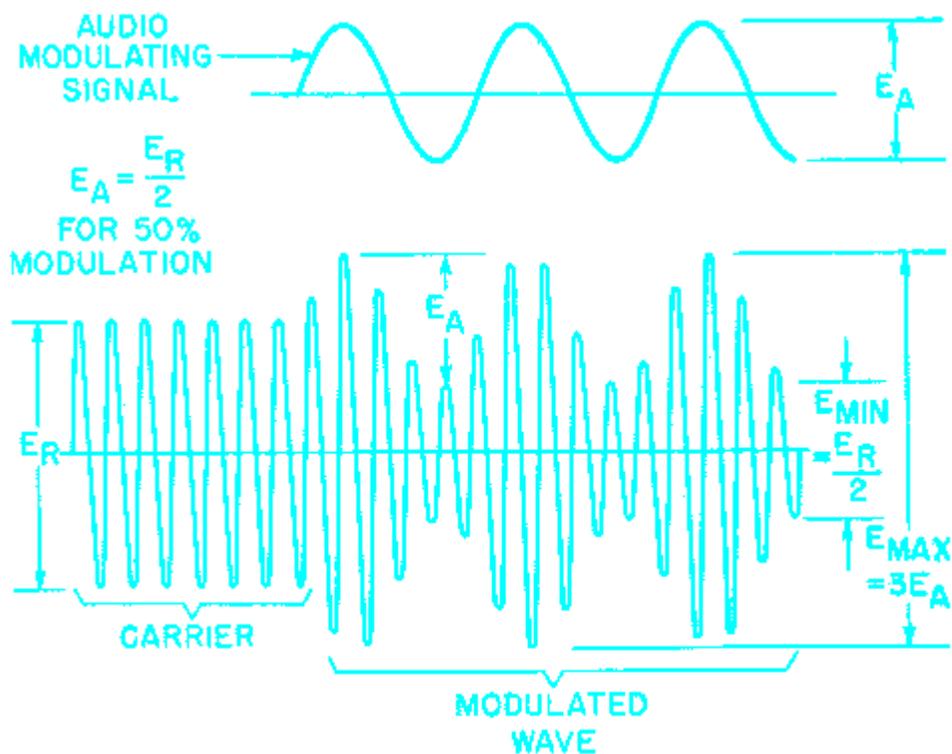
### b. Percentage of Modulation.

(1) In amplitude modulation, it is common practice to express the degree to which a carrier is modulated as a percentage of modulation. When the peak-to-peak amplitude of the modulating signal is equal to the peak-to-peak amplitude of the unmodulated carrier, the carrier is said to be 100 percent modulated. In figure 4, the peak-to-peak modulating voltage,  $E_A$ , is equal to that of the carrier voltage,  $E_R$ , and the peak-to-peak amplitude of the carrier varies from  $2E_R$ , or  $2E_A$ , to 0. In other words, the modulating signal swings far enough positive to double the peak-to-peak amplitude of the carrier, and far enough negative to reduce the peak-to-peak amplitude of the carrier to 0.



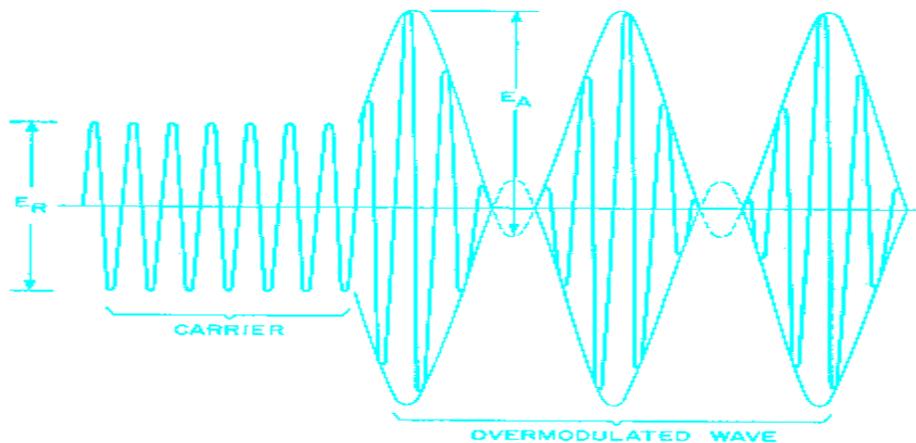
*Figure 4. Carrier modulated 100 percent by a modulating signal.*

(2) If  $E_A$  is less than  $E_R$ , percentages of modulation below 100 percent occur. If  $E_A$  is one-half  $E_R$ , the carrier is modulated only 50 percent (fig. 5). When the modulating signal swings to its maximum value in the positive direction, the carrier amplitude is increased by 50 percent. When the modulating signal reaches its maximum negative peak value, the carrier amplitude is decreased by 50 percent.



*Figure 5. Fifty-percent modulation.*

(3) It is possible to increase the percentage of modulation to a value greater than 100 percent by making  $E_A$  greater than  $E_R$ . In figure 6, the modulated carrier is varied from 0 to some peak-to-peak amplitude greater than  $2E_R$ . Since the peak-to-peak amplitude of the carrier cannot be less than 0, the carrier is cut off completely for all negative values of  $E_A$  greater than  $E_R$ . This results in a distorted signal, and the intelligence is received in a distorted form. Therefore, the percentage of modulation in a-m systems of communication is limited to values from 0 to 100 percent.



*Figure 6. Overmodulation of carrier.*

(4) The actual percentage of modulation of a carrier (M) can be calculated by using the following simple formula  $M = \text{percentage of modulation} = ((E_{\text{max}} - E_{\text{min}}) / (E_{\text{max}} + E_{\text{min}})) * 100$  where  $E_{\text{max}}$  is the greatest and  $E_{\text{min}}$  the smallest peak-to-peak amplitude of the modulated carrier. For example, assume that a modulated carrier varies in its peak-to-peak amplitude from 10 to 30 volts. Substituting in the formula, with  $E_{\text{max}}$  equal to 30 and  $E_{\text{min}}$  equal to 10,  $M = \text{percentage of modulation} = ((30 - 10) / (30 + 10)) * 100 = (20 / 40) * 100 = 50$  percent. This formula is accurate only for percentages between 0 and 100 percent.

### c. Side Bands.

(1) When the outputs of two oscillators beat together, or heterodyne, the two original frequencies plus their sum and difference are produced in the output. This heterodyning effect also takes place between the a-f signal and the r-f signal in the modulation process and the beat frequencies produced are known as side bands. Assume that an a-f signal whose frequency is 1,000 cps (cycles per second) is modulating an r-f carrier of 500 kc (kilocycles). The modulated carrier consists mainly of three frequency components: the original r-f signal at 500 kc, the sum of the a-f and r-f signals at 501 kc, and the difference between the a-f and r-f signals at 499 kc. The component at 501 kc is known as the upper sideband, and the component at 499 kc is known as the lower sideband. Since these side bands are always present in amplitude modulation, the a-m wave consists of a center frequency, an upper side-band frequency, and a lower side-band frequency. The amplitude of each of these is constant in value but the resultant wave varies in amplitude in accordance with the audio signal.

(2) The carrier with the two sidebands, with the amplitude of each component plotted against its frequency, is represented in figure 7 for the example given above. The modulating signal,  $f_A$ , beats against the carrier,  $f_C$ , to produce upper side band  $f_H$  and lower side band  $f_L$ . The modulated carrier occupies a section of the radio-frequency spectrum extending from  $f_L$  to  $f_H$ , or 2 kc. To receive this signal, a receiver must have r-f stages whose bandwidth is at least 2 kc. When the receiver is tuned to 500 kc, it also must be able to receive 499 kc and 501 kc with relatively little loss in response.

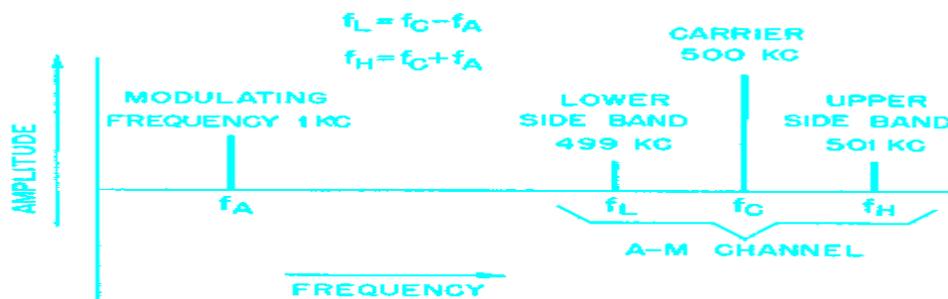


Figure 7. Frequency spectrum of amplitude-modulated wave.

(3) The audio-frequency range extends approximately from 16 to 16,000 cps. To accommodate the highest audio frequency, the a-m frequency channel should extend from 16 kc below to 16 kc above the carrier frequency, with the receiver having a

corresponding bandwidth. Therefore, if the carrier frequency is 500 kc, the a-m channel should extend from 484 to 516 kc. This bandwidth represents an ideal condition; in practice, however, the entire a-m bandwidth for audio reproduction rarely exceeds 16 kc. For any specific set of audio-modulating frequencies, the a-m channel or bandwidth is twice the highest audio frequency present.

(4) The r-f energy radiated from the transmitter antenna in the form of a modulated carrier is divided among the carrier and its two side bands. With a carrier component of 1,000 watts, an audio signal of 500 watts is necessary for 100-percent modulation. Therefore, the modulated carrier should not exceed a total power of 1,500 watts. The 500 watts of audio power is divided equally between the side bands, and no audio power is associated with the carrier.

(5) Since none of the audio power is associated with the carrier component, it contains none of the intelligence. From the standpoint of communication efficiency, the 1,000 watts of carrier-component power is wasted. Furthermore, one side band alone is sufficient to transmit intelligence. It is possible to eliminate the carrier and one side band, but the complexity of the equipment needed cancels the gain in efficiency.

d. Disadvantages of Amplitude Modulation. It was noted previously that random noise and electrical interference can amplitude-modulate the carrier to the extent that communication cannot be carried on. From the military standpoint, however, susceptibility to noise is not the only disadvantage of amplitude modulation. An a-m signal is also susceptible to enemy jamming and to interference from the signals of transmitters operating on the same or adjacent frequencies. Where interference from another station is present, the signal from the desired station must be many times stronger than the interfering signal. For various reasons, the choice of a different type of modulation seems desirable.

<http://nprcet.org/e%20content/cse/ADC.pdf>