AM RADIO BACKGROUND INFORMATION

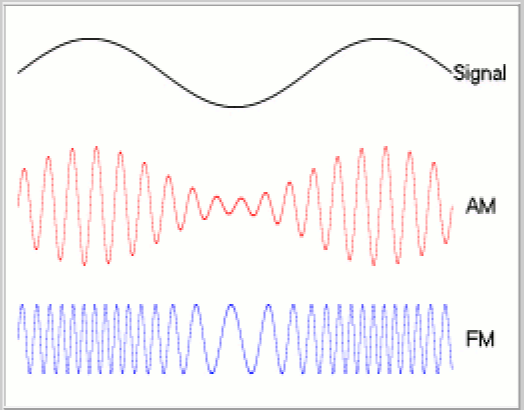
Definition

Amplitude modulation (AM) is a technique used in electronic communication, most commonly for transmitting information via a radio carrier wave that works by varying the strength of the transmitted signal in relation to the information being sent.

Basics

For example, changes in the signal strength can be used to reflect the sounds to be reproduced by a speaker, or to specify the light intensity of television pixels. (Contrast this with frequency modulation, also commonly used for sound transmissions, in which the frequency is varied; and phase modulation, often used in remote controls, in which the phase is varied.)

In the mid-1870s, a form of amplitude modulation—initially called "undulatory currents"—was the first method to successfully produce quality audio over telephone lines. Beginning with Reginald Fessenden's audio demonstrations in 1906, it was also the original method used for audio radio transmissions, and remains in use today by many forms of communication—"AM" is often used to refer to the mediumwave broadcast band.



An audio signal (top) may be carried by an AM or FM radio wave.

Forms of amplitude modulation

As originally developed for the electric telephone, amplitude modulation was used to add audio information to the low-powered direct current flowing from a telephone transmitter to a receiver. As a simplified explanation, at the transmitting end, a telephone microphone was used to vary the strength of the transmitted current, according to the frequency and loudness of the sounds received. Then, at the receiving end of the telephone line, the transmitted electrical current affected an electromagnet, which strengthened and weakened in response to the strength of the current. In turn, the electromagnet produced vibrations in the receiver diaphragm, thus closely reproducing the frequency and loudness of the sounds originally heard at the transmitter.

In contrast to the telephone, in radio communication what is modulated is a continuous wave radio signal (carrier wave) produced by a radio transmitter. In its basic form, amplitude modulation produces a signal with power concentrated at the carrier frequency and in two adjacent sidebands. This process is known as heterodyning. Each sideband is equal in bandwidth to that of the modulating signal and is a mirror image of the other. Amplitude modulation that results in two sidebands and a carrier is often called double sideband amplitude modulation (DSB-AM). Amplitude modulation is inefficient in terms of power usage and much of it is wasted. At least two-thirds of the power is concentrated in the carrier signal, which carries no useful information (beyond the fact that a signal is present); the remaining power is split between two identical sidebands, though only one of these is needed since they contain identical information.

To increase transmitter efficiency, the carrier can be removed (suppressed) from the AM signal. This produces a reduced-carrier transmission or double-sideband suppressed-carrier (DSBSC) signal. A suppressed-carrier amplitude modulation scheme is three times more power-efficient than traditional DSB-AM. If the carrier is only partially suppressed, a double-sideband reduced-carrier (DSBRC) signal results. DSBSC and DSBRC signals need their carrier to be regenerated (by a beat frequency oscillator, for instance) to be demodulated using conventional techniques.

Even greater efficiency is achieved—at the expense of increased transmitter and receiver complexity—by completely suppressing both the carrier and one of the sidebands. This is single-sideband modulation (SSB), widely used in amateur radio due to its efficient use of both power and bandwidth.

A simple form of AM often used for digital communications is on-off keying, a type of amplitude-shift keying by which binary data is represented as the presence or absence of a carrier wave. This is commonly used at radio frequencies to transmit Morse code, referred to as continuous wave (CW) operation.

In 1982, the International Telecommunication Union (ITU) designated the various types of amplitude modulation as follows:

Designation	Description
A3E	double-sideband full-carrier - the basic AM modulation scheme
R3E	single-sideband reduced-carrier
H3E	single-sideband full-carrier
J3E	single-sideband suppressed-carrier
B8E	independent-sideband emission
C3F	vestigial-sideband
Lincompex	linked compressor and expander

Double-sideband AM Wave

A carrier wave is modelled as a simple sine wave, such as**:**

$$c(t) = C \cdot \sin(\omega_c t + \phi_c),$$

where the radio frequency (in Hz) is given by**:** $\omega_c/(2\pi)$.

For generality, C and ϕ_c are arbitrary constants that represent the carrier amplitude and initial phase.

Modulation index

As with other modulation indices, in AM, this quantity, also called modulation depth, indicates by how much the modulated variable varies around its 'original' level. For AM, it relates to the variations in the carrier amplitude.

So if h = 0.5, the carrier amplitude varies by 50% above and below its unmodulated level, and for h = 1.0 it varies by 100%. To avoid distortion in the A3E transmission mode, modulation depth greater than 100% must be avoided. Practical transmitter systems will usually incorporate some kind of limiter circuit, such as a VOGAD, to ensure this.

Amplitude modulator designs

Circuits

A wide range of different circuits have been used for AM, but one of the simplest circuits uses anode or collector modulation applied via a transformer. While it is perfectly possible to create good designs using solid-state electronics, valved (vacuum tube) circuits are shown here. In general, valves are able to more easily yield RF powers, in excess of what can be easily achieved using solid-state transistors. Most high-power broadcast stations still use valves.

Modulation circuit designs can be broadly divided into low and high level.

Low level

Here a small audio stage is used to modulate a low power stage; the output of this stage is then amplified using a linear RF amplifier.

Advantages: The advantage of using a linear RF amplifier is that the smaller early stages can be modulated, which only requires a small audio amplifier to drive the modulator.

Disadvantages: The great disadvantage of this system is that the amplifier chain is less efficient, because it has to be linear to preserve the modulation. Hence Class C amplifiers cannot be employed.

An approach which marries the advantages of low-level modulation with the efficiency of a Class C power amplifier chain is to arrange a feedback system to compensate for the substantial distortion of the AM envelope. A simple detector at the transmitter output (which can be little more than a loosely coupled diode) recovers the audio signal, and this is used as negative feedback to the audio modulator stage. The overall chain then acts as a linear amplifier as far as the actual modulation is concerned, though the RF amplifier itself still retains the Class C efficiency. This approach is widely used in practical medium power transmitters, such as AM radiotelephones.

High level

With high level modulation, the modulation takes place at the final amplifier stage where the carrier signal is at its maximum.

Advantages: One advantage of using class C amplifiers in a broadcast AM transmitter is that only the final stage needs to be modulated, and that all the earlier stages can be driven at a constant level. These class C stages will be able to generate the drive for the final stage for a smaller DC power input. However, in many designs in order to obtain better quality AM the penultimate RF stages will need to be subject to modulation as well as the final stage.

Disadvantages: A large audio amplifier will be needed for the modulation stage, at least equal to the power of the transmitter output itself. Traditionally the modulation is applied using an audio transformer, and this can be bulky. Direct coupling from the audio amplifier is also possible (known as a cascode arrangement), though this usually requires quite a high DC supply voltage (say 30 V or more), which is not suitable for mobile units.

AM demodulation methods

The simplest form of AM demodulator consists of a diode which is configured to act as envelope detector. Another type of demodulator, the product detector, can provide better quality demodulation, at the cost of added circuit complexity.

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