PATRICK S. FINNEGAN

Audio and the A.M. Process

• A.M. radio is our oldest form of broadcasting service. Despite the prophets of doom regarding the impact of f.m. and television, standard a.m. service is still going very strong. So much in fact, that the number of a.m. stations is equal to the number of f.m. and t.v. stations combined. A.M. broadcasting is a very important part of the American scene. Perhaps because a.m. has been around for so long. we may tend to take a patronizing attitude towards it. Although the system does have many natural as well as regulatory limitations placed upon it, when properly operated, a.m. is capable of producing a very good quality, medium fidelity signal.

AMPLITUDE MODULATION

The term a.m. means *amplitude modulation* of the rf carrier. When modulation is taking place, there are three elements present: the rf carrier, one upper, and one lower sideband. This is a full, two sideband system. The sidebands carry the audio modulation, and if the modulation is tone, then the power in each one of the sidebands will be equal to one-fourth the average power of the rf carrier (at

100 per cent modulation). The average power under program modulation will be much less.

The displacement of the sidebands from the carrier is determined solely by the frequency of the audio modulation. For example, if the modulation is 5 kHz tone, there will be a sideband at F_c + 5kHz, and another at F_c − 5 kHz. But if the audio were 10 kHz, then the sidebands would be: F_c + 10 kHz, and F_c − 10 kHz. The occupied bandwidth is twice the audio modulating frequency. Therefore, in the first case this would be 10 kHz, and in the second case, 20 kHz. FCC rules permit the station to occupy a bandwidth of 30 kHz; all emissions beyond this must be severely attenuated.

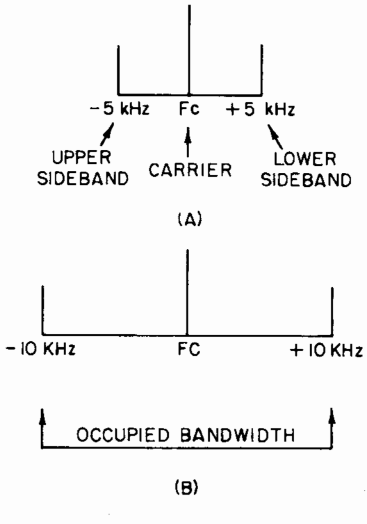
THE PLATE MODULATOR

Various types of modulators are in use—these may be at low or high level. The term *high level* means the transmitter p.a. stage is modulated, while *low level* refers to an earlier stage. One of the most common types is the high level plate modulator.

In a high level plate modulator, modulation takes place in the plate circuit of the p.a. stage. Since the sideband power is equal to 50 per cent of the average carrier power, the modulator must supply this power. To put it another way, the p.a. stage provides the rf carrier, and the modulator supplies the sideband power.

The output of the modulator stage is coupled to the d.c. plate voltage supply of the p.a. stage through a very large audio output transformer, called a *modulation transformer*. This unit is large and bulky because of the high

Figure 1. A.M. is a double sideband system. The displacement from the carrier is determined by the audio modulation signal frequency. (A) is the audio modulation at 5 kHz and (B) is the audio modulation at 10 kHz.



power audio it delivers and also because it is connected into the high voltage d.c. supply. The audio is coupled to the d.c. supply voltage in series with the supply voltage. Both the rf signal and the audio signal must be isolated from the high voltage supply itself, so rf chokes and by-pass capacitors are used for decoupling, and a large choke for the audio decoupling —this is usually called the *modulation choke.*

THE MODULATION PROCESS

Before audio is introduced, the p.a. amplifies the rf signal and supplies this to the antenna system. As soon as audio comes on (assume tone modulation for the discussion) the amplified audio at the output of the modulation transformer adds or subtracts from the d.c. supply voltage to the p.a. stage. When the audio is positive, it adds to the d.c. voltage, causing the p.a. output signal to increase; when the audio goes negative, the supply is reduced and the p.a. output decreases. The amplitude of the rf waveform is thus a replica of the audio signal and the carrier is modulated. When the audio positive peak causes the rf output volt-

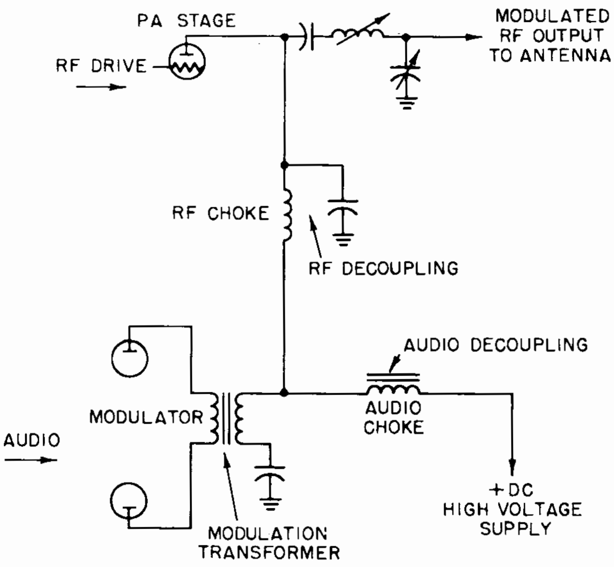


Figure 2. The high level plate modulator. Both rf and af must be decoupled from the power supply.

age to double its unmodulated value, 100 per cent positive modulation is reached, and when the rf carrier reduces to zero on the negative audio peak, we have 100 per cent negative modulation. Since on the positive peak, the rf instantaneous peak voltage has doubled, the peak rf power output is four times its unmodulated power. ($P = E^2/R$)

SUPER MODULATION

The negative modulation peaks must be limited to 100 per cent according to the FCC rules. In recent times, the rules have placed a limit of 125 per cent on positive modulation peaks.

Many audio waveforms, especially those created by the human voice, are non-symmetrical, that is, positive and negative peaks are not equal. These peaks arrive at the modulator output in random fashion, so if a non-symmetrical peak should arrive in a polarity position with a negative high peak, the reproduced audio will sound lower than normal because the peak sets the percentage of modulation. To overcome this, some stations use electronic audio units that equalize the peaks, while others use an audio unit that senses the high peak and *always* makes this positive—switching polarity if necessary. This causes non-symmetrical modulation, allowing the positive modulation to be higher than the negative. There are other audio processors that will *force* the audio into deeper asymmetry, using clipping of the negative peak. This clipping creates an amount of distortion, but it can push the positive modulation to the full 125 per cent—if the transmitter can do it! If it can be accomplished, the sideband power will increase considerably.

Super modulation does place a heavy strain on the transmitter, the system components, and the cooling system. The high rf peaks can cause arc-overs and underrated components can break down. Most older transmitters were not designed with this type of operation in mind, so they may not be able to achieve it or they may break down.

AUDIO PROCESSING

Noise and interference are two of the limiting factors in a.m. Noise is a problem because it ordinarily amplitude-modulates the signal at the same time the program does, and interference occurs because of the low carrier frequencies used in the standard broadcast band. The skywave signals travel for hundreds of miles after sunset, so the majority of stations must reduce power, use directional antennas or both. In spite of these precautions, there are many interfering signals. Another factor creating interference is the growth of cities. They have expanded horizontally over considerable distances. While the term "fringe areas" is often used, conjuring an image of the boondocks, in many cases, especially for local stations, this is part of their main coverage at night! With the population spread out so far, they have difficulty providing an interference-free signal after sunset.

To overcome this, stations have resorted to heavy audio processing before modulation. This audio processing was used long before the supermodulation technique came into practice. The audio is run through AGC amplifiers that contain both signal expanders and compressors. The time constant is long so as to hold up the average of the program signal—changing the relationship between peak and average in the signal and holding the average modulation higher. Peak limiters are used to further compress the peaks, allowing a still higher average modulation. All this processing increases the average modulation and thus the sideband power so that the signal sounds louder in the fringe areas. As a tradeoff, however, the dynamic range of the audio is compressed.

LIMITATIONS

Modulating the transmitter with highly processed audio and on top of that, applying supermodulation techniques, cause many factors to become of greater importance than they are when lesser degrees of modulation are employed.

The high voltage power supply has greater demands placed upon it, since this is where all the power comes from in the first place. Consequently, it must be able to meet the new demands and its regulation must be good. If it cannot deliver, then there will be carrier shift. For example, at the positive modulation peak when the demand is greatest, the power supply d.c. voltage may *drop*, so consequently, the rf power output actually *decreases* instead of increasing! This is negative carrier shift and must be limited to 5 per cent according to FCC rules.

The p.a. and modulator tubes work especially hard and must be linear throughout the modulation amplitude swing. If the p.a. plate hits saturation, then the peak modulation softens and the signal is clipped. On negative peaks, the grid current of the p.a. increases and the driver must be able to supply the additional drive, or again the peak will soften. If the p.a. stage is a tetrode tube, the screen current will rise during negative peaks when plate voltage is zero or very low. This must be controlled, or distortion results. In all these cases, there can be carrier shift, soft modulation peaks, and various forms of distortion. Unless kept under control, these distortions can become very severe.

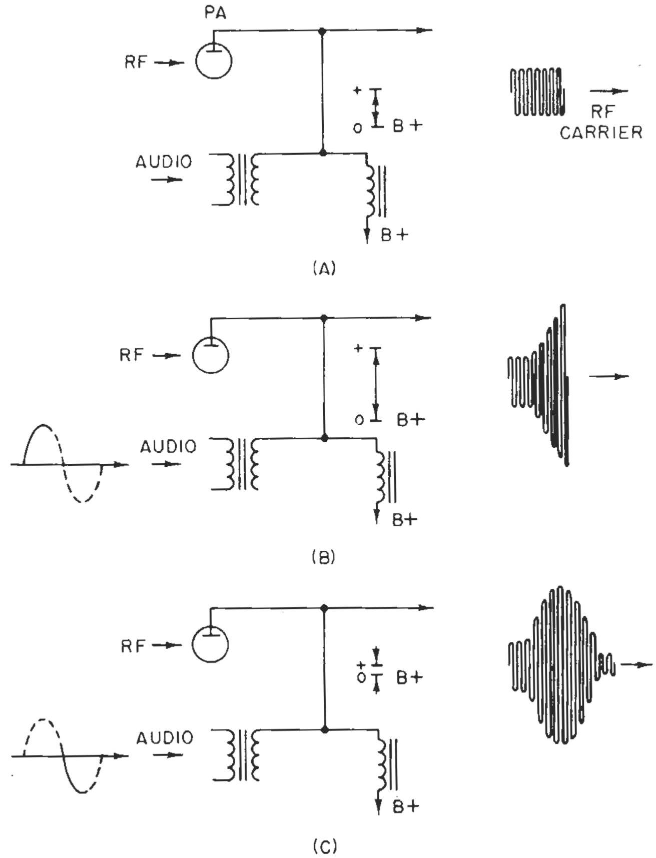


Figure 3. The A.M. modulation process: the audio causes the d.c. supply to p.a. stage to vary with the audio. This causes the p.a. rf output to vary and follow the audio. (A) indicates no audio input, (B) shows audio tone, positive peak and (C) shows audio tone, negative peak.

FIDELITY PROBLEMS

The mass of iron in the modulation transformer and the modulation choke will affect the very low audio frequency response (below 100 Hz). Besides poor response, this can introduce distortion and also set off parasitics at high modulation levels. Those stations on remote control which use over-the-air telemetry modulation of the carrier in the area of 22 to 28 Hz can experience problems with this function.

The upper end of the audio response curve can be rolled off by the capacities of the modulation transformer and the decoupling used at the output of the modulator. Perhaps the single largest limitation of audio response in the a.m. system is in its antenna system. Antennas have internal losses, and these increase as more towers are used. In the effort to get the most radiated rf power out of the antenna, the tuning results in a high Q system, with its attendant narrow bandpass. Coaxial transmission lines are used, so the antenna must match the characteristic impedance of the line *all across* the desired bandpass or there will be standing waves (reflections) where the match is not achieved. The match, then, should be for a bandwidth of 30 kHz. If it is not, the outer ends will be distorted or rolled off. Broadbanding will make the system less efficient, but this is the normal tradeoff in broadbanding any tuned stage. The harmonic filters and matching of the transmitter to the line must also be broadbanded. If the system is not broadbanded, then it will simply act as a low-pass filter, and filter out the higher audio frequencies, limiting the bandwidth.

DISTORTION

Heavy audio processing before modulation, and then non-linear operation and clipping in the p.a. and modulator stages will introduce distortion elements, which must be carefully controlled. When audio clipping does occur, the transient response of the transmitter is very important. If it is poor, there will be transient overshoots at the leading and trailing edge of the flat part of the clipped signal, and this may be followed by *ringing*. These are essentially the same results you would observe on an oscilloscope when using square wave testing of an audio system or television system.

Clipping and non-linear operation also allows intermodulation to occur. This will produce sum and difference frequencies of the two intermodulating audio signals as well as harmonics of both. Many of the harmonics can be filtered out if they are high enough in frequency, but the sum and differences will remain in the audio. When these forms of distortion are allowed to occur, they muddy the reproduced audio so that it lacks brilliance and luster; it has a dead sound. If the amount of distortion becomes too high, then of course, the signal becomes unlistenable and the audience will switch the dial!

SUMMARY

The a.m. system, even with all its limitations, can produce a good quality, medium fidelity signal. But transmitter design as well as improper operation can cause serious fidelity deterioration, as can excessive use of audio processing. The largest single limiting factor to fidelity is the filtering action of the antenna system and its tuning, and the amount of broadbanding it has adjusted into it. ■