

Online Radio & Electronics Course

Reading 30

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AM TRANSMITTERS & RECEIVERS

Revision: our definition of amplitude modulation.

Amplitude modulation is when the modulating audio is combined with a radio frequency carrier in such a way that the total wave power is made to vary in accordance with the modulating audio.

The normal type of AM is double sideband or, to be more specific, double sideband full carrier.

Recall that the carrier does not convey any intelligence to the receiver. The information is in the sidebands. Either sideband contains all of the information.

The **advantage** of double sideband full carrier is simplicity in reception. The **disadvantages** are that it is not very efficient power wise, and the bandwidth is greater than is necessary for other modes, particularly voice communications.

The carrier is used in the transmitter to **heterodyne** (mix) with the audio to convert the audio to radio frequencies (the sidebands), so that they can be radiated from an antenna.

The carrier is transmitted along with the sidebands. The advantage of this is that the carrier is available to the receiver to once again heterodyne with the sidebands, this time to convert the sidebands back to the original audio frequencies, which can then be heard.

If the carrier was not transmitted (SSB), then the receiver would have to generate its own carrier.

Mixing or heterodyning in a transmitter is called **modulating**, whereas in a receiver it is called **demodulating**. The stage in a receiver which does the demodulating is called the demodulator though it is sometimes referred to by an older name, the detector.

The most basic AM (DSB full carrier) receiver is the crystal set. Let's have a look at how a crystal set operates. Figure 1 is the schematic diagram of a crystal set, part of which we discussed in tuned circuits.

A BASIC AM (DSB) RECEIVER (CRYSTAL SET)

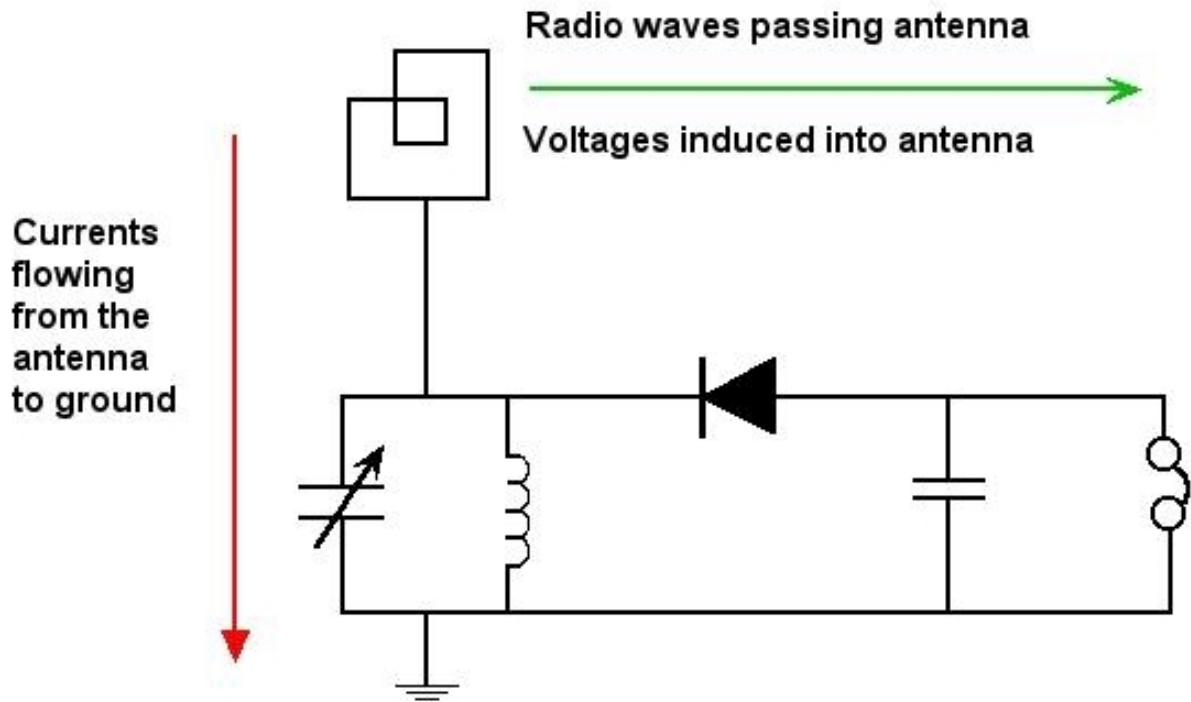


Figure 1.

The AM (double sideband full carrier) electromagnetic wave, and all the others in the air, pass by the antenna and induce voltages into it. The parallel tuned circuit of the crystal set is resonant on only one of these frequencies and voltages on that signal will only be produced across it. The parallel tuned circuit is selecting the desired radio channel and rejecting others.

The AM signal then causes a current to flow in the circuit, which includes a diode.

Now you can't get anything more non-linear than a diode. A diode is very non-linear as it conducts current in one direction only. Being non-linear, the AM signal will mix in the diode. The radio frequency carrier will mix with the sidebands, the resultant of which will be the original modulating audio. There will be all manner of other radio frequencies produced by the mixing in the diode as well - we don't care about them, we only care about the demodulated audio. So the output of the diode will contain the wanted demodulated audio and many other radio frequencies. The capacitor across the headphones has a low reactance to radio frequencies, so the radio frequencies do not go to the headphones (not that it would really matter if they did). The radio frequencies are bypassed by the low reactance of the capacitor - so we are done with them. The low frequency demodulated audio passes through the headphones. The headphones, which will operate on the piezoelectric or the dynamic 'mic' principles, reproduce the sound to the listener's ear.

That was not so hard was it? Perhaps you may need to read through the paragraph several times till you are happy with the way the simple receiver operates.

If we wanted to we could add an audio amplifier and loud speaker to do away with the

headphones and sit back and listen in comfort to the audio.

If there were lots of strong radio stations around and in close proximity frequency wise, more than one tuned circuit could be used to provide the receiver with greater selectivity. These earlier versions of AM receivers (with audio amplification) were called Tuned Radio Frequency (TRF) receivers, because all tuned circuits were tuned to the incoming radio frequency.

Selectivity: The ability of any radio receiver to accept one particular radio signal and reject all others.

Sensitivity: Is the ability of any radio receiver to detect weak signals.

Revision - Non-Linear Device (or stage):

Just to get it firmly in mind, a linear device such as an amplifier is one which faithfully reproduces every signal at its input to the output without distortion. **Signals do not mix together in a linear device.**

A non-linear device, which can be as simple as a diode, or an amplifier operating in Class C, creates distortion of the incoming signals. What goes in **is not** what comes out. Yes, the **nonlinearity causes all the individual frequencies entering the device to heterodyne or mix.** In doing so, **new** frequencies which were not present at the input are produced in the output. The number of mixing products in a non-linear device are enormous, though if we know what we are after we can filter out the garbage and use the mixing products we want (the demodulated audio).

LOW LEVEL (AM) AMPLITUDE MODULATED TRANSMITTER

Figure 2 shows the block diagram of a low level amplitude modulated transmitter.

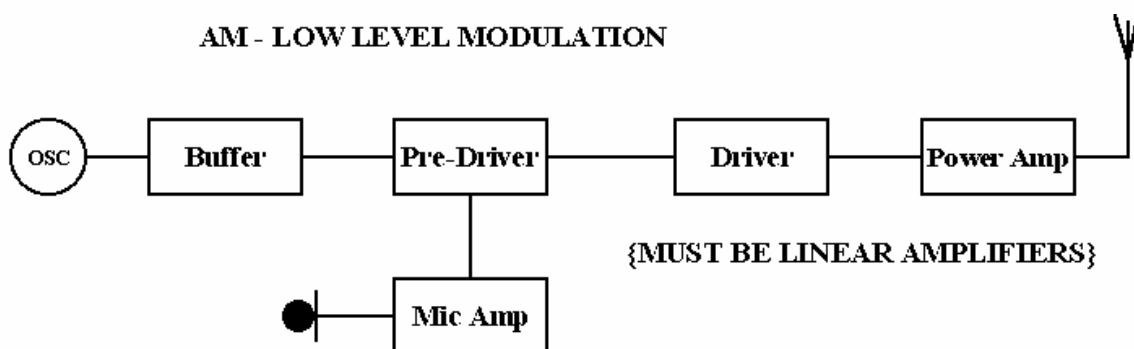


Figure 2.

The carrier wave is produced by the oscillator. The buffer stage after the oscillator is just an amplifier which raises the power level coming from the oscillator to a useable level, without taking too much power (if any) from the oscillator. Trying to draw too much power from an oscillator could stop it from oscillating, or pull it off frequency, hence the buffer amplifier.

The signal from the microphone is amplified to a useable level and fed along with the carrier to the pre-driver. The pre-driver is just another amplifier - however the pre-driver is

nonlinear so it acts as a modulator. The output of the modulator will contain the double sideband full carrier signal, which is usually just referred to as AM.

Important: After the pre-driver, which is acting as a modulator, we have created the signal that we want to transmit. All we need to do then is raise the power level to the desired level before feeding it to the antenna. **All amplifier stages after modulation must be linear.**

The advantage of low level AM modulation then is that **not much audio power is required**. The disadvantage is that all radio frequency amplifiers after the modulator (pre-driver in this case) **must be linear**. This is a disadvantage because linear amplifiers run at lower efficiency Class A or Class B push-pull.

Low-level AM modulation is usually the best method for low power transmitters such as walkie-talkies (handhelds).

HIGH LEVEL (AM) AMPLITUDE MODULATED TRANSMITTER

Figure 3 shows the block diagram of a high level AM transmitter.

With high-level modulation the carrier is created by the oscillator and amplified up to a high power level, in fact the power level we want to transmit. The audio to be modulated is done in a high power stage. In this case the power amplifier or otherwise called the final amplifier.

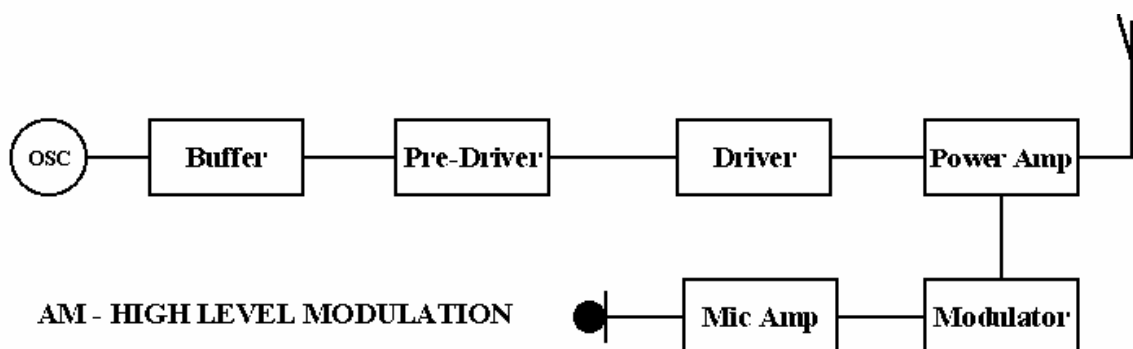


Figure 3.

Because the carrier power is high, we need a lot of audio power to produce 100% modulation. This is a bit misleading, but the stages, microphone amplifier, and modulator are just audio amplifiers to bring the low level from the microphone up to a high level.

Modulation is not occurring in the stage labelled the modulator. Modulation is occurring in the Power Amplifier. For modulation to occur in the power amplifier it must of course be nonlinear, and is nearly always Class C.

The **advantage** of high level modulation is that the carrier (the signal from the oscillator) can be amplified using high efficiency Class C amplifiers. The **disadvantage** is that a large amount of audio amplification is required to modulate the high power carrier.

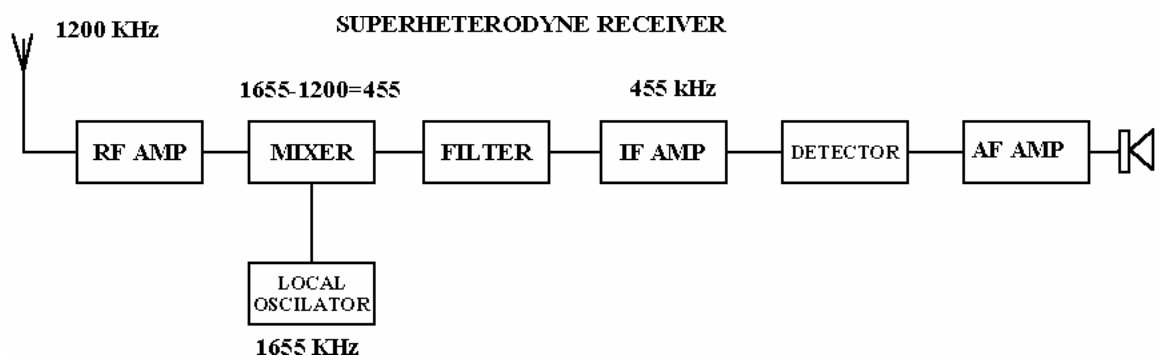
High level AM modulation is typically used in high power AM transmitters like broadcast stations, and amateur high power amateur transmitters which operate in AM mode only.

THE SUPERHETERODYNE RECEIVER

The Superhet has been around for a long time and is still the receiver system of choice in modern receivers. Though we are talking about AM in this reading, the **Superhet can and is used for other modes as well**, but the principles are the same except the stage labelled detector will vary in its operation depending on the mode in use - we are going to stick with AM for now so the detector could just be a diode.

Earlier we mentioned that early receivers were called TRF (tuned radio frequency). Selectivity of a receiver is very important. We only want to hear the radio station to which we are tuned to. In the TRF receiver there would be several tuned circuits like the one on our crystal set. The problem with the TRF is that every time you changed to a new radio channel or signal, you had to re-tune all of these circuits to the new frequency. This was a very fiddly affair to say the least.

Figure 4.



The idea of the Superhet was to convert the signal (station) being received to a single standard frequency. This frequency was called the **intermediate frequency**. The great advantage of the Superhet is that there is only one tuning control and the intermediate frequency amplifier, typically 455 kHz, never has to be adjusted, and can contain many sharply tuned, high Q circuits, or even special crystal filters, tuned to 455 kHz. This means the receiver has a very high selectivity. The I.F. amplifier also has very high gain giving the receiver very good sensitivity.

I think they must have thought up the name of this receiver from heterodyne for "mix", and "super" because it was so darn good compared to the TRF.

The problem is that to take advantage of the highly selective intermediate frequency amplifier, all signals to be listened to have to be converted to the intermediate frequency.

In the block diagram shown in figure 4 the first stage is an RF amplifier. It amplifies an entire band of frequencies coming down the antenna (such as the entire broadcast band, or an entire amateur band).

All of the radio frequency signals with all their information are fed to a mixer, along with a signal from a local oscillator. The mixer is a nonlinear device so frequency conversion takes place.

In the diagram I have shown a 1200 kHz signal arriving at the antenna. Of course there will be many other frequencies at the antenna as well. The 1200 kHz AM signal is amplified by

the RF amplifier, and then fed to the mixer along with a signal from the local oscillator. The local oscillator is the *tuning knob* on the radio. I have shown the local oscillator operating on 1655 kHz.

Now, in the mixer, all sorts of radio signals will be present. However, only the desired 1200 kHz signal will mix with a 1655 kHz local oscillator to produce a 455 kHz intermediate frequency.

So what we have effectively done with the mixer and local oscillator is convert the desired signal on 1200 kHz to 455 kHz, by mixing it with a locally generated signal on 1655 kHz.

This conversion of 1200 kHz to 455 kHz is just that, a frequency conversion. The 455 kHz signal still has its carrier and sidebands intact and all with the same relationship to each other, and contain all the information they ever had - we have just moved them from 1200 kHz to 455 kHz.

The filter following the mixer is a bandpass filter tuned to 455 kHz. (filters of this type are to be discussed) The filter will only pass signals on 455 kHz +/- the bandwidth of the signal we want to receive (a few kilohertz).

From here on the receiver never requires adjustment by the user. The desired station on 455 kHz passes through the bandpass filter and gets amplified by the 455 kHz I.F. (intermediate frequency) amplifier. The I.F. amplifier is sharply tuned to amplify signals (our desired signal) on 455kHz +/- the small bandwidth the signal occupies.

The overall advantage of the Superhet receiver is immensely improved selectivity, sensitivity, and simplification of operation over the TRF.

The intermediate frequency amplifier is very aptly named, as the desired signal is received, and converted to a standard middle (intermediate) frequency before being demodulated.

IMAGE INTERFERENCE

Superhet receivers, which just about covers most receivers, do suffer from one problem, called image interference. It is not common, but when it does happen and you do not understand what image interference is, it can be one of the most perplexing of problems.

A signal (image) can interfere with a superheterodyne receiver if fits the following equation.

$$\text{Image} = \text{Signal} \pm 2 \times \text{IF}$$

Which says that a signal has the capacity to interfere with a superhet receiver if its frequency is equal to the signal frequency (1200 kHz in our example above) plus or minus twice the IF (455 kHz in our example).

So one possible image is:

$$1200 + (2 \times 455) = 2110 \text{ kHz (possible).}$$

And the other:

$$1200 - (2 \times 455) = 290 \text{ kHz (not likely).}$$

Take the first image, the most likely one. I only say this as there is not much activity on 290 kHz. Why could a signal on 2110 kHz potentially interfere with our superhet? Because $2110 \text{ kHz} - 1655 \text{ kHz} = 455 \text{ kHz}$, our I.F. frequency. Image interference is not a major problem though it does occur and is explained here only for completeness - to my knowledge a question on it has never been asked in an exam.

SINGLE, DOUBLE AND TRIPLE CONVERSION

There is no reason why a radio system cannot have more than one intermediate frequency. Most amateur receivers have at least two intermediate frequencies; this just enhances the selectivity further.

The first I.F. could be 10.7 MHz and the second 455 kHz. **Only the first local oscillator need be made variable** as its frequency determines the received signal. Converting from the first I.F. to the second I.F. can be done with a **fixed frequency local oscillator**.

10.7 MHz and 455 kHz are world standard intermediate frequencies and no services are assigned to them, as you could imagine it would be a method to broadcast to all receivers regardless to where they were tuned. There are many other reserved I.F. frequencies as well. The principle of the Superhet is what you need to remember.

In passing, during the Second World War, jamming of receivers was accomplished by transmitting high power signals on the intermediate frequency of 455 kHz.

Also, a clandestine receiver type, and what frequency it is tuned to, (say an unlicensed amateur transceiver), can be identified from a distance by using sensitive receivers to determine the I.F. frequencies from the small amount of radiation given off by the local oscillators. So if you are ever thinking of going into the spy business, remember to use an RF shielded room, which is what the many umm certain organisations do as a matter of course.

The "old" television license man knew if you had a television or not by carrying with him a receiver tuned to a common oscillator frequency within a TV set.

If you have two broadcast band radios, hold them close together and tune one across its entire dial - you will hear a whistle come out of the other when the local oscillator of the one you are using hits an image of the other. This was an old trick used by radio serviceman to test if the local oscillator was working in the radio being repaired.

I know receivers can be made to transmit but I have never been able to do as good a job as Jon Pertwee in one of his Dr. Who episodes.

End of Reading 30

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