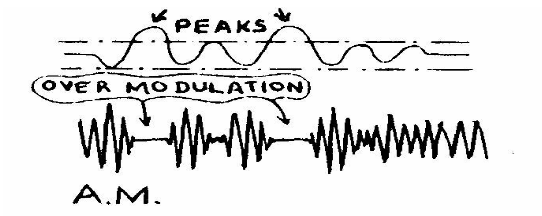
Don't over-do your modulation…..

As you will remember, it is very important to avoid over-modulation. This would distort the amplitude modulated signal and cause undue bandwidth and interference.



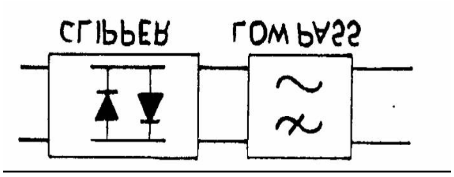
This shows the speech at various amplitudes.
The dot/dash line indicates the level that corresponds to subsequent over-modulation. The resultant modulation envelope shows that the carrier reduces to zero at l00% modulation. If **over-modulation** does occur the carrier is chopped up and the modulation no longer resembles its modulating signal. At the receiving end the signal will be very distorted and unreadable
- but more important, the over-modulated signal will have an increased bandwidth and will be rich in unwanted harmonics. This will result in severe interference to nearby aid harmonically related frequencies.

Over-modulation must be prevented

There are two ways this can be achieved:-
(a) It can be arranged that an indication is given when the depth of modulation exceeds, say, 80%. This serves as a warning that modulating signal should be reduced in level. This could be done by monitoring the output with an oscilloscope or by a modulation meter. Alternatively, it could be arranged that a lamp or light emitting diode (LED) lights when a predetermined level is exceeded.
(b) By automatic means, whereby the modulating signal is prevented from exceeding an amplitude that would result in over-modulation.
It is quite a simple matter to "limit" the audio so that it is kept within the dotted lines

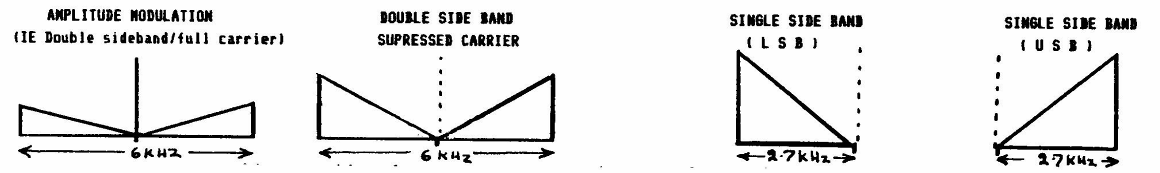
A SIMPLE LIMITER

Remember, silicon diodes begin to conduct when the forward Voltage reaches 0.7 Volt. Two such diodes, connected back-to-back, are put across the speech path at a point where sore than 0.7 Volt would result in over-modulation.
Unfortunately, the speech becomes distorted when the peaks are clipped and this produces audio harmonics.
In order to avoid excessive bandwidth, due to these harmonics1 the limiter should always be followed by a low-pass filter.



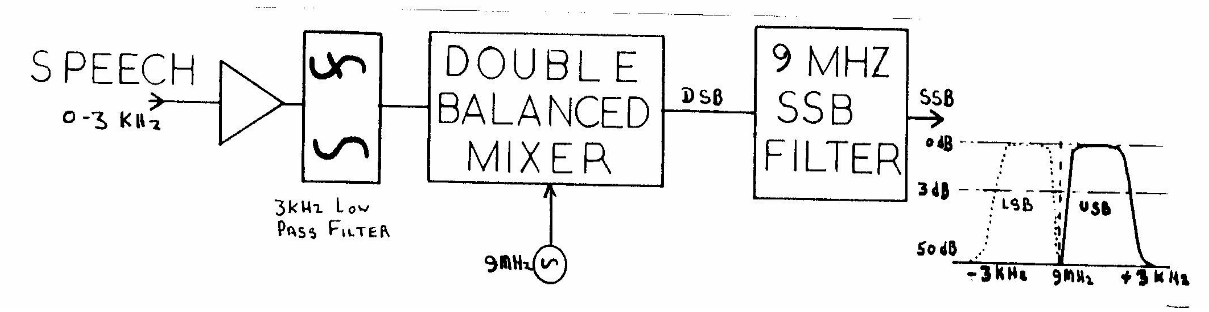
Problems with Amplitude Modulation

Large audio amplifiers and high power modulators are required. It is not an efficient method of communication as the "speech content" of the total signal is small. Most of the power is in the carrier and the speech that is present is duplicated. IE the speech power is split between the upper and lower sidebands. It is possible to do away with the carrier and one of the sidebands. This results in a much more efficient system known as Single Side Band (SSB).



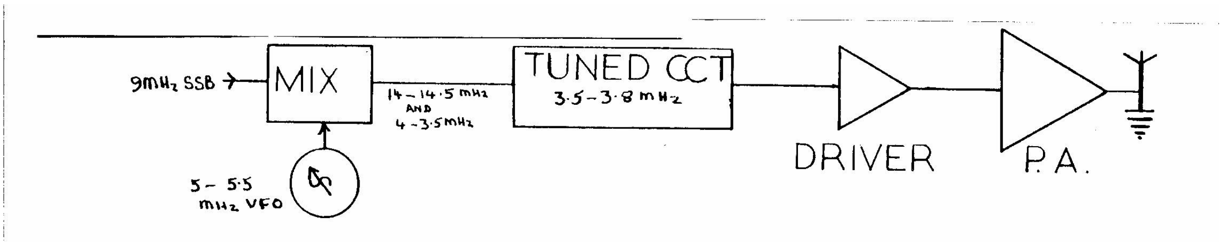
The above Shows the radio frequency spectrum of various modes of transmission. All these examples assume the speech is restricted to 300 Hz to 3 KHz
In SSB all the permitted power is concentrated into one speech side band. It is therefore more efficient but has the disadvantage that both the transmitter and the receiver are more complicated than for simple AM.

Generation of Single Sideband signals



Speech, from the microphone, is amplified and connected via a low pass filter to one input of the double balanced mixer. The carrier, in this case 9 MHz, Is connected to the other input.
The carrier is used in the production of the Single Sideband but is not actually transmitted. As with all mixers, the output will contain both the sum and the difference products. If the audio input contains frequencies up to 3 KHz then the mixer output will be 9.0 to 9.003 MHz & 8.997 to 9.0 MHz. However a double balanced mixer is special and is ideal for SSB production. Both the input signals (speech & carrier) are "balanced out" and are not present at the output of a double balanced mixer.
Thus the mixer output contains both the upper and lower sidebands and, ideally, nothing else.
This mixer has produced what is known as Double Sideband Suppressed Carrier. To obtain Single Sideband ESSE) it is necessary to eliminate the unwanted sideband. This is achieved by passing the DSB through a filter that will pass the wanted sideband and reject the unwanted one. Such filter must have steep sides to the response curve and are quite expensive. The filter is made up of 6 or S crystals connected in lattice formation. It is usual for the pass-band of the filter to be 2.4 KHz wide at the half power points.

9 MHz is a convenient Intermediate frequency as the addition of a further mixer and a VFO will result in the frequencies required for operation on two of our Amateur Bands. (80 Metres & 20 Metres)



This transmitter uses the 9MHz SSB generator, at the top of the page, mixed with the output from a 5.0-5.5 MHz VFO.
The tuned circuit is necessary to select either 3.5 or 14 MHz as it neither permitted or desirable to allow both 80 & 20 Metre frequencies to transmitted at the same time

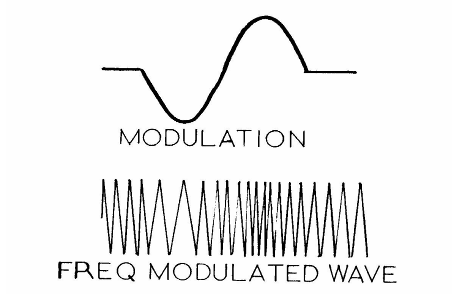
You will note that the output from the mixer will cover a wider range than necessary. If the VFO is tuned from 5 to 5.5 MHz the output will go from 4 to3.5 MHz. Therefore it is only necessary to use the 5.5-5.2 MHz part of the VFO range to cover the British 80 Metre Amateur Band. (3.5 - 3.8 MHz)
Transmitters can be designed to cover the other Amateur Bands by adding a further stage of mixing and suitable filters.

FREQUENCY MODULATION

You may find that it is not easy to understand the concept of Frequency Modulation. Read this explanation a couple of times and then read the RAE Manual covering this topic.

You will remember that In AM It was the amplitude of the carrier that varied under the control of the speech modulation. This Is not the only way that the carrier can be modulated...
In Frequency Modulation, the speech causes the frequency of the carrier to go up and down.

Note that it is only the frequency of the carrier that changes - Its amplitude remains constant. The frequency change of the carrier is proportional to the amplitude of the modulating signal. The resultant change of the carrier from Its nominal frequency Is known as its deviation. It could be said to be the equivalent of AM's "depth of modulation". There is no equivalent, In FM, of over-modulation. In FM, If the modulating frequency is increased in amplitude this purely results in a greater frequency deviation of the carrier. The signal will take up a greater bandwidth.



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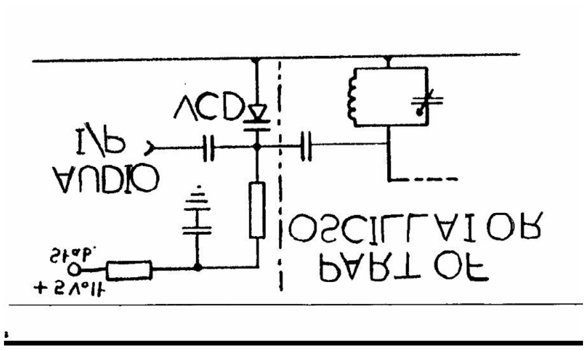
However, the Amateur License states that the bandwidth of an transmission must be no more than the 6 kHz permitted on AM. It is known Narrow Band Frequency Modulation (NBFM).

The frequency of the modulation does not alter the deviation of but it does control the frequency at which the carrier deviates. that last sentence again - it Is an important concept.)

FREQUENCY MODULATORS

With FM, the frequency of the carrier has to be varied by the speech. Thus the modulation process takes place at the oscillator.

The circuit on the right shows how an oscillator is modulated. The most Important component is the Variable Capacitance Diode.
All semiconductor diodes have self capacitance and this will vary according to the voltage across it. Usually the actual change in capacitance is very small.
A variable capacitance diode is a semiconductor diode that has been specially manufactured with this property in mind. A known change in applied voltage will produce a known change in capacitance.



The VCD is connected across the tuned circuit of an oscillator and Is reverse biased to a linear part of the Volts/Capacitance curve. The audio voltage is then superimposed on the bias voltage via C2.
It Is important to ensure that the applied audio voltage does not totally overcome the bias as this would forward bias the diode into conduction.

A conducting diode would damp the tuned circuit and may stop the oscillator.

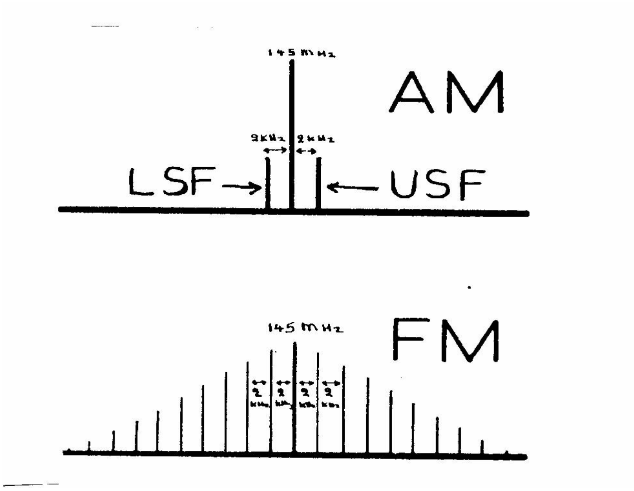
FREQUENCY MODULATION - Its Bandwidth

First of all, lets recap and look at the frequency spectrum when a 145 MHz carrier is *Amplitude Modulated* by a 2 kHz tone.

The result is a carrier, a lower side frequency and an upper side frequency.

However, just look at the spectrum when 145 MHz is *Frequency Modulated* by the same 2 kHz tone. You can see it looks rather like a hedgehog!

In theory there will be an infinite number of side frequencies at 2 kHz intervals. In practice, most of the energy is in the frequencies near to the centre. In fact, side frequencies remote from the carrier are very weak and can usually be ignored.



Some formula..

There is a relationship between the deviation of the carrier (from nominal), and the modulating frequency. It is known as the MODULATION INDEX.

$$\text{MODULATION INDEX} = \frac{\text{DEVIATION FROM CARRIER CENTRE FREQUENCY}}{\text{AUDIO FREQUENCY PRODUCING THIS DEVEIATION}}$$

If, for example, the audio is restricted to 4 kHz and the deviation to $\pm$ 2.5 kHz then the Modulation Index would be 0.625.

Before we go on to something more interesting here is one more formula:

$$\text{DEVIATION RATIO} = \frac{\text{MAXIMUM DEVIATION OF THE CARRIER}}{\text{MAXIMUM MODULATING FREQUENCY}}$$

Confused ?

It is found rather tricky to understand FM - perhaps this explanation will help:

> The *amplitude* of the modulating frequency controls *the amount* that the carrier swings up and down (deviates) from nominal.
>
> The *frequency* of the modulating frequency controls *the rate* at which the carrier swings up and down from nominal.

You will have to read these two statements a few times, and with a bit of luck the concept of FM will click into place.

Why use FM?

Let us have a look at the effect of interference on both an AM and an FM transmission.

Both types of signal show the unwanted spikes of interference modulating the amplitude of the carrier It is possible to pass the AM signal through a clipper to remove peaks of the spikes. This will not completely eliminate the interference but more severe limiting would remove the wanted modulation as well!

However, with FM, the clipper can remove all of the unwanted amplitude modulation and leave the carrier intact. The changing frequency of the carrier contains all the necessary information to give an undistorted interference free audio output. Thus with FM the limiter is able to remove all the interference spikes without affecting the "wanted" frequency modulation.

But with weak FM

Unfortunately, if the strength of the received FM signal Is very low then it will not fully limit and some of the unwanted noise will be heard. Therefore an FM signal has to be reasonably strong to attain the advantage of "interference free reception".

In fact, a very weak FM signal, will sound much noisier than an AM signal of the same strength.

The FM capture effect.

Two AM signals on the same frequency will result in a heterodyne note making it very difficult to 'read' either signal.

With FM, the strongest signal will be captured by the receiver to the total exclusion of the other. This results in the stronger signal being fully readable and quiet. Of course, if the original weak signal increases in strength it can suddenly be captured by the receiver. This can be quite surprising to the listener as he finds himself hearing a different voice!

TVI and RFI

An FM signal, having constant amplitude, is less likely to cause Interference to nearby television and radio receivers.

QUESTIONS for LESSON 10

10.1 What is meant by OVERMODULATION when applied to amplitude modulation?

10.2 What is the disadvantage of using AM in the Amateur Bands?

10.3 List the frequencies of all Amateur Bands between 1.5 MHz and 30.0 MHz.

10.4 What are the advantages to the Amateur who uses narrow band frequency modulation in the VHF and UHF bands?

10.5 What is the minimum age for the Radio Amateur in the United Kingdom?

10.6 Draw a circuit showing how an oscillator can be frequency modulated. Explain its operation.

10.7 A LSB transmitter is operated on 3.740 MHz (suppressed carrier frequency). Assuming that the modulation is restricted to the range 300 Hz to 2.7 kHz what is the frequency range of the output radio frequency?

10.8 Show how to determine the depth of modulation of an AM signal that Is displayed on an oscilloscope.

10.9 What is the advantage of using a double balanced mixer in a SSB generator?

10.10 What is the maximum speed that your callsign may be sent in Morse code for identification purposes?

10.11 What is the wavelength of 18.85 MHz?

10.12 What parameter of an FM transmission changes when the amplitude of the modulating signal is reduced?

10.13 Explain the difference between the modes of transmission known as AlA and A2A.

10.14 What is the second harmonic of a transmission that has a wavelength of two metres?

10.15 Draw the symbol for a low pass filter.

10.16 What is the "RS" report for a fair signal that is read with practically no difficulty?

10.17 A single conversion superhetrodyne receiver has an intermediate frequency of 10.7 MHz. It is receiving a station on 29.6 MHz. As it is known to have a poor front end selectivity what other frequency is likely to be received?

10.18 What Q code is sent to request a signal strength to be sent?

10.19 What time standard must be used by Amateurs in the UK?

10.20 What is the “Henry” used to measure?

