

**South Bristol Amateur Radio Club
Lesson 15 – Transmitters and Receivers**

In the Foundation Course we encountered a generic block diagram for a typical transmitter. This is reproduced below as an aide memoir.

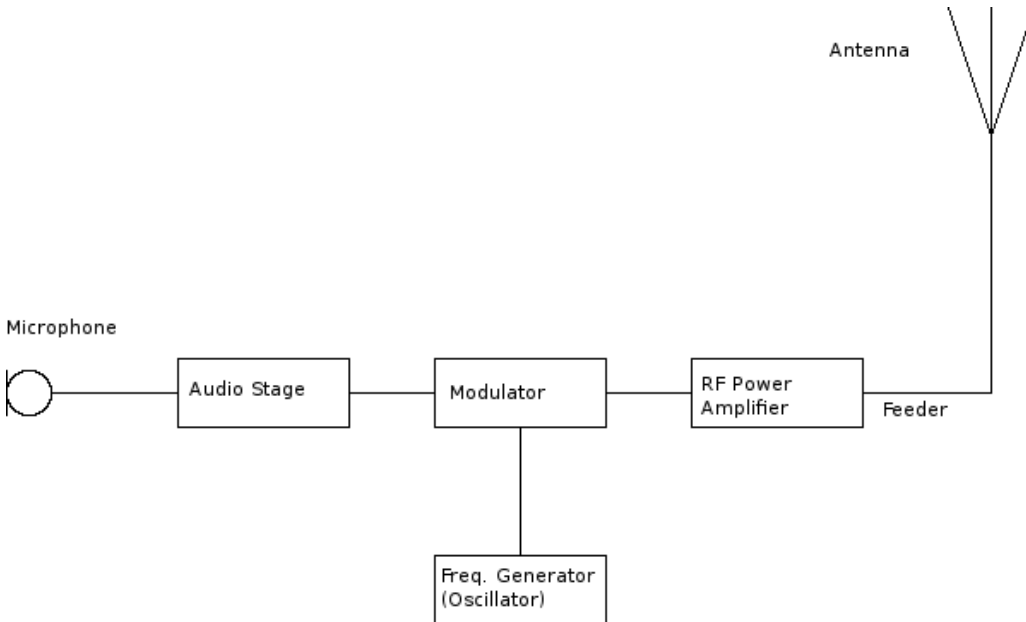


Illustration 1: Simple Transmitter Block Diagram

It should come as no surprise to learn that the above diagram is a simplification and that the actual processes are a little more involved.

The simplest transmitter is a CW transmitter in which the carrier is keyed on and off to generate a tone. The block diagram of a CW transmitter is shown below.

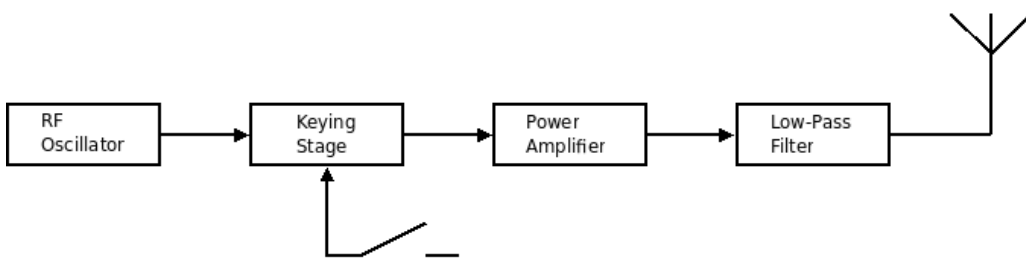


Illustration 2: CW Transmitter Block Diagram

Then we have the AM and FM transmitters, as shown in the two diagrams below.

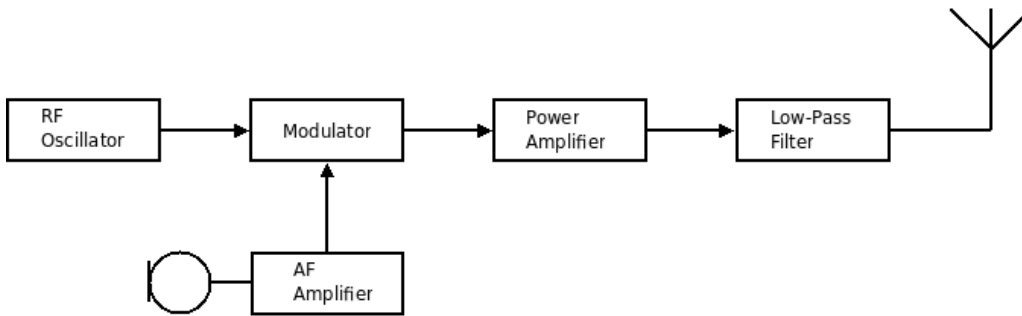


Illustration 3: AM Transmitter

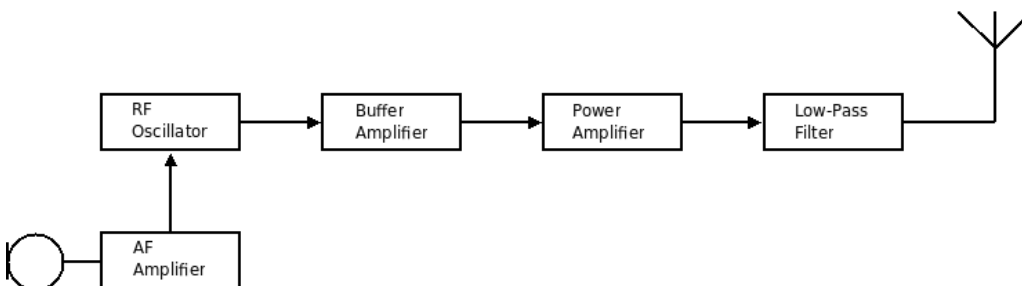


Illustration 4: FM Transmitter

The most complicated transmitter you will encounter is the Single Sideband (SSB) transmitter.

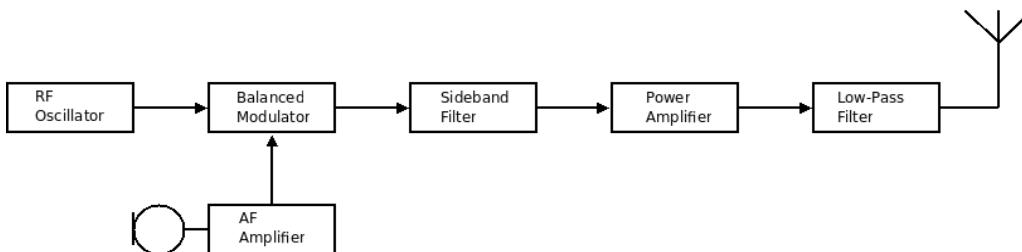


Illustration 5: SSB Transmitter

So it would be useful to have a look at some of the new elements and processes that we have just introduced:

RF Oscillator

We have already met the RF oscillator back in lesson 11. You will recall that there are basically two different types, a crystal oscillator and a variable frequency oscillator, with the latter employing a tuned circuit. Either type may be used in an RF oscillator.

If you recall the relative advantages and disadvantages the crystal oscillator benefits from being stable and relatively insensitive to temperature and mechanical fluctuations. However it is fixed to one frequency and therefore cannot be used for continuous tuning.

By contrast the Variable Frequency Oscillator can cover a wide range of frequencies but is often temperature sensitive and is best housed in a rigid mechanical box to prevent movement and to screen it from RF. It also prefers to be connected via a buffer amplifier which isolates the VFO from the rest of the transmit or receive path so that changes from transmit to receive and vice versa will not affect the VFO.

Power Amplifier

This is simply an amplifier for RF and boosts the low internal signal immediately prior to sending the signal to the antenna.

AF Amplifier

Microphones convert the spoken voice into an electrical signal by using a small diaphragm connected to a coil of wire in a magnetic field. The movement of the coil in the field causes a current to flow. However the amount of current generated by this method is too small and so the microphone is fed into an Audio Amplifier which amplifies the microphone output to a level that can be used in the modulation stage.

Low Pass Filter

All of the transmitters above feature a low pass filter as the final stage. The purpose of a low pass filter is to prevent spurious harmonics of the fundamental (carrier) frequency escaping from the rig.

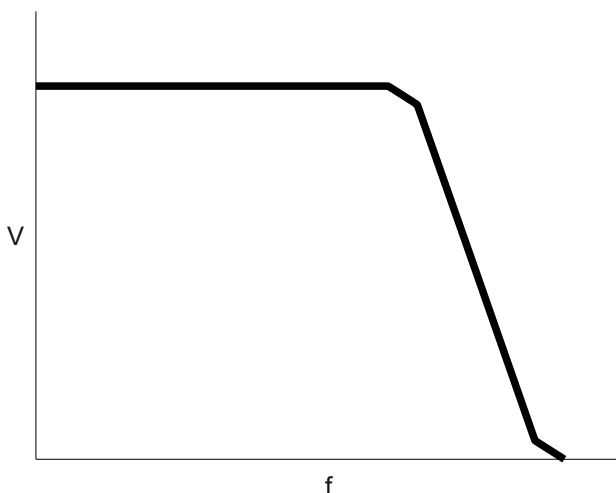
A harmonic is a simple multiple of the fundamental or carrier frequency. They can be generated in almost any part of the active transmitter but are most commonly associated with the amplifier stages.

They can cause interference to other amateur bands or other radio users and are to be avoided. We will deal with these in more detail later.

For now remember that the second harmonic is twice the fundamental frequency, the third harmonic is three times it and so on. It is widely understood that the worst offender is the third harmonic.

Consider a transmitter operating on 51MHz. It could create harmonics at 102MHz, 153MHz, 204MHz and so on, although the higher the multiple the lower the signal strength. None of the frequencies above are amateur bands and therefore any emission in these bands would be considered to be interference.

Low Pass Filter



To avoid these problems a low pass filter that only allows frequencies lower than a given cut off would be employed to prevent the harmonics being sent to the antenna.

A cut off of 60MHz would allow the fundamental frequency to pass without allowing the harmonics to be radiated.

Mixing Frequencies

Modulation is basically the process of mixing two frequencies. When mixing occurs the result is two outputs, one at the sum of the frequencies and the other is the difference between the frequencies.

In the special case when one frequency is RF and the other is AF, which are the two inputs to a modulator, these sum and differences are referred to as sidebands.

CW Transmitter

So in a CW transmitter, the signal path is switched on and off at the keying stage. This is preferable to simply switching the oscillator or power amplifier, although these methods would create Morse code in practice keying the RF oscillator stage acts like turning the rig on and off leading to wide fluctuations in the DC supply and hence changing frequency. This produces "chirp" a bird like note.

Switching the power amplifier is simply difficult because of the potentially high voltages that may be present which can lead to sparks and interference known as "key-clicks".

The presence of the keying stage allows the RF oscillator and the RF amplifier to run continuously avoiding these problems.

AM Transmitter

AM signals, as you will recall, vary in amplitude in response to the AF signals from the microphone.

The AM modulator actually produces an output that includes the carrier and two sidebands. These sidebands are mirror images of each other and contain the same information.

The carrier and both sidebands are amplified by the RF amplifier and transmitted.

Consider an RF signal of 7050kHz modulated with an AF signal 3kHz. The output of the modulation stage would be:

- the carrier at 7050kHz
- the lower sideband at 7047kHz (the difference)
- the upper sideband at 7053kHz (the sum)

The band width of this signal is the difference between the highest and lowest frequencies, in this case 6kHz.

The AF bandwidth required for voice communication is 3kHz so the AF amplifier would normally include a band pass filter to limit the signals from the microphone to a maximum of 3kHz. This means that an AM signal will always have a bandwidth of 6kHz, twice the AF bandwidth.

FM Transmitter

As we know the FM transmitter is different to the AM transmitter because it alters the frequency of the RF Oscillator in response to the AF output from the microphone amplifier.

This is where varicap diodes come into play. The varicap diode changes it's capacitance in response to the potential difference applied to it.

By feeding the output of the AF amplifier to the varicap diode, changes in the AF output result in changes in potential difference across the varicap. Changes in potential difference in the varicap alter the resonant frequency of the RF Oscillator.

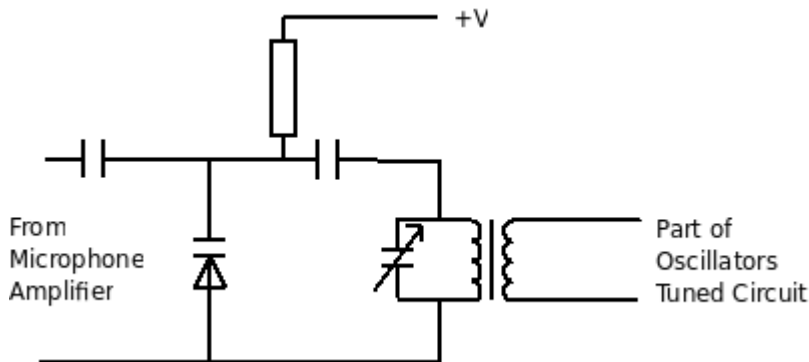


Illustration 6: AF Feed to a Varicap Diode in an Oscillator

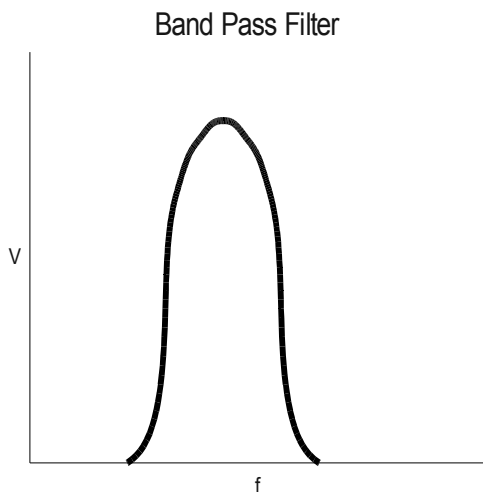
The amount of frequency change is known as the deviation. In amateur equipment deviation is limited to plus and minus 3kHz giving a total bandwidth of 6kHz. Clearly FM channels need to be separated by more than 6kHz to avoid co-channel interference, in fact on the 145Mhz (2m) band channels are separated by 12.5kHz and on the 435MHz (70cm) band they are separated by 25kHz.

SSB Transmitter

As stated earlier this is the most complex transmitter at this level of study.

SSB is in fact a variation on or form of AM. A "Balanced Modulator" is employed in place of the AM modulator. The difference is that whilst in the AM modulator (or mixer) there are 3 outputs (the carrier, the difference or lower sideband, and the sum or upper sideband) in a balanced modulator (or mixer) there are only two outputs, the upper and lower sideband. A balanced modulator effectively removes or suppresses the carrier.

The new stage introduced in the SSB block diagram is sideband filter. This is in fact a narrow band pass filter, so narrow that it is only possible for one of the two sidebands to pass. Thus only one sideband is passed to the RF power amplifier and transmitted.



The advantages of SSB over AM should be obvious. Firstly no power is wasted transmitting the carrier which in fact contains no information, secondly as both sidebands in fact contain the same information only one is required for effective communication. Finally the SSB signal occupies less than half the bandwidth of an AM signal allowing around twice as many signals in the same space.

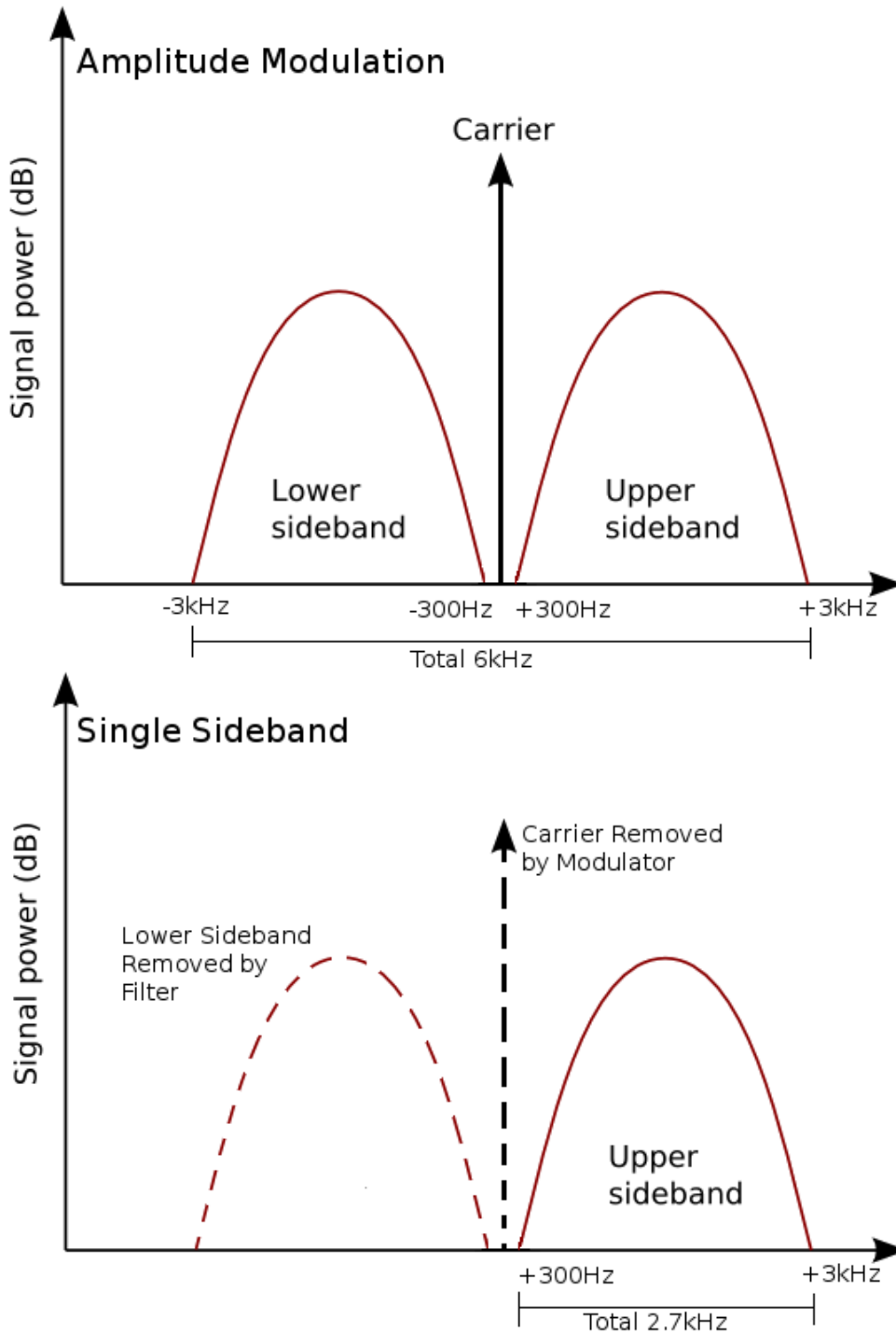


Illustration 7: Bandwidth of AM and SSB

Next Lesson

Modulation and sidebands
 Transmitter interference

Lesson 15 – Summary

At the end of this lesson you should be able to:

- Recall and understand the block diagrams of CW, AM, SSB and FM transmitters
- Understand the functions of the microphone amplifier, AM/FM modulators, balanced modulator for SSB, side band filter, oscillator, power amplifier, and low pass filter.
- Recall and understand the relative advantages and disadvantages of a crystal oscillator and a VFO
- Recall that the resonant frequency of the tuned circuit in the VFO determines the frequency of oscillation
- Recall that the frequency stability of an oscillator can be improved by rigid mechanical construction, screening the oscillator enclosure, and using a regulated DC supply. Understand that a lack of stability (drift) may result in operation outside the amateur bands
- Recall that most modern oscillators are digital synthesisers, which are very stable
- Recall that when two frequencies are mixed together, the mixing process generates new frequencies. Recall that these new frequencies are equal to the sum of and the difference between the original frequencies