Transmitters and Receivers

Transmitter concepts

3A1

Recall that the function of a radio transmitter is to send information from one place to another using electromagnetic radiation/wireless technology.

Recall that the process of adding information to a radio frequency carrier is known as modulation.

The transmitter and receiver (most commonly combined as a transceiver) is the centre of an Amateur Radio station. Depending on the bands that are required, the level of portability, or even the modes of transmission there may be more than 1 transceiver in the station.

The transmitter exists to send information to a distant station using electromagnetic radiation, there are a number of steps in the process that will be covered in this section.

A poorly set up or badly operated transmitter can cause problems for other radio users so it is important to understand the steps in the transmission process.

At its simplest level, the process of transmitting a signal requires that the RF (Radio Frequency) carrier wave is mixed with an AF (audio frequency) signal in a known way so that at the far end the two signals can be reliably unmixed.

The process of mixing an AF signal with an RF signal is known as **modulation**. There are a variety of different ways of performing modulation but it is not necessary to be able to differentiate between the modulation methods at this level, only to be able to recognise the waveforms associated with the common forms of modulation.

3A2

Recall that the audio (or data) signal is modulated onto the radio frequency carrier in the modulation stage of the transmitter.

Recall that modulation is achieved by varying the amplitude or frequency of the carrier, resulting in AM or FM modulation modes.

Recall that information can be carried by AM, SSB or FM.

Recall that data may be transmitted by modulating the carrier using suitable audio tones, commonly two or more, generated by an audio interface such as a computer sound card.

Modulation is the key process of transmitting an intelligible signal and is performed in the **modulator** or the **modulation stage** of a transmitter as shown in the block diagram that follows this section.

The process of **modulation** results in a changed **RF carrier**, with the changes representing the information that the **RF carrier** has been "imprinted" with. The common methods result in the **RF Carrier** having either its **Amplitude** affected or its **Frequency** affected.

The common methods of **modulation** are:

- AM - Amplitude Modulation; where the **amplitude** of the **RF carrier** is adjusted by the modulating AF signal.
- FM - Frequency Modulation; where the **Frequency** of the **RF carrier** is adjusted by the modulating AF signal
- SSB - Single Sideband; a more efficient variation on AM

Data modes such as RTTY (Radio Teletype), PSK31, PSK64, FT8 and SSTV to name a few are very similar to normal voice transmissions. The difference is that where a voice signal contains a whole range of AF tones (from 300Hz - 3,000Hz (3kHz)) a data signal only has a limited number of tones (usually 2 but higher numbers are possible) to represent "0" and "1".

These tones are usually produced by software using a computer or tablet soundcard.

These individual tones are then used to MODULATE the RF CARRIER in the same way as a voice signal would be resulting in the RF CARRIER having either its AMPLITUDE or its FREQUENCY altered in sympathy with the data tone.

3A3

Recall that when radio frequencies are modulated (mixed) with an audio frequency the new frequencies that are generated are called sidebands.

Recall that amplitude modulated signals contain two sidebands and the carrier.

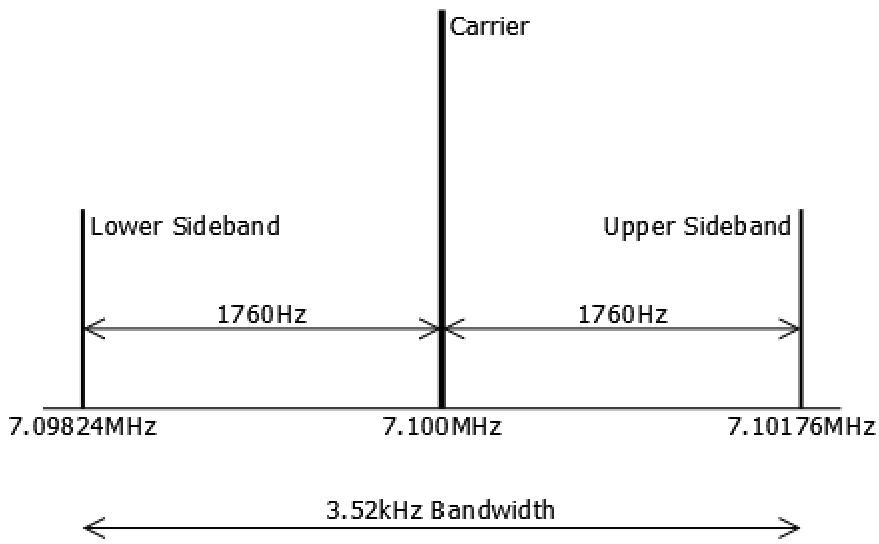
Recall that a SSB modulated signal contains only one sideband.

The process of generating an AM and, by extension, an SSB signal involves mixing the RF Carrier with the audio signal. The Modulation process results in the output from the Modulator being the original carrier plus the mixing products.

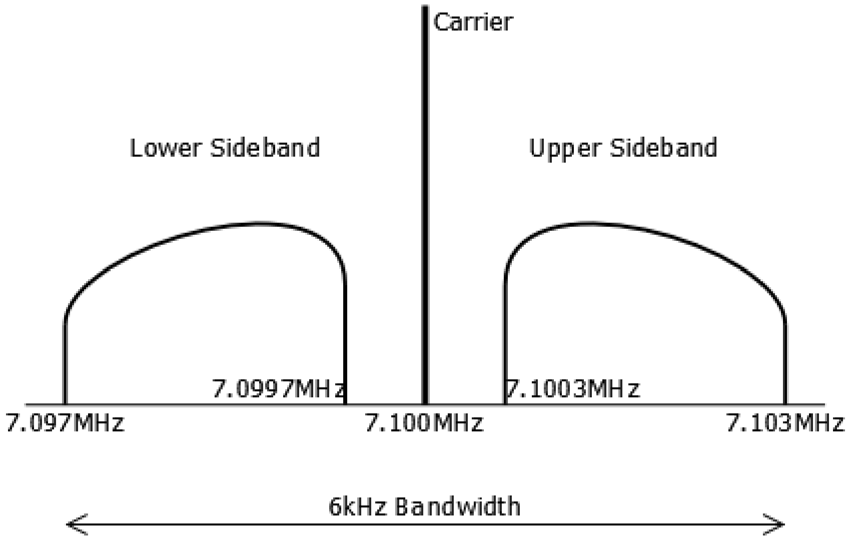
For example, if a single audio tone at 1760Hz (musical note A in octave 6, third A above middle C) is mixed with an RF carrier on 7.1MHz (in the middle of the 40m band), the outputs from the modulation stage will be:

1. A mixing product below the Carrier frequency on 7.098240MHz
2. The Carrier on 7.1MHz
3. A mixing product above the Carrier Frequency on 7.101760MHz

The mixing products are called **sidebands**, and looked at graphically, can be shown as:



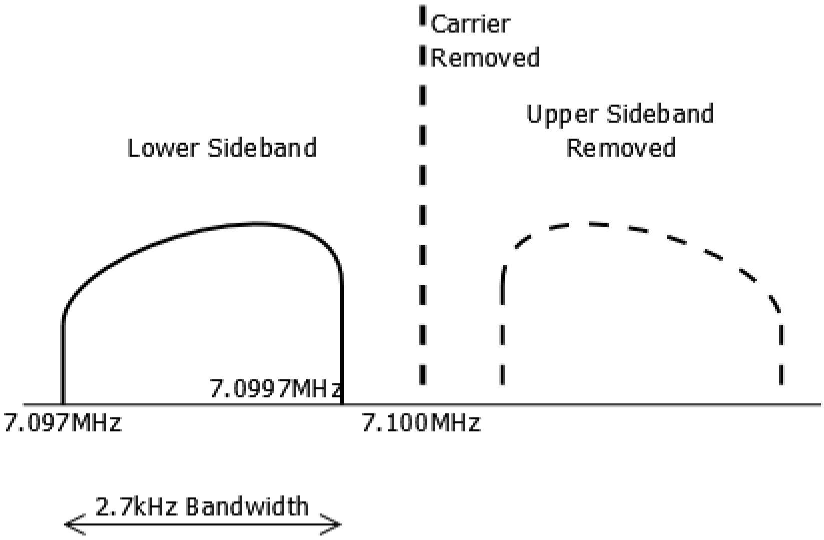
If this model is extended to a full audio signal which contains frequencies from 300Hz - 3000Hz (3kHz), then instead of being a single frequency in the sidebands, the sidebands extend to cover the full range of the audio input as shown below:



This is an **amplitude modulated** signal, it contains 2 sidebands and a carrier.

In an AM signal, as above, the 2 sidebands are mirror images of each other, that is they contain the same information and one can therefore be considered redundant. Furthermore, the Carrier is unnecessary as long as it can be reinserted in the receiver. If one of the sidebands and the carrier is removed the AM signal becomes a Single Sideband (SSB) signal as shown below.

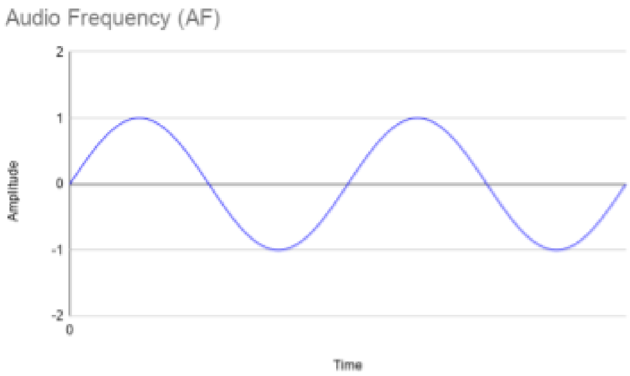
SSB occupies a narrower bandwidth than AM allowing more signals to utilise the same frequency limits, it is also more power-efficient resulting in a greater range.

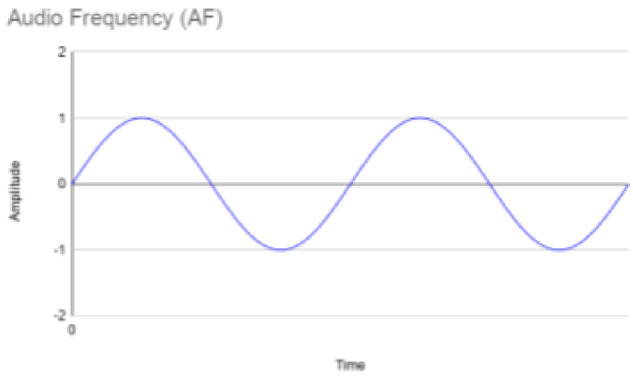

Carrier
Removed
Upper Sideband
Removed
Lower Sideband
7.0997MHz
7.097MHz
7.100MHz
2.7kHz Bandwidth

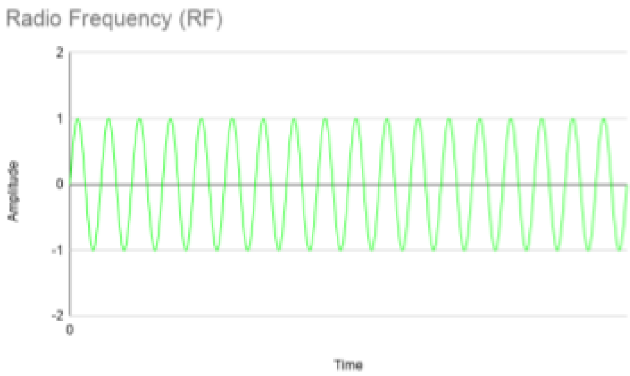
3A4

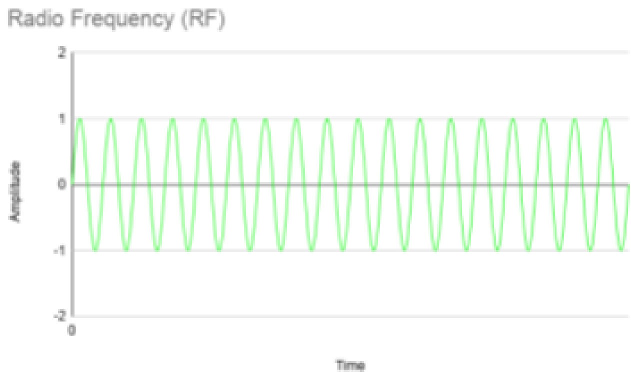
Identify diagrams representing audio, an RF carrier, amplitude modulated, frequency modulated and CW radio signals.

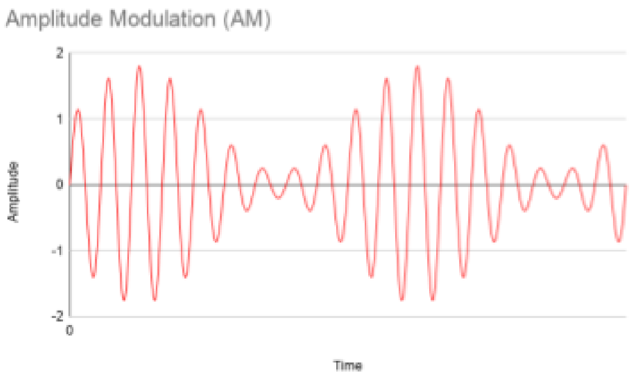
Understand the terms carrier, audio waveform and modulated waveform.

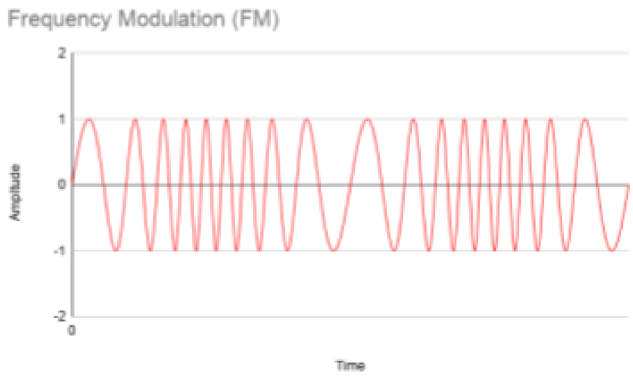








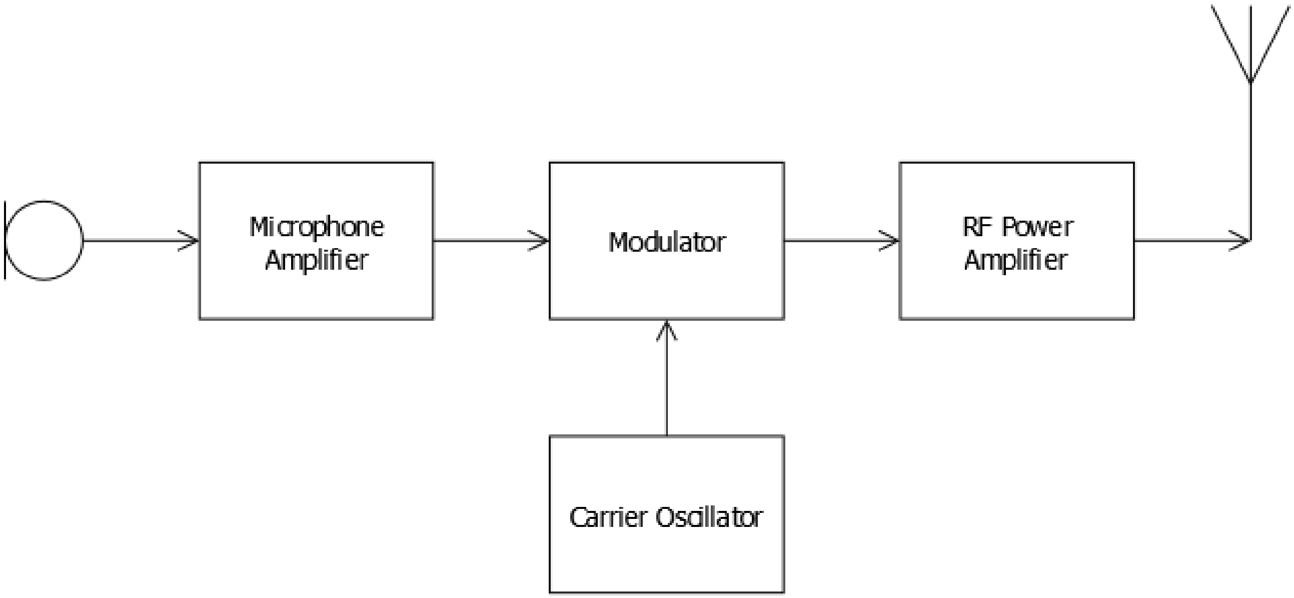




Transmitter architecture

3B1

Identify the items in a simple transmitter block diagram and recall their order of interconnection: Microphone, audio (microphone) amplifier stage, frequency generation stage, modulator stage, RF power amplifier stage, feeder and antenna.



The above diagram shows the basic processes contained within a traditional analogue transmitter.

The **microphone** converts the soundwaves from a person's mouth into an electrical signal. This signal is relatively small and the **microphone amplifier** boosts the signal before feeding it to the **modulator** where the audio signal is mixed with a radio frequency signal produced by the **carrier oscillator**. The resulting modulated signal is then boosted before being fed to the antenna.

Oscillators

3C1

Recall that the oscillator in a simple transmitter sets the frequency on which the transmitter operates.

Recall that incorrect setting of this stage can result in operation outside the amateur band and interference to other users.

The **Carrier Oscillator** is the part of the transmitter that sets the transmit frequency. As you tune your transmitter using the tuning control you are adjusting the **carrier oscillator**.

Depending on the design of your transmitter it is possible to adjust the **carrier oscillator** to operate on frequencies that are outside of the allocated amateur frequencies set out in the Licence Conditions. Operating outside of the amateur bands can cause interference to adjoining users of the RF spectrum.

Microphone amplifiers and modulators

3E1

Recall that the microphone amplifier amplifies the signal from the microphone to the level required to drive the modulator and limits the audio frequencies to those required for communication.

Recall the need to ensure that the microphone gain control (where fitted) is correctly adjusted.

The **microphone** (which could be a morse key or a computer feeding digital tones) generates a small electrical signal that is taken into the **Microphone Amplifier**.

The purpose of the **microphone amplifier** is to increase the small electrical signal produced by the microphone to the levels required to drive the **modulator** and also to filter the audio signal so that it only passes those frequencies necessary for efficient communication to the modulator. This is usually audio frequencies in the region of 300Hx - 3kHz (3,000Hz). This is where the effects of "microphone gain" can be found, on more sophisticated pieces of equipment there will be a microphone gain knob or in some cases a menu setting that controls the amount of amplification and can be tailored to the operator's voice and operating conditions.

It is important that the microphone gain is correctly set. Too little microphone gain can result in a low signal that is difficult to demodulate, too much microphone gain can cause distortion of the transmitted signal.

The **modulator** mixes the incoming audio signal with the radio frequency signal produced by the **carrier oscillator** to produce a modulated signal, that is a radio frequency signal at the frequency of the **carrier oscillator** but modulated with the audio signal from the **microphone**.

RF power amplifiers

3F1

Recall that the RF power amplifier stage increases the power of the modulated RF signal to the final output level.

The modulated signal is then fed to an **RF Power Amplifier** before being transmitted from the **antenna**. Most pieces of equipment will either have an adjustable knob to increase or decrease the final output power which is effectively controlling the amount of amplification the transmitter is permitted to use or will have a range of pre-set power levels accessible from a menu or a button.

3F3

Recall that the RF power amplifier output must be connected to a correctly matched load to work properly and that use of the wrong antenna can result in damage to the transmitter.

If the antenna is not designed for the frequencies that the **carrier oscillator** is set to then there will be a "mis-match" between the transmitter and the antenna. How bad this mis-match is depends on a number of factors that will be looked at further into the course. However, in the worst case, it is possible for the effects of the mis-match to damage the equipment in use.

In the absence of a correctly matched antenna, the transmitter should be connected to a matched "dummy load" to prevent damage to the equipment.

Do not transmit when the equipment is not connected to a matched antenna or a dummy load.

Transmitter interference

3G1

Recall that excessive amplitude modulation causes distorted output and interference to adjacent channels.

Recall that excessive frequency deviation will cause interference to adjacent channels.

Excessive Amplitude Modulation caused by overdriving the microphone amplifier results in peaks that are too high and reduces the troughs to zero. This causes distortion on the transmitted signal but will also result in "splatter" where your signal becomes too wide and interferes with adjacent frequencies or channels.

Similarly too much deviation in a Frequency Modulated signal can cause interference to adjacent channels as the carrier is "dragged" too far from its original frequency by the excessive audio signal.

Both of these situations can be avoided by not setting the microphone gain too high and by speaking clearly, without shouting, across the microphone. Everyone operates differently and if you are using a piece of kit that isn't yours you should check settings before you start using it.

Receiver concepts

3H1

Recall that the function of a radio receiver is to recover information sent from one place to another using electromagnetic radiation/wireless technology.

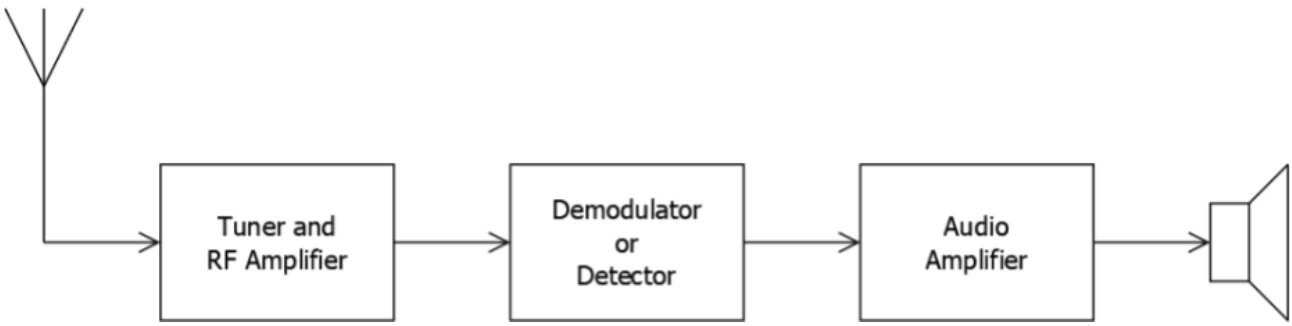
Recall that the process of recovering information from a modulated radio frequency signal is known as demodulation.

The receiver, which is commonly combined with the transmitter in a single transceiver, is essentially the opposite or complement to the transmitter. Clearly, both pieces of kit are required at both ends of the QSO (conversation or contact) for a conversation to take place. Some unlicensed radio enthusiasts only use receivers and report what they have heard, these people are sometimes referred to as Short Wave Listeners or SWLs.

In the same way as a transmitter has a **modulator** to imprint or encode the audio signal onto the transmitted signal a receiver contains a **demodulator** which has to reverse the imprinting or encoding process and recover the original audio signal. It is important that the same method of modulating and demodulating is used. It is not possible to demodulate an AM signal using an FM demodulator and vice versa.

3H2

Identify the items in a simple receiver block diagram and recall their order of interconnection: Antenna, feeder, wanted signal selection and RF amplification, demodulation/detection, audio amplification and loudspeaker or headphones.



The process chain is essentially the opposite of what occurs in a transmitter: The **antenna** picks up a variety of signals which are transferred to the receiver by the **feeder** connecting the **antenna** to the receiver where the **Tuner and RF Amplifier** selects the wanted signal from all of the received signals and boosts it to a level suitable for feeding into the **Demodulator/detector**

Demodulation

3K1

Recall that the detector/demodulator stage recovers the original information from the modulated signal.

Recall that the audio amplifier ensures the recovered modulation is strong enough to drive headphones or a loudspeaker.

The **demodulator/detector** recovers the original audio from the modulated RF signal

The demodulated signal is then fed to the **Audio Amplifier** before being played through a **loudspeaker** (shown in the diagram) or headphones.

Note that if headphones are used then the volume levels should be lowered and the amount of amplification reduced to avoid hearing damage. Some receivers, most notably crystal sets, omit the **audio amplifier** stage altogether and rely on the demodulated audio being fed into high impedance headphones.

SDR transmitters and receivers

3M1

Recall that the SDR receiver takes in all electromagnetic signals from the antenna and digitises this input for processing in software.

Recall that a mathematical operation enables all the signals to be sifted into separate frequency components.

Recall that the required signal is selected using a filter defined in software.

Recall that demodulation is carried out in software.

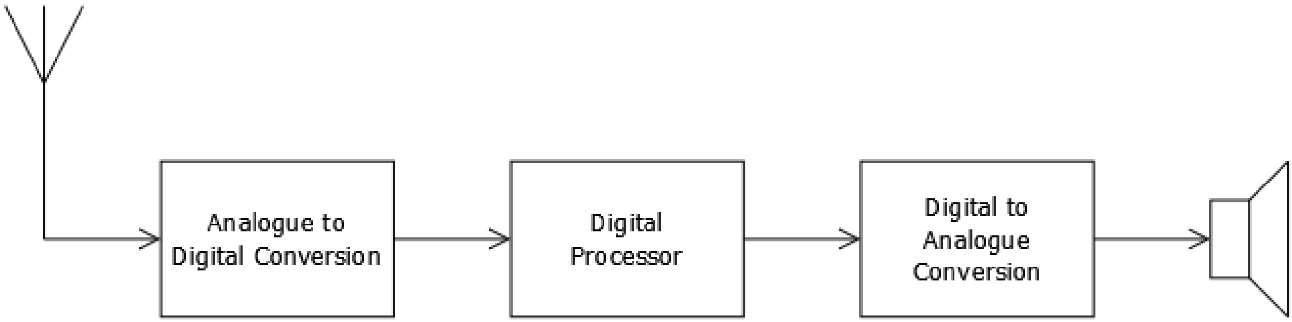
Recall that Software Defined Radio (SDR) receivers convert incoming signals to digital format and then perform filtering and demodulation on the signal using software and that SDR transmitters generate modulated radio signals using software.

There has been an increasing reliance on digital technology in receivers and increasingly in transmitters. Whereas in the past this digital technology was used within an analogue system lowering costs have allowed the entire demodulation process to be handled digitally in software.

The software used in Software Defined Radios allows a wide range of features to be implemented including band scopes and customisable filters.

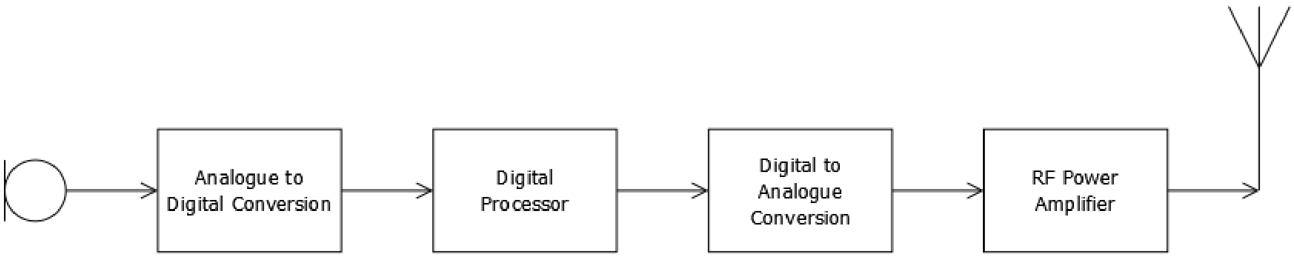
The process is not unlike the traditional receiver or transmitter chain but includes **Analogue to Digital** and **Digital to Analogue** components that allow information to be received and transmitted traditionally and created by microphones or heard on loudspeakers.

The difference is that the entire spectrum that the antenna can receive is converted to a digital stream that is processed in special chips and software.



The similarity between the SDR Receiver (above) and a conventional analogue receiver described earlier is clear.

One of the major advantages of the SDR system is that the performance of the transceiver can be updated or augmented by revisions to the software making the platform both versatile and upgradeable.



An SDR transmitter (above) is similar to the conventional analogue transmitter described earlier, with the Digital Processor taking the role of oscillator and modulator.