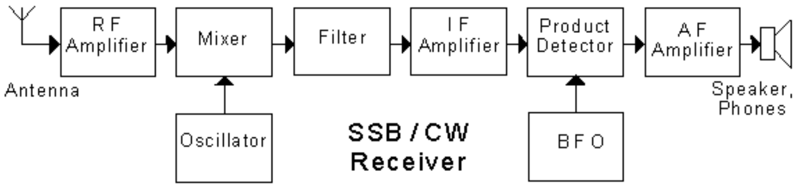
Receivers

How to draw block diagrams

This is is a "block diagram" of a "superhetrodyne" receiver. Before the actual stages are discussed, consider the diagram itself. It is drawn to show the "signal flow" entirely from ***left to right,*** shown by the arrows.



It starts with the antenna (aerial) on the left. The signal flows through many stages, shown by arrows from *left to right*. It ends with the speaker (or phones) on the right.

The "superhet" receiver

The diagram shows a "super-sonic heterodyne" - or "superhet" - receiver, the standard pattern for receivers in general use today. The first thing to note is that ***three*** amplifiers are shown, the RF amplifier, the IF amplifier, and the AF amplifier. Let's look at each in turn.

The Radio Frequency amplifier

This provides amplification for the signal as soon as it arrives from the antenna. The amplified signal is then passed to the "mixer/oscillator". The purpose of the mixer/oscillator is to act as a frequency-changer, to translate the frequency of the incoming signal to the "intermediate frequency", i.e. to the "IF amplifier".

The mixer stage is usually acknowledged as being the noisiest stage in the receiver so an RF amplifier is positioned ahead of it to mask that noise with a higher signal level.

The RF amplifier stage should use a low-noise amplifying device - such as a low-noise transistor - to keep the internally-generated noise of the receiver to as low as possible. All the following amplifying stages will amplify this RF stage noise as well as the signal, so a low-noise device at the start of the receiving process is very important.

The Intermediate Frequency amplifier

It is in the IF amplifier ***where most of the amplification in a receiver takes place***. Sometimes there may be two or more stages of IF amplification. The "IF frequency" is carefully selected, but more about that below. The filter block prior to the amplifier shapes the "passband" of the receiver.

The filter pass-band should be tailored to fit the signal being received - in the interests of keeping out unwanted noise and unwanted signals. A 500 Hz pass-band for CW reception, a 3 kHz pass-band for SSB, and 6 kHz for AM, would be typical.

From the IF stages, the signal passes to a detector. Here demodulation of the radio-frequency signal takes place to produce an audio signal.

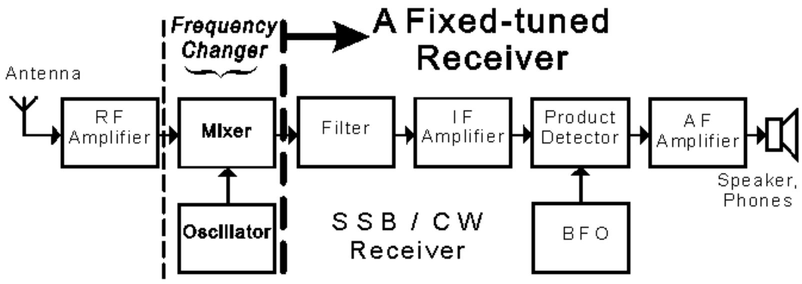
The diagram shows a "product detector" with a Beat Frequency Oscillator - or Carrier Insertion Oscillator (CIO) - for SSB and CW reception.

The Audio Frequency amplifier

Finally the audio signal is amplified in the audio amplifier and passed on to a speaker or phones for the listener to enjoy.

Receiving a signal

The superhet receiver is really in two parts:



1. From IF amplifier onwards, it is a "***fixed frequency receiver***", a receiver pre-tuned and optimised for the reception of a signal on the IF frequency.

2. The RF amplifier and mixer/oscillator receive signals from the antenna and then convert them to the frequency of this optimum receiver - to the IF frequency. It is in the RF amplifier and mixer/oscillator sections of the receiver where the actual operator adjustment and tuning for the selection or "***choice of received signal***" takes place.

Tuning a Superhet Receiver

To change the frequency of the incoming signal to the IF frequency, the tuned circuits in the RF amplifier, the mixer input, and the local oscillator, must be adjustable from the front panel. A look inside a typical conventional superhet receiver cabinet may disclose a "three-gang" tuning capacitor. Each "section" of this component tunes part of the first stages of the receiver.

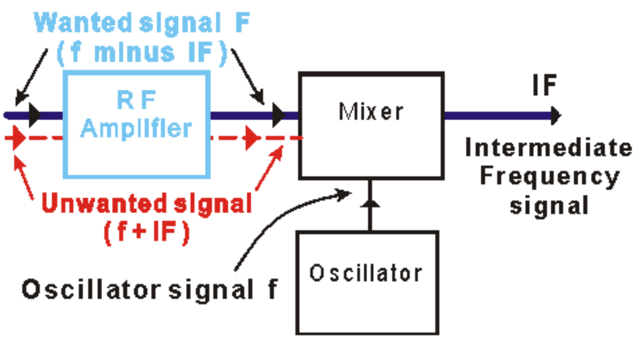
Note that it is the INPUT to the mixer which is tuned by a variable capacitor - the output is fixed-tuned at the IF frequency.

The choice of Intermediate Frequency

There are two conflicts with the choice of the IF Frequency:

A ***low intermediate frequency*** brings the advantage of higher stage gain and higher selectivity using high-Q tuned circuits. Sharp pass-bands are possible for narrow-band working for CW and SSB reception.

A ***high intermediate frequency*** brings the advantage of a lower ***image*** response.



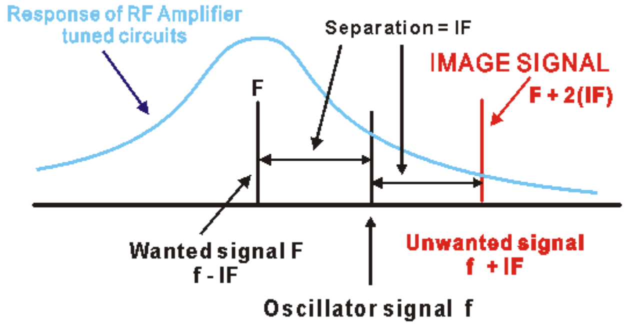
The "image frequency" problem can be seen in this example:

Consider a receiver for 10 MHz using an IF frequency of 100 kHz. The local oscillator will be on either 10.1 MHz - i.e. 100 kHz higher than the required input signal - or on 9.9 MHz. We will consider the 10.1 MHz case - but the principles are the same for the case where the oscillator is LOWER in frequency than the wanted signal frequency. .

Because of the way that mixers work, a signal at 10.2 MHz will also be received. This is known as the IMAGE frequency.

The image rejection of a superhet receiver can be improved by having more tuned circuits set to the required input frequency, such as more tuned circuits in the RF amplifier ahead of the mixer. This brings practical construction difficulties.

Another solution is to choose a high IF frequency so that the required received frequency and the image frequency are well separated in frequency. Choosing an IF of 2 MHz for the 10 MHz receiver would put the local oscillator at 12 MHz, the image frequency then being at 14 MHz.

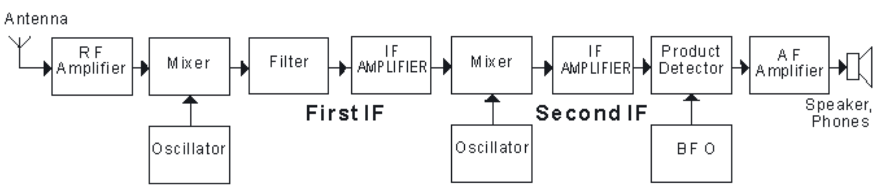


When receiving a signal at 10 MHz, it is easier to reject a signal at 14 MHz (the image in the 2 MHz IF case) than at 10.2 MHz (the image in the 100kHz IF case).

Note that the Image Frequency is ***TWICE*** the IF Frequency removed from the ***WANTED*** signal frequency - on the same side of the wanted frequency as the oscillator.

The "Double Conversion" receiver

The "double-conversion" superhet receiver brings the good points from both IF choices. A high frequency IF is first chosen to bring a satisfactory image response, followed by a low-frequency IF to bring high selectivity and gain.



Double Conversion Receiver

Typical examples would be a 5 MHz first IF and a 100 kHz second IF - but many designs are possible. There may be front-panel-selectable quartz or mechanical filters used at either or both IF's to give added selectivity.

The only two disadvantages of

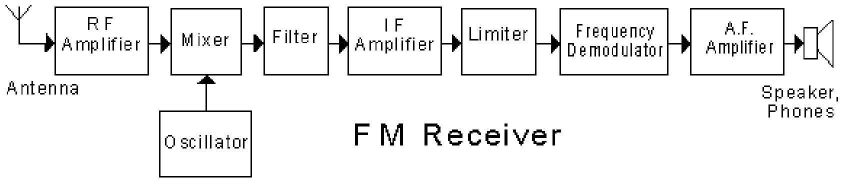
the double-conversion receiver are the added complexity and the additional oscillators required. These oscillators, unless carefully shielded, can mix with each other and produce unwanted signals at spots throughout the spectrum.

Count up the number of oscillators involved - including the BFO / CIO.

The F M Receiver

A receiver for FM signals follows the same general principles as a receiver for CW and SSB reception.

The frequency coverage for an FM receiver is different to that of a SSB / CW receiver. FM is a distinct VHF-and-higher mode. So FM receivers are for VHF and higher reception. In hand-held transceivers, the receiver will be "channelised" for switch-channel reception.



The IF amplifier is much wider in bandwidth than that of a CW/SSB receiver. So the IF amplifier will be higher in frequency - (say) 10.7 MHz.

The demodulator will usually be a "discriminator" and may even be of a "phase-lock-loop" variety. There will be a "limiter" before the descriminator to remove noise peaks and amplitude-changes before detection of the FM signal.

A simple receiver

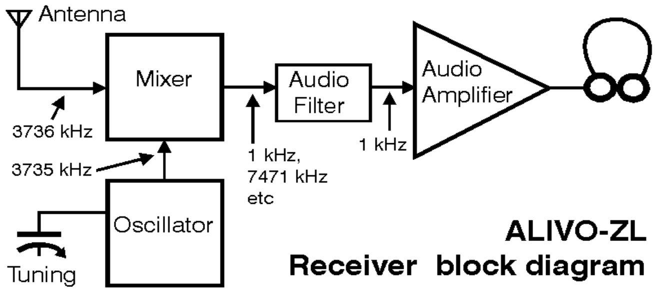
A simple receiver for the reception of amateur radio SSB and CW signals can be constructed by you at home. Yes! You could build it yourself!. It uses the "***direct conversion***" principle.

The details of a simple direct-conversion receiver can be seen at the following web site. The full construction details are given too!

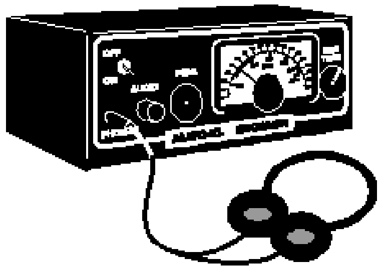
http://www.qsl.net/zl2vh/receiver.html

This receiver consists of a mixer stage and an audio amplifier.

The mixer converts the incoming signal frequency down to a lower frequency - this time right down to audio frequencies. It can be considered to be a superhet receiver with a 0 kHz (zero) intermediate frequency. The derived audio is passed through a simple audio filter to an audio amplifier to drive headphones or speaker.



This block diagram of the simple receiver shows the down-conversion process with a numerical example:



Frequency stability

The ability of a receiver to stay tuned to an incoming signal for a long period is related to the frequency stability of its local oscillator. This same requirement applies to transmitters.

Metal shielding is used around oscillator coils and the components used may be especially selected for high frequency stability. Temperature stability is also important.

Sensitivity

The sensitivity of a receiver is its ability to receive weak signals. Selectivity is more important than sensitivity.

Noise

The first stage in the receiving block-diagram chain, the RF amplifier, sets the noise characteristics for a receiver. The RF amplifier should use a low-noise device and it should generate very little internal noise. Measurement of sensitivity requires test equipment, equipment able to measure the "signal plus noise" audio output from the receiver and the "noise alone" with no signal being received.

The ratio: (S+N)/N (i.e. signal plus noise to noise) is often used with this test for comparing receivers.

There is far more to measuring the sensitivity and other characteristics of a receiver than is often realised! Please refer to standard textbooks on the subject.

Selectivity

The ability to separate two closely spaced signals is a receiver's "selectivity". The characteristics of the filter in the IF amplifier determine the frequency response of the IF stages and the "selectivity".

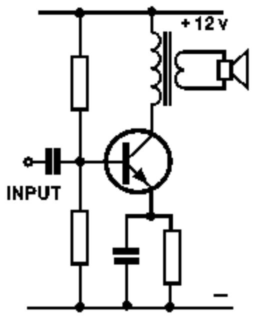
The narrower the filter pass-band, the "higher" the selectivity.

The receiver pass-band should be tailored to the characteristics of the incoming signal. Too wide a pass-band and unwanted noise is received which detracts from the reception of the wanted signal.

We use ***bandwidth*** to measure selectivity. This is how wide a range of frequencies you hear with the receiver tuned to a set frequency. Filters can often be selected by a front-panel switch to provide different receiver bandwidth characteristics.

The audio stage

The audio stage of a receiver amplifies the signal from the detector and raises it to a level suitable for driving headphones or a speaker.



A typical speaker is a load impedance of about 8 ohm. A transformer is generally used to match this low-impedance load to the impedance level required for the best performance of the amplifier.

There are many types of audio amplifier. The circuit shown here is to show the principles. It is typical of that in a very simple radio - with a very small speaker and low audio output.