Super heterodyne Receiver

The non uniform selectivity of the TRF led to the development of the super heterodyne receiver near the end of World War I. Although the quality of the super heterodyne receiver has improved greatly since its original design, its basic configuration has not changed much, and it is still used today for a wide variety of radio communications services. The super heterodyne receiver has remained in use because its gain, selectivity, and sensitivity characteristics are superior to those of other receiver configurations. Heterodyne means to mix two frequencies together in a nonlinear device or to translate one frequency to another using nonlinear mixing. A block diagram of a non-coherent super heterodyne receiver is shown in figure 1.5.1. Essentially, there are five sections to a super heterodyne receiver: the RF section, the mixer/converter section, the IF section, the audio detector section, and the audio amplifier section.

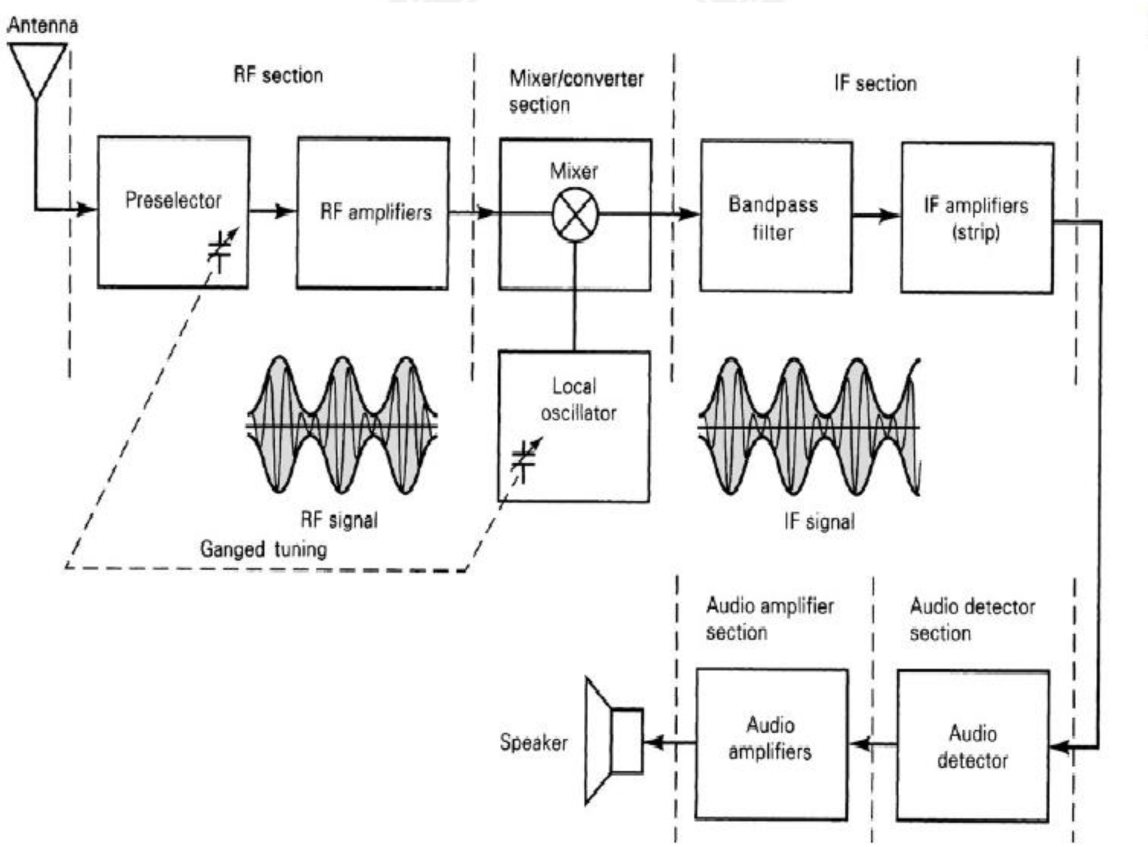

Fig 1.5.1 Superhetrodyne Receiver

Diagram Source Circuit Digest.com

Super heterodyne Principle

In the Super heterodyne Principle, the incoming signal voltage is combined with a signal generated in the receiver. This local oscillator voltage is normally converted into a signal of a lower fixed frequency. The signal at this intermediate frequency contains the same modulation as the original carrier, and it is now amplified and detected to reproduce the original information. The superhet has the same essential components as the TRF receiver, in addition to the mixer, local oscillator and intermediate-frequency (IF) amplifier.

A constant frequency difference is maintained between the local oscillator and the RF circuits; normally through capacitance tuning, in which all the capacitors are ganged together and operated in unison by one control knob. The IF amplifier generally uses two or three transformers, each consisting of a pair of mutually coupled tuned circuits. With this large number of double-tuned circuits operating at a constant, specially chosen frequency, the IF amplifier provides most of the gain (and therefore sensitivity) and bandwidth requirements of the receiver. Since the characteristics of the IF amplifier are independent of the frequency to which the receiver is tuned, the selectivity and sensitivity of the superhet are usually fairly uniform throughout its tuning range and not subject to the variations that affect the TRF receiver. The RF circuits are now used mainly to select the wanted frequency, to reject interference such as the image frequency and (especially at high frequencies) to reduce the noise figure of the receiver.

For further explanation of the Superheterodyne Principle, refer to Figure 6-2. The RF stage is normally a wideband RF amplifier tunable from approximately 540 kHz to 1650 kHz (standard commercial AM band). It is mechanically tied to the local oscillator to ensure precise tuning characteristics. The local oscillator is a variable oscillator capable of generating a signal from 0.995 MHz to 2.105 MHz. The incoming signal from the transmitter is selected and amplified by the RF stage. It is then combined (mixed) with a predetermined local oscillator signal in the mixer stage. (During this stage, a class C nonlinear device processes the signals, producing the sum, difference, and originals.)

The signal from the mixer is then supplied to the IF (intermediate-frequency) amplifier. This amplifier is a very-narrow-bandwidth class A device capable of selecting a frequency of 0.455 kHz ± 3 kHz and rejecting all others.

The IF signal output is an amplified composite of the modulated RF from the transmitter in combination with RF from the local oscillator. Neither of these signals is usable without further processing. The next process is in the detector stage, which eliminates one of the sidebands still present and separates the RF from the audio components of the other sideband. The RF is filtered to ground, and audio is supplied or fed to the audio stages for amplification and then to the speakers, etc.

The following example shows the Super heterodyne Receiver tuning process:

1. Select an AM station, i.e., 640 kHz.
2. Tune the RF amplifier to the lower end of the AM band.
3. Tune the RF amplifier. This also tunes the local oscillator to a predetermined frequency of 1095 kHz.
4. Mix the 1095 kHz and 640 kHz. This produces the following signals at the output of the mixer circuit; these signals are then fed to the IF amplifier:

- 1.095-MHz local oscillator frequency
- 640-kHz AM station carrier frequency
- 445-kHz difference frequency
- 1.735-MHz sum frequency

Because of its narrow bandwidth, the IF amplifier rejects all other frequencies but 455 kHz. This rejection process reduces the risk of interference from other stations. This selection process is the key to the superheterodyne's exceptional performance, which is why it is widely accepted The process of tuning the local oscillator to a predetermined frequency for each station throughout the AM band is known as tracking. A simplified form of the Super heterodyne Principle is also in existence, in which the mixer output is in fact audio. Such a direct conversion receiver has been used by amateurs, with good results.

RF section

The RF section generally consists of a pre selector and an amplifier stage. They can be separate circuits or a single combined circuit. The pre selector is a broad-tuned band pass filter with an adjustable center frequency that is tuned to the desired carrier frequency. The primary purpose of the pre selector is to provide enough initial band limiting to prevent a specific unwanted radio frequency, called the image frequency, from entering the receiver. The pre selector also reduces the noise bandwidth of the receiver and provides the initial step toward reducing the overall receiver bandwidth to the minimum bandwidth required to pass the information signals. The RF amplifier determines the sensitivity of the receiver (i.e., sets the signal threshold). Also, because the RF amplifier is the first active device encountered by a received signal, it is the primary contributor of noise and, therefore, a predominant factor in determining the noise figure for the receiver. A receiver can have one or more RF amplifiers, or it may not have any, depending on the desired sensitivity. Several advantages of including RF amplifiers in a receiver are as follows:

1. Greater gain, thus better sensitivity
2. Improved image-frequency rejection
3. Better signal-to-noise ratio
4. Better selectivity

Mixer/converter section

The mixer/converter section includes a radio-frequency oscillator stage (commonly called a local oscillator) and a mixer/converter stage (commonly called the first detector). The local oscillator can be any of the oscillator circuits, depending on the stability and accuracy desired. The mixer stage is a nonlinear device and its purpose is to convert radio frequencies to intermediate frequencies (RF-to-IF frequency translation). Heterodyning takes place in the mixer stage, and radio frequencies are down-converted to intermediate frequencies. Although the carrier and sideband frequencies are translated from RF to IF, the shape of the envelope remains the same and, therefore, the original information contained in the envelope remains unchanged. It is important to note that although the carrier and upper and lower side frequencies change frequency, the bandwidth is unchanged by the heterodyning process. The most common intermediate frequency used in AM broadcast-band receivers is 455 kHz.

IF section

The IF section consists of a series of IF amplifiers and bandpass filters and is often called the IF strip. Most of the receiver gain and selectivity is achieved in the IF section. The IF center frequency and bandwidth are constant for all stations and are chosen .so that their frequency is less than any of the RF signals to be received. The IF is always lower in frequency than the RF because it is easier and less expensive to construct high-gain, stable amplifiers for the low frequency signals. Also, low-frequency IF amplifiers are less likely to oscillate than their RF counterparts. Therefore, it is not uncommon to see a receiver with five or six IF amplifiers and a single RF amplifier or possibly no RF amplification.

Detector section

The purpose of the detector section is to convert the IF signals back to the original source information. The detector is generally called an audio detector or the second detector in a broadcast-band receiver because the information signals are audio frequencies. The detector can be as simple as a single diode or as complex as a phase-locked loop or balanced demodulator.

Audio amplifier section

The audio section comprises several cascaded audio amplifiers and one or more speakers. The number of amplifiers used depends on the audio signal power desired.

Tuning:

Broadband tuning is applied to the RF stage. The purpose of this is to reject the signals on the image frequency and accept those on the wanted frequency. It must also be able to track the local oscillator so that as the receiver is tuned, so the RF tuning remains on the required frequency. Typically the selectivity provided at this stage is not high. Its main purpose is to reject signals on the image frequency which is at a frequency equal to twice that of the IF away from the wanted frequency. As the tuning within this block provides all the rejection for the image response, it must be at a sufficiently sharp to reduce the image to an acceptable level. However the RF tuning may also help in preventing strong off-channel signals from entering the receiver and overloading elements of the receiver, in particular the mixer or possibly even the RF amplifier.

Amplification:

In terms of amplification, the level is carefully chosen so that it does not overload the mixer when strong signals are present, but enables the signals to be amplified sufficiently to ensure a good signal to noise ratio is achieved. The amplifier must also be a low noise design. Any noise introduced in this block will be amplified later in the receiver.

Mixer / frequency translator block:

The tuned and amplified signal then enters one port of the mixer. The local oscillator signal enters the other port. The performance of the mixer is crucial to many elements of the overall receiver performance. It should eb as linear as possible. If not, then spurious signals will be generated and these may appear as 'phantom' received signals.

Local oscillator:

The local oscillator may consist of a variable frequency oscillator that can be tuned by altering the setting on a variable capacitor. Alternatively it may be a frequency synthesizer that will enable greater levels of stability and setting accuracy.

Intermediate frequency amplifier, IF block :

Once the signals leave the mixer they enter the IF stages. These stages contain most of the amplification in the receiver as well as the filtering that enables signals on one frequency to be separated from those on the next. Filters may consist simply of LC tuned transformers providing inter-stage coupling, or they may be much higher performance ceramic or even crystal filters, dependent upon what is required.

· **Detector / demodulator stage:** Once the signals have passed through the IF stages of the super heterodyne receiver, they need to be demodulated. Different demodulators are required for different types of transmission, and as a result some receivers may have a variety of demodulators that can be switched in to accommodate the different types of transmission that are to be encountered. Different demodulators used may include:

AM diode detector:

This is the most basic form of detector and this circuit block would simple consist of a diode and possibly a small capacitor to remove any remaining RF. The detector is cheap and its performance is adequate, requiring a sufficient voltage to overcome the diode forward drop. It is also not particularly linear, and finally it is subject to the effects of selective fading that can be apparent, especially on the HF bands.

Synchronous AM detector

This form of AM detector block is used in where improved performance is needed. It mixes the incoming AM signal with another on the same frequency as the carrier. This second signal can be developed by passing the whole signal through a squaring amplifier. The advantages of the synchronous AM detector are that it provides a far more linear demodulation performance and it is far less subject to the problems of selective fading.

SSB product detector:

The SSB product detector block consists of a mixer and a local oscillator, often termed a beat frequency oscillator, BFO or carrier insertion oscillator, CIO. This form of detector is used for Morse code transmissions where the BFO is used to create an audible tone in line with the on-off keying of the transmitted carrier. Without this the carrier without modulation is difficult to detect. For SSB, the CIO re-inserts the carrier to make the modulation comprehensible.

Basic FM detector:

As an FM signal carries no amplitude variations a demodulator block that senses frequency variations is required. It should also be insensitive to amplitude variations as these could add extra noise. Simple FM detectors such as the Foster Seeley or ratio detectors can be made from discrete components although they do require the use of transformers.

PLL FM detector:

A phase locked loop can be used to make a very good FM demodulator. The incoming FM signal can be fed into the reference input, and the VCO drive voltage used to provide the detected audio output.

Quadrature FM detector:

This form of FM detector block is widely used within ICs. IT is simple to implement and provides a good linear output.

Audio amplifier: The output from the demodulator is the recovered audio. This is passed into the audio stages where they are amplified and presented to the headphones or loudspeaker.