
Radio Receivers
Al Penney
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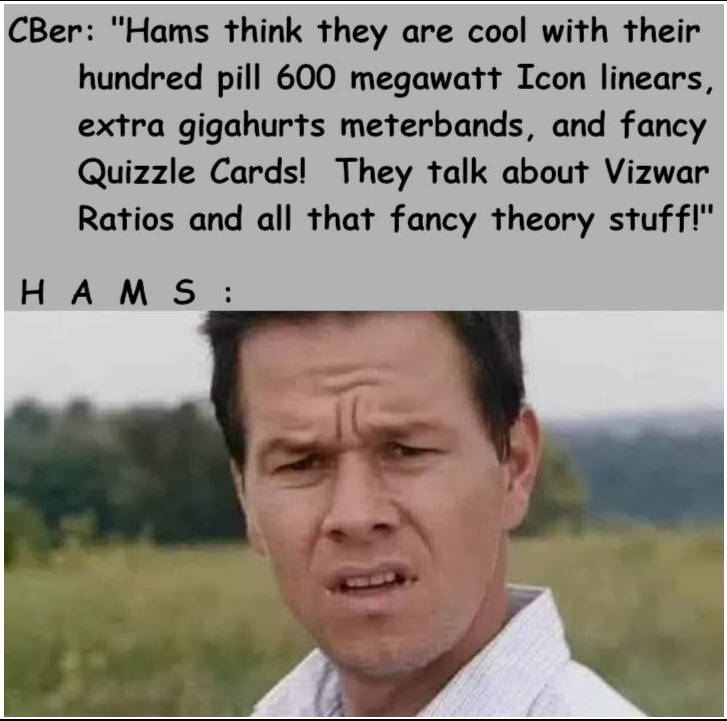
CBer: "Hams think they are cool with their hundred pill 600 megawatt Icon linears, extra gigahurts meterbands, and fancy Quizzle Cards! They talk about Vizwar Ratios and all that fancy theory stuff!"
H A M S :

Objectives

To become familiar with:

– The characteristics of receivers;
– The different stages of various receivers;
– The function and locations of receiver stages; and
– Signal demodulation.

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Role of the Receiver

- The **Antenna** must **capture** the **radio wave.**
- The **desired frequency** must be **selected** from all the EM waves captured by the antenna.
- The **selected signal** is usually very weak and **must be amplified.**
- The **information** carried by the radio wave, usually an audio signal, **must be recovered – Demodulation.**
- The **audio signal** must be **amplified.**
- The amplified **audio signal** must then be **converted** into **sound waves** using a speaker or headphones.

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In radio communications, a **radio receiver**, also known as a **receiver**, a **wireless** or simply a **radio**, is an electronic device that receives radio waves and converts the information carried by them to a usable form. It is used with an antenna. The antenna intercepts radio waves (electromagnetic waves) and converts them to tiny alternating currents which are applied to the receiver, and the receiver extracts the desired information. The receiver uses electronic filters to separate the desired radio frequency signal from all the other signals picked up by the antenna, an electronic amplifier to increase the power of the signal for further processing, and finally recovers the desired information through demodulation.

Radio receivers are essential components of all systems that use radio. The information produced by the receiver may be in the form of sound, moving images (television), or digital data. A radio receiver may be a separate piece of electronic equipment, or an electronic circuit within another device. The most familiar type of radio receiver for most people is a broadcast radio receiver, which reproduces sound transmitted by radio broadcasting stations, historically the first mass-market radio application. A broadcast receiver is commonly called a "radio". However radio receivers are very widely used in other areas of modern technology, in televisions, cell phones, wireless modems and other components of communications, remote control, and wireless networking systems.

How receivers work

A radio receiver is connected to an antenna which converts some of the energy from the incoming radio wave into a tiny radio frequency AC voltage which is applied to the receiver's input. An antenna typically consists of an arrangement of metal conductors. The oscillating electric and magnetic fields of the radio wave push the electrons in the antenna back and forth, creating an oscillating voltage.

The antenna may be enclosed inside the receiver's case, as with the ferrite loop antennas of AM radios and the flat inverted F antenna of cell phones; attached to the outside of the receiver, as with whip antennas used on FM radios, or mounted separately and connected to the receiver by a cable, as with rooftop television antennas and satellite dishes.

Main functions of a receiver

Practical radio receivers perform three basic functions on the signal from the antenna: filtering, amplification, and demodulation

The 3 S's of Receivers

- **Sensitivity**
- **Selectivity**
- **Stability**

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Design of a radio receiver must consider several fundamental criteria to produce a practical result. The main criteria are gain, selectivity, sensitivity, and stability. The receiver must contain a detector to recover the information initially impressed on the radio carrier signal, a process called modulation.

Gain is required because the signal intercepted by an antenna will have a very low power level, on the order of femtowatts. To produce an audible signal in a pair of headphones requires this signal to be amplified a trillion-fold or more. The magnitudes of the required gain are so great that the logarithmic unit decibel is preferred - a gain of 1 trillion times the power is 120 decibels, which is a value achieved by many common receivers. Gain is provided by one or more amplifier stages in a receiver design; some of the gain is applied at the radio-frequency part of the system, and the rest at the frequencies used by the recovered information (audio, video, or data signals).

Selectivity is the ability to "tune in" to just one station of the many that may be transmitting at any given time. An adjustable bandpass filter is a typical stage of a receiver. A receiver may include several stages of bandpass filters to provide sufficient selectivity. Additionally, the receiver design must provide immunity from spurious signals that may be generated within the receiver that would interfere with the desired signal. Broadcasting transmitters in any given area are assigned frequencies so that receivers can properly select the desired transmission; this is a key factor limiting the number of transmitting stations that can operate in a given area.

Sensitivity is the ability to recover the signal from the background noise. Noise is generated in the path between transmitter and receiver, but is also significantly generated in the receiver's own circuits. Inherently, any circuit above absolute zero generates some random noise that adds to the desired signals. In some cases, atmospheric noise is far greater than that produced in the receiver's own circuits, but in some designs, measures such as cryogenic cooling are applied to some stages of the receiver, to prevent signals from being obscured by thermal noise. A very good receiver design may have a noise figure of only a few times the theoretical minimum for the operating temperature and desired signal bandwidth. The objective is to produce a signal-to-noise ratio of the recovered signal sufficient for the intended purpose. This ratio is also often expressed in decibels. A signal-to-noise ratio of 10 dB (signal 10 times as powerful as noise) might be usable for voice communications by experienced operators, but a receiver intended for high-fidelity music reproduction might require 50 dB or higher signal-to-noise ratio.

Stability is required in at least two senses. Frequency stability; the receiver must stay "tuned" to the incoming radio signal and must not "drift" with time or temperature. Additionally, the great magnitude of gain generated must be carefully controlled so that spurious emissions are not produced within the receiver. These would lead to distortion of the recovered information, or, at worst, may radiate signals that interfere with other receivers.

The detector stage recovers the information from the radio-frequency signal, and produces the sound, video, or data that was impressed on the carrier wave initially. Detectors may be as simple as an "envelope" detector for amplitude modulation, or may be more complex circuits for more recently developed techniques such as frequency-hopping spread spectrum.

While not fundamental to a receiver, automatic gain control is a great convenience to the user, since it automatically compensates for changing received signal levels or different levels produced by different transmitters.

Many different approaches and fundamental receiver "block diagrams" have developed to address these several, sometimes contradictory, factors. Once these technical objectives have been achieved, the remaining design process is still complicated by considerations of economics, patent rights, and even fashion.

Sensitivity

- Refers to the **minimum signal level** that the receiver can **detect - "MDS" (minimum discernable signal).**
- Measured in **Microvolts** or **fractions of Microvolts** at 50 Ohm.
- Also measured in **dbm** - db below 1 mW at 50Ω, e.g. minus 130 dbm.
- The **greater the sensitivity** (ie: the smaller the number of microvolts or greatest decibels below 1 mW) the **weaker a signal** it can **receive.**

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The sensitivity of a radio receiver determines the weakest signals that can be successfully receiver. Whether it is an audio signal for which the listening quality deteriorates as the signal falls into the noise, or a data signal where the bit error rate rises and throughput falls.

In this way, the radio receiver sensitivity is a key parameter that has an impact on the performance of any radio communications, broadcast or other system.

In fact, the two main requirements of any radio receiver are that it should be able to separate one station from another, i.e. selectivity, and sensitivity so that signals can be brought to a sufficient level above the noise to be able to use the modulation applied to the carrier that has been transmitted. As a result receiver designers battle with many parameters to make sure that both these requirements and many others are all fulfilled

Methods of specifying sensitivity performance

As the RF sensitivity performance of any receiver is of paramount importance it is necessary to be able to specify it in a meaningful way. A number of methods and figures of merit are used dependent upon the application envisaged:

•***Signal to noise ratio:*** This is a straightforward comparison ratio of a given signal level to the noise within the system.

•***SINAD:*** This receiver sensitivity measurement is slightly more formalised, and it also includes distortion as well as the noise.

•***Noise factor :*** This RF receiver measurement compares the noise added by a unit - this could be an amplifier or other unit within the system or it could be a complete receiver.

•***Noise figure:*** The noise figure, or NF of a unit or system is the logarithmic version of the noise factor. It is widely used for specifications of sensitivity and noise performance of a receiver, element within a system, or the whole system.

•***Carrier to noise ratio, CNR:*** The carrier-to-noise ratio is the signal-to-noise ratio (SNR) of a modulated signal. This term is less widely used than SNR, but may be used when there is a need to distinguish between the performance with regards to the radio frequency pass-band signal and the analogue base band message signal after demodulation.

•***Minimum discernable signal, MDS:*** The Minimum detectable or minimum discernable signal is the smallest signal level that can be detected by a radio receiver, i.e. one that can be processed by its analogue and digital signal chain and demodulated by the receiver to provide usable information at the output.

•***Error vector magnitude, EVM:*** Error vector magnitude, EVM is a measure that can be used to quantify the performance of a digital radio transmitter or receiver. There various points on the constellation diagram set to identify various digital states. In an ideal link, the transmitter should generate the digital data such that it falls as close to these points as possible - the link should not degrade the signal such that the actual received data does not fall onto these points, and the receiver should also not degrade these positions. In reality, noise enters the system and the received data does not fall exactly onto these positions. The error vector magnitude is a measure of how far from the ideal positions the actual received data elements are. Some times EVM may also be known as the Receive Constellation Error, RCE. Error vector magnitude is widely used in modern data communications including Wi-Fi, mobile / cellular and many IoT systems.

•***Bit error rate, BER:*** Bit error rate is a form of measurement used for digital systems. As the signal level falls or the link quality degrades, so the number of errors in the transmission - bit errors - increases. Measuring the bit error rate gives an indication of the signal to noise ratio, but in a format that is often more useful for the digital domain.

•All the receiver sensitivity specification methods use the fact that the limiting factor of the sensitivity of a radio receiver is not the level of amplification available, but the levels of noise that are present, whether they are generated within the radio receiver or outside.

RECEIVER SENSITIVITY is the ability to listen to weak signals, preferably without undue background noise. Minimum discernible signal (MDS) is a measurement of the sensitivity of the receiver. It is usually measured using a spectrum analyser by increasing a test signal on the receiver frequency until it is 3dB above the noise floor of the receiver. The noise you hear in a receiver that is not connected to an antenna is proportional to the bandwidth of the receiver. So for instance reducing the bandwidth from 500Hz to 50Hz reduces the noise power by 10dB (a 10 times reduction in power). Where possible the ARRL MDS test is carried out with a 500Hz bandwidth setting. Of course when you connect the antenna you hear atmospheric noise and other signals in addition to the noise generated within the receiver. Another common measurement of receiver sensitivity is ‘signal to noise ratio’ (or for FM receivers SINAD). Signal to noise is the ratio, expressed in dB, of the level of (signal plus noise) with a signal present to the level of (noise) with no signal present. It is measured by increasing the signal into the receiver until the receiver audio output increases by 10dB (10dB S+N/N) so it is normally around 10dB higher than the MDS, which for an HF receiver should be around -120 to -130dBm in a 500hz bandwidth. SINAD is the ratio of (signal + noise + distortion) to (noise + distortion) and for a VHF or UHF receiver is typically around 12dB for an input to the receiver of 0.25uV (-119dBm).

Noise

Today technology is such that there is little problem in being able to achieve very large levels of amplification within a radio receiver. This is not the limiting factor. In any receiving station or radio communications system, the limiting factor is noise - weak signals are not limited by the actual signal level, but by the noise masks them out. This noise can come from a variety of sources. It can be picked up by the antenna or it can be generated within the radio receiver.

It is found that the level of noise that is picked up externally by a receiver from the antenna falls as the frequency increases. At HF and frequencies below this the combination of galactic, atmospheric and man-made noise is relatively high and this means that there is little point in making a receiver particularly sensitive. Normally radio receivers are designed such that the internally generated noise is much lower than any received noise, even for the quietest locations.

At frequencies above 30 MHz the levels of noise start to reach a point where the noise generated within the radio receiver becomes far more important. By improving the noise performance of the radio receiver, it becomes possible to detect much weaker signals

Signals and Noise

- Another way to specify the **sensitivity** of a receiver is to express how many **microvolts of signal** are required to give a certain **Signal to Noise Ratio (SNR).**
- Some use the **Signal + Noise to Noise Ratio**, or **(S+N)/N.**
- These ratios are specified in dB.
- The **narrower the receiver bandwidth**, the **less noise** is received, so the **weaker the signal** that can be copied.

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Sensitivity

- Very weak signals can be received – **sensitivity is generally not an issue** with modern receivers.
- *Between 1.7 and 24.5 MHz on SSB, the Kenwood TS-890 has a sensitivity of 0.2 microvolts or less.*

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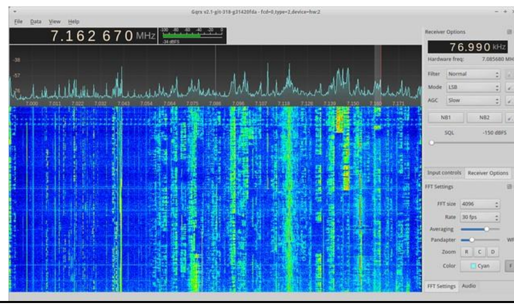
Selectivity

- Refers to the **receiver's ability** to **separate** two **closely spaced signals.**
- The **more selective** a receiver, the **narrower** the **bandwidth and/or the steeper the filter skirt.**



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The selectivity of any radio receiver is of great importance. With the vast number of signals being transmitted it is important that the radio receiver is able receive only the required signal on the wanted frequency and to reject others.

The receiver selectivity performance determines the level of interference that may be experienced, and therefore it is very important that the selectivity enables sufficient rejection of signals on other frequencies to be achieved to enable interference free operation.

Obviously if two signals are present on the same channel then the receiver selectivity is unable to separate them, but where they are on different frequencies the degree of selectivity available should enable them to be separated.

Receiver topology & selectivity

There is a variety of different radio receiver topologies that can be used. The actual receiver technology can have a significant impact on selectivity and the approaches used. Some of the major types of radio receiver are summarised below:

•***Tuned Radio Frequency, TRF, receiver :*** As the name implies this type of receiver relies on the filters in the RF sections of the radio to provide the selectivity. As these are variable and often at a relatively high frequency, selectivity is not as good as that provided by the superheterodyne and direct conversion receivers. Techniques like regeneration and super-regeneration are able to provide significant improvements in selectivity performance, but not to the degree and convenience provided by the other type techniques.

•***Direct conversion receiver:*** The direct conversion receiver also uses a mixer, but rather than converting the signal down to a fixed frequency intermediate frequency, it converts it down to baseband. Typically these receivers are used for data, where the baseband signal is applied to IQ demodulators and passed into a digital signal processing system. For these receivers the main form of filtering required is at the front end to prevent unwanted out-of-band signals entering the mixer and overloading the RF and later stages.

•***Superheterodyne receiver:*** The superheterodyne radio receiver has been in widespread use for many years, and it is still widely used for many high performance applications as well as for broadcast, television, communications and others.

A variety of selectivity and filter requirements are applicable for superheterodyne receivers. Selectivity of the front end is required to ensure sufficient image rejection, and the filters in the IF provide the main adjacent channel rejection.

Receiver selectivity

Selectivity is required in different areas of a radio receiver to ensure that only the wanted signal is received. Front end tuning or selectivity tends to be wideband in nature, or variable to enable the receiver to cover different channels or frequencies.

For the superheterodyne receiver, the main selectivity is provided within the fixed frequency IF stages. Here filters are able to provide very high degrees of selectivity ranging from that required for wideband transmissions including wideband FM, direct sequence spread spectrum and the like, occupying bandwidths of hundreds of kilohertz or megahertz, down to very narrow band transmissions occupying a few kilohertz or even a few Hertz.

Dependent upon the type of transmission the receiver will be used for, the bandwidth required, and hence its selectivity, different types of filter may be used.

There are various formats for the requirements for radio selectivity. The selectivity can be aimed at rejecting signals that may reach the receiver output in a variety of ways.

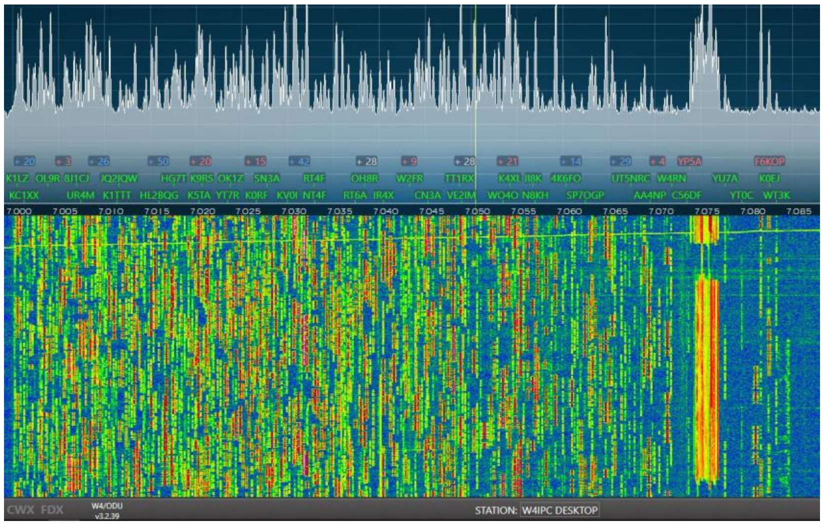
•***Adjacent channel selectivity:*** Adjacent channel selectivity of the form of selectivity that rejects signals on nearby frequencies. It is the what is most commonly referred to as the radio selectivity of the form is not qualified in any way.

•***Image rejection selectivity:*** When using a sueprheterodyne radio, it is possible for signals on what is termed the image frequency to reach the final stages of the receiver. Rejecting these signals is important as they can cause significant levels of interference. The selectivity required to remove these signals is contained within the radio frequency stages of the radio.

•***Spurious signal selectivity:*** Unwanted signals may reach the output of the radio as a result of variety of different unwanted or spurious modes. Rejecting these signals is important and it may often be contained under what may be termed spurious responses selectivity.

Selectivity is a particularly important parameter in any radio receiver whether it is used for broadcast reception or for use within another form of radio communications system such as a two way radio communications link, or a fixed or mobile radio communications application. As a result it is necessary to ensure that any radio receiver is able to select the wanted signal as well as it can. Obviously when signals occupy the same frequency there is little that can be done, but by having a good filter it is possible to ensure that you have the best chance or receiving and being able to copy the signal that is required.

Selectivity



Selectivity

- **Specified** as the **bandwidth** at **6 dB** attenuation, and at **60 dB** attenuation (ie: the –6 dB and –60 dB points).
- Filter Skirt steepness is perhaps **THE key characteristic** that separates the adults from the children in HF receiver design!
- *Example: On SSB the Kenwood TS-870 has a selectivity of 2.3 kHz at – 6 dB and 3.3 kHz at – 60 dB. This is a very selective receiver.*

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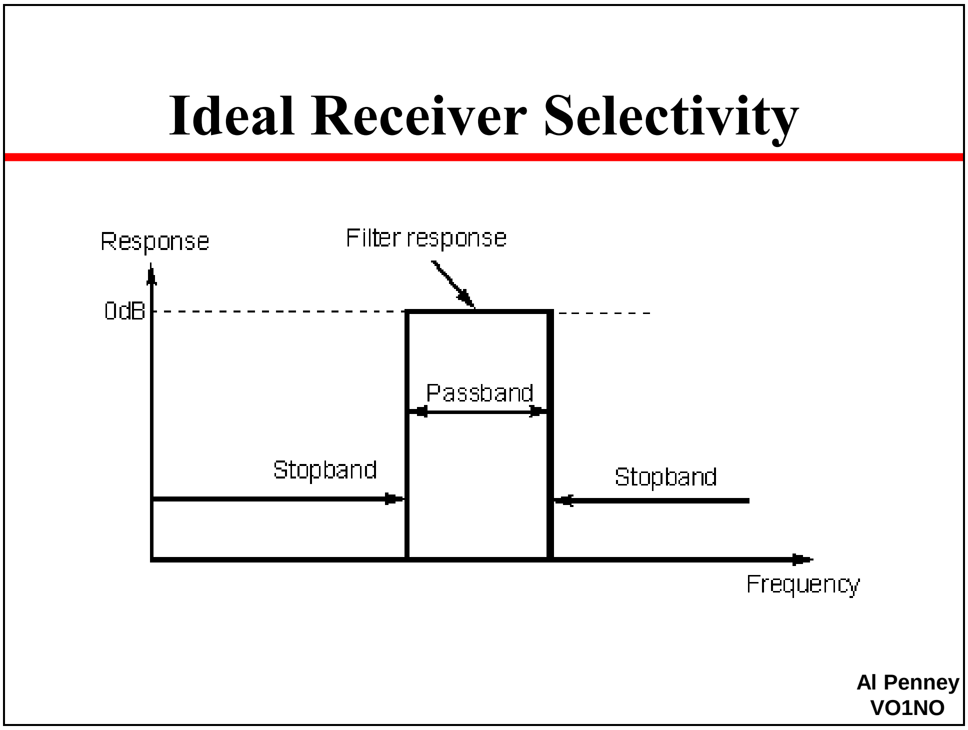


The Adjacent Channel Selectivity, ACS is a measure of the ability of a radio receiver to receive a signal on the wanted channel or frequency in the presence of another signal on an adjacent frequency or channel.

The adjacent channel selectivity is defined as the ratio of the receiver filter attenuation on the wanted channel or frequency to the receiver filter attenuation on the adjacent channel frequency.

In view of this, the receiver filter performance is key when defining the adjacent channel selectivity, ACS, performance.

Radio receiver filter specifications

There are many different filter specifications that can be used to define the performance of a filter and hence the adjacent channel selectivity:

•Stop-band

•Pass-band

•In-band ripple

•Stop-band ripple

•Shape factor

•Response mask

•Input and output impedance

•Intermodulation

Filter parameters

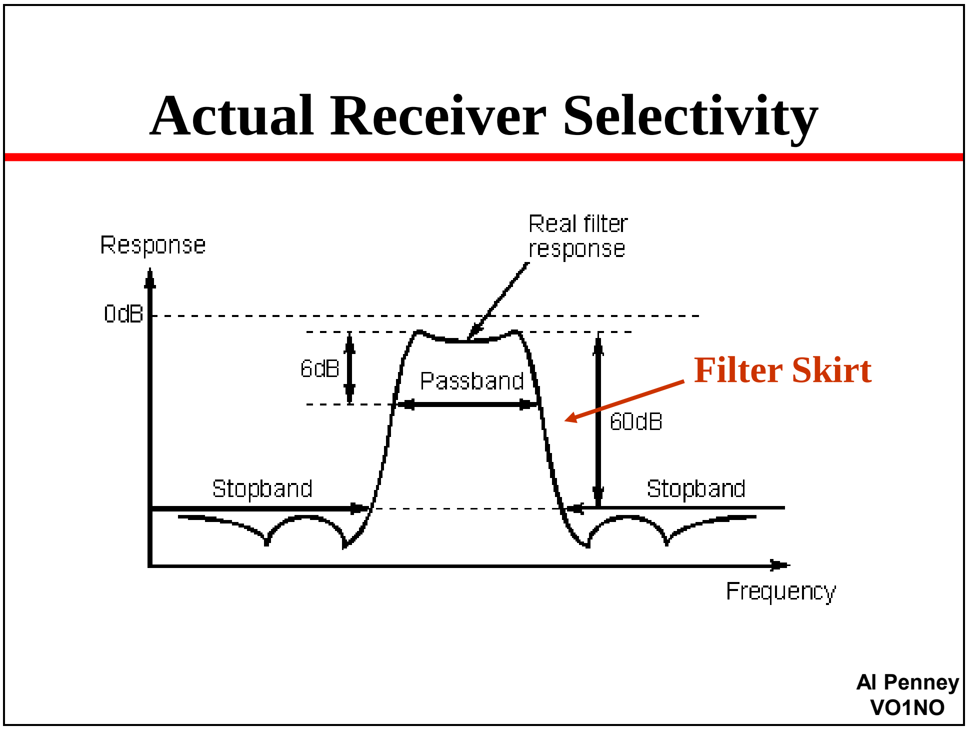
The adjacent channel selectivity performance is primarily associated with the filter performance and there are two main areas of interest for any filter:

•***Pass-band:*** This is the band of frequencies for which the filter is deemed to pass signals.

•***Stop-band:*** This is the band for which the receiver filter is deemed to stop-the unwanted signals proceeding further within the radio. This determines the level of rejection for the adjacent channel selectivity performance.

The diagram above shows the ideal response for a filter. There is an immediate transition between the pass band and the stop band. Also in the pass band the filter does not introduce any loss and in the stop band no signal is allowed through.

The response shown above would provide an ideal adjacent channel selectivity performance, but in reality this cannot be achieved.



In reality it is not possible to realise a filter with these characteristics and a typical response more like that shown below. It is fairly obvious from the diagram that there are a number of differences. The first is that there is some loss in the pass band. Secondly the response does not fall away infinitely fast. Thirdly the stop band attenuation is not infinite, even though it is very large. Finally it will be noticed that there is some in band ripple. It is primarily the different in response between the pass-band and stop-band that govern the adjacent channel selectivity, along wit the rate at which the response falls between the pass-band and stop-band.

In most filters the attenuation in the pass band is normally relatively small. For a typical crystal filter figures of 2 - 3 dB are fairly typical. However it is found that very narrow band filters like those used for Morse reception may be higher than this. Fortunately it is quite easy to counteract this loss simply by adding a little extra amplification in the intermediate frequency stages and this factor is not quoted as part of the receiver specification.

It can be seen that the filter response does not fall away infinitely fast, and it is necessary to define the points between which the pass band lies. For receivers the pass band is taken to be the bandwidth between the points where the response has fallen by 6 dB, i.e. where it is 6 dB down or -6 dB.

A stop band is also defined. For most radio receiver filters this is taken to start at the point where the response has fallen by 60 dB, although the specification for the filter should be checked this as some filters may not be as good. Sometimes a filter may have the stop band defined for a 50 dB attenuation rather than 60 dB.

Filter shape factor

It can be seen that it is very important for the filter to achieve its final level of rejection as quickly as possible once outside the pass band. This can be a key parameter for the adjacent channel selectivity. If the response does not fall fast enough, then the adjacent channel signals may not be attenuated sufficiently.

Ideally the response should fall as quickly as possible. To put a measure on this, a figure known as the shape factor is used on some filters. This is simply a ratio of the bandwidths of the pass band and the stop band. Thus a filter with a pass band of 3 kHz at -6dB and a figure of 6 kHz at -60 dB for the stop band would have a shape factor of 2:1. For this figure to have real meaning the two attenuation figures should also be quoted. As a result the full shape factor specification should be 2:1 at 6/60 dB.

Stability

- The **receiver's ability** to **remain on a frequency** for a period of time.
- **Unintended change** in frequency is **called drift.**
- Specified as **number of Hz drift** over a **period of time** after warmup, or as **ppm (part per million)** for more modern radios.
- **Not an issue for modern receivers**, but is a consideration for older designs, especially those using vacuum tubes.

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Stability is required in at least two senses. Frequency stability; the receiver must stay "tuned" to the incoming radio signal and must not "drift" with time or temperature. Additionally, the great magnitude of gain generated must be carefully controlled so that spurious emissions are not produced within the receiver. These would lead to distortion of the recovered information, or, at worst, may radiate signals that interfere with other receivers.

Other Receiver Characteristics

- **Frequency precision:** ability to determine the frequency.
- **Resettability:** ability to return to a frequency.
- **Interference rejecting features:** filters, DSP, noise blanker, noise limiter, RF preselector, Notch Filters.
- **Dynamic range:** range of signal strength through which the receiver operates properly.

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The dynamic range of a radio receiver is essentially the range of signal levels over which it can operate. The low end of the range is governed by its sensitivity whilst at the high end it is governed by its overload or strong signal handling performance. Specifications generally use figures based on either the inter-modulation performance or the blocking performance.

Cross Modulation

- **Cross Modulation** occurs when a **strong signal** is **too powerful for the receiver's front end** (first RF Amplifier) to pass through without **distortion.**
- It results in the **wanted signal being Amplitude Modulated by the strong unwanted signal** ie: the unwanted signal can be heard on top of the wanted signal.

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Cross Modulation in Radio Receivers

Cross modulation is an effect noticed in radio receivers when the amplitude modulated elements of a strong signal appear on other received signals.

Cross modulation is a parameter used for radio receivers where strong signals with an amplitude modulated component are used. Amplitude and quadrature amplitude modulation are two examples.

It is found that the strong signal may cause sections of the receiver to become non-linear and in this way the varying amplitude transfers over to other signals.

Effectively, cross modulation is the transfer of modulation from one signal, typically a much stronger one, to another signal, typically a weaker one, die to non-linearities in the receiver chain.

Cross modulation basics

Cross modulation normally arises out of imperfect mixer performance in the radio, although it can easily occur in one of the RF amplifiers. As it is a third order effect, a receiver with a good third order intercept point should also exhibit good cross modulation performance.

To specify the cross modulation performance the effect of a strong AM carrier on a smaller wanted signal is noted. Generally the level of a strong carrier with 30% modulation needed to produce an output 20 dB below that produced by the wanted signal. The wanted signal level also has to be specified and 1mV or -47dBm (i.e. a signal 47 dB below 1 mW) is often taken as standard, together with an offset frequency of 20 kHz.

Cross modulation affects

Cross modulation is really only applicable to instances where amplitude modulation is used. In the early days of radio, it was noticed on amplitude modulated signals like broadcast transmissions, but today there are other signals that have amplitude modulation components.

•***AM broadcast receivers:*** This is traditionally the area where cross modulation effects had been noticed. When listing to weaker AM broadcast signals in the presence of very strong off channel signals, the modulation of the stronger signal or signals was transposed onto the weaker wanted signal. When broadcast receivers were located close to a broadcast transmitter, it could become an annoying problem.

•***Analogue television receivers:*** Although analogue television has now virtually been overtaken by digital television, it is still used occasionally and it was found that cross modulation occurred in some areas.

The most widely used form of modulation used with analogue television systems is vestigial sideband, VSB. It is effectively a form of AM where one of the sidebands has a reduced upper bandwidth. In televisions sets cross modulation manifests itself by creating a ghost image under the wanted on-channel station being received. It can be annoying if television stations are not all geographically co-located, and a more distant signal is being received in presence of a much more local and stronger off-channel signal.

While radio receiver cross modulation may not have the visibility in terms of receiver specifications that it previously had, it is still very important, especially in scenarios in which the modulations schemes used have an amplitude component.

Curing Cross Modulation

- To prevent cross modulation, many receivers have an **Attenuator** that inserts a resistive pad (circuit) between the antenna and the receiver.
- This **weakens the strong signal** enough that it **no longer causes problems.**
- If the **interfering signal** is **out of the band altogether,** then an appropriate **filter** between the antenna and the receiver may also help.
- **FM receivers** are **immune to Cross Modulation** as they are **unaffected** by **amplitude variations** on received signals.

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Attenuator – Kenwood TS-950SDX

Intermodulation

- **“Intermod”** is sometimes incorrectly called Cross Modulation, but is a different phenomena.
- It is the result of **two or more signals** of different frequencies **being mixed together**, forming **additional signals at frequencies** that are **not, in general, at harmonic frequencies** (integer multiples) of either.
- The **mixing** usually takes place **inside the receiver,** but can even take place at rusty fence joints!
- **Very prevalent problem** on **2M and 70cm** FM when driving through **downtown!**

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Intermodulation (**IM**) or **intermodulation distortion** (**IMD**) is the amplitude modulation of signals containing two or more different frequencies, caused by nonlinearities or time variance in a system. The intermodulation between frequency components will form additional components at frequencies that are not just at harmonic frequencies (integer multiples) of either, like harmonic distortion, but also at the sum and difference frequencies of the original frequencies and at sums and differences of multiples of those frequencies.

Intermodulation is caused by non-linear behaviour of the signal processing (physical equipment or even algorithms) being used.

As explained in a previous section, intermodulation can only occur in non-linear systems. Non-linear systems are generally composed of *active* components, meaning that the components must be biased with an external power source which is not the input signal (i.e. the active components must be "turned on").

Passive intermodulation (PIM), however, occurs in passive devices (which may include cables, antennas etc.) that are subjected to two or more high power tones. The PIM product is the result of the two (or more) high power tones mixing at device nonlinearities such as junctions of dissimilar metals or metal-oxide junctions, such as loose corroded connectors. The higher the signal amplitudes, the more pronounced the effect of the nonlinearities, and the more prominent the intermodulation that occurs — even though upon initial inspection, the system would appear to be linear and unable to generate intermodulation.

It is also possible for a single broadband carrier to generate PIM if it passes through a PIM generating surface or defect. These distortions would show up as side lobes in a telecommunication signal and interfere with adjacent channels and impede reception.

PIM can be severe problem in modern communication systems. Paths that share both high power transmission and the receive signal are most susceptible to this kind of interference. Once PIM interference finds its way to receive path, it can not be filtered or separated.

Sources of PIM

Ferromagnetic materials are the most common materials to avoid and include ferrites, nickel, (including nickel plating) and steels (including some stainless steels). These materials exhibit hysteresis when exposed to reversing magnetic fields, resulting in PIM generation.

PIM can also be generated in components with manufacturing or workmanship defects, such as cold or cracked solder joints or poorly made mechanical contacts. If these defects are exposed to high RF currents, PIM can be generated. As a result, RF equipment manufacturers perform factory PIM tests on components, to eliminate PIM caused by these design and manufacturing defects.

PIM can also be inherent in the design of a high power RF component where RF current is forced to narrow channels or restricted.

In the field, PIM can be caused by components that were damaged in transit to the cell site, installation workmanship issues and by external PIM sources. Some of these include:

•Contaminated surfaces or contacts due to dirt, dust, moisture or oxidation.

•Loose mechanical junctions due to inadequate torque, poor alignment or poorly prepared contact surfaces.

•Loose mechanical junctions caused during transportation, shock or vibration.

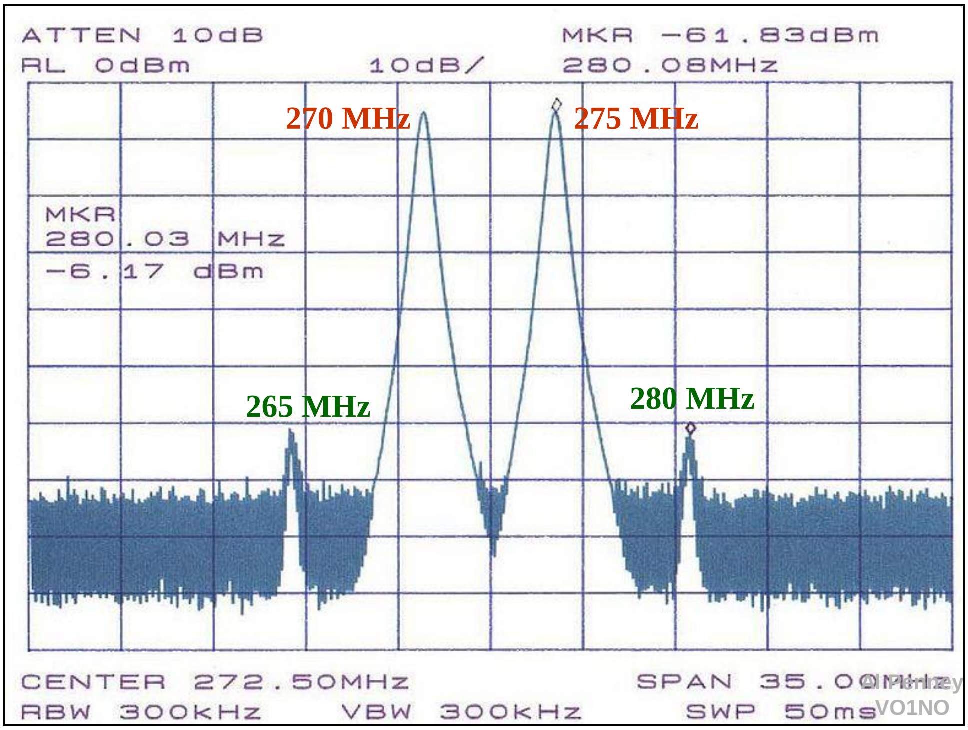
•Metal flakes or shavings inside RF connections.

•Inconsistent metal-to-metal contact between RF connector surfaces caused by any of the following:

•Trapped dielectric materials (adhesives, foam, etc.), cracks or distortions at the end of the outer conductor of coaxial cables, often caused by overtightening the back nut during installation, solid inner conductors distorted in the preparation process, hollow inner conductors excessively enlarged or made oval during the preparation process.

•PIM can also occur in connectors, or when conductors made of two galvanically unmatched metals come in contact with each other.

•Nearby metallic objects in the direct beam and side lobes of the transmit antenna including rusty bolts, roof flashing, vent pipes, guy wires, etc.



Frequency Spectrum of intermodulation distortion in a radio-frequency signal passed through the linear broad-band amplifier I built. The process of intermodulation is due to third-order harmonics of closely spaced signals. I tested this phenomenon with two signals: a Local Oscillator (LO) at 270 MHz, +0dBm, and an RF signal at 275 MHz. (Closer spacing would push the limitations of the RF spectrum analyzer resolution). Clear intermodulation products were seen at 265 and 280 MHz. As seen on the attached graph, the intermodulation power is 55.66 dB lower than the signal power. This graph nicely shows our desired signal peaks, as well as the side-band intermodulation. These closely spaced distortions would likely interfere with our signal, since it would be difficult to build a high-quality filter to cancel them out in our application. However, their overall power is more than 50 dB below the desired signal, which was sufficiently low for our purposes. We used this measurement to estimate the IP3 (third order intercept point) parameter.

Images

- **Signals** on a **different frequency** than the one tuned to, but which are **received anyway.**
- Occurs because of the **frequency conversions** that are conducted **within the receiver.**
- **Image rejection** is specified in **dB.**
- *The image rejection specifications for the Kenwood TS-870 are 80 dB or greater.*

Al Penney
VO1NO

Radio Receiver Image Rejection

Image rejection is a key selectivity parameter for superheterodyne radios - poor image rejection can lead to high levels of received interference.

Image rejection is an important aspect of the design of any radio using the superheterodyne principle.

As a result of the mixing or RF multiplication process, two signals can enter the receiver signal chain - the wanted signal and the image.

To ensure that the image rejection is sufficiently high, adequate RF selectivity must be in place.

Effect of poor image rejection

A receiver with a poor level of image rejection will suffer from much higher levels of interference than one with a high level of image rejection. In view of this, radio receivers to be used in high performance radio communications applications need to have a good image rejection performance.

When a radio receiver has a poor level image rejection signals which should not be received as they are on the image will pass through the IF stages along with the required ones. This means that unwanted signals are received along with the wanted ones and this means that the levels of interference will be higher than those with a high level of image rejection.

In addition to this the image signals will "tune" in the opposite direction to the wanted ones. When they interfere heterodyne notes will be heard and as the receiver is tuned, the pitch of the signals will change. In view of this it is very important to reduce the image response to acceptable levels, particularly for exacting radio communications applications.

Image rejection

It is clearly important to specify the level of image rejection. The specification compares the levels of signals of equal strength on the wanted and image frequencies, quoting the level of rejection of the unwanted signal.

The image rejection of a receiver will be specified as the ratio between the wanted and image signals expressed in decibels (dB)at a certain operating frequency. For example it may be 60 dB at 30 MHz. This means that if signals of the same strength were present on the wanted frequency and the image frequency, then the image signal would be 60 dB lower than the wanted one, i.e. it would be 1/1000 lower in terms of voltage or 1/1000000 lower in terms of power.

The frequency at which the measurement is made also has to be included. This is because the level of rejection will vary according to the frequency in use. Typically it falls with increasing frequency because the percentage frequency difference between the wanted and image signals is smaller.

Natural Noise

- **Natural noise**, called **QRN**, is also called **Static.**
- It comes from **objects in the galaxy** that radiate RF energy, and from **natural phenomena** such as **lightning.**
- The presence of natural noise sets the **Noise Floor** for the band in question at that particular time, and appears as a steady hiss.
- **Lightning** appears as a **burst of static**, and can be dealt with to some degree by noise limiters.

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In radio reception, **radio noise** is unwanted random electrical signals, fluctuating voltages, always present in a radio receiver in addition to the desired radio signal. Radio noise is a combination of natural electromagnetic atmospheric noise ("spherics", static) created by electrical processes in the atmosphere like lightning, manmade radio frequency interference (RFI) from other electrical devices picked up by the receiver's antenna, and thermal noise present in the receiver input circuits, caused by the random thermal motion of molecules. The level of noise determines the maximum sensitivity and reception range of a radio receiver; if no noise were picked up with radio signals, even weak transmissions could be received at virtually any distance by making a radio receiver that was sensitive enough. With noise present, if a radio source is so weak and far away that the radio signal in the receiver has a lower amplitude than the average noise, the noise will drown out the signal. The level of noise in a communications circuit is measured by the signal-to-noise ratio (S/N), the ratio of the average amplitude of the signal voltage to the average amplitude of the noise voltage. When this ratio is below one (0 dB) the noise is greater than the signal, requiring special processing to recover the information.

The limiting noise source in a receiver depends on the frequency range in use. At frequencies below about 40 MHz, particularly in the mediumwave and longwave bands and below, atmospheric noise and nearby radio frequency interference from electrical switches, motors, vehicle ignition circuits, computers, and other man-made sources tends to be above the thermal noise floor in the receiver's circuits. These noises are often referred to as static. Conversely, at very high frequency and ultra high frequency and above, these sources are often lower, and thermal noise is usually the limiting factor. In the most sensitive receivers at these frequencies, radio telescopes and satellite communication antennas, thermal noise is reduced by cooling the RF front end of the receiver to cryogenic temperatures. Cosmic background noise is experienced at frequencies above about 15 MHz when highly directional antennas are pointed toward the sun or to certain other regions of the sky such as the center of the Milky Way Galaxy.

Electromagnetic noise can interfere with electronic equipment in general, causing malfunction, and in recent years standards have been laid down for the levels of electromagnetic radiation that electronic equipment is permitted to radiate. These standards are aimed at ensuring what is referred to as electromagnetic compatibility (EMC).

Man-Made Noise

- Also called **QRM**, Man-Made Noise generally comes from **sparking equipment**, and also from **equipment that generates RF.**
- Some countries use **HF radars** that produce sharp pulses.
- The best solution to most man-made noise is to **eliminate it at the source**, as it is often close to home.
- Start at **home**, and then **search the neighborhood**, using a portable receiver to track down the noise.
- **Digital Signal Processing (DSP)** is of great assistance in reducing QRM.

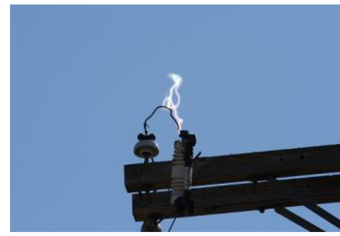
Al Penney
VO1NO

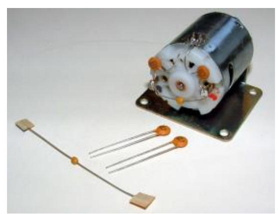
In electronics, **noise** is an unwanted disturbance in an electrical signal. Noise generated by electronic devices varies greatly as it is produced by several different effects.

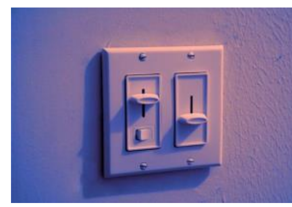
In communication systems, noise is an error or undesired random disturbance of a useful information signal. The noise is a summation of unwanted or disturbing energy from natural and sometimes man-made sources. Noise is, however, typically distinguished from interference, for example in the signal-to-noise ratio (SNR), signal-to-interference ratio (SIR) and signal-to-noise plus interference ratio (SNIR) measures. Noise is also typically distinguished from distortion, which is an unwanted systematic alteration of the signal waveform by the communication equipment, for example in signal-to-noise and distortion ratio (SINAD) and total harmonic distortion plus noise (THD+N) measures.

Man-Made Noise

- Caused by an electromagnetic noise source:
  - Electric motors
  - Power line hardware
  - Defective florescent lights
  - Bug zappers
  - Light dimmers
  - Computer systems
  - Thermostats, etc, etc. etc…..







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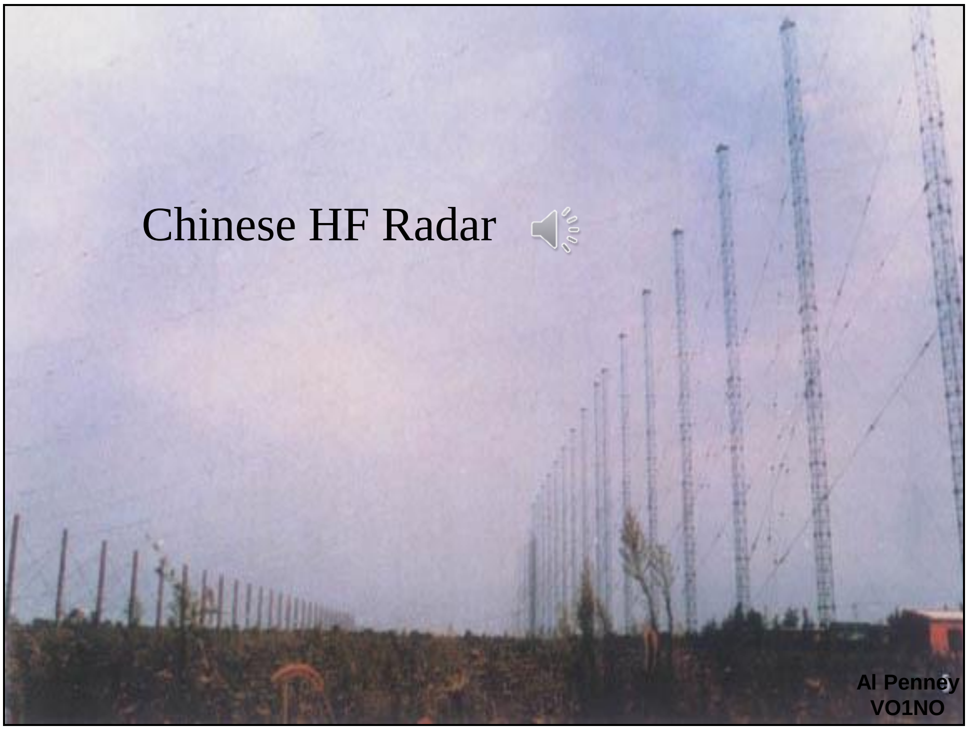
VO1NO

Al Penney
VO1NO

An electric fence can generate radio noise, even if it is in otherwise good working order. This noise is not normal however and it almost always can be corrected. In many cases, this noise is caused by a portion of the fence that may fail as the spark causing the noise weakens the wire. Whenever noise from an electric fence causes harmful interference to a licensed radio service, Part 15 of the FCC rules require the fence operator to correct the problem or cease operation of the fence. Fortunately, in most cases, a little maintenance is all that is required. Let's now take a closer look at the problem of unwanted radio noise from an electric fence, and ways to find and fix it. Virtually all radio interference originating from an electric fence is caused by a spark or arcing across some fence related hardware. The noise can interfere with radio and television reception and propagate for a considerable distance. In some cases, the noise can disrupt radio reception for a radius of over a mile from the fence. The interference is most noticeable on an AM radio and typically heard as a "tick-tick-tick" sound. This is a somewhat unique characteristic of electric fence noise. Fortunately, correcting most of these problems is typically a relatively easy and simple process. Many cases can also be corrected at no cost. For example, it is unlikely for the fence charger to be the culprit and require replacement. Troubleshooting electric fence noise typically involves locating the offending spark gap and correcting it. Bad splices in the fence wire and gate hooks are two of the more common problems associated with electric fence noise.



Over-the-horizon radar, or **OTH** (sometimes called *beyond the horizon*, or **BTH**), is a type of radar system with the ability to detect targets at very long ranges, typically hundreds to thousands of kilometres, beyond the radar horizon, which is the distance limit for ordinary radar. Several OTH radar systems were deployed starting in the 1950s and 1960s as part of early warning radar systems, but these have generally been replaced by airborne early warning systems. OTH radars have recently been making a comeback, as the need for accurate long-range tracking becomes less important with the ending of the Cold War, and less-expensive ground-based radars are once again being considered for roles such as maritime reconnaissance and drug enforcement.

Technology

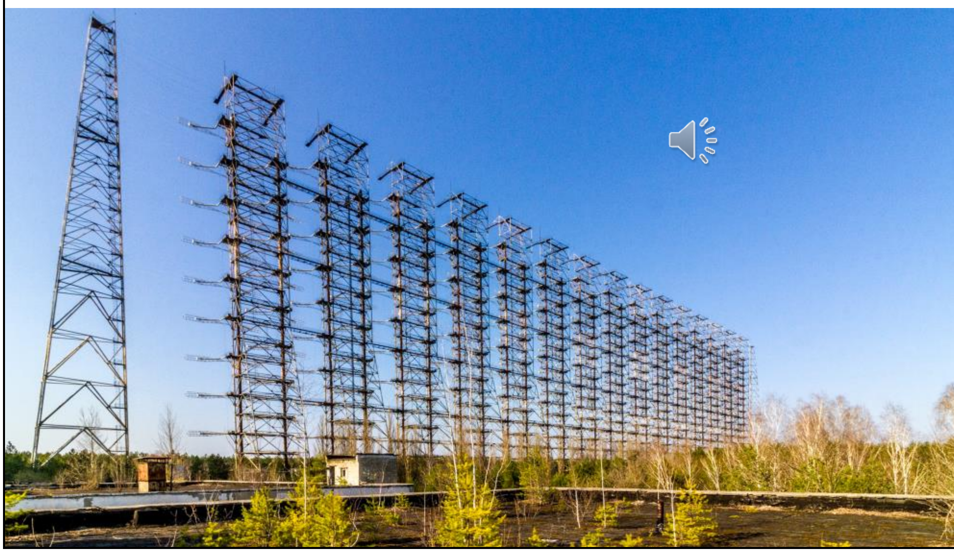
The frequency of radio waves used by most radars, in the form of microwaves, travel in straight lines. This generally limits the detection range of radar systems to objects on their horizon (generally referred to as "line of sight" since the aircraft must be at least theoretically visible to a person at the location and elevation of the radar transmitter) due to the curvature of the Earth. For example, a radar mounted on top of a 10 m (33 ft) mast has a range to the horizon of about 13 kilometres

(8.1 mi), taking into account atmospheric refraction effects. If the target is above the surface, this range will be increased accordingly, so a target 10 m (33 ft) high can be detected by the same radar at 26 km (16 mi). Siting the antenna on a high mountain can increase the range somewhat; but, in general, it is impractical to build radar systems with line-of-sight ranges beyond a few hundred kilometres.

OTH radars use various techniques to see beyond that limit. Two techniques are most commonly used; shortwave systems that refract their signals off the ionosphere for very long-range detection,[1] and surface wave systems, which use low frequency radio waves that, due to diffraction, follow the curvature of the Earth to reach beyond the horizon. These systems achieve detection ranges of the order of a hundred kilometres from small, conventional radar installations. They can scan a series of high frequencies using a chirp transmitter.

The most common type of OTH radar uses skywave or "skip" propagation, in which shortwave radio waves are refracted off an ionized layer in the atmosphere, the ionosphere. Given certain conditions in the atmosphere, radio signals transmitted at an angle into the sky will be refracted towards the ground by the ionosphere, allowing them to return to earth beyond the horizon. A small amount of this signal will be scattered off desired targets back towards the sky, refracted off the ionosphere again, and return to the receiving antenna by the same path. Only one range of frequencies regularly exhibits this behaviour: the high frequency (HF) or shortwave part of the spectrum from 3–30 MHz. The best frequency to use depends on the current conditions of the atmosphere and the sunspot cycle. For these reasons, systems using skywaves typically employ real-time monitoring of the reception of backscattered signals to continuously adjust the frequency of the transmitted signal.

Soviet “Woodpecker”

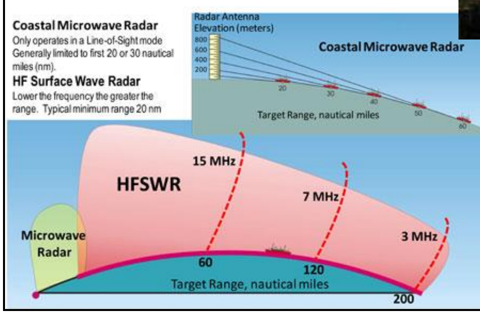


Duga (Russian: Дугá, lit. 'arc' or 'curve') was an over-the-horizon radar (OTH) system used in the Soviet Union as part of its early-warning radar network for missile defense. It operated from July 1976 to December 1989. Two operational *duga* radars were deployed, with one near Chernoble and Chernihiv in the Ukrainian SSR (present-day Ukraine), and the other in eastern Siberia (present-day Russia).

The *duga* system was extremely powerful, reaching over 10 MW, and broadcast in the shortwave radio bands. Given the nickname, the **Russian Woodpecker** by shortwave listeners for their emissions randomly appearing and sounding like sharp, repetitive tapping noises at a frequency of 10 Hz. The random frequency hops often disrupted legitimate broadcasts, amateur radio operations, oceanic commercial aviation communications, and utility transmissions, resulting in thousands of complaints by many countries worldwide. The signal became such a nuisance that some communications receivers began including "Woodpecker Blankers" in their circuit designs.

The unclaimed signal was a source of speculation, giving rise to theories such as Soviet brainwashing and weather modification experiments. However, because of its distinctive transmission pattern, many experts and amateur radio hobbyists realized it was an over-the-horizon radar system. NATO military intelligence had already given it the reporting name *STEEL WORK* or *STEEL YARD*, based on the massive size of the antenna, which spanned 700 metres (2,300 ft) in length and 150 metres (490 ft) in height.[3] This massive structure formed a phased array and was necessary in order to provide high gain at HF as well as facilitating beam-steering, though it's unconfirmed whether the latter was actually used in normal operation. While the amateur radio community was well aware of the system, the OTH theory was not publicly confirmed until after the dissolution of the Soviet Union.

Canadian HF Surface Wave Radar



Noise Blankers

Al Penney
VO1NO

NB 1 – short duration pulse noise such as engine ignitions.

NB 2 – longer suration pulses such as Russian "Woodpecker" Over The Horizon radar.

Receiver Limitations - HF

- Modern HF receivers are already sensitive enough to **hear the natural noise floor,**
- They cannot hear anything below that level.
- Therefore, it does **no good** to make HF receivers **any more sensitive** – they are already sensitive enough.

Al Penney
VO1NO

Radio Signal to Noise S/N Ratio, SNR

The signal to noise ratio, SNR, S/N, is used to define the sensitivity performance of radios particularly at HF. It uses a simple formula to calculate the SNR.

The signal to noise ratio, SNR or S/N ratio is one of the most straightforward methods of measuring radio receiver sensitivity.

It defines the difference in level between the signal and the noise for a given signal level. The lower the noise generated by the receiver, the better the signal to noise ratio.

As with any sensitivity measurement, the performance of the overall radio receiver is determined by the performance of the front end RF amplifier stage. Any noise introduced by the first RF amplifier will be added to the signal and amplified by subsequent amplifiers in the receiver. As the noise introduced by the first RF amplifier will be amplified the most, this RF amplifier becomes the most critical in terms of radio receiver sensitivity performance. Thus the first amplifier of any radio receiver should be a low noise amplifier.

Concept of signal to noise S/N ratio SNR

Although there are many ways of measuring the sensitivity performance of a radio receiver, the S/N ratio or SNR is one of the most straightforward and it is used in a variety of applications. However it has a number of limitations, and although it is widely used, other methods including noise figure are often used as well. Nevertheless the S/N ratio or SNR is an important specification, and is widely used as a measure of receiver sensitivity

The difference is normally shown as a ratio between the signal and the noise, S/N, and it is normally expressed in decibels. As the signal input level obviously has an effect on this ratio, the input signal level must be given. This is usually expressed in microvolts. Typically a certain input level required to give a 10 dB signal to noise ratio is specified.

Signal to noise ratio formula

The signal to noise ratio is the ratio between the wanted signal and the unwanted background noise.

The power levels may be expressed in levels such as dBm (decibels relative to a milliwatt, or to some other standard by which the levels can be compared.

Effect of bandwidth on SNR

A number of other factors apart from the basic performance of the set can affect the signal to noise ratio, SNR specification. The first is the actual bandwidth of the receiver. As the noise spreads out over all frequencies it is found that the wider the bandwidth of the receiver, the greater the level of the noise. Accordingly the receiver bandwidth needs to be stated.

Additionally it is found that when using AM the level of modulation has an effect. The greater the level of modulation, the higher the audio output from the receiver. When measuring the noise performance the audio output from the receiver is measured and accordingly the modulation level of the AM has an effect. Usually a modulation level of 30% is chosen for this measurement.

Signal to noise ratio specifications

In view of the fact that the actual SNR experienced at any time is governed by a number of factors, the conditions under which the signal to noise ratio is experienced need to be stated.

In this way the S/N ratio is stated to include all these conditions. To enable the S/N ratio for different receivers to be compared, generally the performance is stated for set parameters. Typically the input voltage for a signal to noise ratio of 10dB is stated. Other factors like the bandwidth also need to be included along with the type of transmission and for AM the modulation depth (typically 30% is used).

Typically one might expect to see a figure in the region of 0.5 microvolts for a 10 dB S/N in a 3 kHz bandwidth for SSB or Morse. For AM a figure of 1.5 microvolts for a 10 dB S/N in a 6 kHz bandwidth at 30% modulation might be seen.

Points to note when measuring signal to noise ratio

SNR, signal to noise ratio is a very convenient method of quantifying the sensitivity of a receiver, but there are some points to note when interpreting and measuring signal to noise ratio.

To investigate these it is necessary to look at the way the measurements of signal to noise ratio, SNR are made. A calibrated RF signal generator is used as a signal source for the receiver. It must have an accurate method of setting the output level down to very low signal levels. Then at the output of the receiver a true RMS AC voltmeter is used to measure the output level.

•***S/N and (S+N)/N*** When measuring signal to noise ratio there are two basic elements to the measurement. One is the noise level and the other is the signal. As a result of the way measurements are made, often the signal measurement also includes noise as well, i.e. it is a signal plus noise measurement. This is not normally too much of a problem because the signal level is assumed to be much larger than the noise. In view of this some receiver manufacturers will specify a slightly different ratio: namely signal plus noise to noise (S+N/N). In practice the difference is not large, but the S+N/N ratio is more correct.

•***PD and EMF*** Occasionally the signal generator level in the specification will mention that it is either PD or EMF. This is actually very important because there is a factor of 2:1 between the two levels. For example 1 microvolt EMF. and 0.5 microvolt PD are the same. The EMF (electro-motive force) is the open circuit voltage, whereas the PD (potential difference) is measured when the generator is loaded. As a result of the way in which the generator level circuitry works it assumes that a correct (50 Ohm) load has been applied. If the load is not this value then there will be an error. Despite this most equipment will assume values in PD unless otherwise stated, but it is always worth checking if possible.

While there are many parameters that are used for specifying the sensitivity performance of radio receivers, the signal to noise ratio is one of the most basic and easy to comprehend. It is therefore widely used for many radio receivers used in applications ranging from broadcast reception to fixed or mobile radio communications.

Receiver Limitations - VHF

- Noise Floor is much **lower** on VHF/UHF than it is on HF.
- Any **component that generates gain** also **generates internal noise** however– it is unavoidable!
- So, because the noise floor on VHF and UHF is much lower than HF, the **quality of the active device** (transistor) in the **front end of the receiver** determines the **sensitivity of the system.**

Al Penney
VO1NO

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While there are many parameters that are used for specifying the sensitivity performance of radio receivers, the signal to noise ratio is one of the most basic and easy to comprehend. It is therefore widely used for many radio receivers used in applications ranging from broadcast reception to fixed or mobile radio communications.

Can we Increase Selectivity?

- While it is **possible to add filters** (either discrete or virtual using DSP techniques) to increase selectivity, remember that **every mode** has a **defined bandwidth.**
- If the **selectivity is too wide, excess noise** will be received. If **too narrow** however, the **complete signal will not be received.**
- **CW filters of 250 Hz** are common, but going too narrow will result in **"ringing".**
- **Human voice** requires a range of **300 – 2700 Hz.** Using too narrow a filter will make the voice unintelligible.

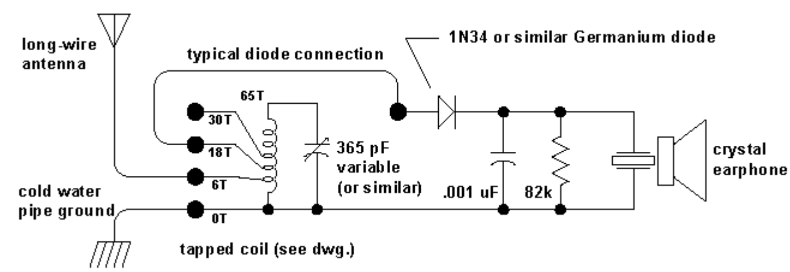
Al Penney
VO1NO

Frequency Calibration

- **YOU** are **responsible** for ensuring that you **operate within the Amateur bands!**
- **Radio dials** can be **analog** or **digital.**
- **DO NOT assume** that they are always **correct!**
- Older radios use **Crystal Calibrators** to enable you to check the accuracy of the dial.
- Newer, synthesized, radios use a **master time base** in the microprocessor to derive frequency information. If that time base is off, so will the calibration.
- Use **WWV / WWVH** or **CHU** to calibrate your radio.

Al Penney
VO1NO

Simple Crystal Radio



Crystal radio with typical connections for a long wire antenna and good ground connections. The diode is connected for weak signals and moderate selectivity.

Al Penney
VO1NO

How Does a Crystal Radio Work

Although the crystal radio is rarely used these days, it does serve as an easy construction project and to illustrate how a radio works.

A crystal radio can be thought of as a radio receiver reduced to its essentials. It consists of at least these components:

•An antenna in which electric currents are induced by radio waves.

•A resonant circuit (tuned circuit) which selects the frequency of the desired radio station from all the radio signals received by the antenna. The tuned circuit consists of a coil of wire (called an inductor) and a capacitor connected together. The circuit has a resonant frequency, and allows radio waves at that frequency to pass through to the detector while largely blocking waves at other frequencies. One or both of the coil or capacitor is adjustable, allowing the circuit to be tuned to different frequencies. In some circuits a capacitor is not used and the antenna serves this function, as an antenna shorter than its resonant length is capacitive.

•A semiconductor crystal detector that demodulates the radio signal to extract the audio signal (modulation). The crystal detector functions as a square law detector, demodulating the radio frequency alternating current to its audio frequency modulation. The detector's audio frequency output is converted to sound by the earphone. Early sets used a "cat whisker detector" consisting of a small piece of crystalline mineral such as galena with a fine wire touching its surface. The crystal detector was the component that gave crystal radios their name. Modern sets use modern semiconductor diodes, although some hobbyists still experiment with crystal or other detectors.

•An earphone to convert the audio signal to sound waves so they can be heard. The low power produced by a crystal receiver is insufficient to power a loudspeaker, hence earphones are used.

Pictorial diagram from 1922 showing the circuit of a crystal radio. This common circuit did not use a tuning capacitor, but used the capacitance of the antenna to form the tuned circuit with the coil. The detector was a cat whisker detector, consisting of a piece of galena with a thin wire in contact with it on a part of the crystal, making a diode contact

As a crystal radio has no power supply, the sound power produced by the earphone comes solely from the transmitter of the radio station being received, via the radio waves captured by the antenna. The power available to a receiving antenna decreases with the square of its distance from the radio transmitter. Even for a powerful commercial broadcasting station, if it is more than a few miles from the receiver the power received by the antenna is very small, typically measured in microwatts or nanowatts. In modern crystal sets, signals as weak as 50 picowatts at the antenna can be heard. Crystal radios can receive such weak signals without using amplification only due to the great sensitivity of human hearing, which can detect sounds with an intensity of only 10^{-16} W/cm^2. Therefore, crystal receivers have to be designed to convert the energy from the radio waves into sound waves as efficiently as possible. Even so, they are usually only able to receive stations within distances of about 25 miles for AM broadcast stations, although the radiotelegraphy signals used during the wireless telegraphy era could be received at hundreds of miles, and crystal receivers were even used for transoceanic communication during that period.

Tuned Circuit:

The tuned circuit, consisting of a coil and a capacitor connected together, acts as a resonator, similar to a tuning fork. Electric charge, induced in the antenna by the radio waves, flows rapidly back and forth between the plates of the capacitor through the coil. The circuit has a high impedance at the desired radio signal's frequency, but a low impedance at all other frequencies. Hence, signals at undesired frequencies pass through the tuned circuit to ground, while the desired frequency is instead passed on to the detector (diode) and stimulates the earpiece and is heard. The frequency of the station received is the resonant frequency *f* of the tuned circuit, determined by the capacitance *C* of the capacitor and the inductance *L* of the coil.

The circuit can be adjusted to different frequencies by varying the inductance (L), the capacitance (C), or both, "tuning" the circuit to the frequencies of different radio stations. In the lowest-cost sets, the inductor was made variable via a spring contact pressing against the windings that could slide along the coil, thereby introducing a larger or smaller number of turns of the coil into the circuit, varying the inductance. Alternatively, a variable capacitor is used to tune the circuit. Some modern crystal sets use a ferrite core tuning coil, in which a ferrite magnetic core is moved into and out of the coil, thereby varying the inductance by changing the magnetic permeability (this eliminated the less reliable mechanical contact).

The antenna is an integral part of the tuned circuit and its reactance contributes to determining the circuit's resonant frequency. Antennas usually act as a capacitance, as antennas shorter than a quarter-wavelength have capacitive reactance. Many early crystal sets did not have a tuning capacitor, and relied instead on the capacitance inherent in the wire antenna (in addition to significant parasitic capacitance in the coil) to form the tuned circuit with the coil.

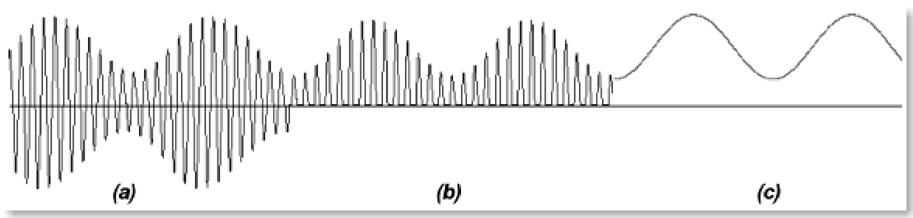
The earliest crystal receivers did not have a tuned circuit at all, and just consisted of a crystal detector connected between the antenna and ground, with an earphone across it. Since this circuit lacked any frequency-selective elements besides the broad resonance of the antenna, it had little ability to reject unwanted stations, so all stations within a wide band of frequencies were heard in the earphone (in practice the most powerful usually drowns out the others). It was used in the earliest days of radio, when only one or two stations were within a crystal set's limited range.

Impedance Matching:

An important principle used in crystal radio design to transfer maximum power to the earphone is impedance matching. The maximum power is transferred from one part of a circuit to another when the impedance of one circuit is the complex conjugate of that of the other; this implies that the two circuits should have equal resistance. However, in crystal sets, the impedance of the antenna-ground system (around 10-200 ohms) is usually lower than the impedance of the receiver's tuned circuit (thousands of ohms at resonance), and also varies depending on the quality of the ground attachment, length of the antenna, and the frequency to which the receiver is tuned.

Therefore, in improved receiver circuits, in order to match the antenna impedance to the receiver's impedance, the antenna was connected across only a portion of the tuning coil's turns. This made the tuning coil act as an impedance matching transformer (in an autotransformer connection) in addition to providing the tuning function. The antenna's low resistance was increased (transformed) by a factor equal to the square of the turns ratio (the ratio of the number of turns the antenna was connected to, to the total number of turns of the coil), to match the resistance across the tuned circuit. In the "two-slider" circuit, popular during the wireless era, both the antenna and the detector circuit were attached to the coil with sliding contacts, allowing (interactive) adjustment of both the resonant frequency and the turns ratio. Alternatively a multiposition switch was used to select taps on the coil. These controls were adjusted until the station sounded loudest in the earphone.

AM Demodulation



Signal **Diode Action** **Low Pass Filter**

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The function of the detector is to extract the audio signal from the IF signal (a). This is carried out by a diode, which strips off the bottom half of the IF signal (b). The result is then passed through a low pass filter to remove the IF, leaving the audio intact (c).

“Baby Grand” Crystal Receiver

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Certainly one of the smallest radios built in the twenties, the Beaver Laboratories' Baby Grand is shown next to a quarter for size reference. This tiny crystal set dates from about 1922, or so. It is not certain if the Baby Grand was originally considered a "novelty" or a "real" crystal receiver.

Crystal radio / cat's whisker sets

There was an enormous variety of crystals sets or cat's whisker radios that were manufactured for the domestic market in the 1920s once radio broadcasting had become established.many of these crystal sets were sold as complete radios, but there was also a booming market in kits and the components. Many people made their own radios at home.

End of the crystal radio

As the number of broadcast stations began to increase, so did the requirement for greater levels of performance. Both improved selectivity and sensitivity were required.

As indirectly heated valves or vacuum tubes became available, this considerably reduced the running costs of these radios as large batteries were no longer required - they could be run from mains electricity.

Also the superheterodyne radio started to become popular as it offered significantly better levels of selectivity and sensitivity. As a result, the crystal set or cat's whisker radio started to decline in use from the middle of the 1920s and early 1930s. By the end of the 1930s few crystal sets were in use.

Tuned Radio Frequency Receiver

- A **Tuned Radio Frequency (TRF)** receiver has **several RF amplifier stages** followed by detector and audio amplifier stages.
- **Each RF amplifier** stage must be **tuned individually.**
- This is a very **cumbersome process!**
- For technical reasons, it is also **difficult** to achieve **sufficient selectivity** as the **frequency increases.**

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Tuned Radio Frequency Receiver: TRF

The TRF, tuned radio frequency radio receiver was widely used in the early days of radio, but is hardly used today.

The tuned radio frequency receiver is one in which the tuning or selectivity is provided at the radio frequency stages.

The tuned radio frequency receiver was used in the early days of wire-less technology but it is rarely used today as other techniques offering much better performance are available.

Earliest tuned radio frequency receivers

It could be argued that the very earliest tuned radio frequency receivers were crystal sets. These sets used a single tuned network, sometimes consisting of a number of coils. The output from this was fed directly into a crystal or "Cat’s Whisker” " detector and then into headphones

Although crystal radios are seldom used these days because their levels of performance can easily be exceeded by other forms of radio, they are ideal for showing some of the basic principles of radio.

Tuned radio frequency receiver basics

The definition of the tuned radio frequency, TRF receiver is a receiver where the tuning, i.e. selectivity is provided by the radio frequency stages.

In essence the simplest tuned radio frequency receiver is a simple crystal set. Tuning is provided by a tuned coil / capacitor combination, and then the signal is presented to a simple crystal or diode detector where the amplitude modulated signal, in this case, is recovered. This is then passed straight to the headphones.

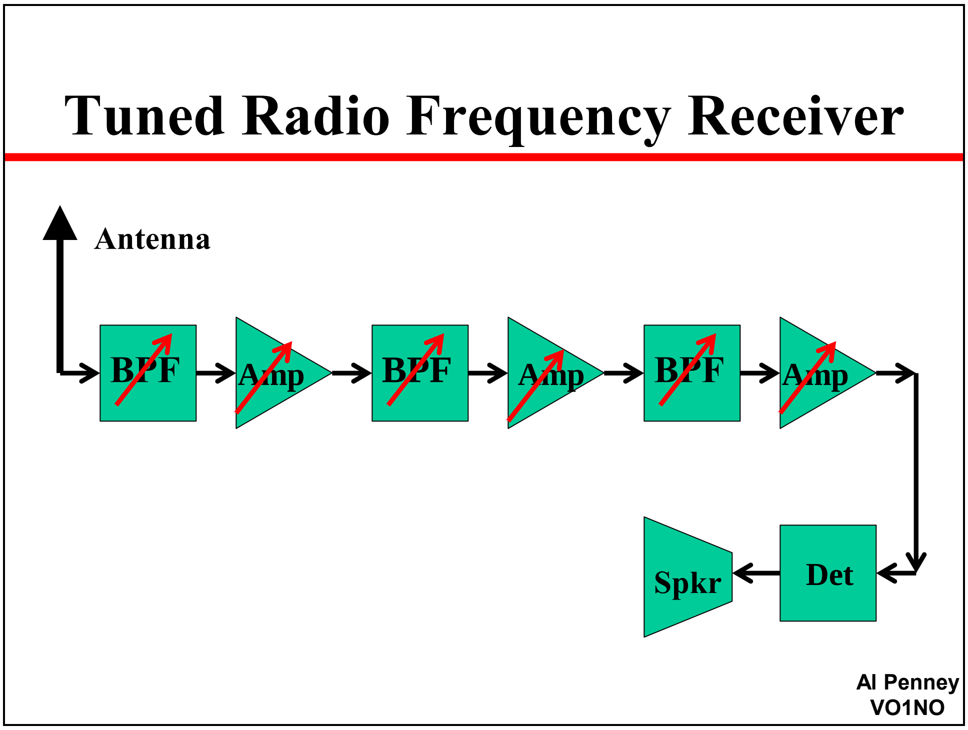
As vacuum tube / thermionic vale technology developed, these devices were added to provide more gain.

Typically a TRF receiver would consist of three main sections:

•***Tuned radio frequency stages:*** This consisted of one of more amplifying and tuning stages. Early sets often had several stages, each proving some gain and selectivity.

•***Signal detector:*** The detector enabled the audio from the amplitude modulation signal to be extracted. It used a form of detection called envelope detection and used a diode to rectify the signal.

•***Audio amplifier:*** Audio stages to provide audio amplification were normally, but not always included.



Very cumbersome to tune!

American Beauty TRF Receiver

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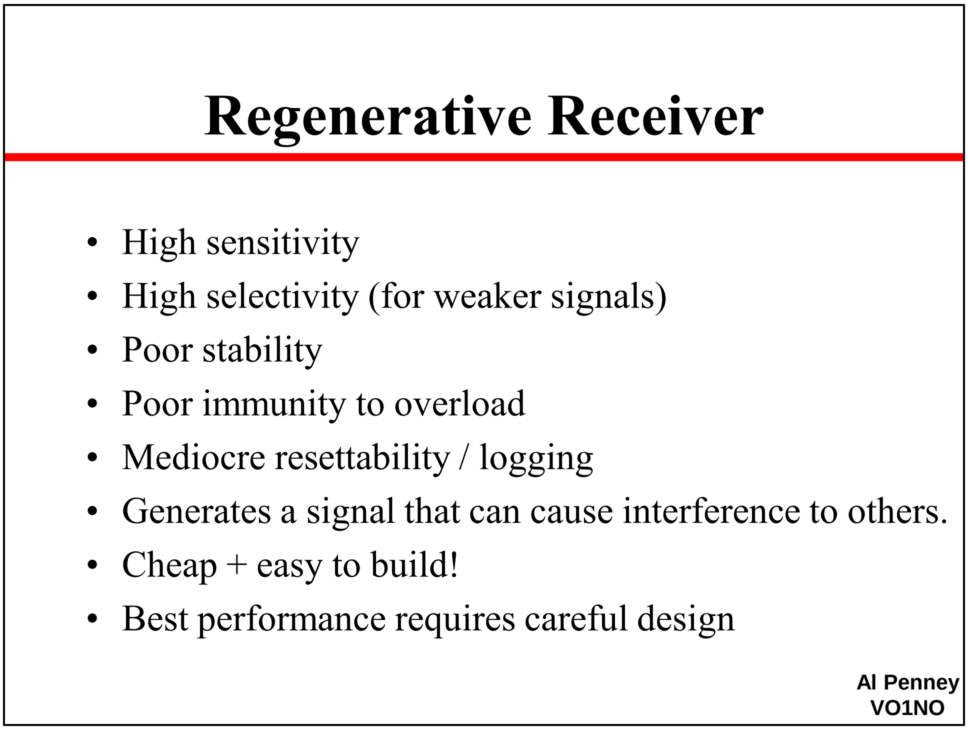
Harry Schwartzberg was president of this small company located in Kansas City, Missouri. The American Beauty is typical of the 1925 to 1926 manufacturing style of TRF receivers built by companies that weren't members of the Independent Radio Manufacturers and therefore couldn't legally build neutrodynes. The circuit uses two standard TRF amplifiers, a Detector, two stages of RC coupled Audio Amplification and one stage of transformer coupled Audio Amplification - six tubes in all. The silk-screened panels became popular in the same time period and in many other models these panels became very elaborate works of art. The American Beauty artwork features a rose in each corner to honor its namesake.



Regenerative Receiver: Regen Radio

The regenerative receiver or regen radio provides a significant increase in gain and selectivity over the standard tuned radio frequency receiver.

The regenerative receiver, regen radio was a popular form of radio receiver in the 1920s and 1930s.

As a result this form of radio deserves its place in this summary of the different types of radio available.

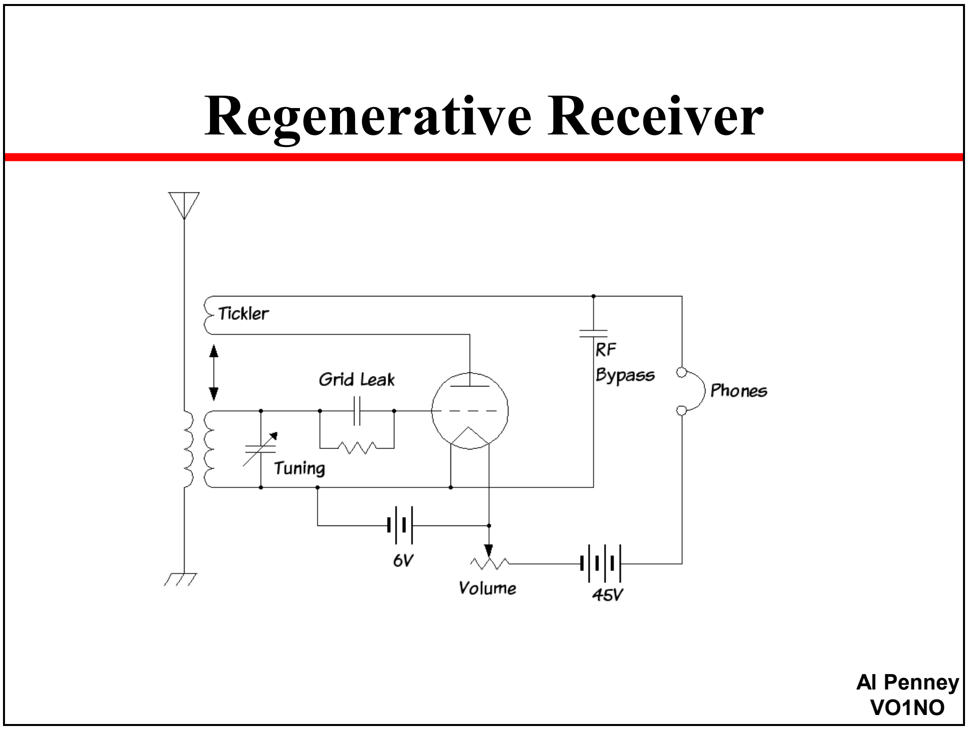
Regenerative receiver history

The regen radio was one of the many inventions in radio technology that was made by Edwin Armstrong. He invented and patented the regenerative circuit while he was at college, in 1914.

Although the invention of the regenerative receiver is generally credited to Armstrong, others contested this. Lee de Forest filed a patent in 1916 and he took out a lawsuit that lasted over 12 years. This bounced back in the courts, finally ending in the US Supreme Court at which point Armstrong lost.

The regenerative receiver was widely used in the 1920s and 30s because it was able to provide high levels of gain and selectivity with a small number of valves or tubes. As costs of these devices were high, and they often ran on batteries, minimising the number of stages was key. As a result the regenerative receiver was a popular radio technology.

The regenerative receiver was particularly popular with radio hams. As they had to build all their equipment in the 1920s and 30s, the simpler construction of the regen radio meant that they were more achievable than the superhet that was really only just beginning to be used.



The **regenerative circuit** (or **self-regenerative circuit**) or "autodyne" allows an electronic signal to be amplified many times by the same vacuum tube or other active component such as a field effect transistor. It consists of an amplifying vacuum tube or transistor with its output connected to its input through a feedback loop, providing positive feedback. This circuit was widely used in radio receivers, called **regenerative receivers**, between 1920 and World War II. The regenerative receiver was invented and patented in 1914 by American electrical engineer Edwin Armstrong when he was an undergraduate at Columbia University. Regenerative receiver circuits are still used in low-cost electronic equipment such as garage door openers. A receiver circuit that used regeneration in a more complicated way to achieve even higher amplification, the **superregenerative receiver**, was invented by Armstrong in 1922, but was not as widely used.

Regenerative receiver basics

The regen receiver operates by introducing positive feedback into the receiver circuit. This positive feedback dramatically increases both the gain and selectivity.

The RF amplifier has a feedback loop that feeds a proportion of the output back to the input so that the signals around the loop are in phase. In this way, any signal that is in the amplifier will be repeatedly amplified, and this can increase the levels of gain by factors of 1000 or more.In theory feeding back the output to the input should provide infinite gain, but in reality factors including the saturation of the amplifier, and phase delays mean that this cannot be achieved in reality.

The other factor of importance is the selectivity. As there is a tuned circuit in the feedback amplifier, the gain increases around the point of resonance rather than away from it. This means that the Q of the coil is effectively multiplied, providing far higher degrees of selectivity.

The improvement in selectivity can also be seen by understanding that the regeneration introduces a negative resistance element into the circuit. This means that the overall resistance within the circuit is reduced. As the Q of the resonant circuit is equal to the reactance divided by the resistance, the Q of the circuit is greatly increased, producing the visible improvement in selectivity.

In this way the regen radio overcomes many of the disadvantages of the basic TRF, and has a performance level that is not far short of the superheterodyne receiver in many aspects.

Operation of the regen receiver

The regenerative radio receiver requires a little more skill to operate it than the more normal superheterodyne receivers.

The regen has what is termed a regeneration or reaction control. This determines the degree of feedback introduced around the circuit.

The adjustment of the level of regeneration or reaction enabling the level of feedback to be controlled. The way that this is controlled along with the tuning enables the receiver to be used to receive different modes of transmission.

•***AM reception:*** For the reception of AM using a regenerative receiver, the feedback regeneration or reaction control is adjusted to provide the maximum gain without allowing the circuit to oscillate. Also the point just before oscillation may result in a little added distortion, so it may be necessary to back the control off very marginally for optimum reception. At this point the level of feedback not only provides additional gain, but also additional selectivity that is sufficient for most situations. It may be that under some circumstances exceedingly strong signals are audible across a wide section of the band.

•***Morse / CW reception:*** When using the regenerative receiver for the reception of Morse or CW signals, the level of feedback is adjusted so that the circuit oscillates. By tuning the receiver a few hundred Hertz away from the signal, the oscillation in the receiver mixes with the incoming signal to provide a beat note, thereby providing an intermittent audio tone as the Morse signal is turned on and off tor present the Morse characters.

•***SSB reception:*** For single sideband, SSB reception, the regenerative receiver again needs to be set into oscillation. This oscillation acts as a beat frequency oscillator / carrier insertion oscillator and reintroduces the suppressed carrier for demodulation. In this way the regenerative receiver is able to resolve SSB signals. Typically the receiver tuning will need to be adjusted to the correct side of the signal so that the signal sounds intelligible.

A word of warning

When operating a regenerative receive close to oscillation, or in oscillation can cause interference to be radiated, especially if no RF pre-amplifier is present to isolate the regenerative detector from the antenna.

Regenerative receiver advantages / disadvantages

The regenerative radio receiver has many advantages that mean it was used in many applications for many years. However it also has some disadvantages that need to be remembered when considering it use.

ADVANTAGES / DISADVANTAGES OF REGENERATIVE RECEIVER

ADVANTAGES

•Provides high performance for few components

•High levels of gain resulting from regeneration

•High Q from use of regeneration

DISADVANTAGES

•Requires more operator skill than other types of receiver

•Can radiate when detector is in oscillator mode, or close to it.

•Can only receive AM, Morse, & SSB – modes like FM are not viable.

Despite its disadvantages, the regenerative receivers till has some benefits, although as other types of receiver offer higher levels of performance and are easier to use. As a result the regenerative receiver is not in widespread use these days.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The **regenerative circuit** (or **self-regenerative circuit**) or "autodyne" allows an electronic signal to be amplified many times by the same vacuum tube or other active component such as a field effect transistor. It consists of an amplifying vacuum tube or transistor with its output connected to its input through a feedback loop, providing positive feedback. This circuit was widely used in radio receivers, called **regenerative receivers**, between 1920 and World War II. The regenerative receiver was invented and patented in 1914 by American electrical engineer Edwin Armstrong when he was an undergraduate at Columbia University. Regenerative receiver circuits are still used in low-cost electronic equipment such as garage door openers. A receiver circuit that used regeneration in a more complicated way to achieve even higher amplification, the **superregenerative receiver**, was invented by Armstrong in 1922, but was not as widely used.

Super Regenerative Receiver: Super Regen Radio

The super regenerative radio receiver was able to provide significant improvements in performance over the tuned radio frequency receiver and the regenerative radio.

The super regenerative radio receiver was used for many years, particularly at VHF and UHF where it was able to offer simplicity of the circuitry and relatively high levels of performance.

The super regenerative radio is not used much these days, although there are a few niche applications . However in the past it was far more widely used, although care had to be taken to ensure it did not radiate interference.

Super regenerative receiver basics

The super regenerative receiver is based on the simpler regenerative radio. It uses a second lower frequency oscillation within the regeneration loop that interrupts or quenches the main RF oscillation.

The second or quench oscillation typically operates at frequencies above the audio range, e.g. 25 kHz to 100 kHz.

In operation the circuit has sufficient positive feedback to bring it to oscillation. Even a small amount of noise will bring the circuit into oscillation.

How does super regeneration work

An explanation of the operation of the super regenerative receiver starts by looking at a regenerative radio.

The output of the RF amplifier in the receiver has positive feedback applied, i.e. some of the output is fed back to the input in-phase. Any signal present at the time will be amplified repeatedly and this can produce signal amplification levels of a thousand times or more.

Although the gain of the amplifier is fixed, it is possible to achieve gain levels approaching infinity by using positive feedback techniques like this with the circuit on the point of oscillation. In reality, infinite gains are not possible because of issues like phase shifts within the circuit and limiting of the voltage rails.

The regeneration introduces a negative resistance into the circuit and this means that the overall positive resistance is reduced. This means that in addition to the additional gain increases, the selectivity or Q of the circuit is improved.

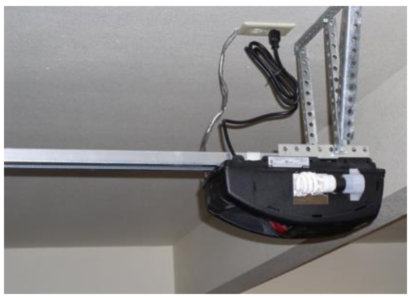
When the circuit is operated with feedback such that the oscillator runs sufficiently into the region of oscillation, a secondary lower frequency oscillation occurs.

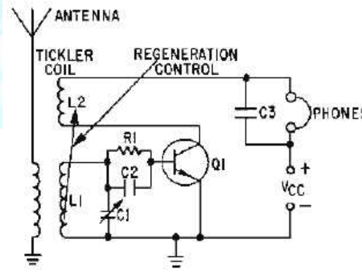
The secondary oscillation breaks up the much higher frequency RF oscillation – periodically breaking up or quenching the main oscillation.

The action of the quenching oscillation, RF signals are able to build up to very high levels. Gain levels can often approach a million or so in a single stage.

The concept was originally discovered by Edwin Armstrong who coined the term super regeneration.

The term has remained and this type of radio is called the super regenerative receiver to this day.





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The Superheterodyne Receiver

- In 1918 **Major Edwin Armstrong** developed the **Superheterodyne receiver** to correct the problems of the TRF radio.
- It **mixes an incoming signal** with a **locally generated RF signal** to produce an **Intermediate Frequency (IF).**
- That IF is then **amplified, detected** and turned into **sound.**
- The Superhet is still the **most popular form of receiver,** accounting for 95% or more!

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Note: In the 8th Ed./First Printing 9th Ed. the LO is called the High Frequency Oscillator

Superhet / Superheterodyne Radio Receiver Basics

The superheterodyne radio was one of the most successful forms of radio being used almost exclusively as the RF circuit design topology of choice until recent years.

One of the most common forms of radio receiver is the superhet or superheterodyne radio receiver. Virtually all broadcast radio receivers, as well as televisions, short wave receivers and commercial radios have used the superheterodyne principle as the basis of their operation.

Invented in 1918 to overcome the issues of lack of selectivity, superhet designs have been at the centre of radio communications technology for nearly 100 years, and only recently are other topologies taking over.

Despite this the superheterodyne radio is still used in many applications and the RF design techniques used are still applicable in many radio communications applications.

The superheterodyne radio receiver, although the RF circuit design is more complicated than some other forms of radio set, offers many advantages in terms of performance, particularly its selectivity. The superhet radio converts signals to a fixed frequency intermediate frequency, and this enables it to remove unwanted signals more effectively than other forms like the TRF (Tuned Radio Frequency) sets or even regenerative radios that were used particularly in the early days of radio.

Superhet radio applications & usage

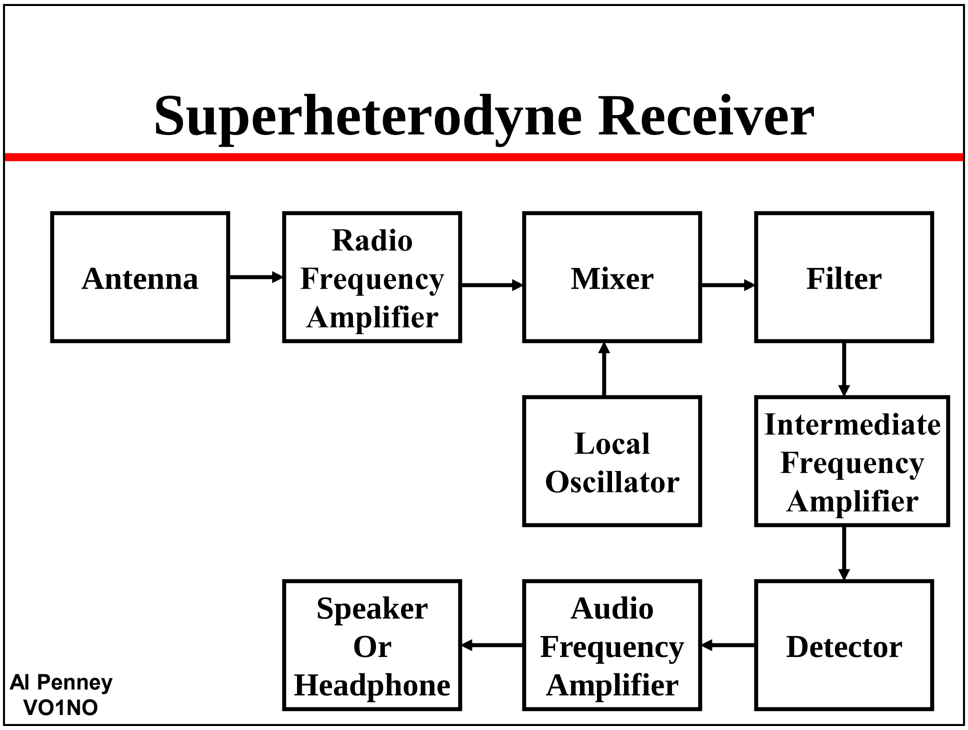
The superhet radio used to be the undoubted radio receiver technique of choice. It was almost universally used. However, nowadays with software defined radios taking over the superhet is used less widely.

The superhet was used in every form of radio from domestic broadcast radios to walkie talkies, television sets, through to hi-fi tuners and professional communications radios, satellite base stations and much more.

Superhet radio history

The story of the development and RF circuit design technology of the superheterodyne radio receiver can be traced back to the earliest days of radio. Reginald Fessenden noticed that signals on adjacent wavelengths created a beat note together. Later in during the First World War the benefits of using radio technology started to be realised and the need to radios that were selective and provided sufficient gain and sensitivity were needed.

Several engineers tackled the problem: Lucien Levy in France, Walter Schottky in Germany and finally the man to whom the superheterodyne technique is credited, Edwin Armstrong who built the first working superhet radio.



The signal that is picked up by the antenna passes into the receiver through an RF amplifier and enters a mixer. Another locally generated signal, produced by the HF Oscillator here but often called the Local Oscillator, is fed into the other port on the mixer and the two signals are mixed. As a result new signal are generated at the sum and difference frequencies.

The output from the mixer is passed into what is termed the Intermediate Frequency or IF stages where the signal is filtered and amplified. Any of the converted signals that fall within the passband of the IF filter will be able to pass through the filter and they will also be amplified by the amplifier stages. Any signals that fall outside the passband of the filter will be rejected.

The IF is then rectified by the detector stage and the resulting audio signal is amplified and turned into sound with the speaker or headphones.

Tuning the receiver is simply accomplished by changing the frequency of the local oscillator. This changes the incoming signal frequency for which signals are be converted down and able to pass through the filter.

The basic principles and theory behind the superheterodyne radio are relatively straightforward and can be understood quite easily.

The key technique that is employed in the development of the superheterodyne receiver theory is that of mixing. This is not the analogue mixing used in audio additive mixers, but non-linear mixing or frequency multiplication that enables frequencies to be changed or translated.

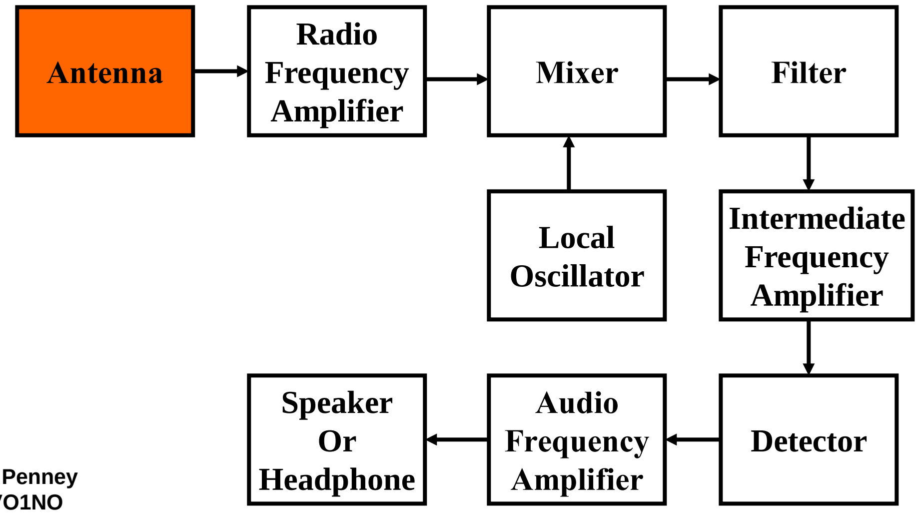
With many radios used for broadcast reception as well as two way radio communication using this principle, it helps to have a basic understanding so these radios can be used to their best, or the RF circuit design can be accomplished to give the optimum performance.

Basic superheterodyne receiver theory

The superheterodyne receiver operates by taking the signal on the incoming frequency, mixing it with a variable frequency locally generated signal to convert it down to a frequency where it can pass through a high performance fixed frequency filter before being demodulated to extract the required modulation or signal.

It is obviously necessary to look ay this in more detail to understand the principle behind what goes on, but the main process in the superheterodyne radio is that of mixing.

Superheterodyne Receiver



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Antenna

- While technically the **antenna** picks up a **wide range of frequencies,** in practice some antennas are more **narrow-banded.**
- **Resonant antennas** eg: a half-wave dipole, are better able to pick up signals around their **design frequency.**
- **Non-resonant antennas** eg: Rhombics, can be used over a much **broader frequency range.**

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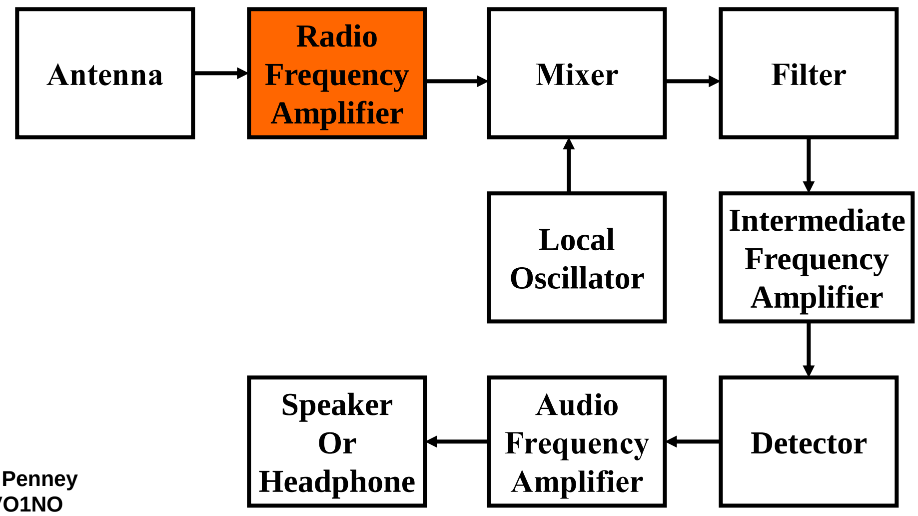
Superheterodyne Receiver



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Radio Frequency Amplifier

- The **RF amplifier** takes the **weak signals** from the antenna and **amplifies them.**
- This is usually a **fairly broadband amp.** In better radios it consists of a **number of separate modules** that cover individual bands. These modules would be selected automatically as the radio is tuned.
- **Older radios** had a **manually tuned continuous preamplifier.**
- This stage does have **tuned circuits** to help **reject strong out-of-band signals** that could cause **Cross Modulation.**

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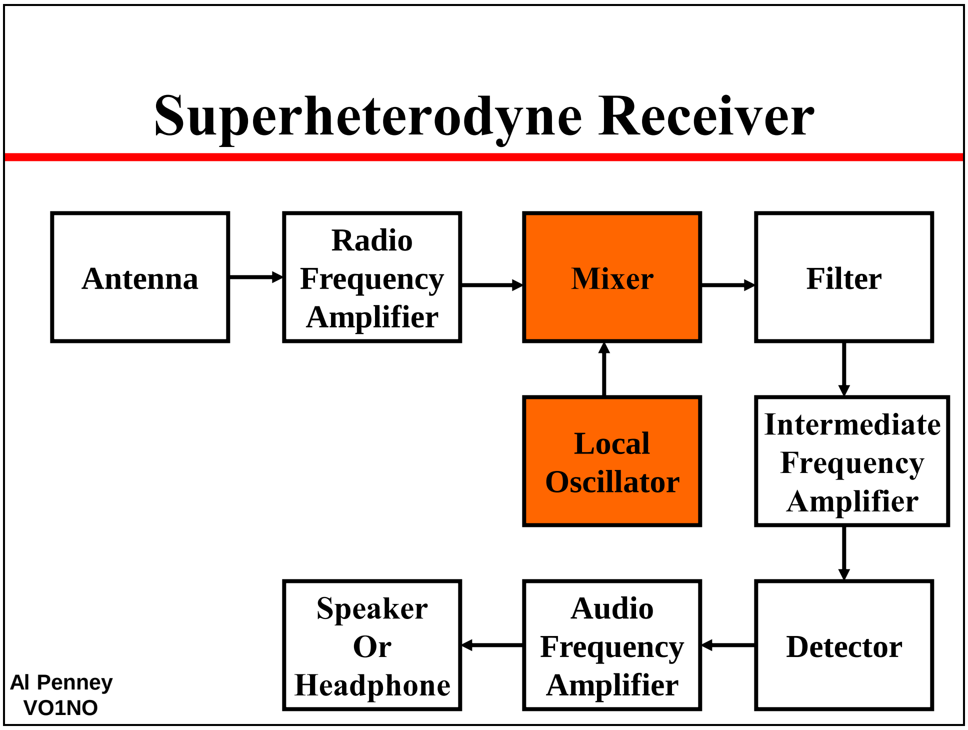
RF tuning & amplification: This RF stage within the overall block diagram for the receiver provides initial tuning to remove the image signal. It also provides some amplification. There are many different approaches used within the RF circuit design for this block dependent its application.

The RF circuit design presents some challenges. Low cost broadcast radios may have an amplifying mixer circuit that gives some RF amplification. HF radios may not want too much RF gain because some of the very strong signals received could overload later stages. The RF design may incorporate some amplification as well as RF attenuation to overcome this issue. Radios for VHF and above will tend to use more gain to have a sufficiently low noise figure to receive the signal.

If noise performance for the receiver is important, then this stage will be designed for optimum noise performance. This RF amplifier circuit block will also increase the signal level so that the noise introduced by later stages is at a lower level in comparison to the wanted signal.



Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

Local (High Frequency) oscillator: Like other areas of the RF circuit design, the local oscillator circuit block within the superhet radio can take a variety of forms.

Early receivers used free running local oscillators. There was a considerable degree of RF circuit design expertise used with these oscillators in high performance superhet radios to ensure the lowest possible drift. High Q coils, low drift circuit configurations, heat management (because heat causes drift), etc . .

Today most receivers use one or more of a variety of forms frequency synthesizers. The most common approach in the RF circuit design is to use a phase locked loop approach. Single and multi-loop synthesizers are used. Direct digital synthesizers are also being used increasingly. Whatever form of synthesizer is used in the RF design, they provide much greater levels of stability and enable frequencies to be programmed digitally in a variety of ways, normally using some form of microcontroller or microprocessor system.

Mixer: The mixer can be one of the key elements within the overall RF design of the receiver. Ensuring that the mixer performance matches that of the rest of the radio is particularly important.

Both the local oscillator and incoming signal enter this block within the superheterodyne receiver. The wanted signal is converted to the intermediate frequency.

The actual implementation requires that the minimum number of spurious signals are generated. In some very low cost broadcast receivers, self oscillating mixers that provide RF amplification from a single transistor may be used, these do not offer high performance. For a high performance radio used for two way radio communications an the like, much better performance is required. To achieve this mixer circuits such as balanced mixers, double balanced mixers, and the like may be seen.

Local Oscillator and Mixer

- The **Local Oscillator** generates an **RF signal** that is **higher or lower** than the desired receive frequency by an amount called the **Intermediate Frequency.**
- It **mixes** with the signal from the **RF Amp** inside the **Mixer.**
- **Output** from the mixer is **the sum and difference** of the two signals.
- One of those two signals is the **Intermediate Frequency.** The choice is an engineering decision.
- ***Note:*** *In the 8th Ed./First Printing 9th Ed. the LO is called the High Frequency Oscillator*

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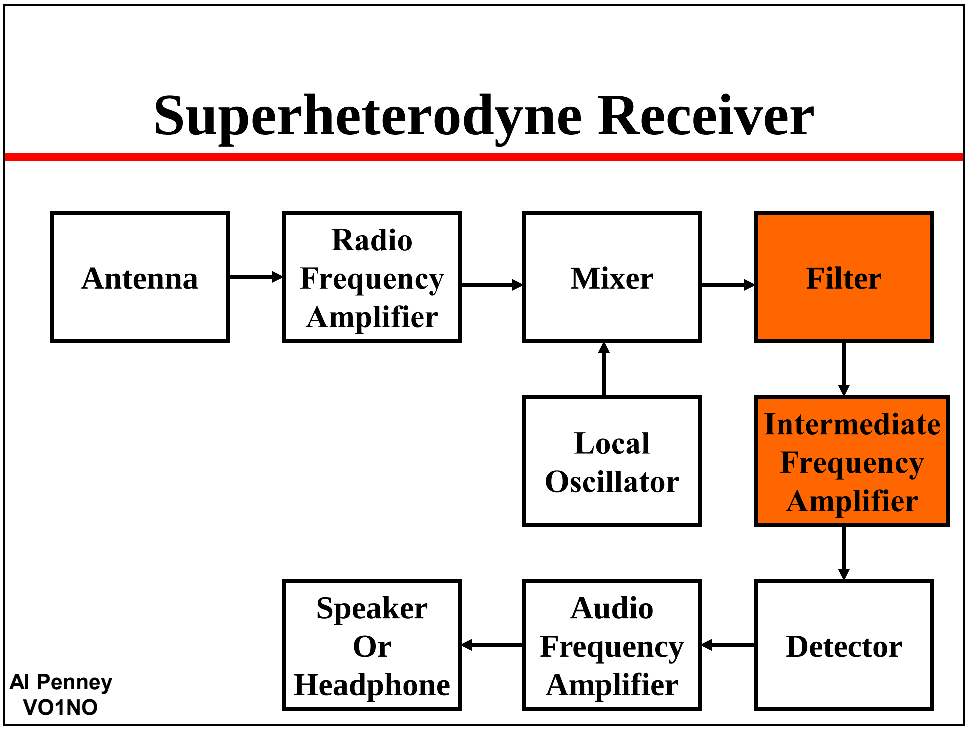

IF amplifier & filter: This superheterodyne receiver block provides the majority of gain and selectivity. Often comparatively little gain will be provided int he previous blocks of the RF circuit design of the radio. The IF stages are where the main gain is provided. Being fixed in frequency, it is much easier to achieve high levels of gain and overall performance.

Originally the IF stage might have included a number of different transistors, FETs or thermionic valves / vacuum tubes, but nowadays it is possible to obtain integrated circuits that contain a complete IF strip.

This circuit block of the radio also provides the adjacent channel selectivity. High performance filters like crystal filters may be used, although LC or ceramic filters may be used within domestic radios. The type of filter will depend upon the radio RF design and its application.

Also within a multi-conversion superhet, the IF may be on a number of different frequencies, typically the earlier stages are at higher frequencies to provide higher levels of image rejection, and later ones at lower frequencies to provide gain and adjacent channel selectivity.

Filter and IF Amplifier

- The **Filter** can be **mechanical, crystal or ceramic.** Newer radios employ a **synthetic filter** using **Digital Signal Processing (DSP)** techniques.
- It **filters out** not just the non-IF signal, but is also the **primary location** where **selectivity** is obtained.
- The IF Amp **can** consist of **several stages that amplify the IF signal.** Because the IF has been pre-defined by the receiver's design, the **IF amp does not need to be tuned** after calibration by the manufacturer.
- A total of 40 – 80 dB gain.

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Receiver Filters

- **Receivers** often have **several filters** that can be switched in as **required by the mode.**
- Examples of the **filter widths** and the usual mode they would be used for are:
  - 250 Hz — CW (for severe interference)
  - 500 Hz — CW (for more relaxed conditions)
  - 2.4 kHz — SSB
  - 6 kHz — AM, possibly SSB if band is not busy

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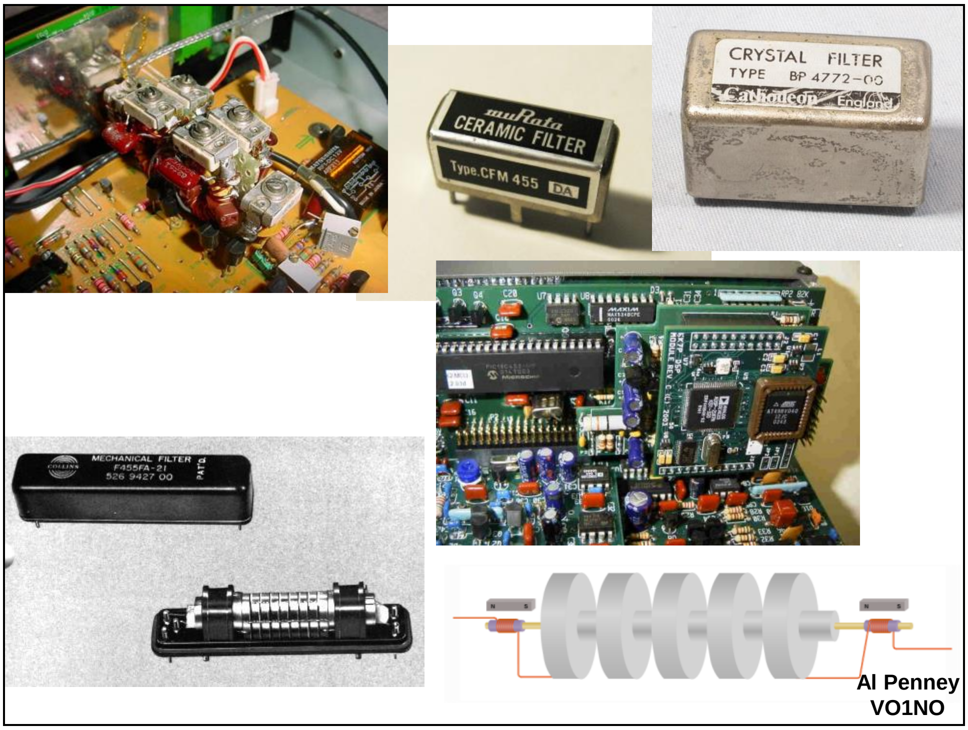
Choosing the right filter bandwidth

It is important to choose the correct bandwidth for a give type of signal. It is obviously necessary to ensure that it is not too wide, otherwise unwanted off-channel signals will be able to pass though the filter. Conversely if the filter is too narrow then some of the wanted signal will be rejected and distortion will occur.

As different types of transmission occupy different amounts of spectrum bandwidth it is necessary to tailor the filter bandwidth to the type of transmission being received. As a result many receivers switch in different filters for different types of transmission. This may be done either automatically as part of a mode switch, or using a separate filter switch.

Typically a filter for AM reception on the long and medium wave bands it is around 9 or 10 kHz and on the short wave bands will have a bandwidth of around 6 kHz. For SSB reception it will be approximately 2.5 kHz. For Morse reception 500 and 250 Hz filters are often used.

Adjacent channel selectivity is an important factor for any receiver whether for HF communications, mobile communications (cell phones), Wi-Fi . . . or for any form of wireless / radio communications. The adjacent channel selectivity of the radio within the system will determine many aspects of performance, especially the way it operates when nearby channels or frequencies are in use.



Filter types

There is a variety of different types of filter that can be used in a receiver. The older broadcast sets used LC filters. The IF transformers in the receiver were tuned and it was possible to adjust the resonant frequency of each transformer using an adjustable ferrite core.

Today ceramic filters are more widely used. Their operation is based on the piezoelectric effect. The incoming electrical signal is converted into mechanical vibrations by the piezoelectric effect. These vibrations are then affected by the mechanical resonances of the ceramic crystal. As the mechanical vibrations are then linked back to the electric signal, the overall effect is that the mechanical resonances of the ceramic crystal affect the electrical signal. The mechanical resonances of the ceramic exhibit a high level of Q and this is reflected in its performance as an electrical filter. In this way a high Q filter can be manufactured very easily.

Ceramic filters can be very cheap, some costing only a few cents. However higher performance ones are also available.

For really high levels of filter performance crystal filters are used. Crystals are made from quartz, a naturally occurring form of silicon, although today's components are made from synthetically grown quartz. These crystals also use the piezoelectric effect and operate in the same way as ceramic filters but they exhibit much higher levels of Q and offer far superior degrees of selectivity. Being a resonant element they are used in many areas where an LC resonant element might be found. They are used in oscillators - many computers have crystal oscillators in them, but they are also widely used in high performance filters.

Normally crystal filters are made from a number of individual crystals. Often a filter will be quoted as having a certain number of poles. There is one pole per crystal, so a six pole crystal filter would contain six crystals and so forth. Many filters used in amateur communications receivers will contain either six or eight poles.

Filters

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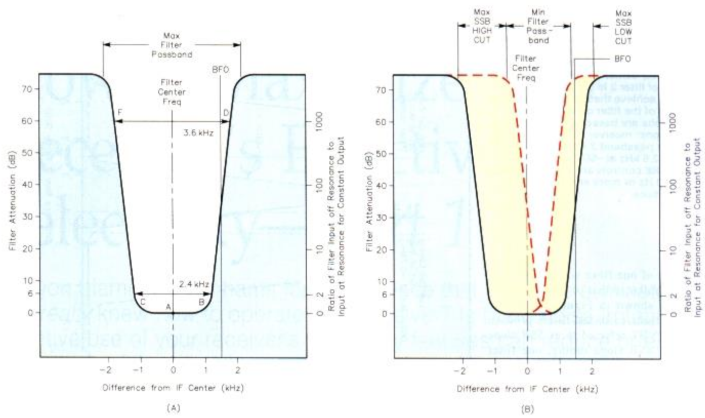
IF Slope Tuning



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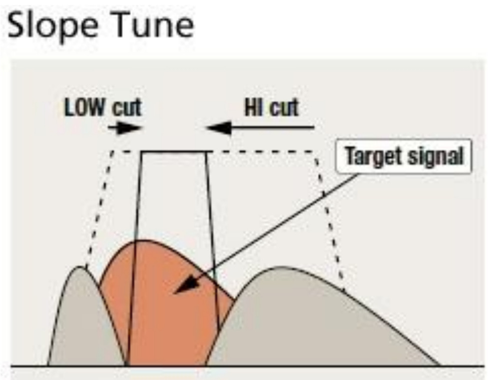

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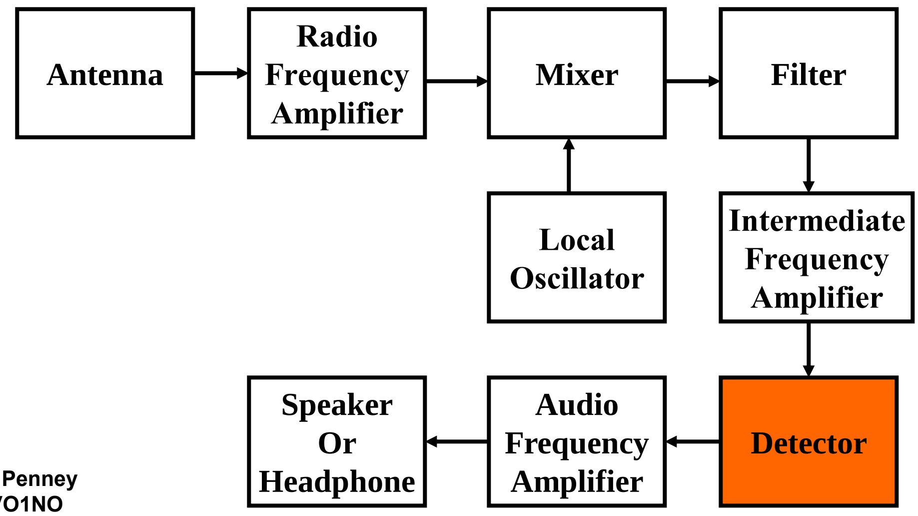
Superheterodyne Receiver



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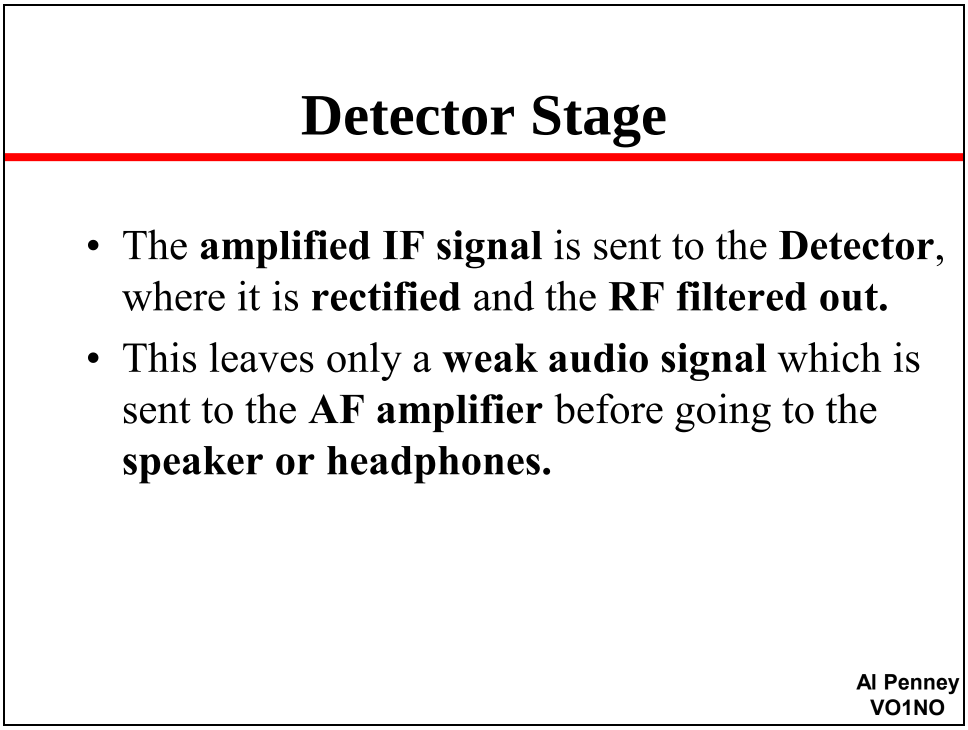


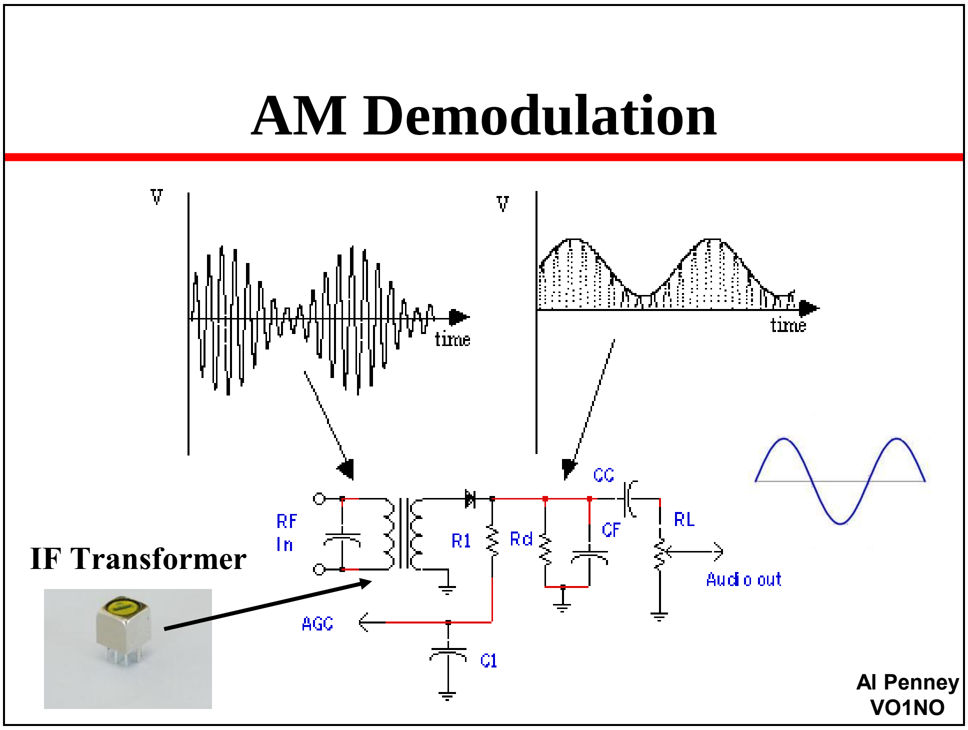
Demodulator: The superheterodyne receiver block diagram only shows one demodulator, but in reality many radio RF designs may have one or more demodulators dependent upon the type of signals being receiver.

Even many broadcast radios will have AM and FM, but professional radios used for monitoring and two way radio communications may require a larger variety in some instances. Having a variety of demodulators will enable many different signal modes to be received and increase the capability of the radio.

Audio amplifier: Once demodulated, the recovered audio is applied to an audio amplifier block to be amplified to the required level for loudspeakers or headphones. Alternatively the recovered modulation may be used for other applications whereupon it is processed in the required way by a specific circuit block.

In many ways, this circuit block within the superheterodyne radio is the most straightforward. For many applications, the audio amplifier will involved some straightforward electronic circuit design, especially if the audio is applied to simple headphones or a loudspeaker. For two way radio communication applications, the audio bandwidth may need to be limited to the "telecommunications" bandwidth of about 300 Hz to 3.3 kHz. Audio filters could be employed as well.

For applications requiring a higher quality output, more thought may need to be applied during the electronic circuit design to achieving high fidelity performance.



An ideal diode conducts only during alternate half cycles of the input signal, and during the conducting half cycles the output current is proportional to the input voltage. An AM signal, applied to a diode detector as shown in figure 1, reproduce the modulating (audio) signal by mixing the AM sidebands with the AM carrier. It may be seen from figure 1 that the peak amplitude of each current pulse in the output is proportional to the peak amplitude of the input voltage during that particular conducting half cycle. Thus the peak, and therefore the average, values of the output current pulses follow the amplitude of the input voltage precisely during conducting half cycles and have the same waveform as the modulation envelope. Whether the output voltage would approach the peak or average value of the input voltage depends on the type of filter used in the output. If the filter is a bypass capacitor, and the internal resistance of the rectifier is small in comparison with the load resistance, then output voltage will tend to follow the peaks of the input voltage. Thus, the capacitor, CF, charges essentially to the peak input voltage during the conducting half cycles, but there is not time for appreciable discharge through the high resistance load during the non-conducting half cycles. If the bypass capacitor is too large, the time constant of the discharge will be so large that the detector output will not be able to follow the modulation envelope when the modulation envelope decreases amplitude rapidly.

In addition to detection, a circuit in figure 1 has been added which is called the automatic gain control (AGC). The AGC voltage is the average value of the detector output voltage since R1 and C1 act as a filter to remove the modulating signal as well as the RF from the AGC system. This AGC voltage is therefore proportional to the amplitude of the carrier in a continuous wave system and may be used to automatically control the gain of one or more RF amplifier stages. Thus for samll input signals the RF amplifier will have high gain, but as the magnitude of the input signal increases, the gain of the RF amplifier decreases. This effect tends to keep the detector output relatively constant and prevents overdriving the RF into the saturation or cutoff regions. AGC is effectively and easily applied to a dual-gate MOSFET in the RF stage.

Superhet Example

- In order to better illustrate how a Superhet receiver works, let's look at an example of how the **frequency conversion process** operates.
- We want to receive a signal on **3.8 MHz (3800 kHz)**
- Assume our receiver has an **IF of 455 kHz.**

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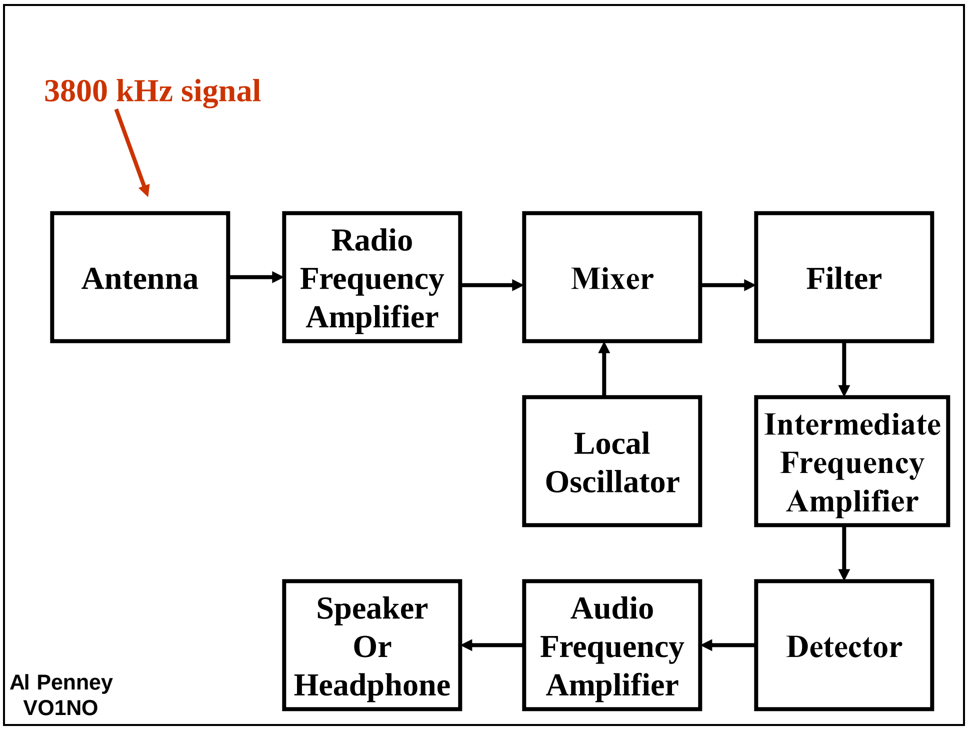
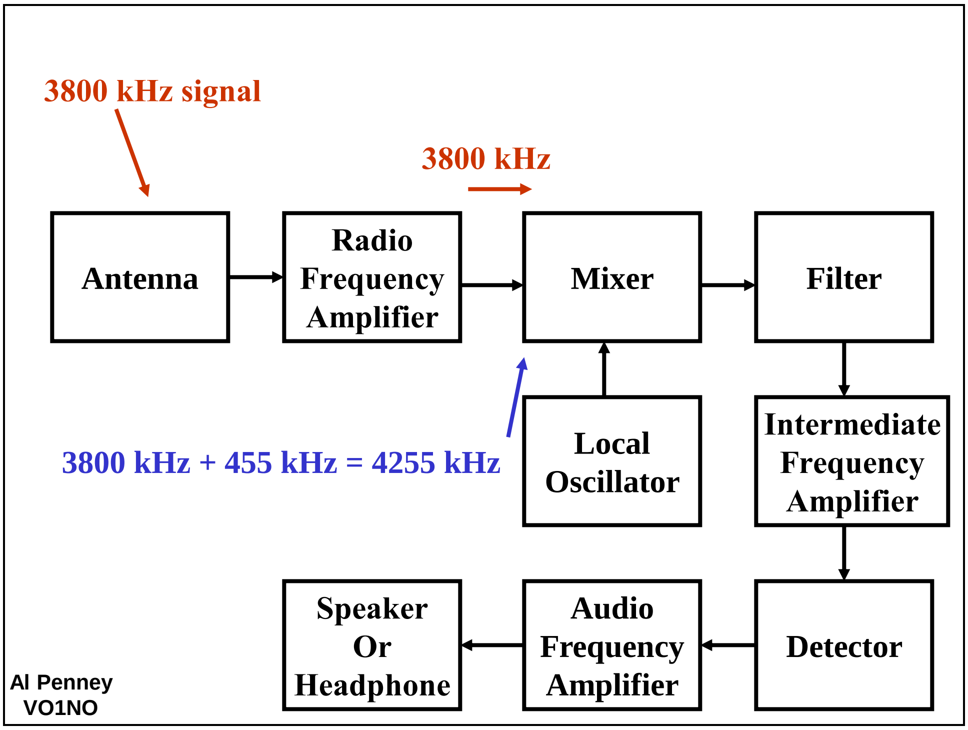


The signal that is picked up by the antenna passes into the receiver through an RF amplifier and enters a mixer. Another locally generated signal, produced by the HF Oscillator here but often called the Local Oscillator, is fed into the other port on the mixer and the two signals are mixed. As a result new signal are generated at the sum and difference frequencies.

The output from the mixer is passed into what is termed the Intermediate Frequency or IF stages where the signal is filtered and amplified. Any of the converted signals that fall within the passband of the IF filter will be able to pass through the filter and they will also be amplified by the amplifier stages. Any signals that fall outside the passband of the filter will be rejected.

The IF is then rectified by the detector stage and the resulting audio signal is amplified and turned into sound with the speaker or headphones.

Tuning the receiver is simply accomplished by changing the frequency of the local oscillator. This changes the incoming signal frequency for which signals are be converted down and able to pass through the filter.



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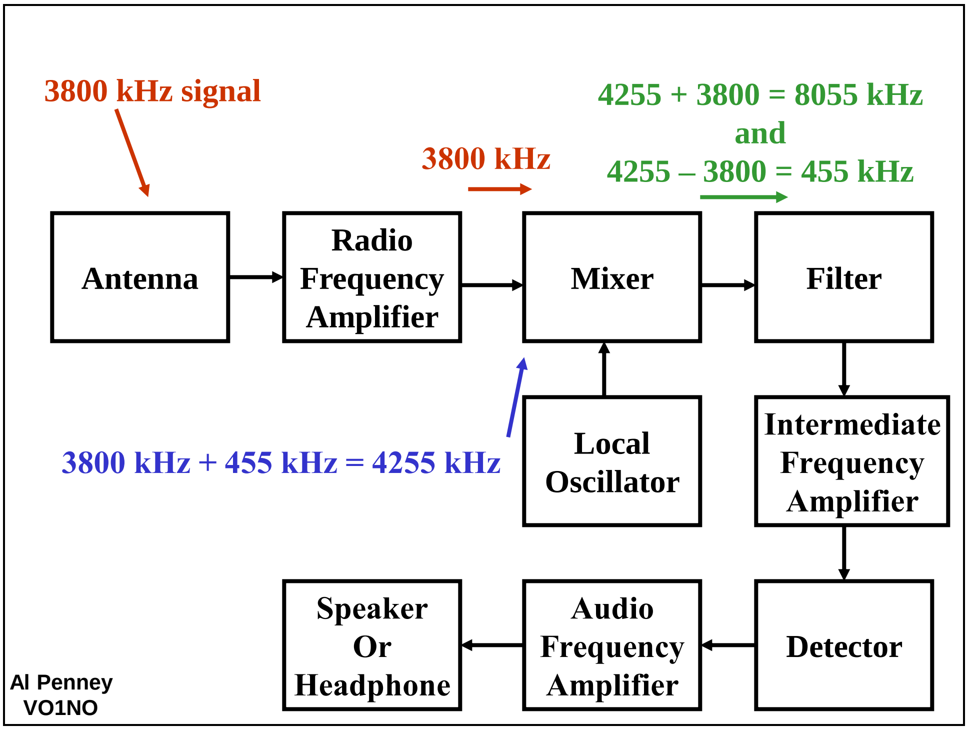

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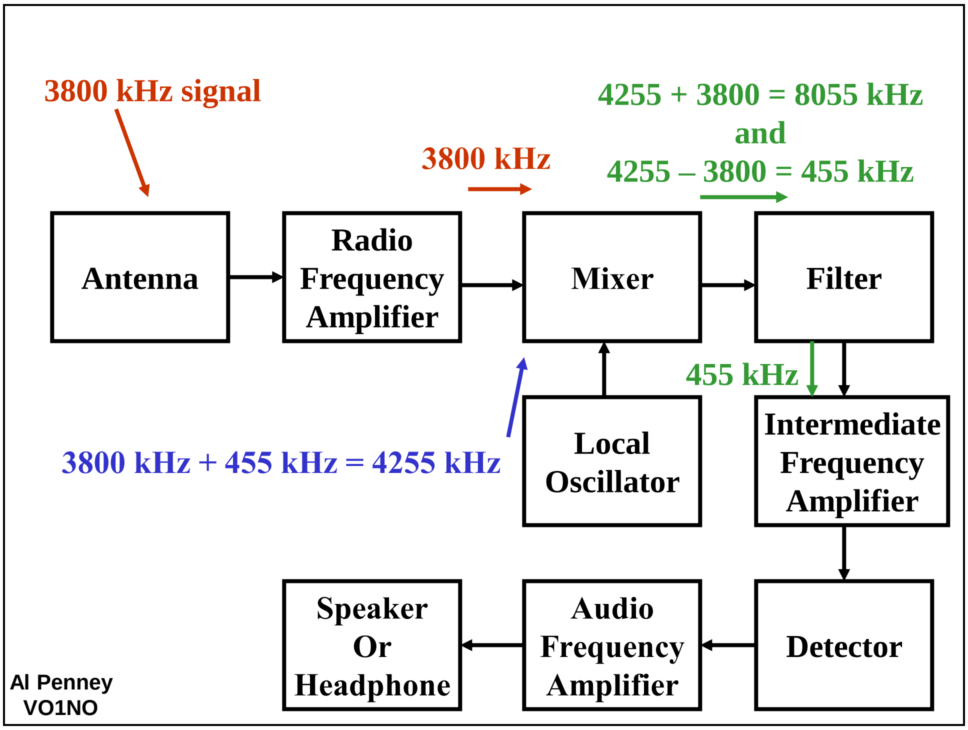

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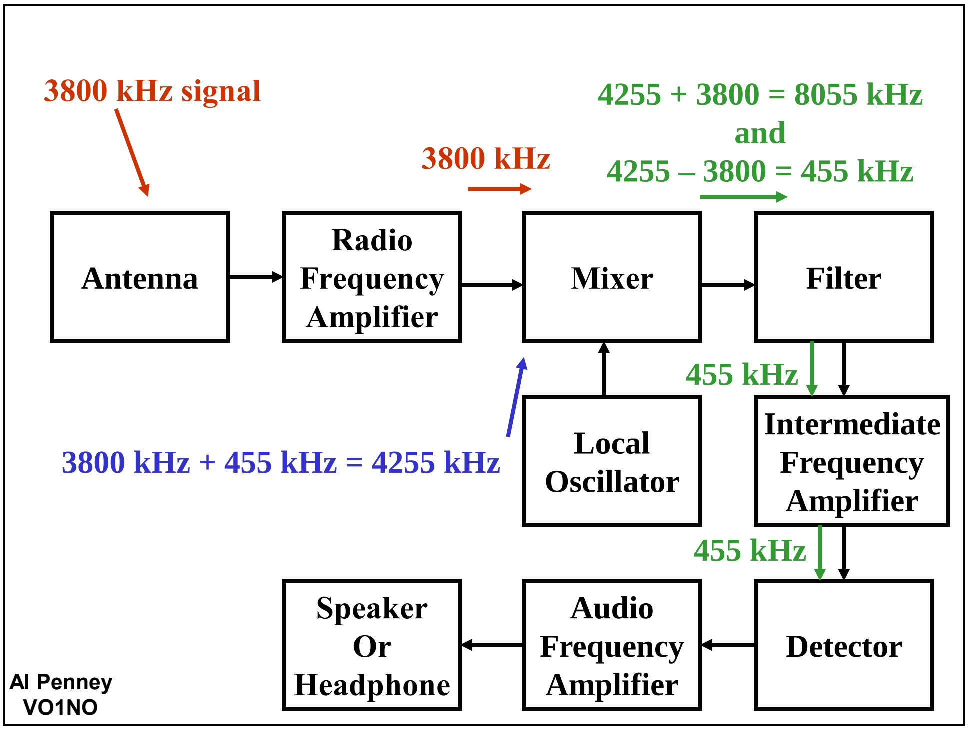

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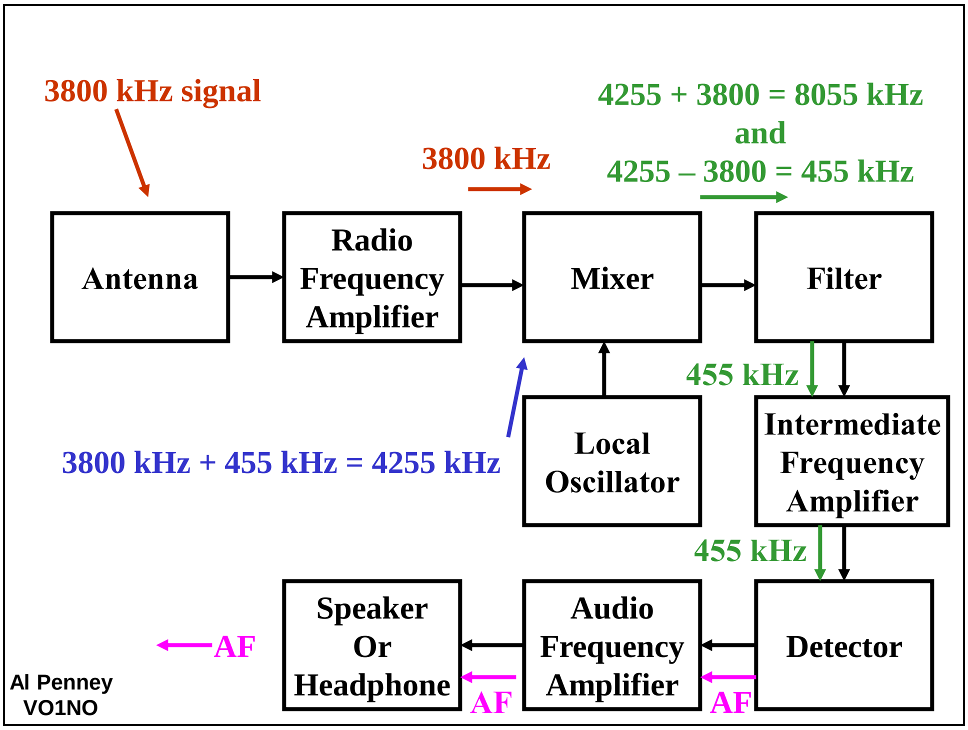

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Advantages of the Superhet

- Much **more sensitive, selective** and **stable** than TRF radios.
- By **converting higher frequencies** to the **IF**, we are able to design much **more selective and sensitive filters and amplifiers** that use **more reliable components.**
- Much **easier** to use.

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Advantages and disadvantages

Superheterodyne receivers have essentially replaced all previous receiver designs. The development of modern semiconductor electronics negated the advantages of designs (such as the regenerative receiver) that used fewer vacuum tubes. The superheterodyne receiver offers superior sensitivity, frequency stability and selectivity. Compared with the tuned radio frequency receiver (TRF) design, superhets offer better stability because a tuneable oscillator is more easily realized than a tuneable amplifier. Operating at a lower frequency, IF filters can give narrower passbands at the same Q factor than an equivalent RF filter. A fixed IF also allows the use of a crystal filter or similar technologies that cannot be tuned. Regenerative and super-regenerative receivers offered a high sensitivity, but often suffer from stability problems making them difficult to operate

Primary Disadvantage

- Superhets have **one big problem** however – they are subject to receiving **images,** or stations that are **not actually on the frequency** we are listening to.
- This occurs when a **station is transmitting** on a frequency **twice the IF** away from the **desired frequency.**

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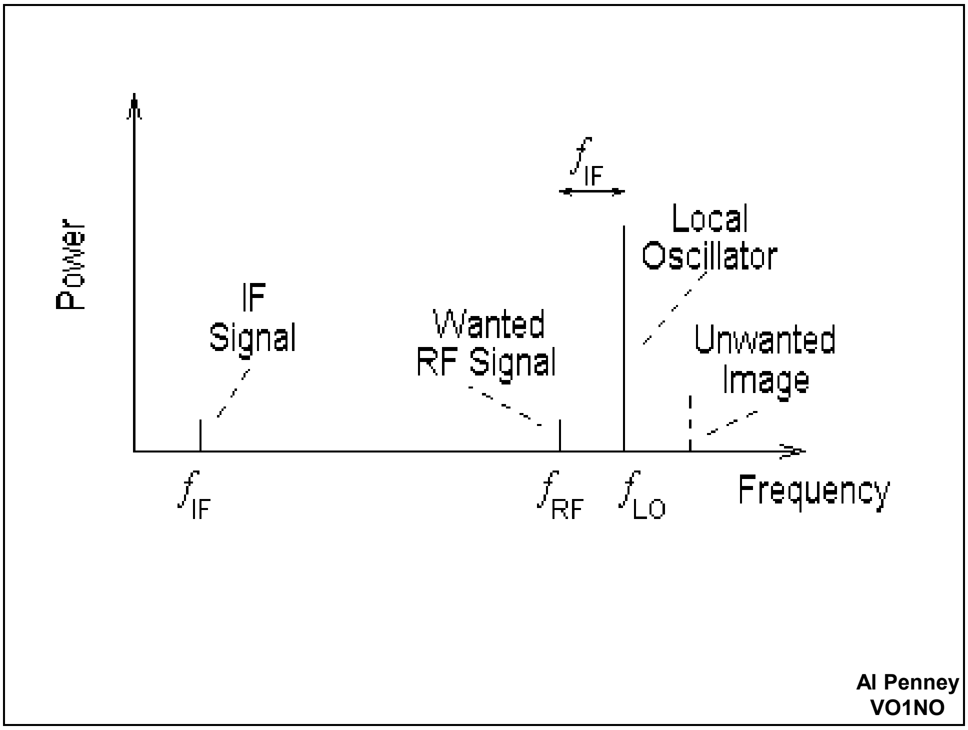
One major disadvantage to the superheterodyne receiver is the problem of *image frequency*. In heterodyne receivers, an image frequency is an undesired input frequency equal to the station frequency plus (or minus) twice the intermediate frequency. The image frequency results in two stations being received at the same time, thus producing interference. Image frequencies can be eliminated by sufficient attenuation on the incoming signal by the RF amplifier filter of the superheterodyne receiver.

For example, an AM broadcast station at 580 kHz is tuned on a receiver with a 455 kHz IF. The local oscillator is tuned to 580 + 455 = 1035 kHz. But a signal at 580 + 455 + 455 = 1490 kHz is also 455 kHz away from the local oscillator; so both the desired signal and the image, when mixed with the local oscillator, will appear at the intermediate frequency. This image frequency is within the AM broadcast band. Practical receivers have a tuning stage before the converter, to greatly reduce the amplitude of image frequency signals; additionally, broadcasting stations in the same area have their frequencies assigned to avoid such images.

The unwanted frequency is called the *image* of the wanted frequency, because it is the "mirror image" of the desired frequency reflected . A receiver with inadequate filtering at its input will pick up signals at two different frequencies simultaneously: the desired frequency and the image frequency. Any noise or random radio station at the image frequency can interfere with reception of the desired signal.



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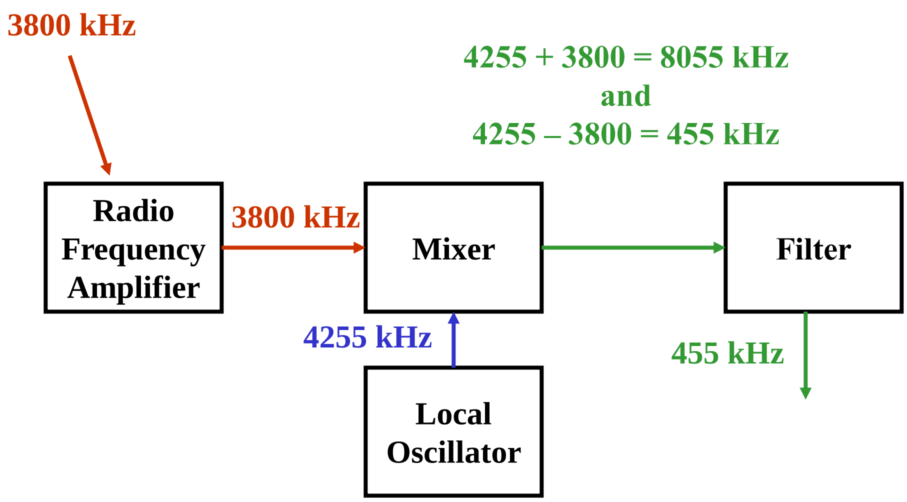
No Image



3800 kHz + 455 kHz = 4255 kHz

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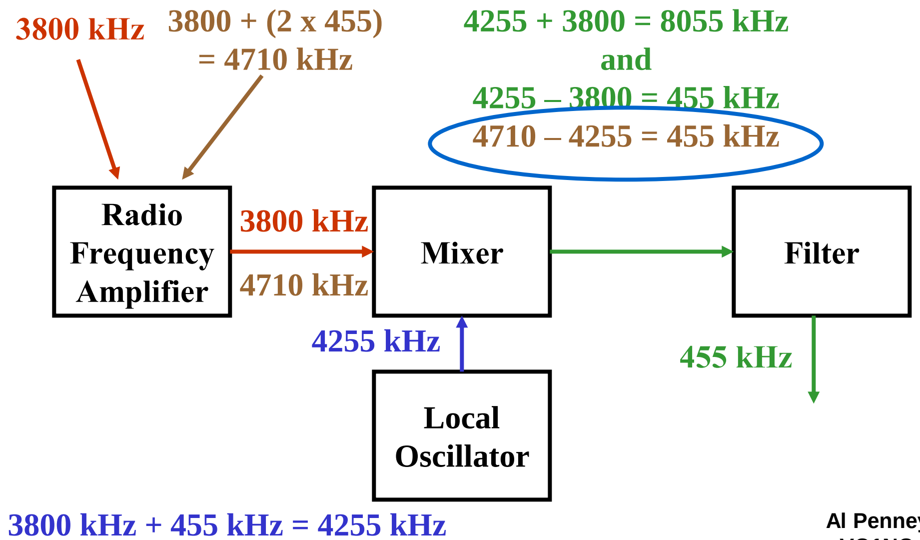
Image



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The Solution!

- More expensive superhets employ **double or triple conversion** to improve **image rejection.**
- The **first IF** is chosen so that it is **larger than the bandwidth** of the **bandpass filters** in the front end of the receiver, and so the image **not make it to mixer stage.**
- The **first IF** signal is then **amplified,** and **converted** again to a **lower IF** to take advantage of the **greater selectivity** available at lower Intermediate Frequencies.

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Images: a problem with the superhet RX

• If intermediate frequency (IF) is 455 kHz:

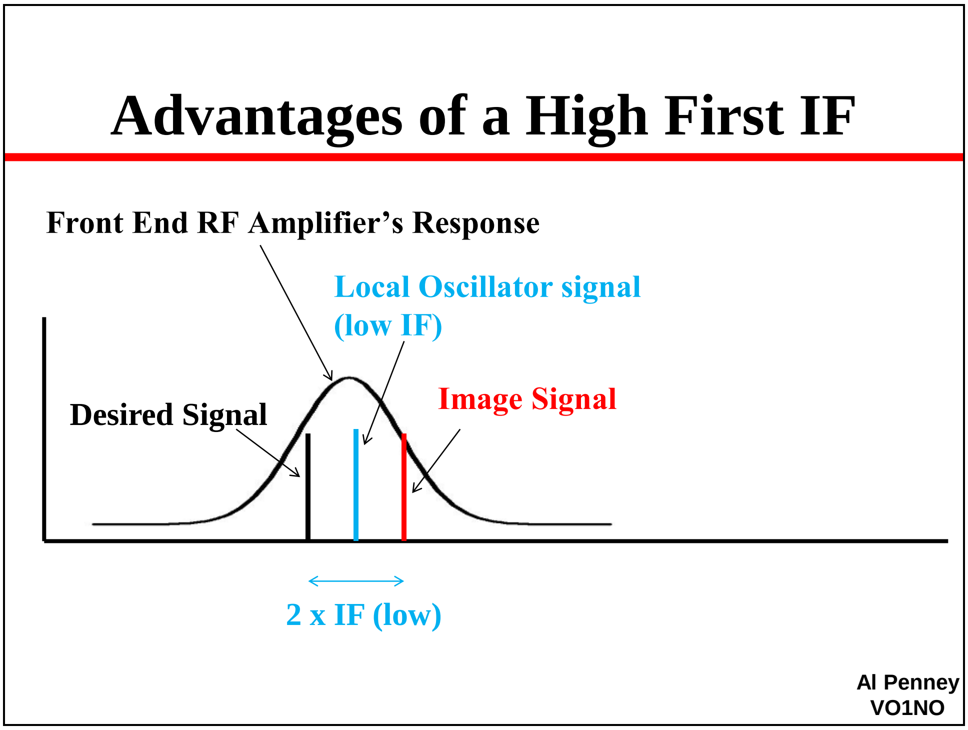
• On 10m, tuned to 28.500 MHz, LO is at 28.045, for 455 kHz IF

• But, signal at 27.590 also gives 455 kHz IF ! (image)

• 28.500:27.590 : 4% difference in frequency

• On 80m : 3.800 MHz real : 2.890 image 24% difference in frequency

• Images: a problem at higher HF frequencies, if only 1 or no RF amp!

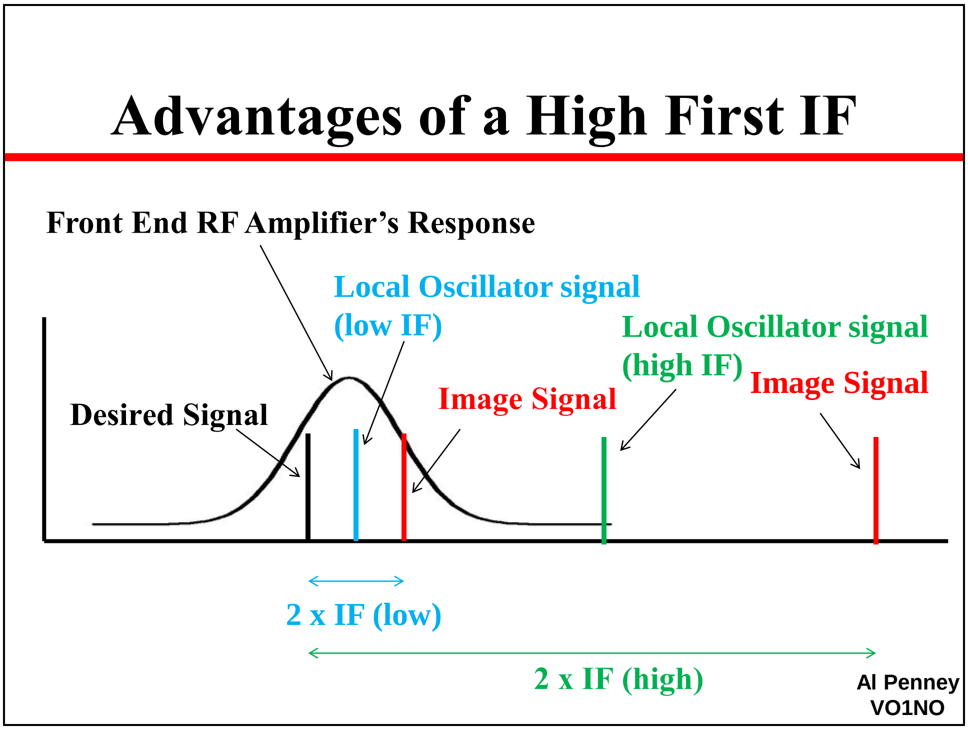


The choice of Intermediate Frequency

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.



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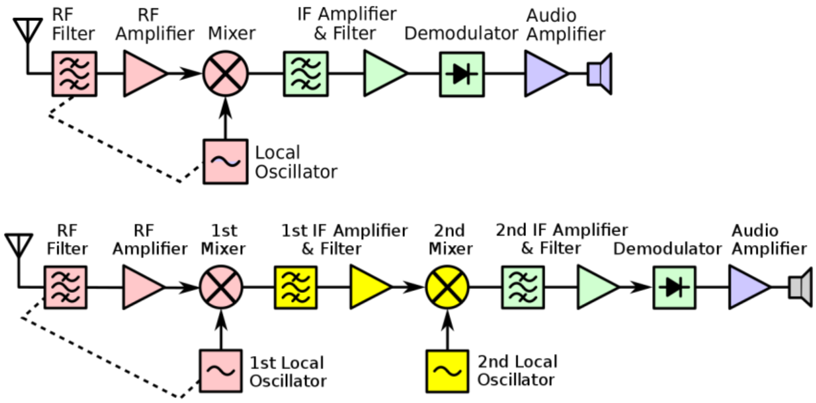
Single versus Dual Conversion Superhet Receiver



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Reason for using double superheterodyne radio receiver

When settling on the radio RF circuit design and choosing the intermediate frequency for a superheterodyne radio receiver there is a trade-off to be made between the advantages of using a low frequency IF or a high frequency one as each has its own advantages and disadvantages.

•***High frequency IF:*** For any intermediate frequency within a superhet radio the image response appears at a frequency equal to twice that of the IF away from the wanted one. Making the IF as high as possible enables the image response to be as far away as possible from the wanted signal, making the RF filtering to remove the unwanted response much easier, and much better levels of rejection can be obtained.

•Accordingly the use of an intermediate frequency with a high frequency provides good image rejection. Some modern HF band communications receivers that cover frequencies up to 30 MHz, may have first IFs of 50 or 60 MHz to ensure a god level of performance.

•***Low frequency IF:*** The advantage of choosing a lower frequency IF is that the filters that provide the adjacent channel rejection are lower in frequency. The use of a low frequency IF enables the performance to be high, while keeping the cost low.

•Although filters like ceramic filters, crystal filters and the like have improved immeasurably in recent years, costs and performance are still better at lower frequencies. Certainly if 60 MHz IFs are used for the main selectivity, then the filters at these frequencies would not perform as well, and they would be considerably more expensive.

Accordingly there are two conflicting requirements which cannot be easily satisfied using a single intermediate frequency. The solution is to use a double conversion superheterodyne topology to provide a means of satisfying both requirements. Sometimes even a triple conversion superhet may be used to provide the required performance and flexibility.

Basic double superheterodyne receiver concept

The basic concept behind the double superhet radio receiver is the use of a high intermediate frequency to achieve the high levels of image rejection that are required, and a further low intermediate frequency to provide the levels of performance required for the adjacent channel selectivity.

Typically the receiver will convert the incoming signal down to a relatively high first intermediate frequency, IF stage. This may even be above the incoming frequency. This high frequency first IF stage enables the high levels of image rejection to be achieved.

As the image frequency lies at a frequency twice that of the IF away from the main or wanted signal, the higher the IF, the further away the image is and the easier it is to reject at the front end.

Once the signal has passed through the first IF stages at the higher frequency, it is then passed through a second mixer to convert it down to a lower intermediate frequency where the narrow band filtering is accomplished so that the adjacent channel signals can be removed.

As the lower frequency, filters are cheaper and the performance is normally better, although filter technology has improved significantly allowing higher frequency filters to be used. A 9 MHz filter, for example, would not be considered as a high frequency filter these days.

Double superheterodyne topologies

While the basic concept for the double superheterodyne radio receiver involving two stages of frequency conversion may remain the same, there are a number of different "styles" that can be adopted:

•***Fixed frequency first oscillator:*** This RF design format for a double conversion superheterodyne receiver was popular before the days of frequency synthesizers and other very stable local oscillators.

•It was widely used in many amateur radio or ham radio receivers where a band of 500 kHz was normally tuned to cover a particular band. This form of receiver was able to provide significant improvements in stability performance as well as improved image rejection, although the wide-band first IF stage was often open to some direct pick-up.

•A switched crystal oscillator in the first conversion would provide a stable first local oscillator oscillator was used to provide the local oscillator for the first conversion. A bandpass filter would be used to provide selectivity and allow a band of frequencies to be passed.

•The second local oscillator would allow tuning over the range allowed by the bandpass filter. When further coverage was required, the first, crystal controlled oscillator, would need to be switched to the next crystal. In this way continuous coverage could be obtained, albeit with a large number of crystals.

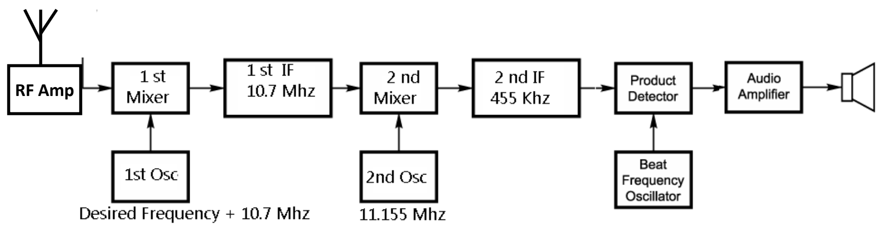
•Apart from providing high levels of image rejection, this concept gave considerably improved levels of frequency stability for receivers of the time. However, it did require that a large number of switched bands was needed and for continuous coverage from 1 to 30 MHz with 500kHz each band, the number of crystals and bands was enormous. Nowadays frequency synthesizers mean that this RF circuit design format is rarely needed or used.

•***Tuned first oscillator:*** This is the most usual format for the RF design of a double conversion superheterodyne receiver. The first conversion uses a variable frequency oscillator which converts the signal to the first IF.

Although little selectivity is generally provided in the first IF, often a filter known as a roofing filter may be used to provide some adjacent channel filtering. This prevents very strong adjacent channel signals from overloading the later stages of the IF. However the main selectivity is still provided in the lower frequency IF stages.

The first local oscillator would typically be some form of frequency synthesizer as these are widely used and relatively cheap and easy to implement. They have excellent stability and can be programmed via a microprocessor enabling facilities like keypad frequency entry, tuning knob (controlled via a processor), scanning and much more.

Dual Conversion Implementation



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FM Receiver

- The **FM receiver** is very similar to an AM receiver up to the IF Amplifier.
- Instead of a Detector however, the FM receiver uses two different stages:
  - **Limiter**
  - **Frequency Discriminator**

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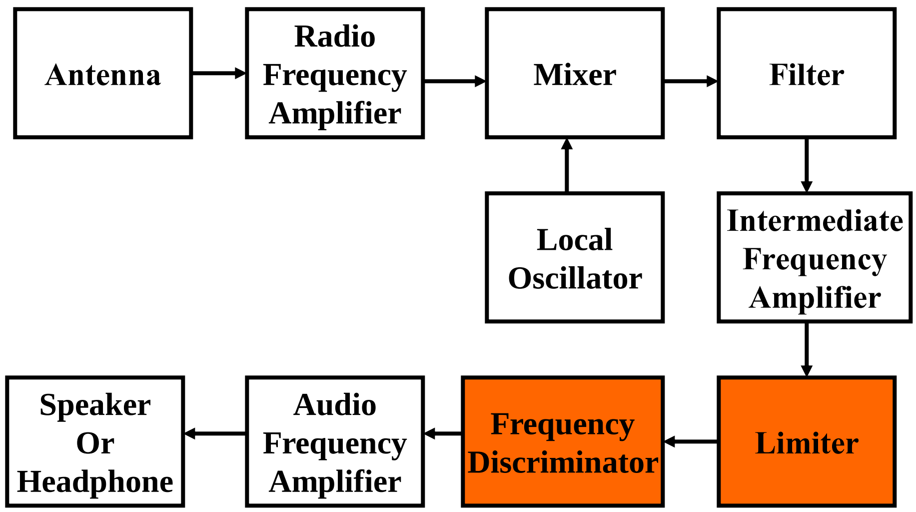
FM Receiver



Limiter

- The **Limiter Stages** are **high gain amplifiers** that **remove all traces of Amplitude Modulation** from the received signal.
- **Static crashes** are mostly **amplitude modulated,** and so are removed by the Limiter.
- This gives FM its greatest benefit – a very high **SNR – Signal to Noise Ratio.**

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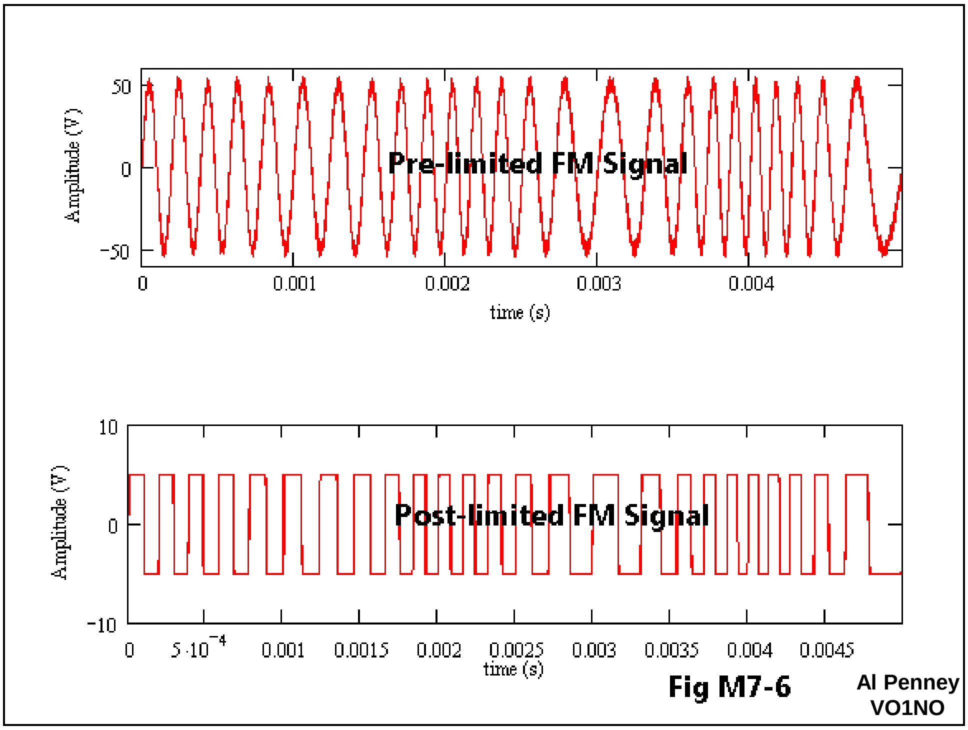
In electronics, a **limiter** is a circuit that allows signals below a specified input power or level to pass unaffected while attenuating (lowering) the peaks of stronger signals that exceed this threshold. Limiting is a type of dynamic range compression. Clipping is an extreme version of limiting.

Limiting is any process by which the amplitude of a signal is prevented from exceeding a predetermined value.

An FM radio receiver usually has at least one stage of amplification that performs a limiting function. This stage provides a constant level of signal to the FM demodulator stage, reducing the effect of input signal level changes to the output. If two or more signals are received at the same time, a high-performance limiter stage can greatly reduce the effect of the weaker signals on the output. This is commonly referred to as the FM capture effect.

Generally, FM demodulators are not affected by amplitude variations, since the baseband is contained in the frequency deviations. Some detectors, including the ratio detector, inherently limit gain by the nature of the circuit design. In AM radio, the information is located in the amplitude variations, and distortion can occur due to spurious signals that could cause the baseband to be misrepresented.



50
0
−50
Amplitude (V)
0
0.001
0.002
0.003
0.004
time (s)
Pre-limited FM Signal
10
0
−10
Amplitude (V)
0
$5 \cdot 10^{-4}$
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.004
0.0045
time (s)
Post-limited FM Signal
Fig M7-6
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Frequency Discriminator

- The **Frequency Discriminator** converts **frequency variations** into **voltage variations.**
- This is fed to the **Audio Frequency Amplifier** and then the **speaker or headphones.**

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Frequency Modulation, FM Detection, Demodulation, Discrimination

In order to use the modulation on an FM signal, it is necessary to extract the modulation, i.e. demodulate or detect the signal.

FM demodulation is also called FM detection and sometimes the phrase "FM discrimination" is used, although this term tends to be used with older circuits and technology.

FM demodulation is a key process in the reception of a frequency modulated signal. Once the signal has been received, filtered and amplified, it is necessary to recover the original modulation from the carrier. It is this process that is called demodulation or detection.

FM demodulator circuits are found in any receiver that uses FM: broadcast receivers, two way radios like walkie talkies and handheld radios that use FM, and any receiver where frequency modulation is used.

FM demodulation basics

In any radio that is designed to receive frequency modulated signals there is some form of FM demodulator or detector.

This circuit takes in frequency modulated RF signals and takes the modulation from the signal to output only the modulation that had been applied at the transmitter.

In order to be able to demodulate FM it is necessary for the radio receiver to convert the frequency variations into voltage variations - it is a frequency to voltage converter. When the carrier frequency deviates to the lower end of the frequency range over which it deviates a lower voltage may be produced, then as it deviates higher in frequency, a higher voltage is produced.

Although it is easier to think of lower frequencies producing lower voltages, there is no need for this to be the case, it could be the other way around.

One of the chief requirements for the FM demodulator is that it should have a response that is as linear as possible over the required bandwidth. In other words a shift of a given frequency produces the same output change wherever it may be found on the curve. If the response is not linear, then distortion will be introduced.

A further requirement for the FM demodulator is that it should not be sensitive to amplitude variations. As the modulation is carried by only the frequency deviation, no amplitude sensitivity is wanted. Any amplitude signal is likely to be noise, and by making the receiver insensitive to amplitude variations, the signal to noise ratio can be improved.

The resilience to noise is a major factor in providing low noise FM reception for applications like high fidelity audio broadcasts. It also means that for mobile radio, or handheld radio communications, the effects of signal level variations and fading due to movement is reduced.

If an FM demodulator is sensitive to amplitude variations as well as frequency variations, then the demodulator can be preceded a limiting amplifier stage. This stage runs into saturation when a signal of sufficient strength is present. By running in saturation, the amplitude variations are removed.

The response that is normally seen for an FM demodulator / FM detector is known as an "S" curve for obvious reasons. There is a linear portion at the centre of the response curve and towards the edge the response becomes very distorted.

As can be anticipated, the detector response curve cannot remain linear over a huge range of frequencies. Instead it should be sufficiently wide to accommodate the width of the deviation of the signal and a bit more to provide additional margin.

Types of FM demodulator

There are several types of FM detector / demodulator that can be used. Some types were more popular in the days when radios were made from discrete devices, but nowadays the PLL based detector and quadrature / coincidence detectors are the most widely used as they lend themselves to being incorporated into integrated circuits very easily and they do not require many, if any adjustments.

To improve the noise performance of the FM receiver, typically the IF stage may operate such that the IF amplifier is driven into limiting. This removes the amplitude variations, that will result in noise, and only allows through the frequency variations.

There main types of FM demodulator found in broadcast receivers, radio communication systems two way radios or walkie talkies / handheld radios, etc, are outlined below:

•***Slope detection:*** This is a very simple form of FM demodulation and it relies on the selectivity of the receiver itself to provide the demodulation. It is not particularly effective and is not used except when the receiver does not have an FM capability.
This form of FM detection has very many limitations: the selectivity curve of the radio will not be at all linear and distortion will arise; the receiver will be sensitive to amplitude variations, etc.

•***Ratio detector:*** This type of detector was one that was widely used when discrete components were used in transistor radios. The ratio detector required the use of a transformer that had a third winding to produce an additional signal which was phase shifted for the demodulation process. The ratio detector used two diodes along with a few resistors and capacitors.
Although it performed well, the ratio FM detector was an expensive form of detector in view of the transformer it used. As all wound components are more expensive than resistors and capacitors, these FM demodulators were expensive to make and after the introduction of integrated circuit technology where different circuits could be used, the ratio detector was rarely used. Nevertheless, in its day it performed well.

•***Foster Seeley FM :*** In the days when radio used discrete components, this was the other main contender for the FM demodulator in radios. The Foster Seeley FM demodulator was very similar in many respects for the ratio detector. However instead of using a third winding on the transformer, it used a separate choke.
Like the Ratio detector the Foster Seeley detector fell out of widespread use when integrated circuits were introduced as other forms of FM demodulator were far easier to implement with ICs and their performance as superior.

•***Phase locked loop demodulator:*** It is possible to use a phase locked loop to demodulate FM. The PLL FM detector provides excellent performance and does not require many, if any adjustments in manufacture. The other advantage of the PLL FM demodulator is that it is easily incorporated within an integrated circuit, and can therefore be added with very little incremental cost to an overall receiver chip, and hence the radio receiver.

The phase locked loop or PLL FM demodulator operated because the loop was set to track the instantaneous frequency of the incoming FM signal. To keep the loop in lock, the voltage controlled oscillator within the loop needed to track the frequency of the incoming signal. The tune voltage for the VCO varied in line with the instantaneous frequency of the signal, and hence provided the demodulated output of the audio or other modulation signal.

•***Quadrature detector:*** The quadrature FM detector is now widely used in FM radio ICs. It is easy to implement and provides excellent levels of performance. The quadrature . coincidence form of FM demodulator is very easily incorporated into an integrated circuit and can be added with virtually no additional cost. This makes it a very attractive option for modern receiver designs. Many integrated circuits that are designed to provide the functionality of a compete receiver or an IF strip, incorporate a quadrature detector/ coincidence detector, and therefore FM demodulation can be added at virtually no cost to the final receiver.

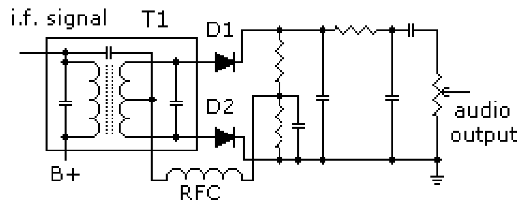
These FM demodulators are used in different applications. The different types of FM demodulator provide designers with a choice of approaches dependent upon the application: broadcast, two way radio communications including walkie talkies and handheld radios, high specification communications receivers and the like.

Although the PLL FM detector and the quadrature detectors are most widely used, along with phase locked loop based circuits. The Foster Seeley and ratio FM detectors are still used on some occasions, but they are normally only found in older radios using discrete components.

Frequency Discriminator

Common types include :

Foster-Seeley Detector
Ratio Detector
Quadrature Detector
Slope detector
Phase-locked Loop



Foster-Seeley Detector

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This discriminator simply works on the principal that with no modulation applied to the carrier there is no ouput at the detector. Briefly T1 converts the f.m. signal to a.m. and when rectified the output is still zero because they would be equal but opposite in polarity, if modulation is applied then there is a shift in the phase of the input component with a corresponding difference in the signals out of the diodes. The difference between these outputs is the audio.

As an aside, this is somewhat similar to some Automatic Fine Tuning (A.F.T.) schemes in some a.m. receivers, notably early T.V. receivers. With no frequency variation there is no output, with frequency drift there will be an output difference (in either direction) which is amplified and applied to front end tuning diodes for correction.

The Foster-Seeley discriminator is a widely used FM detector. The detector consists of a special center-tapped transformer feeding two diodes in a full wave DC rectifier circuit. When the input transformer is tuned to the signal frequency, the output of the discriminator is zero. When there is no deviation of the carrier, both halves of the center tapped transformer are balanced. As the FM signal swings in frequency above and below the carrier frequency, the balance between the two halves of the center-tapped secondary is destroyed and there is an output voltage proportional to the frequency deviation.

The ratio detector is a variant of the Foster-Seeley discriminator, but one diode conducts in an opposite direction. The output in this case is taken between the sum of the diode voltages and the center tap. The output across the diodes is connected to a large value capacitor, which eliminates AM noise in the ratio detector output. While distinct from the Foster-Seeley discriminator, the ratio detector will similarly not respond to AM signals, however the output is only 50% of the output of a discriminator for the same input signal.

The phase-locked loop detector requires no frequency-selective LC network to accomplish demodulation. In this system, a voltage controlled oscillator (VCO) is phase locked by a feedback loop, which forces the VCO to follow the frequency variations of the incoming FM signal. The low-frequency error voltage that forces the VCO's frequency to track the frequency of the modulated FM signal is the demodulated audio output.

Receiving SSB and CW

- The **SSB/CW receiver** is very similar to an AM receiver up to the IF Amplifier.
- Instead of a Detector however, the SSB/CW receiver uses two different stages:
  - **Product Detector**
  - **Beat Frequency Oscillator (BFO).**

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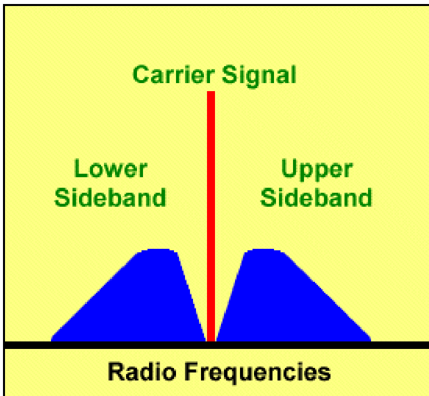
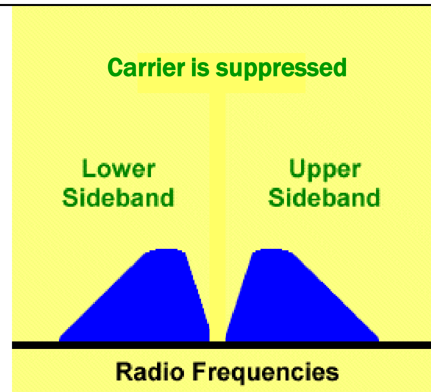


Amplitude Modulation



Double Sideband Suppressed Carrier

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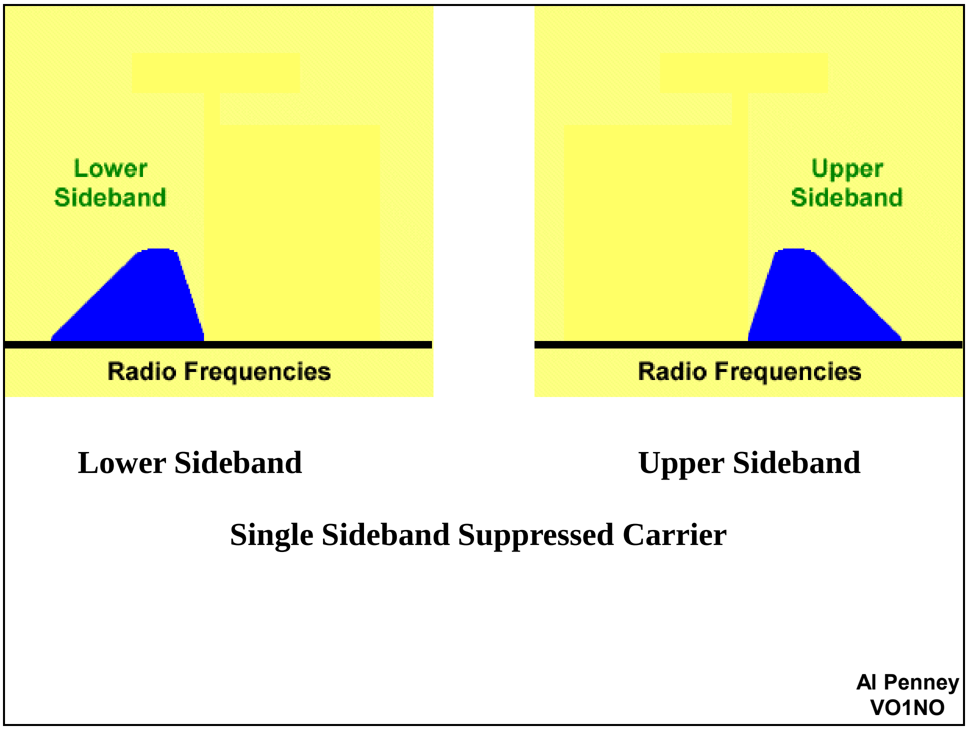
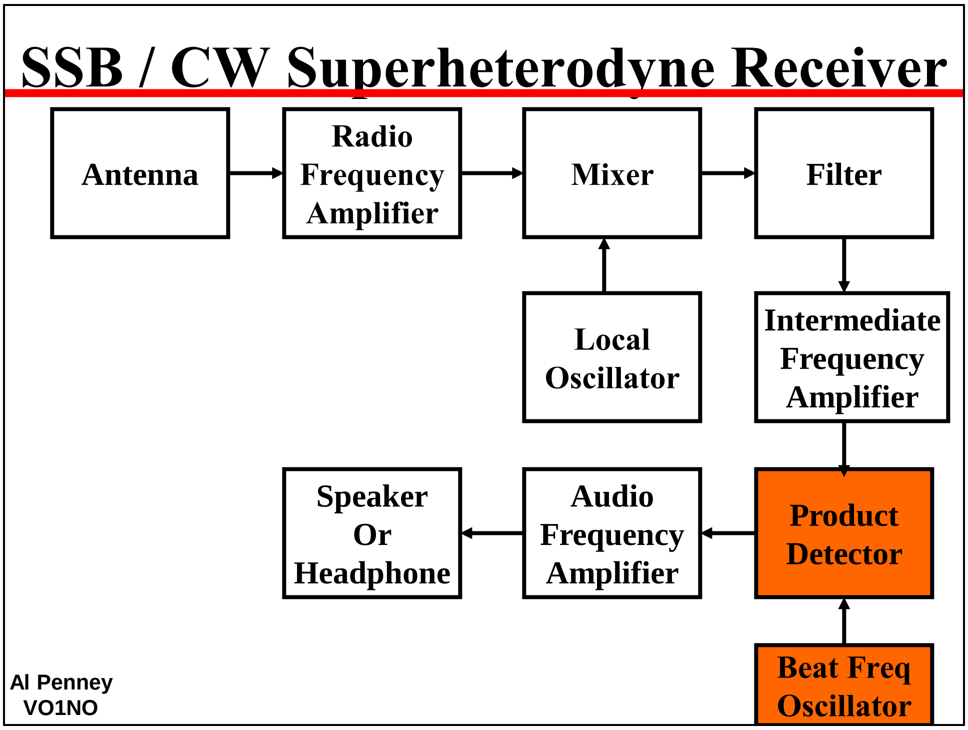


SSB demodulation basics

As described in previous pages, single sideband is a form of amplitude modulation where the carrier and one sideband have been suppressed or reduced in level.


SSB / CW Superheterodyne Receiver
Antenna
Radio Frequency Amplifier
Mixer
Filter
Local Oscillator
Intermediate Frequency Amplifier
Speaker Or Headphone
Audio Frequency Amplifier
Product Detector
Beat Freq Oscillator
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Product Detector

- Because the **carrier** has been **removed** from an SSB transmission, it **must be re-inserted** so that the original audio can be recovered.
- This is accomplished using the **Product Detector.**
- The **source** of the **carrier** is the **Beat Frequency Oscillator (BFO).**

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A product detector is a type of demodulator used for AM and SSB signals, where the original carrier signal is removed. Rather than converting the envelope of the signal into the decoded waveform like an envelope detector, the product detector takes the product of the modulated signal and a local oscillator, hence the name. At least partially, it mixes the signal with the output of the local oscillator. This can be accomplished by heterodyning. The received signal is mixed, in some type of nonlinear device, with a signal from the local oscillator, to produce an intermediate frequency, referred to as the beat frequency, from which the modulating signal is detected and recovered.

SSB demodulation basics

As described in previous pages, single sideband is a form of amplitude modulation where the carrier and one sideband have been suppressed or reduced in level.

In order to demodulate single sideband, SSB, it is necessary to reintroduce the carrier. To achieve this two main elements are required:

•***Oscillator:*** The oscillator signal is needed to provide the locally produced carrier signal to re-introduce into the signal. When used in conjunction with SSB demodulation the oscillator may be referred to by other names:

•*Beat frequency oscillator, BFO:* This term dates back to the time when a local oscillator was used to produce a beat note when used with Morse code. The same type of oscillator was used for SSB demodulation and the term persisted.

•*Carrier insertion oscillator, CIO:* This name is very self explanatory and indicates it is used to re-insert the carrier. It is a more correct term than BFO, but not was widely used.

•***Mixer:*** The mixer is used to mix the local oscillator signal and the incoming single sideband signal together. The output from the mixer is the demodulated audio signal.

•*Product detector:* This term emanates from the fact that the output is a product of the inputs – exactly what is required for SSB demodulation. Producing a product or multiplication of the value of the inputs is the function of a mixer, but the term product detector was used in the early days of the use of SSB, and has remained in use, although it is less widely used than it was previously.

Receiving SSB

When receiving SSB it is necessary to have a basic understanding of how a receiver works. Most radio receivers that will be used to receive SSB modulation will be of the superheterodyne type. Here the incoming signals are converted down to a fixed intermediate frequency. It is at this stage where the BFO signal is mixed with the incoming SSB signals.

It is necessary to set the BFO to the correct frequency to receive the form of SSB, either LSB or USB, that is expected. Many radio receivers will have a switch to select this, other receivers will have a BFO pitch control which effectively controls the frequency. The BFO needs to be positioned to be in the correct position for when the signal is in the centre of the receiver passband. This typically means that it will be on the side of the passband of the receiver. To position the BFO, tune the SSB signal in for the optimum strength, i.e. ensure it is in the centre of the passband, and then adjust the BFO frequency for the correct pitch of the signal. Once this has been done, then the main tuning control of the receiver can be used, and once a signal is audible with the correct pitch, then it is also in the centre of the receiver passband.

Tuning an SSB signal with the BFO set is quite easy. First set the receiver to the SSB position or the BFO to ON, and then if there is a separate switch set the LSB / USB switch to the format that is expected and then gradually tune the receiver. Adjust the main tuning control so that the pitch is correct, and the signal should be comprehensible. If it is not possible to distinguish the sounds, then set the LSB / USB switch to the other position and re-adjust the main tuning control if necessary to return the signal to the correct pitch, at which point the signal should be understandable..

With a little practice it should be possible to easily tune in SSB signals.

Beat Frequency Oscillator (BFO)

- The **BFO** is an **oscillator** that replaces the **carrier** in an **SSB transmission.**
- **CW transmissions** also require a carrier to **“beat” against (mix with)** to produce an **audio tone.**
- Older receivers use a BFO that could be **varied in frequency** as the **operating mode** is changed from **USB to LSB to CW.**
- Modern radios **automatically switch** the **operating frequency** of the BFO as the mode is changed.

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In a radio receiver, a **beat frequency oscillator** or **BFO** is a dedicated oscillator used to create an audio frequency signal from Morse code radiotelegraphy (CW) transmissions to make them audible. The signal from the BFO is mixed with the received signal to create a heterodyne or beat frequency which is heard as a tone in the speaker. BFOs are also used to demodulate single-sideband (SSB) signals, making them intelligible, by essentially restoring the carrier that was suppressed at the transmitter. BFOs are sometimes included in communications receivers designed for short wave listeners; they are almost always found in communication receivers for amateur radio, which often receive CW and SSB signals.

The beat frequency oscillator was invented in 1901 by Canadian engineer Reginald Fessenden. What he called the "heterodyne" receiver was the first application of the heterodyne principle.

Overview

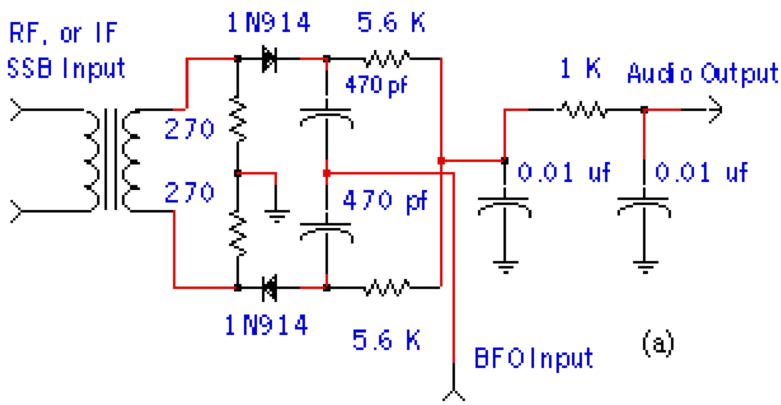
In continuous wave (CW) radio transmission, also called radiotelegraphy or on-off keying and designated by the International Telecommunication Union as emission type A1A, information is transmitted by pulses of unmodulated radio carrier wave which spell out text messages in Morse code. The different length pulses of carrier, called "dots" and "dashes" or "dits" and "dahs", are produced by the operator switching the transmitter on and off rapidly using a switch called a telegraph key. This was the first type of radio transmission, and during the early 20th century was widely used for private person-to-person messages by amateurs and commercial telegram traffic. With the rise of other types of modulation its use has declined, and CW is now only used for personal hobbyist messages by radio amateurs and is otherwise obsolete.

Since the pulses of carrier have no audio modulation, a CW signal received by an AM radio receiver simply sounds like silence.[3] In order to make the carrier pulses audible in the receiver, a beat frequency oscillator is used. The BFO is a radio frequency electronic oscillator that generates a constant sine wave at a frequency f_{BFO} that is offset from the intermediate frequency f_{IF} of the receiver. This signal is mixed with the IF before the receiver's second detector (demodulator). In the detector the two frequencies add and subtract, and a beat frequency (heterodyne) in the audio range results at the difference between them: $f_{audio} = |f_{IF} - f_{BFO}|$ which sounds like a tone in the receiver's speaker. During the pulses of carrier, the beat frequency is generated, while between the pulses there is no carrier so no tone is produced. Thus the BFO makes the "dots" and "dashes" of the Morse code signal audible, sounding like different length "beeps" in the speaker. A listener who knows Morse code can decode this signal to get the text message.

The first BFOs, used in early tuned radio frequency (TRF) receivers in the 1910s-1920s, beat with the carrier frequency of the station. Each time the radio was tuned to a different station frequency, the BFO frequency had to be changed also, so the BFO oscillator had to be tunable across the entire frequency band covered by the receiver.

Since in a superheterodyne receiver the different frequencies of the different stations are all translated to the same intermediate frequency (IF) by the mixer, modern BFOs which beat with the IF need only have a constant frequency. There may be a switch to turn off the BFO when it is not needed, when receiving other types of signals, such as AM or FM. There is also usually a knob on the front panel to adjust the frequency of the BFO, to change the tone over a small range to suit the operator's preference.

Product Detector



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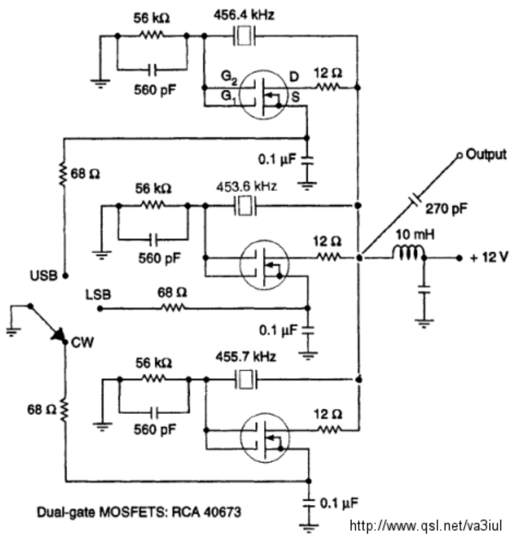
A product detector is a mixer used to down convert an input signal to baseband. The term, product detector, is normally used when referring to single sideband (SSB), or double sideband (DSB) demodulation, or continuous wave (CW). Essentially, it is a detector whose output is approximately equal to the product of the beat-frequency oscillator (BFO) and the RF signals applied to it. Output from the product detector is at audio frequency. Some RF filtering may be necessart at the detector output to prevent unwanted IF or BFO voltage from reaching the audio amplifier which follows the detector. In figure 2, a product detector is used to demodulate a SSB signal. The lowpass filter that follows the mixer passes only the down conversion, or difference, frequency band. Since the SSB, or DSB, signal is transmitted with no carrier, or with a supressed carrier, the frequency of the re-injected carrier in figure 2 will not be exactly the same as that of the carrier that was suppressed in the generation of the SSB, or DSB, signal. If the frequency of the re-injected carrier is not sufficiently close, then the output audio will appear to have a "Donald Duck" quality as a result of all the demodulated frequencies being in error by a constant offset.

Beat Frequency Oscillator



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Audio Filters

- Hams sometimes employed **active or passive external audio filters** with older receivers in an effort to **remove interference** and **improve selectivity.**
- A **Notch Filter** can be used to **remove an interfering carrier signal** (ie: CW signal).
- To **improve CW selectivity,** an audio **bandpass filter** for **750 – 850 Hz** would be appropriate.
- Modern radios incorporate **DSP techniques** even more effectively, at the **IF stages** rather than the audio stages.

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MFJ- 784B DSP Filter

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Signal Strength Meters

- An **S-Meter** enables you to make comparisons between received signals.
- Unfortunately, even on identical receivers, most S-meters are **not properly calibrated** and will give **different readings** when using the same antenna.
- The scale is divided into **9 increments**, designated **S0 to S9,** up to the **center point of the meter.** The scale is then **graduated in dB,** usually in multiples of 10.
- A **signal strength report** would be **"S6"** or **"S9 plus 15 dB".**

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An **S meter** (signal strength meter) is an indicator often provided on communications receivers, such as amateur radio receivers or shortwave broadcast receivers. The scale markings are derived from a system of reporting signal strength from S1 to S9 as part of the R-S-T system. The term **S unit** can be used to refer to the amount of signal strength required to move an S meter indication from one marking to the next.

Technical description

Analogue S meters are actually sensitive microammeters, with a full scale deflection of 50 to 100 μA. In AM receivers, the S meter can be connected to the main detector or use a separate detector at the final IF stage. This is the preferred method for CW and SSB receivers. Another approach in the days of electronic tubes (valves) was to connect the S meter to the screen grid circuit of the final IF amplifier tube. A third option is to connect the S meter to the AGC line through a suitable level conversion circuit.

In FM receivers, the S meter circuit must be connected to the IF chain before any limiter stages.

In the 1930s, it was already agreed that S9 corresponds to 50 μV at the input terminal of the receiver, but this was not a measure of the power received as the input impedance of receivers was not standardized.

The International Amateur Radio Union (IARU) Region 1 agreed on a technical recommendation for S Meter calibration for HF and VHF/UHF transceivers in 1981.

IARU Region 1 Technical Recommendation R.1 defines S9 for the HF bands to be a receiver input power of -73 dBm. This is a level of 50 microvolts at the receiver's antenna input **assuming** the input impedance of the receiver is 50 ohms.

For VHF bands the recommendation defines S9 to be a receiver input power of -93 dBm. This is the equivalent of 5 microvolts in 50 ohms.

The recommendation defines a difference of one S-unit corresponds to a difference of 6 decibels (dB), equivalent to a voltage ratio of two, or power ratio of four.

Signals stronger than S9 are given with an additional dB rating, thus "S9 + 20dB", or, verbally, "20 decibels over S9", or simply "20 over 9" (or even the simpler "20 over").

Accuracy

Most S meters on traditional analog receivers are not calibrated and in practice can only provide a relative measure of signal strength based on the receiver's AGC voltage. Some S meters on traditional analog receivers are calibrated to read S9 for an input of -73 dBm but do not provide the correct 6 dB per S unit correspondence.

Often the correlation between a radio listener's qualitative impression of signal strength and the actual strength of the received signal on an analog receiver is poor, because the receiver's AGC holds the audio output fairly constant despite changes in input signal strength.

SDRs (Software Defined Radios) acquire and process signals differently, and determine S-readings by direct measurement of RF signal amplitude. Consequently, many SDR systems with bit depths of 14-bits or more are accurately calibrated from one end of the S scale to the other right out of the box. In cases where this is not so, a few minutes with a signal generator to set the reference level are all that is required. Low bit depth SDRs such as an 8-bit design can be somewhat accurate, but as they distinguish much coarser differences in input levels, precision at the low end of the S scale will suffer.

Even with a high quality SDR, it is worth keeping in mind that the S meter is measuring the strength of the signal at the 50 ohm input of the receiver, *not* at the antenna. For example, if the radio's input is 50 ohms, but the antenna's impedance is significantly higher, power transfer from the antenna into the radio will suffer, and signal levels will be lower than if they were fed to an input with a matching high impedance. Many antennas vary in impedance over various frequency ranges, particularly in the case of wideband designs. What is useful to know is that the relative signal strengths at any one frequency will remain meaningful, even if they are not from one frequency to another.

S-Meter Standards

- According to the standards adopted by the **International Amateur Radio Union (IARU)** in 1981, **S9 corresponds to a signal strength of 50 microvolts at the receiver's 50 ohm impedance antenna input.**
- Each **S unit** then reflects a **6dB change in signal strength.**
- This is **rarely achieved,** as S-meters are often **not linear in their response.**
- Still, they give a relative indication of signal strengths!

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S-Meter

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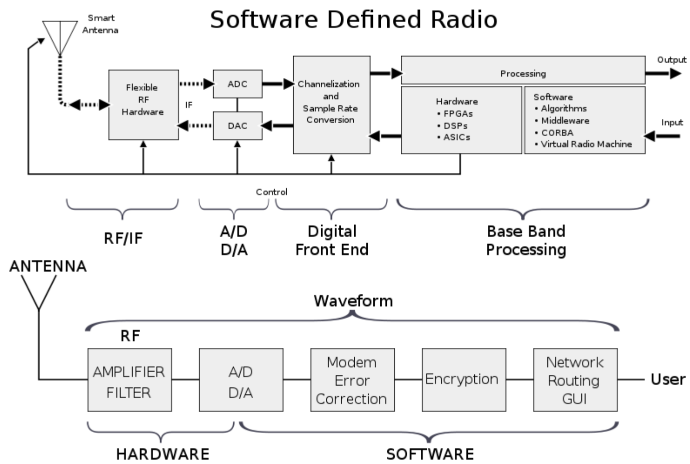
Software Defined Radios



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Software-defined radio (**SDR**) is a radio communication system where components that have been traditionally implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system. While the concept of SDR is not new, the rapidly evolving capabilities of digital electronics render practical many processes which were once only theoretically possible.

A basic SDR system may consist of a personal computer equipped with a sound card, or other analog-to-digital converter, preceded by some form of RF front end. Significant amounts of signal processing are handed over to the general-purpose processor, rather than being done in special-purpose hardware (electronic circuits). Such a design produces a radio which can receive and transmit widely different radio protocols (sometimes referred to as waveforms) based solely on the software used.

Software radios have significant utility for the military and cell phone services, both of which must serve a wide variety of changing radio protocols in real time.

In the long term, software-defined radios are expected by proponents like the SDRForum (now The Wireless Innovation Forum) to become the dominant technology in radio communications. SDRs, along with software defined antennas are the enablers of the cognitive radio.

A software-defined radio can be flexible enough to avoid the "limited spectrum" assumptions of designers of previous kinds of radios, in one or more ways including:

•Spread spectrum and ultrawideband techniques allow several transmitters to transmit in the same place on the same frequency with very little interference, typically combined with one or more error detection and correction techniques to fix all the errors caused by that interference.

•Software defined antennas adaptively "lock onto" a directional signal, so that receivers can better reject interference from other directions, allowing it to detect fainter transmissions.

•Cognitive radio techniques: each radio measures the spectrum in use and communicates that information to other cooperating radios, so that transmitters can avoid mutual interference by selecting unused frequencies. Alternatively, each radio connects to a geolocation database to obtain information about the spectrum occupancy in its location and, flexibly, adjusts its operating frequency and/or transmit power not to cause interference to other wireless services.

•Dynamic transmitter power adjustment, based on information communicated from the receivers, lowering transmit power to the minimum necessary, reducing the near-far problem and reducing interference to others, and extending battery life in portable equipment.

•Wireless mesh network where every added radio increases total capacity and reduces the power required at any one node. Each node transmits using only enough power needed for the message to hop to the nearest node in that direction, reducing the near-far problem and reducing interference to others.

Understanding the Software Defined Radio Receiver SDR

The software designed radio receiver, SDR uses software to perform many of the basic functions of the receiver - using software it is easy to reconfigure and use the software on many platforms and for many different functions

Software defined radio technology has advanced significantly in recent years. Advances in hardware mean that costs have fallen and performance has rise.

This means that software defined radios are now seen in everything from high end radio communications equipment, to the simple USB plug in modules available at very low cost.

The software defined radio, SDR, technology is able to provide some significant advantages over traditional hardware based radio designs. Using the power of digital processing, software defined radios are being used in many different applications in many different areas.

Basic SDR concept

The basic concept of the SDR software radio is that the radio can be totally configured or defined by the software.

In an ideal world the incoming signal is immediately converted to a digital format, and the signal is then processed totally digitally.

Conversely for transmit, the signal is generated digitally, and converted to the final analogue signal at the antenna.

This approach has the advantages that the radio can be totally reconfigured for a new application, simply by changing the software. Updates can be made to keep up with new modulation formats, new applications, etc, simply by updating the software.

It also means that a common hardware platform can be used across a variety of different products and applications, thereby reducing costs, whilst maintaining or improving the performance.

Advantages and disadvantages of software defined radios

As with any technology thee are advantages and disadvantages to the use of software defined radio technology.

Advantages of SDR technology

•It is possible to achieve very high levels of performance.

•Performance can be changed by updating the software (it will not be possible to update hardware dependent attributes though).

•It is possible to reconfigure radios by updating software

•The same hardware platform can be used for several different radios.

Disadvantages of SDR technology

•Analogue to digital converters limit top frequencies that can be used by the digital section.

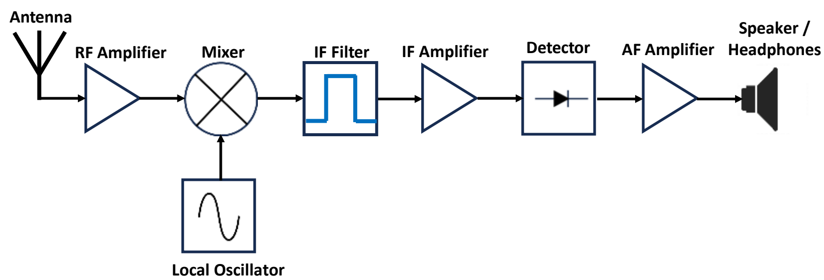
•For **very** simple radios the basic platform may be too expensive.

•Development of a software defined radio requires both hardware and software skills.

Software defined radios are being used increasingly. As processing power becomes cheaper to implement, so SDR based radios are being increasingly used for high end applications and also increasingly they are moving into lower end radios as well.

One of the major advantages of SDR technology is that it can be configured to exactly meet the requirements of the user - small changes to the software can make the radio fit the requirements exactly. Also with open source software like the GNU software, it is becoming increasingly easy to implement.

Superheterodyne AM Receiver



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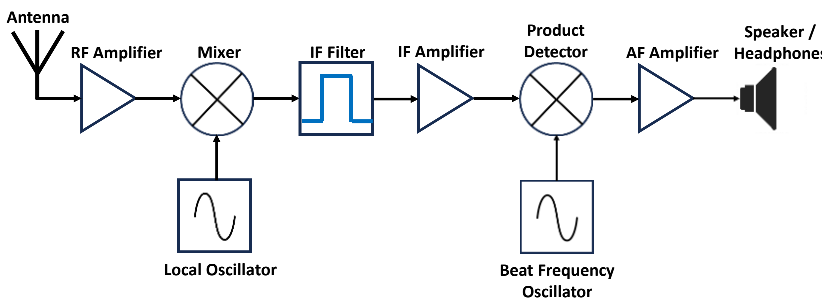
Superheterodyne SSB/CW Receiver



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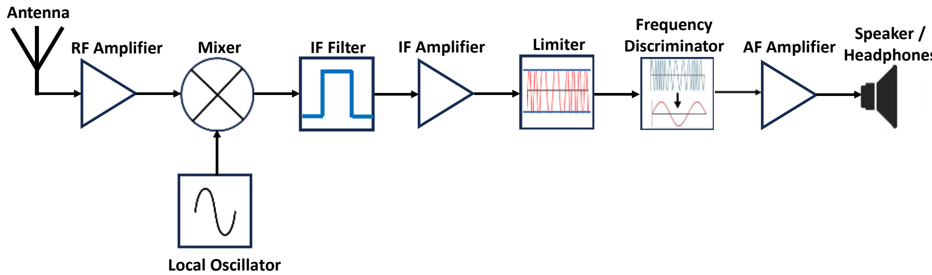
Superheterodyne FM Receiver



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Kenwood TS-850 Transceiver

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Kenwood TS-850 Transceiver

Kenwood TS-850 Transceiver

Questions?


RACAL
G7VOT
MEGACYCLES
METER
MAINS
A.F. GAIN
AE ATTENUATOR
Al Penney
VO1NO

For Next Class:

- Review Chapter 14 of Basic Study Guide;
- Read Chapter 15 of Basic Study Guide; and
- Go through the Question Bank.

Al Penney
VO1NO

Review Question 1

In a frequency modulation receiver, the is connected to the input of the radio frequency amplifier.

- mixer
- frequency discriminator
- limiter
- antenna

Al Penney
VO1NO

Review Question 1

In a frequency modulation receiver, the is connected to the input of the radio frequency amplifier.

- mixer
- frequency discriminator
- limiter
- antenna

< antenna >

Al Penney
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Review Question 2

In a frequency modulation receiver, the is in between the antenna and the mixer.

- audio frequency amplifier
- local oscillator
- intermediate frequency amplifier
- radio frequency amplifier

Al Penney
VO1NO

Review Question 2

In a frequency modulation receiver, the is in between the antenna and the mixer.

• audio frequency amplifier

• local oscillator

• intermediate frequency amplifier

• radio frequency amplifier

< radio frequency amplifier >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

Al Penney
VO1NO

Review Question 3

In a frequency modulation receiver, the output of the local oscillator is fed to the:

- limiter
- antenna
- mixer
- radio frequency amplifier

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VO1NO

Review Question 3

In a frequency modulation receiver, the output of the local oscillator is fed to the:

- limiter
- antenna
- mixer
- radio frequency amplifier

< mixer >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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VO1NO

Review Question 4

In a frequency modulation receiver, the output of the is connected to the mixer.

- local oscillator
- frequency discriminator
- intermediate frequency amplifier
- speaker or headphones

Al Penney
VO1NO

Review Question 4

In a frequency modulation receiver, the output of the is connected to the mixer.

• local oscillator

• frequency discriminator

• intermediate frequency amplifier

• speaker or headphones

< local oscillator >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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VO1NO

Review Question 5

In a frequency modulation receiver, the is in between the mixer and the intermediate frequency amplifier.

- limiter
- frequency discriminator
- radio frequency amplifier
- filter

Al Penney
VO1NO

Review Question 5

In a frequency modulation receiver, the is in between the mixer and the intermediate frequency amplifier.

- limiter
- frequency discriminator
- radio frequency amplifier
- filter

< filter >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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VO1NO

Review Question 6

In a frequency modulation receiver, the is located between the filter and the limiter.

- mixer
- radio frequency amplifier
- intermediate frequency amplifier
- local oscillator

Al Penney
VO1NO

Review Question 6

In a frequency modulation receiver, the is located between the filter and the limiter.

• mixer

• radio frequency amplifier

• intermediate frequency amplifier

• local oscillator

< intermediate frequency amplifier >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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VO1NO

Review Question 7

In a frequency modulation receiver, the is in between the intermediate frequency amplifier and the frequency discriminator.

- radio frequency amplifier
- limiter
- filter
- local oscillator

Al Penney
VO1NO

Review Question 7

In a frequency modulation receiver, the is in between the intermediate frequency amplifier and the frequency discriminator.

• radio frequency amplifier

• limiter

• filter

• local oscillator

< limiter >

Note: Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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VO1NO

Review Question 8

In a frequency modulation receiver, the. is located between the limiter and the audio frequency amplifier.

- speaker or headphones
- local oscillator
- frequency discriminator
- intermediate frequency amplifier

Al Penney
VO1NO

Review Question 8

In a frequency modulation receiver, the. is located between the limiter and the audio frequency amplifier.

- speaker or headphones
- local oscillator
- frequency discriminator
- intermediate frequency amplifier

< frequency discriminator >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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VO1NO

Review Question 9

In a frequency modulation receiver, the is located between the speaker or headphones and the frequency discriminator.

- intermediate frequency amplifier
- radio frequency amplifier
- audio frequency amplifier
- limiter

Al Penney
VO1NO

Review Question 9

In a frequency modulation receiver, the is located between the speaker or headphones and the frequency discriminator.

- intermediate frequency amplifier
- radio frequency amplifier
- audio frequency amplifier
- limiter

< audio frequency amplifier >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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VO1NO

Review Question 10

In a frequency modulation receiver, the connects to the audio frequency amplifier output.

- intermediate frequency amplifier
- frequency discriminator
- limiter
- speaker or headphones

Al Penney
VO1NO

Review Question 10

In a frequency modulation receiver, the connects to the audio frequency amplifier output.

• intermediate frequency amplifier

• frequency discriminator

• limiter

• speaker or headphones

< speaker or headphones >

Note: In the 8th Ed./First Printing 9th Ed. the LO is called the HFO

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Review Question 11

In a single sideband and CW receiver, the antenna is connected to the .

- local oscillator
- intermediate frequency amplifier
- radio frequency amplifier
- product detector

Al Penney
VO1NO

Review Question 11

In a single sideband and CW receiver, the antenna is connected to the .

- local oscillator
- intermediate frequency amplifier
- radio frequency amplifier
- product detector

< radio frequency amplifier >

Al Penney
VO1NO

Review Question 12

In a single sideband and CW receiver, the output of the is connected to the mixer.

- radio frequency amplifier
- filter
- intermediate frequency amplifier
- audio frequency amplifier

Al Penney
VO1NO

Review Question 12

In a single sideband and CW receiver, the output of the is connected to the mixer.

• radio frequency amplifier

• filter

• intermediate frequency amplifier

• audio frequency amplifier

< radio frequency amplifier >

Al Penney
VO1NO

Review Question 13

In a single sideband and CW receiver, the is connected to the radio frequency amplifier and the local oscillator.

- mixer
- beat frequency oscillator
- product detector
- filter

Al Penney
VO1NO

Review Question 13

In a single sideband and CW receiver, the is connected to the radio frequency amplifier and the local oscillator.

- mixer
- beat frequency oscillator
- product detector
- filter

< mixer >

Al Penney
VO1NO

Review Question 14

In a single sideband and CW receiver, the output of the is connected to the mixer.

- local oscillator
- intermediate frequency amplifier
- beat frequency oscillator
- product detector

Al Penney
VO1NO

Review Question 14

In a single sideband and CW receiver, the output of the is connected to the mixer.

• local oscillator

• intermediate frequency amplifier

• beat frequency oscillator

• product detector

< local oscillator >

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VO1NO

Review Question 15

In a single sideband and CW receiver, the is in between the mixer and intermediate frequency amplifier.

- product detector
- filter
- radio frequency amplifier
- beat frequency oscillator

Al Penney
VO1NO

Review Question 15

In a single sideband and CW receiver, the is in between the mixer and intermediate frequency amplifier.

- product detector
- filter
- radio frequency amplifier
- beat frequency oscillator

< filter >

Al Penney
VO1NO

Review Question 16

In a single sideband and CW receiver, the is in between the filter and product detector.

- radio frequency amplifier
- intermediate frequency amplifier
- audio frequency amplifier
- beat frequency oscillator

Al Penney
VO1NO

Review Question 16

In a single sideband and CW receiver, the is in between the filter and product detector.

• radio frequency amplifier

• intermediate frequency amplifier

• audio frequency amplifier

• beat frequency oscillator

< intermediate frequency amplifier >

Al Penney
VO1NO

Review Question 17

In a single sideband and CW receiver, the output is connected to the audio frequency amplifier.

- local oscillator
- beat frequency oscillator
- intermediate frequency amplifier
- product detector

Al Penney
VO1NO

Review Question 17

In a single sideband and CW receiver, the output is connected to the audio frequency amplifier.

• local oscillator

• beat frequency oscillator

• intermediate frequency amplifier

• product detector

< product detector >

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VO1NO

Review Question 18

In a single sideband and CW receiver, the output of the is connected to the product detector.

• beat frequency oscillator

• mixer

• radio frequency amplifier

• audio frequency amplifier

Al Penney
VO1NO

Review Question 18

In a single sideband and CW receiver, the output of the is connected to the product detector.

- beat frequency oscillator
- mixer
- radio frequency amplifier
- audio frequency amplifier

< beat frequency oscillator >

Al Penney
VO1NO

Review Question 19

In a single sideband and CW receiver, the is connected to the output of the product detector.

- local oscillator
- radio frequency amplifier
- audio frequency amplifier
- intermediate frequency amplifier

Al Penney
VO1NO

Review Question 19

In a single sideband and CW receiver, the is connected to the output of the product detector.

• local oscillator

• radio frequency amplifier

• audio frequency amplifier

• intermediate frequency amplifier

< audio frequency amplifier >

Al Penney
VO1NO

Review Question 20

In a single sideband and CW receiver, the is connected to the output of the audio frequency amplifier.

- beat frequency oscillator
- speaker or headphones
- mixer
- radio frequency amplifier

Al Penney
VO1NO

Review Question 20

In a single sideband and CW receiver, the is connected to the output of the audio frequency amplifier.

- beat frequency oscillator
- speaker or headphones
- mixer
- radio frequency amplifier

< speaker or headphones >

Al Penney
VO1NO

Review Question 21

The figure in a receiver's specifications which indicates its sensitivity is the:

- bandwidth of the IF in kilohertz
- number of RF amplifiers
- RF input signal needed to achieve a given signal plus noise to noise ratio
- audio output in watts

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Review Question 21

The figure in a receiver's specifications which indicates its sensitivity is the:

- bandwidth of the IF in kilohertz
- number of RF amplifiers
- RF input signal needed to achieve a given signal plus noise to noise ratio
- audio output in watts

< RF input signal needed to achieve a given signal plus noise to noise ratio >

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VO1NO

Review Question 22

If two receivers of different sensitivity are compared, the less sensitive receiver will produce:

- less signal or more noise
- a steady oscillator drift
- more than one signal
- more signal or less noise

Al Penney
VO1NO

Review Question 22

If two receivers of different sensitivity are compared, the less sensitive receiver will produce:

- less signal or more noise
- a steady oscillator drift
- more than one signal
- more signal or less noise

< less signal or more noise >

Al Penney
VO1NO

Review Question 23

Which of the following modes of transmission is usually detected with a product detector?

- Double sideband full carrier
- Frequency modulation
- Pulse modulation
- Single sideband suppressed carrier

Al Penney
VO1NO

Review Question 23

Which of the following modes of transmission is usually detected with a product detector?

- Double sideband full carrier
- Frequency modulation
- Pulse modulation
- Single sideband suppressed carrier

< Single sideband suppressed carrier >

Al Penney
VO1NO

Review Question 24

A receiver designed for SSB reception must have a BFO (beat frequency oscillator) because:

• it beats with the received carrier to produce the other sideband

• it reduces the passband of the IF stages

• it phases out the unwanted sideband signal

• the suppressed carrier must be replaced for detection

Al Penney
VO1NO

Review Question 24

A receiver designed for SSB reception must have a BFO (beat frequency oscillator) because:

• it beats with the received carrier to produce the other sideband

• it reduces the passband of the IF stages

• it phases out the unwanted sideband signal

• the suppressed carrier must be replaced for detection

< the suppressed carrier must be replaced for detection >

Al Penney
VO1NO

Review Question 25

A receiver receives an incoming signal of 3.54 MHz, and the local oscillator produces a signal of 3.995 MHz. To which frequency should the IF be tuned?

- 3.995 MHz
- 3.54 MHz
- 455 kHz
- 7.435 MHz

Al Penney
VO1NO

Review Question 25

A receiver receives an incoming signal of 3.54 MHz, and the local oscillator produces a signal of 3.995 MHz. To which frequency should the IF be tuned?

- 3.995 MHz
- 3.54 MHz
- 455 kHz
- 7.435 MHz

<455 kHz >

Al Penney
VO1NO

Review Question 26

What kind of filter would you use to attenuate an interfering carrier signal while receiving an SSB transmission?

- An all pass filter
- A pi-network filter
- A notch filter
- A band pass filter

Al Penney
VO1NO

Review Question 26

What kind of filter would you use to attenuate an interfering carrier signal while receiving an SSB transmission?

- An all pass filter
- A pi-network filter
- A notch filter
- A band pass filter

< A notch filter >

Al Penney
VO1NO

Review Question 27

The three main parameters against which the quality of a receiver is measured are:

- sensitivity, selectivity and stability
- selectivity, stability and frequency range
- sensitivity, stability and cross-modulation
- sensitivity, selectivity and image rejection

Al Penney
VO1NO

Review Question 27

The three main parameters against which the quality of a receiver is measured are:

• sensitivity, selectivity and stability

• selectivity, stability and frequency range

• sensitivity, stability and cross-modulation

• sensitivity, selectivity and image rejection

< sensitivity, selectivity and stability >

Al Penney
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Review Question 28

A communications receiver has four filters installed in it, respectively designated as 250 Hz, 500 Hz, 2.4 kHz, and 6 kHz. If you were listening to single sideband, which filter would you utilize?

- 500 Hz
- 2.4 kHz
- 250 Hz
- 6 kHz

Al Penney
VO1NO

Review Question 28

A communications receiver has four filters installed in it, respectively designated as 250 Hz, 500 Hz, 2.4 kHz, and 6 kHz. If you were listening to single sideband, which filter would you utilize?

- 500 Hz
- 2.4 kHz
- 250 Hz
- 6 kHz

<2.4 kHz >

Al Penney
VO1NO

Review Question 29

A communications receiver has four filters installed in it, respectively designated as 250 Hz, 500 Hz, 2.4 kHz and 6 kHz. You are copying a CW transmission and there is a great deal of interference. Which one of the filters would you choose?

- 6 kHz
- 250 Hz
- 500 Hz
- 2.4 kHz

Al Penney
VO1NO

Review Question 29

A communications receiver has four filters installed in it, respectively designated as 250 Hz, 500 Hz, 2.4 kHz and 6 kHz. You are copying a CW transmission and there is a great deal of interference. Which one of the filters would you choose?

- 6 kHz
- 250 Hz
- 500 Hz
- 2.4 kHz

<250 Hz >

Al Penney
VO1NO

Review Question 30

Selectivity can be placed in the audio stages of a receiver by the utilization of RC active or passive audio filters. If you were to copy CW, which of the following bandpasses would you choose?

- 750 - 850 Hz
- 2100 - 2300 Hz
- 300 - 2700 Hz
- 100 - 1100 Hz

Al Penney
VO1NO

Review Question 30

Selectivity can be placed in the audio stages of a receiver by the utilization of RC active or passive audio filters. If you were to copy CW, which of the following bandpasses would you choose?

- 750 - 850 Hz
- 2100 - 2300 Hz
- 300 - 2700 Hz
- 100 - 1100 Hz

<750 - 850 Hz >

Al Penney
VO1NO

Review Question 31

In a SSB transmission, the carrier is:

• transmitted with one sideband

• inserted at the transmitter

• of no use at the receiver

• reinserted at the receiver

Al Penney
VO1NO

Review Question 31

In a SSB transmission, the carrier is:

• transmitted with one sideband

• inserted at the transmitter

• of no use at the receiver

• reinserted at the receiver

< reinserted at the receiver >

Al Penney
VO1NO

Review Question 32

To increase the level of very weak radio signals from an antenna, you would use:

- an audio amplifier
- an RF amplifier
- an RF oscillator
- an audio oscillator

Al Penney
VO1NO

Review Question 32

To increase the level of very weak radio signals from an antenna, you would use:

- an audio amplifier
- an RF amplifier
- an RF oscillator
- an audio oscillator

< an RF amplifier >

Al Penney
VO1NO

Review Question 33

One important application for diodes is recovering information from transmitted signals. This is referred to as:

- regeneration
- ionization
- biasing
- demodulation

Al Penney
VO1NO

Review Question 33

One important application for diodes is recovering information from transmitted signals. This is referred to as:

- regeneration
- ionization
- biasing
- demodulation

< demodulation >

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VO1NO

For Next Class:

- Review Chapter 14 of Basic Study Guide;
- Read Chapter 15 of Basic Study Guide; and
- Go through the Question Bank.

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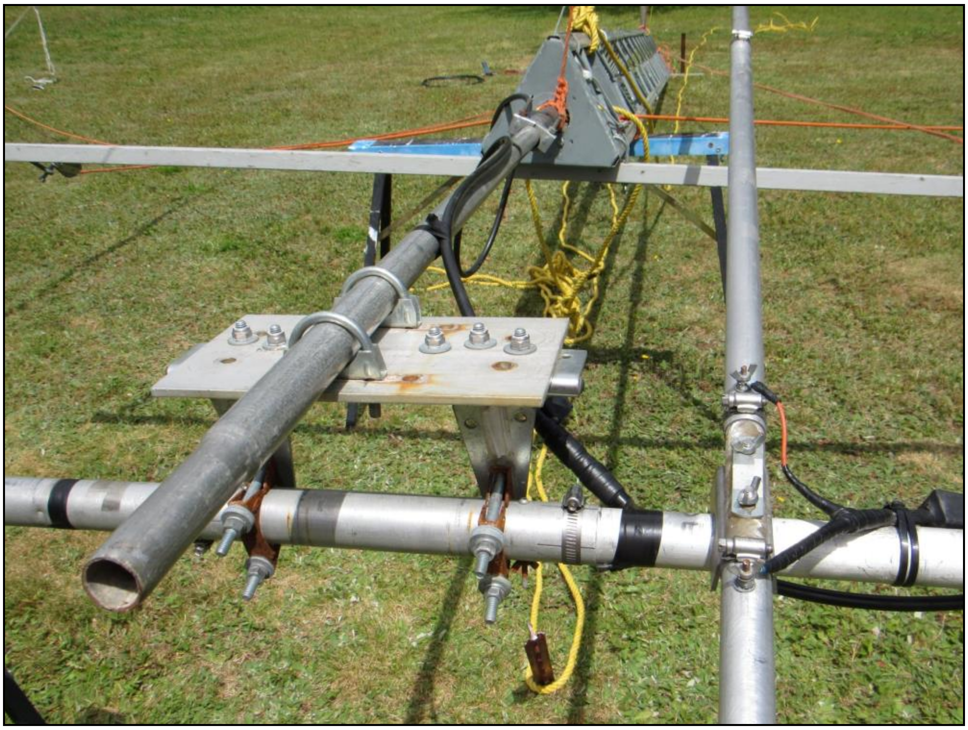
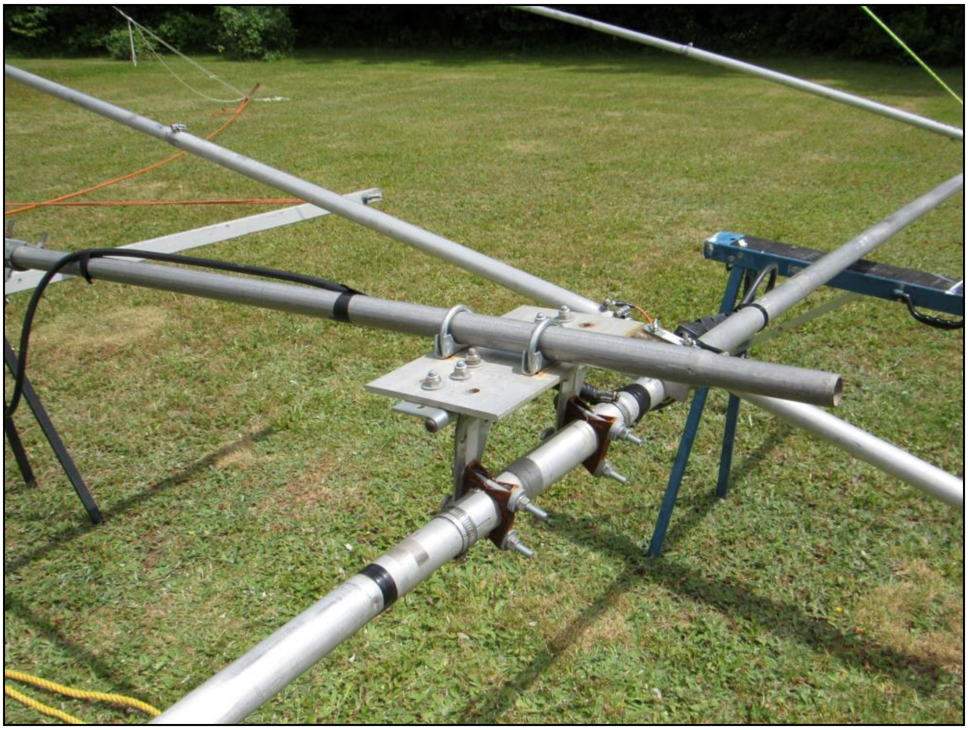
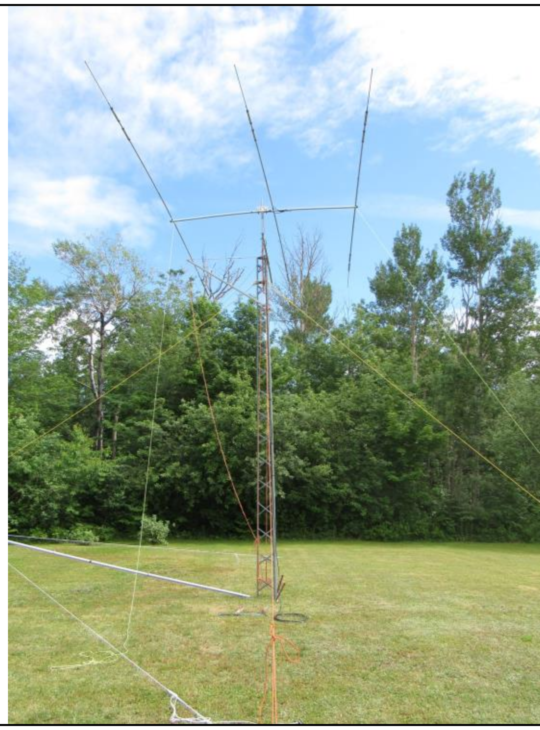
Questions?

Falling Derrick
and
Antenna Hinge Plate





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Questions?


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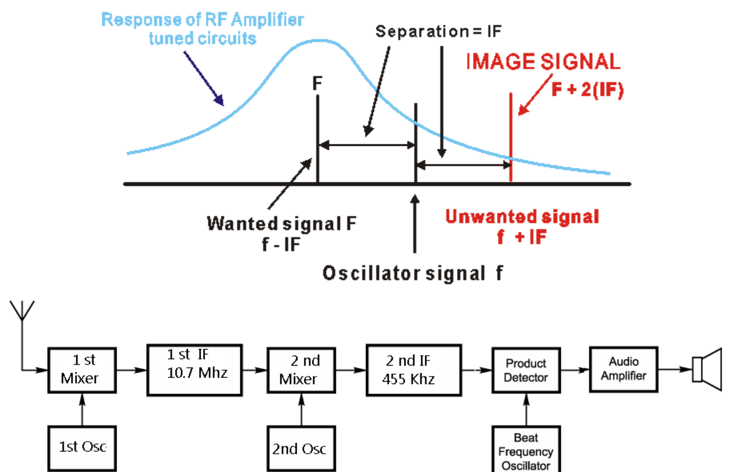

Dual Conversion Superhetrodyne Receiver Fig 7-3

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