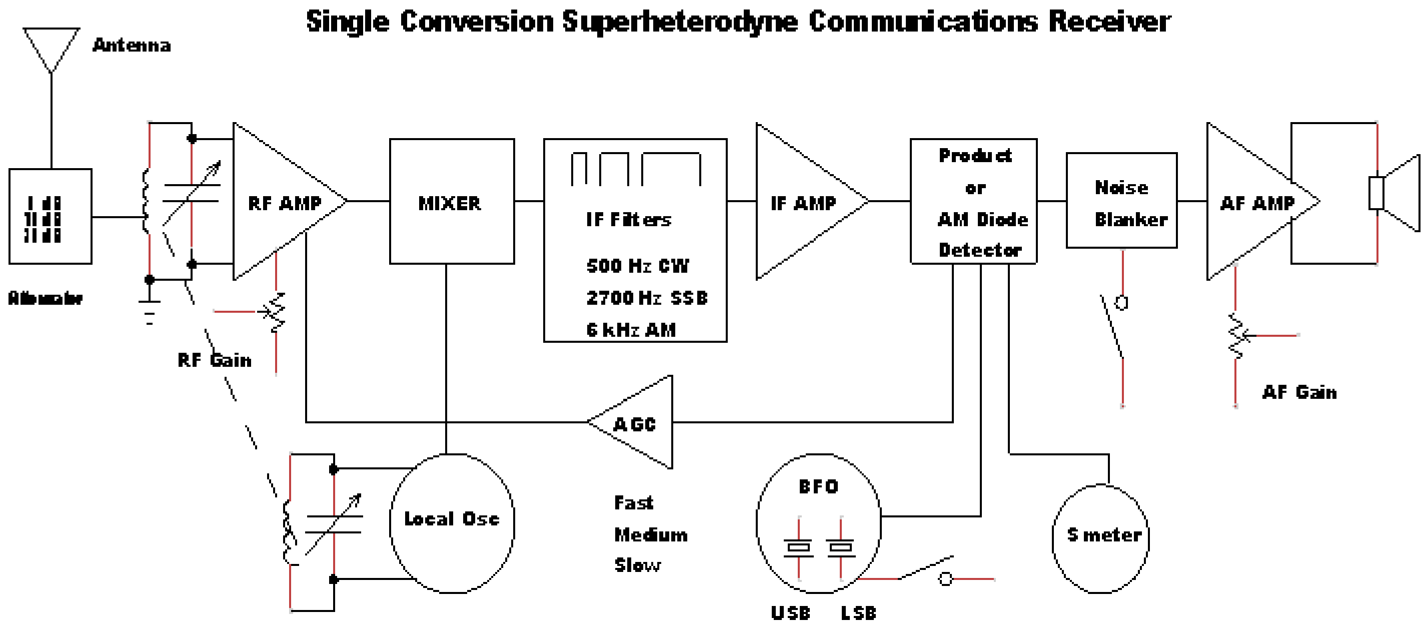
Single Conversion Superheterodyne Communications Receiver



- The **Superheterodyne receiver** is one of the most common radio receiver circuit architectures since it was invented by US engineer Edwin Armstrong in 1918.

  see http://en.wikipedia.org/wiki/Superheterodyne_receiver

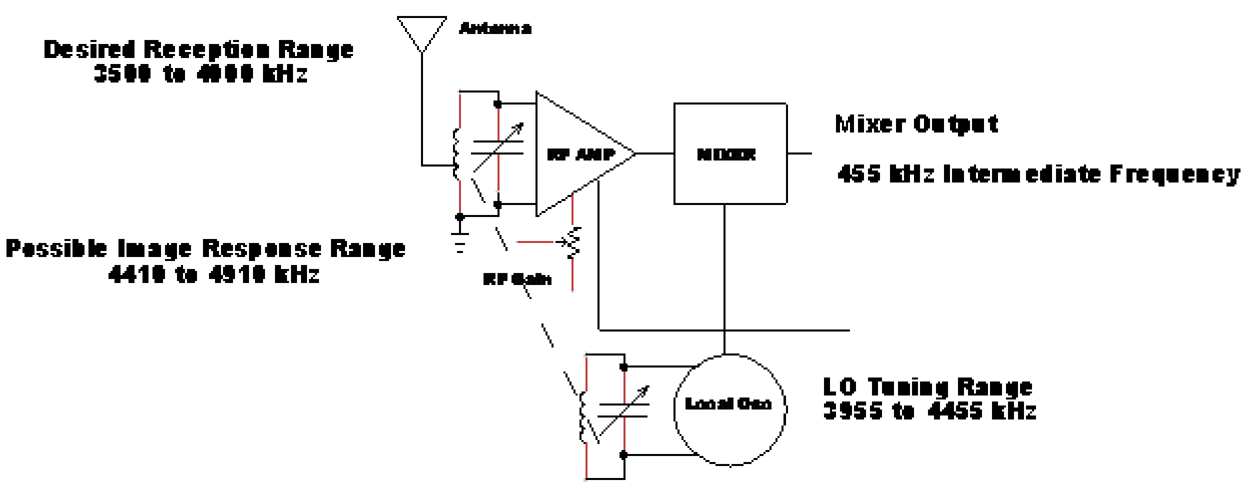
- The basic aspect of design of the **Superheterodyne** receiver is to produce a **"beat" frequency from combining two frequencies**. **The "beat" frequencies are the sum and difference of the two frequencies involved.** *see http://en.wikipedia.org/wiki/Heterodyne*

- In a **Superheterodyne** receiver, the **two frequencies** that are combined are the incoming signal from the **desired radio station** that is often amplified by the RF (radio frequency) amplifier, and the signal produced in the receiver by the **"local oscillator" or (LO)**; these **two signals are combined together in the "mixer".**

- The resultant **"beat frequency" output of the "mixer"** is called the **<u>"intermediate frequency" (IF</u>**).
- The **<u>"local oscillator" (LO)</u>** is typically a variable frequency oscillator that is the **<u>main frequency tuning control of the radio.</u>** This is most often tuned over a range of frequencies above the desired reception range of frequencies by an amount equal to the value of the "intermediate frequency" (IF) established in the design of the radio.

- Assume the IF is designed to be **<u>455 kHz</u>** and the **<u>desired reception range of the receiver is 3500 to 4000 kHz</u>**. Then **<u>the LO tuning range will be 3955 to 4455 kHz.</u>** *See question B-003-010-006.*

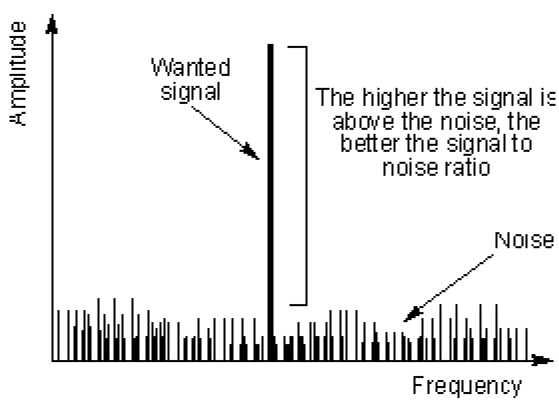
- However, in this example above, it is **<u>also possible</u>** the receiver will be able to tune (with some degree of reduced sensitivity) **<u>4410 to 4910 kHz</u>**. This **<u>undesired</u> range** of reception is known as the **<u>"image response</u>**" of the superheterodyne receiver.



- The **"Pre-selector"** uses **tuned resonant circuits** ahead of the RF amplifier to **reject out-of-band signals** such as reception of **unwanted "Image Response" frequencies**.

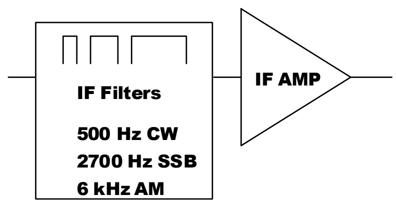
- The **RF (radio frequency) amplifier** will **provide the amplification for weak signals** and will increase the **sensitivity** of the receiver. The **amplification gain of the RF amplifier** in a good communications receiver is usually controlled by an **RF gain control.**

- The **good RF amplifier must be low in internal noise** generation since **sensitivity** of receiver is typically a **measure of an input signal level to produce a 10 dB Signal + Noise/ Noise ratio** at the output of the receiver. A typical sensitivity specification for good receiver may be given as **0.2 uV for 10 dB S+N / N .** *See questions B-003-010-002, -003, -008*



- Ahead of the RF Amplifier, **a good receiver will have an Attenuator** that prevents very strong signals from overloading the RF amplifier that may result in non-linear operation and suppressing the receive ability to receive signals through the tuning range of the receiver on a particular band. The attenuator section normally provides the user 10 or 20 dB attenuation of input signals as may be required for stable operation of the receiver.

- In a Superheterodyne circuit, the "IF" is normally a fixed frequency filter and amplifier system. In a communications receiver, the **IF filter bandwidth defines the "selectivity" of the receiver.**

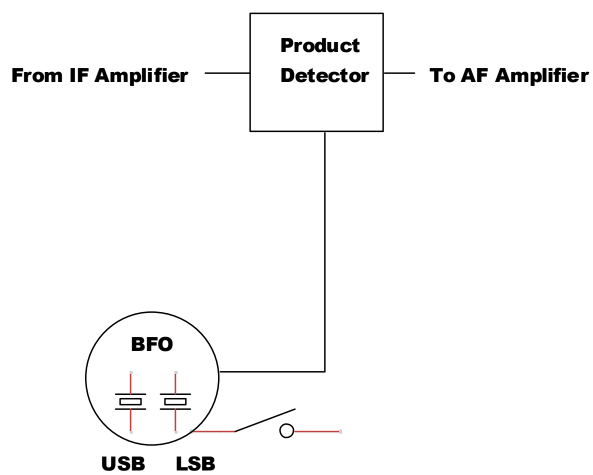


- In an ideal communications receiver, the IF will have multiple selectivity filters for different modes of operation; eg. **500 Hz is good for CW, 2.4 or 2.7 kHz is good for SSB and a 6 kHz filter would allow reception of an AM signal**. **Having insufficient selectivity for a given mode of reception means that while receiving a desired signal, you may also receive considerable interference from adjacent frequency signals.** *With reference to a radio receiver, the term IF "filter" is mentioned in exam questions: B-003-003-005, -006 -007 and B-003-005-002, -003, -005, -008 . Also see question B-003-010-008, -009 and -010*

- In modern Software Defined Radio (SDR) technology, the bandwidth of the selectivity window is often made continuously variable to the user and therefore can be adjusted for optimum performance and rejection of interference.

- The gain of the IF amplifier contributes to the overall gain of the receiver. *The IF amplifier is mentioned in exam questions B-003-005-001, -002, -004, -005, -006, -007, -009, and B-003-003-002, -004, -005, -006, -007, -008, -009, -010*

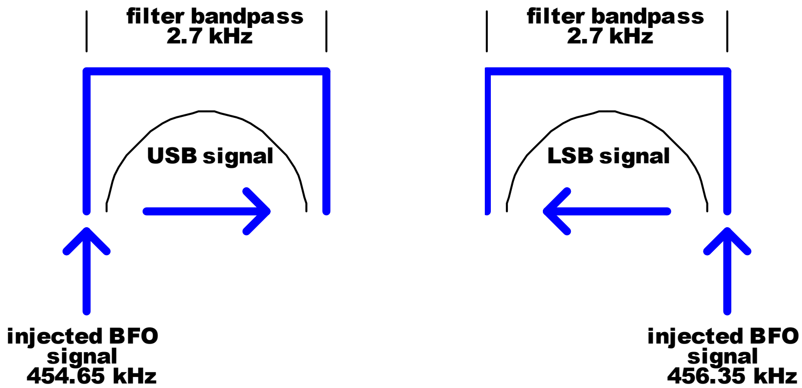
- For a CW and SSB receiver, the **IF amplifier output is fed into a "Product Detector"** which is essentially a **mixer** that **combines** the **IF signal** (at 455 kHz in this example) with a signal from the **"Beat Frequency Oscillator" (BFO)** to produce a resultant **"beat frequency"** that is audible as an output.



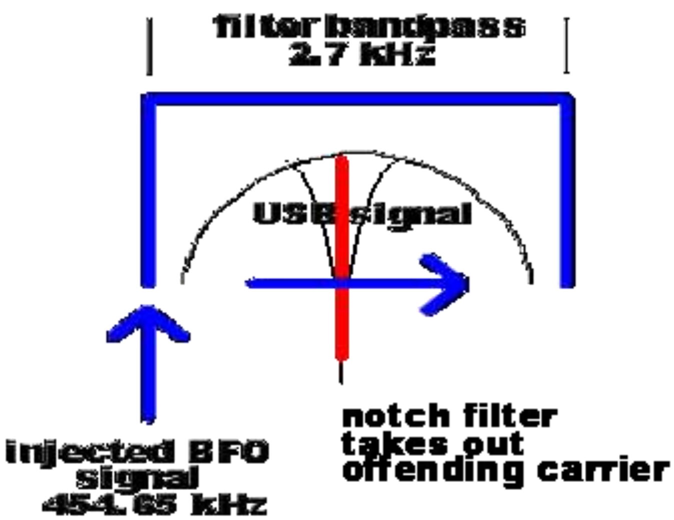
- *The exam questions mentioning the **BFO or beat frequency oscillator** include: B-003-010-005, B-003-005-010, and B-003-005-003, -004, -005, -006, -007, -008 .*

- *Similarly, exam questions that mention **product detector** include: B-003-010-004, and B-003-005-001, -003, -004, -005, -006, -007, -008, -009*

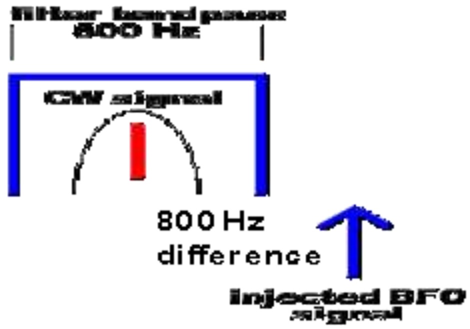
- Assuming a 2.7 kHz wide IF filter is used for SSB and the middle of bandpass is 455 kHz, then the placement of the BFO signals for USB and LSB would follow this illustration:



- An "IF" stage may incorporate a sharp notching filter, in addition to the normal IF filters. The notch filter is adjustable in frequency positioning across the IF bandpass. This "notch" filter is very selective in order to reduce a Carrier Wave signal without bothering too much, the reception of the desired SSB signal. *See question B-003-010-007 .*

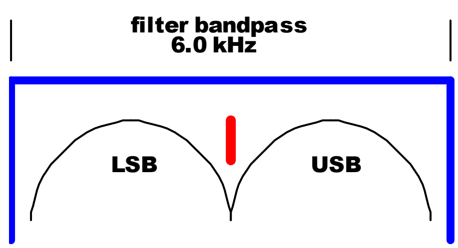


- Assuming a **500 Hz wide IF filter** is selected for **CW** reception and tuned into the middle of IF bandpass at 455 kHz.



- The **<u>difference</u>** in frequency of a **<u>CW signal in the middle of IF bandpass</u>** and the injected **<u>BFO signal</u>** will be the frequency of **<u>CW audio tone heard</u>** ; this is **<u>normally set</u>** to about **<u>800 Hz</u>** by the positioning of the BFO frequency. This is the "beat" frequency between the two.

- For an AM signal, the IF bandpass is set for 6 kHz and no BFO injection is required if a diode detector is used. The received carrier wave will remain between the two sidebands of the AM signal in the middle of the IF bandpass for proper demodulation without a BFO signal.



- An output from the product detector usually drives an **AGC (automatic gain control)** circuit. The **AGC is a feedback circuit that controls gain of the RF amplifier** (and sometimes the IF amplifier as well). **The gain of the receiver RF amplifier by the AGC is reduced for strong signals and increased for weak signals.**

- **The AGC usually has switchable recovery time constants labeled "fast", "medium" and "slow".** These switchable time constants permit the radio user to select the best AGC recovery time depending on listening circumstances. A fast recovery may be necessary when listening to both strong and weak signals in close succession. Slow recovery time periods will be typically used for a one-on-one SSB voice contact so that the noise inherent on the frequency is muted between pauses in speech. Most receivers also allow the AGC to be turned off completely. The AGC recovery time constants for **fast, medium and slow** may be in the order of **50 ms, 250 ms and 1 second** respectively.

- *The information here about receiver AGC is supplemental; there are no direct questions on the Basic exam about AGC.*

- A good receiver will typically have some sort of **Noise Blanker** that "**tries" to suppress impulse noise**. This may be a circuit that simply "clips" the tops and bottoms from the desired audio wave on which noise pulses are superimposed. More sophisticated noise suppression circuits use fast attack and adjustable electronic techniques to actually attenuate the noise spike waveform based on its anticipated pulse width. Other systems use sophisticated digital signal processing techniques that are beyond the scope of this discussion. ***The term "Noise Blanker" is only mentioned in question B-001-007-008 and is not part of the right answer.***

- The last stage of the superheterodyne is the **<u>Audio Frequency (AF) Amplifier.</u>** This stage increases the output of the detector to a sufficient amount to power a **<u>loud speaker or set of earphones</u>** which are the devices that have acoustic connection to the radio user**.** The **<u>AF amplifier</u>** will be fitted with an **<u>AF Gain Control</u>** often called a **Volume Control**. *Many exam questions and answers will mention "Audio Frequency Amplifier" including: B-003-003-002, -008, -009, -010, and B-003-005-002, -006, -007, -008, -009, -010 .*

- An "S" meter is not shown in the block diagram of the communications receiver at the head of this chapter. Ideally, the "S" meter will be calibrated so that S "9" equates to 50 uV or - 73 dBm signal level (across the 50 ohm impedance of the receiver antenna connections) . On a good communications receiver, any change to the RF gain control or receiver attenuator should not affect the reading of input signal level on the "S" meter. Not all receivers have design compensation for maintaining good "S" meter accuracy.

<u>**Single conversion vs Double conversion**</u>

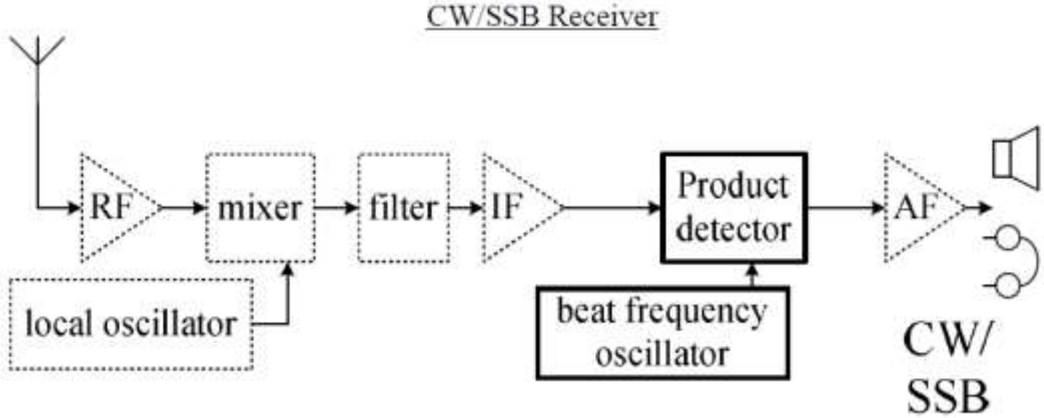
- Some receivers are designed with two (or more) stages of conversion where there are multiple mixers, local oscillators and intermediate frequencies before detection and resolving modulation intelligence.

- One of the main reasons for double conversion is to have a relatively high "intermediate frequency" as the first "IF", followed by conversion to a lower second "intermediate frequency".

- A <u>**higher first IF frequency**</u> makes it <u>**easier to reduce the "image" response**</u> to unwanted frequencies by producing a **greater separation between the desired reception range of frequencies and those of the unwanted reception range of the "image response"** . Front end "pre-selectors" are only "so selective" and therefore, are more effective when the first "IF" is high.

- *There are no questions on the Basic exam dealing with Single vs Double conversion design in radio superheterodyne receivers.*

The exam questions are based on a simpler block diagram for the CW / SSB receiver.

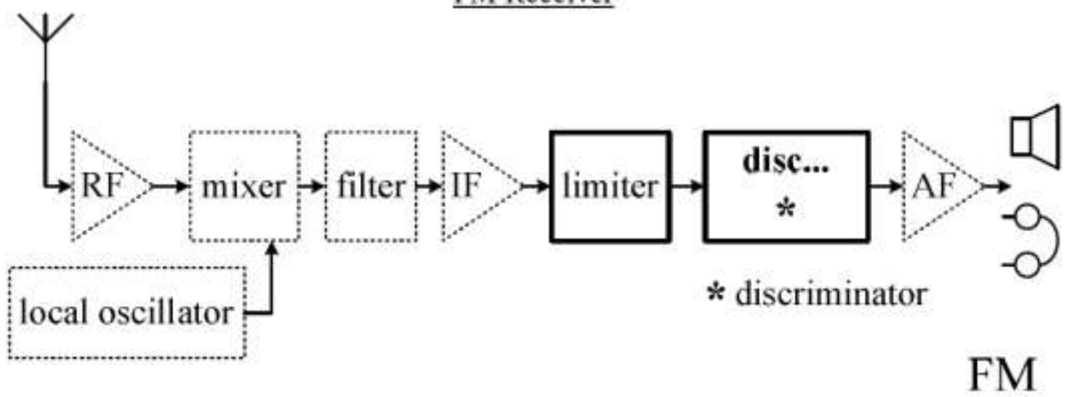


RF Amplifier	Amplifies the signal arriving from the antenna.
Mixer	Converts received frequency to Intermediate Frequency.
Local Oscillator	Supplies one input to the mixer.
IF Filter	Passes desired mixing result.
Intermediate Frequency Amplifier	Amplifies the IF signal.
Product Detector	Mixes the IF with the BFO to produce an audible signal.
Beat Frequency Oscillator	Supplies one input to BFO ("carrier re-insertion").
Audio Amplifier	Amplifies the audio signal to drive the speaker/headphones.

Note question B-003-010-008

Next Lesson will discuss the following Block diagram and workings of the FM (frequency modulation) receiver.

FM Receiver



RF Amplifier	Amplifies the signal arriving from the antenna.
Mixer	Converts received frequency to Intermediate Frequency.
Local Oscillator	Supplies one input to the mixer.
IF Filter	Passes desired mixing result.
I F Amplifier	Amplifies the IF signal.
LIMITER	Maintains a constant amplitude IF signal to the Discriminator.
DISCRIMINATOR	Extracts the original modulation from the FM signal.
Audio Amplifier	Amplifies the audio signal to drive the speaker/headphones.