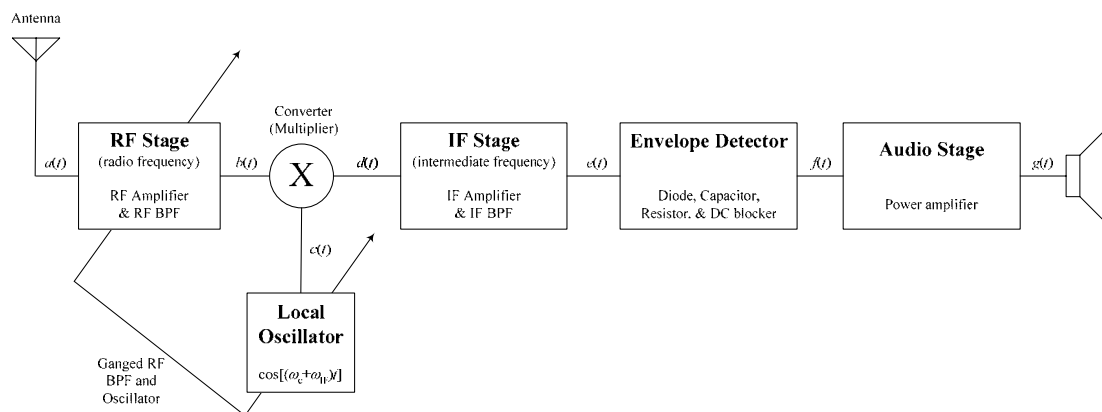


Superheterodyne AM Radio Receiver

Since the inception of the AM radio, it spread widely due to its ease of use and more importantly, its low cost. The low cost of most AM radios sold in the market is due to the use of the full amplitude modulation, which is extremely inefficient in terms of power as we have seen previously. The use of full AM permits the use of the simple and cheap envelope detector in the AM radio demodulator. In fact, the AM demodulator available in the market is slightly more complicated than a simple envelope detector. The block diagram below shows the construction of a typical AM receiver and the plots below show the signals in frequency-domain at the different parts of the radio.



Description of the AM Superheterodyne Radio Receiver

Signal $a(t)$ at the output of the Antenna: The antenna of the AM radio receiver receives the whole band of interest. So it receives signals ranging in frequency from around 530 kHz to 1650 kHz as shown by $a(t)$ in the figure. Each channel in this band occupies around 10 kHz of bandwidth and the different channels have center frequencies of 540, 550, 560, ..., 1640 kHz.

Signal $b(t)$ at the output of the RF (Radio Frequency) Stage: The signal at the output of the antenna is extremely weak in terms of amplitude. The radio cannot process this signal as it is, so it must be amplified. The amplification does not amplify the whole spectrum of the AM band and it does not amplify a single channel, but a range of channels is amplified around the desired channel that we would like to receive. The reason for using a BPF in this stage although the desired channel is not completely separated from adjacent channels is to avoid possible interference of some channels later in the demodulation process if the whole band was allowed to pass (assume the absence of this BPF and try demodulating the two channels at the two edges of the AM band, you will see that one of these cannot be demodulated). Also, the reason for not extracting the desired channel alone is that extracting only that channel represents a big challenge since the filter that would have to extract it must have a constant bandwidth of 10 kHz and a center frequency in the range of 530 kHz to 1650 kHz. Such a filter is extremely difficult to design since it has a high Q-factor (center frequency/bandwidth) let alone the fact that its center frequency is variable. Therefore, the process of extracting only one channel is

left for the following stages where a filter with constant center frequency may be used. Note in the block diagram above that the center frequency of the BPF in the RF stage is controlled by a variable capacitor with a value that is modified using a knob in the radio (the tuning knob).

Signal $c(t)$ at the output of the Local Oscillator: This is simply a sinusoid with a variable frequency that is a function of the carrier frequency of the desired channel. The purpose of multiplying the signal $b(t)$ by this sinusoid is to shift the center frequency of $b(t)$ to a constant frequency that is called IF (intermediate frequency). Therefore, assuming that the desired channel (the channel you would like to listen to) has a frequency of f_{RF} and the IF frequency that we would like to move that channel to is f_{IF} , one choice for the frequency of the local oscillator is to be $f_{RF} + f_{IF}$. The frequency of the local oscillator is modified in the radio using a variable capacitor that is also controlled using the same tuning knob as the variable capacitor that controls the center frequency of the BPF filter in the RF stage. The process of controlling the values of two elements such as two variable capacitors using the same knob by placing them on the same shaft is known as GANGING.

Signal $d(t)$ at the output of the Multiplier (Usually called frequency converter or mixer): The signal here should contain the desired channel at the constant frequency f_{IF} regardless of the original frequency of the desired channel. Remember that this signal does not only contain the desired channel but it contains also several adjacent channels and also contain images of these channels at the much higher frequency $2f_{RF} + f_{IF}$ (since multiplying by a cosine shifts the frequency of the signal to the left and to the right). When this type of radios was first invented, a standard was set for the value for the IF frequency to be 455 kHz. There is nothing special about this value. A range of other values can be used.

Signal $e(t)$ at the output of the IF Stage: Now that the desired channel is located at the IF frequency, a relatively simple to create BP filter with BW of 10 kHz and center frequency of f_{IF} can be used to extract only the desired channel and reject all adjacent channels. This filter has a constant Q factor of about $455/10 = 45.5$ (which is not that difficult to create), but more importantly has a constant center frequency. Therefore the output of this stage is the desired channel alone located at the IF frequency. This stage also contains a filter that amplifies the signal to a level that is sufficient for an envelope detector to operate on.

Signal $f(t)$ at the output of the Envelope Detector: The signal above is input to an envelope detector that extracts the original unmodulated signal from the modulated signal and also rejects any DC that is present in that signal. The output of that stage becomes the original signal with relatively low power.

Signal $g(t)$ at the output of the Audio Stage (Power Amplifier): Since the output of the envelope detector is generally weak and is not sufficient to drive a large speaker, the use of an amplifier that increases the power in the signal is necessary. Therefore, the output of that stage is the original audio signal with relatively high power that can directly be input to a speaker.

