Tuned Radio Frequency Receiver (TRF) – The most elementary receiver design, consisting of RF amplifier stages, detector and audio amplifier stages.
Receiver characteristics

- Sensitivity – The minimum RF input signal to a receiver required to produce a specified audio signal at output. The ability to drive output transducers.
- Noise floor: the input noise of a receiver the signal must be well above this value to work.
- Selectivity – The extent to which a receiver can differentiate between the desired signal and other signals (unwanted radio signal and noise).
- TRF Selectivity – The receiver input Q (this parameter remains the same but the bandwidth and center frequency can change).
Let's look at an example

<table>
<thead>
<tr>
<th>AM Frequency</th>
<th>Min</th>
<th>Nom</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center frequency</td>
<td>550</td>
<td>1000</td>
<td>1550</td>
</tr>
<tr>
<td>Nominal bandwidth</td>
<td></td>
<td>10000</td>
<td></td>
</tr>
<tr>
<td>Q design</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Bandwidth at edges</td>
<td>5500</td>
<td></td>
<td>15500</td>
</tr>
</tbody>
</table>

Use EQ 1-25 page 39 to calculate Q
What does this mean

The FCC sets the bandwidth of the transmitter to 10kHz

$$\text{BW} = \frac{F_c}{Q}$$

At 550 kHz the BW = 5.5 kHz
or about 50% the design losing half the information

At 1550 kHz the BW = 15.5 kHz the receiver could not
distinguish adjacent stations

The conclusion the simple receiver design shown will not work
A tuned LC tank circuit can easily set the input center frequency

Plot $v(\text{out})/V(\text{in})$ in dB vs. frequency
Figure 3-2  Nonlinear device used as a detector.
Figure 3-3  Diode detector.
AM Detector terms from previous slide

- The carrier and sideband frequencies of the AM signal are separated in frequency by an amount equal to the intelligence frequency.
- Detection of the AM signals require a nonlinear electrical network.
- Diode Detectors (Envelope Detectors) - are the simplest AM detection circuit. It consists of a nonlinear diode and a low pass filter.
- The diode rectifies the signal, allowing only half of the alternating waveform through. The capacitor is used to store the charge and provide a smoothed output from the detector, and also to remove any unwanted radio frequency components. The resistor is used to enable the capacitor to discharge
Synchronous Detection

- Synchronous Detectors - Called Product detectors or Heterodyne detectors are composed of an oscillator, mixer, and low pass filter stage used to obtain the intelligence from an AM signal. They offer the following advantages:
  1. Low distortion under 1%
  2. Greater to follow fast-modulation such as pulse-modulation or high-fidelity applications
  3. The ability to provide high gain instead of the attenuation of diode detectors.
  4. Smaller bandwidth may be possible
Synchronous Detection

What happens if IF AM or IF Oscillator have a frequency shift
Signal can be tighter on a heterodyne or synchronous receiver.

A good example is

- LSB = 899 kHz
- carrier = 900 kHz
- USB = 901 kHz
- Therefore data is 1 kHz
Superheterodyne receivers

• The Super heterodyne receiver gives good selectivity over the whole band which is a problem in TRF.
• The stages are as follows:
  • RF stage, mixer stage and Local Oscillator (LO) that are tuned together by a Ganged capacitor setup.
  • Intermediate Frequency (IF) Amplifier which provides the bulk of the radio-frequency signal amplification at a fixed frequency. This allows for constant BW over the entire band of the receiver.
  • A detector that has feedback to the other stages that is controlled by Automatic Gain Control (AGC).
• Finally there is an audio and power amplifier stage to restore the signal.
Figure 3-6  Superheterodyne receiver block diagram.
Superheterodyne receivers

- First Detector – The Mixer in a super heterodyne receiver that mixes the RF signal with the LO signal to form the IF signal.
- The standard frequency in an IF Amplifier for an AM signal is 455 kHz. $f_{lo} - f_c = 455$ kHz.

The mixer output is $f_{lo} + f_c$  
the local oscillator frequency minus the carrier frequency
the local oscillator frequency plus the carrier frequency

Tracking is the ability of circuit to give a constant IF frequency (455 kHz) over entire range of input carrier frequencies
Figure 3-7  Frequency conversion process.
Figure 3-8  Frequency conversion and Variable ganged capacitor
Superheterodyne Tuning

• Tracking: It is not possible for a receiver to track perfectly over a wide range of frequency. To obtain a degree of tracking the following is employed.
  – Trimmer – A small variable capacitance in parallel with each section of the ganged capacitors is added to assist in high end frequency tracking.
  – Padded Capacitor – A small variable capacitor in series with each ganged capacitor is added to provide near-perfect tracking of the low end frequency tracking.
  – Final adjustment is made at mid-frequency by a slight adjustment of the inductors at each tank circuit.
Figure 3-10  Tracking considerations.
Electronic Tuning

• Special diodes are designed to offer a method that relies on the capacitance produced by a reverse-biased diode. The names of the diodes are:
  – Varactor Diode
  – Varicap Diode
  – VVC Diode

• Reverse-bias formula for diode capacitance

\[
C_d = \frac{C_o}{\sqrt{(1 + 2|V_R|)}}
\]

\(C_o\) = diode capacitance at zero bias

\(V_R\) = diode reverse bias voltage
Figure 3-11  Varactor diode symbols and C/V characteristic.
Figure 3-12  Broadcast-band AM receiver front end with electronic tuning.
Superheterodyne Analysis

- Image Frequency – The undesired input frequency in a super heterodyne receiver that produces the same intermediate frequency as the desired input signal.
- Double Conversion – A super heterodyne receiver design that has two separate mixers, LO’s and IF’s in order to avoid image frequency problems.
- The benefits of RF amplification are:
  1. Improved image frequency rejection.
  2. More gain and thus better sensitivity.
  3. Improved noise characteristics.
Figure 3-13  Image frequency illustration.
### Image frequency calculation

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier</td>
<td>6.20E+05</td>
<td>Hz</td>
</tr>
<tr>
<td>IF</td>
<td>4.55E+05</td>
<td>Hz</td>
</tr>
<tr>
<td></td>
<td>flo-620e3 = 455 e3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>flc = 1075e3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>image flo+IF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1075e3+455e3 = 1530e3</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3-14  Image frequency not a problem.

Will require an RF front end filter
Superheterodyne Analysis

• Mixers, Converters and First Detectors are all names for the circuit that works in conjunction with the LO to provide frequency conversion which supplies the IF Amplifier with the proper frequency.

• Cross-Modulation – distortion the results from undesired mixer outputs.

• Self-excited Mixer (Autodyne Mixer) – Single stage in a super heterodyne receiver that creates the LO signal and mixes it with the applied RF signal to form the IF signal.
Figure 3-17  Typical IF amplifiers.

Includes AGC control
Superheterodyne Analysis

• **Image Frequency** – The undesired input frequency in a super heterodyne receiver that produces the same intermediate frequency as the desired input signal.

• **Double Conversion** – A super heterodyne receiver design that has two separate mixers, LO’s and IF’s in order to avoid image frequency problems.

• **The benefits of RF amplification are:**
  1. Improved image frequency rejection.
  2. More gain and thus better sensitivity.
  3. Improved noise characteristics.
Superheterodyne Analysis

• Mixers, Converters and First Detectors are all names for the circuit that works in conjunction with the LO to provide frequency conversion which supplies the IF Amplifier with the proper frequency.

• Cross-Modulation – distortion the results from undesired mixer outputs.

• Self-excited Mixer (Autodyne Mixer) – Single stage in a super heterodyne receiver that creates the LO signal and mixes it with the applied RF signal to form the IF signal.
Automatic gain Control

• An envelope detector that has negative feedback to the other stages is controlled by Automatic Gain Control (AGC).

• Without AGC you would not be able to tune in or keep channels tuned in as you move.

• The volume would change between the weak and strong signals.
Weak signal

strong signal

AGC time constant about 1 second
The filter DC term is feedback to adjust the bias of the transistor.
Receiver characteristics

• Using two separate channels for music can enrich the listening experience for AM stereo.

• To accomplish this a reference 25 Hz signal is used to differentiates between the left and right channels. 25 Hz is added to the left channel. When the receiver detects 25 Hz it lights up an indicator to show stereo reception.

• Dynamic Range in a receiver is the dB difference between the largest tolerable receiver input level and its sensitivity level.
Figure 3-23  AM stereo block diagram.

Transmitter
Review: dB

- Usually in dB, dBm or dBu
- \( \text{dB} = 10 \log \left[ \frac{\text{Power Out}}{\text{Power In}} \right] \)
- 3dB => Signal has doubled
- 10 dB => Signal Gone up by a factor of 10
- As dB’s add => Signal Multiplies
  - 6 dB = Factor of 4, 9dB = Factor of 8, etc.

- \( \text{dBm} = 10 \log \left[ \frac{\text{Power Out}}{1 \text{m Watt}} \right] \)
- \( \text{dBu} = 10 \log \left[ \frac{\text{Power Out}}{1 \text{u Watt}} \right] \)
Figure 3-26  Receiver block diagram.

Gain analysis
### Mixer troubleshooting chart

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Troubleshooting Checks</th>
<th>Likely Trouble</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Reception</td>
<td>Power ok; converter working</td>
<td>No input signal at base of $Q_1$; $L_1$ or $L_2$ open; transistor bad</td>
</tr>
<tr>
<td>Stations fade in and out</td>
<td>$Q_1$’s emitter voltage fluctuates</td>
<td>Converter operation erratic; $C_3$ leaky or open</td>
</tr>
<tr>
<td>No station heard from mid – to low – AM band</td>
<td>DMM voltage changes when radio is tuned</td>
<td>LO not tracking across AM band $C_1$ or $C_4$ faulty</td>
</tr>
<tr>
<td>No station heard from mid – to high– AM band</td>
<td>DMM voltage changes when radio is tuned</td>
<td>LO not tracking across AM band $C_1$ or $C_4$ faulty</td>
</tr>
</tbody>
</table>

See schematic page 144
Figure 3-28 Regulated power supply.
Look at output of power supply with respect to ground voltage OK not problem
No voltage check check fuse (turn off power) make sure circuit plugged in
If fuse OK check output of bridge

Output waveform at point D should be almost perfect dc

With filter cap installed