Electronic-Circuit II
Chap 4. Communication Systems

Radio Receivers

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Course Homepage
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Outline

- Characteristics of Receivers
- Tuned Radio frequency Receivers
- Heterodyning
- Need for Heterodyning
- Super-heterodyne receiver
- Frequency Converter Circuits (Circuit Diagram and working principle only)

Parameters of Radio Receivers

- Sensitivity
  - ability to recover weak signals and process them into readable data
  - The most common way to express receiver sensitivity is to state the number of ac signal micro volts at the antenna, needed to produce a given signal-to-noise (S/N) ratio
- Selectivity
  - Ability of a receiver to respond to a desired signal but not undesired ones

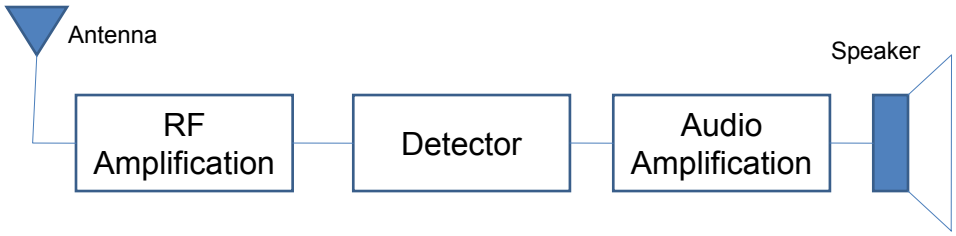
Parameters of Radio Receivers contd…

- Dynamic Range
  - ability of a receiver to maintain a fairly constant output and to keep its sensitivity—in the presence of signals ranging from the very weak to the extremely strong
  - expressed in dB and is typically over 100 dB
- Stability
  - The ability to remain tuned to a station once it has been set
- Fidelity
  - The ability to preserve the exact shape of the information

Commercial Receivers

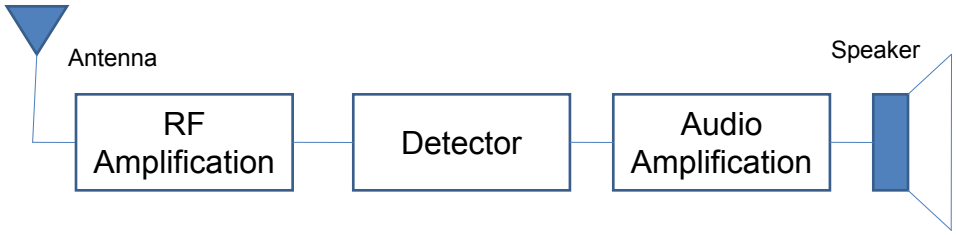
- Of the various forms of receivers proposed at one time or another, only two have any real practical or commercial significance – the tuned radio frequency (TRF) receiver & Superheterodyne receiver
- The best way of justifying the existence and overwhelming popularity of the superheterodyne receiver is by showing the shortcomings of the TRF type

TRF Receiver Block Diagram



- TRF receivers were the first radio receivers for broadcast AM
- These receivers generally had three stages of RF amplification

TRF Receiver Block Diagram contd…



- Each RF amplification stage was preceded by a separate variable-tuned circuit
- The three tuned circuit were all adjusted by separate variable capacitor controls
- To receive a station required proper adjustment of all three, and a good deal of time and practice was necessary

De-merits of TRF receivers

- Variation of BW over the tuning range
- Unable to achieve sufficient selectivity at high frequencies, partly as a result of the enforced use of single-tuned circuits
- Double-tuned RF amplifiers were not possible although it was realized that they would naturally yield better selectivity
- This was due to the fact that all such amplifiers had to be tunable and the difficulties of making several double-tuned amplifiers tune in unison were too great
- Insufficient adjacent-frequency rejection

Numerical

- A TRF receiver is to be designed with a single tuned circuit using a 10μH inductor.

a)Calculate the capacitance range of the variable capacitor required to tune from 550 to 1550 kHz. (Ans: 8.37 nF)

b)The ideal 10-kHz BW is to occur at 1100 kHz. Determine the required Q.(Ans: 110)

c)Calculate the BW of this receiver at 550 kHz and 1550 kHz. (Ans: 14.1 kHz)

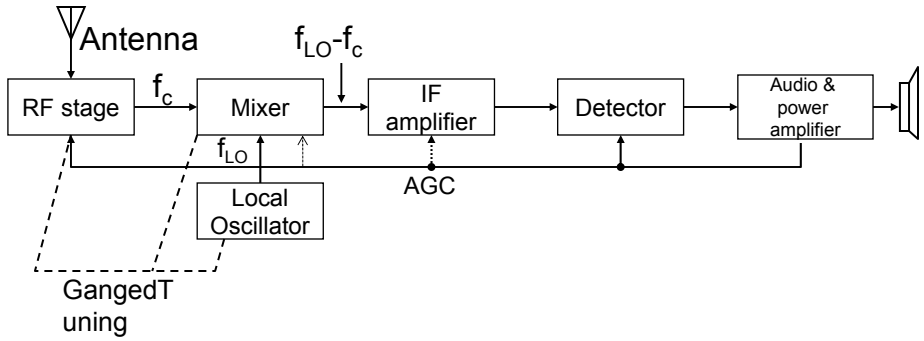
Heterodyning

- Heterodyning:
  - heterodyning is the generation of new frequencies by mixing two or more signals in a nonlinear device such as a vacuum tube, transistor, diode mixer
  - The mixing of each two frequencies results in the creation of two new frequencies, one at the sum of the two frequencies mixed, and the other at their difference.
  - A low frequency produced in this manner is sometimes referred to as a beat frequency.

Superheterodyne Receiver

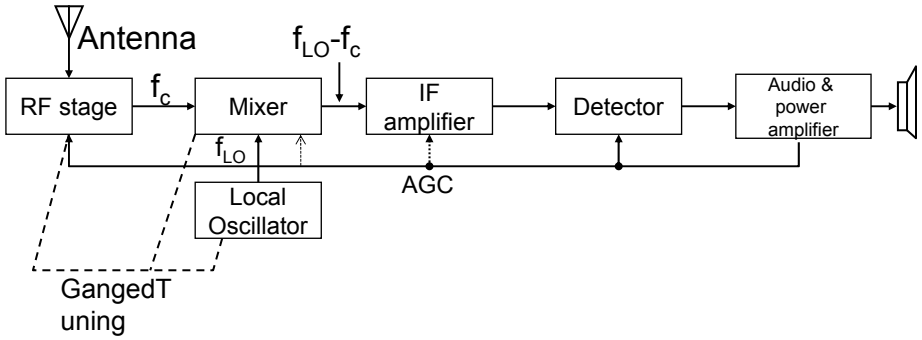
- The basic selectivity problem in TRF systems led to the development and general usage of the superheterodyne receivers
- It was introduced in the early 1930s
- This basic receiver configuration is still dominant after all these years, an indication of its utility
- The superheterodyne receiver became popular because of its better selectivity, sensitivity and stability.

Superheterodyne Receiver



- The first stage is a standard RF amplifier. It's basically a tuned amplifier that picks up the desired station
- The next stage is the mixer, which accepts two inputs [the output of the RF amp and a steady sine wave from the local oscillator (LO)]. Mixer is also known as First Detector

Superheterodyne Receiver contd..

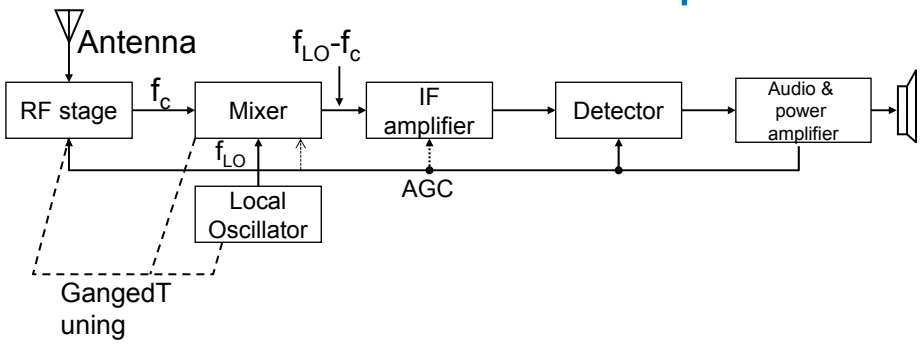


- The mixer is a non linear device and its function is to mix the AM signal with a sine wave to generate a new set of sum and difference frequencies
- The next stage is the Intermediate frequency (IF) where selectivity is obtained

IF Amplifier Stage

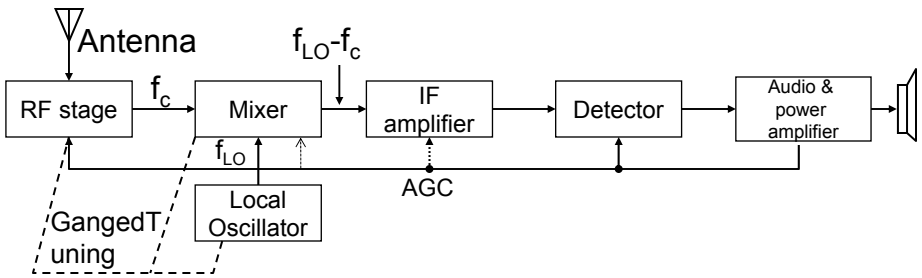
- The IF amplifier provides the bulk of radio-frequency signal amplification at a fixed frequency
- An IF amplifier is not a whole lot different from an RF stage except it operates at a fixed frequency
- This allows for a constant BW over the entire band of the receiver
- Since, the IF frequency is usually lower than the RF, voltage gain of the signal is more easily attained at the IF frequency
- Adequate selectivity and sharp band pass filter can't be achieved if f_c is very high and especially if f_c is tunable

Detector and Audio amplifier



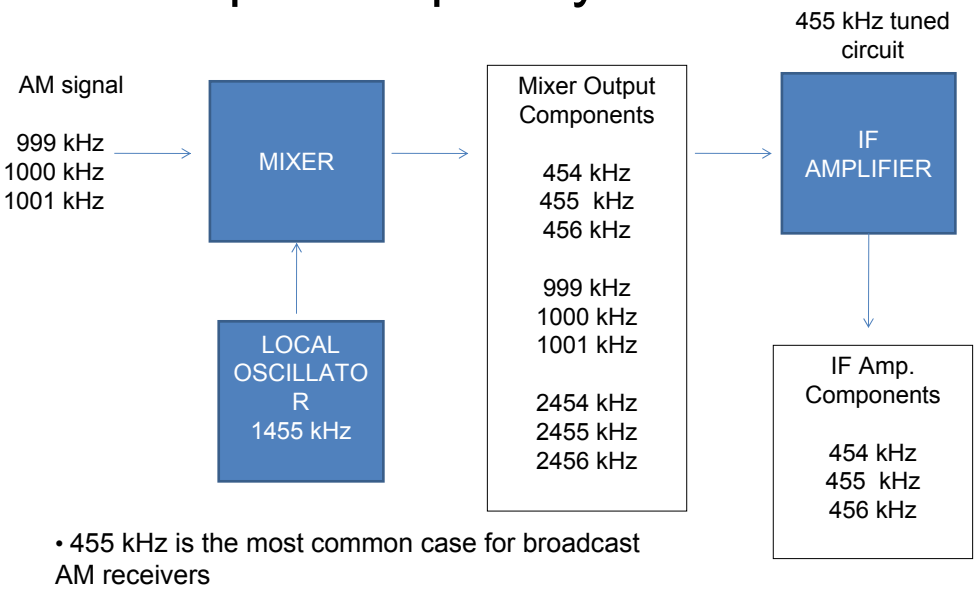
- Following the IF amplifier stage is the detector, which extracts the intelligence from the radio signal
- This signal is subsequently amplified by the audio amplifiers into the speaker
- Ganged tuning is the process used to tune two or more circuits with a single control

Automatic Gain Control (AGC)



- A dc level proportional to the received signal's strength is extracted from the detector stage and fed back to the IF amplifiers and sometimes to the mixer and/or the RF amplifier.
- This is the automatic gain control (AGC) which allows relatively constant receiver output for widely variable received signals

Example Frequency Conversion



• 455 kHz is the most common case for broadcast AM receivers

Question ?

- What should be the frequency of the local oscillator if the carrier frequency is 1600 kHz, 792 kHz ?

Primary Advantage of Superheterodyne Receiver over TRF Receiver

- *Constant selectivity* over a wide range of received frequencies
- This is due to the fact that bulk of the amplification in this receiver occurs in the IF amplifier at a fixed frequency, which allows for relatively simple and yet highly effective frequency selective circuits

Image Frequency Problem

- Image Frequency Illustration

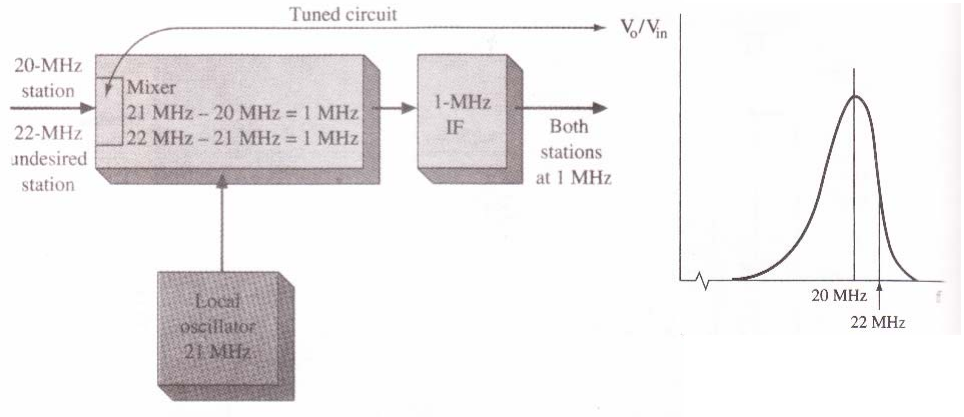


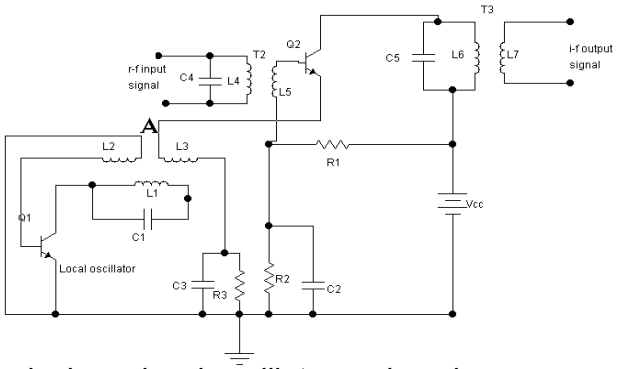
Image Frequency contd…

- Defⁿ of Image Frequency
  - Undesired input frequency in a superheterodyne receiver that produces the same intermediate frequency as the desired Input signal
- Image Frequency Rejection in Receivers
  - A technique known as double conversion is employed to solve the image frequency problems
  - Double conversion consists of two separate mixers, local oscillators, and IF to avoid image frequency problems
  - The image frequency must pass through two tuned circuits (tuned to the desired frequency) before it is mixed

Numerical

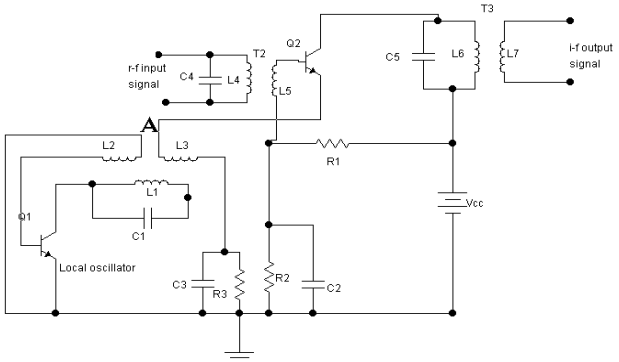
- Determine the image frequency for a standard broadcast band receiver using a 455 kHz IF and tuned to a station at 620 kHz. (Ans: 1530 KhZ)
- Determine the image frequency for a standard broadcast band receiver using a 455 kHz IF and tuned to a station at 792 kHz.

Frequency Conversion Circuits (circuit and working principle)



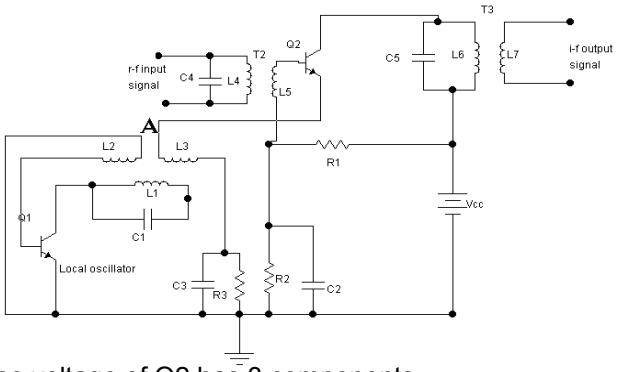
- Circuit employing a local oscillator and a mixer
- L1, C1 & Q1 produces the carrier frequency (Local oscillator)
- L2 provides positive feedback to establish oscillation
- L3 injects the carrier frequency to the emitter of the mixer Q2
- C4 & L4 tuned modulating frequency, L5 couples it to the base of Q2

Frequency Conversion Circuits (circuit and working principle)



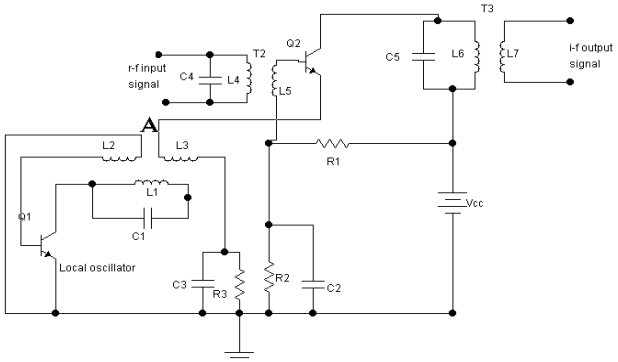
- R1 & R2 provide fixed bias to the base of Q2
- R3 provides emitter swapping
- C2 and C3 bypass ac voltage across R2 & R3 respectively
- C5 & L6 are tuned to a certain IF (Intermediate frequency)
- L7 is coupled to the load

Frequency Conversion Circuits (circuit and working principle)



- Emitter-base voltage of Q2 has 3 components
  - Fixed bias by R1 & R2
  - Modulating signal coupled by L5
  - Carrier frequency coupled by L3

Frequency Conversion Circuits (circuit and working principle)



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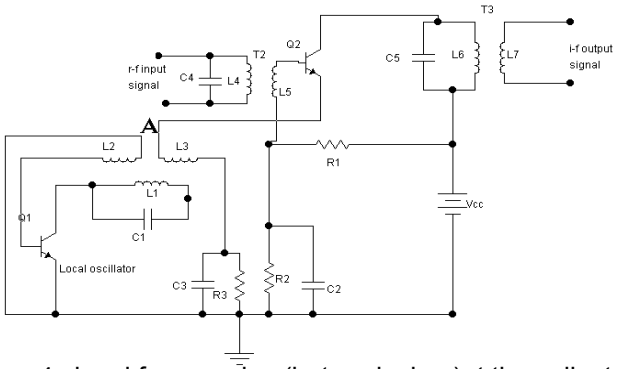
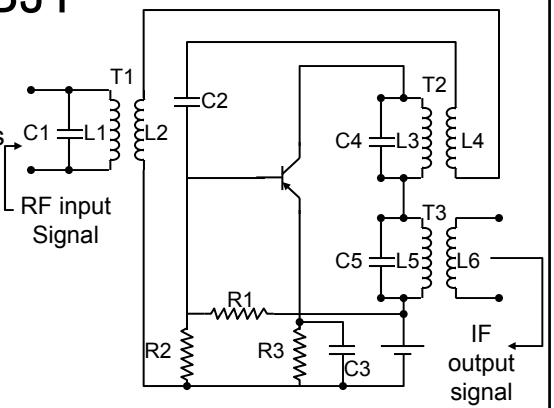
Frequency Conversion Circuits (circuit and working principle)



- Mixer Q2 has 4 signal frequencies (heterodyning)at the collector
  - Modulating signal
  - Carrier signal (Local oscillator signal)
  - Signal with frequency the sum of modulating & carrier frequency
  - Signal with frequency the difference of modulating & carrier frequency

Frequency Conversion using single BJT

- R1 & R2 provide biasing
- C3 bypasses any ac component across R3
- L4 provides positive feedback to bas of Q1
- Parallel combination of L3 & C4 determines the oscillation frequency
- L1 & C1 are tuned to the RF input & L2 couples the signal to the base of Q1
- Four signal frequencies (due to heterodyning) are produced
- Parallel combination of L3 & C4 selects the required frequency, & L6 couples it to load



Frequency conversion circuit using a single Transistor

- C2 introduces sufficient impedance such that L2L4C2 does not load R2