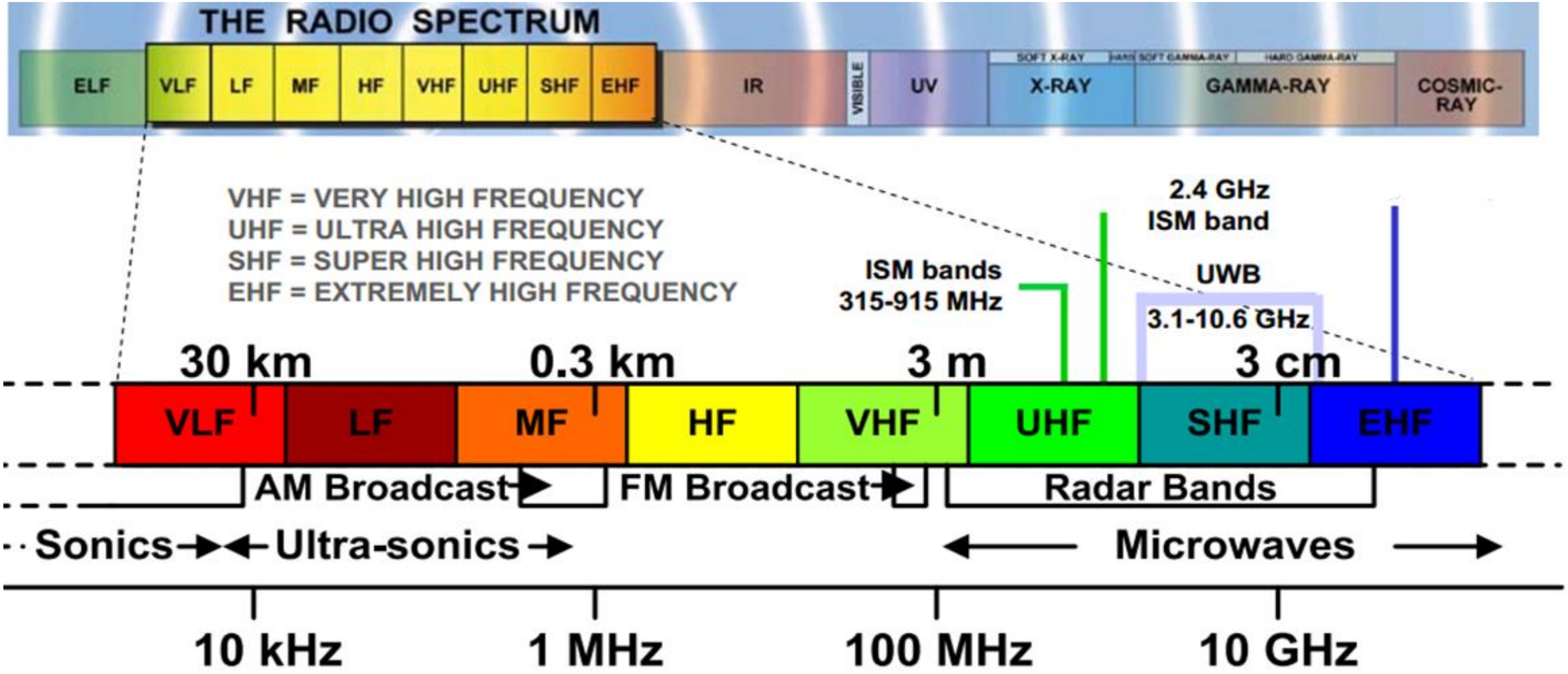
APPLICATIONS - RADIO RECEIVERS

EEEN 462 – ANALOGUE COMMUNICATION

Monday, 30 June 2025

REVIEW OF RADIO SPECTRUM



ISM/SRD BAND DEFINITIONS

1. **Industrial, Scientific and Medical (ISM)** radio frequency bands were originally reserved by the International Communication Union for the use of RF energy for industrial, scientific and medical purposes rather than communications.
2. The original applications in these bands included:
   a) Radio-frequency process heating
   b)Microwave ovens
   c)Medical diathermy machines

3. **Short-range device (SRD)** are RF transmitters that operate at low-power and over short distances. The are used as cable-replacement and in wireless sensor networks.

Examples of **Short-range communication Devices** include:

a) Wireless Fidelity (WiFi)
b) Bluetooth
c) Zigbee

ISM/SRD BAND APPLICATIONS

FREQUENCY RANGE		BANDWIDTH	REGION
13.553 MHz	13.567 MHz	14 kHz	Worldwide
26.957 MHz	27.283 MHz	326 kHz	Worldwide
40.660 MHz	40.700 MHz	40 kHz	Worldwide
433.050 MHz	434.790 MHz	1.74 MHz	Region 1 only
902.000 MHz	928.000 MHz	26 MHz	Region 2 only
2.400 GHz	2.500 GHz	100 MHz	Worldwide
5.725 GHz	5.875 GHz	150 MHz	Worldwide

RECAP - ITU RADIO REGIONS

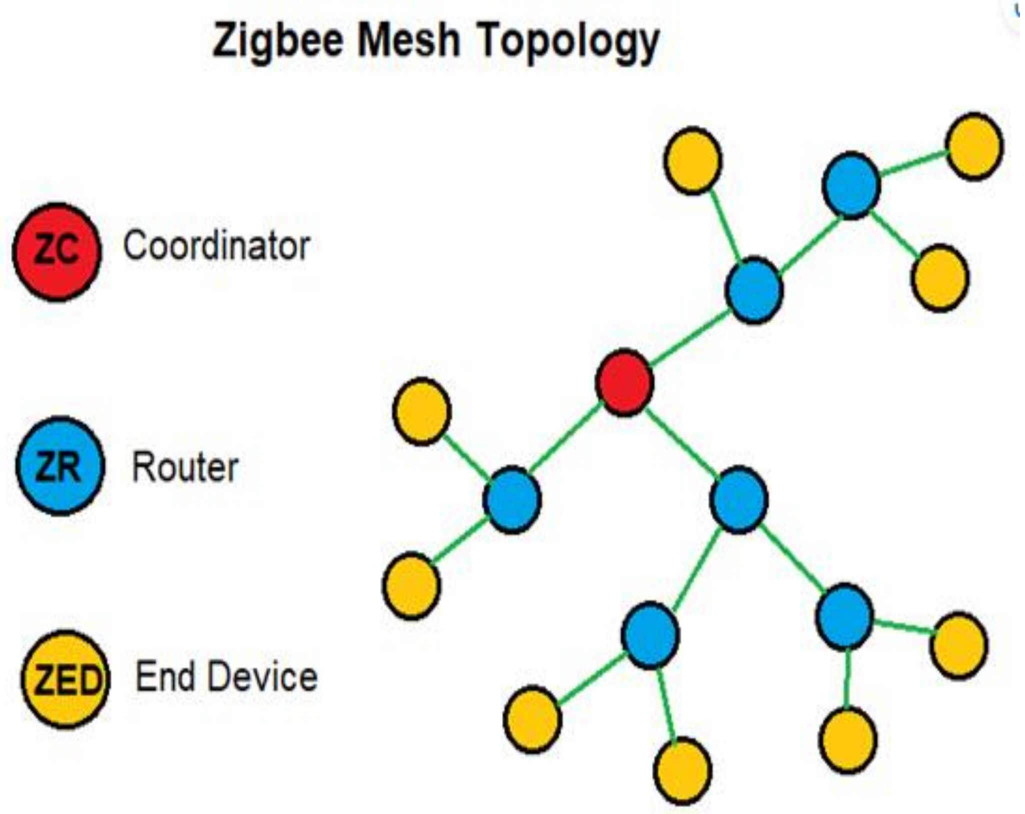
SHORT-RANGE DEVICES (SRD) - BLUETOOTH

1. **Bluetooth** is a wireless technology standard for exchanging data over short distances in the ISM band from 2.4 to 2.485 GHz.
2. Bluetooth is used in fixed and mobile devices, and building personal area networks (PANs).
3. **Bluetooth invented by Ericsson** in 1994 as a wireless alternative to RS-232 data communication.
4. Named after 10^{th} Century Danish King.

Bluetooth allows you to connect wirelessly several devices to a PC, laptop or phone.

SHORT-RANGE DEVICES (SRD) - ZIGBEE

1. **Zigbee is a wireless protocol used by IoT devices** that communicate with each other over a network in the 2.4 GHZ ISM band.
2. **Zigbee** devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones.



FUNCTIONS OF RADIO RECEIVERS

Functions of a Radio Receiver are to:

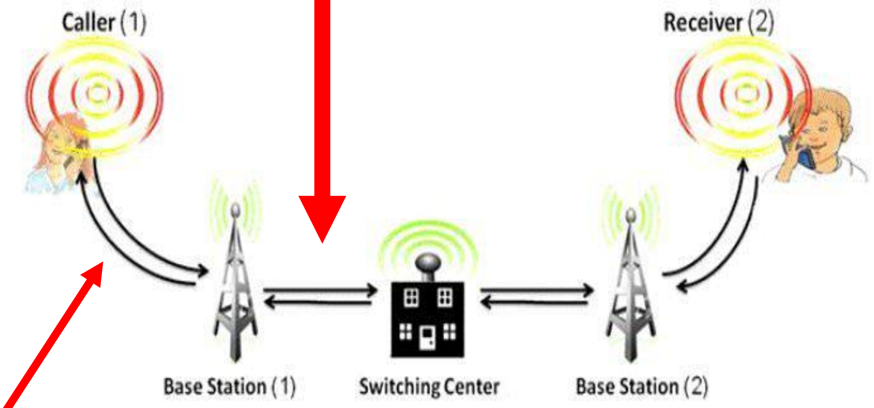
1. intercept the incoming radio signal by the antenna
2. Select the desired signal and reject unwanted signals
3. Amplify the RF signal
4. Demodulate the Signal
5. Amplify the demodulated signal.

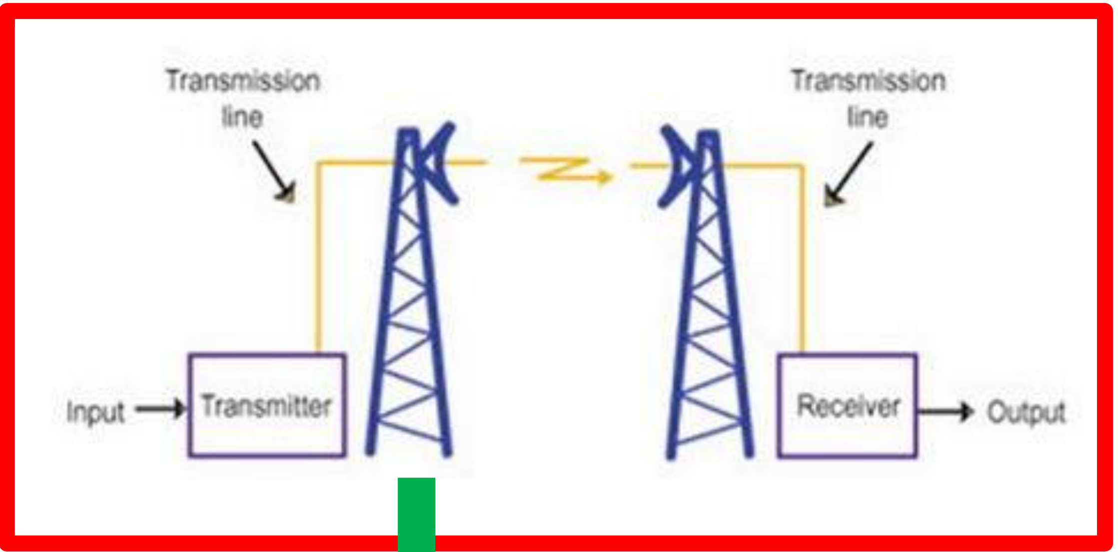
TYPES OF RADIO RECEIVERS

Radio receivers can be classified according:

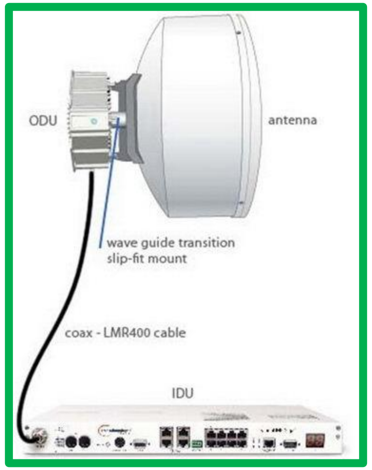
1. Type of Modulation as:
   a) **AM Receivers** for receiving amplitude modulated signals
   b) **Angle receivers** for receiving Frequency and Phase Modulated signals
2. Type of application, as:
   a) **Communication receivers** used are used in communication systems, e.g telecommunications.
   b) **Radar receivers** used to detect Radar (Radio Detection and Ranging) signals
   c) **Television receivers** used to receive TV signals is VHF and UHF bands)
3. Principle of operation, as:
   a) **Tuned Radio Frequency (TRF) receivers**
   b) **Superheterodyne Receivers**

COMMUNICATION TRANSMITERS/RECEIVERS





Um Interface
Uplink: 890 – 915 MHz
Downlink: 935 – 960 MHz

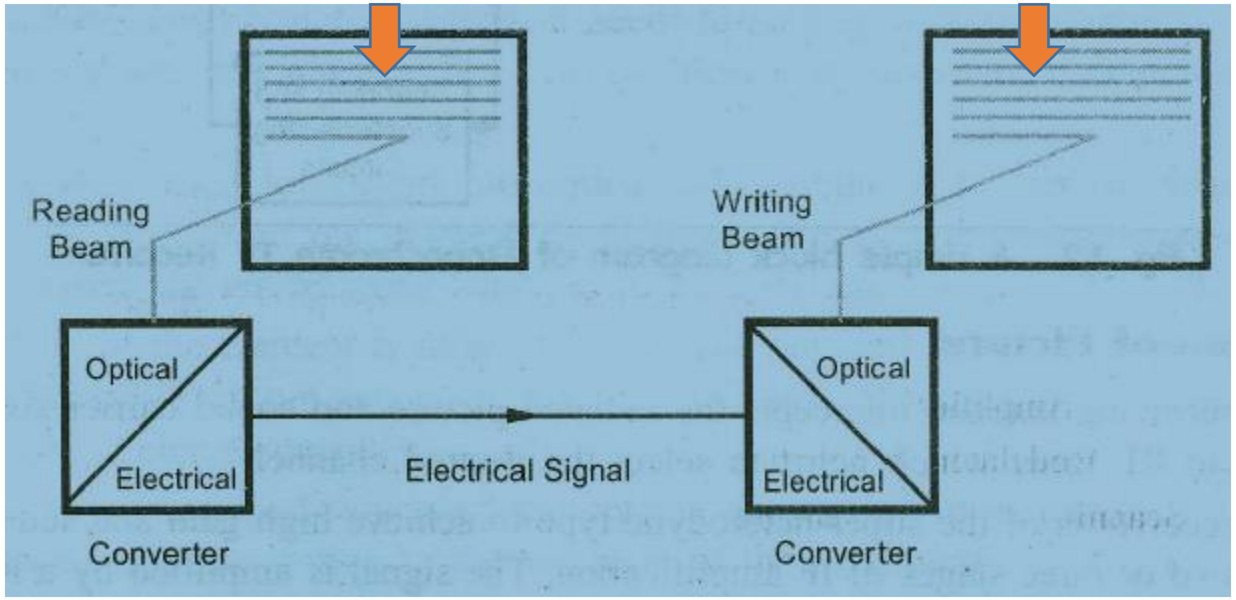


TELEVISION

Television may be defined as the transmission images of moving and stationary objects generally with accompanying sound as electromagnetic waves and the reception and reconversion of the received waves into visual images.

Original Moving or Stationary Object

Displayed Moving or Stationary Object



BRIEF HISTORY OF TELEVISION

- **1884:** Paul Nipkow patents the first electromechanical Television System
- **1927:** Philo Taylor demonstrates the first Electronic Television.
- **1950:** First Colour Television developed by Columbia Broadcasting Corporation.

TYPES OF TV SYSTEMS

- 525 Lines with 60 Frames/Sec: USA - Developed by National Television System Committee (NTSC) in 1953
- 625 Lines with 50 frames/Sec: European – Phase Alternation by Lines (PAL), developed in Germany in 1967
- 819 Lines: French - Sequential Coloureuses A Memmoirs (SECAM) – Developed in France.

TERRESTRIAL TELEVISION FREQUENCIES

<u>VHF Band:</u>

41 – 68 MHz – Analogue TV

174-230 MHz – Digital Terrestrial Sound and Audio Broadcasting

<u>UHF Band:</u>

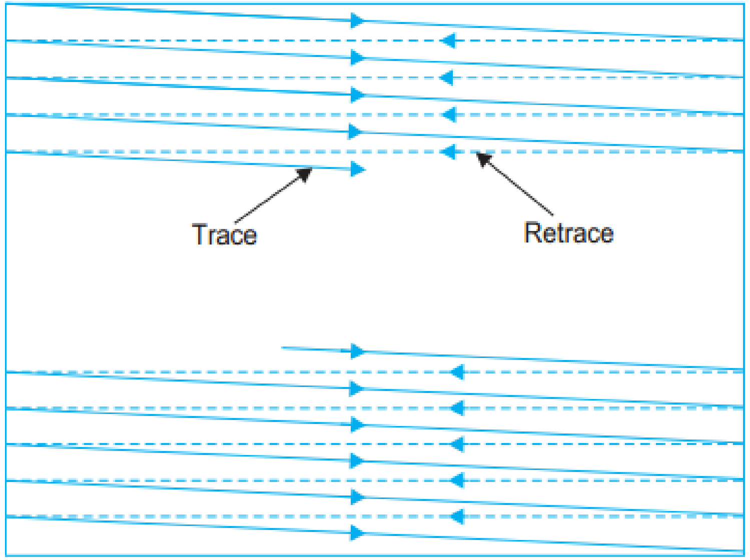
470 – 806 MHz – Analogue TV

470-806 MHz – Digital Terrestrial Sound and Audio Broadcasting

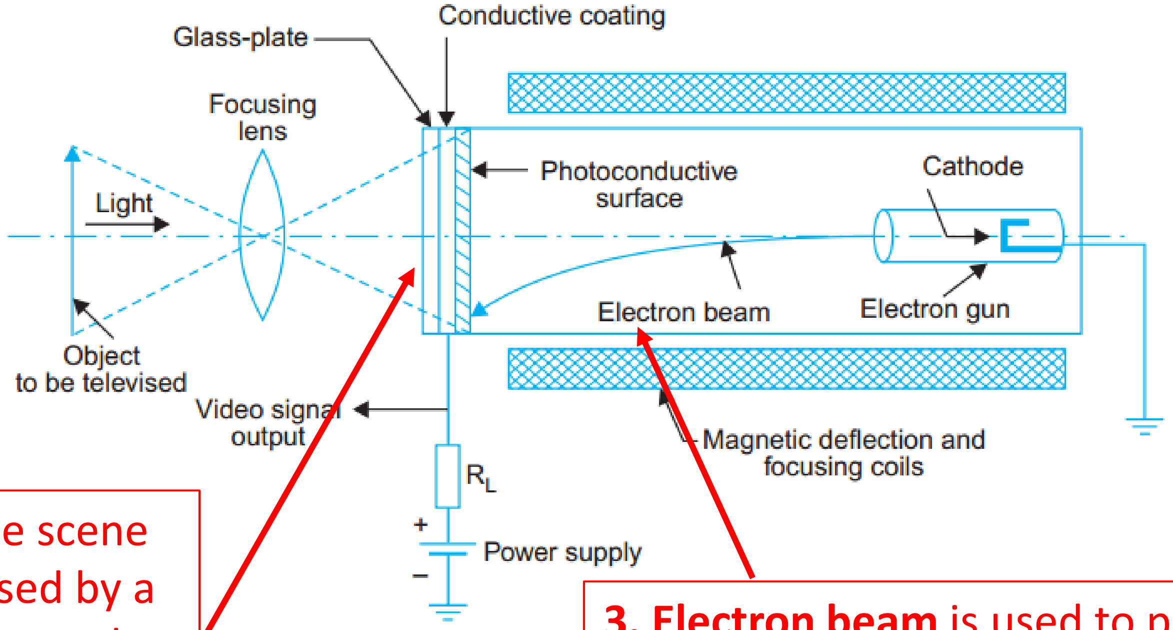
PRINCIPLE OF TELEVISION VIDICON CAMERA

- **A TV camera** is used to convert optical information into electrical signal, the amplitude of which varies in accordance with variations of brightness.

2. The conductive coating has high resistance when no light falls on it which decreases with increasing light intensity



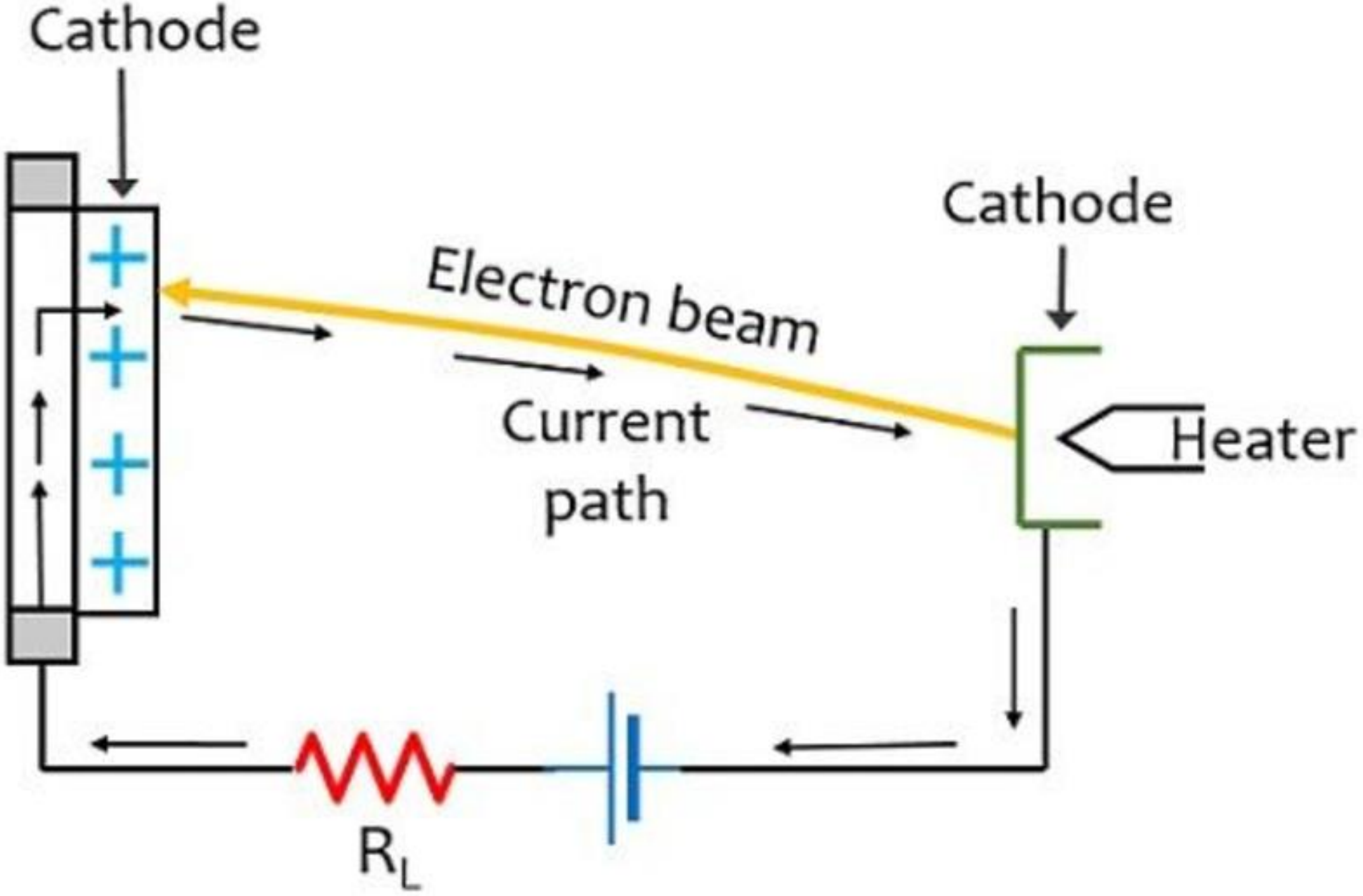
Scanning beam covering the target area



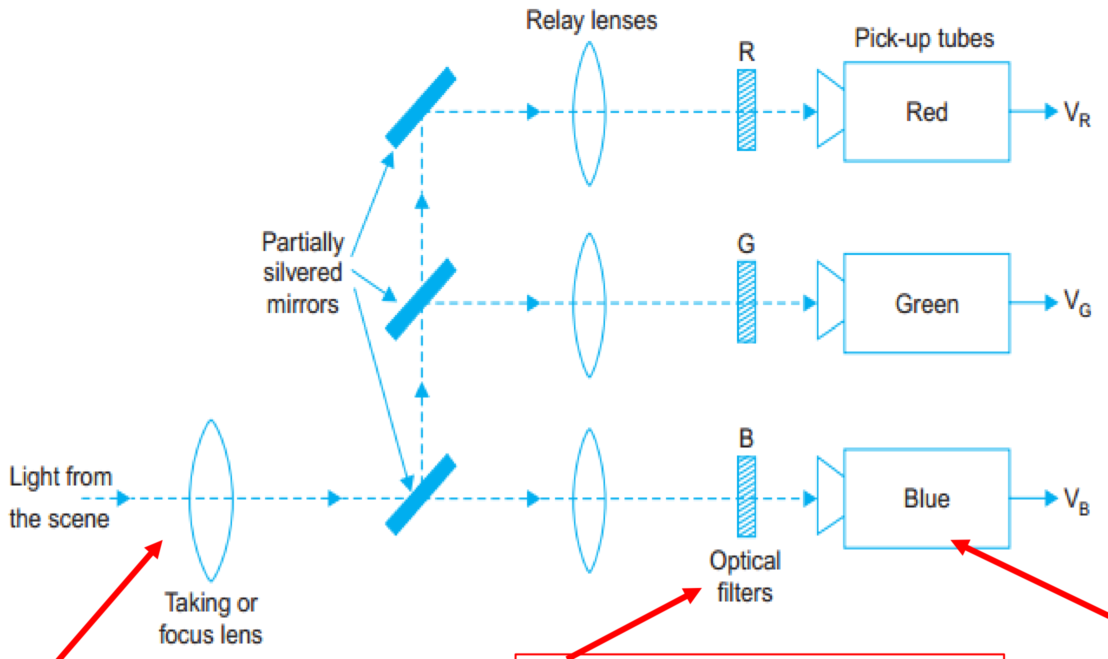
1. An optical image of the scene to be transmitted is focused by a lens assembly on the rectangular glass face-plate of the camera tube.

3. Electron beam is used to pick-up picture information on the target plate in terms of varying resistance at each point

PRINCIPLE OF TELEVISION VIDICON CAMERA



COLOUR TV VIDICON CAMERA



1. Light from the scene falls on the focus lens

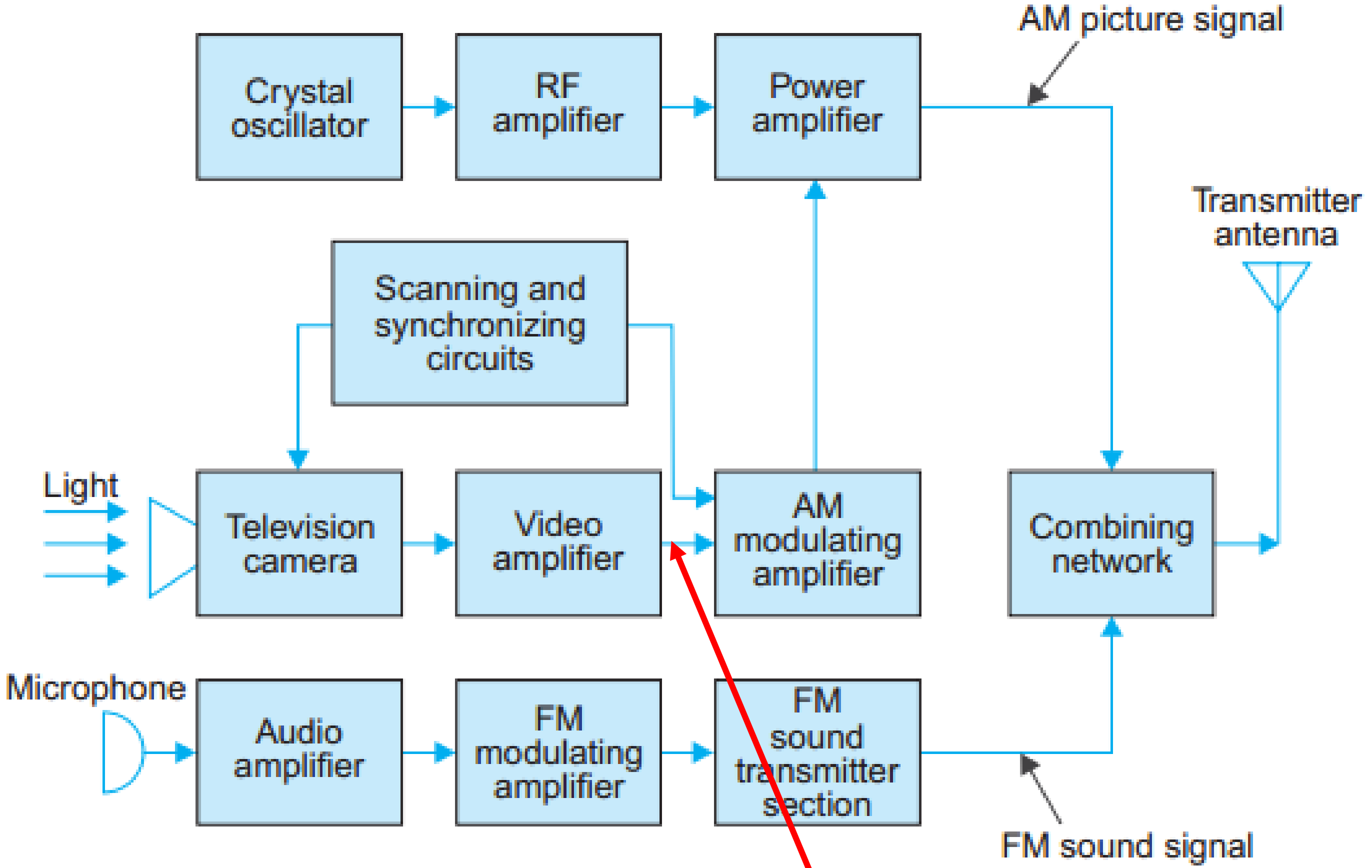
2. Colour filters receive reflected light split it into R, G and B colour lights.

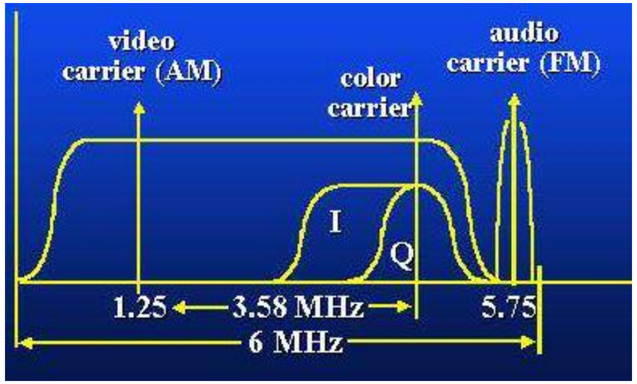
3. Camera tubes (vidicons) receive light of only one primary colour.

MODERN CAMERA

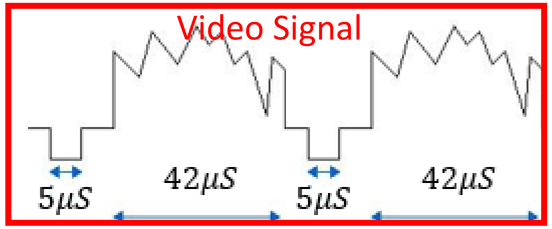
- **Today, CCD (charge coupled device) chips** are universally used in the cameras and the principle of the deflected electron beam is now only pre-served in TV receivers.

BLOCK DIAGRAM OF TELEVISION TRANSMITTER





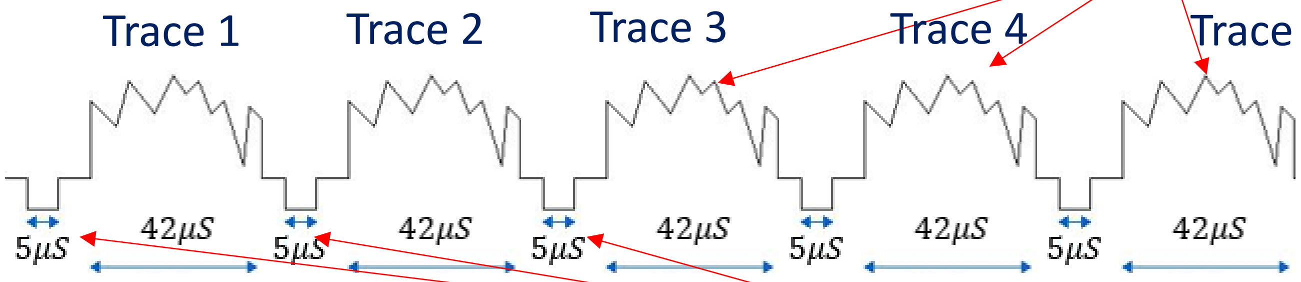
Spectrum of Combined Signal

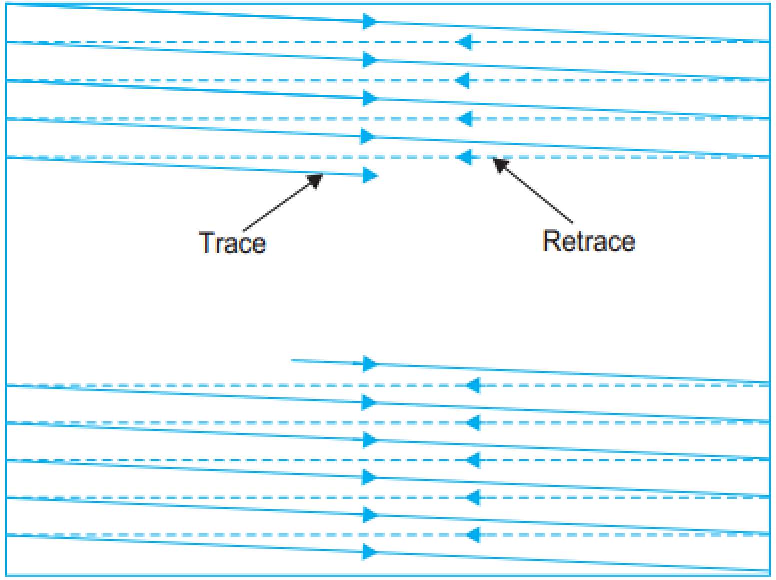


SYNCHRONIZATION

- **<u>Synchronizing pulses</u>** are transmitted during the retrace, i.e., fly-back intervals of horizontal and vertical motions of the camera scanning beam.
- **Sych pulses (see drawing)** are processed at the receiver and fed to the picture tube sweep circuitry thus ensuring that the receiver picture tube beam is in step with the transmitter camera tube beam.

<u>Luminance</u> represents the brightness of each pixel in a horizontal sweep

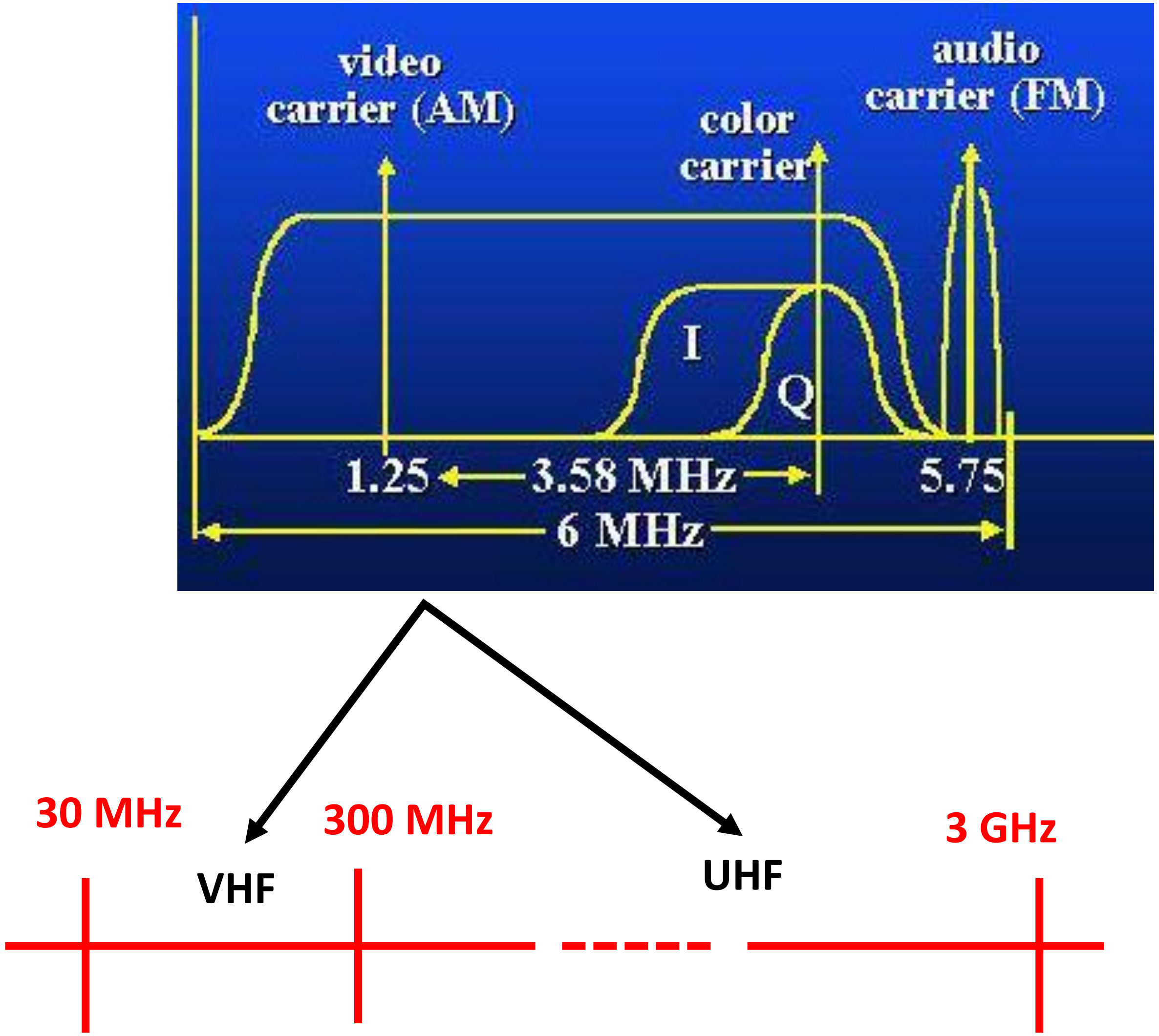




<u>Horizontal sync</u> pulses trigger the horizontal sweep in the TV to reset back to the left to begin another scan line.

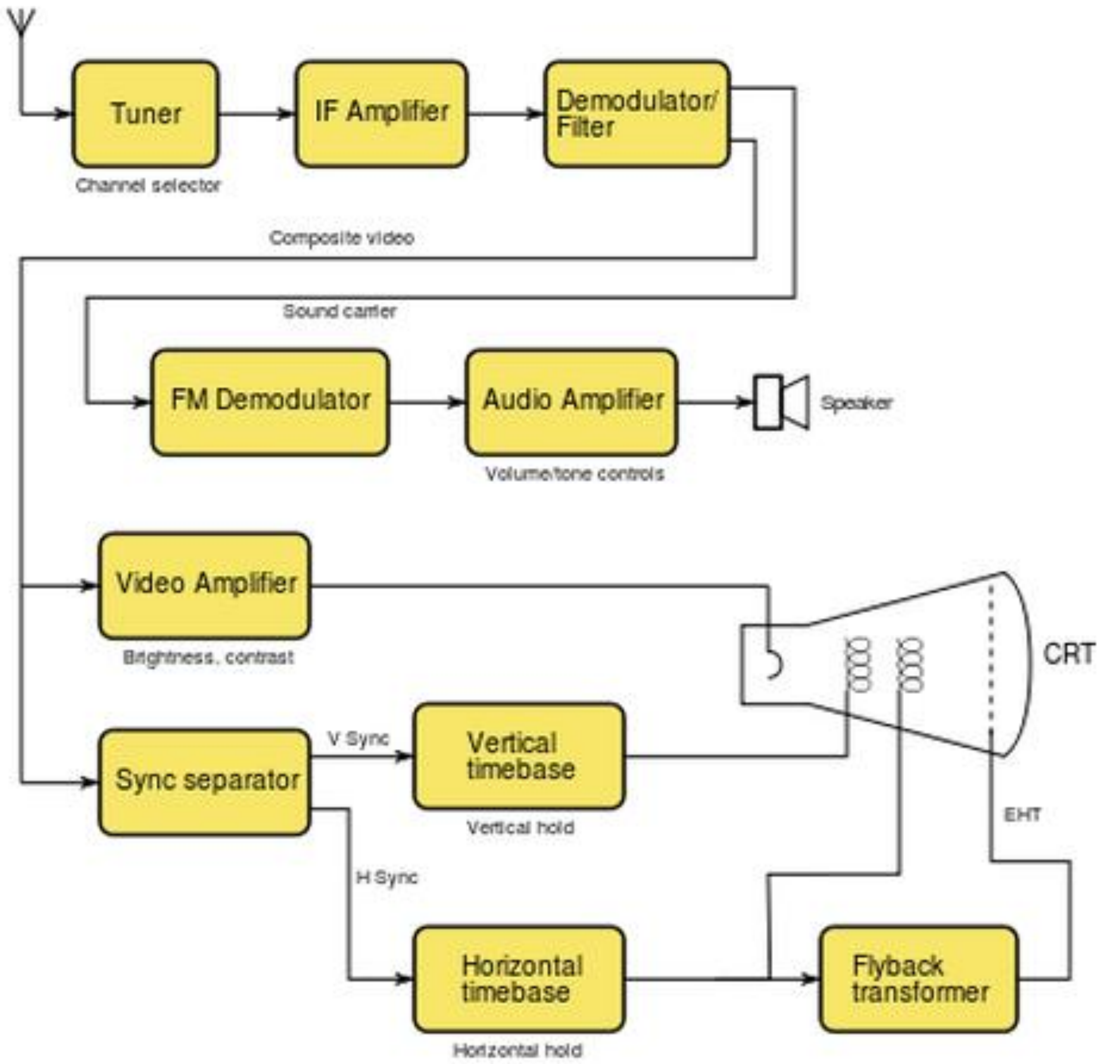
TELEVISION SPECTRUM

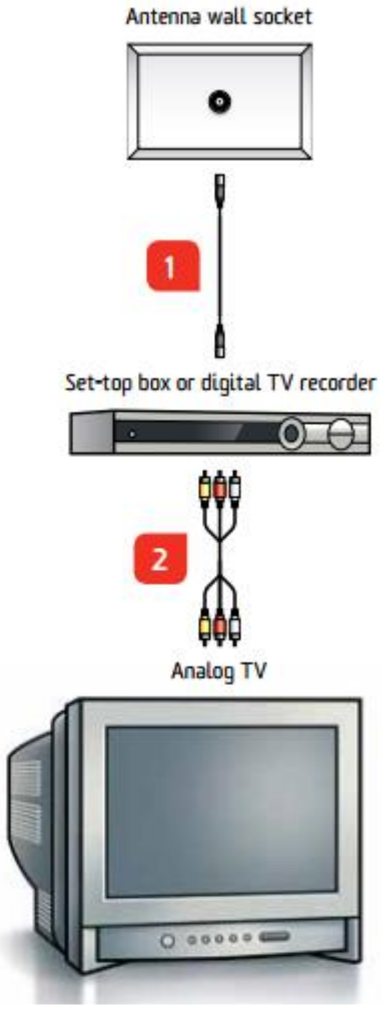
1. The baseband TV signal occupies the frequency range 0 – 6 MHz as shown.



2. The **Video signal** is used to modulate a **carrier** in the frequency in VHF or UHF band.

MONOCHROME ANALOGUE TELEVISION RECEIVER



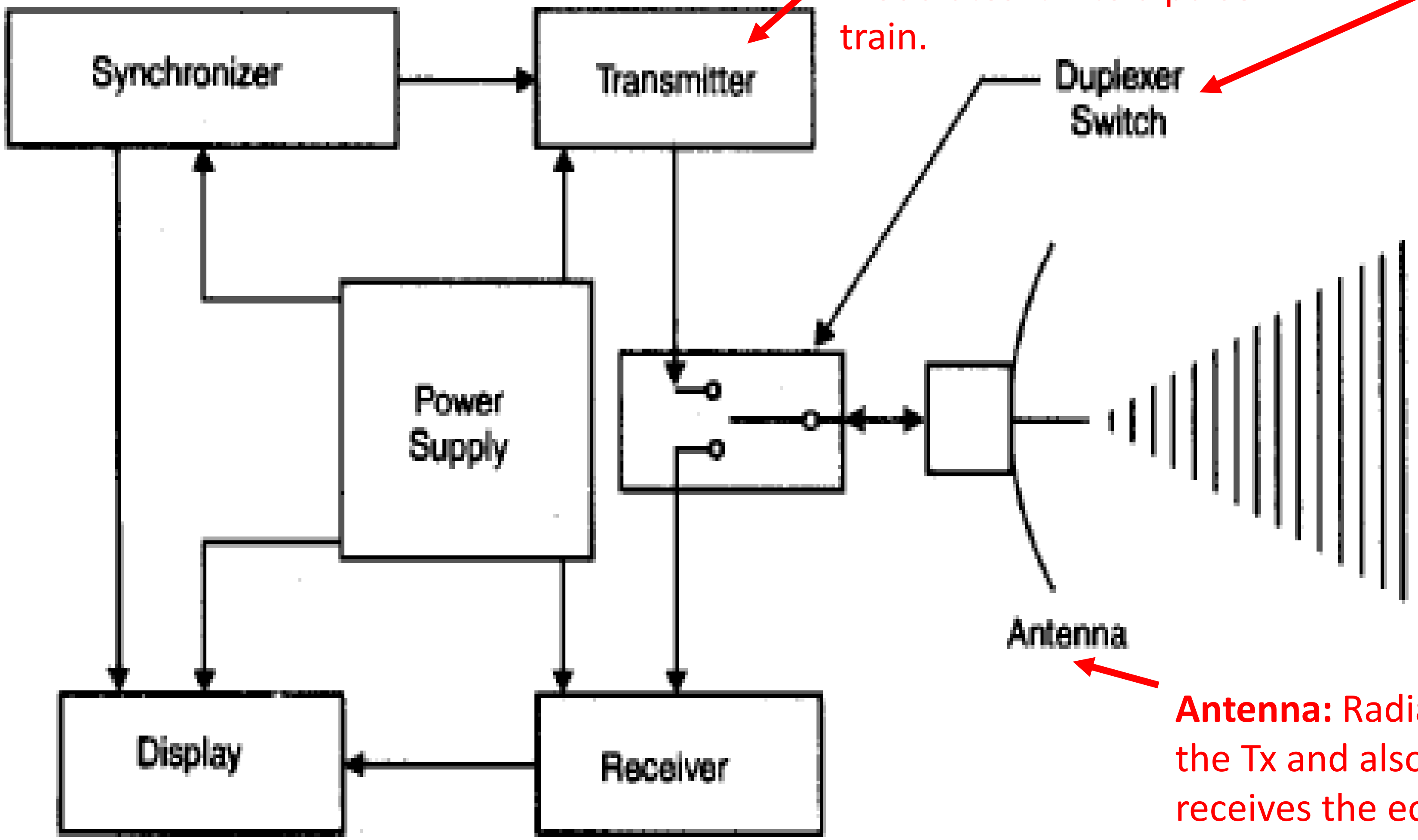


Connecting Analogue TV to Digital

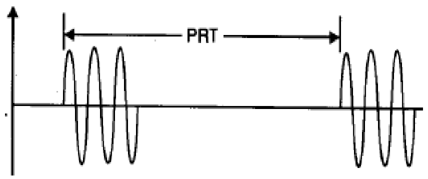
RADAR RECEIVER

Transmitter: Creates the wave to be sent and modulates it into a pulse train.

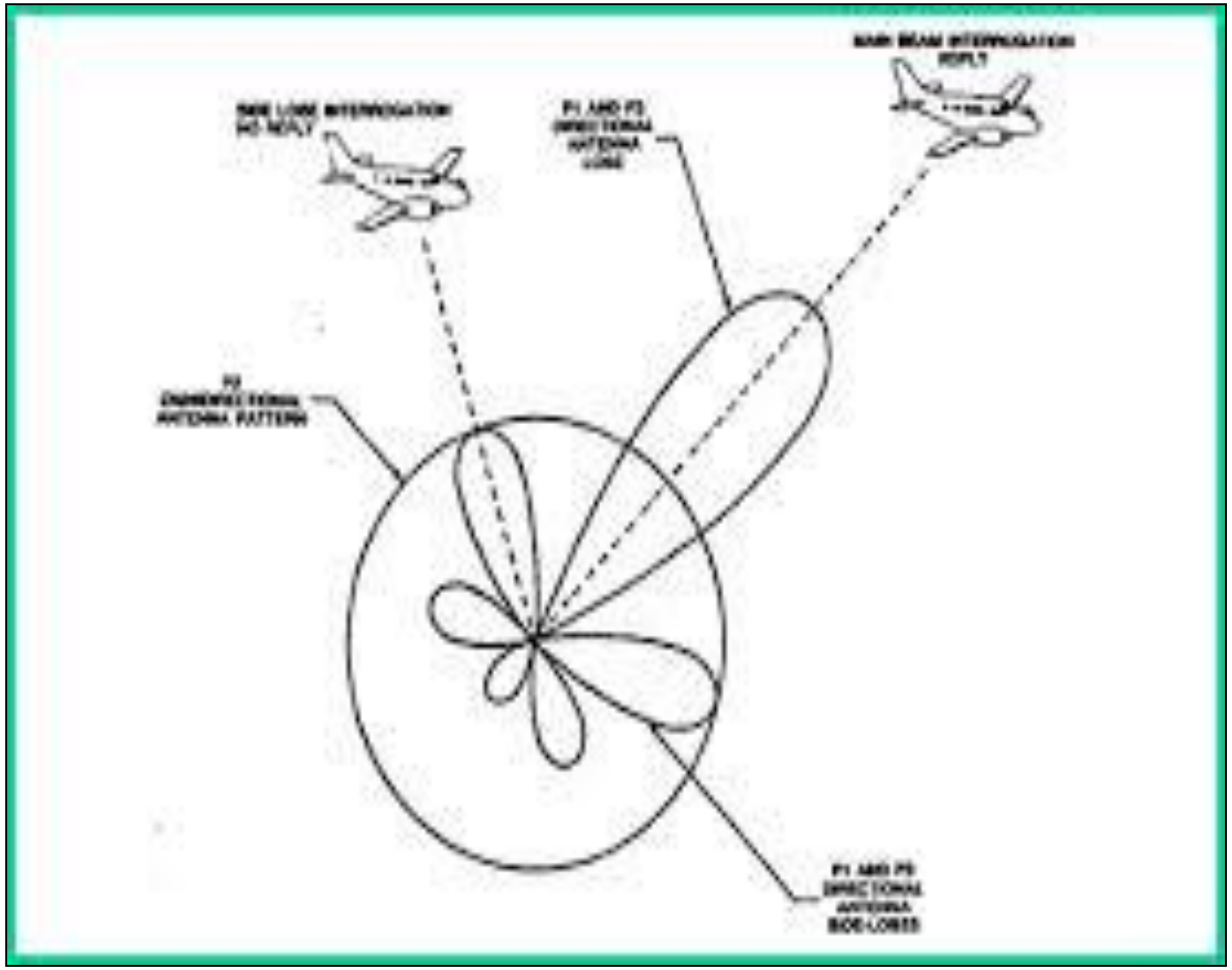
Duplexer: Protects the receiver from the high power transmitted signal

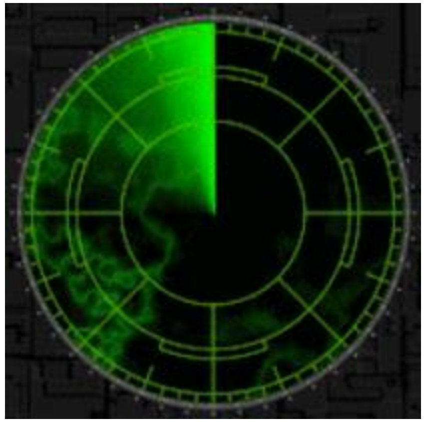


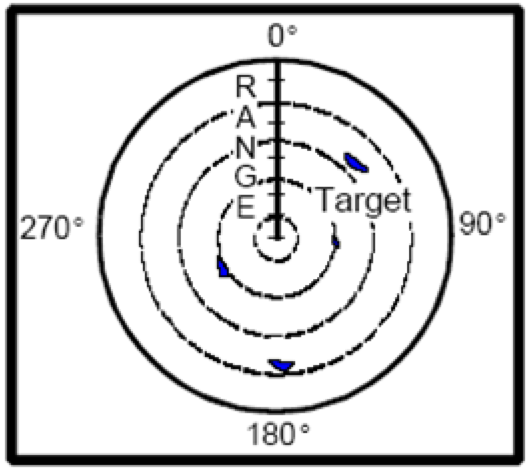
Antenna: Radiates the Tx and also receives the echo signal from target



APPLICATION OF RADAR IN AT AIRPORTS

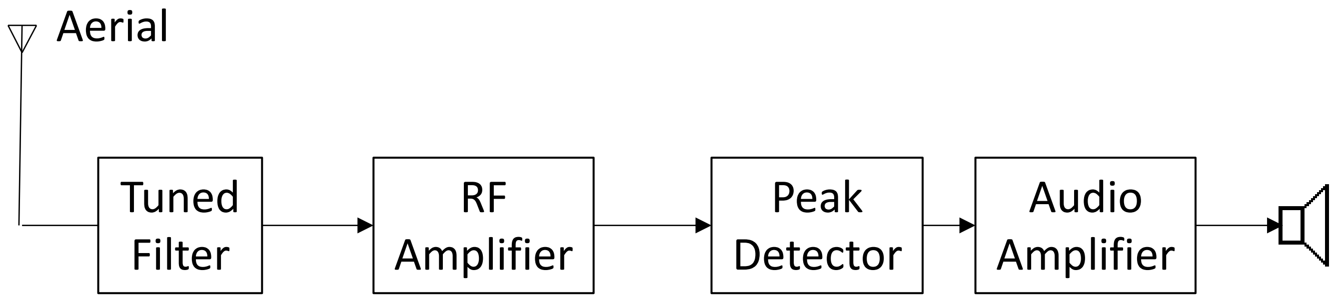






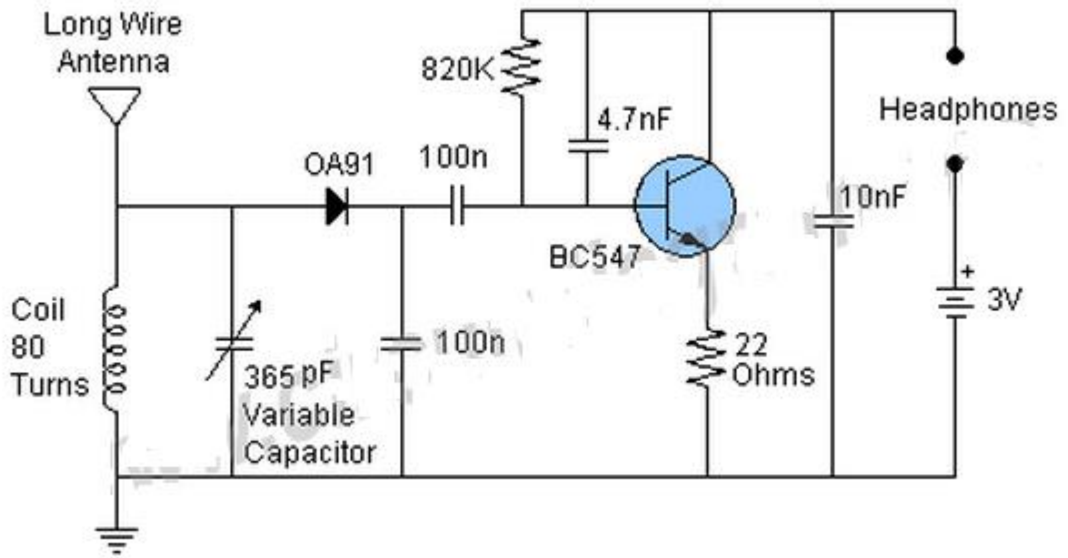
ENVELOPE DETECTOR (from Previous Lecture)

- The envelope detector recovers the transmitted signal riding on the carrier by extracting the envelope of the received signal.
- The AM Envelope receiver circuit consists of 4 major parts:
  1. The tuned tank
  2. The RF amplifier
  3. The peak/envelope detector
  4. The audio amplifier

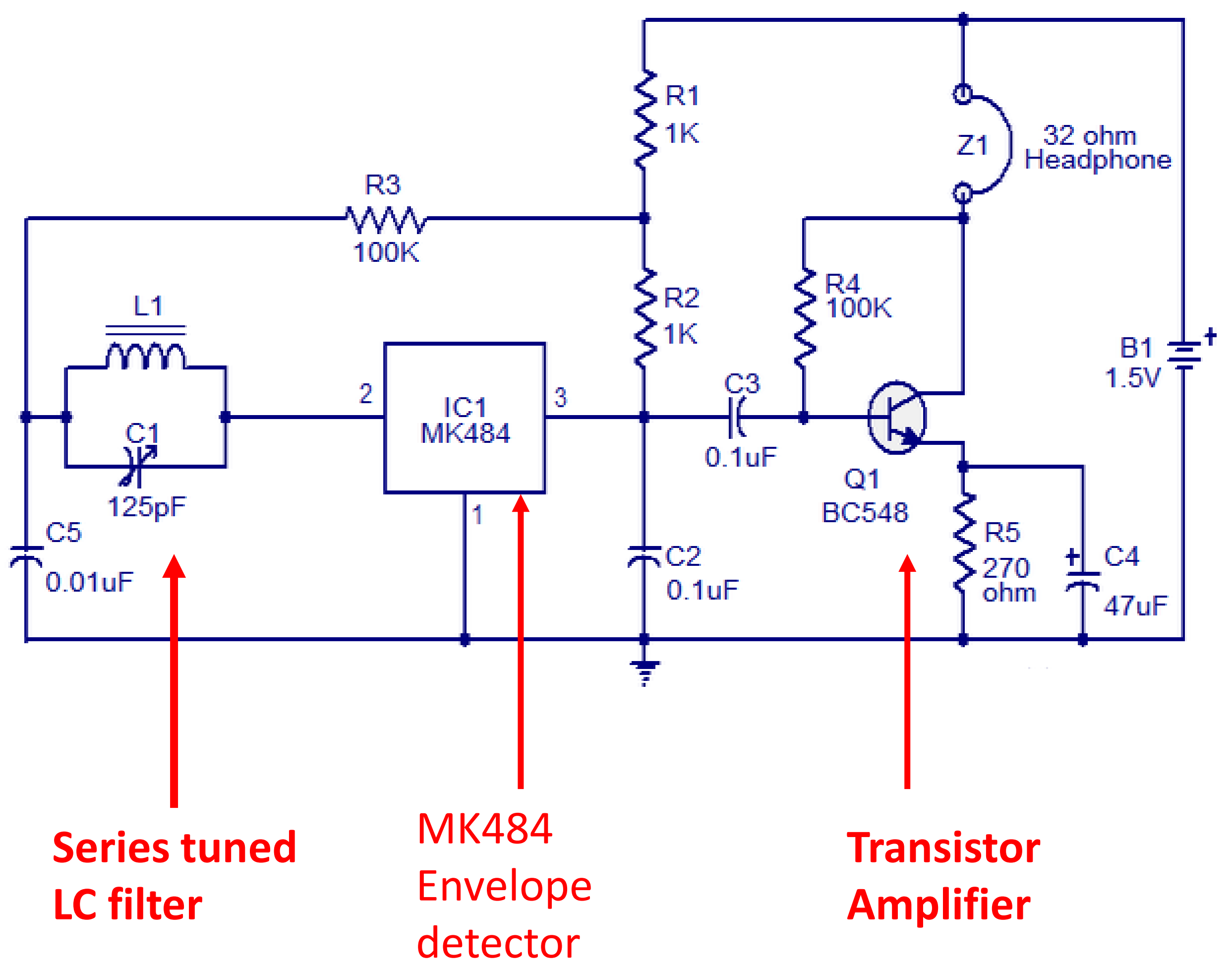


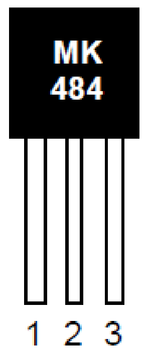
SINGLE TRANSISTOR ENVELOPE RECEIVER (from Previous Lecture)

1. The 80 turns coil and 365pF variable capacitor form a tank circuit
2. The germanium diode and the 100nF capacitor form the envelope detector
3. The general purpose BC547 transistor together with the biasing components form the audio amplifier.
4. The coil is equal to 80 turns of 26 s.w.g. Enameled copper wire wound on an empty card board toilet roll or an off cut piece of plastic waste pipe



PRACTICAL AM RECEIVER CIRCUIT USING MK484 (from Previous Lecture)





BASIC TRANSMISSION PROBLEM - FADING

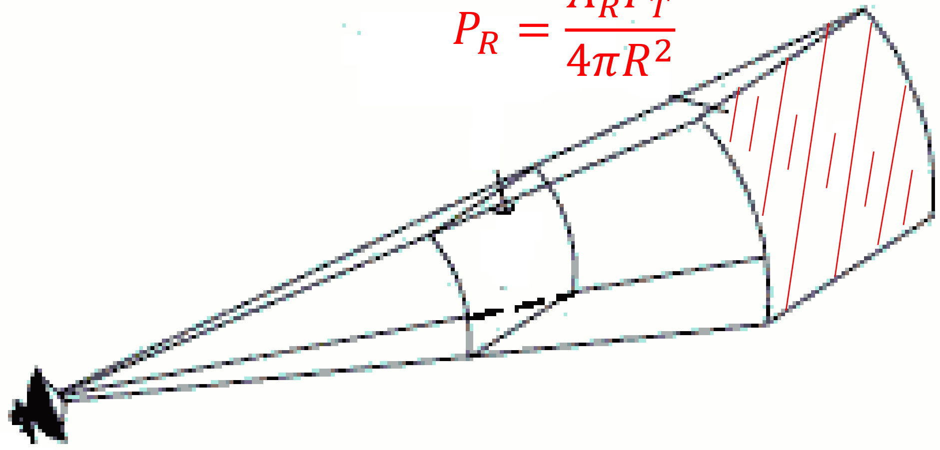
1. Consider a transmitter, TX, which is radiating a total power, P_T. All of this power will pass through a sphere of radius, r, centred on the transmitter.
2. The total surface area of such a sphere will be $4\pi R^2$
3. If the TX antenna is isotropic (omnidirectional), an area, A_R , laid on the sphere will intercept a power.
4. Therefore the received power will be:

$$P_R = \frac{A_R P_T}{4\pi R^2}$$

1. This equation is generally referred to as the **Friis Equation.**
2. Friis equation we can see that the received power is directly proportional to the transmitted power P_T but inversely proportional to the square of the distance R.

- Even if P_T is in KW, the received signal power several kms will be very small.

$$P_R = \frac{A_R P_T}{4\pi R^2}$$



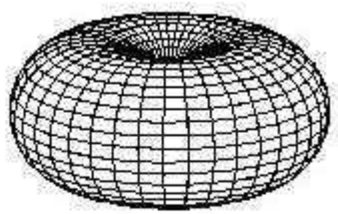
OVERCOMING FADING

1. Increase the Transmit power

2. Increase the gain of the transmit antenna instead of making them omni-directional

3. Increase the gain of the receive antenna

$$P_R = \frac{G_T G_R A_R P_T}{4\pi R^2}$$



Radiation Pattern of Omni-directional Antenna

Omni-directional Antenna

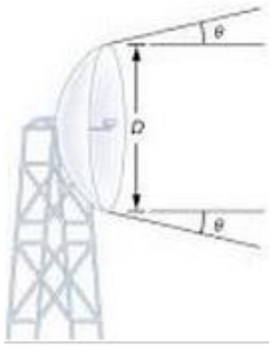
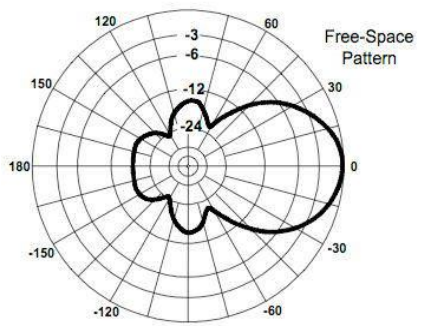
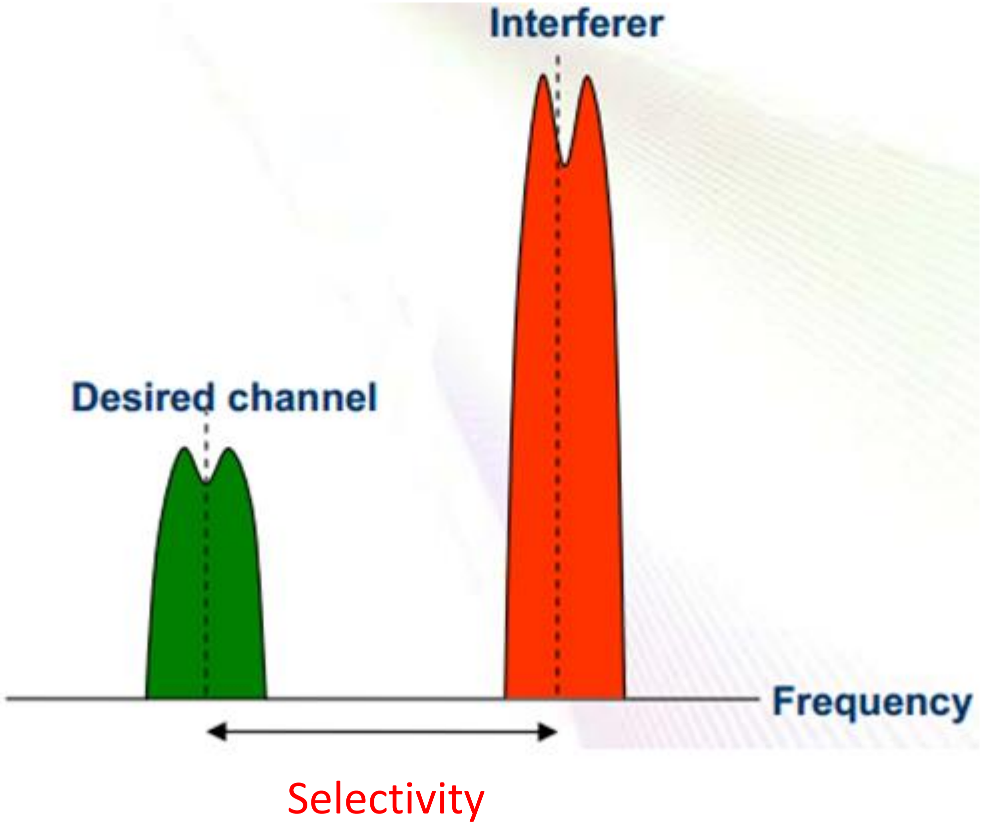


Figure E9-1



PROBLEM OF BASIC RECEIVER - SELECTIVITY

- **Selectivity** measures the ability of the receiver to distinguish between two adjacent channels.



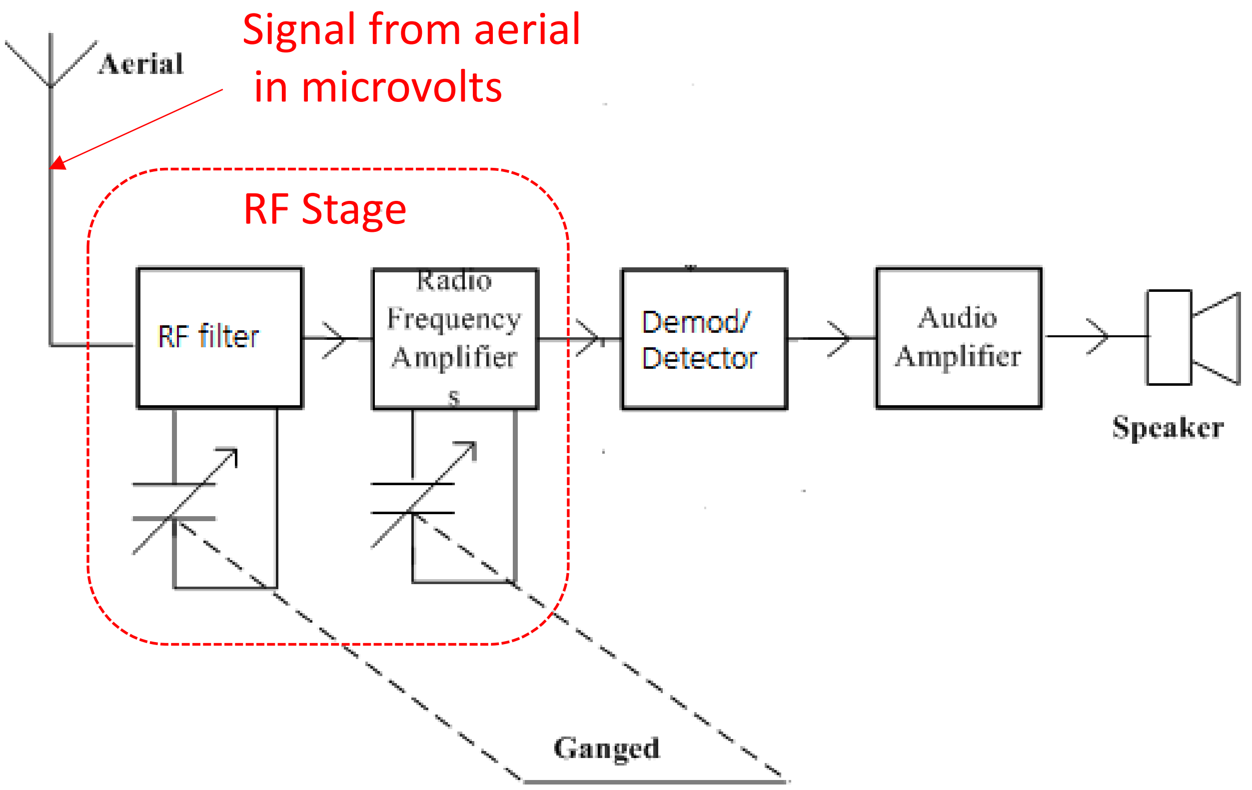
TRF, HOMODYNE, HETERODYNE & SUPERHETERODYNE

EEEN 462 – ANALOGUE COMMUNICATION SYSTEMS

Friday, November 22, 2024

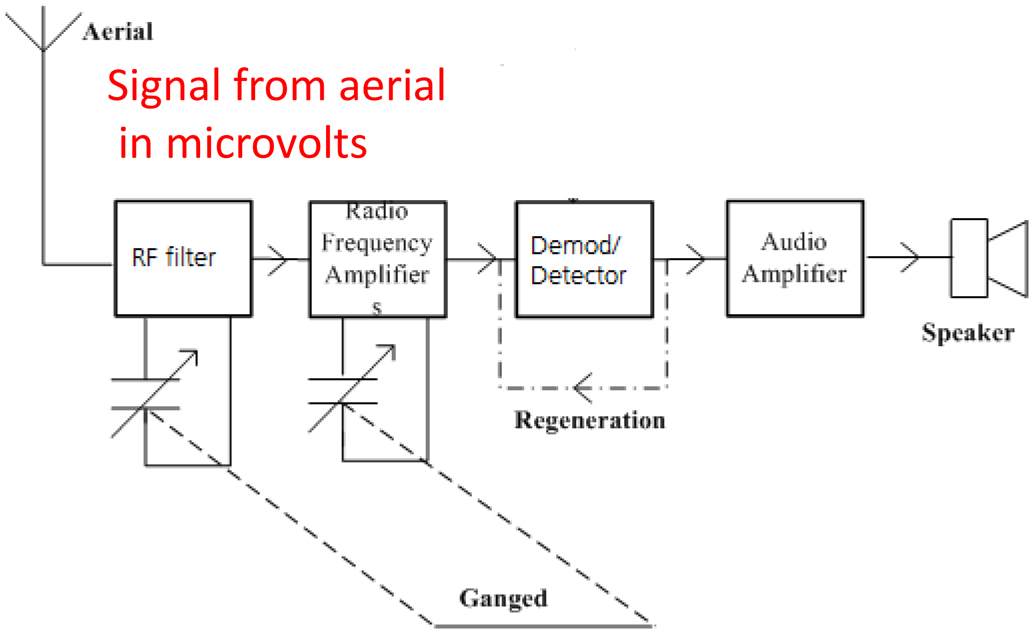
TUNED RADIO FREQUENCY (TRF) RECEIVER

1. A tuned Radio Frequency (TFR) receiver consists of:
   a) **RF Stage** – a tuned Radio Frequency amplifier
   b) **Demodulator or detector** which demodulates the signal
   c) **Audio Amplifier** amplifies the demodulated signal
2. Receiver was widely used in the 1920s but was replaced in the 1930s with the superhetrodyne receiver



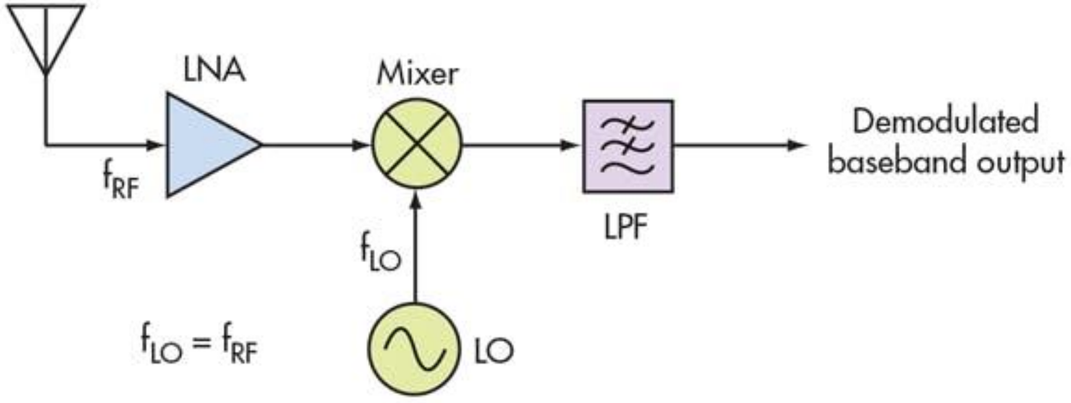
REGENERATIVE TFR RECEIVERS

1. **Regenerative Receiver** is a TRF receiver with positive feedback from its output to increase the gain of that stage.
2. The inclusion of regeneration or "reaction" increases the sensitivity of the receiver.
3. However, if too much regeneration is applied, the set may go into self-oscillation and "howl.
4. It is possible under these circumstances (depending on the design of the receiver) that the set will re-transmit a radio signal from the aerial, possibly causing interference to other users.



HOMODYNE RECEIVER

1. **Homodyne (also called synchrodyne, or zero-IF receiver)** is a radio receiver design that demodulates the incoming radio signal using synchronous detection driven by a local oscillator whose frequency is identical to, or very close to the carrier frequency of the intended signal.
2. This is in contrast to the standard superheterodyne receiver where this is accomplished only after an initial conversion to an intermediate frequency.



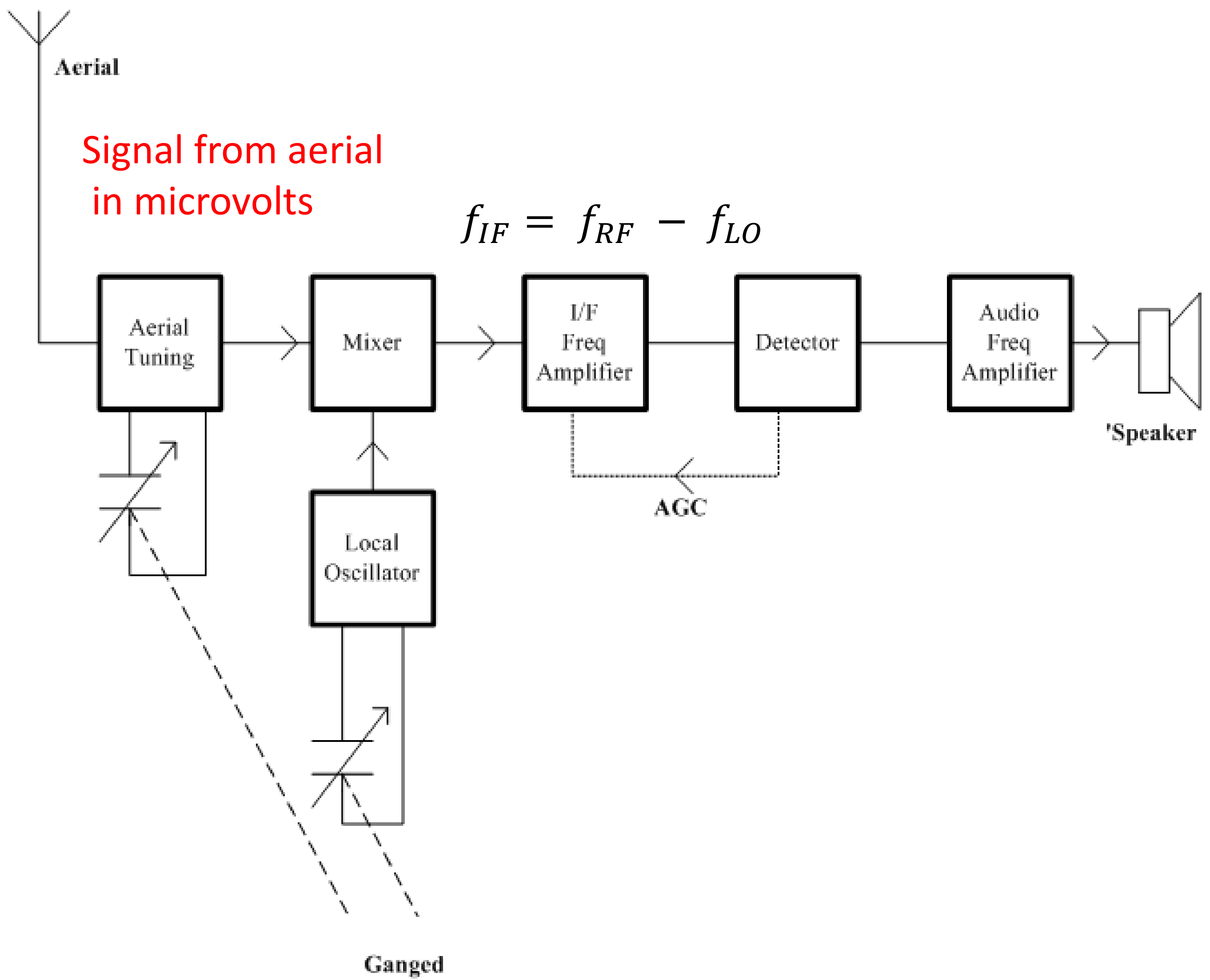
WHY DO WE NEED INTERMEDIATE FREQUENCY?

1. **All radio receivers require an amplifier** at the Radio Frequency (RF) stage.
2. The problem is designing an amplifiers that has a flat response in the whole tunable RF band.
3. One solution is to have multiple amplifiers covering the entire band, but that would be expensive.
4. The **superheterodyne receiver** converts all signals in the tunable frequency range to one frequency called the Intermediate frequency (IF).

Further Reading:
The Evolution And Importance Of Intermediate Frequency

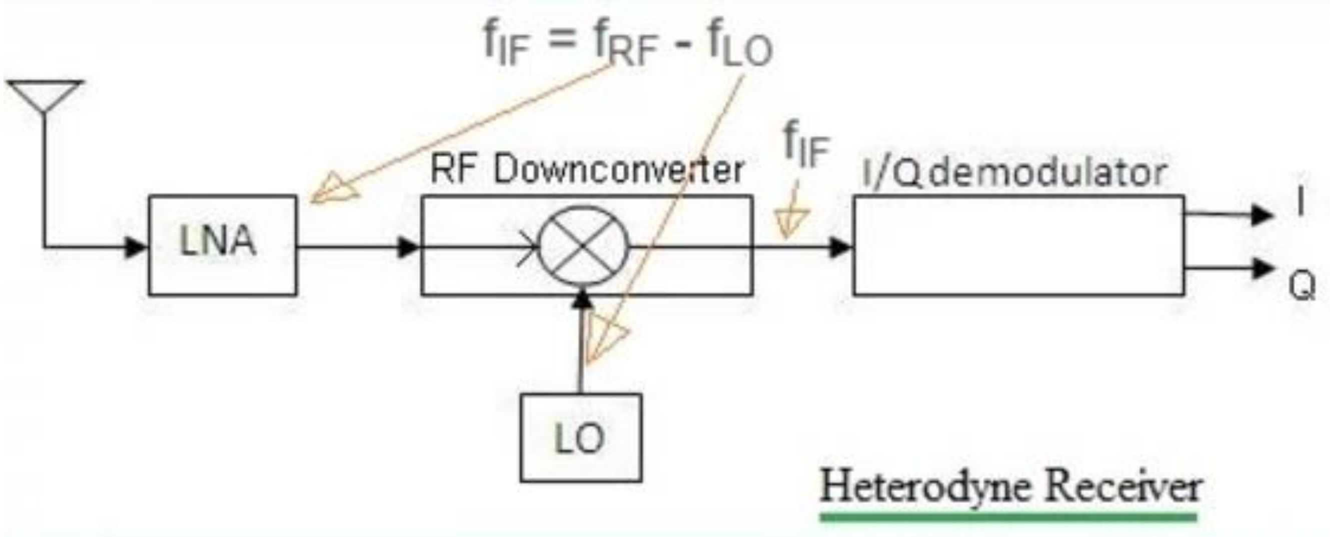
HETERODYNE RECEIVER

1. **Heterodyne receiver** uses frequency mixing to convert a received signal to a fixed Intermediate Frequency (IF), which can be more conveniently processed than the original radio carrier frequency.
2. **heterodyne** is derived from the Greek roots hetero- "different", and -dyne "power".



HETERODYNE RECEIVER /02

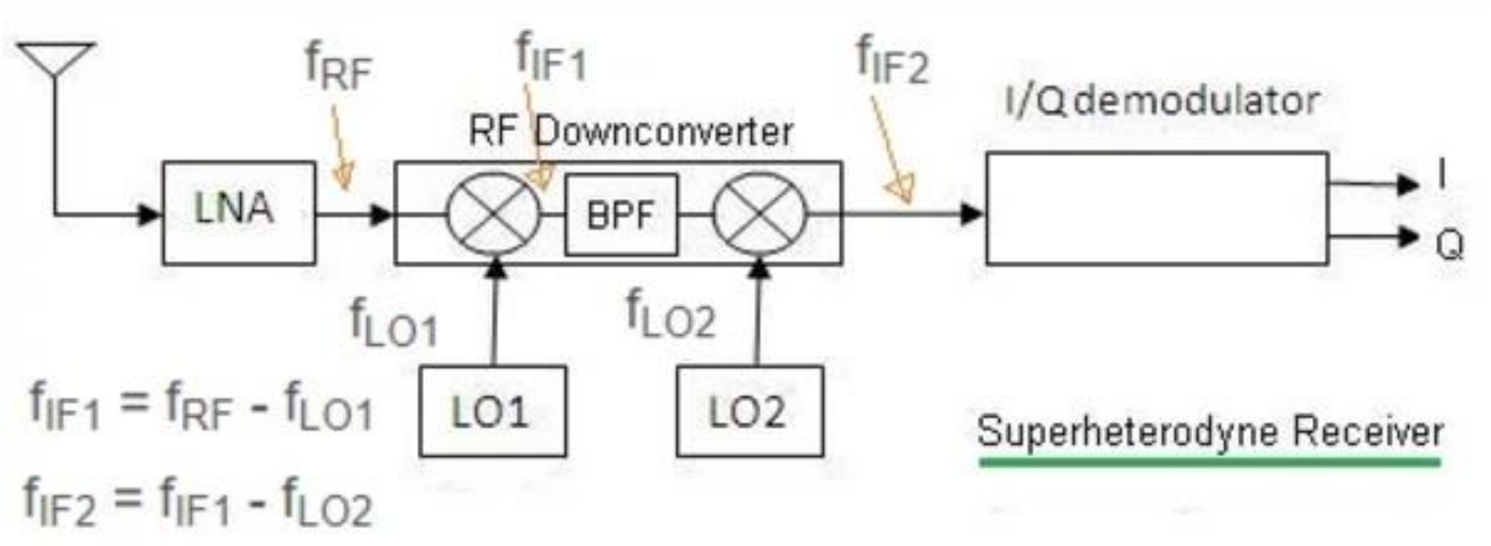
Heterodyne receiver uses single RF mixer for conversion of modulated RF signal to baseband I/Q signals.



SUPERHETERODYNE RECEIVER

Superheterodyne receiver uses dual RF mixers for conversion of modulated RF signal to baseband signals.

1. **Superheterodyne** is a contraction of "supersonic heterodyne", where:
   a) **supersonic** indicates frequencies above the range of human hearing.
   b) **heterodyne** is derived from the Greek roots hetero- "different", and -dyne "power".



ADVANTAGES OF SUPERHETERODYNE RECEIVER

The advantages of superheterodyne receiver are:

1. All processing takes place at lower frequencies. The devices are cheaper at such lower frequencies compare to higher frequencies.
2. It is easy to filter IF signal compared to RF signal.
3. It offers better sensitivity compare to homodyne receiver architecture.
4. Heterodyne uses single conversion and Superheterodyne uses double conversion. This prevents image noise fold-over due to use of two IF frequencies before conversion to baseband.

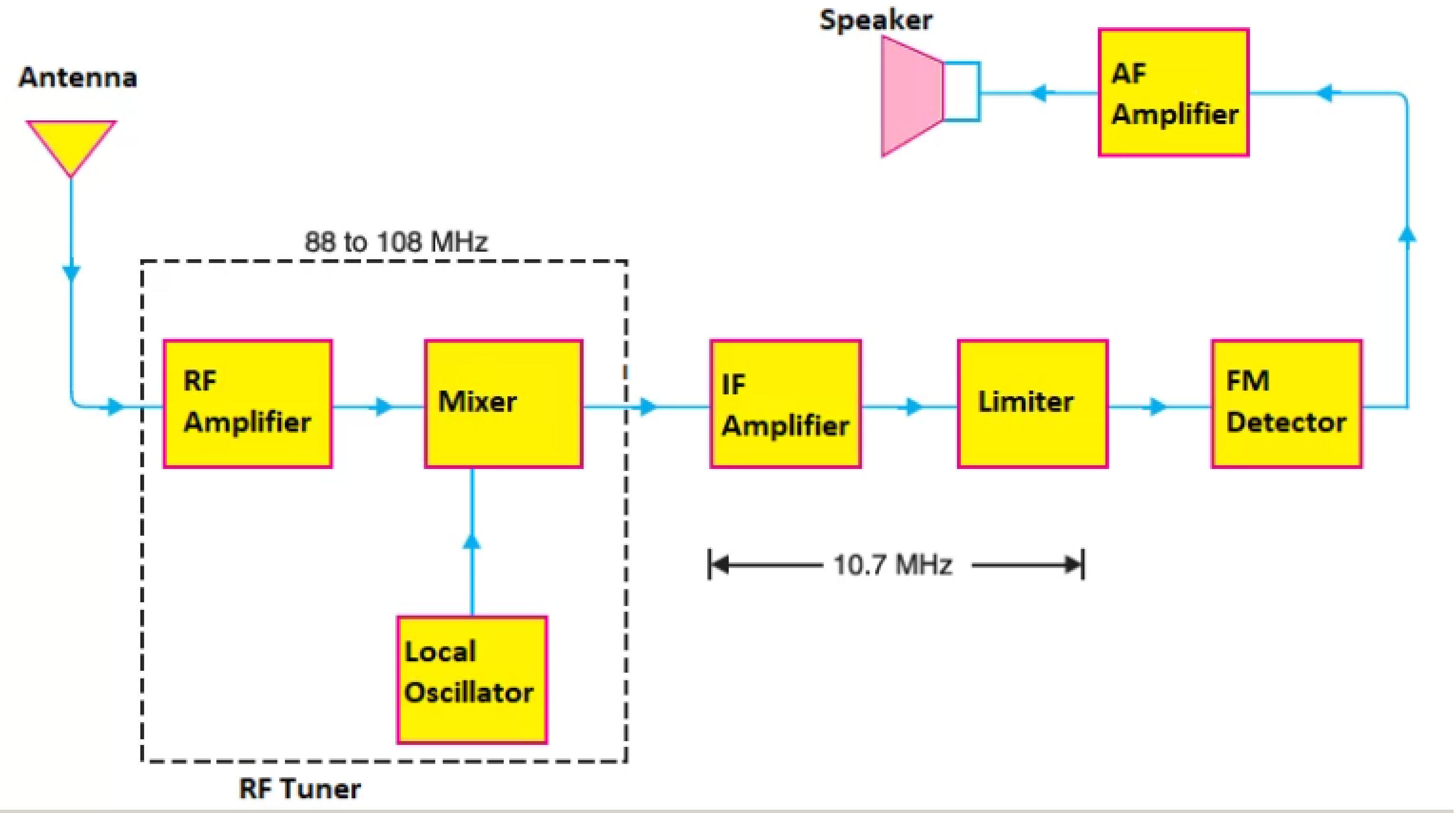
DISADVANTAGES OF HETERODYNE ARCHITECTURES

The disadvantages of superheterodyne Receiver and heterodyne receiver architecture types are:

1. It requires additional LOs (Local Oscillators) and RF Mixers to convert signal from RF to IF before conversion to baseband. This increases cost of overall receiver.
2. Filters are needed to remove any LO leakage as well as undesired frequency components to prevent image frequencies. This also increases cost as well as complexity of the receiver.

FM RECEIVER

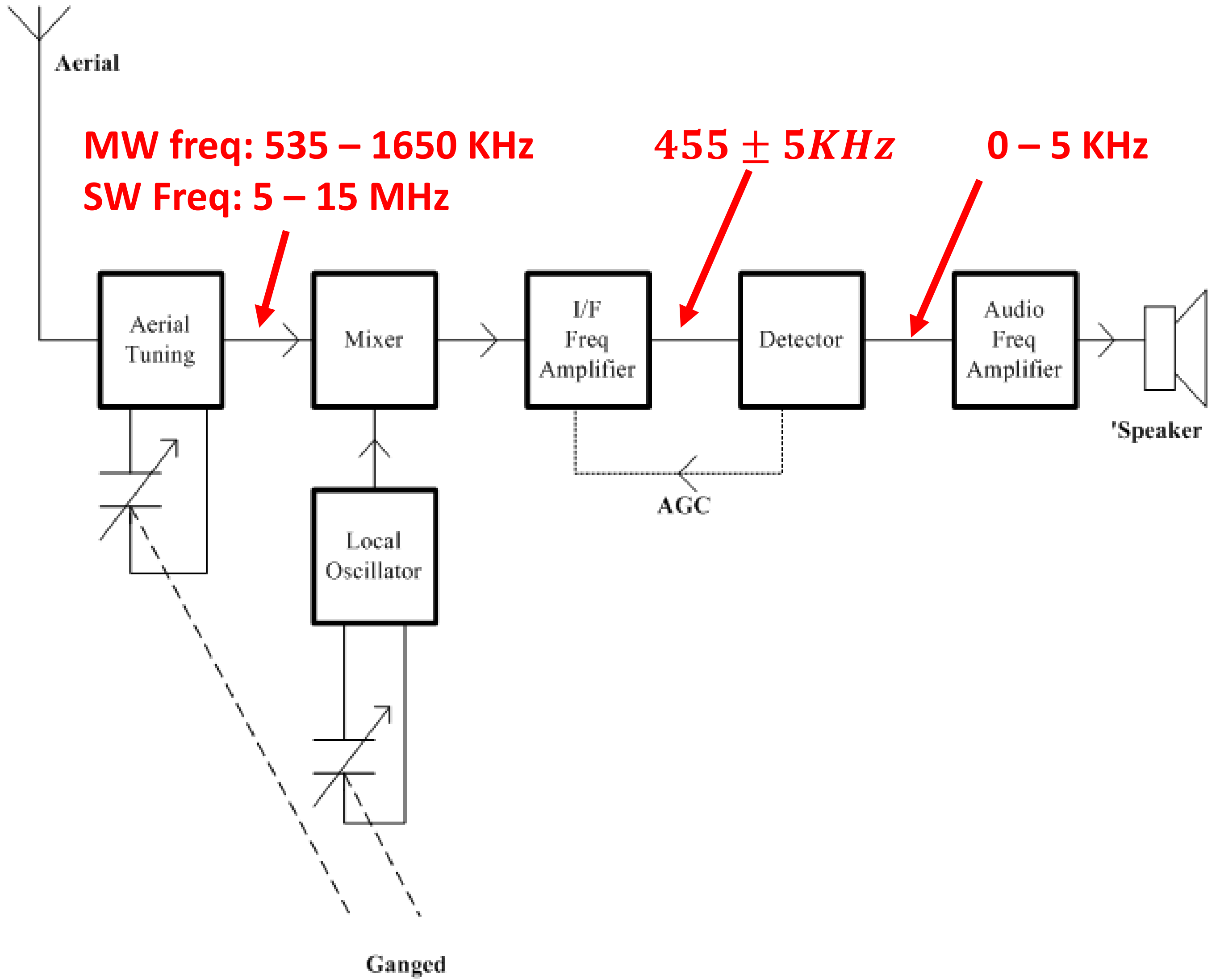
1. The FM receiver is a heterodyne receiver.
2. The intermediate frequency (IF) of an FM receiver is around 10.7 MHz.



MW & SHORTWAVE RECEIVER

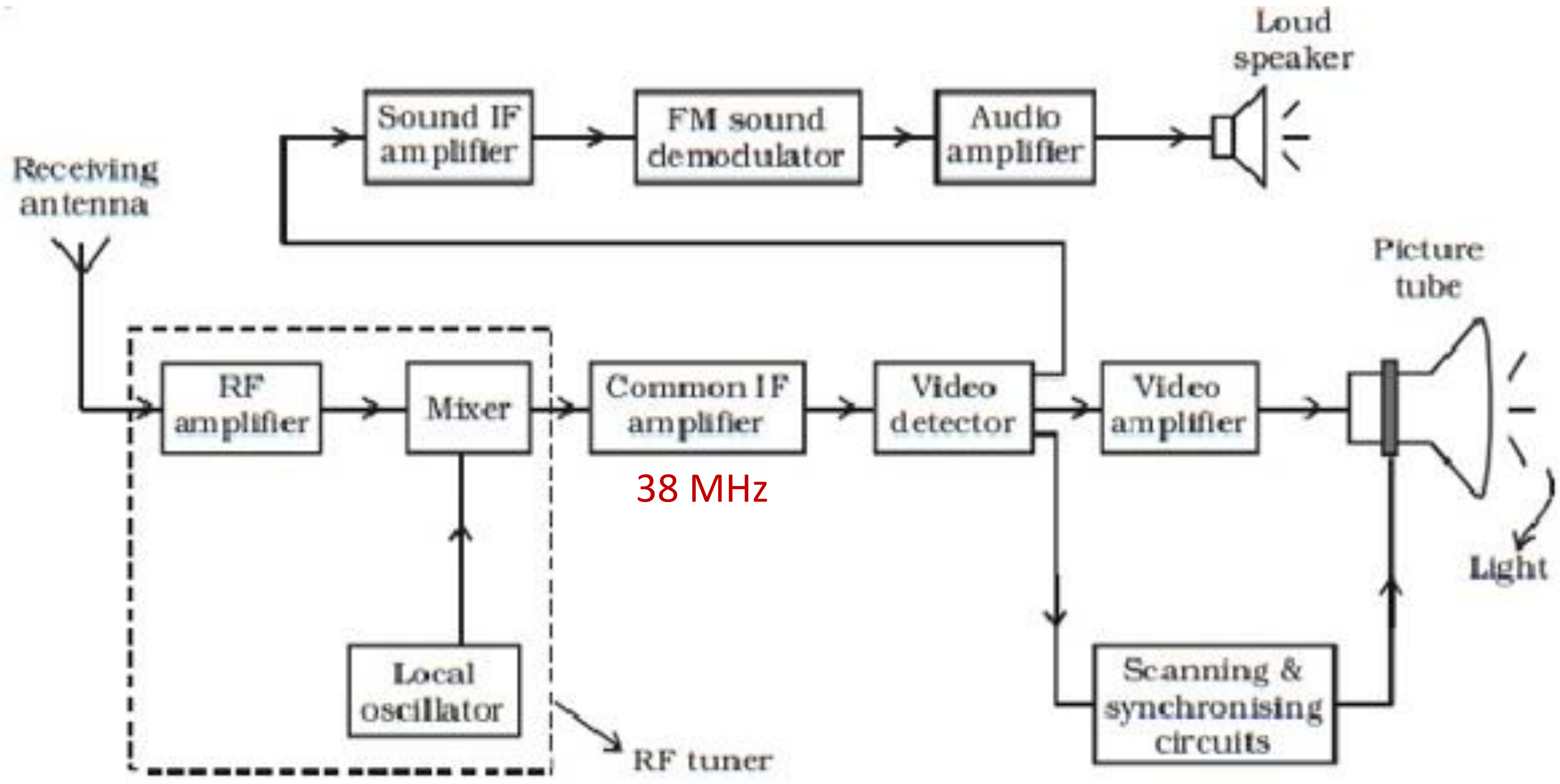
MW and shortwave receivers use heterodyne architecture.

1. Two frequency bands:
   a) Medium Wave – 535 kHz – 1650 KHz
   b) Short Wave – 5 – 15 MHz
2. Intermediate Frequency of 455 KHz



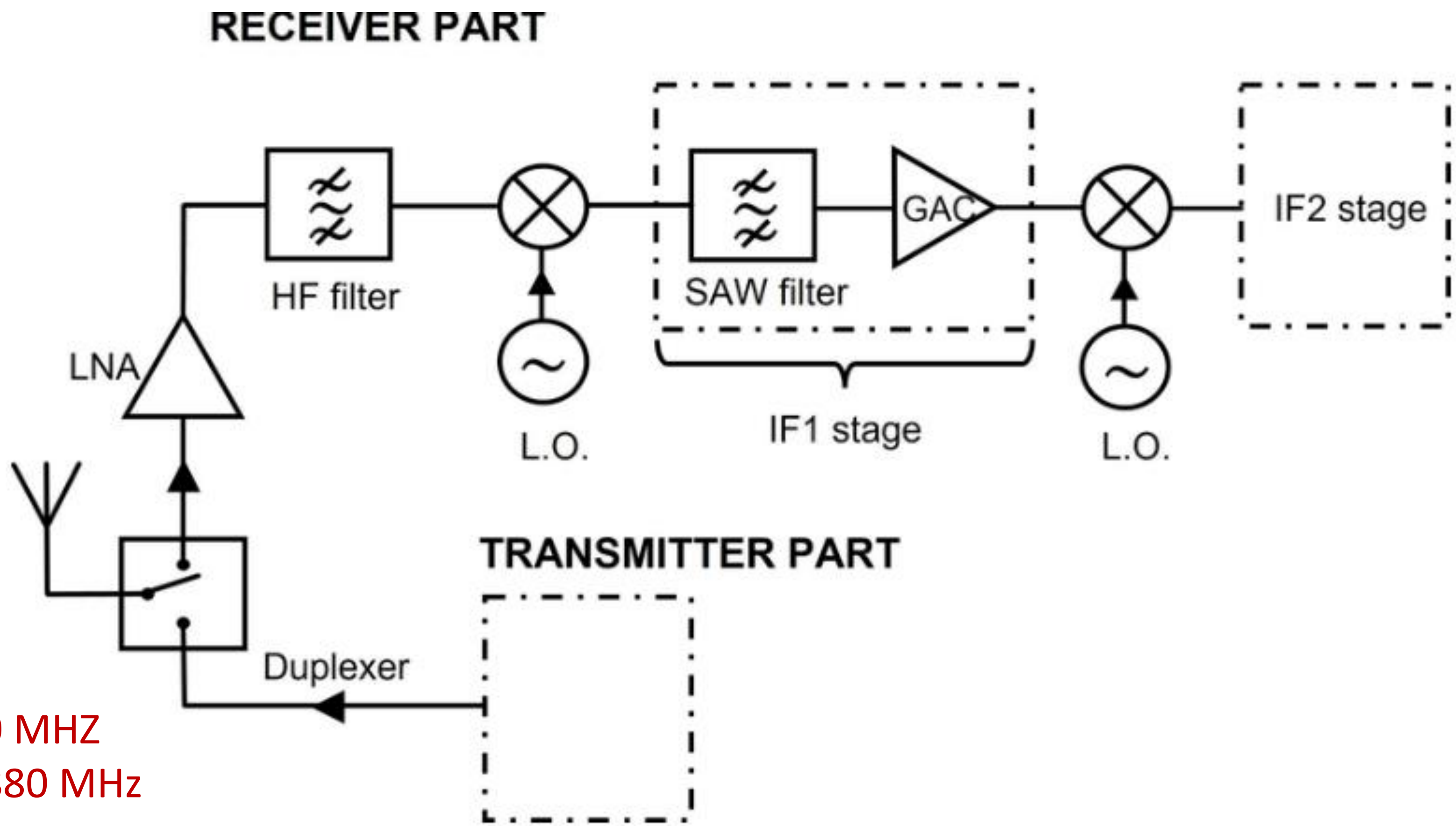
ANALOG TV RECEIVER

1. Analogue TV receiver uses superheterodyne receivers.
2. The Intermediate frequency is 38 MHz.



RECEIVER IN GSM PHONE

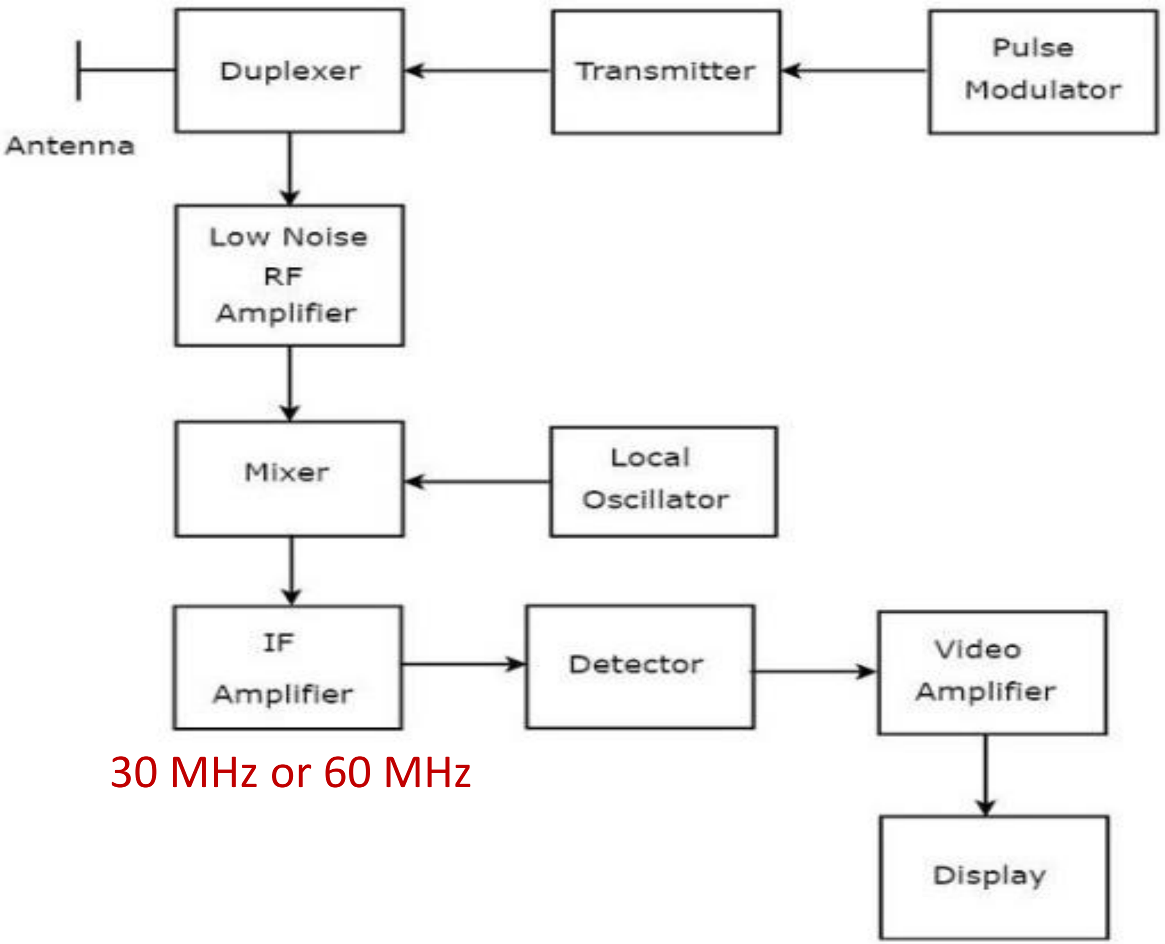
GSM phone uses a superheterodyne architecture.



880 – 960 MHZ
1710 – 1880 MHz

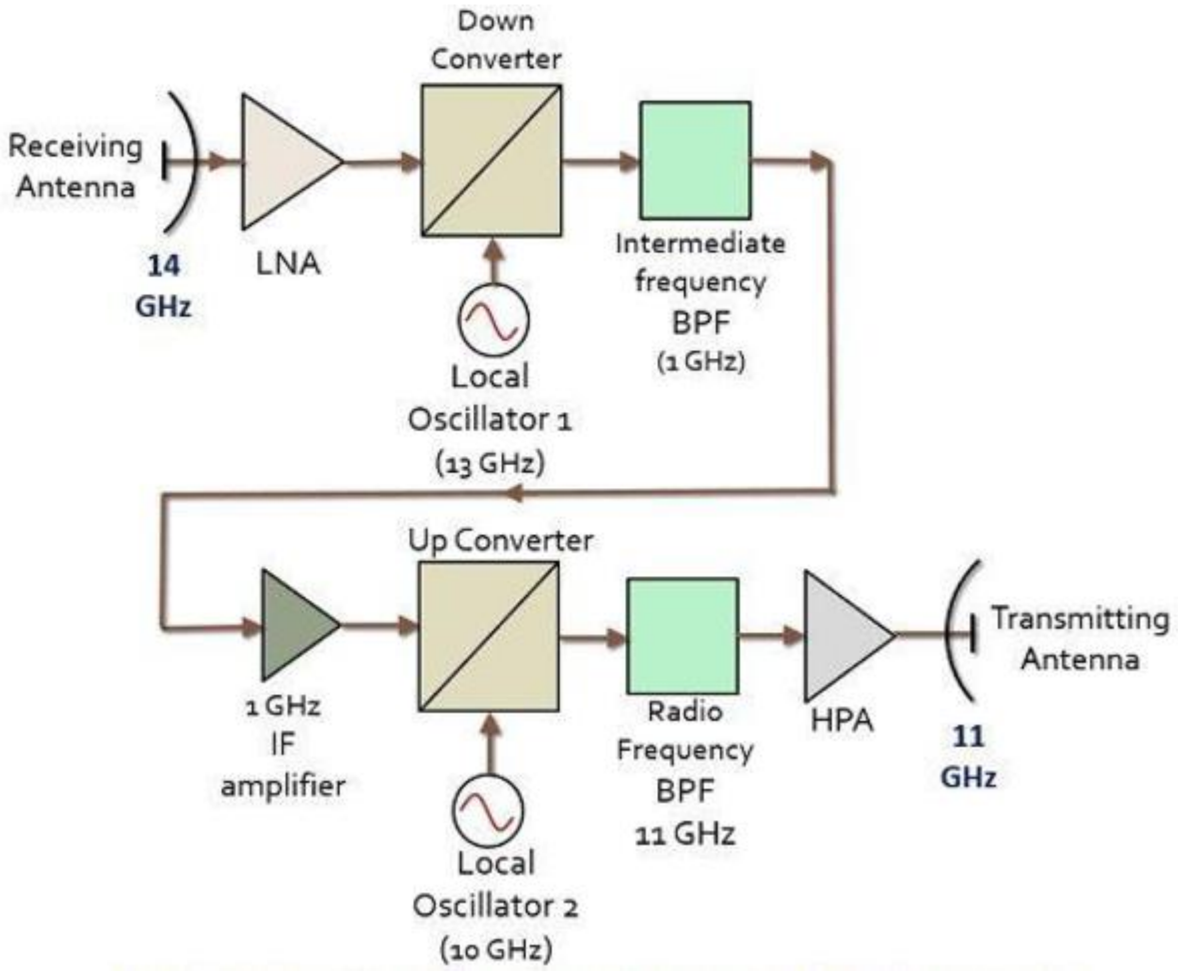
PULSE RADAR RECEIVER

The intermediate frequency of a radar system is usually 30 MHz or 60 MHz.



SATELLITE TRANSPONDER

1. **A satellite transponder** is a series of interconnections that form a communication channel between the transmitting antenna and the receiving antenna.
2. A typical communication satellite contains about 15-30 transponders.



(a) Block diagram of a 14/11 GHz Ku-Band Transponder