Unit → 3

1.) Microwave Signals...

Microwave are ~~the~~ a class of EM waves typically defined by their frequency range, which spans from 300 MHz to 300 GHz. (Wavelengths from 1m to 1 milimeter). These waves are crucial in modern communication and radar system due to their unique propagation characteristics and their ability to carry large amount of data.

★ Characteristics of microwave signals...

- High frequency and short wavelength :-
  This result in high resolution and data - carrying capacity.
- Line-of-sight Propagation :-
  Microwaves typically do not diffract around obstacles and requires a clear path between transmitter and receiver.
- Directional transmission :-
  They can be easily focused using parabolic antennas or waveguides.
- Minimal Interference :-
  Microwaves are less prone to noise and interference compared to lower frequency bands.

★ Applications of microwave signals...

- Radar System (military and civillans)
- Satellite and space communication.
- Wireless broadband networks.
- Microwave Ovens.
- Medical Theory (e.g. diathermy).
- Remote sensing and navigation.

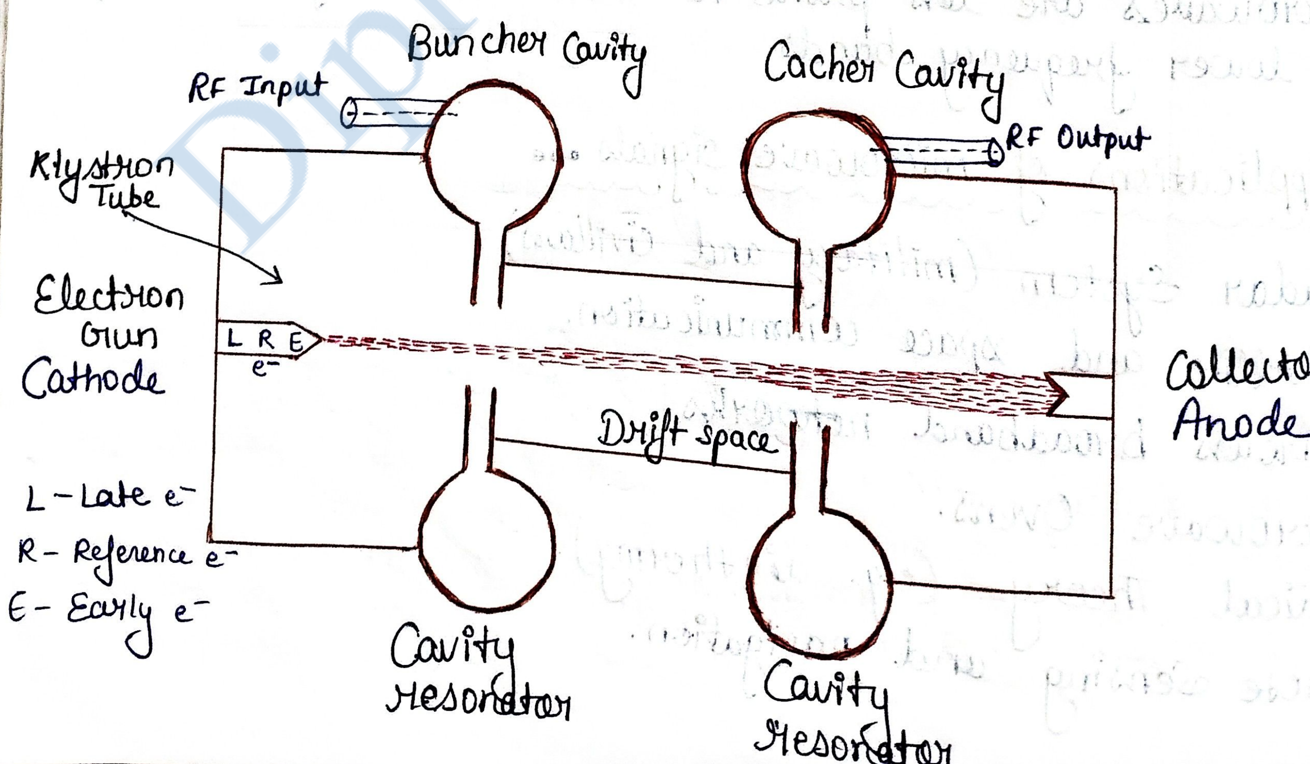
Microwave devices...

Microwave devices are specialised components that generate, amplify or manipulate microwave signals, they are broadly classified into two types.

- Oscillator (Which generate microwave energy).
- Amplifier (Which boost signal strength).

Two Cavity klystron...

- Two Cavity klystron is an amplifier that amplifies RF signal.
- Two cavity klystron Amplifier Functions based on the principle of Velocity Modulation.
- It consists of Two Cavities: Buncher Cavity and Cacher Cavity.
- RF Input is buncher cavity and Amplified RF output is carried out from Cacher Cavity.
- The essential elements of klystron are electron beams and cavity resonators.
- Electron beams are ~~employed~~ produced from a source and the Cavity klystrons are employed to amplify the signals. A Collector is present at the end to collect the electrons.



- The electrons emitted by the Cathode are accelerated towards the first resonator (Buncher Cavity). The collector at the end is at the same potential as the resonator.

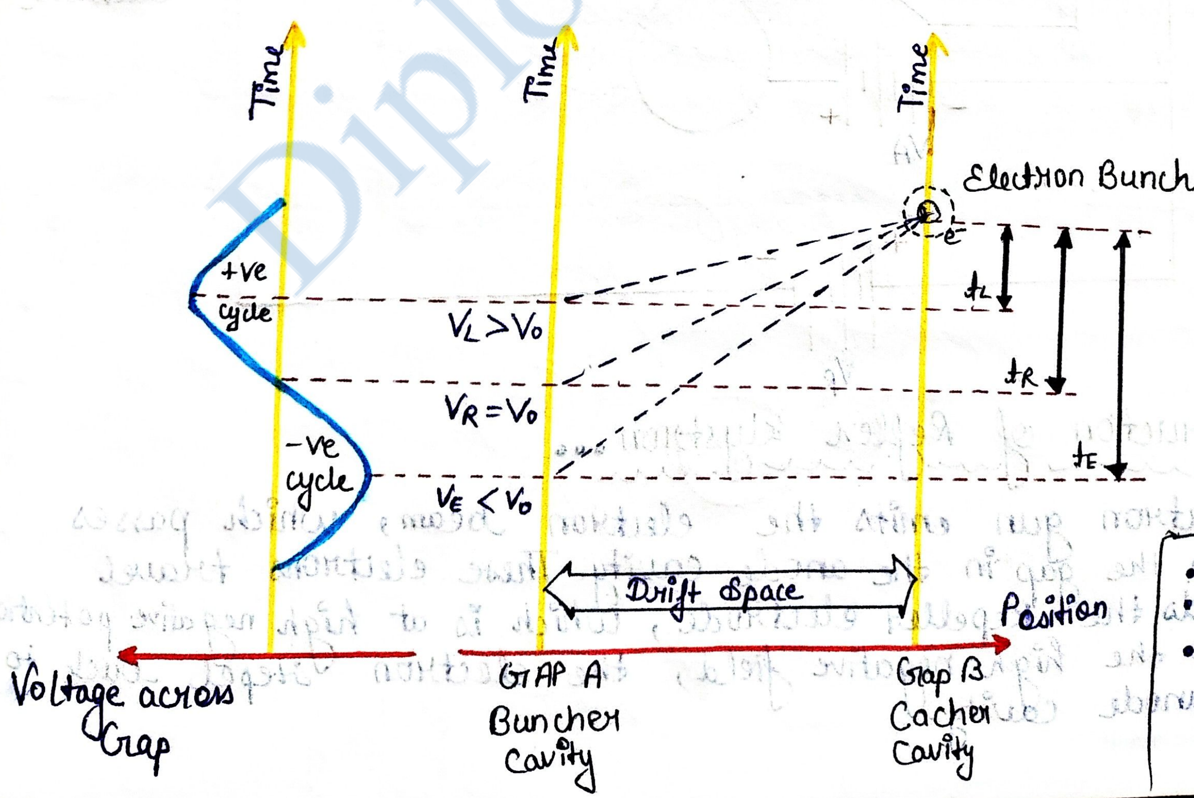
- Hence the electrons have a constant speed in the gap between the Cavity resonators.

- Initially, the first cavity resonator (Buncher Cavity) is supplied with a weak high frequency signal, which has to be amplified.

- The signal will initiate an electromagnetic field inside the cavity. This signal is passed through a coaxial cable. Due to this field, the electrons that pass through the cavity resonator are modulated.

- On arriving at the second resonator (Cacher Cavity), the electrons are induced with another EMF at the same frequency.
  This field is strong enough to extract a large signal from the second cavity (Cacher Cavity).

★ Applegate diagram of two Cavity klystron Amplifier...

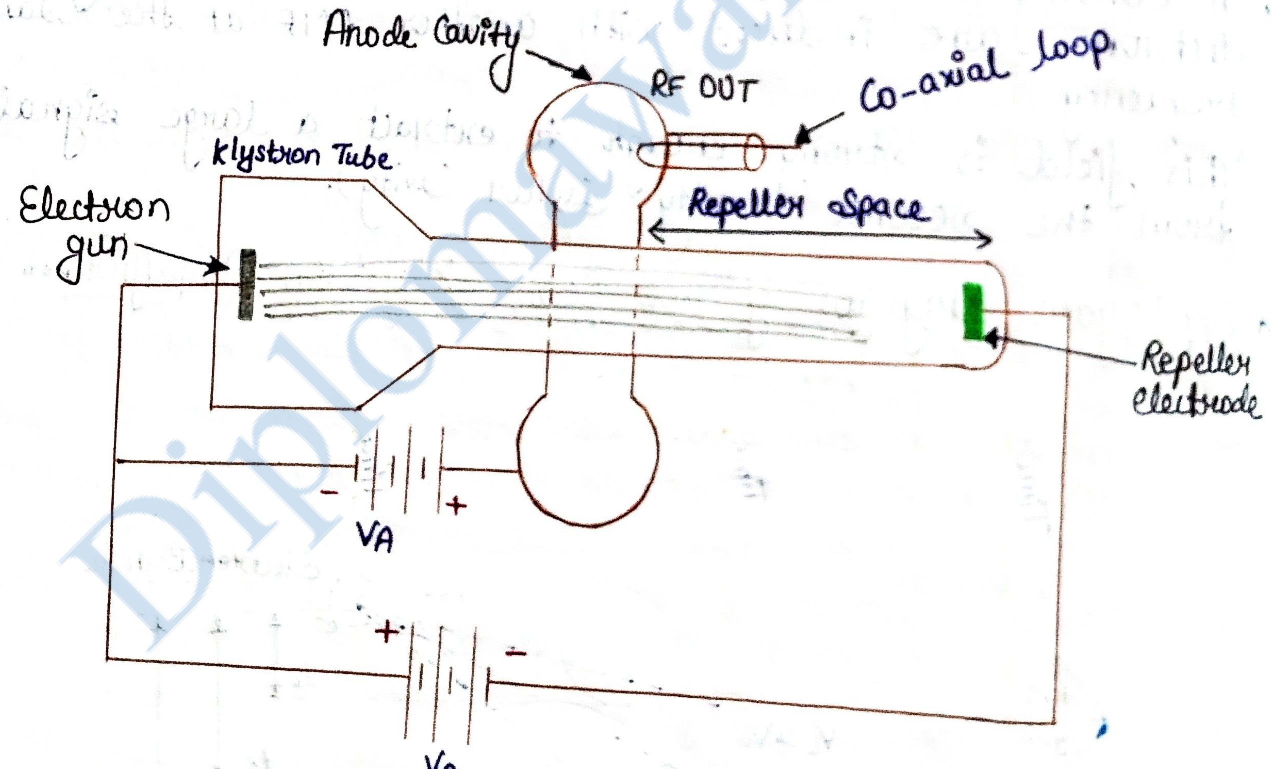


- Satellite Sys
- Radar

Reflex Klystron...

- Reflex klystron is a Microwave oscillator.
- A Reflex klystron is a Vacuum Tube that generates microwave frequencies.
- This microwave generator, is a klystron that works on reflections and oscillations in a single cavity, which has a variable frequency.
- Reflex klystron consists of an electron gun, a cathode filament, an anode cavity, and an electrode at the cathode potential. It provides low power and has low efficiency.
- Mainly it is used in the laboratory as a Microwave source and it is also used in RADARS.

★ Structure of Reflex klystron...



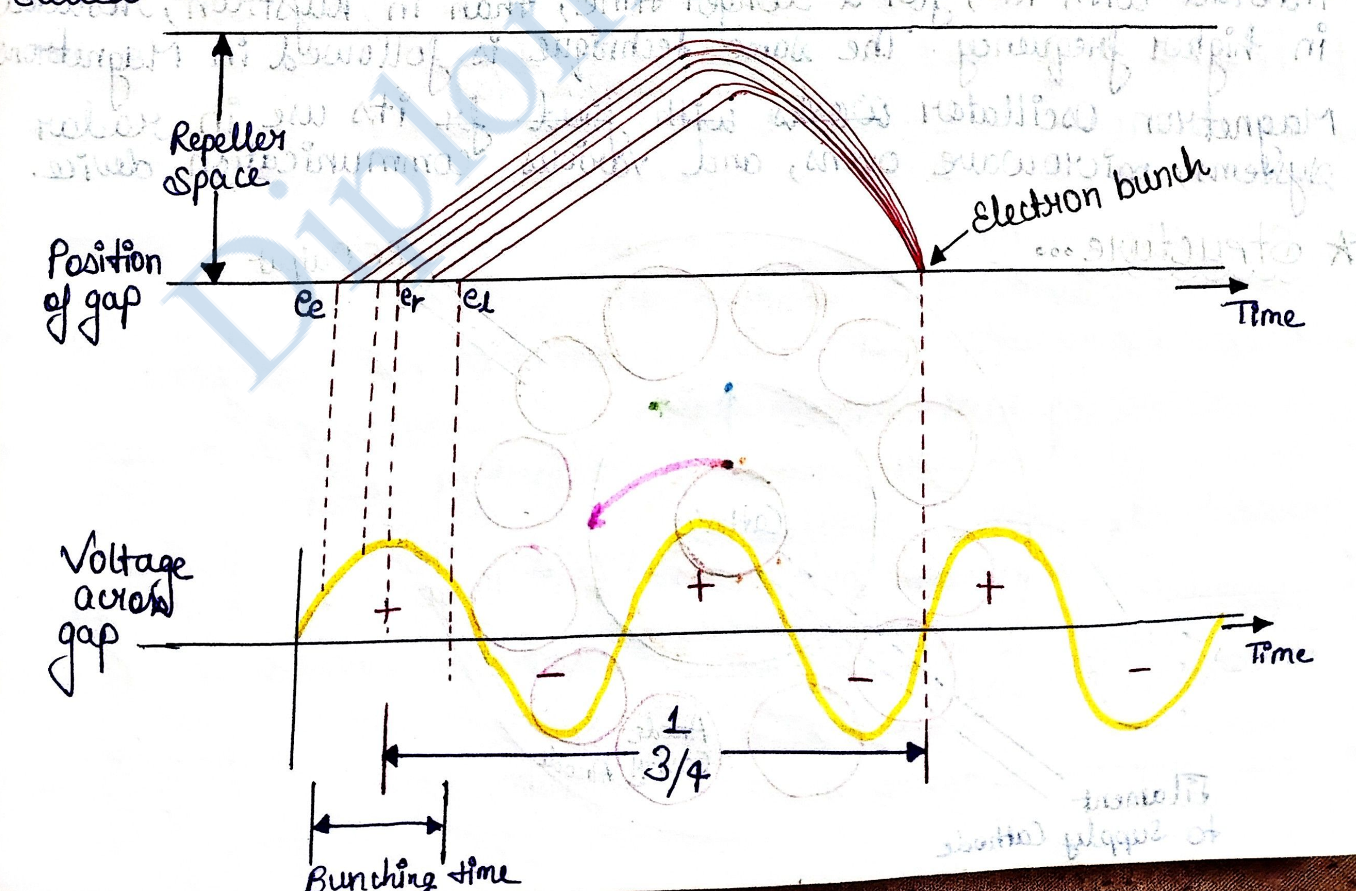
★ Construction of Reflex klystron...

- The electron gun emits the electron beam, which passes through the gap in the anode cavity. These electrons travel towards the Repeller electrode, which is at high negative potential. Due to the high negative field, the electron repel back to the anode cavity.

- In their return journey, the electrons give more energy to the gap and these oscillations are sustained. From the above figure, It is assumed that oscillations already exist in the tube and they are sustained by its operation. The electrons while passing through the anode cavity, gain some velocity.

★ Operation of Reflex klystron...

- The electron beam is accelerated towards the anode cavity. Let us assume that a reference electron e_r crosses the anode cavity but has no extra velocity and it repels back after reaching the Repeller electrode, with the same velocity.
- Another electron, let's say e_e which has started earlier than this reference electron, reaches the Repeller first, but returns slowly, reaching at the same time as the difference electron.
- We have another electron, the late electron e_l, which starts later than both e_r and e_e, however, it moves with greater velocity while returning back, reaching at the same time as e_r and e_e.
- Now these three electrons, namely e_r, e_e and e_l reach the gap at the same time, forming an electron bunch. This travel time is called as transit time, which should have an optimum value.



- The anode cavity accelerates the electrons while going and gains their energy by retarding them during the return journey. When the gap voltage is at maximum positive, this lets the maximum negative electrons to retard.

The optimum transit time is represented as

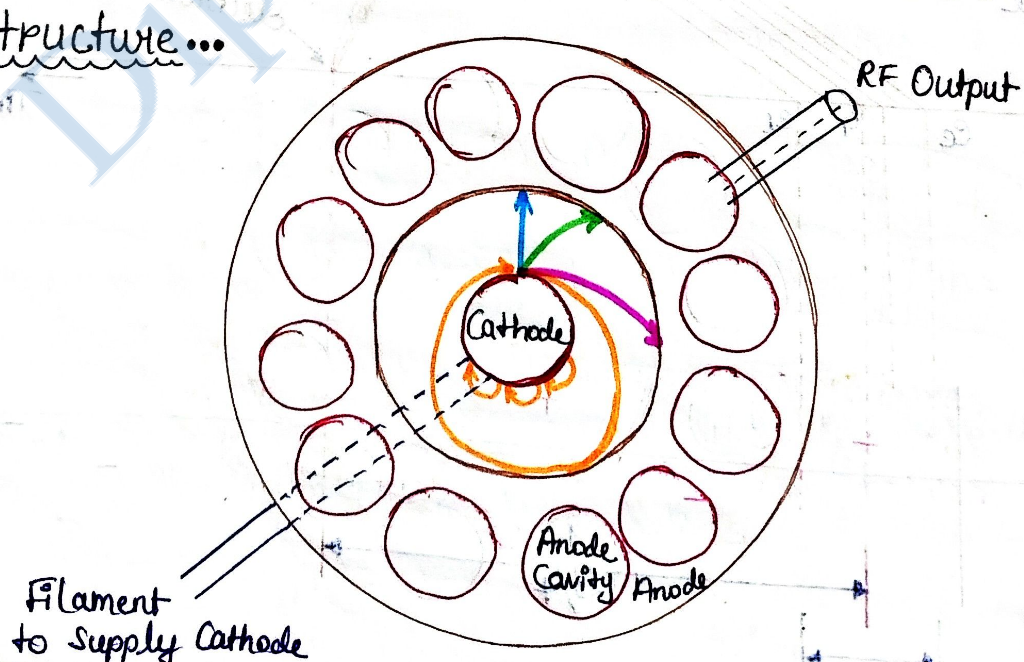
$$T = n + \frac{3}{4}$$ where n is an integer.

This transit time depends upon the Repeller and anode voltage.

2.) Magnetron...

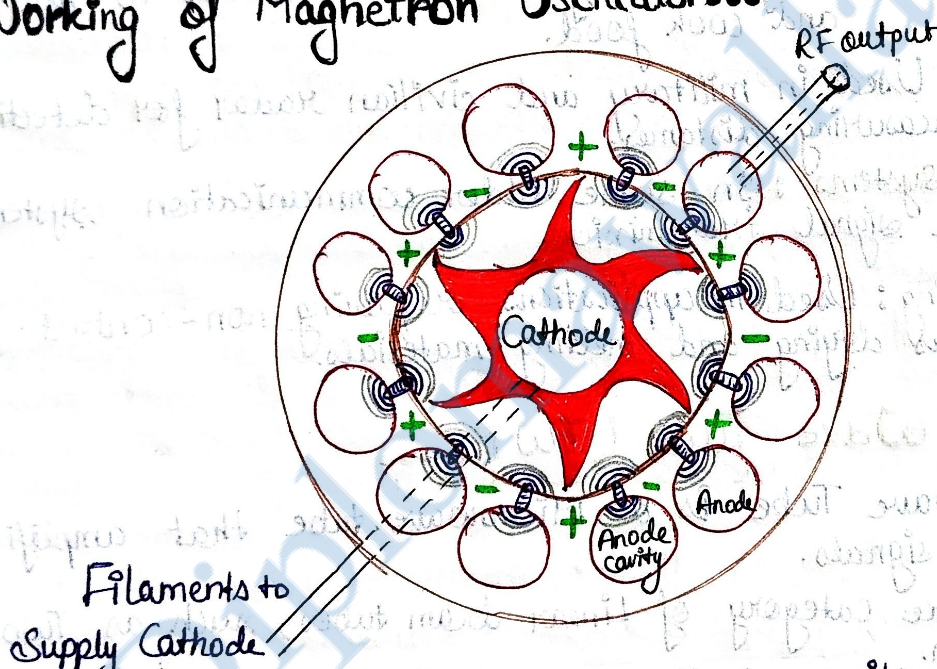
- Magnetron Oscillator is a type of microwave tube that generates high-frequency microwave oscillations.
- Magnetron Oscillator is Multi Cavity Device available with 8 to 20 cavities.
- Magnetron oscillator works with fixed frequency based on structure and available with frequency range from 0.6GHz to 30GHz.
- Magnetrons are the cross-field tubes in which the electric and magnetic fields across, i.e. run perpendicular to each other.
- In TWT, it was observed that electrons when made to interact with RF, for a longer time, than in klystron, resulted in higher frequency. The same technique is followed in Magnetrons
- Magnetron Oscillator ~~works with fixed fr~~ is widely known for its use in radar systems, microwave ovens, and various communication device.

★ Structure...



- Magnetron Oscillator is Multi Cavity Device available with 8 to 20 cavities. Adjacent Cavity is having a 180-degree shift with each other, These cavities are Anode.
- Filaments are connected with cathode to generate electrons.
- Strong magnet is placed generating Magnetic field (Direction of H field is coming out of the figure).
- Output coupling is done with the use of coaxial loop. It can be done with the use of Waveguide.
- Without a magnetic field Electrons will go from Cathode to Anode directly.
- Due to the magnetic field, Electrons will flow a curved path.

★ Working of Magnetron Oscillator...



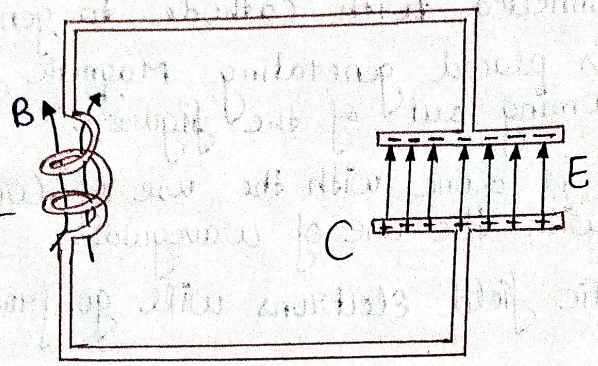
- Electron Emission: The heated cathode emits electrons, which are accelerated towards the anode by an applied electric field.
- Magnetic Field Interaction: The applied magnetic field causes the electrons to spiral and move in circular paths.
- Resonant Cavities: The spiraling electrons pass by the resonant activities, inducing oscillations at microwave frequencies.
- Energy Extraction: The oscillating electromagnetic fields in the cavities couple to an output waveguide or antenna, producing a coherent microwave signal.

★ Equivalent Circuit of Magnetron Oscillator...

- Magnetron Cavities are forming equivalent model of L (Inductor) and C (Capacitor) parallel combination. [Tank Ckt].

- Resonant occurs at frequency F.

$$F = \frac{1}{2\pi\sqrt{LC}}$$



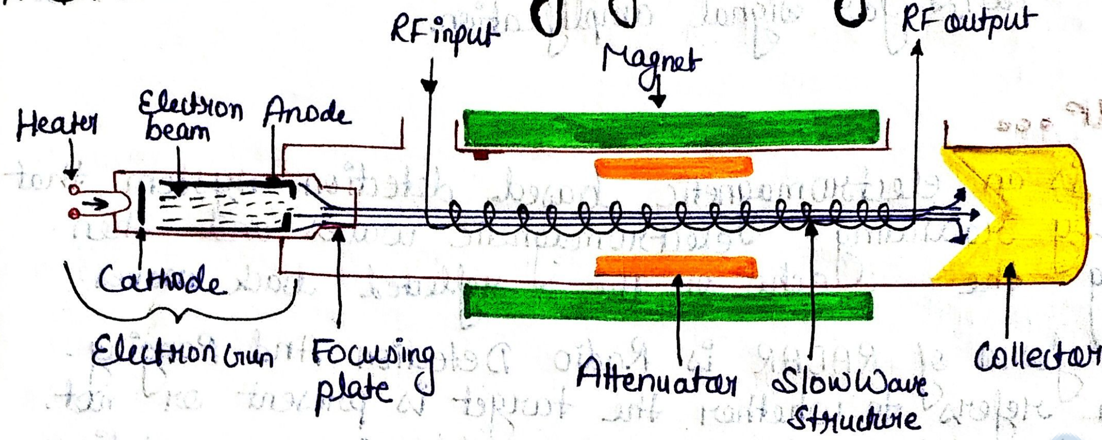
Application...

- Microwave Ovens: Magnetrons generate microwaves to heat and cook food.
- Radar Systems: Used in military and civilian radar for detecting objects and measuring distances.
- Communication systems: In some older communication systems for long-range signal transmission.
- Industrial Heating: Used in applications requiring non-contact heating, such as drying and melting materials.

Travelling Wave Tube (TWT)...

- Travelling Wave Tube is a Microwave tube that amplifies Microwave / RF signals.
- It belongs to the category of Linear beam tubes, such as Two Cavity klystron.
- Travelling Wave Tube offers wideband Frequency Amplification compared to other tubes.
- Travelling Wave Tube accounts for 50% of the total microwave tubes.
- Travelling wave tubes are broadband microwave devices which have no cavity resonators like klystrons. Amplification is done through the prolonged interaction between an electron beam and Radio Frequency (RF) field.
- Travelling Wave Tube is commonly employed in radar, satellite communications, and other applications requiring high-power, high-frequency signal amplification.

★ Structure and Working of Travelling Wave Tube...



- **Electron Gun & Collector :** An electron gun at one end of the tube emits a beam of electrons and the collector at the other end receives an electron beam.

- **Slow-Wave Structure :** The electron beam travels through a structure called a slow-wave structure (often a helix or a coupled-cavity structure) that slows down the RF signal to match the velocity of the electrons.

- **RF Signal Interaction :** As the RF signal and electron beam travel together, the RF signal induces velocity modulation in the electron beam. This modulation results in the bunching of electrons. Due to the bunching of electrons, RF Input is amplified at RF output.

★ Parameters of Travelling Wave Tube...

- Frequency Range : 300MHz to 50MHz.
- Power gain : 40 dB to 70 dB (Usually 60 dB).
- Power Range : Few watts to Mega Watts.
- Bandwidth : 10% to 20%.

★ Application of Travelling Wave Tube...

- **Radar Systems :** They are used in radar transmitters to amplify the radar signal, ensuring it can travel long distances.
- **Satellite Communication :** TWTs are widely used in satellite transponders to amplify signals for transmission to and from satellities.
- **Electronic Warfare :** TWTs are employed in electronic warfare systems for jamming and other signal amplification tasks.

- **Broadcasting:** High power television and radio transmitters often use TWTs for signal amplification.

3.) Radar...

- RADAR is an electromagnetic based detection system that works by radiating electromagnetic waves and then studying the echo or the reflected back waves.

- The full form of RADAR is Radio Detection And Ranging. Detection refers to whether the target is present or not. The target can be stationary or movable, i.e, non-stationary. Ranging refers to the distance between the Radar and the target.

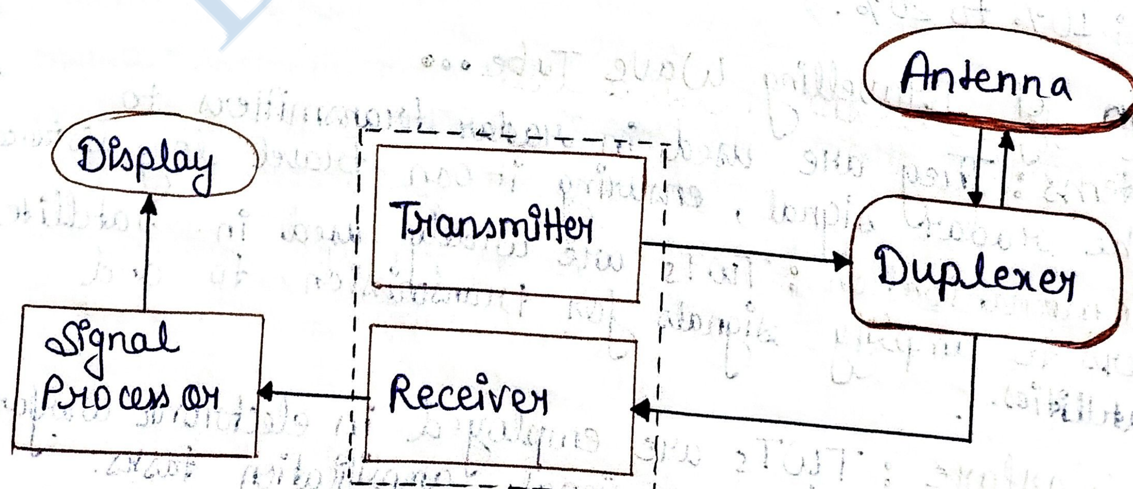
- RADAR or Radio Detection and Ranging is an electronic system that makes the use of radio frequency waves for detecting and measuring the distance, direction, and velocity of objects.

- A radar system transmits radio waves to the object and analyzes their reflections to perform these measurements.

- Hence, a radar system can detect the objects which are impossible to see with human sight. The most important feature of radar system is that they also work in adverse weather conditions like darkness and fog.

Parts of a RADAR System...

The block diagram of typical radar system :-



Components of Radar System...

1.) Antenna Unit:-

It comprises of two main components namely, a radar antenna and an electric motor. The antenna radiates radio wave to the objects and receives the reflected waves from the objects. The electric motor rotates the antenna in a specific direction to ensure reliable tracking of objects.

2.) Transceiver Unit:-

It acts as the heart of radar system and consists of a transmitter and a receiver. The transmitter is responsible for generating and transmitting radio or microwaves, while the receiver is provided to receive the reflected signals from the objects. This transmission and reception of radio waves take place through the antenna unit.

3.) Duplexer :-

It is a device that provides bidirectional flow of signals through a single path. In radar systems, it is used for isolating transmitter and receiver while allowing them to share the same antenna.

4.) Signal Processing Unit :-

This is also known as radar processor. This unit is responsible for analyzing the signals received by the receiver unit to determine the distance, velocity, and direction of the objects.

5.) Display :-

This component of the radar system provides a visual representation of results produced by the processor unit. It shows information like distance, velocity, movement patterns, current position, etc. of the objects.

Working Principle...

The working of a radar system is based on the transmission and reflection of radio frequency electromagnetic waves.

The step-by-by-step operation of a typical radar system explained below:-

Step 1:- Radar system generates a pulse of radio waves using a transmitter and sends it towards an object through the antenna unit.

Step 2:- The radio waves propagate to the object.

Step 3:- After hitting the object, some portion of the radio waves reflects back by the objects surface.

Step 4:- The reflected radio waves then received by the antenna.

Step 5:- The received radio waves are processed and analyzed by the signal processor to determine the distance, direction, and velocity of the object. These observations are then shown on a display screen.

Application...

- Radar systems are widely being used in aviation industry for managing the air traffic and ensuring safe ~~nag~~ navigation of air crafts.
- Radar systems are also a valuable tool in defense operations and are used for detecting and tracking enemy ships, aircrafts, and missiles.
- Radar Systems are also employed for ship navigation and avoiding collusions.
- Radar systems are also used in autonomous vehicles applications like ADAS (Advanced Driver Assistance Systems) or ACC (Adaptive Cruise Control).
- In weather forecasting, radar systems are used to determine the weather patterns and predict storms.