UNIT-2: TRAVELLING WAVE TUBES AND MAGNETRONS

HELIX TWTS - Significance - Types and Characteristics of Slow Wave Structures; Structure of TWT And Amplification Process (Qualitative Treatment)

M -TYPE TUBES - Introduction - Cross Field Effects – Magnetrons - Cylindrical Travelling Wave Magnetron - Hull Cutoff And Hartree Conditions - Modes Of Resonance And PI-Mode Operation - O/P Characteristics - Illustrative Problems.

Introduction:

Microwave resonators are tunable circuits used in microwave oscillators, amplifiers, wave meters and filters.

At the tuned frequency, the circuit resonates where the average energies stored in the electric field (or in the capacitor) W_e and magnetic field (or in the inductor) W_m are equal and the circuit impedance becomes purely real.

The total energy is therefore twice the electric or magnetic energy stored in the resonator.

Resonant Frequency: Resonant frequency f_r at which energy in the cavity attains maximum value = $2W_e$ or $2W_m$.

The Quality factor Q which is a measure of the frequency selectivity of a cavity.

Q= 2π (Maximum energy stored / Energy dissipated per cycle)

Drawback of Klystron:

1. Klystrons are essentially narrow band devices as they utilise cavity resonators to velocity modulate the electron beam over a narrow gap.
2. In klystron and magnetrons, the microwave circuit consists off a resonant structure which limits the bandwidth (or the operating frequency range) of the tube.

Travelling Wave Tube amplifier:

A travelling wave tube amplifier (TWT) circuit uses a helix slow wave non resonant microwave guiding structure and thus a broad band microwave amplifier.

Two main constituents of a TWT are,

(i) An electron beam and
(ii) A structure supporting a slow electromagnetic wave

In case of the TWT, microwave circuit is a non resonant and the wave propagate with the same speed as the electrons in the beam.

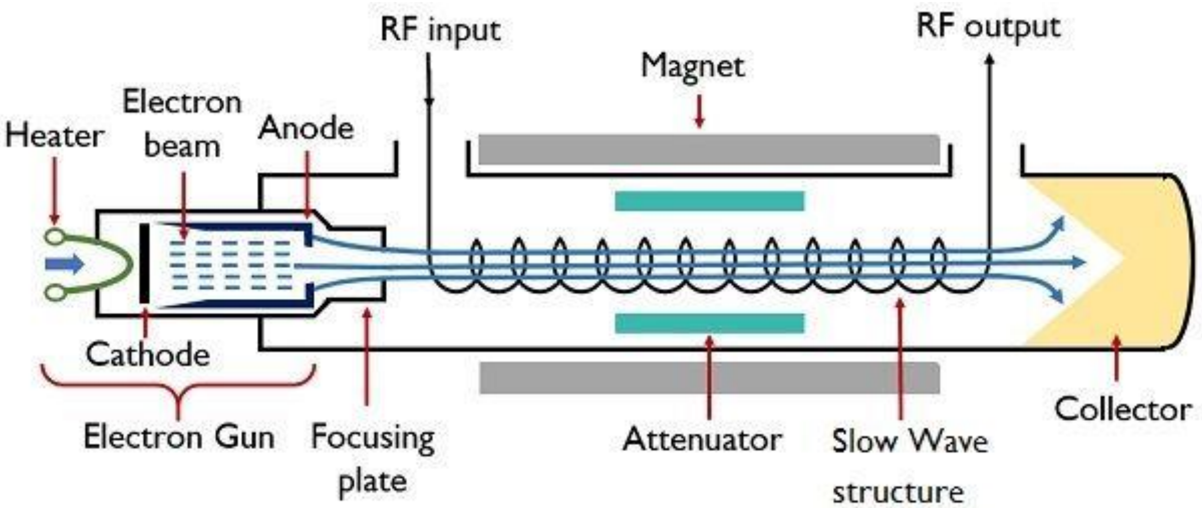
The initial effect on the beam is a small amount of velocity modulation caused by the weak electric fields associated with the travelling wave.

This velocity modulation later translates to current modulation, which then induces an RF current in the circuit, causing amplification.

Major differences between the TWT and Klystron:

(1) The interaction of electron beam and RF field in the TWT is continuous over the entire length of the circuit, but the interaction in the klystron occurs only at the gaps of a few resonant cavities.
(2) The wave in the TWT is a propagating wave, the wave in the klystron is not propagating.
(3) In the coupled-cavity TWT there is a coupling effect between the cavities, where as each cavity in the klystron operates independently.

<u>Helix Travelling-Wave Tube:</u>



Constructional Structure of Travelling Wave Tube

Operation:

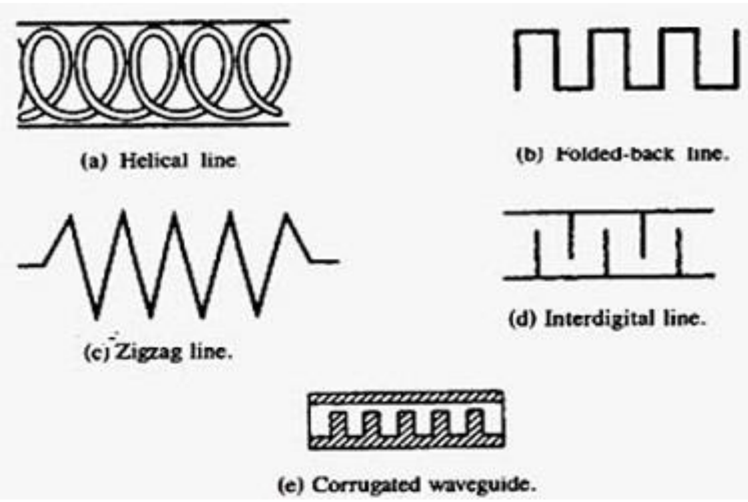
1. Electron beam is focused by a constant magnetic field along the electron beam and the slow wave structure. This is termed an 0-type travelling wave tube.
2. The slow-wave structure is either the helical type or folded-back line.
3. The applied signal propagates around the turns of the helix and produces an electric field at the center of the helix, directed along the helix axis.
4. The axial electric field progresses with a velocity that is very close to the velocity of light –multiplied the ratio of helix pitch to helix circumference.
5. When the electron enter to the helix tube, an interaction takes place between the moving axial electric field and the moving electrons. The electrons transfer the energy to the wave on the helix.
6. This interaction causes the signal wave on the helix to become larger.
7. The electron entering the helix at zero field are not affected by the signal wave, those electrons entering the helix at the accelerating field are aceelerrated, and those at the retarding field are decelerated.

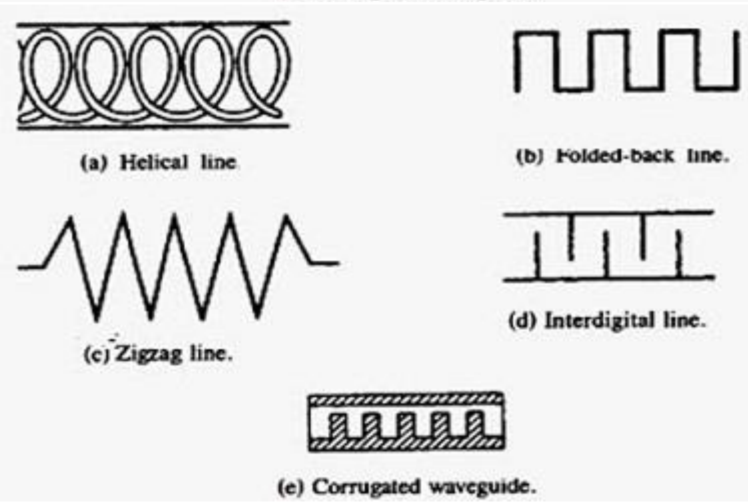
8. As the electrons travel further along the helix, they bunch at the collector end. The bunching shifts the phase by $\pi/2$.
9. Each electron in the bunch encounter a stronger retarding field. Then the microwave energy of the electrons is delivered by the electron bunch to the wave on the helix. The amplification of the signal wave is accomplished.

Attenuator: An attenuator is placed over a part of the helix near the output end to attenuate any reflected wave due to impedance mismatch that can be fed back to the input to cause oscillations.

Magnet: The magnet produces an axial magnetic field to prevent spreading of the electron beam as it travels down the tube.

Slow-wave Structure: Slow-wave structure are special circuits that are used in microwave tubes to reduce the wave velocity in a certain direction so that the electron beam and the signal wave can interact.





Several non-resonant periodic circuits / slow-wave structure are designed for producing large gain over a wide bandwidth.

The gain-bandwidth product is limited by the resonant circuit, the ordinary resonator cannot generate a large output.

As the operating frequency is increased, both the inductance and capacitance of the resonant circuit must be decreased in order to maintain resonance at the operating frequency.

Characteristics of TWT:

1. Frequency range: 3GHz and higher
2. Bandwidth: about 0.8GHz.
3. Efficiency: 20 to 40 %
4. Power output: upto 10 KW average.
5. Power gain: upto 60 dB.