Microwave tubes

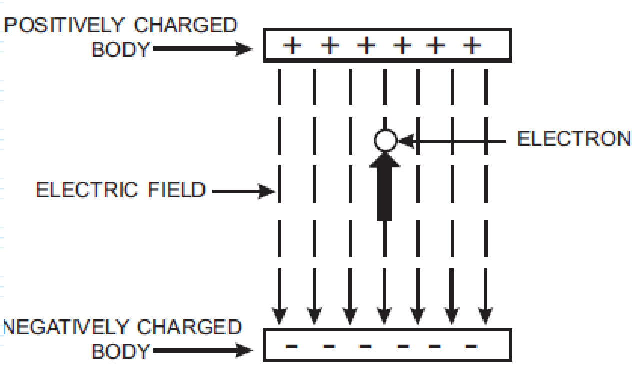
The efficiency of conventional tubes is largely independent of frequency up to a certain limit. When frequency increases beyond that limit, several factors combine to rapidly decrease tube efficiency. Tubes that are efficient in the microwave range usually operate on the theory of VELOCITY MODULATION, a concept that avoids the problems encountered in conventional tubes.

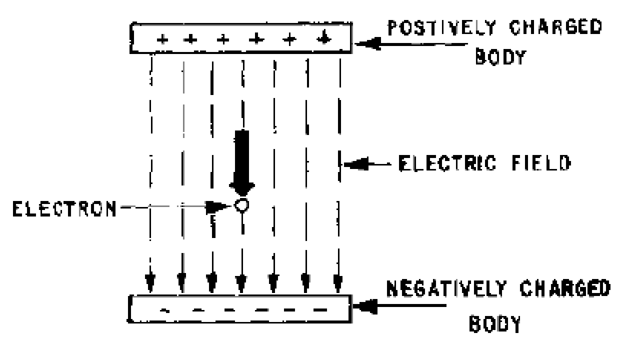
As the frequency increases the effect of capacitance and other elements needs to be considered , while designing

Q: What is velocity Modulation ?

A clear understanding of microwave tubes must start with an understanding of how electrons and electric fields interact. An electron has mass and thus exhibits **kinetic energy** when in motion. The amount of **kinetic energy in an electron is directly proportional to its velocity**;

An electron can **be accelerated or decelerated** by an electrostatic field. Figure shows an electron **moving in an electrostatic field.** The direction of travel (shown by the heavy arrow) is against the electrostatic lines of force which are from positive to negative. The negatively charged electron will be attracted to the positively charged body and will increase in velocity. As its velocity increases, the energy level of the electron will also increase. Similar is true if electron is moved in opposite direction.

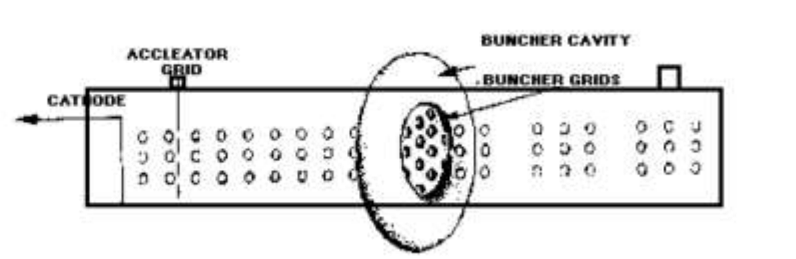




Similar Concept is carried out in **Microwave tubes**. A change in electron velocity causes the tube to produce **BUNCHES of electrons.** These bunches **are separated by spaces in which there are relatively few electrons**. Velocity modulation is then defined as **that variation in the velocity of a beam of electrons** caused by the alternate speeding up and slowing down of the electrons in the beam.

The first Requirement in this regard is "Producing an electronic beam , which is done via a cathode electron gun

Construction of Working Gun



Step 1 The first requirement in obtaining velocity modulation is to produce a stream of electrons which are all traveling at the same speed. The electron stream is produced by an electron gun.

Step 2 : Input signal is applied at accelerator grid .

Step 3 The electron beam then passes through a pair of closely spaced grids, called BUNCHER GRIDS. The buncher grids are the dashed lines at the center of the buncher cavity and are at the same dc potential as the accelerator grid

Q: So how does velocity Modulation works

General Operation

The operation of a velocity-modulated tube depends on a **change in the velocity of the electrons passing through its electrostatic field**. A change in electron velocity causes the tube **to produce BUNCHES of electrons.** These bunches are separated by **spaces in which there are relatively few electrons**. **Velocity modulation is then defined as that variation in the velocity of a beam of electrons caused by the alternate speeding up and slowing down of the electrons in the beam.**

Principle

Flow of Single Elctron

Point A

The manner in which the buncher produces bunches of electrons is better understood by considering the motions of individual electrons, as illustrated in figure A.

Point B

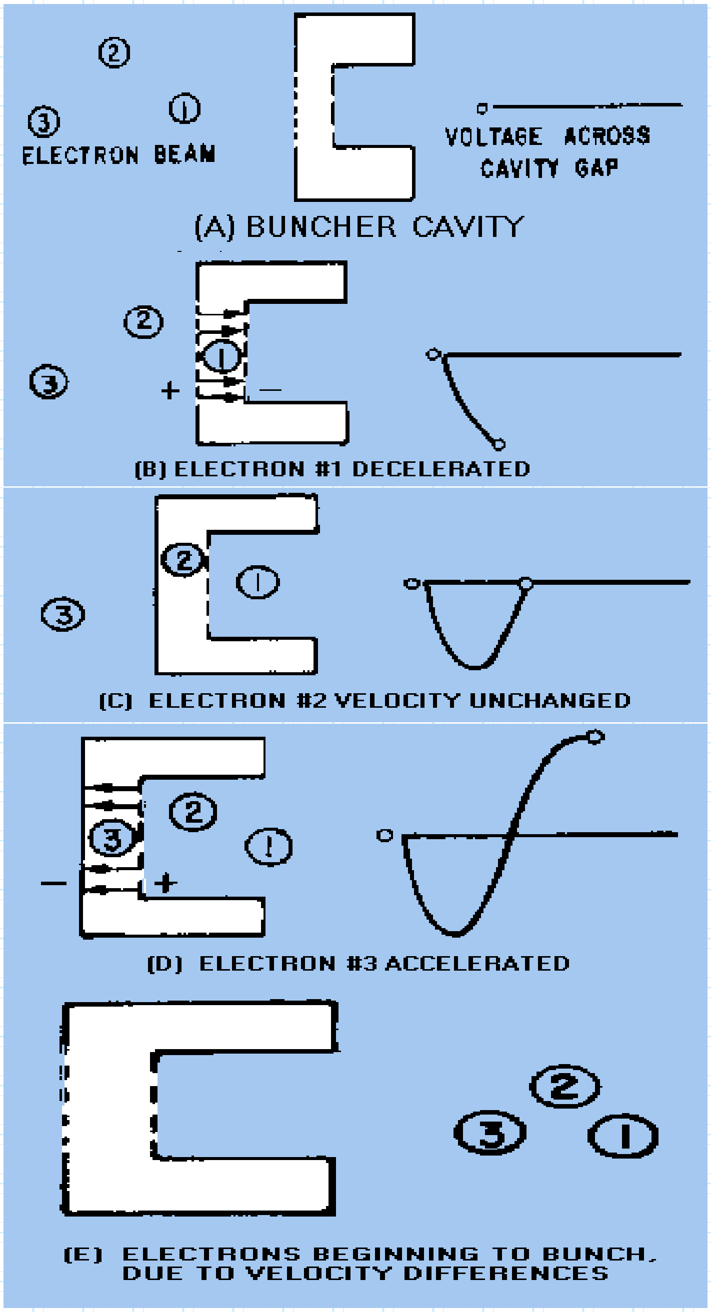
When the voltage across the grids is negative, as shown in view (B), electron 1 crossing the gap at that time is slowed.

Point C

View (C) shows the potential across the gap at 0 volts; electron 2 is not affected. Electron 3 enters the gap

Point D
when the voltage across the gap is positive and its velocity is increased.

Point E
The combined effect is shown in view (E).



Q: The energy gained by the accelerated electrons is balanced by the energy lost by the decelerated electrons. So how it is useful ?

No useful power has been produced at this point. The energy gained by the accelerated electrons is balanced by the energy lost by the decelerated electrons. However, a new and useful beam distribution will be
As the electrons **drift into the field-free area** beyond the buncher cavity, bunches continue to form because of the new velocity relationships between the electrons. Unless the beam is acted upon by some other force, **these bunches will tend to form and disperse until the original beam distribution is eventually reformed.** The net effect of velocity modulation is to form a current-density modulated beam that varies at the same rate as the grid-signal frequency. The next step is to take useful power from the beam.

Catcher Cavity

A second cavity, called a CATCHER CAVITY, must be placed at a point of maximum bunching to take useful energy from the beam The physical position of the catcher cavity is determined by the frequency of the buncher-grid signal because this signal determines the transit time of the electron bunches.

The Traveling-Wave Tube

The TRAVELING-WAVE TUBE (twt) is a

- high-gain,
- low-noise,
- wide-bandwidth microwave amplifier.

Features

It is capable of gains greater than 40 dB with bandwidths exceeding an octave**. (A bandwidth of 1 octave is one in which the upper frequency is twice the lower frequency.)**

Operating Frequency

Traveling-wave tubes have been designed for frequencies as low as 300 megahertz and as high as 50 gigahertz.

The twt is primarily a voltage amplifier. The wide-bandwidth and low-noise characteristics make the twt ideal for use as an rf amplifier in microwave equipment.

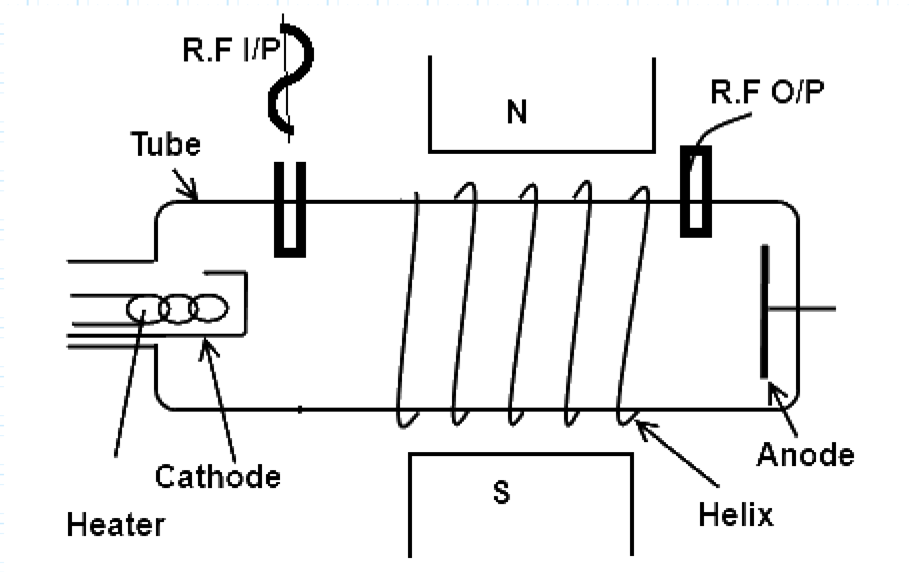
Physical Construction

Electronic Gun

The physical construction of a typical twt is shown in figure .The twt contains an electron gun which produces and then accelerates an electron beam along the axis of the tube.

Magnet
The surrounding magnet provides a magnetic field along the axis of the tube to focus the electrons into a tight beam.

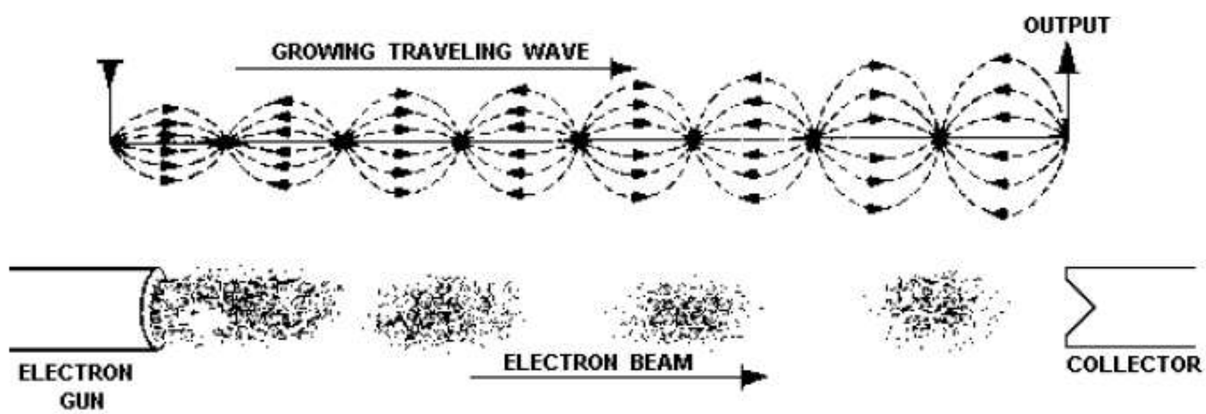
Attenuator
The attenuator prevents any reflected waves from traveling back down the helix.



Working

When we switch on the circuit the cathode starts the emission of electrons. The focusing electrodes focus these electrons in a narrow beam at the center of tube. These electrons travel toward the anode and if no signal is applied at the helix then the emitted electrons will be collected by the anode without any obstruction.
When the R.F signal is applied at the input of the helix, the positive half cycle will accelerate the speed of electrons emitted by the cathode and negative cycle will de accelerate the speed of electrons emitted by the cathode. As a result the electrons will be found in bunches and it will travel towards the anode within the helix. The volume of bunch will become stronger and stronger as the electrons approaches towards the anode end.
Therefore, at the output end of the helix, there will be a strong electric field created by the buncher which will result to produce the amplified output signal.
The magnet is used around the helix in order to produce the strong magnetic field which causes the electron beam to remain in the center.

The electron- beam bunching already starts at the beginning of the helix and reaches its highest expression on the end of the helix. If the electrons of the beam were accelerated to travel faster than the waves traveling on the wire, bunching would occur through the effect of velocity modulation. Velocity modulation would be caused by the interaction between the traveling-wave fields and the electron beam. Bunching would cause the electrons to give up energy to the traveling wave if the fields were of the correct polarity to slow down the bunches. The energy from the bunches would increase the amplitude of the traveling wave in a progressive action that would take place all along the length of the twt



Characteristics of a TWT

1. The attainable power-amplification is essentially dependent on the following factors:
2. constructive details (e.g. length of the helix)
3. electron beam diameter (adjustable by the density of the focussing magnetic field)
4. power input
5. voltage on the helix

Magnetron

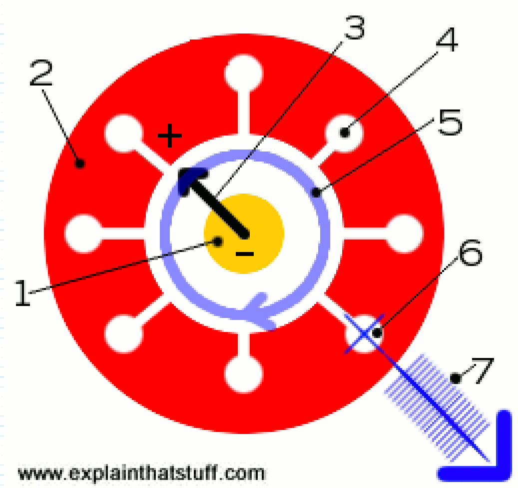
Construction

Magnetron is the combination of a **simple diode vacuum tube** with **built in cavity resonators** and an **extremely powerful permanent magnet. The diameter of each cavity is equal to a one-half wavelength at the desired operating frequency.** The anode is usually made of copper and is connected to a high-voltage positive direct current.

Operation of Magnetron

All cavity magnetrons consist of a hot filament (cathode) kept at, or pulsed to, a high negative potential by a high-voltage, direct-current power supply. The cathode is built into the center of an vacuated, lobed, circular chamber. Circular cathode emits electrons when heated.

How does a magnetron resonate? It works a bit like a TV set:

1. There's a heated **cathode** (a solid metal rod) at the center of the magnetron.
2. A ring-shaped **anode** surrounds the cathode
3. If we switched on a simple magnetron like this, **electrons** would boil off from the cathode and zip across to the anode in straight lines much like the electron beam in a TV set. But there are two added extra bits in a magnetron that change things completely.
4. First, the anode has holes or slots cut into it called **cavities** or **resonant cavities**. Second, a powerful magnet is placed underneath the anode to generate a magnetic field along the length of the tube (parallel to the cathode and,
5. Now when the electrons try to zip from cathode to anode, they are traveling through an electric field (stretching between the anode and cathode) and a magnetic field (produced by the magnet) at the same time. So, like any electrically charged particles moving in a magnetic field, they feel a force and follow a **curved path** (circle) instead of a straight one, whizzing around the space between the anode and the cathode.
6. As the electrons nip past the cavities, the cavities resonate and emit **microwave radiation**. Think of the electrons passing energy to the cavities, making then resonate like someone blowing on the open end of a flute—only producing microwaves instead of sound waves.
7. 

Magnetros are capable if developing extremely high levels of microwave power. Thousand and even millions of watts of power can be produced by a magnetron. Pulsed magnetron are commonly used in radar systems. Continuous-wave magnetrons are also used and can generate hundreds and even thousands of watts of power. A typical application for a continuous magnetron is for heating purposes in microwave ovens.