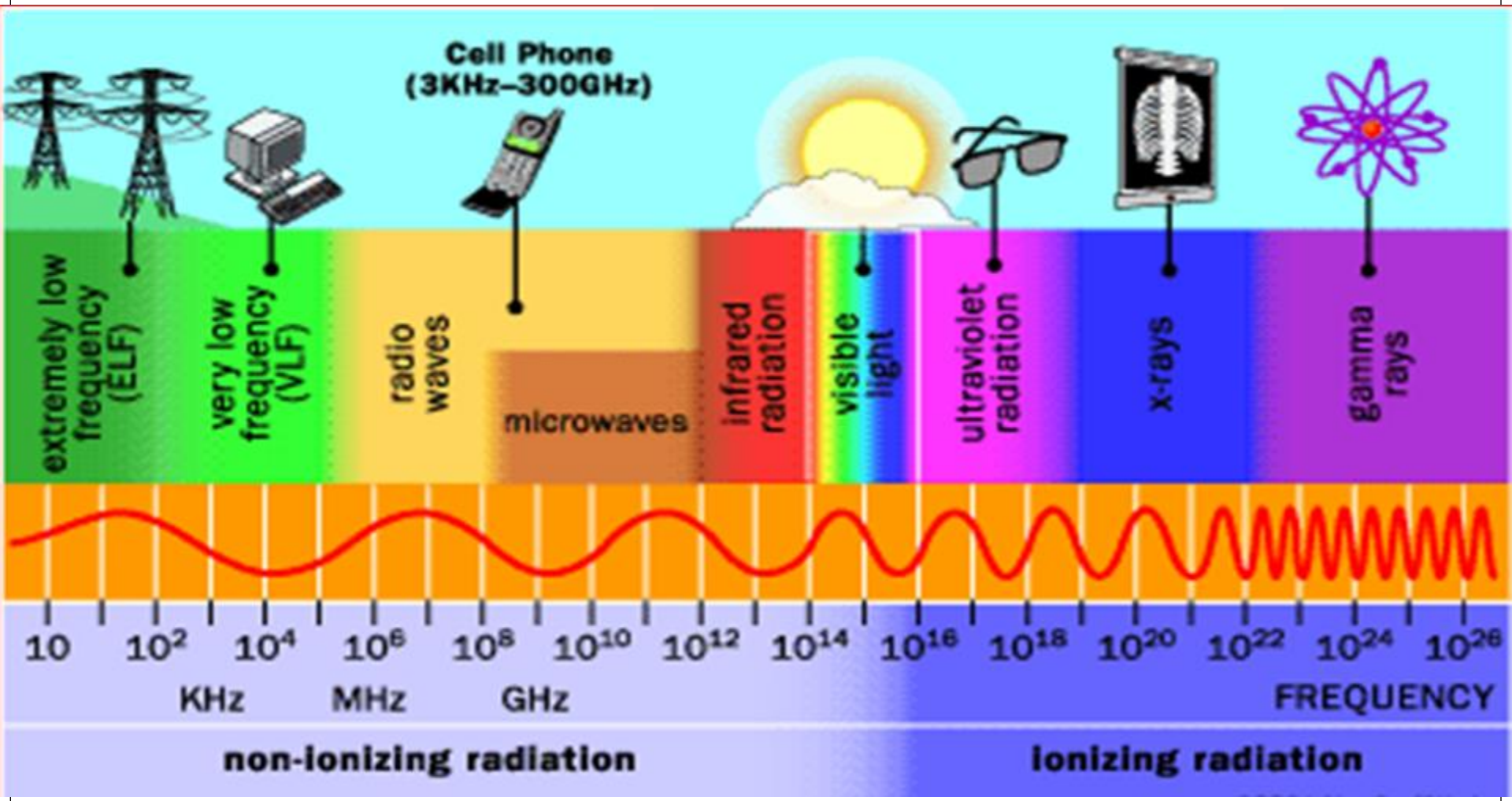
RF and Microwave Engineering

MICROWAVE TUBES

OUTLINE

1. Introduction of Microwaves
2. High frequency limitation of conventional tubes
3. Types of Microwave tubes
4. Reflex klystron-Mechanism of operation
5. Mode of oscillation
6. Power output and Efficiency

Electromagnetic Spectrum



Microwaves

- **Microwaves are the electromagnetic waves**
  - wavelengths ranging from few cm to mm
  - frequencies ranging from 1GHz to 1000 GHz
- **Advantage**
  - Power requirement is very less compared to LF signals
  - Larger Bandwidth : The band width of microwaves is larger than the low frequency signals - more information can be transmitted using single carrier
  - Improved directive properties
  - Less Fading effect and more reliable

Applications Of Microwaves

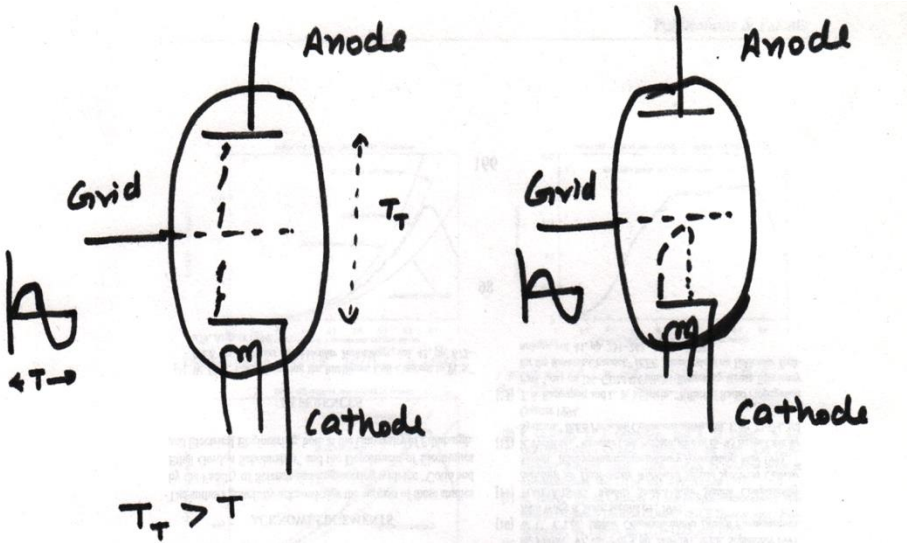
- Wireless Communications (space, cellular phones, cordless phones, WLANs, Bluetooth, satellites etc.)
- Radar and Navigation (Airborne,vehicle, weather radars, GPS etc.)
- Remote sensing (Meteorology, mining, land surface, aviation and marine traffic etc.)
- RF Identification (Security, product tracking, animal tracking, toll collection etc.)
- Broadcasting (AM,FM radio, TV etc.)
- Heating (Baking, Food process, Ovens, Drying, Mining, rubber industry)
- Bio-medical application(Diagnostics)

High Frequency Limitations of Conventional Tubes

- Conventional tubes fails to operate above 1 GHz.Reasons:

  (1) Transit Time effect

  ➢ The time taken by an electron to travel from cathode to anode



  (2) stray reactance

  ➢ Due to lead wire inductance and Inter-electrode capacitance

Solution to this problem??

is

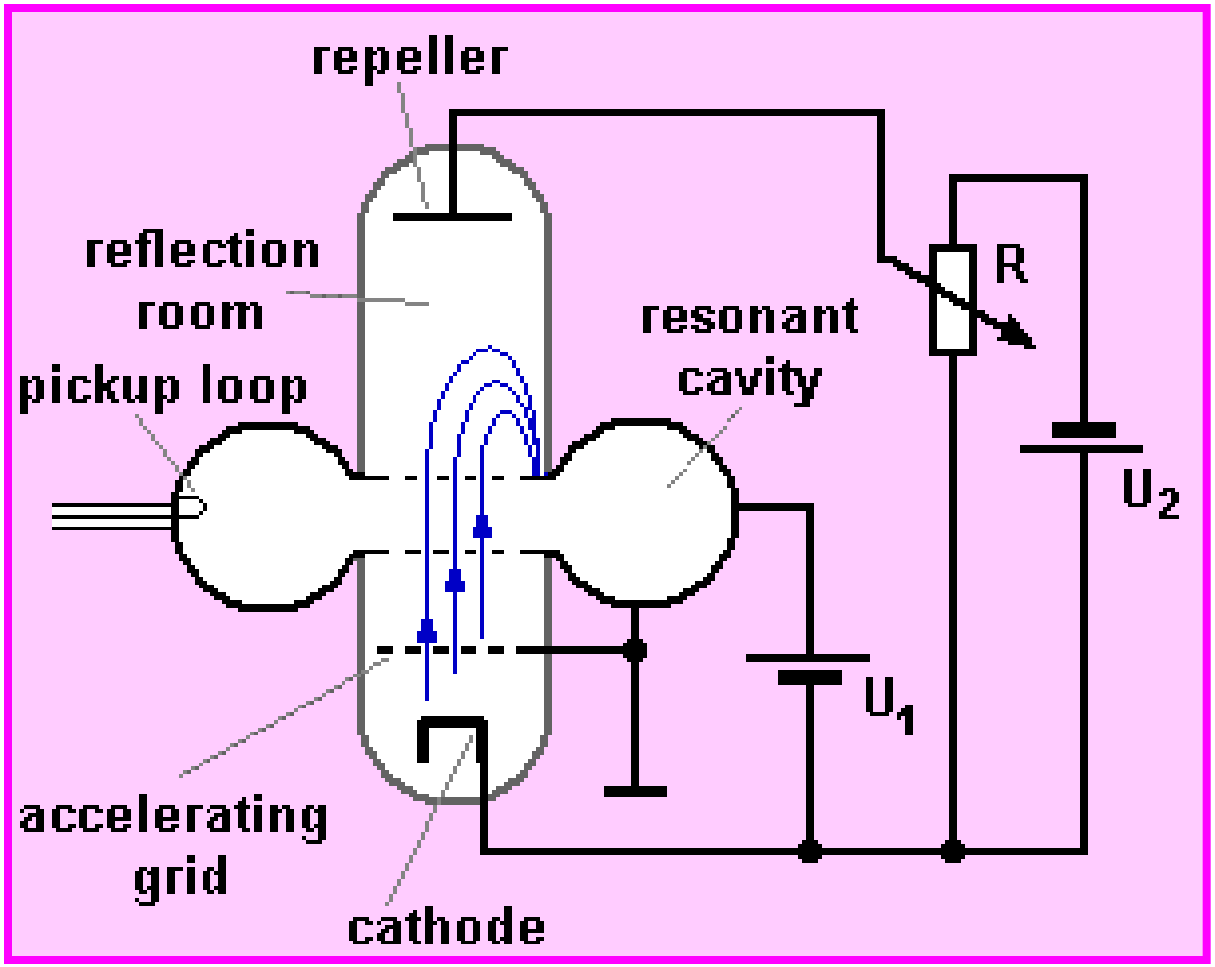
Microwave tubes

Microwave Tubes

- Klystron
- Traveling Wave Tube
- Magnetron

REFLEX KLYSTRON

Reflex Klystron oscillator



Mechanism of operation

- A reflex klystron consists of an electron gun, an accelerating grid, a single re-entrant cavity and a repeller plate
- Electrons are emitted from cathode'K' is accelerated by the grid 'G' and passes through the cavity anode A to the repeller space
- Due to DC energy, RF noise is generated in the cavity
- Electrons passing through cavity gap experiences

Velocity Modulation

Mechanism of operation

- The electrons
  - ‘a’ which encountered the positive half cycle of the RF field in the cavity gap d will be accelerated,
  - ‘b’ which encountered zero RF field will pass with unchanged original velocity, and
  - ‘c’ which encountered the negative half cycle will be decelerated on entering the repeller space.
- All these velocity modulated electrons will be repelled back to the cavity by the repeller due to the negative potential.

Mechanism of operation

- The repeller distance L and the repeller voltage can be adjusted to receive all the electrons at a same time on the positive peak of the cavity RF cycle.
- Thus the velocity modulated electrons are bunched together and **lose their kinetic energy when they encounter the positive peak of the cavity RF field.**
- ➢ This loss of energy is transferred to the cavity to conserve total power.
- ➢ When power delivered by the electrons is equal to the power loss in the cavity- **Microwave oscillation** is started

Mode of Oscillation

- These bunched electrons deliver maximum power at any instant of positive peak of RF cycle
- If **T is the time period at the resonant frequency**, t_o is the time taken by the reference electron to travel in the repeller space between entering the repeller space and returning to the cavity at positive peak voltage on formation of the bunch

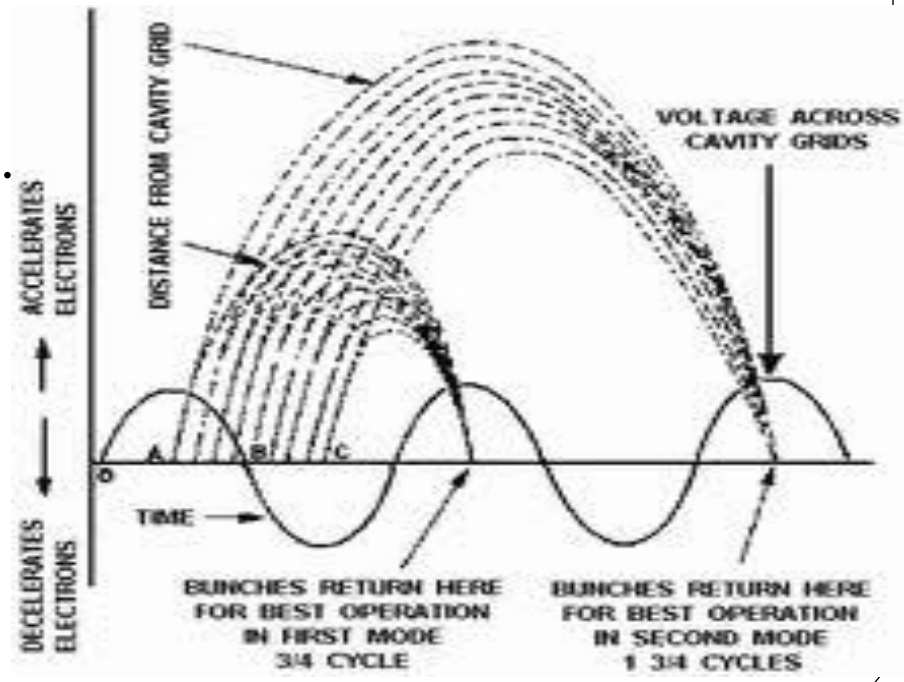
Then, $t_o = (n + ¾)T = NT$

Where $N = n + ¾$, $n = 0,1,2,3.....$

N – mode of oscillation

The Power output of lowest mode?

is **Maximum**



Analysis of Reflex Klystron:

- Velocity Modulation
- Transit time
- Density Modulation and beam current
- Power output
- Efficiency

Velocity modulation

Basic assumptions:

- Cavity grid and repeller plate are parallel and large
- No RF field is excited in repeller space
- No electron interception by the cavity anode grid
- No debunching action in the cavity space
- $V_1 << V_0$

Performance Characteristics

1. Frequency: 2– 200 GHz
2. Power: 10 mW – 2.5 W
3. Theoretical efficiency : 22.78 %
4. Practical efficiency : 10 % - 20 %
5. Tuning range : 5 GHz at 2 W – 30 GHz at 10 mW

Applications

- The reflex klystrons are used in

1. Radar receivers
2. Local oscillator in microwave receivers
3. Portable microwave links
4. Pump oscillator in parametric amplifier

Biological effects of microwaves

- A part of radiofrequency (RF) radiation, which covers 0.5 MHz to 300 GHz range produces adverse biological effects.

Ionizing radiation and non-ionizing radiation

- Ionization is a process - electrons are stripped from atoms and molecules and this can produce molecular changes that can lead to damage in biological tissue, including effects on DNA, the genetic material.

- The energy levels associated with RF and microwave radiations are not great enough to cause the ionization of atoms and molecules, therefore, it is a type of non-ionizing radiation.

Non ionizing radiation

- Microwave energy is non-ionizing electromagnetic radiation.
- Ionizing radiation messes up molecules, non-ionizing radiation merely heats them.
- In general, it does not have sufficient energy to kick an electron off an atom thus producing charged particle in a body and cause biological damage.
- The only proven harmful effect from exposure to microwave (or RF) radiation is thermal.
- RF radiation can enter deep into the body and heat human organs.

Effect of microwaves in human body

- The blood vessels are dilating and the blood flow increases substantially as the thermoregulatory mechanism is activated in order to keep the body temperature constant.

- With rising body temperature the metabolic rate rises, which may lead to Stress-Adaptation-Fatigue Syndrome.

Effects produced by the electromagnetic waves at different frequency level

- Above 10 GHz (3 cm wavelength or less) heating occurs mainly in the outer skin surface.
- From 3 GHz to 10 GHz (10 cm to 3 cm) the penetration is deeper and heating higher
- From 150 MHz to about 1 GHz (200 cm to 25 cm wavelength), penetration is even deeper and because of high absorption, deep body heating can occur.
- Any part of the body that cannot dissipate heat efficiently or is heat sensitive may be damaged by microwave radiation of sufficient power.

Effects of Microwave energy

Power level (mW /cm2)	Long-term effect on human body	Remarks
0.01	Nothing	
0.1	Nothing	
1	Nothing	
5	Nothing	Accepted standard for microwave oven leakage
10	Nothing	Accepted standard for maximum continuous exposure to radiated emissions (cell phones, etc.)
30	You can feel heat	
100	Cataracts can be produced	Summer sunlight is at this level
1000	Pain is induced	

The **GOOD NEWS** is... with Microwave radiation

- Boil water
- Cook meat
- Fry eggs

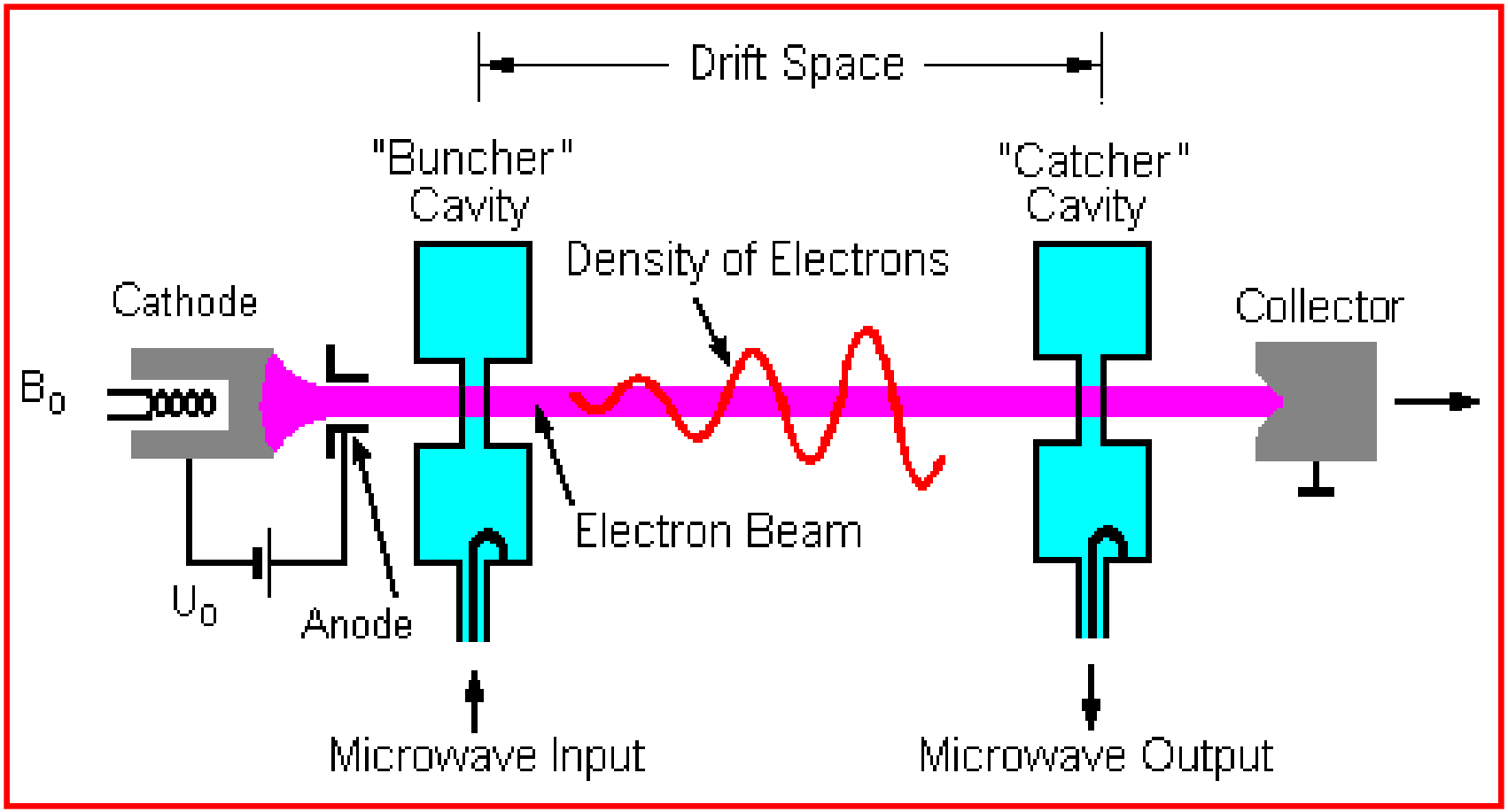
The **BAD NEWS** is...
with Microwave radiation

Your head and brain heat up significantly when you talk on your cell phone or cordless phone.

Statistics shows that you are now exposed to electromagnetic radiation daily, 100 million times greater than your grandparents. So….

AVOID FREQUENT USE OF CELL PHONES!!!

Multicavity Klystron



Application

- **As power output tubes**
  1. in UHF TV transmitters
  2. in troposphere scatter transmitters
  3. satellite communication ground station
  4. radar transmitters
- **As power oscillator** (5 – 50 GHz), if used as a klystron oscillator

TRAVELING-WAVE TUBE (TWT)