ENTREPRENEURSHIP DEVELOPMENT AND MANAGEMENT

Unit-1

ENTREPRENEURSHIP

Introduction

ENTREPRENEURSHIP DEFINITION

There may be a no. of definition of entrepreneurship one example is to start and run a business by arranging money, human resource and other resources production of product/service sell it and earn the profit.

Function of ENTREPRENEUR

- Take Risk
- Arrange Resources
- Production of new product/Service
- Selling product/Service
- Pay for all resources
- Earn Profit

BARRIERS IN ENTREPRENEURSHIP

- Competency
- Resources
- Finance
- Knowledge
- Market Conditions
- Risk taking capacity
- Fear
- Opportunity
- Govt. Policies
- Etc.

FORMS OF BUSINESS ORGANISATIONS

- Sole Proprietorship.
- Partnership/ Limited Liability Partnerships
- Others
  - Company.
  - Corporations or Statutory Bodies.
  - Co-operative Societies.
  - Hindu Undivided Family.

- **NSIC (National Small Industries Corporation)**
- **NRDC (National Research Development Corporation)**
- **MSME(Micro, Small & Medium Enterprises)**
- **SIDBI(Small Industries Development Bank of India)**
- **NABARD(National Bank for Agriculture and Rural Development)**
- **NIESBUD(National Institute of Entrepreneurship and Small Business Development)**
- **HARDICON**
- **Commercial Banks,**
- **SFC(State Financial Corporation)**
- **TCO**
- **KVIB(Khadi and Village Industries Board)**
- **DIC**
- **Technology Business Incubators (TBI)**
- **Science and Technology Entrepreneur Parks**

UNIT-2

Market survey and Opportunity Identification

Scanning of Business Environment

- Economical Factors
- Legal Factors
- Socio-cultural Factors
- Political Factors
- Technological Factors
- Environmental Factors

National Industrial Policy & Business Opportunity

- Ease to do Business
- Permissions
- Govt. Help/ Subsidy
- Employment
- Wages
- Environment

Haryana Industrial Policy & Business Opportunity

- Ease to do Business
- Permissions
- Govt. Help/ Subsidy
- Employment
- Wages
- Environment
- Security

Market Survey

- Financial
- Personnel
- General
- Raw Material
- Technical
- Sales

Assessment of Demand & Supply

- Demand and Supply are two correlated factors and supply should be in the proportion of demand.
- Factors which may affect demand

1. Weather
2. Change in Technology
3. Govt. Policies
4. Fashion/Trends
5. Change in Quality

Identifying Business Opportunity

- Demand of the Product
- Investment
- Returns
- Risk

Consideration in Product Selection

- Present Demand and Supply
- Future Demand of Product
- Cost
- Competition
- Investment
- Availability of resources

Convert an Idea into Business Opportunity

- Planning
- Financial Arrangement
- Permissions
- Arrangement of Land, Man Power, Machine etc.
- Production
- Sales
- Improvement

UNIT-3

Project Report Preparation

Project Report

- Project report is the collection of data of present and future resources, demand, production, supply, quality, quantity, profit, market and expected relation between all above factors.

Need of Project Report

- It gives a direction to the Entrepreneur.
- It is required for Financial Arrangements and various permissions
- It helps in the arrangement of Land & other infrastructure.

Preliminary Project Report

- It is a brief summery of data of present and future resources, demand, production, supply, quality, quantity, profit, loss, market.
- It gives a rough estimate of the project.

Detailed Project Report

- It gives the detailed information of the project. Almost all factors and information are mentioned in this report and entire firm/industry including entrepreneur try to follow it.

Common Errors in Project Report Preparation

- Too much information
- Avoiding competitors
- Too small margins
- Avoiding vendors
- Ignoring '<u>what if</u>'
- Over stress on '<u>what if</u>'
- Setting vey high/low goal
- Less stress on skilled personnel
- Avoiding or not taking stakeholder's view
- Less stress on store/inventory

Exercise on Project Report Preparation

- Selection of Product
- Market Survey
- Meeting with Stakeholders
- Technical Knowledge
- Hiring Competent Person/Consultancy

UNIT-4

Introduction to Management

DEFINITION OF MANAGEMENT

It is a process of planning, decision making, organizing, leading, motivation and controlling the human resources, financial, physical, and information resources of an organization to reach its goals efficiently and effectively.

Importance of Management

Management is important at each and every step of any business or organization to use resources efficiently and to get the maximum profit by providing a quality product or service.

Functions of management:

- Importance and process of planning
- Organising
- Staffing
- Directing
- Controlling

Principles of management by Henri Fayol

- 1.Division of Work
- 2. Authority and Responsibility
- 3. Discipline
- 4. Unity of Command
- 5. Unity of Direction
- 6. Subordination of Individual Interest
- 7. Remuneration
- 8. Centralization
- 9. Scalar Chain
- 10. Order
- 11. Equity
- 12. Stability
- 13. Initiative
- 14. Motivation

Principles of management by F.W. Taylor

- Replacement of Old Rule of Thumb Method
- Scientific Selection and Training of Workers
- Co-Operation between Labour and Management
- Maximum Output
- Equal Division of Responsibility
- Mental Revolution

STRUCTURE OF AN ORGANISATION

President

Vice President

SR. Managers

Managers

Supervisors

Workers

Leadership

- It is the quality by which one can guide, motivate others to do their best to achieve the goal.

Need of Leadership

- Give direction to group efforts
- Integrate
- Motivation
- Cooperation
- Inspiration
- Team Spirit

Qualities of a leader

Responsible
Self-aware
Vision
Assertive
Self-belief
Ability To Listen
Appreciation
Result Oriented
Focus
Loyal
Reliability

Manager Vs leader

Manager	Leader
Goal	Vision
Direct	Lead
Organize	Innovate
Control	Inspire

Types of leadership

- Authoritarian Leadership
- Participative Leadership
- Delegative Leadership
- Transactional Leadership
- Transformational Leadership

Motivation

Motivation :-

A factor that encourages someone to do something.

Factors affecting motivation :-

1. Leadership
2. Rewards
3. Work Environment
4. Trust

Management Areas

Human Resource Management

Material and Store Management

Marketing and sales

Financial Management

UNIT - 1 : INRODUCTION AND CONCEPT OF PLC

Concept of PLC: A PLC is a microprocessor based specialized computer. It is designed to operate in noisy industrial environment. It can perform control functions of many types and complex in nature. It has a large numbers of input and output terminals. It has an operating system in its internal ROM which helps a user to program it using a simple language. It uses ladder programming its function is to process according to these parameters it can be easily programmed controlled and operated. It does not required highly skilled person for operate.

BUILDING BLOCKS OF PLC

It consists of following block

(i) ***Input module and output module:*** They provides PLC connections to the industrial process to be controlled. Thee inputs to the controller are signals from limit switches, push buttons, sensor and other on-off device. The PLCS are also capable of accepting signals from analog devices, multi-bit digital signals depending upon types of input module. The PLC output at output module is used to operate motors, valves buzzer, solenoid, lamp etc required to execute the process.

(ii) ***CPU:*** Thee CPU is called central processing unit. It is the brain of PLC. It is similar to that used in computers. It controls the functions and sequences of operation of all the blocks of PLC. It execute the various arithmetic and logic operation on the PLC input and intermediate results produce the appropriate output signals.

(iv) Memory: Memory is used to hold the system software, user program data and results CPU reads programs instruction and input data from memory, processes the data according to the instruction and store the result in the memory. The memory chips used in PLCS are RAM, ROM, PROM, EPROM and NOVRAM.

(v) Power supply: Power supply section provides the d.c and a.c. supply to the different sections of the PLC as per their requirement. Input a.c. supply is rectifier and regulated to provides various operational D.C. valves normally +5V and -5V d.c. supply is required for PLC.

(vi) Programming Device: A programming device is used for programming the PLC. The programming device is usually detachable from the PLC cabinet so that it can be shared between different controllers. Hand held terminals, industrial terminals and the personal computer can be used as programming device.

LIMITATIONS OF RELAYS

The following are the limitations of relays-

(1) The relays based control system are bigger in size. So they require large space.

(2) The relays take large amount of time to actuate as compared to the PLC devices.

(3) It is very difficult to diagnose a problem in a relay control system.

(4) It is difficult to expand the relay based system. Whole panel should be replaced by new design and system.

(5) Relays based system suffers from contact wear and reliability problem.

ADVANTAGE OF PLCs OVER RELAYS

The following are the advantages of PLC over relays.

(1) Flexibility: The PLC based control system is very flexible and can be easily modified than relay system. Since PLC are controlled through software's, thus to change a process, only a modification in the program is required.

(2) Simulation Feature: PLC programming software come with the simulation features. Thus, a PLC programmed circuit can be re-run and evaluated in lab.

(3) Space Requirement: PLC based systems are very compact in size and can be installed in much small area than relay based system.

(4) Maintenance: As the software programs are not subject to wear and tear,so PLC requires a very low maintenance that relay system.

(5) Speed of operation: The operational speed for the PLC program is very fast where as, relay based system takes large amount of time to actuate the operation.

ARCHITECTURE/DIFFERENT PROGRAMMING LANGUAGE OF PLC

PLC has following five programming languages .

(1) Ladder diagram: Ladder diagram is the main programming is the main programing method used for PLC's. It is the modified representation of electrical relay logic wiring diagrams. It is very easy method to learn. It contains simple graphical symbol's

(2) Instruction List: It is a low-level textural language with a structure similar assembly language. Programs are in the from of instruction list. These instructions can be derived directly from the ladder logic diagrams and entered into the PLC through a programming terminal. It requires minimum memory space and execution is fast, It is difficult to read or understand instruction list program.

(3) Sequential Functional Charts: It is process oriented high level graphical language. It resembles flowcharts in which steps are denoted by rectangle's while transitions are denoted by horizontal lines. Each step and transitions Associated with functional black representing the code written in ladder logic or structured text it is used for programming sequential operations.

(4) Functional Block diagram: is also graphical programming language. The main concept of this language blocks and generates the output. A function block is a program instruction unit which when executed yields one or more output values.
(5) Structured Text: It is high level, textural programming language. It is similar to a computer high level language like pascal and BASIC languages. It is very flexible and easy language. Its program can be created is any text editor. It is best suited for processes requiring complex math, algorithms or decision making.

APPLICATION OF PLC IN INDUSTRY

The various applications of PLC are as-

(1)Conveyor system: Controls all sequential operates, alarms and safety logic.

(2)Production system: Control and monitors automatic production machines at high efficiency rates.

(3)Power plant system: Monitors and controls burning rates, temperature generate, sequencing of valves and analog controller jet valves.
(4) Automated ware housing: Controls and optimizes the movements of stacking cranes. and provides high turn around of materials.

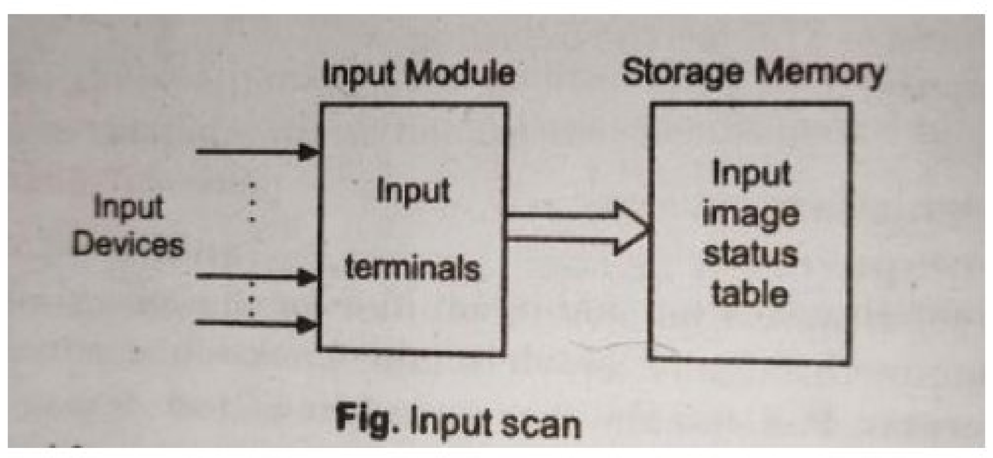
UNIT- 2 : WORKING OF PLC

OPERATION AND PRINCIPLES OF PLC

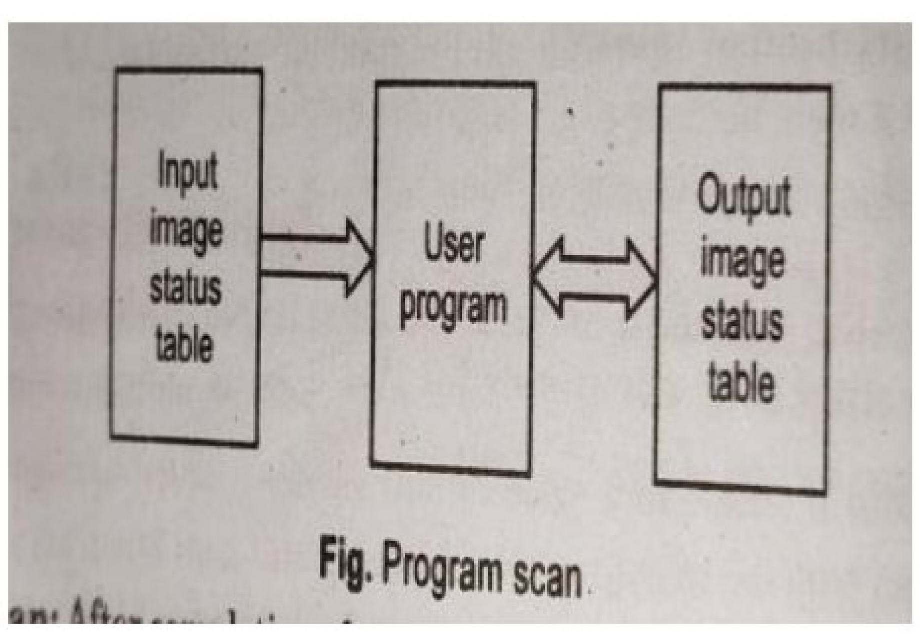
PLC operation-The PLC operation is made up of mainly three parts-

(1) Input scan (2) Program Scan (3)Output scan

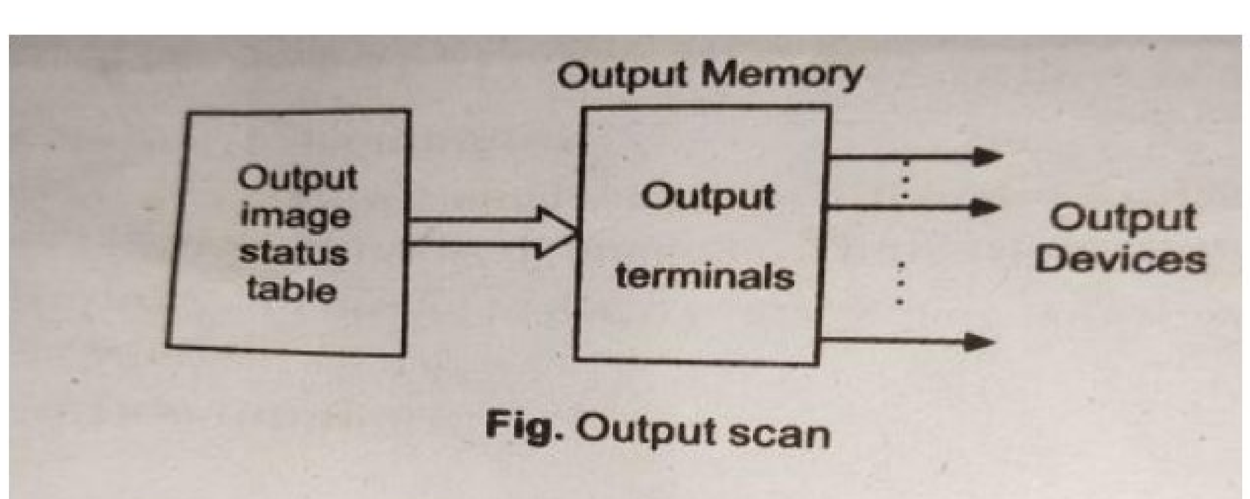
(i) Input Scan: The PLC operation starts with input scan. During the input scan input terminals are read and the input image status table is updated accordingly.



(2) Program scan: After the input scan, program scan is executed. During program scan, data in input states table is used for user program. Program instructions are executed in sequence from left to right and top to bottom. According to the results of instructions, outputs status table is updated after each rung.

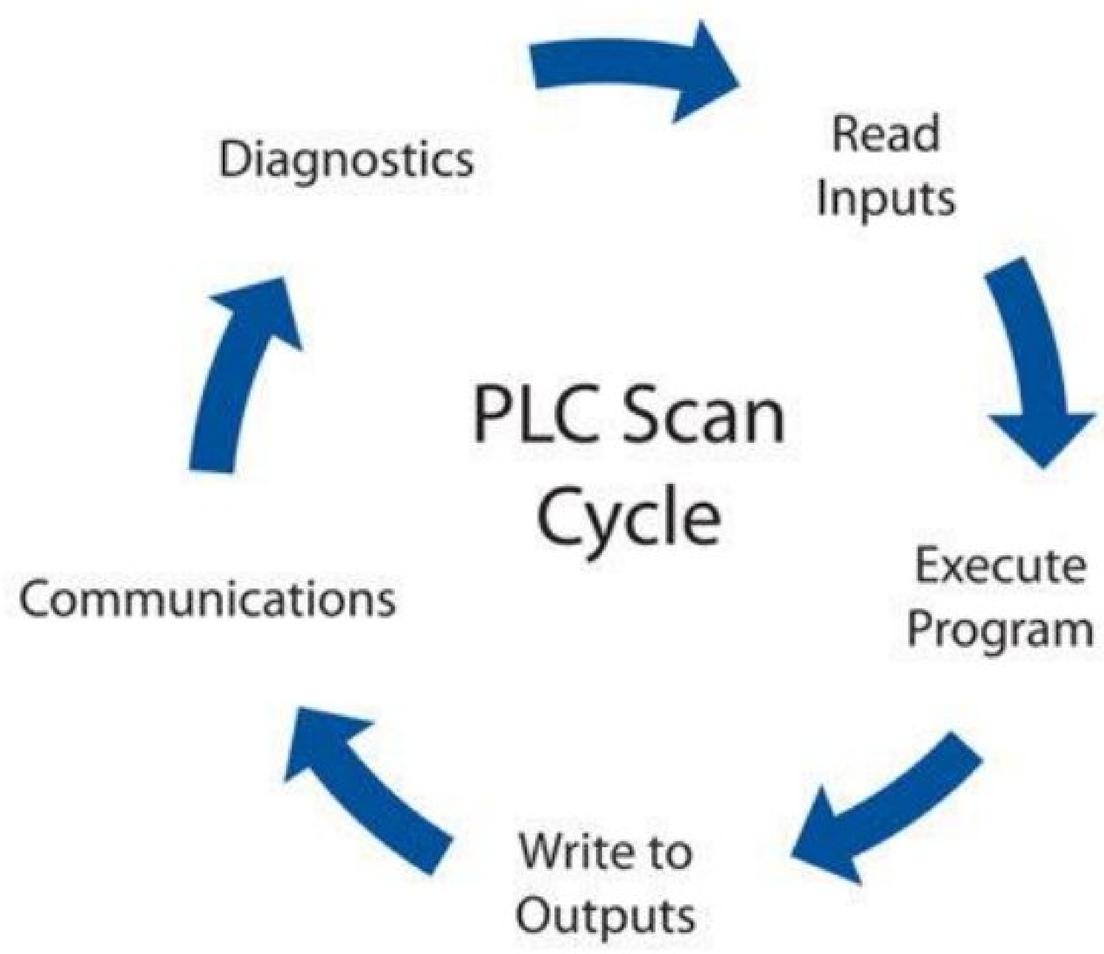


(3) Output Scan: After completion of program scan, output scan is executed During output scan, data stored in output status table is transfered to output terminals. After completion of output scan, input scan is again started. And this process is repeated again.



SCAN CYCLE

The scan cycle is the cycle in which the PLC gathers the inputs, runs your PLC program, and then updates the outputs. This will take some amount of time often measured in milliseconds (ms). The amount of time it takes for the PLC to make one scan cycle is called the scan time of the PLC



MEMORY STRUCTURE OF PLC

The memory within PLC can be divided into two categories.

(1) User memory or Program File Memory

(2)Storage memory or Data File Memory

(1) User Memory : It contains system program file main ladder Program, interrupt subroutine and subroutine files. System program file contain various system related information and user program information. Main ladder program file contains user - programmed instructions defining how the controller is to operate.

(2) data file memory: This is also called storage memory,. This memory area is organized is 16 bit word registers. It store information needed to carryout the user program like the state of discrete input And output devices, the present value and accumulated value of counters and timers, etc.

INPUT /OUTPUT STRUCTURE OF PLC

The input and output modules of PLC provides an interfacing between the inputs like sensors, switch etc and output like contactors, coils, relays etc. with the CPU of PLC.

The input module accepts the signals from the outside world from different on-off sensors, switches etc. and converts these signals which are understandable for the PLC processor. The output of the PLC convert the signals so as to used for external devices like motors, solenoid, coils etc. The /o module of the PLC designed with terminal assembly for the connection of external inputs and outputs. This terminal assebmly contains terminal provision for each input and output, indication LED 's status.

The I/o section of PLC is classified into following different modules-

(i) Discrete I/O modules (ii) Analog I/0 modules (iii) Register I/O modules

PROGRAMMING TERMINAL FOR PLC

PLC Can be programmed by using various types programming devices. The programmer enter, edited and check the ladder program to be executed.

The most common equipments or devices for programming of PLC are the following-

(i) Persona Computer (PC) (ii) Hand help unit (iii) Full size programmer/ monitor

(i) Personal computer: It is used for programming PLC using specialised PLC progamming softwares. A personal computer communicates with PLC through a serial port. Programming through PC provides more facilities and memory to store large numbers of ladder programs. PLC simulators are used for PC testing of programs.

(ii) Hand Held Unit: It is a small size compact device for programming the PLC. It is of palm – size unit with dual function keypads and liquid crystal display. Due to compact and light weight these are easy to carry and are usefull for modification of PLC ladder programms at work place.

(iii) Full size Programmer / Monitor: It has a complete key board and a large monitor like CRO or LCD screen. Because of its large size display, it can show considerable amount of display at a time and are more user friendly. It communicate with the PLC through a cable connected to a special programming part on the PLC.

POWER SUPPLY FOR PLC

The PLC has two section of power supply--

(1) Internal power supply

(ii) External power supply Internal power supply provides supply to CPU module.

It requires a +5v and - 5V d.c supply and should be highly regulated. External power supple section feed supply to input output modules. The power supply requirement depends upon types of interface used by the PLC. This requires+5V+24V, + 120V d.c. supply as well as AC. supply. The block diagram of PLC power supply shown as-

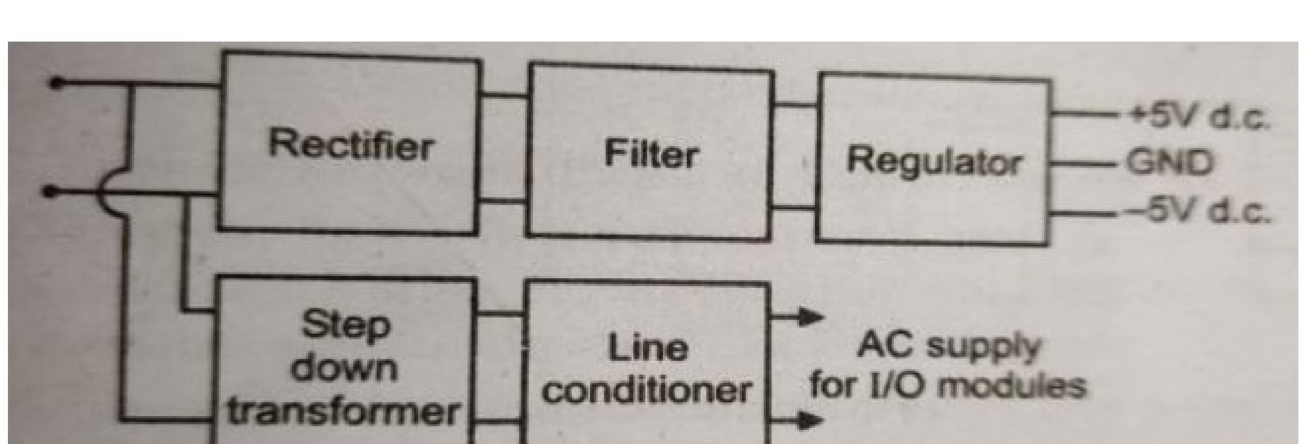


Fig. PLC Power supply

UNIT - 3 : INSTRUCTION SET

Latches //

A latch is like a sticky switch – when pushed it will turn on, but stick in place, it must be pulled to release it and turn it off. A latch in ladder logic uses one instruction to latch

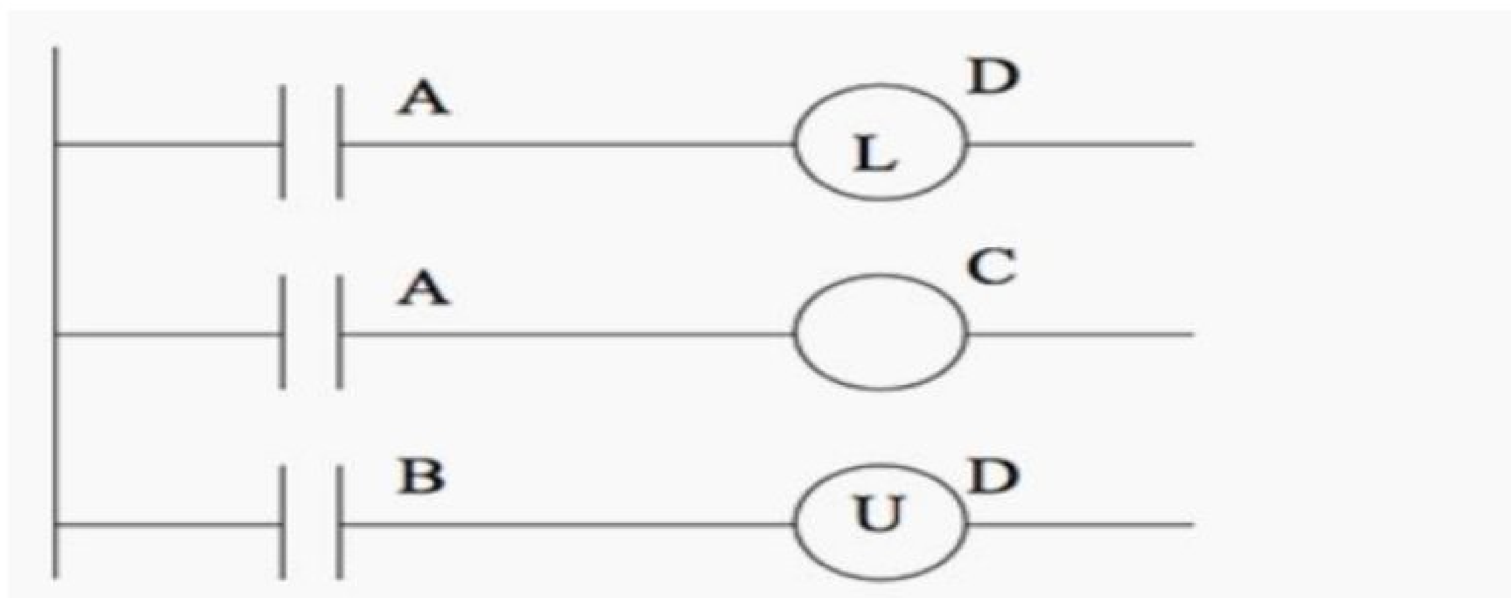


Figure 1 – A Ladder Logic Latch

Master Control Relays

In an electrical circuit, Master control relays are used to shut down a section of an electrical system. In ladder logic, MCR is used to turn ON one section of a programming line. An MCR option should be opened and closed properly.

A master control relay (MCR) is a relay that is used to disable whole section or a part of control circuit in case of emergency conditional for repair-maintenance purpose. All the PLCS are provides this MCR function though an internal software relay. The symbols of MCR is as follow-

There is a section of ladder logic implemented between the MCR instruction lines. All the instructions in the line are executed only if the MCR line is turned ON. When the first MCR coil in inactive, the ladder logic is still examined, but all of the outputs are forced off.

TIMER INSTRUCTION LIKE RETENTIVE TIMERS

The Retentive Timer instruction is a retentive instruction that begins to count time base intervals when rung conditions become true. The Retentive Timer instruction retains its accumulated value when any of the following occurs: Rung conditions become false.

RESETTING OF TIMERTIMER

The Reset Timer block is a Sensing block and a Stack block.

The block sets the timer's value back to 0.0. When this block is present, the project typically utilizes the Timer output block; usually the timer must be reset at the beginning of a project for the Timer block to hold the right value.

There are no blocks that set the timer to a chosen value. The timer can only be specifically set to 0, using this block.

COUNTER INSTRUCTIONS

This instruction is denoted by the 'C' in LD programming. And it is part of the mathematical function.

The role of the counter in PLC is to control and to operate the device in the sequential order.

This sequential order can be in ascending order or descending order.

Basically, PLC counter operates into four modes such as up mode, down mode, bidirectional mode, and the quadrature mode.

Counters in PLC are classifieddifferent parts.

Up Counter (operates up mode)

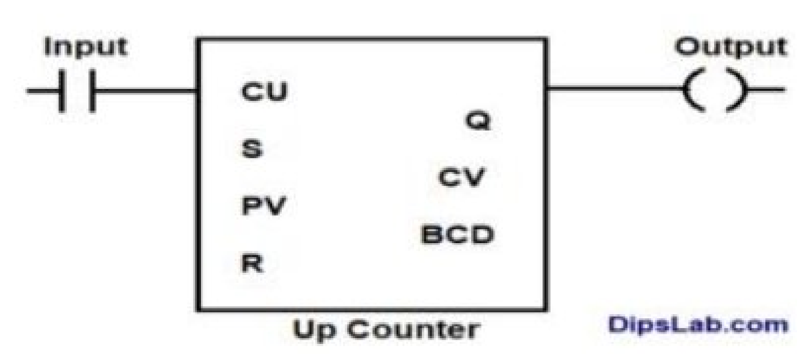
Down Counter (operated in down mode)

UP COUNTER

Up counter counts from zero to the preset value. Basically, it increases the pulse or number.

Up counter is known as the 'CTU' or 'CNT' or 'CC' or 'CTR'.

Up counter function block diagram:

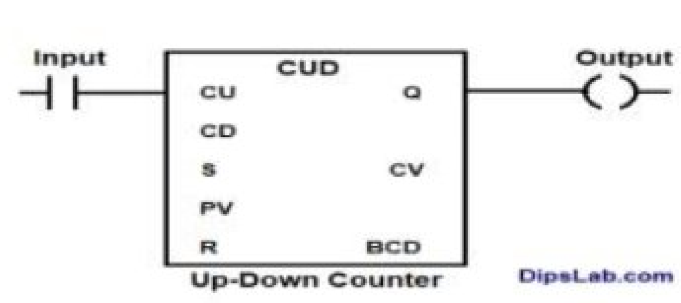


DOWN COUNTER

The down counter counts from the preset value to zero. It decreases the pulse or number.

Down counter is shortly known as the 'CTD' or 'CD'.

Down counter function block diagram:



RESETTING OF COUNTERS

Reset counter function is to set the counter back to the initial or normal state. If you want to start the counting from the initial value, you can use this function.

In case of digital pulse counting, reset counter functions work differently for up and down counter.

For up counter, reset counter function sets the pulse or value back to a lower value.

For down counter, reset or value back to a higher

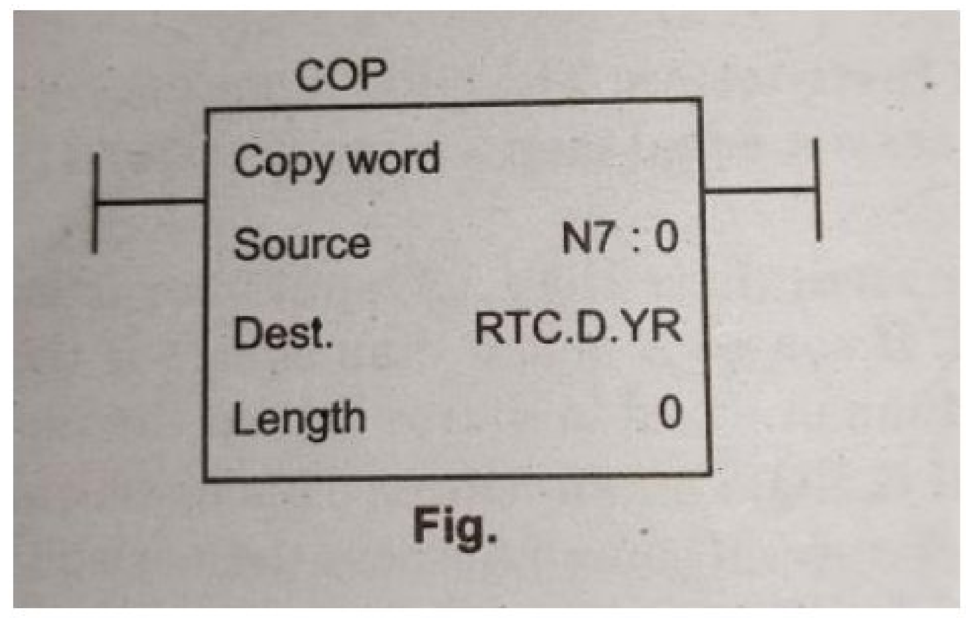
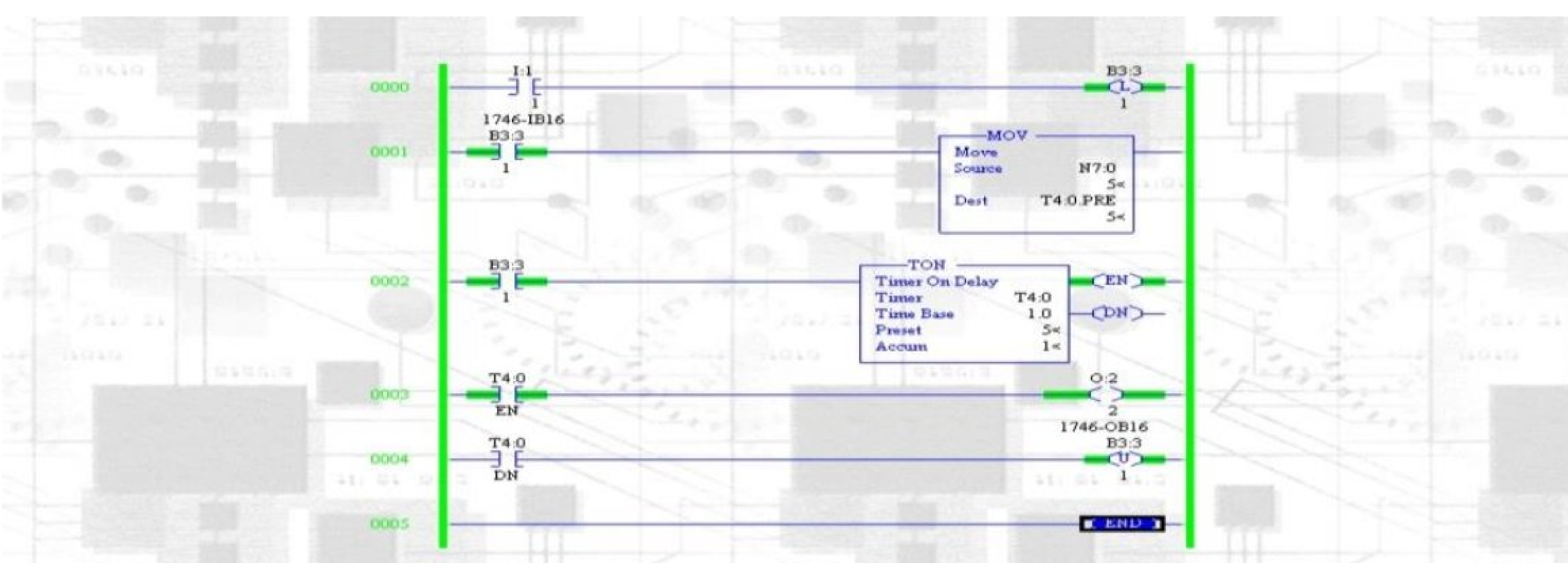


Fig.

counter function sets the pulse value.

MOV INSTRUCTIONS

The MOV instruction moves a Source value to a Destination location. is an output instruction that moves a copy of a value from a Source to a desired Destination. This instruction is placed on the right side of the rung, and is carried out on each scan providing the rung conditions are true.



RTC FUNCTION

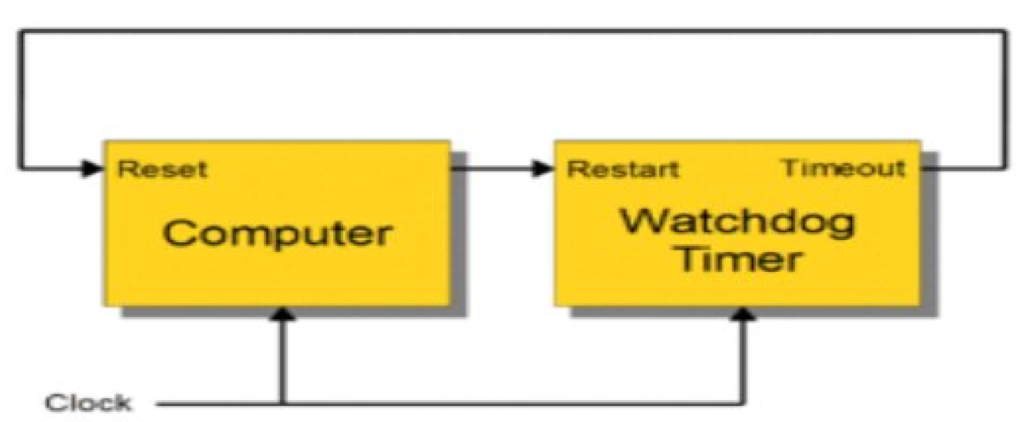
Real time clock (RTC) instruction in PLC programming used to provide hardware setting information. This function file used to set the day, date and time. This function is used to synchronize. The system time with the setting in the controller. The real time clock function file uses eight different word elements. Programmer use the MSG (Message)

Instruction to write RTC funetion file. The RTC file instruction is only read only type of instruction. The copy (COP) instruction can be used to adjust RTC settings in a ladder logic as follows-

A real-time clock (RTC) is an electronic device (most often in the form of an integrated circuit) that measures the passage of time. Although the term often refers to the devices in personal computers, servers and embedded systems, RTCs are present in almost any electronic device which needs to keep accurate time.

WATCH DOG TIMER

A watchdog timer is a simple countdown timer which is used to reset a microprocessor after a specific interval of time. In a properly operating system, software will periodically "pet" or restart the watchdog timer.



COMPARISON INSTRUCTIONS LIKE EQUAL, NOT EQUAL, GRATER, GRATER THAN EQUAL, LESS THEN, LESS THAN EQUAL.

Equal: CMP ==

Not Equal: CMP <>

Greater Than: CMP >

Less Than: CMP <

Greater Than or Equal: CMP >=

Less Than or Equal: CMP <=

PLC Comparison Instructions

Equal: CMP == Tests whether two values are equal. If values are equal then this instruction is logically true.

Not Equal: CMP <> Tests whether two values are not equal. If values are not equal then this instruction is logically true.

Greater Than: CMP > Compares two values, If the value of IN0 is greater than the value of IN1 then this instruction is logically true.

Less Than: CMP < Compares two values, If the value of IN0 is less than the value of IN1 then this instruction is logically true.

Greater Than or Equal: CMP >= Compares two values, If the value of IN0 is greater than or equal to the value of IN1 then this instruction is logically true.

Less Than or Equal: CMP <= Compares two values, If the value of IN0 is less than or equal to the value of IN1 then this instruction is logically true.

ARITHMETIC INSTRUCTIONS (ADD, SUB, DIV, MUL, ETC.)

The PLC arithmetic functions consist of many instructions like Comparison, Mathematical, Logarithmic, etc.

Arithmetic Instruction- PLC programming software uses math instructions to perform the arithmetic operation on value or data stored in memory location. In arithmetic instructions these are two source operands and one destination. The following are arithmetic instructions used in PLC programming.

(i) ADD Instruction- This instruction is used to add the source A and source B contents when input rung condition is true. The result obtained is to be stored in the destination.

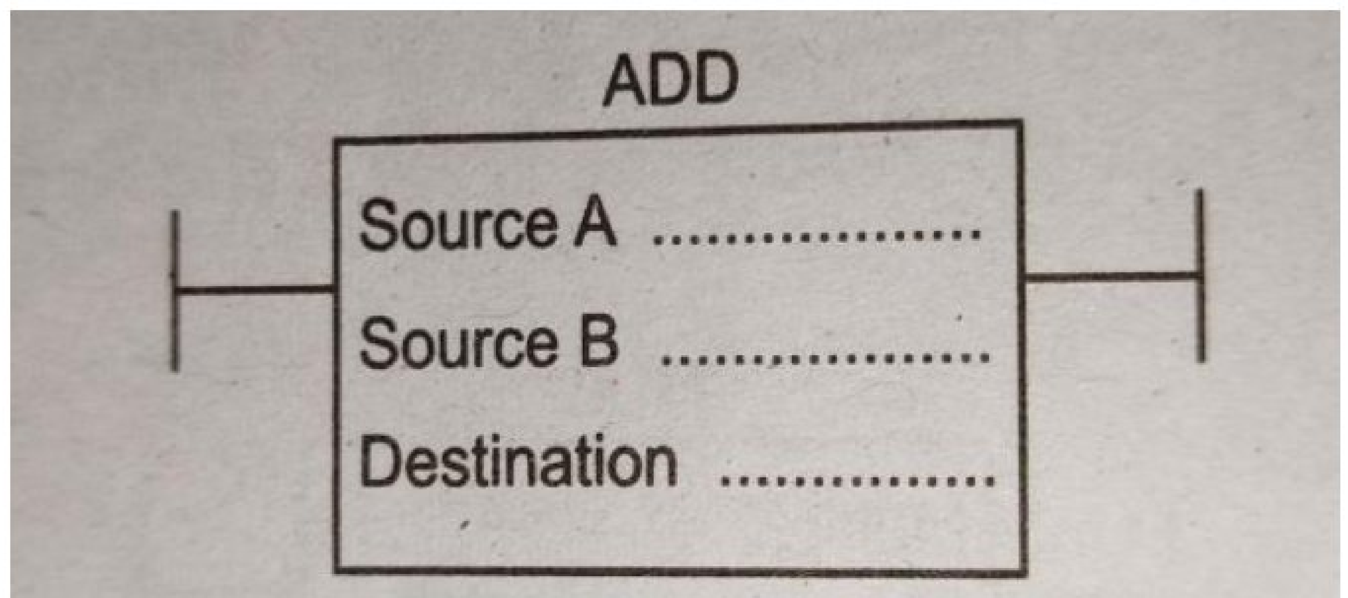


Fig. ADD Instruction Symbol

(ii) Subtract (SUB) Instruction- This instruction is used to subtract the source B contents from source A, when the input rung condition is True. The result obtained is to be stored in the destination.

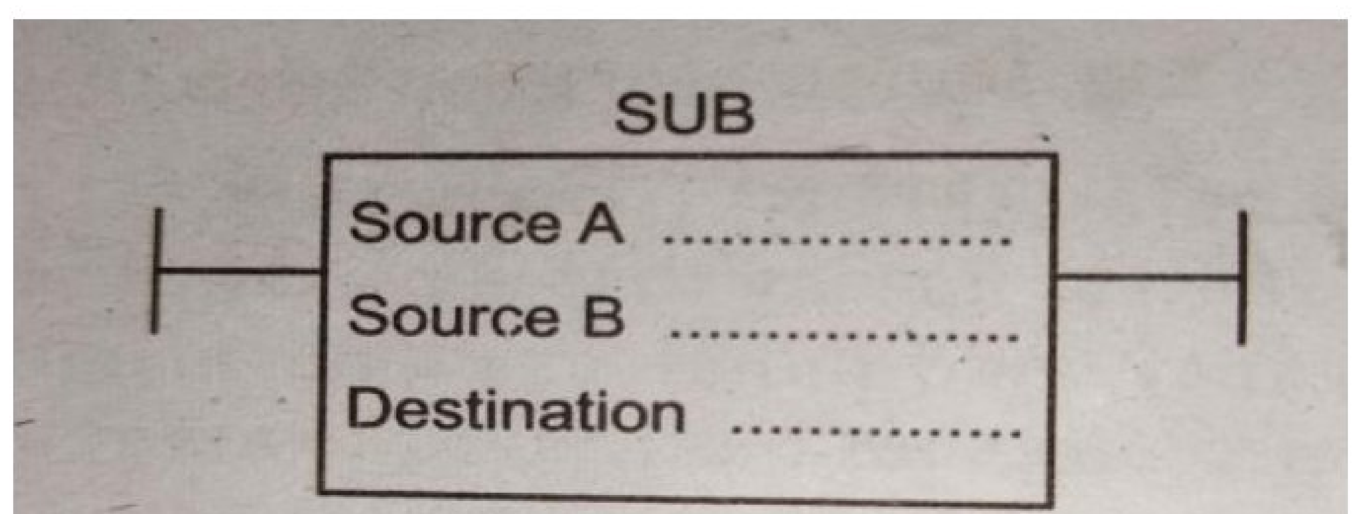


Fig. SUB Instruction Symbol

(iii) Multiply (MUL) Instruction-- This instruction is used to multiply source A value with source B, when input rung condition is true. The result obtained is to be stored in the destination.

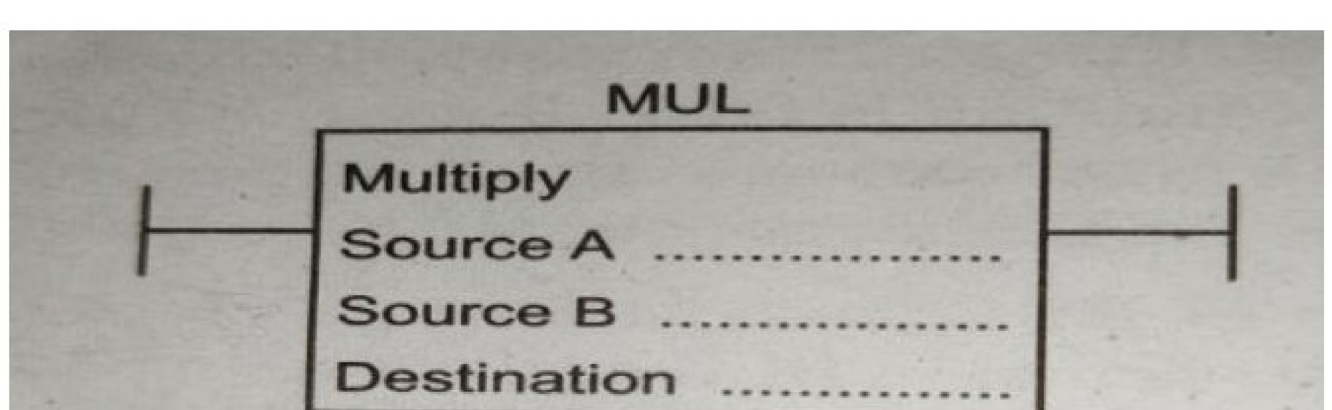


Fig. MUL Instruction symbol

(iv) Divide (DIV) Instruction - This instruction is used to divide source A value with source B when input rung condition is true. The result obtained is to be stored in the destination.

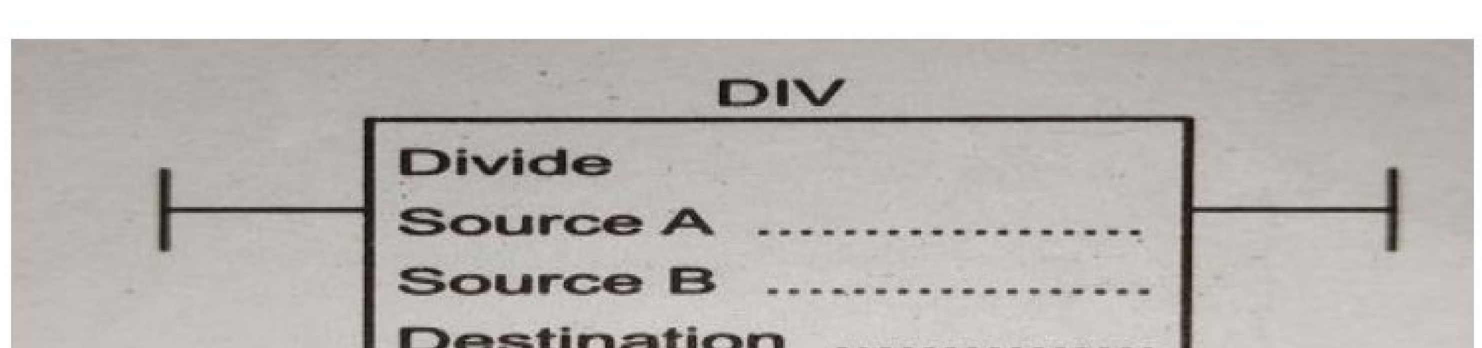


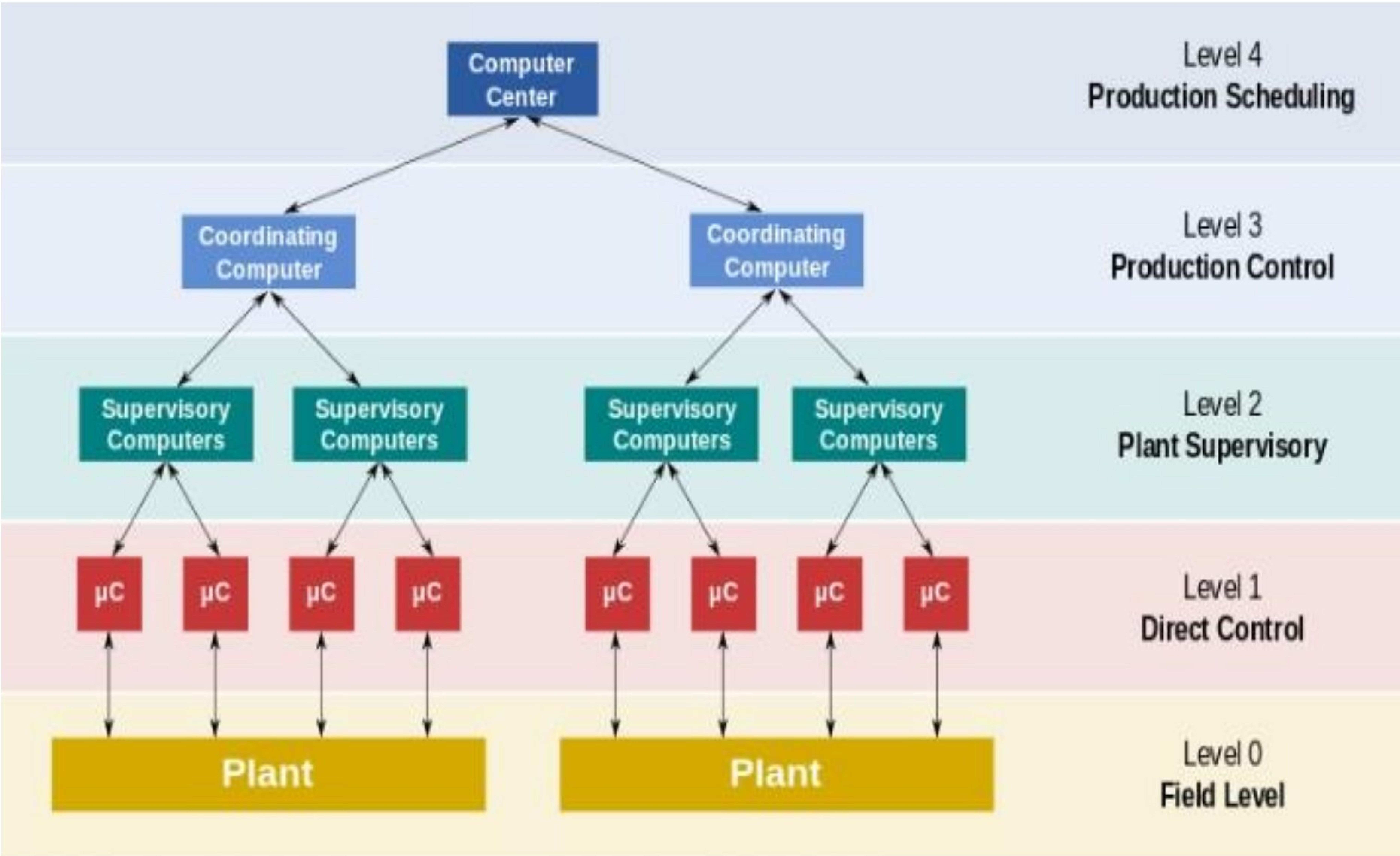
Fig. DIV Instruction symbol

UNIT - 4 : CONCEPT OF DCS

Distributed Control System:

A DCS or distributed control system is similar to a PLC in that it has rugged computer controllers however the DCS contains multiple autonomous controllers that are distributed throughout a system, also used for automating processes.

Structure of DCS:



Explanation:

The key attribute of a DCS is its reliability due to the distribution of the control processing around nodes in the system. This mitigates a single processor failure. If a processor fails, it will only affect one section of the plant process, as opposed to a failure of a central computer which would affect the whole process. This distribution of computing power local to the field Input/Output (I/O) connection racks also ensures fast controller processing times by removing possible network and central processing delays.

The accompanying diagram is a general model which shows functional manufacturing levels using computerised control.

Referring to the diagram;

Level 0 contains the field devices such as flow and temperature sensors, and final control elements, such as control valves

Level 1 contains the industrialised Input/Output (I/O) modules, and their associated distributed electronic processors.

Level 2 contains the supervisory computers, which collect information from processor nodes on the system, and provide the operator control screens.

Level 3 is the production control level, which does not directly control the process, but is concerned with monitoring production and monitoring targets

Level 4 is the production scheduling level.

Levels 1 and 2 are the functional levels of a traditional DCS, in which all equipment are part of an integrated system from a single manufacturer.

Levels 3 and 4 are not strictly process control in the traditional sense, but where production control and scheduling takes place.

DCS inputand output Hardware:

The processors receive information from input modules, process the information and decide control actions to be signalled by the output modules. ... The DCS sends the setpoint required by the process to the controller which instructs a valve to operate so that the process reaches and stays at the desired setpoint.

Features of DCS :

DCS ensures fulfillment of all main functions of control, visualization, registration and reporting of process including:

- Automatic regulation.
- Program (logic) control.
- Remote control (start, shutdown, change of set points)
- Alarms and notifications management.
- Collection and processing of process and equipment data.

Applications of DCS:

Distributed control systems (DCS) are dedicated systems used in manufacturing processes that are continuous or batch-oriented.

Processes where a DCS might be used include:

- Chemical plants
- Petrochemical (oil) and refineries
- Pulp and paper mills (see also: quality control system QCS)
- Boiler controls and power plant systems
- Nuclear power plants
- Environmental control systems
- Water management systems
- Water treatment plants
- Sewage treatment plants
- Food and food processing
- Agrochemical and fertilizer
- Metal and mines
- Automobile manufacturing
- Metallurgical process plants
- Pharmaceutical manufacturing
- Sugar refining plants
- Agriculture applications

Difference between PLC and DCS:

PROGRAMMABLE LOGIC CONTROLLERS (PLC)vs DISTRIBUTED CONTROL SYSTEMS (DCS)

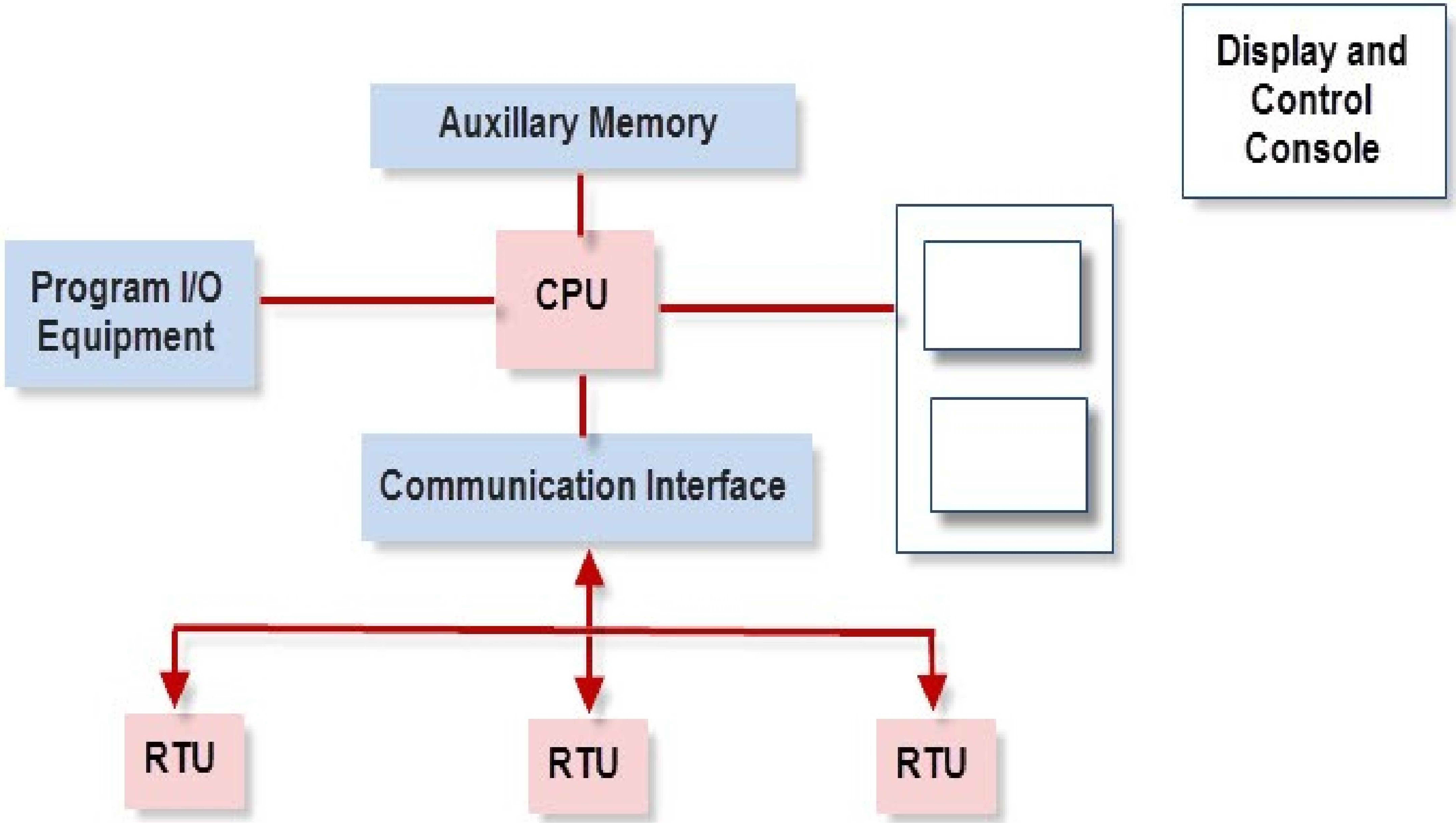
- **Speed of response:** PLCs are can respond to a change within one-tenth of a second. DCS are slower than PLCs. Typical respond time of DCS is 30ms.
- IO **capacity**: A PLC is capable of handling few hundred IOs. When it comes to analog IOs, it can handle tens of them. A DCS can handle thousands of IOs. It can handle hundreds or even thousands of analogs IOs and PID functions
- **Logic development:** PLC can programmed be programmed based on our application. DCS comes with built-in control functions that need to be configured based on the application.
- **Redundancy:** PLCs can be made redundant with additional hardwares which makes them expensive than DCS. Redundancy is a default feature of distributed control systems.
- **Architecture:** PLCs have a simple and flexible architecture. A PLC system consists of controllers, IO modules, HMIs and an engineering software. DCS systems are less flexible. They come with controllers, IO systems, database servers, engineering and operating servers.
- **Application:** PLCs are best suited for dedicated applications that changes less often. DCS is suitable for complex processes that require advanced process control capability.
- **Cost:** plc are Less expensive,Dcs are More expensive

Remote terminal unit:

A remote terminal unit is a microprocessor-controlled electronic device that interfaces objects in the physical world to a distributed control system or SCADA system by transmitting telemetry data to a master system, and by using messages from the master supervisory system to control connected objects.

Concept of SCADA:

Supervisory control and data acquisition (SCADA) is a system of software and hardware elements that allows industrial organizations to: ... Directly interact with devices such as sensors, valves, pumps, motors, and more through human-machine interface (HMI) software.



Block diagram of SCADA system with single computer

Hardware Architecture:

The Hardware architecture of this system is classified into two parts:

- ✓ **Client Layer:** For man machine interface
- ✓ **Data Server Layer:** For data processing

The SCADA station consist of only a single PC. The devices and data servers communicate with each other through RTUs or PLCs. The PLCs are either directly connected to the data servers or through buses and networks. This system uses LAN and WAN for communicating between devices and the master station.

Software Architecture:

Servers are used mainly for real time database and multitasking and are responsible for handling and gathering of data.

The software architecture of this system consists of programs that provide trending, diagnostic information. Programs also help in managing information like logistic information, maintenance schedules, detailed schematics of a specific machine or sensor and troubleshooting guides.

Compare SCADA and DCS:

1) DCS is the acronym for Distributed control systems;
SCADA is the acronym for Supervisory Control And Data Acquisition

2) DCS is process oriented;
SCADA is data-gathering oriented.

3) DCS is process state driven;
SCADA system is event driven.

4) A DCS is a process control system that uses a network to interconnect sensors, controllers, operator terminals and actuators. A DCS typically contains one or more computers for control and mostly use both proprietary interconnections and protocols for communications.
SCADA may be called Human-Machine Interface (HMI). SCADA systems are used to monitor or to control chemical, physical or transport processes.

5) Distributed Control System (DCS) consists of one or more controllers used to implement advanced process control techniques.
Supervisory Control and Data Acquisition (SCADA) systems cannot carry out advanced process control techniques.

6) DCS is more integrated and can do more higher-end stuff, but
SCADA systems are more flexible.

Concept of Electrical Drives:

The system which is used for controlling the motion of an electrical machine, such type of system is called an electrical drive. In other words, the drive which uses the electric motor is called electrical drive. The electrical drive uses any of the prime movers like diesel or a petrol engine, gas or steam turbines, steam engines, hydraulic motors and electrical motors as a primary source of energy. This prime mover supplies the mechanical energy to the drive for motion control.

AC Drives Control:

- An ac drive is a device that is used to control the speed of an electric motor. The speed is controlled by changing the frequency of the electrical supply to the motor.
- The three-phase voltage in the national electrical grid connected to a motor creates a rotating magnetic field in it. The rotor of the electrical motor will follow this rotating magnetic field.

Slip Power Recovery Controlled AC Drives:

The slip power recovery (SPR) drive is an external system connected to the rotor circuit in place of the external resistors. The SPR provides speed and torque control like the resistors but can also recover the power taken off the rotor and feed it back into the power system to avoid energy waste.

Advantages:

① Instead of other speed control methods working range can be obtained at any speed.

Disadvantages:

① Motor turns ration is less than unity.

Synchronous Motor Control:

The principle of operation of a synchronous motor is based on the interaction of the rotating magnetic field of the stator and the constant magnetic field of the rotor. The concept of the rotating magnetic field of the stator of a synchronous motor is the same as that of a three-phase induction motor.

Subject: Microwave

Semester-6th

Unit-1

Introduction to microwaves

Microwaves are a form of electromagnetic radiation with wavelengths ranging from about one meter to one millimeter; with frequencies between 300 MHz (1 m) and 300 GHz (1 mm).

A more common definition in radio-frequency engineering is the range between 1 and 100 GHz (wavelengths between 0.3 m and 3 mm).

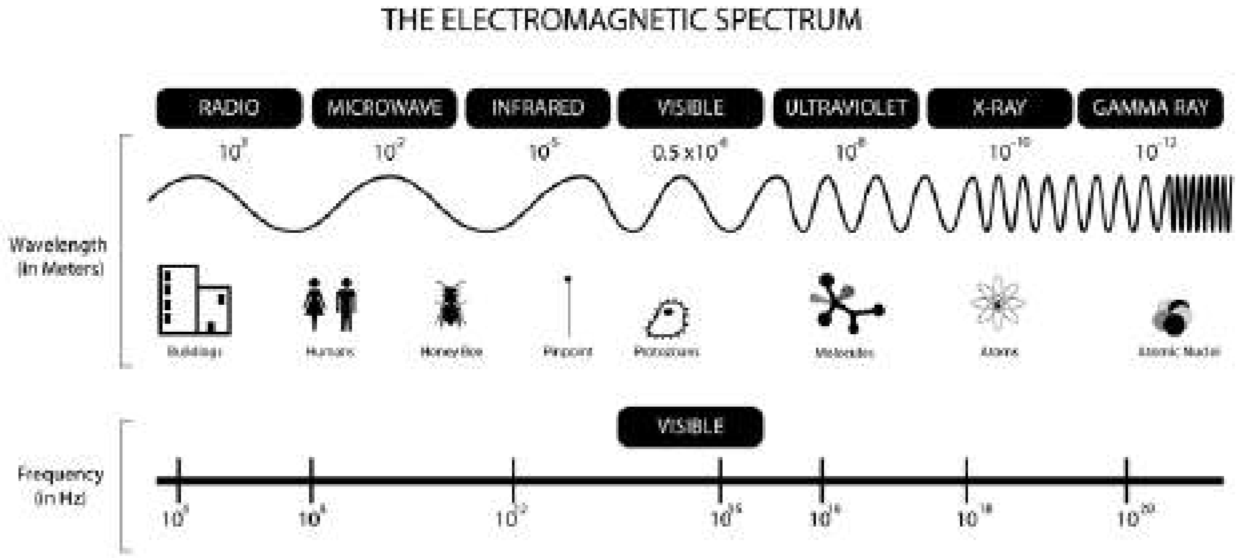
This region is further divided into a number of bands, with designations such as L, S, C, X and K

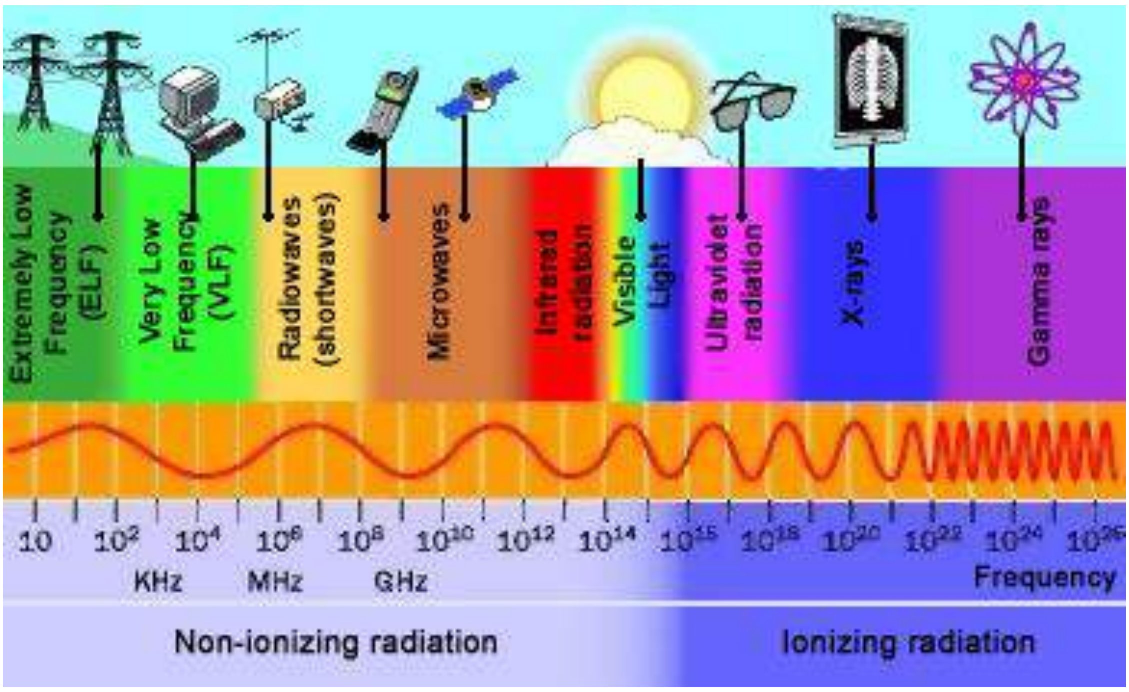
Band		Frequency	Wavelength	
VLF	Very Low Frequency	3Khz - 30Khz	100 km - 10 km (Myriametric)	
LF	Low Frequency	30Khz - 300Khz	10 km - 1 km (Kilometric)	
MF	Medium Frequency	300Khz - 3Mhz	1 km - 100 m (Hectometric)	ADF
HF	High Frequency	3Mhz - 30Mhz	100 m - 10 m (Decametric	
VHF	Very High Frequency	30Mhz - 300Mhz	10 m - 1 m (Metric)	VOR, ILS (Loc) & Marker Beacons
UHF	Ultra High Frequency	300Mhz - 3Ghz	1 m - 10 cm (Decimetric)	SSR, DME, High Alt Radio Alt
SHF	Super High Frequency	3Ghz - 30Ghz	10 xm - 1 cm (Centimetric)	Airborne Wx Radar, Low Alt Radio Alt
EHF	Extremely High Frequency	30Ghz - 300Ghz	1 cm - 1 mm (Millimetric)	

Radio Band Designation

Frequency	Radio Band
30-300Hz	ELF(Extremely Low Frequency)
300-3000Hz	ULF(Ultra Low Frequency)
3-30KHz	VLF(Very Low Frequency)
30-300KHz	LF(Low Frequency)
300-3000KHz	MF(Medium Frequency)
3-30MHz	HF(High Frequency)
30-300MHz	VHF(Very High Frequency)
300-3000Mhz	UHF(Ultra High Frequency)
3-30Ghz	SHF(Super High Frequency)
30-300GHz	EHF(Extremely High Frequency)

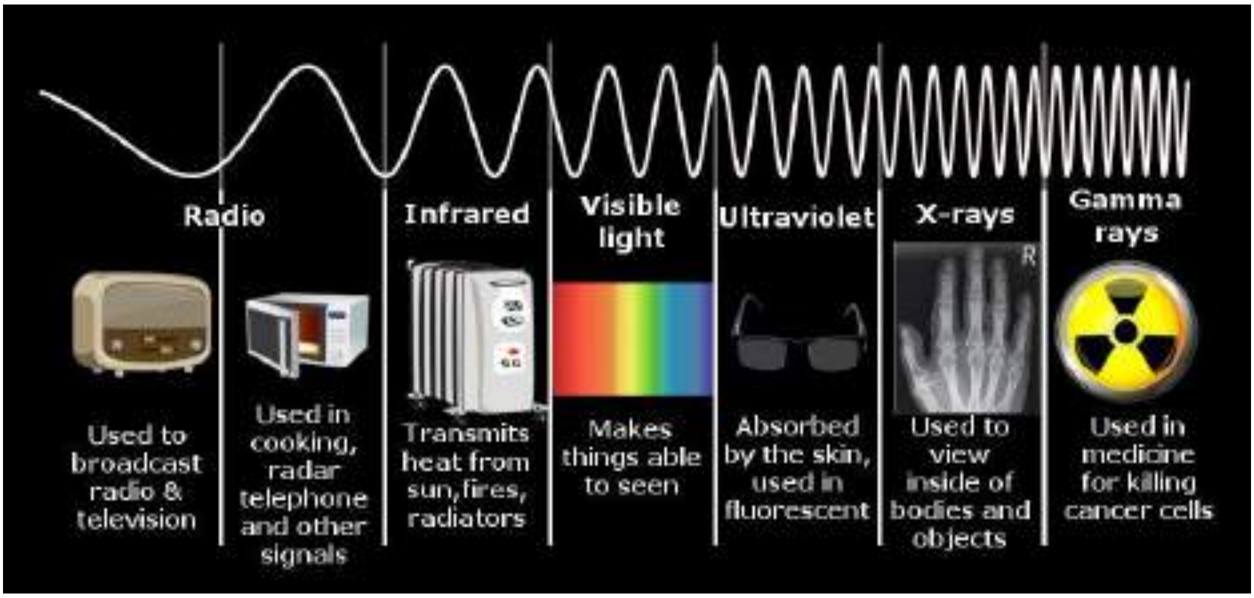
Frequency	IEEE Radar Band
1-2 GHz	L-band
2-4GHz	S-Band
4-8GHz	C-Band
8-12GHz	X-band
12-18GHz	Ku Band
18-27GHz	K Band


THE ELECTROMAGNETIC SPECTRUM
RADIO
MICROWAVE
INFRARED
VISIBLE
ULTRAVIOLET
X-RAY
GAMMA RAY
Wavelength (in Meters)
Buildings
Humans
Honey Bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (in Hz)
VISIBLE


Extremely Low Frequency (ELF)
Very Low Frequency (VLF)
Radiowaves (shortwaves)
Microwaves
Infrared radiation
Visible Light
Ultraviolet radiation
X-rays
Gamma rays
10 10² 10⁴ 10⁶ 10⁸ 10¹⁰ 10¹² 10¹⁴ 10¹⁶ 10¹⁸ 10²⁰ 10²² 10²⁴ 10²⁶
KHz
MHz
GHz
Frequency
Non-ionizing radiation
Ionizing radiation

What are Microwaves?

- Microwaves are a form of electromagnetic energy, like light waves or radio waves
- Microwaves are used extensively in communications
  - such as to relay long-distance telephone signals, television programs and computer information across the earth or to a satellite in space.
- Good for transmitting information because it can penetrate haze, light rain and snow, clouds, and smoke.
- Also used in radars and in detecting speeding cars.
- Microwave has become most familiar as the energy source for cooking food.



How are microwaves used?

- **Heating food**
  A microwave oven uses microwaves to generate heat and warm food.
- **Communications**
  Microwaves are used to send communications signals to and from satellites. They also carry signals for mobile phones, wireless computer networks and personal digital assistants.

- **Radar (<u>ra</u>dio <u>d</u>etection <u>a</u>nd <u>r</u>anging)**
  Radar equipment bounces microwaves off moving objects to detect them.
- **Astronomy**
  Large microwave receivers called radiotelescopes study microwaves emitted from space.

Publication type	Applications discussed
Review	Various, including preheating and vulca of ceramics, pasteurization, sterilizatio
Book	Various, from baking and drying to blan the key area of process measurement a heating of food products
Review	Heating of food
Review	Drying
Book	Food processing
Review	Food pasteurization and sterilization
Review	Various, including curing, drying, heatin
Review	Textile processing
Review	Drying
Review	Ceramic processing
Book	Drying
Review	Microwave-assisted freeze-drying of foo
Review	Drying of fruits and vegetables

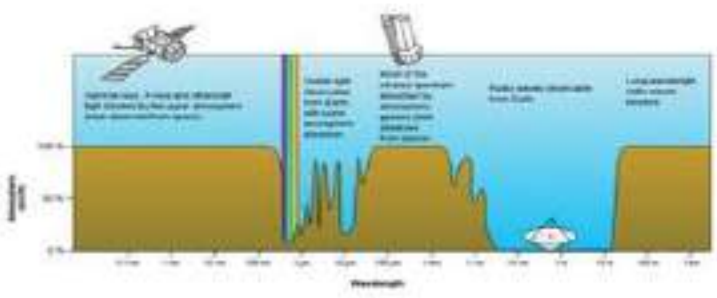
Microwave Applications

- **Communication**
  - Before the advent of fiber-optic transmission, most long-distance telephone calls were carried via networks of microwave radio relay links using FDM.
  - Wireless LAN protocols, such as Bluetooth and the IEEE 802.11 specifications, also use microwaves in the 2.4 GHz ISM band.
  - Wireless internet access IEEE 802.11a uses microwaves at 3.5-4 GHz range.
  - Metropolitan area network (MAN) protocols, such as WiMAX (Worldwide Interoperability for Microwave Access) are based on standards such as IEEE 802.16, designed to operate between 2 to 11 GHz.
  - Mobile Broadband Wireless Access (MBWA) protocols based on standards specifications such as IEEE 802.20 operate between 1.6 and 2.3 GHz.

Most common applications are within the range of 1 to 40 GHz. Microwaves are suitable for wireless transmission (wireless LAN protocol Ex- Bluetooth) signals having higher bandwidth. Microwaves are commonly used in radar systems where radar uses microwave radiation to detect the range, distance, and other characteristics of sensing devices and mobile broadband applications. Microwave technology is used in radio for broadcasting and telecommunication of transmission because due to their small wavelength, highly directional waves smaller and therefore more practical than they would be at longer wavelengths (lower frequencies) before the introduction of Fiber optic transmission. Microwaves are generally used in telephone for long distance communication.

Microwave Bands:

Microwaves are found at the higher end of the radio spectrum, but they are commonly different with radio waves based on the technology using them. Microwaves are divided into sub-bands based on their wavelengths which are providing different information. The frequency bands of microwaves are as follows:



Microwave Bands

Band	Frequency Range (GHz)
L	1 to 2
S	2 to 4
C	4 to 8
X	8 to 10
Ku	12 to 18
K	18 to 26.5
Ka	26.5 to 40
Q	30 to 50
U	40 to 60
V	50 to 75
E	60 to 90 (millimeter waves)
W	75 to 110
F	90 to 140
D	110 to 170

Microwave frequency bands and their frequency range

L-Band:

L bands are having the frequency rage between 1 GHz to 2 GHz and their wavelength in free space is 15cm to 30cm. These ranges of waves are used in navigations, GSM mobile phones, and in military applications. They can be used to measure the soil moisture of rain forests.

S-Band:

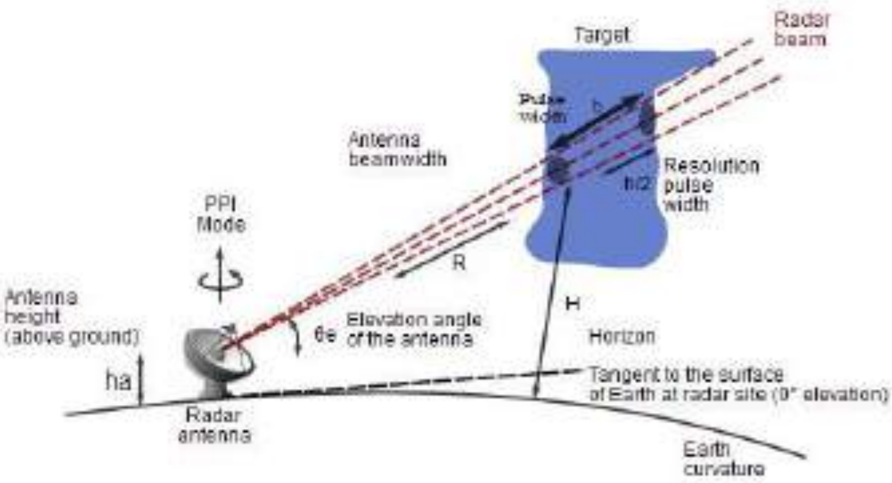
S band microwaves are having the frequency range between 2 GHz to 4 GHz and their wavelength range is 7.5cm to 15 cm. These waves can be used in navigation beacons, optical communications, and wireless networks.

C-Band:

C band waves are having the range between 4 GHz to 8 GHz and their wavelength is in between 3.75 cm to 7.5 cm. C band microwaves penetrate clods, dust, smoke, snow, and rain to reveal the earth's surface. These microwaves can be used in long-distance radio telecommunications.

X-Band:

The frequency range for S-band microwaves is 8 GHz to 12 GHz having the wavelength in between 25 mm to 37.5 mm. These waves are used in satellite communications, broadband communications, radars, space communications and amateur radio signals.



Radar applications using microwaves

Ku-Band:


Wave meter for measuring in the Ku band

These waves are occupying the frequency range between 12 GHZ to 18 GHz and having the wavelength in between 16.7 mm to 25 mm. "Ku" refers to Quartz-under. These waves are used in satellite communications for measuring the changes in the energy of the microwave pulses and they can determine speed and direction of wind near costal areas.

K-Band and Ka-Band:

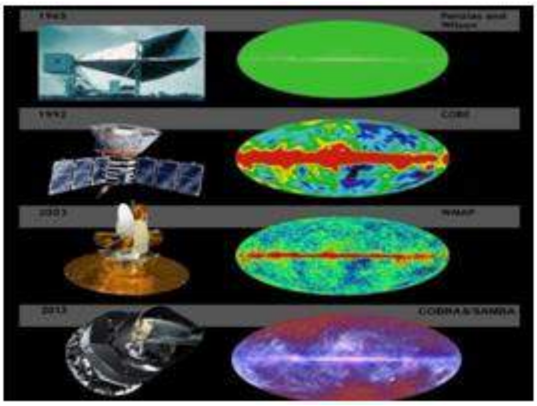
The frequency range for K band waves in between 18 GHz to 26.5 GHz. These waves are having the wavelength in between 11.3 mm to 16.7 mm. For Ka band the frequency range is 26.5 GHz to 40 GHz and they are occupying the wavelength in between 5 mm to 11.3 mm. These waves are used in satellite communications, astronomical observations, and radars. Radars in this frequency range provide short range, high resolution and high amount of data at the renewing rate.

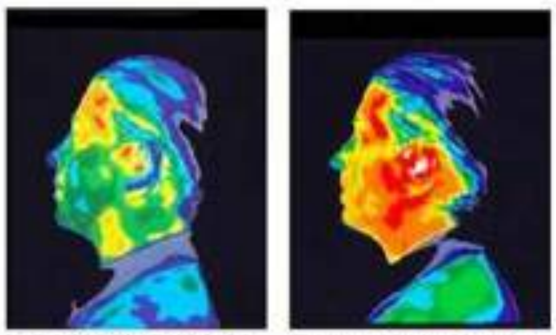
V-Band:

This band stays for a high attenuation. Radar applications are limited for a short range of applications. The frequency range for these waves is 50 GHz to 75 GHz. The wavelength for these microwaves is in between 4.0 mm to 6.0 mm. There are some more bands like U, E, W, F, D, and P having very high frequencies which are used in several applications.

Microwave Radiation and its Effect on Health:

Radiation is an energy that comes from a source and travels through some medium or space. Generally RF radiation will be produced by several devices like TV and Radio transmitters, induction heaters and dielectric heaters. Microwave radiation will be produced by radar devices, dish antennas, and microwave ovens.





Thermographic Image of the head with no exposure to harmful cell phone radiation.

Thermographic Image of the head after a 15-minute phone call. Yellow and red areas indicate thermal (heating) effects that can cause negative health effects.

Microwave radiation effect after phone call

Due to the microwave radiation, the body temperature may increase. There is a higher risk of heat damage with organs which are having poor temperature control, such as lens of eyes. Since radiation energy absorbed by the body varying with the frequency, measuring the rate of absorption is very difficult.

5 Advantages of using Microwave technology:

1. It does not require any cable connection.
2. They can carry high quantities of information due to their high operating frequencies.
3. We can able to access more numbers of channels.
4. Low cost land purchase: each tower occupies small area.
5. High frequency/short wavelength signals require small antenna.

5 Disadvantages:

1. Attenuation by solid objects: birds, rain, snow and fog.
2. It's much expensive to build long towers.
3. Reflected from flat surfaces like water and metal.
4. Diffracted (split) around solid objects.
5. Refracted by atmosphere, thus causing beam to be projected away from receiver.

- Applications of Microwaves in the field of communications

1. Before the advert of fiber optic transmission, most long-distance telephone calls well carried via microwave point-to-point links through sites like the AT&T Long Lines. Starting in the early 1950's frequency was used to send up to 5,400 telephone channels on each microwave radio channels combined into one antenna or the hop to the next site, up to 70 km away.

2. Wireless LAN protocols, such as Bluetooth and the IEEE 802.11 specifications, also use microwave in the 2.4 GHz ISM band, although 8.2.11a uses ISM band and U-NII frequencies in the 5 GHz range. Licensed long-range (up to about 25 km). Wireless Internet Access services can be found in many countries in the 3.5 – 4.0 GHz range.

3. Metropolitan Area Networks: MAN protocols, such as WiMAX (Worldwide interoperability for Microwave Access) based in the IEEE 8.2.16 specification. The IEEE 8.2.16 specification was designed to operate between 2 to 11 GHz. The commercial implementations are in the 2.3GHz, 2.5GHz, 3.5GHz and 5.8GHz range.

4. Wide Area Mobile Broadband Wireless Access: MBWA protocols based on standards specifications such as IEEE 8.2.20 or ATIS/ANSI HC-SDMA (e.g. iBurst) are designed to operate between 1.6 and 2.3GHz to give mobility and in-building penetration characteristics similar to mobile phones but with vastly greater spectral efficiency.

5. Cable TV and Internet access on coaxial cable as well as broadcast television use some of the lower microwave frequencies. Some mobile phone networks, like GSM, also use the lower microwave frequencies.

6. Microwave radio is used in broadcasting and telecommunication transmissions because, due to their short wavelength, highly directive antennas are smaller and therefore more practical than they would be at longer wavelengths (lower frequencies). There is also more bandwidth in the microwave spectrum than in the rest of the radio spectrum; the usable bandwidth below 300 MHz is less than 300 MHz while many GHz can be

used above 300 MHz. Typically, microwaves are used in television news to transmit a signal from a remote location to a television station from a specially equipped van.

Applications of Microwaves in the field of Remote Sensing

1. Radio Detecting and ranging (RADAR) uses microwave radiation to detect the range, speed, and other characteristics of remote objects. Development of radar was accelerated during World War II due to its great military utility. Now radar is widely used for applications such as air traffic control, navigation of ships, and speed limit enforcement, whether monitoring and predication, geological survey.
2. A Gunn diode oscillator and waveguide are used as a motion detector for automatic door openers (although these are being replaced by ultrasonic devices).
3. Radiometry, spectrometry for the study of naturally propagated EM waves.
4. Radio astronomy.

- Applications of Microwaves in the field of Biomedical

1. Microwave imaging, photo-acoustic imaging in biomedicine.
2. Thermotherapy, LASER therapy for cancer sell treatment.

- Applications of Microwaves in the field of Navigation

1. Global Navigation Satellite System (GNSS) including the American Global Positioning System (GPS) and the Russian GLONASS broadcast navigational signals in various bands between about 1.2 GHz and 1.6 GHz.

- Applications of Microwaves in the field of Power

1. A microwave passes (non-ionizing) microwave radiation (at a frequency near 2.45 GHz) through food, causing dielectric heating by absorption of energy in the water, fats and sugar contained in the food. Microwave ovens become common kitchen appliances in Western countries in the late 1970s, following development of expensive cavity magnetrons.

2. Microwave heating is used in industrial processes for drying and curing products.

3. Many semiconductor processing techniques use microwaves to generate plasma for such purpose as reactive ion etching and plasma-enhanced chemical vapor deposition (PECVD).

4. Microwaves can be used to transmit power over long distances, and post-World War II research was done to examine possibilities. NASA worked in the 1970s and early 1980s to research the possibilities of using Solar power satellite (SPS) systems with large solar arrays that would been power down to the Earth's surface via microwaves.

5. Less-than-lethal weaponry exists that uses millimeter waves to heat a thing layer of human skin to an intolerable temperature so as to make the targeted person move away. A two-second burst of the 95 GHz focused beam heats the skin to a temperature of 130 F (54^0C) at a depth of $1/64^{th}$ of an inch (0.4 mm). The United States Air Force and marines are currently using this type of Active Denial System.

Unit-2

Microwave Devices

Limitation of Vaccum Tubes: At microwave frequencies(in order of GHz) internal stray capacitances arise in active devices such as MOSFET's,OP-AMP's... which causes the gain of such devices to reduce at these frequencies.

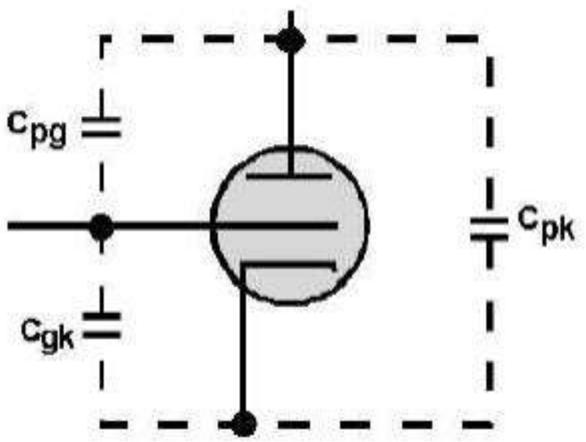
Stray capacitances are formed when two layers are separated by a small distance (such as diffusion region and substrate in MOSFET). The reactance of a capacitor is given Xc=1/(2∗pi∗f∗C). Thus at high frequencies internal capacitances get shorted and thus the output reduces.

Following are the limitations of conventional active devices like transistors or tubes at microwave frequencies

1) **Interelectrode capacitance.**

What is interelectrode capacitance?

Vacuum has a dielectric constant of 1. As the elements of the triodes are made of metal and are separated by a dielectric, capacitance exists between them. This capacitance is interelectrode capacitance.



The capacitance between the plate and grid is Cpg. The grid-to-cathode capacitance is Cgk. The total capacitance across the tube is Cpk.

Now, we know that the capacitive reactance is given by

$$X_c = 1/2\pi fC$$

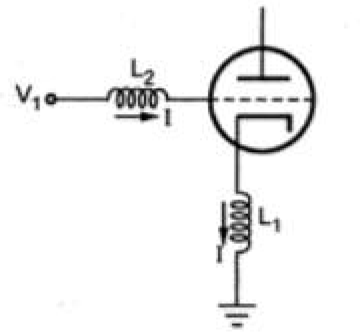
So as the input frequency increases, the effective grid to cathode impedance decreases due to decrease in reactance of interelectrode capacitance. At higher frequencies (greater than 100MHz) it becomes so small that signal is short circuited with the tube. Also, gain of the device reduces significantly.

This effect can be minimized by taking smaller (reducing the area) electrodes and by increasing distance between them (i.e. reducing capacitance because C=epsilon*A/d) therefore by increasing reactance.

2) Lead inductance.

Lead or stray inductance are effectively in parallel within the device with the interelectrode capacitance. Inductive reactance is given by:

$$XL = 2\pi f L$$



As the frequency increases, the effective reactance of the circuit also increases. This effect raise the frequency limit to the device. The inductance of cathode lead is common to both grid and plate circuits. This provides a path for degenerative feedback which reduces the overall efficiency of the circuit.

3) Transit time

Transit time is the time required for electrons to travel from the cathode to the plate. At low frequency, the transit time is very negligible. But, however at higher frequencies, transit time becomes an appreciable portion of a signal cycle which results in decrease in efficiency of device.

4) Gain bandwidth product

Gain bandwidth product is independent of frequency. So for a given tube higher gain can be only obtained at the expense of narrower bandwidth.

5) Skin effect

This effect is introduced at higher frequencies. Due to it, the current flows from the small sectional area to the surface of the device. Also at higher frequencies, resistance of conductor increases due to which the there are losses.

$R=\rho l(\sqrt{f})$

6) Dielectric loss

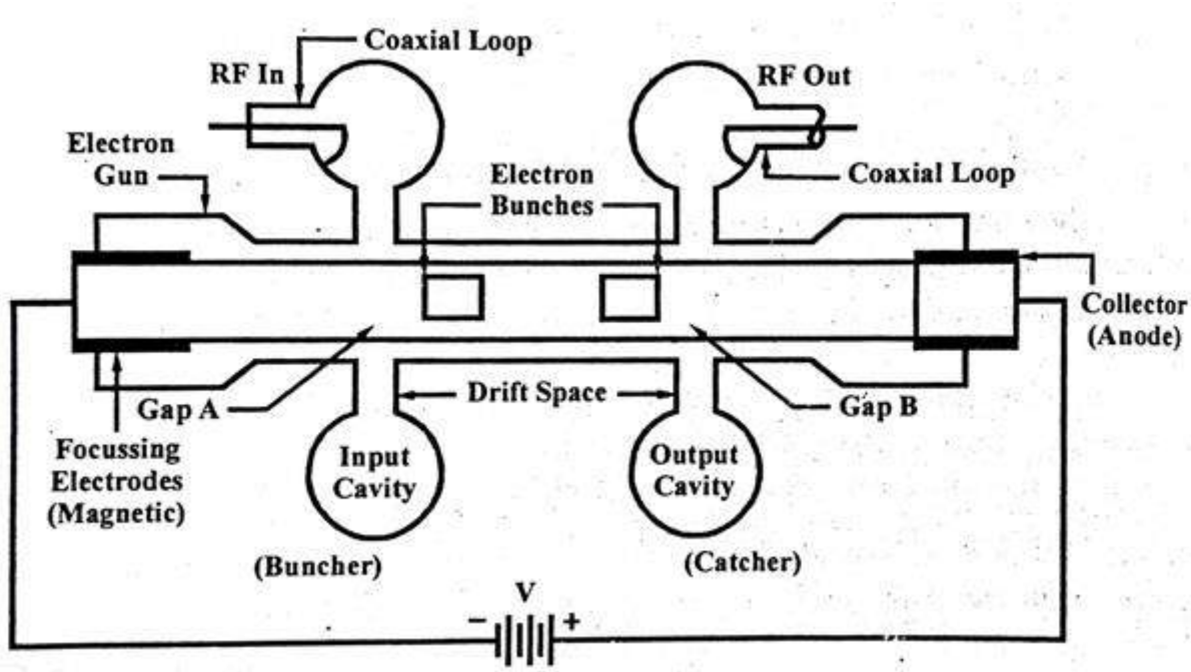
Dielectric material is generally different silicon plastic encapsulation materials used in microwave devices. At higher frequencies the losses due to these materials are also prominent.

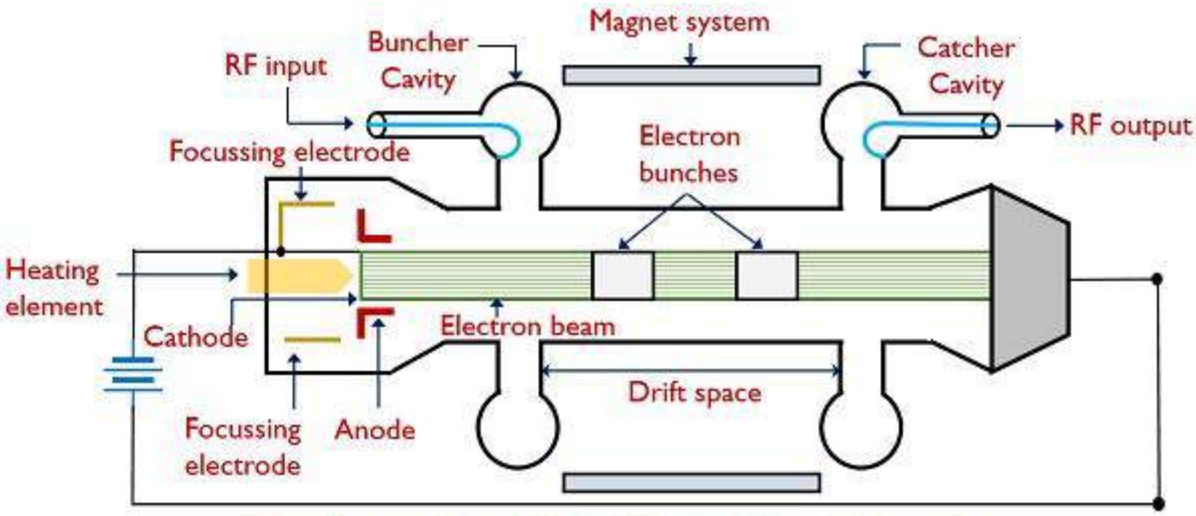
Two Cavity Klystron Ampilifier:

For the generation and amplification of Microwaves, there is a need of some special tubes called as **Microwave tubes**. Of them all, **Klystron** is an important one.

The essential elements of Klystron are electron beams and cavity resonators. Electron beams are produced from a source and the cavity klystrons are employed to amplify the signals.

The klystron is a device for amplifying microwave frequency signals that achieve high levels of power gain by and use the concept of "electron bunching". Klystrons are used in satellite systems, television broadcast, and radar, as well as particle accelerators and medicine. Klystrons can be used in the UHF region (300 MHz to 3 GHz) up to 400 GHz.





Structure of Two-Cavity Klystron

Electronics Desk

Electron beams are 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. The collector at the end is at the same potential as the resonator. Hence, usually the electrons have a constant speed in the gap between the cavity resonators.

Initially, the first cavity resonator is supplied with a weak high frequency signal, which has to be amplified. The signal will initiate an electromagnetic field inside the cavity.

Electron are generated from cathode terminal and move towards catcher cavity. In catcher cavity, there is already a signal feeded which is to be amplified. Interaction between electrons and RF signal takes place. Because of which bunching takes place. Electrons which passes through zero of the RF signal, no change is velocity occurs. Electrons which passes , when signal at positive potential , velocity of electrons increases. Electron which passes, when signal at negative potential , velocity of electrons decreases. In this way velocity modulation take place. And bunches formation takes place. During bunches electron gain too much high energy. This is released when these bunches passes through catcher cavity during the retarding phase of the signal. Output is taken from the catcher cavity with the help of coupling loops.

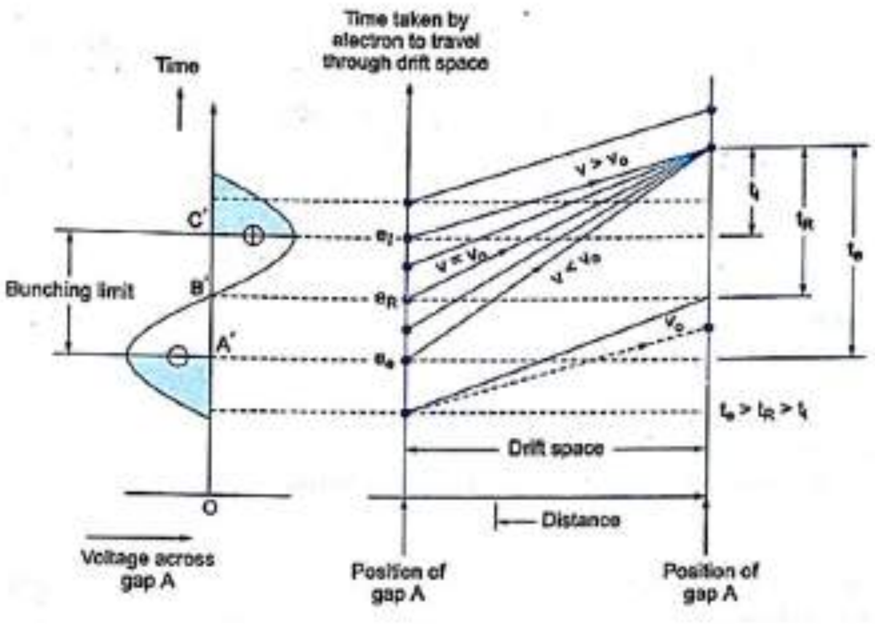


Fig. Apple gate diagram of a klystron amplifier

The applications of klystron amplifiers are

- These amplifiers can generate far higher microwave power o/ps than solid state microwave devices like gunn diodes.
- Klystron amplifiers are used in modern systems, they are used from hundreds of MHz (UHF) through hundreds of GHz.
- These amplifiers can be found in satellite, radar, wideband high-power communication, medicine, high-energy physics.
- At SLAC, these amplifiers are normally employed which have o/ps in the range of 50 MW & 50 kW (time-averaged) at 2856 Mega Hertz.
- The Radar uses two klystrons that offer a total o/p power of 1 MW at 2380 Mega Hertz.
- Global Resource Corporation (GRC) currently using a klystron amplifier to convert the hydrocarbons in daily materials, coal, automotive waste, oil sands, diesel fuel, oil shale and oil sands intonatural gas.

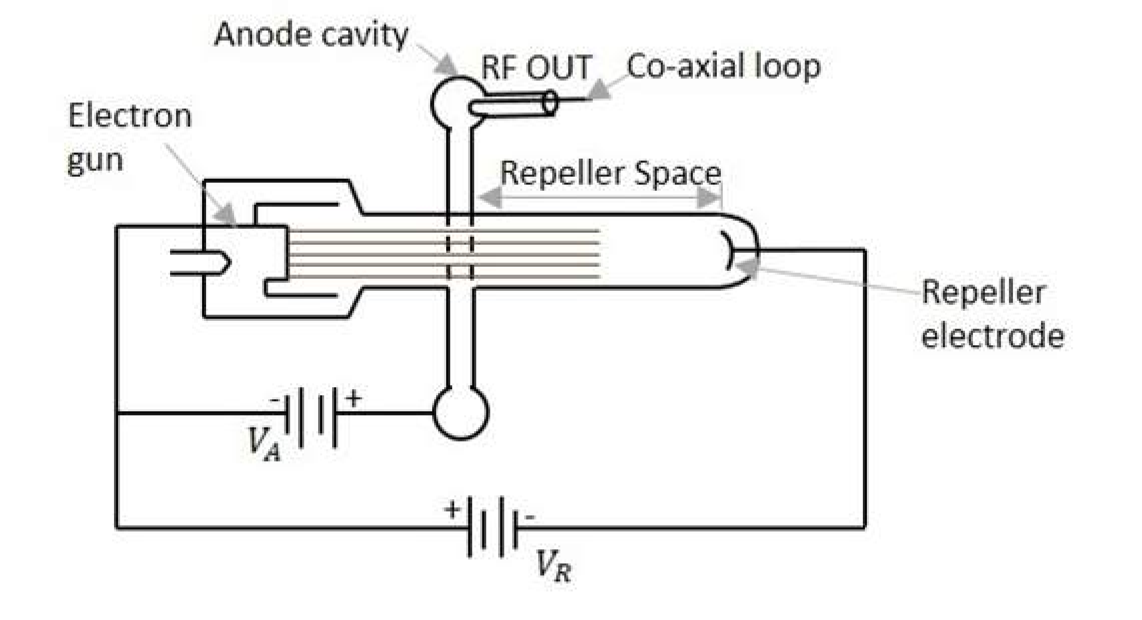
Reflex Klystron:

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.

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 electrons repel back to the anode cavity. In their return journey, the electrons give more energy to the gap and these oscillations are sustained. The constructional details of this reflex klystron is as shown in the following figure.



Constructional details of Reflex Klystron

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.

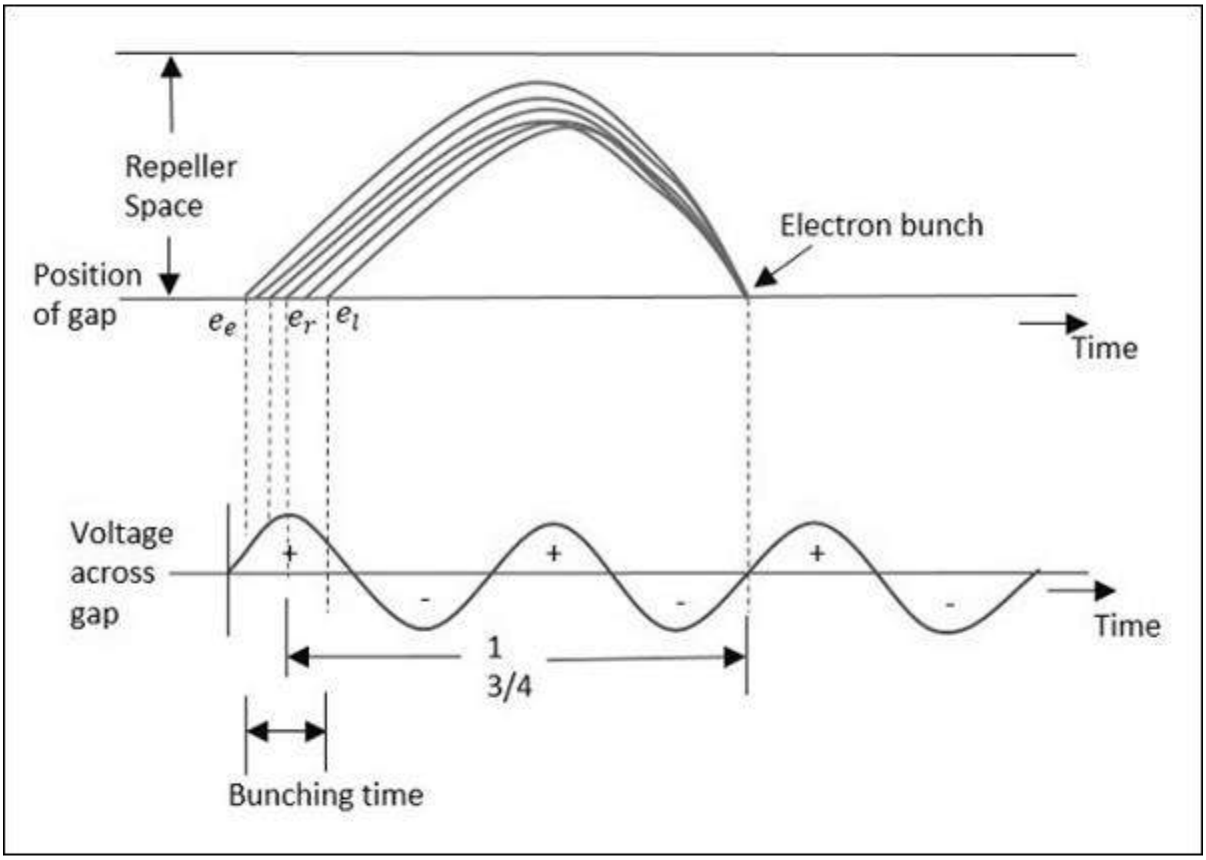
Operation of Reflex Klystron

The operation of Reflex Klystron is understood by some assumptions. The electron beam is accelerated towards the anode cavity.

Let us assume that a reference electron $\mathbf{e_r}$ 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 $\mathbf{e_e}$ which has started earlier than this reference electron, reaches the Repeller first, but returns slowly, reaching at the same time as the reference electron.

We have another electron, the late electron $\mathbf{e_l}$, which starts later than both $\mathbf{e_r}$ and $\mathbf{e_e}$, however, it moves with greater velocity while returning back, reaching at the same time as er and ee.

Now, these three electrons, namely $\mathbf{e_r}$, $\mathbf{e_e}$ and $\mathbf{e_l}$ 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 following figure illustrates this.



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+3/4

where n is an integer

This transit time depends upon the Repeller and anode voltages.

Applications of Reflex Klystron

Reflex Klystron is used in applications where variable frequency is desirable, such as −

- Radio receivers
- Portable microwave links
- Parametric amplifiers
- Local oscillators of microwave receivers
- As a signal source where variable frequency is desirable in microwave generators.

Travelling Wave Tube Amplifier:

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 RFRF field.

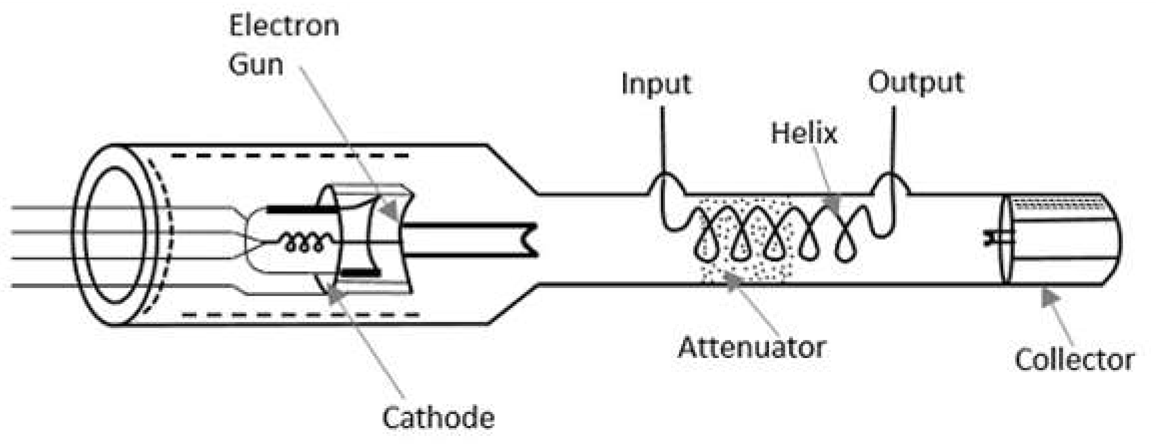
Construction of Travelling Wave Tube

Travelling wave tube is a cylindrical structure which contains an electron gun from a cathode tube. It has anode plates, helix and a collector. RF input is sent to one end of the helix and the output is drawn from the other end of the helix.

An electron gun focusses an electron beam with the velocity of light. A magnetic field guides the beam to focus, without scattering. The RF field also propagates with the velocity of light which is retarded by a helix. Helix acts as a slow wave structure. Applied RF field propagated in helix, produces an electric field at the center of the helix.

The resultant electric field due to applied RF signal, travels with the velocity of light multiplied by the ratio of helix pitch to helix circumference. The velocity of electron beam, travelling through the helix, induces energy to the RF waves on the helix.

The following figure explains the constructional features of a travelling wave tube.

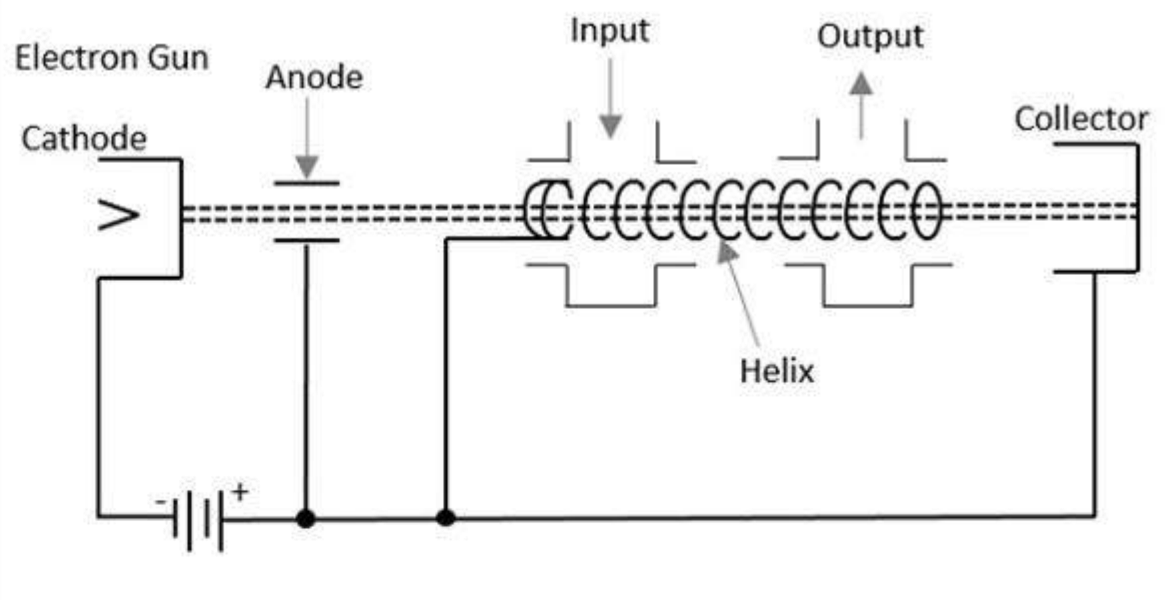


Physical construction of TWT

Thus, the amplified output is obtained at the output of TWT. The axial phase velocity Vp is represented as

$$V_p = V_c(\text{Pitch}/2\pi r)$$

Where **r** is the radius of the helix. As the helix provides least change in Vp phase velocity, it is preferred over other slow wave structures for TWT. In TWT, the electron gun focuses the electron beam, in the gap between the anode plates, to the helix, which is then collected at the collector. The following figure explains the electrode arrangements in a travelling wave tube.



Schematic Electrode Arrangement in TWT

Operation of Travelling Wave Tube

Electrons are emitted from the cathode which is there in the Electron gun. Electrons are focused and accelerated and allowed to move in the tube. TWT is a broad band amplifier. In which interaction between electrons and signal takes place continuously. RF signal which is to be amplified is fed at the slow wave structure (Slow wave structure reduces the velocity of signal) . To keep intact both RF and electrons, signal's velocity is reduced.

Bunches formation takes place. Electrons which passes through zero of the RF signal, no change is velocity occurs. Electrons which passes , when signal at positive potential , velocity of electrons increases. Electron which passes, when signal at negative potential , velocity of electrons decreases. Bunches transfer their energy to RF signal which is to be amplified. Highly Out Put signal is taken from another end.

The output becomes larger than the input and results in amplification.

Applications of Travelling Wave Tube

There are many applications of a travelling wave tube.

- TWT is used in microwave receivers as a low noise RF amplifier.
- TWTs are also used in wide-band communication links and co-axial cables as repeater amplifiers or intermediate amplifiers to amplify low signals.
- TWTs have a long tube life, due to which they are used as power output tubes in communication satellites.
- Continuous wave high power TWTs are used in Troposcatter links, because of large power and large bandwidths, to scatter to large distances.
- TWTs are used in high power pulsed radars and ground based radars.

Magnetron:

Unlike the tubes discussed so far, Magnetrons are the cross-field tubes in which the electric and magnetic fields cross, 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 efficiency. The same technique is followed in Magnetrons.

Types of Magnetrons

There are three main types of Magnetrons.

Negative Resistance Type

- The negative resistance between two anode segments, is used.
- They have low efficiency.
- They are used at low frequencies <500MHz<500MHz.

Cyclotron Frequency Magnetrons

- The synchronism between the electric component and oscillating electrons is considered.
- Useful for frequencies higher than 100MHz.

Travelling Wave or Cavity Type

- The interaction between electrons and rotating EM field is taken into account.
- High peak power oscillations are provided.
- Useful in radar applications.

Cavity Magnetron

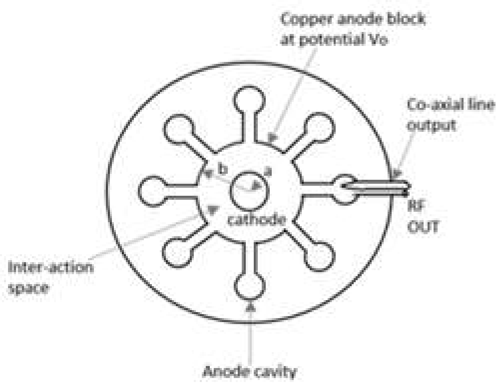
The Magnetron is called as Cavity Magnetron because the anode is made into resonant cavities and a permanent magnet is used to produce a strong magnetic field, where the action of both of these make the device work.

Construction of Cavity Magnetron

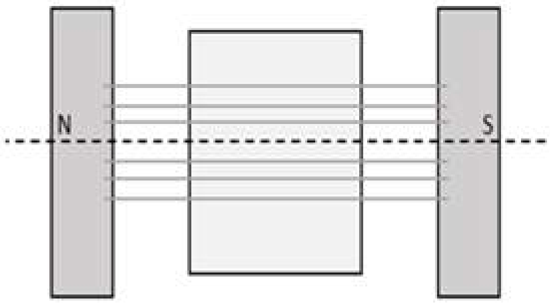
A thick cylindrical cathode is present at the center and a cylindrical block of copper, is fixed axially, which acts as an anode. This anode block is made of a number of slots that acts as resonant anode cavities.

The space present between the anode and cathode is called as **Interaction space**. The electric field is present radially while the magnetic field is present axially in the cavity magnetron. This magnetic field is produced by a permanent magnet, which is placed such that the magnetic lines are parallel to cathode and perpendicular to the electric field present between the anode and the cathode.

The following figures show the constructional details of a cavity magnetron and the magnetic lines of flux present, axially.



Construction details of a Cavity Magnetron



Magnetic flux lines in Magnetron (axial)

This Cavity Magnetron has 8 cavities tightly coupled to each other. An N-cavity magnetron has N modes of operations. These operations depend upon the frequency and the phase of oscillations. The total phase shift around the ring of this cavity resonators should be $2n\pi$where nn is an integer.

If ϕv represents the relative phase change of the AC electric field across adjacent cavities, then

$\phi v = 2\pi n/N$

Where $n = 0, \pm 1, \pm 2, \pm(N/2-1), \pm N/2$

Which means that N2 mode of resonance can exist if N is an even number.

If,

$n = N/2$ then $\phi v = \pi$

This mode of resonance is called as π−mode

$n = 0$ then $\phi v = 0$

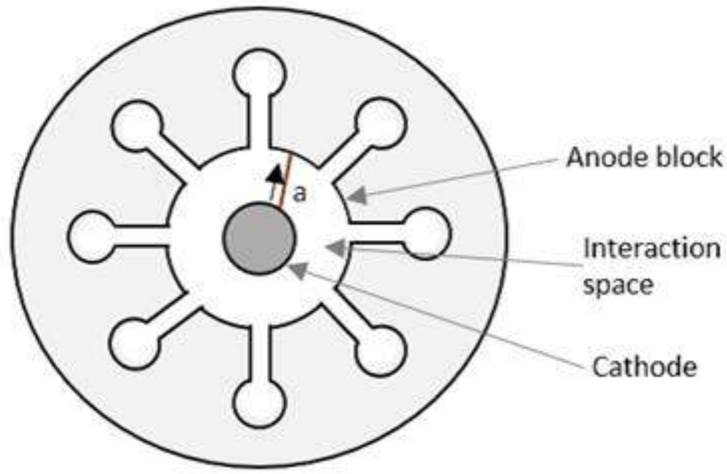
This is called as the **Zero mode**, because there will be no RF electric field between the anode and the cathode. This is also called as **Fringing Field** and this mode is not used in magnetrons.

Operation of Cavity Magnetron

When the Cavity Klystron is under operation, we have different cases to consider. Let us go through them in detail.

Case 1

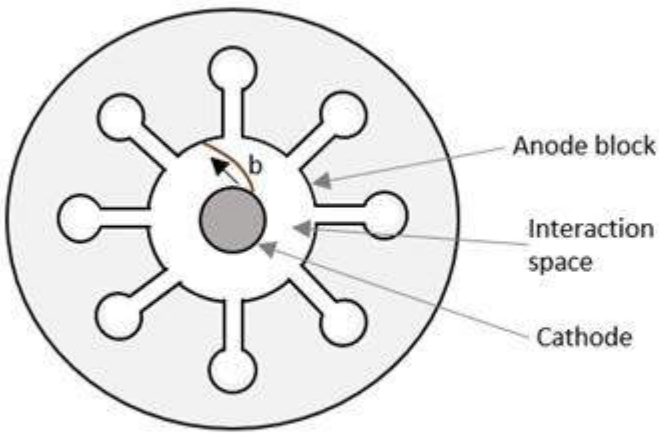
If the magnetic field is absent, i.e. B = 0, then the behavior of electrons can be observed in the following figure. Considering an example, where electron **a** directly goes to anode under radial electric force.



Movement of electron **a**, when no magnetic field is present

Case 2

If there is an increase in the magnetic field, a lateral force acts on the electrons. This can be observed in the following figure, considering electron **b** which takes a curved path, while both forces are acting on it.



Movement of electron **b** when small magnetic field is present

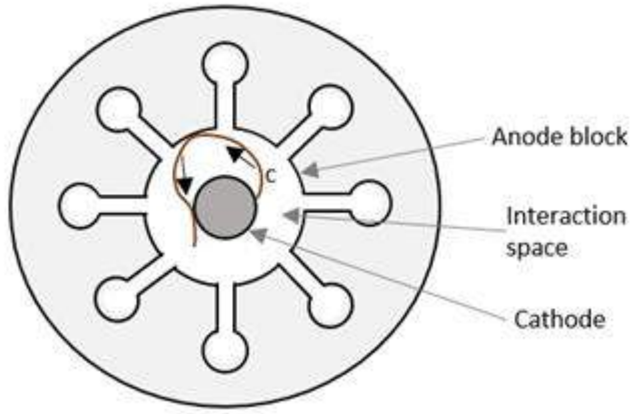
Radius of this path is calculated as

R=mveBR=mveB

It varies proportionally with the velocity of the electron and it is inversely proportional to the magnetic field strength.

Case 3

If the magnetic field **B** is further increased, the electron follows a path such as the electron **c**, just grazing the anode surface and making the anode current zero. This is called as "**Critical magnetic field**" (Bc)(Bc), which is the cut-off magnetic field. Refer the following figure for better understanding.



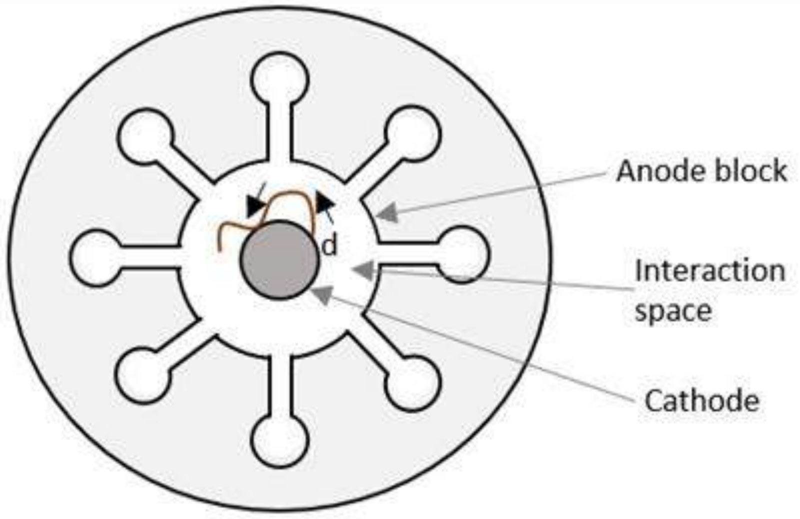
Movement of electron **c** when the magnetic field is critical magnetic field i.e. $B = B_c$

Case 4

If the magnetic field is made greater than the critical field,

B>Bc

Then the electrons follow a path as electron **d**, where the electron jumps back to the cathode, without going to the anode. This causes "**back heating**" of the cathode. Refer the following figure.



Movement of electron **d** when excessive magnetic field is present

This is achieved by cutting off the electric supply once the oscillation begins. If this is continued, the emitting efficiency of the cathode gets affected.

Operation of Cavity Magnetron with Active RF Field

We have discussed so far the operation of cavity magnetron where the RF field is absent in the cavities of the magnetron staticcasestaticcase. Let us now discuss its operation when we have an active RF field.

As in TWT, let us assume that initial RF oscillations are present, due to some noise transient. The oscillations are sustained by the operation of the device. There are three kinds of electrons emitted in this process, whose actions are understood as electrons **a**, **b** and **c**, in three different cases.

Case 1

When oscillations are present, an electron **a**, slows down transferring energy to oscillate. Such electrons that transfer their energy to the oscillations are called as **favored electrons**. These electrons are responsible for **bunching effect**.

Case 2

In this case, another electron, say **b**, takes energy from the oscillations and increases its velocity. As and when this is done,

- It bends more sharply.

- It spends little time in interaction space.
- It returns to the cathode.

These electrons are called as **unfavored electrons**. They don't participate in the bunching effect. Also, these electrons are harmful as they cause "back heating".

Case 3

In this case, electron **c**, which is emitted a little later, moves faster. It tries to catch up with electron **a**. The next emitted electron **d**, tries to step with **a**. As a result, the favored electrons **a**, **c** and **d** form electron bunches or electron clouds. It called as "Phase focusing effect".

This whole process is understood better by taking a look at the following figure.

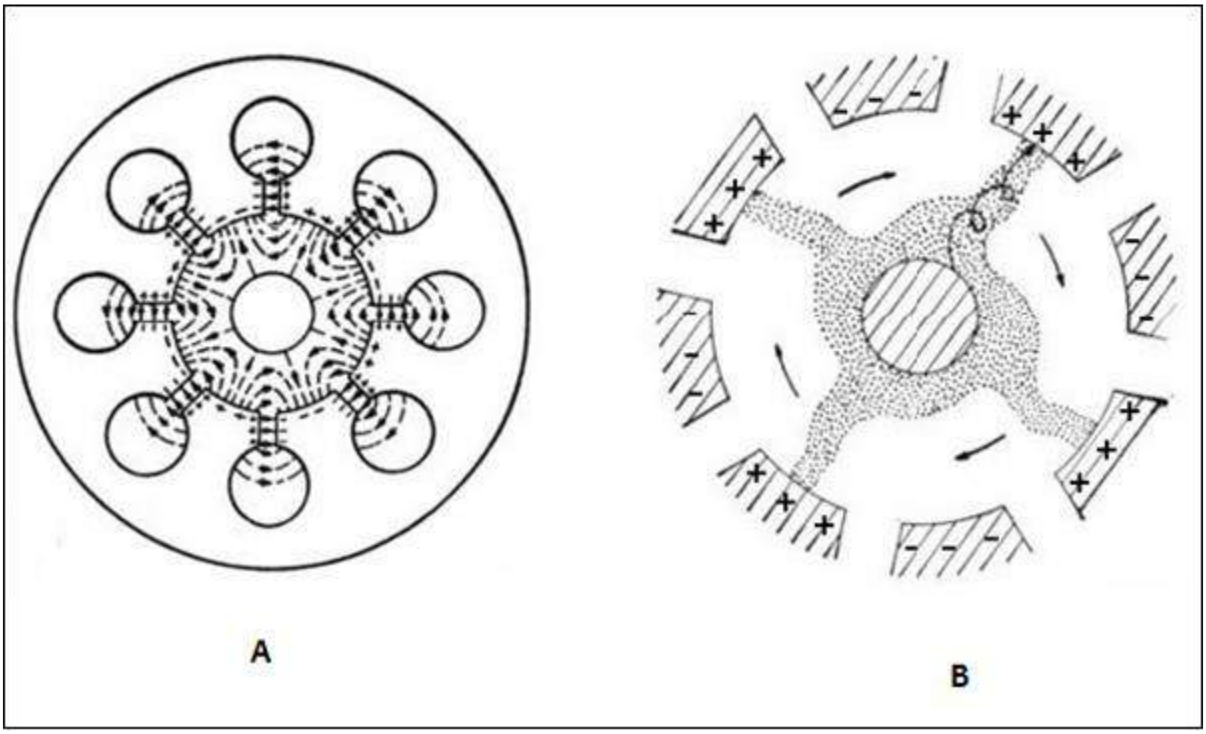


Figure A shows the electron movements in different cases while figure B shows the electron clouds formed. Due to favoured electrons Signal is amplified which is assumed to be there in the cavities. And oscillations are sustained. In this way magnetron act as oscillator.

Unit-3

Waveguide

Generally, if the frequency of a signal or a particular band of signals is high, the bandwidth utilization is high as the signal provides more space for other signals to get accumulated. However, high frequency signals can't travel longer distances without getting attenuated. We have studied that transmission lines help the signals to travel longer distances.

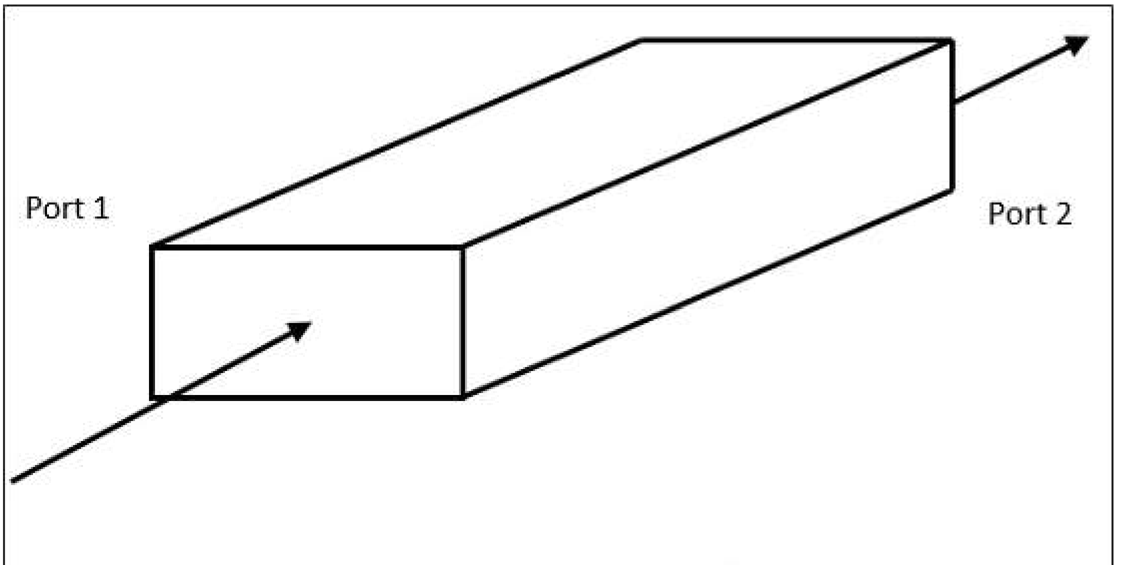
Microwaves propagate through microwave circuits, components and devices, which act as a part of Microwave transmission lines, broadly called as Waveguides.

A hollow metallic tube of uniform cross-section for transmitting electromagnetic waves by successive reflections from the inner walls of the tube is called as a **Waveguide**.

A **waveguide** is a structure that guides waves, such as electromagnetic waves or sound, with minimal loss of energy by restricting the transmission of energy to one direction.

A waveguide is an electromagnetic feed line used in microwave communications

The following figure shows an example of a waveguide.



A two-port rectangular waveguide

A waveguide is generally preferred in microwave communications. Waveguide is a special form of transmission line, which is a hollow metal tube. Unlike a transmission line, a waveguide has no center conductor.

The main characteristics of a Waveguide are −

- The tube wall provides distributed inductance.
- The empty space between the tube walls provide distributed capacitance.
- These are bulky and expensive.

Advantages of Waveguides

Following are few advantages of Waveguides.

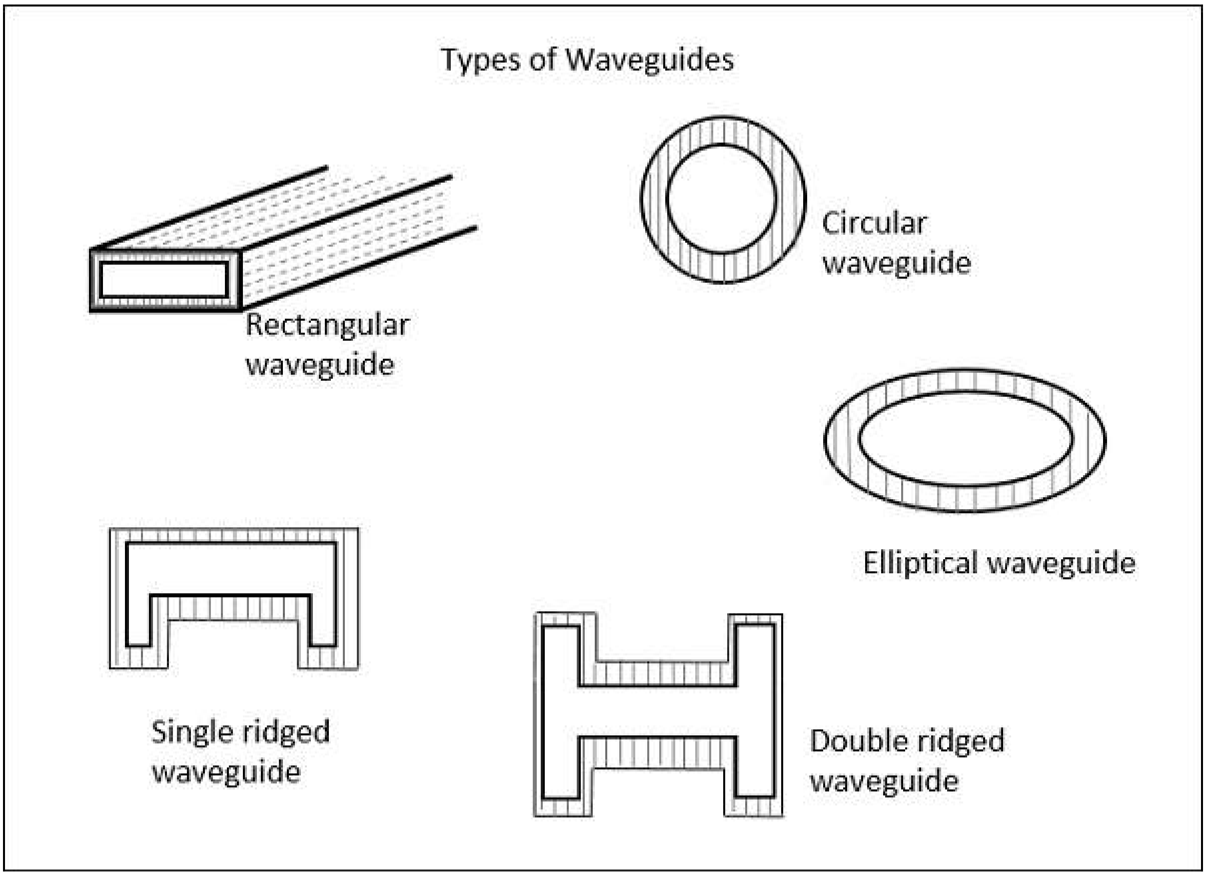
- Waveguides are easy to manufacture.
- They can handle very large power in kilowatts
- Power loss is very negligible in waveguides.
- They offer very low loss low value of alpha−attenuation through waveguide, it experiences lower losses than a coaxial cable.

Types of Waveguides

There are five types of waveguides.

- Rectangular waveguide
- Circular waveguide
- Elliptical waveguide
- Single-ridged waveguide
- Double-ridged waveguide

The following figures show the types of waveguides.



The types of waveguides shown above are hollow in the center and made up of copper walls. These have a thin lining of Au or Ag on the inner surface.

Let us now compare the transmission lines and waveguides.

Transmission Lines Vs Waveguides

The main difference between a transmission line and a wave guide is −

- A **two conductor structure** that can support a TEM wave is a transmission line.
- A **one conductor structure** that can support a TE wave or a TM wave but not a TEM wave is called as a waveguide.

The following table brings out the differences between transmission lines and waveguides.

Transmission Lines	**Waveguides**
Supports TEM wave	Cannot support TEM wave
All frequencies can pass through	Only the frequencies that are greater than cut-off frequency can pass through

Two conductor transmission	One conductor transmission
Reflections are less	A wave travels through reflections from the walls of the waveguide
It has a characteristic impedance	It has wave impedance
Propagation of waves is according to "Circuit theory"	Propagation of waves is according to "Field theory"
It has a return conductor to earth	Return conductor is not required as the body of the waveguide acts as earth
Bandwidth is not limited	Bandwidth is limited
Waves do not disperse	Waves get dispersed

Phase Velocity

Phase Velocity is the rate at which the wave changes its phase in order to undergo a phase shift of 2π radians. It can be understood as the change in velocity of the wave components of a sine wave, when modulated.

$V_p = \omega/\beta$

Group Velocity

Group Velocity can be defined as the rate at which the wave propagates through the waveguide. This can be understood as the rate at which a modulated envelope travels compared to the carrier alone. This modulated wave travels through the waveguide.

The equation of Group Velocity is represented as

$V_g = d\omega/d\beta$

The velocity of modulated envelope is usually slower than the carrier signal.

Relationship between Free space wavelength and cutoff frequency:

$$\lambda_{guide} = \frac{\lambda_{freespave}}{\sqrt{1 - \frac{(\lambda_{freespace})^2}{(\lambda_{cutoff})^2}}}$$

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2}$$

Where λ is free space wavelength

λ_g is guided wavelength

λ_c cutoff wavelength

Cut off frequency: It is the frequency below which signal can not travel through waveguide. Above which signal are passed through waveguide. It is denoted by f_c

Cut of wavelength: It is the wavelength above which signal can not travel through waveguide. Below which signal are passed through waveguide. It is denoted by λ_c

UNIT-4

Microwave Components

Waveguide Components:

1. Bends
2. Circulator
3. Attenuator
4. Directional Coupler
5. Isolator
6. Matched termination
7. TEE
8. Twists
9. Detector Mount
10. Slotted Section
11. Adapter
12. Horn Antenna

BENDS:

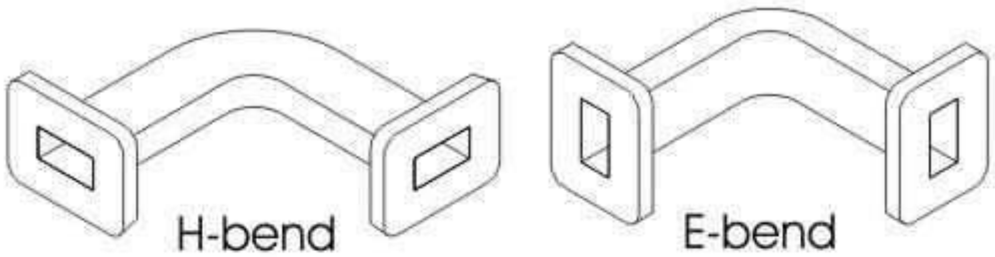
Waveguide bends are used to direct high frequency signals propagating through a waveguide in a specific direction. These bends allow the change in direction of a signal within a waveguide, with minimal loss, reflection and distortion of the electric and magnetic fields.

Unlike coaxial cables which can be bent on demand, waveguide structures are more rigid and require the use of bends to get the signal from one point to another.

Types of Waveguide bends:

Waveguide E bends - An E-bend changes or distorts the E-Field (Electric Field) of the propagating signal. In order to minimize reflections, the radius of the bend should be greater than two wavelengths of the signal.

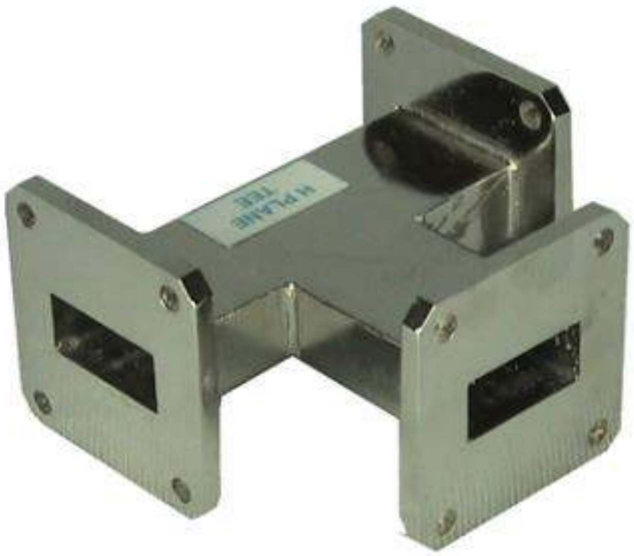
Waveguide H bends - An H-bend changes or distorts the H-Field (Magnetic Field) of the propagating signal. In order to minimize reflections, the radius of the bend should be greater than two wavelengths of the signal.



The bend angle is usually 30 degrees, 45 degrees or 90 degrees, however this can be customized based on the requirement. When selecting the waveguide bend the waveguide size and the flange type need to be selected - these usually vary based on the frequency at which you are planning to use the specific waveguide bend.

Waveguide TEE:

A Waveguide Tee is a 3-port device that can be used to either divide or combine power in a waveguide system. It is formed when three waveguides tubes are connected in the form of the English alphabet 'T'. This is where its name is derived from.

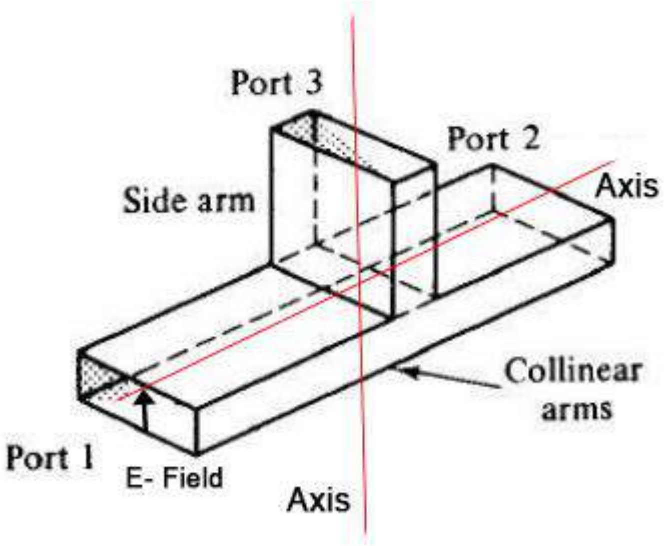


There are two main types of Waveguide Tees:

1. E-Plane Waveguide Tee

A waveguide tee is a 3 port device that is similar to a power divider. When the axis of the side arm is parallel to the Electric Field (E) of the collinear, then the tee is called a E-Plane Tee Junction. The outputs we get in this type of tee are

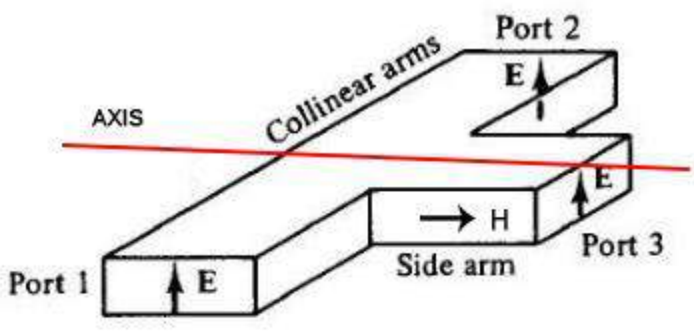
180° out of phase with each other, irrespective of from which port the input is fed.



If the input signal is fed to port 3, then the output will be split across port 1 and 2 and will be 180 degrees out of phase with each other.

2. H-Plane Waveguide Tee

When the axis of the side arm of the waveguide tee is parallel to the flow of the Magnetic Field (H) from port 1 and is perpendicular to the flow of the Electric Field (E), then the tee is called a H-Plane Waveguide Tee.



An H-Plane Waveguide Tees can be thought of as a two way in-phase power divider/combiner i.e it is additive in nature. When two input signals are fed to port 1 & 2, the output at port 3 is in phase and additive and when the input signal is fed to port 3, the signal is split in to two equal parts that are in-phase at port 1 & 2

Directional coupler:

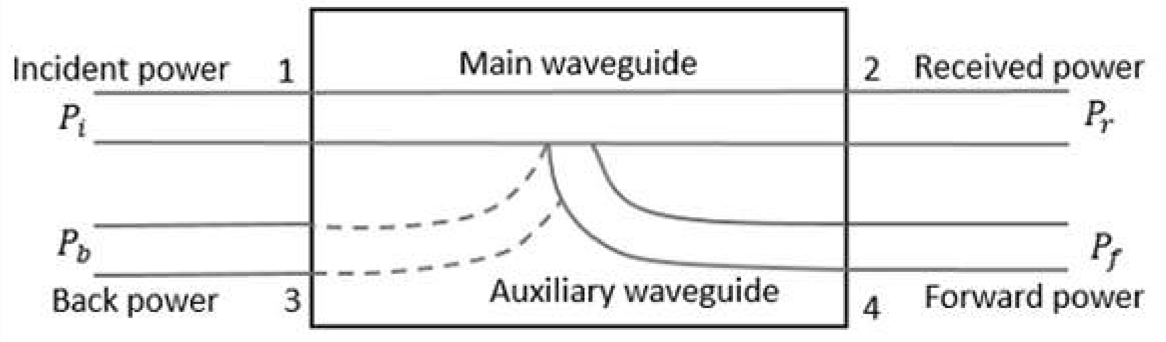
Directional coupler is used to couple the Microwave power which may be unidirectional or bi-directional.

Properties of Directional Couplers

The properties of an ideal directional coupler are as follows.

- All the terminations are matched to the ports.
- When the power travels from Port 1 to Port 2, some portion of it gets coupled to Port 4 but not to Port 3.
- As it is also a bi-directional coupler, when the power travels from Port 2 to Port 1, some portion of it gets coupled to Port 3 but not to Port 4.
- If the power is incident through Port 3, a portion of it is coupled to Port 2, but not to Port 1.
- If the power is incident through Port 4, a portion of it is coupled to Port 1, but not to Port 2.
- Port 1 and 3 are decoupled as are Port 2 and Port 4.

Ideally, the output of Port 3 should be zero. However, practically, a small amount of power called **back power** is observed at Port 3. The following figure indicates the power flow in a directional coupler.



Directional Coupler indicating powers

Where

- Pi = Incident power at Port 1
- Pr = Received power at Port 2
- Pf = Forward coupled power at Port 4
- Pb = Back power at Port 3

Following are the parameters used to define the performance of a directional coupler.

Coupling Factor **CC**

The Coupling factor of a directional coupler is the ratio of incident power to the forward power, measured in dB.

C=10log10 Pi/ Pf

Directivity **DD**

The Directivity of a directional coupler is the ratio of forward power to the back power, measured in dB.

D=10log10 Pf / Pb

Isolation

It defines the directive properties of a directional coupler. It is the ratio of incident power to the back power, measured in dB.

I=10log10 Pi / Pb

Isolation in dB = Coupling factor + Directivity

Attenuator: Attenuators are passive resistive elements that do the opposite of amplifiers, they kill gain. The attenuators are basically passive devices which control power levels in microwave system by absorption of the signal. Attenuator which attenuates the RF signal in a waveguide system is referred as **waveguide attenuator**. There are two main types fixed and variable. They are achieved by insertion of resistive films.

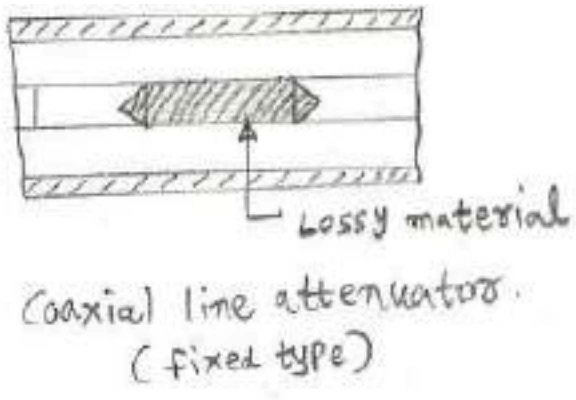


Fig.1 coaxial line attenuator

This figure depicts coaxial line based fixed type of attenuator. Here resistive film is fixed at the centre conductor which absorb the power and as a result of power loss and hence microwave signal gets attenuated. This is referred as coaxial line attenuator.

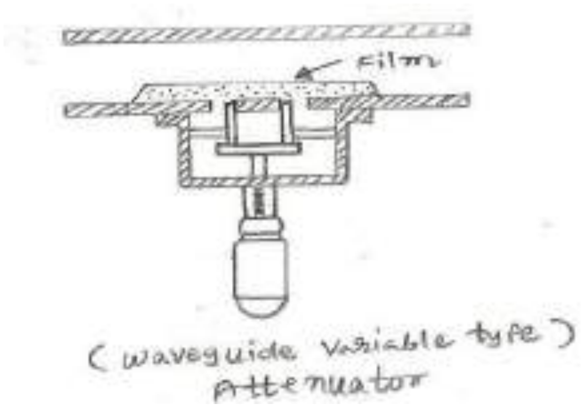


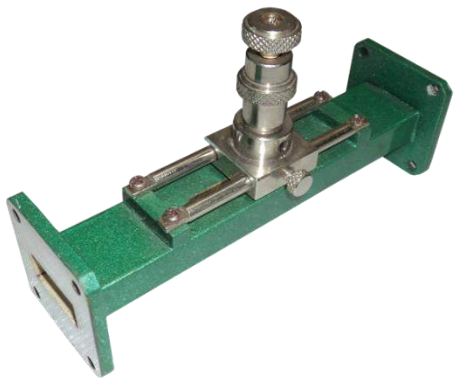
Fig.2 waveguide attenuator

This figure depicts waveguide based fixed type of attenuator. Here thin dielectric strip with coated resistive film is placed at the centre of waveguide. Film is placed in the waveguide parallel to the maximum E field.

In a variable type of waveguide attenuator, resistive vane is moved from one side of the wall to the centre by using screw where E field is considered to be maximum. This resistive film is shaped to give linear attenuation variation.

Detector Mount:

Detector Mount are used detect the low frequency signals with the help of the IN23 detector diode. The Detector Diode is mounted on the broad wall of the waveguide. A shorting plunger is used to tune the max power near the detector diode



Twists:

Twists are made from a section of the standard waveguide, which has been precisely twisted, maintaining the internal dimension of the waveguide. These are used to rotate the plane of polarization of waveguide transmission line.

Slotted Section:

This system consists of a transmission line (Waveguide), a travelling probe carriage and facility for attaching/detecting instruments. The slot made in the center of broad face do not radiate from any power of dominant mode. Slotted section is basically used to measure standing wave ratio (VSWR). The precession built probe carriage having centimeters scale with a vernier reading of 0.1mm least count is used to measure the position of the probe. Additionally slotted section can be used to measure impedance, reflection coefficient and the return loss.

Matched Termination:

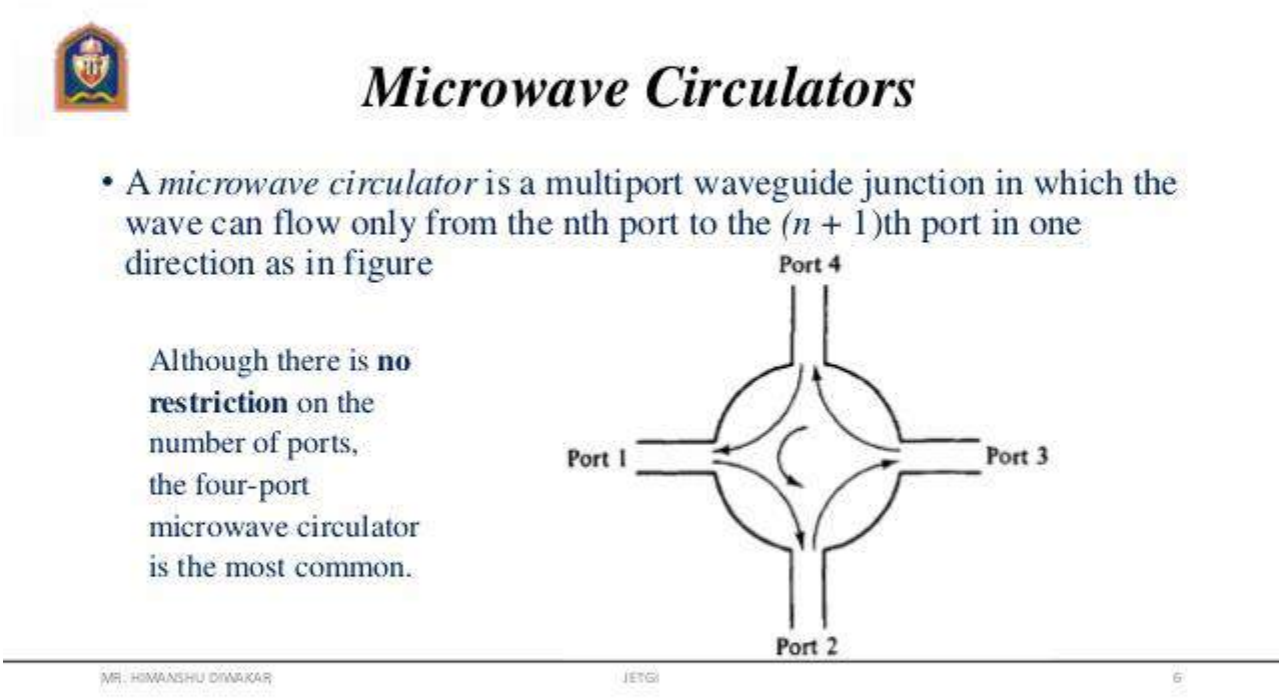
In making measurement of waveguide component it is often desirable to absorb the power propagated down the waveguide. These are designed in such a way to absorb the maximum energy without having appreciable reflection assuring low VSWR.

Circulator:

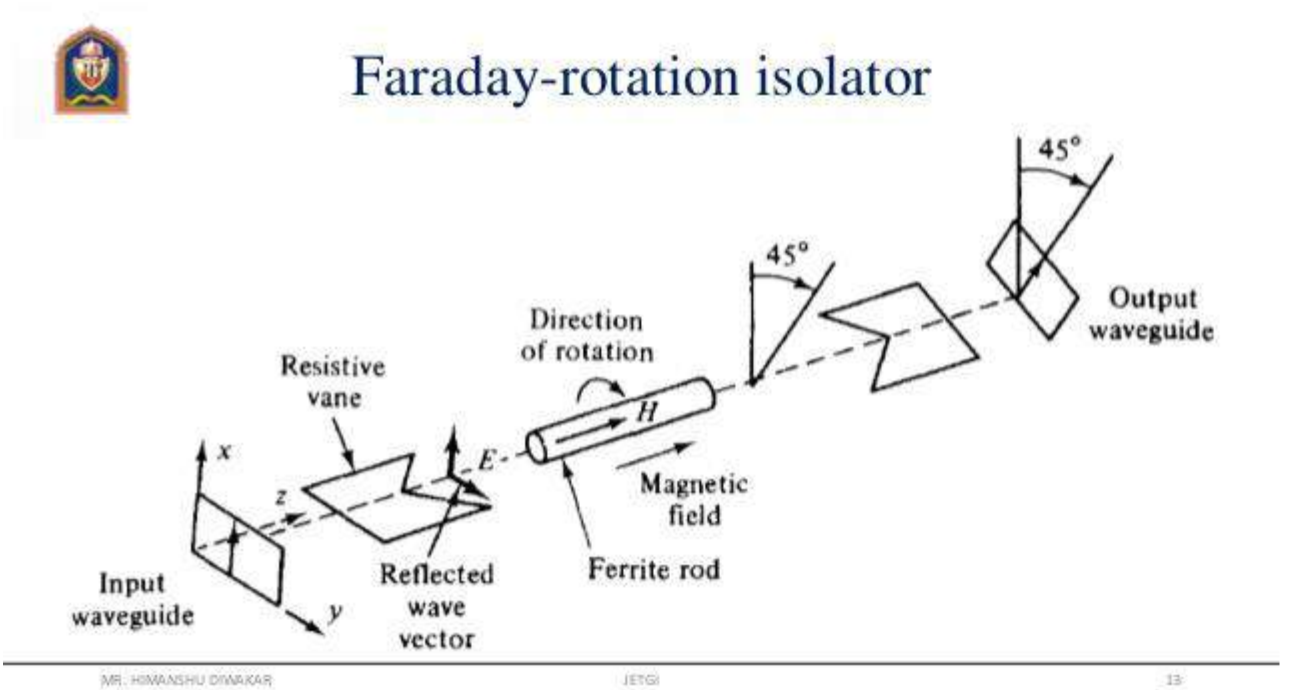
Circulator is a device in which microwave or radio frequency signals entering any port are passed on to the next port in rotation only.
A port in this context is the point where external waveguide or transmission line is connected to the device. Microwave circulator is a multi-port device in which

power is circulated from nth port to (n+1)th port only in One Direction. A 4 port circulator is most commonly used.

The following figure shows a 4 port circulator schematic. Circulator is not reciprocal component. All the 4 ports are matched and transmission of power takes place in a cyclic order only. An ideal circulator it is perfectly lossless.



Isolator:



Microwave Isolators

- An *isolator* is a nonreciprocal transmission device that is used to isolate one component from reflections of other components in the transmission line.
- An ideal isolator completely absorbs the power for propagation in one direction and provides lossless transmission in the opposite direction.
- Thus the isolator is usually called *uniline*.

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An isolator is a non-reciprocal device, with a non-symmetric scattering matrix. An ideal isolator transmits all the power entering port 1 to port 2, while absorbing all the power entering port 2

Cont'd

- Isolators can be made by inserting a ferrite rod along the axis of a rectangular waveguide as shown in above Figure.
- The input resistive card is in the *y-z* plane, and the output resistive card is displaced 45° with respect to the input card. The dc magnetic field, which is applied longitudinally to the ferrite rod, rotates the wave plane of polarization by 45°.
- The degrees of rotation depend on the length and diameter of the rod and on the applied dc magnetic field.
- An input TE10 dominant mode is incident to the left end of the isolator. Since the TE10 mode wave is perpendicular to the input resistive card, the wave passes through the ferrite rod without attenuation.

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Cont'd

- The wave in the ferrite rod section is rotated clockwise by 45° and is normal to the output resistive card. As a result of rotation, the wave arrives at the output end without attenuation at all.
- On the contrary, a reflected wave from the output end is similarly rotated clockwise 45° by the ferrite rod.
- However, since the reflected wave is parallel to the input resistive card, the wave is thereby absorbed by the input card.
- The typical performance of these isolators is about 1-dB insertion loss in forward transmission and about 20- to 30-dB isolation in reverse attenuation.

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Horn Antenna:

To improve the radiation efficiency and directivity of the beam, the wave guide should be provided with an extended aperture to make the abrupt discontinuity of the wave into a gradual transformation. So that all the energy in the forward direction gets radiated. This can be termed as **Flaring**. Now, this can be done using a horn antenna.

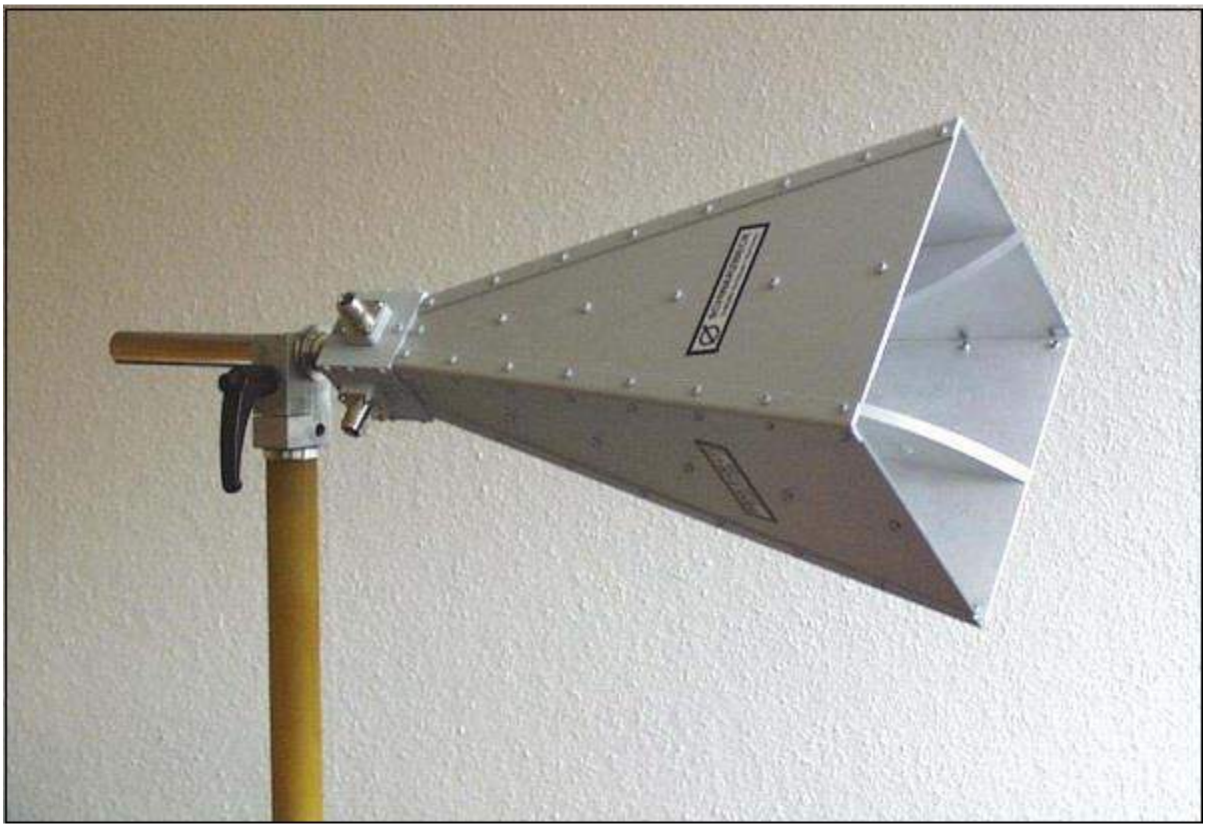
Frequency Range

The operational frequency range of a horn antenna is around **300MHz to 30GHz**. This antenna works in **UHF** and **SHF** frequency ranges.

A **horn antenna** or **microwave horn** is an antenna that consists of a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies, above 300 MHz.. They are used as feed antennas (called feed horns) for larger antenna structures such as parabolic antennas,

Construction & Working of Horn Antenna

The energy of the beam when slowly transform into radiation, the losses are reduced and the focussing of the beam improves. A **Horn antenna** may be considered as a **flared out wave guide**, by which the directivity is improved and the diffraction is reduced.



The above image shows the model of a horn antenna. The flaring of the horn is clearly shown. There are several horn configurations out of which, three configurations are most commonly used.

Sectoral horn

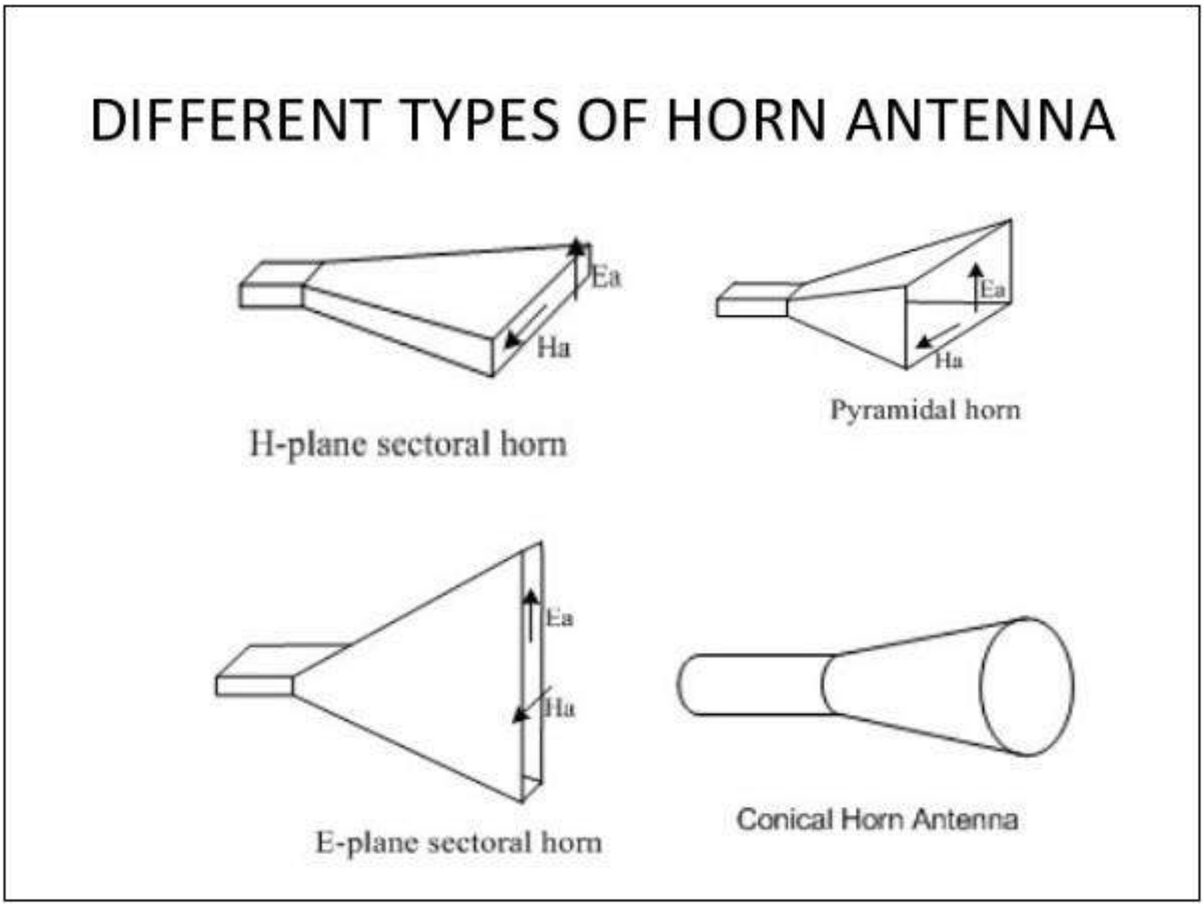
This type of horn antenna, flares out in only one direction. Flaring in the direction of Electric vector produces the **sectorial E-plane horn**. Similarly, flaring in the direction of Magnetic vector, produces the **sectorial H-plane horn**.

Pyramidal horn

This type of horn antenna has flaring on both sides. If flaring is done on both the E & H walls of a rectangular waveguide, then **pyramidal horn antenna** is produced. This antenna has the shape of a truncated pyramid.

Conical horn

When the walls of a circular wave guide are flared, it is known as a **conical horn**. This is a logical termination of a circular wave guide.



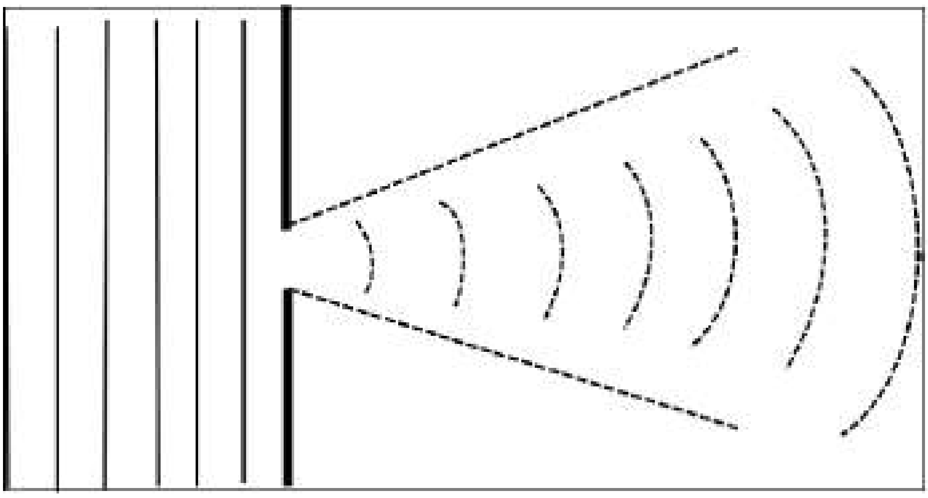
The above figures show the types of horn configurations, which were discussed earlier.

Flaring helps to match the antenna impedance with the free space impedance for better radiation. It avoids standing wave ratio and provides greater directivity and narrower beam width. The flared wave guide can be technically termed as **Electromagnetic Horn Radiator**.

Flare angle, **Φ** of the horn antenna is an important factor to be considered. If this is too small, then the resulting wave will be spherical instead of plane and the radiated beam will not be directive. Hence, the flare angle should have an optimum value and is closely related to its length.

Radiation Pattern

The radiation pattern of a horn antenna is a Spherical Wave front. The following figure shows the **radiation pattern** of horn antenna. The wave radiates from the aperture, minimizing the diffraction of waves. The flaring keeps the beam focussed. The radiated beam has high directivity.



Advantages

The following are the advantages of Horn antenna −

- Small minor lobes are formed
- Impedance matching is good
- Greater directivity
- Narrower beam width
- Standing waves are avoided

Disadvantages

The following are the disadvantages of Horn antenna −

- Designing of flare angle, decides the directivity
- Flare angle and length of the flare should not be very small

Applications

The following are the applications of Horn antenna −

- Used for astronomical studies
- Used in microwave applications

UNIT-5

Microwave Communication System

Microwave transmission is the transmission of information by microwave radio waves.

In the electromagnetic spectrum, waves within the frequencies 1GHz to 300GHz are called microwaves.

Features of Microwaves

- Microwaves travel in straight lines, and so the transmitter and receiver stations should be accurately aligned to each other.
- Microwave propagation is line – of – sight propagation. So, towers hoisting the stations should be placed so that the curvature of the earth or any other obstacle does not interfere with the communication.
- Since it is unidirectional, it allows multiple receivers in a row to receive the signals without interference.
- Microwaves do not pass through buildings. So, indoor receivers cannot be used effectively.
- Microwaves are often refracted by the atmospheric layers. The refracted rays take longer time to reach the destination than the direct rays. This causes out of phase transmission, called multipath fading.
- Microwaves need unidirectional antennas to send out signals. Two types of antennas are needed −
  - **Parabolic Dish Antenna** − It is used by the receiving station. It is parabolic in shape, which concentrates all energy to a small beam thus achieving a strong signal with high SNR.
  - **Horn Antenna** − It has a stem with a curved head. In sending stations, outgoing waves from the stem are broadcast by the curved head as a series of parallel beams. In the receiving station, the rays are collected by the curved head and deflected in the stem.

Applications

- Long distance telephone communication
- Cellular phones
- Television networks

- Satellites
- Wireless LANs

The basic function of a microwave link is same as that of copper or fiber optic link. Both provide the means of communication system. Co-axial cables and fiber optical cables carry voltage and light signals through them whereas a microwave radio communication system uses electromagnetic waves in microwave range to establish the communication.

Microwave communication system deals with a study of the signal path between the transmitter and receiver.

The signal path depends on the atmosphere medium under microwave communication and signal strength depends upon atmosphere condition, frequency of operation and type of propagation.

Basic Microwave Communication Link:

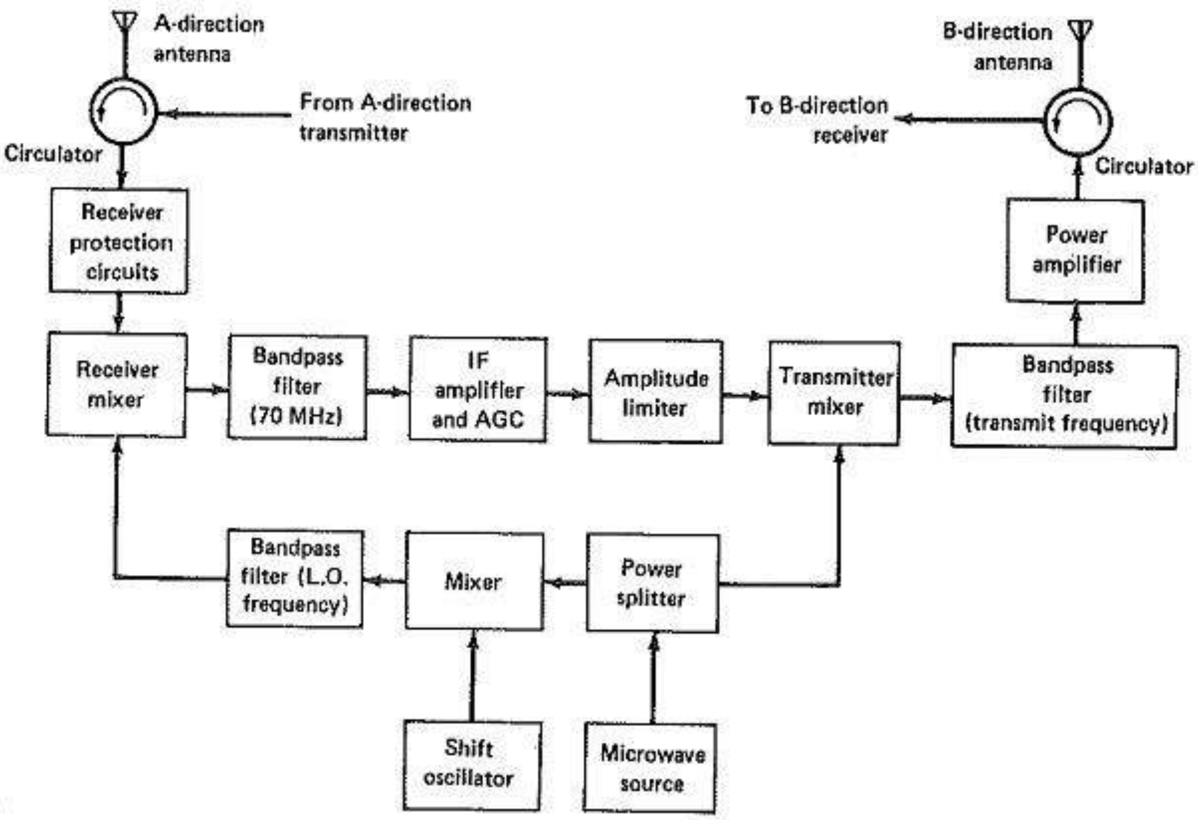


FIGURE 15-5 Simplified block diagram of microwave link carrier chain, shown receiving from A direction and transmitting in B direction.

Microwave communication link provide the means for the communication system. It uses microwave range to establish the communication range.

The basic blocks are explained below:

Antenna**:** mostly parabolic reflector types of antennas are used. Hog horn type of antennas are used in high density links.

Circulator: A circulator is used to isolate transmitter with the receiver input and to couple transmitter to antenna and antenna to receiver input.

Protection circuitry: it provides safety to the mixer from overloads

Mixer (Receiver): it has two out puts. One is the incoming signal and the other is signal from lower band pass filter. This signal has a frequency which is 70 MHz higher than that of incoming signal. So, mixer gives an IF signal of 70MHz. a Schottky barrier diode is used in the receiver mixer.

Band Pass Filter: it provides the necessary selectivity to the receiver.

IF Amplifier and AGC: it is responsible for the amplification of the signal. It has many stages and its gain through AGC. It hasto be linear broad band and low noise amplifier.

Amplitude limiter: As the signal is frequency modulated one so an amplitude limiter is used to avoid unwanted amplitude variations.

Mixer (Transmitter): It is used to convert IF frequency to transmitting microwave frequency. Generally, varactor diode are employed in this mixer.

Power Amplifier: Transmitted power from a repeater station can be in the the range of .25 W to 10 When the required transmitted power (depending on the distance repeater) is in the range of 1 to 5 and frequency below 6 GHz, FET power amplifiers are generally used. When the power is above 5 W and frequencies above 6 GHz,TWT are used for amplification.

Microwave source: Earlier klystron and gunn oscillators were used as source of microwave frequencies. Now, VHF transistor crystal oscillators has taken their place which is used with a varactor multiplier.

Power Splitter: It divides the output power from a microwave source and feeds a large portion to the transmitter mixer which converts it to transmitting microwave frequency.The second portion is fed to the balanced mixer.

Shift Oscillator: It provides one of the input to the balanced in such a way that output frequency from the balanced mixer is such that it produces 70 MHz IF at the output of receiver mixer.

A microwave link generally incorporates 600-2700channels per carrier. And number of carriers in each direction can be 4 to 12.

The most common example of microwave repeater station is tower erected by mobile companies which have approximate height of 25 meters.These are located in remote areas so as to have their own uninterruptible power supplies backed by batteries.

TROPOSPHERE:

The **troposphere** is the lowest layer of Earth's atmosphere, and is also where nearly all weather conditions take place. The lowest region of the atmosphere, extending from the earth's surface to a height of about 6–10 km.

Properties of Troposphere:

- Most of the mass (about 75-80%) of the atmosphere is in the troposphere. Most types of clouds are found in the troposphere.
- Almost all weather occurs within this layer.
- The troposphere is by far the wettest layer of the atmosphere; all of the layers above contain very little moisture.

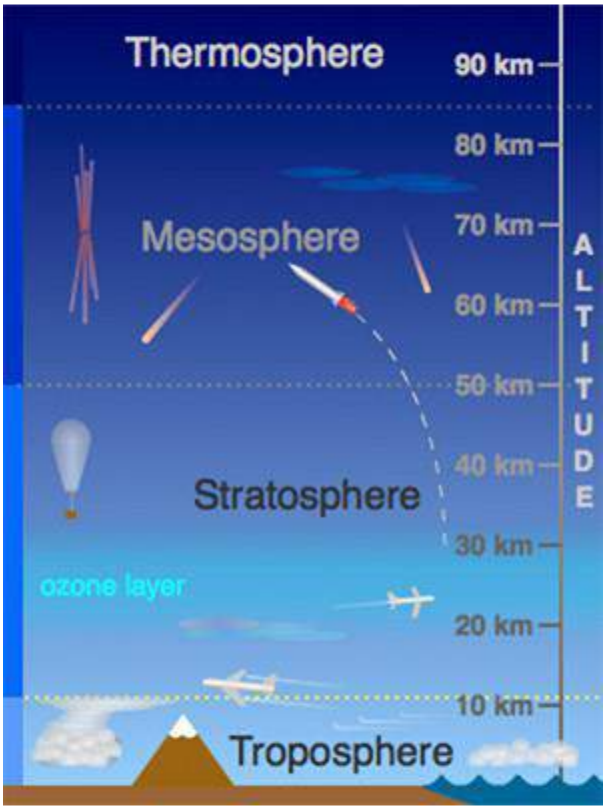
The bottom of the troposphere is at Earth's surface. The troposphere extends upward to about 10 km (6.2 miles or about 33,000 feet) above sea level. The height of the top of the troposphere varies with latitude (it is lowest over the poles and highest at the equator) and by season (it is lower in winter and higher in summer).

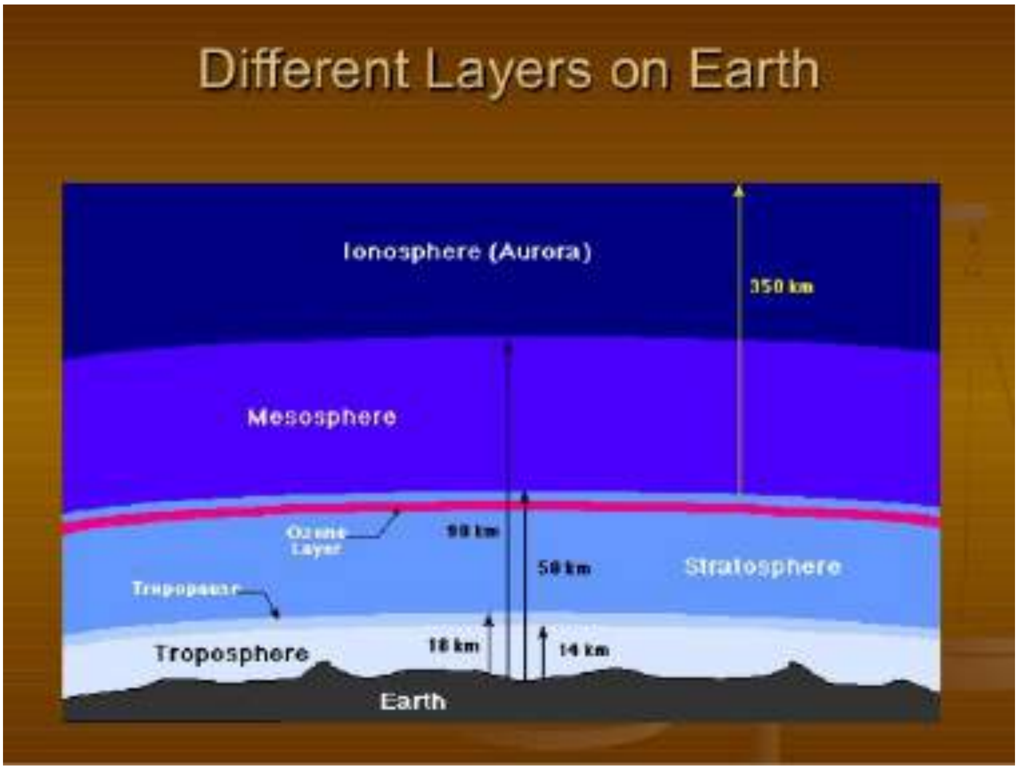
- It can be as high as 20 km (12 miles or 65,000 feet) near the equator, and as low as 7 km (4 miles or 23,000 feet) over the poles in winter.

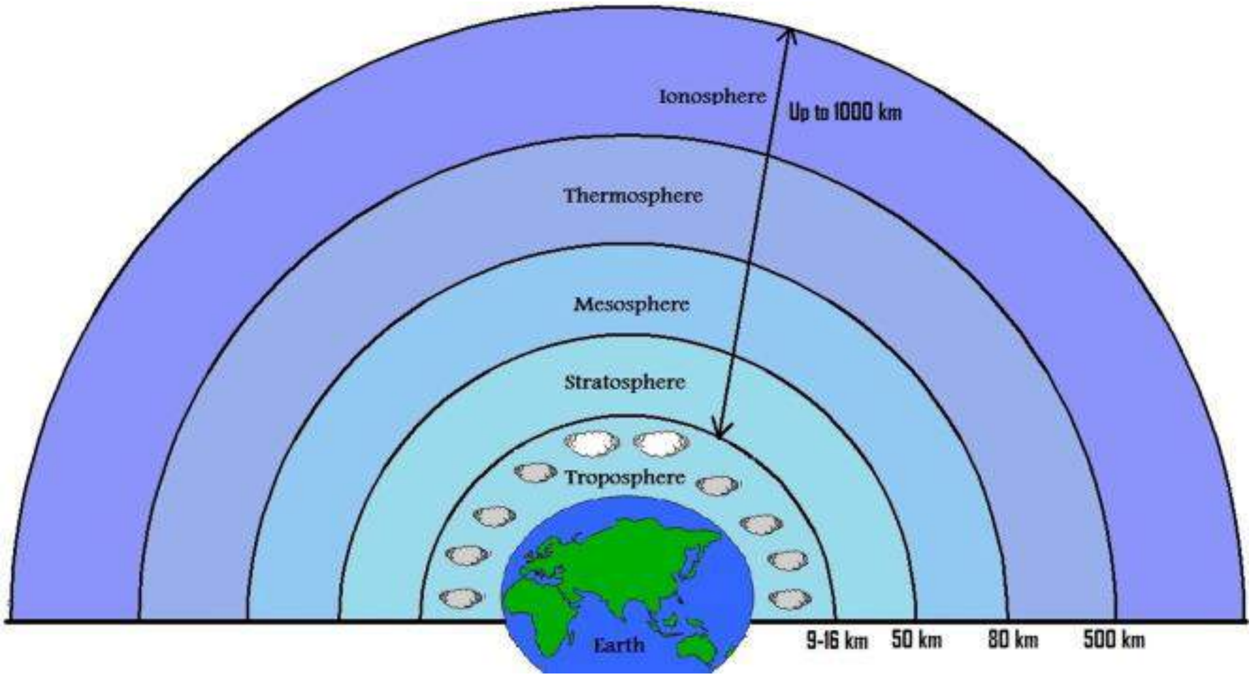
- Air is warmest at the bottom of the troposphere near ground level. Air gets colder as one rises through the troposphere. That's why the peaks of tall mountains can be snow-covered even in the summertime.

- Air pressure and the density of the air also decrease with altitude. That's why the cabins of high-flying jet aircraft are pressurized.

- The layer immediately above the troposphere is called the stratosphere. The boundary between the troposphere and the stratosphere is called the "tropopause".

- 





Troposcatter Communications :

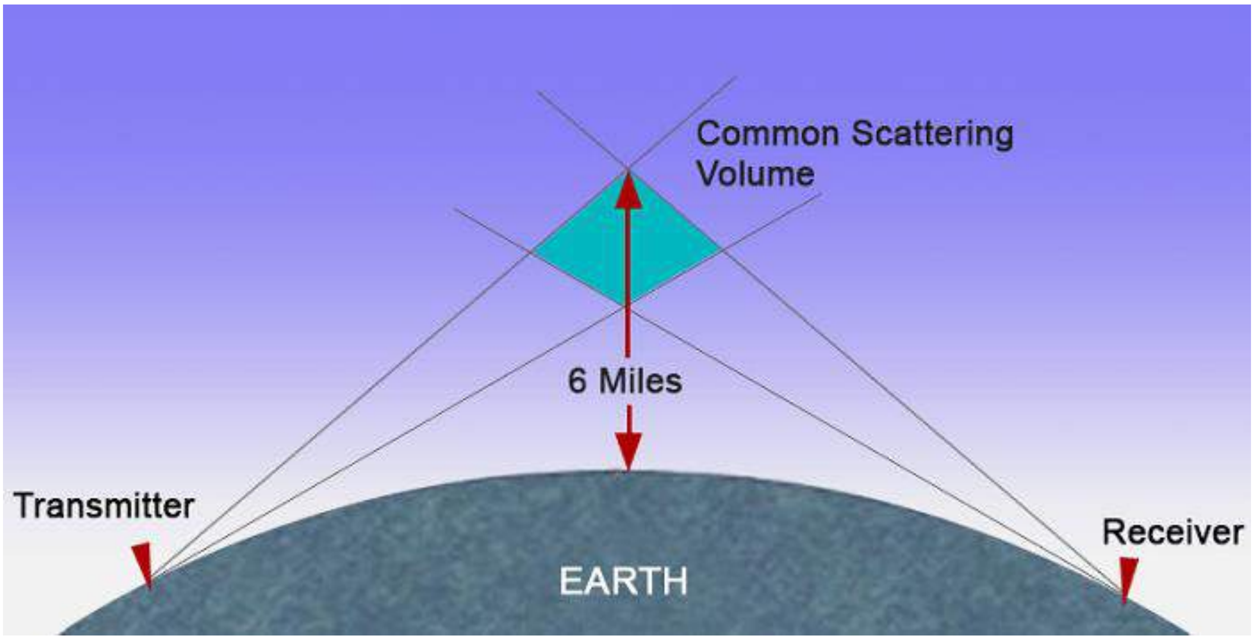
As the name implies, troposcatter uses the troposphere as the region that affects the radio signals being transmitted, returning them to Earth so that they can be received by the distant receiver. Troposcatter relies on the fact that there are areas of slightly different dielectric constant in the atmosphere at an altitude of between 2 and 5 kilometres.

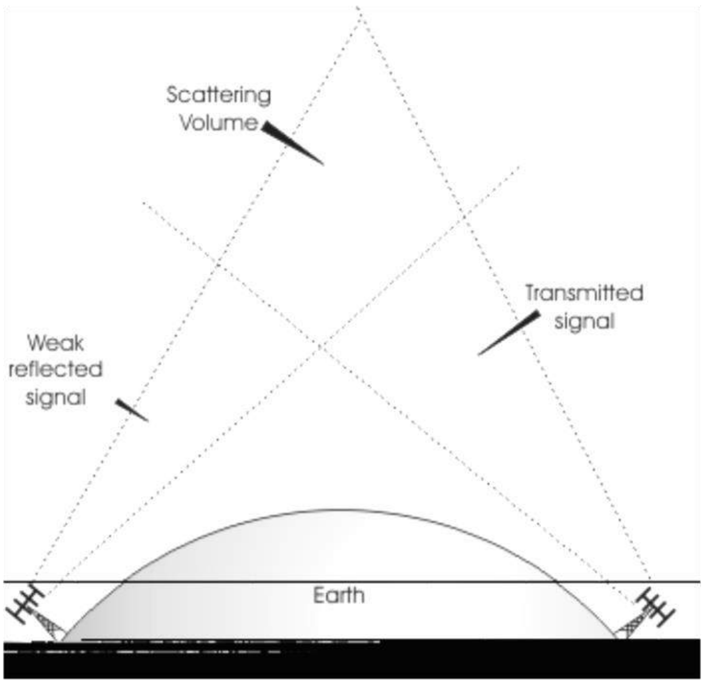
Troposcatter is most pronounced at UHF and microwave radio frequencies (300 MHz and above). Mostly Troposcatter Communication occurs at frequencies of .3-10 GHz. A transmitter launches a high power signal, most of which passes through the atmosphere into outer space. The area within which the scattering takes place is called the scatter volume, and its size is dependent upon the gain of the antennas

Troposcatter Communications are used for beyond line of sight (over the horizon) point to point communications between remote geographic areas where cable links are not feasible.

A troposcatter system has an antenna at both ends, capable of both transmitting and receiving signals, aimed at a fixed point in the troposphere slightly above the horizon. The common region where the antenna beams intersect is the area where the forward scattering phenomenon takes place.

In troposcatter propagation, when a signal is aimed towards the troposphere, some part of the radio signal is scattered back to the Earth due to forward scattering in the troposphere. This returning signal is received by a receiver at the other end. But in troposcatter propagation, only a small portion of the signal is scattered forward and reaches the receiver, a major part of the signal is either lost in space or reflects in other directions.





The principle of troposcatter radio communications

The first two layers of the atmosphere

- **Troposphere** = bottommost layer
  - Air for breathing, weather
  - Temperature declines with altitude
  - **Tropopause** = limits mixing between troposphere and the layer above it
- **Stratosphere** = 11-50 km (7-31 mi) above sea level
  - Drier and less dense, with little vertical mixing
  - Colder in its lower regions
  - Contains UV radiation-blocking ozone, 17-30 km (10-19 mi) above sea level

APPLICATIONS:

- Troposcatter is often used for commercial radio communications applications, normally on frequencies above 500 MHz for over the horizon links.
- It is ideal for remote telemetry, or other links where low to medium rate data needs to be carried.
- Troposcatter provides a means of communication that is much cheaper than using satellites.
- Troposcatter requires high power transmitters, sensitive receivers and high gain antennas, it provides a very convenient data transmission system for many radio communications applications
- It is used in various communication systems like
    - A line of sight communication and satellite communication
    - Radar communication
    - Microwave linking

Space wave propagation limitations

- These waves are affected by the curvature of the earth.
- The propagation of these waves happens along the line of sight distance which is defined as the distance between the transmitting antenna and the receiving antenna which is also known as the range of communication.

Tropospheric Scatter Propagation

The technique is of practical importance at VHF, UHF and Microwaves.

The UHF and Microwave Signals are found to be propagated much beyond to the Line of Sight Propagation through the forward scattering in the tropospheric irregularities.

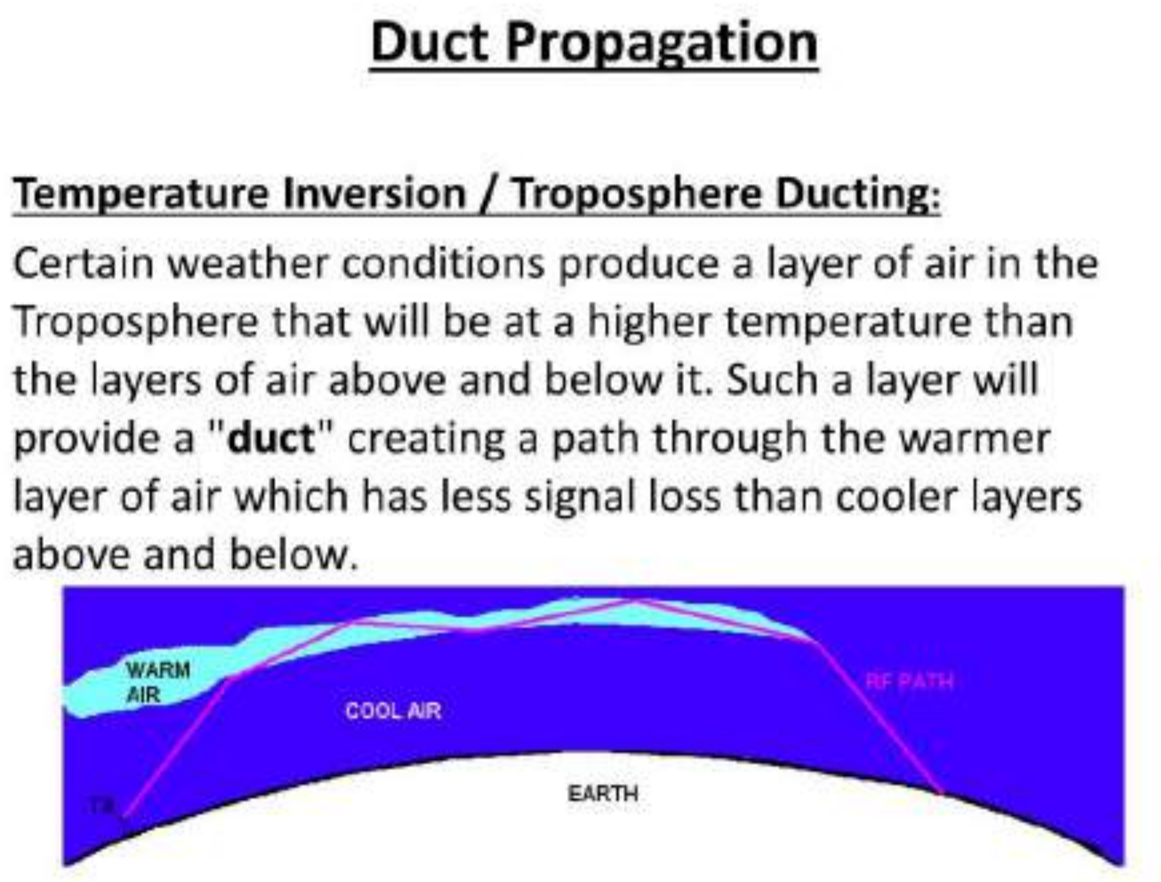
The Mode of Propagation which uses properties of scattering in Troposphere is known as Tropospheric Scatter Propagation.

Here comes a term, the method for improving the reliability of troposcatter links is known as Diversity Operations.

DUCT PROPAGATION:

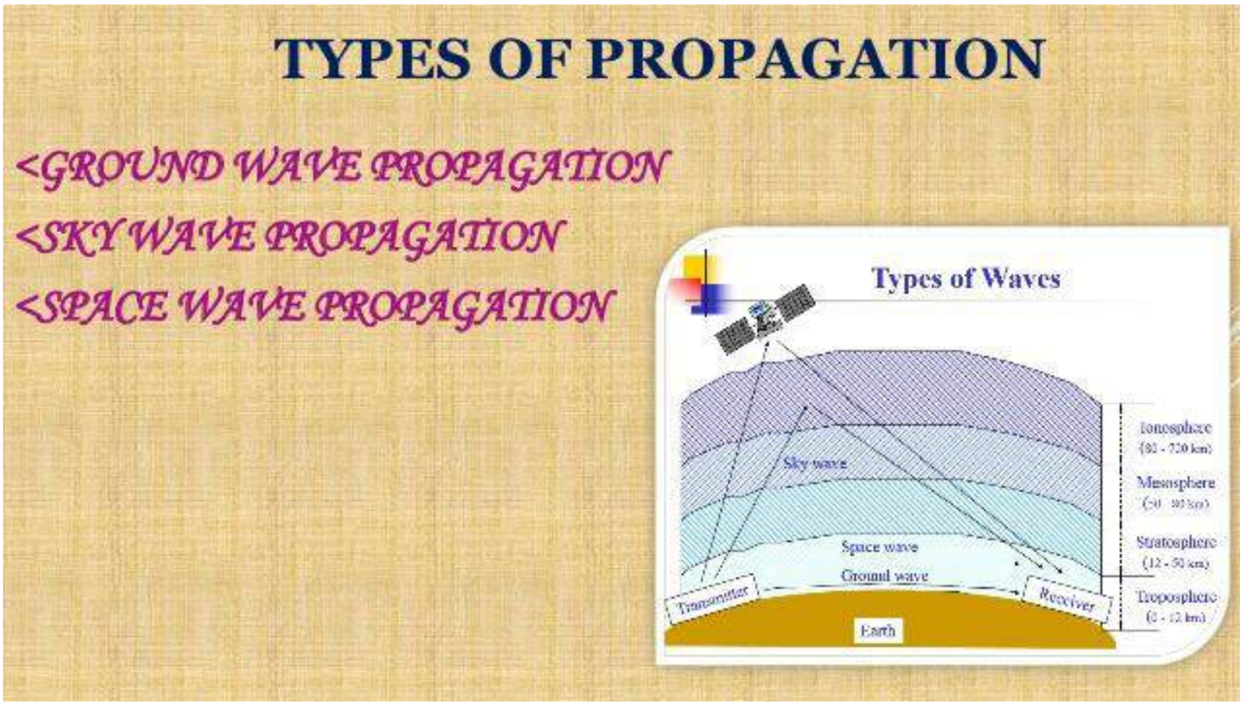
A layer of troposphere bounded above and below by layers that have different refractive index, whichconfines and propagates an abnormally high proportion of VHF (very high frequency) and UHF (ultrahigh frequency) radiation. This results in freak long-distance communications and radar pickup ranges.

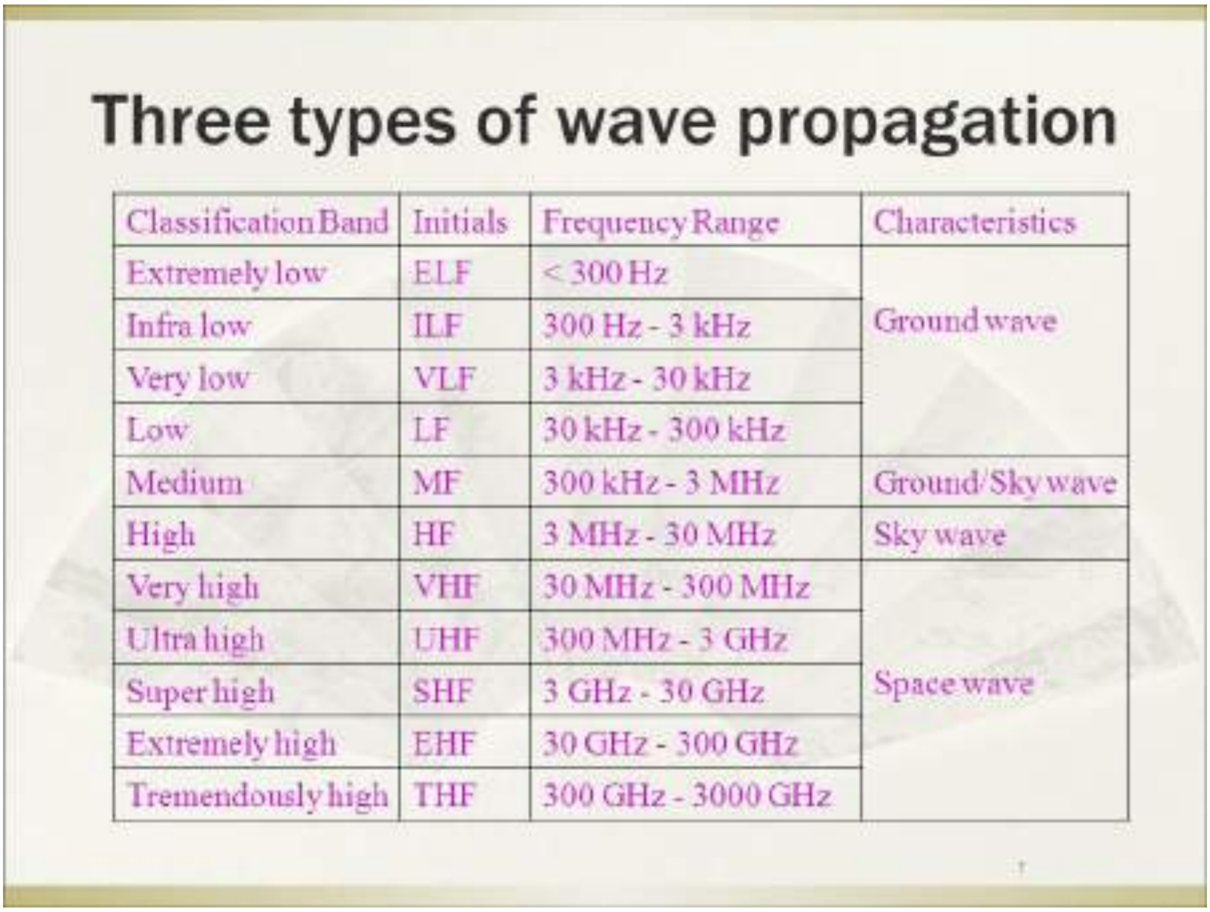
This is normally caused by an inversion layer. The thickness of such a layer is seldom more than 100 m (300 ft). Layers caused by temperature inversions form ducts that can carry signals much farther than typical line if sight communications



The increase of temperature with height, rather than the decrease in the temperature is known as the phenomenon of temperature inversion.

TYPES OF PROPAGATION:





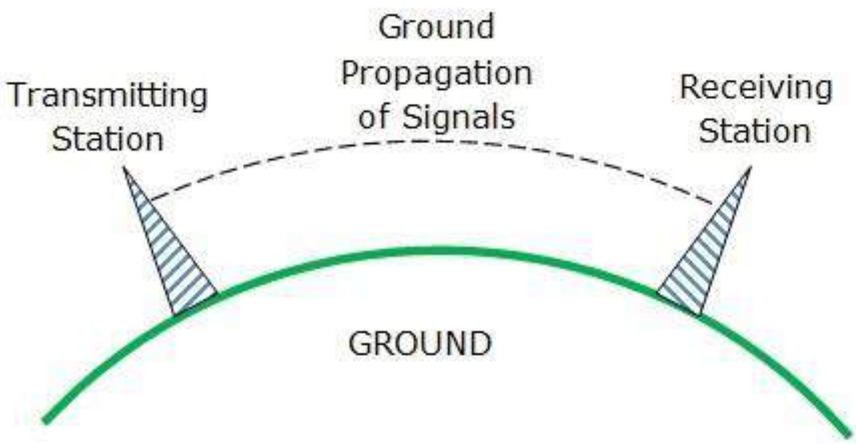
Three types of wave propagation

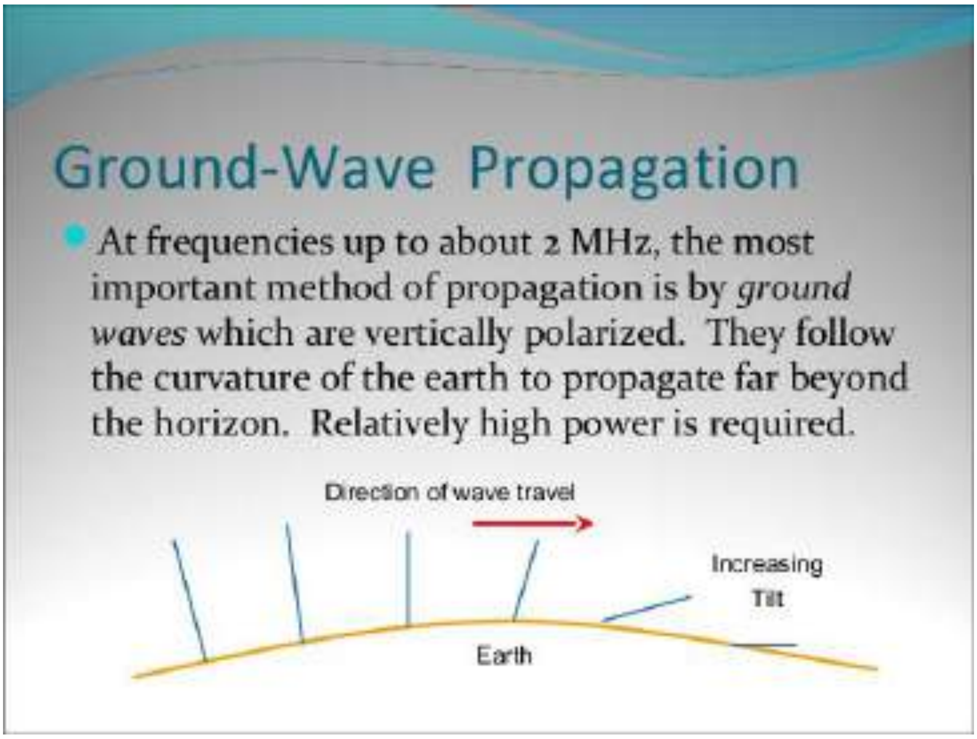
Classification Band	Initials	Frequency Range	Characteristics
Extremely low	ELF	< 300 Hz	Ground wave
Infra low	ILF	300 Hz - 3 kHz	
Very low	VLF	3 kHz - 30 kHz	
Low	LF	30 kHz - 300 kHz	
Medium	MF	300 kHz - 3 MHz	Ground/Sky wave
High	HF	3 MHz - 30 MHz	Sky wave
Very high	VHF	30 MHz - 300 MHz	Space wave
Ultra high	UHF	300 MHz - 3 GHz	
Super high	SHF	3 GHz - 30 GHz	
Extremely high	EHF	30 GHz - 300 GHz	
Tremendously high	THF	300 GHz - 3000 GHz	

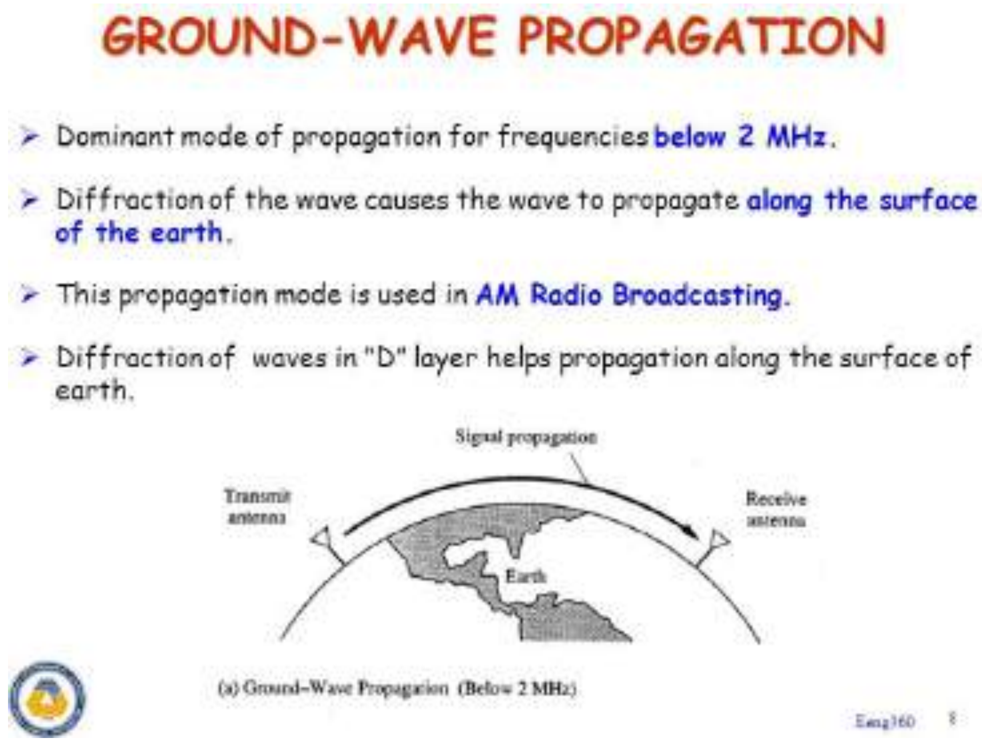
Ground Propagation:

It is a method of propagation, in which radio waves travel through the lowest layers of the atmosphere along the earth's surface, following the earth's curvature. The frequency of these signals is low (≤ 2MHz), and the distance they travel is directly proportional to the power in signal.

- **A ground wave is an electromagnetic wave that travels along the surface of earth. Therefore, ground wave is sometimes called surface waves. Ground waves must be vertically polarized.**

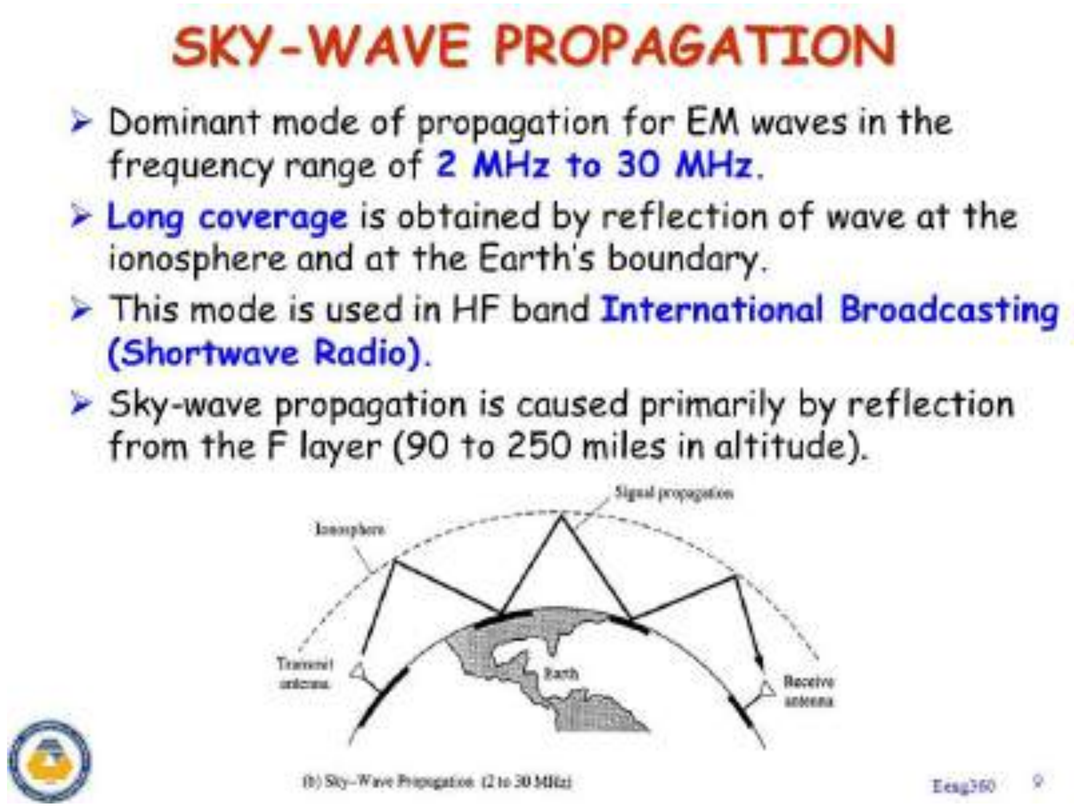






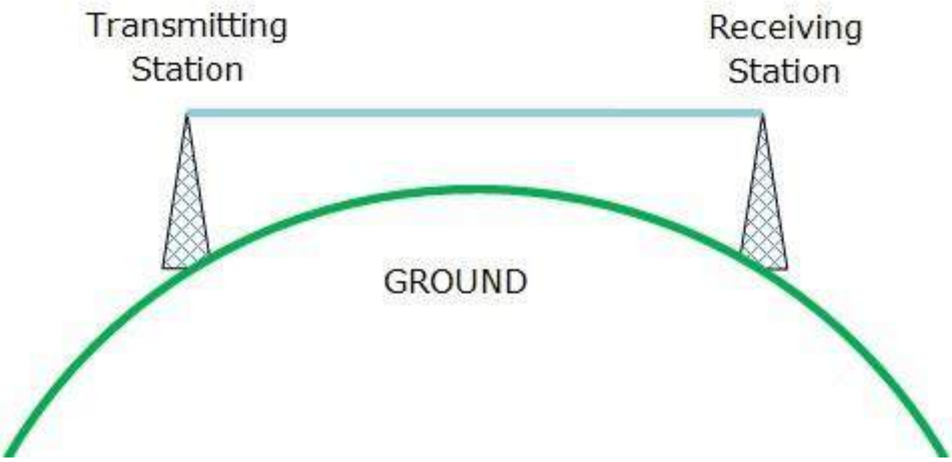
Sky Wave Propagation: In sky propagation, high frequency radio waves (2–30 MHz) are reflected back from the ionosphere towards the earth's surface. They can be used to transmit signals over a large geographical area since their distance is not bounded by the earth's curvature

Sky wave are Electromagnetic waves that propagate above the horizon level



Line – of – Sight Propagation(Space Wave Propagation)

In line – of – sight propagation, very high frequency waves (> 30 MHz) travel at straight lines from the source antenna (transmitter) to the destination antenna (receiver). These waves are easily disrupted by present of objects in their path. So the antennas are placed tall enough above obstructions. They are unidirectional facing each other.

- 

Space wave propagation of electromagnetic energy includes radiated energy that travels in the lower few miles of earth 'atmosphere. Space wave includes both direct and grounded reflected waves. Space wave propagation with direct waves is commonly called Line of Sight Transmission.

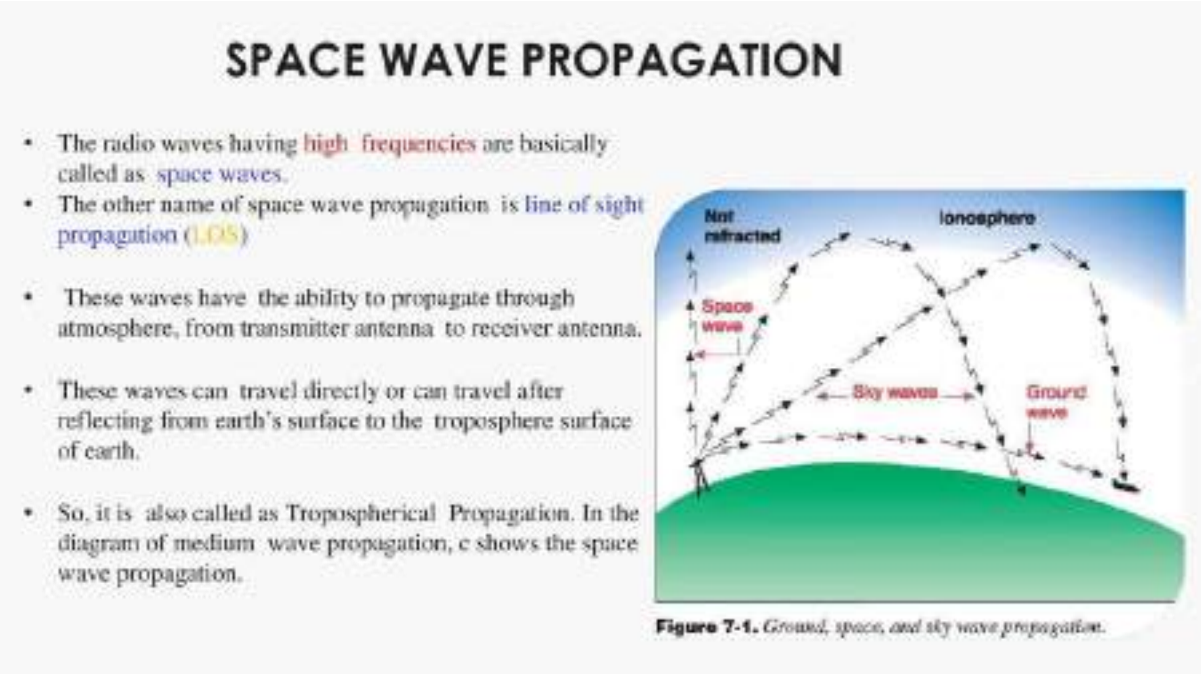


Figure 7-1. *Ground, space, and sky wave propagation.*

Frequency Range of Troposphere Scatter Propagation (30 MHz to 300 MHz)

The **space waves** can travel through atmosphere from transmitter antenna to receiver antenna either directly or after reflection from ground in the earth's troposphere region.

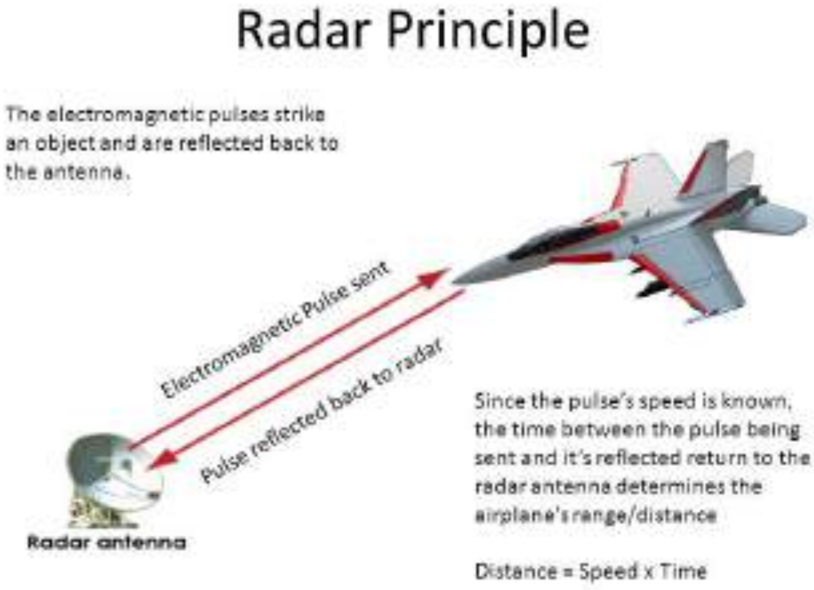
Unit-6

Radar System

RADAR stands for **Radio Detection and Ranging System.**

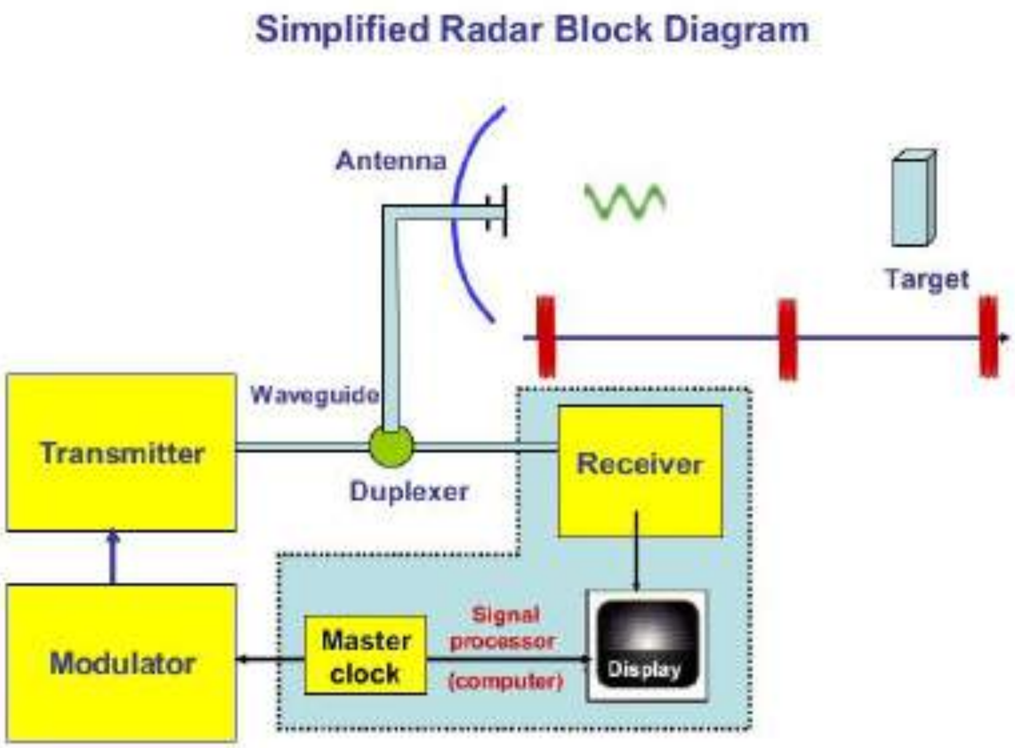
- **Radar** is a detection system that uses radio waves to determine the range, angle, or velocity of objects.
- It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain.
- A radar system consists of a
    - transmitter producing electromagnetic waves in the radio or microwaves domain,
    - a transmitting antenna,
    - a receiving antenna (often the same antenna is used for transmitting and receiving)
    - a receiver
    - processor to determine properties of the object(s).

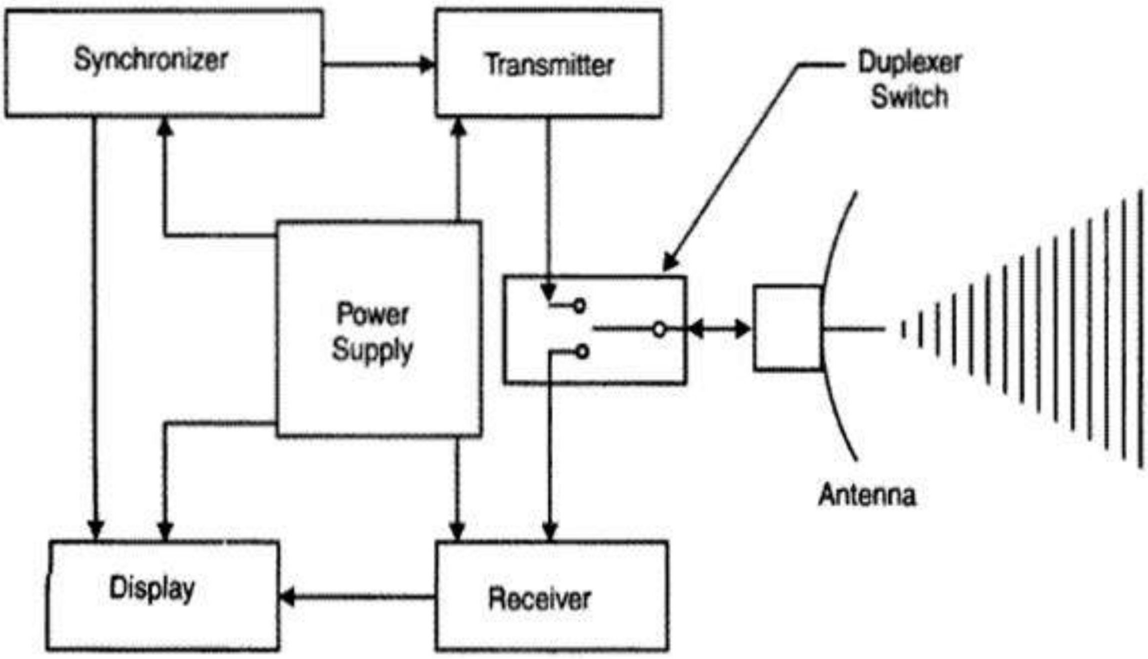
It works by radiating energy into space and monitoring the echo or reflected signal from the objects. It operates in the UHF and microwave range. Radio waves (pulsed or continuous) from the transmitter reflect off the object and return to the receiver, giving information about the object's location and speed.



A Basic Idea of RADAR

The RADAR system generally consists of a transmitter which produces an electromagnetic signal which is radiated into space by an antenna. When this signal strikes any object, it gets reflected or reradiated in many directions. This reflected or echo signal is received by the radar antenna which delivers it to the receiver, where it is processed to determine the geographical statistics of the object. The range is determined by the calculating the time taken by the signal to travel from the RADAR to the target and back. The target's location is measured in angle, from the direction of maximum amplitude echo signal, the antenna points to. To measure range and location of moving objects, Doppler Effect is used.





- **Transmitter:** It can be a power amplifier like a Klystron, Travelling Wave Tube or a power Oscillator like a Magnetron. The signal is first generated using a waveform generator and then amplified in the power amplifier.
- **Waveguides:** The waveguides are transmission lines for transmission of the RADAR signals.
- **Antenna:** The antenna used can be a parabolic reflector, planar arrays or electronically steered phased arrays.

- **Duplexer:** A duplexer allows the antenna to be used as a transmitter or a receiver. It can be a gaseous device that would produce a short circuit at the input to the receiver when transmitter is working.
- **Receiver:** It can be super heterodyne receiver or any other receiver which consists of a processor to process the signal and detect it.
- **Threshold Decision:** The output of the receiver is compared with a threshold to detect the presence of any object. If the output is below any threshold, the presence of noise is assumed.

RADAR Applications :

- ❖ **Military Applications:**
  - In air defense it is used for target detection, target recognition and weapon control (directing the weapon to the tracked targets).
  - In missile system to guide the weapon.
  - Identifying enemy locations in map.
- ❖ **Air Traffic Control:**
  - To control air traffic near airports. The Air Surveillance RADAR is used to detect and display the aircraft's position in the airport terminals.
  - To guide the aircraft to land in bad weather using Precision Approach RADAR.
  - To scan the airport surface for aircraft and ground vehicle positions
- ❖ **Remote Sensing:**
  - RADAR can be used for observing weather or observing planetary positions and monitoring sea ice to ensure smooth route for ships.
- ❖ **Ground Traffic Control:**

- RADAR can also be used by traffic police to determine speed of the vehicle, controlling the movement of vehicles by giving warnings about presence of other vehicles or any other obstacles behind them.

- **Space**
    - To guide the space vehicle for safe landing on moon
    - To observe the planetary systems
    - To detect and track satellites
    - To monitor the meteors

Radars can be classified into the following two types based on the type of signal with which Radar can be operated.

- **Pulse Radar**
- **Continuous Wave Radar**

Pulse Radar

The Radar, which operates with pulse signal is called the **Pulse Radar**. Pulse Radars can be classified into the following two types based on the type of the target it detects.

- Basic Pulse Radar
- Moving Target Indication Radar

❖ Basic Pulse Radar

The Radar, which operates with pulse signal for detecting stationary targets, is called the **Basic Pulse Radar** or simply, Pulse Radar. It uses single Antenna for both transmitting and receiving signals with the help of Duplexer.

Antenna will transmit a pulse signal at every clock pulse. The duration between the two clock pulses should be chosen in such a way that the echo signal corresponding to the present clock pulse should be received before the next clock pulse.

❖ Moving Target Indication Radar

The Radar, which operates with pulse signal for detecting non-stationary targets, is called Moving Target Indication Radar or simply, **MTI Radar**. It uses single Antenna for both transmission and reception of signals with the help of Duplexer.

MTI Radar uses the principle of **Doppler effect** for distinguishing the non-stationary targets from stationary objects.

Continuous Wave Radar

The Radar, which operates with continuous signal or wave is called **Continuous Wave Radar**. They use Doppler Effect for detecting non-stationary targets. Continuous Wave Radars can be classified into the following two types.

- Unmodulated Continuous Wave Radar
- Frequency Modulated Continuous Wave Radar

❖ Unmodulated Continuous Wave Radar

The Radar, which operates with continuous signal (wave) for detecting non-stationary targets is called Unmodulated Continuous Wave Radar or simply, **CW Radar**. It is also called CW Doppler Radar.

This Radar requires two Antennas. Of these two antennas, one Antenna is used for transmitting the signal and the other Antenna is used for receiving the signal. It measures only the speed of the target but not the distance of the target from the Radar.

❖ Frequency Modulated Continuous Wave Radar

If CW Doppler Radar uses the Frequency Modulation, then that Radar is called the Frequency Modulated Continuous Wave **(FMCW)** Radar or FMCW Doppler Radar. It is also called Continuous Wave Frequency Modulated Radar or CWFM Radar.

This Radar requires two Antennas. Among which, one Antenna is used for transmitting the signal and the other Antenna is used for receiving the signal. It measures not only the speed of the target but also the distance of the target from the Radar

Radar Range Equation:

We know that **Power density** is nothing but the ratio of Power and Area. So, the power density, Pdi at a distance, R from the Radar (Assuming that the Power is radiating in all directions) can be mathematically represented as –

$$\text{Power Density } (P_d) = Pt/4\pi R^2 \quad (1)$$

Where,

Pt is the amount of power transmitted by the Radar transmitter

$4\pi R^2$ represents the area of a sphere with radius R

The above power density is valid for an isotropic Antenna. In general, Radars use directional Antennas. Therefore, the power density, due to directional Antenna will be −

$$P_d = Pt * G_t / 4\pi R^2 \qquad (2)$$

Where G_t = Gain of Antenna
This is the radiated power density of the directive antenna. The target intercepts and reflects part of this energy. The Portion of the power reflected by the target in the direction of the receiving antenna will depend on the target scattering characteristics.

The amount of power, which is reflected back towards the Radar depends on its cross section.

Reflected Power from the target = $Pt*G*\sigma/4\pi R^2$

target cross section = σ

So, the power density of reflected target power (Pdr)of echo signal at Radar can be mathematically represented as –

$$Pdr = Pt*G*\sigma/(4\pi R^2)^2 \qquad (3)$$

The amount of **power,** P_r **received** by the Radar depends on the effective aperture, Ae of the receiving Antenna.

$$Pr = Pt*G*\sigma*Ae/(4\pi R^2)^2 \qquad (4)$$

From here we calculate R(Range)

$$R = [Pt*G*\sigma*Ae/(4\pi)^2 Pr]^{1/4} \qquad (5)$$

When Pr = Smin , R = Rmax

$$Rmax = [Pt*G*\sigma*Ae/(4\pi)2Smin]1/4 \qquad (6)$$

Gain of directional Antenna, G and effective aperture, Ae.

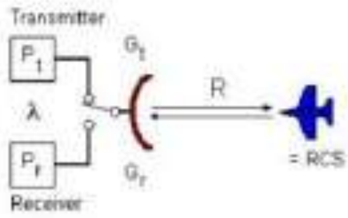
$$G = 4\pi Ae/\lambda^2 \qquad (7)$$

Putting value of (7) in Equation (6)

$$\Rightarrow R_{Max} = [P_t\, G\, \sigma\, A_e^2 / \; 4\,\pi\,\lambda^2 \; S_{min}]^{1/4}$$

$$A_e = G\,\lambda^2 / 4\pi$$

$$R_{max} = \sqrt[4]{\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 P_{min}}}$$



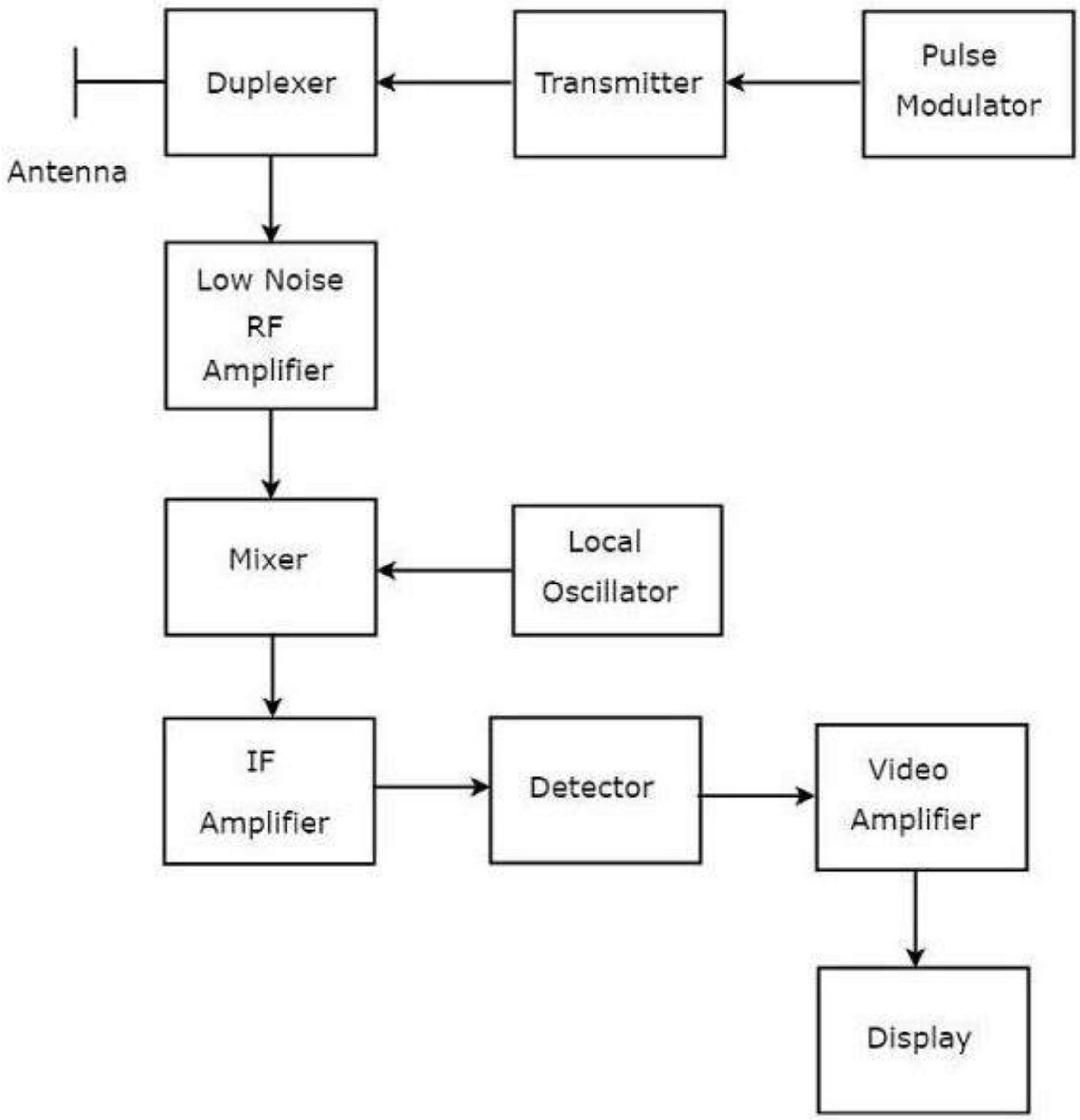
Where,

R_{max} = Radar Range
P_t = Transmitted Pulse Peak Power
G = Maximum Power Gain of Antenna
A_e = Antenna Aperture
σ = Radar Cross Section Area (RCS)
P_{min} = Minimum Detectable Signal of Receiver

s

Block Diagram of Pulse Radar

Pulse Radar uses single Antenna for both transmitting and receiving of signals with the help of Duplexer. It is widely used for detecting range of objects.Following is the **block diagram** of Pulse Radar –



Let us now see the **function** of each block of Pulse Radar –

- **Pulse Modulator** – It produces a pulse-modulated signal and it is applied to the Transmitter.
- **Transmitter** – It transmits the pulse-modulated signal, which is a train of repetitive pulses.
- **Duplexer** – It is a microwave switch, which connects the Antenna to both transmitter section and receiver section alternately. Antenna transmits the pulse-modulated signal, when the duplexer connects the Antenna to the transmitter. Similarly, the signal, which is received by Antenna will be given to Low Noise RF Amplifier, when the duplexer connects the Antenna to Low Noise RF Amplifier.

- **Low Noise RF Amplifier** − It amplifies the weak RF signal, which is received by Antenna. The output of this amplifier is connected to Mixer.
- **Local Oscillator** − It produces a signal having stable frequency. The output of Local Oscillator is connected to Mixer.
- **Mixer** − We know that Mixer can produce both sum and difference of the frequencies that are applied to it. Among which, the difference of the frequencies will be of Intermediate Frequency (IF) type.
- **IF Amplifier** − IF amplifier amplifies the Intermediate Frequency (IF) signal. The IF amplifier shown in the figure allows only the Intermediate Frequency, which is obtained from Mixer and amplifies it. It improves the Signal to Noise Ratio at output.
- **Detector** − It demodulates the signal, which is obtained at the output of the IF Amplifier.
- **Video Amplifier** − As the name suggests, it amplifies the video signal, which is obtained at the output of detector.
- **Display** − In general, it displays the amplified video signal on CRT screen.

Benefits or advantages of Pulsed Radar

Following are the benefits or **advantages of Pulsed Radar**:

➡Pulse doppler radar is used to reject unwanted echoes using doppler filters.

➡It can measure range and velocity in the presence of multiple targets.

➡It offers higher S/N ratio.

➡Medium PRF pulsed radar offers better range accuracy and range resolution.

➡It offers better performance for airborne low speed targets.

Drawbacks or disadvantages of Pulsed Radar

Following are the **disadvantages of Pulsed Radar**:

➡High PRF pulsed radar has poor range accuracy and target resolution is also poor. Moreover it has range ambiguities.

➡Medium PRF pulsed radar does not have any clutter free region.

UNAMBIGUOUS RANGE:

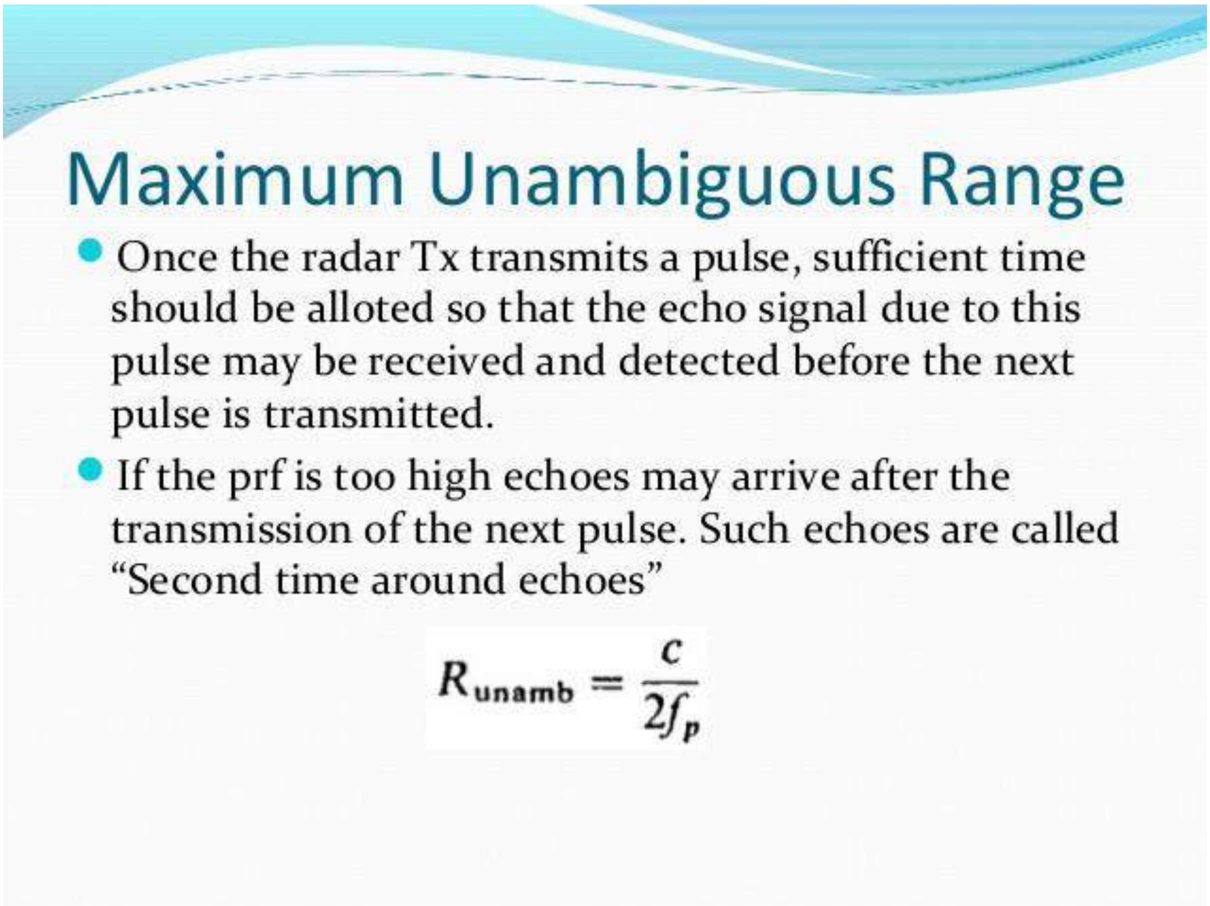
The Range beyond which target appears as second time around echos is known as maximum ambiguous range.

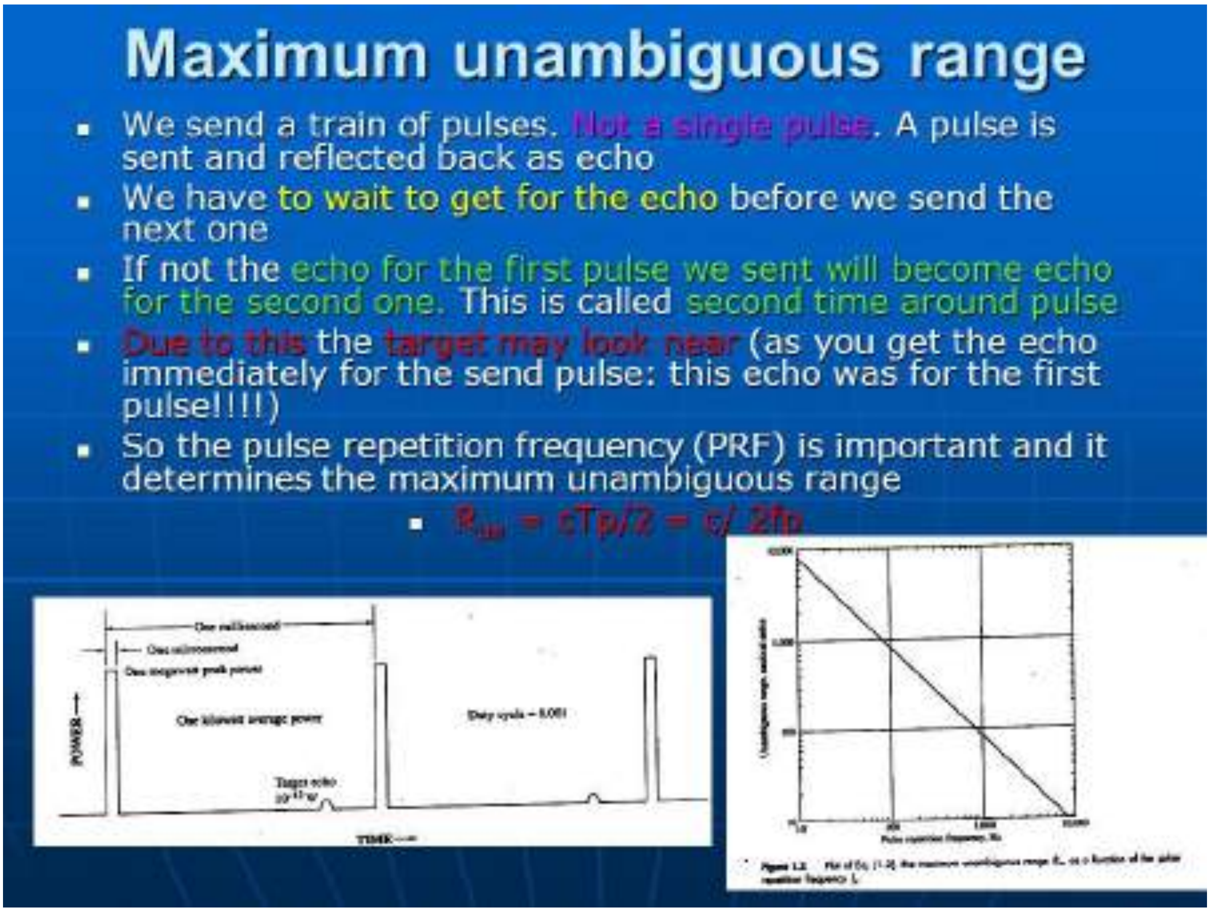
The maximum unambiguous range (Rmax) is the longest range that can be detected by transmitting a pulse which travel round trip and still produce reliable information.

$$R_{unamb} = C * PRT/2$$

Where C= Velocity of Light

PRT= Pulse Repetition Frequency





Doppler Effect:

If the target is not stationary, then there will be a change in the frequency of the signal that is transmitted from the Radar and that is received by the Radar. This effect is known as the Doppler effect.

According to the Doppler effect, we will get the following two possible cases −

- The frequency of the received signal will increase, when the target moves towards the direction of the Radar.
- The frequency of the received signal will decrease, when the target moves away from the Radar.

$$f_d = 2V_r / \lambda$$

Where,

- fd is the Doppler frequency
- Vr is the relative velocity

OR

$$fd=2Vrf/C$$

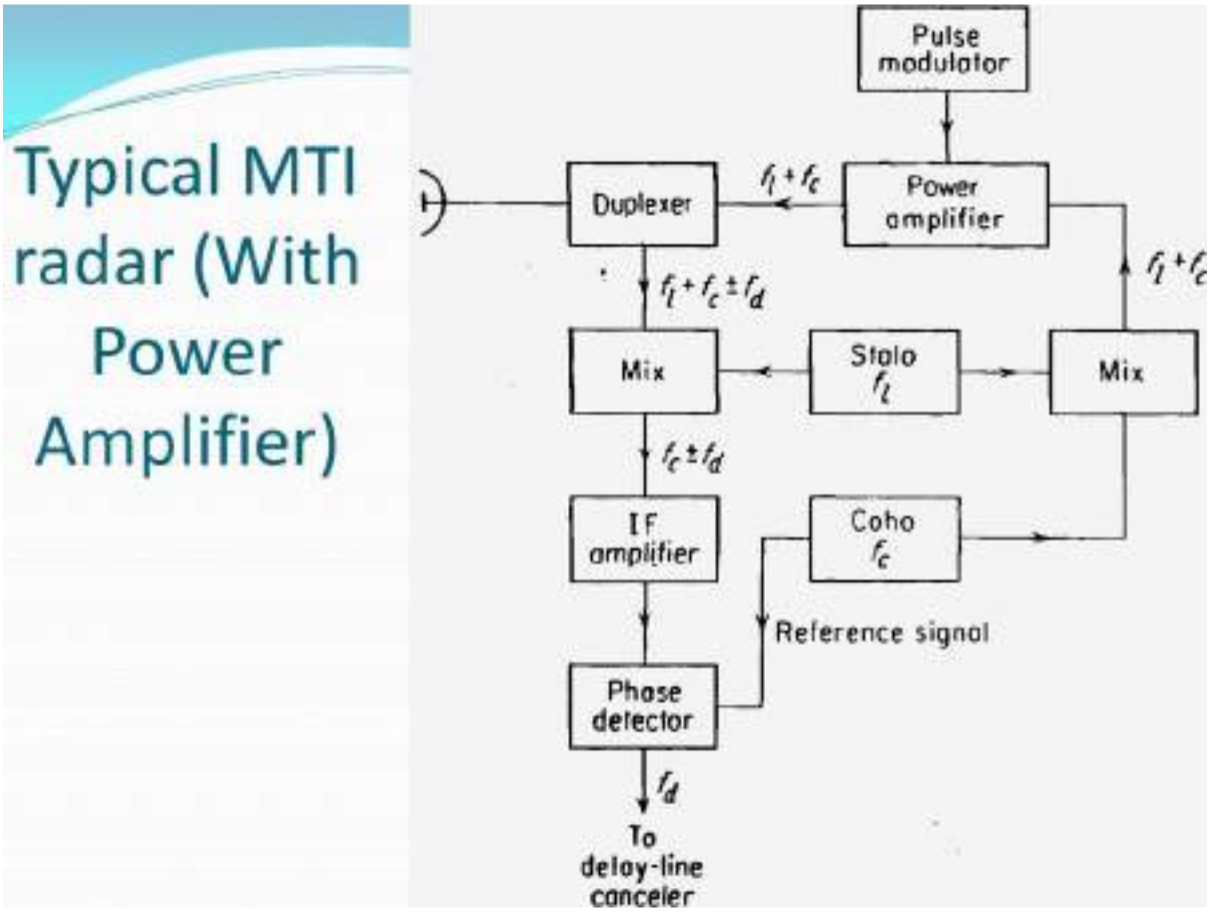
Where,

- F is the frequency of transmitted signal
- C is the speed of light and it is equal to 3×108m/sec
- Vr is the relative velocity
  By detecting fd , Relative velocity can be found out.

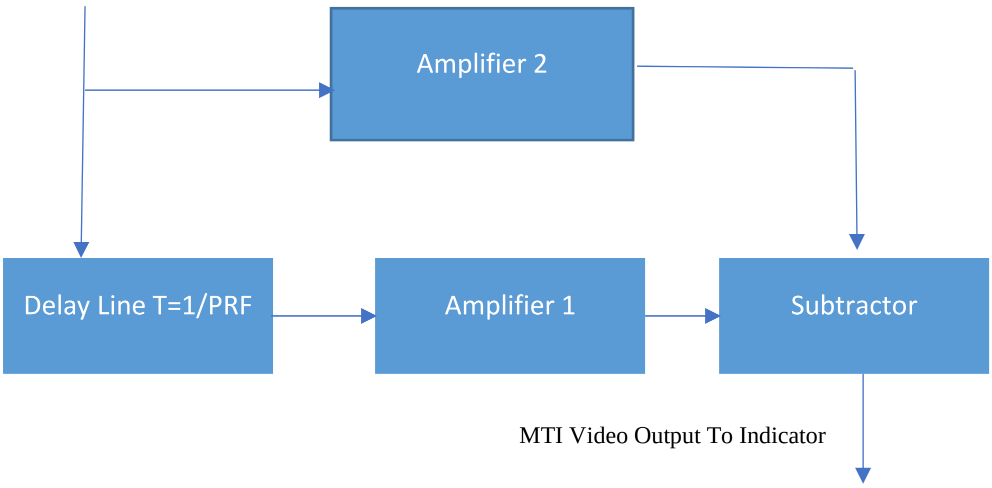
MTI RADAR

MTI stands for Moving Target Indicator. The MTI Radar is used for detecting targets such as aircrafts. It uses Doppler'effect for its working operation. The moving target is detected by cancelling the clutters due to stationary objects like high rise buildings, water tanks etc in the received echo. Clutters are basically the echoes received from the stationary objects.

Basically , the moving Target Indicators system compares a set of received echoes with those received during previous sweep. Those echoes whose phase has remained constant are then cancelled out. Phase of stationary objects remain constant but due to moving targets do show a phase change.



Delay line canceller



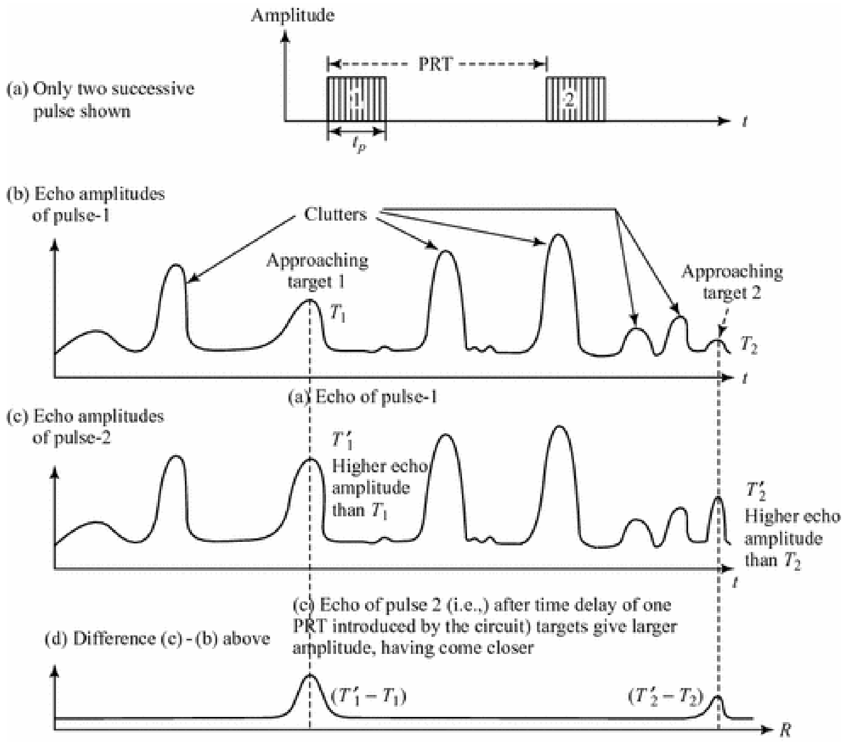
The **function** of each block of MTI Radar with power amplifier transmitter is mentioned below.

- **Pulse Modulator** − It produces a pulse modulated signal and it is applied to Power Amplifier.
- **Power Amplifier** − It amplifies the power levels of the pulse modulated signal.
- **Local Oscillator** − It produces a signal having stable frequency fl. Hence, it is also called stable Local Oscillator. The output of Local Oscillator is applied to both Mixer-I and Mixer-II.
- **Coherent Oscillator** − It produces a signal having an Intermediate Frequency, fc. This signal is used as the reference signal. The output of Coherent Oscillator is applied to both Mixer-I and Phase Detector.
- **Mixer-I** − Mixer can produce either sum or difference of the frequencies that are applied to it. The signals having frequencies of fl and fc are applied to Mixer-I. Here, the Mixer-I is used for producing the output, which is having the frequency fl+fc.
- **Duplexer** − It is a microwave switch, which connects the Antenna to either the transmitter section or the receiver section based on the requirement. Antenna transmits the signal having frequency fl+fc when the duplexer connects the Antenna to power amplifier. Similarly, Antenna receives the signal having frequency of fl+fc±fd when the duplexer connects the Antenna to Mixer-II.
- **Mixer-II** − Mixer can produce either sum or difference of the frequencies that are applied to it. The signals having frequencies fl+fc±fd and fl are applied to Mixer-II. Here, the Mixer-II is used for producing the output, which is having the frequency fc±fd.
- **IF Amplifier** − IF amplifier amplifies the Intermediate Frequency (IF) signal. The IF amplifier shown in the figure amplifies the signal having frequency fc±fd . This amplified signal is applied as an input to Phase detector.
- **Phase Detector** − It is used to produce the output signal having frequency fd from the applied two input signals, which are having the frequencies of fc+fd and fc. The detector compares the IF signal with the

reference signal from COHO oscillator. This phase difference is the Doppler Frequency. Phase detector gives the output both for fix and moving targets. Phase difference is constant for all fixed targets but varies for moving targets. The output of phase detector can be connected to Delay line canceller.

- **Delay Line**: Delay line subtract the output for each pulse from preceding one by delaing earlier ouput by time equal to pulse interval(1/PRF)

For Fixed Targets, the magnitude and Polarity of the Output will remain the same, However Output'magnitude Will change for Moving targets.



Benefits or advantages of MTI Radar

Following are the benefits or **advantages of MTI Radar**:

➡MTI radar can distinguish between moving target and stationary target.

➡It uses low PRF (Pulse Repetition Frequency) to avoid range ambiguities.

➡MTI principle is used in air surveillance radar which operates in presence of clutter.

➡It is simpler compare to pulse doppler radar.

➡Antenna bandwidth is high.

➡It is economical.

➡It does not require waveforms with multiple PRF.

➡It is preferred at UHF frequencies.

Drawbacks or disadvantages of MTI Radar

Following are the **disadvantages of MTI Radar**:

➡Blind speed does not get detected by pulse MTI radar. Blind speed is defined as magnitude of radial component of velocity of target when moving target appears as stationary target.

➡They can have doppler ambiguities.

Continuous Wave RADAR

As opposed to pulsed radar systems, continuous wave (CW) radar systems emit electromagnetic radiation at all times. The Radar, which operates with continuous signal (wave) for detecting non-stationary targets, is called Continuous Wave Radar or simply CW Radar. This Radar requires two Antennas. Among which, one Antenna is used for transmitting the signal and the other Antenna is used for receiving the signal.

CW Doppler Radars give accurate measurement of relative velocities. Hence, these are used mostly, where the information of velocity is more important than the actual range. In a CW RADAR electromagnetic radiation is emitted instead of pulses. It is basically used for speed measurement.

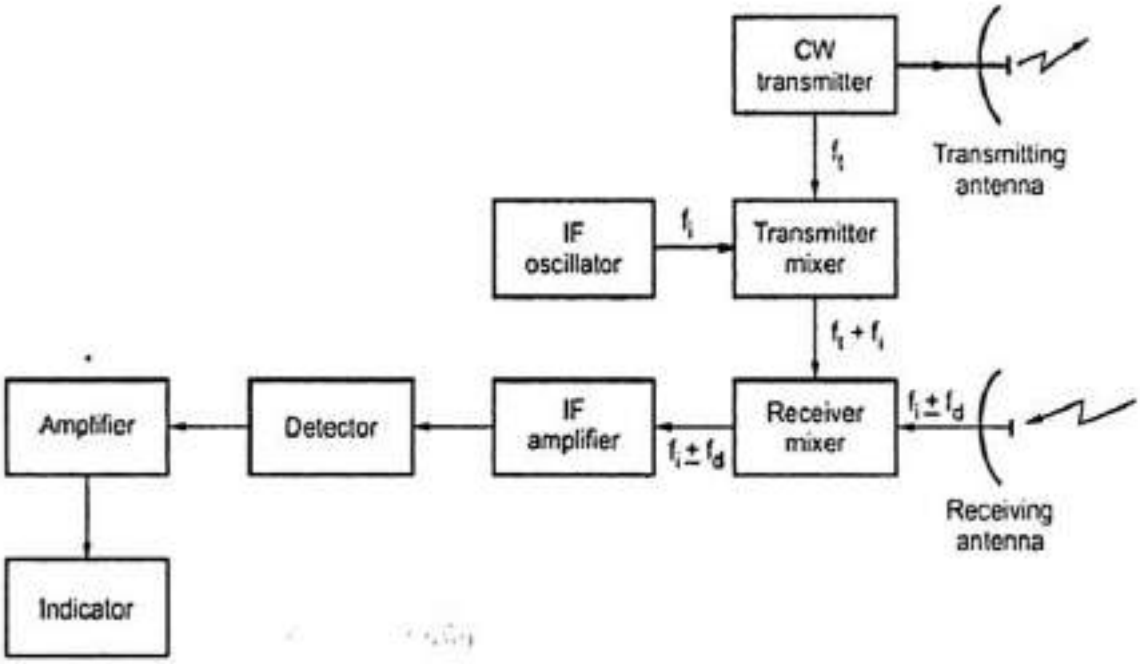


Fig. CW Doppler radar

The block diagram of CW Doppler Radar contains a set of blocks and the **function** of each block is mentioned below.

- **CW Transmitter** − It produces an analog signal having a frequency of ft. The output of CW Transmitter is connected to both transmitting Antenna and Transmitter Mixer-I.
- **Local/IF Oscillator** − It produces a signal having a frequency of fi. The output of Local Oscillator is connected to Transmitted Mixer-I.
- **Mixer-I** − Mixer can produce both sum and difference of the frequencies that are applied to it. The signals having frequencies of ft and fi are applied to Mixer-I. So, the Mixer-I will produce the output having frequencies ft+fi or ft−fi
- **Receiver Mixer-II** − Mixer can produce both sum and difference of the frequencies that are applied to it. The signals having frequencies of ft+fi and fo±fd are applied to receiver Mixer-II. So, the Mixer-II will produce the output having frequencies of fi±fd.
- **IF Amplifier** − IF amplifier amplifies the Intermediate Frequency (IF) signal. The IF amplifier shown in the figure allows only the Intermediate Frequency, fi±fd and amplifies it.
- **Detector** − It detects the signal, which is having Doppler frequency, fd

- **Doppler Amplifier** − As the name suggests, Doppler amplifier amplifies the signal, which is having Doppler frequency, fd
- **Indicator** − It indicates the information related relative velocity and whether the target is inbound or outbound.

Advantages :

- Single frequency transmission and hence narrow receiver bandwidth
- Duty cycle is unity, so mean power can be as high as transmitters will permits.
- Ability to see moving targets in presence of large number of echoes from stationary target to which it is blind.
- Target velocity can be measured using Doppler shift.
- Zero minimum range.
- Simple to design and construct.

Disadvantages:

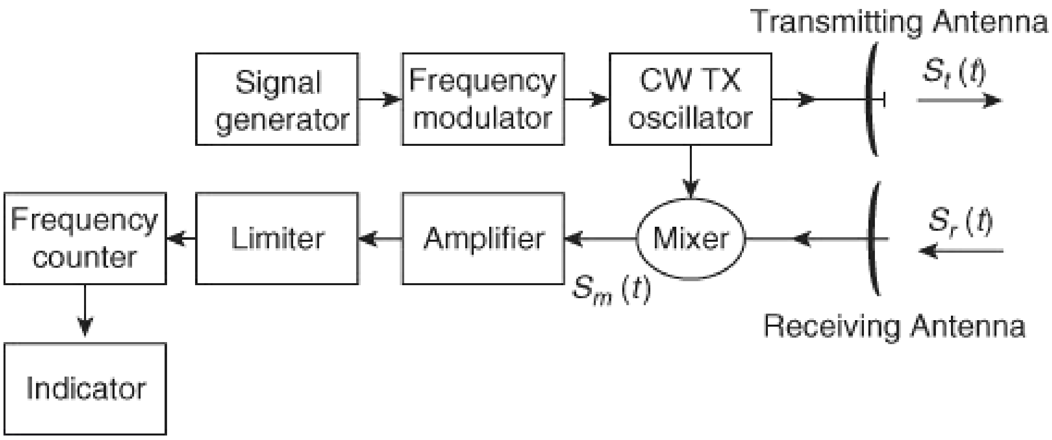
- No timing marks, so unable to measure range.
- Separate antennas are required for receiver and transmitter.
- Cannot detect targets crossing its beam at right angles

Applications:

- Measurement of the relative velocity of a moving target.
- Human Gait Recognition
- In Doppler Radar.

Frequency Modulated Continuous Wave Radar:

Simple continuous wave radar devices without frequency modulation have the disadvantage that it cannot determine target range because it lacks the timing mark necessary to allow the system to time accurately the transmit and receive cycle and to convert this into range. A very important type of FMCW radar pulse is the linear FM sweep. In this case, the range to the target is found by detecting the frequency difference between the received and emitted radar signals. The range to the target is proportional to this frequency difference, which is also referred to as the beat frequency.



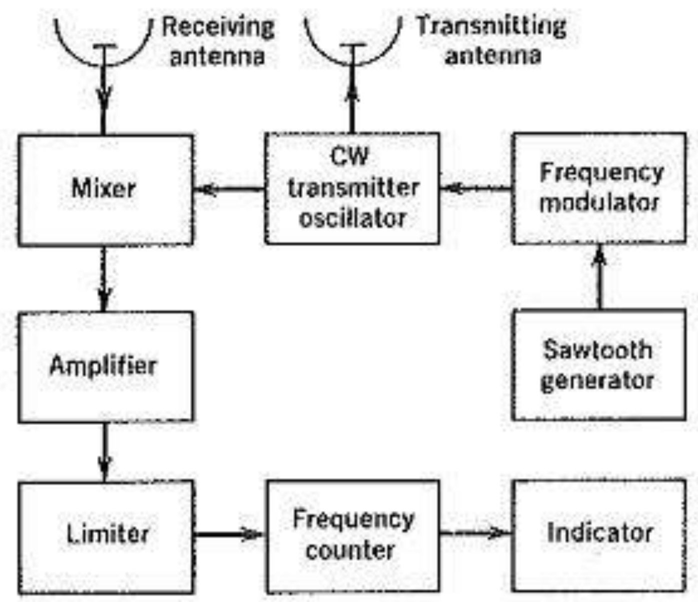


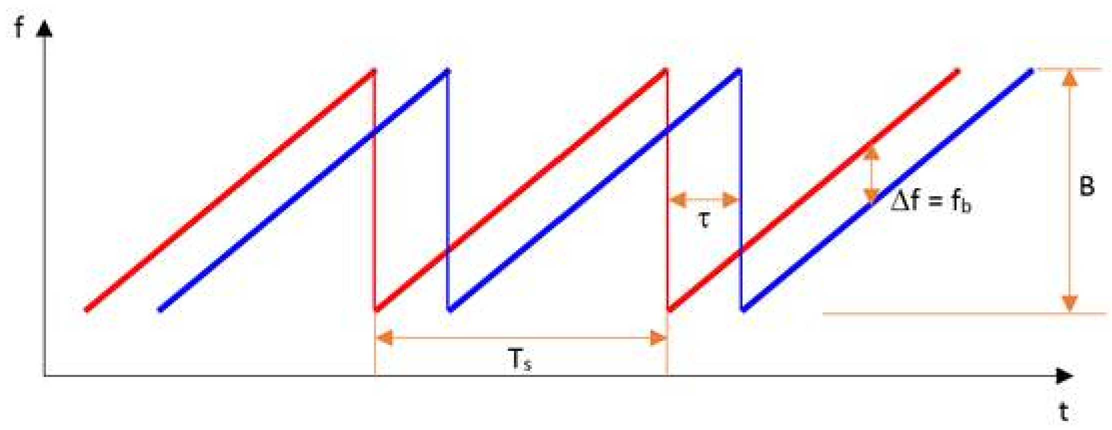
FIGURE 16-16 Block diagram of simple FM CW radar altimeter.

The sawtooth waveform generated by sawtooth generator is frequency modulated and thus signal after frequency modulation, is transmitted by Transmitter. Portion of transmitted signal acts as reference signal to produce beat frequency. The frequency of transmitted signal increases linearly with increasing amplitude of modulating signal.

The transmitted signal hits at the target and reflects back to a receive antenna. The frequency difference between the received signal and the transmitted signal increases with delay, and the delay is linearly proportional to the range, that is the distance of the target from the radar. The echo from the target is then mixed with the transmitted signal and down-converted to produce a beat signal which is linearly proportional to the target range after demodulation.

- Signal is amplified by the amplifier.
- Limiter is used to remove unwanted amplitude variations .
- Frequency counter and Indicator are used to display the reading.

The figure below shows the transmitted and received ramp signals:



The delay τ is equal to the round-trip wave travel time and given by:

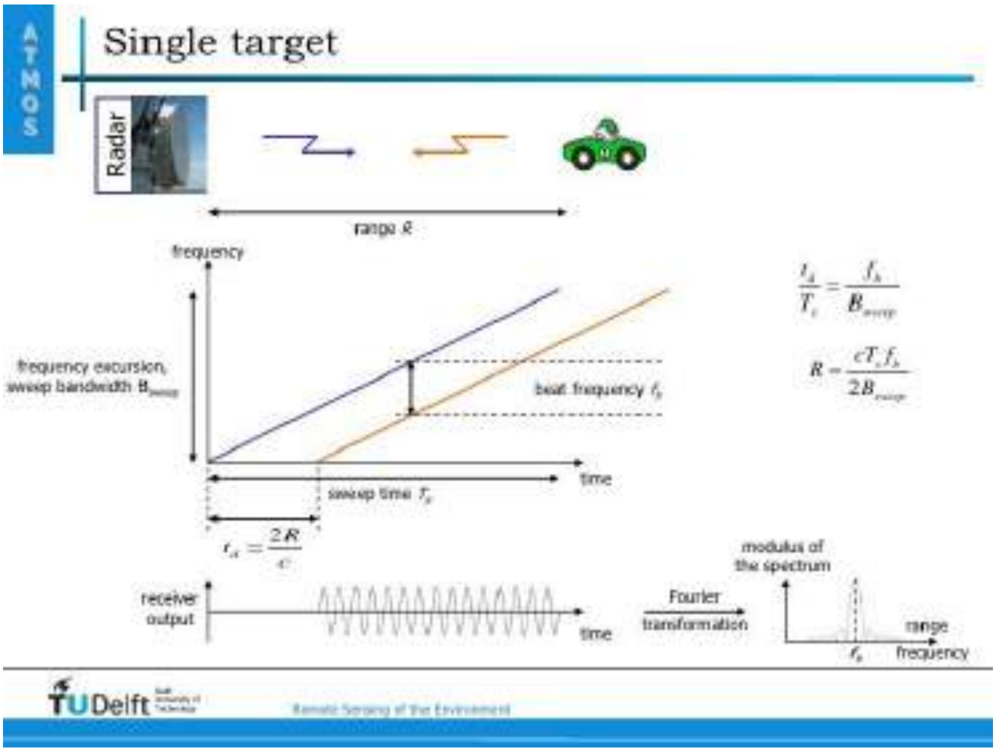
$$\tau=2R/ c$$

where R is the target range and c is the free-space speed of light. The beat frequency at the output of the receiver is given by:

$$fb=B\ \tau/Ts$$

where B is the total frequency deviation of the chirp signal and T_s is the sweep time (chirp period). The target range is thus found from the following equation:

R=cTs fb /2B



Earth is assumed to be stationary and and therefore there is no Doppler frequency shift. However if there is relative velocity between aircraft and earth, a doppler frequency shift is superimposed on FM beat frequency due to Doppler’s effect. Even then the range can be computed as the average frequency difference.

Advantages of FMCW Radar

- High-resolution distance measurement suits well for imaging applications.
- Quick updating of measurement because of continuous transmitting signals.
- Functions well in all types of weather (rain, humidity, fog, and dusty) and atmospheric conditions, because electromagnetic radiations of short wavelength are used.
- Better in detecting tangential motion than Doppler-based systems.

Disadvantages of FMCW Radar

- Costlier than other competing technologies.
- Radar is most susceptible to interference from other radio devices.

- More computing power is required.
- It can be a disadvantage in defense applications because they can be easily blocked by electronic warfare systems.

Applications of FMCW Radar

- Used in high accuracy applications where repeatability and reliability are required because FMCW radars provide accurate range measurement.
- In transportation, it is used as automotive collision avoidance radars and marine radars.
- Because of its resistance to dust, steam, heat, these are mostly used in the blast furnace of a steel mill.

RADAR DISPLAY: A **radar display** is an electronic device to present radar data to the operator. The radar system transmits pulses or continuous waves of electromagnetic radiation, a small portion of which backscatter off targets (intended or otherwise) and return to the radar system. The receiver converts all received electromagnetic radiation into a continuous electronic analog signal of varying (or oscillating) voltage that can be converted then to a screen display.

Oscilloscopes

Early radar displays used adapted oscilloscopes with various inputs. An oscilloscope generally receives three *channels* of varying (or oscillating) voltage as input and displays this information on a cathode ray tube. The oscilloscope amplifies the input voltages and sends them into two deflection magnets and to the electron gun producing a spot on the screen. One magnet displaces the spot horizontally, the other vertically, and the input to the gun increases or decreases the brightness of the spot. A bias voltage source for each of the three channels allows the operator to set a zero point.In a radar display, the output signal from the radar receiver is fed into one of three input channels in the oscilloscope. Early displays generally sent this information to either X channel or Y channel to displace the spot on the screen to indicate a return. More modern radars typically used a rotating or otherwise moving antenna to cover a greater area of the sky

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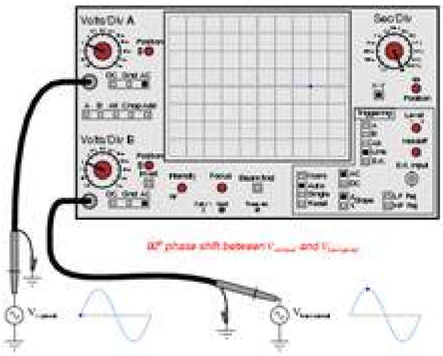
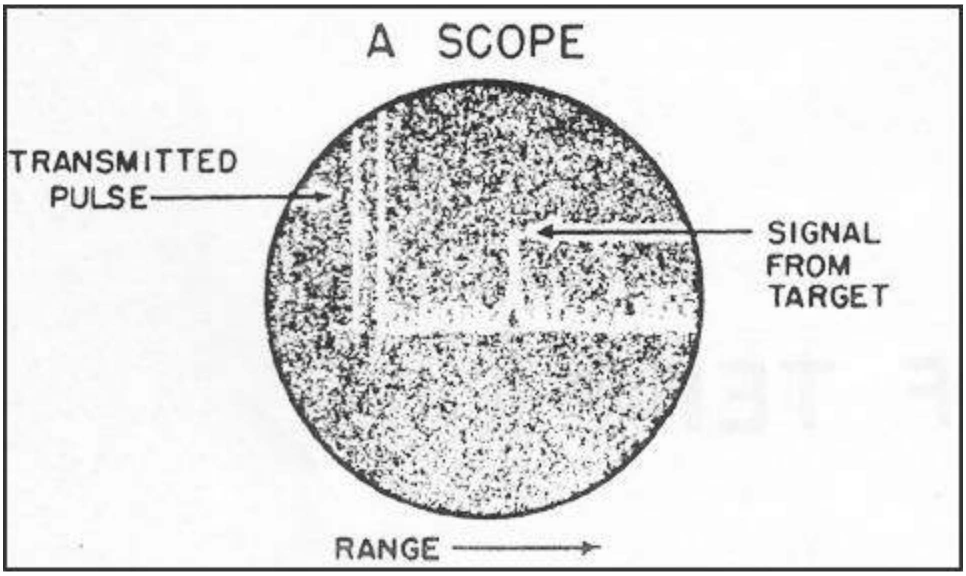


A-Scope:

The A-scope display, presents only the range to the target and the relative strength of the echo. Such a display is normally used in weapons control radar systems. The bearing andelevation angles are presented as dial or digital readouts that correspond to the actual physical position ofthe antenna.

It is a two dimensional Radar display. The horizontal and vertical coordinates represent the range and echo amplitude of the target respectively. In A-Scope, the deflection modulation takes place. It is more suitable for **manually tracking Radar**.

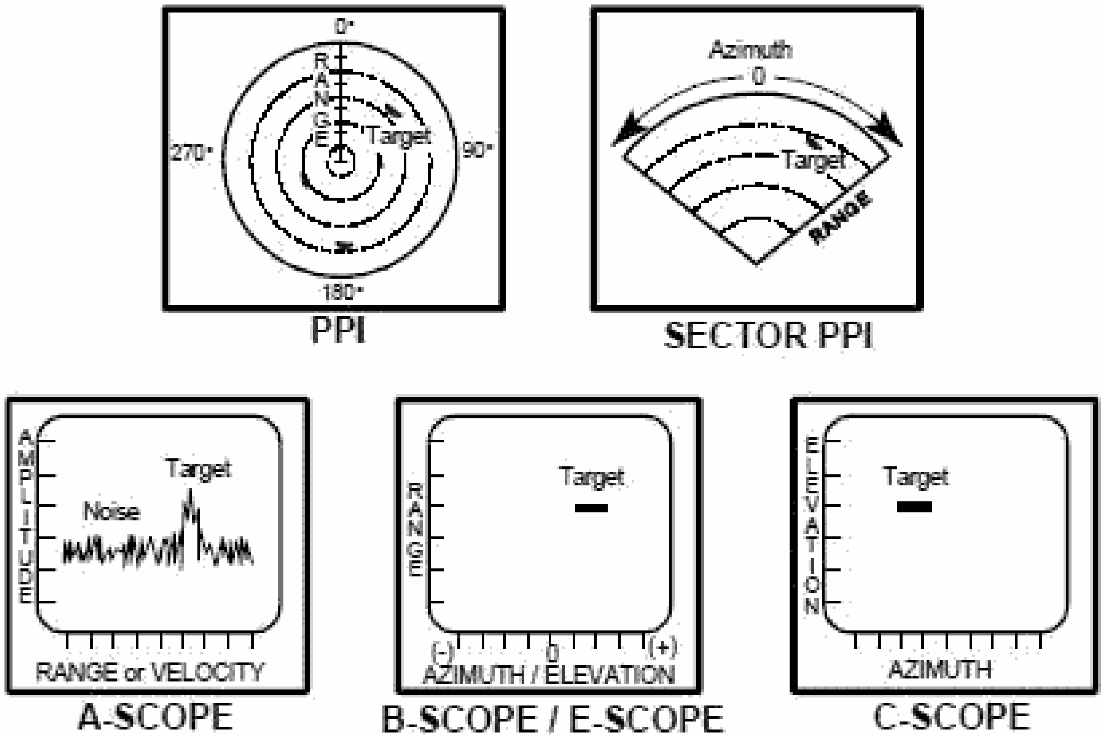


B-Scope :

It is a two dimensional Radar display. The horizontal and vertical coordinates represent the azimuth angle and the range of the target respectively. In B-Scope, intensity modulation takes place. It is more suitable for **military Radars**.

Plane Position Indicator:

The PPI display provides a 2-D "all round" display of the airspace around a radar site. The distance out from the center of the display indicates range, and the angle around the display. It displays the information of echo signal as plan view. Range and azimuth angle are displayed in polar coordinates. Hence, it is called the Plan Position Indicator or the PPI display.



Wireless and Mobile Communication

Wireless Communication

Unit-1

- Wireless communication is the technology in which there is no physical medium between transmitter and receiver.

Advantages of Wireless Communication

- **Advantages :**
- **Freedom from wires :**
  Can be configured with the use of any physical connection.
- **Easy to setup :**
  Wireless network is easy to expand and setup
- **Better or global coverage :**
  It provides global reach by providing networking in places such as rural areas, battlefield, etc… where wiring is not feasible.
- **Flexibility :**
  Wireless network is more flexible and adaptable compared to wired network.
- **Cost-effectiveness :**
  Since it is easy to install and doesn’t require cables, wireless network is relatively cheaper.
- **Mobile and portable :**
  Wireless network is easy to carry and re-install in another place.

Disadvantages :

- As communication is done through open space, it is less secure.
- Unreliability
- More open to interference.
- Increased chance of jamming.
- Transmission speed is comparably less.

Applications of Wireless Communication :

Satellite

Remote control

Wi-Fi

Paging system

Wi-Max

Security systems

Mobile phones

Bluetooth

GPS

GSM

Cellular Concept

Unit-2

1G

- Analog Technology
- Basic Mobility
- Only Voice
- Incompatibility
- Very Limited Users
- Equipment Size and weight

2G

- Digital Technology
- Advanced Mobility
- Voice and data Service(SMS)
- Compatibility
- Large no. of Users
- Light weight and small size of equipments
- No Internet/Multimedia Facility

2.5G & 2.75G

- Enhanced version of 2G technology
- Data rates 114Kbps/384Kbps(2.75G)
- GPRS(General Packet Radio Service)2.5G
- EDGE (Enhanced Data Rates for GSM)2.75G
- Internet/Multimedia Applications(MMS)
- Data only equipments were also available

Cell:-

It is the geographic area that is covered by a single base station in a cellular network.

Cell Site:-

A cell site is a cellular mobile device site where antennas and electronic communications equipment are tower, or other raised structure to create a cell in a cellular network

Capacity of cell:-

Maximum number of mobile station in the cell which can make call simultaneously. It depends on the frequency band allocated to the cell.

Frequency Reuse

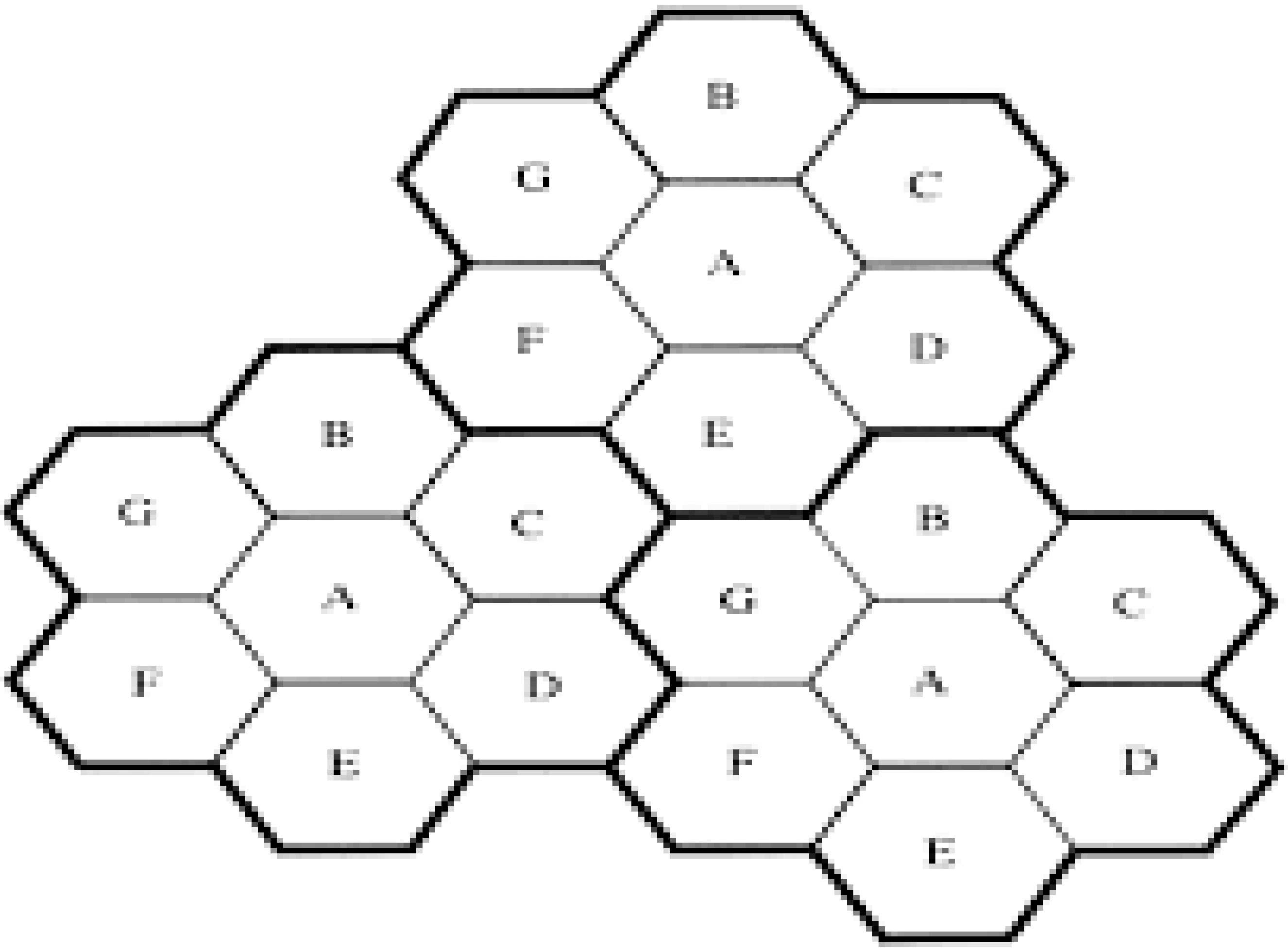
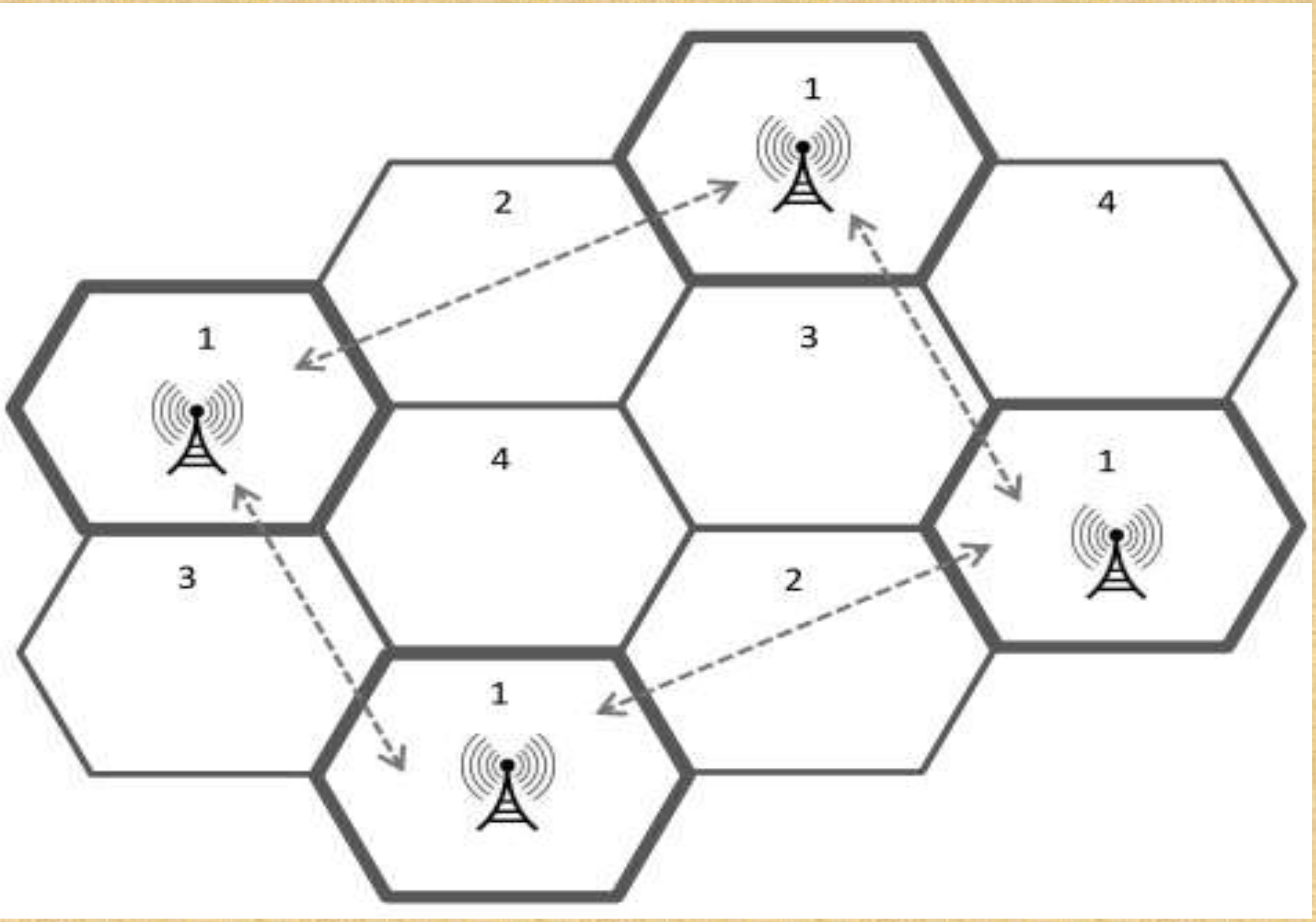
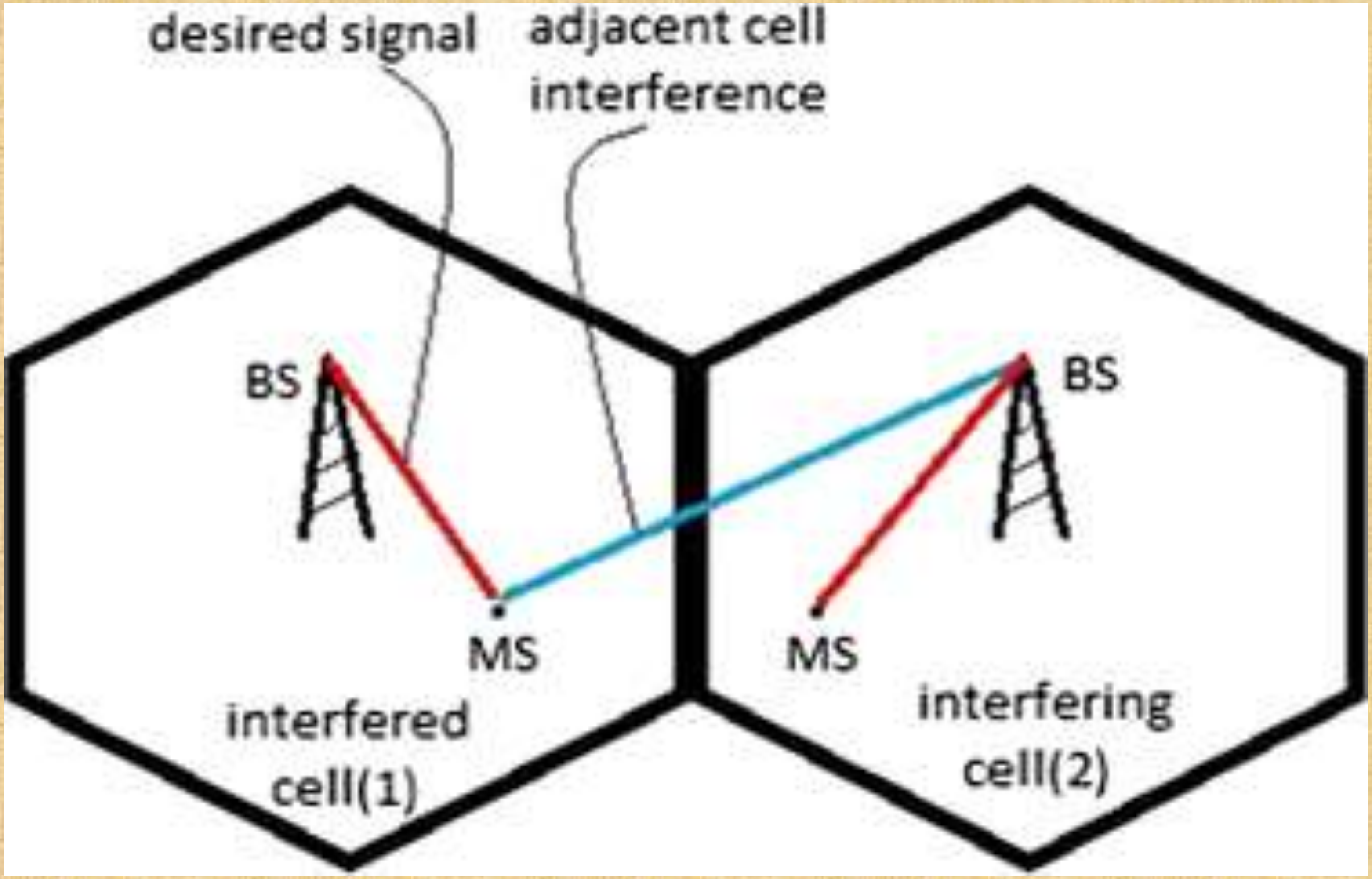


Illustration of the cellular frequency reuse concept.

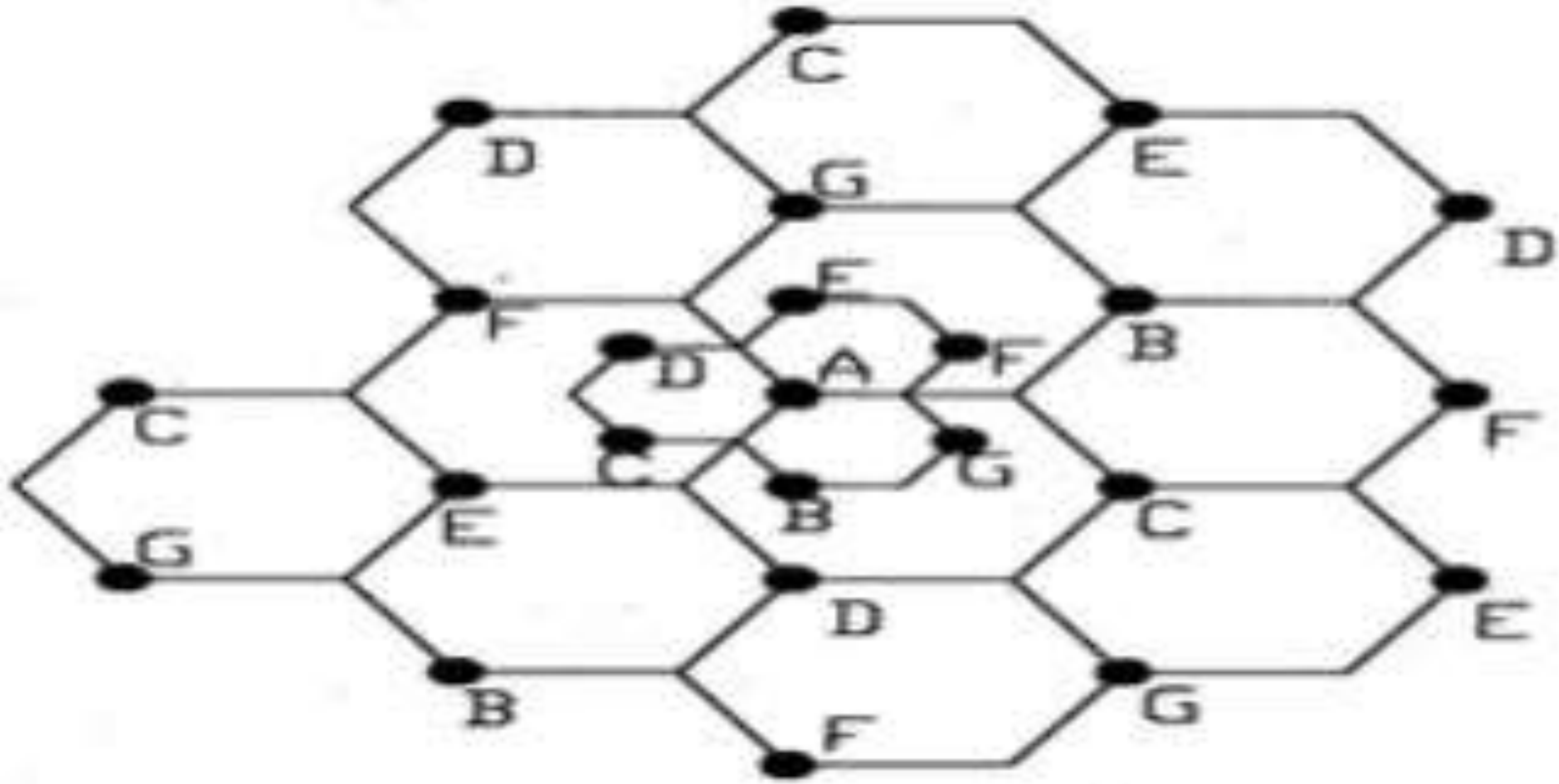
Co-channel Interference



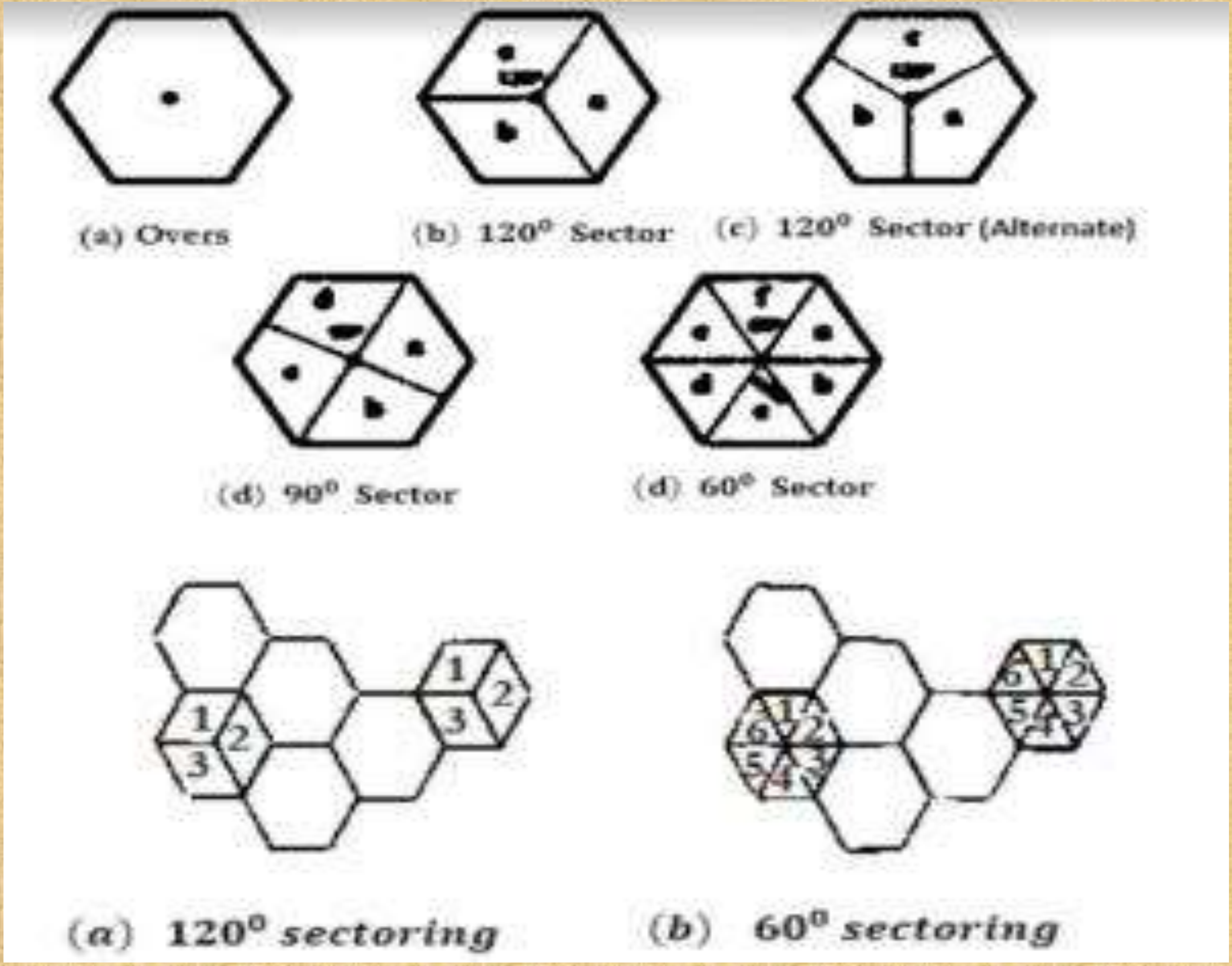
Adjacent Channel Interference



Cell Splitting



Cell Sectoring



Multiple Access Techniques

Unit-3

Multiple Access Techniques

- Techniques by using which no. of users share a single/common channel at same time.

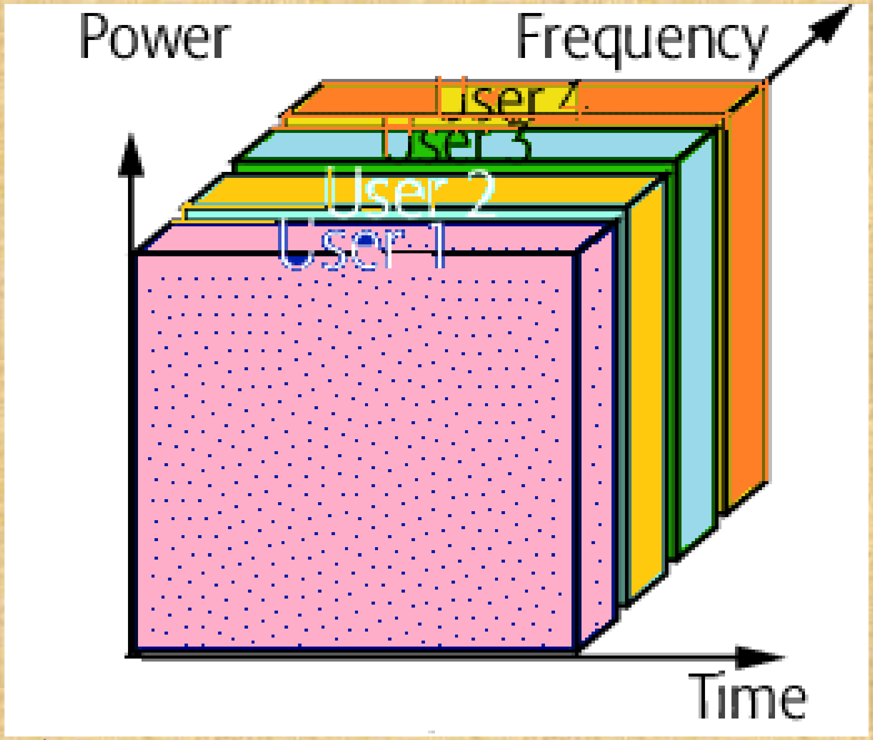
  (Channel is either uplink or downlink)

Multiple Access Techniques

FDMA	• Freq. Division Multiple Access
TDMA	• Time Division Multiple Access
CDMA	• Code Division Multiple Access

Frequency Division Multiple Access

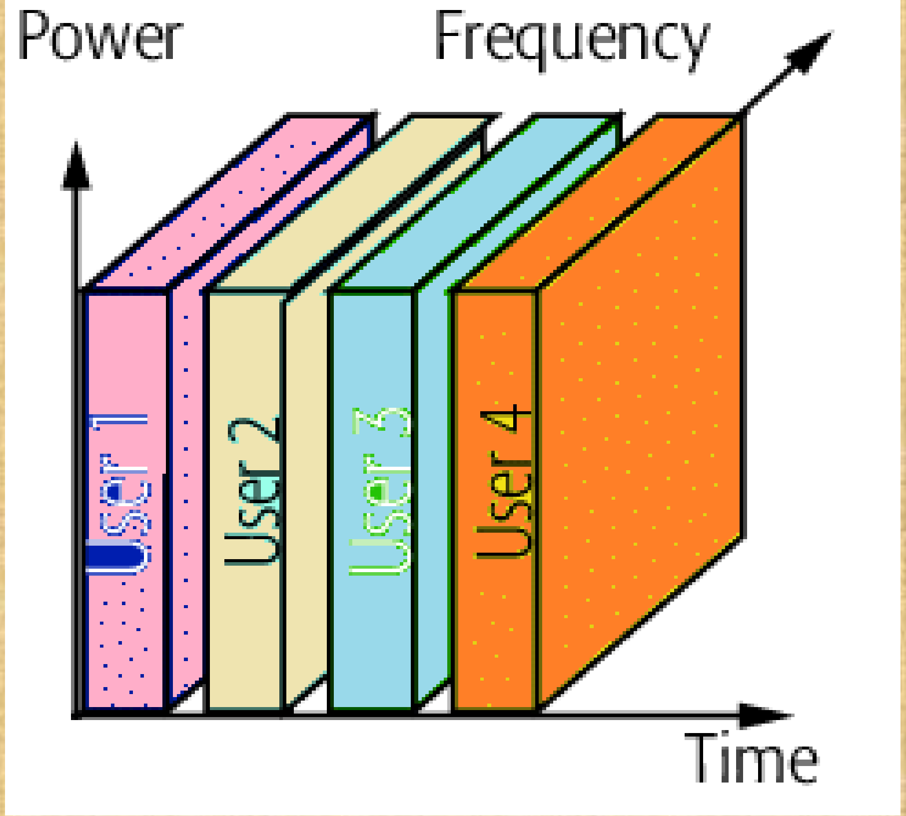
FDMA is a technique in which number of users share a common channel at same time but at different frequencies.



Time Division Multiple Access

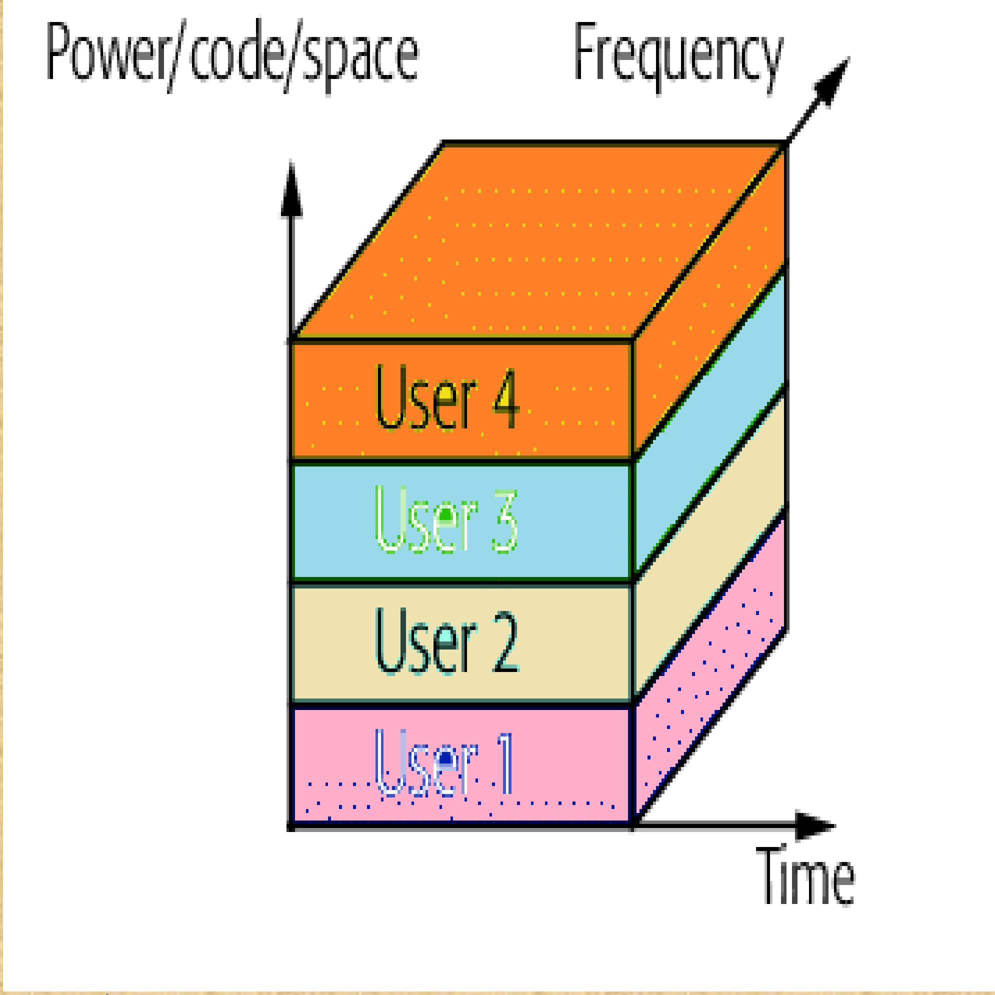
- TDMA is a technique in which number of users share a common channel at same frequency but at different time(time slot).

(Time slot is very small here in milliseconds or microseconds)



Code Division Multiple Access

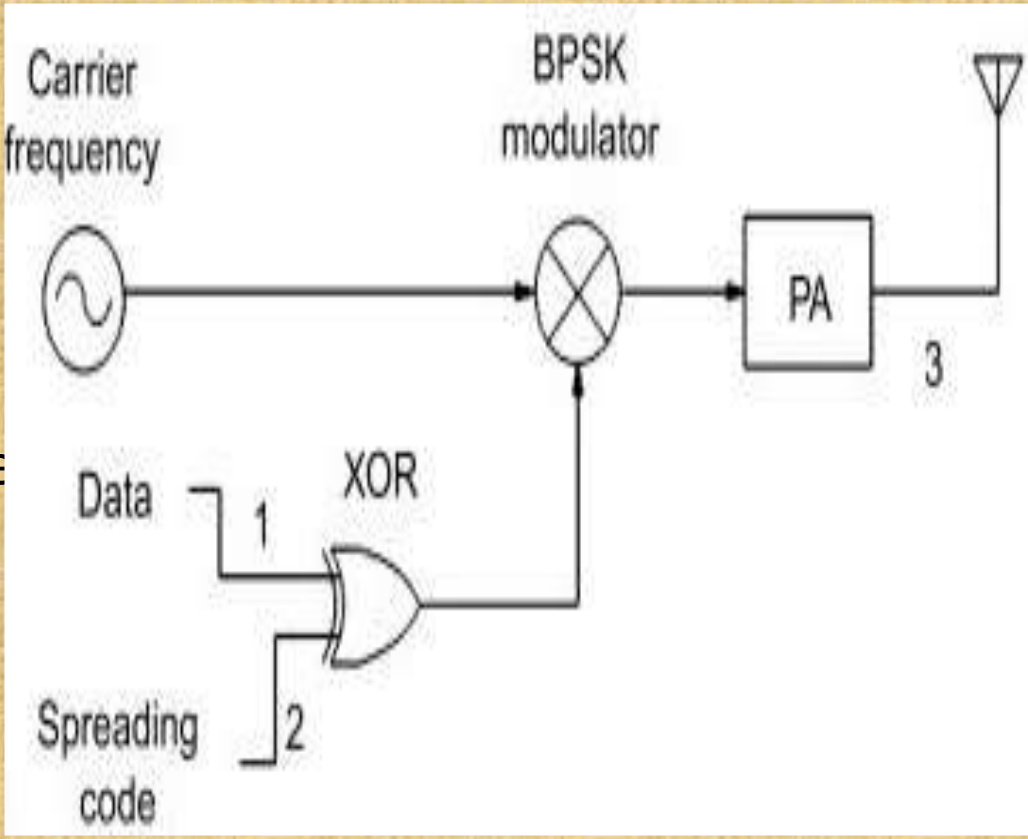
- CDMA is a technique in which number of users share a common channel at same time and frequency but each user receives the signal with a unique code by using which user can decode signal and extract the information meant for it only .



DSSS

- *Direct Sequence Spread Spectrum*

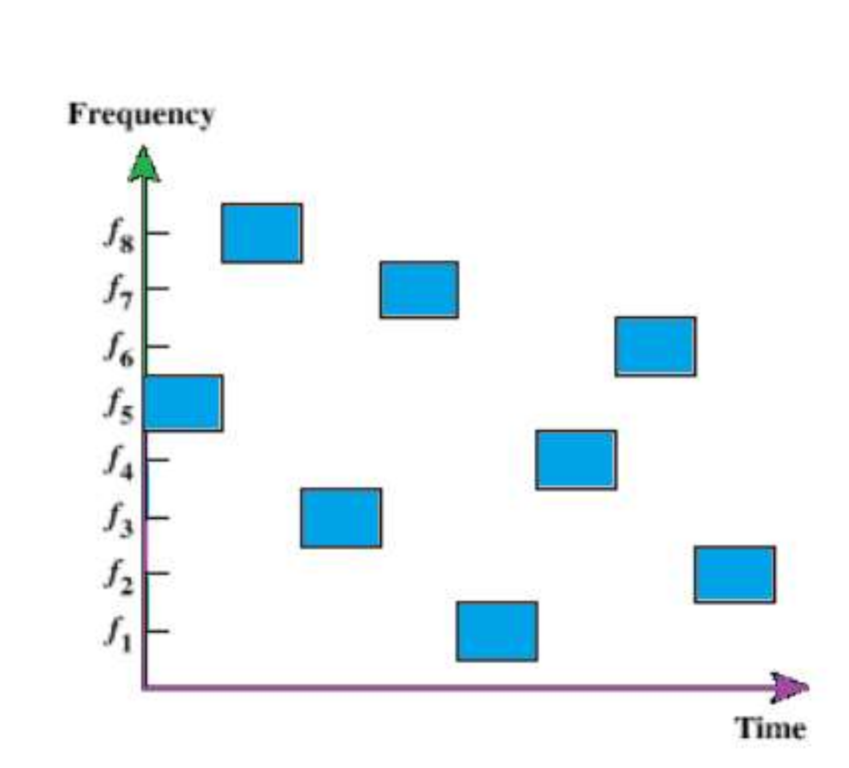
It spreads the digital version of analog signal over a wide bandwidth by multiplying with chipping code.



FHSS

- ***Frequency Hopping Spread Spectrum***

It transmits the signal by shifting carrier across a number of channels as per pseudorandom code which is already known to transmitter and receiver



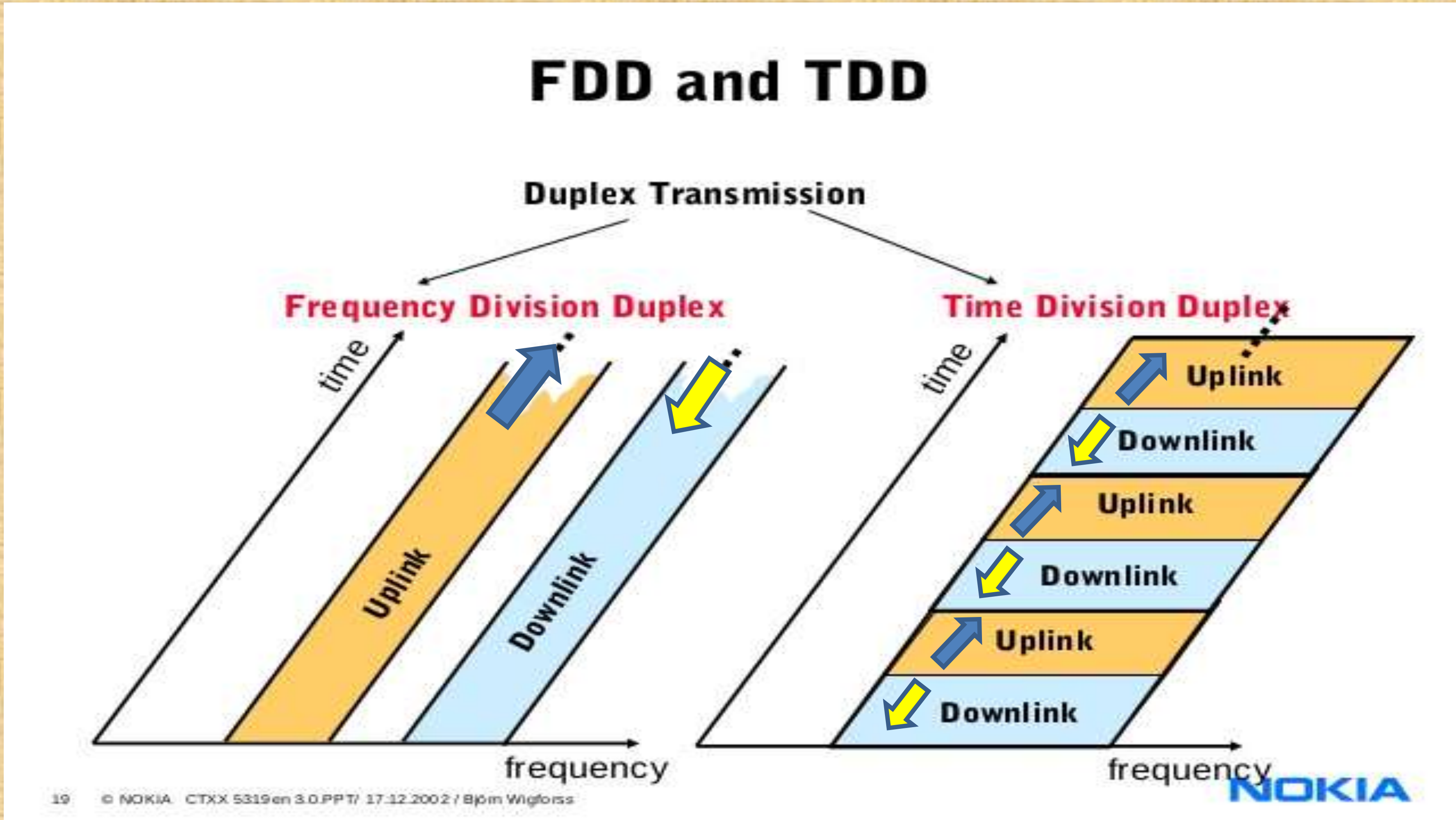
Duplexing

- Duplexing is the method to use a channel for two way communication.

There are two types of Duplexing:-

1. FDD (Frequency Division Duplexing)
2. TDD (Time Division Duplexing)

FDD and TDD



FDD and TDD
Duplex Transmission
Frequency Division Duplex
Time Division Duplex
time
Uplink
Downlink
frequency
time
Uplink
Downlink
Uplink
Downlink
Uplink
Downlink
frequency
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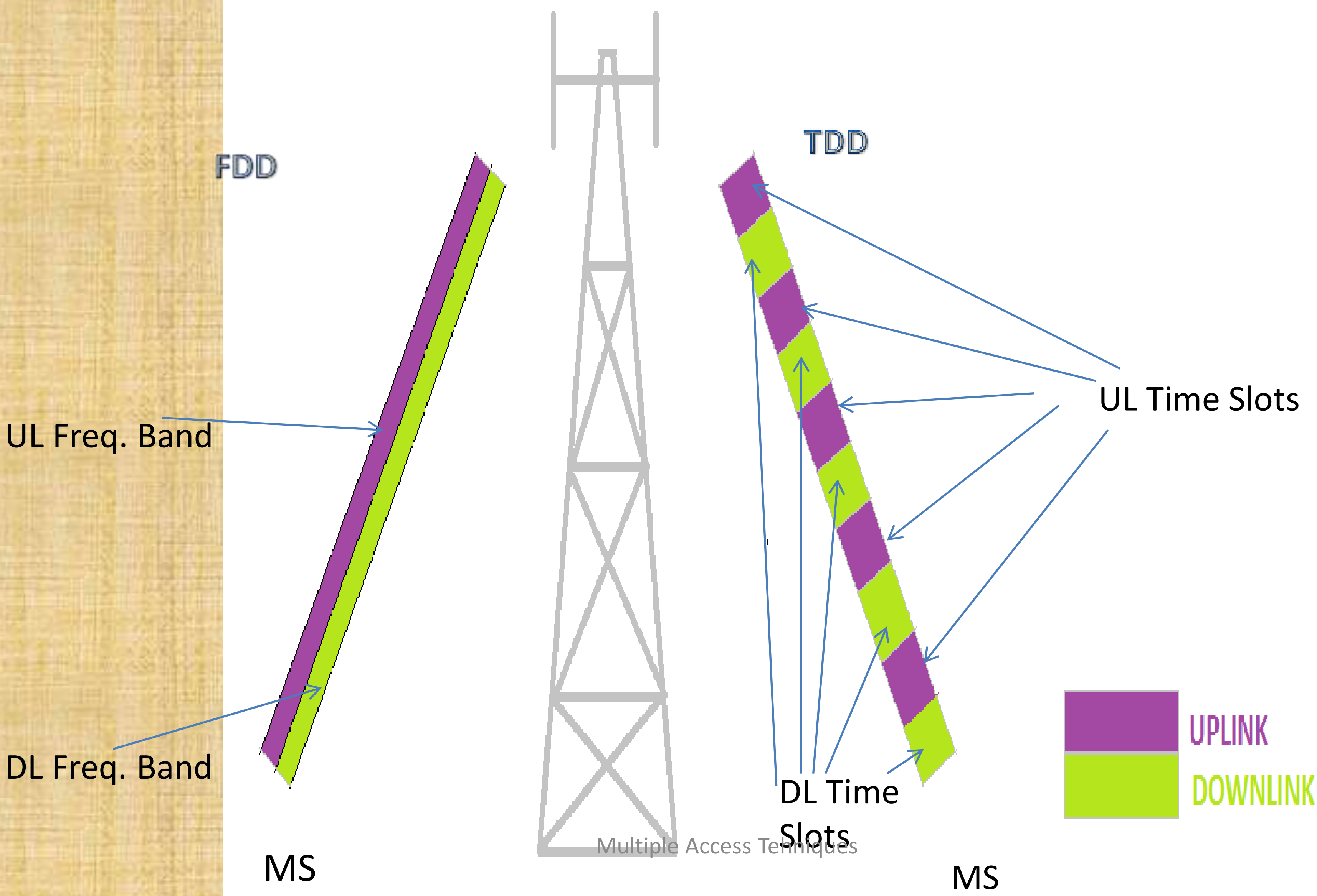
FDD and TDD


FDD
TDD
UL Freq. Band
DL Freq. Band
UL Time Slots
DL Time Slots
UPLINK
DOWNLINK
MS
MS

FDD (Frequency Division Duplexing)

- In FDD there are two channels one for uplink and another for downlink.
- In 900GSM

869MHz to 894MHz   Bandwidth 25MHz(D/L)

824MHz to 849MHz   Bandwidth 25MHz(U/L)

If a subscriber uses 824MHz for Uplink then 869MHz will be used for Downlink

* Difference between U/L and D/L frequency is 869 - 824 = 45Mhz

FDD (Frequency Division Duplexing)

Advantages

- 1. No need of synchronization
- 2. Comparatively simple

Disadvantages

- 1. Wider Bandwidth
- 2. Special Antenna Techniques are required like MIMO and beam forming.

TDD (Time Division Duplexing)

- It is the method in which single channel is used for uplink and downlink in time slots.

  In some applications Size and dedicated no. of time slots may be different for uplink and downlink or it may use dynamic bandwidth.

TDD (Time Division Duplexing)

Advantages

- 1. Need Single Channel
- 2. No Guard band is required

Disadvantages

- 1.Synchronization and timing precision is required.
- 2. Guard time is required between time slots

Mobile Communication Systems

Unit-4

Global System for Mobile Communication (GSM)

Global system for mobile communication (GSM) is wide area wireless communications system that uses digital radio transmission to provide voice, data, and multimedia communication services.

A GSM system coordinates the communication between a mobile stations, base stations, and switching systems. Each GSM radio channel is 200 KHz wide channels that are further divided into frames that hold 8 time slots.

The GSM system includes mobile stations, base stations, and interconnecting switching systems.

GSM Architecture

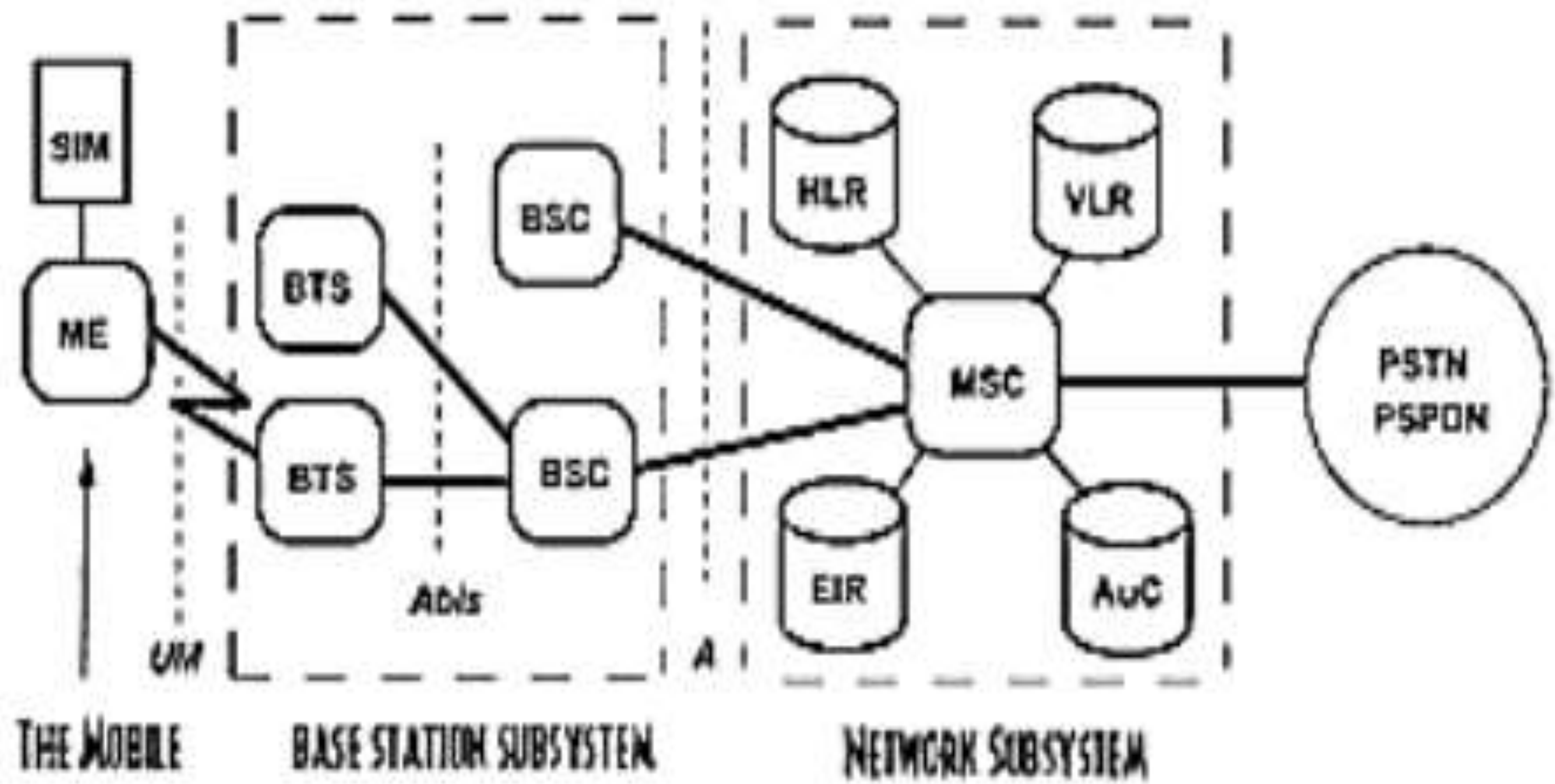


Fig: GSM architecture

Code Division Multiple Access

Code **D**ivision **M**ultiple **A**ccess (CDMA) is a digital cellular technology for mobile communication. CDMA provides the base for modern technologies like CDMA One, CDMA2000, and WCDMA.

CDMA plays an important role in building more secure radio communication systems.

Comparison between CDMA and GSM

S.No.	GSM	CDMA
1.	Global System for Mobile communication	Code Division Multiple Access
2.	FDMA(Frequency division multiple access) and TDMA (Time division multiple access) Technology	CDMA (Code division multiple access) Technology
3.	Low cost mobile and base stations	Higher cost mobile and base stations
4.	900MHz, 1800MHz, and 1900MHz bands	800MHz to 1900MHz bands
5.	GSM is less secure	CDMA is more secure
6.	Lower data rates	High data rates
7.	Worldwide roaming	Limited roaming
8.	Less prone to radiation emission	More prone to radiation emission

Introduction to 3G & 4G

Unit-5

3G/UMTS/IMT-2000

- High Speed Data Service
- Data Rates up to 2Mbps
- Internet/ Multimedia Applications

  (Whatsapp)

Video Streaming

TV Broadcast

Video Calls

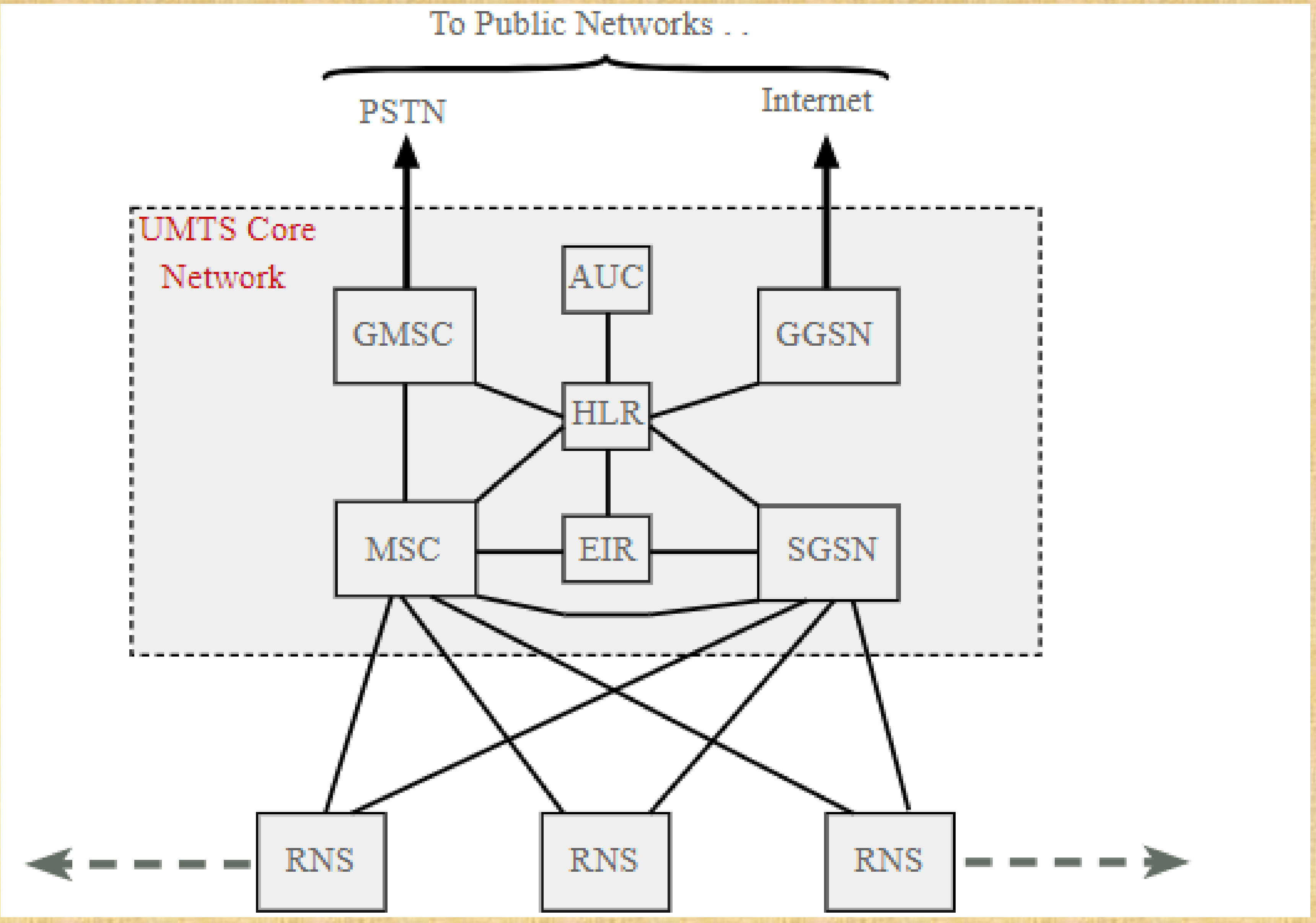
2G & 3G Comparison

Technology	2G	3G
Access Technique	TDMA	WCDMA
Carrier Bandwidth	200KHz	5MHz
Frame Length	4.6ms	10ms
Hand Off	Hard & Soft	Soft

3G+

- HSPA(High Speed Packet Access)
- HSUPA 3.6Mbps
- HSDPA 7.2Mbps
- HSUPA+ 22Mbps
- HSDPA+ 168Mbps

Architecture



4G/LTE

- Data rates may vary from 100Mbps to 1Gbps
- Based on IP based switching
- Improved Latency
- Support of Scalable Bandwidth
- FDD & TDD
- Uplink   SC-FDMA
- Downlink OFDMA

Comparison of 3G & 4G

Technology	3G	4G
Frequency Band	1.8-2.5GHz	2-8GHz
Band width	5-20MHz	100MHz
Data Rate	2Mbps	1Gbps
Switching	Circuit/Packet	Packet
Internet	Broadband	Ultra broadband

5G

- Heterogeneous traffic & users
- OMA
- NOMA
- Very Efficient Latency
- B/W (450MHz-6GHz and 24.25GHz-52.6GHz)

Application of 5G

- Faster Phones
- Wearable Device
- Remote Controlled Devices(Drones)
- Smart Vehicles
- Broadband access anywhere
- Smart Homes
- Sensors in industry/Govt. offices/traffic control etc.

Bad Effects of Mobile Phones

- Impaired Concentration
- Bacteria and Germs Transmission
- Eye problem
- Risk to Unborn
- Neurodegeneration disorder
- Heart Risk
- Loss of Hearing
- Brain Cancer

How to reduce the risk

- Avoid to use phone in low coverage area
- Hold the phone from bottom
- Avoid calls use text(SMS)
- Shorten the call duration
- To use phone outdoor
- Use wired earphone/headphone
- Switch off phone when not in use

Troubleshooting GSM Mobile Phone

Unit-6

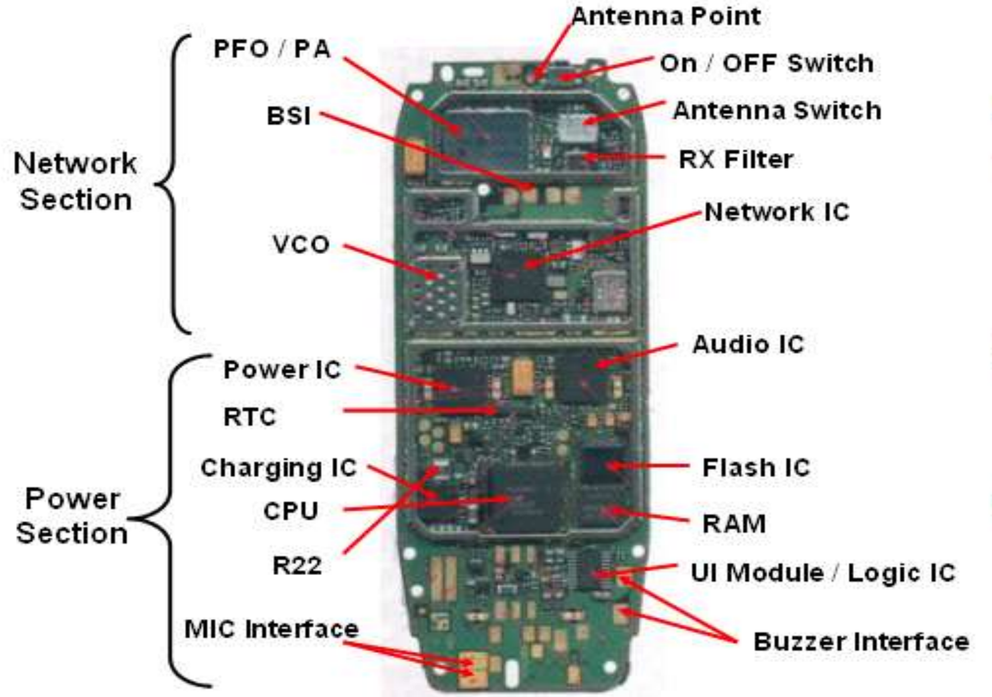
There may be some fault in the device due to many reasons like

1. Long use
2. Heating
3. Improper use
4. Effect of weather
5. Water
6. Improper Charging
7. Raditions
8. Etc.

Common Problems

- Not Charging
- Voice is not clear
- Person on other side not getting your voice
- No Display
- No light in display
- Not ringing
- No network
- Keypad is not working
- Fast battery discharge
- Etc.

Nokia 3310 Mobile Phone PCB Diagram



NOTES:

1. UEM =
   Logic IC
   + Charging IC
   + Audio IC
   + Power IC

2. PFO =
   Antenna
   Switch
   + PFO

3. Flash IC =
   RAM + Flash
   IC

http://www.mobilecellphonerepairing.com/

Network Fault Antenna Switch, PFO, FEM, RF IC, VCO, RX-Filter, TX-Filter, RF Antenna, RF Crystal, External Antenna Socket, Network Signal and Supply Control and Interface Section.

- 2. Power ON Fault
- Battery (*3.7 V*), Battery Connector Jack, Power IC, CPU, Flash IC, S-RAM IC, RF Crystal, RF Clock Section Component, RF IC, Power ON / OFF Trigger Components.

3. Charging Fault
Charger (*5-6 V*), Battery (*3.7 V*), Charger Connector, Charger Volt Fuse, Coil, Charger Over Volt Protector, Charging IC, Power IC, Charging Regulator, Charging Volt Output Components, Charger and Charger Volt Detector Components.
4. SIM Fault
SIM Card, SIM Socket, SIM Signal and Supply Interface Components, Resistance, Coil, Power IC, CPU etc.
5. Ringer Fault
Ringer, Ringer Signal Input and Output Components, Audio Amplifier IC, Power IC, CPU etc.

6. Ear Speaker Fault

Ear Speaker, Ear Speaker Signal Components, Audio Amplifier IC, CPU, Power IC etc.

7. Micro SD Card Fault / MMC Fault

Micro SD Card, Micro Card Connector, Micro Card Detector Switch, Micro Card Detector Signal Components, CPU etc.

8. USB and Bottom Connector fault

USB and Bottom Connector, USB and Signal Interface Connector Components, USB Signal Interface IC, USB Driver IC, CPU etc.

9. Keypad Fault

Key Tip, Key Pad Dot Sheet, Key Signal Filters, Key Signal Varactors, Key Board to Key Connector, CPU etc.

10. Display Fault

LCD, LCD Connector, LCD Supply Components, LCD Signal Interface Filter IC, CPU, LCD Signal Interface Resistance etc.

11. MIC Sound Fault

MIC, MIC Interface Connection, MIC Signal and Supply Components, Power IC, CPU etc.

12. Backlight (LED) Fault

LED, Backlight Driver IC, Backlight Driver Section Components, Power IC, CPU etc.

13. Bluetooth Fault

Bluetooth Antenna, Bluetooth Driver IC, Bluetooth Section Crystal, CPU etc.

14. FM Radio Fault

Hands Free Lead, Hands Free Connector, FM and Bluetooth IC,FM Driver IC, CPU etc.

15. Vibrator Fault

Vibrator Motor, Vibration Supply Components, Power IC, Vibrator Driver IC etc.