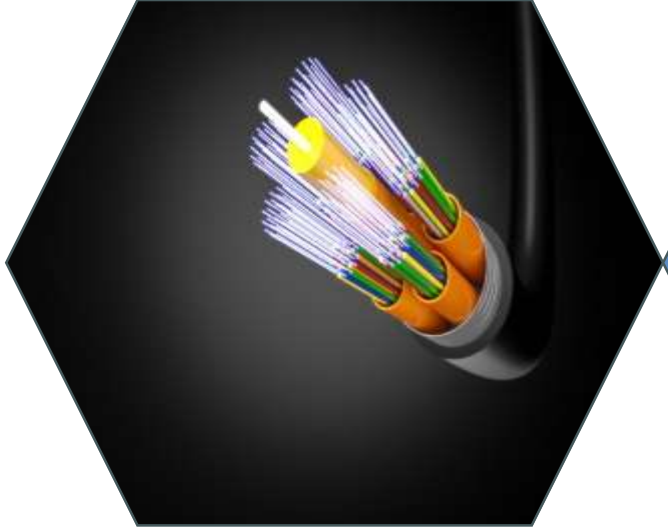

Communication Theory -II

Prepared by :
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Basic Course Information

Course Title	Communication Theory-II
Course Code	EEE 437
Credit	03
Marks	150

SYNOPSIS/RATIONALE

Radar, satellite, and optical communication systems play a critical role in modern technology, enabling advancements in defense, remote sensing, global connectivity, and high-speed data transmission. The integration of these technologies serves diverse applications, from weather monitoring and global navigation to scientific research and high-capacity communication networks.

OBJECTIVE

- To provide students with a comprehensive understanding of radar, satellite, and optical communication technologies, their principles, and their applications in modern industries. The course aims to equip learners with the knowledge and skills necessary to design, analyze, and implement these systems for diverse engineering and scientific applications.

Course Learning Outcome (CLO)

CLO1:

Demonstrate a comprehensive understanding of the fundamental principles, underlying physics, and engineering concepts of radar, satellite, and optical communication systems.

CLO2

Evaluate the performance characteristics and limitations of these systems under different operational scenarios and environmental conditions.

CLO3

Design and simulate basic radar, satellite, and optical communication modules using modern engineering tools and software.

CLO4

Address real-world challenges by applying communication system principles in applications such as defense, global connectivity, and remote sensing.

ASSESSMENT PATTERN

CIE- Continuous Internal Evaluation (90 Marks)

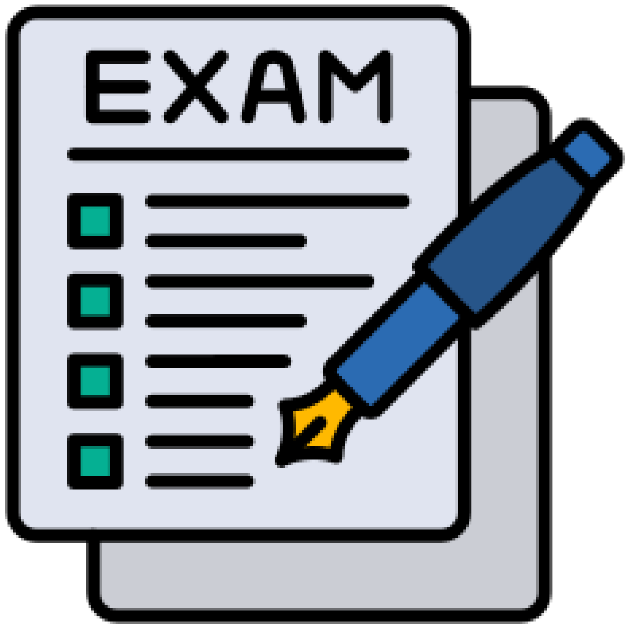
Bloom's Category Marks (out of 90)	**Tests Mid-term (45)**
Remember	08
Understand	08
Apply	08
Analyze	08
Evaluate	08
Create	05

Class Test	**15**
Presentation	**15**
Attendance	**15**

ASSESSMENT PATTERN

SEE- Semester End Examination (60 Marks)

Bloom's Category	Tests
Remember	10
Understand	10
Apply	10
Analyze	10
Evaluate	10
Create	10



COURSE CONTENT

1. **Introduction to Communication** SystemsOverview of communication technologies.Significance of radar, satellite, and optical systems.

2. **Radar Communication** Principles of radar operation: Transmission, reception, and signal processing.Applications: Weather forecasting, surveillance, and navigation.Advances in radar technologies: Phased arrays and synthetic aperture radar.

3. **Satellite Communication** Fundamentals of satellite orbits and frequency bands.Communication subsystems: Transponders, antennas, and ground stations.Applications: Telecommunications, navigation (GPS), and remote sensing.Emerging trends: LEO constellations and satellite internet.

4. **Optical Communication** Basics of light-based communication and fiber optics.Free-space optical communication (FSO) and inter-satellite links.Advantages, challenges, and innovations in optical communication.

Course Schedule

Week	Course Content	Teaching-Learning Strategy	Sources	Assessment Strategy	Aligned CLOs
1	Basic characteristics of sinusoidal functions, signal transmission concepts, types of communication media, principles of fiber optic communication	Lectures, discussions, visual aids	Slides, textbooks	Quiz, participation, short exercises	CLO1, CLO2
2	Twisted pair cable and coaxial cable characteristics, transmission media types	Demonstrations, problem-solving	Slides, practical examples	Hands-on activities, worksheet	CLO1
3	Wireless and satellite propagation principles	Case studies, group discussions	Research papers, slides	Quiz, group presentations	CLO1, CLO3
4	Basics of light-based communication, numerical aperture, and refraction concepts	Experiments, interactive problem-solving	Lab manuals, slides	Lab report, quiz	CLO1, CLO2, CLO4
5	Total internal reflection, single and multi-mode fibers, optical fiber properties	Interactive lectures, Q&A sessions	Textbooks, slides	Worksheet, participation	CLO1
6	Optical communication systems: connectors, advantages, and limitations	Visual aids, discussions	Research papers, slides	Midterm exam	CLO1, CLO3

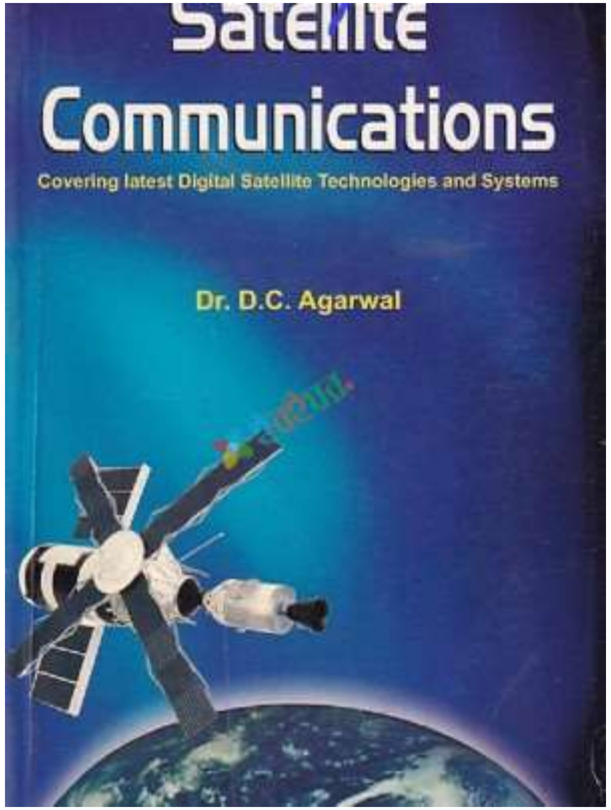
Course Schedule

7	Radar communication: principles, applications, and advances	Lectures, practical case analysis	Reference books, slides	Case study analysis	CLO1, CLO4
8	Satellite communication: orbits, subsystems, applications	Interactive discussions, group projects	Videos, slides	Group presentation	CLO1, CLO3
9	Satellite communication: emerging trends and challenges	Debates, research-based learning	Research papers, slides	Essay, participation	CLO2, CLO4
10	Advanced radar technologies: phased arrays, synthetic aperture radar	Demonstrations, problem-solving	Textbooks, slides	Problem-solving exercises	CLO1, CLO3
11	Optical fiber innovations, free-space communication	Discussions, hands-on sessions	Lab manuals, slides	Lab report, short presentation	CLO2, CLO3
12	Optical communication applications in telecommunications and medical fields	Lectures, case studies	Textbooks, slides	Participation, quiz	CLO1, CLO4

Course Schedule

13	Radar: noise, clutter, and interference management	Problem-solving, group discussions	Research papers, slides	Problem-solving exercises	CLO2, CLO3
14	Satellite system innovations: LEO, MEO, and GEO satellites	Interactive sessions, case analysis	Research papers, slides	Group presentation	CLO1, CLO3
15	Advances in optical fiber technology: Graded-index fibers and innovations	Discussions, hands-on activities	Lab manuals, slides	Lab report	CLO1, CLO2
16	Review of radar, satellite, and optical communication systems	Summary lectures, brainstorming	All previous materials	Comprehensive test	CLO1, CLO2, CLO3, CLO4
17	Real-world problem solving: integrated communication system design	Capstone project, presentations	Research papers, slides	Final project evaluation	CLO2, CLO3, CLO4

Reference Books

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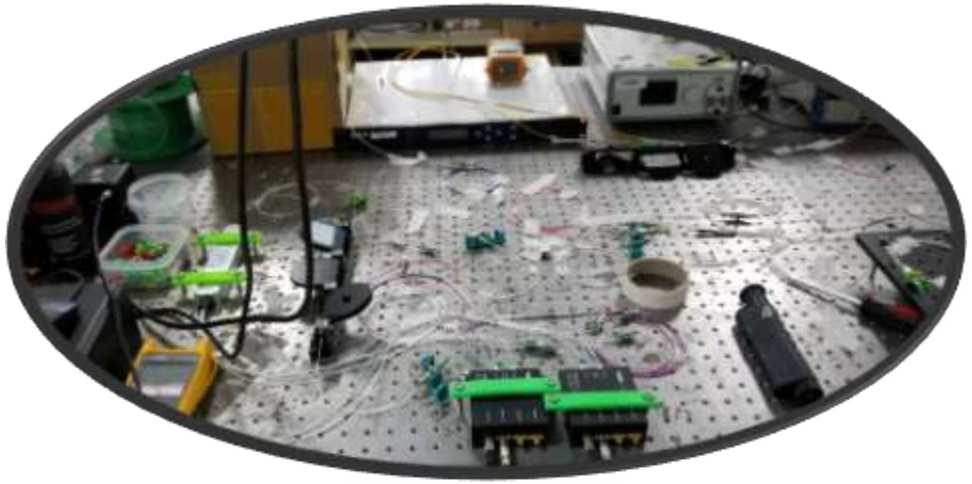
COMMUNICATION MEDIA

- ❖Basic concepts of signal transmission in transmission media
- ❖Types of communication media
- ❖Principles of fiber optic communication
- ❖Twisted pair cable and coaxial cable
- ❖Wireless and satellite propagation



TRANSMISSION MEDIA

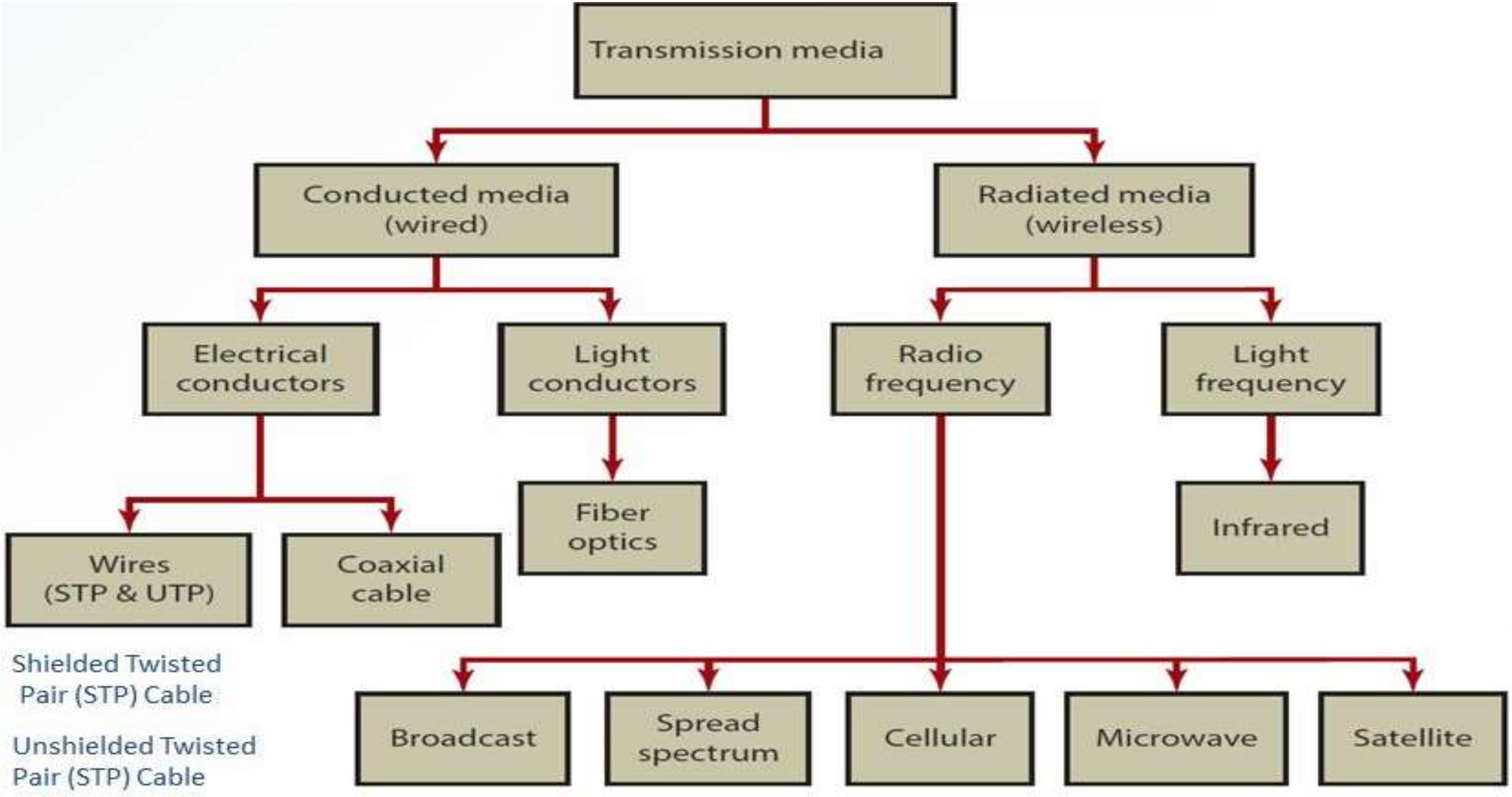
- A transmission medium in communication is the path traveled by the communication signal from the transmitter to the receiver. Several design factors relating to the transmission medium and the signal determine the data rate and distance.

- For each transmitter-receiver pair, the bit is sent by propagating electromagnetic waves, electrical pulses, or optical pulses across a medium.

- The physical medium can take many shapes and forms and does not have to be of the same type for each transmitter-receiver pair along the path.

- The greater the bandwidth of a signal, the higher the data rate that can be achieved. Impairments, such as attenuation, limit the distance. For guided media, twisted pair generally suffers more impairment than coaxial cable, which in turn suffers more than optical fiber.

TYPES OF TRANSMISSION MEDIA



FREQUENCIES AT WHICH VARIOUS GUIDED MEDIA AND UNGUIDED TRANSMISSION TECHNIQUES OPERATE

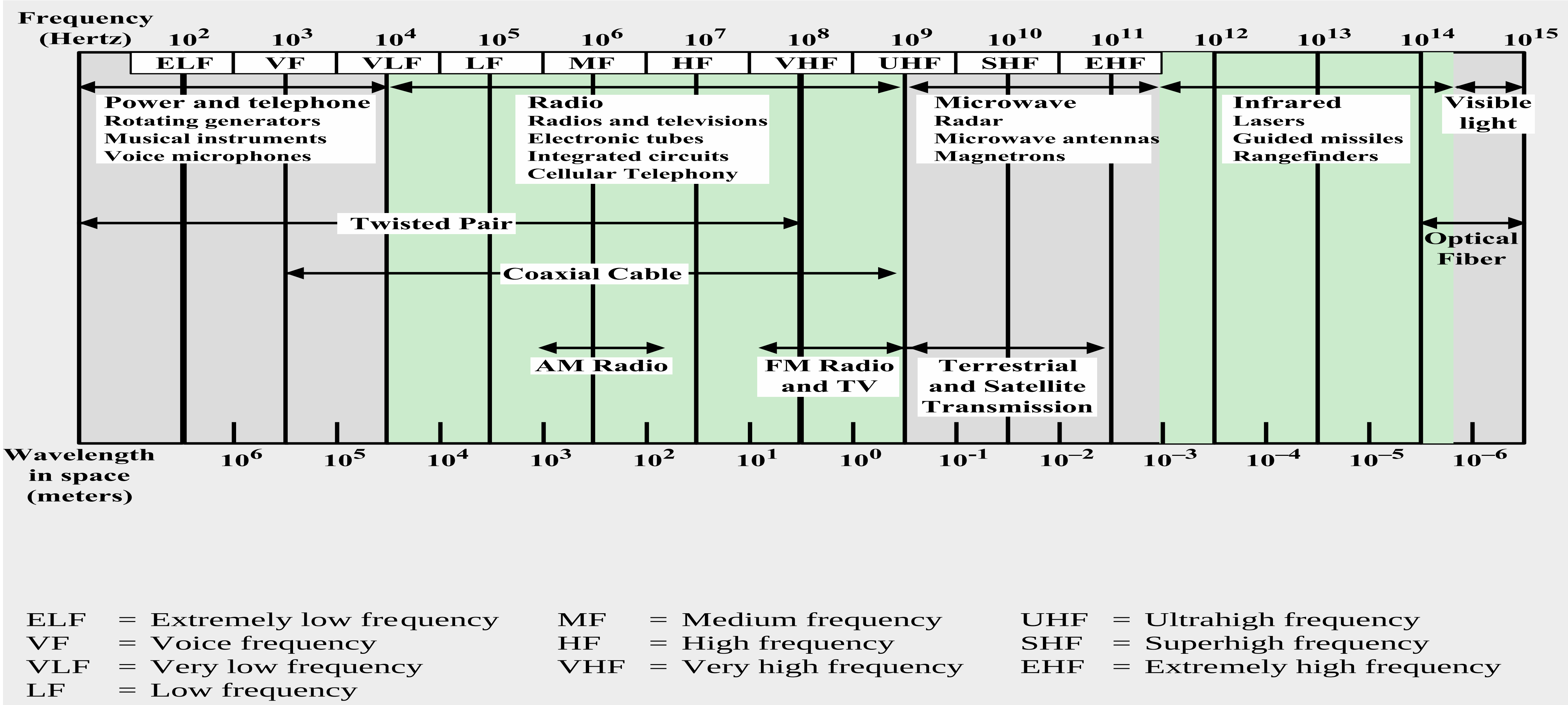


Figure 1: Electromagnetic Spectrum for Telecommunication

NATURE OF LIGHT

- Light is an electromagnetic wave (Electric field and magnetic field). Sometimes light behaves as a wave and sometimes light behaves as a particle.
- According to the electromagnetic theory of light, light has all the characteristics of electromagnetic waves, which can be described by Maxwell Equations.

- **Particle Characteristics**
  - Light has energy
  - Light is made up of particles called photons (the smallest quantity of monochromatic light)
  - The energy of a photon is described by $E_p = hf$, where f is the frequency of light and h = 6.626 x 10^{-34} J*s (Planck's constant).
  - Energy of light depends on its speed: $E=mc^2$ (Einstein's Equation.)
  - The speed of light changes as it enters denser materials

- **Light is electromagnetic radiation**
  - Impacted by many parameters: reflection, refraction, loss, polarization, scattering, etc.

NATURE OF LIGHT

- Most of the frequencies in fiber optic systems are in the Infrared. Wavelength and frequency are related by: $\lambda = \frac{v}{f}$

where *v* is the velocity of the wave in the medium. In free space, v = c = 3 x10^8 m/s.

- All materials slow down the light waves, so $v < c$ in all materials.

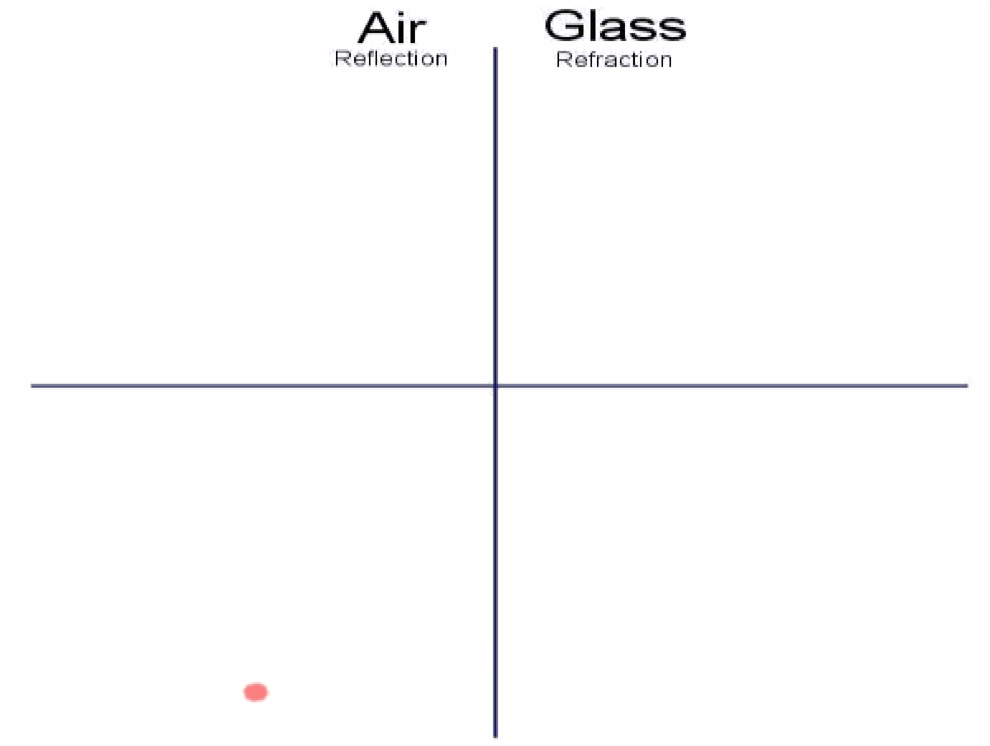
- **Example 1:** If the wavelength (λ) of a signal is 0.85 μm, find the frequency and period. In this example the medium is not specified, so let us assume that the medium is free space.

$$f = \frac{c}{\lambda} = \frac{3\times 10^8\, m/s}{0.85\times 10^{-6}\, m} = 3.53\times 10^{14}\, Hz$$

$$T = \frac{1}{f} = \frac{1}{3.53\times 10^{14}\, Hz} = 0.28\times 10^{-14}\, s$$

RULES FOR RAYS

- A ray describes the direction of wave propagation.
  - Constant speed is decided by the refractive index
  - Travels straight in a homogeneous medium
  - Reflection occurs at the surface
  - Refraction occurs at the boundary
  - Reflection: Incidence angle equals reflection angle
  - Refraction: Snell’s law



REFRACTION

- Refraction is the "bending" of light rays when light moves from one medium to a different one. It takes place because light travels at different speeds in different media. The speed of light in a vacuum is $c = 3\text{x}10^8$ m/s. The index of refraction of a material is defined by: $n = \frac{c}{v}$

where ***c*** is the speed of light in a vacuum and ***v*** is the speed of light in the material, ***n*** is the refractive index.

- **Example:** Calculate the speed of light in diamond (n = 2.42), alcohol (1.329), ice (1.309), salt (1.544), sugar solution 80% (1.49)

$$v = \frac{c}{n} \qquad v = \frac{3\times10^8 \text{ m/s}}{2.42} \qquad v = 1.24\times10^8 \text{ m/s}$$

LAW OF REFRACTION

- **Snell's "Law"**, also called the law of refraction, gives the relationship between angles and indices of refraction:

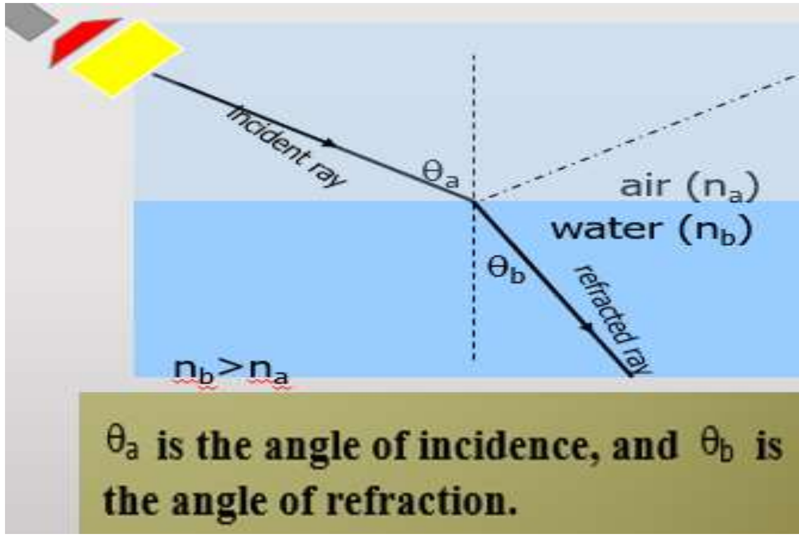
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

n_1 = incident index

n_2 = refracted index

θ_1 = incident angle

θ_2 = refracted angle



- When light travels from a medium with a smaller index of refraction to a medium with a larger index of refraction, it bends toward the normal.
- When the light goes from a medium with a larger index of refraction to a medium with a smaller index of refraction, it bends away from normal.

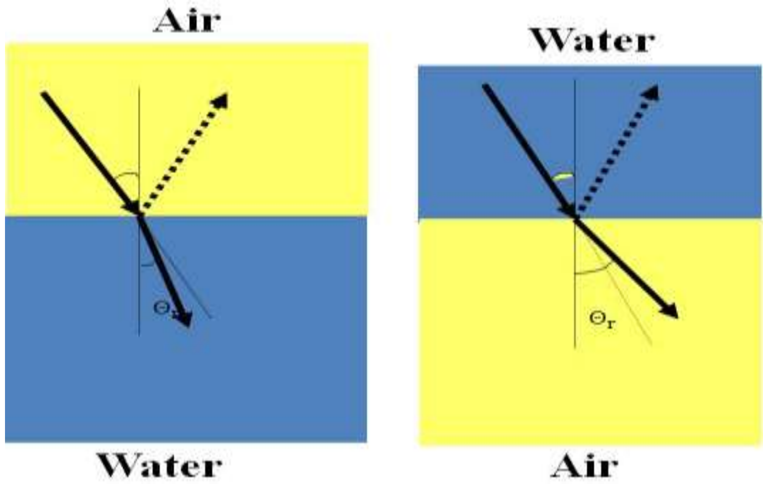


Figure 3: Angles and indices of refraction

TOTAL INTERNAL REFLECTION

- When a ray of light strikes a medium boundary at an angle larger than a particular **critical angle** with respect to the normal to the surface, all of the light is reflected.
- **Total internal reflection is the complete reflection of a light ray reaching an interface with a less dense medium when the angle of incidence exceeds the critical angle.**

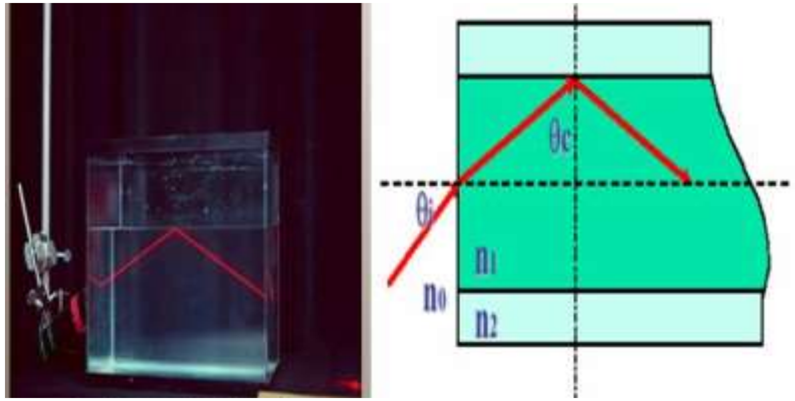
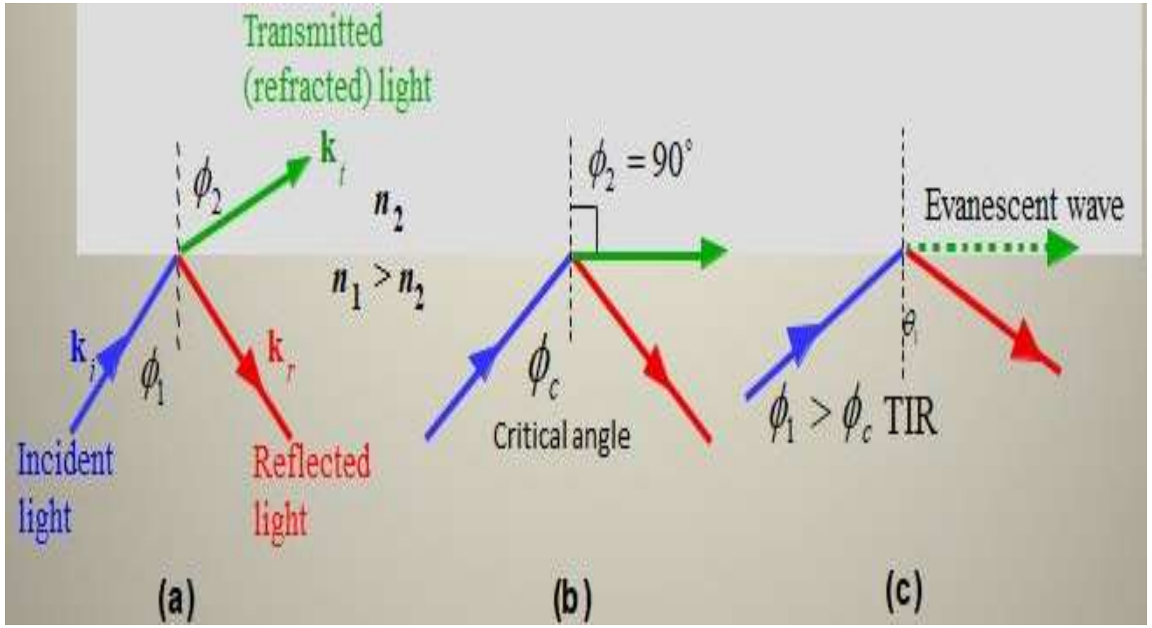


Figure 4: Total internal reflection



$$\phi_1 < \phi_c$$
$$\phi_1 = \phi_c$$
$$\phi_1 > \phi_c$$
$$\sin \phi_c = \frac{n_2}{n_1}$$

- ***Light wave traveling in a more dense medium strikes a less dense medium. Depending on the incidence angle with respect to the ϕ_c , the wave may be transmitted (refracted) or reflected.***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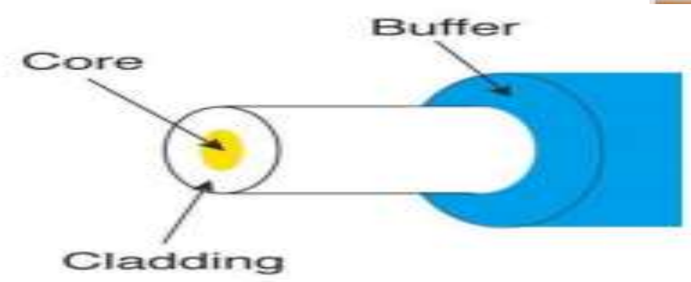
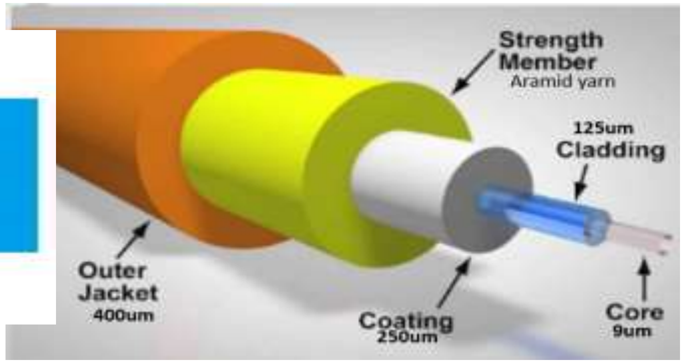
BASIC FIBRE PROPERTIES

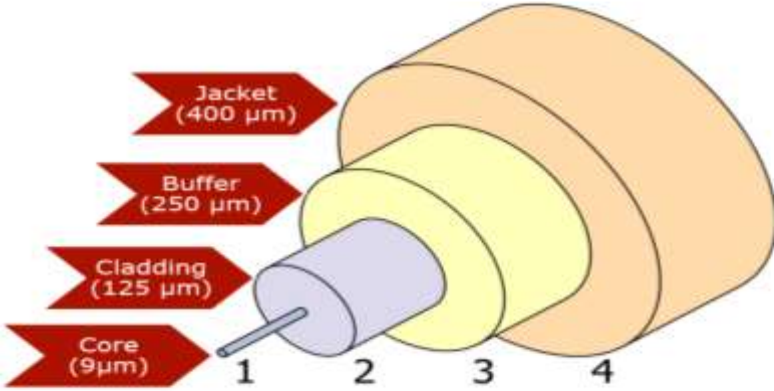
❖ Optical fiber cable is a high-speed data transmission medium. The capacity of fiber optic transmission capacity is over a thousand times more than copper's. It is capable of transmitting large amounts of data.

❖ It is:

- cylindrical
- dielectric
- waveguide
- low loss
- usually fused silica (SiO_2)



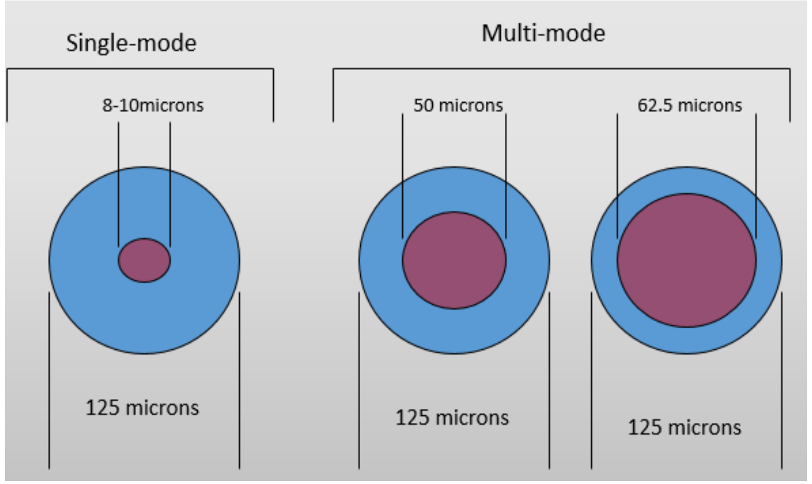


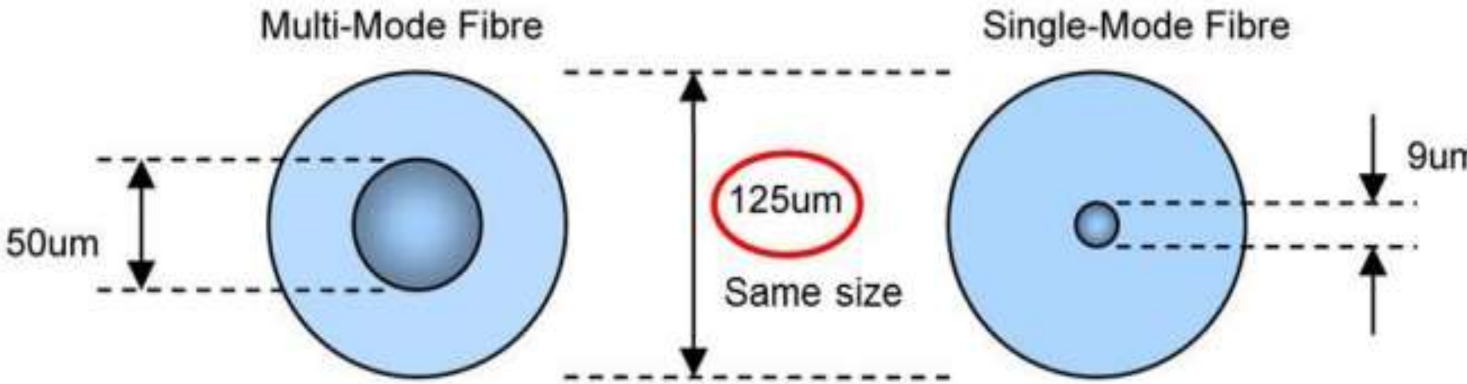


❖ The **optical fiber** is a device that works on the principle of **Total Internal Reflection (TIR)** by which light signals can be transmitted from one place to another with a negligible loss of energy.

BASIC FIBER PROPERTIES

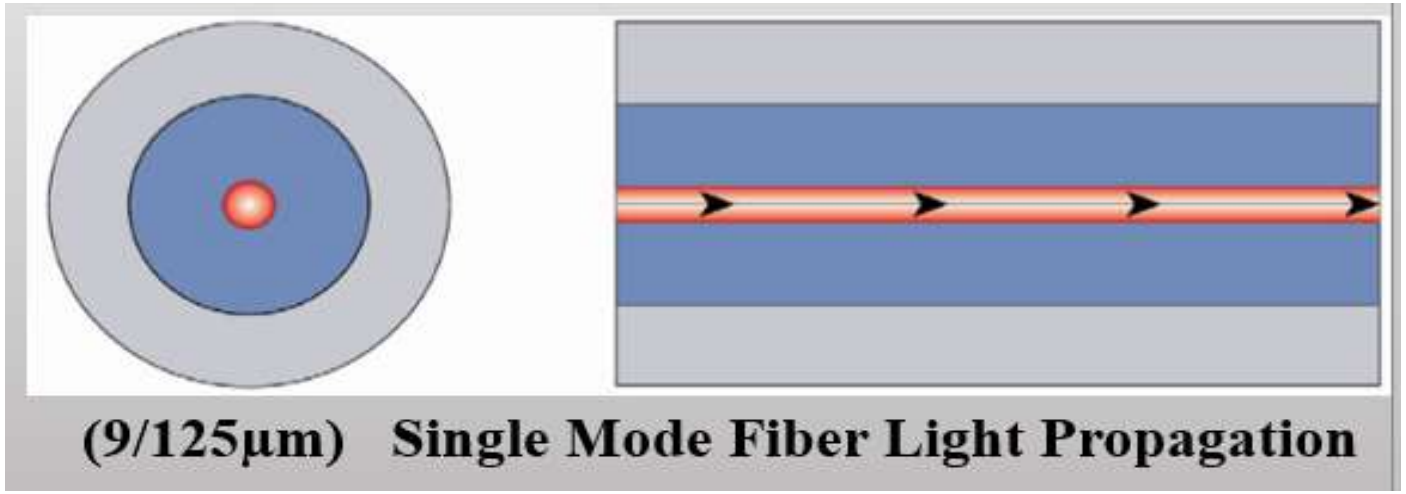
- The **optical core** is the light-carrying component of the fiber. The **cladding** surrounding the core is made of pure silica and has a slightly lower index of refraction than the core. This lower refractive index causes the light in the core to reflect when encountering the cladding and remains trapped within the core. Buffer coat acts as a shock absorber to protect the core and cladding from damage.
- Operation is based on total internal reflection. There are two main types of fiber optic cables. These are Single Mode Fiber (SMF) and Multi-Mode Fiber (MMF). It is impossible to differentiate between SMF/SSMF and MMF with the naked eye. There is no difference in the outward appearances; both are 125 microns in size - only the core size differs.





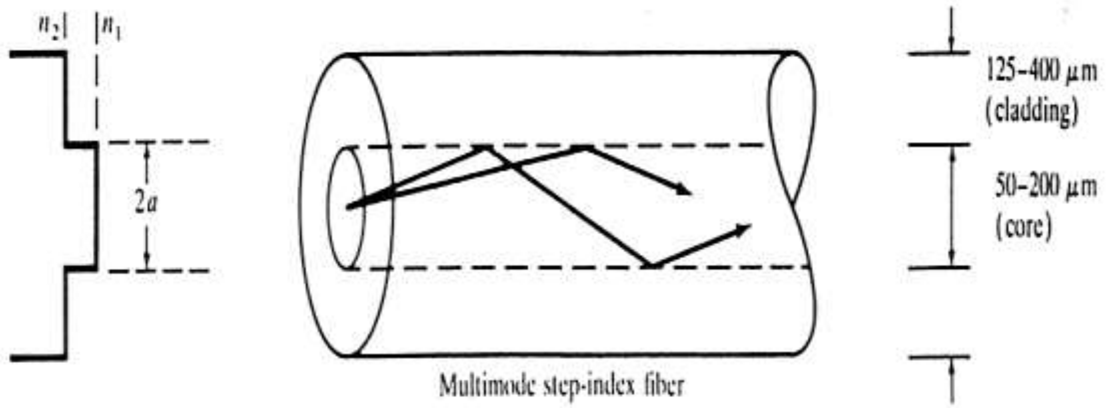
BASIC FIBER PROPERTIES (SMF/SSMF)

- ❖ It is used in all long-haul applications (supports long-distance transmission)
- ❖ Has a core diameter of 9 microns
- ❖ Its numerical aperture is very small
- ❖ It supports only one mode in which the entire light energy is concentrated.
- ❖ The single-mode fibers carry higher bandwidth than multimode fibers.
- ❖ It requires a monochromatic and coherent light source (laser diodes)
- ❖ Less attenuation

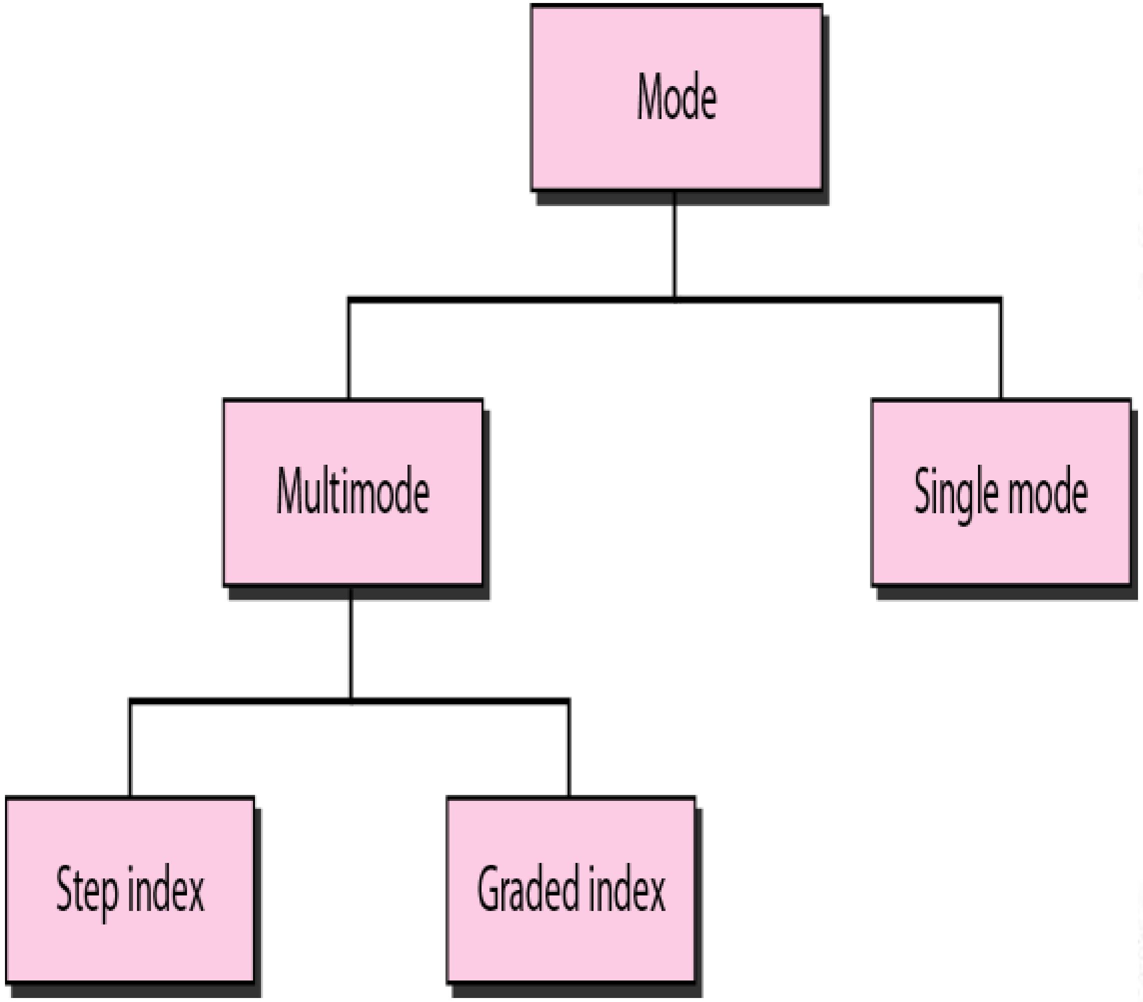


BASIC FIBER PROPERTIES (MMF)

- MMF has a much wider core (typically 50µm or 62.5µm)
- Allows multiple modes of light to propagate
- The larger core diameter of MMF facilitates the use of lower-cost optical transmitters
- It is relatively easy to work with
- Light is easily coupled to and from it
- Sources like LEDs can be used as high sources with multimode fibers
- Coupling losses are less than those of the single-mode fiber
- Larger numerical aperture allows more modes, which causes larger dispersion. The dispersion is mostly intermodal
- Attenuation is high



OPTICAL FIBER TRANSMISSION MODES



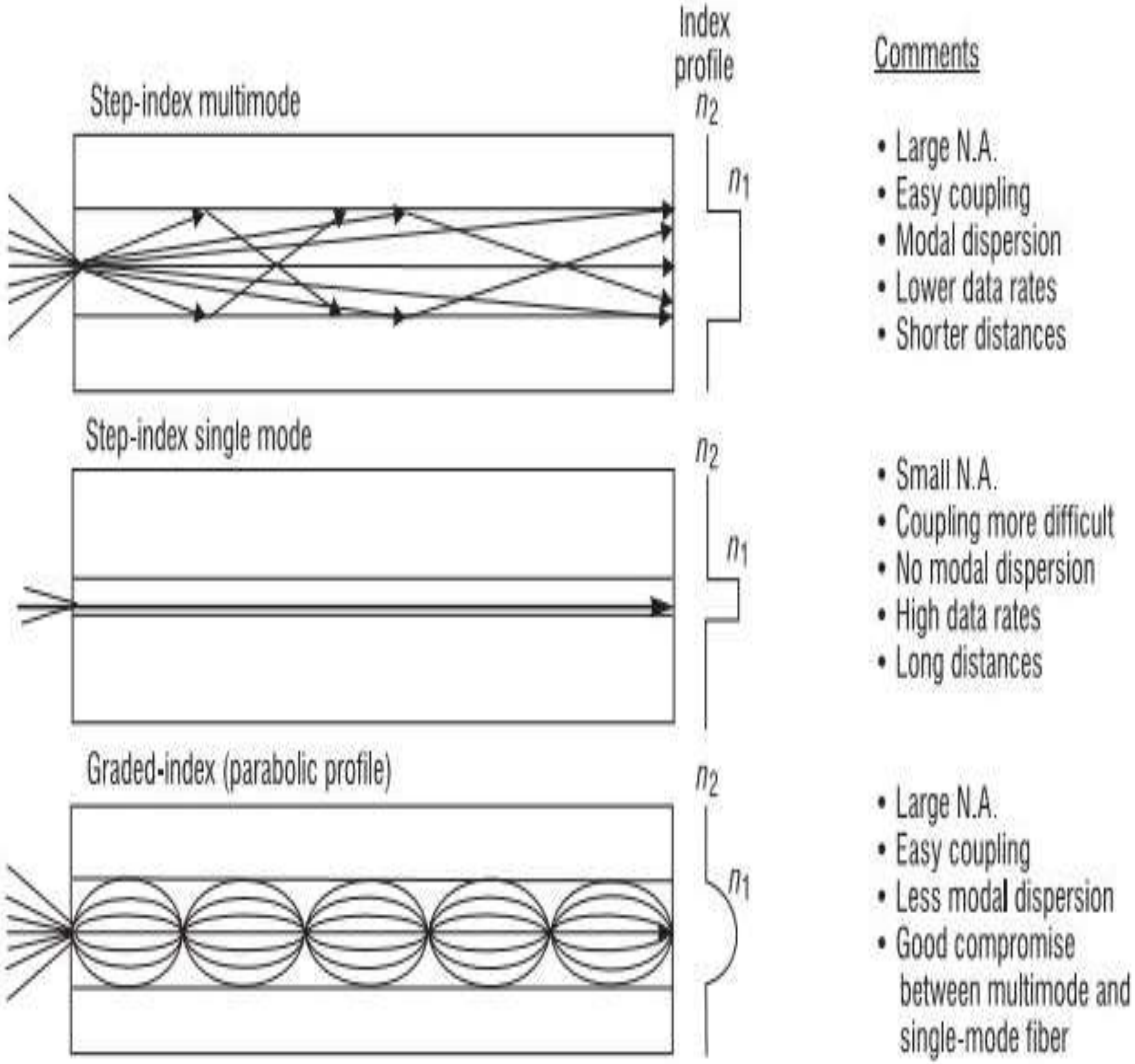


Figure 3: Propagation modes

OPTICAL FIBER TRANSMISSION MODES

- **Single-mode step-index fiber:** Single-mode step-index fiber allows for only one path, or mode, for light to travel within the fiber. The core diameter of a typical single-mode fiber is between 5 μm and 10 μm with a 125 μm cladding. Single-mode fibers are used in applications in which low signal loss and high data rates are required.
- **Step-index multimode fiber:** Step-index multimode fiber has a relatively large core diameter and numerical aperture. The core/cladding diameter of a typical multimode fiber used for telecommunication is 62.5/125 μm. The term “multimode” refers to the fact that multiple modes or paths through the fiber are possible. Step index multimode fiber is used in applications that require relatively short distances (< 3 km) such as a local area network or a campus network backbone.
- **Graded-index fiber:** Graded-index fiber is a compromise between the large core diameter and N.A. of multimode fiber and the higher bandwidth of the single-mode fiber. With the creation of a core whose index of refraction decreases parabolically from the core center toward the cladding, light traveling through the center of the fiber experiences a higher index than light traveling in the higher modes. This means that the higher-order modes travel faster than the lower-order modes, which allows them to “catch up” to the lower-order modes, thus decreasing the amount of modal dispersion, which increases the bandwidth of the fiber.

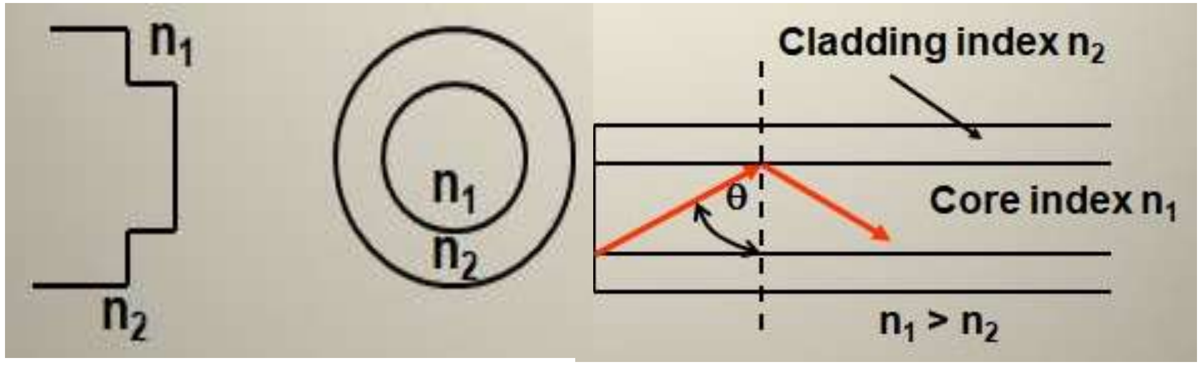
STEP-INDEX FIBER

Step Index Fiber (SI Fiber) single-mode fiber

$$\sin\theta_c = \frac{n_2}{n_1}$$

The fractional refractive index change:

$$\Delta = \frac{n_1 - n_2}{n_1}$$



Fiber	n_1	n_2	NA	α_o
All-glass	1.48	1.46	0.24	13.9°
Plastic-Clad Silica	1.46	1.4	0.41	24.2°
All-plastic	1.49	1.39	0.53	32°

Example: Compute α_o for an all-glass fiber having NA = 0.24.

Answer: $NA = n_o \sin\alpha_o = \sqrt{n_1^2 - n_2^2}$

If n_o= 1 (air), we have that

$$\sin\alpha_o = 0.24$$

$$\alpha_o = 14° \qquad 2\alpha_o = 28°$$

α_o **is the half angle of the acceptance cone.**

GRADED-INDEX FIBER (GRIN)

- One approach to minimize dispersion in a multimode fiber is to use a graded index fiber (GRIN). The index of refraction in the core has an engineered profile. This will result in the different modes propagating along the fiber at close to the same speed ***(velocities along the paths)***. The GRIN, therefore has less of a dispersion problem than a multimode step index fiber.

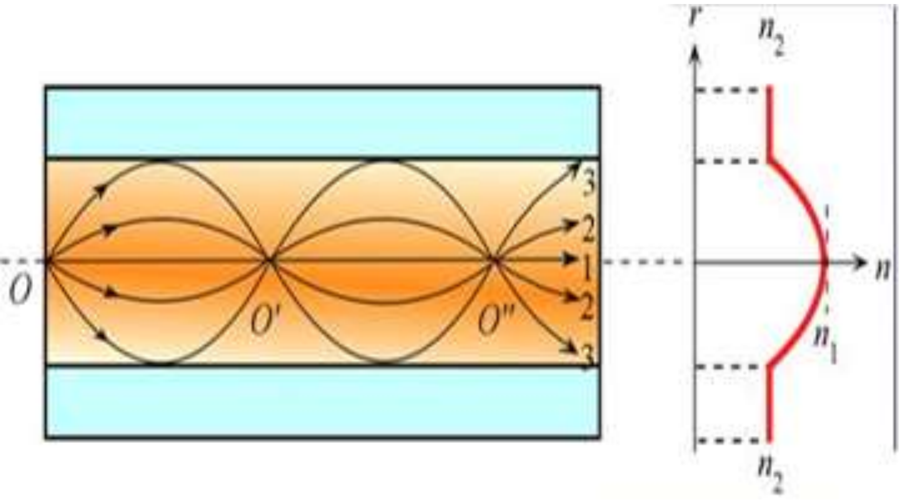


Figure 4: Graded Index (GRIN) Fiber

- The refractive index of graded index fiber in the mathematical term is expressed as:
- **In the core**:

$$n(r) = n_1\sqrt{1-2\left(\frac{r}{a}\right)^{\alpha}\Delta}, \quad r \le a$$

- ***a*** is the radius of the core
- ***r*** is the radial distance from the core axis
- α is a design parameter. It is usually close to 2

GRADED-INDEX FIBER (GRIN)

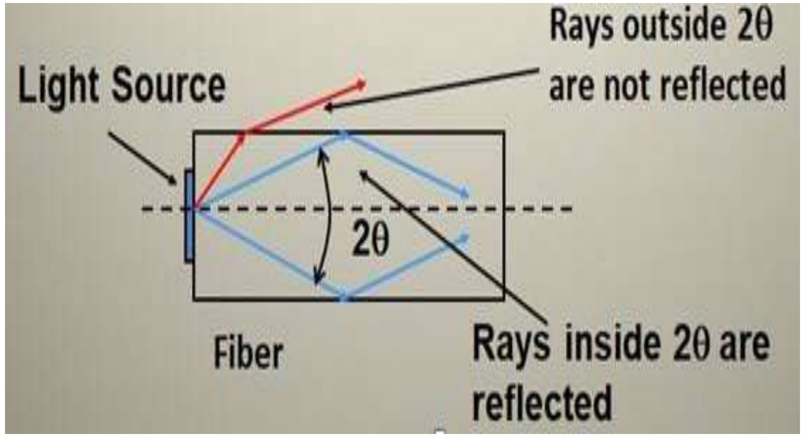
In the cladding

$$n(r) = n_1\sqrt{1-2\Delta} = n_2, \qquad r \geq a$$

Δ refractive index change

The mode volume for parabolic profile $M \approx \dfrac{V^2}{4}$

$$\Delta = \frac{n_1 - n_2}{n_1}$$

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NUMERICAL APERTURE OF OPTICAL FIBER

- **Numerical Aperture (NA) is the measure of the ability of an optical fiber to collect or confine the incident light ray inside it.** It is among the most basic property of optical fiber.

OR

- **NA shows the efficiency with which light is collected inside the fiber to get propagated.** Numerical aperture determines the light-gathering ability of the fiber. **It is a measure of the amount of light that can be accepted by a fiber**

- The light-gathering efficiency of an optical fiber is the key characteristic while transmitting a signal through an optical fiber. NA is related to the **acceptance angle**. Typical fibers have an NA in the range of 0.1 to 0.5.

- ***The acceptance angle is the maximum angle through which light enters the fiber. Hence the acceptance angle and numerical aperture are related to each other.***

NUMERICAL APERTURE

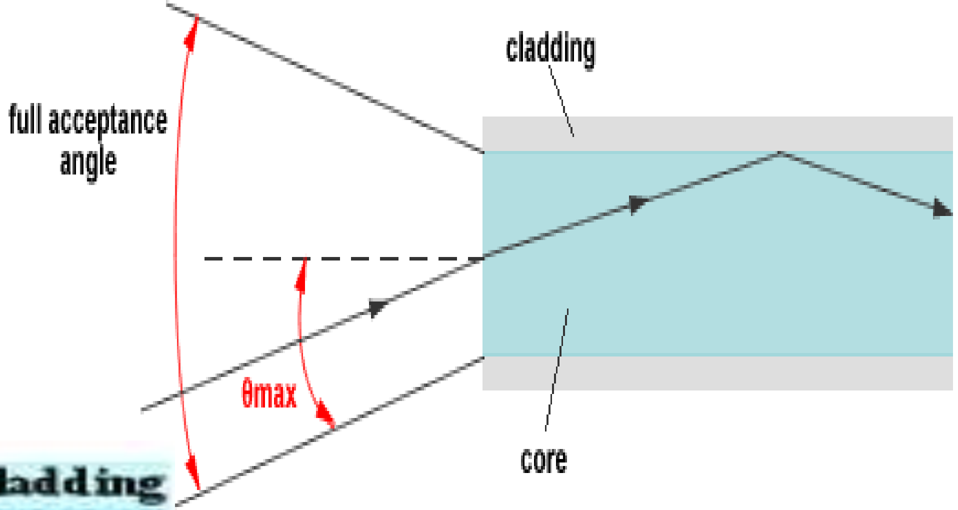
❖The numerical aperture NA is defined as the sine of the acceptance angle. $NA = \sin\theta_0$

$$\sin\theta_0 = \sqrt{{n_1}^2 - {n_2}^2}$$

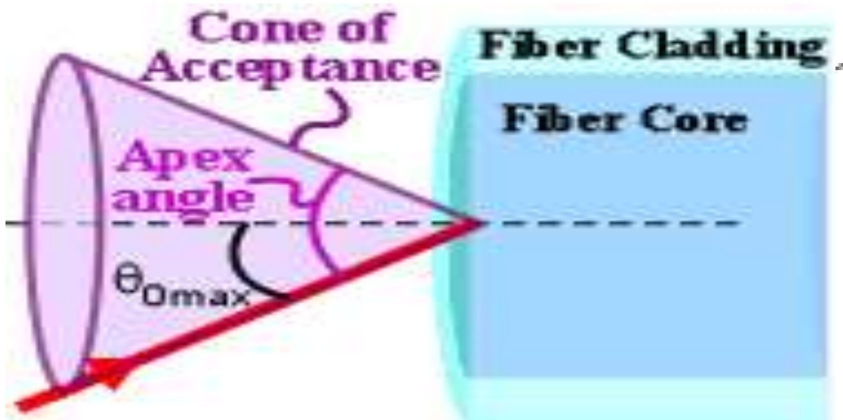
$$\therefore NA = \sqrt{{n_1}^2 - {n_2}^2}$$

$$NA = n_1\sqrt{2\Delta}$$

- The light rays within the acceptance cone can propagate through total internal reflection.



$$\mathrm{NA} = n\sin\theta_{0\max} = \sqrt{n_1^{\,2} - n_2^{\,2}} \approx n_1\sqrt{2\Delta}$$



FIBER MODES

- Light propagates in optical fiber in the form of modes. Fiber mode refers to the way waves propagate down a fiber.

- The geometry of the fiber as well as the existence of waves traveling forward and backward allows only certain ray angles to propagate.

- In order to find a mode propagation constant and cut-off frequencies of various modes of the optical fiber, first, we have to calculate the **normalized frequency**, (V). **V number (normalized frequency) defines the number of possible modes for a fiber.** It is defined as:

$$V = \frac{2\pi a}{\lambda}\sqrt{n_1^{\ 2} - n_2^{\ 2}} = \frac{2\pi a}{\lambda}\mathrm{NA}$$

where ***a*** is the radius of the fiber core, λ is the wavelength of light, are the refractive indices of the core & cladding.

- For single-mode propagation, V<2.405.

FIBER MODES

1. Calculate the number of allowed modes in a multimode step index fiber when the core diameter =100 μm, core index =1.468, and cladding index of 1.447 at the wavelength of 850nm.

$$V = \frac{2\pi a}{\lambda}(n_1^2 - n_2^2)^{1/2} = 91.44, \qquad M \approx \frac{V^2}{2} = 4181,$$

2. Let n_1 = 1.48, n_2 = 1.46, core diameter = 50 μm, and λ = 0.82 μm. Find V in the multimode step index fiber.

$$V = 2\pi\left(\frac{25}{0.82}\right)\sqrt{1.48^2 - 1.46^2} = 46.5 \qquad M = \frac{V^2}{2} = \frac{(46.5)^2}{2} = 1078$$

NOTE:

- ❖ Number of modes for step index fiber $M=V^2/2$, where V is the cut off frequency or normalized frequency or V-number
- ❖ The number of modes for graded index fiber is $M=V^2/4$

FIBER MODES

3. A step-index fiber has a core diameter of 100 μm and a refractive index of 1.480. The cladding has a refractive index of 1.460. Calculate the numerical aperture of the fiber, acceptance angle from air, and the number of modes sustained when the source wavelength is 850 nm.

Solution:

Normalized refractive index
$\Delta = (n_1 - n_2) / n_1 = \mathbf{0.0135}$

The numerical aperture is

$NA = (n_1{}^2 - n_2{}^2)^{1/2} = (1.480^2 - 1.460^2)^{1/2} =$ **0.2425 or 25.3%**

From, $\sin\alpha_{max} = NA/n_o = 0.2425/1$

Acceptance angle $\alpha_{max} = \mathbf{14°}$

Total acceptance angle $2\alpha_{max} = \mathbf{28°}$

V-number in terms of the numerical aperture can be written as,

$V = (2\pi a/\lambda)NA = [(2\pi 50\ \mu m)/(0.85\ \mu m)](0.2425) = 89.62$

The number of modes, $M \approx V^2/2 = \mathbf{4016}$

BASIC FIBER OPTIC COMMUNICATION SYSTEM

- A basic fiber optic system consists of a transmitting device that converts an electrical signal into a light signal, an optical fiber cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal.

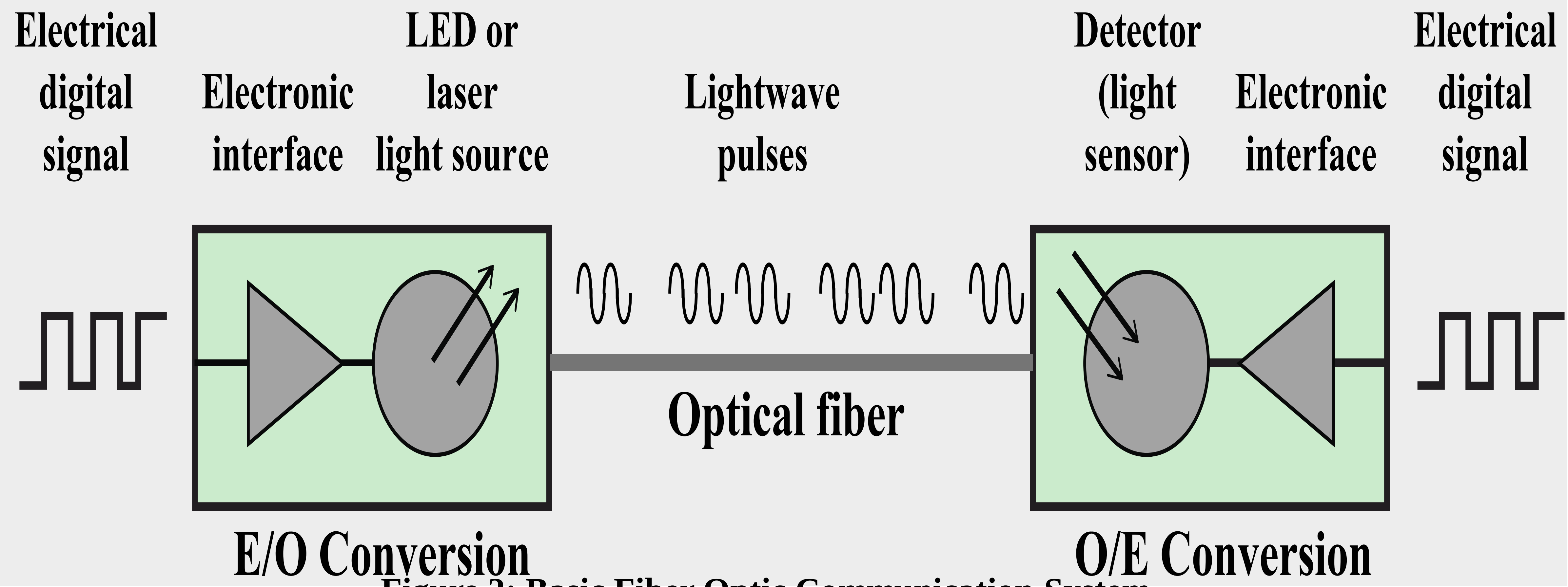


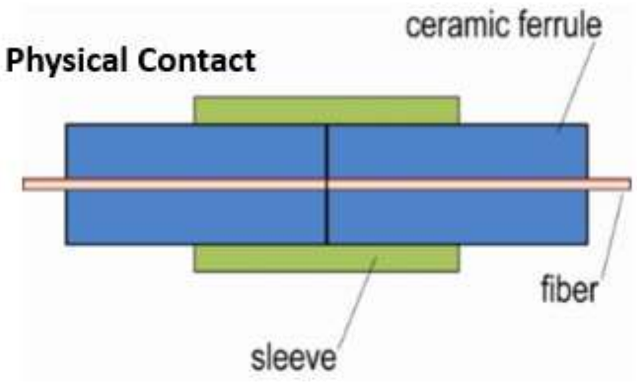
Figure 2: Basic Fiber Optic Communication System

OPTICAL FIBER CONNECTORS

- A connector terminates the optical fiber inside a ceramic ferrule, using epoxy to hold the fiber in place. The connectors can be mated and unmated at any time.

- **Advantages:**
  - The connection is robust.
  - Can be chosen according to the application.
  - Can be connected and disconnected hundreds or even thousands of times without damaging the connectors.

- **Disadvantages:**
  - The connection takes longer than fusion splicing.
  - requires special tools, and the insertion loss can be higher when compared with fusion splicing.



TYPES OF OPTICAL FIBER CONNECTORS

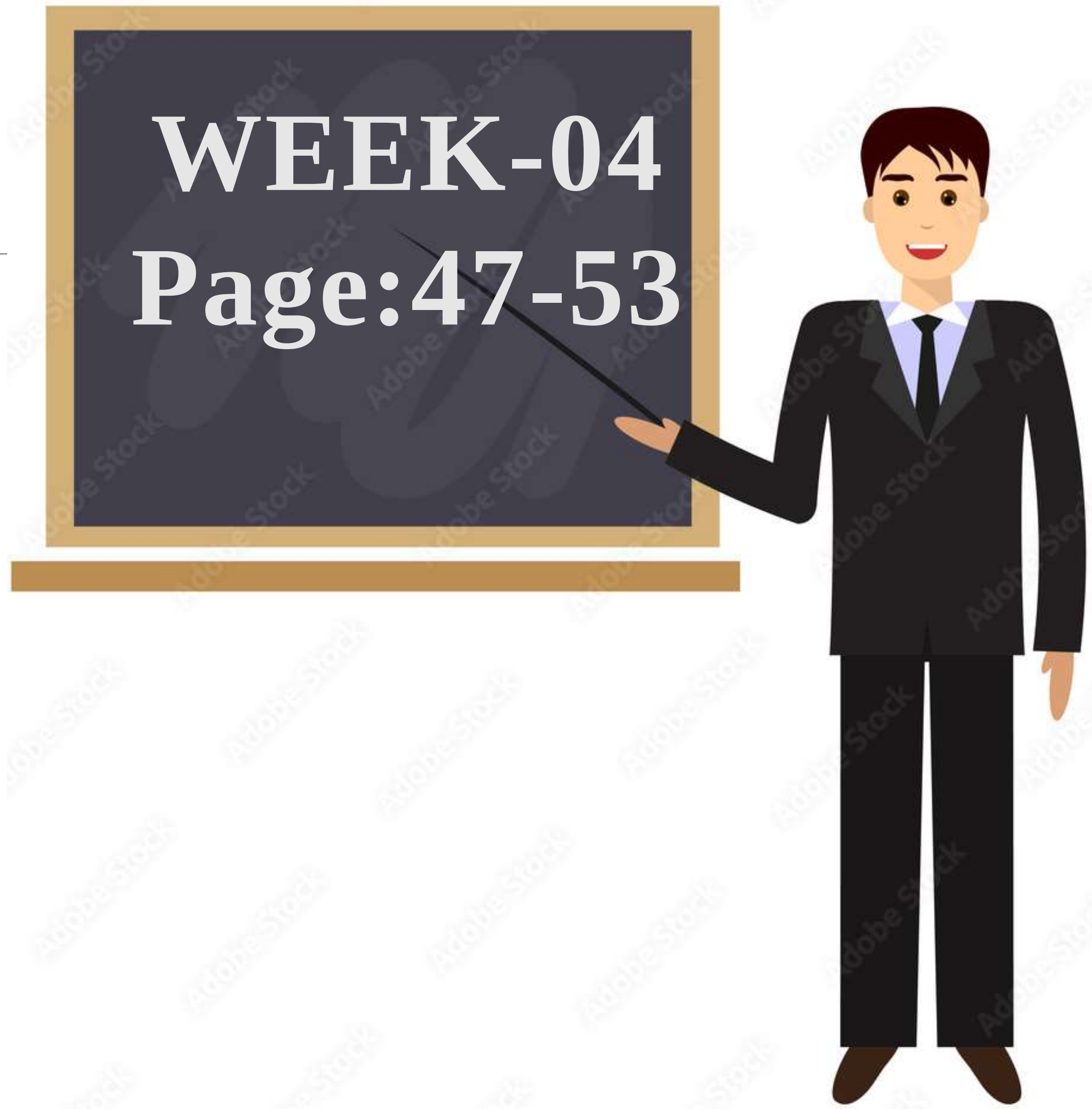
FIBER CONNECTORS	FUNCTION
	**ST Straight Tip Connector:** The bayonet interlock maintains the spring-loaded force between the two fiber cores.
	**FC-Ferrule Connector:** The connector has a screw threading and is keyed allowing the ferrule to be angle polished providing low back reflection (light is reflected back to the transmitter, most often at the connector interface due to an index of refraction change).
	**SC-Subscriber Connector:** Offer a push-pull design (which reduces the possibility of end-face damage when connecting) and provides good packing density. They are still used in datacom and telecom applications
	**LC-Lucent Connector:** Supplanting SC connectors because of their smaller size and excellent design. They are also used extensively on small form pluggable transceivers. (SFP)

OPTICAL FIBER COLOUR CODING

1	Blue
2	Orange
3	Green
4	Brown
5	Slate
6	white
7	Red
8	Black
9	Yellow
10	Violet
11	Rose/pink
12	Aqua

ADVANTAGES OPTICAL FIBER

- Fiber cables are smaller than conducting cables and weigh much less
- Fibers are strong and flexible, enabling them to go around corners. Glass fibers have a very high tensile strength
- Fiber can carry more signals than a conducting cable
- Fibers are not affected by (current, radiation, chemicals, etc.)
- Long distance transmission due to low attenuation(Optical fiber loss can be as low as 0.2 dB/km)
- Lower system cost (fewer repeaters due to low attenuation of fibers)
- Fibers reject interference. The following forms of interference have no affect on fiber systems. (RFI, EMI, EMP, etc.)
- Fiber systems are difficult to tap. (banking, computer networks, military systems)
- Thousands of channels can be multiplexed together over one strand of fiber
- Fibers are compatible with conventional electronics
- Corrosion resistant: Fiber, as opposed to wire systems, resist corrosion.
- Large temperature range: Glass melts at high temperatures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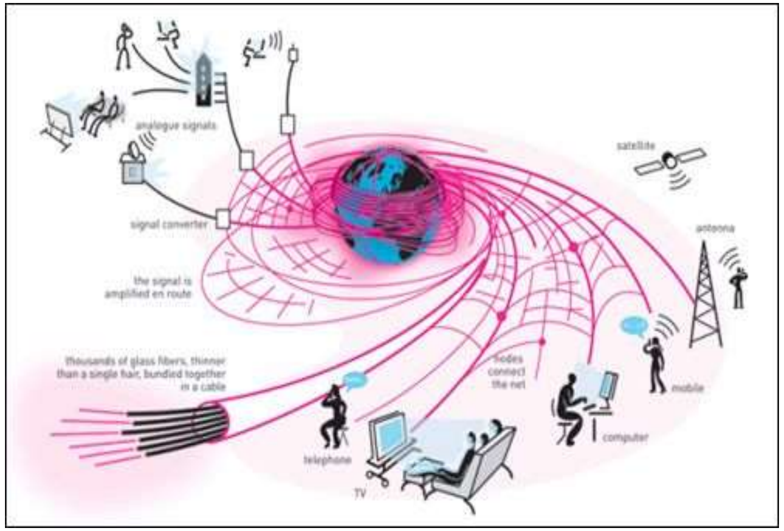
LIMITING CHARACTERISTICS OF FIBER

- ❖Scattering loss
- ❖Dispersion
- ❖Non-Linear effects
- ❖Splicing loss
- ❖Connection loss

GENERAL HEALTH AND SAFETY GUIDELINES

- ❖Wear glasses or safety glasses
- ❖Dispose of all scraps properly:
- ❖Do not drop scraps on the floor
- ❖Work gloves help prevent cuts and bruises from sharp or rough edges on pipes/ducts and othe objects
- ❖Do not eat or drink anywhere near the work area
- ❖Never look into a fiber unless you know no light is present - use a power meter to check it
- ❖Cap unused connectors
- ❖High power sources might burn the retina with invisible light

APPLICATIONS OF FIBER



- Telecommunication applications
- Fiber-optic sensors
- Medical applications
- Networking applications
- Computer network (LA N, WAN)
- LA N, WAN
- Cable TV
- Military applications such as tactical communications and fiber-guided missiles.
- CCTV
- Other video applications such as remote monitoring and surveillance.
- Aircraft, ship and automobile, and Industrial applications

TWISTED PAIR CABLE

- The least expensive and most commonly used guided transmission medium is twisted-pair copper wire. For over a hundred years it has been used by telephone networks. Twisted-pair cabling consists of copper wires that are twisted into pairs.

- Twisted pair consists of two insulated copper wires, each about 1 mm thick, arranged in a regular spiral pattern. The wires are twisted together to reduce the electromagnetic and crosstalk interference from similar pairs close by. Out of these two wires, only one carries the actual signal and another is used for ground reference.

- Typically, a number of pairs are bundled together in a cable by wrapping the pairs in a protective shield. A wire pair constitutes a single communication link.

- Often used at customer facilities and also over distances to carry voice as well as data communications. The transmission speed ranges from 2 million bits per second to 10 billion bits per second.

TWISTED PAIR CABLE

- Because Ethernet is the foundation for most local networks, twisted pair is the most commonly encountered type of network cabling. A twisted pair cable is susceptible to electromagnetic interference (EMI), a type of noise. A source of interference, known as crosstalk, occurs when cables are bundled together for long distances.
- To eliminate this, pairs of wires carry signals in opposite directions so that the two magnetic fields also occur in opposite directions and cancel each other out. This process is known as **cancellation.** The number of twists per unit length affects the amount of resistance that the cable has to interference.
- CAT-3 has 3-4 turns per foot making it less resistant to interference. CAT-5 has 3-4 turns per inch, making it more resistant to interference.
- There are two types of twisted-pair cables: **Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP).** UTP cable is the most common networking media. UTP cable is inexpensive, offers high bandwidth, and is easy to install.

SHIELDED AND UNSHIELDED TWISTED PAIR CABLES

SHIELDED TWISTED PAIR CABLES

The pair is wrapped with metallic foil to insulate the pair from electromagnetic interference. It is more expensive and harder to work with.

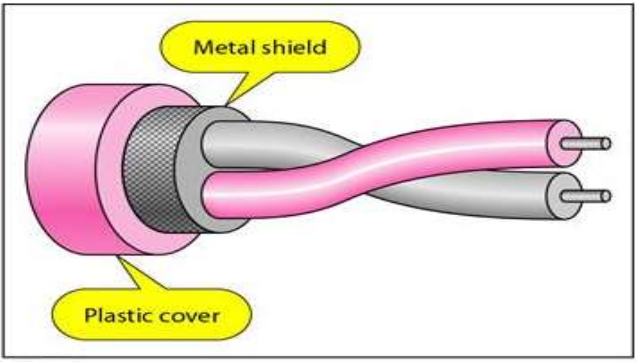
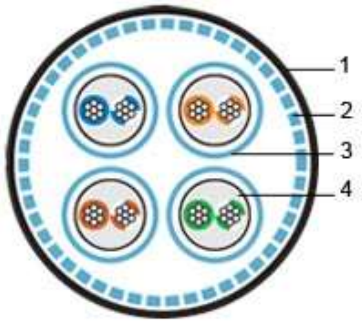


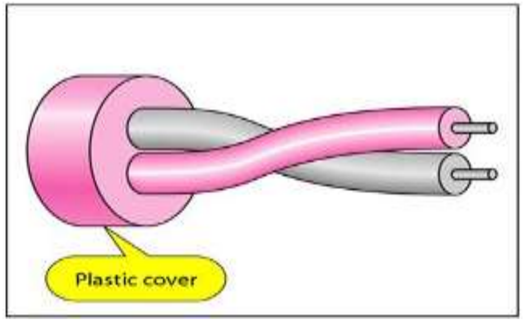
Figure 2: Shielded Twisted Pair Cables



1 – Jacket
2 – Shield-braid
3 – Shield-foil
4 – Stranded twisted pair

UNSHIELDED TWISTED PAIR CABLES

- Each wire is insulated with only plastic wrap, but the pairs are encased in an outer covering. It has no cover to protect the wires. There are two types of UTP. 3 UTP and 5 UTP.
- The 3 UTP data rate is up to 16 Mbps.
- The 5 UTP rate is up to 100 Mbps. It is more expensive and has a better performance. More tightly twisted than Category 3 cables



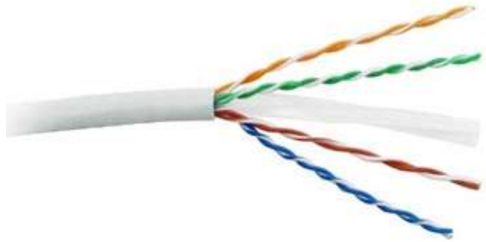
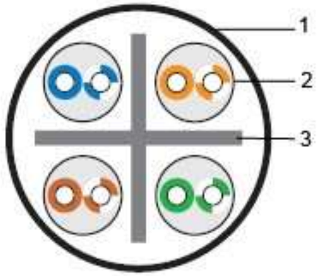


Figure 2: Unshielded Twisted Pair Cables



1 – Jacket
2 – Solid twisted pair
3 – Spacer

SHIELDED TWISTED PAIR CABLES

- It has a conducting metallic shield covering individual twisted pairs. This will block out electromagnetic interference to prevent unwanted noise from the communication circuit. Drain wires are also used in STP cables together with metallic shields for grounding purposes.

- The main purpose of the drain wire is to carry away unwanted interference noise to the ground. A way to improve the characteristics of unshielded twisted pairs is to shield the twisted pair with a metallic braid or sheathing that reduces interference. This shielded twisted pair (STP) provides better performance at higher data rates. However, it is more expensive and more difficult to work with than unshielded twisted pairs.

- STP cables are similar to UTP cables, except there is a metal foil or braided-metal-mesh cover that encases each pair of insulated wires

ADVANTAGES OF TWISTED PAIR CABLES

- ❖Inexpensive and readily available
- ❖Flexible and lightweight
- ❖Easy to work with and install

DISADVANTAGES TWISTED PAIR CABLES

- ❖Susceptibility to interference and noise
- ❖Attenuation problem
- ❖Relatively low bandwidth (3000Hz)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UNSHIELDED TWISTED PAIR CABLES

- This type of cable is used to connect workstations, hosts, and network devices. It comes with many different numbers of pairs inside the jacket, but the most common number of pairs is four. Each pair is identified by a specific color code.

- The wire pairs are then covered with a plastic outer jacket. UTP cables are of small diameter and it doesn’t need grounding. Since there is no shielding for UTP cabling, it relies only on "cancellation" to avoid noise. All Categories of data-grade UTP cable are traditionally terminated into an RJ-45 connector.

- Unshielded twisted pair (UTP) is commonly used for computer networks within a building, that is, for LANs. Data rates for LANs using twisted pairs today range from 10 Mbps to 10 Gbps. The data rates that can be achieved depend on the thickness of the wire and the distance between the transmitter and receiver. **UTP has seven** categories, each suitable for specific use. In computer networks, Cat-5, Cat-5e, and Cat-6 cables are mostly used. UTP cables are connected by RJ45 connectors- RJ stands for Registered Jack.

Category	Speed	Use
1	1 Mbps	Voice Only (Telephone Wire)
2	4 Mbps	LocalTalk & Telephone (Rarely used)
3	16 Mbps	10BaseT Ethernet
4	20 Mbps	Token Ring (Rarely used)
5	100 Mbps (2 pair) 1000 Mbps (4 pair)	100BaseT Ethernet Gigabit Ethernet
5e	1,000 Mbps	Gigabit Ethernet
6	10,000 Mbps	Gigabit Ethernet

COAXIAL CABLE

- ❖Coaxial cable is widely used for cable television systems, office buildings, and other work sites for local area networks, long-distance telephone transmission, etc.

- ❖The ~~cables consist of copper or aluminum wire wrapped with an insulating layer. Coaxial cable~~ has a central core conductor (copper) surrounded by a braided mesh. Both conductors share a common center axial, hence the term “co-axial”.

- ❖It is used to carry high-frequency electrical signals with low losses. The dimensions of the cable and connectors are controlled to give precise, constant conductor spacing, which is needed for it to function efficiently as a transmission line.

- ❖It is used by cable television companies to provide services. It is also used for connecting the various components which make up satellite communication systems.

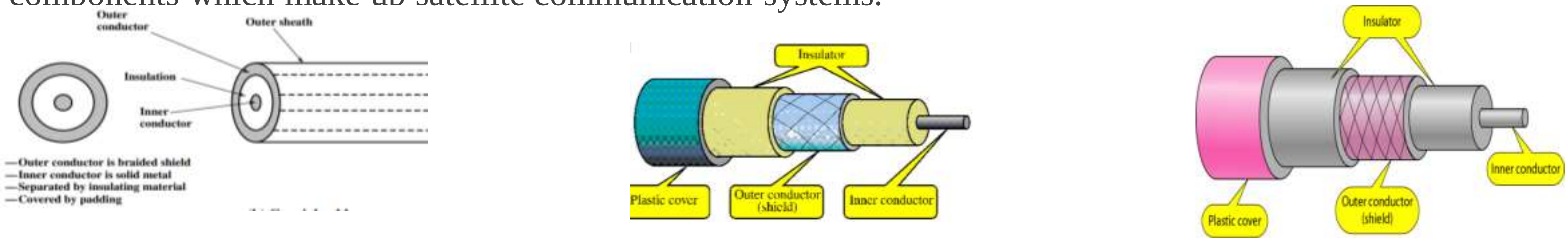

Figure 20: Image of Coaxial Cable

COAXIAL CABLE

- Coaxial cable also carries data in the form of electrical signals. It provides improved shielding compared to UTP, so it has a lower signal-to-noise ratio and can therefore more carry data.
- Although coaxial has improved data-carrying characteristics, twisted pair cabling has replaced coaxial in local area networking uses. Among the reasons for the replacement is that, compared to UTP, coaxial is physically harder to install, more expensive, and harder to troubleshoot.
- In general, coaxial cables carry signals of higher frequencies (100KHz–500MHz) than UTP cables. The outer metallic wrapping serves both as a shield against noise and cross-talk and as the second conductor that completes the circuit
- Coaxial cables provide high bandwidth rates of up to 450 Mbps. There are three categories of coaxial cables namely, RG-59 (Cable TV), RG-58 (Thin Ethernet), and RG-11 (Thick Ethernet). RG stands for Radio Government.

TYPES OF COAXIAL CABLES

- Thick coaxial and thin coaxial.
- Thin coaxial cable is also referred to as thinnet. 10Base2 refers to the specifications for thin coaxial cables carrying Ethernet signals. The 2 refers to the approximate maximum segment length being 200 meters. The maximum segment length is 185 meters.
- Thin coaxial cable has been popular in school networks, especially linear bus networks. Thick coaxial cable is also referred to as thicknet.
- 10Base5 refers to the specifications for thick coaxial cable carrying Ethernet signals. The 5 refers to the maximum segment length being 500 meters. Thick coaxial cable has an extra protective plastic cover that helps keep moisture away from the center conductor.
- This makes thick coaxial a great choice when running longer lengths in a linear bus network. One disadvantage of thick coaxial is that it does not bend easily and is difficult to install

ADVANTAGES OF COAXIAL CABLE

- Higher bandwidth
- Much less susceptible to interference than twisted pair

DISADVANTAGES OF COAXIAL CABLE

- High attenuation rate makes it expensive over long distance
- Bulky
- Bandwidth: coaxial > twisted-pair


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ATTENUATION OF TYPICAL GUIDED MEDIA

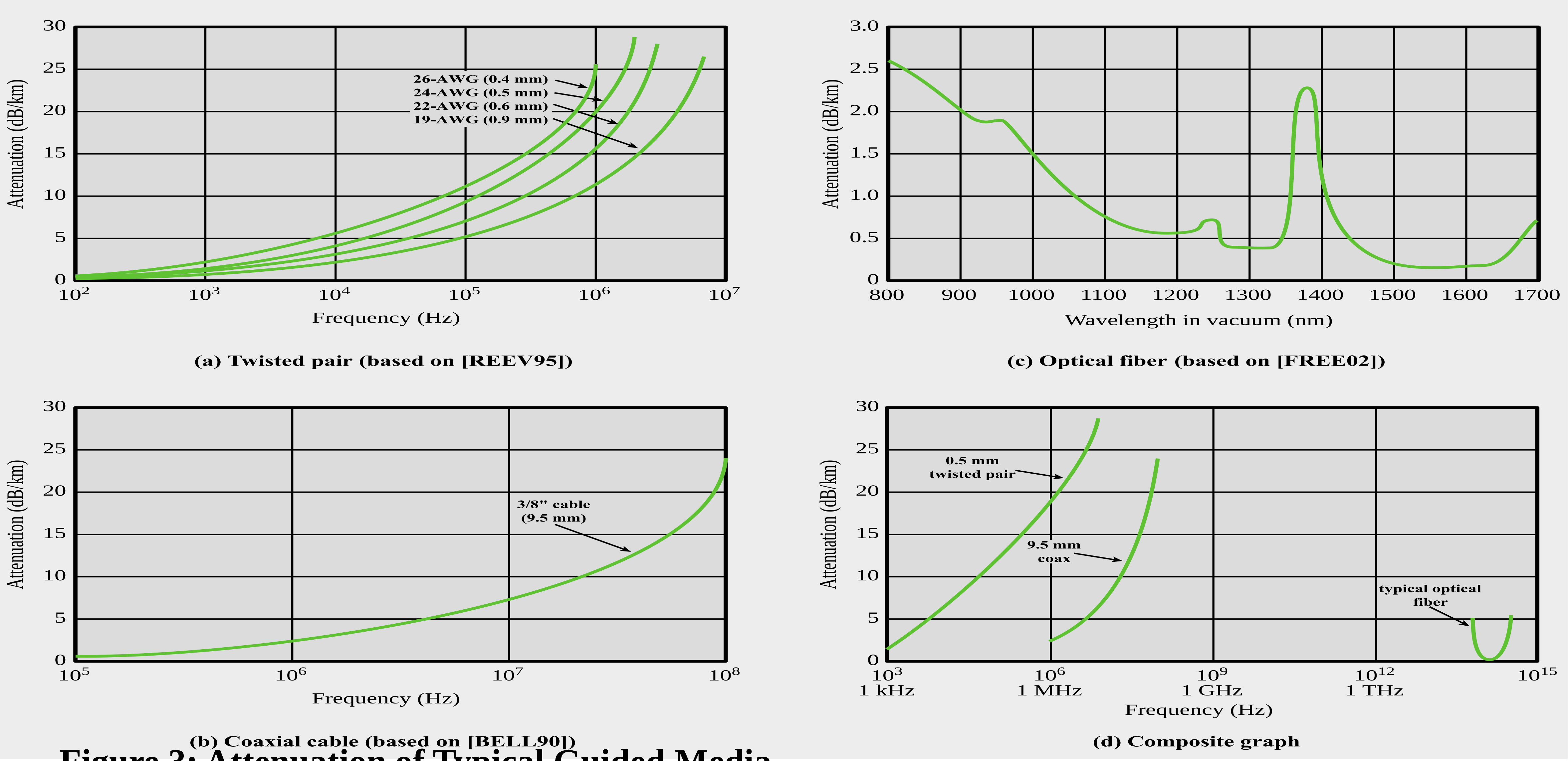


Figure 3: Attenuation of Typical Guided Media

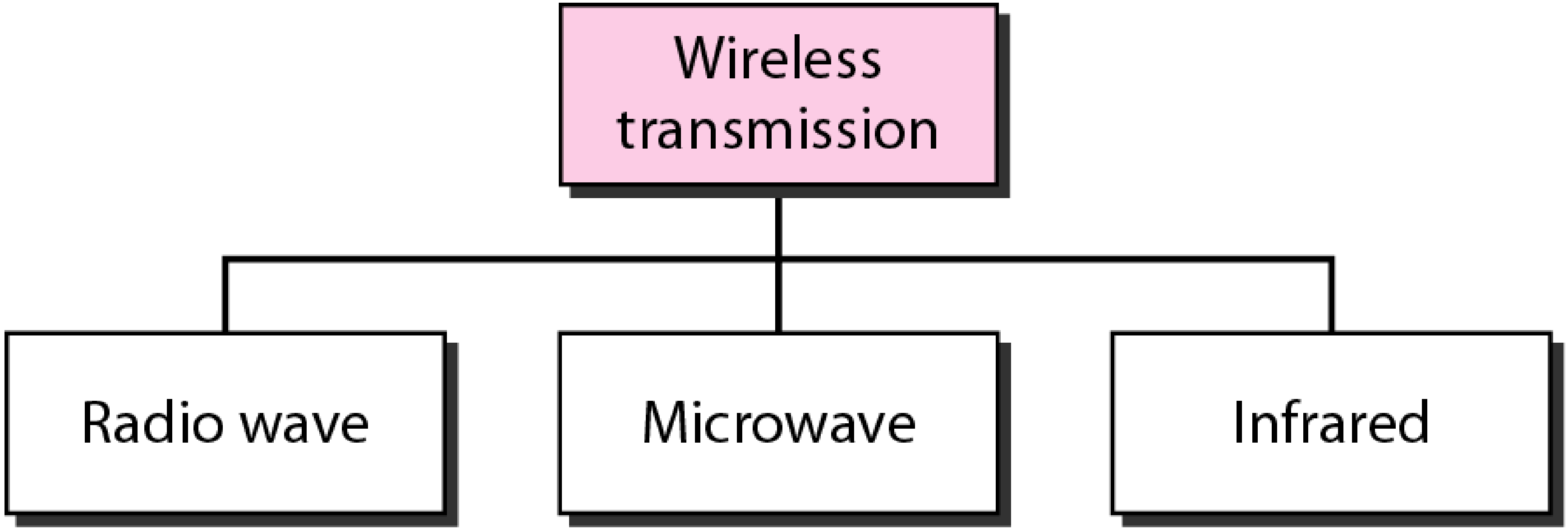
POINT-TO-POINT TRANSMISSION CHARACTERISTICS OF GUIDED MEDIA

- For guided transmission media, the transmission capacity, in terms of either data rate or bandwidth, depends critically on the distance and on whether the medium is point-to-point or multipoint. The table below indicates the characteristics typical of the common guided media for long-distance point-to-point applications.

Table 1: Common guided media for long-distance point-to-point applications

	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μs/km	2 km
Twisted pairs (multipair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μs/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 μs/km	40 km

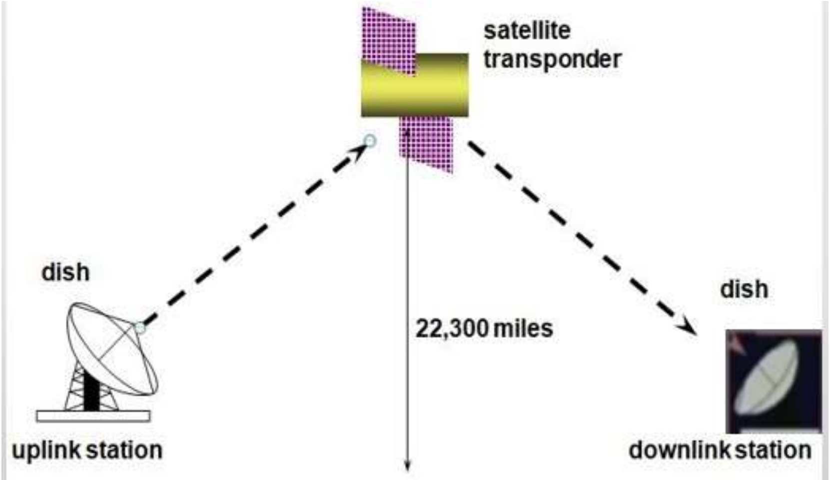
WIRELESS TRANSMISSION

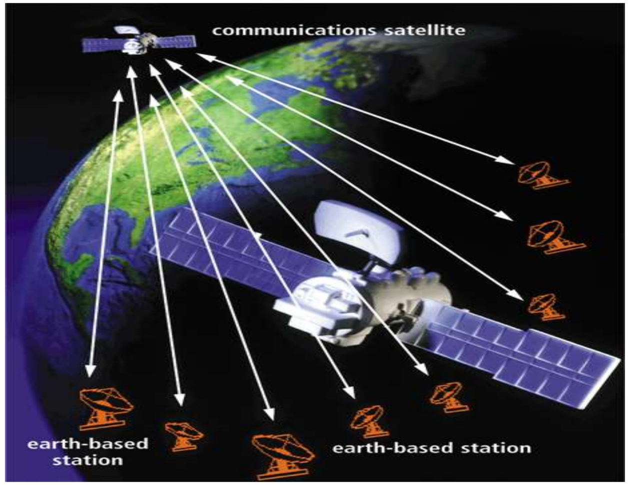


- Radio waves are used for multicast communications, such as radio and television, and paging systems. They can penetrate through walls. They are highly regulated. Use omnidirectional antennas
- Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs. Higher frequency ranges cannot penetrate walls. Use directional antennas – point-to-point line-of-sight communications.
- Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

SATELLITE COMMUNICATIONS

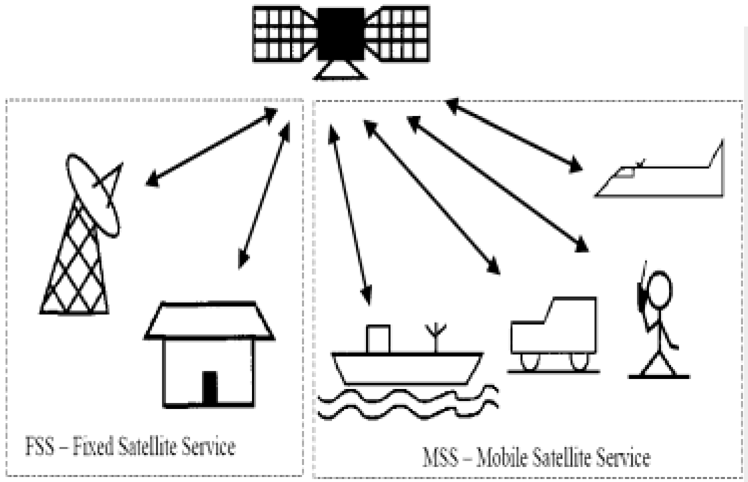
- The satellites use microwave radio signals as their telecommunications medium which are not deflected by the Earth's atmosphere. The satellites are stationed in space above the equator. These Earth-orbiting systems are capable of receiving and relaying voice, data, and TV signals.
- A communications satellite receives microwave signals from an earth-based station, amplifies them, and broadcasts the signal over a wide area
- When using a satellite for long-distance communications, the satellite acts as a repeater.
- An earth station transmits the signal up to the satellite (uplink), which in turn retransmits it to the receiving earth station (downlink).
- Different frequencies are used for **uplink/downlink.**





HOW DO SATELLITES WORK?

- ❖ If two Stations on Earth want to communicate through radio broadcast but are too far away to use conventional means, the two stations can use a satellite as a relay station for their communication.
- ❖ One Earth Station sends a transmission to the satellite. The satellite Transponder converts the signal and sends it down to the second earth station.
- ❖ ***Earth stations communicate by sending signals to the satellite on an uplink. The satellite then repeats those signals on a downlink. The broadcast nature of the downlink makes it attractive for services such as the distribution of television programming***



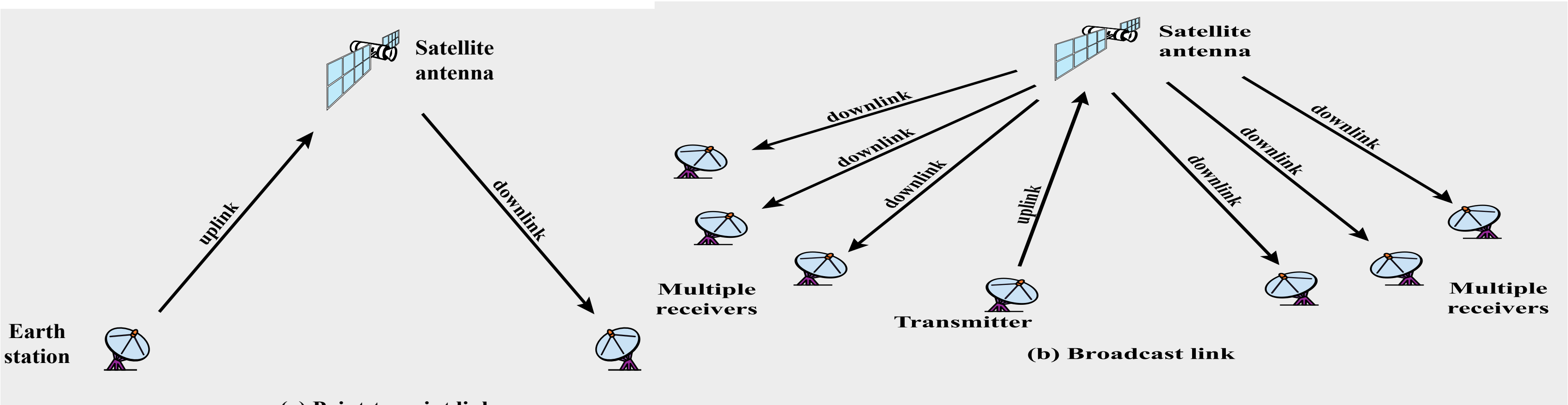


Figure 4.9 Satellite Communication Configurations

RELATED TERMS

- **Earth Stations** – antenna systems on or near earth
- **Uplink** – transmission from an earth station to a satellite or the link from a ground station up to a satellite.
- **Downlink** – transmission from a satellite to an earth station or the link from a satellite down to one or more ground stations or receivers
- **Transponder** – electronics in the satellite that convert uplink signals to downlink signals
- ***Some companies sell uplink and downlink services to television stations, corporations, and to other telecommunication carriers.***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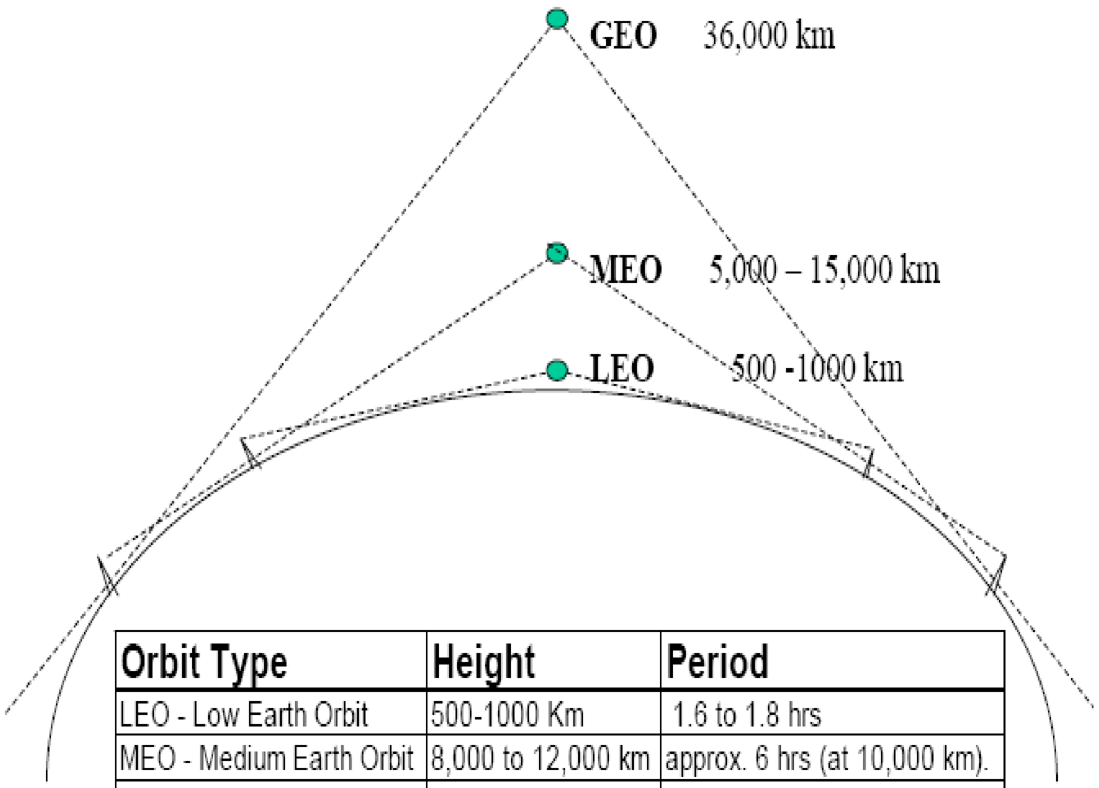
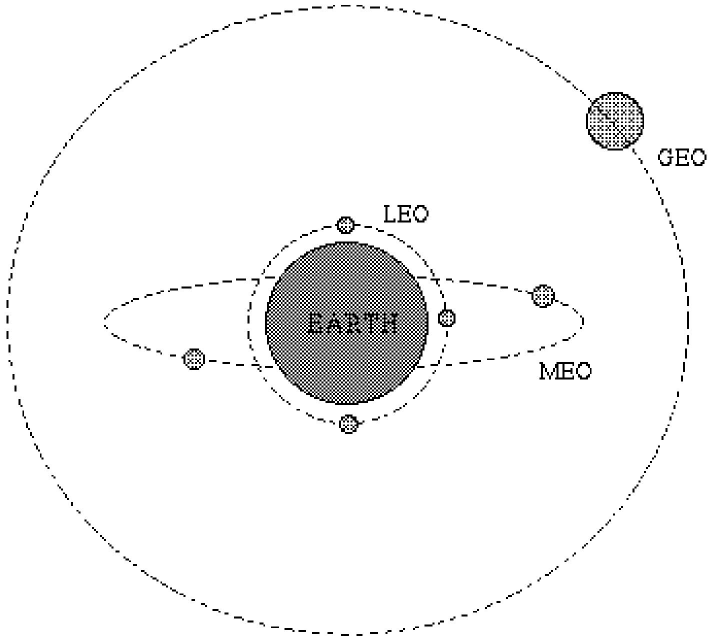
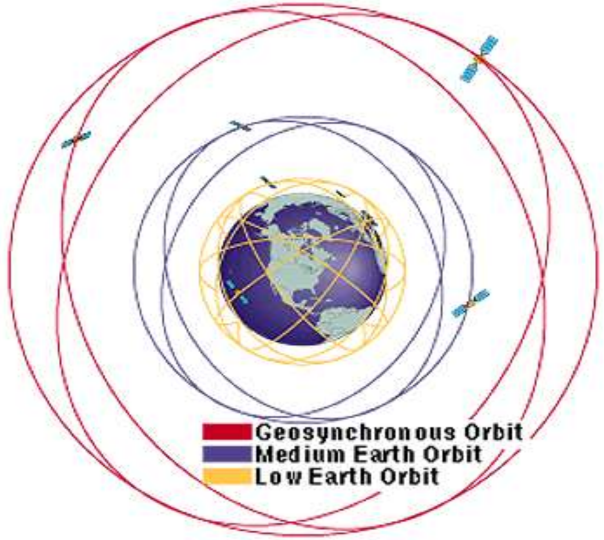
SATELLITE ORBITS



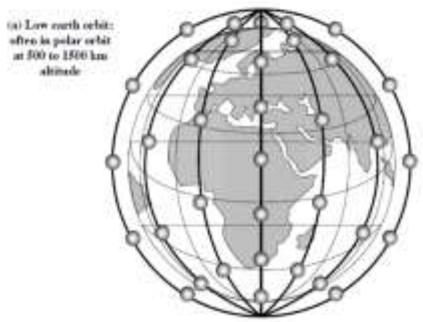
Orbit Type	Height	Period
LEO - Low Earth Orbit	500-1000 Km	1.6 to 1.8 hrs
MEO - Medium Earth Orbit	8,000 to 12,000 km	approx. 6 hrs (at 10,000 km).
GEO - Geostationary	approx. 36,870 km	approx. 24 hrs

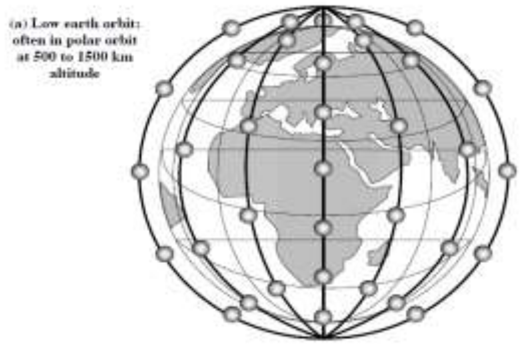




LOW EARTH ORBITS (LEO)

- LEO satellites are much closer to the Earth than MEO satellites, ranging from **500 to 1,500 km** above the surface.
- A network of LEO satellites is necessary for LEO satellites to be useful (66 satellites are needed to cover the earth).
- Earth stations must track satellites or have Omni directional antennas
- Mainly used for data communication such as email, video conferencing, paging, military intelligence, and weather forecast. **It has low power, more satellites, and a small footprint**
  - Orbit period ranges from 1.5 to 2 hours
  - Shorter delays - between 1-10 ms typical. Round-trip signal propagation delay of less than 20 ms
  - Signal-to-noise ratio is better with LEOs
  - They move at extremely high speeds and are not fixed in space in relation to the Earth.





LOW EARTH ORBITS (LEO)

ADVANTAGES

- A LEO satellite's proximity to Earth compared to a GEO satellite gives it a better signal strength and less of a time delay, which makes it better for point-to-point communication.
- A LEO satellite's smaller area of coverage is less of a waste of bandwidth.

DISADVANTAGES

- A network of LEO satellites is needed, which can be costly
- LEO satellites have to compensate for Doppler shifts caused by their relative movement.
- Atmospheric drag affects LEO satellites, causing gradual orbital deterioration.

MEDIUM EARTH ORBITS (MEO)

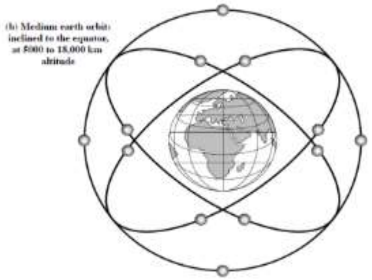
- ❖ A MEO satellite is in orbit somewhere between 5,000 km to 15,000 km above the earth’s surface. MEO satellites are visible for much longer periods of time than LEO satellites, usually between 2 to 8 hours.
- ❖ MEO satellites have a larger coverage area than LEO satellites. They include navigation satellites (GPS, Galileo, Glonass).
- ❖ High bandwidth, High power, High latency. The Orbit period is 6 hours. Round trip signal propagation delay less than 50 ms

ADVANTAGE

- ➢A MEO satellite’s longer duration of visibility and wider footprint means fewer satellites are needed in an MEO network than in an LEO network.

DISADVANTAGE

- ➢ A MEO satellite’s distance gives it a longer time delay and a weaker signal than an LEO satellite, though not as bad as a GEO satellite.



GEOSYNCHRONOUS ORBIT (GEO)

- These satellites are in orbit 35,000 km above the earth's surface along the equator. It includes commercial and military communications satellites, satellites providing early warning of a ballistic missile launch. **It has a high latency.**
- Orbital Period is equal to 23 h 56 m 4.091s. Objects in a Geostationary orbit revolve around the Earth at the same speed as the Earth rotates. This means GEO satellites remain in the same position relative to the surface of the earth.
- Three satellites can cover the earth (120° apart). Theoretically, three geostationary satellites provide 100% Earth coverage
- GEO satellites require more power for communications. The signal-to-noise ratio for GEOs is worse because of the distances involved
- Since they appear stationary, GEOs do not require tracking. GEOs are good for broadcasting to wide areas

GEOSYNCHRONOUS ORBIT (GEO)

- **ADVANTAGES**
  - A GEO satellite's distance from earth gives it a large coverage area
  - GEO satellites have a 24-hour view of a particular area
  - Ideal for satellite broadcast and other multipoint applications
  - No problem with frequency changes
  - Tracking of the satellite is simplified
- **DISADVANTAGES**
  - A GEO satellite's distance also causes it to have a comparatively weak signal
  - There is a time delay in the signal, which is bad for point-to-point communication

OTHER ORBITS

Molniya Orbit Satellites:

- Used by Russia for decades.
- Molniya Orbit is an elliptical orbit. The satellite remains in a nearly fixed position relative to earth for eight hours.
- A series of three Molniya satellites can act like a GEO satellite.
- Useful in near-polar regions.

High Altitude Platform (HAP):

- One of the newest ideas in satellite communication.
- A blimp or plane around 20 km above the earth's surface is used as a satellite.
- HAPs would have a very small coverage area but would have a comparatively strong signal.
- Cheaper to put in position, but would require a lot of them in a network.

ADVANTAGES OF SATELLITE COMMUNICATION

- ❖Can reach over a large geographical area
- ❖Easy to install new circuits
- ❖Circuit costs independent of distance
- ❖Broadcast possibilities
- ❖Provision of service to remote or underdeveloped areas
- ❖User has control over its own network
- ❖ Satellite-to-satellite communication is very precise.

DISADVANTAGES OF SATELLITE COMMUNICATION

- ❖Large upfront capital costs (space segment and launch)
- ❖Interference and propagation delay
- ❖Congestion of frequencies and orbits
- ❖Satellite bandwidth is gradually becoming used up

USES SATELLITE

- Point to Point Communication (transmit signals and data over long distances)
- Broadcast Service Satellites (Satellite TV/Radio)
- Mobile Service Satellites (Satellite phones)
- Weather forecasting
- Internet communication
- Global Positioning Systems
- Military intelligence
- Experimental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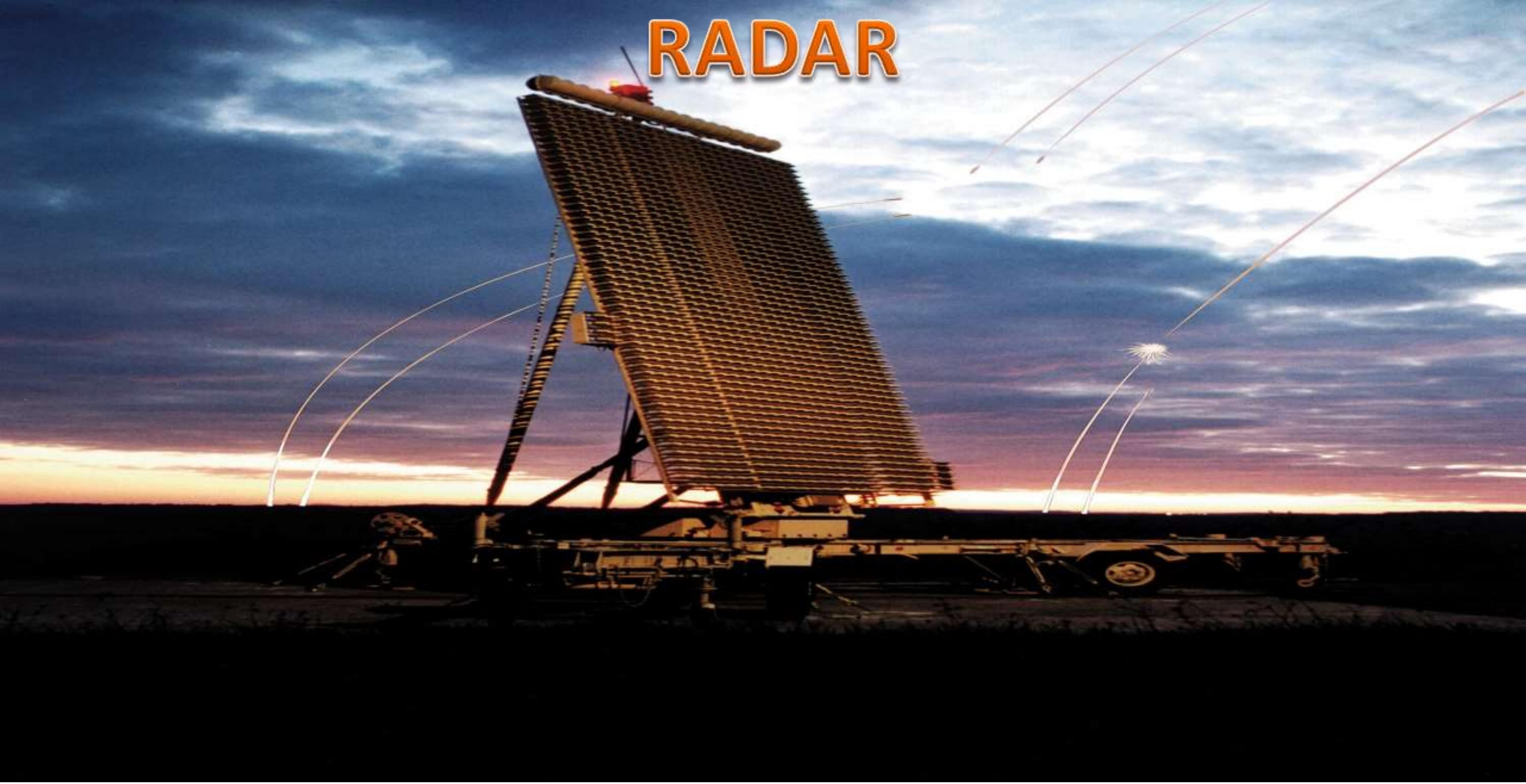
RADAR

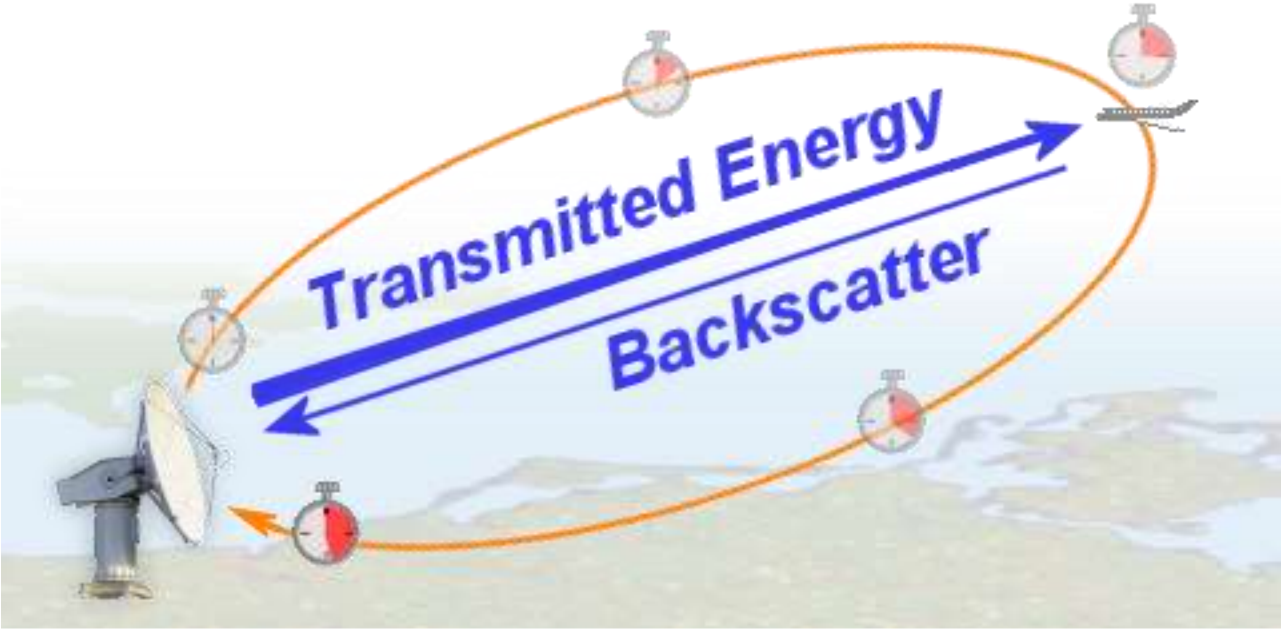


What is RADAR ?

- **RADAR** is an acronym for **RA**dio **D**etection **A**nd **R**anging.

- RADAR is an object detection system that uses electromagnetic waves to identify the range,altitude,direction or speed of both moving and fixed objects such as aircrafts,ships,motor vehicles,weather formations and terrain.

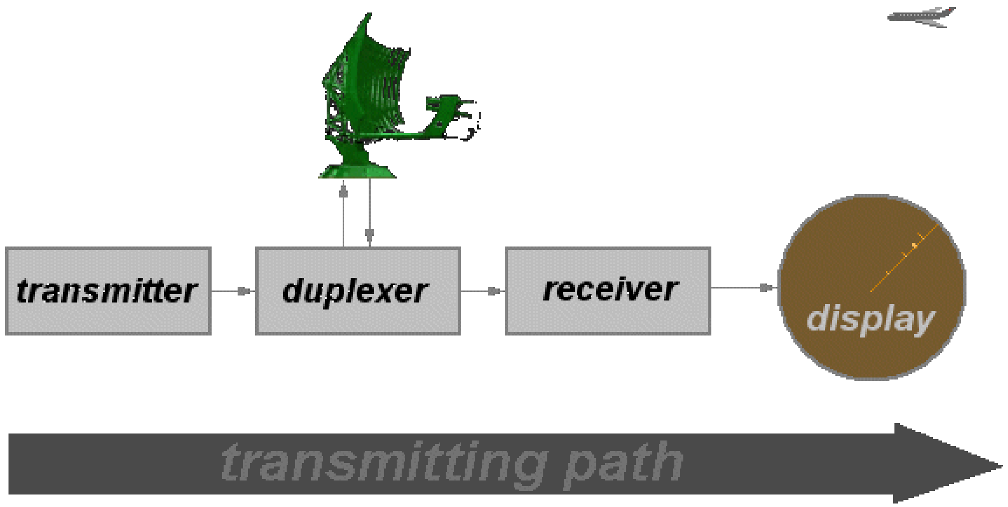
Principle of Operation



- Reflection of electromagnetic waves

- Measurement of running time of transmitted pulses

Radar Basic Principles



- Transmitter
- Duplexer
- Receiver
- Radar Antenna
- Indicator

Principle of Measurement

- **Distance Determination.**
- **Direction Determination.**
- **Elevation Angle.**
- **Range Resolution.**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Distance Determination

- The distance is determined from the running time of the high frequency transmitted signal and the propagation c_0. The actual range of a target from the radar is known as **slant range**. Slant range is the line of sight distance between the radar and the object illuminated. Since the waves travel to a target and back, the round trip time is dividing by two in order to obtain the time the wave took to reach the target. Therefore the following formula arises for the slant range:

  $R = c_0 \cdot t/2$ where: c_0 = speed of light = $3 \cdot 10^8\ {}^{m}/_{s}$

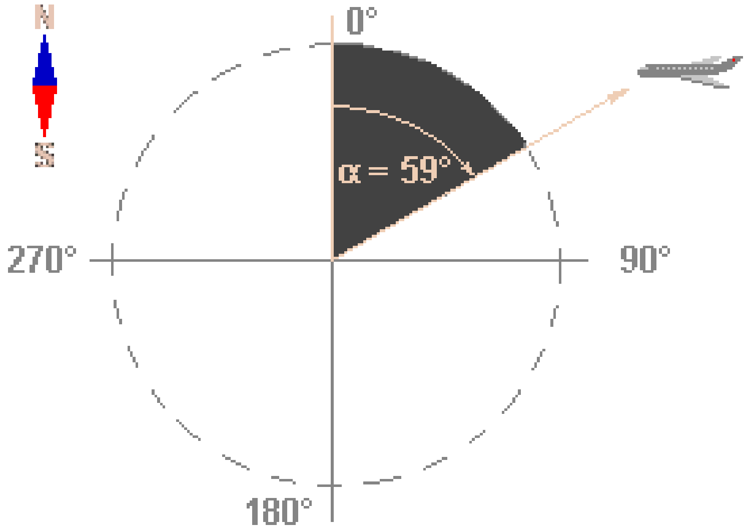
  t = measured running time [s]

  R = slant range antenna - aim [m]

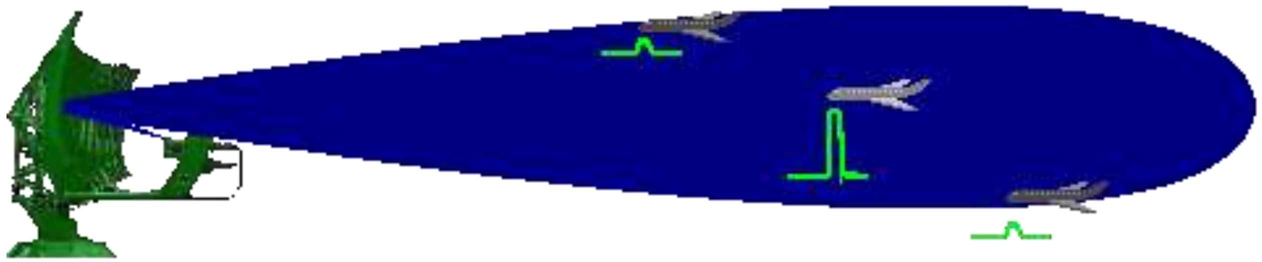
  The distances are expressed in kilometers or nautical miles (1 NM =1.852 km).

Direction Determination

- The angular determination of the target is determined by the directivity of the antenna. Directivity, sometimes known as the directive gain, is the ability of the antenna to concentrate the transmitted energy in a particular direction. By measuring the direction in which the antenna is pointing when the echo is received, both the azimuth and elevation angles from the radar to the object or target can be determined.

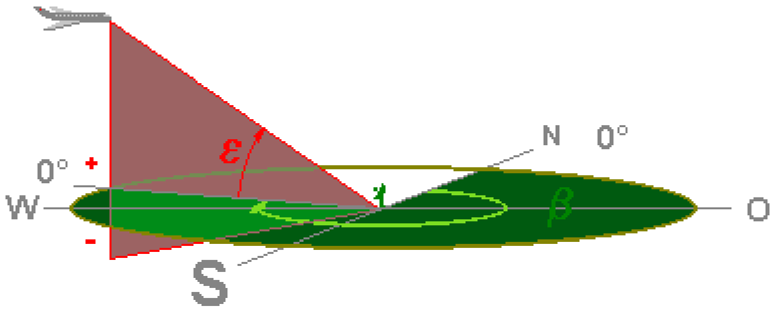


Direction Determination



- The antennas of most radar systems are designed to radiate energy in a one-directional lobe or beam that can be moved in bearing simply by moving the antenna. The point of maximum echo, determined by the detection circuitry or visually by the operator, is when the beam points direct at the target. Weapons-control and guidance radar systems are positioned to the point of maximum signal return and maintained at that position either manually or by automatic tracking circuits.

Elevation Angle



- Altitude or height-finding search radars use a very narrow beam in the vertical plane. The beam is mechanically or electronically scanned in elevation to pinpoint targets.

- The elevation angle is the angle between the horizontal plane and the line of sight, measured in the vertical plane. The Greek letter Epsilon (ε) describes the elevation angle. The elevation angle is positive above the horizon (0° elevation angle), but negative below the horizon.

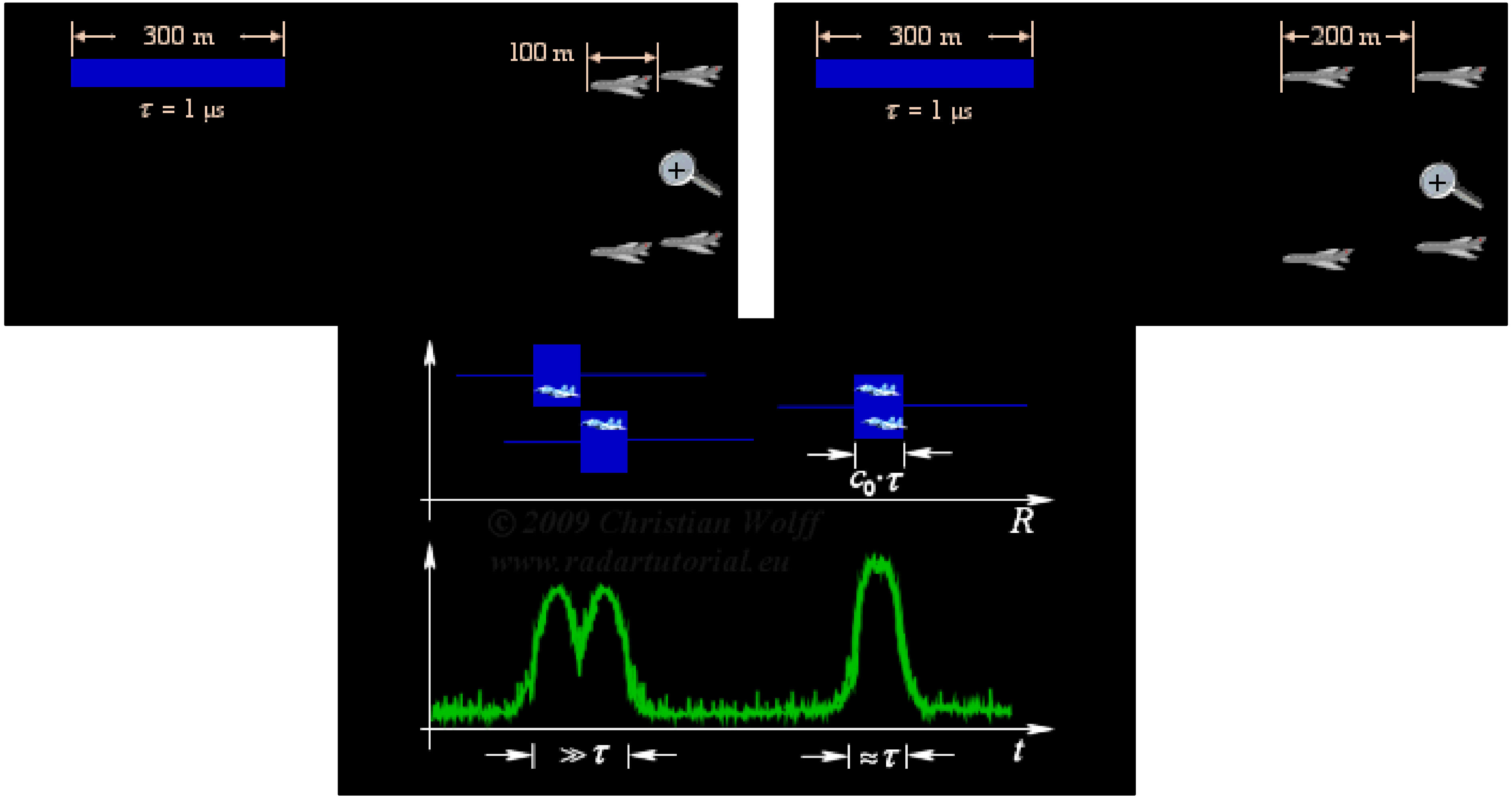
Range Resolution

- Range resolution is the ability of a radar system to distinguish between two or more targets on the same bearing but at different ranges. The degree of range resolution depends on the width of the transmitted pulse, the types and sizes of targets, and the efficiency of the receiver and indicator. Pulse width is the primary factor in range resolution. A well-designed radar system, with all other factors at maximum efficiency, should be able to distinguish targets separated by one-half the pulse width time τ. Therefore, the theoretical range resolution cell of a radar system can be calculated from the following equation:

  $\mathbf{S_r \geq c_0 \cdot \tau / 2}$ where: c_0 = speed of light = $3 \cdot 10^8\ {}^{m}/_{s}$

  τ = pulse width time

Range Resolution

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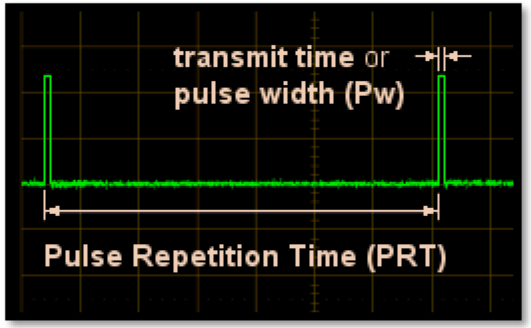
Radar Timing

- Pulse Repetition Frequency.
- Duty Cycle.
- Dwell Time.

Pulse Repetition Frequency

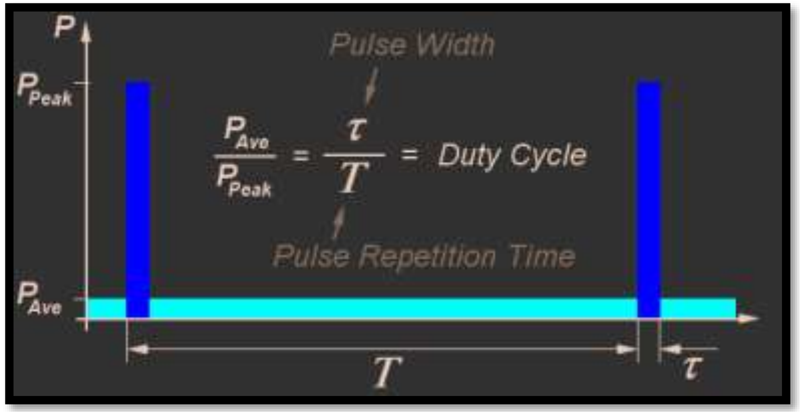


- The Pulse Repetition Frequency (PRF) of the radar system is the number of pulses that are transmitted per second.

- Radar systems radiate each pulse at the carrier frequency during transmit time (or Pulse Width PW), wait for returning echoes during listening or rest time, and then radiate the next pulse..The time between the beginning of one pulse and the start of the next pulse is called pulse-repetition time (prt) and is equal to the reciprocal of prf as follows:

  PRT = 1/PRF

Duty Cycle



- The product of pulse width (pw) and pulse-repetition frequency (prf) is called the **duty cycle** of a radar system.

- Duty cycle is the fraction of time that a system is in an “active” state. In particular, it is used in the following contexts: Duty cycle is the proportion of time during which a component, device, or system is operated.

Dwell Time

- The time that an antenna beam spends on a target is called dwell time T_D.
  The dwell time of a 2D–search radar depends predominantly on:
  1) the antennas horizontally beam width Θ_{AZ} and
  2) the turn speed n of the antenna (rotations per minute).
  The dwell time can be calculated using the following equation:

$$T_D = (\Theta_{AZ} \cdot 60)/(360° \cdot n) \qquad ; \text{ in [seconds]}$$

Radar Equation

- The power P_r returning to the receiving antenna is given by the radar equation:

$$P_r = \frac{P_t G_t A_r \sigma F^4}{(4\pi)^2 R_t^2 R_r^2}$$

where
P_t = transmitter power
G_t = gain of the transmitting antenna
A_r = effective aperture (area) of the receiving antenna
σ = radar cross section, or scattering coefficient of the target
F = pattern propagation factor
R_t = distance from the transmitter to the target
R_r = distance from the target to the receiver.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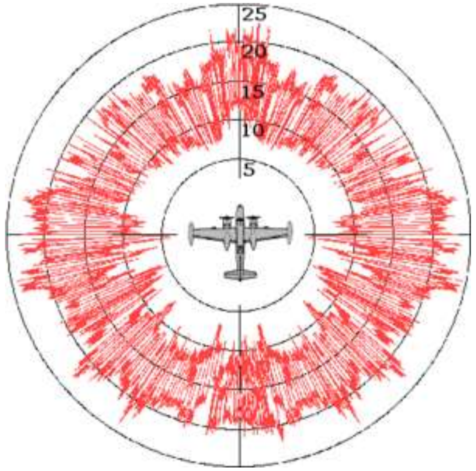
Radar Cross Section

- The size and ability of a target to reflect radar energy can be summarized into a single term, σ, known as the radar cross-section, which has units of m^2. If absolutely all of the incident radar energy on the target were reflected equally in all directions, then the radar cross section would be equal to the target's cross-sectional area as seen by the transmitter. In practice, some energy is absorbed and the reflected energy is not distributed equally in all directions. Therefore, the radar cross-section is quite difficult to estimate and is normally determined by measurement.

- The target radar cross sectional area depends on:
  1) The airplane’s physical geometry and exterior features,
  2) The direction of the illuminating radar,
  3) The radar transmitters frequency,
  4) The used material types.



Interference

- Noise.
- Clutter.
- Jamming.

Noise

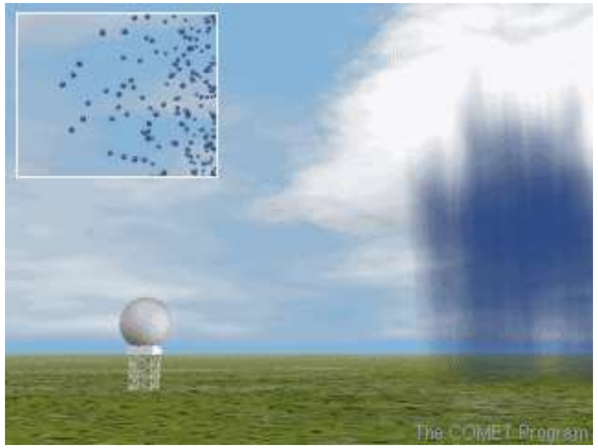
- Signal noise is an internal source of random variations in the signal, which is generated by all electronic components. Noise typically appears as random variations superimposed on the desired echo signal received in the radar receiver. The lower the power of the desired signal, the more difficult it is to discern it from the noise (similar to trying to hear a whisper while standing near a busy road).

- Noise figure is a measure of the noise produced by a receiver compared to an ideal receiver, and this needs to be minimized.

- Noise is also generated by external sources, most importantly the natural thermal radiation of the background scene surrounding the target of interest.

- There will be also flicker noise due to electrons transit, but depending on 1/f, will be much lower than thermal noise when the frequency is high.

Clutter



- Clutter refers to radio frequency (RF) echoes returned from targets which are uninteresting to the radar operators. Such targets include natural objects such as ground, sea, precipitation (such as rain, snow or hail), sand storms, animals (especially birds), atmospheric turbulence, and other atmospheric effects, such as ionosphere reflections, meteor trails, and three body scatter spike. Clutter may also be returned from man-made objects such as buildings and, intentionally, by radar countermeasures such as chaff.

- Clutter may also originate from multipath echoes from valid targets due to ground reflection, atmospheric ducting or ionospheric reflection/refraction.

Clutter

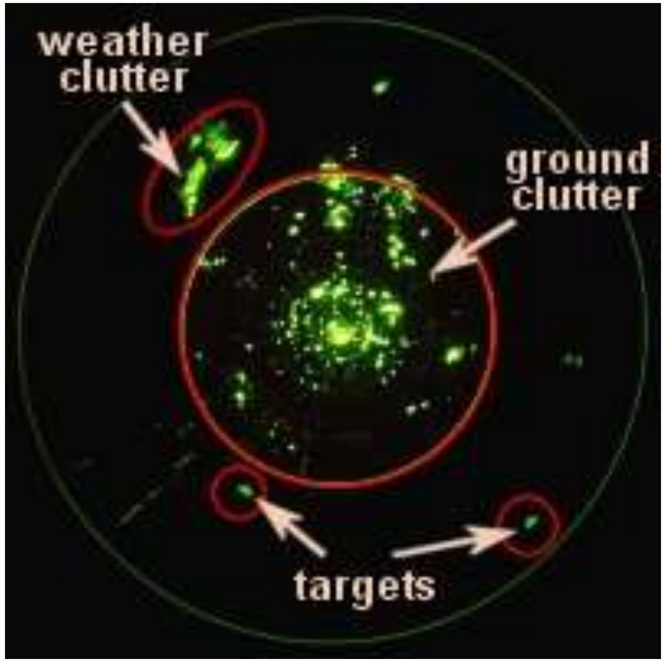
- The basic types of clutter can be summarized as follows:

1) **Surface Clutter** – Ground or sea returns are typical surface clutter. Returns from geographical land masses are generally stationary, however, the effect of wind on trees etc means that the target can introduce a Doppler Shift to the radar return. This Doppler shift is an important method of removing unwanted signals in the signal processing part of a radar system. Clutter returned from the sea generally also has movement associated with the waves.

2) **Volume Clutter** – Weather or chaff are typical volume clutter. In the air, the most significant problem is weather clutter. This can be produced from rain or snow and can have a significant Doppler content.

Clutter

3) **Point Clutter** – Birds, windmills and individual tall buildings are typical point clutter and are not extended in nature. Moving point clutter is sometimes described as angels. Birds and insects produce clutter, which can be very difficult to remove because the characteristics are very much like aircraft.

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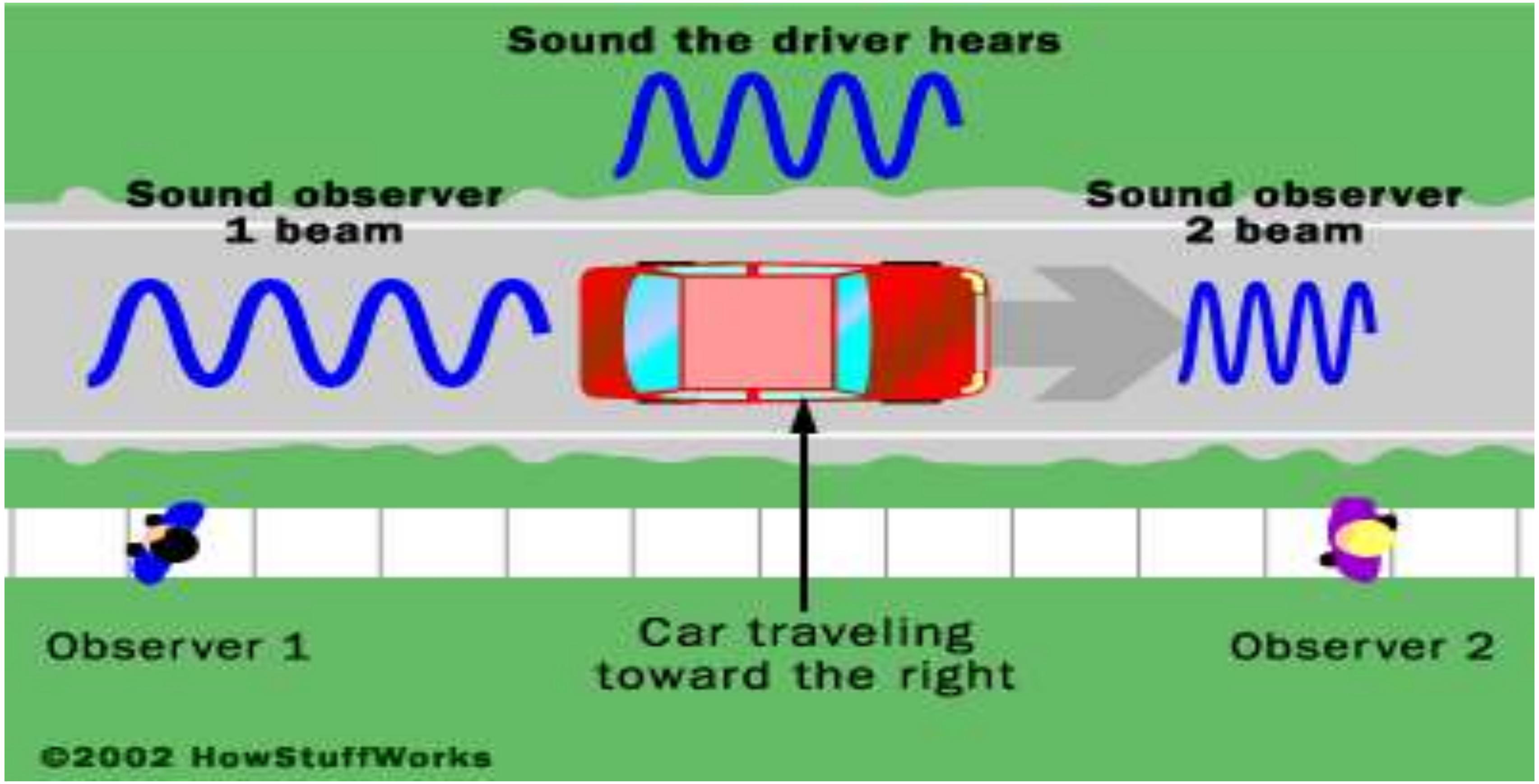
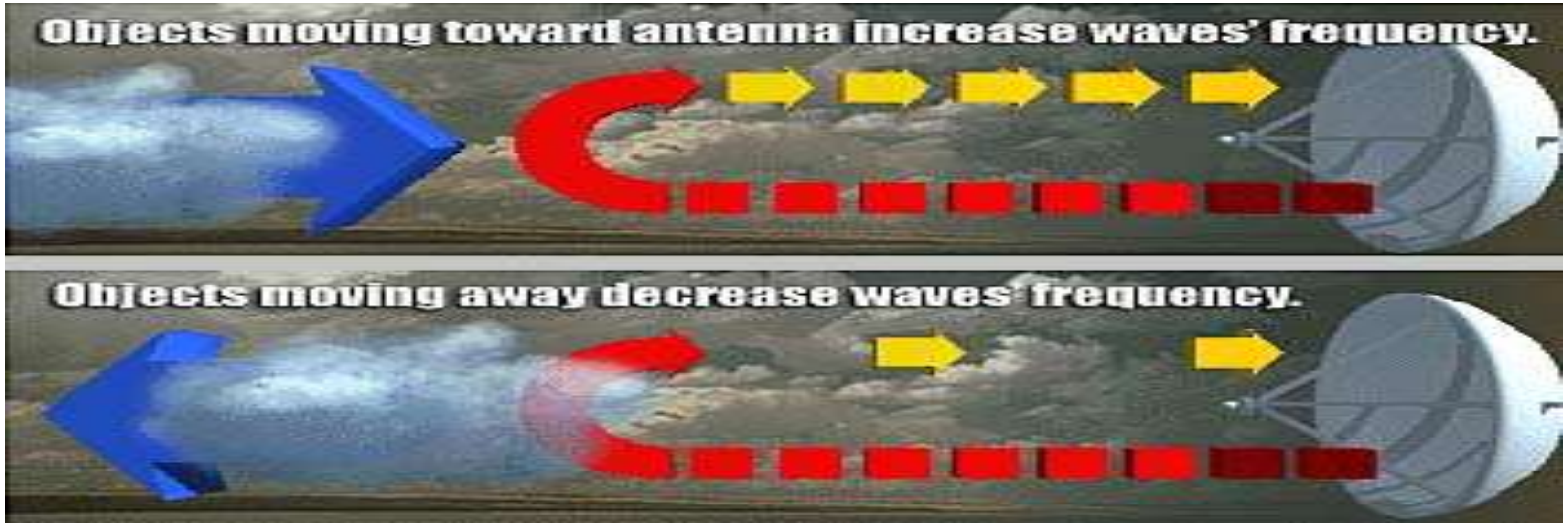
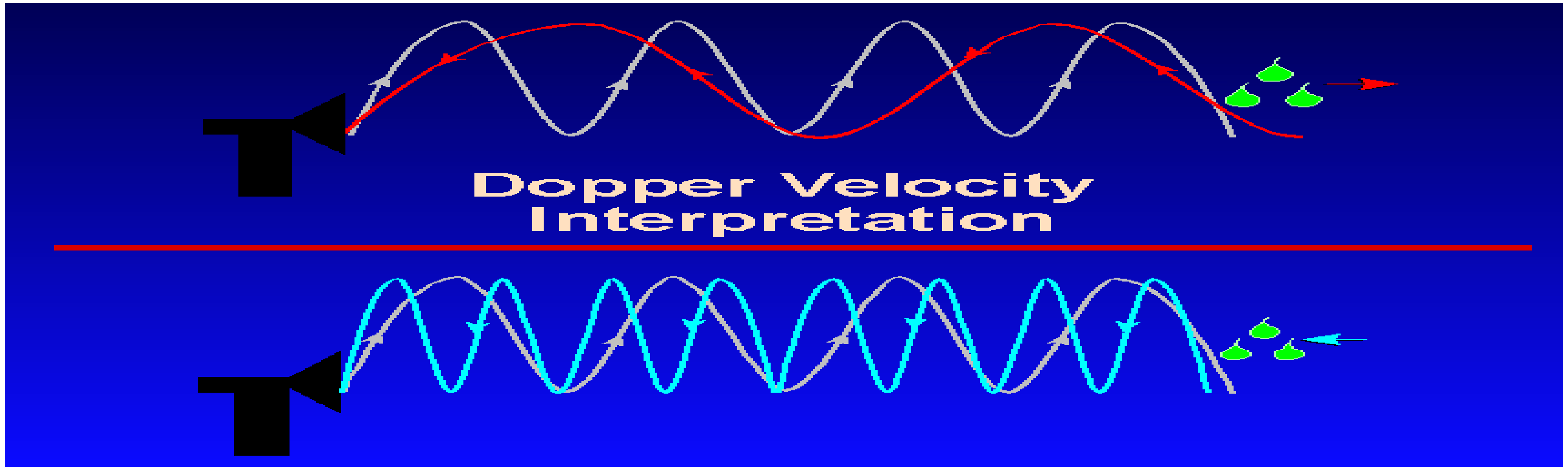
Doppler Effect

- In radar technology the Doppler Effect is using for two tasks:
  1) Speed measuring and
  2) **MTI** - **M**oving **T**arget **I**ndication



Doppler Effect

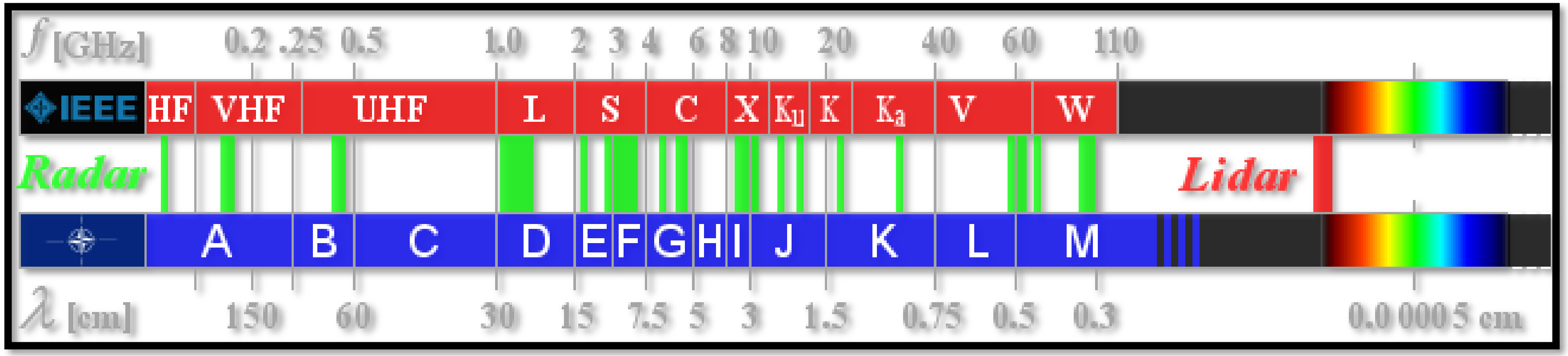




Jamming

- Radar jamming refers to radio frequency signals originating from sources outside the radar, transmitting in the radar's frequency and thereby masking targets of interest. Jamming may be intentional, as with an electronic warfare (EW) tactic, or unintentional, as with friendly forces operating equipment that transmits using the same frequency range. Jamming is considered an active interference source, since it is initiated by elements outside the radar and in general unrelated to the radar signals.

Radar Frequency Bands



Air Defense Radars

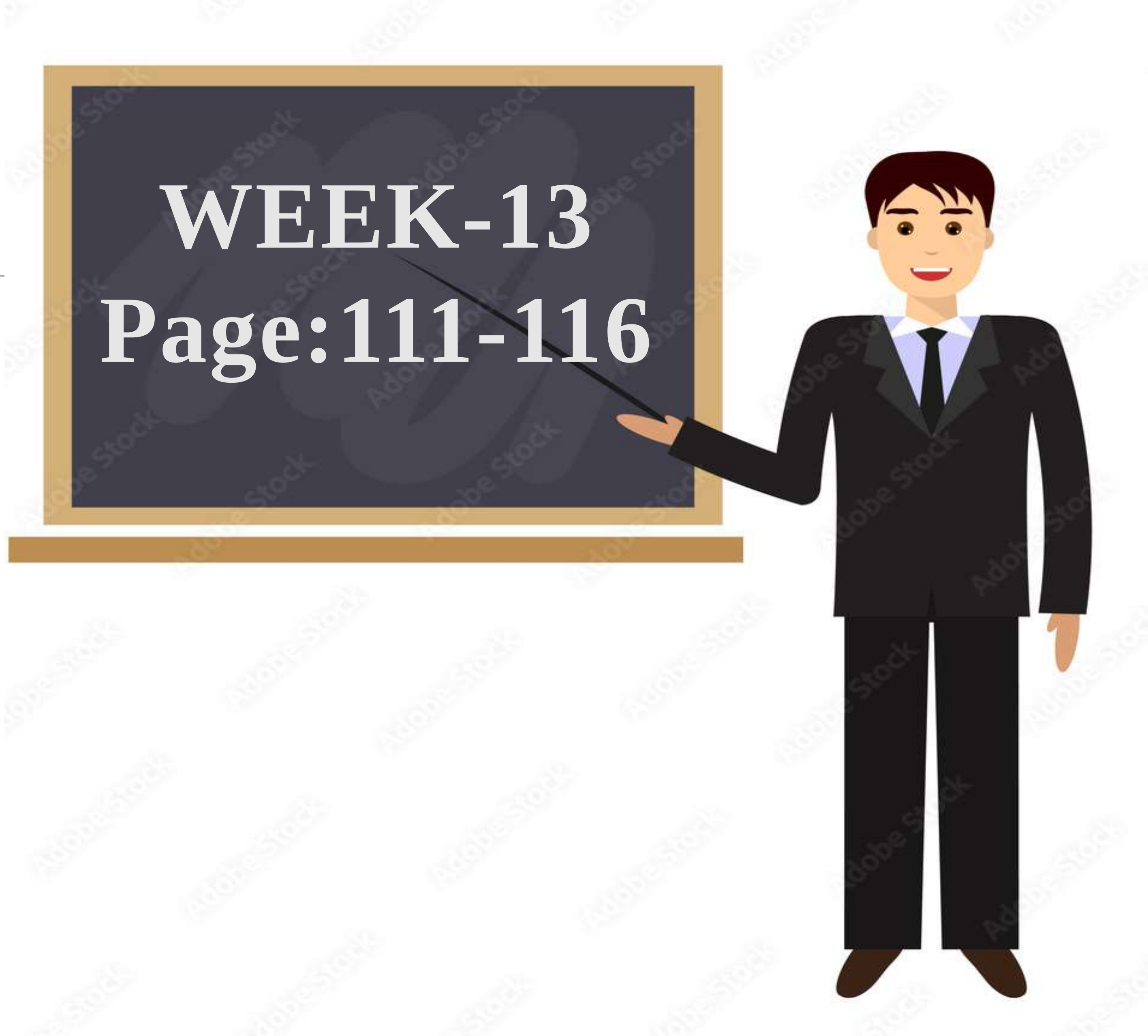
- The maximum range of Air-Defense Radar can exceed 300 miles, and the bearing coverage is a complete 360-degree circle.

- Another function of the Air-Defense Radar is guiding combat air patrol (CAP) aircraft to a position suitable to intercept an enemy aircraft.

- Major Air-Defense Radar Applications are:
  1) Long-range early warning (including airborne early warning, AEW)
  2) Ballistic missile warning and acquisition
  3) Height-finding
  4) Ground-controlled interception (GCI)

Air Traffic Control Radar

- The following Air Traffic Control (ATC) surveillance, approach and landing radars are commonly used in Air Traffic Management (ATM):
  1) En-route radar systems,
  2) Air Surveillance Radar (ASR) systems,
  3) Precision Approach Radar (PAR) systems,
  4) surface movement radars and
  5) special weather radars.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En-Route Radars

- En-route radar systems operate in L-Band usually. These radar sets initially detect and determine the position, course, and speed of air targets in a relatively large area up to 250 nm.

Air Surveillance Radar

- Airport Surveillance Radar (ASR) is an approach control radar used to detect and display an aircraft's position in the terminal area. These radar sets operate usually in E-Band, and are capable of reliably detecting and tracking aircraft at altitudes below 25,000 feet (7,620 m) and within 40 to 60 nautical miles (75 to 110 km) of their airport.

Precision Approach Radar

- The ground-controlled approach is a control mode in which an aircraft is able to land in bad weather. The pilot is guided by ground control using precision approach radar. The guidance information is obtained by the radar operator and passed to the aircraft by either voice radio or a computer link to the aircraft.

Surface Movement Radar

- The Surface Movement Radar (SMR) scans the airport surface to locate the positions of aircraft and ground vehicles and displays them for air traffic controllers in bad weather. Surface movement radars operate in J- to X- Band and use an extremely short pulse-width to provide an acceptable range-resolution.

Special Weather Radar

- Weather radar is very important for the air traffic management. There are weather-radars specially designed for the air traffic safety.


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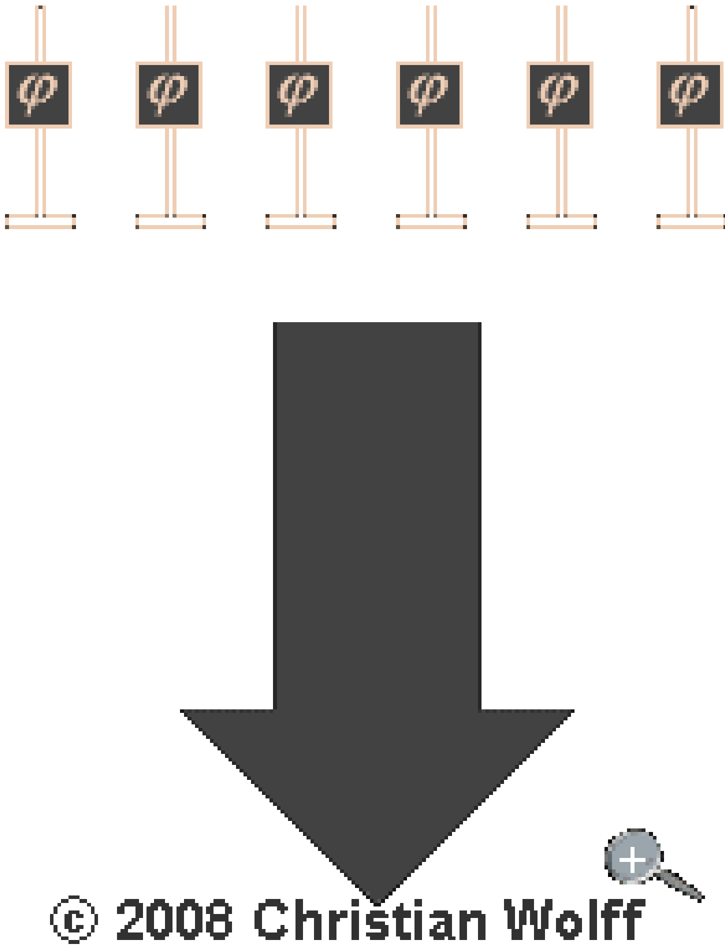
Phased array Antenna

Advantages	Disadvantages
•high gain width los side lobes •Ability to permit the beam to jump from one target to the next in a few microseconds •Ability to provide an agile beam under computer control •arbitrarily modes of surveillance and tracking •free eligible Dwell Time •multifunction operation by emitting several beams simultaneously •Fault of single components reduces the capability and beam sharpness, but the system remains operational	•the coverage is limited to a 120 degree sector in azimuth and elevation •deformation of the beam while the deflection •low frequency agility •very complex structure (processor, phase shifters) •still high costs

Phased array Antenna



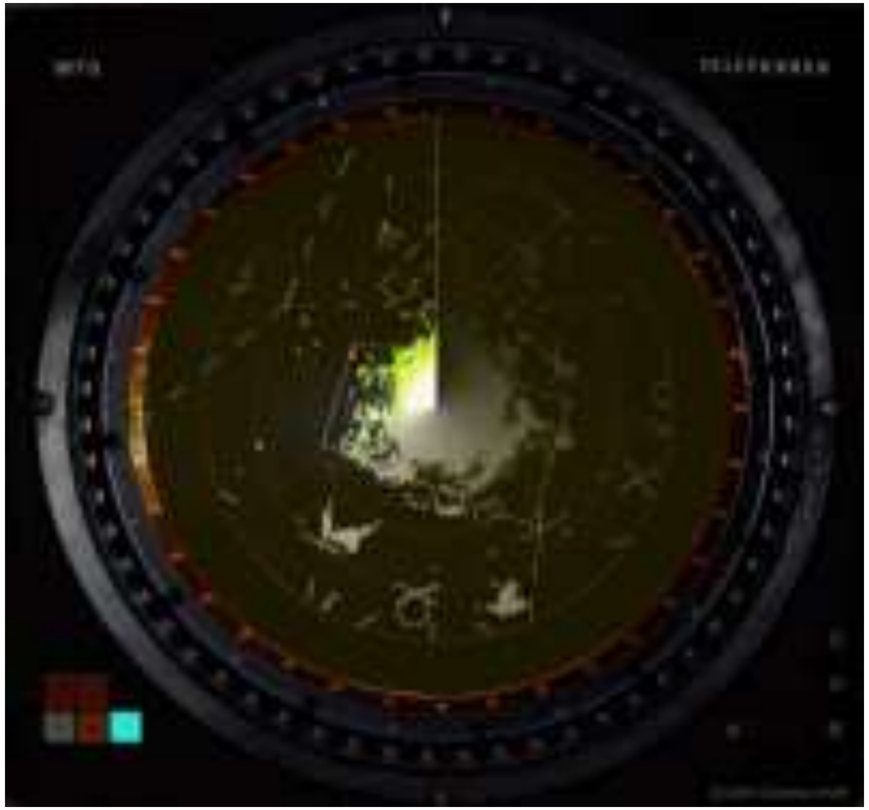
Types of Scan

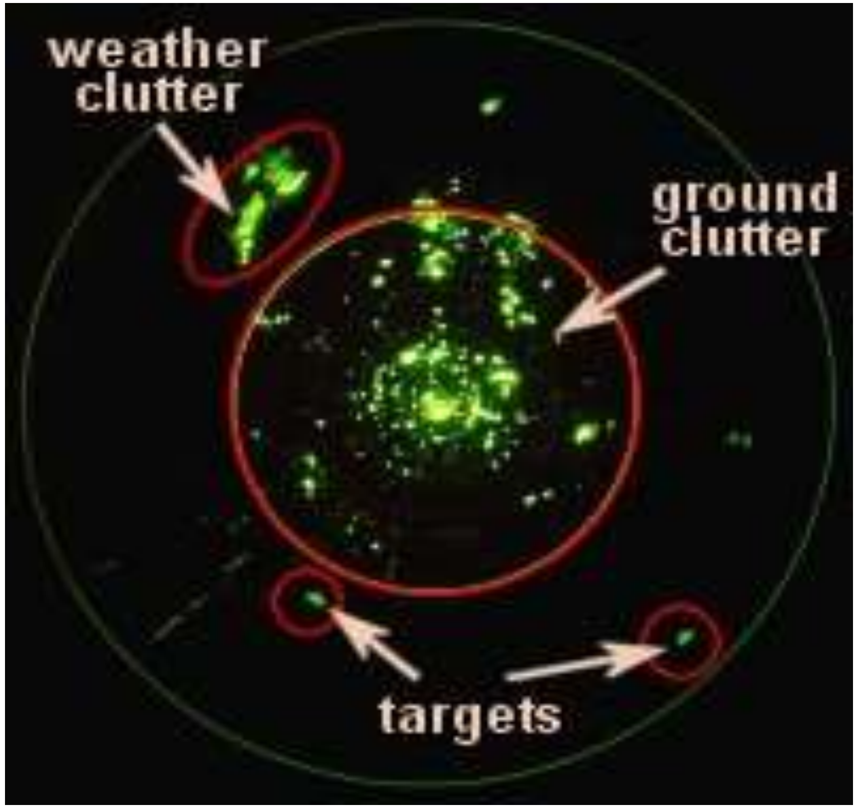
- **Primary Scan**: A scanning technique where the main antenna aerial is moved to produce a scanning beam, examples include circular scan, sector scan etc

- **Secondary Scan**: A scanning technique where the antenna feed is moved to produce a scanning beam, examples include conical scan, unidirectional sector scan, lobe switching etc.

- **Palmer Scan**: A scanning technique that produces a scanning beam by moving the main antenna and its feed. A Palmer Scan is a combination of a Primary Scan and a Secondary Scan.

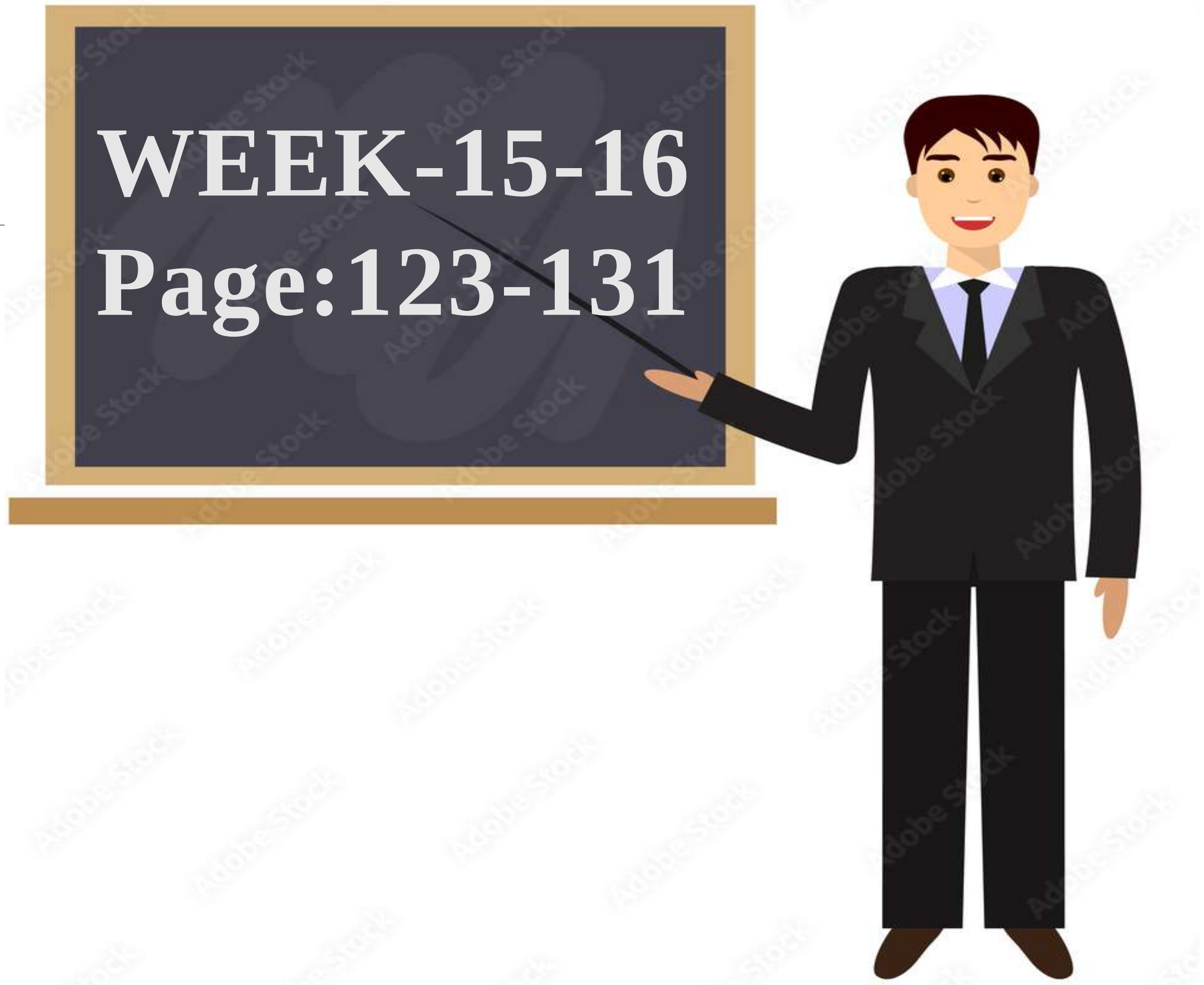
PPI Scope





Stealth Technology

- **Material.**
- **Shape, Directivity and Orientation.**
- **Active Cancellation.**
- **Radar Absorbent Paint.**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Material

- Materials such as metal are strongly radar reflective and tend to produce strong signals. Wood and cloth (such as portions of planes and balloons used to be commonly made) or plastic and fibreglass are less reflective or indeed transparent to RADAR making them suitable for radomes. Even a very thin layer of metal can make an object strongly radar reflective.

- Submarines have extensive usage of rubber mountings to isolate and avoid mechanical noises that could reveal locations to underwater passive sonar arrays.

Shape, Directivity and Orientation

- The surfaces of the F-117A are designed to be flat and very angled. This has the effect that RADAR will be incident at a large angle (to the normal ray) that will then bounce off at a similarly high reflected angle; it is forward-scattered. The edges are sharp to prevent there being rounded surfaces. Rounded surfaces will often have some portion of the surface normal to the RADAR source. As any ray incident along the normal will reflect back along the normal this will make for a strong reflected signal.

- With **purpose shaping**, the shape of the target's reflecting surfaces is designed such that they reflect energy away from the source.

F-117A

VISBY CLASS CORVETTE

Active Cancellation

- With active cancellation, the target generates a radar signal equal in intensity but opposite in phase to the predicted reflection of an incident radar signal . This creates destructive interference between the reflected and generated signals,resulting in reduced RCS.

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- With active cancellation, the target generates a radar signal equal in intensity but opposite in phase to the predicted reflection of an incident radar signal . This creates destructive interference between the reflected and generated signals,resulting in reduced RCS.

Radar Absorbent Paint

- The SR-71 Blackbird and other planes were painted with a special **"iron ball paint“.** This consisted of small metallic-coated balls. RADAR energy is converted to heat rather than being reflected.

- One of the most commonly known types of RAM is iron ball paint. It contains tiny spheres coated with carbonyl iron or ferrite. Radar waves induce molecular oscillations from the alternating magnetic field in this paint, which leads to conversion of the radar energy into heat. The heat is then transferred to the aircraft and dissipated.


SR-71 Blackbird


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Revision

THANK YOU