SCHEME :K

Name : ______________________
Roll No.: ________ Year : 20 ___ 20 __
Exam Seat No. : __________________

LABORATORY MANUAL FOR

OPTICAL NETWORK AND SATELLITE COMMUNICATION (316332)

ELECTRONICS ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)

Vision

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

Mission

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

Quality Policy

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programs.

Core Values

MSBTE believes in the following:

- Skill development in line with industry requirements
- Industry readiness and improved employ ability of Diploma holders
- Synergistic relationship with industry
- Collective and Cooperative development of all stake holders
- Technological interventions in societal development
- Access to uniform quality technical education

A Laboratory Manual
for
Optical Network and Satellite Communication

(316332)
Semester-VI
(DE/EJ/EK/ET/EX/IE/TE)

Maharashtra State Board of Technical Education, Mumbai
(Autonomous) (ISO21001:2018) (ISO/IEC27001:2013)

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(Autonomous) (ISO21001:2018)(ISO/IEC27001:2013)
4th Floor, Government Polytechnic Building 49, Kherwadi, Bandra (East), Mumbai – 400051

Maharashtra State Board of Technical Education

Certificate

This is to certify that Mr./Ms.……..…………………………..…………… Roll No ……..……of the Sixth Semester of Diploma in ……………………. ……..……..… of the Institute……………………………………………… ………………… (Code …….) has attained pre-defined practical outcomes (PROs) satisfactorily in course **Optical Network and Satellite Communication (Course Code: 316332)** for the academic year 20… - 20…. as prescribed in the curriculum.

Place: ……………….   Enrollment No: ..…………

Date: …....................   Exam Seat No: ……………

Course Teacher   **Head of the Department**   **Principal**

Seal of the Institute

Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programs with outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher; instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, The practical skills are difficult to develop through 'chalk and duster' activity in the classroom situation. Accordingly, the 'K' scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age old practice of conducting practical to 'verify the theory' (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical.

Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown the read necessary precautions to be taken, which will help the to apply in solving real-world problems in their professional life.

This manual provides guide lines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

This course Optical Network And Satellite Communication focuses on the exchange of data and information, in which optical networks are important for high-speed, high-bandwidth, and secure communication on Earth, while satellite communication is crucial for global connectivity, especially in remote areas. Their combination, known as optical satellite communication, offers the benefits of both extremely high data rates and security through light-based transmission, and the vast coverage of space.

Although all care has been taken to check for mistakes in this laboratory manual, yet it is impossible to claim perfection especially as this is the first edition. Any such errors and suggestions for improvement can be brought to our notice and are highly welcome.

Programme Outcomes (POs) to be achieved through Practical of this Course

Following programme outcomes are expected to be achieved through the practical of this course.

PO1: Basic and Discipline specific knowledge: Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the broad based Electronics engineering problems.

PO2: Problem analysis: Identify and analyze broad based Electronics engineering problems using codified standard methods.

PO3: Design/ development of solutions: Design solutions for broad based technical problems and assist with the design of Electronics system's components or processes to meet specified needs.

PO4: Engineering Tools, Experimentation and Testing: Apply modern Electronics engineering tools and appropriate technique to conduct standard tests and measurements.

PO5: Engineering practices for society, sustainability and environment: Apply appropriate Electronics technology in context of society, sustainability, environment and ethical practices.

PO6: Project Management: Use Electronics engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about broad based engineering activities.

PO7: Life-long learning: Ability to analyze individual needs and engage in updating in the context of Electronics technological changes.

List of Industry Relevant Skills

This course aims to help the student to attain the following industry-identified outcomes by undertaking the laboratory work suggested in this practical manual 'Maintain optical and satellite communication systems.'

1. Identification of optical components and cables.
2. The ability to properly strip and clean fiber optic cables is a Fundamental skill that prevents signal loss and ensures strong connections.
3. The ability to perform system diagnostics, find network faults, and troubleshoot issues systematically using equipment and logical analysis.
4. Proficiency in both mechanical and fusion splicing is critical for joining two fibers together. Fusion splicing, in particular, requires high precision and the use of specialized, delicate equipment
5. A deep understanding of RF principles is crucial for working with satellite signals.
6. The ability to calculate and interpret the signal strength and quality (C/N and Eb/N0) for both uplink and down link.
7. Effectively conveying complex technical information to team members and other stakeholders is essential, particularly in a high-pressure environment.
8. Using software like MATLAB, Simulink, or Systems Tool Kit (STK) for orbital mechanics, link budget analysis, and system modeling.

Guidelines to Teachers

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each practical.
3. Involve students in the performance of each practical.
4. Teacher should ensure that the respective skills and competencies are developed in the students after the completion of the practical exercise.
5. Teachers should give opportunities to students for hands-on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by the industry.
8. Finally give practical assignments and assess the performance of students based on task assigned to check whether it is as per the instructions.
9. Teacher is expected to refer complete curriculum document and follow guidelines for implementation.
10. At the beginning of the practical, which is based on the simulation, teacher should make the students acquainted with simulation software environment.
11. Teacher should utilize projector to demonstrate the procedure for software installation / application to the group of students.

Instructions for Students

1. Listen carefully to the lecture given by the teacher about course, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and make a record of all observations.
3. Do the calculations and plot the graph wherever it is required in the practical.
4. Students shall develop maintenance skills as expected by industries.
5. Student shall attempt to develop related hand-on skills and gain confidence.
6. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual.
7. Student should develop the habit to submit the practical on date and time.
8. Student should prepare well while submitting a write-up of exercise.
9. Attach / paste separate papers wherever necessary.

Practical Course Outcome Matrix

Course Outcomes (COs)

CO1 - Interpret the functions of the various units of optical fiber communication system.
CO2 - Evaluate the performance characteristics of optical sources and detectors.
CO3 - Establish analog and digital fiber optic link.
CO4 - Analyze various parameters influencing performance of transmitted and received Signals in Satellite communication systems.
CO5 - Maintain Satellite earth segment.

Sr. No.	Title of practical	CO1	CO2	CO3	CO4	CO5
1	* Identification of optical components and cables.	✓				
2	Identification of core, cladding and coating of optical fiber cable.	✓				
3	* Find numerical aperture of optical fiber.	✓				
4	***** Test the performance of an Avalanche Photo diode (APD) (Virtual lab can be used in case of non-availability of instruments in the lab)		✓			
5	* Analysis of Photo diode Characteristics (Virtual lab can be used in case of non- availability of instruments in the lab)		✓			
6	* Measurement of light intensity and photo current at various positions for a given photo diode.		✓			
7	Find the bit error rate (BER) at the optical channel receiver.		✓			
8	* Measurement of various parameters of eye pattern.		✓			
9	Measurement of attenuation loss in optical fiber.			✓		
10	* Measurement of bending loss of given optical fiber cable.			✓		
11	Measurement of optical power using optical meter			✓		
12	* Computation of Link Power Budget for Fiber Optics Using Coding (Use open source simulation software).			✓		
13	* Computation of rise time budget w.r.t fiber optics through coding (Use open source simulation software).			✓		
14	* Establishing an Active satellite link and demonstrating link failure operations				✓	
15	Establish a direct communication link between the Uplink Transmitter and the Downlink Receiver using a				✓	

	tone signal.					
16	Establishing audio video satellite link between transmitter and receiver				√	
17	Simultaneous Transmission and Reception of Audio, Video, and Tone/Voice Signals via Satellite Link				√	
18	Evaluating satellite link performance by transmitting telecommands and receiving telemetry data.				√	
19	Transmission and reception of function generator waveforms through satellite communication link.				√	
20	* Calculation of Satellite Look Angles (Azimuth & Elevation) Using Coding (Use open source simulation software).				√	
21	Simulating and validating Kepler's laws of planetary motion using code.(Use any relevant open source software).				√	
22	Simulation of Satellite Eclipse Periods through coding.(Use open source simulation software).				√	
23	* Measurement of the carrier-to-noise ratio (C/N) of the established satellite link.					√
24	* Establish a direct communication link between two PCs using RS-232 serial ports.					√
25	* Find rain attenuation through coding (Use open source simulation software).					√
26	* Simulation of satellite link budget through coding (Use open source simulation software).					√
27	Analysis of reliability in satellite system.					√
28	* Find EIRP or any given satellite communication link through coding.(Use open source simulation software).					√

Content Page

List of Practical and Formative Assessment Sheet

13	* Computation of rise time budget w.r.t fiber optics through coding (Use open source simulation software).	70					
14	* Establishing an Active satellite link and demonstrating link failure operations	76					
15	Establish a direct communication link between the Uplink Transmitter and the Downlink Receiver using a tone signal.	81					
16	Establishing audio video satellite link between transmitter and receiver	89					
17	Simultaneous Transmission and Reception of Audio, Video, and Tone/Voice Signals via Satellite Link	96					
18	Evaluating satellite link performance by transmitting telecommands and receiving telemetry data.	104					
19	Transmission and reception of function generator waveforms through satellite communication link.	117					
20	* Calculation of Satellite Look Angles (Azimuth & Elevation) Using Coding (Use open source simulation software).	124					
21	Simulating and validating Kepler's laws of planetary motion using code.(Use any relevant open source software).	131					
22	Simulation of Satellite Eclipse Periods through coding.(Use open source simulation software).	144					
23	* Measurement of the carrier-to-noise ratio (C/N) of the established satellite link.	152					

24	* Establish a direct communication link between two PCs using RS-232 serial ports.	159						
25	* Find rain attenuation through coding (Use open source simulation software).	166						
26	* Simulation of satellite link budget through coding (Use open source simulation software).	174						
27	Analysis of reliability in satellite system.	189						
28	* Find EIRP or any given satellite communication link through coding.(Use open source simulation software).	197						
				TOTAL				

Note: Out of above suggestive LLOs-

'*' Marked Practical (LLOs) are mandatory.

Minimum 80% of above list of lab practical are to be performed.

Judicial mix of LLOs are to be performed to achieve desired outcomes.

Practical No.1: Identification of optical components and cables.

I Practical Significance

This practical is designed to provide hands-on experience with identification of optical Components and cables, which is fundamental to understanding optical communication systems. In modern telecommunications and networking industries, professionals must be skilled in optical Component identification, measurement techniques, and system characterization. This practical directly relates to real-world applications in fiber optic network installation, maintenance, and trouble shooting in telecommunication infrastructure, data centers, and metropolitan area networks. Students will familiarize themselves with various optical components including single-mode and multimode fibers.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Interpret the functions of the various units of optical fiber communication system.

IV Laboratory Learning Outcome

LLO 1.1 Identify optical components, cables.

V Relevant Affective Domain related Outcomes

- Work effectively in laboratory teams to achieve common learning objectives.
- Demonstrate awareness of proper safety procedures and equipment handling techniques.

VI Relevant Theoretical Background

Fig 1.1 Shows the Fiber optical communication system which consists of information source, Electrical transmits, optical fiber source, optical detector and Electrical receiver. The diagram illustrates the basic block architecture of an optical fiber communication system. The process begins with an information source, whose signal is converted into an electrical form by the electrical transmitter. This electrical signal then modulates an optical source, typically a laser or LED, to generate an optical signal. The signal is then transmitted through the optical fiber media, where it travels to the receiving end. At the receiver, the optical detector converts the incoming optical signal back into an electrical signal. This reconstructed electrical signal is processed by the electrical receiver and finally delivered accurately to the destination, completing the communication link. This step-by-step pathway highlights the conversion and transmission of information from its origin to the endpoint using optical fiber technology.

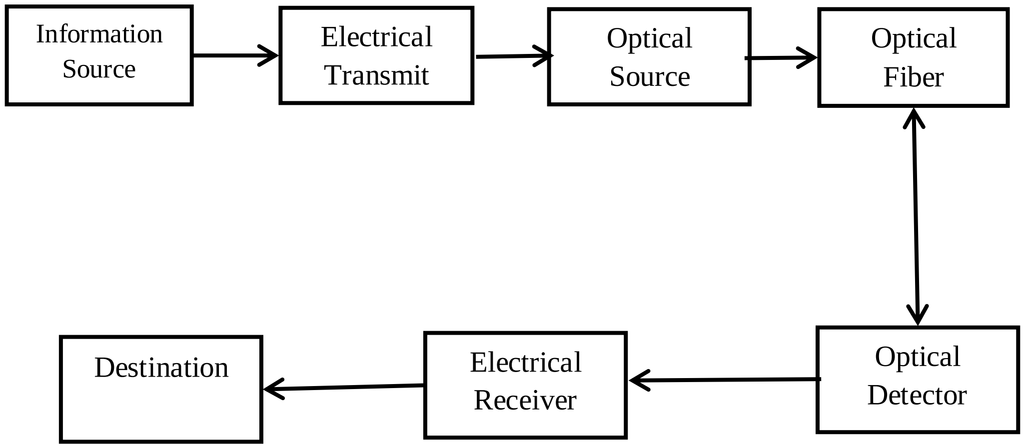


Fig 1.1 Block diagram of Fiber optical communication system

Different components of optical fiber cable can be observed in the given diagram. Cladding in optical fibers is one or more layers of materials of lower refractive index in intimate contact with a core material of higher refractive index.

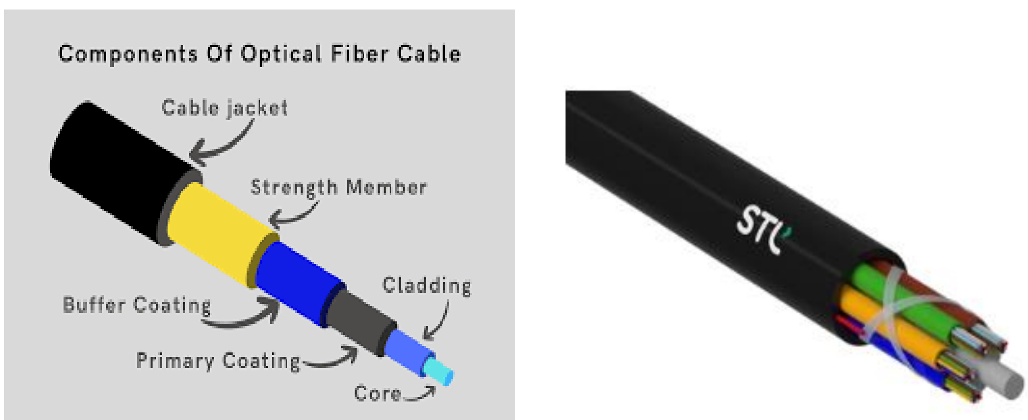


Fig.1.2 Cladding in optical fiber

VII Circuit diagram/Block diagram/Flowchart

A. Suggestive Components

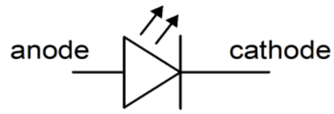
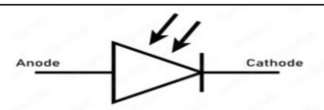
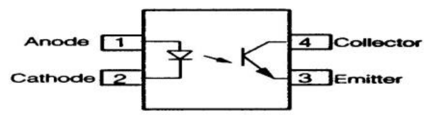
Sr.No.	Component	Symbol
1	**LED**	
2	**Photodiode**	
3	**Opto-coupler**	

Fig.1.3 List of component

B. Actual Components used in laboratory.

VIII Required Resources with specifications

Table No. 1.1

Sr.No.	Name of Resource	Suggested Broad Specification	Quantity
1	Fiber optic cables	9/125 μm for single-mode and 50/125 μm or 62.5/125 μm for multimode	1 Each
2	LED	1.25V, 1.5V, 1.8V, 2.5V, 3.3V or 5V	1 Each
3	Photodiode	λ p = 870 nm (maximum)	1
4	DMM	DC,0-1.5/3 Amp,0-2.5/5 Amp,0-5/10 Amp,0-150/300V,0-250/500V,0- 75/150VAC-0-1000V,0-10A	1

Sr.No.	Name of Resource	Suggested Broad Specification	Quantity
5	LUX Meter	3 1/2 digit 18 mm, LCD range 1 to 50000LUX/over input	1
6	Magnifying glass	Magnifier 2X	1
7	Opto-coupler	Operating temperature -55 to +125℃, Forward current within power dissipation	1

IX Precaution to be followed

Handle every component and cable carefully.

X Procedure

1. List the optical fiber components
2. Observe the Core, Cladding, Primary coating, Buffer coating, strength member and cable jacket.
3. Test and observe the working of LED.
4. Test and observe the working of Opto-coupler.
5. Test and observe the working of photodiode.

XI Resources used

Table No. 1.2

Sr.No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach a separate page)

1.

2.

3.

4.

XIII Observation Table

Table No. 1.3

Sr.No.	Name of component	Specifications	Remark

XIV Result

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……………………………………………………………………………………………

XV Interpretation of result

……………………………………………………………………………………………

……………………………………………………………………………………………

XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Identify the main components of optical fiber cable.
2. List the types of optical fiber components.
3. Read the matter printed on optical fiber cable and interpret it.

[Space for Answers](If required attach a separate page)

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XVIII Suggested References for further reading

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ,ISBN :9781119737360

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suiTable No. instrument	20%
4	Working in teams	10%
Product Related:10Marks		**40%**
1	Interpretation of result	10%
2	Conclusion	10%
3	Answers to sample practical related questions	15%
4	Submitting the journal in time	05%
	Total (25Marks)	**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.2: Identification of core, cladding and coating of optical fiber cable.

I Practical Significance

This practical provides essential hands-on experience in understanding the physical structure of optical fiber cables, which is crucial for telecommunications professionals. The ability to identify and understand the core, cladding, and coating layers of optical fibers is fundamental for fiber optic network installation, splice preparation, connector termination, and system troubleshooting. Understanding the three-layer structure is critical for proper handling, installation, and maintenance of optical fiber systems in industrial applications.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Interpret the functions of the various units of optical fiber communication System.

IV Laboratory Learning Outcome

LLO 2.1 Identify core, cladding, and coating of optical fiber.

V Relevant Affective Domain related outcomes

- Work effectively in laboratory teams to achieve common learning objectives
- Demonstrate awareness of proper safety procedures and equipment handling techniques.

VI Relevant Theoretical Background

The optical fiber consists of three main parts: the core, cladding, and coating. The core is the central light-guiding region with a diameter ranging from 8 to 62.5 micrometers, made of ultra-pure silica glass doped to achieve a slightly higher refractive index, denoted as n_1, than the surrounding layers. The cladding, with a diameter of about 125 micrometers, is composed of pure silica glass and has a lower refractive index (n_2) that ensures total internal reflection, confining the light within the core. Surrounding the cladding is the coating, a protective layer made of polymers to guard the delicate glass structure. The coating includes a soft, flexible primary layer about 12.5 micrometers thick and a harder secondary layer around 17.5 micrometers thick, giving a total coated diameter of approximately 250 micrometers.

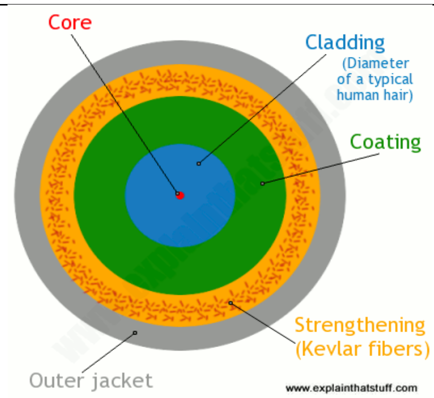

Fig. 2.1 Parts of Optical Fiber

VII Circuit diagram/Block diagram/Flowchart

A. Suggestive block diagram

NA

B. Actual diagram used in laboratory

NA

VIII Required Resources with specifications

Table No. 2.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Splicing, Cutting and Fiber Stripper	Fiber Stripper length :60mm, dimension:420x300x110mm	1 Each
2	Fiber optic cable	1 meter Single mode and Multimode	2 pieces
3	Magnifying glass	Magnifier 2X	1

IX Precautions to be followed

1. Handle optical fibers carefully to avoid breakage and maintain minimum bending radius >30mm.
2. Keep optical connector end faces clean using appropriate cleaning materials and techniques.
3. Store optical components in protective cases when not in use to prevent damage.

X Procedure

1. Identify the optical fiber cables.
2. Prepare the wire.

3. Insert the wire in the stripper.
4. Using stripper remove cladding.
5. Using magnifying glass observe the glass fiber.

XI Resources used

Table No. 2.2

Sr. No.	**Name of Resource**	**Specifications**	**Quantity**

XII Actual Procedure (If required attach a separate page)

1.

2.

3.

XIII Observation Table

Table No. 2.3

Sr. No.	**Name of component**	**Specifications**	**Remark**

XIV Result

……………………………………………………………………………………………

……………………………………………………………………………………………

XV Interpretation of result

……………………………………………………………………………………………

………..……………………………………………………………………………………

XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Identify the different types of optical fiber cable.
2. Give the wavelengths which are used in multimode fiber.
3. List the parts of optical fiber cable.

[Space for Answers.] (If required attach a separate page)

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XVIII Suggested references for further reading

Sr.No	Author	Title	Publisher with ISBN Number
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2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ISBN :9781119737360

XIX Assessment Scheme:

Performance Indicators		Weightage
Process Related: 15Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable. instrument	20%
4	Working in teams	10%
Product Related:10Marks		**40%**
1	Interpretation of result	10%
2	Conclusion	10%
3	Answers to sample practical related questions	15%
4	Submitting the journal in time	05%
Total (25Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.3: Find numerical aperture of Optical fiber

I Practical Significance

The numerical aperture (NA) is a fundamental parameter that defines the light-gathering ability of an optical fiber and directly impacts system design and performance. This practical provides hands-on experience in measuring one of the most critical optical parameters used in fiber optic system engineering. Understanding NA is crucial for selecting appropriate fibers for specific applications, calculating link budgets, and troubleshooting system performance issues in telecommunications networks.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Interpret the functions of the various units of optical fiber communication System.

IV Laboratory Learning Outcome.

LLO 3.1 Measure numerical aperture of optical fiber to find the refractive index.

V Relevant Affective Domain related outcomes.

- Work effectively in laboratory teams to achieve common learning objectives.
- Demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

It is the numeric value expressing the amount of light that can enter the cone, because ray incident on the cone axis at an angle less than the critical angle (θc) only can undergo total internal reflection. Rest of the rays is scattered. Numerical aperture is an important factor in design of communication links. Numerical aperture refers to the maximum angle at the light incident on the fiber end is totally internal reflected and is transmitted properly along the fiber. The cone formed by the rotation of this angle along the axis of the fiber is the cone of acceptance of fiber. The light ray should strike the fiber end within its cone of acceptance; else it is refracted out of the fiber core. Numerical aperture is the measure of the power launching efficiently of an optical fiber. When N.A. is small, then the light available from various directions from the source, only a portion of light is accepted by an optical fiber and the remaining is rejected.

VII Circuit diagram/block diagram/flowchart

A. Suggestive diagram

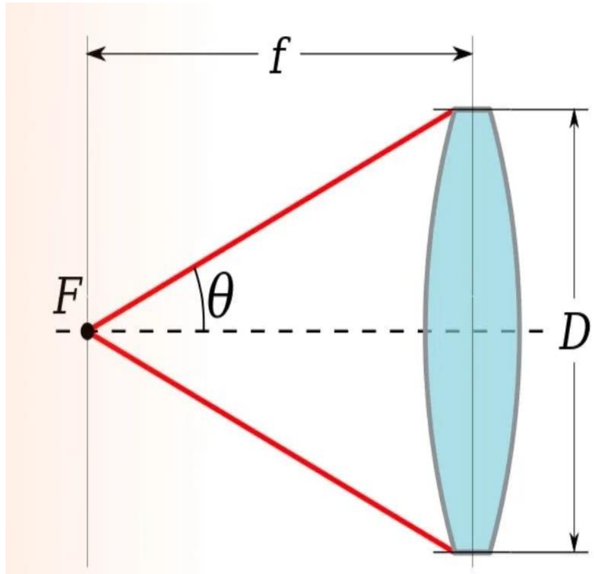

Fig.3.1 Ray diagram of Numerical aperture

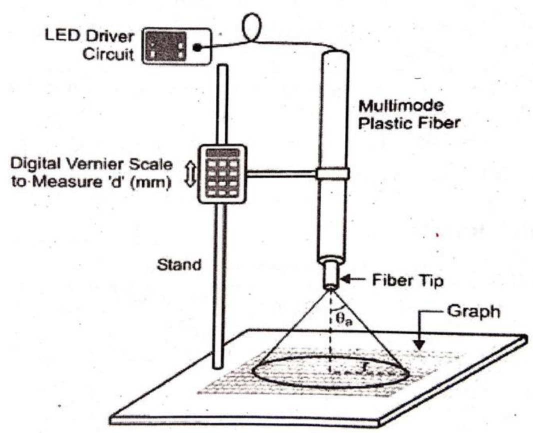

Fig.3.2 Practical setup for Numerical aperture

B. Actual diagram

VIII Required Resources with specifications

Table No. 3.1

Sr. No	Name of Resource	Specification	Quantity
1	Optical fiber samples	SMF 9/125 µm, MMF 50/125 µm	5-10 pieces
2	Fiber optic cleaning kit	Alcohol, wipes, cleaning cassettes	1 set
3	Cutting and trimming tools	Precision fiber cleaver	1 unit
4	Optical connectors	SC, LC, ST, FC types	2 each type
5	Light source	LED 850/1300 nm	1 unit

IX Precautions to be followed

1. Do not touch optical connector ferrules with bare hands to avoid contamination
2. Store optical components in protective cases when not in use to prevent damage
3. Avoid direct exposure to laser sources; use appropriate safety eyewear when required

X Procedure

1. Take the circuit board and connect power supply to LED.
2. Connect one end of optical fiber in vertical manner over the graph paper and other end very close to light source with coupler
3. Vary the diameter between graph paper and optical fiber such as 2mm, 3mm, 4mm and so on, to get concentrated cone of light.
4. Mark the circle of light area falling on the graph paper through optical fiber using sharp pencil.
5. Measure the diameter (D) of circle. Calculate the radius (r) using the relation r = D

XI Resources used

Table No. 3.2

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach a separate page).

1.
2.
3.
4.

XIII Observation Table

Table No. 3.3

Sr.No.	Distance (d)(mm)	Distance (D) (mm)	Radius (r =D/2) mm	X=$\sqrt{r^2+d^2}$	NA =$\frac{r}{x}$
1	2 mm				
2	3 mm				
3	4 mm				
4	5 mm				
5	6 mm				

Calculations :

X= $\sqrt{r^2+d^2}$

NA = $\frac{r}{x}$

XIV Result

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XV Interpretation of result.

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Define numerical aperture (NA) of optical fiber
2. Give significance of numerical aperture
3. State the purpose of NA measurement/calculation.
4. Can NA is measured theoretically? Give equation.

[Space for Answers If required attach a separate page]

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XVIII Suggested references for further reading

Sr. No	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication,	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ,ISBN :9781119737360

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related:10Marks		**40%**
1	Calculated theoretical values of given component	10%
2	Interpretation of result	05%
3	Conclusion	05%
4	Answers to sample practical related questions	15%
5	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.4: Test the performance of an Avalanche Photodiode (APD)

I Practical Significance

This practical focuses on evaluating the performance characteristics of Avalanche photodiode as detectors, which are critical components in fiber optic communication systems. Test the performance of an avalanche photodiode (APD) is essential to understand how optical signals are detected in modern telecommunications networks. Industry professionals require comprehensive knowledge of component for designing efficient optical communication systems, optimizing signal quality.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Evaluate the performance characteristic of optical sources and detectors

IV Laboratory Learning Outcome

LLO4.1 Test the performance of an Avalanche Photodiode (APD).

V Relevant Affective Domain related outcomes

- Understand the importance of accuracy and integrity in technical measurements and documentation
- Work effectively in laboratory teams to achieve common learning objectives
- Demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

In an avalanche photodiode (APD), light detection relies on the conversion of incident optical power into a proportional electrical current. When photons strike the semiconductor junction, they generate electron-hole pairs, initiating the photodiode operation. Unlike a regular PIN photodiode, an APD operates under a high reverse bias, enabling the avalanche effect—where primary charge carriers gain sufficient energy to ionize atoms and create secondary carriers, providing an internal multiplication gain. The device's quantum efficiency represents how effectively incident photons generate charge carriers, influencing its sensitivity. However, the avalanche process introduces excess noise known as avalanche noise, in addition to thermal and shot noise inherent to semiconductor devices. The APD's bandwidth, determined by carrier transit times and multiplication dynamics, defines how quickly it can respond to rapidly varying optical signals, making it suitable for high-speed optical fiber communication systems requiring high sensitivity and fast response.

V II Circuit diagram/Block diagram/flowchart

A. Suggestive Circuit diagram

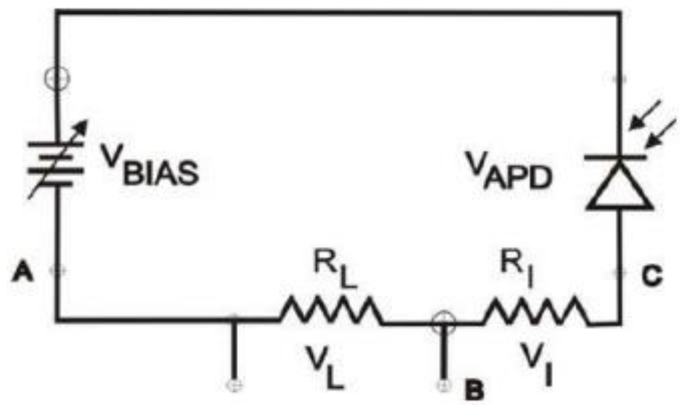

Fig 4.1 Circuit diagram of Avalanche photodiode

B. Actual block diagram

VIII Required Resources with specifications

Table No. 4.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Fiber optic trainer kit	660 nm & 950 nm Fiber Optic LED channel with Transmitter & Receiver, Built in DC Power Supply, Data Generator with selectable clock (64/ 128/ 256 KHz),Full Duplex Analog & Digital Trans-receiver	1
2	APD detector	Wavelength range 300 to 1700 nm	2 units
3	DMM	DC,0-1.5/3 Amp,0-2.5/5 Amp,0-5/10 Amp,0-150/300V,0-250/500V,0- 75/150VAC-0-1000V,0-10A	1

IX Precautions to be followed

1. Keep optical connector end faces clean using appropriate cleaning materials and techniques
2. Do not touch optical connector ferrules with bare hands to avoid contamination
3. Store optical components in protective cases when not in use to prevent damage

X Procedure

1. Set up the practical arrangement according to the circuit diagram/block diagram
2. Follow the detailed procedure as outlined in the laboratory manual for test the performance of an avalanche photodiode (APD).
3. Record all observations systematically in the table

XI Resources used

Table No. 4.2

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure .(If required attach separate page)

1

2

3

4

5

XIII Observation Table

Table No. 4.3

Sr. No.	Parameter	Measured value	Unit	Remark
1	Bias Voltage			
2	Wave length			
3	Photocurrent			
4	Gain			

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Give the working principle of Avalanche photodiode.
2. State important parameters of Avalanche photodiode.
3. State the evaluation of performance characteristics of optical sources and detectors

[Space for Answers](If required attach separate page)

XVIII Suggested references for further reading

Sr. No	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication,	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ,ISBN :9781119737360
3	Biswanath Mukherjee	Optical Communication networks	Mc Graw Hill, ISBN-13,978-0070444355

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related:10 Marks		**40%**
1	Interpretation of result	10%
2	Conclusion	10%
3	Answers to sample practical related questions	15%
4	Submitting the journal in time	5%
	Total (25Marks)	**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 5: Analysis of Photodiode Characteristics

I Practical Significance

This practical focuses on evaluating the performance characteristics of optical sources and detectors, which are critical components in fiber optic communication systems. Analysis of photodiode characteristics is essential for understanding how optical signals are generated, transmitted, and detected in modern telecommunications networks. Industry professionals require comprehensive knowledge of these components for designing efficient optical communication systems, optimizing signal quality, and troubleshooting network performance issues.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expect outcome through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Evaluate the performance characteristics of optical sources and detectors.

IV Laboratory Learning Outcome

LLO5.1 Evaluate the performance of given photodiode (detector) using LED as an optical source.

V Relevant Affective Domain related outcomes

- Develop curiosity about emerging technologies and commitment to life long Professional development.
- Demonstrate awareness of proper safety procedures and equipment handling techniques.

VI Relevant Theoretical Background

This practical focuses on understanding the working principles of sources and detectors used in fiber optical communication systems. It explores how photodiodes converts optical signals into corresponding electrical signals, emphasizing the role of the avalanche effect in avalanche photodiodes (APDs) for achieving internal current gain. The concept of quantum efficiency explains the effectiveness of photon-to-electron conversion, while dark current represents undesired leakage current present even in the absence of light. The responsivity quantifies the detector's sensitivity by relating output current to input optical power. Additionally, the practical examines various noise sources such as thermal, shot, and avalanche noise, which affect signal quality, and analyzes the detector's bandwidth to determine its frequency response and suitability for high-speed communication systems. There are two semiconductors, P- type and N-type between them there is a depletion region. The photons incident on PN junction, that causes the current to flow through the circuit.

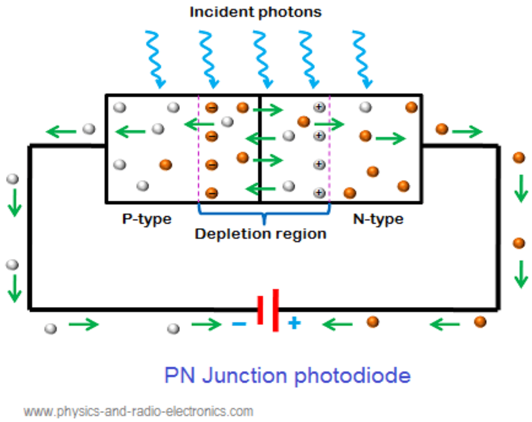

Fig.5.1 PN Junction photodiode

VII Circuit diagram/Block diagram/flowchart

A. Suggestive diagram

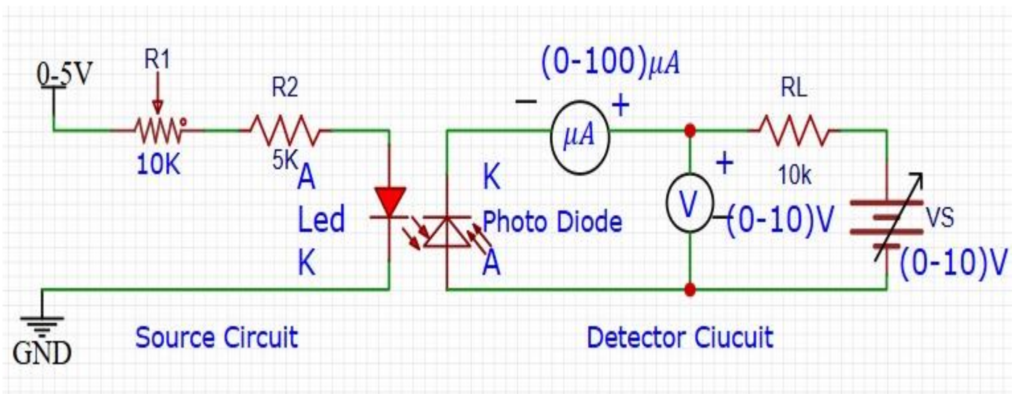

Fig.5.2 Circuit diagram of photodiode

B. Actual Circuit diagram

VIII Required Resources with specifications

Table No. 5.1

Sr.No.	Name of Resource	Suggested Broad Specification	Quantity
1	Photodiode Trainer kit	230V+/- 10%	1
2	Micro-Ammeter	0-100 uA	1
3	Power supply	0-30 V DC	1
4	Voltmeter	0-10 V	1
5	Resistors	5K and 10K Ω	2 each

IX. Precautions to be followed

1. Handle every instrument carefully
2. Note down the readings properly.
3. Do not exceed voltage over permissible range.

X. Procedure

1. Select the components as per the circuit diagram.
2. Connect the component of source circuit and detector circuit as per the diagram.
3. Align source and detector close to each other such that light of LED will be incident on the photodiode.
4. Adjust the resistance R1 (Position I) such that LED will not emit the light, measure the photo current (Ip) in the detector circuit.
5. Change the position of R1 (Position II) and increase the intensity of light. At this position measure current Ip.
6. Again change the position of R1 (Position III) , and measure current Ip for medium intensity of light.
7. Repeat the step 6 for the position of R1 (Position IV) and measure current Ip for high intensity of light. Note the readings.

XI. Resources used

Table No. 5.2

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			
5			

XII. Actual Procedure. (If required attach separate page)

1.

2.

3.

4.

XIII Observation Table

Table No. 5.3

Sr.No.	Light Intensity	Photo Current (Ip)
1	Position I no light condition	
2	Position II low light condition	
3	Position III medium light condition	
4	Position IV high light condition	

XIV. Result

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. List the types of sources available for optical fiber ccommunication.
2. Can we use source other than LED?
3. Does the photo current increases if intensity of light increases?

[Space for Answers. If required attach separate page]

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XVIII. Suggested references for further reading

Sr. No	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	"Fiber Optic Communication	Mc Graw Hill Higher Education, New Delhi ,2013, ISBN: 9781259006876
2	Biswanath Mukherjee	Optical Communication networks	Mc Graw Hill, ISBN-13,978-0070444355

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related:15 Marks	**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
	Product Related:10 Marks	**40%**
1	Calculated theoretical values of given component	10%
2	Interpretation of result	05%
3	Conclusion	05%
4	Answers to practical related questions	15%
5	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.6: Measurement of light intensity and photocurrent at various positions for a given photodiode.

I Practical Significance

This practical focuses on evaluating the performance characteristics of optical sources and detectors, which are critical components in fiber optic communication systems. Measurement of light intensity and photocurrent at various positions for a given photodiode is essential for understanding how optical signals are generated, transmitted, and detected in modern telecommunications networks. Industry professionals require comprehensive knowledge of these components for designing efficient optical communication systems, optimizing signal quality, and troubleshooting network performance issues.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences:‘ Maintain optical and satellite communication systems.’

III Course Level Learning Outcome

Evaluate the performance characteristics of optical sources and detectors.

IV Laboratory Learning Outcome.

LLO6.1 Test the performance of the given photo-diode (Detector) using LASER as an optical source.

V Relevant Affective Domain related outcomes

- Develop curiosity about emerging technologies and commitment to lifelong Professional development.
- Demonstrate awareness of proper safety procedures and equipment handling techniques.

VI Relevant Theoretical Background

Photodiodes convert incident optical power into an electrical current, forming the core of fiber optic detectors. The photodiode adds internal gain through impact ionization, improving sensitivity but introducing excess noise. Quantum efficiency measures how effectively photons generate charge carriers, while dark current represents leakage current in the absence of light. Responsivity links optical input to electrical output, depending on wavelength and device structure. Noise in photo detection comprises thermal noise, shot noise and avalanche noise. Bandwidth describes how detector response varies with frequency, influencing the system’s ability to faithfully reproduce high-speed optical signals. Together, these concepts determine how light intensity and photocurrent vary with position of the photodiode, how signals degrade in noise, and how detector performance scales with wavelength, bias and device design. Light amplification by stimulated Emission of Radiation(LASER) diode. From the fabrication process LED can be improved to LASER diode which works with the photon absorption, spontaneous emission and stimulated emission. In LASER two ends are made of RI causing the number of reflections of photon until a resonant LASER beam comes out, the emission is continuous.

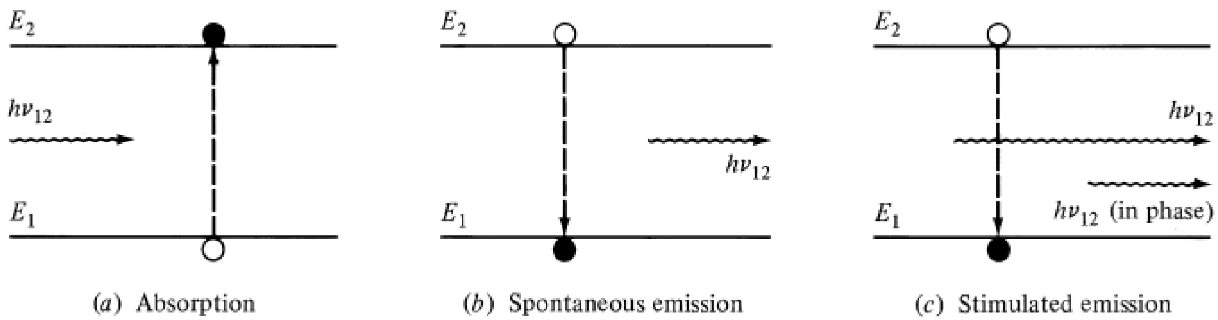

Fig. 6.1 Emission of LASER Beam

VII Circuit diagram/Block diagram/ Flowchart

A. Suggestive circuit diagram.

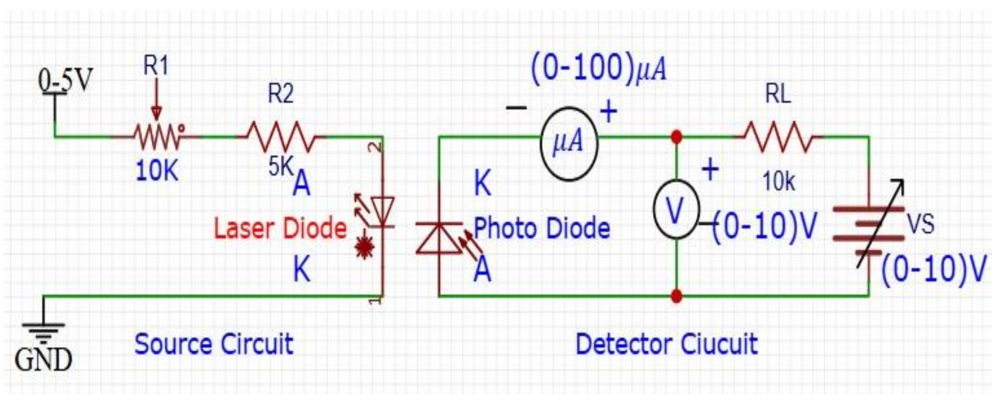

Fig.6.2 Circuit diagram of photodiode

B. Actual circuit diagram

VIII Required recourses with specifications

Table No. 6.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Optical fiber Trainer kit	230V+/- 10%, 50 Hz,	1
2	Micro-ammeter	0-100 uA	1
3	Power supply	0-30 V DC,	1
4	Voltmeter	0-10 V,DC	1
5	Resistors	5k and 10K Ohm	2 each
6.	Laser diode	Wavelength upto 650nm, LD - 650-20-3-50.	1

IX. Precautions to be followed

1. Handle every instruments carefully.
2. Note down the readings properly.
3. Do not exceed voltage over permissible range.

X. Procedure

1. Select the components as per the circuit diagram
2. Connect the component of source circuit and detector circuit as per the diagram.
3. Align source and detector close to each other such that light of Laser will be incident on the Photodiode
4. Adjust the resistance R1 (Position I) such that Laser will not emit the light.
5. Measure the photo current Ip in the detector circuit.
6. Change the position of R1 (Position II) and increase the intensity of light. At this position measure current Ip for low light condition.
7. Again change the position of R1 (Position III) and measure current Ip for medium intensity of light.
8. Repeat the step 6 for the position of R1(Position IV) high light condition. Note the readings.

XI Resources used

Table No. 6.2

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			
5			
6			

XII Actual Procedure (If required attach separate page).

1.
2.
3.
4.
5.
6.

XIII Observation Table

Table No. 6.3

Sr. No.	Light Intensity	Photo current (Ip)µA
1	Position I no light condition	
2	Position II low light condition	
3	Position III medium light condition	
4	Position IV high light condition	

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Compare : Optical fiber communication and radio wave communication.
2. List the types of emission of LASER diode.
3. LASER or LED which is better for photodiode characteristics.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested References for further reading.

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	"Fiber Optic Communication	Mc Graw Hill Higher Education, New Delhi ,2013, ISBN: 9781259006876
2	Biswanath Mukherjee	Optical Communication networks	Mc Graw Hill, ISBN-13,978-0070444355

XI X Assessment Scheme

Performance Indicators		Weightage
Process Related:15Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related:10Marks		**40%**
1	Calculated theoretical values of given component	10%
2	Interpretation of result	05%
3	Conclusion	05%
4	Answers to practical related questions	15%
5	Submitting the journal in time	05%
Total (25Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.7 Find the bit error rate (BER) at the optical channel receiver.

I Practical Significance

This practical focuses on evaluating the bit error rate at the optical channel receiver. Find the bit error rate (BER) at the optical channel receiver is essential for understanding how optical signals are generated, transmitted, and detected in modern telecommunications networks. Industry professionals require comprehensive knowledge of these components for designing efficient optical communication systems, optimizing signal quality.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences. 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Evaluate the performance characteristics of optical sources and detectors.

IV Laboratory Learning Outcome

LLO 7.1 Measure the bit error rate at the optical receiver.

V Relevant Affective Domain related outcomes

- Work effectively in laboratory teams to achieve common learning objectives
- Demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

Bit Error Rate (BER) is the number of bit errors divided by the total number of bits transmitted during a specific time interval. A bit error occurs when a transmitted bit is received incorrectly due to factors like noise, interference, or distortion. BER is a key performance metric for digital communication systems.

BER=Number of bits in Error/Total number of transmitted Bits

BER equals the fraction with numerator Number of Bits in Error and denominator Total Number of Transmitted Bits end-fraction. For a given system and modulation scheme, BER is a function of the Signal to noise ratio i.e. Eb/N0 ratio (energy per bit to noise power spectral density), which is related to SNR. Channel impairments such as fading, attenuation, interference, and distortion can increase BER. The use and strength of error detection and forward error correction techniques can significantly reduce BER after post Processing.

VII Circuit diagram/Block diagram/Flowchart .

A. Suggestive diagram

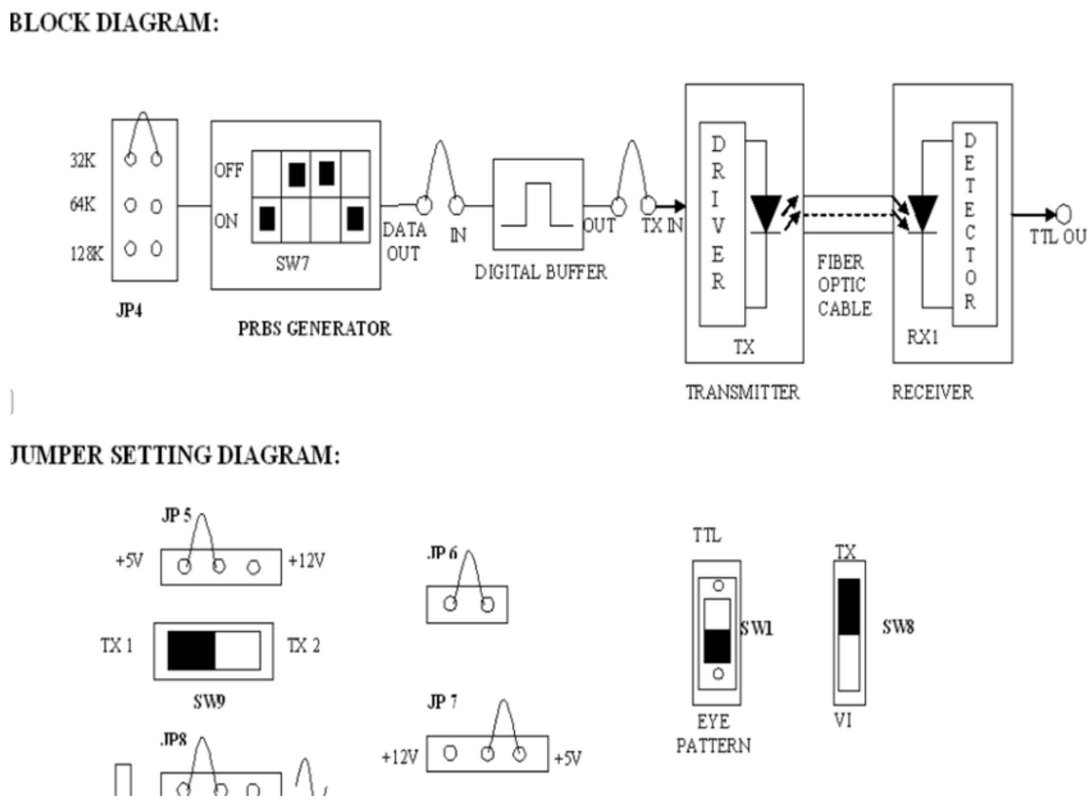

Fig. 7.1 Block diagram of Bit Error Rate

B. Actual block diagram

VIII Required Resources with specifications

Table No. 7.1

Sr.No.	Name of Resource	Specifications	Quantity
1	Bit error rate tester	1.6Gb/s Pattern generator/error detector	01
2	Fiber Optic Link	1,2,3,4, 5 m	01 unit
3	DSO	60 MHz/100 MHz/200 MHz bandwidth,500MS/s to 1 GS/s real -time sample rate,50 GS/s sample rate for repetative waveforms, High resolution color LCD displayh	01
4	Optical fiber Trainer kit	230V+/- 10%, 50 Hz,	01

IX Precautions to be followed

1. Avoid direct exposure to laser sources; use appropriate safety eyewear when required
2. Handle glass fibers with care to avoid cuts from broken fiber ends
3. Follow manufacturer's specifications for operating power levels and environmental conditions
4. Ensure proper grounding of all test equipment before making connection

X Procedure

1. Connect the practical setup as per the block diagram.
2. Switch ON the power supply to DSO.
3. Configure the data source to generate a known sequence of bits (pseudo-random binary sequence, PRBS).
4. Adjust the signal amplitude and ensure the system is operational without added noise. The error counter should ideally show zero errors.
5. Introduce a controlled amount of noise into the channel (using the built-in noise source on the kit).
6. Measure the received signal level and the noise level to determine the SNR (or adjust the SNR via the Controls.
7. Note down the "Total Number of Transmitted Bits" and the "Number of Error Bits" from the error counter over a fixed period.
8. Calculate the BER using the formula mentioned in the theoretical background.
9. Repeat steps 5-8 for different levels of noise (varying SNR values).

XI Resources used

Table No. 7.2

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach separate page).

1.
2.
3.
4.
5.
6.

XIII Observation Table

Table No. 7.3

Sr. No.	No. of bits transmitted	No. of bits received	No .of bit errors	Calculated BER
1				
2				
3				
4				
5				

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Give the significance of Bit Error Rate.
2. List different equipments required for BER calculation.
3. Does the modulation technique affect BER ?

[Space for Answers .If required attach separate page]

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XVIII Suggested References for further reading

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	"Fiber Optic Communication	Mc Graw Hill Higher Education, New Delhi,ISBN : 9781259006876.
2	Biswanath Mukherjee	Optical Communication networks	Mc Graw Hill, Higher Education, New Delhi ISBN-13,978-0070444355

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related:10Marks		**40%**
1	Calculated theoretical values of given component	10%
2	Interpretation of result	05%
3	Conclusion	05%
4	Answers to sample practical related questions	15%
5	Submitting the journal in time	05%
Total (25Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.8: Measurement of various parameters of eye pattern

I Practical Significance

This practical focuses on evaluating the performance characteristics of optical sources and detectors, which are critical components in fiber optic communication systems. Measurement of various parameters of eye pattern is essential for understanding how optical signals are generated, transmitted, and detected in modern telecommunications networks. Industry professionals require comprehensive knowledge of these components for designing efficient optical communication systems, optimizing signal quality, and troubleshooting network performance issues.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected Outcome through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Evaluate the performance characteristics of optical sources and detectors.

IV Laboratory Learning Outcome

LLO8.1 Measure various parameters of the observed eye pattern

V Relevant Affective Domain related outcomes

- To Work effectively in laboratory teams to achieve common learning objectives
- To demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

An eye diagram is a useful tool for understanding signal impairments in the physical layer of high-speed digital data systems, verifying transmitter output compliance, and revealing the amplitude and time distortion elements that degrade the BER for diagnostic purposes. By taking high-bandwidth instantaneous samples of a high-speed digital signal, an eye diagram is the sum of samples from superimposing the 1's, 0's, and corresponding transition measurements. The eye-pattern technique is a simple but powerful measurement method for assessing the data-handling ability of a digital transmission system. This method has been used extensively for evaluating the performance of wire systems and can also be applied to optical fiber data links. The eye-pattern measurements are made in the time domain and allow the effects of waveform distortion to be shown immediately on an oscilloscope.

VII Circuit diagram/block diagram/flowchart

A)Suggestive diagram

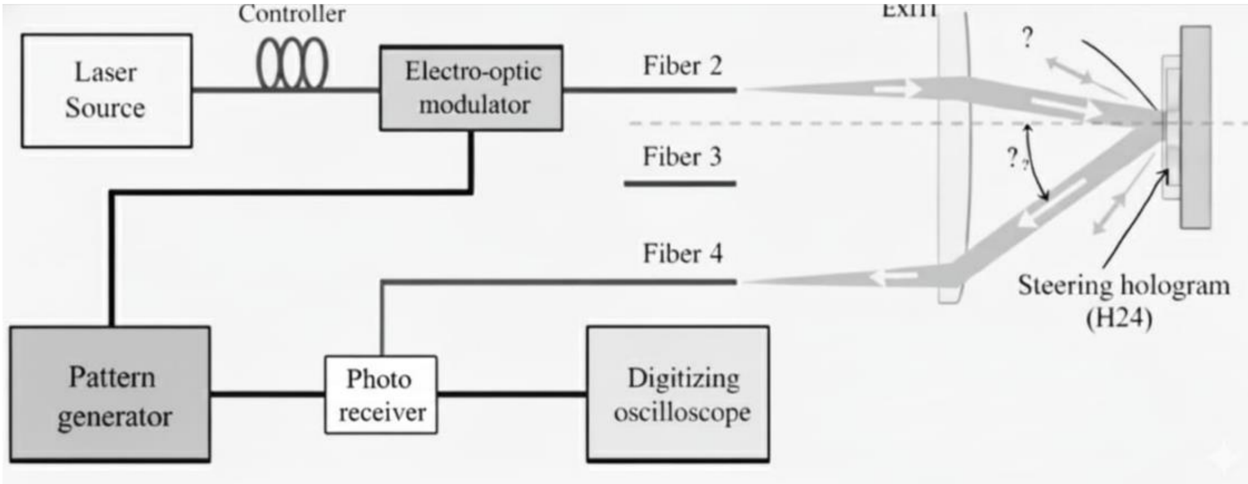

Fig.8.1 block diagram of eye diagram pattern

B) Actual diagram used in laboratory

VIII Required Resources with specifications

Table No. 8.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Optical fiber Trainer kit	230V+/- 10%, 50 Hz,	01
2	DSO	60 MHz/100 MHz/200 MHz bandwidth,500MS/s to 1 GS/s real -time sample rate,50 GS/s sample rate for repetative waveforms, High resolution color LCD display	01
3	Fiber optic cables	1 1 to 5 meter	01

IX Precautions to be followed

1.Handle optical fibers carefully to avoid breakage and maintain minimum bend radius >30mm.

2. Keep optical connector end faces clean using appropriate cleaning materials and techniques.
3. Do not touch optical connector ferrules with bare hands to avoid contamination.

X Procedure

1. Measure the various parameters of eye pattern
2. Record all measurements systematically in the observation Table No.
3. Repeat measurements multiple times to ensure accuracy and reliability

XI Resources used

Table No. 8.2

Sr.No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach separate page).

1.
2.
3.
4.
5.

XIII Observation Table

Table No. 8.3

Sr. No.	Eye Pattern Parameter	Specifications	Remark

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Give the significance of eye pattern diagram.
2. State different eye pattern parameters.
3. State the applications of eye diagram.

[Space for Answers.] (If required attach separate page)

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XVIII Suggested references for further reading.

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	"Fiber Optic Communication	Mc Graw Hill Higher Education, New Delhi,ISBN : 9781259006876.
2	Biswanath Mukherjee	Optical Communication networks	Mc Graw Hill, Higher Education, New Delhi ISBN-13,978-0070444355

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related:10 Marks		**40%**
1	Interpretation of result	10%
2	Conclusion	10%
3	Answers to samplepractical related questions	15%
4	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.9: Measurement of attenuation loss in optical fiber.

I Practical Significance

This practical is designed to provide hands-on experience in establishing and analyzing fiber optical communication links. Measurement of attenuation loss in optical fiber is fundamental for understanding how optical signals are transmitted through fiber optical networks with minimal loss and optimal performance. This knowledge directly applies to designing, installing, and maintaining fiber optical communication systems in telecommunications, data centers, and industrial networks.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences: Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Establish analog and digital fiber optic link

IV Laboratory Learning Outcome

LLO 9.1 Measure the power and find the attenuation loss in given length of optical fiber cable

V Relevant Affective Domain related outcomes

- Work effectively in laboratory teams to achieve common learning objectives.
- Demonstrate awareness of proper safety procedures and equipment handling techniques.

VI Relevant Theoretical Background

Attenuation loss, also known as fiber loss, is the decrease in the intensity of light signals as they propagate through an optical fiber. This loss is typically measured in decibels per kilometer (dB/km).The attenuation loss can be reduced by using:

1. High quality cables.

2. By optimizing cable installations.

3. Using low loss fibers like G 655 and G 657, which are suitable for long distance transmission and access networks.

4. Ensure high quality connectors. Using appropriate tools.

An Optical Time Domain Reflectometer (OTDR) is a fiber optic instrument used to characterize, troubleshoot, and maintain optical telecommunication networks. OTDR testing is performed by transmitting and analysing pulsed laser light traveling through an optical fiber. The measurement is said to be unidirectional as the light is insert at extremity of a fiber optical cable link. An OTDR contains a laser diode source, a photodiode detector, and a highly accurate timing circuit (or time base). The laser emits a pulse of light at a specific wavelength. This pulse of light travels along the fiber being tested, as the pulse moves down the fiber portions of the transmitted light are scattered back down the fiber on the photo detector in the OTDR. The intensity of this returning light and the time taken for it to arrive back at the detector tells us the loss value (insertion and reflection), type and location of an event in the fiber link.

VII Circuit diagram/Block diagram/flowchart

A. Suggestive diagram

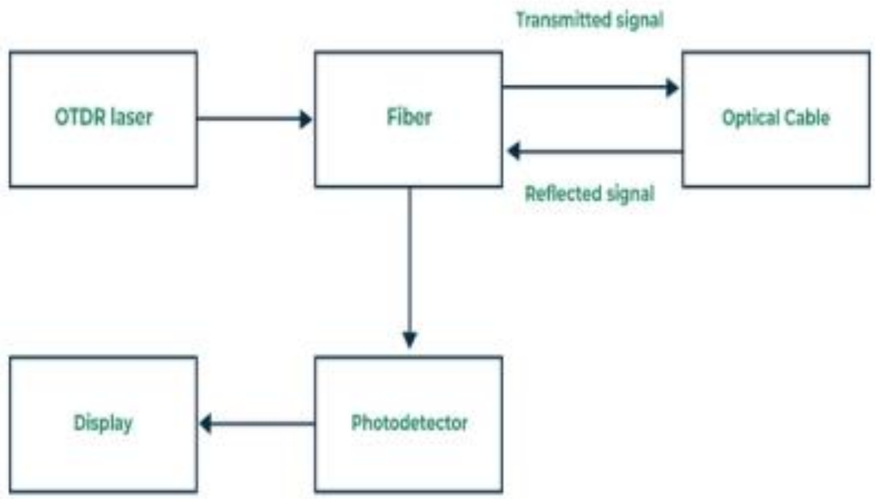

Fig 9.1 Block diagram of Attenuation loss

Fig.9.2 Front panel of Optical power meter

B. Actual diagram

VIII Required Resources with specifications

Table No. 9.1

Sr.No.	Name of Resource	Suggested Broad Specification	Quantity
1	Photo detector	Wavelength Sensitivity: 940 nm Reverse Light Current: 40 μA	01
2	Optical Cable	1 meter,5 meter ,10 meter ,15 meter single mode	01 each
3	Optical Power meter	-70dB m to +10dB m	01

IX Precaution to be followed

1. Handle every component and cable carefully.
2. Avoid direct exposure to laser sources; use appropriate safety eyewear when required.
3. Handle glass fibers with care to avoid cuts from broken fiber ends.
4. Follow manufacturer's specifications for operating power levels and environmental conditions.

X Procedure :

1. Prepare the set up of measuring attenuation loss as per block diagram
2. Measure input power and output power by using optical power meter.
3. Calculate the attenuation loss by using the formula.
4. Repeat the steps no 2 and 3 for 4 different length of optical cable.

XI Resources used

Table No. 9.2

Sr.No.	**Name of Resource**	**Specifications**	**Quantity**

XII Actual Procedure (If required attach separate page).

1.
2.
3.
4.

XIII Observation Table

Table No. 9.3

Sr.No.	**Length of the cable**	**P in**	**Pout**	**Attenuation loss=10/Llog$_{10}$ (Pout/Pin)**
1				
2				
3				
4				

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. List the causes of losses in optical fibers.
2. Compare between attenuation & amplification.
3. State the methods for minimizing attenuation loss in optical communication..
4. State the functions of front panel of Optical power meter.

[Space for Answers if required attach separate page]

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XVIII Suggested references for further reading

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication	Mc Graw Hill Higher Education, New Delhi,ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ISBN :9781119737360

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Conclusion	10%
3	Answers to sample practical related questions	15%
4	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.10 Measurement of bending loss of given optical fiber cable

I Practical Significance

This practical is designed to provide hands-on experience in establishing and analyzing fiber optic communication links. Measurement of bending loss of given optical fiber cable is fundamental for understanding how optical signals are transmitted through fiber optic networks with minimal loss and optimal performance. This knowledge directly applies to designing, installing, and maintaining fiber optic communication systems in telecommunications, data centers, and industrial networks.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected Outcome through various teaching learning experiences ‘Maintain optical and satellite communication systems.’

III Course Level Learning Outcome

Evaluate the performance characteristics of optical sources and detectors.

IV Laboratory Learning Outcome

LLO10.1 Measure the bending loss in optical fiber.

V Relevant Affective Domain related outcomes

- Develop curiosity about emerging technologies and commitment to lifelong professional Development.
- Demonstrate awareness of proper safety procedures and equipment handling techniques.

VI Relevant Theoretical Background

Optical fibers suffer radiation losses at bends or curves on their paths. There are two types of bends in optical fibers

(a) Macroscopic bending loss (having a larger radius than that of the fiber diameter)

(b) Microscopic bending loss (random microscopic bends of the fiber axis)

Macroscopic Bending Loss: When an optical fiber is bent with a large curve or loop, some of the light inside escapes out of the core instead of continuing through it. This happens because the light can no longer reflect properly within the curved section. Such losses are called macroscopic bending losses. They usually occur when the fiber is bent with a radius larger than its diameter, like when the cable is coiled or turned sharply. Proper handling and maintaining gentle bends help reduce this type of loss.

Microscopic Bending Loss: Microscopic bending loss happens due to very tiny, invisible bends or irregularities along the fiber’s axis. These small bends are often caused by manufacturing imperfections, mechanical stress, or uneven pressure during cable installation. Even though these bends are too small to see, they scatter light and cause small but continuous power losses. Ensuring smooth cable installation and using protective coatings helps minimize this type of loss.

V II Circuit diagram/Block diagram/Flowchart

A. Suggestive diagram

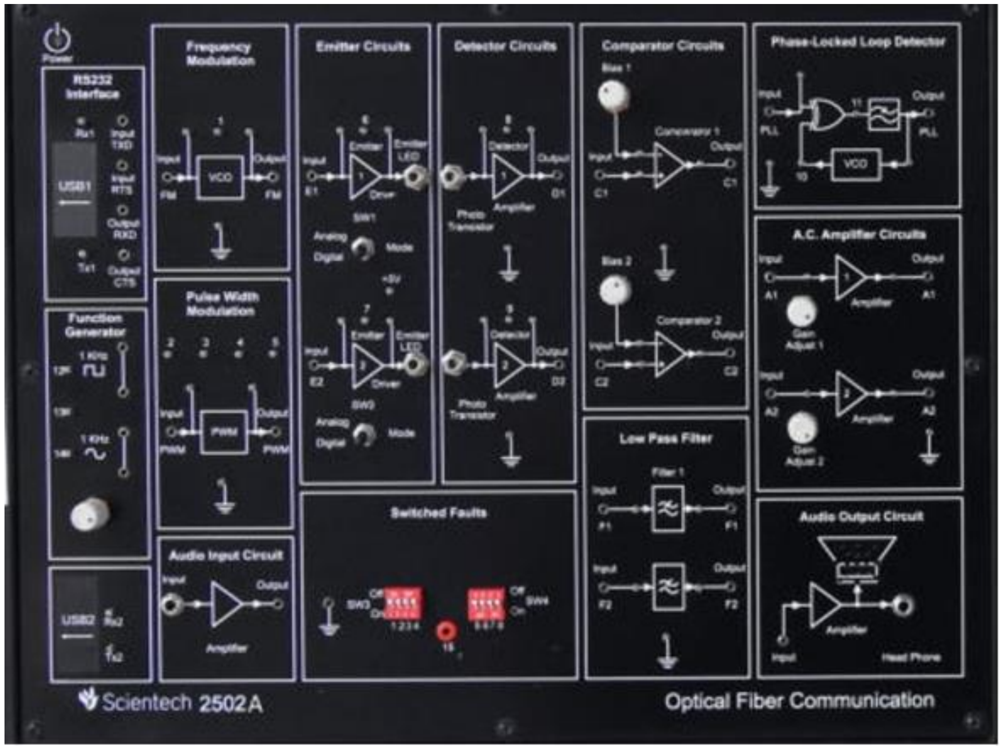

Fig.10.1 Fiber optic Trainer kit

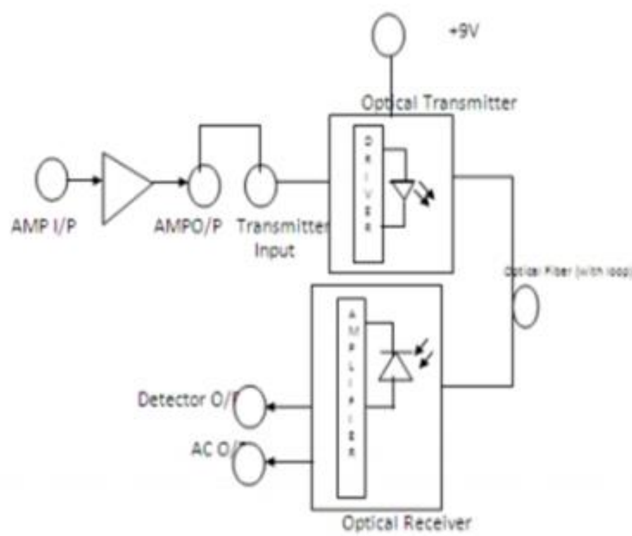

Fig.10.2 practical set up for bending loss

B. Actual diagram used in the laboratory

VIII Required Resources with specifications

Table No. 10.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Fiber optic cables	9/125 µm for single-mode and 50/125 µm or 62.5/125 µm for multimode	1
2	Fiber optic Trainer kit	660 nm & 950 nm Fiber Optic LED channel with Transmitter & Receiver, Built in DC Power Supply, Full Duplex Analog & Digital Trans-receiver	1
3	DC Power supply	0-30V, 0-3 A	1
4	CRO/DSO	60 MHz/100 MHz/200 MHz bandwidth,500MS/s to 1 GS/s real -time sample rate,50 GS/s sample rate for repetative waveforms, High resolution color LCD display	1

IX Precautions to be followed

1. Handle every component and cable carefully
2. Avoid sharp bends and fiber stress.
3. Keep connectors clean.
4. Maintain constant launch conditions.

X Procedure

1. Connect power supply cord to the main power plug & to trainer ST2501.
2. Make the connections as shown in figure 10.1.
3. Function Generator 1 KHz sine wave output to input socket of emitter Circuit via 4 mm lead.

4. Connect 0.5 m optic fiber between emitter output and detectors input.
5. Connect Detector output to amplifier input socket via 4mm lead.
6. Switch 'On' the power supply of the trainer and oscilloscope.
7. Set the Oscilloscope channel 1 to 0.5 V/ Div and adjust 4-6 div amplitude by using X 1 probe with the help of variable pot in function generator at input of Emitter.
8. Observe the output signal from detector (TP8) on CRO.
9. Adjust the amplitude of the received signal as that of transmitted one with the help of gain adjusts potentiometer in AC amplifier block. Note this amplitude and name it V1.
10. Wind the fiber optic cable on the mandrel and observe the corresponding AC Amplifier output on CRO, it will be gradually reducing, showing loss due to bends.

XI Resources used

Table No. 10.2

Sr. No.	**Name of Resource**	**Specifications**	**Quantity**

XII Actual Procedure (If required, attach separate page)

1.

2

3

4

XIII Observation Table

Table No. 10.3

Sr. No.	**Input Power (dBm)**	**Output Power (dBm)**	**Bending Loss (dB)**
1			
2			
3			
4			

XIV Result

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XV Interpretation of result

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XVI Conclusion and Recommendation

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XVII Practical-related questions

Note: Below are a few sample questions for reference. The teacher must design more such questions so as to ensure the achievement of the identified CO.

1. State the two types of bending losses in optical fiber.
2. Mention the main cause of macroscopic bending loss.
3. Explain the procedure for calculation of bending loss.

[Space for Answers.](If required, attach a separate page.)

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XVIII Suggested references for further reading

Sr.No	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ,ISBN :9781119737360
3	Biswanath Mukherjee	Optical Communication networks	Mc Graw Hill, ISBN-13,978-0070444355

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15 Marks		**60 %**
1	Handling of the components	10 %
2	Identification of components	20 %
3	Measuring value using suitable instrument	20 %
4	Working in teams	10 %
Product Related:10 Marks		**40 %**
1	Calculated theoretical values of given component	10 %
2	Interpretation of result	10 %
3	Conclusion	10 %
4	Answers to sample practical related questions	10 %
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 11: Measurement of optical power using optical meter

I Practical Significance

This practical is designed to provide hands-on experience in establishing and analyzing fiber optical communication links. Measurement of optical power using optical meter is fundamental for understanding how optical signals are transmitted through fiber optic networks with minimal loss and optimal performance. This knowledge directly applies to designing, installing, and maintaining fiber optic communication systems in telecommunications, data centers, and industrial networks.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Establish analog and digital fiber optic link.

IV Laboratory Learning Outcome

LLO 11.1 Measure optical power using optical meter.

V Relevant Affective Domain related outcomes

- Work effectively in laboratory teams to achieve common learning objectives.
- Demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

The core of an optical power meter is a photo detector (usually a photo diode made of Silicon, Germanium or InGaAs), which converts incoming light energy into a proportional electrical current. This current is then amplified and processed to produce a reading on a display. For relative measurement, the theory relies on the logarithmic nature of the decibel scale to efficiently , represent the large dynamic range of power levels in optical systems. Energy meter working is easy to understand. Its working principle follows Faraday's law of electromagnetic induction. This law states that a magnetic field gets generated around a conductor when current flows through it. Electrical energy consumption is measured in these meters using this principle. An optical power meter is an essential tool for working with optical networks. It is used to measure the strength of light signals in fiber optical cables. Understanding how this device works helps to achieve accurate and reliable results in optical power measurement tasks.

V II Circuit diagram/block diagram /flowchart

A. Suggestive diagram

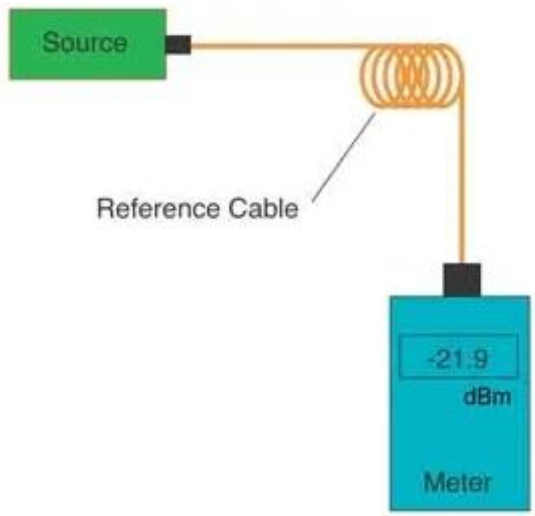

Fig. 11.1 Measurement of optical power using optical meter

B. Actual diagram

VIII Required Resources with specifications

Table No. 11.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Optical power meter	-70dbm to +10 dbm (standard)	1 unit
2	Optical fiber cables	1,2,3,4,5meter length single mode and multimode	1 piece each
3	Fiber Optic trainer kit	230V+/- 10%	1
4	Fiber optic cleaning kit	Alcohol, wipes, cleaning cassettes	1

IX Precautions to be followed

1. Handle optical fibers carefully to avoid breakage and maintain minimum bend radius >30mm
2. Keep optical connector end faces clean using appropriate cleaning materials and techniques
3. Do not touch optical connector ferrules with bare hands to avoid contamination
4. Store optical components in protective cases when not in use to prevent damage

X Procedure

1. Set up the practical arrangement according to the circuit diagram.
2. Take optical cable of different lengths and measure the power
3. Repeat measurement of power for multiple times to ensure accuracy and reliability
4. Compare measured values with theoretical expected values
5. Identify the error in measurements.

XI Resources used

Table No. 11.2

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach separate page)

1.

2.

3.

4.

XIII Observation Table

Table No. 11.3

Sr. No.	Length of the optical Cable	Measured Power	Theoretical Power	Error (%)
1	1 meter			
2	2 meter			
3	3 meter			
4	4 meter			
5	5 meter			

%Error = |Measured Power-Theoretical power|/Theoretical Power x 100

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Compare between OTDR & Optical meter.
2. Give the unit of optical power.
3. Mention the main components of Optical power meter.

[Space for Answers If required attach separate page]

XVIII Suggested References for further reading

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication,	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ,ISBN :9781119737360
3.	Biswanath Mukherjee	Optical Communication networks	Mc Graw Hill, ISBN-13978-0070444355

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related:10Marks		**40%**
1	Calculated theoretical values of given component	10%
2	Interpretation of result	05%
3	Conclusion	05%
4	Answers to sample practical questions	15%
5	Submitting the journal in time	05%
Total (25Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 12 Computation of Link Power Budget for Fiber Optics using coding

I Practical Significance

This practical is designed to provide hands-on experience in establishing and analyzing fiber optic communication links. Computation of link power budget for fiber optics using coding is fundamental for understanding how optical signals are transmitted through fiber optic networks with minimal loss and optimal performance. This knowledge directly applies to designing, installing, and maintaining fiber optic communication systems in telecommunications, data centers, and industrial networks.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III Course Level Learning Outcome

Establish analog and digital fiber optic link.

IV Laboratory Learning Outcome

LLO 12.1 Calculate the Link Power Budget as per equation.

V Relevant Affective Domain related outcomes

- Work effectively in laboratory teams to achieve common learning objectives.
- Demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

This practical involves a complete link analysis of a digital fiber optic system, where the main goal is to ensure that the transmitted signal reaches the receiver with adequate power and acceptable distortion. Attenuation quantifies how much optical power is lost in the fiber and components, and is used in the link power budget to compare total link loss with the available power difference between transmitter output and receiver sensitivity, giving the power margin for reliable operation. Dispersion causes pulse broadening, which is handled in the rise time budget by combining source, fiber, and receiver rise times to verify that the overall temporal response supports the desired bit rate without excessive inter-symbol interference. System gain expresses how much loss the link can tolerate, derived from transmitter power and receiver sensitivity, while safety margins are added in both power and rise time budgets to account for ageing, temperature variations, connector degradation, and future system upgrades, ensuring robust performance under worst-case condition.

A link budget equation including the key effects for a wireless radio transmission system, expressed logarithmically, might look like:

$P_{RX} = PTx + GTx - Ltx - Lfs - L_M + G_{RX} - L_{RX}$

Where,

P_{RX}, received power (dBm)

PTx, transmitter output power (dBm)

GTx, transmitter antenna gain (dBi)

Ltx, transmitter losses (coax, connectors...) (dB)

Lfs, path loss (dB)

L_M, miscellaneous losses (fading margin, body loss, polarization mismatch, other losses, ...) (dB)

G_{RX}, receiver antenna gain (dBi)

L_{RX}, receiver losses (coax, connectors, ...) (dB)

VII Circuit diagram/Block diagram/Flowchart

A. Suggestive diagram

NA

B. Actual diagram

NA

VIII Required Resources with specifications

Table No. 12.1

Sr. No.	Name of Resource	Suggested Broad Specifications	Quantity
1	Desktop/Laptop	i3/i5,8GBRAM,500GB HDD/256GB SSD, Windows 10/11	01
2	Software	MATLAB or any other open source software	01
3	UPS 6KVA Online	online UPS, 6KVA capacity, Input230V AC, output 230VAC, Backup -10-15 min.	01
4	Internet connectivity	LAN or Wi-fi	01

IX Precautions to be followed

1. Ensure proper earthing to the computer system
2. Input each constant in given program carefully for proper output.
3. Save and close all open programs and figures properly after completing the practical

X Procedure

1. Double click on matlab icon to Run matlab or open online matlab from website https://matlab.mathworks.com/
2. Type the given code in editor window of MATLAB software.
3. Example inputs are given in the program itself.
4. Observe the output of program in command window of MATLAB software

%MATLAB Code for computation of Link Power Budget

```
% compute fiber optic link power budget
%Some example values for practical
% Transmitted power (dBm): -3dbm
% Receiver minimum power (dBm): -30 dbm
%Safety margin (dB): 3
% Connector loss (dB): 0.7 db
% Splice loss (dB): 0.1 db
% Fiber attenuation (dB/km): 0.35
% Total fiber length (km): 10 km
% Number of connectors: 2
% Number of splices: 2
% --- User Inputs ---
Pt = input('Enter the transmitted power in dBm: '); % Transmitted power (dBm)
Pr_min = input('Enter the receiver sensitivity in dBm: '); % Receiver minimum power (dBm)
margin = input('Enter the safety margin in dB: '); % Safety margin (dB)
loss_connector = input('Enter the connector loss per connector in dB: '); % Connector loss (dB)
loss_splice = input('Enter the splice loss per splice in dB: '); % Splice loss (dB)
attenuation_fiber = input('Enter the fiber attenuation in dB/km: '); % Fiber attenuation (dB/km)
fiber_length_km = input('Enter the total fiber length in km: '); % Total fiber length (km)
num_connectors = input('Enter the number of connectors: '); % Number of connectors
```

```
num_splices = input('Enter the number of splices: '); % Number of splices
% --- Calculations ---
% Total power loss
total_loss = (fiber_length_km * attenuation_fiber) + ...
            (num_connectors * loss_connector) + ...
            (num_splices * loss_splice);
% Calculate the link budget
link_budget = Pt - (total_loss + margin);
% --- Display Results ---
fprintf('\n--- Link Budget Calculation ---');
fprintf('\nTotal power loss = %.2f dB', total_loss);
fprintf('\nLink budget = %.2f dB', link_budget);
% Check if the link budget is positive
if link_budget >= 0
   fprintf('\n\nThe link is viable. The received power is above the minimum sensitivity.\n');
else
   fprintf('\n\nThe link is not viable. The received power is below the minimum sensitivity.\n');
end
```

XI Resources used

Table No. 12.1

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach separate page)

1.
2.
3.
4.

XIII Observation Table

NA

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Define Link power budget
2. Give the equation of link power budget & signify each term.
3. State the significance of link power budget calculations.

[Space for Answers](If required attach separate page)

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XVIII Suggested references for further reading

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication,	MC Graw Hill Higher Education, NewDelhi,ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ISBN :9781119737360

Web Refernces:

Sr.No.	**Link / Portal / VLab**	**Description**
1	"https:\ilide.info-fibre-optic-power-budget-analysis-matlab-code-pr_aa3aefe2327f1729d6349f327076846d.pdf"	Link Power Budget calculation

XIX Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related: 15Marks	**60 %**
1	Practical Implementation with Specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
	Product Related:10Marks	**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	10%
4	Practical Implementation with specified time	10%
	Total (25Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 13 Computation of rise time budget w.r.t. fiber optics through coding

I Practical Significance

A practical on rise time budget in fiber optics should explain the theory, give a sample link, and then use simple code (e.g., Python/MATLAB/C) to calculate the total system rise time and compare it with the allowable rise time for a given bit rate. Computation of rise time budget w.r.t fiber optics through coding is fundamental for understanding how optical signals are transmitted through fiber optic networks with minimal loss and optimal performance. This practical gives the students a method to calculate rise time budget with respect to fiber optics.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences: ‘Maintain optical and satellite communication systems.’

III Course Level Learning Outcome

Establish analog and digital fiber optic link.

IV Laboratory Learning Outcome

LLO 13.1 Determine the rise time budget.

V Relevant Affective Domain related outcomes

- Work effectively in laboratory teams to achieve common learning objectives.
- Demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

Rise time budget analysis determines the dispersion limitation of an optical fiber link and hence the maximum data rate for acceptable ISI (Inter-symbol Interference).Rise time budget refers to the total time taken by an optical signal to rise from 10% to 90% of its maximum amplitude. It is a measure of the system's ability to transmit high-speed data accurately. A smaller rise time budget indicates a faster system with better performance. The rise time budget is crucial in optical communication systems as it directly affects the bit error rate (BER) and the overall system reliability.

Several factors affect the rise time budget in optical communications systems.

These includes :

1. Transmitter characteristics, such as LASER switching time and modulator’s response time.
2. Fiber dispersion, which causes pulse broadening and increases the rise time.

3. Receiver characteristics, such as the photo detector's response time and the amplifier's bandwidth.

VII Circuit diagram/Block diagram /Flowchart

A. Suggestive diagram

NA

B. Actual diagram

NA

VIII Required Resources with specifications

Table No. 13.1

Sr. No.	Name of Resource	Suggested Broad Specifications	Quantity
1	Desktop/Laptop	Inteli3/i5,8GBRAM,500GB, HDD/256GB SSD, Windows 10/11	01
2	Software	MATLAB, or any other open source software	01
3	UPS 6KVA Online	online UPS, 6KVA capacity, Input230V AC, outpı 230VAC, Backup -10-15 min.	01
4	Internet connectivity	LAN or Wi-fi	01

IX Precautions to be followed

1. Ensure proper earthing to the computer system
2. Input each constant in given program carefully for proper output.
3. Save and close all open programs and figures properly after completing the practical.

X Procedure

1. Double click on matlab icon to Run matlab or open online matlab from website

   https://matlab.mathworks.com/

2. Type the given code in editor window of MATLAB software.
3. Example inputs are given in the program itself.
4. Observe the output of program in command window of MATLAB software

% MATLAB Code for computation of rise time budget

```
% Fiber Optic System Rise Time Budget Calculation
% 1. Define System Parameters and individual rise times (in nanoseconds)
```

```
% These values would typically come from component datasheets or calculations
% based on fiber properties (dispersion, length, source bandwidth).
% Transmitter rise time (ttx) in ns
ttx = 0.1; % Example value: 0.1 ns
% Receiver rise time (trx) in ns
trx = 0.5; % Example value: 0.5 ns
% Fiber rise time due to Group Velocity Dispersion (GVD) (tGVD) in ns
% Formula: tGVD = |D| * L * delta_lambda, where D is dispersion (ps/km-nm),
% L is length (km), and delta_lambda is spectral width (nm)
D = 18;        % ps/(km*nm)
L = 150;       % km
delta_lambda = 0.25; % nm
tGVD_ps = abs(D * L * delta_lambda); % Calculate in ps
tGVD = tGVD_ps / 1000; % Convert to ns
% Fiber rise time due to Modal Dispersion (tmod) in ns
% For single-mode fiber, tmod is typically 0.
% For multimode fiber, this would be a specific value.
tmod = 0; % Example value: 0 ns for single-mode fiber
% 2. Calculate the total system rise time (tsys) using the RSS method
% tsys = sqrt(ttx^2 + trx^2 + tGVD^2 + tmod^2)
tsys = sqrt(ttx^2 + trx^2 + tGVD^2 + tmod^2);
% 3. Define the desired data rate (Bit Rate, BR)
BR_Mbps = 622; % Example data rate: 622 Mbps
BR_bps = BR_Mbps * 1e6; % Convert to bps
% 4. Calculate the allowed bit period (Tb)
Tb = 1 / BR_bps; % Bit period in seconds
Tb_ns = Tb * 1e9; % Convert to ns
% 5. Determine the system compatibility using the rise time budget rule
% For Non-Return-to-Zero (NRZ) signaling, tsys should be <= 70% of Tb.
% For Return-to-Zero (RZ) signaling, tsys should be <= 35% of Tb.
signaling_format = 'NRZ'; % Choose 'NRZ' or 'RZ'
if strcmp(signaling_format, 'NRZ')
```

```
    allowed_tsys = 0.7 * Tb_ns;
elseif strcmp(signaling_format, 'RZ')
    allowed_tsys = 0.35 * Tb_ns;
else
    disp('Invalid signaling format specified.');
    return;
end
% 6. Display the results and check the budget
disp(['Total system rise time (tsys): ', num2str(tsys), ' ns']);
disp(['Allowed rise time for ', signaling_format, ' signaling: ', num2str(allowed_tsys), ' ns']);
disp(['Bit period (Tb): ', num2str(Tb_ns), ' ns']);
if tsys <= allowed_tsys
    disp('**BUDGET MET**: The system can operate at the specified data rate.');
else
    disp('**BUDGET EXCEEDED**: The system rise time is too high for the specified data rate and signaling format.');
end
```

XI Resources used

Table No. 13.2

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach separate page)

1.

2.

3.

4.

XIII Observation Table

NA

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Define the rise time budget.
2. State the factors affecting rise time budget.
3. Give the significance of rise time budget.

[Space for Answers](If required attach separate page)

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XVIII Suggested references for further reading

Sr.No.	Author	Title	Publisher with ISBN Number
1	Keiser, Gerd	Fiber Optic Communication	Mc Graw Hill Higher Education, NewDelhi,ISBN : 9781259006876.
2	Agrawal, G.	Fiber-Optic Communication Systems	John Wiley and sons, New York, ISBN :9781119737360

Web Reference:

Sr.No.	Link / Portal / V Lab	Description
1	"https:\ilide.info-fibre-optic-power-budget-analysis-matlab-code-pr_aa3aefe2327f1729d6349f327076846d.pdf"	Rise time budget calculation

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15Marks	**60 %**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
	Product Related:10Marks	**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Practical Implementation with specified time	05%
	Total (25Marks)	**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 14: Establishing an active satellite link and demonstrating link failure Operations

I Practical Significance

This practical introduces students to satellite communication systems and the analysis of various parameters that influence signal transmission and reception. Establishing an active satellite link and demonstrating link failure operations is essential for understanding modern satellite communication infrastructure, which provides critical services including global connectivity, broadcasting, navigation, and emergency communications. Industry professionals working in telecommunications, aerospace, and satellite system design require this knowledge for system optimization and troubleshooting.

II Industry/Employer Expected Outcome

The aim of this course is to attend the following industry/employer expected outcome through various teaching learning experiences: ‘Maintain optical and satellite communication systems.’

III Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV Laboratory Learning Outcome

LLO 14.1 Test satellite link operation

V Relevant Affective Domain related outcomes

- Work effectively in laboratory teams to achieve common learning objectives.
- Demonstrate awareness of proper safety procedures and equipment handling techniques

VI Relevant Theoretical Background

Satellite communication systems use different orbits, antennas, and frequency bands to create an active uplink–downlink path, and link failure occurs if any key parameter (power, pointing, or propagation) drops below the required link budget margin. In a theory practical, each of the following concepts is treated analytically rather than with real hardware, but the same equations apply to real satellite links. Different satellite orbits are mainly classified by their altitude and orientation: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), Geostationary/Geosynchronous Orbit (GEO/GSO), Polar and Sun-synchronous orbits, plus some special high-eccentricity and transfer orbits. Each type is chosen based on mission needs such as communication, navigation, weather monitoring, or remote sensing. A simplified block diagram of a satellite communication link between an earth station transmitter and receiver. Information input is first encoded and then applied to a modulator, whose output is translated to a higher radio frequency by an up converter and boosted by a high power amplifier before being fed to the large transmit antenna and sent to the satellite repeater. The satellite receives this uplink signal, amplifies and retransmits it back toward Earth, where a receiving antenna collects it and passes it through a low noise block converter that down converts and amplifies the weak signal. The signal then goes to a receiver and demodulator, which extract the original baseband data, and finally a decoding stage recovers the information output for the end user.

VII Circuit diagram/block diagram /flowchart

A. Suggestive diagram

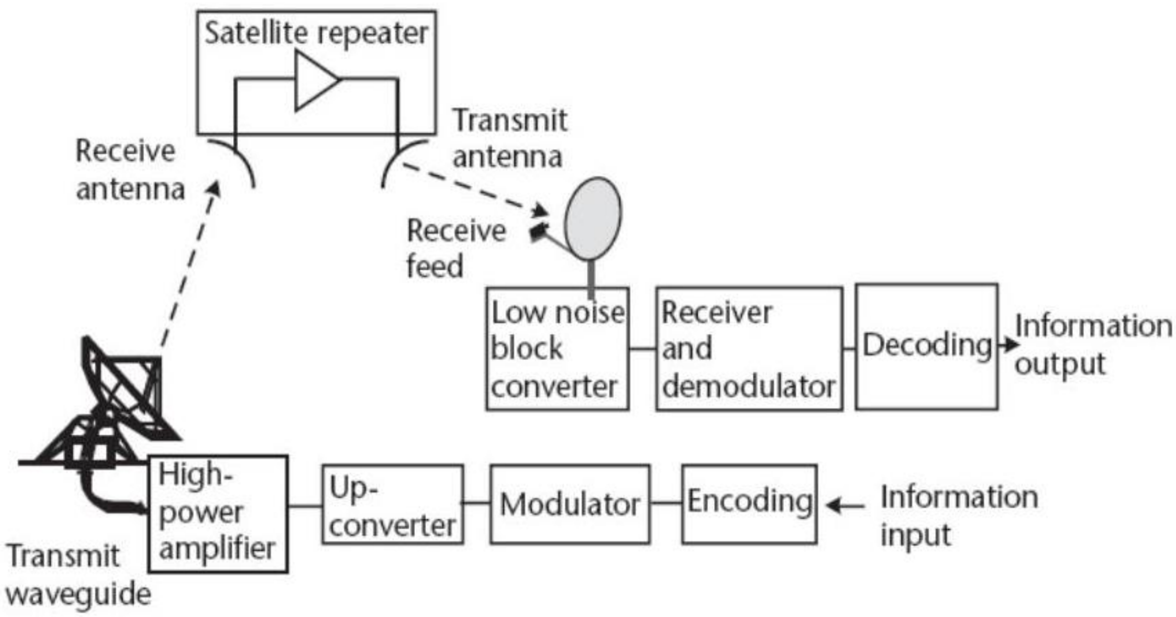

Fig.14.1Block diagram satellite system

B. Actual diagram

VIII Required Resources with specifications

Table No. 14.1

Sr.No.	Name of Resource	Suggested Broad Specifications	Quantity
1	Satellite Trainer kit	ST 2272/STC 24 kit : Uplink frequency max.2468MHz,Bandwidth 16 MHz, 5.8 Audio and video modulation. Radiated power output 25mW (approx).	01
2	Spectrum Analyzer	Frequency range : 2.4 to 2.495 GHZ, resolution 26 KHZ to 3 MHZ, resolution bandwidth - 58.036 to 812.500KHZ	01

IX Precautions to be followed

1. Make the connections on satellite trainer kit
2. Switch on the trainer kit.
3. Ensure the Spectrum Analyzer settings to be proper

X Procedure

1. First determine the frequency band
2. Determine the satellite communication parameters such as transponder gain, noise figure and output Power.
3. Define earth station parameters for both uplink and downlink including antenna gain.
4. Calculate the uplink budget for uplink path from earth station to satellite.
5. Calculate the downlink budget for downlink path from satellite to earth station.
6. Carrier to noise ratio calculation.

XI Resources used

Table No. 14.2

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach separate page)

1.

2.

3.

4.

5.

XIII Observation Table

Table No. 14.3

Sr. No.	Parameter name	Value
1	Frequency band	
2	Transponder Gain	
3	Noise Figure	
4	Output Power	
5	Carrier to noise ratio	

XIV Result

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XV Interpretation of result

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. State the function of low noise block converter.
2. State reason for difference in uplink and downlink frequency in satellite communications.
3. Give importance of following terms with respect to satellite i) Footprint ii) Orbit iii) Azimuth angle

[Space for Answers] (If required attach separate page)

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XVIII Suggested References for further reading

Sr.No.	Author	Title	Publisher with ISBN Number
1	Katiyar, Sapna	Satellite Communication	Katson publications,3rd edition 2013, ISBN-978-93- 5014-481-76
2	Rao Raja K.N.	Satellite communication concepts and applications.	PHI learning Private limited, New Delhi, second edition 2012, ISBN-978-81-2034725-0

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related:15Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related:10Marks		**40%**
1	Interpretation of result	10%
2	Conclusion	10%
3	Answers to sample practical questions	15%
4	Submitting the journal in time	05%
Total (25Marks)		100 %

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 15: Establish a Direct Communication Link between the Uplink Transmitter and Downlink Receiver Using a Tone Signal

I. Practical Significance

Practical intended to help students to understand the basic process of establishing a direct communication link between a transmitter and a receiver using a tone signal.

It demonstrates the transmission, reception, and verification of analog signals through a communication link similar to satellite systems.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III. Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV. Laboratory Learning Outcome

LLO 15.1 Create a direct communication link between the Uplink Transmitter and Downlink Receiver using a tone signal.

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

A satellite uplink is defined as when a signal is sent from a ground-based station or receiver up to a satellite in orbit Satellite uplinks are useful for when a 'lesser' station needs to send its signals to a larger network. The vantage point of a satellite is the ideal place to propagate such signals farther and wider, which is why satellite uplinks are useful in telecommunications. From the user perspective, an uplink begins with a signal that needs to go elsewhere with the help of the satellite. It's the opposite of a downlink. An uplink begins with the data from the source, which travels to a modulator. The modulator takes the data and turns it into a modulated signal to be transmitted, where it then goes to an up converter that turns it into a very high-frequency signal. Once passed through a power amplifier, the signal goes to a satellite dish and is transmitted to the satellite. The inverse of unlinking, a satellite downlink occurs when a signal travels from a satellite to a ground-based station or receiver. Information taken in this way is accordingly a download, with an upload being the respective result of a satellite uplink. Downlinks are useful for satellites taking photographs, video, or other information that needs to be beamed back to Earth for processing and study. With modern technology, this can be handled through purely digital means, Earth that needed to be developed. From the user perspective, a downlink originates from elsewhere and comes to the user with a signal to be received A satellite downlink begins with the signal from the satellite being sent to, and received by, a satellite dish. It then passes to a power amplifier, which filters out noise and clarifies the total strength of the signal. It then passes to a down converter, which works counter to an up converter and reduces the frequency of the signal. Finally, the signal moves to a demodulator, where the original information is filtered out from the carrier signal and sent to a router to be sent to the appropriate network components. (https://brightascension.com/satellite-uplink-and-downlink-how-does-it-work/)

VII. Circuit diagram / Block diagram / Flowchart

A. Suggestive Block Diagram

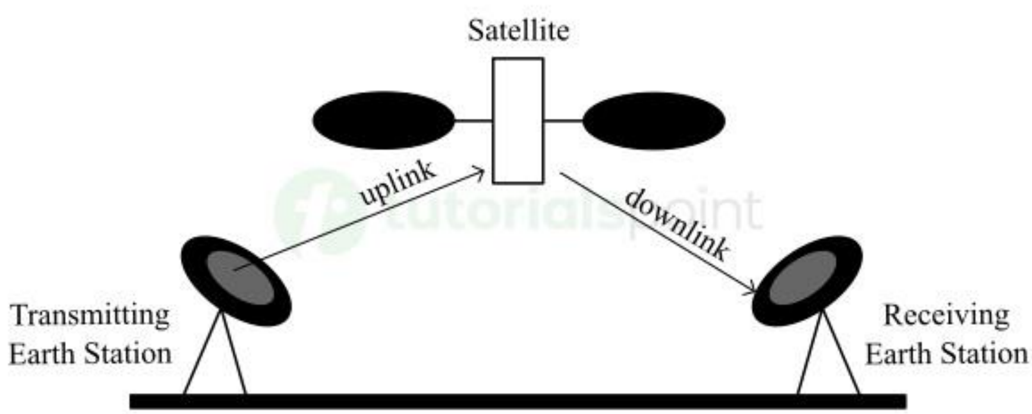

Fig. 15.1: Block Diagram of satellite Communication

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 15.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Uplink Transmitter	2450-2468 MHz up-linking selectable frequencies, Wide band RF amplifier, FM Modulation of Audio and Video, Detachable Dish Antenna.	01
3	Downlink Receiver	Receives and demodulate signals simultaneously. Built in speaker for audio and video output, Detachable Dish Antenna.	01
4	Connecting cables	BNC - BNC lead	01

IX. Precautions to be Followed

1. Check all connections before switching ON the power supply.
2. Ensure frequency matching between transmitter and receiver.
3. Avoid high transmission power to prevent equipment damage.
4. Keep coaxial cables properly terminated to avoid reflections.
5. Handle RF modules with care to prevent static damage.

X. Suggested Procedure

Fig. 15.2: Uplink Transmitter with Detachable Dish Antenna

1. Power ON uplink transmitter and attach dish antenna
2. Select the uplink frequency to 2468 MHz

Fig. 15.3: Uplink Transmitter with Frequency display

1. Set the "Channel B" to 'Tone' mode using the 'Channel Select B' key, so as to transmit tone signal from Uplink Transmitter. The 'Tone' signal is transmitted through 'Audio II' channel of the transmitter
2. The tone signal can be observed on oscilloscope at 'Tone Generator' section of Uplink Transmitter.

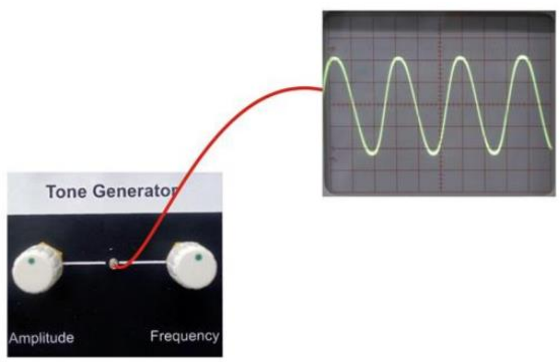

Fig. 15.4: Tone Signal observation on CRO

3. Place Downlink Receiver at a convenient distance of 5 - 7m

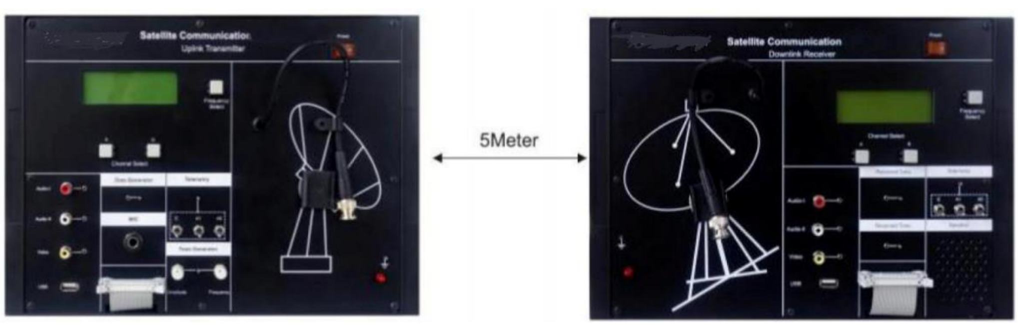

Fig. 15.5: Uplink Transmitter and Downlink Receiver Placement

4. Attach Antenna to the Downlink Receiver with BNC - BNC lead.
5. Switch 'ON' the Downlink Receiver and frequency display will come on. The receiving frequency can be selected by 'Frequency Select' key. The available frequencies are 2414/ 2432/ 2450/ 2468 MHz.
6. Select the Downlink Receiver frequency same as to Uplink Transmitting frequency.
7. Set the 'Channel B' to 'Tone' mode using 'Channel Select B key, so as to receive tone signal from Uplink Transmitter.

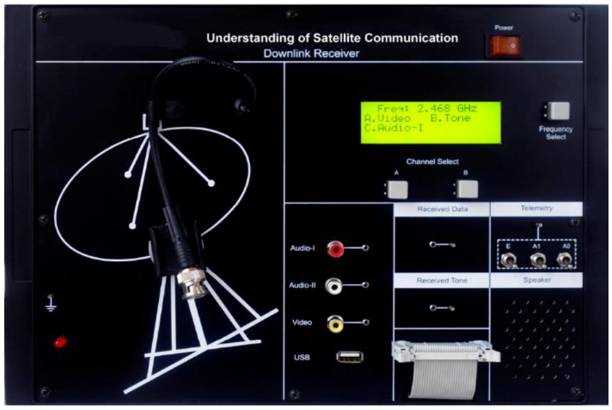

Fig. 15.6: Downlink Receiver while Receiving Tone Signal

8. The tone signal can be observed on oscilloscope at 'Received Tone' section of Downlink Receiver. Observe the variations in the frequency and the amplitude of the received tone signal by varying the frequency and amplitude of tone signal at 'Tone Generator' section of Uplink Transmitter
9. Now set the 'Channel B' to 'Speaker' mode using 'Channel Select B key, so as to hear the tone signal. The Tone signal is switched to Speaker of Receiver.

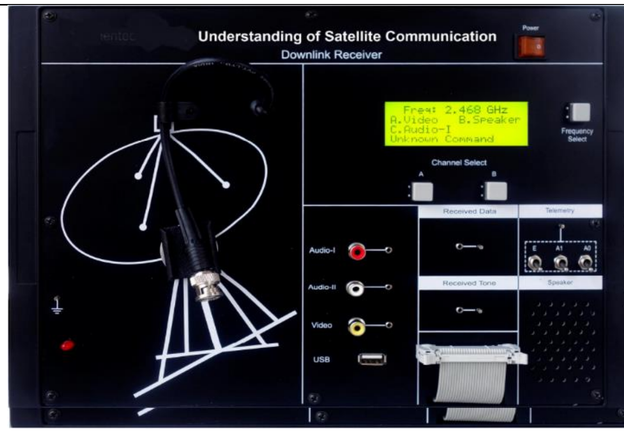

Fig. 15.6: Setting of Downlink Receiver for Hearing Tone Signal on Speaker

XI. Resources used

Table No. 15.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

Table No. 15.3

Sr. No.	Input Frequency (Hz)	Transmitted Signal Amplitude (V)	Received Signal Amplitude (V)	Remark
1				
2				

XIV. Result

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XV. Interpretation of result

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XVI. Conclusions and Recommendations

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XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Explain the purpose of using a tone signal in this experiment.
2. Mention importance of impedance matching in communication links.
3. Give the possible reasons for signal attenuation while transmitting RF signals.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested references for further reading

Sr. No.	Link / Portal / V Lab	Description
1	https://scientechworld.com/product/satellite-communication/	Satellite Communication
2	https://www.tutorialspoint.com/satellite_communication/index.htm	Satellite Communication
3	https://brightascension.com/satellite-uplink-and-downlink-how-does-it-work/	Satellite Communication

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		60%
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 16: Establishing audio video satellite link between transmitter and receiver

I. Practical Significance

Practical intended to help students to develop skills for the basic process of establishing a direct communication link between real time audio and video signal. It demonstrates the transmission, reception, and verification of analog signals through a communication link similar to satellite systems.

II. Industry /Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: Maintain optical and satellite communication systems.

III. Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV. Laboratory Learning Outcome

LLO 16.1 Establish audio video satellite link between transmitter and receiver.

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

The signal moves to a demodulator, where the original information is filtered out from the carrier signal and sent to a router to be sent to the appropriate network components. Here, the communication takes place between first earth station (transmitter) and second earth station (receiver) on earth’s surface through a satellite in one direction. Example: Broadcasting satellite services like Radio, TV and Internet services. Space operations services like Telemetry, Tracking and Commanding services, Radio determination satellite service like Position location service. Two-way

Satellite Communication Link Service: - In two-way satellite communication link, the information can be exchanged between any two earth stations through a satellite. That means, it provides only point to point connectivity. Here, the communication takes place between first earth station (transmitter) and second earth station (receiver) on earth's surface through a satellite in two (both) directions.

VII. Block diagram/Circuit diagram/Flowchart

A. Suggestive Block Diagram

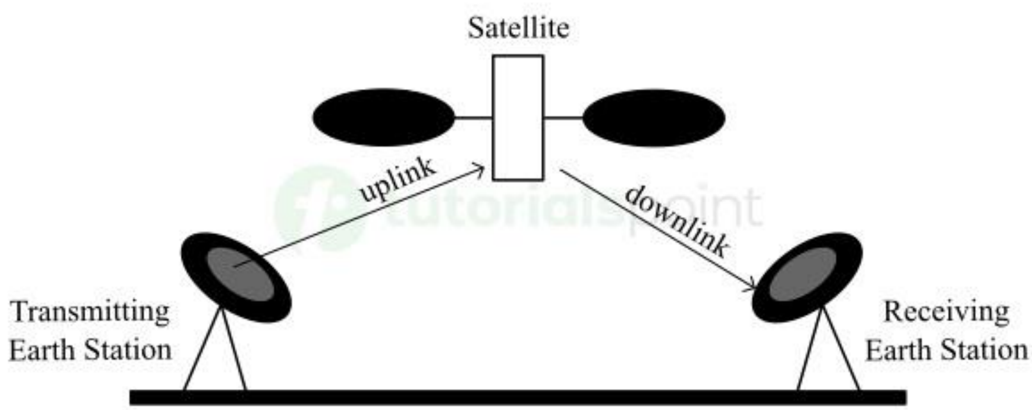

Fig. 16.1: Block Diagram of satellite Communication

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 16.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Uplink Transmitter	2450-2468 MHz up-linking selectable frequencies, Wide band RF amplifier, FM Modulation of Audio and Video, Detachable Dish Antenna.	01
3	Downlink Receiver	Receives and demodulate signals simultaneously. Built in speaker for audio and video output, Detachable Dish Antenna.	01
4	Connecting cables	BNC – BNC connectors for DSO/CRO	01
5	CRO/DSO	60 MHz/100 MHz/200 MHz bandwidth,500MS/s to 1 GS/s real -time sample rate,50 GS/s sample rate for	01

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
		repetitive waveforms, High resolution color LCD display	
6	TV monitor	AV support	

IX. Precautions to be Followed

1. Check all connections before switching ON the power supply.
2. Ensure frequency matching between transmitter and receiver.
3. Avoid high transmission power to prevent equipment damage.
4. Keep coaxial cables properly terminated to avoid reflections.
5. Handle RF modules with care to prevent static damage.

X. Suggested Procedure

Setting at Uplink Transmitter:

1. Carry out the following settings at all two units starting from Uplink Transmitter then Satellite Transponder and at last Downlink Receiver. This sequence of operation must be followed to avoid any kind of improper operation of the system. Now set the "Channel A" to 'Video' mode using the `Channel Select A' key, so as to transmit video signals from Uplink Transmitter. The video signals are transmitted through `Video' channel of the transmitter.

Fig 16.1: Connect the audio/video signal at the input

2. Socket provided on uplink transmitter, video at video input and audio at audio-I input

Fig.16.2 Setting at Satellite Transponder

3. Keep the toggle switch to 'Telemetry off' position provided at Satellite Transponder unit.

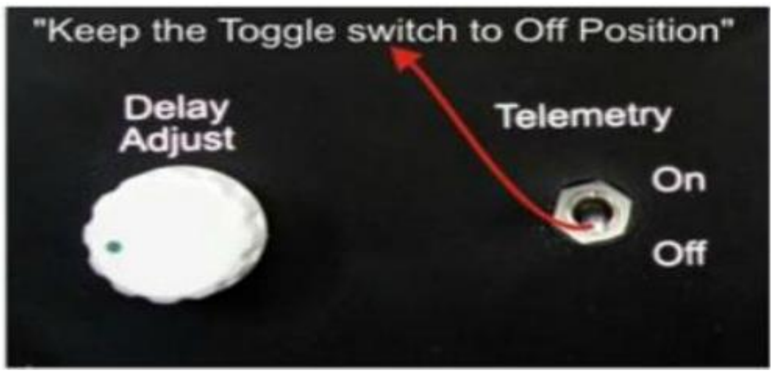

Fig. 16.3: Toggle switch telemetry off position

4. Setting at Downlink Receiver

Fig. 16.4: Uplink Transmitter and Downlink Receiver Placement

5. Connect TV monitor to the Audio/Video output of Downlink Receiver. (Video from Video Output, audio from Audio I output) Set TV in AV Mode.

Fig. 16.5: The TV Monitor Connection to Display Video and Audio signal

XI. Resources used

Table No. 16.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

Table No. 16.3

Sr. No.	Uplink Frequency (MHz)	Downlink Frequency (MHz)	Audio and video signal Quality	Remark
1				
2				

XIV. Result

…………………………………………………………………………………………………...…

……………………………………………………………………………………………..

XV. Interpretation of result

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XVI. Conclusion and Recommendation

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XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Identify reasons for audio distortion during transmission.
2. Recommend improvements to enhance AV transmission quality.
3. Connect the AV source and receiver block diagram as per the practical.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested references for further reading

Sr. No.	Link / Portal / V Lab	Description
1	https://scientechworld.com/product/satellite-communication/	Satellite Communication
2	https://imdpune.gov.in/training/satellite/satellite_communication_for_training.pdf	Satellite Communication

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
	Product Related: 10 Marks	**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 17: Simultaneous Transmission and Reception of Audio, Video, and Tone/Voice Signals via Satellite Link

I. Practical Significance

Practical intended to help students to develop skills for the basic process of establishing a direct communication link between audio and video and tone/voice signal simultaneously. It demonstrates the transmission, reception, and verification of analog signals through a communication link similar to satellite systems.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: Maintain optical and satellite communication systems.

III. Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV. Laboratory Learning Outcome

LLO 18.1 Test the performance of satellite link by sending telecommand and receive the telemetry Data.

IV. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

The process of signal transmission via satellite involves several sequential steps, each playing a crucial role in ensuring efficient communication. Initially, the signal is generated by the transmitter and modulated to carry the required information, whether it is audio, voice, or video. Following this, the baseband signal undergoes frequency up-conversion, wherein it is converted to a higher frequency suitable for satellite transmission. This conversion process entails mixing the baseband signal with a carrier frequency. Subsequently, the up converted signal is amplified using a high-power amplifier to ensure it can effectively traverse the long distance to the satellite. Once amplified, the signal is directed to the feed horn, which serves to transmit it toward the parabolic reflector. The reflector then focuses the signal into a narrow beam and directs it precisely toward the satellite. Upon reaching the satellite, the signal is received, amplified once more, and retransmitted back to earth, often to multiple ground stations. This intricate process ensures the successful transmission of signals over vast distances via satellite, enabling seamless communication and data exchange across the globe.

VII. Block diagram/Circuit diagram/Flowchart

A. Suggestive Block Diagram

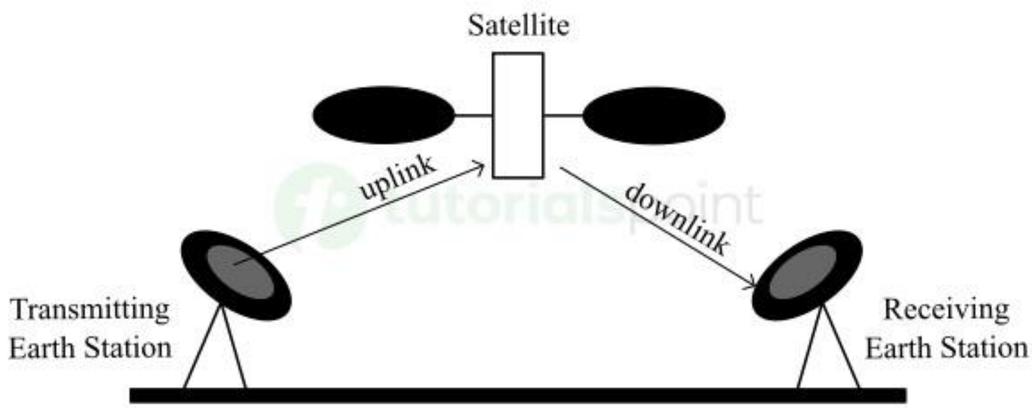

Fig. 17.1: Block Diagram of satellite Communication

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 17.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Uplink Transmitter	2450-2468 MHz up-linking selectable frequencies, Wide band RF amplifier, FM Modulation of Audio and Video, Detachable Dish Antenna.	01
2	Downlink Receiver	Receives and demodulate signals simultaneously. Built in speaker for audio and video output, Detachable Dish Antenna.	01
3	Connecting cables	BNC – BNC connectors for DSO/CRO	01

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
4	CRO	60 MHz/100 MHz/200 MHz bandwidth,500MS/s to 1 GS/s real -time sample rate,50 GS/s sample rate for repetitive waveforms, High resolution color LCD display	01
5	TV monitor	AV support	01

IX. Precautions to be followed

1. Check all connections before switching ON the power supply.
2. Ensure frequency matching between transmitter and receiver.
3. Avoid high transmission power to prevent equipment damage.
4. Keep coaxial cables properly terminated to avoid reflections.
5. Handle RF modules with care to prevent static damage.

X. Suggested Procedure

Setting at Uplink Transmitter:

Carry out the following settings at all two units starting from Uplink Transmitter then Satellite Transponder and at last Downlink Receiver. This sequence of operation must be followed to avoid any kind of improper operation of the system. Now set the "Channel A" to 'Video' mode using the `Channel Select A' key, so as to transmit video signals from Uplink Transmitter. The video signals are transmitted through `Video' channel of the transmitter.

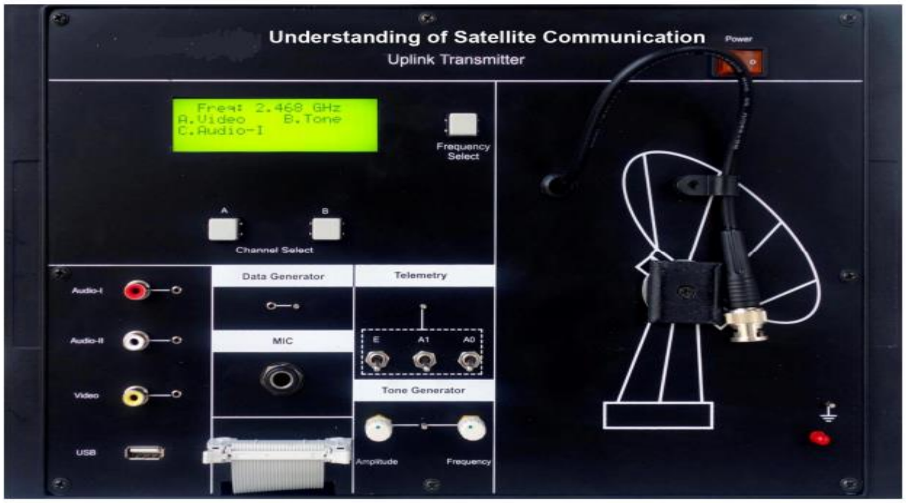

Fig 17.1: Connect the audio/video signal at the input

1. Socket provided on uplink transmitter, video at video input and audio at audio-I input

Fig.17.2 Setting at Satellite Transponder

2. Keep the toggle switch to 'Telemetry off' position provided at Satellite Transponder unit.

Fig. 17.3: Toggle switch telemetry off position

3. **Setting at Downlink Receiver**

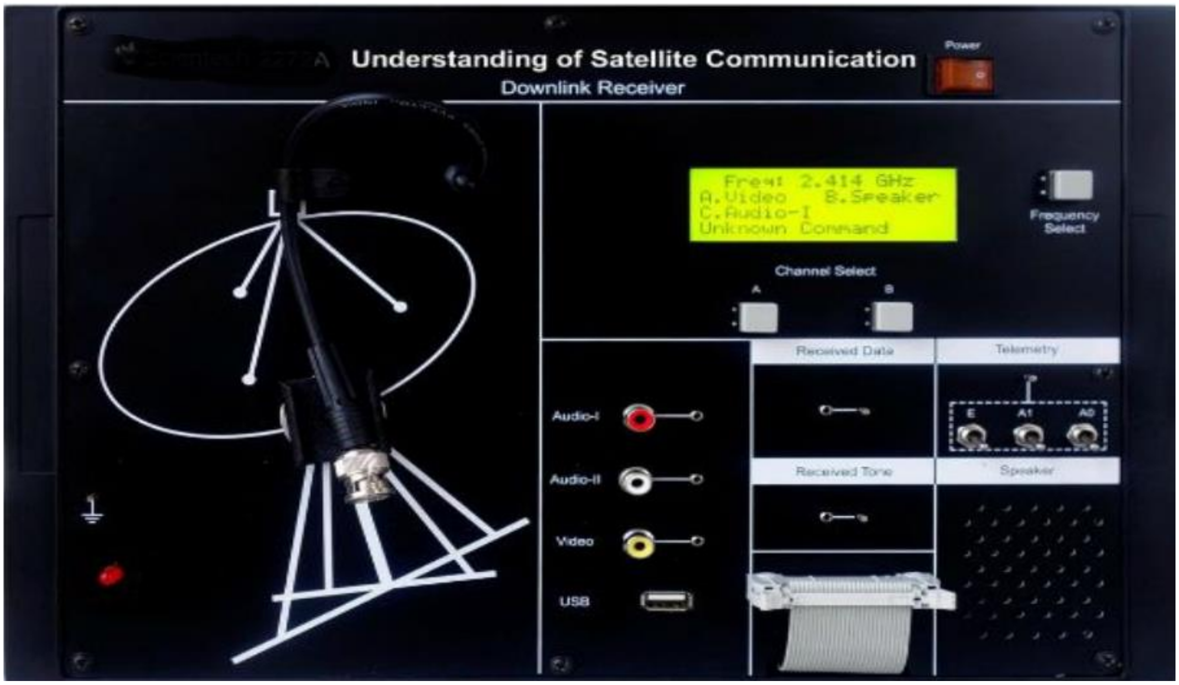

Fig. 17.4: Uplink Transmitter and Downlink Receiver Placement

4. Connect TV monitor to the Audio/Video output of Downlink Receiver. (Video from Video
5. Output, audio from Audio I output) Set TV in AV Mode.

Fig. 17.5: The TV monitor will display video and audio signal that you have connected to Uplink

Fig. 17.6: The TV monitor will display video and audio and tone/voice signal that you have connected to Uplink

XI. Resources used

Table No. 16.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

Table No. 16.3

Sr. No.	Uplink Frequency (MHz)	Downlink Frequency (MHz)	Audio and video and tone/voice signal Quality (Good, bad, weak)	Remark
1				
2				

XIV. Result

……

…………………………………………………………………………………………………

XV. Interpretation of result

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…………………………………………………………………………………………………

XVI. Conclusion and Recommendation

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…………………………………………………………………………………………………

XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Identify reasons for audio distortion during transmission.
2. Recommend improvements to enhance AV transmission quality.
3. Connect the AV source and receiver block diagram as per the practical.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested references for further reading.

Sr.No.	Link / Portal / V Lab	Description
1	https://scientechworld.com/product/satellite-communication/	Satellite Communication
2	https://imdpune.gov.in/training/satellite/satellite_communication_for_training.pdf)	Satellite Communication

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 18: Evaluating satellite link performance by transmitting telecommands and receiving telemetry data

I. Practical Significance

This practical develops the ability of students to evaluate end-to-end satellite communication performance by analyzing how telecommands (TC) are transmitted to the satellite and how telemetry (TM) data is received. It familiarizes students with real-time link impairments, coding/decoding, and quality monitoring essential for space communication systems.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: ‘Maintain optical and satellite communication systems.

III. Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV. Laboratory Learning Outcome

LLO 18.1 Test the performance of satellite link by sending telecommand and receive the telemetry Data.

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for installation and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

The basic function of all but the simplest spacecraft requires extensive contact with ground stations for control, command, communication, and data return, and sufficient computer processing power to run all spacecraft subsystems with, in many cases, a high degree of autonomy. A spacecraft Command and Data Handling (C&DH) system handles all data sent and received by the spacecraft, including science data and spacecraft or payload operations. The system is connected to RF transmitter and receiver units that are the sole point of passage for data entering or leaving the spacecraft. A space link is a communications link between a spacecraft and its associated ground system or between two spacecraft. A space link protocol is a communications protocol designed to be used over a space link, or in a network that contains one or multiple space links. The basic data flow over a space link is made of Telemetry (TM) and Telecommand (TC) data. Thus, the TM downlink and TC uplink provide a communication channel between the spacecraft and the ground operators. On the uplink, the C&DH system receives and decodes all commands and data for both platform and payload operations from the communications system. These commands (TCs) are then directed to the appropriate subsystem or executed directly at platform level.

VII. Circuit diagram / block diagram / flow chart

A. Suggestive Block Diagram

NA

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 18.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online matlab	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus software)	01
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX. Precautions to be Followed

1. Ensure proper earthing to the computer system
2. Input each constant in given program carefully for proper output.
3. Save and close all open programs and figures properly after completing the practical.

X. Suggested Procedure

1. Double click on matlab icon to Run matlab or open online matlab from website https://matlab.mathworks.com/

2. Define constants
3. Write proper code of MATLAB
4. Check proper conditions for Telecommand and Telemetry
5. Observe the output in figure window and command window

MATLAB Code for satellite link performance by transmitting telecommands and receiving telemetry data:

```
clc; clear; close all;

%% ============================================================
%            USER-DEFINED INPUT SECTION
% ============================================================

disp("=== USER INPUTS FOR SATELLITE LINK ===");

R        = input("Enter slant range R (meters): ");            % e.g., 38000e3
f_up     = input("Enter uplink frequency f_up (Hz): ");         % e.g., 14e9
f_down   = input("Enter downlink frequency f_down (Hz): ");     % e.g., 12e9
Rb_up    = input("Enter uplink data rate (bps): ");             % e.g., 2000
Rb_down  = input("Enter downlink data rate (bps): ");           % e.g., 1e6
Pt_up    = input("Enter uplink Tx power (W): ");                % e.g., 50
Pt_down  = input("Enter downlink Tx power (W): ");              % e.g., 10
D_tx_up  = input("Enter uplink Tx antenna diameter (m): ");     % e.g., 3
D_rx_up  = input("Enter uplink Rx antenna diameter (m): ");     % e.g., 1
D_tx_down= input("Enter downlink Tx antenna diameter (m): ");   % e.g., 1
D_rx_down= input("Enter downlink Rx antenna diameter (m): ");   % e.g., 3
eta      = input("Enter antenna efficiency (0-1): ");           % e.g., 0.6
Tsys_up  = input("Enter uplink system noise temperature (K): "); % e.g., 500
Tsys_down= input("Enter downlink system noise temp (K): ");     % e.g., 300

%% ============================================================
%            CONSTANTS
% ============================================================
c = 3e8;                  % speed of light
k = 1.380649e-23;         % Boltzmann constant

%% ============================================================
%            ANTENNA GAINS (dBi)
% ============================================================
lambda_up   = c / f_up;
lambda_down = c / f_down;

G_tx_up  = 10*log10(eta*(pi*D_tx_up /lambda_up)^2);
G_rx_up  = 10*log10(eta*(pi*D_rx_up /lambda_up)^2);

G_tx_down = 10*log10(eta*(pi*D_tx_down/lambda_down)^2);
```

```
G_rx_down = 10*log10(eta*(pi*D_rx_down/lambda_down)^2);

%% ==============================================================
%              FREE SPACE PATH LOSS
% ==============================================================
FSPL_up   = 20*log10(4*pi*R / lambda_up);
FSPL_down = 20*log10(4*pi*R / lambda_down);

%% ==============================================================
%              UPLINK RECEIVED POWER
% ==============================================================
Pt_up_dBW = 10*log10(Pt_up);
Pr_up_dBW = Pt_up_dBW + G_tx_up + G_rx_up - FSPL_up;

%% C/N0
N0_up_dBW = 10*log10(k*Tsys_up);
CN0_up    = Pr_up_dBW - N0_up_dBW;

%% Eb/N0
EbN0_up = CN0_up - 10*log10(Rb_up);

%% ==============================================================
%              DOWNLINK RECEIVED POWER
% ==============================================================
Pt_down_dBW = 10*log10(Pt_down);
Pr_down_dBW = Pt_down_dBW + G_tx_down + G_rx_down - FSPL_down;

N0_down_dBW = 10*log10(k*Tsys_down);
CN0_down    = Pr_down_dBW - N0_down_dBW;

EbN0_down = CN0_down - 10*log10(Rb_down);

%% ==============================================================
%                 BPSK SIMULATION
% ==============================================================
Nbits = 1e5;

data_up = randi([0 1], Nbits, 1);
data_down = randi([0 1], Nbits, 1);

% BPSK Mapping
tx_up   = 2*data_up - 1;
tx_down = 2*data_down - 1;

% SNR (same as Eb/N0 for BPSK)
SNR_up = EbN0_up;
SNR_down = EbN0_down;

% AWGN
```

```
rx_up = add_awgn(tx_up, SNR_up);
rx_down = add_awgn(tx_down, SNR_down);

% Detect
est_up = rx_up > 0;
est_down = rx_down > 0;

% BER
BER_up = mean(est_up ~= data_up);
BER_down = mean(est_down ~= data_down);

%% ============================================================
%              PRINT RESULTS
% ============================================================
fprintf("\n==========================================\n");
fprintf("           SATELLITE LINK RESULTS\n");
fprintf("==========================================\n");

fprintf("\n----------- UPLINK (Telecommand) -----------\n");
fprintf("Received Power       : %.2f dBW\n", Pr_up_dBW);
fprintf("C/N0                 : %.2f dB-Hz\n", CN0_up);
fprintf("Eb/N0                : %.2f dB\n", EbN0_up);
fprintf("BER (Simulated)      : %.3e\n", BER_up);

fprintf("\n----------- DOWNLINK (Telemetry) -----------\n");
fprintf("Received Power       : %.2f dBW\n", Pr_down_dBW);
fprintf("C/N0                 : %.2f dB-Hz\n", CN0_down);
fprintf("Eb/N0                : %.2f dB\n", EbN0_down);
fprintf("BER (Simulated)      : %.3e\n", BER_down);

fprintf("\n==========================================\n");
fprintf("Simulation complete.\n");

%% ============================================================
%          USER-DEFINED AWGN FUNCTION (NO TOOLBOX)
% ============================================================
function y = add_awgn(x, SNR_dB)
   SNR = 10^(SNR_dB/10);
   Px = mean(abs(x).^2);
   N0 = Px / SNR;
   noise = sqrt(N0/2) * randn(size(x));
   y = x + noise;
end
```

```
clc; clear; close all;

%% =============================================================
%                USER-DEFINED INPUT SECTION
% =============================================================

disp("=== USER INPUTS FOR SATELLITE LINK ===");

R         = input("Enter slant range R (meters): ");              % e.g., 38000e3
f_up      = input("Enter uplink frequency f_up (Hz): ");          % e.g., 14e9
f_down    = input("Enter downlink frequency f_down (Hz): ");      % e.g., 12e9
Rb_up     = input("Enter uplink data rate (bps): ");              % e.g., 2000
Rb_down   = input("Enter downlink data rate (bps): ");            % e.g., 1e6
Pt_up     = input("Enter uplink Tx power (W): ");                 % e.g., 50
Pt_down   = input("Enter downlink Tx power (W): ");               % e.g., 10
D_tx_up   = input("Enter uplink Tx antenna diameter (m): ");      % e.g., 3
D_rx_up   = input("Enter uplink Rx antenna diameter (m): ");      % e.g., 1
D_tx_down= input("Enter downlink Tx antenna diameter (m): ");     % e.g., 1
D_rx_down= input("Enter downlink Rx antenna diameter (m): ");     % e.g., 3
eta       = input("Enter antenna efficiency (0-1): ");            % e.g., 0.6
Tsys_up   = input("Enter uplink system noise temperature (K): "); % e.g., 500
Tsys_down= input("Enter downlink system noise temp (K): ");       % e.g., 300

%% =============================================================
%                 CONSTANTS
% =============================================================
c = 3e8;                       % speed of light
k = 1.380649e-23;              % Boltzmann constant
```

```
%% ============================================================
%                  ANTENNA GAINS (dBi)
% ============================================================
lambda_up   = c / f_up;
lambda_down = c / f_down;

G_tx_up  = 10*log10(eta*(pi*D_tx_up /lambda_up)^2);
G_rx_up  = 10*log10(eta*(pi*D_rx_up /lambda_up)^2);

G_tx_down = 10*log10(eta*(pi*D_tx_down/lambda_down)^2);
G_rx_down = 10*log10(eta*(pi*D_rx_down/lambda_down)^2);

%% ============================================================
%                  FREE SPACE PATH LOSS
% ============================================================
FSPL_up   = 20*log10(4*pi*R / lambda_up);
FSPL_down = 20*log10(4*pi*R / lambda_down);

%% ============================================================
%                  UPLINK RECEIVED POWER
% ============================================================
Pt_up_dBW = 10*log10(Pt_up);
Pr_up_dBW = Pt_up_dBW + G_tx_up + G_rx_up - FSPL_up;

%% C/N0
N0_up_dBW = 10*log10(k*Tsys_up);
CN0_up    = Pr_up_dBW - N0_up_dBW;

%% Eb/N0
EbN0_up = CN0_up - 10*log10(Rb_up);
```

```
%% ==============================================================
%                DOWNLINK RECEIVED POWER
% ==============================================================
Pt_down_dBW = 10*log10(Pt_down);
Pr_down_dBW = Pt_down_dBW + G_tx_down + G_rx_down - FSPL_down;

N0_down_dBW = 10*log10(k*Tsys_down);
CN0_down    = Pr_down_dBW - N0_down_dBW;

EbN0_down = CN0_down - 10*log10(Rb_down);
```

```
%% ==============================================================
%                    BPSK SIMULATION
% ==============================================================
Nbits = 1e5;

data_up = randi([0 1], Nbits, 1);
data_down = randi([0 1], Nbits, 1);

% BPSK Mapping
tx_up   = 2*data_up - 1;
tx_down = 2*data_down - 1;

% SNR (same as Eb/N0 for BPSK)
SNR_up = EbN0_up;
SNR_down = EbN0_down;

% AWGN
rx_up = add_awgn(tx_up, SNR_up);
rx_down = add_awgn(tx_down, SNR_down);
```

```
% Detect
est_up = rx_up > 0;
est_down = rx_down > 0;

% BER
BER_up = mean(est_up ~= data_up);
BER_down = mean(est_down ~= data_down);

%% ============================================================
%                PRINT RESULTS
% ============================================================
fprintf("\n============================================\n");
fprintf("           SATELLITE LINK RESULTS\n");
fprintf("============================================\n");

fprintf("\n----------- UPLINK (Telecommand) -----------\n");
fprintf("Received Power        : %.2f dBW\n", Pr_up_dBW);
fprintf("C/N0                  : %.2f dB-Hz\n", CN0_up);
fprintf("Eb/N0                 : %.2f dB\n", EbN0_up);
fprintf("BER (Simulated)       : %.3e\n", BER_up);

fprintf("\n----------- DOWNLINK (Telemetry) -----------\n");
fprintf("Received Power        : %.2f dBW\n", Pr_down_dBW);
fprintf("C/N0                  : %.2f dB-Hz\n", CN0_down);
fprintf("Eb/N0                 : %.2f dB\n", EbN0_down);
fprintf("BER (Simulated)       : %.3e\n", BER_down);

fprintf("\n============================================\n");
fprintf("Simulation complete.\n");

%% ============================================================
%            USER-DEFINED AWGN FUNCTION (NO TOOLBOX)
% ============================================================
function y = add_awgn(x, SNR_dB)
    SNR = 10^(SNR_dB/10);
    Px = mean(abs(x).^2);
    N0 = Px / SNR;
    noise = sqrt(N0/2) * randn(size(x));
    y = x + noise;
end
```

Command Window

```
=== USER INPUTS FOR SATELLITE LINK ===
Enter slant range R (meters): 38000e3
Enter uplink frequency f_up (Hz): 14e9
Enter downlink frequency f_down (Hz): 12e9
Enter uplink data rate (bps): 2000
Enter downlink data rate (bps): 1e6
Enter uplink Tx power (W): 50
Enter downlink Tx power (W): 10
Enter uplink Tx antenna diameter (m): 3
Enter uplink Rx antenna diameter (m): 1
Enter downlink Tx antenna diameter (m): 1
Enter downlink Rx antenna diameter (m): 3
Enter antenna efficiency (0-1): .6
Enter uplink system noise temperature (K): 500
Enter downlink system noise temp (K): 300

===========================================
           SATELLITE LINK RESULTS
===========================================

----------- UPLINK (Telecommand) -----------
Received Power      : -98.22 dBW
C/N0                : 103.39 dB-Hz
Eb/N0               : 70.38 dB
BER (Simulated)     : 0.000e+00

----------- DOWNLINK (Telemetry) -----------
Received Power      : -106.55 dBW
C/N0                : 97.28 dB-Hz
Eb/N0               : 37.28 dB
BER (Simulated)     : 0.000e+00
```

XI. Resources used

Table No. 18.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

NA

XIV . Result

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XV. Interpretation of result

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XVI. Conclusion and Recommendation

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XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Earth, received and processed by the satellite, and then how a response is generated and
2. Down linked as telemetry.

3. Evaluate the overall performance of an existing satellite Telemetry, Tracking, and Command (TT&C) system based on operational data (e.g., bit error rates, fade margins, command execution success rates) and recommend specific changes for improvement.
4. Analyze the impact of Doppler shift on tracking accuracy.
5. Measure the received signal level (RSL) for telemetry reception on the training kit and plot the graph.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested References for further reading.

Sr. No.	Link / Portal / V Lab	Description
1	https://matlab.mathworks.com/	Telemetry and Telecommand
2	https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Onboard_Computers_and_Data_Handling/Telemetry_Telecommand	Telemetry and Telecommand

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 19: Transmission and reception of function generator waveforms through satellite communication link

I Practical Significance

Practical intended to help students to develop skills for to understand how baseband analog waveforms (sine, square, triangular) are transmitted through a satellite link. It demonstrates the transmission, reception, and verification of analog signals through a communication link similar to satellite systems.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: Maintain optical and satellite communication systems.

III. Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV. Laboratory Learning Outcome

LLO 19.1 Interpret the result of the satellite link signal using function generator.

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for installation and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

The communications satellite link is defined by several basic parameters, some used in communications system definitions, others unique to the satellite environment summarizes the parameters used in the evaluation of satellite communications links. Two one- way free-space or air links between Earth Stations A and B are shown. The portion of the link from the earth station to the satellite is called the uplink, while the portion from the satellite to the ground is the downlink. Note that either station has an uplink and a downlink. The electronics in the satellite that receives the uplink signal, amplifies and possibly processes the signal, and then reformats and transmits the signal back to the ground, is called the transponder, design by the triangular amplifier symbol in the figure (the point of the triangle indicates the direction of signal transmission). Two transponders are required in the satellite for each two-way link between the two ground stations as shown. The antennas on the satellite that receive and transmit the signals are usually not included as a part of the transponder electronics – they are defined as a separate element of the satellite payload

VII. Block diagram/Circuit diagram/Flowchart

A. Suggestive Block Diagram

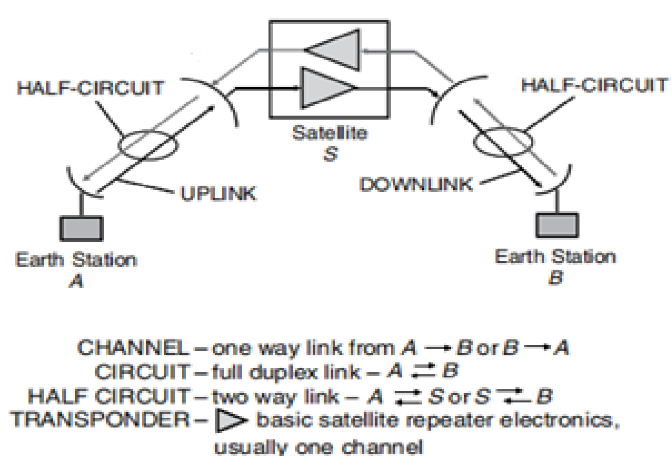

Fig.no.19.1: transfer of baseband analog signal

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 19.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Uplink Transmitter	2450-2468 MHz up-linking selectable frequencies, Wide band RF amplifier, FM Modulation of Audio and Video, Detachable Dish Antenna.	01
2	Downlink Receiver	Receives and demodulate signals simultaneously. Built in speaker for audio and video output, Detachable Dish Antenna.	01
3	Connecting cables	BNC – BNC connectors for DSO/CRO	01

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
4	CRO/DSO	60 MHz/100 MHz/200 MHz bandwidth,500MS/s to 1 GS/s real -time sample rate,50 GS/s sample rate for repetitive waveforms, High resolution color LCD display	01
5	Function generator	Frequency 5Mhz	01

IX Precautions to be Followed

1. Check all connections before switching ON the power supply.
2. Ensure frequency matching between transmitter and receiver.
3. Avoid high transmission power to prevent equipment damage.
4. Keep coaxial cables properly terminated to avoid reflections.
5. Handle RF modules with care to prevent static damage.

X Suggested Procedure

Once you get the set up ready as per the practical 2, proceed as follows.

Connect Function generator Sine wave output to Audio-I socket provided on Uplink Transmitter.

Fig 19.1: Connect Function generator Sine wave output to Audio-I socket

Feed the signal of 1 KHz Sine wave, Connect Audio-I socket of Downlink Receiver to the Oscilloscope.

Fig.19.2: Connect Audio-I socket of Downlink Receiver to the Oscilloscope.

XI Resources used

Table No. 19.2

Sr. No.	Name of Resource	Specifications	Quantity

XII Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII Observation Table

Table No. 19.3

Sr. No.	Analog signals transmitted	Analog signals received	Signals (sine, rectangular, triangular)	Remark
1				
2				

XIV Result

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……..

XV Interpretation of result

……

……..

XVI Conclusion and recommendation

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……..

XVII .Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Describe the basic difference between an active and a passive satellite, and state which type is used in your practical.
2. Illustrate with a block diagram the signal path from the function generator to the final display on the oscilloscope.
3. Determine the cause of any signal degradation or interference observed during the practical session.
4. Determine the cause of any signal degradation or interference observed during the practical session.

[Space for Answers] (If required attach separate page)

……

……

XVIII Suggested references for further reading

Sr. No.	Author	Title	Publisher with ISBN Number
1	John Wiley & Sons	Satellite Communications Systems: Systems, Techniques and Technology	Wiley ISBN:9781119673811

Sr.No.	Link / Portal / V Lab	Description
1	https://scientechworld.com/product/satellite-communication/	Satellite Communication

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
	Product Related: 10 Marks	**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.20: Calculation of Satellite Look Angles (Azimuth & Elevation) Using Coding.

I. Practical Significance

In satellite communication, the ground antenna must be correctly pointed toward the satellite to establish a strong communication link. The directions in which the antenna is pointed are described by two important angles:

1. Azimuth (horizontal direction from North)
2. Elevation (height above the horizon)

By calculating these angles using coding, we can accurately align antennas for communication, broadcasting, weather forecasting, and navigation purposes.

This practical helps students understand how satellite geometry and Earth location affect communication performance**.**

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: ‘Maintain optical and satellite communication systems.

III Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV Laboratory Learning Outcome

LLO 20.1 Estimate satellite Look Angles (Azimuth & Elevation) through coding.

V Relevant Affective Domain related outcome

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

IV Relevant Theoretical Background

A geostationary satellite appears fixed at one point in the sky because it revolves around Earth at the same rotational speed as the Earth itself (approximately 24 hours).

Such satellites are usually located at an altitude of 35,786 km above the equator.

- Latitude (φ): North–South position of the observer on Earth.
- Longitude (λ): East–West position of the observer.
- Satellite Longitude (λ_s): East–West position of the satellite sub-point (projection of satellite on

Earth's equator).

- Earth Radius (R_e): 6371 km.
- Satellite Height (h): 35,786 km (for geostationary satellite).

The look angles describe the direction from the observer's location to the satellite.

They are calculated as:

Elevation (E):

$$E = \tan^{-1}\left(\frac{\cos(\lambda_s - \lambda)\cos(\phi) - \frac{R_e}{R_e+h}}{\sqrt{1 - [\cos(\lambda_s - \lambda)\cos(\phi)]^2}}\right)$$

Azimuth (A):

$$A = \tan^{-1}\left(\frac{\sin(\lambda_s - \lambda)}{\tan(\phi)}\right)$$

VII .Circuit diagram/Block diagram/flowchart

A. Suggestive diagram

N.A.

B. Actual Circuit diagram

N.A.

VIII. Required Resources/apparatus/equipment with specifications

Table No. 20.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online matlab	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus software)	01
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX. Precautions to be followed

1. Check the rules/syntax of programming
2. Enter correct latitude, longitude, and satellite longitude values.
3. Verify formulas before running the program.
4. Ensure positive values for East longitudes and negative for West longitudes (Indian longitudes are East positive).
5. Save the code and test it with known sample data before using new inputs.

X. Procedure

1. Start MATLAB open new file
2. Type sample code for look angle calculation in file
3. Save and run file
4. Enter proper values of all parameters
5. Observe the reading

Sample Program:

Look angle calculation using MATLAB

```
%Look angle calculation using Maltlab
fprintf('\n\n');
fprintf('..........Look Angle parameters........\n\n');
Ls=input('satellite latitude =');
ls=input('satellite longitude =');
Le=input('Earth station latitude =');
le=input('Earth station longitude =');
rs=input('The distance between earth centre to satellite in meter =');
fprintf('\n');
Re=6378*10^3; %radius of earth in meter
gama=acosd(cosd(Ls)*cosd(Le)*cosd(ls-le)+sind(Ls)*sind(Le));
d1=(Re^2+rs^2-2*Re*rs*cosd(gama));
d=sqrt(d1); %slant distance
El=acosd((rs*sind(gama))/d);
a=abs(le-ls);
alfa=asind(sind(a)*cosd(Ls)/sind(gama));
fprintf('..........Look Angle calculation........\n\n');
if(Le>0 && ls>0)
Az=180-alfa;
fprintf('The azimuth angle in degree is= %f \n',Az);
elseif(Le>0 && ls<0);
Az=180+alfa;
fprintf('The azimuth angle in degree is= %f \n',Az);
elseif(Le<0 && ls>0)
```

```
Az=alfa;
fprintf('The azimuth angle in degree is= %f =\n',Az);
else
Az=360-alfa;
fprintf('The azimuth angle in degree is= %f \n',Az);
end
fprintf('Elevation angle is = %f \n',El);
```

Drive/ons20.m

```
%Look angle calculation using MATLAB
fprintf('\n\n');
fprintf('..........Look Angle parameters........\n\n');
Ls=input('satellite latitude =');
ls=input('satellite longitude =');
Le=input('Earth station latitude =');
le=input('Earth station longitude =');
rs=input('The distance between earth centre to satellite in meter =');
fprintf('\n');
Re=6378*10^3; %radius of earth in meter
gama=acosd(cosd(Ls)*cosd(Le)*cosd(ls-le)+sind(Ls)*sind(Le));
d1=(Re^2+rs^2-2*Re*rs*cosd(gama));
d=sqrt(d1); %slant distance
El=acosd((rs*sind(gama))/d);
a=abs(le-ls);
alfa=asind(sind(a)*cosd(Ls)/sind(gama));
fprintf('..........Look Angle calculation........\n\n');
if(Le>0 && ls>0)
Az=180-alfa;
fprintf('The azimuth angle in degree is= %f \n',Az);
elseif(Le>0 && ls<0);
Az=180+alfa;
fprintf('The azimuth angle in degree is= %f \n',Az);
elseif(Le<0 && ls>0)
Az=alfa;
fprintf('The azimuth angle in degree is= %f =\n',Az);
else
Az=360-alfa;
fprintf('The azimuth angle in degree is= %f \n',Az);
end
fprintf('Elevation angle is = %f \n',El);
```

).m ×

3 Drive/ons20.m

```
%Look angle calculation using MATLAB
fprintf('\n\n');
fprintf('..........Look Angle parameters........\n\n');
Ls=input('satellite latitude =');
ls=input('satellite longitude =');
Le=input('Earth station latitude =');
le=input('Earth station longitude =');
rs=input('The distance between earth centre to satellite in meter =');
fprintf('\n');
Re=6378*10^3; %radius of earth in meter
gama=acosd(cosd(Ls)*cosd(Le)*cosd(ls-le)+sind(Ls)*sind(Le));
d1=(Re^2+rs^2-2*Re*rs*cosd(gama));
```

Command Window

```
..........Look Angle parameters........

satellite latitude =50
satellite longitude =0
Earth station latitude =48.26
Earth station longitude =11.66
The distance between earth centre to satellite in meter =6378000

..........Look Angle calculation........

The azimuth angle in degree is= 287.219272
Elevation angle is = 3.908387
>> |
```

XI. Resources used

Table No. 20.1

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

Table No. 20.2

Sr. No.	Satellite latitude	Satellite longitude	Earth station latitude	Earth station longitude	Distance between earth Centre to satellite	Azimuth angle output	Elevation angle output
1							
2							
3							
4							

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more suchquestions so as to ensure the achievement of identified CO.

1. Analyze how satellite longitude shift affects azimuth values?
2. Evaluate the effect of incorrect look angle calculation on received signal.
3. Justify the need to automate look angle calculation rather than manual computation.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested References for further reading.

Sr. No.	Link / Portal / V Lab	Description
1	https://www.n2yo.com	Real-time satellite tracking
2	https://celestrak.org	Satellite data and orbital parameters
3	Bureau of Indian Standards (BIS)	IS Code on Earth Station Antenna Alignment.

Sr. No.	Author	Title	Publisher with ISBN Number
1	Dennis Roddy, 5th Edition.	Satellite Communications	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781265372545
2	Taub & Schilling.	Principles of Communication Systems	Mc Graw Hill Higher Education, New Delhi, ISBN : 9780070648111

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		60%
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 21: Simulating and validating Kepler's laws of planetary motion using code

I. Practical Significance

This practical bridges physics and computational modeling by simulating planetary motion using code. It enhances understanding of orbital mechanics and validates Kepler's laws through numerical methods.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: 'Maintain optical and satellite communication systems'.

III. Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV. Laboratory Learning Outcome

LLO 21.1 Verify Kepler's laws of motion

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for installation and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

First Law (Law of Ellipses): Each planet moves in an elliptical orbit with the Sun at one of the two foci. This means that the distance between the planet and the Sun varies throughout its orbit. The equation of an ellipse in polar coordinates is:

$$r = [a (1 - e^2)] / [1 + e \cos(\theta)]$$

where,

r = Distance of the planet from the Sun

a = Semi-major axis of the ellipse

e = Eccentricity of the ellipse ($0 \leq e < 1$)

θ = True anomaly (angle between perihelion and the planet's position)

Second Law (Law of Equal Areas): A line segment joining a planet and the Sun sweeps out equal areas in equal intervals of time. This means that a planet moves faster near the Sun (perihelion) and slower when it is farther away (aphelion).

Mathematically:

$$dA / dt = \text{constant}$$

where,

A = Area swept

t = Time interval

Third Law (Harmonic Law): The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit: $T^2 \propto a^3$

In terms of proportionality:

$$T^2 / a^3 = \text{constant}$$

Where,

T = Orbital period of the planet

a = Semi-major axis

Applications of Kepler's Laws

These laws are fundamental in astronomy, astrophysics, and space exploration, predicting planetary positions in orbits, designing satellite trajectories and orbital man oeuvres.

VII. Circuit diagram / Block diagram / Flowchart

A. Suggestive Block Diagram

NA

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 21.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online matlab	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus	01

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
		software)	
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX. Precautions to be Followed

1. Ensure proper earthing to the computer system
2. Input each constant in given program carefully for proper output.
3. Save and close all open programs and figures properly after completing the practical.

X. Suggested Procedure

1.Double click on matlab icon to Run matlab or open online matlab from website https://matlab.mathworks.com/

2.Define constants

3.Write proper code of MATLAB

4.Check proper initial conditions for proper verification of kepler laws.

5.Observe the output in figure window and command window.

MATLAB Code:

% Matlab code to validate Kepler's First Law

```
% Kepler's First Law: Elliptical Orbit Simulation
% Constants
G = 6.67430e-11;      % Gravitational constant (m^3/kg/s^2)
M = 1.989e30;         % Mass of the Sun (kg)
dt = 3600;            % Time step (1 hour)
steps = 10000;        % Number of simulation steps
% Initial conditions (Earth-like orbit)
r = [1.496e11; 0];    % Initial position (m)
v = [0; 29780];       % Initial velocity (m/s)
positions = zeros(2, steps);
% Simulation loop
for i = 1:steps
   r_mag = norm(r);
   a = -G * M * r / r_mag^3;
```

```
    v = v + a * dt;
    r = r + v * dt;
    positions(:, i) = r;
end
% Plotting the orbit
figure;
plot(positions(1, :), positions(2, :), 'b');
hold on;
plot(0, 0, 'ro', 'MarkerSize', 10, 'MarkerFaceColor', 'r'); % Sun at origin
title('Kepler''s First Law: Elliptical Orbit');
xlabel('x (m)');
ylabel('y (m)');
axis equal;
grid on;
legend('Planet Orbit', 'Sun');
```

```
% Kepler's First Law: Elliptical Orbit Simulation
% Constants
G = 6.67430e-11;       % Gravitational constant (m^3/kg/s^2)
M = 1.989e30;          % Mass of the Sun (kg)
dt = 3600;             % Time step (1 hour)
steps = 10000;         % Number of simulation steps

% Initial conditions (Earth-like orbit)
r = [1.496e11; 0];     % Initial position (m)
v = [0; 29780];        % Initial velocity (m/s)
positions = zeros(2, steps);

% Simulation loop
for i = 1:steps
    r_mag = norm(r);
    a = -G * M * r / r_mag^3;
    v = v + a * dt;
    r = r + v * dt;
    positions(:, i) = r;
end

% Plotting the orbit
figure;
plot(positions(1, :), positions(2, :), 'b');
hold on;
plot(0, 0, 'ro', 'MarkerSize', 10, 'MarkerFaceColor', 'r'); % Sun at origin
title('Kepler''s First Law: Elliptical Orbit');
xlabel('x (m)');
ylabel('y (m)');
axis equal;
grid on;
legend('Planet Orbit', 'Sun');
```

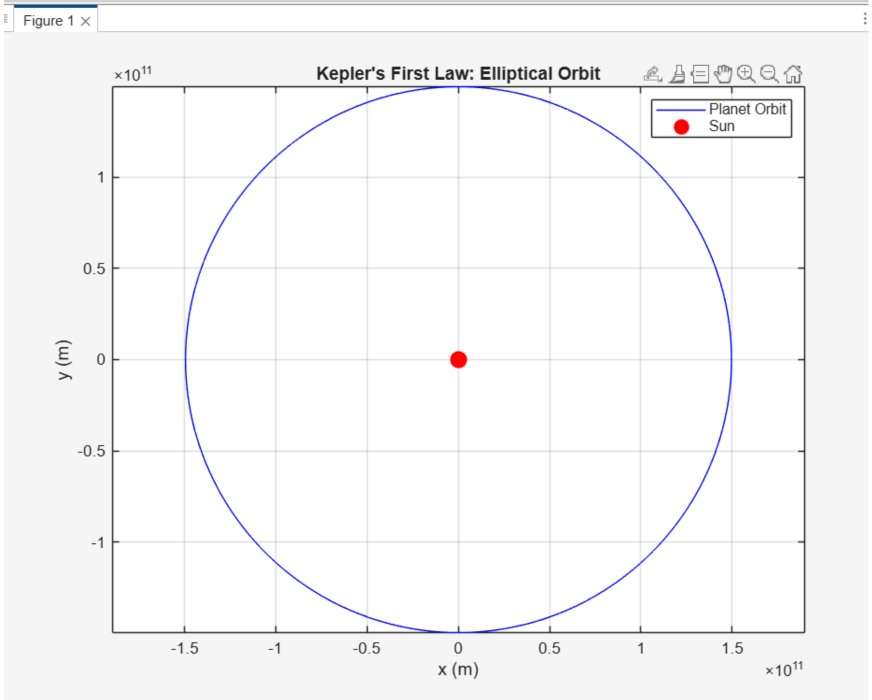

Fig.21.1: Output of Kepler's first law

% Matlab code to validate Kepler's Second Law

```
clear; clc; close all;
% Kepler's Second Law: Equal Area Sweep Simulation
% Constants
G = 6.67430e-11;      % Gravitational constant (m^3/kg/s^2)
M = 1.989e30;         % Mass of the Sun (kg)
dt = 3600;            % Time step (1 hour)
steps = 10000;        % Number of simulation steps
% Initial conditions (Earth-like orbit)
r = [1.496e11; 0];    % Initial position (m)
v = [0; 29780];       % Initial velocity (m/s)
positions = zeros(2, steps);
areas = zeros(1, steps - 1);
% Simulation loop
for i = 1:steps
   r_mag = norm(r);
   a = -G * M * r / r_mag^3;
```

```
    v = v + a * dt;
    r = r + v * dt;
    positions(:, i) = r;
end
% Calculate swept areas using triangle method
for i = 2:steps
    r1 = positions(:, i - 1);
    r2 = positions(:, i);
    area = 0.5 * abs(det([r1, r2])); % Area of triangle formed with origin
    areas(i - 1) = area;
end
% Plot orbit
figure;
subplot(1,2,1);
plot(positions(1, :), positions(2, :), 'b');
hold on;
plot(0, 0, 'ro', 'MarkerSize', 10, 'MarkerFaceColor', 'r');
title('Kepler''s Second Law: Orbit');
xlabel('x (m)');
ylabel('y (m)');
axis equal;
grid on;
% Plot area swept per time step
subplot(1,2,2);
plot(areas);
title('Area Swept Over Time');
xlabel('Time Step');
ylabel('Area (m^2)');
grid on;
```

```matlab
% Kepler's Second Law: Equal Area Sweep Simulation
% Constants
G = 6.67430e-11;        % Gravitational constant (m^3/kg/s^2)
M = 1.989e30;           % Mass of the Sun (kg)
dt = 3600;              % Time step (1 hour)
steps = 10000;          % Number of simulation steps

% Initial conditions (Earth-like orbit)
r = [1.496e11; 0];      % Initial position (m)
v = [0; 29780];         % Initial velocity (m/s)
positions = zeros(2, steps);
areas = zeros(1, steps - 1);

% Simulation loop
for i = 1:steps
    r_mag = norm(r);
    a = -G * M * r / r_mag^3;
    v = v + a * dt;
    r = r + v * dt;
    positions(:, i) = r;
end

% Calculate swept areas using triangle method
for i = 2:steps
    r1 = positions(:, i - 1);
    r2 = positions(:, i);
    area = 0.5 * abs(det([r1, r2])); % Area of triangle formed with origin
    areas(i - 1) = area;
end

   % Plot orbit
   figure;
   subplot(1,2,1);
   plot(positions(1, :), positions(2, :), 'b');
   hold on;
   plot(0, 0, 'ro', 'MarkerSize', 10, 'MarkerFaceColor', 'r');
   title('Kepler''s Second Law: Orbit');
   xlabel('x (m)');
   ylabel('y (m)');
   axis equal;
   grid on;

   % Plot area swept per time step
   subplot(1,2,2);
   plot(areas);
   title('Area Swept Over Time');
   xlabel('Time Step');
   ylabel('Area (m^2)');
   grid on;
```

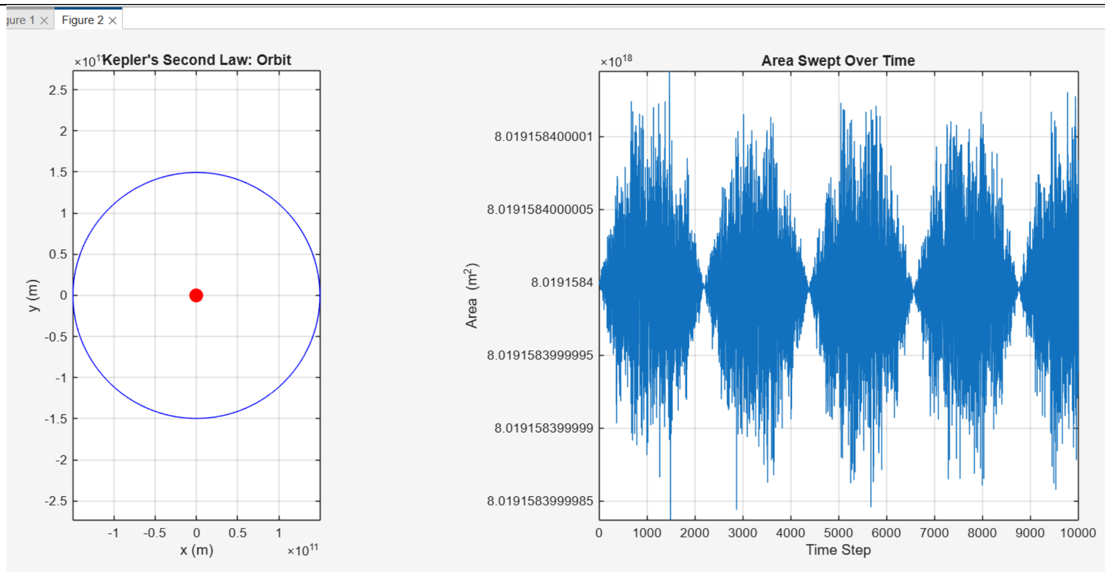

Fig.21.2: Output of Kepler's second law

% Matlab to validate Kepler's Third Law

```
clear; clc; close all;
% Kepler's Third Law: T^2 ∝ R^3 Simulation
% Constants
G = 6.67430e-11;      % Gravitational constant (m^3/kg/s^2)
M = 1.989e30;         % Mass of the Sun (kg)

% Define semi-major axes for different planets (in meters)
a_values = [0.39, 0.72, 1.0, 1.52, 5.2] * 1.496e11;  % Mercury to Jupiter
% Calculate orbital periods using T = 2*pi*sqrt(a^3 / GM)
T_values = 2 * pi * sqrt(a_values.^3 / (G * M));    % in seconds
T_years = T_values / (365.25 * 24 * 3600);          % convert to years
% Plot T^2 vs a^3
figure;
plot(a_values.^3, T_values.^2, 'bo-');
title('Kepler''s Third Law: T^2 vs a^3');
xlabel('a^3 (m^3)');
ylabel('T^2 (s^2)');
grid on;
% Display results
```

```
disp('Planetary Data (Kepler''s Third Law)');
disp('-----------------------------------');
disp('  a (AU)     T (years)');
for i = 1:length(a_values)
    fprintf('  %.2f\t\t%.2f\n', a_values(i)/1.496e11, T_years(i));
end
```

```
% Kepler's Third Law: T^2 ∝ R^3 Simulation

% Constants
G = 6.67430e-11;        % Gravitational constant (m^3/kg/s^2)
M = 1.989e30;           % Mass of the Sun (kg)

% Define semi-major axes for different planets (in meters)
a_values = [0.39, 0.72, 1.0, 1.52, 5.2] * 1.496e11;  % Mercury to Jupiter

% Calculate orbital periods using T = 2*pi*sqrt(a^3 / GM)
T_values = 2 * pi * sqrt(a_values.^3 / (G * M));     % in seconds
T_years = T_values / (365.25 * 24 * 3600);           % convert to years

% Plot T^2 vs a^3
figure;
plot(a_values.^3, T_values.^2, 'bo-');
title('Kepler''s Third Law: T^2 vs a^3');
xlabel('a^3 (m^3)');
ylabel('T^2 (s^2)');
grid on;

% Display results
disp('Planetary Data (Kepler''s Third Law)');
disp('-----------------------------------');
disp('  a (AU)     T (years)');
for i = 1:length(a_values)
    fprintf('  %.2f\t\t%.2f\n', a_values(i)/1.496e11, T_years(i));
end
```

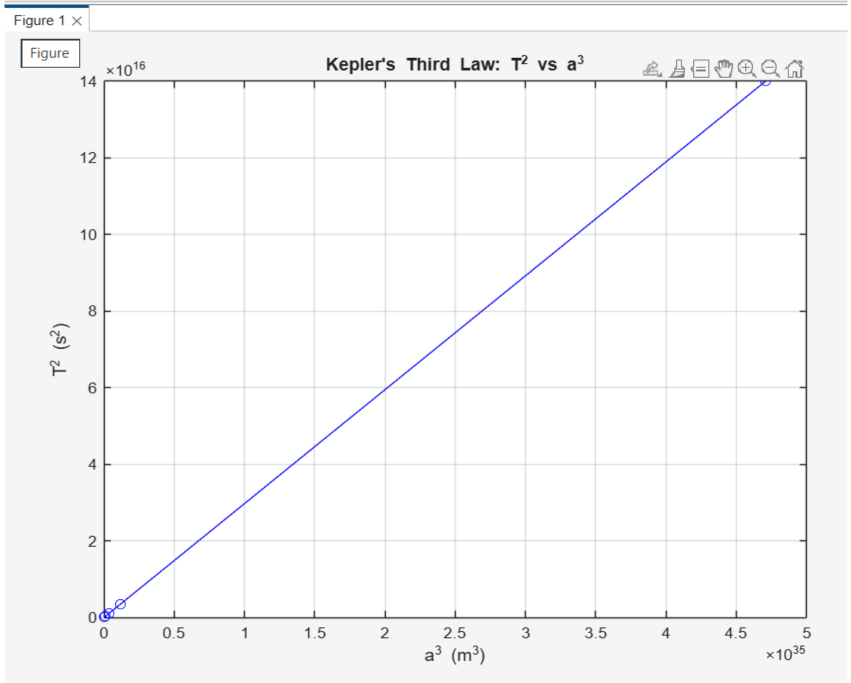

Fig.21.1: Output of Kepler's Third law

XI. Resources used

Table No. 21.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

N.A.

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and Recommendation

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XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Modify the initial velocity and position parameters in your code to produce orbits with different eccentricities, from near-circular to highly elliptical.
2. Implement functions to calculate the distance of the planet from the Sun at various points and the orbital period for a given orbit.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested References for further reading

Sr. No.	Link / Portal / V Lab	Description
1	https://dencityapp.in/experiment/keplers-laws/	Kepler’s Laws
2	https://en.wikipedia.org/wiki/Kepler%27s_laws_of_planetary_motion	Kepler's laws of planetary motion

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60%**
1	Practical Implementation with Specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely Submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 22: Simulation of Satellite Eclipse Periods through coding

I. Practical Significance

Finding the Satellite eclipse periods while they passes through earth shadow is important consideration in satellite design and operations, because it directly impacts the onboard power generation, thermal conditions and attitude control systems. Understanding and accurately predicting these eclipse periods is essential to ensure a satellite's continuous and reliable functioning.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: ‘Maintain optical and satellite communication systems’.

III. Course Level Learning Outcome

Analyze various parameters influencing performance of transmitted and received signals in satellite communication systems.

IV. Laboratory Learning Outcome

LLO 22.1 Estimate Satellite Eclipse Periods.

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for installation and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

Eclipse occurs when Earth’s equatorial plane coincides with the plane the Earth’s orbit around the sun. Near the time of spring and autumnal equinoxes (A solar equinox is a moment in time when the Sun appears directly above the equator, rather than to its north or south. On the day of the equinox, the Sun appears to rise directly east and set directly west. This occurs twice each year, around 20 March and 23 September). When the sun is crossing the equator, the satellite passes into sun’s shadow. This happens for some duration of time every day. These eclipses begin 23 days before the equinox and end 23 days after the equinox. They last for almost 10 minutes at the beginning and end of equinox and increase for a maximum period of 72 minutes at a full eclipse. The solar cells of the satellite become non-functional during the eclipse period and the satellite is made to operate with the help of power supplied from the batteries. The solar cells of the satellite become non-functional during the eclipse period and the satellite is made to operate with the help of power supplied from the batteries. A satellite will have the eclipse duration symmetric around the time t=Satellite Longitude/15 + 12 hours. The eclipse will happen at night but for satellites in the east it will happen late evening local time. For satellites in the west eclipse will happen in the early morning hour's local time. An earth caused eclipse will normally not happen during peak viewing hours if the satellite is located near the longitude of the coverage area. Modern satellites are well equipped with batteries for operation during eclipse statistical data, so these values are an approximation based on real data observed in several ground stations.

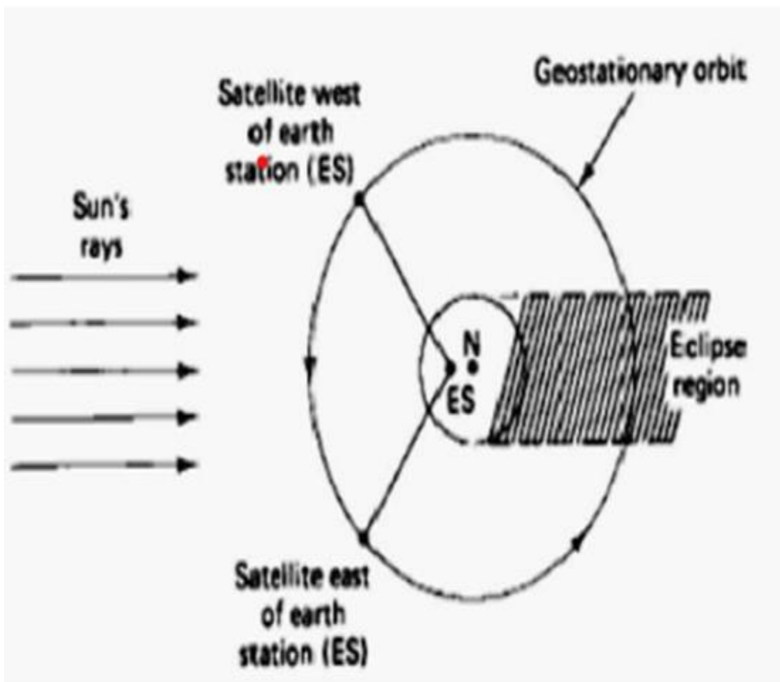

Fig. 22.1: A satellite east of the earth station enters eclipse during daylight busy hours at the earth station. A Satellite west of earth station enters eclipse during night hours.

(courtesy: https://www.rcet.org.in/uploads/academics/regulation2021/rohini_24240497485.pdf)

VII. Circuit diagram / Block diagram / Flowchart

A. Suggestive Block Diagram

NA

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 22.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online matlab	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus software)	01
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX. Precautions to be Followed

1. Ensure proper earthing to the computer system
2. Input each constant in given program carefully for proper output.
3. Save and close all open programs and figures properly after completing the practical.

X. Suggested Procedure

1. Double click on matlab icon to Run matlab or open online matlab from website https://matlab.mathworks.com/
2. Define constants
   (i) Universal gravitational constant G = 6.67430e-11
   (ii) Mass of Earth M_earth = 5.972e24
   (iv) Standard gravitational parameter for Earth mu_earth = G * M_earth
   (vi) Mean equatorial radius of Earth R_earth = 6378.137e3
3. Write proper code of Matlab
4. Enter orbital height at apoapsis in kilometer:7200.607 Km
5. Enter orbital height at Periapsis in kilometer:7200.607 Km
6. The resulting semi major axis is:the 13570.47 Km
7. The orbital period is 4.37 hours (262.22 minutes)

MATLAB Code for satellite eclipse period:

```
% Define constants
G = 6.67430e-11; % Universal gravitational constant (m^3 kg^-1 s^-2)
M_earth = 5.972e24; % Mass of Earth (kg)
mu_earth = G * M_earth; % Standard gravitational parameter for Earth (m^3 s^-2)
R_earth = 6378.137e3; % Mean equatorial radius of Earth (m)

% Prompt the user for the orbital heights in kilometers
prompt_apo = 'Enter the orbital height at apoapsis in kilometers: ';
h_apoapsis_km = input(prompt_apo);
prompt_peri = 'Enter the orbital height at periapsis in kilometers: ';
h_periapsis_km = input(prompt_peri);

% Convert heights to radii in meters
r_apoapsis = (h_apoapsis_km * 1000) + R_earth;
r_periapsis = (h_periapsis_km * 1000) + R_earth;
% Calculate the semi-major axis in meters
a_m = (r_apoapsis + r_periapsis) / 2;
a_km = a_m / 1000;

% Calculate the orbital period using Kepler's Third Law
T_seconds = 2 * pi * sqrt(a_m^3 / mu_earth);
% Convert the period to more readable units (minutes and hours)
T_minutes = T_seconds / 60;
T_hours = T_minutes / 60;

% Display the results
fprintf('Orbital Apoapsis: %.2f km\n', h_apoapsis_km);
fprintf('Orbital Periapsis: %.2f km\n', h_periapsis_km);
fprintf('The resulting semi-major axis is %.2f km.\n', a_km);
```

fprintf('The orbital period is %.2f hours (%.2f minutes).\n', T_hours, T_minutes);

```
% Define constants
G = 6.67430e-11; % Universal gravitational constant (m^3 kg^-1 s^-2)
M_earth = 5.972e24; % Mass of Earth (kg)
mu_earth = G * M_earth; % Standard gravitational parameter for Earth (m^3 s^-2)
R_earth = 6378.137e3; % Mean equatorial radius of Earth (m)

% Prompt the user for the orbital heights in kilometers
prompt_apo = 'Enter the orbital height at apoapsis in kilometers: ';
h_apoapsis_km = input(prompt_apo);
prompt_peri = 'Enter the orbital height at periapsis in kilometers: ';
h_periapsis_km = input(prompt_peri);

% Convert heights to radii in meters
r_apoapsis = (h_apoapsis_km * 1000) + R_earth;
r_periapsis = (h_periapsis_km * 1000) + R_earth;

% Calculate the semi-major axis in meters
a_m = (r_apoapsis + r_periapsis) / 2;
a_km = a_m / 1000;

% Calculate the orbital period using Kepler's Third Law
T_seconds = 2 * pi * sqrt(a_m^3 / mu_earth);

% Convert the period to more readable units (minutes and hours)
T_minutes = T_seconds / 60;
T_hours = T_minutes / 60;

% Display the results
fprintf('Orbital Apoapsis: %.2f km\n', h_apoapsis_km);
fprintf('Orbital Periapsis: %.2f km\n', h_periapsis_km);
fprintf('The resulting semi-major axis is %.2f km.\n', a_km);
fprintf('The orbital period is %.2f hours (%.2f minutes).\n', T_hours, T_minutes);
```

XI. Resources used during performance

Table No. 22.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

Table No. 22.3

Sr. No.	Types of orbital height(Km)	Orbital height(Km)	Resulting semi-major axis (Km)	Orbital period(hours)
1	Orbital height at Apoapsis (Km)			
2	Orbital height at Periapsis (Km)			

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and Recommendation

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XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Evaluate the impact of eclipse duration on satellite solar panel design.
2. Assess the importance of battery capacity during eclipse periods.
3. Propose a method to minimize power loss during eclipse using hybrid energy management

[Space for Answers] (If required attach separate page)

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XVIII. References/Suggestions for further reading

Sr.No.	Link / Portal / V Lab	Description
1	https://in.mathworks.com/help/aerotbx/ug/matlabshared.satellitescenario.satellite.eclipse.html	Eclipse analysis
2	https://www.rcet.org.in/uploads/academics/regulation2021/rohini/24240497485.pdf	Satellite in East and west
3	https://en.wikipedia.org/wiki/Equinox	quinox

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60%**
1	Practical Implementation with Specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
	Product Related: 10 Marks	**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely Submission	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 23: Measurement of the carrier-to-noise ratio (C/N) of the established satellite link

I. Practical Significance

Practical intended to help students to develop skills for measuring C/N which transforms abstract communication theory into a measurable quantity, providing students with a practical framework for analyzing, optimizing, and troubleshooting a complete communication system.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: 'Maintain optical and satellite communication systems.'

III. Course Level Learning Outcome

Maintain Satellite earth segment.

IV. Laboratory Learning Outcome

LLO 23.1 Measure carrier-to-noise ratio (C/N) of established satellite link.

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

In telecommunications, the **carrier-to-noise ratio**, often written **CNR** or ***C/N***, is the signal-to-noise ratio (SNR) of a modulated signal. The term is used to distinguish the CNR of the radio frequency passband signal from the SNR of an analog base band message signal after demodulation. For example, with FM radio, the strength of the 100 MHz carrier wave with modulations would be considered for CNR, whereas the audio frequency analogue message signal would be for SNR; in each case, compared to the apparent noise. If this distinction is not necessary, the term SNR is often used instead of CNR, with the same definition. High *C/N* ratios provide good quality of reception, for example low bit_error_rate (BER) of a digital message signal, or high SNR of an analog message signal. The carrier-to-noise ratio is defined as the ratio of the received modulated carrier signal power *C* to the received noise power *N* after the receiver filters. When both carrier and noise are measured across the same impedance, this ratio can equivalently given as CNR= $(V_C/V_N)^2$

Where,

V_C and V_N are the root mean square (RMS) voltage levels of the carrier signal and noise respectively.

C/*N* ratios are often specified in decibels (dB):

$$\mathrm{CNR_{dB}} = 10\log_{10}\left(\frac{C}{N}\right) = C_{dBm} - N_{dBm}$$

or in term of voltage

$$\mathrm{CNR_{dB}} = 10\log_{10}\left(\frac{V_C}{V_N}\right)^2 = 20\log_{10}\left(\frac{V_C}{V_N}\right).$$

VII. Block diagram

A. Suggestive Block Diagram

NA

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 23.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Uplink Transmitter	2450-2468 MHz up-linking selectable frequencies, Wide band RF amplifier, FM Modulation of Audio and Video, Detachable Dish Antenna.	01
2	Downlink Receiver	Receives and demodulate signals simultaneously. Built in speaker for audio and video output, Detachable Dish Antenna.	01
3	Connecting cables	BNC - BNC connector for CRO/DSO	01
4	CRO	60 MHz/100 MHz/200 MHz bandwidth,500MS/s to 1 GS/s real -time sample rate,50 GS/s sample rate for repetitive waveforms, High resolution color LCD display	01
5	Function generator	Frequency 5Mhz	01
6	Spectrum Analyzer	9 KHz-7GHz	01

IX. Precautions to be Followed

1. Check all connections before switching ON the power supply.
2. Ensure frequency matching between transmitter and receiver.
3. Avoid high transmission power to prevent equipment damage.
4. Keep coaxial cables properly terminated to avoid reflections.
5. Handle RF modules with care to prevent static damage.

X. Procedure

1. Connect the Satellite Uplink Transmitter to AC Mains.
2. Switch 'ON' the transmitter by Mains switch and frequency display will light up.
3. Transmitting frequency can be selected by Frequency Select switch. The frequency can be changed from 2450-2468 MHz.
4. Connect Antenna to Uplink Transmitter with BNC -BNC lead.
5. Place Downlink Receiver at a convenient distance of 5-7 meter.
6. Place a Satellite Transponder between Transmitter and Receiver at a convenient distance; preferably all three can be placed in equidistant triangle of distance 5-7M.
7. Connect the Satellite Transponder to the AC Mains and switch it 'ON' by mains switch.
8. Connect the Downlink Receiver to the AC Mains and switch it 'ON' by mains switch.
9. The Downlink Receiver Frequency can be changed from 2414-2432 MHz.
10. Attach Antenna to the Downlink Receiver with BNC - BNC lead.
11. Align both the Transmitter and Receiver Antenna's in line such that both are in parallel alignment.
12. Adjust transmitter uplink frequency to 2468 MHz and transponder receiver frequency also, to 2468 MHz.
13. Keep Downlink Frequency of Transponder to 2414 MHz.
14. Keep the Downlink Receiver 00 2414 MHz.
15. Disable Tone mode for transmission. In this case only carrier will get transmitted from Uplink Transmitter

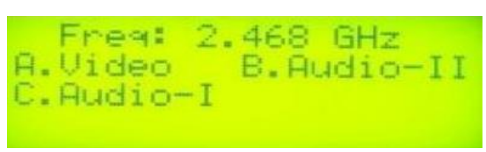

Fig 23.1: Display View

16.Observe the Carrier waveform on Spectrum Analyzer and measure its power.

17.Now switch "off" the Transmitter and measure the power again.

18.Now subtract amplitude of noise from previously received signal (Carrier noise), you can get actual Carrier signal amplitude.

Fig.23.2: Transmitter and Spectrum Analyzer

19.Calculate Carrier to noise ratio from the formula.

20.Carrier +Noise Power (in dB) = C1

21.Noise Power (in dB) = N

22.Carrier to noise ratio (In dB) C = C1 – N

Calculation:

23.To calculate the carrier to noise ratio of established satellite link.

24.Observe the Carrier waveform on Spectrum Analyzer and measure its power. It is power of Carrier and Noise without any input, Cdbm = -35.3dBm

25.Now switch "OFF" the Uplink Transmitter and measure the power again. (It is power of Noise,. Ndbm. = -99.8 dBm

26.The display gives the reading directly in terms of dB.

27.Now to calculate Carrier to noise ratio proceed as follows

Calculation:

28.CNR Is a pre-detection measurement performed on RF signals. It Is the ratio of raw carrier power to raw noise power. Technically speaking, when measuring CNR against real thermal noise, one actually Is measuring (C+N) / N. CNR is generally accepted to be pre-detection measurement that is, one made at RF.

29. Refer the figure 23.2 as example only

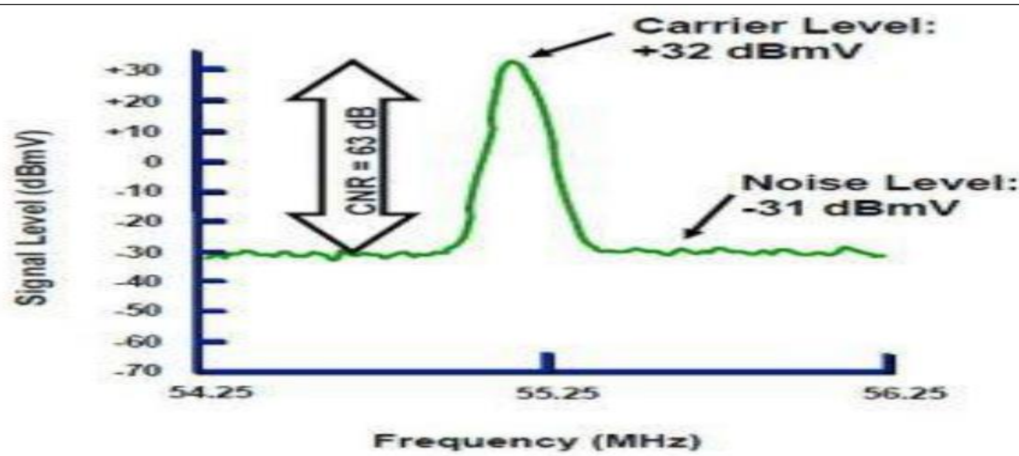

Fig.23.2: Frequency Vs. Signal Level Graph

XI. Resources used

Table No. 23.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

N.A.

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and Recommendation

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XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. List the primary components of a satellite link budget that affect the C/N ratio.
2. Summarize the key differences between carrier-to-noise ratio (C/N) and signal-to-noise ratio (S/N) in the context of digital satellite systems.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested references for further reading

Sr.No.	Link / Portal / V Lab	Description
1	https://scientechworld.com/product/satellite-communication/	Satellite Communication
2	https://en.wikipedia.org/wiki/Carrier-to-noise_ratio	Carrier to noise ratio
3	https://in.mathworks.com/help/satcom/ref/satellitecnr.html	Satellite CNR

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
	Product Related: 10 Marks	**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 24: Establish a direct communication link between two PCs using RS-232 serial ports

I. Practical Significance

This practical is intended to learn a communication method that establish a direct communication link between two PCs using RS-232. The practical will enable the student to use RS-232 cable to assess the speed of transfer of data

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: Maintain optical and satellite communication systems.

III. Course Level Learning Outcome

Maintain Satellite earth segment.

IV. Laboratory Learning Outcome

LLO 24.1 Use RS 232 ports to set up a PC-PC satellite communication link.

V. Relevant Affective domain related Outcomes

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

RS-232 is a communication method to directly connect two DTEs (Data Terminal Equipment) like computer terminal, printer, etc. using RS-232 serial cable RS-232 cable to connect the teleprinters directly to one another without the modems. It is also used to serially connect a computer to a printer, since both are DTE, and is known as a Printer Cable. The RS-232 (Recommended Standard) is asymmetric as to the definitions of the two ends of the communications link, assuming that one end is a DTE and the other is a DCE (Data Communication Equipment), e.g. a modem. In RS-232 connection transmit and receive lines are cross-linked. Depending on the purpose, sometimes also one or more handshake lines are cross-linked. A serial port complying with the RS-232 standard was once a standard feature of many types of computers. Personal computers used them for connections not only to modems, but also to printers, computer mice, data storage, uninterruptible power supplies, and other peripheral devices.

VII. Circuit diagram /Block diagram /Flowchart

A. Suggestive Block Diagram

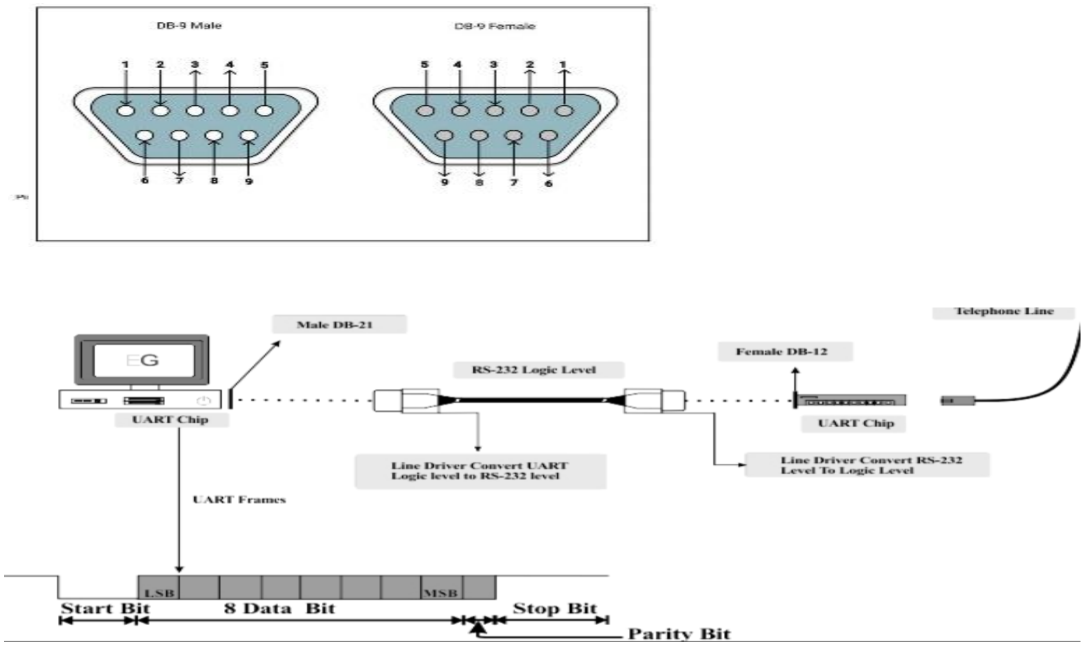

Fig. 24.1: Diagram Explaining Serial Data Exchange Between PC and Device Using RS232

Table No. 24.1

Pin No.	Pin Name	Full form/ acronym	Function
1	DCD	Data carrier detect	Output signal from the modem (DTE) and input to the PC (DTE).
2	RxD	Receive data	Receive data serially
3	TxD	Transmit data	Transmit data serially
4	DTR\	Data terminal ready	Active low signal used to inform the modem that the computer is working proper
5	GND	Ground	Ground
6	DSR\	Data set ready	Active low signal and activated if there is proper communication between modem and telephone

Pin No.	Pin Name	Full form/ acronym	Function
7	RTS\	Request to send	Active low output from the Data Terminal Equipment (DTE)/computer to the modem
8	CTS\	Clear to send	Input signal to the DTE is used by the DTE to start transmission.
9	RI	Ring indicator	Output from the modem (DCE) and an input to a PC (DTE)

Note: DTE = Data Terminal Equipment = PC

DCE = Data Communication Equipment = Modem

B. Actual Block Diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 24.2

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Personal Computers (For additional Terminals, Windows Operating system Installed	Intel P-IV, 2Gbyte, DDR2, 500Gbyte HDD, keyboard onwards Installed with Windows 7 wards and internet connectivity	02
2	Connecting cable (Null Modem)	RS-232 with 9 -pin	01

IX. Precautions to be Followed

1. Make sure serial ports are enabled in CMOS setup.
2. Because of cross connection, the DTR output line can be used for simple flow control.
3. Incoming data is allowed when the output is set, and blocked if the output is not set.

X. Suggested Procedure

Setting up direct cable connection in Windows:

Step-by-step instructions for setting up direct cable connection in Windows 95 and Windows 98.

1. The Null modem cable is required for these steps to work properly.
2. Make sure serial ports are enabled in CMOS setup.

3. For Direct Cable Connection to work, First install the software used for the communication.

To install Direct Cable Connection,

- Click Start, Settings ► Control Panel, and double-click on Add Remove Programs. Then click ►the Windows Setup tab, double- click the Communications icon,
- check the Direct Cable Connection box. If this box is already checked, it is recommended that uncheck the box and then place the check back in the box to ensure that the complete program is installed into the computer.
- Once completely installed, reboot the computer.

4. Once back in Windows click Start ► Settings ►Control Panel, double-click on Network, and then ►click File and Print Sharing.

- In File and Print Sharing, check the box next to "I want to be able e to give others access to my files" also while in this window enable Print sharing.
- Click Ok,
- If Windows attempts to locate the drivers but is not able to, do this two times and reboot the computer again to ensure these Settings are updated.

5. Once back into Windows, ►double-click My Computer, right-click on the drive you want to share your information on (e .g., C: drive) and click Properties. Once in Properties click the Sharing tab, click ►the option for Shared As, enter a Share Name, click ► the Apply, and then reboot the computer.
6. Once the above steps have been completed, then decide which computer will be host and which computer will be guest. Once this is determined, **first set up** the host computer by clicking on Start► Programs► Accessories ►Communications► click on Direct Cable Connection. In Direct Cable Connection choose the option for ►host, ►select the port, if so desired ► specify a password, and then click► Next. Computer should then wait for the guest computer to send signal to the host computer.
7. Once the above steps have been completed, on the second computer follow the above steps 1-5 again. Once done, click ► Start, ►Programs, ►Accessories, Communications, ► click on ► Direct Cable Connection. In the Direct Cable Connection box choose ►Guest, choose the
8. Once the Host and the Guest have been set up you should establish a connection; Now user can browse the hard drive that was shared through Network Neighbourhood.

XI. Resources used

Table No. 24.3

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.

2.

3.

4.

5.

XIII. Observation Table

N.A.

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and Recommendation

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XVII. Practical Related Questions:

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Share file from first computer to second computer
2. Can user share files/folder from second to first computer?

3. Can user share printer from second computer?
4. Compare the speed of communication in LAN and in RS-232 communication

[Space for Answers] (If required attach separate page)

XVIII. Suggested references for further reading

Sr.No.	Link / Portal / V Lab	Description
1	https://scientechworld.com/product/satellite-communication/	Satellite Communication
2	https://imdpune.gov.in/training/satellite/satellite_communication_for_training.pdf)	Satellite Communication

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 25: Find rain attenuation through coding

I. Practical Significance

Rain attenuation is a critical factor affecting the availability and quality of satellite links, especially for Ku-band, Ka-band, and above. These practical enables students to model rain attenuation using ITU-R recommendations and simulate its impact using coding. It helps students to understand fade margin requirements and link reliability under varying rain conditions.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: ‘Maintain optical and satellite communication systems.’

III. Course Level Learning Outcome

After this practical, students should be able to: ‘Maintain Satellite earth segment.’

IV. Laboratory Learning Outcome

LLO 25.1 Estimate rain attenuation through simulation.

V. Relevant Affective Domain related outcome(s)

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for installation and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

Rain attenuation the operation of the satellite, if it encounters a rainy area, the radio waves emitted by the satellite will not only be partially absorbed by the rain, but the rain will also scatter the radio waves to a certain extent. Under the joint intervention of the two effects, the satellite radio waves will be attenuated. In addition, the scattering effect may also cause some interference to the radio, resulting in a depolarization effect. These phenomena can be called rain attenuation. Rain attenuation is a common, yet often misunderstood weather phenomenon that interrupts wireless communication signals in the presence of rain. It occurs with all types of satellite systems e.g. Geostationary Earth Orbit (GEO), Medium Earth Orbit, Low Earth Orbit and Global Positioning System. Due to the higher operating frequency for a Ku or Ka band SATCOM system, the signal’s wavelength is generally shorter as compared to the C band. Therefore, it is more susceptible to signal degradation as the wavelength approaches the size of a typical raindrop. The two major causes of rain fade are: Absorption – water molecules in a rain droplet absorb portions or all of the signal energy of the passing radio wave. With shorter wavelength, there will be more interaction between the radio wave and water molecules, leading to increased energy losses. Scattering-this is a physical process, caused by either refraction or diffraction, in which the direction of the radio wave deviates from its original path as it passes through a medium containing raindrop. This disperses the energy of the signal from its initial travel direction. The accumulation of these different reactions ultimately leads to a decrease in the level of received signal, thus resulting in rain attenuation.

VII. Block diagram/Circuit diagram/Flowchart

A. Suggestive diagram

NA

B. Actual diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 25.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online MATLAB	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus software)	01
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX. Precautions to be followed

1. Ensure proper earthing to the computer system
2. Input each constant in given program carefully for proper output.
3. Save and close all open programs and figures properly after completing the practical

X. Procedure

1. Double click on matlab icon to Run matlab or open online matlab from website https://matlab.mathworks.com/
2. Type the given code in editor window of MATLAB software.
3. Example inputs are given in the program itself.
4. Observe the output of program in command window of MATLAB software

%MATLAB Code for Rain attenuation

```
function attenuation_dB = calculateRainAttenuation(frequency_GHz, rainRate_mmph, pathLength_km, elevationAngle_deg, polarizationTilt_deg)
 % Calculate rain attenuation using ITU-R P.838-3 model without toolboxes.
% frequency_GHz: Signal frequency in GHz.
% rainRate_mmph: Rainfall rate in mm/h.
% pathLength_km: Length of the propagation path in km.
% elevationAngle_deg: Elevation angle of the path in degrees.
% polarizationTilt_deg: Polarization tilt angle in degrees (0 for horizontal, 90 for vertical).
% Constants for ITU-R P.838-3 (k and alpha values are frequency dependent)
% These values are typically obtained from ITU-R P.838-3 Table No.s or formulas.
% For simplicity, we'll use a simplified approximation for k and alpha.
% In a full implementation, you would use frequency-dependent formulas or look-up Table No.s.
        % Example k and alpha values for a specific frequency range (e.g., 10-20 GHz)
% These are illustrative and should be replaced with actual ITU values for accuracy.
if frequency_GHz >= 1 && frequency_GHz <= 100
 k_h = 0.0000387 * (frequency_GHz)^2.0; % Example horizontal k
 k_v = 0.0000357 * (frequency_GHz)^1.9; % Example vertical k
 alpha_h = 0.81 * (frequency_GHz)^0.1; % Example horizontal alpha
 alpha_v = 0.78 * (frequency_GHz)^0.1; % Example vertical alpha
else
 % Handle frequencies outside the example range or use more general formulas
 error('Frequency out of supported range for this simplified example.');
end
% Calculate effective k and alpha for given polarization tilt and elevation angle
% These formulas account for the combined effect of horizontal and vertical polarization
% and the projection of the path onto the horizontal plane.
        % Convert angles to radians
theta_rad = deg2rad(elevationAngle_deg);
tau_rad = deg2rad(polarizationTilt_deg);
% Calculate k and alpha for the specific polarization and elevation
k = (k_h + k_v + (k_h - k_v) * cos(2 * tau_rad) * cos(theta_rad)^2) / 2;
```

```
    alpha = (k_h * alpha_h + k_v * alpha_v + (k_h * alpha_h - k_v * alpha_v) * cos(2 * tau_rad)
*
    cos(theta_rad)^2) / (2 * k);
    % Calculate specific attenuation (dB/km)
    specificAttenuation_dB_per_km = k * (rainRate_mmph)^alpha;
    % Calculate total rain attenuation (dB)
    attenuation_dB = specificAttenuation_dB_per_km * pathLength_km;
end
    % Example usage:
    frequency = 20; % GHz
    rainRate = 50; % mm/h
    pathLength = 10; % km
    elevationAngle = 30; % degrees
    polarizationTilt = 0; % degrees (horizontal)
    rainAttenuation = calculateRainAttenuation(frequency, rainRate, pathLength, elevationAngle,
    polarizationTilt);
    fprintf('Rain Attenuation: %.2f dB\n', rainAttenuation);
```

```
function attenuation_dB = calculateRainAttenuation(frequency_GHz, rainRate_mmph, pathLength_km, elevationAngle_deg, polarizationTilt_deg)
    % Calculate rain attenuation using ITU-R P.838-3 model without toolboxes.
    % frequency_GHz: Signal frequency in GHz.
    % rainRate_mmph: Rainfall rate in mm/h.
    % pathLength_km: Length of the propagation path in km.
    % elevationAngle_deg: Elevation angle of the path in degrees.
    % polarizationTilt_deg: Polarization tilt angle in degrees (0 for horizontal, 90 for vertical).

    % Constants for ITU-R P.838-3 (k and alpha values are frequency dependent)
    % These values are typically obtained from ITU-R P.838-3 tables or formulas.
    % For simplicity, we'll use a simplified approximation for k and alpha.
    % In a full implementation, you would use frequency-dependent formulas or look-up tables.

    % Example k and alpha values for a specific frequency range (e.g., 10-20 GHz)
    % These are illustrative and should be replaced with actual ITU values for accuracy.
    if frequency_GHz >= 1 && frequency_GHz <= 100
        k_h = 0.0000387 * (frequency_GHz)^2.0; % Example horizontal k
        k_v = 0.0000357 * (frequency_GHz)^1.9; % Example vertical k
        alpha_h = 0.81 * (frequency_GHz)^0.1; % Example horizontal alpha
        alpha_v = 0.78 * (frequency_GHz)^0.1; % Example vertical alpha
    else
        % Handle frequencies outside the example range or use more general formulas
        error('Frequency out of supported range for this simplified example.');
    end

    % Calculate effective k and alpha for given polarization tilt and elevation angle
    % These formulas account for the combined effect of horizontal and vertical polarization
    % and the projection of the path onto the horizontal plane.

    % Convert angles to radians
    theta_rad = deg2rad(elevationAngle_deg);
    tau_rad = deg2rad(polarizationTilt_deg);

    % Calculate k and alpha for the specific polarization and elevation
    k = (k_h + k_v + (k_h - k_v) * cos(2 * tau_rad) * cos(theta_rad)^2) / 2;
    alpha = (k_h * alpha_h + k_v * alpha_v + (k_h * alpha_h - k_v * alpha_v) * cos(2 * tau_rad) * cos(theta_rad)^2) / (2 * k);

    % Calculate specific attenuation (dB/km)
    specificAttenuation_dB_per_km = k * (rainRate_mmph)^alpha;

    % Calculate total rain attenuation (dB)
    attenuation_dB = specificAttenuation_dB_per_km * pathLength_km;
end

% Example usage:
frequency = 20; % GHz
rainRate = 50; % mm/h
pathLength = 10; % km
elevationAngle = 30; % degrees
polarizationTilt = 0; % degrees (horizontal)

rainAttenuation = calculateRainAttenuation(frequency, rainRate, pathLength, elevationAngle, polarizationTilt);
fprintf('Rain Attenuation: %.2f dB\n', rainAttenuation);
```

X. Resources used

Table No. 25.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1
2.
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4.
5.

XIII. Observation Table

N.A.

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more suchquestions so as to ensure the achievement of identified CO.

1. Mention two techniques used to overcome rain fade.

2. List the frequency bands most affected by rain attenuation.
3. Explain why rain attenuation increases with both frequency and rain rate.

[Space for Answers] (If required attach separate page)

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XVIII. Suggested references for further reading

Sr. No.	Author	Title	Publisher with ISBN Number
1	Dennis Roddy, 5th Edition.	Satellite Communications	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781265372545

Sr.No.	Link / Portal / V Lab	Description
1	https://in.mathworks.com/help/aerotbx/ug/matlabshared.satellitescenario.satellite.eclipse.html	Satellite Communication
2	https://in.mathworks.com/help/aerotbx/ug/matlabshared.satellitescenario.satellite.eclipse.html	Carrier to noise ratio
3	https://antesky.com/rain-attenuation-and-solutions-to-decrease/	Satellite CNR

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.26: Simulation of satellite link budget through coding.

I Practical Significance

This practical helps students understand how to estimate the power performance of a satellite communication link using link budget analysis. By simulating the link through coding (MATLAB), students can visualize how factors such as transmit power, antenna gain, path loss, and noise temperature affect the overall system performance. It bridges theoretical knowledge with real-world system design used in industry

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: 'Maintain optical and satellite communication systems.

III. Course Level Learning Outcome

Maintain Satellite earth segment.

IV Laboratory Learning Outcome

LLO 26.1 Investigate satellite link budget.

V Relevant Affective Domain related outcome(s)

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

VI . Relevant Theoretical Background

A satellite link budget is an accounting of all gains and losses from the transmitter to the receiver.

It ensures that the received power is strong enough to maintain required quality (C/N ratio). Link budget analysis is a prerequisite to design a satellite communication system, as it assists in quantifying the link performance. It involves accounting for all the power gains and losses, adding the gains and subtracting the losses that a radio frequency (RF) signal experiences within a satellite communication system. This is a simple link budget equation, to help design a proper link. Received Power (dBm) = transmitted power (dBm) + gains (dB) – losses (dB*)* Link budget calculations use power budget analysis to establish an approximate level of performance without resorting to link-level simulation. Link budget specifies the system parameters necessary to ensure that the information is received intelligibly with an adequate signal-to-noise (SNR) ratio.

There are multiple factors that influence the satellite communication link design, but you can broadly classify the significant factors into these three groups.

- Transmitter and receiver system — This includes effective isotropic radiated power (EIRP) at Tx, feeder loss on both Tx and Rx, gain over noise temperature (G/T) at Rx, high power amplifier (HPA) power backoff at the Tx, and antenna pointing loss.
- In free space — This includes polarization loss experienced as a Tx-Rx pair, free space path loss (FSPL), antenna noise temperature, rain fade, and other atmospheric attenuations.
- Satellite — This includes losses due to adjacent channel interference (ACI), satellite carrier spacing, satellite parameters such as orbital elements, and carrier parameters such as modulation technique used.

Following figure shows the significant factors that influence a link design. The losses are indicated in red, gains are indicated in green, and the satellite specific information parameters are shown in yellow.

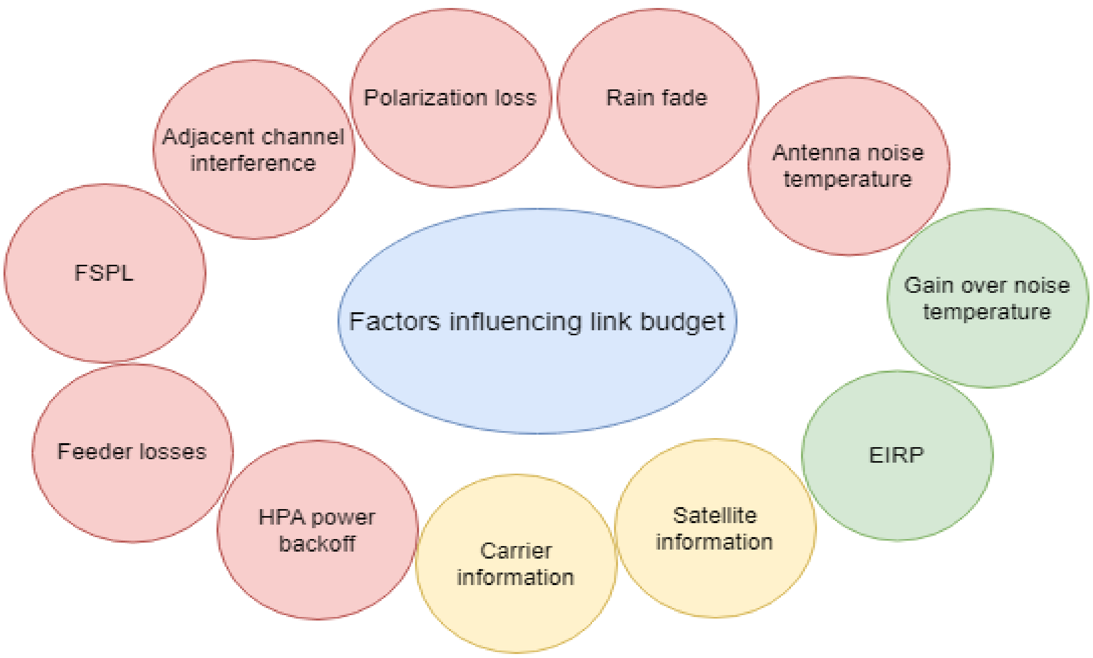

Fig. 26.1: Factors Affecting A Link Design

(Courtesy:https://in.mathworks.com/help/satcom/gs/satellite-link-budget.html)

- **EIRP**

EIRP is the amount of power that would have to be radiated by an isotropic antenna to produce the equivalent power from the actual antenna in the direction with highest antenna gain.

EIRP is the total radiated power (P_t) from a transmitter antenna times the antenna gain (G_t).

- **Feeder Loss**

This loss occurs in several components between the antenna and the receiver or the transmitter device, such as couplers, filters, and waveguides. Feeder loss is due to the resistance and imperfections in the transmission line material, which causes part of the signal energy to be dissipated as heat.

- **FSPL**

FSPL refers to the spread of the signal through space, which results in loss of the strength of the signal. Calculate FSPL using Friis transmission equation, according to which the loss is proportional to the square of the distance and the square of the frequency.

- **Polarization Loss**

Polarization mismatch between the transmitter and the receiver antennas leads to electromagnetic (EM) power loss. EM waves are characterized by electric and magnetic fields. A basic property of plane EM waves in free-space is that the directions of the electric and magnetic field vectors are orthogonal to their direction of propagation. EM wave polarization refers to the orientation of the electric field vector.

- **Antenna Pointing Loss**

Correct alignment between an Earth station and satellite antennas provides maximum gain. Misalignment can occur either at the satellite or at the Earth station. Satellite-based misalignment must be considered during the design of the satellite, but the Earth station-based misalignment is the antenna pointing loss, and it is typically less than 1 dB. Calculating antenna misalignment losses (AML) requires statistical data, so these values are an approximation based on real data observed in several ground stations.

- **Antenna Noise Temperature**

Antenna noise temperature represents the noise level an antenna produces in a given environment. This measurement is not the physical temperature of the antenna. The total noise temperature of the antenna depends mainly on sky noise (T_{sky}) and ground noise (T_{gnd}).

- **G/T**

Antenna gain over noise temperature is a figure of merit to characterize the performance of an antenna, where G is the antenna gain, in decibels, at the receiver frequency, and T is the equivalent noise temperature of the receiving system in kelvin. T, referred to as system noise temperature, combines both antenna noise temperature and low noise amplifier (LNA) temperature.

- **HPA Power Backoff**

When you feed HPA a multiple carrier signal as input, it amplifies the signal and, in the process, generates unwanted intermodulation (IM) products. When the amplifier operates in the linear region, these IM products do not interfere with the main signals. However, as the amplifier approaches the saturation point and enters the non-linear region of operation, the interference increases and these IM products start to interfere with the main signal, lowering the output signal quality.

- **Rain Fade**

Rainfall attenuates radio waves by scattering and absorbing energy from the wave. Rain attenuation increases with increasing frequency and is worse at Ku-band compared to C-band. Studies have shown that the rain attenuation for horizontal polarization is considerably greater than for vertical polarization. The link margin must compensate for a rain fade.

- **Satellite Information**

This includes information related to satellite aspects such as orbital position, received *G*/*T* obtained from satellite operators or *G*/*T* contour maps, and saturation flux density. This information helps effectively calculate a satellite link budget.

- **Carrier Information**

This includes information such as user data rate in megabits per second (Mbps), type of modulation technique used, forward error correction (FEC) code rate, roll off factor, and bit error rate (BER). This information helps to analyze the link budget for a space-to-ground link and the inverse.

- **Satellite Carrier Spacing**

The level of ACI is a function of several parameters: orbital separation between the desired and the interfering satellites, antenna side lobe performance of the interfering uplink Earth station, antenna side lobe performance of the receiving Earth station, and spectral power density of the carriers.

VII. Circuit diagram/Block diagram/Flowchart

A) Suggestive diagram

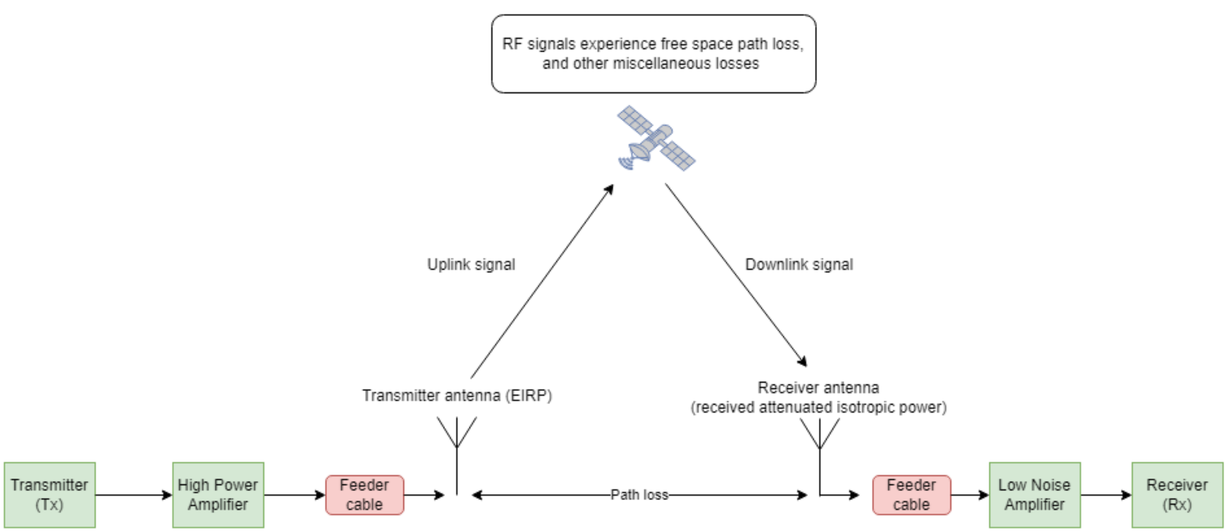

Fig. 26.2: Satellite Communication

(courtesy: https://in.mathworks.com/help/satcom/gs/satellite-link-budget.html)

B) Actual diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 26.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online matlab	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus software)	01
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX. Precautions to be followed

1. Use consistent units (GHz, km, W, Hz) in all calculations.
2. Avoid mixing **dBW** and **dBm** without conversion (1 dBW = 30 dBm).
3. Enter correct system parameters before running the simulation.
4. Save your code and outputs after each run.
5. Verify formulas and constants (e.g., 92.45) are correct for km–GHz units.
6. Interpret results physically; unrealistic values often mean unit errors.

X Procedure

1. Open MATLAB or Python software.
2. Define all required constants and link parameters (power, gain, frequency, distance, losses).
3. Compute EIRP using transmit power and antenna gain.
4. Calculate FSPL for uplink and downlink frequencies.
5. Compute received power at satellite and ground station.
6. Determine noise power using system temperature and bandwidth.
7. Calculate C/N, Eb/N0, and Link Margin.
8. Change parameters (e.g., Tx power, frequency, rain loss) to observe effects.

MATLAB Code for budget link calculation:

```
fprintf('.........The uplink parameters.........\n\n');
C=3*10^8;
PI=3.14;
K=1.23*10^-23;
d=42164000;
Kdb=mag2db(K);
Ptu=input('Enter the transmit power in watt ='); %transmit power
Ptudb=pow2db(Ptu);
Wvtudb=input('Enter the waveguides loss in db =');%waveguides losses
Gtudb=input('Enter the transmit antenna gain in db =');
EIRPudb=Ptudb+Gtudb-Wvtudb;
Fu=input('Enter the uplink frequency in GHz =');%uplink frequencies
Fu=Fu*10^9;
lamdau=C/Fu;%wavelength
FSLu=((4*PI*d)/lamdau)^2;%free space calculation
FSLudb=mag2db(FSLu);
Ludb=input('Enter the other losses present in the free space in db =');%loss %present in space except the free spaceloss
Lutdb=FSLudb+Ludb;%total loss in atmosphere
Gru=input('Enter the receiver antenna gain =');%for this time the receiver %antenna gain is % satellite antenna gain
Grudb=mag2db(Gru);
Wvrudb=input('Enter the received waveguide loss in db =');%received %waveguides loss in db
Prudb=EIRPudb+Grudb-Lutdb-Wvrudb;%received power or simply is known as %carrier power
Tsysu=input('Enter the system noise temperature in Kelvin =');
Tsysudb=mag2db(Tsysu);
GTRudb=Grudb-Wvrudb-Tsysudb;%gain to temperature ratio for satellite antenna
Nubw=input('Enter the noise bandwidth in Hz =');
Nubwdb=mag2db(Nubw);
Noudb=Kdb+Tsysu+Nubwdb;
```

```
CNRudb=Prudb-Noudb;%C/N ratio in db
fprintf('\n');
% link budget analysis for downlink
fprintf('.........The downlink parameters.........\n\n');
Ptd=input('Enter the transmit power in watt ='); %transmit power
Ptddb=pow2db(Ptd);
Wvtddb=input('Enter the waveguides loss in db =');%waveguides losses
Gtddb=input('Enter the transmit antenna gain in db =');
EIRPddb=Ptddb+Gtddb-Wvtddb;
Fd=input('enter the downlink frequency in GHz =');%uplink frequencies
Fd=Fd*10^9;
lamdad=C/Fd;%wavelength
FSLd=((4*PI*d)/lamdad)^2;%free space loss calculation
FSLddb=mag2db(FSLd);
Lddb=input('Enter the other losses present in the free space in db =');%loss %present in space
% except the free spaceloss
Ldtdb=FSLddb+Lddb;%total loss in atmosphere
Grd=input('Enter the received antenna gain =');% the receiver antenna gain
Grddb=mag2db(Grd);
Wvrddb=input('Enter the received waveguide loss in db =');%received %waveguides loss in
db
Prddb=EIRPddb+Grddb-Ldtdb-Wvrddb;%received power also known as %carrier power
Tsysd=input('Enter the system noise temperature in kelvin =');
Tsysddb=mag2db(Tsysd);
GTRddb=Grddb-Wvrddb-Tsysddb;%gain to temperature ratio
Ndbw=input('Enter the noise bandwidth in Hz =');
Ndbwdb=mag2db(Ndbw);
Noddb=Kdb+Tsysd+Ndbwdb;
CNRddb=Prddb-Noddb;%C/N ratio in db
CNRt=((db2mag(CNRudb))^-1)+(db2mag(CNRddb)^-1);%total C/T ratio in db for %Uplink
and
% downlink
CNRtdb=mag2db(CNRt);
```

```
fprintf('\n\n');
fprintf('........the Uplink calculation........\n\n');
fprintf('Transmit power in db is = %f\n',Ptudb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvtudb);
fprintf('EIRP in db is = %f\n',EIRPudb);
fprintf('Free space loss is in db = %f\n',FSLudb);
fprintf('The receiver antenna gain in db is = %f\n',Grudb);
fprintf('The received power in db is = %f\n',Prudb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvrudb);
fprintf('The system noise temperature in db is = %f\n',Tsysudb);
fprintf('The received antenna gain to system noise temperature ratio in db is = %f\n',GTRudb);
fprintf('The noise power bandwidth in db is = %f\n',Nubwdb);
fprintf('The noise power in the given bandwidth in db is = %f\n',Noudb);
fprintf('The Carrier to noise power ratio in db is = %f',CNRudb);
fprintf('\n\n');
fprintf('........the downlink calculation........\n\n');
fprintf('Transmit power in db is = %f\n',Ptddb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvtddb);
fprintf('EIRP in db is = %f\n',EIRPddb);
fprintf('Free space loss is in db = %f\n',FSLddb);
fprintf('The receiver antenna gain in db is = %f\n',Grddb);
fprintf('The received power in db is = %f\n',Prddb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvrddb);
fprintf('The system noise temperature is db is = %f\n',Tsysddb);
fprintf('The received antenna gain to systme noise temperature ratio in db is = %f\n',GTRddb);
fprintf('The noise power bandwidth in db is = %f\n',Ndbwdb);
fprintf('The noise power in the given bandwidth in db is = %f\n',Noddb);
fprintf('The Carrier to noise power ratio in db is = %f\n',CNRddb);
fprintf('\n\n');
fprintf('.......for uplink and downlink.......\n\n');
fprintf('The combined carrier to noise power ratio in db is=%f',CNRtdb);
fprintf('\n\n');
```

Enter following parameters after execution of code

.........The uplink parameters.........

Enter the transmit power in watt =85

Enter the waveguides loss in db =2

Enter the transmit antenna gain in db =51

Enter the uplink frequency in GHz =6.1

Enter the other losses present in the free space in db =1

Enter the receiver antenna gain =23

Enter the received waveguide loss in db =0.5

Enter the system noise temperature in Kelvin =450

Enter the noise bandwidth in MHz =2.5

.........The downlink parameters.........

Enter the transmit power in watt =10

Enter the waveguides loss in db =1.2

Enter the transmit antenna gain in db =30

enter the downlink frequency in GHz =3.6

Enter the other losses present in the free space in db =2

Enter the received antenna gain =41

Enter the received waveguide loss in db =1

Enter the system noise temperature in kelvin =140

Enter the noise bandwidth in MHz =2.5

Expected result after entering above parameters

........the Uplink calculation........

Transmit power in db is = 19.294189

Wave guide loss for uplink in db is = 2.000000

EIRP in db is = 68.294189

Free space loss is in db = 401.285601

The receiver antenna gain in db is = 27.234557

The received power in db is = -307.256855

Wave guide loss for uplink in db is = 0.500000

The system noise temperature in db is = 53.064250

The received antenna gain to system noise temperature ratio in db is = -26.329694

The noise power bandwidth in db is = 127.958800

The noise power in the given bandwidth in db is = 119.756902

The Carrier to noise power ratio in db is = -427.013757

........the downlink calculation........

Transmit power in db is = 10.000000

Wave guide loss for uplink in db is = 1.200000

EIRP in db is = 38.800000

Free space loss is in db = 392.124508

The receiver antenna gain in db is = 32.255677

The received power in db is = -324.068830

Wave guide loss for uplink in db is = 1.000000

The system noise temperature is db is = 42.922561

The received antenna gain to systme noise temperature ratio in db is = -11.666884

The noise power bandwidth in db is = 127.958800

The noise power in the given bandwidth in db is = -190.243098

The Carrier to noise power ratio in db is = -133.825733

.......for uplink and downlink.......

The combined carrier to noise power ratio in db is=427.013757

```
fprintf('.........The uplink parameters.........\n\n');
C=3*10^8;
PI=3.14;
K=1.23*10^-23;
d=42164000;
Kdb=mag2db(K);
Ptu=input('Enter the transmit power in watt ='); %transmit power
Ptudb=pow2db(Ptu);
Wvtudb=input('Enter the waveguides loss in db =');%waveguides losses
Gtudb=input('Enter the transmit antenna gain in db =');
EIRPudb=Ptudb+Gtudb-Wvtudb;
Fu=input('Enter the uplink frequency in GHz =');%uplink frequencies
Fu=Fu*10^9;
lamdau=C/Fu;%wavelength
FSLu=((4*PI*d)/lamdau)^2;%free space calculation
FSLudb=mag2db(FSLu);
Ludb=input('Enter the other losses present in the free space in db =');%loss %present in space except the free spaceloss
Lutdb=FSLudb+Ludb;%total loss in atmosphere
Gru=input('Enter the receiver antenna gain =');%for this time the receiver %antenna gain is
% satellite antenna gain
Grudb=mag2db(Gru);
Wvrudb=input('Enter the received waveguide loss in db =');%received %waveguides loss in db
Prudb=EIRPudb+Grudb-Lutdb-Wvrudb;%received power or simply is known as %carrier power
Tsysu=input('Enter the system noise temperature in Kelvin =');
Tsysudb=mag2db(Tsysu);
GTRudb=Grudb-Wvrudb-Tsysudb;%gain to temperature ratio for satellite antenna
Nubw=input('Enter the noise bandwidth in Hz =');
Nubwdb=mag2db(Nubw);
Noudb=Kdb+Tsysu+Nubwdb;
CNRudb=Prudb-Noudb;%C/N ratio in db
fprintf('\n');
```

```
% link budget analysis for downlink
fprintf('.........The downlink parameters.........\n\n');
Ptd=input('Enter the transmit power in watt ='); %transmit power
Ptddb=pow2db(Ptd);
Wvtddb=input('Enter the waveguides loss in db =');%waveguides losses
Gtddb=input('Enter the transmit antenna gain in db =');
EIRPddb=Ptddb+Gtddb-Wvtddb;
Fd=input('enter the downlink frequency in GHz =');%uplink frequencies
Fd=Fd*10^9;
lamdad=C/Fd;%wavelength
FSLd=((4*PI*d)/lamdad)^2;%free space loss calculation
FSLddb=mag2db(FSLd);
Lddb=input('Enter the other losses present in the free space in db =');%loss %present in space
% except the free spaceloss
Ldtdb=FSLddb+Lddb;%total loss in atmosphere
Grd=input('Enter the received antenna gain =');% the receiver antenna gain
Grddb=mag2db(Grd);
Wvrddb=input('Enter the received waveguide loss in db =');%received %waveguides loss in db
Prddb=EIRPddb+Grddb-Ldtdb-Wvrddb;%received power also known as %carrier power
Tsysd=input('Enter the system noise temperature in kelvin =');
Tsysddb=mag2db(Tsysd);
GTRddb=Grddb-Wvrddb-Tsysddb;%gain to temperature ratio
Ndbw=input('Enter the noise bandwidth in Hz =');
Ndbwdb=mag2db(Ndbw);
Noddb=Kdb+Tsysd+Ndbwdb;
CNRddb=Prddb-Noddb;%C/N ratio in db
CNRt=((db2mag(CNRudb))^-1)+(db2mag(CNRddb)^-1);%total C/T ratio in db for %Uplink and
```

```
% downlink
CNRtdb=mag2db(CNRt);
fprintf('\n\n');
fprintf('........the Uplink calculation........\n\n');
fprintf('Transmit power in db is = %f\n',Ptudb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvtudb);
fprintf('EIRP in db is = %f\n',EIRPudb);
fprintf('Free space loss is in db = %f\n',FSLudb);
fprintf('The receiver antenna gain in db is = %f\n',Grudb);
fprintf('The received power in db is = %f\n',Prudb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvrudb);
fprintf('The system noise temperature in db is = %f\n',Tsysudb);
fprintf('The received antenna gain to system noise temperature ratio in db is = %f\n',GTRudb);
fprintf('The noise power bandwidth in db is = %f\n',Nubwdb);
fprintf('The noise power in the given bandwidth in db is = %f\n',Noudb);
fprintf('The Carrier to noise power ratio in db is = %f',CNRudb);
fprintf('\n\n');
fprintf('........the downlink calculation........\n\n');
fprintf('Transmit power in db is = %f\n',Ptddb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvtddb);
fprintf('EIRP in db is = %f\n',EIRPddb);
fprintf('Free space loss is in db = %f\n',FSLddb);
fprintf('The receiver antenna gain in db is = %f\n',Grddb);
fprintf('The received power in db is = %f\n',Prddb);
fprintf('Wave guide loss for uplink in db is = %f\n',Wvrddb);
fprintf('The system noise temperature is db is = %f\n',Tsysddb);
fprintf('The received antenna gain to systme noise temperature ratio in db is = %f\n',GTRddb);
fprintf('The noise power bandwidth in db is = %f\n',Ndbwdb);
fprintf('The noise power in the given bandwidth in db is = %f\n',Noddb);
fprintf('The Carrier to noise power ratio in db is = %f\n',CNRddb);
fprintf('\n\n');
fprintf('.......for uplink and downlink.......\n\n');
fprintf('The combined carrier to noise power ratio in db is=%f',CNRtdb);
```

Command Window

```
>> satBudget
.........The uplink parameters.........

Enter the transmit power in watt =85
Enter the waveguides loss in db =2
Enter the transmit antenna gain in db =51
Enter the uplink frequency in GHz =6.1
Enter the other losses present in the free space in db =1
Enter the receiver antenna gain =23
Enter the received waveguide loss in db =0.5
Enter the system noise temperature in Kelvin =450
Enter the noise bandwidth in Hz =2.5

.........The downlink parameters.........

Enter the transmit power in watt =10
Enter the waveguides loss in db =1.2
Enter the transmit antenna gain in db =30
enter the downlink frequency in GHz =3.6
Enter the other losses present in the free space in db =2
Enter the received antenna gain =41
Enter the received waveguide loss in db =1
Enter the system noise temperature in kelvin =140
Enter the noise bandwidth in Hz =2.5
```

```
........the Uplink calculation........

Transmit power in db is = 19.294189
Wave guide loss for uplink in db is = 2.000000
EIRP in db is = 68.294189
Free space loss is in db = 401.285601
The receiver antenna gain in db is = 27.234557
The received power in db is = -307.256855
Wave guide loss for uplink in db is = 0.500000
The system noise temperature in db is = 53.064250
The received antenna gain to system noise temperature ratio in db is = -26.329694
The noise power bandwidth in db is = 7.958800
The noise power in the given bandwidth in db is = -0.243098
The Carrier to noise power ratio in db is = -307.013757

........the downlink calculation........

Transmit power in db is = 10.000000
Wave guide loss for uplink in db is = 1.200000
EIRP in db is = 38.800000
Free space loss is in db = 392.124508
The receiver antenna gain in db is = 32.255677
The received power in db is = -324.068830
Wave guide loss for uplink in db is = 1.000000
The system noise temperature is db is = 42.922561
The received antenna gain to systme noise temperature ratio in db is = -11.666884
The noise power bandwidth in db is = 7.958800
The noise power in the given bandwidth in db is = -310.243098
The Carrier to noise power ratio in db is = -13.825733


       .......for uplink and downlink.......

       The combined carrier to noise power ratio in db is=307.013757
```

XI. Resources used

Table No. 26.3

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.

XIII. Observation Table

N.A.

XIV. Result

……

……

XV Interpretation of Result

……

……

XVI Conclusion and recommendation

……

……

XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more suchquestions so as to ensure the achievement of identified CO.

1. Define EIRP and explain its importance in a link budget.
2. Design a complete satellite downlink budget for DTH broadcast of Ku-band
3. Mention two ways to improve satellite link performance.

[Space for Answers]

……

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XVIII Suggested references for further reading

Sr. No.	Author	Title	Publisher with ISBN Number
1	Dennis Roddy, 5th Edition.	Satellite Communications	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781265372545
2	Pratt, Bostian, and Allnutt, 3rd Edition	Satellite Communications Systems Engineering.	Mc Graw Hill Higher Education, New Delhi, ISBN :9781119482178

Sr. No.	Link / Portal / VLab	Description
1	https://nptel.ac.in/courses/117105131	NPTEL Satellite Communication Course
2	https://www.rfwireless-world.com	Link Budget and RF design tutorials
3	https://www.satsig.net/link-budget.htm	Satellite Link Budget Calculator
4	MATLAB Documentation: Communications Toolbox	Satellite Link Budget Example

XIX Assessment scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No:.27: Analysis of reliability in satellite system

I. Practical Significance

Reliability analysis ensures uninterrupted satellite communication by identifying failure probability and performance consistency of subsystems like power, transponders, antennas, and ground link. It is crucial for satellite mission success, quality of service in telecommunication networks, global navigation satellite system, and broadcast uptime.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: 'Maintain optical and satellite communication systems'.

III. Course Level Learning Outcome

After this practical, students should be able to: 'Maintain Satellite earth segment.'

IV. Laboratory Learning Outcome

LLO 27.1 Test the reliability of satellite system.

V. Relevant Affective Domain related outcome

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for installation and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

Reliability engineering is a sub-discipline of systems engineering that emphasizes the ability of equipment to function without failure. Reliability is defined as the probability that a product, system, or service will perform its intended function adequately for a specified period of time; or will operate in a defined environment without failure. Reliability is closely related to availability, which is typically described as the ability of a component or system to function at a specified moment or interval of time. The reliability function is theoretically defined as the probability of success. In practice, it is calculated using different techniques, and its value ranges between 0 and 1, where 0 indicates no probability of success while 1 indicates definite success. This probability is estimated from detailed (physics of failure) prevention, and management of high levels of "lifetime" engineering uncertainty and risks of failure. Although stochastic parameters define and affect reliability, reliability is not only achieved by mathematics and statistics. Nearly all teaching and literature on the subject emphasize these aspects and ignore the reality that the ranges of uncertainty involved largely invalidate quantitative methods for prediction and measurement.

VII. Circuit diagram/Block diagram/Flowchart

A) Suggestive diagram

NA

B) Actual diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. 27.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online matlab	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus software)	01
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX. Precautions to be followed

1. Ensure proper earthing to the computer system
2. Input each constant in given program carefully for proper output.
3. Save and close all open programs and figures properly after completing the practical

X. Procedure

1. Double click on matlab icon to Run matlab or open online matlab from website https://matlab.mathworks.com/
2. Write given code in editor window of MATLAB software.
3. Define system parameters.
4. Define failure rates for satellite components.
5. Calculate individual component reliabilities.
6. Analyze a combined series-parallel system.
7. Observe the result in command window of MATLAB software.

MATLAB Code for analysis of reliability in satellite system:

```
% SATELLITE RELIABILITY ANALYSIS
% This script analyzes the reliability of a satellite system using a simple
% series-parallel model, without requiring any toolboxes.

% Clear workspace and command window for a fresh start
clear;
clc;
% --- Step 1: Define system parameters ---
% Define time period for reliability analysis (e.g., 5 years)
time_hours = 5 * 365 * 24;

% Define failure rates (failures per hour) for satellite components
% These values are hypothetical for demonstration.
lambda_battery = 1.0e-5;    % Failure rate for the power system (e.g., battery)
lambda_payload = 1.5e-5;    % Failure rate for the communication payload
lambda_sensor = 2.0e-5;     % Failure rate for a critical sensor
lambda_thruster = 0.5e-5;   % Failure rate for a thruster

% --- Step 2: Calculate individual component reliabilities ---
% Calculate the reliability of each component using the exponential model: R = exp(-lambda*t)
R_battery = exp(-lambda_battery * time_hours);
R_payload = exp(-lambda_payload * time_hours);
R_sensor = exp(-lambda_sensor * time_hours);

% --- Step 3: Analyze a series system configuration ---
% Assume all primary components are in series.
% If any one fails, the entire satellite mission fails.
R_series_system = R_battery * R_payload * R_sensor;

% --- Step 4: Analyze a system with parallel redundancy ---
% Assume a redundant thruster system (parallel configuration).
```

```
% The system fails only if BOTH the primary and redundant thruster fail.
% Reliability of a single thruster
R_single_thruster = exp(-lambda_thruster * time_hours);
% Reliability of the parallel thruster subsystem
R_parallel_thruster = 1 - (1 - R_single_thruster) * (1 - R_single_thruster);

% --- Step 5: Analyze a combined series-parallel system ---
% The overall system has the following components in series:
% (Battery) -- (Payload) -- (Sensor) -- (Parallel Thruster Subsystem)
R_total_system = R_battery * R_payload * R_sensor * R_parallel_thruster;

% --- Step 6: Display results ---
fprintf('--- Satellite System Reliability Analysis ---\n');
fprintf('Analysis for a mission duration of %.0f hours (%.1f years)\n\n', time_hours, time_hours / (365*24));

fprintf('Individual Component Reliabilities:\n');
fprintf('  Battery Reliability:       %.4f\n', R_battery);
fprintf('  Payload Reliability:       %.4f\n', R_payload);
fprintf('  Sensor Reliability:        %.4f\n', R_sensor);
fprintf('  Single Thruster Reliability: %.4f\n\n', R_single_thruster);

fprintf('System Configuration Reliabilities:\n');
fprintf('  Series System Reliability (no redundancy): %.4f\n', R_series_system);
fprintf('  Parallel Thruster Subsystem Reliability:   %.4f\n', R_parallel_thruster);
fprintf('  Total System Reliability (with redundant thruster): %.4f\n', R_total_system);
```

```
% SATELLITE RELIABILITY ANALYSIS
% This script analyzes the reliability of a satellite system using a simple
% series-parallel model, without requiring any toolboxes.

% Clear workspace and command window for a fresh start
clear;
clc;

% --- Step 1: Define system parameters ---
% Define time period for reliability analysis (e.g., 5 years)
time_hours = 5 * 365 * 24;

% Define failure rates (failures per hour) for satellite components
% These values are hypothetical for demonstration.
lambda_battery = 1.0e-5;    % Failure rate for the power system (e.g., battery)
lambda_payload = 1.5e-5;    % Failure rate for the communication payload
lambda_sensor = 2.0e-5;     % Failure rate for a critical sensor
lambda_thruster = 0.5e-5;   % Failure rate for a thruster

% --- Step 2: Calculate individual component reliabilities ---
% Calculate the reliability of each component using the exponential model: R = exp(-lambda*t)
R_battery = exp(-lambda_battery * time_hours);
R_payload = exp(-lambda_payload * time_hours);
R_sensor = exp(-lambda_sensor * time_hours);

% --- Step 3: Analyze a series system configuration ---
% Assume all primary components are in series.
% If any one fails, the entire satellite mission fails.
R_series_system = R_battery * R_payload * R_sensor;
```

```
% --- Step 4: Analyze a system with parallel redundancy ---
% Assume a redundant thruster system (parallel configuration).
% The system fails only if BOTH the primary and redundant thruster fail.
% Reliability of a single thruster
R_single_thruster = exp(-lambda_thruster * time_hours);
% Reliability of the parallel thruster subsystem
R_parallel_thruster = 1 - (1 - R_single_thruster) * (1 - R_single_thruster);

% --- Step 5: Analyze a combined series-parallel system ---
% The overall system has the following components in series:
% (Battery) -- (Payload) -- (Sensor) -- (Parallel Thruster Subsystem)
R_total_system = R_battery * R_payload * R_sensor * R_parallel_thruster;

% --- Step 6: Display results ---
fprintf('--- Satellite System Reliability Analysis ---\n');
fprintf('Analysis for a mission duration of %.0f hours (%.1f years)\n\n', time_hours, time_hours / (365*24));

fprintf('Individual Component Reliabilities:\n');
fprintf('  Battery Reliability:        %.4f\n', R_battery);
fprintf('  Payload Reliability:        %.4f\n', R_payload);
fprintf('  Sensor Reliability:         %.4f\n', R_sensor);
fprintf('  Single Thruster Reliability: %.4f\n\n', R_single_thruster);

fprintf('System Configuration Reliabilities:\n');
fprintf('  Series System Reliability (no redundancy): %.4f\n', R_series_system);
fprintf('  Parallel Thruster Subsystem Reliability:   %.4f\n', R_parallel_thruster);
fprintf('  Total System Reliability (with redundant thruster): %.4f\n', R_total_system);
```

Command Window

New to MATLAB? See resources for Getting Started.

```
--- Satellite System Reliability Analysis ---
Analysis for a mission duration of 43800 hours (5.0 years)

Individual Component Reliabilities:
  Battery Reliability:       0.6453
  Payload Reliability:       0.5184
  Sensor Reliability:        0.4164
  Single Thruster Reliability: 0.8033

System Configuration Reliabilities:
  Series System Reliability (no redundancy): 0.1393
  Parallel Thruster Subsystem Reliability:   0.9613
  Total System Reliability (with redundant thruster): 0.1339
>>
```

XI. Resources used

Table No. 27.2

Sr. No.	Name of Resource	Specifications	Quantity

XII .Actual Procedure (If required attach separate page)

1.
2.
3.
4.

XIII. Observation Table

N.A.

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identified CO.

1. Describe the main effects of atmospheric drag on a Low Earth Orbit (LEO) satellite's orbit and how this impacts its long-term reliability.
2. Interpret the meaning of the Carrier-to-Noise (C/N) ratio and its importance for reliable satellite link design.
3. Identify two approaches used for equipment reliability in the event of a communication capacity failure.

[Space for Answers](If required attach separate page)

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XVIII. Suggested references for further reading

Sr. No.	Author	Title	Publisher with ISBN Number
1	Dennis Roddy, 5th Edition.	Satellite Communications	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781265372545

Sr.No.	Link / Portal / V Lab	Description
1	https://in.mathworks.com/help/aerotbx/ug/matlabshared.satellitescenario.satellite.eclipse.html	Satellite Communication
2	https://in.mathworks.com/help/aerotbx/ug/matlabshared.satellitescenario.satellite.eclipse.html	Carrier to noise ratio
3	https://en.wikipedia.org/wiki/Reliability_engineering	Satellite Communication

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.28: Find EIRP of any given satellite communication link through coding

I. Practical Significance

This practical focuses on maintaining and operating satellite earth segment equipment and systems. Find EIRP of any given satellite communication link through coding is important for professionals working in satellite ground stations, VSAT networks, and satellite communication service providers.

II. Industry/Employer Expected Outcome

This course aims to help the student to attain the following industry-identified outcomes through various teaching learning experiences: Maintain optical and satellite communication systems.

III. Course Level Learning Outcome

Maintain Satellite earth segment.

IV. Laboratory Learning Outcome

LLO 28.1 Calculate EIRP of any given satellite communication link.

V. Relevant Affective Domain related outcome

- Demonstrate working as a leader or a team member.
- Follow ethical practices.
- Follow systematic procedures for connection and configuration.
- Document observations clearly and ethically.

VI. Relevant Theoretical Background

Effective Isotropic Radiated Power (EIRP) of a satellite is defined as the measure of the power radiated by an antenna in a specific direction. It is a critical parameter in the link budget calculation to determine the signal strength at the receiving earth station. Theory and Formula EIRP is the product of the power fed into the satellite antenna and the antenna's gain in the direction of the receiver. In logarithmic units (decibels), the formula is: EIRP is the product of the power fed into the satellite antenna and the antenna's gain in the direction of the receiver. In logarithmic units (decibels), the formula is:

$$\mathrm{EIRP(dBW)} = \mathrm{Transmitter\ Power(dBW)} + \mathrm{Antenna\ Gain(dBi)} - \mathrm{Losses(dB)}$$

Where:

Transmitter Power **(P_t):** The output power from the satellite's power amplifier (often in Watts or dBW).

- Antenna Gain **(G_t):** The gain of the satellite's transmitting antenna relative to an isotropic radiator (usually in dBi, which means gain relative to an isotropic antenna).

- Losses**:** Any power losses in the transmission line, connectors, or other components between the amplifier and the antenna (in dB).

An **Effect Isotropic Radiated power** is an accounting of all gains and losses from the transmitter to the receiver. Following figure shows the significant factors that influence a link design. The losses are indicated in red, gains are indicated in green, and the satellite specific information parameters are shown in yellow.

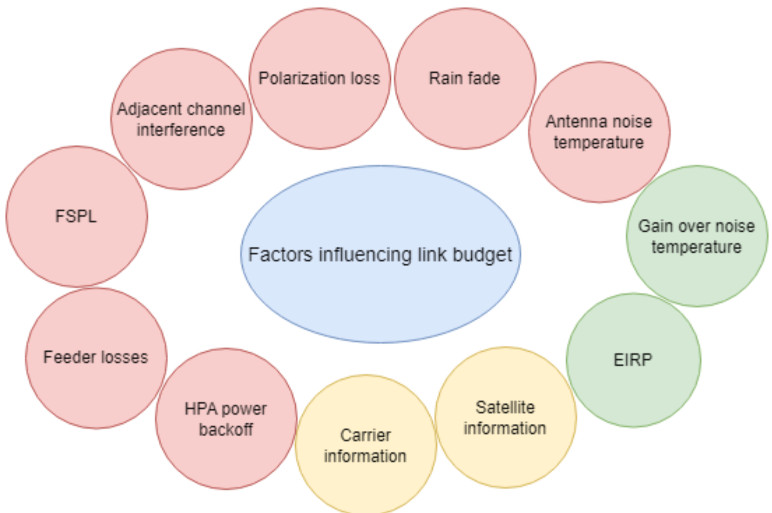

Fig. 28.1: Factors Affecting Communication Link Design

(Courtesy: https://in.mathworks.com/help/satcom/gs/satellite-link-budget.html)

- **EIRP**

EIRP is the amount of power that would have to be radiated by an isotropic antenna to produce the equivalent power from the actual antenna in the direction with highest antenna gain.

EIRP is the total radiated power (P_t) from a transmitter antenna times the antenna gain (G_t).

- **Feeder Loss**

This loss occurs in several components between the antenna and the receiver or the transmitter device, such as couplers, filters, and waveguides. Feeder loss is due to the resistance and imperfections in the transmission line material, which causes part of the signal energy to be dissipated as heat.

- **FSPL**

FSPL refers to the spread of the signal through space, which results in loss of the strength of the signal. Calculate FSPL using Friis transmission equation, according to which the loss is proportional to the square of the distance and the square of the frequency.

- **Polarization Loss**

Polarization mismatch between the transmitter and the receiver antennas leads to electromagnetic (EM) power loss. EM waves are characterized by electric and magnetic fields. A basic property of plane EM waves in free-space is that the directions of the electric and magnetic field vectors are orthogonal to their direction of propagation. EM wave polarization refers to the orientation of the electric field vector.

- **Antenna Pointing Loss**

Correct alignment between an Earth station and satellite antennas provides maximum gain. Misalignment can occur either at the satellite or at the Earth station. Satellite-based misalignment must be considered during the design of the satellite, but the Earth station-based misalignment is the antenna pointing loss, and it is typically less than 1 dB. Calculating antenna misalignment losses (AML) requires statistical data, so these values are an approximation based on real data observed in several ground stations.

VII. Circuit diagram/Block diagram/Flowchart

A. Suggestive diagram

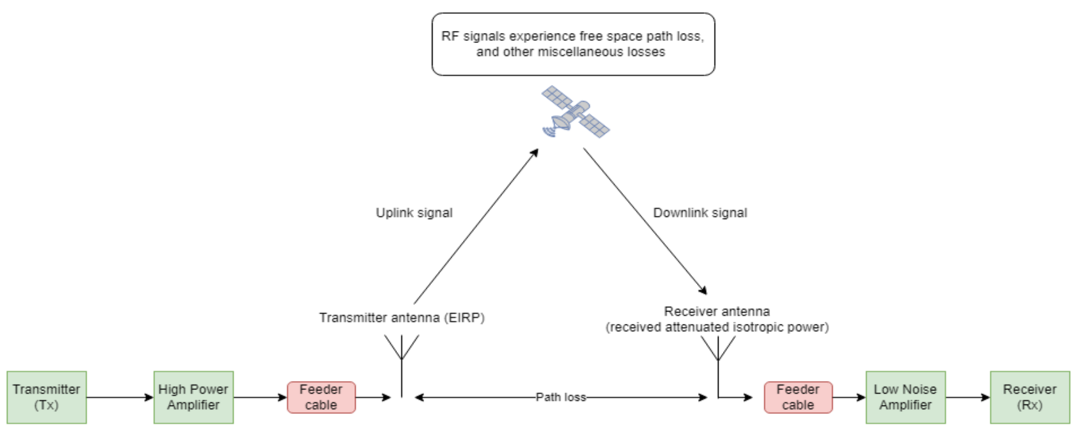

Fig. 28.2: Satellite Communication System

(Courtesy: https://in.mathworks.com/help/satcom/gs/satellite-link-budget.html)

B. Actual diagram

NA

VIII. Required Resources/apparatus/equipment with specifications

Table No. No.28.1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC	i5/i7 processor, 4GB RAM, simulation software	01
2	MATLAB	MATLAB R2018a or later/online matlab	01
3	Antivirus Software	Quick Heal Total Security, Version 24.0 (or the latest available version, or any equivalent antivirus software)	01
4	UPS 6 KVA online	Online UPS, 6 KVA capacity, input: 230V AC, output: 230V AC, Backup: 10–15 min, LCD display	01

IX Precautions to be followed

1.Use consistent units (dBw,dBi, dB) in all calculations.

2.Avoid mixing **dBW** and **dBm** without conversion (1 dBW = 30 dBm).

3.Enter correct system parameters before running the simulation.

4.Save your code and outputs after each run.

5.Interpret results physically; unrealistic values often mean unit errors.

X Procedure

1.Open MATLAB or Python software.

2.Enter the transmitter power in watts

3.Enter transmitter antenna gain in dBi

4.Enter total system losses in dB.

5.Convert transmitter power from watts to dBw

6.Convert EIRP dBw back to watts for comparison.

MATLAB Code for EIRP of any given satellite communication link calculation:

```
% EIRP Calculation for a satellite communication link.
% Display a header for the user
fprintf('EIRP Calculation for Satellite Link\n');
fprintf('-----------------------------------\n');
% Input transmitter power in Watts
P_watts = input('Enter transmitter power (in Watts): ');

% Input antenna gain in dBi
```

G_tx_dBi = input('Enter transmitter antenna gain (in dBi): ');

% Input total system losses in dB (e.g., cable loss)

L_dB = input('Enter total system losses (in dB): ');

% Convert transmitter power from Watts to dBW

P_tx_dBW = 10 * log10(P_watts);

% Calculate EIRP in dBW

EIRP_dBW = P_tx_dBW + G_tx_dBi - L_dB;

% Convert EIRP from dBW back to Watts for comparison

EIRP_watts = 10^(EIRP_dBW / 10);

% Results

fprintf('\n--- Calculation Results ---\n');

fprintf('Transmitter power (dBW): %.2f dBW\n', P_tx_dBW);

fprintf('EIRP: %.2f dBW\n', EIRP_dBW);

fprintf('EIRP: %.2f Watts\n', EIRP_watts);

```
% Effective Isotropically Radiated Power (EIRP) Calculation for a
% satellite communication link.
% Display a header for the user
fprintf('EIRP Calculation for Satellite Link\n');
fprintf('-----------------------------------\n');

% Input transmitter power in Watts
P_watts = input('Enter transmitter power (in Watts): ');

% Input antenna gain in dBi
G_tx_dBi = input('Enter transmitter antenna gain (in dBi): ');

% Input total system losses in dB (e.g., cable loss)
L_dB = input('Enter total system losses (in dB): ');

% Convert transmitter power from Watts to dBW
P_tx_dBW = 10 * log10(P_watts);

% Calculate EIRP in dBW
EIRP_dBW = P_tx_dBW + G_tx_dBi - L_dB;

% Convert EIRP from dBW back to Watts for comparison
EIRP_watts = 10^(EIRP_dBW / 10);

% Results
fprintf('\n--- Calculation Results ---\n');
fprintf('Transmitter power (dBW): %.2f dBW\n', P_tx_dBW);
fprintf('EIRP: %.2f dBW\n', EIRP_dBW);
fprintf('EIRP: %.2f Watts\n', EIRP_watts);
```

Command Window

```
>> EIRP28
EIRP Calculation for Satellite Link
------------------------------------
Enter transmitter power (in Watts): 10
Enter transmitter antenna gain (in dBi): 30
Enter total system losses (in dB): 2

--- Calculation Results ---
Transmitter power (dBW): 10.00 dBW
EIRP: 38.00 dBW
EIRP: 6309.57 Watts
>>
```

XI Resources used

Table No. 28.2

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure (If required attach separate page)

1.
2.
3.
4.
5.

XIII. Observation Table

N.A.

XIV. Result

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XV. Interpretation of result

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more suchquestions so as to ensure the achievement of identified CO.

1. Explain importance of EIRP in satellite communication system.
2. List different parameters in EIRP like transmitter power, antenna gain.
3. Define different losses in EIRP.

[Space for Answers] (If required attach a separate page)

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XVIII. Suggested references for further reading

Sr. No.	Author	Title	Publisher with ISBN Number
1	Dennis Roddy, 5th Edition.	Satellite Communications	Mc Graw Hill Higher Education, New Delhi, ISBN : 9781265372545
2	Roger L. Freeman, 2nd Edition	Fundamentals of Telecommunications	Mc Graw Hill Higher Education, New Delhi, ISBN : 9780471710455

Sr. No.	Link / Portal / VLab	Description
1	https://in.mathworks.com/help/satcom/gs/satellite-link-budget.html	Satellite Link Budget
2	https://www.rfwireless-world.com	Link Budget and RF design tutorials
3	https://www.satsig.net/link-budget.htm	Satellite Link Budget Calculator

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60%**
1	Practical Implementation with specified time	10%
2	Observation and documentation	20%
3	Following procedure and maintaining lab discipline	20%
4	Demonstration	10%
Product Related: 10 Marks		**40%**
1	Correctness of Practical	10%
2	Documentation quality	10%
3	Answers to practical related questions	15%
4	Timely submission of the journal	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	