



Université Mohamed Khider de Biskra
Faculté des Sciences et de la Technologie
Département de génie électrique

MÉMOIRE DE MASTER

Science and Technology
Field: Telecommunication
Option: Network and Telecommunication

Réf. : Entrez la référence du document

Présenté et soutenu par :
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Le : lundi 26 mai 2025

Design and Simulation of Microwave Transmission

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Abstract:

his thesis Design and Simulation of Microwave Transmission aims to connect two or more points using this technology, analyze the results, explore possible obstacles to propagation, understand how the devices work, simulate in the real environment, and determine the speed of data transmission and reception.

Keywords: Line of sight, Indoor Unit (IDU), Outdoor Unit (ODU), Intermediate Frequency (IF), Flat panel

Résumé:

Ce mémoire intitulé Conception et Simulation de la Transmission Micro-ondes a pour but de relier deux points ou plus en utilisant cette technologie, d'analyser les résultats, d'explorer les obstacles potentiels à la propagation, de comprendre le fonctionnement des appareils, de simuler dans un environnement réel, et de connaître la vitesse d'envoi et de réception des données.

Mots-clés : Ligne de vue, Unité intérieure (IDU), Unité extérieure (ODU), Fréquence intermédiaire (IF), Panneau plat

ملخص:

تقوم هذه المذكرة بتصميم ومحاكاة نظام نقل الموجات الدقيقة بهدف ربط نقطتين أو أكثر بهذه التقنية، وتحليل النتائج، واستكشاف العوائق المحتملة للانتشار، ومعرفة طريقة عمل الأجهزة، مع المحاكاة في أرض الواقع، ومعرفة سرعة إرسال واستقبال البيانات.

الكلمات المفتاحية: خط الرؤية، الوحدة الداخلية، الوحدة الخارجية، التردد الوسيط، اللوحة المسطحة

Dedication

I Genuinely Express My Gratitude to My Family Who Placed Their Trust in Me and Provided Their Unwavering Support Throughout This Endeavor. I Am Also Deeply Grateful to My Friends Who Stood by Me and Helped. To Everyone Who Offered Their Support, Whether Near or Far, Your Kindness Has Been Invaluable. I Hope This Work Brings Some Benefit to The Reader and That Even a Small Part of It Contributes to Your Growth and Learning.

Acknowledgments

All praise and thanks are due to Allah, the Most Merciful and Most Compassionate, who bestowed upon me His grace and guidance, enabling me to complete this graduation thesis.

First and foremost, I would like to extend my most profound and heartfelt thanks to my esteemed supervisor, Dr. **Touba Mostafa**, who not only served as an unwavering pillar of support throughout this challenging endeavor but also took on the role of a wise elder brother, providing invaluable guidance and mentorship. His exceptional assistance, coupled with his admirable character traits, has been a source of true inspiration for me, as he exemplifies the virtues of humility and dedication, thereby establishing a remarkable benchmark for all of us who have had the privilege to learn from him.

In addition, I wish to convey my deep and heartfelt gratitude to my cherished family, whose steadfast and unwavering support, encouragement, and belief in my potential have proven to be of immeasurable value throughout this arduous journey, providing me with the emotional and moral fortitude necessary to persevere.

I would also like to extend special thanks to my fellow students, as well as to all the dedicated professors who stood by us during this academic pursuit, tirelessly sharing their wealth of knowledge and insights with boundless patience and generosity, which has greatly enriched our learning experience and fostered a collaborative spirit among us.

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GENERAL INTRODUCTION

General Introduction

Wireless telecommunication has emerged as a fundamental instrument for connecting extensive distances, diminishing infrastructural expenditures, and accommodating demanding ecological circumstances. In the contemporary technologically sophisticated milieu, this modality of communication has progressed markedly, facilitating instantaneous information interchange among numerous nodes with elevated dependability and efficacy.

This graduation thesis focuses on the Design and Simulation of Microwave Transmission, with the primary goal of establishing a dedicated network between institutions. This network aims to support high-volume data transfers and ensure real-time communication without delays or interruptions throughout the year.

The study begins with a theoretical exploration of microwave transmission, outlining key concepts and findings. It then delves into the hardware and tools used in this field, explaining how microwave signals are transmitted and received. A detailed geographic site analysis is conducted to determine the optimal placement for transmission equipment. This is followed by simulations to validate performance, analyze data, and anticipate potential challenges.

Ultimately, this thesis aims to enhance technical skills and deepen understanding in the ever-evolving field of wireless communication. Through practical scenarios and simulations, it provides a solid foundation for analyzing results and developing solutions, preparing the student to work confidently and competently in this dynamic industry.

Chapter I: Fundamentals of Microwave Transmission

I.1. Introduction

Frequency Range: Microwaves showcase a class of electromagnetic waves characterized by wavelengths from approximately one meter to one millimeter, which correlates with frequencies that lie between 300 MHz and 300 GHz. Diverse sources furnish a multitude of definitions for the frequency ranges that microwaves encompass, incorporating both Ultra High Frequency (UHF) and Extremely High Frequency (EHF) bands. A more widely recognized definition within radio-frequency engineering situates the microwave range between 1 GHz and 100 GHz, with wavelengths spanning from 0.3 meters to 3 millimeters. Furthermore, the Super High Frequency (SHF) band, which extends from 3 GHz to 30 GHz, is encompassed within the broader microwave spectrum, featuring wavelengths between 10 and 1 cm. Frequencies within this domain are frequently identified by their IEEE radar band classifications, such as the S, C, X, Ku, K, and Ka bands, which are critical for the categorization of diverse applications in radar, communications, and satellite systems.

Applications in Broadcasting: Microwave technology has garnered extensive utilization within the broadcasting sector, particularly in electronic news gathering (ENG) and outside broadcasts (OB). These technologies function as essential conduits in the transmission of live events and data back to studios. The conveyance of such content may transpire through two principal mechanisms: terrestrial microwave links and satellite microwave links. Terrestrial links facilitate the transmission of signals over relatively shorter distances across the Earth's surface, whereas satellite links amplify this capability to significantly greater distances, thereby enabling global transmission. A significant characteristic of microwave transmission in broadcasting is its capacity to uphold superior-quality, dependable connectivity, even in secluded or challenging environments. This technology is widely employed in television broadcasting, news dissemination, and remote surveillance, enabling the incessant and unbroken transmission of data between field teams and broadcasting hubs.

Transmission Methods: Microwave transmission is conventionally accomplished through two distinct methodologies: terrestrial and satellite-based transmission. Usually across distances of up to 64 kilometers, terrestrial microwave transmission involves the direct conveyance of signals between microwave towers or dishes. These systems need line-of-sight between the transmission and reception stations, hence suggesting that the signals

must go over an unblocked route. By contrast, satellite microwave transmission consists of sending signals to an orbiting satellite, which then sends the data back to Earth covering even larger distances. For communication across continents and distant areas lacking adequate terrestrial infrastructure, satellite microwave systems are absolutely necessary and offer significant benefits for worldwide coverage.

Roles and Responsibilities of Microwave Engineers:

The field of microwave engineering requires specialized expertise in the deployment, maintenance, operation, and planning of microwave communication systems. Engineers working in this domain undertake a variety of critical tasks, including:

Deployment: Engineers are responsible for the design, installation, and setup of microwave transmission systems, whether they are terrestrial or satellite-based. This process involves careful site selection for transmission towers or satellite dishes, ensuring proper alignment, and minimizing potential interference to guarantee efficient system performance.

Maintenance: Once the systems are deployed, engineers must ensure their continued operation by conducting regular maintenance. This may include diagnosing issues, replacing faulty components, upgrading system hardware, and making adjustments to optimize performance and ensure long-term reliability.

Operation: During the operational phase, engineers are tasked with monitoring system performance. This encompasses evaluating signal potency, diagnosing any interruptions, and executing remedial measures to uphold the stability and dependability of the communication network.

Planning: Engineers are also involved in the planning and design of future microwave communication networks. This aspect of their role includes conducting feasibility studies, selecting the most appropriate frequencies, and accounting for environmental factors that could affect signal transmission. Effective planning ensures that microwave systems can meet future demands, accommodate technological advancements, and maintain reliable service across a range of environments.

Microwave engineers fulfill a vital function in guaranteeing the efficacy of contemporary communication networks, ranging from satellite communications to terrestrial radio and television transmissions. Their proficiency in administering high-frequency signals is

essential for the worldwide dissemination of information, accentuating the significance of microwave technology in today's interlinked world.

I.2. Microwave Transmission Basics

Microwave communication fundamentally depends on deploying high-frequency electromagnetic waves that move through direct line-of-sight (LOS) corridors. In contrast to lower-frequency radio waves, microwaves exhibit a lack of diffraction around obstructions such as hills, do not conform to the curvature of the earth as ground waves, and do not reflect off the ionosphere. This constraint imposes a limitation on terrestrial microwave communication links, which are typically confined by the visual horizon, thus restricting effective communication to distances ranging from 40 to 60 kilometers under standard atmospheric conditions.

The curvature of the Earth fundamentally limits the transmission of microwave signals beyond a designated range. Alignment makes sure that the microwave equipment or dishes at each end of the communication channel are perfectly positioned to achieve line-of-sight (LOS). This makes the limitation less severe. The importance of alignment is paramount, as it is critical for creating an unimpeded signal trajectory and thereby enhancing overall communication effectiveness.

In addition, signals in the higher frequencies of the microwave spectrum are affected by gas absorption in the atmosphere. This makes communication even more limited to about one kilometer. These considerations underscore the critical nature of meticulous positioning and alignment within microwave communication systems to guarantee efficient and reliable operational performance.

I.3. Los, NLos, and nLos in Wireless Communication

I.3.1. Line of Sight (Los)

Line of Sight (LOS) communication denotes a direct unimpeded trajectory between the transmitter and receiver antennas, permitting radio waves to propagate in a linear fashion. LOS conditions reduce signal degradation and interference, facilitating superior-quality wireless connections with foreseeable performance, particularly crucial for high-frequency bands such as microwave and millimeter waves. LOS links are essential in point-to-point wireless networks and are generally devised utilizing sophisticated tools that integrate topographical and environmental data to guarantee an unimpeded trajectory.[8] [9]

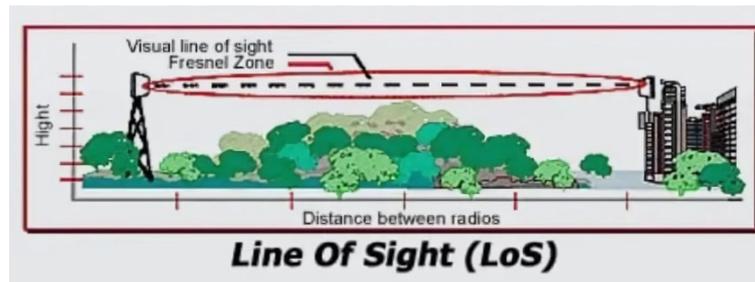


Figure I- 1 Line of Sight

I.3.2. Near-Line of Sight (nLoS)

Near-Line of Sight (nLOS) occurs when the direct path between transmitter and receiver is mostly clear but partially obstructed by minor obstacles such as foliage, small buildings, or terrain irregularities. While the signal path remains largely direct, these partial obstructions cause slight attenuation and scattering, potentially reducing signal strength but still maintaining relatively good quality. Wireless systems designed for nLOS conditions use adaptive techniques like beamforming and robust modulation to mitigate the impact of these partial obstructions. [10] [11]

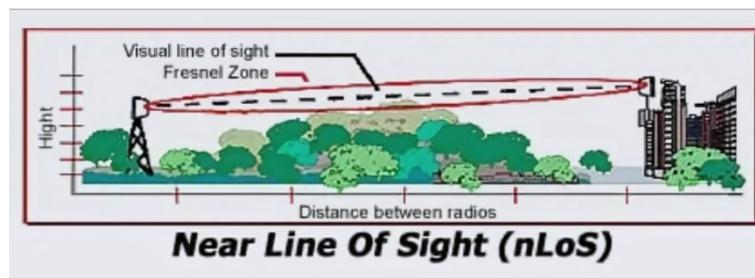


Figure I- 2 Near-Line of Sight

I.3.3. Non-Line of Sight (NLoS)

Non-Line of Sight (NLOS) describes a scenario where the direct path between transmitter and receiver is completely blocked by obstacles, forcing signals to propagate via reflection, diffraction, or scattering. This results in significant path loss and multipath fading, challenging the link reliability and throughput. NLOS links require advanced design considerations, including environmental modeling and the use of technologies such as mesh networking or operation at lower frequencies for better penetration. [9] [11]

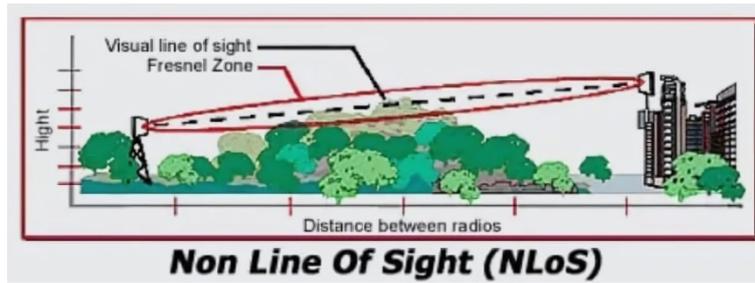


Figure I- 3 Non-Line of Sight

I.4. Fresnel Zone

The Fresnel zone is a technique for determining the requisite extent of expected clearance necessary to avert a wireless signal from being diminished by an obstruction in the trajectory between the connection. [8]

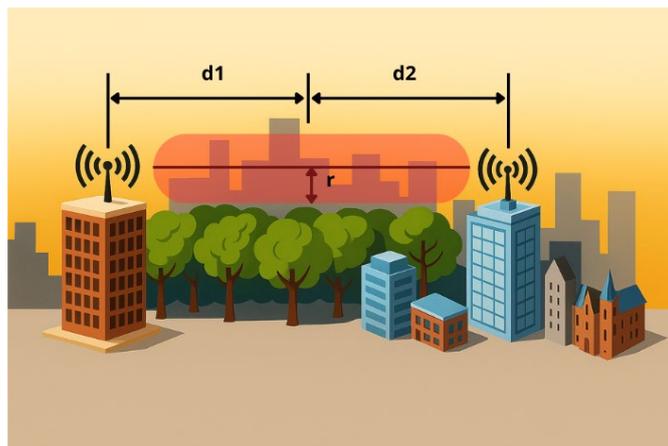


Figure I- 4 Fresnel Zone

The formula for determining the necessary Fresnel zone is:

$$r = 17.32 \sqrt{\frac{d1*d2}{freq*total\ dist}} \quad (1.1)$$

- **Components of the equation:**
 - **r:** Radius of the Fresnel zone in meters.
 - **72.1:** Constant factor to adjust units.

- **d1 and d2:** Distances from the transmitter to the obstacle and from the obstacle to the receiver, respectively in kilometers.
- **freq:** Frequency of the transmitted signal in gigahertz.
- **total dist:** Total distance from the transmitter to the receiver.

I.5. Microwave Bands

I.5.1. Electromagnetic spectrum

Electromagnetic spectrum		
Name	Wavelength	Frequency (Hz)
Gamma ray	< 0.02 nm	> 15 EHz
X-ray	0.01 nm – 10 nm	30 EHz – 750 PHz
Ultraviolet	10 nm – 400 nm	30 PHz – 750 THz
Visible light	390 nm – 750 nm	400 THz – 770 THz
Infrared	750 nm – 1 mm	300 GHz – 400 THz
Microwave	1 mm – 1 m	300 GHz – 300 MHz
Radio	1 m – 100 km	300 MHz – 3 Hz

Table I- 1: Electromagnetic spectrum

Wavelength and Frequency:

Wavelength and frequency constitute two essential principles in the examination of electromagnetic waves. Wavelength denotes the spatial interval between two successive peaks in a wave, whereas frequency signifies the quantity of cycles or oscillations that the wave accomplishes within one second. Due to the inverse correlation between wavelength and frequency, one can derive one parameter from the other by employing the appropriate mathematical equation.

$$\lambda = \frac{c}{f} \quad (I.2)$$

Where:

- λ is the wavelength (in meters).
- c is the velocity of light in a vacuum, approximately $3 * 10^8$ meters/second.
- f is the frequency (in hertz).

Application to Microwaves:

For microwaves, which function within the frequency spectrum of 300 GHz to 300 MHz, the wavelength can be determined utilizing the following equation.

Let us compute the wavelength corresponding to the frequencies of 300 MHz and 300 GHz:

Wavelength Calculation for 300 MHz:

$$\lambda = \frac{3 * 10^8}{300 \times 10^6} = 1 \text{ meter}$$

Wavelength Calculation for 300 GHz:

$$\lambda = \frac{3 * 10^8}{300 \times 10^9} = 1 \text{ mm}$$

Results:

- For the wavelength at a frequency of 300 MHz, we find that the wavelength is **1 meter**.
- For the wavelength at a frequency of 300 GHz, we find that the wavelength is **1 mm**.

These results are derived using the mathematical equation that connects wavelength and frequency, helping to understand how electromagnetic waves propagate through different spaces and their impact on technological systems such as microwaves.

I.5.2. Microwaves Bands in Mobile Communications

Classification	Frequency (GHz)	Corresponding Radar Bands
UHF (Ultra High Frequency)	300 MHz - 3 GHz	L Band
SHF (Super High Frequency)	3 GHz - 30 GHz	S Band: 2 - 4 GHz
		C Band: 4 - 8 GHz
		X Band: 8 - 12 GHz
EHF (Extremely High Frequency)	30 GHz - 300 GHz	Ku Band: 12 - 18 GHz
		K Band: 18 - 27 GHz
		Ka Band: 27 - 40 GHz

Table I- 2: IEEE Frequency Band Designations

Microwave antennas are available in multiple frequency bands, including:

- Traditional band 4 GHz to 42 GHz:
 - 4GHz Band: 3600-4200 MHz
 - 5GHz Band: 4.4GHz - 5GHz
 - 5.8GHz Band: 5.725GHz - 5.850GHz
 - Lower 6GHz Band: 5.925GHz - 6.425GHz
 - Upper 6GHz Band: 6.425GHz - 7.125GHz
 - 7GHz Band: 7.125GHz - 7.725GHz
 - 8GHz Band: 8.200GHz - 8.750GHz
 - 11GHz Band: 10.7GHz - 11.7GHz
 - 13GHz Band: 12.5GHz - 13.25GHz
 - 15GHz Band: 14.0GHz - 15.35GHz
 - 18GHz Band: 17.0GHz - 19.70GHz
 - 23GHz Band: 21.20GHz - 23.60GHz
 - 26GHz Band: 24.25GHz - 26.50GHz
 - 38GHz Band: 37.00GHz - 40.000GHz
 - 42GHz Band: 40.5GHz - 43.5GHz

- V-band (58-62GHz) available for Millimeter Wave Links.
- E-band (71-76GHz, 81-86GHz) available for Millimeter Wave Links.

Note: As the frequency increases, the loss also increases. High frequencies are suitable for short distances, whereas lower frequencies are more effective for longer distances.

I.6. Propagation

Microwaves propagate exclusively along line-of-sight trajectories; in contrast to lower frequency radio waves, they do not propagate as ground waves that conform to the Earth's surface, nor do they reflect off the ionosphere (skywaves).

While at the lower end of the frequency band they possess the capability to penetrate building walls sufficiently for effective reception, it is typically necessary to establish rights of way that are cleared to the first Fresnel zone. Consequently, on the terrestrial surface, microwave communication links are constrained by the visual horizon to approximately (48–64 km).

Microwaves are subject to absorption by atmospheric moisture, with the degree of attenuation escalating in correspondence with frequency, thus becoming a critical factor at the higher end of the frequency spectrum. Commencing around 40 GHz, atmospheric gases also initiate absorption of microwaves, resulting in a limitation of microwave transmission to a range of only a few kilometers above this frequency.

The spectral band structure induces absorption peaks at designated frequencies. Beyond 100 GHz, the absorption of electromagnetic radiation by the Earth's atmosphere is exceedingly pronounced, until the atmosphere regains transparency in the so-called infrared and optical window frequency bands.

The equation for calculating free space Propagation is:

$$L_{fs} = 32.44 + 20 \log(F) + 20 \log(D)$$

- **Components of the equation:**
 - **D**= distance between the transmitter and receiver in kilometers (km)

- F = frequency in megahertz (MHz)
- **32.44** = unit conversion constant (applicable when D is in kilometers and F is in megahertz)

I.7. Regulatory Bodies in Microwave Communications

I.7.1. Role of National and International Regulatory Authorities

The regulation of microwave communications is overseen by both national and international regulatory authorities, which ensure that the use of frequencies is organized and harmonized across various sectors and regions. Their role includes managing frequency allocation, ensuring equitable access to spectrum, avoiding interference between communication systems, and promoting efficient use of radio frequencies.

- **National Regulatory Agencies (NRA):** These agencies are accountable for distributing and overseeing frequencies within their corresponding nations. They ensure that communication systems, including microwave links, operate efficiently and comply with national policies. The governing bodies pertinent herein encompass
 - Egypt's **NTRA** (National Telecommunications Regulatory Authority),
 - the United States' **FCC** (Federal Communications Commission),
 - Algeria's **ARPT** (Autorité de Régulation de la Poste et des Télécommunications),
 - Germany's **Bundesnetzagentur** (Federal Network Agency).
- **International Regulatory Entities:** At the global tier, regulatory bodies orchestrate frequency allocation to ensure that radio frequencies may be employed efficiently across international frontiers. These entities encompass:

International Telecommunication Union (ITU): A specialized organization of the United Nations that orchestrates worldwide telecommunications norms and frequency distributions.

European Conference of Postal and Telecommunications Administrations (CEPT): Works on the harmonization of telecommunications policies in Europe.

Body of European Regulators for Electronic Communications (BEREC): A European Union-wide authoritative entity designed to guarantee competition, infrastructural advancement, and consumer safeguarding within the communications sector. [1]

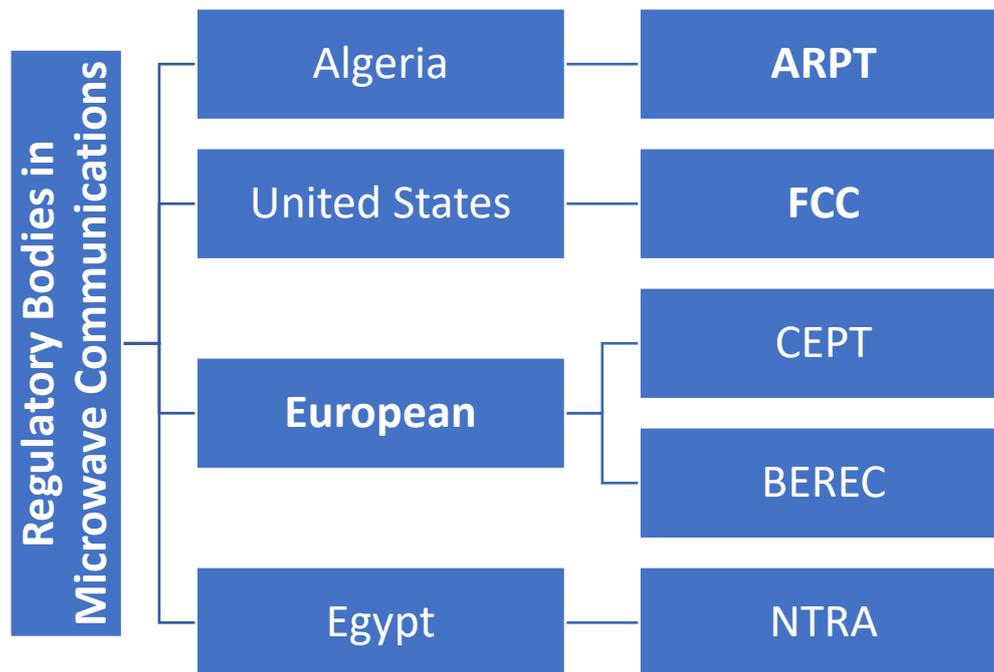


Figure I- 5 Regulatory Bodies in Microwave Communications

I.7.2. Regulatory Authorities in Algeria

The Regulatory Authority for Post and Electronic Communications (ARPCE) mostly controls microwave transmission and frequency management in Algeria. Founded by Law No. 2000-03, ARPCE is required to assure efficient management of frequency spectrum, supervise licensing, and ensure compliance with national and international telecommunications standards. The National Frequency Agency (ANF), founded in 2005, runs under ARPCE and is particularly in charge of monitoring spectrum use, interference prevention, and frequency allotment optimization. Issuing licenses, establishing technical and operational standards, and enforcing electromagnetic compatibility (EMC) rules are among ARPCE's duties. This system guarantees that microwave transmissions, such as point-to-point communications, mobile backhaul, and satellite links, operate effectively, without damaging interference, and within international standards established by the International Telecommunication Union (ITU). [2]

I.7.3. Regulatory Authorities in Europe

Microwave frequency control in Europe is harmonized at national and supranational levels. The European Conference of Postal and Telecommunications Administrations (CEPT) is the primary authority at the European level and works closely with the European Telecommunications Standards Institute (ETSI). These organizations work together to create and coordinate technical standards as well as spectrum use policies. The National Regulatory Authority (NRA) in each nation is responsible for carrying out these policies locally; examples are Ofcom in the United Kingdom, Bundesnetzagentur in Germany, and ARCEP in France. These NRAs supervise interference control, enforce technical standards, and handle spectrum licensing. Through thorough studies and recommendations, ETSI and CEPT work to guarantee that microwave transmission throughout Europe complies with consistent criteria, facilitating interoperability and reducing cross-border disturbance. [3].

I.7.4. Regulatory Authorities in the United States

The Federal Communications Commission (FCC) mostly controls microwave transmission regulation in the United States. Created by the Communications Act of 1934, the FCC oversees spectrum allotment, licensing, and enforcement of rules to avoid user interference among users. Detailed technical regulations in Title 47 of the Code of Federal Regulations govern microwave frequencies, especially those between 1 GHz and 100 GHz. Among the duties of the FCC are frequency allocation, licensing processes, power restrictions, antenna criteria, and electromagnetic compatibility regulations. It also works closely with international organizations, such as ITU-R, to provide worldwide spectrum management consistency, thereby enabling effective use and technical innovation in telecommunications. [4].

I.7.5. Case Analyses

I.7.5.1. Algerian Case Study:

A relevant case study illustrating ARPCE's regulatory strategy is the recent deployment of microwave lines for mobile backhaul expansion by Algerian telecom companies. ARPCE managed the licensing process by clearly defining the frequency ranges for microwave links, particularly the 18 GHz and 23 GHz bands, and established strict technical requirements for antennas, power limits, and managing interference. Operators have to

show adherence to ARPCE's technical criteria and provide thorough frequency coordination strategies. The agency's involvement in preemptive interference checks greatly reduced cross-link interference and improved spectrum efficiency. This regulatory approach allowed rapid network building in underprivileged areas, improved service quality, and increased network capacity. [5]

I.7.5.2. European Case Study:

A significant example in Europe is the CEPT and ETSI-led harmonization initiative on Fixed Service (FS) applications' usage of microwave frequencies. ETSI created ETSI EN 302 217, defining thorough requirements for point-to-point microwave communications, including channel spacing, antenna performance, and interference thresholds. Following these recommendations, National Regulatory Authorities (NRAs) across Europe effectively helped to roll out microwave-based high-capacity broadband services. A prominent case was Germany's Bundesnetzagentur working with neighboring nations to control cross-border microwave communications, especially in border areas, thereby greatly lowering frequency interference events. Better broadband connection, economic efficiency, and efficient regional spectrum use came from this partnership. [6].

I.7.5.3. American Case Study:

The FCC's control of microwave frequencies for the rollout of 5G infrastructure shows its regulatory efficacy in the United States. The FCC designated several microwave bands—24 GHz, 28 GHz, and 39 GHz—for 5G backhaul and fixed wireless access services in past years. To hasten infrastructure rollout, it applied simplified licensing processes and technical standards. Especially, the FCC held spectrum licensing auctions to encourage resource usage and competition among service providers. Strict EMC rules and necessary strategies to reduce interference also ensured that new 5G microwave links could work reliably alongside existing satellite and radar systems, which significantly accelerated the national rollout of 5G. [7].

I.8. Advantages of Microwaves

- Supports augmented bandwidth and consequently a greater volume of information is conveyed. For this rationale, microwaves are employed for point-to-point communications.
- Enhanced antenna gain is achievable.
- Antenna dimensions are diminished, as the frequencies are elevated.
- The impact of fading is mitigated through the utilization of line-of-sight propagation.
- Provides a substantial reflection area within radar systems.
- Satellite and terrestrial communications with elevated capacities are feasible.
- Efficient spectrum utilization with a broad array of applications across all accessible frequency ranges of operation.

I.9. Disadvantages of Microwaves

- The financial investment for apparatus or installation expenses is substantial.
- They are substantial and consume a greater volume of space.
- Electromagnetic disruption may transpire.

I.10. Conclusion

Microwave systems function predominantly within the 5.8 to 80 GHz spectrum, encapsulated within the EHF and SHF frequency bands, providing high-capacity wireless connectivity. Their operational range is conventionally constrained to approximately 64 kilometers owing to the curvature of the Earth. The attainment of dependable communication is contingent upon the preservation of an unobstructed Line of Sight (LOS) between antennas, thereby ensuring minimal signal obstruction. Frequency allocation is meticulously governed by regulatory bodies to avert interference and enhance spectrum efficacy. In summation, proficient microwave communication necessitates both technical accuracy and adherence to regulatory standards for optimal operational performance.

Chapter II:
Design of
Microwave System

II.1. Introduction

Grasping the architecture and operational concepts of a microwave transmission system is essential for understanding the effective functioning of these systems in contemporary communication networks. This chapter examines the intricate design aspects of microwave systems, emphasizing the significance of understanding the system's configuration, the attributes of its ports, and the specific roles of each component. Emphasis is centered on the transmission and reception of signals, encompassing their strength and quality, along with the techniques for converting analog or digital data to facilitate seamless communication with other network devices. This chapter examines the diverse types and configurations of signal receivers, demonstrating the processes of signal capture, processing, and retransmission to ensure dependable communication across intricate network contexts. This chapter seeks to elucidate microwave system design, enhancing both theoretical comprehension and practical implementations in telecommunications.

II.2. Types of Microwave Systems

Microwave systems can be categorized into three main types based on their installation configurations: full indoor, full outdoor, and split systems. Each configuration has its unique characteristics, advantages, and applications, which are crucial for determining the appropriate system for specific needs. This answer will explore these configurations, highlighting their features and applications.

II.2.1. Full Indoor

- Full indoor microwave systems are designed to have all components housed within an indoor environment. This setup is often used in environments where external conditions are harsh or where security and maintenance access are critical.
- These frameworks generally encompass all requisite constituents such as transceivers, modems, and power sources within a singular indoor apparatus, which facilitates installation and upkeep.
- Full indoor systems are less exposed to environmental factors, potentially increasing their lifespan and reliability.

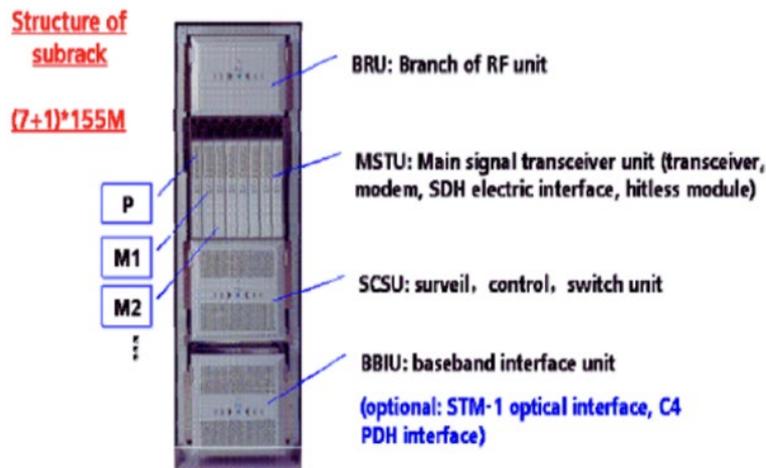


Figure II- 1 Full Indoor

II.2.2.Full Outdoor

- Full outdoor microwave systems are designed to operate entirely outside, with all components housed in weatherproof enclosures. This configuration is ideal for remote or rural areas where indoor space is limited or unavailable.
- These systems are often used in telecommunications for backhaul links, where they can be mounted on towers or rooftops to provide line-of-sight communication over long distances.
- The primary advantage of full outdoor systems is their ability to be deployed in locations where indoor space is not feasible, reducing the need for extensive cabling and infrastructure.

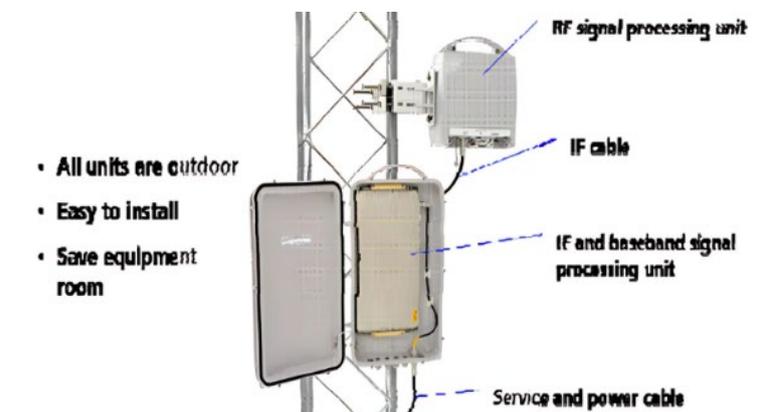


Figure II- 2 Full Outdoor

II.2.3.Split Mount

- Split microwave systems consist of separate indoor and outdoor units, connected by a communication link. This configuration allows for flexibility in installation and can optimize performance by placing components in their most effective environments.

- The indoor unit (IDU) typically handles digital processing tasks such as modulation and demodulation, while the outdoor unit (ODU) manages radio frequency (RF) tasks and signal transmission [1] [2].
- Split systems are advantageous in scenarios where environmental conditions or space constraints make it impractical to house all components in one location. They also allow for easier maintenance and upgrades, as components can be accessed separately [3] [4].

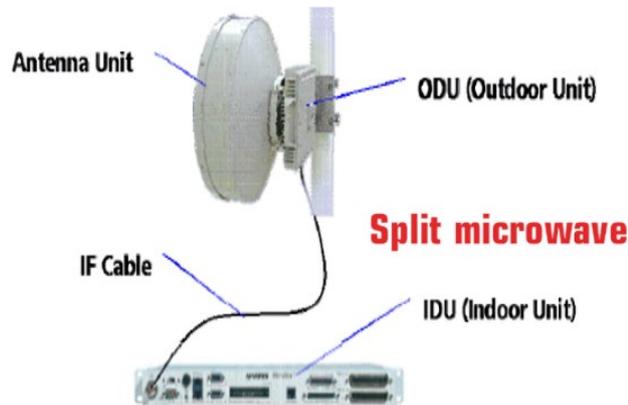


Figure II- 3 Split Mount

Applications and Considerations:

- The selection among these configurations is contingent upon numerous variables, encompassing ecological circumstances, accessible area, and particular application stipulations.
- Full indoor systems are suitable for controlled environments where space and security are not issues. Full outdoor systems are ideal for remote installations where infrastructure is minimal.
- Split systems offer a balance, providing flexibility and ease of maintenance, making them suitable for urban environments where space is limited but access to components is necessary [5].

While each configuration has its advantages, the choice of system should also consider potential drawbacks. Full indoor systems may require more space and cooling, while full outdoor systems might face challenges with weatherproofing and maintenance access. Split systems, while flexible, can involve more complex installation and potential signal loss over the communication link between units. Consequently, the resolution ought to be predicated upon an exhaustive evaluation of the particular requirements and limitations of the proposed utilization.

II.3. Indoor Unit

The Indoor Unit (IDU) in a microwave transmission system is a critical component that integrates seamlessly with other network devices such as routers and switches. It receives data in various formats, including SDH (Synchronous Digital Hierarchy) and PDH (Plesiochronous Digital Hierarchy). This device is responsible for both receiving and transmitting data in the form of frequencies; it converts incoming data—whether voice files, internet traffic, or other types of data—into intermediate frequency (IF) signals for transmission. Conversely, it receives frequency signals and converts them back into usable data formats. This conversion process occurs within a dedicated part known as the IF card (Intermediate Frequency card), which handles transmission and reception via IF cables. IF cables are types of coaxial cables designed specifically to carry intermediate frequency signals while maintaining signal integrity.

- **Baseband Circuitry:** The indoor unit (IDU) contains the baseband circuitry necessary for processing signals before transmission and after reception.
- **Modulation and Demodulation:** It houses the modulator and demodulator, which are essential for converting signals to and from the intermediate frequency (IF) used in transmission.
- **Power Supply:** The IDU supplies power to the outdoor unit (ODU) via the IF coaxial cable, ensuring the ODU operates effectively.
- **DC Power Management:** It receives primary DC power through a main fuse and filtering function, which includes an input filter to reduce common mode noise.
- **Connection to Outdoor Unit:** The IDU is connected to the ODU by a single coaxial IF cable, which can span distances up to 100 meters, facilitating communication between the units. [6]

II.3.1. Interface of IDU Ports

The Indoor Unit (IDU) comprises multiple slots dedicated to various boards that provide radio traffic, modem, power supply, and service functionalities. Below are some key ports and interfaces present in the IDU:



○	15	PM	1	RCU	5	RMU/RTU/RSU	16	○	
			2	RCU/RTU/RSU	6	RMU/RTU/RSU			
	14	PM	3	RMU/RTU/RSU	7	RMU/RTU/RSU			RFA
			4	RMU/RTU/RSU	8	RMU/RTU/RSU			
○	13	RPU							

Figure II- 4 Interfaces of the ZTE NR8250 IDU Device

Table II - 1: Interfaces of the ZTE NR8250 IDU Device

Unit Type	Board	Interface and Function	Slots
RCU	RCUC2	Radio Core Cross Unit C Interfaces: 1 × NMS/GbE + 2 × GbE + 1 × LMT + 1 × CLK/MON + 1 × USB	1, 2
	RMUE	Radio Modem Unit E 1 IF interface. Supports QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM	3-8
RMU	RMUH	Radio Modem Unit H 1 IF interface. Supports QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM and XPIC function	3-8
	RMUF	Radio Modem Unit F 1 IF interface. Supports QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM, 1024QAM light, 2048QAM; MIMO and XPIC function	3-8
	RMUM	Radio Modem Unit M 2 IF interfaces. Supports QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM, 1024QAM light, 2048QAM, 4096QAM;	3-8

		MIMO and XPIC function	
RSU	RSUA	Radio Service Unit A Interfaces: 1 × EDI + 2 × SC + 1 × EOW	3-8
PM	PM3/PM5	Provides power supply for the IDU Input: -48 V DC	3-8
RPU	RPUA	Provides power supply for the ODU Input: -48 V DC Output: 200 W	3-8
	RPUC	Provides power supply for the ODU and NR8950 Input: -48 V DC Output: 800 W	3-8
RFA	RFAB	Fan	9
RTU	RTUA	Radio Traffic Unit A Interface: 16 × E1 (75 Ω/120 Ω)	2-8
	RTUB	Radio Traffic Unit B Interface: 2 × STM-1 + 1 × STM-4 + 1 × STM-1 + 8 × E1 (75 Ω/120 Ω)	2-8
	RTUC	Radio Traffic Unit C Interface: 32 × E1 (75 Ω/120 Ω)	2-8
	RTUD	Radio Traffic Unit D Interface: 16 × E1 (75 Ω/120 Ω)	2-8
	RTUNO	Radio Traffic Unit N (optical interface) Interface: 2 × GbE (optical interface/electrical interface) + 2 × GbE (optical interface)	2-8
	RTUNE	Radio Traffic Unit N (Electrical interface) Interface: 2 × GbE (electrical interface) + 2 × GbE (electrical interface/optical interface)	2-8
	RTUHO	Radio Traffic Unit H (optical interface) Interface: 3 × GbE (optical interface) + 8 × E1	2-8
	RTUNE	Radio Traffic Unit H (electrical interface) Interface: 3 × GbE (electrical interface) + 8 × E1	2-8
	RTUH1	Radio Traffic Unit H1 (electrical interface) Interface: 2 × GbE (electrical interface) + 2 × GbE (electrical interface/optical interface) + 16 × E1	2-8

	RTUIO	Radio Traffic Unit I (optical interface) Interface: 1 × 10GbE (optical interface)	2-8
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II.4. Outdoor Unit

The outdoor unit in a microwave system, often referred to as a microwave outdoor unit (ODU), is a critical component that facilitates the transmission and reception of microwave signals. Its primary function is to convert intermediate frequency (IF) signals into microwave frequency signals and vice versa, enabling effective communication in various systems, including mobile communication networks. The outdoor unit is typically mounted close to an antenna to minimize signal loss and enhance transmission efficiency. Below, the key aspects of the outdoor unit's function and design are discussed in detail.

Key Functions of the Outdoor Unit:

- Frequency Conversion:** The outdoor unit is responsible for converting intermediate frequency signals into microwave frequency signals. This is achieved through a radio frequency module that performs frequency conversion and power amplification before transmitting the signals to a duplexer. The duplexer then handles the low-noise amplification of received signals, which are subsequently down-mixed and amplified for transmission to the indoor unit. [7]
- Signal Transmission and Reception:** The outdoor unit is equipped with a transmitting module that sends signals to an antenna. It also includes a duplexer that filters and outputs signals to the antenna, and a receiving module that processes incoming signals. This setup ensures efficient signal transmission and reception, crucial for maintaining robust communication links. [8]
- Integration with Antenna Systems:** Outdoor units are often integrated with antenna systems to form a compact and efficient communication device. This amalgamation diminishes the dimensions and mass of the comprehensive apparatus, rendering it more appropriate for diverse utilizations, encompassing mobile and stationary wireless systems. [9]

Design and Technological Features:

- Component Integration:** Modern outdoor units are highly integrated, featuring components such as a millimeter wave transceiver board, intermediate frequency board, and frequency synthesizer board. These components work together to

manage signal processing and power control, ensuring the unit's efficient operation. [10]

- **Use of Advanced Materials:** The construction of outdoor units often involves advanced materials like ceramic for the transceiver board, which enhances the unit's performance and durability. This choice of materials is crucial for maintaining signal integrity and reducing noise in high-frequency applications. [10]
- **System Expansion Capabilities:** Some outdoor units are designed to work with outdoor coupler units (OCUs), which allow for the expansion of the system to accommodate multiple outdoor units. This capability is particularly beneficial for large-scale communication networks that require extensive coverage and capacity. [11]

Broader Perspectives:

While the primary function of the outdoor unit in a microwave system is to facilitate efficient signal transmission and reception, it is important to consider its role within the broader context of communication systems. Outdoor units are integral to the infrastructure of mobile and fixed wireless networks, enabling high-speed data transmission and reliable connectivity. Nevertheless, the formulation and implementation of these systems must also consider ecological variables, such as thermal variations and tangible impediments, which can affect efficacy. Additionally, advancements in technology, such as the integration of metamaterials and system-on-chip (SOC) technology, continue to drive improvements in the efficiency and compactness of outdoor units, making them more adaptable to diverse applications. [9]



Figure II- 5 Interfaces of the Outdoor Unit

II.5. If Cable

Intermediate Frequency (IF) cables play a pivotal role in telecommunications infrastructure by physically connecting the Indoor Unit (IDU) and the Outdoor Unit (ODU). The IDU, located inside the building, is responsible for signal processing functions such as modulation and demodulation. In contrast, the ODU is mounted externally—often on rooftops or towers—and manages the transmission and reception of radio frequency signals through antennas.

The IF cable carries intermediate frequency signals between these two units, ensuring seamless communication and data transfer. This connection is vital for maintaining signal quality while bridging the spatial separation between the controlled indoor environment and the exposed outdoor antenna system.

Regarding length, IF cables can vary significantly depending on the specific installation and system requirements. While shorter lengths are common, it is not unusual for IF cables to extend up to 100 meters. This flexibility allows for practical placement of the ODU in optimal outdoor locations while situating the IDU in accessible indoor spaces.

However, with increased cable length comes the risk of signal attenuation and degradation. Therefore, careful selection of cable type and length is essential to preserve signal integrity, minimize losses, and maintain overall system performance.

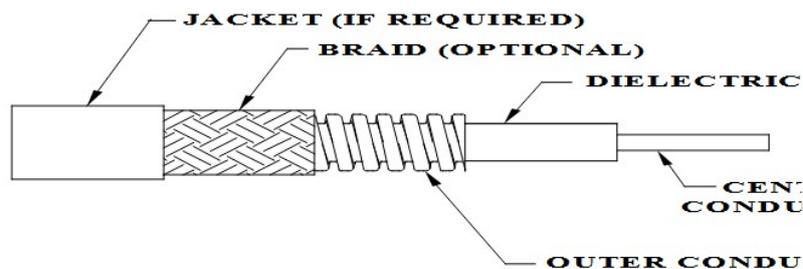


Figure II- 6 If Cable

- Cable Losses:**

Type	Size	450	700	800	900	1700	1800	2000	2100	2300	2500	3400	5000
		M	M	M	M	M	M	M	M	M	M	M	M
LDF 4	1/2"	4.749	6.009	6.456	6.855	9.744	10.058	10.666	10.961	11.535	12.09	14.401	18.01
AL5	7/8"	2.703	3.421	3.676	3.903	5.551	5.73	6.077	6.246	6.573	6.89	8.21	10.273
LDP 6	5/4"	1.784	2.285	2.465	2.627	3.825	3.958	4.216	4.342	4.588	4.828	/	/
AL7	13/8"	1.599	2.037	2.193	2.333	3.36	3.472	3.692	3.798	4.006	4.208	/	/

Table II - 2: Cable Losses

Interpretation of the Table

This table illustrates the relationship between the size of a coaxial cable and the signal loss that occurs as the signal travels through it. The cable size plays a fundamental role in determining the degree of signal attenuation. In essence, the higher the loss measured in decibels (dB), the greater the weakening of the signal as it passes through the cable.

For instance, at a frequency of 5000 MHz, the LDF4 cable with a 1/2-inch diameter experiences a signal loss of 18.01 dB per 100 meters. This means that the signal significantly degrades before reaching the full 100-meter length, indicating substantial attenuation and a reduction in signal quality.

Therefore, the choice of cable type and size directly impacts the efficiency of signal transmission. Larger cables, such as the AL7 with a 13/8-inch diameter, typically exhibit lower signal loss, making them more effective in preserving signal strength over longer distances.

II.6. Antenna

II.6.1. Parabolic Antenna

Numerous applications extensively utilize circular microwave antennas due to their diminutive dimensions, omnidirectional emission patterns, and ease of integration. This section provides an overview of the typical surface area and power output of circular microwave antennas.

Surface Area of Circular Microwave Antennas

- **General Dimensions:** Circular microwave antennas can range in size from small patches to large arrays. For instance, a circular patch antenna designed for wireless communication might have a circumference of 8.82 mm when installed on an FR-4 substrate with a height of 1.6 mm [13]. In contrast, a high-power radial line slot antenna might have an aperture diameter of 54 cm [14].
- **Substrate and Material Considerations:** The choice of substrate material and its dielectric constant can influence the antenna's size. For example, antennas using an FR-4 substrate with a dielectric constant of 4.2 are common in microstrip designs [13] [15].

- **Design Variations:** Some designs incorporate slots or other modifications to improve performance, which can affect the overall surface area. For example, a two-slotted circular microwave antenna designed for hyperthermia applications operates at 2.45 GHz and offers improved gain and directivity compared to conventional designs [16].

Power Output of Circular Microwave Antennas

- **High-Power Applications:** Circular antennas for high-power applications, like the radial line slot antenna, can handle power levels exceeding 600 MW and achieve a gain of 29.0 dBi at 9.42 GHz [14].

- **Wireless Power Transfer:** In wireless power transfer systems, circular antennas are often integrated with rectifiers to convert RF power to DC power. For instance, a circularly polarized implantable rectenna achieves a conversion efficiency of up to 45% at an input power of 0 dBm [17].

- **Focused Power Transmission:** Some systems employ focused microwave power transmission to enhance efficiency. A focused transmitting array antenna can convert radio frequency to direct current with an efficiency of 66.5% when focused, which is much better than regular systems that don't use focusing.

Considerations and Variations

While the above sections provide a general overview, it is important to note that the specific design and application of a circular microwave antenna can lead to variations in both surface area and power output. One important relationship is that as the frequency increases, the physical size of the antenna gets smaller, while lower frequencies require larger antennas. This is because lower frequencies correspond to longer wavelengths, which in turn necessitate larger antenna dimensions to efficiently transmit or receive signals. Additionally, environments with high congestion or interference often benefit from using enclosed parabolic antennas covered with plastic radomes to shield against unwanted frequencies and protect the antenna structure.

Depending on their design and function, microwave antennas fall into several types or classes, each optimized for specific applications and performance criteria. Two critical phenomena affecting antenna performance are interference and reflection. **Interference**

refers to the disruption of signal transmission caused by overlapping waves from various sources, which can degrade signal quality. **Reflection** occurs when radio waves bounce off surfaces, potentially causing multipath effects that can either amplify or distort the received signal, depending on the phase relationship.

Moreover, factors such as operating frequency, intended use (e.g., communication, power transmission), and environmental conditions (e.g., rain attenuation) continue to influence antenna parameters. Technological advancements in antenna technology are driving the development of more efficient, compact, and application-specific designs.

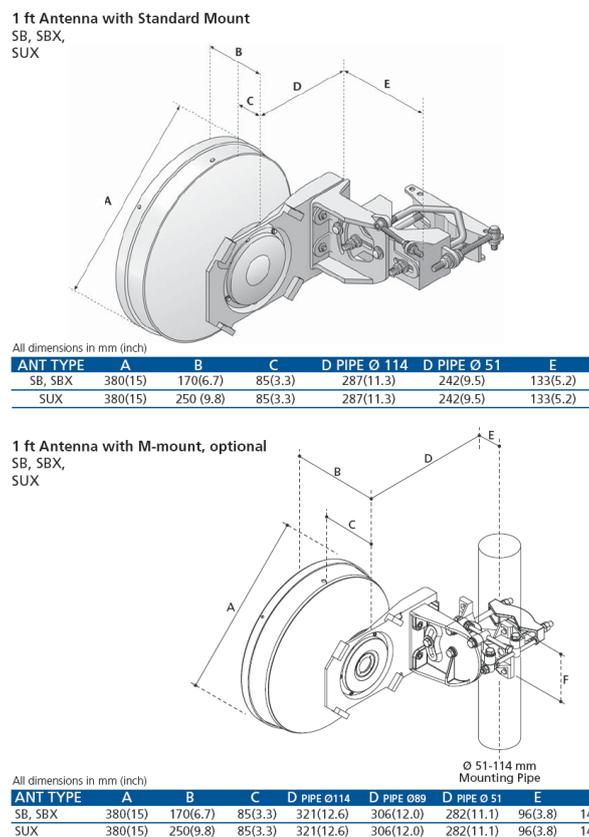


Figure II- 7 Parabolic Point to Point Antennas 2.3 - 2.5 GHz [19]

II.6.2. Flat Panel Antenna

Flat panel microwave antennas are distinguished by their diminutive configuration and effective power emission, rendering them appropriate for a multitude of utilizations, encompassing satellite communication and wireless energy transmission. These antennas

typically exhibit a planar architecture that facilitates heightened directivity and gain, whilst preserving a low profile. The surface area and power emission attributes of these antennas are affected by their design and the particular application for which they are designated. Below are the key characteristics of flat panel microwave antennas based on the provided research papers.

Surface Area Characteristics

Planar Design: Flat panel antennas are designed with a planar structure, often comprising multiple layers, such as metal plates and dielectric substrates, to achieve a compact form factor. This design is crucial for applications where space is limited, such as in satellite communication systems. [20][21]

Array Configuration: Many flat panel antennas are configured as arrays, which can be arranged in various geometries, such as 4×4 or 1×16 arrays, to enhance their performance. For instance, a 4×4 flat-panel array was designed with dimensions of $3.74 \lambda_0 \times 3.74 \lambda_0 \times 0.106 \lambda_0$ at 28 GHz, indicating a relatively compact surface area for high-frequency applications. [21]

Integration with Other Components: These antennas often integrate additional components, such as active devices for signal amplification and RF-to-DC conversion networks, which can influence the overall surface area. The integration of these components is designed to optimize the antenna's performance while maintaining a minimal footprint. [20][22]

Power Output Characteristics

High Gain and Directivity: Flat panel antennas are engineered to provide high gain and directivity, which are essential for efficient signal transmission and reception. For example, a flat-panel mmWave antenna array achieved a peak gain of 21.3 dBi at 28.5 GHz, demonstrating its capability to focus energy effectively in a specific direction. [21]

Beamwidth and Polarization: The beamwidth of these antennas can vary, with some designs offering wide beamwidths to cover larger areas. A flat-panel rectenna, for instance, exhibited a half-power coverage of 144.6° with a peak gain of 3.34 dBi, suitable for applications requiring broad coverage. [22]

Efficiency and Conversion: The power output is also characterized by the efficiency of RF-to-DC conversion, particularly in applications involving wireless power transfer. A flat-panel rectenna achieved a peak RF-to-DC conversion efficiency of 51.8%, highlighting its effectiveness in energy harvesting applications. [22]

While flat panel microwave antennas offer significant advantages in terms of compactness and efficiency, there are challenges and considerations that must be addressed. For instance, the control of mechanical and electrical tolerances is crucial to ensure consistent performance, and further research is needed to improve sidelobe behavior and overall design accuracy [23]. Additionally, the integration of complex feed networks and the need for precise impedance matching can complicate the design process, requiring careful consideration of the antenna's operational environment and intended application. [24]



Figure II- 8 Flat Panel Antenna

II.7. Transmitter And Receiver

Microwave transmission systems encompass the utilization of transmitters and receivers to convey and obtain signals across microwave frequencies. These systems are fundamental to numerous communication technologies, facilitating high-velocity data transmission

across extensive distances. The architecture and efficacy of microwave transmitters and receivers are pivotal for enhancing performance, reducing interference, and guaranteeing effective signal processing. The following sections delve into the components and mechanisms of microwave transmitters and receivers.

II.7.1. Transmitter Section (Microwave Transmitter)

The transmitter is responsible for converting baseband signals—such as voice, video, or data—into modulated high-frequency microwave signals that can be efficiently transmitted over long distances using antennas. It comprises four main sections: baseband, modulation and intermediate frequency (IF), mixer and up-conversion, and RF power amplification.

✚ Preemphasis Network:

- The preemphasis circuit enhances the high-frequency components of the baseband signal before modulation.
- This methodology enhances the signal-to-noise ratio (SNR) by offsetting anticipated high-frequency degradation during conveyance.
- Commonly applied in FM communication systems.

✚ Modulator:

- The modulator encodes the baseband signal onto a carrier frequency—typically an intermediate frequency (IF)—using analog or digital modulation schemes such as amplitude modulation (AM), frequency modulation (FM), or phase shift keying (PSK).
- It translates the original signal into a format more suitable for RF transmission

✚ IF Amplifiers and Bandpass Filters:

- Amplify the modulated IF signal and apply bandpass filtering to eliminate noise and unwanted frequency components.
- This ensures a clean, strong signal prior to frequency up-conversion.

✚ Mixer / Converter:

- Combines the IF signal with a high-frequency signal generated by the microwave oscillator to produce a radio frequency (RF) signal.

- This process, called up-conversion, translates the signal to a microwave frequency suitable for transmission.

Microwave Generator:

- A local oscillator generating stable, high-frequency microwave signals (typically in the GHz range).
- Supplies the reference signal for frequency translation in the mixer.

RF Power Amplifier and Bandpass Filter:

- Amplifies the RF signal to a level sufficient for transmission over long distances.
- Bandpass filtering ensures spectral purity by removing harmonics or spurious frequencies.

Transmit Antenna:

- Converts the amplified RF electrical signal into electromagnetic waves.
- Radiates the signal directionally or omnidirectionally into free space or towards another station.

II.7.2.Receiver Section (Microwave Receiver)

The receiver performs the reverse operation of the transmitter. It captures microwave signal, shifts it down to an intermediate frequency signal, demodulates it, and rebuilds the original baseband signal.

Receive Antenna:

- Captures incoming microwave electromagnetic waves and converts them back into electrical RF signals.
- Usually aligned with the transmitting antenna for line-of-sight communication.

RF Amplifier and Bandpass Filter

- Amplifies the weak received signal and removes out-of-band noise or interference using filtering techniques.

Mixer / Converter

- Down-converts the high-frequency RF signal to a lower intermediate frequency using a local microwave oscillator signal.
- This step simplifies further amplification and demodulation.

Microwave Generator

- Generates the reference signal required for the down-conversion process.
- Must be frequency-locked or synchronized with the transmitter's oscillator to ensure accurate demodulation.

IF Amplifiers and Bandpass Filters

- Further amplify and clean the IF signal to prepare it for demodulation.

Demodulator

- Extracts the original baseband signal from the modulated IF signal.
- Reverses the modulation process applied by the transmitter.

Deemphasis Network

- Restores the original frequency characteristics of the signal by attenuating high-frequency components that were preemphasized at the transmitter.
- Ensures accurate reproduction of the original signal.

Baseband Output

- The final recovered signal, ready for further processing or delivery to end-user devices (e.g., speakers, screens, or storage).

While microwave transmission systems offer numerous advantages, they also face challenges such as signal attenuation, interference, and the need for precise alignment of antennas. Advances in technology continue to address these issues, with ongoing research focusing on improving modulation techniques, enhancing antenna design, and integrating optical components to boost performance and reduce costs. These developments are crucial for expanding the capabilities and applications of microwave communication systems.

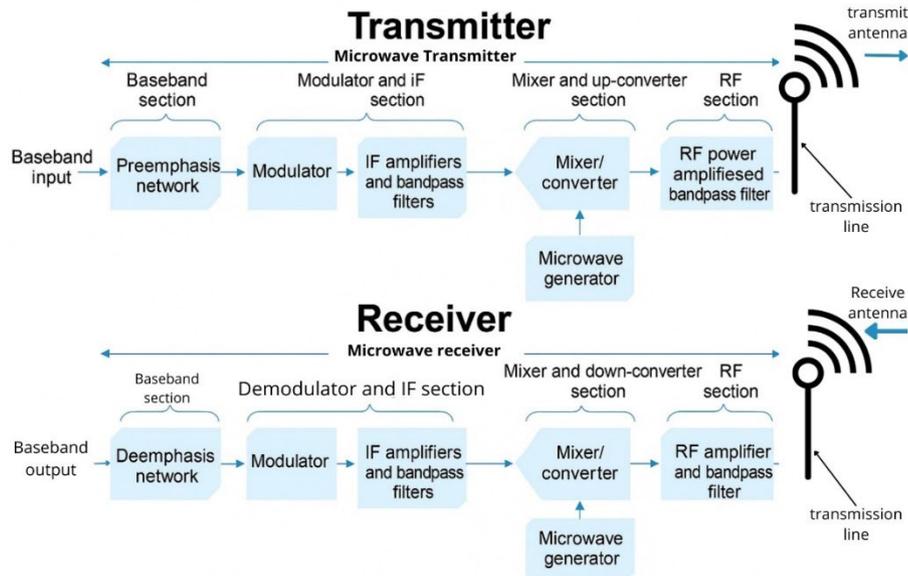


Figure II- 9 transmitter and receiver

II.8. Signal Path

Frequency (IF) signal and the Local Oscillator (LO) signal are fed into the mixer as input ports. The mixer exploits its nonlinear properties to combine these two input signals, producing new frequency components that are sums and differences of the input frequencies. The key output frequencies are given by:

Frequency Conversion Modes in RF Mixers

Up Frequency Conversion:

The IF signal and the LO signal are input into the mixer, and the output at the RF port contains the sum and difference frequencies. The primary goal is to translate the lower IF frequency to a higher RF frequency, suitable for transmission.

Down Frequency Conversion:

The RF signal and the LO signal serve as inputs, and the output at the IF port is the frequency difference, effectively translating a high RF frequency down to a lower IF frequency for easier processing in the receiver.

Low-Side LO vs. High-Side LO Frequency Configurations in RF Mixers:

The relative position of the Local Oscillator (LO) frequency to the Radio Frequency (RF) affects the system classification into Low-Side or High-Side LO configurations. This positioning determines the location of the frequency, an undesired frequency component that can interfere with the desired signal. The exact relationships differ depending on whether the mixer is performing **up-conversion** or **down-conversion**.

- **RF Up-Conversion**

In up-conversion, the mixer combines the Intermediate Frequency (IF) and LO frequencies to produce the higher RF output frequency.

Low-Side LO System ($F_{LO} < F_{RF}$)

The RF frequency is given by:

$$F_{RF} = F_{LO} + F_{IF}$$

High-Side LO System ($F_{LO} > F_{RF}$)

The RF frequency is:

$$F_{RF} = F_{LO} - F_{IF}$$

- **RF Down-Conversion**

In down-conversion, the mixer combines the RF and LO frequencies to produce a lower IF output frequency.

Low-Side LO System ($F_{LO} < F_{RF}$)

The IF frequency is:

$$F_{IF} = F_{RF} - F_{LO}$$

High-Side LO System ($F_{LO} > F_{RF}$)

The IF frequency is:

$$F_{IF} = F_{LO} - F_{RF}$$

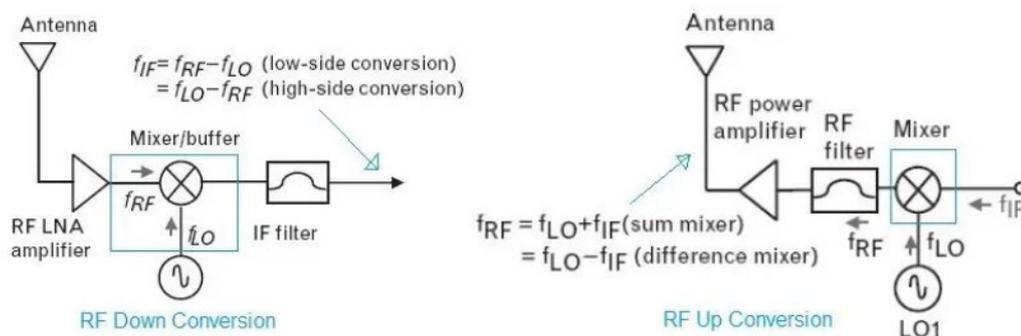


Figure II- 10 RF mixer in up/down conversion circuit design [12]

II.9. Conclusion

This chapter presents a comprehensive examination of the design and technical facets of microwave systems. Different systems manifest in diverse forms, each tailored to specific communication requirements. The Indoor Unit (IDU) is a vital component, functioning as the primary center for signal processing and system control. Recent breakthroughs have created integrated technologies that condense many devices into a single unit, enabling efficient connectivity via high-speed cables. This integration helps boost the important frequencies needed for sending and receiving signals, making sure they are effectively transmitted to and from the IDU. This chapter emphasizes how advancements in microwave system design improve performance and streamline network architecture, establishing a basis for future telecommunications development.

Chapter III:
**Simulation and Its Real-
World Application**

III.1.Introduction

This chapter elucidates diverse facets of executing a network design initiative utilizing LINKPlanner, from the preliminary site configuration to the conclusive analysis phase. The attributes and instruments delineated in this segment are predicated on the most recent iteration of LINKPlanner, a multifaceted and user-friendly link planning instrument devised by Cambium Networks. The version used in this chapter is LINKPlanner v6.3.3. LINKPlanner is designed to help engineers effectively plan wireless networks, whether they are point-to-point (PTP) or point-to-multipoint (PMP).

LINKPlanner enables operators to predict network efficacy, thereby enabling the optimization of deployment expenditures and the reduction of the total cost of ownership. This instrument guarantees that the selected configuration adheres to performance and reliability benchmarks by providing precise performance forecasts early in the design trajectory. It optimizes the design of highly reliable wireless connections, even in challenging environments, by integrating factors such as topography profiles, antenna configurations, and weather effects like rain fade.

In this chapter, we will outline the functionalities of LINKPlanner, which include the ability to produce comprehensive performance reports, optimize network designs based on real-world scenarios, and simulate multiple link configurations. By means of graphical representations and reports, users can investigate "what-if" scenarios, visualize their network design in Google Earth, and ultimately improve the installation process, thereby guaranteeing a successful network deployment. [1]

III.2.LINKPlanner Simulation Software "As a Cloud Version"

Cambium Networks' LINKPlanner is a comprehensive and intuitive tool designed to facilitate the planning and optimization of wireless networks. Initially released as a standalone software program in versions 4 and 5, LINKPlanner evolved with the release of version 6.3, transitioning to As a Cloud Version. This modification facilitates augmented accessibility and cooperation, as it eradicates the necessity for local installation and empowers users to utilize the instrument from any apparatus with an internet connectivity. Tailored for both Point-to-Point (PTP) and Point-to-Multipoint (PMP) configurations, the

Simulation and Its Real-World Application

cloud version of LINKPlanner empowers network engineers to design robust and efficient wireless infrastructures with confidence. Key Features and Capabilities

Integrated Terrain Analysis: LINKPlanner seamlessly imports path profiles, leveraging terrain data to simulate real-world conditions. This integration allows for accurate modeling of environmental factors such as rain fade, enabling engineers to anticipate and mitigate potential performance issues before deployment.

Advanced Scenario Modeling: Users can conduct "what-if" analyses by adjusting variables like geography, distance, antenna height, and transmit power. This flexibility aids in optimizing system performance and throughput, ensuring that the designed network meets specific requirements and constraints.

Comprehensive Reporting and Documentation: LINKPlanner generates detailed performance reports, including metrics like predicted receive power, modulation schemes, and link availability. Additionally, it produces bills of materials and installation guidelines, streamlining the deployment process and reducing the risk of errors.

Multi-Platform Support: Available as a free cloud-based tool, LINKPlanner can now be accessed from anywhere via internet-enabled devices. It remains compatible with both Microsoft® Windows® and Intel®-based Mac® systems, offering accessibility to a wide range of users and facilitating collaboration across different operating environments.

III.3.Interface LINKPlanner

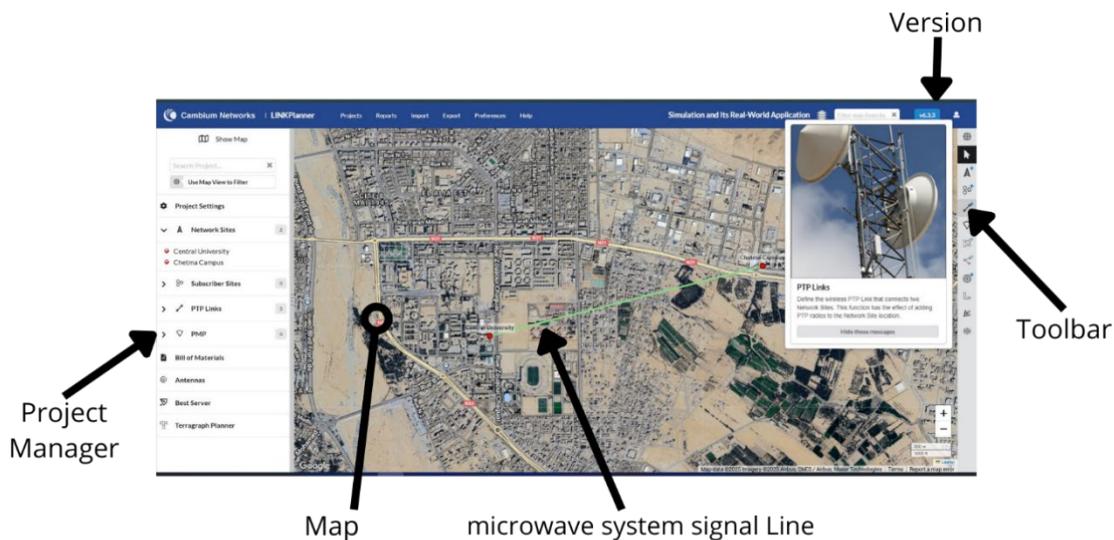


Figure III- 1 Interface LINKPlanner

III.3.1. Toolbar

III.3.1.1. Point-to-Point “PTP” (P2P)

Point-to-point (PTP) microwave communication constitutes a technique for conveying information between two stationary sites utilizing microwave radio frequencies. This technology is extensively employed in telecommunications owing to its capacity to deliver high-capacity, dependable connections across extensive distances devoid of the necessity for tangible cables. The efficacy of PTP microwave systems is affected by numerous determinants, encompassing antenna configuration, frequency choice, and ecological conditions. The following sections explore these aspects in detail, drawing insights from recent research.

Antenna Design and Performance

A high-gain, dual-circularly polarized leaky-wave antenna (LWA) has been developed for PTP communications, offering a fixed beam and a peak gain of 27.2 dBic at 28 GHz. This design is notable for its low profile, with a height of only $0.15\lambda_0$, making it suitable for compact installations [2].

The use of dual-circular polarization in antennas can enhance signal quality by reducing interference and improving signal clarity, which is crucial for maintaining reliable PTP links [2].

Frequency Selection and Propagation

Millimeter-wave (mmWave) frequencies, such as 28 GHz, 60 GHz, and 140 GHz, are increasingly used in PTP microwave systems due to their large bandwidths, which enable higher data rates. However, these frequencies also experience higher path loss, which can affect signal strength [3].

Environmental factors, such as rain and vegetation, can impact the performance of mmWave PTP links. While rain does not significantly affect system capacity, it is essential to consider these factors during network planning to ensure optimal performance [3].

Technological Advancements

Machine learning-aided ray tracing has been proposed to improve the efficiency of radio propagation modeling in PTP systems. This approach reduces computational load by prioritizing potentially valid paths, maintaining high accuracy while scaling linearly with scene complexity [4].

Photonic-assisted systems have been developed for instantaneous frequency measurement, offering fast response times and high accuracy over wide frequency ranges. These systems can enhance the performance of PTP microwave links by providing precise frequency measurements [5].

Environmental and Network Considerations

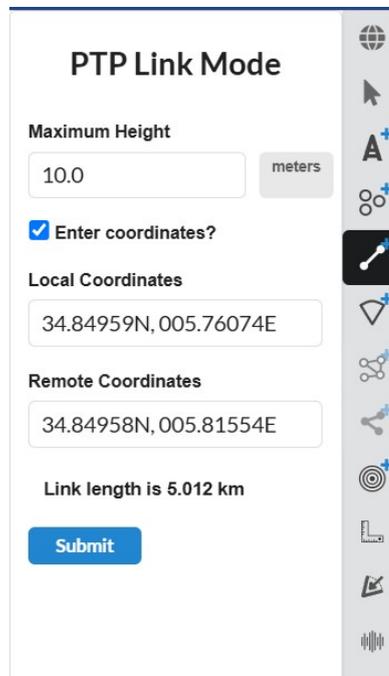
Fixed wireless access (FWA) applications utilize PTP microwave links to provide internet connectivity, creating a wireless mesh network. The performance of these networks depends on the radio propagation characteristics and the wireless technology used [3].

Network planning algorithms are essential for defining routes and ensuring that the available capacity of wireless links is utilized effectively. These algorithms consider factors such as the location of customer devices and the number of subscribers [3].

While PTP microwave systems offer numerous advantages, including high data rates and reliability, they also face challenges such as path loss at higher frequencies and environmental interference. Advances in antenna design, frequency measurement, and

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network planning are crucial for overcoming these challenges and optimizing the performance of PTP microwave links. Furthermore, the amalgamation of machine learning methodologies in radio propagation modeling signifies a promising trajectory for forthcoming inquiry and advancement in this domain.



The screenshot displays the 'PTP Link Mode' interface. It features a title 'PTP Link Mode' at the top. Below the title, there is a 'Maximum Height' section with a text input field containing '10.0' and a 'meters' unit selector. A checkbox labeled 'Enter coordinates?' is checked. The 'Local Coordinates' section has a text input field with '34.84959N, 005.76074E'. The 'Remote Coordinates' section has a text input field with '34.84958N, 005.81554E'. Below these fields, it states 'Link length is 5.012 km'. A blue 'Submit' button is located at the bottom. On the right side, there is a vertical toolbar with various icons: a globe, a mouse cursor, a letter 'A' with a plus sign, a network diagram icon, a link icon, a target icon, a right-angle symbol, a graph icon, and a signal strength icon.

Figure III- 2 PTP Link Mode

- **Maximum height:** It is the height of the tower where the microwave signal antenna is installed.
- **Local coordinates:** It is the coordinates of the first point.
- **Remote coordinates:** It is the coordinates of the second point.

III.3.2. Project Manager

III.3.2.1. Network Site

Here, the name is changed, and the geographical location of any point added is determined.

Name	Latitude	Longitude	Maximum Height (m)	Description	Node Type	PTP Links	PMP Network Devices	Mesh Links	Number of Subscriber Modules	Conne... Subscr...	Uncon... Subscr...	Tot DL
Network Site 002	34.85166N	005.77672E	10.0				1	0	0	0	0	0
Network Site 004	34.85166N	005.77672E	15.0				1	0	0	0	0	0
Network Site 006	34.85166N	005.77672E	20.0				1	0	0	0	0	0
Network Site 008	34.85166N	005.77672E	30.0				1	0	0	0	0	0
Network Site 010	34.85166N	005.77672E	100.0				1	0	0	0	0	0
Subscriber Site 001	34.84642N	005.74560E	15.0				1	0	0	0	0	0
Subscriber Site 001	34.84642N	005.74560E	10.0				1	0	0	0	0	0
Subscriber Site 001	34.84642N	005.74560E	30.0				1	0	0	0	0	0
Subscriber Site 001	34.84642N	005.74560E	100.0				1	0	0	0	0	0
Subscriber Site 001	34.84642N	005.74560E	20.0				1	0	0	0	0	0

Figure III- 3 Network Site

Name: Geographical Point Name.

Latitude:

Latitude is a geographic coordinate that specifies the north-south position of a point on the Earth's surface. Measured in degrees, latitude uses the equator as the zero-degree reference line, dividing the Earth into the Northern and Southern Hemispheres. The values of latitude range from 0° at the equator up to 90° at the poles, with the North Pole located at 90°N and the South Pole at 90°S . Lines of latitude, also called parallels, are imaginary circles that run parallel to the equator and remain equidistant from each other, unlike lines of longitude which converge at the poles. Latitude plays a significant role in influencing climate and weather patterns around the world. Regions near the equator generally experience warmer temperatures due to the more direct angle of sunlight, whereas areas closer to the poles have colder climates because sunlight strikes the surface at a lower angle. Understanding latitude is essential in geography and navigation, as it provides a foundational framework for locating positions on Earth, enabling effective global communication, mapping, and travel.

This value can be effortlessly obtained by numerous mapping and geographic instruments, such as Google Earth, Google Maps, or any GPS-enabled apparatus that provides precise location data. Users can determine the exact latitude of any location in real-time by entering an address or utilizing a map interface, thereby making it an indispensable tool for the precise installation of communication towers at the specified point. [6]

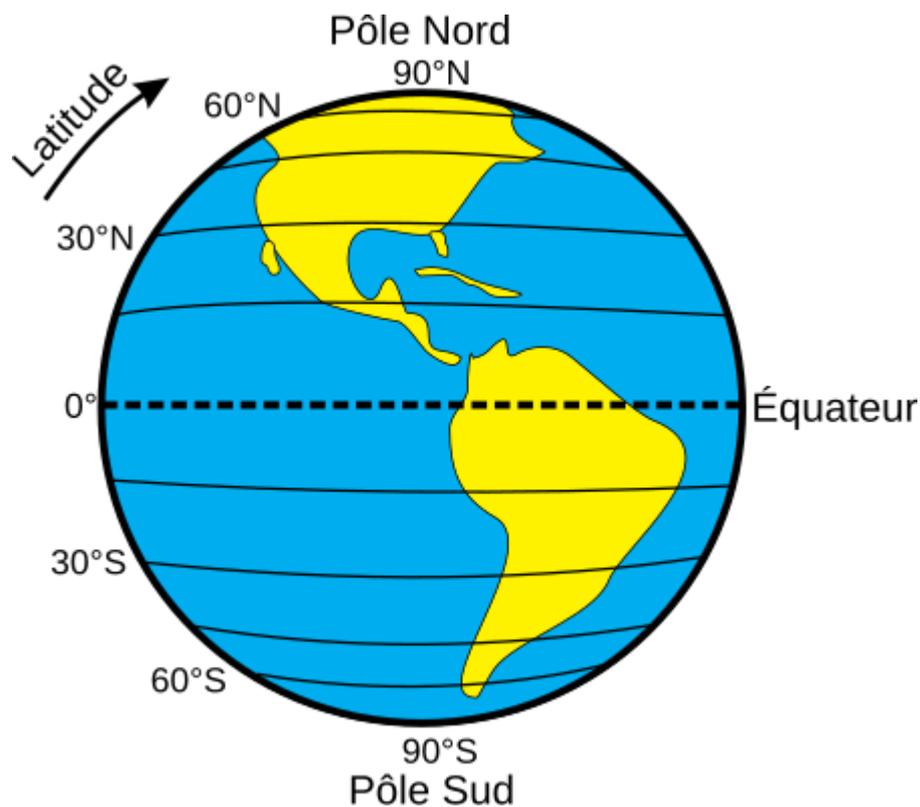


Figure III- 4 latitude

Longitude

Longitude is a geographic coordinate that specifies the east-west position of a point on the Earth's surface. Quantified in degrees, longitude employs the prime meridian located at Greenwich, England, as the zero-degree reference line, partitioning the Earth into the Eastern and Western Hemispheres. The values of longitude stretch from 0° at the prime meridian, reaching $+180^\circ$ in the eastern direction and -180° in the western direction. Lines of longitude, also called meridians, are great circles running from the North Pole to the South Pole, converging at the poles unlike the parallel lines of latitude. Longitude, in conjunction with latitude, constitutes the foundation of the geospatial coordinate framework imperative for precise navigation across maritime, aerial, and terrestrial domains.

This coordinate can be easily obtained through many geographic tools and mapping services such as Google Maps, Google Earth, or GPS-enabled devices that provide exact location data in real-time. Such precise longitude measurements are indispensable in applications including the installation and alignment of communication infrastructure,

Simulation and Its Real-World Application

ensuring that structures like communication towers are placed accurately at their intended locations.[6]

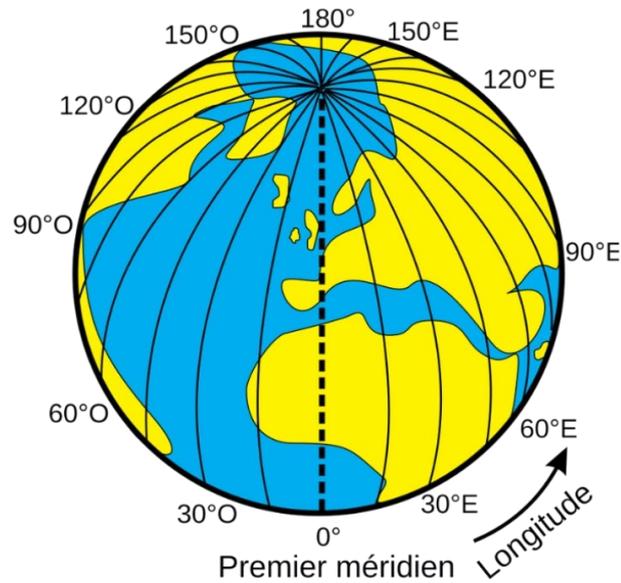


Figure III- 5 longitude

III.3.2.2. PTP links

Name	Range (km)	Band	Product	Regulation	Link Availability
Central University of Biskra to Chetma University Campu...	2.905	5.8 GHz	PTP 670	Other	0.000
Subscriber Site 001 to Network Site 004	2.905	5.8 GHz	PTP 670	Other	0.000
Subscriber Site 001 to Network Site 006	2.905	5.8 GHz	PTP 670	Other	99.993
Subscriber Site 001 to Network Site 008	2.905	5.8 GHz	PTP 670	Other	100.000
Subscriber Site 001 to Network Site 010	2.905	80 GHz	PTP 850EX-P (preliminary)	FCC	99.999

Figure III- 6 PTP Links

Name: Name of the site or the two sites.

Range (km): Distance or range in kilometers.

Band:

The frequency bands supported by the LINKPlanner software range from as low as 900 MHz up to 80 GHz. These bands are categorized into standardized segments commonly used in wireless communications:

- Sub-1 GHz Band: 900 MHz
- 2 GHz Band: 2.4 GHz, 2.5 GHz
- 3 GHz Band: 3.5 GHz, 3.6 GHz
- 4 GHz Band: 4.7 GHz, 4.8 GHz, 4.9 GHz
- 5 GHz Band: 5.1 GHz, 5.2 GHz, 5.3 GHz, 5.4 GHz, 5.8 GHz, 5.9 GHz
- Lower 6 GHz Band: approximately 6 GHz range, Lower segment
- Upper 6 GHz Band: approximately 6 GHz range, Upper segment
- 7 GHz Band: 7 GHz
- 8 GHz Band: 8 GHz
- 10 GHz Band: 10 GHz, 11 GHz, 13 GHz, 15 GHz
- 18 GHz Band: 18 GHz
- 23 GHz Band: 23 GHz, 24 GHz, 26 GHz, 28 GHz
- 32 GHz Band: 32 GHz, 38 GHz
- 60 GHz Band (V-band): 60 GHz
- 80 GHz Band (E-band): 80 GHz

This wide range of supported frequency bands, reaching up to the E-band at 80 GHz, allows LINKPlanner to model and optimize wireless links for a broad spectrum of applications, including both sub-6 GHz conventional bands and millimeter-wave high-frequency bands used for high-capacity, short-range communications.

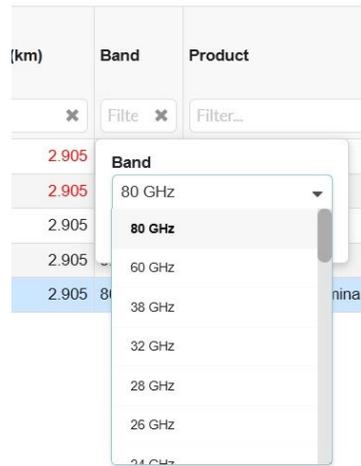


Figure III- 7 Band

Product:

In the devices offered by Cambium Networks, the Outdoor Unit (ODU) provides an integrated solution that combines both the antenna and radio transceiver within a single external enclosure, ensuring streamlined installation, enhanced durability, and optimized performance in various deployment environments.

Why Is the Antenna Square (Flat Panel) Instead of Circular (Parabolic Dish)?

Traditional antennas often use parabolic dish designs, which are circular and highly effective at focusing signals with great gain. However, these dishes require mechanical adjustment to change the direction of the beam, a process that can be slow and labor-intensive.

In contrast, square or flat panel antennas, often implemented as phased array systems, represent a modern technological advancement. These antennas allow for electronic beam steering, meaning the signal direction can be changed electronically without any physical movement of the antenna.

This electronic steering capability offers significant advantages, including much faster installation and alignment, as well as more precise control over the signal direction. Such features are especially valuable in environments where quick deployment and frequent adjustments are necessary.

Simulation and Its Real-World Application

Therefore, the use of a square or flat panel antenna reflects the adoption of advanced and cutting-edge technology that improves both operational efficiency and network performance.

➤ Band	5.8 GHz	38 GHz	80 GHz	
Equipment for point-to-point link	PTP 450b Connectorized	PTP 820G with RFU-C	PTP 850E	
	PTP 450b High Gain			
	PTP 450b Mid-gain	PTP 820S	PTP 850EX (preliminary)	
	PTP 450b Retro			
	PTP 450i			
	PTP 450i ATEX/HAZLOC			
	PTP 670			
	PTP 670 ATEX/HAZLOC			
	PTP 700 BSA			PTP 850EX-P (preliminary)
	PTP 700 C+I			
	PTP 700 C-Only			
	PTP 450 (retired)			

Table III- 1: Equipment for point-to-point link

➤ PTP 700:

- The PTP 700 Beam Steering is a next-generation point-to-point wireless device operating in the same sub-6 GHz spectrum but featuring advanced **electronic beam steering** technology.
- It utilizes a phased array antenna composed of multiple individual antenna elements that allow rapid and precise electronic steering of the RF beam without mechanical movement.
- Benefits include simplified and faster link alignment, enhanced interference mitigation through null steering, and improved link performance with better spectral efficiency.
- The device covers $\pm 60^\circ$ azimuth electronically and supports automatic alignment processes that include coarse and fine scans to optimize beam direction.
- It uses **AES 128-bit and 256-bit encryption compliant with FIPS-197** to guarantee data confidentiality and security during transmission.
- Weighing approximately 9.1 kg and consuming about 40W of power, the PTP 700 Beam Steering offers reduced weight and power consumption compared to mechanical positioners.
- It is designed for harsh environments and tactical installations requiring quick setup, stable connectivity, and secure communications. [7]



Figure III- 8 PTP 700

➤ PTP 670:

- The PTP 670 is a fixed wireless backhaul solution operating in the 4.9 to 6.05 GHz frequency band, designed to deliver up to 450 Mbps aggregate throughput.
- It features an integrated flat panel antenna with 23 dBi gain or can be used with external connectorized antennas.
- The system employs Dynamic Spectrum Optimization (DSO) to continuously select the best channel for minimizing interference and maximizing link reliability.
- It supports Time Division Duplex (TDD) with adaptive modulation ranging from BPSK to 256 QAM for optimal throughput under varying conditions.
- The unit uses **AES 128-bit and 256-bit encryption compliant with FIPS-197** standards to ensure secure data transmission.
- The PTP 670 unit is rated for harsh environments with IP66/67 protection and operates in temperatures from -40°C to 75°C.
- Typical applications include small-cell backhaul, video surveillance, LTE macro and small-cell connectivity, disaster recovery, and last-mile access.[8]



Figure III- 9 PTP 670

➤ **PTP 850EX-P (preliminary):**

- The **PTP 850EX** operates in the millimeter-wave frequency bands of **71–76 GHz and 81–86 GHz**, supporting extremely high throughput suitable for carrier-grade wireless backhaul solutions.
- It offers advanced modulation techniques up to **1024 QAM** combined with Adaptive Coding and Modulation (ACM), enabling dynamic adjustment of link parameters to maximize spectral efficiency and maintain robust connections in varying conditions.
- The radio supports multiple channel bandwidths (250 MHz to 2 GHz), allowing scalable capacity with throughput up to **10 Gbps**, meeting the growing demand for high-capacity wireless links.
- Security-wise, the PTP 850EX includes **secure management protocols such as HTTPS, SNMPv3, SSH, and SFTP**, alongside authentication systems including **RADIUS and TACACS+**, ensuring secure device access and management.
- Although explicit details on radio link-layer encryption are not provided, the device's adherence to Cambium Networks' security standards strongly suggests the implementation of **AES-based encryption** to protect data integrity and confidentiality.
- The PTP 850EX complies with strict industry standards for electromagnetic compatibility (EMC), safety, and ingress protection, notably an **IP67 rating**, making it suitable for deployment in harsh environmental conditions.
- It integrates advanced networking features including support for VLANs, Quality of Service (QoS), and redundancy configurations (1+0, 2+0 XPIC, 1+1 HSB), enhancing reliability and flexibility in service provider networks.
- The device is designed for outdoor installation with robust environmental tolerance, operating within temperature ranges of **-40°C to +55°C** and equipped with rugged hardware dimensions for ease of deployment. [9]



Figure III- 10 PTP 850EX-P

➤ **PTP 820S**

- Operates within the 6–38 GHz frequency band.
- Supports advanced modulation techniques up to 2048 QAM combined with Adaptive Coding and Modulation (ACM) for dynamic link optimization.
- Supports protection configurations such as 1+0, 1+1 Hot Standby (HSB), and 2+0 Single/Dual Path for enhanced network reliability.
- Equipped with multiple Ethernet interfaces including 10/100/1000Base-T and SFP ports.
- Management protocols include SNMP, REST APIs, and SDN support (NETCONF/YANG).
- Supports up to 4,000 VLANs and offers Quality of Service (QoS) with 8 priority queues and deep buffering to reduce latency and packet delay variation.
- Complies with stringent industry standards for EMC, ingress protection (IP66), and safety (IEC 60950 series, UL, CSA).
- Operates in harsh outdoor environments with a temperature range of -33°C to +55°C (extendable to -45°C to +60°C).
- Power consumption ranges up to 42 watts depending on frequency and configuration.
- Implements AES 256-bit encryption with secure management protocols including HTTPS, SNMPv3, SSH, and SFTP.

- Supports authentication via RADIUS and TACACS+ for secure device access. [10]



Figure III- 11 PTP 820S

Regulation: This refers to the governing bodies and their established rules or authorizations that permit organizations or companies to operate wireless equipment on specific frequency bands. For example, in Algeria, the national regulatory authority, ARPT grants such permissions, while in the United States, the Federal Communications Commission (FCC) is responsible for regulating the use of radio frequencies. These regulations ensure orderly use of the spectrum, prevent interference, and guarantee compliance with safety and technical standards. A detailed discussion of these regulatory frameworks was provided in Chapter One.

Link Availability: Is Expressed as A Percentage Indicating the Likelihood That a Wireless Link Will Be Available and Maintain a Stable Connection. A Value Of 100% Means the Link Is Always Available Without Interruption, while 0% Means There Is No Connectivity at All. In Real-World Scenarios, Link Availability Is Affected by Physical Obstacles Such as Mountains, Tall Buildings, And the Distance Between Communication Points. These Factors Can Cause Signal Degradation, Reflection, Or Blockage, Which Reduce the Availability Percentage. Understanding Link Availability Helps Network Planners Assess How Reliable a Wireless Connection Will Be In A Given Environment And Optimize The Design Accordingly.



Aggregate Throughput (Mbps):

Total data transfer rate in megabits per second. This metric indicates the maximum combined speed at which data can be transmitted over a wireless link. It is a critical factor in evaluating the performance of Point-to-Point (PTP) wireless communication products, reflecting their capacity to handle bandwidth-intensive applications efficiently.

PRODUCT	APPROXIMATE MAX THROUGHPUT (MBPS)
PTP 850EX-P (PRELIMINARY)	~10 Gbps
PTP 670	600 Mbps – 1 Gbps
PTP 700	1,000 Mbps (1 Gbps)
PTP 820 S	Up to approximately 2,000 Mbps (2 Gbps)

Table III- 2: Aggregate Throughput PTP

- ✚ **Link Loss (dB):** Signal loss over the link in decibels.
- ✚ **Left Height (m):** Antenna height at the left site in meters.
- ✚ **Right Height (m):** Antenna height at the right site in meters.

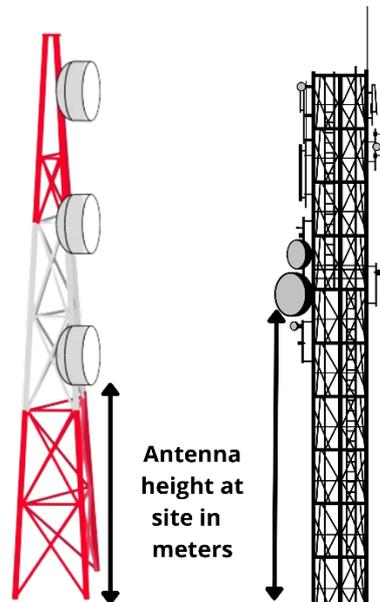


Figure III- 12 Left and Right Height

- ✚ **Left Gain (dBi):** Antenna gain at the left site in decibels.
- ✚ **Right Gain (dBi):** Antenna gain at the right site in decibels.

III.3.2.3. PMP

It contains three elements, each task element has elements Network, Devices Mesh Links, PMP Links:

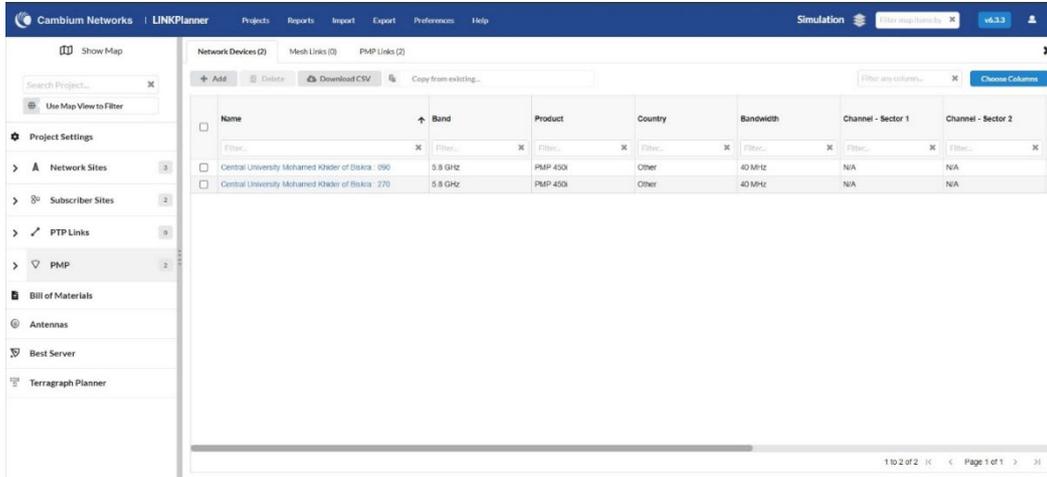


Figure III- 13 PMP

III.3.2.3.1. Network Devices

Network devices include signal transmission units designed to broadcast signals over long distances. For example, four such transmission devices can be arranged in a triangular formation to create a circular coverage area, enhancing network reach and connectivity.

-  **Name:** Name of the site or link
-  **Band:** Frequency band used
-  **Product:** Name of the product or device used

 Band	 5.8 GHz
Equipment for long-distance signal transmission	PMP 450i
	PMP 450 MicroPop
	PMP 450i ATEX/HAZLOC
	PMP 450 (retired)
	PMP 450v 4x4 (preliminary)
	PMP 450m

Table III- 3: Equipment for long-distance signal transmission

- PMP 450i
 - The PMP 450i radios are signal transmission devices designed to provide reliable wireless broadband communication.
 - Maximum Signal Range: The devices support deployment ranges up to 64 kilometers, depending on environmental conditions and configuration.
 - Frequency Bands: Operate in ultra-wide bands of either 3 GHz or 5 GHz.
 - Physical Design: Rugged metal enclosure compliant with IP-66 and IP-67 standards, suitable for harsh environments; optional ATEX/HAZLOC certification for hazardous locations.
 - Radio Performance: Utilizes 2x2 OFDM MIMO technology capable of delivering up to 300 Mbps per sector within a 40 MHz channel.
 - Antenna Options: Available with integrated sector antennas at 10°, 90°, and 120° azimuth angles, optimized for frequency reuse and high gain.
 - Network Interfaces: Support for 100/1000BaseT Ethernet with full duplex and auto-negotiation.
 - Network Protocols: Compatible with IPv4 and IPv6, supporting standard protocols including UDP, TCP/IP, ICMP, Telnet, SNMP, HTTP, and FTP.
 - Management: Supports IPv4/IPv6 dual stack with HTTPS, SNMPv2c/v3, and Cambium Networks' cnMaestro network management system.
 - Power and Protection: Typical power consumption around 15W; input voltage range from 48 to 59 V DC (802.3at PoE compatible). Built-in surge protection compliant with EN61000-4-5.
 - Environmental Tolerance: Operating temperature from -40°C to +75°C with 0–100% condensing humidity; capable of withstanding high wind speeds up to 322 km/h.
 - Performance Metrics: Adaptive modulation from QPSK to 256QAM, maximum deployment ranges up to 64 km, and low latency typically between 3 to 5 ms.

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- Security: Supports FIPS-197 AES encryption at 128-bit and 256-bit (256-bit requires an optional license).
- Software and Upgrades: Software Defined Radio (SDR) platform allows for flexibility and future enhancements; supports advanced interference mitigation features.
- Deployment Tools: Complemented by LINKPlanner software for accurate link planning, network simulation, and performance prediction.
- Advanced Models: PMP 450v series offers operation in the 5.15 to 7.125 GHz range with 4x4 MIMO, channel aggregation, and throughput capacities up to 1.5 Gbps.
- Subscriber Modules: Available in 2x2 and 4x4 MIMO configurations, supporting multiple channel bandwidths with capacities ranging from 300 Mbps to over 900 Mbps.
- GPS and AFC Support: Devices designed to operate with Automated Frequency Coordination (AFC) using GPS-based location data for 6 GHz spectrum usage compliance.
- Integration: Works seamlessly with Cambium's cnPilot, cnMatrix, and cnMaestro platforms for comprehensive network management and monitoring.[11]



Figure III- 14 PMP 450i

III.3.2.3.2. PMP LINKs

Name: Identifier or name of the subscriber site

Product: The product or device model used at the subscriber site

Subscriber Module Equipment: These are devices installed at customer locations that receive wireless signals from a central access point. They enable connectivity in Point-to-Multipoint (PMP) wireless networks by acting as endpoints for data transmission.

➤ Product	➤ Subscriber Module
Subscriber Module Equipment	PMP 450b High Gain
	PMP 450b Connectorized
	PMP 450b Mid-gain
	PMP 450b Omni
	PMP 450b Retro
	PMP 450i
	PMP 450i ATEX/HAZLOC
	PMP 450v 2x2 (preliminary)
	PMP 450v 4x4 (preliminary)
	PMP 450 (retired)
	PMP 450d (retired)

Table III- 4: Subscriber Module Equipment

➤ PMP 450b High Gain

Interface and Connectivity:

- Gigabit Ethernet interface supporting 100/1000 BaseT full duplex with auto-negotiation.
- Supports IPv4 and IPv6 protocols alongside UDP, TCP/IP, ICMP, Telnet, SNMP, HTTP, and FTP.
- Network management via Cambium Networks cnMaestro™, supporting SNMPv2c and v3, HTTP/HTTPS, Telnet, and FTP.

Radio and Frequency:

Simulation and Its Real-World Application

- Operates in the ultra-wide frequency band from 4.9 GHz to 5.9 GHz.
- Channel width configurable at 5, 10, 15, 20, 30, or 40 MHz.
- Channel spacing adjustable in 2.5 MHz increments.
- 2x2 MIMO OFDM physical layer.

Performance:

- Maximum aggregate throughput up to 300 Mbps in a 40 MHz channel.
- Packet processing capability over four times greater than the previous 450 subscriber module.
- Adaptive modulation levels: QPSK, 16QAM, 64QAM, and 256QAM, requiring SNR from 10 dB up to 32 dB.
- Ultimate sensitivity: -94 dBm.
- Maximum deployment range: up to 64 km in point-to-multipoint mode, and up to 200 km in point-to-point mode.
- Typical latency between 3 and 5 milliseconds.
- Supports Automatic Repeat reQuest (ARQ) for improved reliability.
- Supports DiffServ Quality of Service (QoS).

Security:

- Encryption using FIPS-197 compliant 128-bit and 256-bit AES, with optional licenses for attached access points.
- Antenna Options:
 - Available in Mid-Gain (17 dBi) and High-Gain (24 dBi) integrated antennas, plus connectorized versions.
 - Mid-Gain antenna: 15° azimuth beamwidth, 30° elevation beamwidth.
 - High-Gain antenna: 7° azimuth and elevation beamwidths.
- Dual linear polarization (Horizontal + Vertical).

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- Front-to-back isolation > 20 dB (mid-gain), > 25 dB (high-gain).
- Physical and Environmental:
- Operating temperature range: -40°C to +60°C.
- Humidity tolerance: 0 to 100% non-condensing.
- Environmental ratings: IP67 for connectorized model, IP55 for integrated antennas.
- Wind survival: up to 200 kph.
- Device weights: 0.6 kg (mid-gain), 0.9 kg (connectorized), 3.1 kg (high-gain).
- Dimensions vary according to antenna type.

Power:

- Input voltage range: 20 to 32 V DC.
- Typical power consumption: 9 W (12 W peak).
- Supports Automatic Transmit Power Control (ATPC).

Certifications:

- Complies with regional regulatory certifications including FCC, ISED Canada, and ETSI EN standards.



Figure III- 15 PMP 450b High Gain 24 dBi

Simulation and Its Real-World Application

- SM Height (m): Height of the subscriber module antenna in meters
- SM Rx Max Usable Mode: Maximum usable receive modulation and coding scheme at the subscriber module
- ND Rx Max Usable Mode: Maximum usable receive modulation and coding scheme at the network device or access point
- SM Antenna: Type/model of antenna used at the subscriber module
- SM Latitude: Latitude coordinate of the subscriber site
- SM Longitude: Longitude coordinate of the subscriber site
- Link Loss (dB): Total signal loss in decibels over the wireless link

III.4.Point-to-Point “PTP” (P2P)

III.4.1.Link between Central University and Chetma Campus

III.4.1.1.Site

It is the geographical location of these points.

Name	Central University Mohamed Khider of Biskra	Chetma Campus
Latitude	34.84562N	34.85028N
Longitude	5.75068E	5.77263E

Table III- 5: geographical location PTP

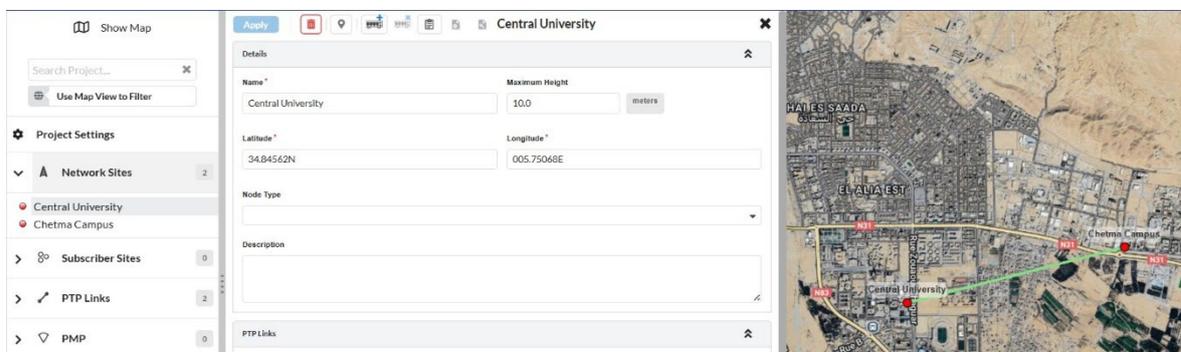


Figure III- 16 Central University

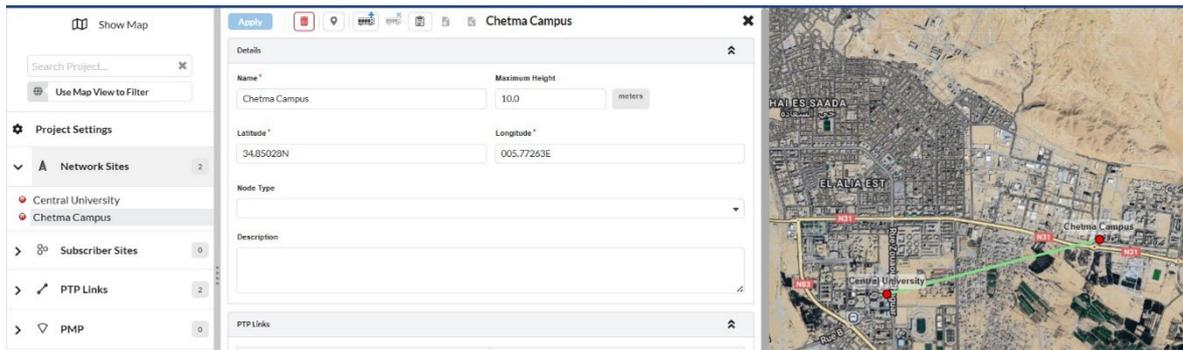


Figure III- 17 Chetma Campus

III.4.1.2.Product Used

Link between Central University and Chetma Campus	
Frequency Band	Product
5.8GHz	PTP 670
38GHz	PTP 820S
80GHz	PTP 850EX-P

Table III- 6: Product Used

III.4.1.3.Antenna Height

Product	Name	Central University	Chetma Campus	results
		Mohamed Khider of Biskra		
		Left Height (m)	Right Height (m)	
PTP 670	Antenna Height	10 – 20 m	10 – 20 m	(NLos)
PTP 670		21 – 23 m	21 m	(nLos)
PTP 670		24 m	21 m	(Los)
PTP 820S		22 m	21 m	(Los)
PTP 850EX-P		24 m	21 m	(Los)

Table III- 7: Antenna Height

III.4.1.4.Results

III.4.1.4.1. Non-Line of Sight (NLOS) Connection Using PTP 670

This section discusses the non-line of sight (NLOS) condition observed between the two points: the Central University Mohamed Khider of Biskra and the Chetma Campus. The absence of a direct visual connection is primarily due to the insufficient height of the tower on which the antenna unit is mounted. Consequently, this results in signal disruption caused by obstructions along the visual line of sight path, impacting the reliability of the microwave link.

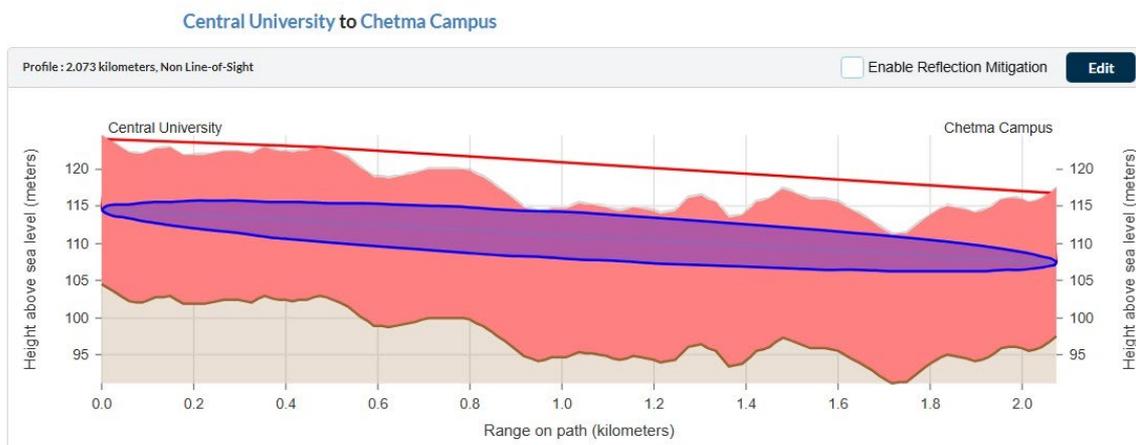


Figure III- 18 Non-Line of Sight (NLOS) Central University to Chetma Campus

III.4.1.4.2. Near-Line of Sight (nLOS) Connection Using PTP 670

This section addresses the near-line of sight (nLOS) connection established between the Central University Mohamed Khider of Biskra and the Chetma Campus using the PTP 670 system. In this case, the antenna units have a partial visual connection, with minor obstructions that may slightly affect signal quality. Despite these obstructions, the link maintains reliable performance due to adaptive modulation and error correction capabilities inherent in the PTP 670 equipment.

Simulation and Its Real-World Application

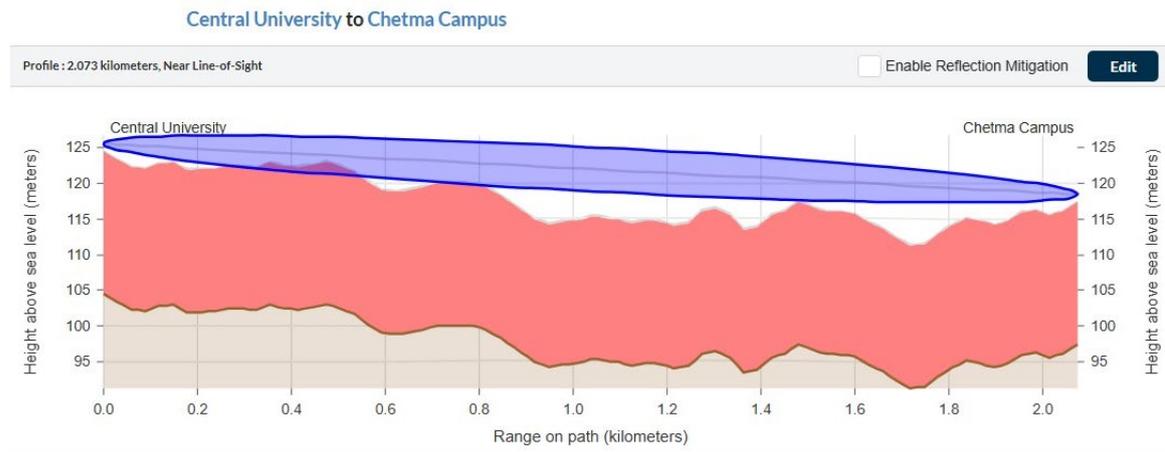


Figure III- 19 Near-Line of Sight (nLOS) Central University to Chetma Campus

Important Results and Conclusions:

- The link shows excellent IP availability at 100%, indicating highly reliable connectivity.
- The substantial system gain and gain margin suggest a robust setup capable of maintaining signal integrity over the 2.073 km distance.
- The use of a 5.8 GHz band with adaptive modulation helps achieve a high data rate of 450.98 Mbps, suitable for high-demand applications.
- The minimal annual link unavailability of just 1 second per year highlights the system's effectiveness and reliability in maintaining continuous service.
- The prediction model used, ITU-R P.530-17, supports the accuracy of these performance predictions under typical conditions.

Simulation and Its Real-World Application

	Performance to Central University	Performance to Chetma Campus
Mean IP	225.49 Mbps	225.49 Mbps
IP Availability	100.0000 % for 1.0 Mbps	100.0000 % for 1.0 Mbps

Link Summary			
Link Length	2.073 km	System Gain	161.28 dB
Band	5.8 GHz	System Gain Margin	39.08 dB
Regulation	Other	Mean Aggregate Data Rate	450.98 Mbps
Modulation	Adaptive	Annual Link Availability	100.0000 %
Bandwidth	45 MHz	Annual Link Unavailability	1 secs/year
Total Path Loss	122.20 dB	Prediction Model	ITU-R P.530-17

Figure III- 20 Results of Near-Line of Sight (nLOS) Connection Using PTP 670

III.4.1.4.3. Line of Sight (LOS) Connection Using PTP 670

This section describes the line of sight (LOS) connection established between the Central University Mohamed Khider of Biskra and the Chetma Campus using the PTP 670 system. The direct visual path between antenna units ensures optimal signal strength and minimal interference, resulting in high-quality and reliable communication. The LOS condition is ideal for microwave links and maximizes system performance.

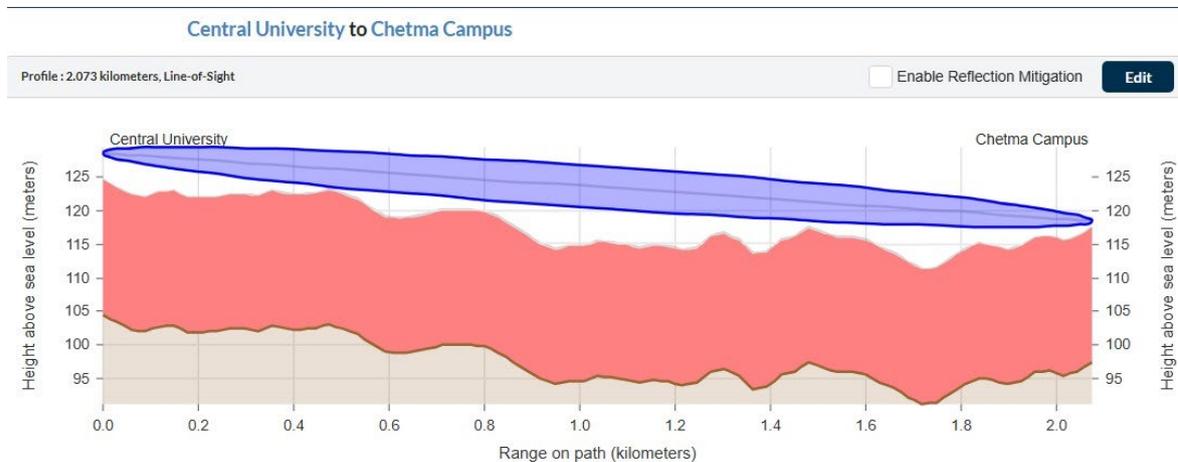


Figure III- 21 line of sight (LOS) Central University to Chetma Campus

Important Results and Conclusions:

- The link shows **high reliability and robustness**, with an **annual availability of 100.0000%** and only **1 second of unavailability per year**.
- The **total link length** is **2.073 km**.
- The system operates in the **5.8 GHz frequency band**.

- **Modulation is adaptive**, and the regulation type is classified as “**Other**”.
- The link has an available **bandwidth of 45 MHz**.
- The **total path loss** experienced is **114.07 dB**.
- The **system gain** is **161.28 dB**, providing a **gain margin of 47.21 dB**, which indicates strong signal strength and resilience against potential losses.
- The **mean aggregate data rate** achieved is **451.71 Mbps**, reflecting high capacity.
- Identical performance metrics at both sites confirm a **symmetric and well-maintained network infrastructure**.
- All performance and availability predictions are based on the **ITU-R P.530-17 model**.
- The use of the **5.8 GHz band combined with adaptive modulation** optimizes the link for **high data rates and efficient bandwidth usage**, suitable for high-demand applications.

	Performance to Central University	Performance to Chetma Campus
Mean IP	225.86 Mbps	225.86 Mbps
IP Availability	100.0000 % for 1.0 Mbps	100.0000 % for 1.0 Mbps

Link Summary			
Link Length	2.073 km	System Gain	161.28 dB
Band	5.8 GHz	System Gain Margin	47.21 dB
Regulation	Other	Mean Aggregate Data Rate	451.71 Mbps
Modulation	Adaptive	Annual Link Availability	100.0000 %
Bandwidth	45 MHz	Annual Link Unavailability	1 secs/year
Total Path Loss	114.07 dB	Prediction Model	ITU-R P.530-17

Figure III- 22 Results of line of sight (LOS) Connection Using PTP 670

III.4.1.4.4. Line of Sight (LOS) Connection Using PTP 820S

This section discusses the line of sight (LOS) connection between the Central University Mohamed Khider of Biskra and the Chetma Campus, established using the PTP 820S system. The clear visual path between the antenna units allows for high-capacity data transmission with minimal signal loss and interference. The PTP 820S equipment leverages advanced modulation techniques to maintain robust and efficient communication over this LOS link.

Simulation and Its Real-World Application

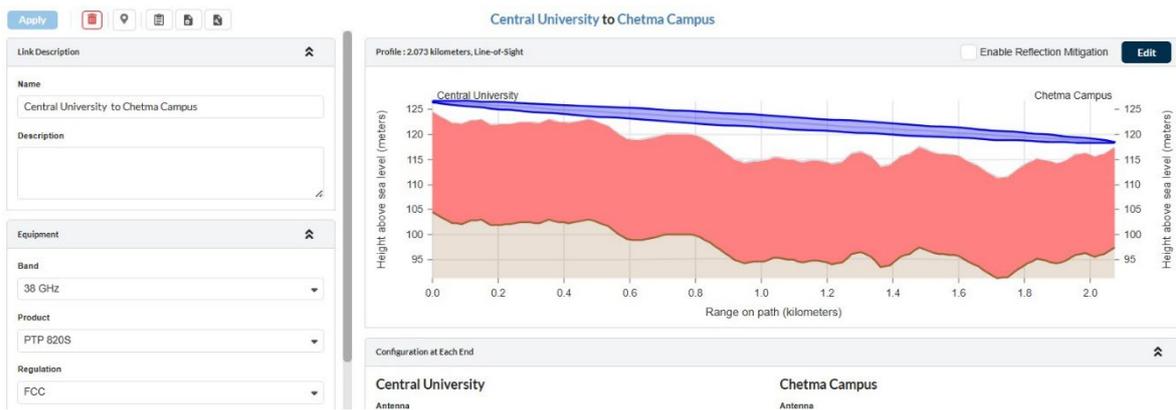


Figure III- 23 line of sight (LOS) Central University to Chetma Campus Using ptp 820s

Important Results and Conclusions:

- **Link Length:** The total distance of the link is 2.073 km.
- **Band and Frequency:** Operates on a 38 GHz band with a bandwidth of 50 MHz
- **Regulation:** Governed by FCC standards.
- **Modulation:** Uses adaptive modulation techniques.
- **System Gain and Loss:** Total path loss is 130.75 dB, with a system gain of 179.50 dB.
- **System Gain Margin:** 48.75 dB.
- **Data Rate and Frame Size:** Mean aggregate data rate is 885.38 Mbps with a frame size of 1518 Bytes.
- **Availability:** Annual link availability is 100.000% with an unavailability of 12 seconds per year.
- **Prediction Model:** Utilizes the ITU-R P.530-17 model for predictions.
- The identical performance metrics at both locations indicate a well-optimized link with consistent quality and service between the two campuses.
- The high system gain combined with low annual unavailability underscores the link's reliability and operational efficiency.

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- The employment of adaptive modulation alongside compliance with FCC regulations ensures robust, flexible communication capabilities.
- The results validate the effectiveness of the ITU-R P.530-17 model in accurately predicting and sustaining high standards of link performance.

	Performance to Central University	Performance to Chetma Campus
Mean IP	442.69 Mbps	442.69 Mbps
IP Availability	100.0000 % for 1.0 Mbps	100.0000 % for 1.0 Mbps

Link Summary			
Link Length	2.073 km	System Gain Margin	48.75 dB
Band	38 GHz	Mean Aggregate Data Rate	885.38 Mbps
Regulation	FCC	Annual Link Availability	100.0000 %
Modulation	Adaptive	Annual Link Unavailability	12 secs/year
Bandwidth	50 MHz	Frame Size	1518 Bytes
Total Path Loss	130.75 dB	Prediction Model	ITU-R P.530-17
System Gain	179.50 dB		

Figure III- 24 Results of line of sight (LOS) Connection Using PTP 820S

III.4.1.4.5. Line of Sight (LOS) Connection Using PTP 850EX-P

This section examines the line of sight (Los) connection established between the Central University Mohamed Khider of Biskra and the Chetma Campus using the PTP 850EX-P system. The unobstructed visual path between the antenna units facilitates high-throughput and low-latency communication. The PTP 850EX-P utilizes advanced radio technologies and adaptive modulation to optimize link stability and performance over this Los connection.

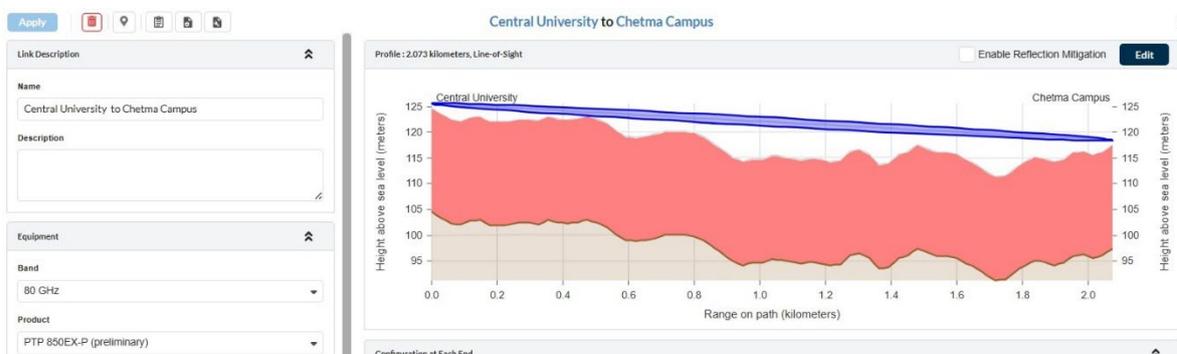


Figure III- 25 line of sight (LOS) Central University to Chetma Campus Using PTP 850EX-P

Important Results and Conclusions:

- **Link Length:** The communication link spans 2.073 km.
- **Frequency Band:** Operates in the 80 GHz frequency band.
- **Modulation:** Uses adaptive modulation to optimize transmission quality.
- **Bandwidth:** Provides a substantial bandwidth of 2000 MHz
- **Total Path Loss:** Recorded at 137.55 dB, indicating signal strength loss over the distance.
- **System Gain:** A high system gain of 183.40 dB helps maintain signal integrity.
- **System Gain Margin:** The system gain margin is 45.85 dB.
- **Data Rate and Availability:** Mean aggregate data rate is 19.999 Gbps with an annual link availability of 99.9999%.
- **Frame Size:** The system uses a frame size of 1518 Bytes.
- **Prediction Model:** Performance metrics are predicted using the ITU-R P.530-17 model.
- The high data rate and near-perfect availability demonstrate a robust infrastructure with efficient data handling capabilities.
- Adaptive modulation combined with wide bandwidth facilitates high throughput and reliable communication over the 2.073 km link.
- The system's high gain and low unavailability (approximately 2.5 seconds per year) emphasize its reliability and effectiveness in maintaining continuous service.
- These characteristics are essential for applications demanding high-speed, reliable data transmission, such as academic and research activities in university environments.

Note:

The code **ITU-R P.530-17** indicates that the simulations were conducted under favorable weather conditions without rain-induced attenuation. This means the wireless link performance was evaluated assuming clear atmospheric conditions, free from precipitation effects that could degrade signal quality.

III.5.Point-to-MultiPoint (PMP)

III.5.1.Link Between the Central University, Chetma Campus, and Hajib Campus

III.5.1.1.Site

It is the geographical location of these points.

Name	Hajib Campus	Central University Mohamed Khider of Biskra	Chetma Campus
Latitude	34.78635N	34.84562N	34.85028N
Longitude	5.58961E	5.75068E	5.77263E

Table III- 8: geographical location PMP

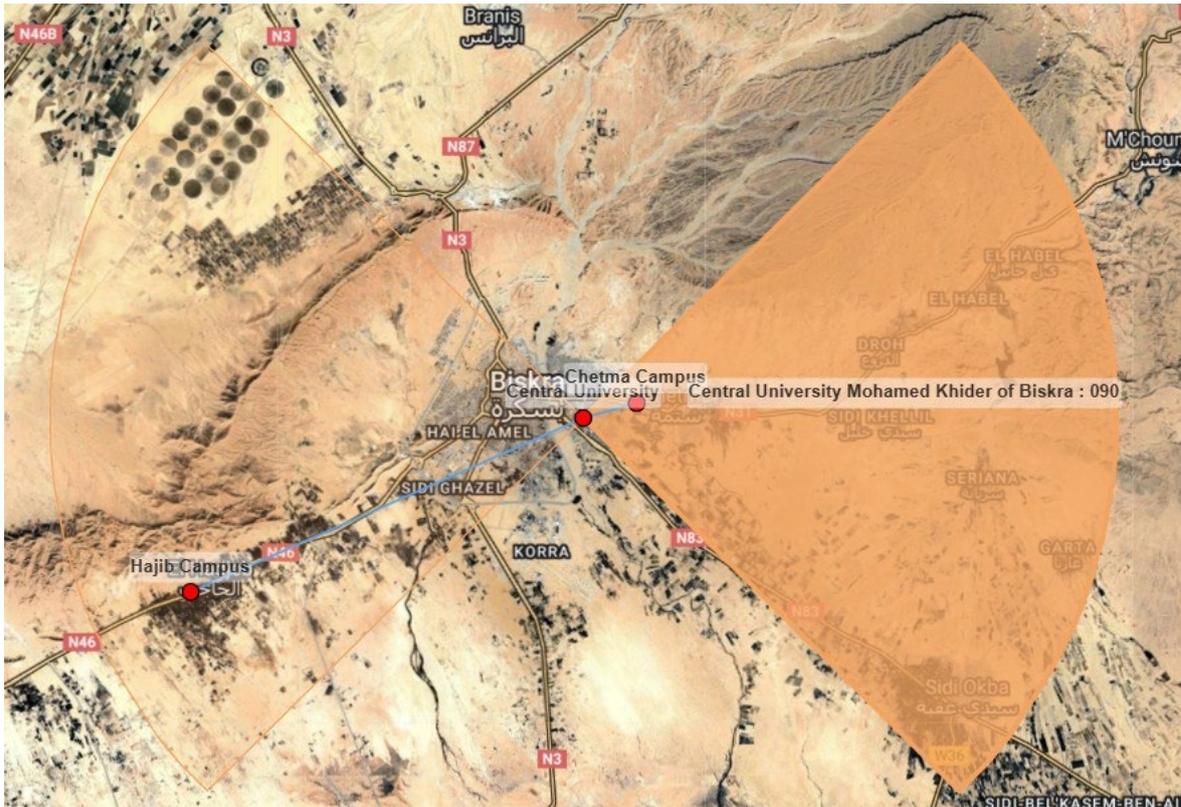


Figure III- 26 Link Between the Central University Chetma Campus

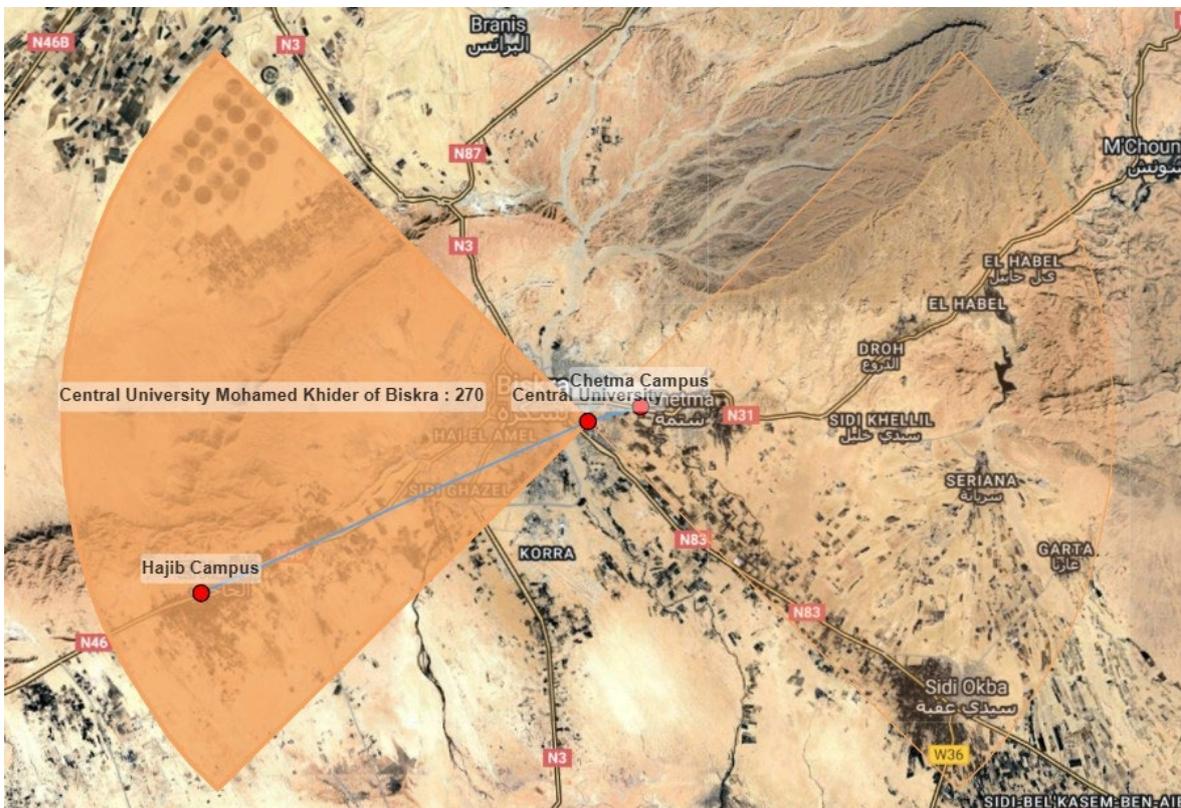


Figure III- 27 Link Between the Central University Chetma Campus

III.5.1.2.Product Used

		Central University, Azimuth 90 °		Central University, Azimuth 270 °	Chetma Campus
Product	PMP 450b High Gain	Frequency Band			PMP 450b High Gain
		5.8GHz			
		PMP 450i	PMP 450i		

Table III- 9 Product Used in PMP

III.5.1.3.Antenna Height

Name	Hajib Campus	Central University, Azimuth 270 °	Central University, Azimuth 90 °	Chetma Campus	results
	Left Height (m)	Middle Left Height (m)	Middle right Height (m)	Right Height (m)	
Product	PMP 450b High Gain	PMP 450i	PMP 450i	PMP 450b High Gain	
Antenna Height	10 – 21 m	10 – 24 m	10 – 19 m	10 – 20 m	(NLos)
	22 – 23 m	25– 28 m	20 – 22 m	21 m	(nLos)
	24 m	29 m	23 m	22 m	(Los)

Table III- 10: Antenna Height

III.5.1.4.Results

III.5.1.4.1. Non-Line of Sight (NLOS) High-Gain Connection Using PMP 450b Between Central University via PMP 450i

This section discusses the Non-Line of Sight (NLOS) condition observed among three points: Central University of Mohamed Khider in Biskra, Chetma Campus, and Hajib Campus. The lack of direct line-of-sight connectivity is primarily due to insufficient tower height where the antenna unit was installed. Consequently, signal interruption occurs because of obstacles along the visible path, adversely affecting the reliability of the microwave link.

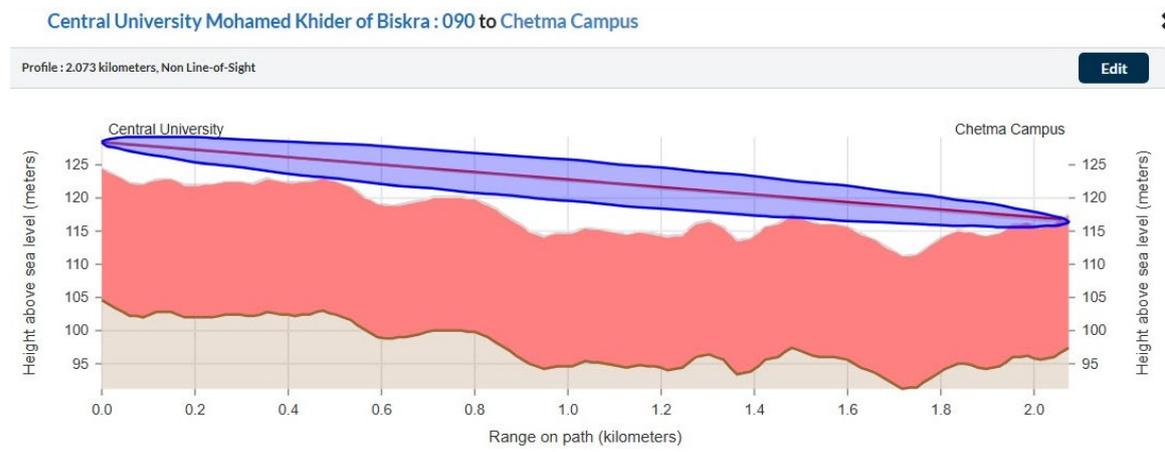


Figure III- 28 Non-Line of Sight (NLOS) Central University Azimuth 90 ° to Chetma Campus

The image is a summary from a research study focusing on a telecommunications setup at Central University Mohamed Khider of Biskra. It details various parameters of a point-to-multipoint (PMP) communication link between the main campus and Chetma Campus.

- **ND Name:** Central University Mohamed Khider of Biskra: 090
- **Site Name:** Central University
- **SM Name:** Chetma Campus
- **Link Type:** Non-Line-of-Sight
- **ND Equipment Type:** PMP 450i (running Release 24.1)
- **SM Equipment Type:** PMP 450b High Gain (running Release 24.1)

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- **Fresnel Zone Clearance:** -0.8 meters
- **Link Distance:** 2.073 kilometers
- **Free Space Path Loss:** 114.09 dB
- **Excess Path Loss:** 17.20 dB
- **RF Frequency Band:** 5.8 GHz (5725 to 5925 MHz)
- **RF Channel Bandwidth:** 40 MHz
- **Downlink Data:** 75 %

Important Results and Conclusions:

- The link operates in a Non-Line-of-Sight (NLOS) environment, which is challenging for maintaining strong signal quality.
- The negative Fresnel Zone Clearance indicates potential obstructions affecting the signal path.
- The RF Frequency Band of 5.8 GHz is typically used for broadband wireless access, suggesting high data throughput capabilities.
- The Excess Path Loss and Free Space Path Loss values are critical for assessing the efficiency and reliability of the link.

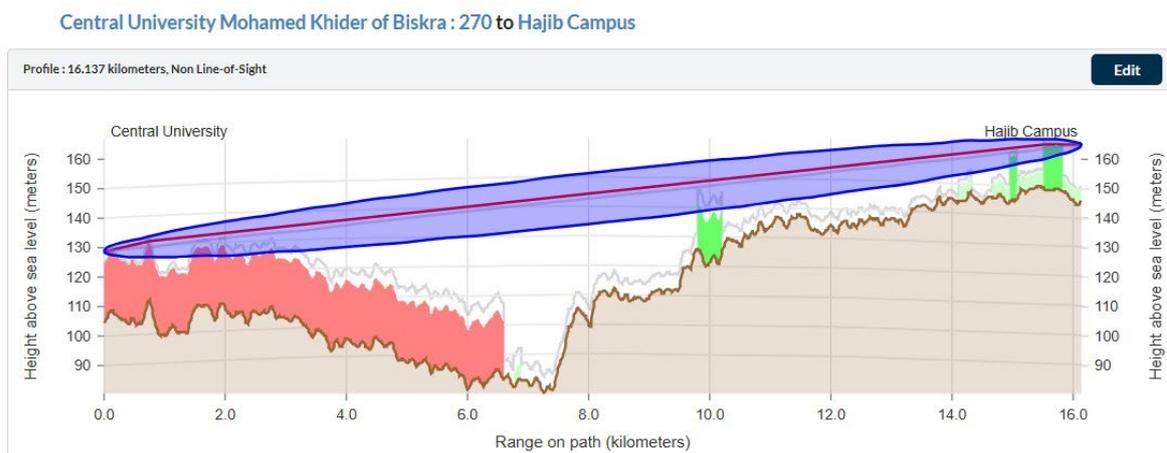


Figure III- 29 Non-Line of Sight (NLOS) Central University Azimuth 270 ° to Hajib Campus

The image is a summary from a research paper detailing the specifications and results of a wireless network setup at Central University Mohamed Khider of Biskra. It provides technical data about the network devices and their performance metrics.

- **ND Name and Site Name:** The network device is located at Central University Mohamed Khider of Biskra, specifically at the Hajib Campus.
- **Link Type:** The connection is a Non-Line-of-Sight (NLoS) type, utilizing PMP 450i equipment for the network device (ND) and PMP 450b High Gain for the subscriber module (SM).
- **Fresnel Zone Clearance:** The clearance is negative, at -5.4 meters, indicating potential obstructions in the signal path.
- **Link Distance and Free Space Path Loss:** The link spans 16.137 kilometers, with a free space path loss of 13.91 dB.
- **Excess Path Loss:** The excess path loss is relatively high at 28.95 dB, suggesting additional attenuation due to environmental factors.
- **RF Frequency Band and Channel Bandwidth:** Operates in the 5.8 GHz band (5725 to 5925 MHz) with a channel bandwidth of 40 MHz.
- **Downlink Data:** The downlink data capacity is at 75%, indicating the proportion of the total potential data transmission capacity being utilized.

Important Conclusions:

- The use of high-gain equipment in a NLoS setup helps in managing the significant path losses and maintaining a substantial downlink data rate.
- The negative Fresnel zone clearance could be a critical factor affecting signal quality, necessitating further investigation or adjustments in the physical setup or equipment configuration to optimize performance.

III.5.1.4.2. Near-Line of Sight (nLOS) High-Gain Connection Using PMP 450b Between Central University via PMP 450i

This section addresses the Near-Line of Sight (nLOS) scenario, where the signal path between points is mostly clear but includes minor obstructions that do not completely block the line of sight. In such cases, signal degradation is less severe compared to NLOS

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conditions, and reliable connectivity can still be maintained with the appropriate equipment and configuration, such as using high-gain antennas like the PMP 450i.

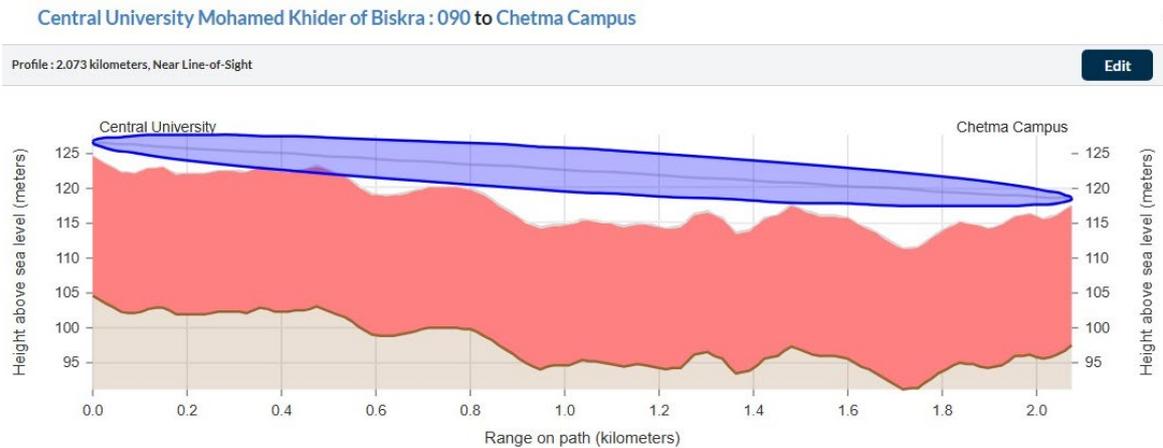


Figure III- 30 Near-Line of Sight (nLOS) Central University Azimuth 90 ° to Chetma Campus

The image is a summary table from a research paper related to telecommunications at Central University Mohamed Khider of Biskra. It provides detailed specifications and measurements for a point-to-multipoint (PMP) communication setup between the main campus and the Chetma Campus.

- **ND Name:** Central University Mohamed Khider of Biskra: 090
- **Site Name:** Central University
- **SM Name:** Chetma Campus
- **Link Type:** Near Line-of-Sight
- **ND Equipment Type:** PMP 450i (running Release 24.1)
- **SM Equipment Type:** PMP 450b High Gain (running Release 24.1)
- **Fresnel Zone Clearance:** -0.9 meters
- **Link Distance:** 2.073 kilometers
- **Free Space Path Loss:** 114.09 dB
- **Excess Path Loss:** 4.07 dB
- **RF Frequency Band:** 5.8 GHz (5725 to 5925 MHz)
- **RF Channel Bandwidth:** 40 MHz
- **Downlink Data:** 75 %

Important Results and Conclusions:

Simulation and Its Real-World Application

- The link operates in a near line-of-sight condition, which is critical for maintaining signal integrity over the 2.073 km distance.
- The negative Fresnel zone clearance indicates potential obstructions affecting the line-of-sight.
- The system uses a high-frequency band (5.8 GHz), suitable for high data rate transmissions, with a substantial channel bandwidth of 40 MHz
- The downlink data performance is at 75%, which might suggest room for optimization or challenges due to environmental factors or equipment settings.

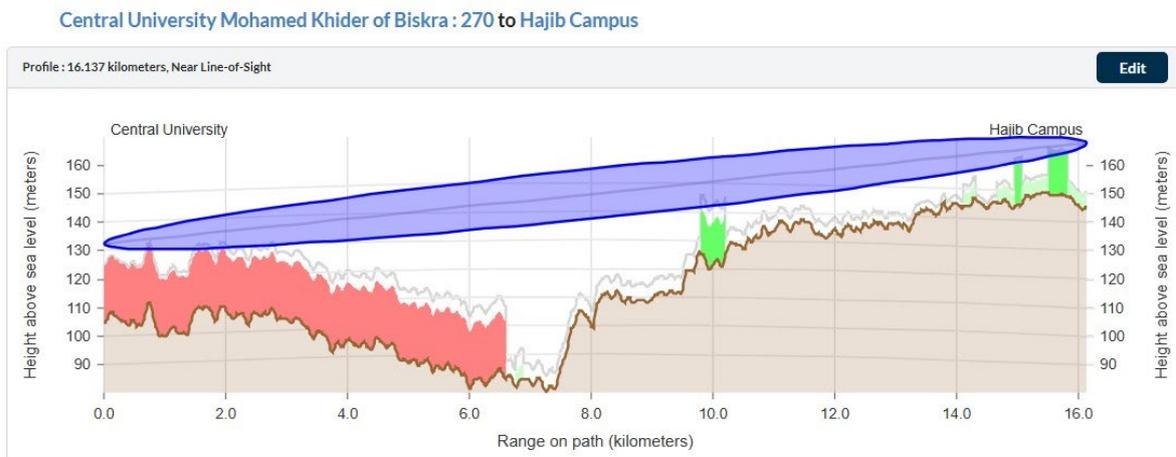


Figure III- 31 Near-Line of Sight (nLOS) Central University Azimuth 270 ° to Hajib Campus

The image is a summary from a research study focusing on a wireless communication link setup between Central University Mohamed Khider of Biskra and Hajib Campus. It details various technical parameters and specifications of the network deployment.

- **ND Name:** Central University Mohamed Khider of Biskra: 270
- **Site Name:** Central University
- **SM Name:** Hajib Campus
- **Link Type:** Near Line-of-Sight
- **ND Equipment Type:** PMP 450i (running Release 24.1)
- **SM Equipment Type:** PMP 450b High Gain (running Release 24.1)
- **Fresnel Zone Clearance:** -1.9 meters
- **Link Distance:** 16.137 kilometers
- **Free Space Path Loss:** 131.91 dB

- **Excess Path Loss:** 7.25 dB
- **RF Frequency Band:** 5.8 GHz (5725 to 5925 MHz)
- **RF Channel Bandwidth:** 40 MHz
- **Downlink Data:** 75 %

Important Results and Conclusions:

- The link operates in a near line-of-sight condition, which is crucial for minimizing obstructions and ensuring signal integrity over the 16.137 km distance.
- The negative Fresnel Zone Clearance indicates potential obstructions close to the signal path, which could impact the link quality.
- The Free Space Path Loss is significantly high at 131.91 dB, suggesting challenges due to the long distance and frequency used.
- The system operates within the 5.8 GHz band, which is typical for point-to-multipoint links, providing a balance between range and bandwidth.
- The downlink data capacity is at 75%, indicating a substantial utilization of the available bandwidth, which might affect the throughput under high-demand scenarios.

III.5.1.4.3. Line of Sight (LOS) High-Gain Connection Using PMP 450b Between Central University via PMP 450i

This section covers the Line of Sight (LOS) condition, where there is a clear, unobstructed direct path between the transmitting and receiving points. LOS connections typically provide the highest link reliability and throughput due to minimal signal attenuation and interference. The use of PMP 450i equipment in LOS scenarios ensures optimal performance, with stable microwave links and maximum data capacity.



Figure III- 32 Line of Sight (LOS) Central University Azimuth 90 ° to Chetma Campus

Wireless Link Specifications – Central University to Chetma Campus

- **Link Type:** Line-of-Sight (LOS)
- **Equipment:**
 - ND: PMP 450i (Release 24.1)
 - SM: PMP 450b High Gain (Release 24.1)
- **Link Distance:** 2.073 kilometers
- **Operating Frequency:** 5.8 GHz (5725 to 5925 MHz)
- **RF Channel Bandwidth:** 40 MHz
- **Free Space Path Loss:** 114.09 dB
- **Fresnel Zone Clearance:** 0.1 meters
- **Downlink Data Utilization:** 75%
- **Excess Path Loss:** 0 dB

Physical Installation Specifications

- **Site Coordinates:**
 - Latitude: 34.85028N
 - Longitude: 005.77263E
- **Site Elevation:** 119 meters above mean sea level (AMSL)
- **Platform Variant:** PMP 450b High Gain
- **Antenna Type:** Cambium Networks 7° High Gain Integrated
- **Antenna Beamwidth:** 7°
- **Antenna Gain:** 22.4 dBi
- **Antenna Height:** 22 meters above ground level (AGL)

- **Antenna Tilt Angle:** 0.2° uptilt

Radio Commissioning and Settings

- **Antenna Azimuth:** 255.78° from True North
- **Magnetic Declination:** 2.39° E \pm 0.31°, changing at 0.09° E per year
- **ND Output Power:** 27 dBm
- **ND Antenna Gain Toward SM:** 15.3 dBi
- **Channel Bandwidth:** 40 MHz
- **MIMO Rate Adapt Algorithm:** Enabled
- **Max Downlink Modulation Mode:** x8
- **Max Uplink Modulation Mode:** x8
- **Operational Transmit Power:** 20 dBm
- **Predicted Receive Power:** -49 dBm \pm 5 dB during alignment

Performance Metrics and Availability

- **Predicted Receive Power:**
 - ND: -56 dBm \pm 5 dB
 - SM: -49 dBm \pm 5 dB during alignment
- **Minimum Modulation Mode Required:** QPSK MIMO-A (x1)
- **Maximum Usable Modulation Mode:**
 - ND: x7 (128QAM MIMO-B)
 - SM: x8 (256QAM MIMO-B)
- **Minimum Availability Required:** 99.00%
- **Predicted Availability:** 100.00%

Minimum Performance Mode Required

- Capacity to Central University: 8 Mbps
- Capacity to Chetma Campus: 50 Mbps

Maximum Usable Performance Mode

- Capacity to Central University: 66 Mbps
- Capacity to Chetma Campus: 198 Mbps

Key Points:

- LOS configuration over medium distance ensures minimal obstruction and signal integrity.
- Use of high-gain equipment supports stable and efficient connectivity.
- Fresnel zone clearance and zero excess path loss indicate a clear signal path with minimal degradation.
- High antenna gain and elevated placement reduce obstructions and enhance signal coverage.
- Slight uptilt optimized for local terrain and improved link stability.
- Precise geographic positioning essential for accurate equipment alignment and performance.
- Antenna and radio parameters adjusted considering magnetic declination for optimal transmission/reception.
- Enabled MIMO Rate Adapt supports high throughput and robust data transmission.
- Power settings and predicted receive power ensure efficient operation within site-specific conditions.
- Signal strength is strong with minimal margin for error, indicating good link quality.
- Wide range of modulation modes offers operational flexibility based on link conditions.
- Predicted full availability demonstrates high reliability and system robustness.

Central University Mohamed Khider of Biskra : 270 to Hajib Campus

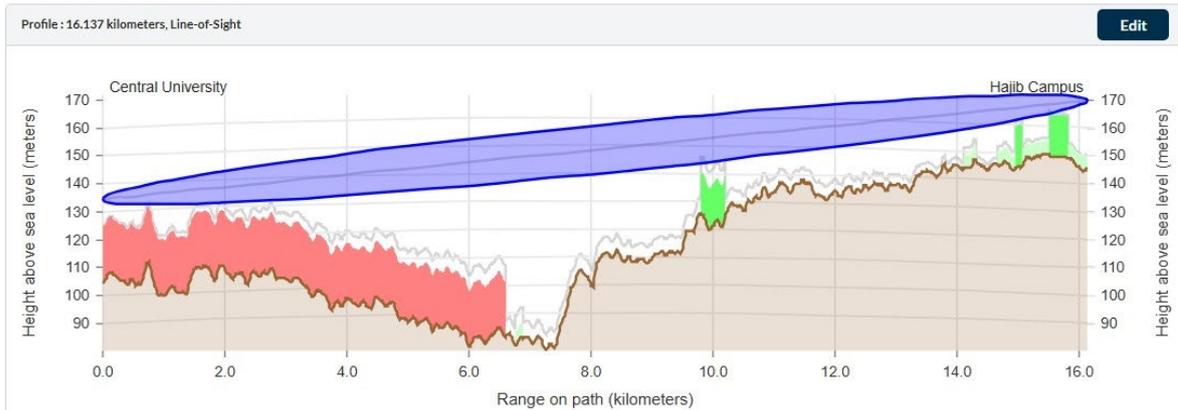


Figure III- 33 Line of Sight (LOS) Central University Azimuth 270 ° to Hajib Campus

Wireless Link Specifications – Central University to Hajib Campus

- **Link Type:** Line-of-Sight (LOS)
- **Equipment:**
 - ND: PMP 450i (Release 24.1)
 - SM: PMP 450b High Gain (Release 24.1)
- **Link Distance:** 16.137 kilometers
- **Operating Frequency:** 5.8 GHz (5725 to 5925 MHz)
- **RF Channel Bandwidth:** 40 MHz
- **Free Space Path Loss:** 131.91 dB
- **Fresnel Zone Clearance:** 0.1 meters
- **Downlink Data Utilization:** 75%
- **Excess Path Loss:** 0 dB

Physical Installation Specifications

- **Site Coordinates:**
 - Latitude: 34.78635N
 - Longitude: 005.58961E
- **Site Elevation:** 170 meters above mean sea level (AMSL)

- **Platform Variant:** PMP 450b High Gain
- **Antenna Type:** Cambium Networks 7° High Gain Integrated
- **Antenna Beamwidth:** 7°
- **Antenna Gain:** 22.4 dBi
- **Antenna Height:** 24 meters above ground level (AGL)
- **Antenna Tilt Angle:** -0.2° down tilt

Radio Commissioning and Settings

- **Antenna Azimuth:** 65.91° from True North (63.55° Magnetic North)
- **Magnetic Declination:** 2.35° E ± 0.31°, changing at 0.09° E per year
- **ND Output Power:** 27 dBm
- **ND Antenna Gain Toward SM:** 13.9 dBi
- **Channel Bandwidth:** 40 MHz
- **MIMO Rate Adapt Algorithm:** Enabled
- **Max Downlink Modulation Mode:** x8
- **Max Uplink Modulation Mode:** x8
- **Operational Transmit Power:** 27 dBm
- **Predicted Receive Power:** -69 dBm ± 5 dB during alignment

Performance Metrics and Availability

- **Predicted Receive Power:**
 - ND: -69 dBm ± 5 dB
 - SM: -59 dBm ± 5 dB during alignment
- **Minimum Modulation Mode Required:** QPSK MIMO-A (x1)
- **Maximum Usable Modulation Mode :** 8QAM MIMO-B (x3)
- **Minimum Availability Required:** 99.00%

Simulation and Its Real-World Application

- **Predicted Availability:** 99.9838%

Minimum Performance Mode Required

- Capacity to Central University: 8 Mbps
- Capacity to Hajib Campus: 25 Mbps

Maximum Usable Performance Mode

- Capacity to Central University: 33 Mbps
- Capacity to Hajib Campus: 99 Mbps

Key Points:

- LOS setup over a long distance (16.137 km) ensures minimal obstruction with a clear signal path.
- High-gain antennas (22.4 dBi) and elevated installation height (24 m AGL) enhance coverage and signal quality.
- Minimal Fresnel zone clearance (0.1 m) and zero excess path loss indicate optimal path conditions.
- Slight antenna down tilt (-0.2°) optimized for site topology to improve link stability.
- Precise geographic positioning and elevation important for accurate alignment and performance.
- Radio settings incorporate magnetic declination adjustments for optimal antenna orientation.
- Use of MIMO Rate Adapt Algorithm and 40 MHz channel bandwidth allows robust, flexible data throughput.
- Power and predicted receive power levels ensure reliable signal strength despite long distance.
- Modulation modes range from basic QPSK to 8QAM, enabling adaptive operation based on signal quality.

Simulation and Its Real-World Application

- High predicted availability (99.98%) reflects strong reliability and system resilience.

Note:

The code **VB with ITU rain P.530-17** indicates that the simulations were conducted under rainy conditions. The signal attenuation due to rain was modeled following the ITU-R Recommendation P.530-17, which provides standardized methods for predicting rain-induced propagation impairments. This rainfall effect significantly influences wireless signal quality and link performance by increasing attenuation during precipitation events.

III.6.Conclusion

This chapter on simulation has emphasized the reality of two essential forms of wireless link arrangements: Point-to-Point (PTP) and Point-to-Multipoint (PMP). The use of the LINKPlanner software facilitated the simulation process effectively, offering an intuitive interface combined with precise and reliable results.

For accurate network planning, it is essential that engineers precisely determine the tower location by capturing its latitude, longitude, and antenna unit height. Crucially, these height measurements should be referenced relative to the mean sea level to ensure consistency and accuracy in elevation data—an indispensable factor for proper link alignment and performance.

The choice of equipment is primarily dictated by the operating frequency band, as this determines the suitable devices that will deliver optimal performance in the intended deployment environment.

Environmental conditions profoundly impact signal quality. Factors such as terrain features and physical obstructions, atmospheric effects like rain, dust, and gaseous composition, as well as propagation phenomena including diffraction and scattering, all contribute to signal degradation and must be carefully considered during link design.

Microwave systems play a vital role in enabling data transmission and reception under both normal and adverse conditions, including disaster scenarios. Their reliability and resilience make them a foundational component of wireless communication networks.

Overall, this chapter highlights the critical integration of technical precision, environmental awareness, and appropriate tool usage to achieve robust and efficient wireless communication link design.

General Conclusion

This thesis presents a comprehensive study of microwave transmission, encompassing both theoretical foundations and practical simulation aspects. By doing this work, we have improved our understanding of the basic principles of microwave communication and shown how to use this knowledge effectively in real-life situations. The ability to link institutions and facilitate seamless data transmission is greatly enhanced by the insights gained here, which also enable us to interpret results accurately and address potential challenges. Furthermore, this study reaffirms the critical role of wireless communication within organizational networks and their branches.

The first chapter laid the groundwork by exploring the fundamental theoretical concepts of microwave transmission, including the essential principles involved in establishing a microwave link between two points.

The second chapter shifted focus to the physical devices used in microwave systems, highlighting their functionalities and interactions. It explained the processes of data transmission, reception, and frequency amplification necessary for effective communication.

In the third chapter, we examined practical scenarios of microwave connectivity, including both point-to-point and point-to-multipoint configurations. This section detailed the scientific and technical parameters affecting data transfer speeds through simulations, providing a clearer understanding of these results and ways to optimize them. Importantly, it emphasized the growing significance of wireless communication technologies.

Engaging in this project has been an invaluable opportunity, allowing hands-on experience with advanced devices and precise outcome measurements. It has significantly enriched the knowledge base acquired throughout our academic journey and specialized training in communication networks. Moreover, it introduced new perspectives and deeper expertise in our field.

From a practical standpoint, we recommend utilizing open-source software such as LINKPlanner for microwave link simulations. This tool offers robust features, an extensive device library, and the capability to load comprehensive environmental data, streamlining the simulation process. Finally, we advocate for increased attention to the wireless communication sector, given its rapid evolution and essential place in institutional network planning and deployment.

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