



Addis Ababa University
Addis Ababa Institute of Technology
School of Electrical and Computer Engineering
Communication Engineering Graduate Program

*Designing and Optimizing Repeater Using Telecom Microwave Antenna
case of Fana Broadcasting Corporate (FBC) and Ethiotelcom*

By:

Efnan Merga

Advisor:

Dr. Murad Ridwan

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in
Partial Fulfillment of the Requirement for the Degree of Master's Science in
Communication Engineering

March, 2025

Addis Ababa University
Addis Ababa Institute of Technology
School of Electrical and Computer Engineering
Communication Engineering Graduate Program

*Designing and Optimizing Repeater Using Telecom Microwave Antenna
case of Fana Broadcasting Corporate (FBC) and Ethio telecom*

By:

Efnan Merga

Approval by Board of Examiners

Signature

Date

Chairman, School Graduate Committee:

Advisor's Name:

Internal Examiner's Name:

External Examiner's Name:

Declaration

I declare that this thesis is entirely my own work and does not include any content from other educational institutions without proper acknowledgement. To the best of my knowledge, it does not contain previously published material by another person without recognition.

Name of the Student

Signature

Date

This thesis has been submitted for examination with my approval as a university advisor.

Name of the Advisor

Signature

Date

Addia Ababa, Ethiopia

ABSTRACT

Microwave antennas are widely utilized in telecommunications, radar systems, satellite communications, and television broadcasting to transmit programs—such as relaying an outside broadcast to a main studio—as well as in other applications requiring the transmission of high-frequency electromagnetic waves over long distances.

Fana Broadcasting Corporation (FBC) currently utilizes microwave links to transmit public and governmental programs from temporary outside broadcast (OB) studios across Addis Ababa to its main headquarters studio. However, the city’s complex terrain and the rapid rise of tall buildings frequently obstruct the line of sight between transmitters and receivers, leading to an increased occurrence of failures during live television broadcasts. This thesis addresses the identified challenges by designing and optimizing an EthioTelecom microwave antenna to function as a repeater for broadcasting. It evaluates the impact of substituting ITU-R parameters with Localized values, such as rain fading, to enhance performance.

Key Words: *Microwave Antenna, Rain Attenuation, Radio Mobile, path loss Model, Field strength, Fresnel Zone, Total Propagation loss, fade margin.*

Acknowledgments

First and foremost, I am deeply grateful to God for blessing me with wisdom, good health, and all the essential provisions I have needed throughout the years.

I would like to extend my heartfelt gratitude to my advisor, Dr. Murad Ridwan, for his invaluable guidance and unwavering support throughout the course of this thesis. His advice and encouragement were instrumental in achieving several key breakthroughs.

I am also deeply grateful to the faculty and staff of the Electrical and Computer Engineering School, particularly those in the Communication Stream, for their support and mentorship.

Lastly, I would like to express my appreciation to my friends and colleagues for their encouragement and assistance. A special thanks goes to my wife, Simbo, and my children, Naaf and Milki, whose love, sacrifice, and support have been truly invaluable.

Table of Contents

Dedication	iv
Acknowledgements	iv
Table of Contents	v
List of Tables	vii
List of Figures	viii
List of Abbreviations	ix
Chapter 1: Introduction	1
1.1 Background	1
1.2 Microwave communication systems	4
1.3 Statement of the Problem	7
1.4 Objective	7
1.5 Literature Review	8
1.6 Organization of the Thesis	9
Chapter 2: OVER REVIEW OF RAIN ATTENUATION AND MICROWAVE LINK	11
2.1 Microwave Link	11
2.2 Parameters in microwave Link	12
2.2.1 Fresnel zone	12
2.2.2 Line of site	13
2.2.3 Free Space Loss	14
2.3 Propagation Path Loss Models	15
Chapter 3: METHODOLOGY OF DESIGNING OPTIMIZING	17
3.1 Designing Methods	17
3.1.1 Link Budget	18
3.2 Effective Isotropic Radiated Power	19
3.2.1 Rain Attenuation:	21
Chapter 4: ANALYSIS OF RESULTS AND DISCUSSION	24
4.1 Site survey	24

4.2	Link Analysis and Simulation Studies	25
4.3	Full System Simulation Results	26
4.4	Comparison of simulation results with Existing systems	27
4.5	Comparison of Received Power (Receiver signal Level -RSL) Calculated Man- ually from local parameters with that of the ITU-Parameters calculated from Radio Mobile Software	31
Chapter 5: CONCLUSION AND RECOMMENDATION		37
5.1	Conclusion	37
5.2	Recommendation for Future Work	38
Bibliography		41

List of Tables

4.1	Selected repeater site.	25
4.2	Total path loss (TPL), fading margin and field strength associated with selected repeater sites.	26
4.3	RM Software tools results from TX selected repeater sites to FBC (main studio)	26
4.4	Overall system results transmitted from Meskel square to selected repeater sites and to FBC.	27
4.5	Overall system results transmitted from Millenium Hall to selected repeater sites and to FBC.	27
4.6	Overall system results transmitted from Janmeda to selected repeater sites and to FBC.	28
4.7	The practical parameter of MW link of Temporary studios	28
4.8	Practical measurements that transmitted from three temporary studios to FBC Main Studio.	29
4.9	Existing system simulation result	29
4.10	Proposed solution with the selected repeaters.	30
4.11	Description of the link profile from Ethio telecom	32
4.12	Simulation result of ITU-R and Calculated Local Values	35

List of Figures

1.1	A schematic illustration of a microwave link.	2
1.2	Split-mount Microwave equipment.	3
2.1	Fresnel Zone.	13
2.2	Atypical line of sight microwave link.	14
2.3	Free Space Loss (FSL)	15
3.1	Microwave link design development.	17
3.2	Power in a link system	19
3.3	Effective Isotropic Radiated Power (EIRP)	20
3.4	Signal-to-Noise Ratio	20
4.1	Graphic results of field strength and Margin.	30
4.2	Graphic results of Total Propagation loss	30
4.3	Active Meteorological Station distribution of Addis Ababa	31
4.4	ITU-R 838-3 Reference	33
4.5	Rm simulation result from Meskel Square to Gomakuteba	34
4.6	Graphic representation of Received Power for ITU-R and LOCAL parameter Values	36

List of Abbreviations

LOS	Line of sight
ATS	Automatic Transfer Switch
ATPC	Automatic Transmit Power Control
Mbps	Mega bit per second
QAM	Quadrature Amplitude Modulation
Erfc	Error function
SNR	Signal to Noise Ration
RF	Radio Frequency
dBm	decibel in mil
EM	field Electromagnetic Field
EMW	Electromagnetic Wave
FCC	Federal Communication Commission
FEW	Fixed Wireless Access
FM	Fade Margin
FSL	Free Space Loss
GPS	Global Position System
GSM	Global System for Mobile Communication
HF	High Frequency
ITU-R	International Telecommunication Union –Radio communication (Recommendation)
IEEE	Institute of Electrical and Electronics
Engineering	
IRL	Isotropic Receiver Level
EIRP	Effective Isotropic Radiated Power
ITU	International Telecommunication Union
BER	Bit Error Rate
FCC	Federal Communications Commission
VSWR	Voltage Standing Wave Ratio
VCO	Voltage Controlled Oscillator
FIR	Finite Impulse Radio
AWGN	Additive white Gaussian Noise
MW	Microwave
RSL	Receiver Signal Level
FSL	Free Space Loss
C/N	Carrier to Noise ratio

ATG	Bandwidth Pass Filter
LATT	Latitude
LONG	Longitude
LUF	Lowest Usable Frequency
NLOS	Non-Line of Sight
ODU	Outdoor Unit
FBC	Fana Broadcasting Corporate
IDU	Indoor Unit
DMNG	Digital Mobile News Gathering
DSNG	Digital Satellite News Gathering
PL	Path Loss
EM	field Electromagnetic Field
IRL	Lowest Usable Frequency
EMW	Electromagnetic Wave
FM	Fade Margin
FSL	Free Space Loss
RF	Radio Frequency
PTP	Point to Point
RF	Radio Frequency
IF	Intermediate Frequency
MOS	Minimum Output Signal
MIS	Minimum Input Signal
MUF	Maximum Usable Frequency
MS	Mobile Station
PL	Path Loss
RCS	Radar Cross Section
RF	Radio Frequency
RX	Receiver
DBM	Decibel Mill Watt
DBW	Decibel Watt
DBI	Decibel Isotropic
EBC	Ethiopia Broadcasting Corporation
ECC	Electronic Communication Committee
RMP	Radio Mobile Path
SOM	System Operating Margin
T-R	Transmitter-Receiver
TX	Transmitter
UHF	Ultra High Frequency

Chapter 1: **Introduction**

1.1 Background

Microwave communication offers an economical and easily deployed option that can traverse challenging landscapes. It serves as a practical way to link various wireless sites across diverse terrains where laying continuous cables or fiber-optic lines would be unfeasible or unworkable. Point-to-point microwave communication involves the transfer of data between two sites, providing exclusive connectivity via directional antennas.

These connections typically need an unobstructed view between the antennas that send signals and employ a concentrated beam of microwave radio waves to send audio and data between the two locations. When creating a point-to-point microwave link system, several technical aspects must be considered, including the microwave line-of-sight link, link budget, and the assessment of free-space path loss..

A microwave communication system relies on line-of-sight (LOS) transmission, meaning the placement of the transmitter and receiver is crucial. The choice between a **parabolic dish** and a **horn antenna** depends on factors like gain, beamwidth, and application

For radio frequency transmission, an antenna requires a power source, an external

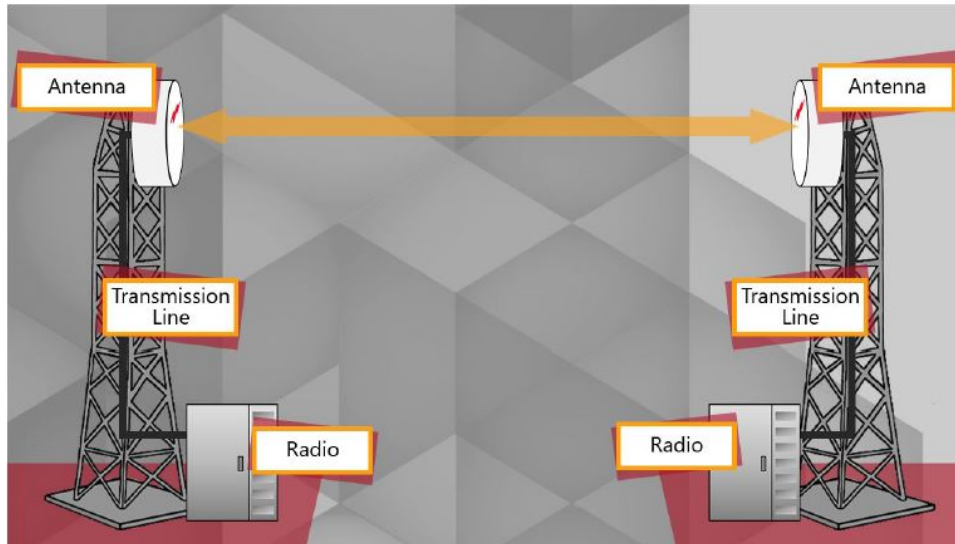


Figure 1.1: A schematic illustration of a microwave link.

radio unit, and a specialized cable called an Intermediate Frequency (IF) cable, which in this case is a coaxial cable.

A split-mount system consists of an indoor unit (IDU), an outdoor unit (ODU) [12], and an antenna, whereas a fully outdoor system integrates the IDU and ODU into a single unit. The IDU is responsible for receiving baseband signals, digitizing them, and converting them into an IF signal through coaxial cables.

The outdoor unit (ODU) plays a key role in converting the Intermediate Frequency (IF) signal into a Radio Frequency (RF) signal while also boosting its power. It houses all the RF components required to transform the modem's carrier signal into a microwave signal.

Generally, the ODU is powered via IF cables that also carry the IF signal; however, in certain instances, it can be powered by separate cables.

The antenna's role is to direct the RF signal in the intended direction. It facilitates both the transmission and reception of signals in free space and is usually positioned at the top of a communication tower, as illustrated in Figure 2.1 below. Microwave link antennas

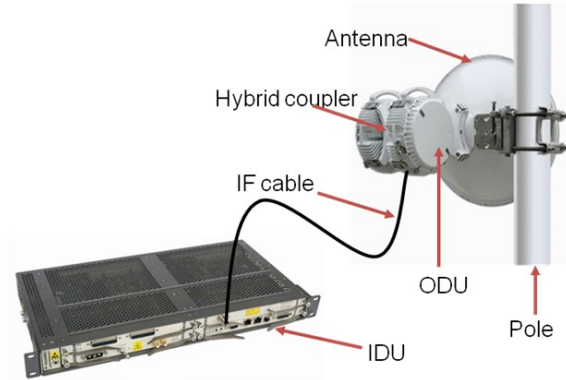


Figure 1.2: Split-mount Microwave equipment.

have a strong directional focus, concentrating both transmitted and received signals in a specific direction. To reduce waveguide losses, the antenna is directly attached to the outdoor unit (ODU), which is then connected to the indoor unit (IDU) using a single coaxial cable.

In a microwave radio system, communication starts with an information source, such as audio, video, or data. The modulated signal is then transmitted through a coaxial cable to the Outdoor Unit (ODU), where it undergoes RF processing before being transmitted. The energy emitted by the RF transmitter is boosted by the transmitting antenna before being transmitted as radio waves in specific directions, determined by the antenna's design and orientation.

This directional characteristic of microwave antennas allows for long-distance communication with minimal power consumption by concentrating the received signal and directing the transmitted energy efficiently toward the receiver.

As a radio wave moves through the atmosphere, it experiences different propagation effects such as free-space loss, reflection, diffraction, and scattering. When the RF receiver captures the signal, it not only receives the transmitted wave but also converts electromagnetic fields from noise and interference sources into power.

Finally, the RF receiver processes this power to recover exactly the source information that was originally transmitted.

1.2 Microwave communication systems

Automatic Transmit Power Control

ATPC is an electronic process that regulates the radio frequency transmission power at the transmitting site based on the received power level at the opposite site. This ensures that higher transmission power or the maximum allowable power is used only when necessary, such as during challenging microwave propagation conditions.

Transmitter

In a microwave link, the transmitter generates a microwave signal that carries the information to be transmitted [19]. The primary functions of the transmitter include the following::

- Produce an appropriate local oscillator (LO) signal within the RF band.
- Utilize the local oscillator signal to convert the adjusted intermediate frequency (IF)

signal to the desired transmission frequency.

- Amplify the RF signal while maintaining linearity.
- In the branching system, merge the local carrier with other carriers and transmit the combined signal to the antenna

Horn Antenna

Horn antennas are widely used in high-frequency applications because of their directional properties, ease of fabrication, and broad bandwidth. Their flared design helps to match the impedance of the waveguide to free space, reducing signal reflection and improving radiation efficiency.

Their applications extend beyond radar and microwave communication to areas like satellite communication, radio astronomy, and electromagnetic compatibility (EMC) testing.

Microwave repeaters

A microwave beam travels in a straight line and cannot diffract when it encounters obstacles. Therefore, the line-of-sight between two communication points must remain unobstructed. If an obstacle is present, a microwave repeater station should be installed at the obstruction site or another suitable location to maintain communication. Microwave repeater stations are categorized into two types: passive repeaters and active repeaters.

Active Repeaters : An active repeater site consists of two fully equipped microwave radio terminals, along with antennas, waveguides or coaxial cables, and other necessary components. It requires a housing for the equipment, a power source, and a structure for

mounting the antennas. Active repeaters can be classified into three types: IF repeaters, Baseband repeaters, and RF repeaters.

Passive Repeaters :

Passive repeaters are used when the cost of an active repeater is too high in comparison. They are not only more affordable to construct but also significantly reduce operational expenses. Passive repeaters offer an ecological advantage over active repeaters, as they do not require access roads or power line rights-of-way to the repeater site.

Automatic transfer switch

An Automatic Transfer Switch (ATS) must be capable of switching between different power sources, primarily the main power supply. In addition to transferring the load to a backup generator, an ATS can also activate the generator when it detects a drop in voltage from the primary source. The transfer switch ensures that the backup generator operates independently by isolating it from the utility grid while supplying temporary power [19]. This separation prevents the generator from being connected to utility lines, protecting it from overload and ensuring safety, as utility workers assume the lines are de-energized.

Polarization :

All signals transmitted within a frequency band possess a characteristic known as polarization. Polarization defines the orientation of the electric field emitted by the antenna.

1.3 Statement of the Problem

Fana Broadcasting Corporate (FBC) utilizes microwave links to transmit public and government programs across Addis Ababa to its main studio. However, the city's landscape and the growing number of high-rise buildings pose major obstacles to maintaining a clear Line of Sight (LOS) between transmitters and receivers. Because of those significant problems, I select Ethio telecom microwave antenna which is in optimal path and line of site with temporary studios and the main studio.

To enhance the design and optimization of local microwave antennas for broadcasting, it is essential to compare ITU-R values with local parameters such as rain attenuation. This comparison will help identify preferred values that account for the unique environmental factors affecting signal quality in the city.

1.4 Objective

General objectives

This thesis investigates the design and optimization of a repeater using Ethio telecom's microwave antenna for efficient broadcasting. Evaluates the effects of substituting standard ITU-R parameters with local values, such as rain attenuation.

Specific objectives

- Study and select Ethio telecom microwave antennas with the optimal path from tem-

porary studio stations to the main studio.

- Calculate the rain loss by using local parameters.
- Examining and determining site locations, assessing path profiles, evaluating tower heights, analyzing rain fading effects, confirming reflection points, and verifying clearance.
- Assessing the entire system and implementing a solution for the most critical situations.

1.5 Literature Review

Numerous studies have been conducted regarding the design and optimization of microwave antennas as well as the impact of rain attenuation on the strength of microwave links. Below is a list of a few.

In [10], F. D. Diba proposed calculating precipitation rate distributions for various regions of Ethiopia using a 15-minute sampling rain rate and applied the R-H model for time conversion. Additionally, Ethiopia has refined its precipitation rate contour maps to a 0.01 percent exceedance level.

He analyzed rain attenuation across different frequencies and distances using the ITU-R model, concluding that due to the uneven distribution of rainfall along the link, signal degradation is more significant for shorter link paths during precipitation compared to longer distances. While many researchers have examined the impact of rain on radio links

in tropical regions, several tropical and central African areas remain insufficiently studied. In [18], T. Kinfе proposed and utilized different location to improve the coverage. The thesis addresses adding output power and Antenna height as a solution to cover DTTV in Addis Ababa. But the thesis does not consider which areas have been covered with Strong and weak link quality and not consider the building height for the future.

In [12], B. Teshome proposed, designs, and installs repeaters connecting many temporary studios to the main studio. However, the thesis does not address the implications of employing Local Parameters vs. ITU-R during design. Furthermore, he installs more than 10 repeaters for a single transmission, which is too expensive to install for each event from various patterns of events.

In [9], M. Chalachew presents to estimate and analyze the optimal rain attenuation forecast for various areas in Ethiopia. The major goal of this thesis is to compare the values for rain attenuation between LOCAL and ITU-R, although comparing the link strength of different pathways is also essential.

Numerous studies have been carried out in calm climates for microwave antennas, and others for Rain attenuation. But small studies have been detailed in almost tropical and equatorial climates, in which Ethiopia falls; subsequently, this study fills the gap.

1.6 Organization of the Thesis

This thesis is structured as follows:

Chapter 1 introduces the study by outlining the background, problem statement,

research objectives, methodology, literature review, and scope. Chapter 2 provides an overview of microwave communication and the rain attenuation model. Chapter 3 details the research methodology, including rainfall data collection, link budget measurement, data processing, and microwave modeling. Chapter 4 presents and analyzes the simulation results, comparing the ITU-R model outcomes with locally calculated values. Chapter 5 concludes the study with key findings and recommendations.

Chapter 2: **OVER REVIEW OF RAIN ATTENUATION AND MICROWAVE LINK**

2.1 Microwave Link

A microwave link is a communication system that transmits radio waves within the microwave frequency range, connecting a transmitter and a receiver. Broadcasters rely on microwave links to deliver programs from the studio to a distant transmitter location.

As a vital component of modern telecommunications, microwave links enhance connectivity and facilitate efficient communication.

Although fiber optic connections have grown in popularity in recent years, most telecom companies continue to depend on microwave links for communication between their switching centers.

Many public and private organizations utilize this technology to connect their corporate offices, enabling quick and seamless access to the main server.

One of the major benefits of microwave links is their broadband capability, which allows for the high-speed transmission of large volumes of data, making them highly adaptable.

[19].

Microwave links are also enhancing security systems, contributing to advancements in satellite communication, data transmission, biomedical engineering, and cellular networks. With its numerous advantages, microwave communication continues to evolve and expand rapidly. [12].

- Large bandwidth
- Line of sight propagation
- Antenna size reduction
- Can accommodate a large number of channels
- Less Power requirement, especially in case of repeaters
- Environmentally Stable

2.2 Parameters in microwave Link

2.2.1 Fresnel zone

The initial step in setting up a reliable link, whether point-to-point or point-to-multipoint, is ensuring a clear line of sight and that at least 60% of the first Fresnel zone is free from obstructions.

This becomes increasingly important as the distance between the antennas grows. If the Fresnel zone is blocked, the received signal strength at the receiving end will be weaker than anticipated, even if the other antenna is in view.

The Fresnel zone is the region through which the signal propagates. Any obstruction within

this area can cause portions of the radio signal to bend or diffract, diverting it from its direct path.

In practical terms, this bending reduces the amount of RF energy that reaches the receiving antenna in a point-to-point radio link.

The size or radius of the Fresnel zone is determined by the signal frequency—higher fre-

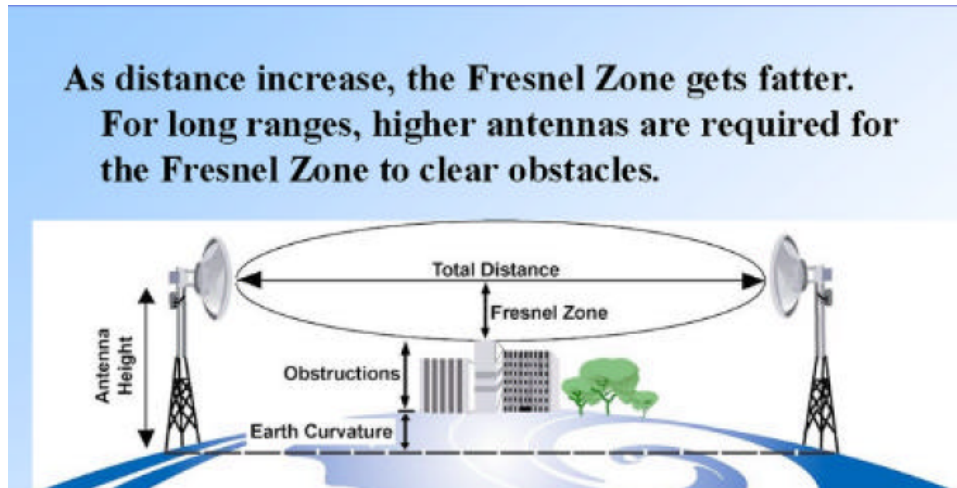


Figure 2.1: Fresnel Zone

quencies result in a smaller Fresnel zone. As shown in Figure 2.1, the Fresnel zone is widest at its midpoint. Similar to Free Space Loss (FSL), the antennas used do not influence the Fresnel zone.

2.2.2 Line of site

For effective point-to-point radio communication, microwave antennas must be installed at elevated positions to ensure there are no obstructions between them. This direct

connection is commonly known as Line of Sight (LOS).

Before establishing these links, it is essential to verify a clear path between sites. However, merely having a visible path does not guarantee a strong signal. Other factors, such as terrain suitability for wave propagation, must also be considered to ensure optimal signal strength [19]

Figure 2.2 shows a LOS where one microwave antenna has a direct link to another antenna placed at far end.

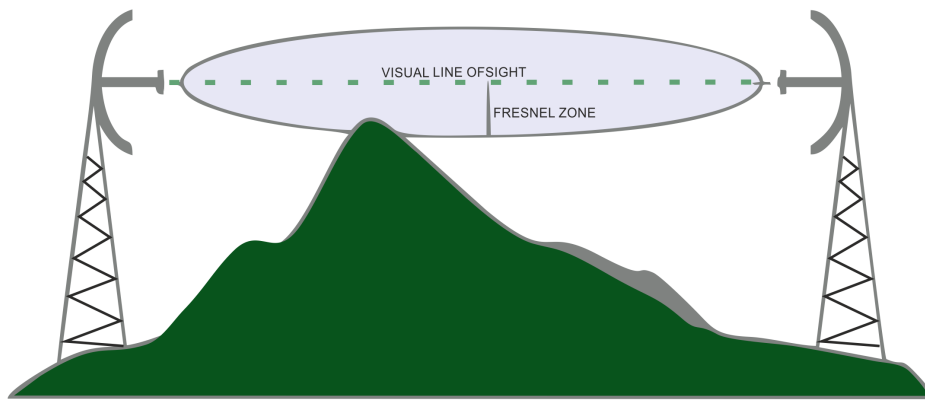


Figure 2.2: Atypical line of sight microwave link.

2.2.3 Free Space Loss

As signals spread out from a radiating source, the energy is spread out over a larger surface area. As this occurs, the strength of that signal gets weaker [12]. Free Space Loss (FSL), expressed in decibels (dB), measures the reduction in signal strength over a given distance. Figure 2.3 shows the formula for calculating FSL and illustrates the theoretical loss at different distances.

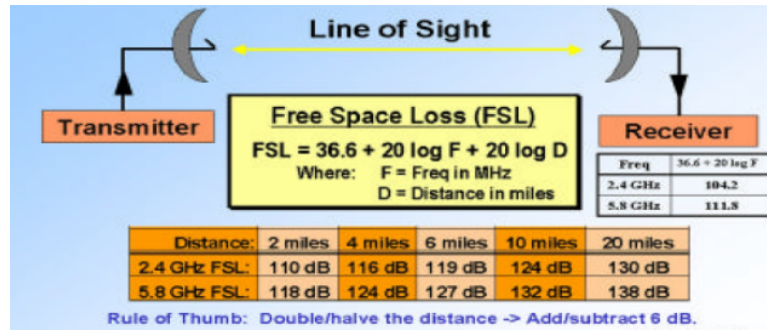


Figure 2.3: Free Space Loss (FSL)

The type of antenna used does not affect FSL, as all antennas behave like point source radiators at large distances. Interestingly, the FSL difference between a 2.4 GHz link and a 5.8 GHz link remains approximately 8 dB, regardless of the distance [12].

$$\mathbf{FSL} = 92.4 + 20\log f + 20\log D \quad (2.1)$$

Where f = frequency in GHz, D = distance is in km, \mathbf{FSL} = free-space loss dB.

FSL calculations focus solely on path loss and do not take into account factors such as transmitter power, antenna gain, or receiver sensitivity. These elements are typically considered when designing a link budget and are incorporated into radio and wireless survey tools.

2.3 Propagation Path Loss Models

Electromagnetic waves enable the transfer of information between a transmitter and a receiver. However, as the signal travels, its strength weakens due to interactions with the surrounding environment.

Path loss models predict this reduction using mathematical formulas and algorithms. These models are classified into three types: deterministic (which applies physical laws governing wave propagation), empirical (based on real-world measurements and observations), and stochastic (which relies on a series of random variables).

A propagation model outlines the typical signal behavior and establishes the maximum cell range by factoring in the highest acceptable propagation loss.

It is influenced by various factors, including environmental conditions (such as urban, coastal, rural, forested, or dense areas), distance, frequency, atmospheric conditions, and whether the transmission occurs indoors or outdoors.

Transmit Power

Transmit power is the radio frequency energy released from a transmitter's antenna port. It is measured in dBm, watts, or milliwatts and excludes the antenna's gain or any signal loss in the coaxial cable.

Higher transmit power typically results in longer link distances and better signal quality, but it also increases power consumption and must adhere to regulatory limits..

Receiver Sensitivity:

Receiver sensitivity refers to the minimum power level required at the receiver antenna to reliably detect and demodulate a microwave signal. A higher sensitivity allows for longer link distances and better performance in challenging conditions.

Fade Margins Maintaining a sufficient fade margin is vital in microwave link design. If the margin is too small, the link could become unstable, impacting its reliability and service quality. The equation considers the unpredictable and imperfect nature of radio wave propagation.

Chapter 3: METHODOLOGY OF DESIGNING OPTIMIZING

3.1 Designing Methods

The process is iterative, undergoing multiple redesign phases until the desired quality and availability are met. As illustrated in Figure 3.1, an initial fade margin is determined based on loss and attenuation calculations and is then used for preliminary fade predictions in the fading analysis. [19]. The fade margin accounts for threshold degradation if

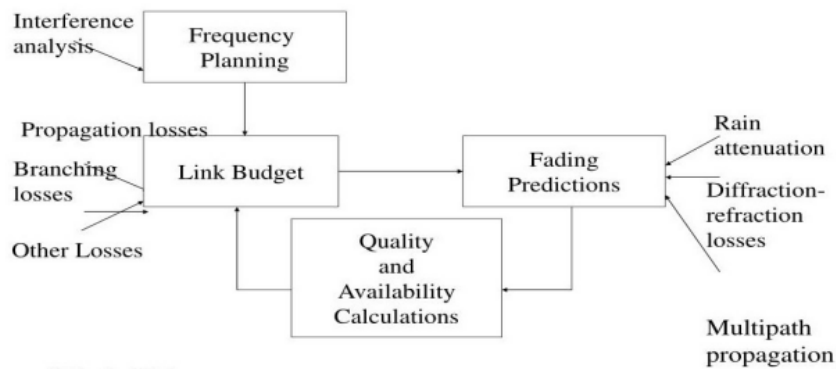


Figure 3.1: Microwave link design development.

interference is considered in frequency planning calculations. In fading predictions, which

are crucial for quality and availability assessments, the adjusted fade margin is used as the effective fade margin.

Frequency planning

Short-distance microwave links are typically assigned higher frequencies, as shorter distances benefit from these frequencies.

On the other hand, lower frequencies are favored for longer transmission hops. Due to their shorter wavelengths, microwave frequencies generally require a line-of-sight (LOS) propagation path.

3.1.1 Link Budget

The effectiveness of a communication link is largely determined by the quality of the equipment used. A link budget is a method for evaluating link performance. As shown in Figure 3.2 [19] below, the received power is influenced by three key factors: transmit power, transmitting antenna gain, and receiving antenna gain.

For a link to be successful, the transmitted power, after factoring in free space loss along the path, must be higher than the receiver's minimum required signal level.

The difference between the received power and the minimum required signal level is called the link margin. This margin should be positive and as large as possible to ensure dependable communication [12].

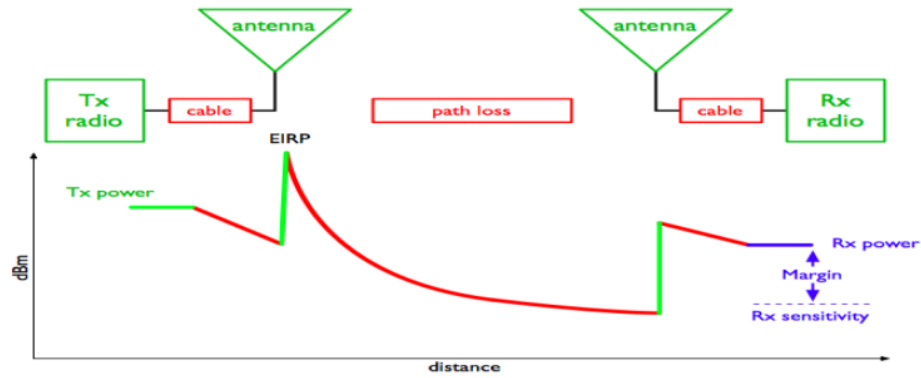


Figure 3.2: Power in a link system

3.2 Effective Isotropic Radiated Power

represents the actual RF power measured at the main lobe of an antenna, also known as the focal point. It is calculated by adding the antenna’s gain (in dBi) to the transmit power (in dBm). As a measure of power, EIRP is expressed in dBm and is calculated using the following formula:

$$\text{EIRP(dBm)} = \text{Pt(dBm)} + \text{Gt(dBi)} \quad (3.1)$$

Where: • Pt is the transmit power of the antenna in decibels-milliwatts (dBm). Gt is the gain of the antenna in decibels-isotropic (dBi). Figure 3.3 below shows how +24 dBm of power (250 mW) can be “boosted” to +48 dBm or 64 Watts of radiated power.

Signal-to-Noise Ratio (SNR)

is the ratio (usually measured in dB) between the signal level received and the noise floor level for that particular signal [12]. In practice, receiver demodulators primarily focus on

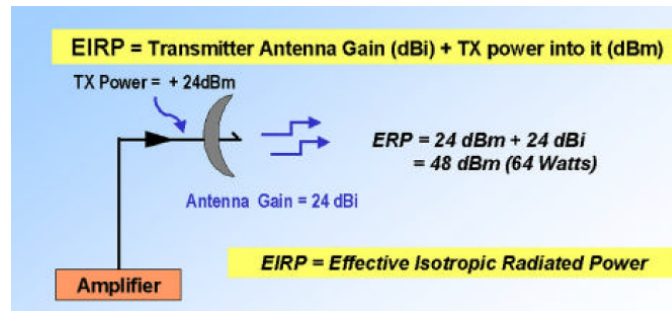


Figure 3.3: Effective Isotropic Radiated Power (EIRP)

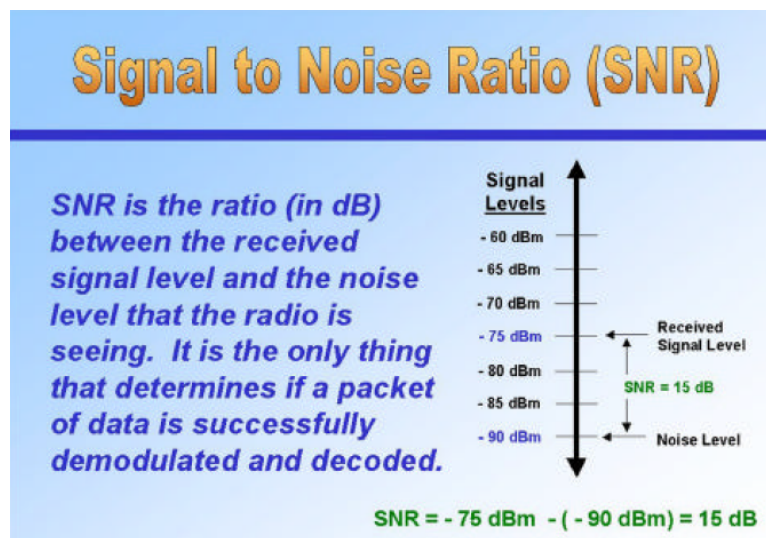


Figure 3.4: Signal-to-Noise Ratio

the Signal-to-Noise Ratio (SNR). Weaker signals are indicated by larger negative values, while the absolute strength of the signal or noise is generally unimportant unless the noise floor is excessively high.

3.2.1 Rain Attenuation:

Rain attenuation is one of the primary challenges in microwave communication. As both hop length and frequency increase, the impact of rain attenuation becomes more significant, particularly for frequencies above 10 GHz. Regardless of the transmission rate, the transmitted information must remain within a single-channel bandwidth.

Rain Fading: Available rainfall data is typically presented as a statistical representation of the amount of rainfall recorded at a specific measurement location over some time.

The overall annual rainfall in a region has a minimal correlation with rain attenuation in that area. Therefore, a margin is incorporated to account for rain effects at a specific availability level.

A higher fade margin, ranging from 45 to 60 dB, can help mitigate the impact of rain attenuation fading. The ITU has developed a series of guidelines for estimating rain fade effects [9].

Rainfall is measured in millimeters per hour (mm/hr) and expressed with a percentage probability. These values are determined for different "rainfall zones." For instance, Addis Ababa (located at latitude 9, longitude 38) falls under ITU Zone "E," where peak rainfall reaches 22 mm/h for 0.01% of the time.

This indicates that rainfall levels remain below 22 mm/h for 99.99% of the time [14]. It defines global climate zones along with their precipitation characteristics, as documented by the ITU.

Additionally, it correlates the rainfall rate (R) with the percentage of time it is exceeded annually within a specific rainfall region.

The depth of rain fade in dB can be calculated from:

$$\mathbf{L}_{\text{rain}} = \mathbf{R}\mathbf{D}_{\text{rain}} \quad (3.2)$$

where \mathbf{L}_{rain} is the rain loss in dB, \mathbf{R} is the specific attenuation (dB/Km), and \mathbf{D}_{rain} is the path length through the troposphere in km. It can be taken as the distance through which the path remains beneath cloud level. For most MW links, this is the entire length of the link (for satellite links, it can be calculated from angle to the horizon).

The specific attenuation [10].can be found from:

$$\mathbf{R} = \mathbf{k}_v \mathbf{R}_{(0.01)}^{\alpha_v} \quad (3.3)$$

Therefore,

$$\mathbf{L}_{\text{rain}} = \mathbf{k}_v \mathbf{R}_{(0.01)}^{\alpha_v} \mathbf{D} \quad (3.4)$$

where, \mathbf{L}_{rain} = rain loss in dB, $\mathbf{R}_{0.01}$ = Rain rate in $\frac{mm}{hr}$, \mathbf{k}_v and α_v are given from ITU-R depending on the frequency. \mathbf{D} = distance between transmitter and receiver in km. The values of k and α can be found from ITU-R Recommendation P.838 (Table-5) [14].

Reducing the Effects of Rain: When allowed, cross-band diversity proves to be highly effective. Route diversity can also be successfully implemented when path separations exceed approximately 8 km. Some critical links utilize radios equipped with Au-

Automatic Transmitter Power Control. Vertical polarization experiences significantly less rainfall attenuation (by 40% to 60%) compared to horizontal polarization frequencies. For circular polarization, the average value of \mathbf{R} for both vertical and horizontal polarization should be used.

Chapter 4: ANALYSIS OF RESULTS AND DISCUSSION

The findings of the thesis are presented in this chapter.

4.1 Site survey

The selection of repeater stations was based on the following key factors:

- clear line of sight, distance between microwave antenna pairs,
- terrain assessment,
- potential obstructions along the link path,
- availability of existing infrastructure, and required antenna height.

To extract the needed information there are some basic steps were followed:

The first survey required the utilization of topographical maps, such as GEO CONTEXT-PROFILE and Google Earth, to conduct preliminary selection.

After the initial selection, physical altitude measurements were conducted at the chosen sites. Subsequently, line-of-sight clearance and signal strength were evaluated. Following these assessments, six existing sites were finalized based on the criteria outlined in Table 4.1.

It is important to note that selecting sites alone does not guarantee link quality. Achieving optimal link performance also depends on choosing an appropriate antenna tower height that aligns with the site's topology. Additionally, antenna height selection

No.	Site Name	LAT/LONG	Reason of selection
1	Meskel Square	9°00'37"N/38°45'40"E	Governmental and public events are held, like Damera, Meskel, exhibitions
2	Gomakuteba	09°01'06" N/038°44'49.6" E	Nearest site to FBC/, Receiver station on FBC
3	Millennium Hall	8°59'6.7" N / 38°47'3" E	celebration of New Year, Music Festivals
4	Janmeda	9°02'26"N / 38°46'15"E	Religious celebrities like Timket
5	Entoto	08°59'25" N, 038°47'22" E	Tourism project park and have height altitude to see the whole A.A
4	Unity Park	9°02'26"N / 38°46'15"E	Special Events

Table 4.1: Selected repeater site.

must comply with relevant regulations and consider the maximum building height within the city.

4.2 Link Analysis and Simulation Studies

The thesis assessed link quality by considering three essential performance parameters:

- attenuation caused by atmospheric conditions (rain attenuation) and topography,
- free space loss,
- and diffraction loss resulting from obstructions in the terrain profile along the path.

A. Total Path Loss, fade margin, and field strength associated with repeater stations and temporary studios

Path loss and fading are key factors that contribute to weak signal links. To study this, the fading margin and path loss for three chosen temporary stations in Addis Ababa—Meskel Square, Janmeda, and Millennium Hall—were simulated using the Radio Mobile tool software. The findings are summarized in Table 4.2.

When calculating loss, Radio Mobile considers various factors, including free space loss, obstruction loss, and losses due to static, urban environments, and forests.

The fading margin represents the difference between the receiver threshold and the required statistical threshold, which depends on network parameters related to location, conditions, and time probability.

Rx.	Tx from Meskel Square			Tx from Millenium Hall			Tx from Janmeda		
	E-field (dBv/m)	TPL(dB)	margin(dB)	E-field (dBv/m)	TPL(dB)	margin(dB)	E-field (dBv/m)	TPL(dB)	margin(dB)
Gomakuteba	109.8	119.9	67.62	102.9	126.7	60.67	102.3	127.0	60.08
Entoto	108.4	121.3	55.19	87.9	141.8	47.79	80.0	149.5	39.85
Unity Park	87.6	141.9	47.59	104.2	125.3	64.06	95.8	133.7	55.64

Table 4.2: Total path loss (TPL), fading margin and field strength associated with selected repeater sites.

FBC has set up temporary studios in Addis Ababa for live program broadcasting, often used for public events like religious programs, government celebrations, and various gatherings throughout the city.

To ensure high-quality transmission from these temporary sites, a stable link between the repeater stations and the FBC main studio is crucial.

However, the constantly changing landscape of Addis Ababa poses challenges in maintaining these connections.

Therefore, the performance metrics for the link between the FBC main studio and the selected repeater stations are summarized in Table 4.3.

Tx.	Rx at FBC Main Studio		
	E-field (dBv/m)	TPL(dB)	margin(dB)
Gomakuteba	89.9	101.3	54.15
Entoto	71.5	113.9	58.6
Unity Park	72.2	110.6	59.3

Table 4.3: RM Software tools results from TX selected repeater sites to FBC (main studio)

4.3 Full System Simulation Results

The previous section presented the results for temporary studios and particular repeater stations.

This section analyzes and ranks the most stable connection among them, based on the overall simulation results of the system which encompass links from temporary studios to repeater stations and from repeater stations to FBC.

Tables 4.4 to 4.6 illustrate the complete link performance for the three selected temporary studios and corresponding repeater stations.

Based on the archived RMS tool results, which compare field strength, margin, and total propagation loss, the best sites are identified as follows:

1. **Gomakoteba:** Offers the highest link quality across all temporary studios.
2. **Entoto:** Ranks second in link quality for Millennium Hall, followed by Unity Park.
3. **Unity Park:** Provides better link quality for Meskel Square and Janmeda compared to

Rx.	Total system results from Meskel Square to selected repeaters station-FBC			
	E-field (dBv/m)	TPL(dB)	margin(dB)	Rank
Gomakuteba	210.7	246.7	128.3	1
Entoto	190.5	255.9	110.11	3
Unity Park	186.1	273.1	105.87	2

Table 4.4: Overall system results transmitted from Meskel square to selected repeater sites and to FBC.

Rx.	Total system results from Millenium Hall to selected repeaters station-FBC			
	E-field (dBv/m)	TPL(dB)	margin(dB)	Rank
Gomakuteba	219.1	238.2	136.69	1
Entoto	183.0	276.3	102.71	2
Unity Park	215.6	243.6	135.30	3

Table 4.5: Overall system results transmitted from Millenium Hall to selected repeater sites and to FBC.

Entoto.

Overall, Gomakoteba exhibits the highest average link quality, followed by Unity Park and Entoto, respectively.

In this analysis, several key parameters play a crucial role in the design and establishment of microwave antennas. These include free space loss calculation, path profile analysis, fade margin, frequency planning, attenuation, rain fading predictions, reflection point calculation, tower heights, Signal-to-Noise Ratio (SNR), and the Fresnel zone.

However, considering the latest topology and geographical conditions of Addis Ababa, these parameters have been evaluated using locally obtained values.

4.4 Comparison of simulation results with Existing systems

Existing field test This section of the thesis compares the link quality of current systems with the proposed approach. To do so, the parameters of the existing systems were collected for the three temporary studios. as shown in Tables 4.8 and 4.9.

Subsequently, the RM simulation tool was used to evaluate key link parameters, including field strength, net propagation loss, and fade margin. It is important to note that the parameters of the existing system were collected at a power level of 1W (30dBm).

Furthermore, while simulating for proposed solution the best repeater link quality is se-

Rx.	Total system results from Janmeda to selected repeaters station-FBC			
	E-field (dBv/m)	TPL(dB)	margin(dB)	Rank
Gomakuteba	201.5	238.2	136.1	1
Entoto	175.1	248.1	94.77	3
Unity Park	194.3	264.9	113.92	2

Table 4.6: Overall system results transmitted from Janmeda to selected repeater sites and to FBC.

TX power (Janmeda, Meskel Square, Millenium Hall)	30dBm
Polarization	Vertical
(Latitude /Longitude) Janmeda	9°02'26" N 38°46'15" E
(Latitude /Longitude) Millenium Hall	8°59'6.7" .N / 38°47'3" E
(Latitude /Longitude) Meskel Square	9°00'37" N/38°45'40" E
Antenna height of Janmeda	4m
Antenna height of Millenium Hall	4.5m
Antenna height of Meskel Square	4.5m

Table 4.7: The practical parameter of MW link of Temporary studios.

lected for each three temporary studios.

Rx Power	TX-Janmeda and RX-FBC	TX-Meskel Square and RX-FBC	TX-Millennium Hall and RX-FBC
	-66dBm	-52dBm	-78dBm
Polarization	Vertical	Vertical	Vertical
Antenna height at FBC	3.5	3.5	3.5
Unity Park	72.2	110.6	59.3

Table 4.8: Practical measurements that transmitted from three temporary studios to FBC Main Studio.

	Temporary studio in Janmeda			Temporary studio in Meskel Square			Temporary studio in Janmeda		
	E-field (dBv/m)	TPL(dB)	margin(dB)	E-field (dBv/m)	TPL(dB)	margin(dB)	E-field (dBv/m)	TPL(dB)	margin(dB)
RX at FBC	38.8	28.05	80.7	65.6	104.4	48.97	52.3	132.8	20.59

Table 4.9: Existing system simulation result

The graph in Figure 4.2 below comparing Field Strength and Margin shows that the existing system's performance declines while the proposed solution's performance rises. Additionally, in the Total Path Loss (TPL) graph, the existing system's performance increases as the proposed solution's performance decreases. Therefore, we can conclude that the proposed solution is a more efficient and effective transmission method.

Rx.	from Janmeda to Repeaters, from repeaters to FBC			from Meskel Square to Repeater, from repeater to FBC			from Mil. Hall to Repeater, from repeater to FBC		
	E-field (dBv/m)	TPL(dB)	margin(dB)	E-field (dBv/m)	TPL(dB)	margin(dB)	E-field (dBv/m)	TPL(dB)	margin(dB)
Gomakuteba	109.8	119.9	67.62	102.9	126.7	60.67	102.3	127.0	60.08
Entoto	108.4	121.3	55.19	87.9	141.8	47.79	80.0	149.5	39.85
Unity Park	87.6	141.9	47.59	104.2	125.3	64.06	95.8	133.7	55.64

Table 4.10: Proposed solution with the selected repeaters.

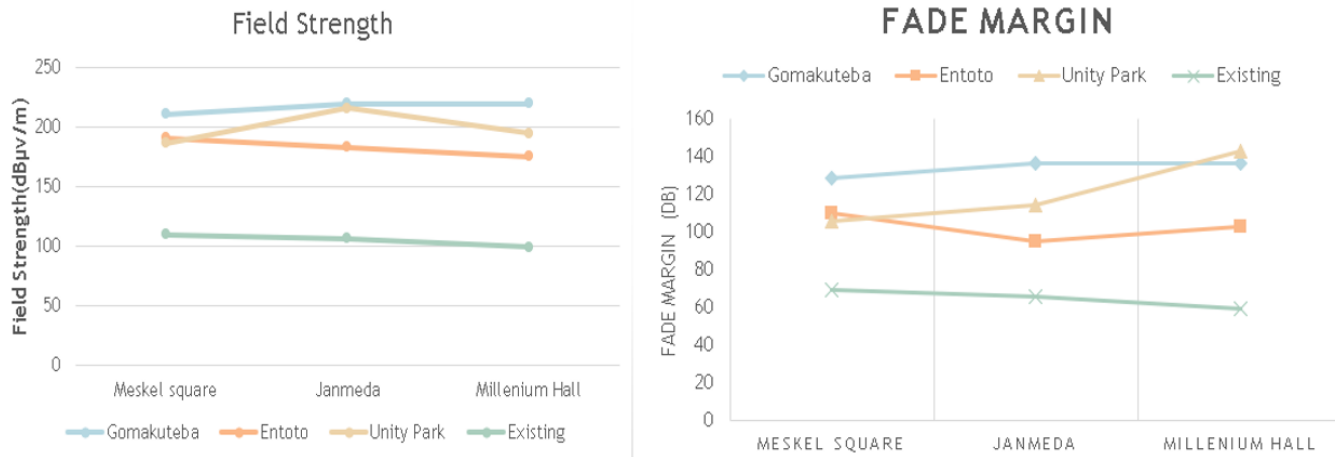


Figure 4.1: Graphic results of field strength and Margin

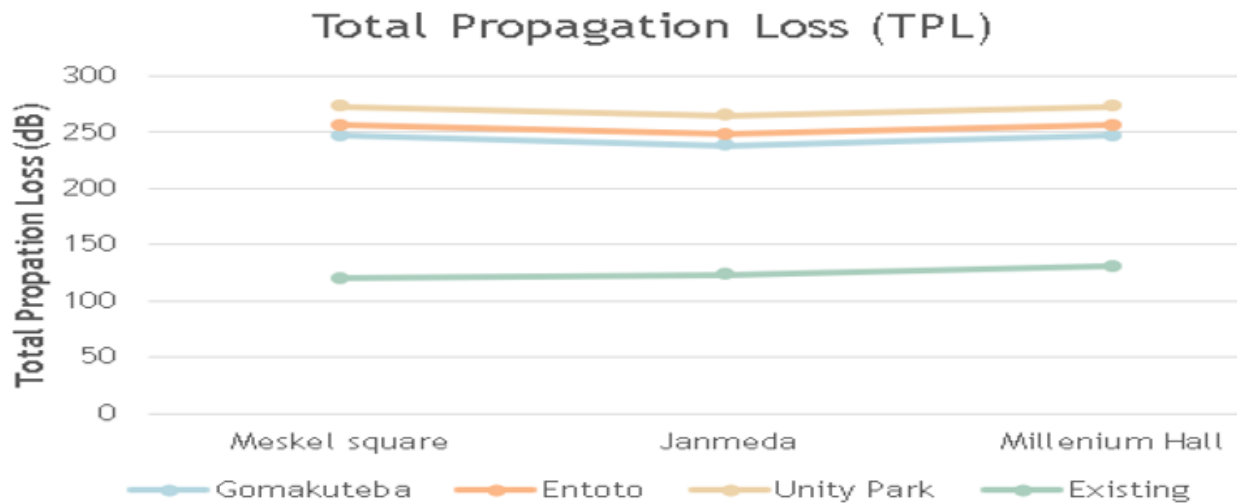


Figure 4.2: Graphic results of Total propagation loss

4.5 Comparison of Received Power (Receiver signal Level -RSL) Calculated Manually from local parameters with that of the ITU-Parameters calculated from Radio Mobile Software

Local Parameters Obtained from Ethiopian Metereology Institute (EMI) and Ethio telecom.

From Ethiopian Metereology Institute of ten years of data collection from Active Mete-

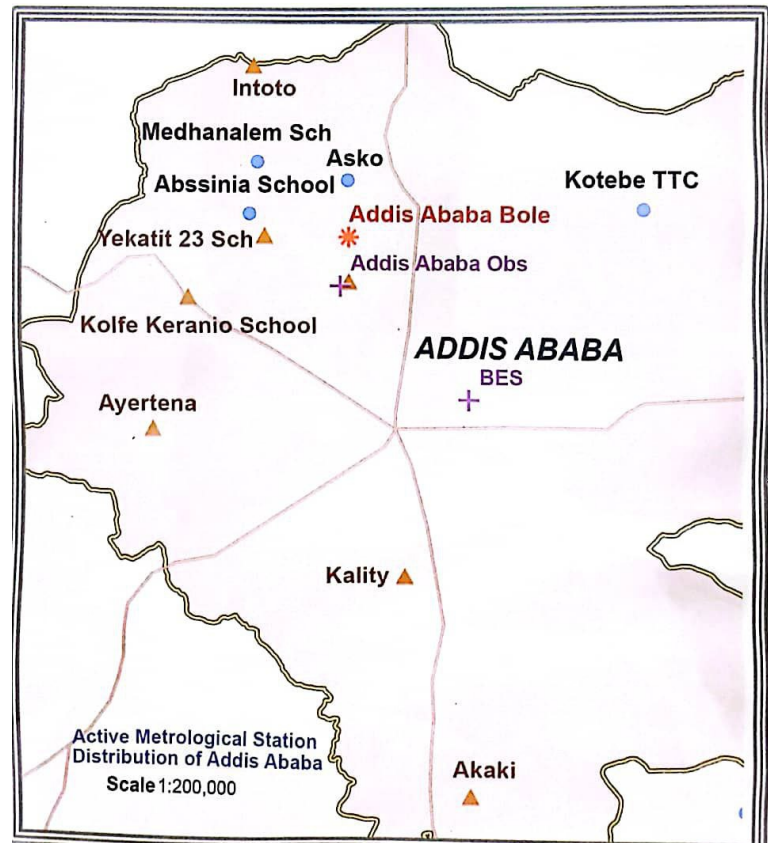


Figure 4.3: Active Meteorological Station distribution of Addis Ababa

orological Station distribution of Addis Ababa of Rain Attenuation, Rain Rate ($R_{0.01}$) is 27.8 mm/hr.

- As a reference let's compare the path from Meskel Square to Gomakuteba microwave link by using the local parameters collected from Ethio telecom.

Parameters	Meskel Square	Gomakuteba
Polarization	Vertical	vertical
Latitude	9°00'37"N	9° 1'7.06"N
Longitude	38°45'40"E	38°44'51.61"E
Antenna Height (m)	4.5	40
Antenna Gain (dBi)	42	42
Frequency (MHz)	11000	11000
Tx line lose (dB)	0.91	0.91
Atmospheric Absorption loss (dB)	0.35	0.35
Link distance (km)	1.8	1.8
Rx Threshold Level (dBm)	-76.2	-76.2
Tx Power level (dBm)	30	30

Table 4.11: Description of the link profile from Ethio telecom [9].

As we have seen in Chapter 3:

$$\mathbf{L}_{\text{rain}} = \mathbf{R}\mathbf{D}_{\text{rain}} \quad (4.1)$$

where \mathbf{L}_{rain} is the rain loss in dB, \mathbf{R} is the specific attenuation (dB/Km), and \mathbf{D}_{rain} is the path length through the troposphere in km. [?]

$$\mathbf{R} = \mathbf{k}_v \mathbf{R}_{(0.01)}^{\alpha_v} \quad (4.2)$$

Therefore,

$$\mathbf{L}_{\text{rain}} = \mathbf{k}_v \mathbf{R}_{(0.01)}^{\alpha_v} \mathbf{D} \quad (4.3)$$

where, \mathbf{L}_{rain} = rain loss in dB, $\mathbf{R}_{0.01}$ = Rain rate in $\frac{mm}{hr}$, $\mathbf{k}_v = \alpha_v = \mathbf{D}$ = distance between transmitter and receiver in km. The values of $\mathbf{k}_v = 0.01731$ and $\alpha_v = 1.1617$ can be found from ITU-R Recommendation P.838 (Table-5) for frequency of 11GHz.

Therefore,

$$\begin{aligned} \mathbf{L}_{\text{rain}} &= \mathbf{k}_v \mathbf{R}_{(0.01)}^{\alpha_v} \mathbf{D} \\ &= 0.01731(27.8)^{(1.1617)} \\ &= \mathbf{1.4828dB} \end{aligned}$$

$$\mathbf{T}_L = \mathbf{L}_{\text{rain}} + \mathbf{A}_L + \mathbf{T}_{xL} \quad (4.4)$$

$$\begin{aligned} \mathbf{T}_L &= 1.4828dB + 0.35dB + 0.91dB \\ &= \mathbf{2.7428dB} \end{aligned}$$

Where, T_L = Total loss, L_{rain} = Rain loss, Atmospheric loss and Tx_L = Transmission line loss

TABLE 5 (continued)

Frequency (GHz)	k_H	α_H	k_V	α_V
11	0.01772	1.2140	0.01731	1.1617
12	0.02386	1.1825	0.02455	1.1216
13	0.03041	1.1586	0.03266	1.0901
14	0.03738	1.1396	0.04126	1.0646
15	0.04481	1.1233	0.05008	1.0440
16	0.05282	1.1086	0.05899	1.0273
17	0.06146	1.0949	0.06797	1.0137
18	0.07078	1.0818	0.07708	1.0025
19	0.08084	1.0691	0.08642	0.9930
20	0.09164	1.0568	0.09611	0.9847
21	0.1032	1.0447	0.1063	0.9771
22	0.1155	1.0329	0.1170	0.9700

Figure 4.4: ITU-R 838-3 Reference

$$\mathbf{FSL} = 92.4 + 20\log f(\text{GHz}) + 20\log D(\text{km}) \quad (4.5)$$

$$\mathbf{FSL} = 117.9\text{dB}$$

where, $f = 11\text{GHz}$, $D = 1.8\text{km}$
 Finally, we can calculate \mathbf{P}_r as:

$$\mathbf{P}_r = \mathbf{P}_t + \mathbf{G}_{tx} + \mathbf{G}_{rx} - \mathbf{FSL} - \mathbf{L}_T \quad (4.6)$$

$$\begin{aligned} \mathbf{P}_r(\text{Local}) &= 30 + 42 + 42 - 117.9 - 2.7428 \\ &= \mathbf{-6.64 \text{ dBm}} \end{aligned}$$

Since, \mathbf{P}_r = Recieved power, \mathbf{P}_t = Transmitted Power, \mathbf{G}_{tx} = Transmission gain, \mathbf{G}_{rx} = Recieved gain, \mathbf{FSL} = Free Space Loss, \mathbf{L}_T = Total loss

$$\mathbf{FadeMargin} = \mathbf{Pr} - \mathbf{RTH} \quad (4.7)$$

$$\begin{aligned} \mathbf{FadeMargin} &= -6.64 - (-76.2) \\ &= \mathbf{69.54\text{dB dB}} \end{aligned}$$

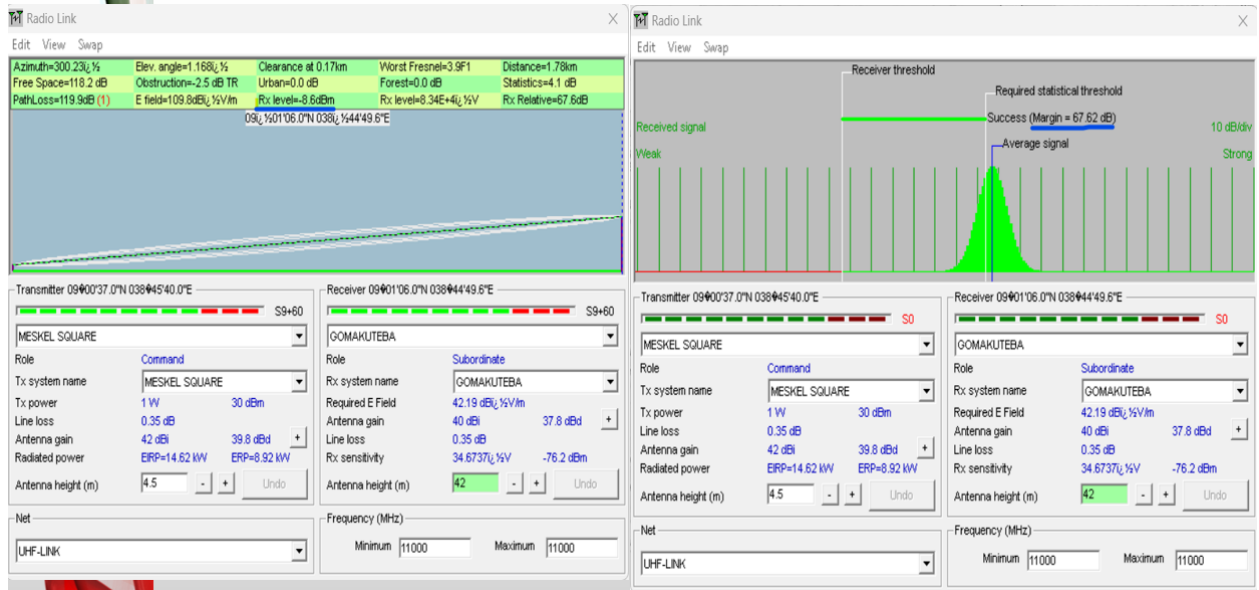


Figure 4.5: Rm simulation result from Meskel Square to Gomakuteba

From the outcome of the Meskel Square to Gomakuteba simulation link using the Radio Mobile tool software, which uses ITU-R parameters, the simulation results for the received signal level (RSL) and the fade margin are -5.1dBm and 67.62dB respectively.

This comparison shows that the RSL and Fade Margin computed using the local parameters are higher than those simulated using the ITU-R values.

The whole Simulation results of ITU-R and Calculated Local Values of received power of all paths is presented in Table 4.10 below.

Received power (dBm) from	ITU-R (dBm)	LOCAL (dBm)
M/Hall to/from G/kuteba to FBC	-15.7	-5.31
M/Hall to/from U/Park to FBC	-27.1	-19.5
M/Hall to/from Entoto to FBC	-49.7	-46.2
M/sq to/from G/kuteba to FBC	-24.1	-8.1
M/Sq to/from Entoto to FBC	-29.5	-45.2
M/Sq to/from U/park to FBC	-46.5	-26.98
Janmeda to/from G/kuteba to FBC	-27.8	-21.1
Janmeda to/from Entoto to FBC	-57.7	-38.67
Janmeda to/from U/Park to FBC	-38.7	-19.52

Table 4.12: Simulation result of ITU-R and Calculated Local Values.

As observed in the graph Figure 4.6 , the received power is increasing for nearly all paths, except for the route between Meskel Square to/from Entoto to FBC.

This is primarily due to the longest distance of the Meskel Square to Entoto path as compared to the others, as well as the presence of tall buildings obstructing the line of sight between the transmitter and receiver.

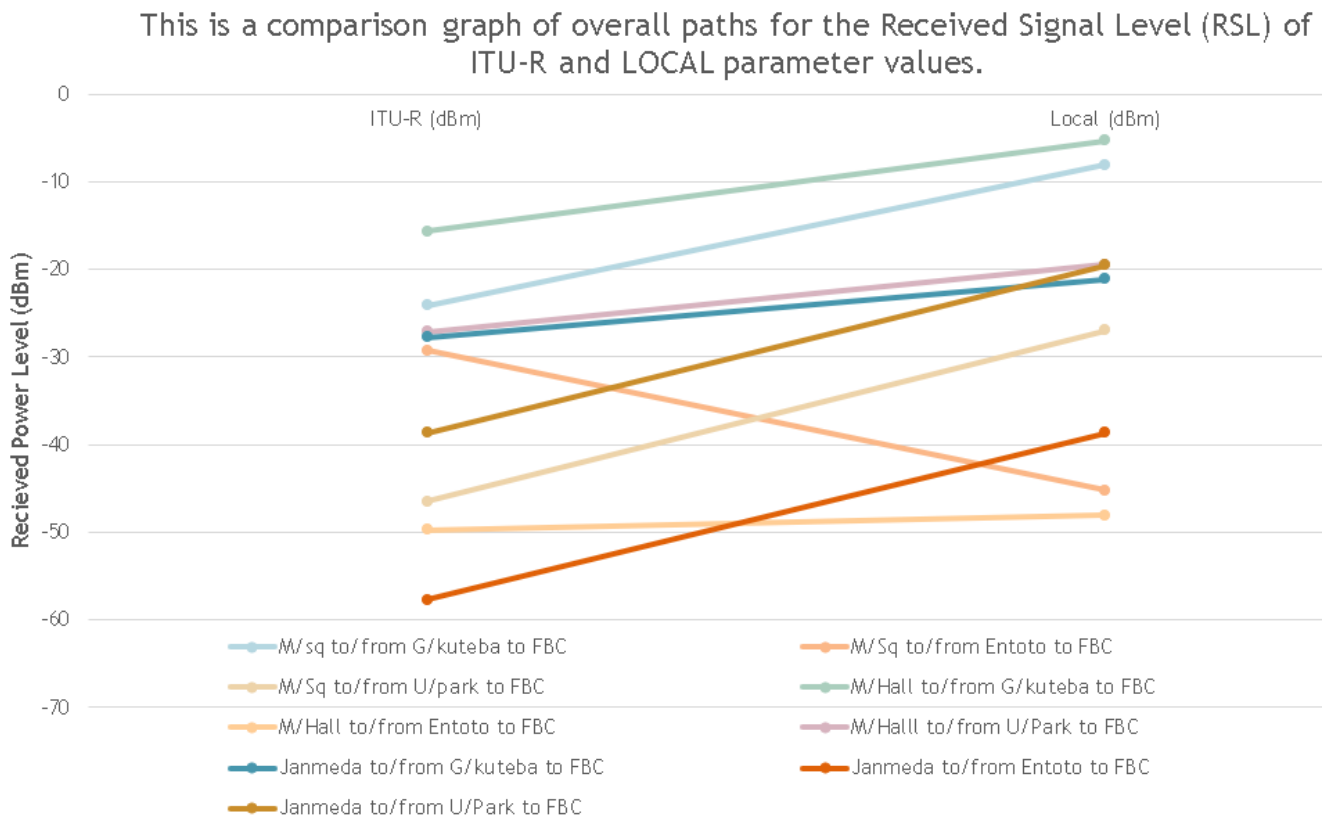


Figure 4.6: Graphic representation of Received Power for ITU-R and LOCAL parameter Values

Chapter 5: CONCLUSION AND RECOMMEN- DATION

5.1 Conclusion

This thesis focuses on designing point-to-point and point-to-multipoint microwave link communication, connecting temporary studios to repeaters and repeaters to the FBC Main Studio.

A geo-context profiler was utilized to accurately determine locations for path profile data, as the quality of service for live program broadcasting heavily relies on the reliability and performance of microwave links. However, the topographical nature of Addis Ababa, along with the rapid construction of tall buildings, poses challenges for line-of-sight communication.

To address this challenge, the thesis focused on three heavily used temporary studios of Fana Broadcasting Corporation—Meskel Square, Janmeda, and Millennium Hall—to demonstrate a potential mitigation approach.

The proposed approach focused on strategically selecting microwave antenna repeater stations that ensure a clear line of sight (LOS) with the temporary studios, followed by an assessment of link quality using key performance parameters.

In the second phase, Ethio telecom’s microwave antenna repeater stations were evaluated to identify those offering the best link quality with the temporary studios. Based on the simulation results from the Radio Mobile Software tool, GomaKuteba, Unity Park, and Entoto were selected as the top-performing repeater stations for ensuring optimal link quality.

The thesis compared the existing systems with the proposed system based on selected performance criteria. The results indicated an average improvement of 79.25% in field strength, while propagation loss increased by 42.8% on average. Additionally, the fade margin showed a significant enhancement of 68.42%.

Although the propagation loss increased by 42.8%, which was expected, the overall system performance remains promising.

The previously outlined phases were conducted to validate the accuracy of the com-

parison between ITU-R and local parameters. The results indicate that utilizing local parameters instead of ITU recommendations for designing and optimizing microwave links for broadcasting is 95.32% more reliable and efficient.

This thesis investigates rain attenuation as a single parameter in relation to various transmission losses. Expanding this analysis to include additional losses could provide even more insightful results..

5.2 Recommendation for Future Work

The following areas of study are worthy of consideration to carry out further study. The research and findings in this thesis can be advanced by considering the following points. In this thesis a careful planning and detailed analysis of Ethio telecom microwave Antenna repeater site selection are done.

In this Thesis, the data collection from Ethiopian Meteorological Institute and Ethio telecom are done for only Addis Ababa and the transmission losses are only considered for rain attenuation.

For the future work, its recommended to collect the required data for other cities of Ethiopia and consider other losses like Atmospheric losses, Absorption losses, cable(connector) losses.

APPENDIX A

A DEFINITION OF TERMS

- Antenna** - A device for receiving and transmitting electromagnetic signal
- Antenna Feed**- is the mechanism by which signal energy is radiated toward the parabolic reflector for transmission.
- Attenuation**- Reduction of signal's voltage level as it travels down a line, measured in decibels
- Azimuth**- in directional radio transmission, the azimuth is the direction in degrees (bearing) that an antenna is transmitting to its far-end counterpart.
- Bandwidth** - refers to the range of frequencies the antenna will radiate effectively Ducting-surface and elevated ducts are formed like conditions of super refraction and substandard refraction.
- Directivity** - Antenna directivity means that maximum antenna gain compared with its gain that is averaged in all direction.
- Elevation** - is a perpendicular distance or vertical height of an objective above sea level
- Fade Margin** - is a "fudge factor" included in the system gain equation that considers the nonideal and less predictable characteristics of radio wave, such as multi-path propagation, and terrain sensitivity
- Fading** - is the variation of the strength of a received radio carrier signal due to atmospheric changes or ground and water reflections in the propagation path.
- Free Space** - the space that does not interfere with the normal radiation and propagation of values **Free Space Loss** - is the loss incurred by an electromagnetic wave as it propagates in a straight line through a vacuum with no absorption or reflection of energy from nearby objects.
- Fresnel Zones** - Radio frequency line of sight is defined by Fresnel Zones which are ellipse shaped areas between any two radios
- Gain** - an increase in signal strength when transmitted from one point to another, often expressed in decibel, ratio of the output current, voltage or power of an amplifier
- Ionosphere** - the upper portion of the atmosphere which absorbs large quantities of radiant energy from the sun becoming heated and ionized
- Interference** - the mutual action of two or more waves at the same frequency, as of sound and light, in reinforcing or neutralizing each other according to their relative phases on meeting static, unwanted signal producing a distortion of sounds or images and preventing good reception
- Latitude** - the location of the point north or south of the equator measured in degrees, minutes and seconds of an arc Longitude-the location of the point east or west of the prime meridian measured in degrees, minutes and seconds of an arc.
- Microwave** - an electromagnetic wave in the radio frequency spectrum above 890MHZ
- Noise- any condition that interferes with the desired signal to the detected signal by the control
- Noise Factor (F) and Noise Figure (NF)** - are the figures of merit used to indicate

how much the signal-to-noise ratio deteriorate as a signal passes through a circuit or series of circuit

Parabolic Antenna - A highly directional used at a distance from 40-20 miles to achieve maximum transfer between the transmitter and receiver Percent Reliability- provides means of translating system reliability by relating to system outage time

Reflection - the return of signal as it strikes a conductive medium such as metal surface or earth's surface

Refraction - is the change of direction of a ray as it passes obliquely from one medium to another with different velocities of propagation.

Reliability - probability that is functioning the time it will be needed

Bibliography

- [1] Lehpamer, H. *Microwave transmission network [1]* , *Second Edition*, ISBN: 0071701222, (McGraw-Hill professional, 2010)
- [2] N.A.Gunathilake, H.H.Srathnasiri, and M.H.D.Wimalarathne, *Optimum Parameter Analysis of Microwave Link Design in Sri Lanka* (Saitm,Malabe,Sri Lanka, 2016.).
- [3] P.M.Ghosp, Md.A.Hassain, and K. K.Karmakar, *Comparison among Different Large Scale Path Loss Models for High Site in Urban* (IJSCE, Vol.2, Iss.2, May, 2012.)
- [4] P.Sharma, *Comparative Analysis of Propagation Path Loss Models with Field Measured Data* (Cambridge University Press, Cambridge, UK, vol.2 (6), 2008-2013.)
- [5] F.J.Oluwo and O.Y.Olajide, *Radio Frequency Propagation Mechanisms and Empirical Model of Hilly Areas* (Vol.3, No.3, pp.372-376, Nigeria, Jun.2013.)
- [6] Polat , *Analysis Implementation of Predication Models for the Design of Fixed Terrestrial Point-to-Point System*) (Westview Press, Boulder, CO, Jan.2015).
- [7] M.A.Alim, M.M.Rahman, M.M. Hossain, and A.Al.Nahid,*Analysis of Large Scale Propagation Model for Mobile Communication in Urban Area* (Van Nostrand Reinhold, New York, vol-7, No.1, 2010.).
- [8] G.P. Agmal, *Microwave and Nonlinear Fiber Optics* (Academic Press, San Diego, CA, 2001), Chap. 2.
- [9] Meseret Chalachew, *Rain Attenuation Estimation and Modeling for Terrestrial Microwave and Millimetric Band in Ethiopia* (Addis Ababa, Ethiopia, 2022).
- [10] Feyisa Debo Diba, *Radio wave propagation modeling under precipitation and clear air at microwave and millimetric bands over wireless links in the horn of Africa* (Addis Ababa, Ethiopia, 2017).

- [11] Sanjeeva Gupta, *Microwave Engineering* (M.G.Hill, 1957.)
- [12] Birhanu Teshome. *Planning Efficient Microwave Link for EBC* (Addis Ababa, Ethiopia, 2018)
- [13] J. S. Seybold, *Introduction to RF Propagation*, (John Wiley Sons, 2005.)
- [14] ITU-R, *The radio refractivity index: Its formula and refractivity data* (Institution of Telecommunication Union, Geneva, Switzerland, Recommendation of ITU-R P. 453-9, Feb. 2012).
- [15] N.M. Shebani, Abdulati E. Mohammed, Mohammed A. Mosbah, and Y. A. Hassan, *Simulation and Analysis of Path Loss Models for WiMax Communication System* (Norway, 1993).
- [16] Matthew M. Radmanesh, *Radio Frequency. Microwave Electronics. Mc-Graw* (San Diego, CA, 1942).
- [17] Christopher Haslett, *Essentials of radio wave propagations* (Cambridge university, 2007).
- [18] Tiblet Kinfе, *Coverage Planning of Digital Terrestrial Television Broadcasting in Case of Addis Ababa* (Addis Ababa, Ethiopia, 2018)
- [19] Gemechu Dengia, *MICROWAVE LINK DESIGN BETWEEN JIMMA MAIN CAMPUS AND AGARO BRANCH* (Jimma, Ethiopia, 2018)