بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of science, Physics Department

Auto Controlling of a Microwave Signal Link via a Designing Electronic Circuit and Software Method to Correct the Signal Weakness due to the Effect of Dust Storms.

التحكم الذاتي في إشارة الميكرويف بتصميم دائرة إلكترونية وطريقة برمجة حاسوبية لمعالجة ضعف الإشارة الناتج من تأثير العواصف الترابية .

A thesis Submitted to fulfillment of the requirement for the degree of doctor of philosophy in physics

By

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الآيـــــــــــــه

(وَقَضَىٰ رَبُّكَ أَلَّا تَعْبُدُوا إِلَّا إِيَّاهُ وَبِالْوَالِدَيْنِ إِحْسَانًا ۚ إِمَّا يَبْلُغَنَّ عِندَكَ الْكِبَرَ أَحَدُهُمَا أَوْ
كِلَاهُمَا فَلَا تَقُل لَّهُمَا أُفٍّ وَلَا تَنْهَرْهُمَا وَقُل لَّهُمَا قَوْلًا كَرِيمًا (23) وَاخْفِضْ لَهُمَا جَنَاحَ الذُّلِّ
مِنَ الرَّحْمَةِ وَقُل رَّبِّ ارْحَمْهُمَا كَمَا رَبَّيَانِي صَغِيرًا (24))

صدق الله العظيم

سورة الإسراء الآيات (23- 24)

DEDICATION

This Thesis is beautifully dedicated

To

My Dear Father and Mother ……

Who's Advice and support me during my life.

To

My Dear Family ……

For Their Love and Invaluable Support.

Musaab

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In preparation of my assignment, I had to take the help and guidance of some respected persons, who deserve my deepest gratitude. As the completion of this assignment gave me much pleasure, I would like to show my gratitude ***Prof. Mohammed Habib Ahmed Elkanzi,*** on Omdurman Islamic University and ***Prof: Mubarak Dirar Abdalla***, on Sudan University for science and technology for giving me a good guidelines for assignment throughout numerous consultations. I would also like to expand my gratitude to all those who have directly and indirectly guided me in writing this assignment

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Abbreviations and Acronyms

RF	Radio Frequency
GHz	Gigahertz
MHz	Megahertz
KHz	Kilohertz
WLAN	Wireless Local Area Network
DBS	Direct Broadcast System
MLS	Microwaves Landing System
GPS	Global Positioning System
EW	Electronic Warfare
HF	High Frequency
PSTN	Public Switched Telephone Network
GSM	Global System for Mobile Communication
FDMA	Frequency Division Multiple Access
TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
OFDMA	Orthogonal Frequency Division Multiple Access
LOS	Line Of Sight
AWGN	Additive White Gaussian Noise
ISI	Inter Symbol Interference
SWR	Standing wave ration
NIST	National Institute of Standards and Technology
FSPL	Free Space Pathloss Model
SNR	Signal to Noise Ratio
BER	Bit Error Rate

EIRP	Equivalent Isotropic Radiated Power
RSL	Receiver Sensitivity Limit
QAM	Quadrature Adaptive Modulation
QPSK	Quadrature Phase Shift Keying
AM	Adaptive Modulation
AMC	Adaptive Modulation and Coding Scheme
EDGE	Enhanced Data rates for GSM Evolution
MCS	Modulation and Coding Schemes
UMTS	Universal Mobile Telecommunications System
HSDPA	High-Speed Downlink Packet Access
PSK	Phase Shift Keying
ATPC	Automatic Transmit Power Control

Abstract:

Dust storms are significant meteorological phenomena which occur for a percentage of time in arid and semi-arid areas especially at African and Middle East, and this phenomena effect of signal attenuation signal level especially at Ku band and higher frequency with direct impact on telecommunications system performance

A study on dust storm effect on Microwave links in arid area covering a wide range of radiofrequency especially in 18GHz was running in Khartoum, Sudan. The study used Management system (computerized system) to monitoring Transmitted and Received Signal levels of one Microwave links operating at (18GHz) as well as an automatic weather station at Khartoum international airport for data collection concerning the effect of dust storm on signal attenuation. This data describe measurement results and reports for dust storms as they affect the radio wave propagation specially frequencies above 10GHz. The effect of dust storms on propagation is studied by measuring the storm parameters, visibility and attenuation due to these storms. The measurement results have been compared with the attenuation prediction models like Elshaikh and Goldhirsh Model. The estimation of these models are under the real measured estimations.

Few prediction models have been developed to calculate the attenuation due to dust storm in dB/km. All prediction models have assumed that the intensity of dust storm is uniformly distributed around the area covered by the dust storm.

However, real dust storm is a complex phenomenon which is difficult to be described by theoretical physical or mathematical models .moreover these models did not suggested or built ascertain system to get rid of dust storm attenuation effect.in this work an electronic circuit together with software program was designed and used to get rid of signal attenuation. This system read the received signal level is beyond the threshold level, it stimulates the transmitter to readjust itself till the received signal level reaches or become above the threshold level. The experimental test of this system shows that it succeeded getting rid of attenuation.

المستخلص

تعتبر ظاهرة العواصف الترابية من الظواهر الجوية الهامة والتي تحدث لفترة زمنية كبيرة نسبيا في المناطق الصحراوية وشبة الصحرواية ، التجارب والقياسات التي اجريت مؤخرا علي الوصلات الميكروية اثبتت ان ظاهرة العواصف الترابية يمكن ان تضعف الاشارات الماكروية بصورة كبيرة خاصة في الترددات ku- band

اجريت دراسات على تأثير العواصف الترابية على وصلات الميكروويف في المنطقة القاحلة التي تغطي مجموعة واسعة من الترددات الراديوية في الخرطوم السودان خاصة في 18GHz استخدمت الدراسة نظام مراقبة المحطات الميكروية (النظام المحوسب) لرصد مستويات الإشارات المرسلة والمستقبلة لواحدة من وصلات الموجات الميكروية التي تعمل علي 18GHz وكذلك استخدمت هذه الدراسة محطة الطقس الأوتوماتيكية الموجودة في مطار الخرطوم الدولي لجمع البيانات المتعلقة بتاثير العواصف الترابية علي توهين الاشارة هذه البيانات تصف نتائج القياس والتقارير للعواصف الترابية لأنها تؤثر على اداء الموجات اللاسلكية خاصة الترددات فوق 10 غيغاهرتز وبالتالي تؤثر علي جودة الاتصالات لزلك درس تأثير العواصف الترابية عن طريق قياس معايير العاصفة والرؤية والتوهين بسبب هذه العواصف. قورنت نتائج القياس مع نماذج التنبؤ بالتوهين مثل نموزج الشيخ وقولدرش واتضح ان تنبؤات النمازج اقل من نتائج القياس.

تم تطوير نماذج قليلة للتنبؤ لحساب التوهين الناجم عن العاصفة الترابية بوحدة(dB/km) افترضت جميع نماذج التنبؤ أن كثافة العواصف الترابية موزعة بشكل موحد حول المنطقة التي تغطيها العواصف الترابية ، علاوة علي ذلك فان هذه النمازج لم تقترح او تبني منظومة معينة للتخلص من تاثير العواصف الترابية في توهين الاشارة

في هذا العمل تم تصميم واستخدام دائرة الكترونية مع برمجيات للتخلص من توهين الاشارة هذه المنظومة تقرأ مستوي الاشارة المستقبلة وعندما يكون مستوي هذه الاشارة اقل من المستوي الحرج فان المنظومة تحث المرسل علي اعادة ضبط الاشارة لتصل او تتجاوز المستوي الحرج. وقد بينت التجربة العملية لهذه المنظومة نجاحها في التخلص من التوهين

فإن ومن خلال هذا البحث تم التوصل الي ان العاصفة الترابية الحقيقية هي ظاهرة معقدة يصعب وصفها بواسطة النماذج الفيزيائية أو الرياضية في هذا البحث ، نقارن بين نماذج التنبؤ بالتوهين الموجودة القائمة على العواصف الترابية المقاسة والتوهين المقاس في السودان.

Chapter One

Introduction to Microwaves

1.1Microwave/Radio Frequency Wave

Today wireless technology is used in many applications well integrated into our everyday life. Planning a good, stable and reliable microwave network can be quite challenging. Careful planning and detailed analysis is required for a microwave radio system before the equipment can be installed. A poorly designed path can result in periodic system outages, resulting in increased system latency, decreased throughput, or worst case, a complete failure of the system.

The term *microwave* refers to alternate current signals with frequencies between 300 MHz and 300 GHz with a corresponding electrical wavelength between $\lambda = c/f = 1$ m and $\lambda = 1$ mm respectively. Signals with wavelengths on the order of millimeters are called *millimeters waves*. The relation between the frequency f and wavelength λ being $f\lambda = c$, where c is velocity of propagation of the radio wave, which is equal to that of light waves in frees pace 3x108 m/sec.

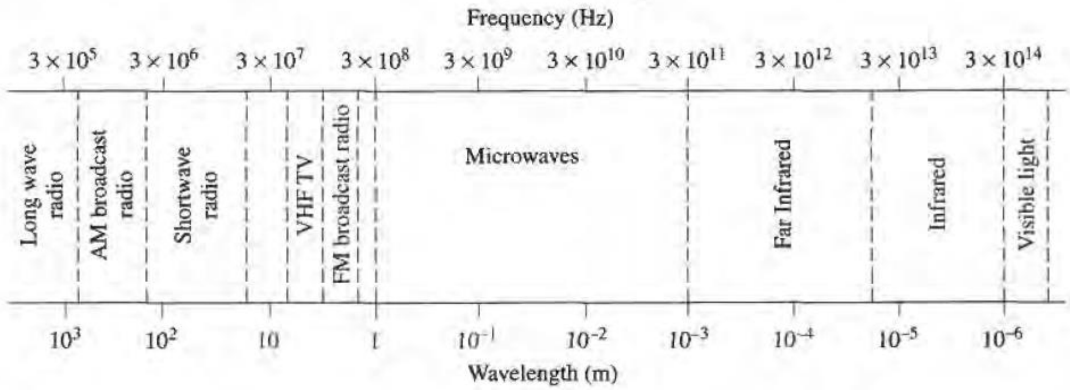
Any frequency within the electromagnetic spectrum associated with radio wave propagation is referred as Radio Frequency (RF). When an RF current is supplied to an antenna, an electromagnetic field is created that then is able to propagate through space. Many wireless technologies are based on RF field propagation.

1.2Historical Background for Microwaves

The term microwaves refers to alternating current signals with frequencies between 300 MHz (3 x 10^8 Hz) and 300 GHz (3 x 101r), with a corresponding electrical wavelength between), $\lambda = c/f = 1\,\text{m}$ and $\lambda = 1\,\text{mm}$, respectively. Signals with wavelengths on the order of millimeters are called millimeter waves. Table 1.1 shows the location of the microwave frequency band in the electromagnetic spectrum. Because of the high frequencies (and short wavelengths), standard circuit theory generally cannot be used directly to solve microwave network problems. In a sense, standard circuit theory is an approximation or special use of the broader theory of electromagnetics as described by Maxwell's equations. This is due to the fact that, in general, the lumped circuit element approximations of circuit theory are not valid at microwave frequencies. Microwave components are often distributed elements, where the phase of a voltage or current changes significantly over the physical extent of the device, because the device dimensions are on the order of the microwave wavelength. At much lower frequencies, the wavelength is large enough that there is insignificant phase variation across the dimensions of the component. The other extreme of frequency can be identified as optical engineering, in which the wavelength is much shorter than the dimensions of the component. In this case Maxwell's equations can be simplified to the geometrical optics regime, and optical systems can be designed with the theory of geometrical optics. Such techniques are sometimes applicable to millimeter wave systems, where they are referred to as *quasioptical* [1].

In microwave engineering, then, one must often begin with Maxwell's equations and their solutions. It is in the nature of these equations that mathematical complexity arises

Table 1.1: electromagnetic spectrum



Typical Frequencies	
AM broadcast band	535–1605 kHz
Short wave radio band	3–30 MHz
FM broadcast band	88–108 MHz
VHF TV (2–4)	54–72 MHz
VHF TV (5–6)	76–88 MHz
UHF TV (7–13)	174–216 MHz
UHF TV (14–83)	470–890 MHz
US cellular telephone	824–849 MHz
	869–894 MHz
European GSM cellular	880–915 MHz
	925–960 MHz
GPS	1575.42 MHz
	1227.60 MHz
Microwave ovens	2.45 GHz
US DBS	11.7–12.5 GHz
US ISM bands	902–928 MHz
	2.400–2.484 GHz
	5.725–5.850 GHz
US UWB radio	3.1–10.6 GHz

Approximate Band Designations	
Medium frequency	300 kHz to 3 MHz
High frequency (HF)	3 MHz to 30 MHz
Very high frequency (VHF)	30 MHz to 300 MHz
Ultra high frequency (UHF)	300 MHz to 3 GHz
L band	1–2 GHz
S band	2–4 GHz
C band	4–8 GHz
X band	8–12 GHz
Ku band	12–18 GHz
K band	18–26 GHz
Ka band	26–40 GHz
U band	40–60 GHz
V band	50-75 GHz
E band	60-90 GHz
W band	75-110 GHz
F band	90-140 GHz

Since Maxwell's equations involve vector differential or integral operations on vector field quantities, and these fields are functions of spatial coordinates. One of the goals of this book, however, is to try to reduce the complexity of a field theory solution to a result that can be expressed in terms of simpler circuit theory. A field theory solution generally provides a complete description of the electromagnetic field at every point in space, which is usually much more information than we really need for most practical purposes. We are typically more interested in terminal quantities such as power, impedance, voltage, and current, which can often be expressed in terms of circuit theory concepts. I t is this complexity that adds of the challenge, as well as the rewards, of microwave engineering [1].

1.3Wireless Communication

The basic motto of communication system is to ensure the exchange of information in/ between the people. When this communications without wired then it's refereed to wireless communications. Now a day this wireless communications gets more attention from the Communication industry and provide better quality information transfer between portable devices. Autonomous sensor networks, Multimedia, Videoconferencing, Distance learning and Internet enabled cell phone are the Valuable Applications of this technology.

1.4 Radio Frequency / Microwave Applications

The main part of radio frequency microwave signals can be classified in following terms.

1.4.1 Communication

The communication part concludes satellite and space systems, extensive distances, wired telephone, naval, mobiles telephone, airbus, roads vehicle, personal, and WLAN other than that there are also two significant subcategories of communications should be considered which are optical communication and television and radio broadcasting.

1.4.2 Television and Radio Broadcasting

In this category of communication radio frequency or microwaves are utilized as the carriers for audio and video signals. Direct Broadcast System (DBS) is an example which is deliberately designed to connect or link satellites systems directly to home users.

1.4.3 Optical Communications

In optical communication microwave modulator is used in the broadcasting part of a low pass optical fiber and microwave demodulator on the other side. The microwave signal operates as a transforming signal with the carrier optical signal. In case of larger frequency channels, optical communication is useful.

1.4.4 Radar and Navigation

This part comprises of air defense, airbus, ships direction, elegant weapons, police and weather and collision avoidance. The navigation system is used for the direction and supervision of airbus, ship and road vehicles. The typical applications are:

1. Microwaves Landing System - MLS used to direct airbus to land securely at airports.
2. Global Positioning System - GPS used to find exact positioning or spot on the globe.

1.4.5 Remote Sensing

In remote sensing many satellite systems monitor globe consistently for weather situations meteorology, ozone layer, soil, agriculture, crop protection from frost, forests, thickness of snow, sea icebergs and other parts such as examining and discovery of resources.

1.4.6 Domestic and Industrial Application

This area deals with microwave ovens, clothes dryers (microwaves), liquefied heating systems, humidity sensors, tank gauges, automatic doors opener, automatic toll tax detection, control and monitoring of motorway traffic, chip fault recognition, power transmission, food protection, bug control etc.

1.4.7 Medical Applications and Surveillance

This deals with breeding of cats, heart functional reaction, bleeding control, sterilization. On the other hand surveillance concludes security alarm systems, burglar detection and Electronics Warfare (EW) receivers for monitoring of traffic signals.

1.4.8 Astronomy and Space Exploration

The astronomy and space deals with enormous dish antennas which are used for monitoring, collecting and record incoming microwave signals from external space, giving critical information about other planets, stars, other objects and galaxies.

1.5 Wireless Application and Mobile Cellular Networks

The smaller distance communication in and between buildings in a local area network (LAN) can be accomplished using RF and microwaves. Connecting buildings via cables creates serious problems in congested metropolitan areas because the cable has to be run underground from the upper floors [2]. Cellular companies frequently use to get hard schedules to make sure of services for clients to produce abrupt profits. In order to revolve up their networks, companies require

12 replacing the data of cell sites to their mobile switching stations. They must have taken microwave due to its consistency, speed of employment and cost payback over fiber or leased wired line. Microwave radio is deeply deployed in the rising 2.5G and 3G mobile infrastructures to maintain data handling. The larger numbers of cell sites required to support a new generation mobiles.

1.5.1 Last Mile Access

A considerable section of business grounds require broadband connectivity, wireless networks give the ideal means for connecting new clients to defeat the last mile bottleneck. If an operator prefers to use non-licensed or multi-point wireless tools to fix customers, even then high ability microwave offers the perfect way out for backhaul of client traffic from contact hubs to the nearby fiber point.

1.5.2 Private Networks and Developing Nations

These days' companies may have high speed LAN and WAN network necessities. They need to unite elements of their industry on same ground, city or country. However, microwave radio communication is capable to offer fast, high capacity links which are compatible with quick and gigabit Ethernet connections, enabling LANs to be comprehensive without dependence on fiber.

There are various countries which resist with distantly telephone communications and require upgrading their systems to the most recent digital technology, the microwave radio has habitually permitted developing nations the way of setting up telecommunications rapidly over usual immature and unusable land such as desert, forest and frozen land where spreading cable would be all but impracticable. The modern digital microwave radio systems shape the foundation for several worldwide public networks.

1.5.3 Disaster Recovery

In case of natural disasters, it usually shatter pre-established network. Thus, microwave is often used to reinstate connections when communication means i.e. equipment has been broken by earthquakes, water floods, hurricanes or human conflicts such as assault by terrorist or wars etc. These days microwave communication is used widely for speedily restore infrastructure in countries like Kuwait, Iraq, Serbia, Afghanistan and Kosovo, where existing communications has been mostly destroyed or damaged.

1.5.4 Control and Monitoring

Railroads and public transport organizations are the most important users of microwave and play an important role for these companies to control and monitoring information and switching stations.

1.6 Advantages and Disadvantages of Microwave

Compared with the coaxial cable communication system, the microwave relay system has the following advantages in small-/medium-capacity transmission circuits [4].

1) Lower cost

2) Quick construction (Microwave link is possible to deploy in a day)

3) Flexible channel capacity (Microwave link is flexible in the capacity that can be increase effortlessly at negligible or even no cost. Moreover, microwave radio link can be reinstalled depending on the customer requirement or if

network demands changes. Therefore, losing clients does not make a sense that assets are lost as in case of fiber optic.

4) Easy to be applied in complex terrain areas (Microwave is easily crossable in terrain areas. Whereas, in various metropolitan cities and authorities, road digging is totally banned to deploy fiber optic or prohibited or even expensive).

5) Able to overcome natural obstacles

Therefore, the microwave relay system is widely used in transporting various signals such as TV, phone, fax, and data.

6) Microwave radio infrastructure is owned by operator therefore, no dependence on competitors

7) Microwave radio infrastructure is already available for various networks in the shape of rooftops, cellular poles and residing towers of microwave radio transmission.

8) Microwave radio systems are not inclined to common disastrous breakdown of fiber cable systems occurred by cable cuts, it may be fixed in no time rather than waiting for hours or days

9) It is controllable in the time of natural disasters for example flood, earthquakes.

10) Operational cost is minimal recurring.

On the other hand, the microwave system has the following disadvantages:

11) Limited by frequency bands, the capacity of the microwave relay system is much smaller than that of optical cable transmission.

12) With the development of technologies, the transmission distance of optical cable transmission is increased and the cost is reduced. In most large-capacity circuits, microwave relay circuits are not applicable. Radio transmission is only used in small-capacity circuits.

13). Microwave required a line-of-sight because signals travel in straight lines.

1.7 Applications of Microwave Engineering

Just as the high frequencies and short wavelengths of microwave energy make for difficulties in analysis and design of microwave components and systems, these same factors provide unique opportunities for the application of microwave systems. This is because of the following considerations [5]:

- Antenna gain is proportional to the electrical size of the antenna. At higher frequencies, more antenna gain is therefore possible for a given physical antenna size, which has important consequences for implementing miniaturized microwave systems
- More bandwidth (information-carrying capacity) can be realized at higher frequencies. An I% bandwidth at 600 MHz is 6 MHz (the bandwidth of a single television channel), and at 60 GHz a l% bandwidth is 600 MHz (100 television channels), Bandwidth is critically important because available frequency bands in the electromagnetic spectrum are being rapidly depleted.
- Microwave signals travel by line of sight and are not bent by the ionosphere as are lower frequency signals. Satellite and terrestrial communication links with very high capacities are thus possible, with frequency reuse at minimally distant locations.
- The effective reflection area (radar cross section) of a radar target is usually proportional to the target's electrical size. This fact, coupled with the frequency characteristics of antenna gain, generally makes microwave frequencies preferred for radar systems
- Various molecular, atomic, and nuclear resonances occur at microwave frequencies, creating a variety of unique applications in the areas of basic

science, remote sensing, medical diagnostics and treatment, and heating methods.

The majority of applications of today's microwave technology are to communications systems, radar systems, environmental remote sensing, and medical systems. As the frequency allocations listed in Figure 1 show, RF and microwave communications systems are pervasive, especially today when wireless connectivity promises to provide voice and data access to "everyone, anywhere, at any time,"

Probably the most ubiquitous use of microwave technology is in cellular telephone systems, which were first proposed in the 1970s. By 1997 there were more than 200 million cellular subscribers worldwide, and the number of subscribers and the capabilities of this service continue to grow. Satellite systems have been developed to provide cellular (voice), video, and data connections worldwide. Large satellite telephony systems, such as kidium and Globalstar, unfortunately suffered from both technical drawbacks and weak business models, and have failed with losses of several billion dollars each. But smaller satellite systems, such as the Global Positioning Satellite (GPS) system and the Direct Broadcast Satellite (DBS) system, have been extremely successful. Wireless Local Area Networks (WLANs) provide high-speed networking between computers over short distances, and the demand for this capability is growing very fast. The newest wireless communications technology is Ultra-Wide Band (UWB) radio, where the broadcast signal occupies a very wide frequency band but with a very low power level to avoid interference with other systems

Radar systems find application in military, commercial, and scientific systems. Radar is used for detecting and locating air, ground, and seagoing targets, as well as for missile guidance and fire control. In the commercial sector, radar technology is used for air traffic control, motion detectors (door openers and security alarms), vehicle collision avoidance, and distance measurement. Scientific applications of radar include weather prediction, remote sensing of the atmosphere, the oceans, and the ground, and medical diagnostics and therapy. Microwave radiometry which is the passive sensing of microwave energy emitted from an object, is used for remote sensing of the atmosphere and the earth, as well as medical diagnostics and imaging for security applications [5].

1.8 Research Problem

Planning a good, stable and reliable microwave network can be quite challenging at the same time, it poses several interesting optimization problems .The theme of thesis work an iterative technique has been presented to explain the Sequential communication of signal transmission for long and short distance radio Communication through microwave link with better efficiency.

Wireless communication provides a good technical solution to offer information and telecommunication services with high bandwidth provision without the reliance on fixed infrastructure, wireless is also essential for mobile services and cellular networks, the emerging market is now for broadband data provision and multimedia, Broadband fixed wireless access schemes aim to deliver a range of multimedia services to the subscribers with greater capacity to the user than services based on wired Communication. Service providers are currently facing challenge due to the congested frequencies spectrum which has imposed the use of higher and higher frequencies. Delivering high-capacity service by wireless leads to a move towards higher frequency bands, which are less congested and can provide significant bandwidth.

However, higher frequency bands are more sensitive to weather condition and the microwave signal attenuation due to atmospheric particles increase rapidly at higher frequency bands. Consequently, rain, snow, cloud, fog, dust storms and other phenomena cause signal attenuation which can seriously limit the performance of wireless communication systems for the frequencies above 10GHz.

Microwave signal attenuation due to dust storm is one of those potential problems and technical challenges need to be investigated in order to provide reliable wireless communication services Sand and dust storms occur in many parts of the world, especially at African and Middle East and arid parts of Asia.

Dust storms are becoming more frequent in some parts of the world, there is significant correlation between the increased occurrence of dust storms and the climate change phenomenon.

If the transmission medium is perfect then the receiver will get the exact signal which was send by transmitter during transmission, but generally communication means are not up to the mark so, the received signal will not be same as it transmitted. This impairment of signals leads to errors in signal information, Communication lines suffer from different problem like, Free Space Loss, Rain Attenuation, Atmospheric Absorption, Terrain/Humidity Factor, Composite Fade Margin, Frequency Diversity, Reliability and Space Diversity

1.9 Objective

Dust storm are meteorological phenomena occur for a percentage of time in arid and semi-arid areas especially at Africa and middle east ,measurement at existing microwave links have showed dust storms can potentially result in serious attenuation in signal level especially at Ku band and higher frequency with direct impact on telecommunication system performance

In this project work an iterative technique has been presented to explain the sequential communication of signal transmission for long and short distance radio communication through microwave link with better efficiency, the objective of our work is to analysis signal attenuation during dust storm in Khartoum, Madani and Port Sudan in different path loss model and modulation technique that can help to build efficient microwave link to established wireless communication.

The main objective of this project is to check the stability of the signal level of the Microwave in real live network in dust storm, four Microwave links at 18GHz in different lengths were under study in Khartoum, Madani and Port Sudan, we used Management System (U2000 - computerize system) to monitor the Transmitted and Received Signal Levels (TRSL) have been recorded for one year from 1 Jan 2016 to 31 Dec 2016, to comprises the four microwave links data acquisition and processing system and we compare with data from An Automatic Weather Station Forecasters (AWS) operating at Khartoum International Airport. Visibility reduction is measured using the near infrared link and create software program to upgrade the signal level automatic.

Dust storms are significant meteorological phenomena which attenuates signal level especially at Ku band and higher frequencies with direct impact on telecommunications system performance.

Few prediction models have been developed to calculate the attenuation due to dust storm in dB/km, all prediction models have assumed that the intensity of dust storm is uniformly distributed around the area covered by the dust storm. It has been found that the dust storm intensity is not uniformly distributed along the horizontal path. However, to predict the total attenuation due to dust storm that a microwave link might suffer, an adjustment factor is needed to account for the variation of dust storm intensity along the propagation path.

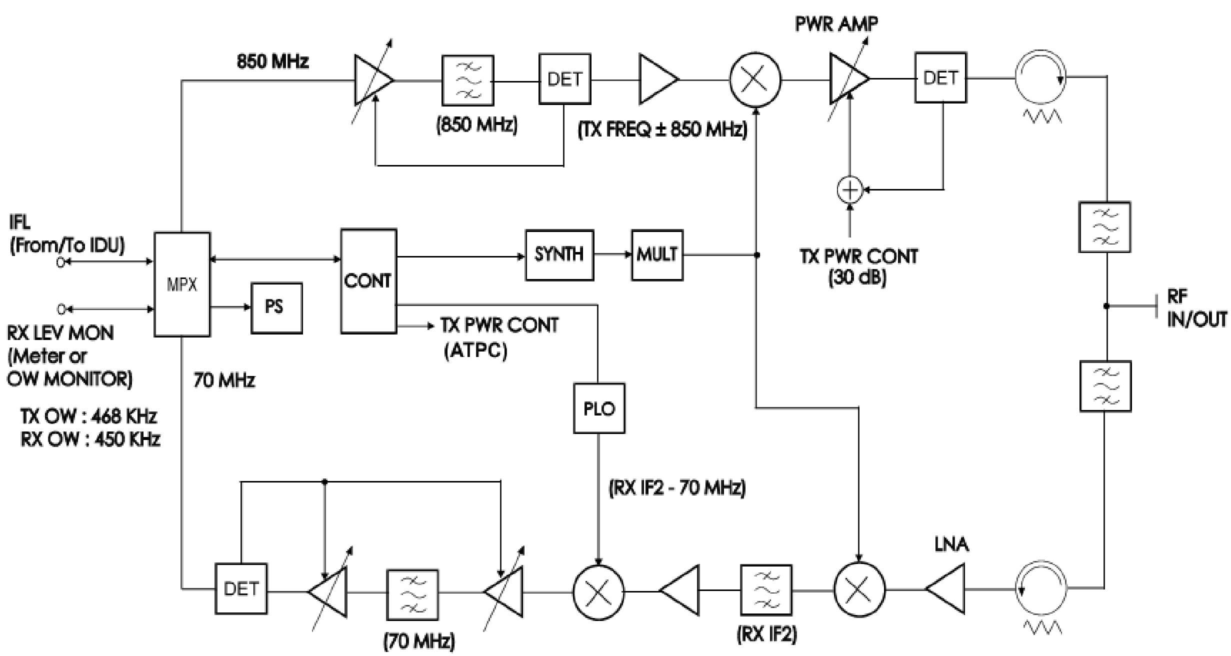


Figure 1.1: Block diagram of Paso link ODU (13~38G)

1.10 Layout of the Thesis

The thesis consists of five chapter, chapter one is the introduction, chapter tow is Literature review include previous studies, material and methods are in chapter three. The software and flowchart are in chapter four. Chapter five is concentered with result, discussion and conclusion.

Chapter Two

Literature review

2.1 Introduction

Before going into the details of the Microwave link in Wireless communications one need to understand what is meant by communication, the communication is when information such as voice, data, image and video is transferred to one place and received at another place with some distance. The basic aim of a communication system is to ensure the sharing of data information among people over some distance.

2.2 Communication System's Basic Structure

Basically every communication system consists of a transmitter, a transmission medium and a receiver and Figure 2.1are shows the basic part of a communication system.

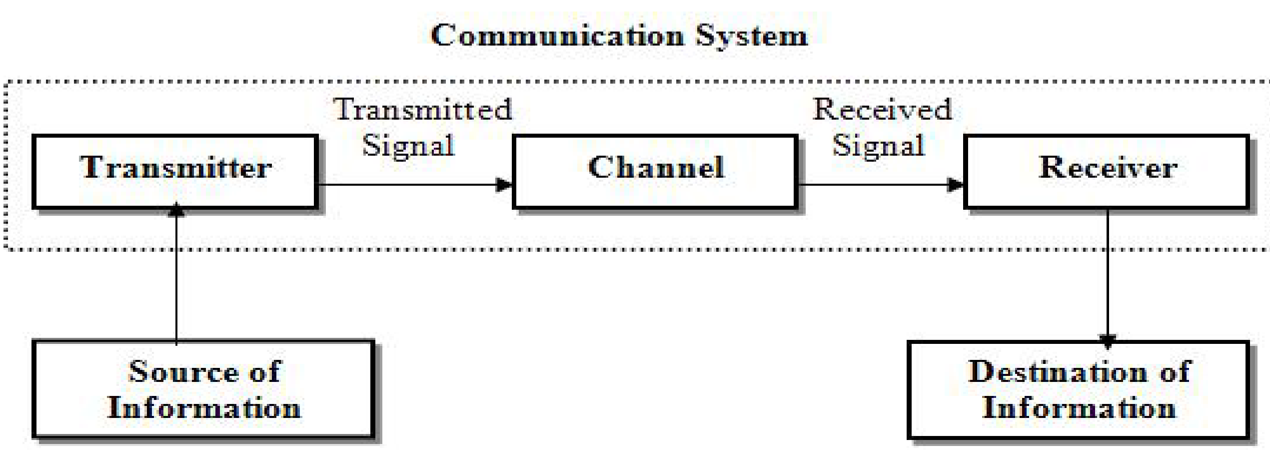


Figure 2.1: Basic Structure of Communication System

The Transmitter converts the source message into an electrical signal, the transmitter is basically responsible for encoding the message and then this encoded message is multiplied by carrier frequency i.e. modulate the signal and then transmitted over the channel. At the receive end, the receiver demodulate the received signal and decode it and generate the original message. Minimal distortion at the receiver end is referred as a good communication property.

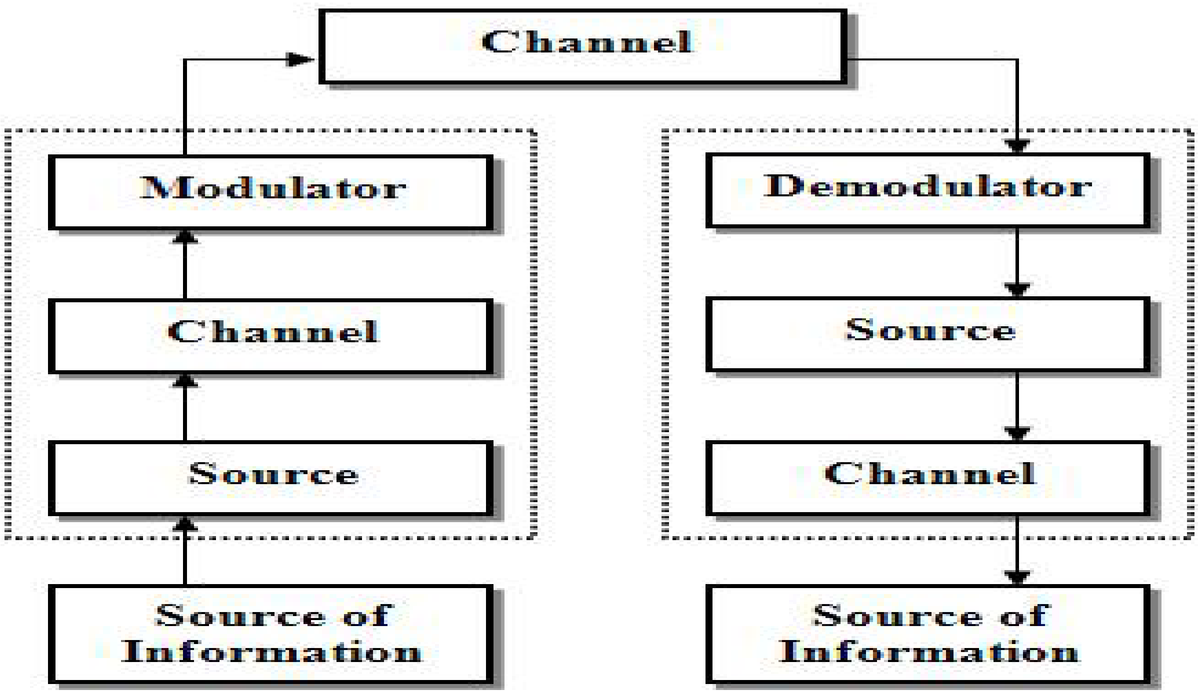


Figure 2.2. Communication System

The transmission standard from transmitter to the receiver can be categorized as direct medium and indirect medium. The direct medium is usually wired communications while the indirect medium is normally relied on wireless communication. The Public telephone, optical fiber and LAN based networks are examples of wired transmission whereas GSM, GPRS, 3G W-CDMA/UMTS, WiMAX, 3.9G LTE, WLAN and TV broadcasting are examples of wireless communication.

Communication systems could also be categorized as analog and digital communication. The existence of transmission impairments makes the difficulty in order to reproduce the analog signals at the receiver. All analog and digital systems transmit analog signals. These signals are poorly exaggerated by the noise or distortion. On the other hand digital systems offer fine performance and improved efficiency which is exempted from obligation to noise. Because of these favorable circumstances digital systems are more appropriate and popular. The communication system such as digital or analog may depends on modulation scheme. This scheme is described as the distinction of the carrier waves in provisions to the frequency, amplitude and phase in a radio signal or electromagnetic wave which tidy to make it appropriate for communication [6].

2.3 Some Important Terms Used In Communication Systems

Communication systems are based on different channels communication through which data is transferred. There are some important terms used in communication which are:

2.3.1 Multiplexing

It is used to transmit multiple signals through a single medium. While, DE multiplexing is obtained at the receiver side to detached the multiplex radio signals. It is an integral part of transmitter.

2.3.2 Multiple Accesses

This term of communication system allows various users to connect who want to contribute for the similar channel. Following are the most common of multiple access technologies:

2.3.3 Frequency Division Multiple Access – FDMA

In FDMA scheme, the frequency band is allocated to each single user by separating the frequency band into further smaller bands. This allocation of frequency band is done after guaranteeing lowest interference among frequency bands.

2.3.4Time Division Multiple Access – TDMA

The TDMA scheme is basically used for shared resources for wireless networks. It uses the same frequency band for all users in different time intervals. For utilization of complete frequency band during the period, a separate time slot is allocated to each user. In 2nd Generation (2G) Cellular networks TDMA channel access scheme is used and GSM used the combination of FDMA and TDMA schemes.

2.3.5 Code Division Multiple Access - CDMA

One of the basic ideas of data communication is to allow transmitters for sending data information over single communication, simultaneously. In this way various users can share bandwidth of different frequencies. This idea is called multiplexing. CDMA channel scheme makes a data transmission to multiple users through assigned code for each transmitter to permit multiple users to be multiplexed over the same channel. Frequency Division Multiple Access separates access by frequency whereas Time Division Multiple Access separates access through time, while CDMA deals with both frequency and time.

2.3.6 Orthogonal Frequency Division Multiple Access - OFDMA

In OFDMA, the carrier signal is separated into different smaller subsets. For a single user this separated carrier signal subset is used to send data. To get quality of service OFDMA may be used beside OFDM.

2.4 Forms of Communication

In today's communication are wireless communication has taken on an entirely depth understanding. However, it can generally be categorized into following forms:

2.4.1 Point to Point Communication

The point to point communication describes that transmission take place among two points which are too much away from themselves. The common understanding of point to point communication is voice call among two communicators.

2.4.2 Point to Multipoint Communication

The point to multipoint communication describes that only one transmitter is present at the transmitter side and various receivers are present at the receiver side. For example video conferencing

2.4.3 Broadcasting

The Broadcasting communication describes that all users receive the conveyed signal. In this situation, the transmitter is generally at the middle position and it throws information to each receiver. Examples of broadcasting are TV and radio.

2.4.4 Simplex

When information is sent only in one direction then it's called a simplex mode of communication.

2.4.5 Half Duplex

In half duplex the data is transferred in both directions but at different time break such as from sender side to receiver side at once then from receiver part to sender part at other time then it's known as half duplex communications.

2.4.6 Full Duplex

When the information is send to both directions simultaneously such as in half duplex then the transmitter and receiver can correspond concurrently. Mobile Global System for Mobiles – GSM, Hands Free for Voice over IP, 3G video networks etc are examples of full duplex communication

2.5 Transmission Impairments

Electrical signals contains data or information with different voltage level which represents the data information steams. If the transmission medium is perfect then the receiver will get the exact signal which was send by transmitter during transmission, but generally communication means are not up to the mark so, the received signal will not be same as it transmitted. This impairment of signals leads to errors in signal information [7]. Communication lines suffer from different problems.

1. Fading
2. Noise
3. Delay Distortion
4. Attenuation
5. Doppler shift

2.5.1 Fading

Fading is define as the noise or distortion gained by a carrier-modulated signal during transmission over certain propagation media such as multipath fading [6, 7]. It can be characterized as follows:

1. Rayleigh Fading
2. Ricean Fading
3. Frequency selective Fading
4. Slow Fading
5. Fast Fading
6. Flat Fading

2.5.1.1 Rayleigh Fading

In Rayleigh fading when there is no Line Of Sight (LOS) path exists between transmitter and receiver which have only indirect path than in result the received signal contains sum of all scattered and reflected waves [7].

2.5.1.2 Ricean Fading

This type of fading present in a condition when there exist a LOS and non LOS path between receiver and transmitter i.e. received signal consist of scattered and direct multipath waves [7].

2.5.1.3 Frequency Selective Fading

Take place when signal bandwidth and delay spread is larger than bandwidth of a channel and symbol period respectively [7].

2.5.1.4 Slow Fading

Exist in a condition when Doppler Spread Spectrum is lower and coherence time is more than symbol period in channel [7].

2.5.1.5 Fast Fading

It takes place in condition when Doppler Spread Spectrum is higher and coherence time is smaller than symbol period in channel [7].

Coherence Time: duration of time when channel impulse response is invariant.

Symbol Time: time required to complete one symbol

2.5.1.6 Flat Fading

Is a type of fading in which ratio of rising and falling of all parts of the received radio signal is same [7].

2.5.2 Noise

The data which is not used to transfer or transmit signal other than source is known as noise. It can be classified into following sub categories:

- AWGN
- Inter Symbol Interference
- Impulse Noise
- Intermodulation
- Cross Talk
- Thermal Noise

2.5.2.1 AWGN Noise

AWGN contains uniform continuous spectrum frequency over specified frequency band which affect the signal transmitted signal.

2.5.2.2 Inter Symbol Interference (ISI)

Is a form of noise or distortion of signal interference for one symbol with frequent symbols? ISI is generally caused by channel's multipath propagation and the essential response of non-linear frequency. ISI communication is less reliable.

2.5.2.3 Impulse Noise

Occurs due to frequent disturbance caused by lighting and voltage spikes in equipment and result generate errors in transmission.

2.5.2.4 Intermodulation

Is a noise occurs due to non-linear characteristics of medium, when two signals sent through the medium with interferences and different frequencies. When these signals interfere with each other new frequencies occurs and they create redundant signals. These signals need to be filter out.

2.5.2.5 Cross Talk

Is a redundant noise occurred due to paths mixture of two signals which are near to each other?

2.5.2.6 Thermal Noise

Thermal noise occurs due to the "*thermal interruption of electrons in a conductor also known as White* Noise". It can be calculated for given bandwidth using the following equation:

$$N=KTB \qquad (2.1)$$

Where:

N = Noise power in watts

k = Boltzmann's constant. 1.3803 × 10–23 J/K

T = Temperature in Kelvin

B = Bandwidth in Hz

2.5.3 Delay Distortion

When different components of frequency arrive at different times, which deform the signal's amplitude and delay the signals at receiver end then delay distortion occurs. Following are the circumstances or factors involve in channel's delay distortion:

- Scattering
- Reflection
- Diffraction

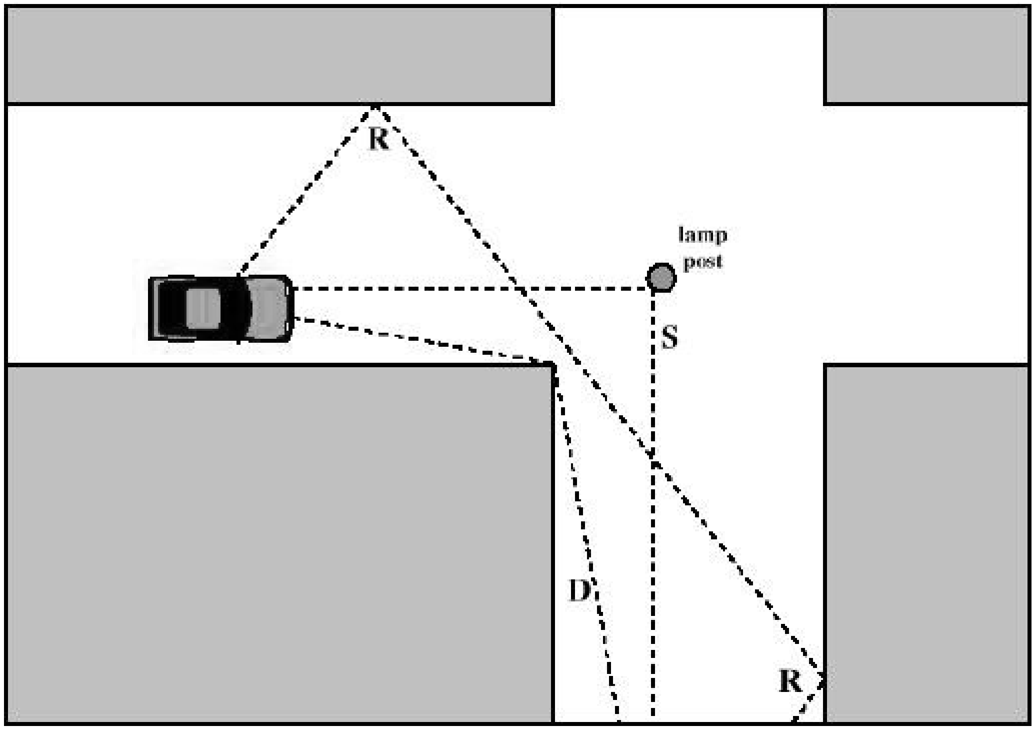


Figure 2.3. Sketch of three important Propagation Mechanisms Reflection (R), Scattering (S), and Diffraction (D) [7].

2.5.3.1 Scattering

Scattering occurs when the radio channel contains objects whose dimensions are approximately the same as or smaller than the propagating wavelength. Scattering, which follows the same physical principles as diffraction, causes energy to be radiated in many different directions. As frequencies increase, the wavelengths become shorter, and the reflective surface appears rougher, thus resulting in more diffused reflections as opposed to specular reflections.

Although not a serious problem for terrestrial microwave point-to point links, scattering attenuation through clouds can be a serious issue for satellite systems. While cloud-related losses are usually very low below 15 GHz, they become an increasingly serious concern with increasing frequency. The millimeter bands above 40 GHz are virtually unusable for satellite work, and even the *Ka* band (20–35 GHz) window could be exposed. Of course, the same caveats concerning path length also apply, so for a satellite link, the steeper the elevation angle, the better.

At ranges far beyond the horizon, the propagation loss is dominated by troposcatter. Propagation in the troposcatter region is the result of scattering by small imperfections within the atmosphere's refractive structure. Above the tropopause the temperature is constant; there is little humidity and no movement in the air, thus few irregularities to scatter radio signals.

2.5.3.2 Reflection

Reflection occurs when an electromagnetic wave strikes a nearly smooth, large surface, such as a water surface, and a portion of the energy is reflected from the surface and continues propagating along a path that defines an angle with the surface equal to that of the incident ray. Obstruction dimensions are very large compared to the signal wavelength.

The strength of the reflected wave is determined by the reflection coefficient, a value that depends on the frequency and polarization of radiation, the angle of incidence, and the roughness of the reflecting surface.

For shallow incidence angles and smooth seas, typical values of the reflection coefficient are near unity, i.e., the reflected wave is almost as strong as the incidence wave causing so-called specular reflection.

The law of reflection states that for specular reflection the angle at which the wave is incident on the surface equals the angle at which it is reflected.

Reflection rays from different surfaces may interfere constructively or destructively at a receiver causing multipath propagation.

2.5.3.3 Diffraction

Diffraction occurs when an impenetrable body obstructs the radio path between the transmitter and receiver. Energy tends to follow along the curved surface of an object. Diffraction is one of the important physical phenomena which have been studied using different approaches. Based on Huygens ’ Principle, secondary waves form behind the obstructing body, and the study is usually mainly based on physical optics.

The ability of the electromagnetic wave to propagate beyond the horizon by diffraction is highly dependent on frequency; the lower the frequency, the more the wave is diffracted. Over-the-horizon communication systems, for example, are based on this principle.

When the clearance of the radio path over the underlying terrain becomes small, diffraction phenomena take place, and they reduce the received signal strength. To determine how close the radio path can approach an obstacle before diffraction losses begin to occur, we can use the concept of the first Fresnel zone.

2.5.4 Attenuation

Attenuation is defined as power loss of the propagated signal with respect to time and distance, These signals required to be strong sufficiently in a way that receiver can distinguish and detect the required signals, there is possibility that receiver may not be able to detect the signal at all if the attenuation level is high. Therefore, for unswerving communication, delay and attenuation must be stable [8]. Attenuation can be derived as signal power Ps at transmitter and signal power Pd at receiver, then Ps > Pd. Power attenuation Ap in dBs is:

$$A_p = 10 \text{ Log}_{10} \left({}^{P_s}/_{P_d} \right) \quad (2.2)$$

2.5.5 Doppler Shift

Various copies of same signals can be received at receiver end because of transmission of multipath radio's. The Doppler shift is known as when object is moving with little speed (velocity) then there will be a shift of frequencies in each received signals. It can be derived as:

$$f_d = (v\, f_c/\lambda) \cos \alpha \quad (2.3)$$

Where

fd = Doppler shift frequency

v = velocity of moving object,

λ = wavelength of signal

α = angle w.r.t reference point.

2.6 Considerable Parameters of Microwave

This section describes the most considerable parameters of microwaves antennas.

2.6.1 Microwave Antenna

Any conductor that can intercept an RF field can be an antenna. The Basic Principle of Microwave antennas are similar to those of antenna used at lower frequencies. Basically an antenna converts RF power into Electromagnetic radiation. More briefly an antenna is transducer which is specially designed to transmit and receive electromagnetic wave. A good transmitting antenna is often a good receiving antenna. For designing wireless systems, engineers must select an antenna that fulfils the system's requirements to firmly close the link between the remote points of the communications system.

Figure 2.4. Passive relay station (Plane reflectors)

Figure 2.5 Passive relay station (Parabolic reflectors)

2.6.1.1 The Isotropic Antenna

Isotropic Antenna means is an antenna that transmits equally in all directions. It is hard to achieve isotropic antenna in real life. Actually isotropic antennas do from a very important functions are used as a standards by which can determine how directional some other real life antennas are and what their antenna gain might be. All antennas are therefore compared to the theoretical workings of an isotropic antenna [9].

2.6.2 Parameters of Antenna

There are various considerable vital parameters that influence an antenna's performance and it can be synchronization during the designing procedure [9].

Following are the main considerable parameters for antenna:

1. Input Impedance
2. Radiation Pattern
3. Directivity
4. Polarization
5. Gain
6. Efficiency

2.6.2.1 Input Impedance

Input Impedance is the most important parameter that’s related to the antenna and its transmission line. It is used to determine the transferring power from the antenna to transmission line and vice versa. Between antenna and transmission line the Impedance match is expressed by the term Standing wave ration (SWR) or reflection coefficient and is expressed in decibels. [9].

2.6.2.2 Radiation Pattern

The radiation pattern is the geometric pattern of the comparative field strengths of the field discharged by the antenna. It would be sphere in case of perfect isotropic antenna and a dipole antenna would be a toroid. Antenna radiation pattern is usually shown by a graph of three dimensions, or for vertical and horizontal cross sections may be represented by polar plots. The graph must illustrate back and side lobes, where the gain of the antenna is at maximum or minimum. [10].

2.6.2.3 Directivity

Antenna Directivity means that maximum antenna gain compared with its gain that is averaged in all direction. Directivity go antenna always independent of its radiation efficiency. [10].

2.6.2.4 Polarization

The antenna polarization describes the electromagnetic wave polarization emitted by the antenna beside a vector initiating at the antenna and pointed along the principal direction of transmission. The polarization position of the wave is defined by the shape and direction of an ellipse produced by tracing the boundary of the electromagnetic field vector against time. However each antenna is elliptically polarized, mainly antennas are specified by the best polarization circumstances of spherical or linear polarization. [10].

2.6.2.5 Gain of antennas

The hypothetical isotropic antenna radiates power equally in all direction and measures any real type antenna gain with compare to the isotropic antenna. Actually the antenna gain means the amount of energy radiate in the direction compared to the isotropic antenna radiate the amount of energy in same direction. The maximum gain is that the direction antenna radiates most power.

We can calculate the gain of parabolic antennas by using the following formula:

$$G = 20\text{Log}(D) + 20\text{Log}(F) + 17.8 \qquad (2.4)$$

Where,

G: Gain of antennas

D: diameter of the parabolic antenna (unit: m)

F: operating frequency (unit: GHz)

G: antenna gain (unit: dB)

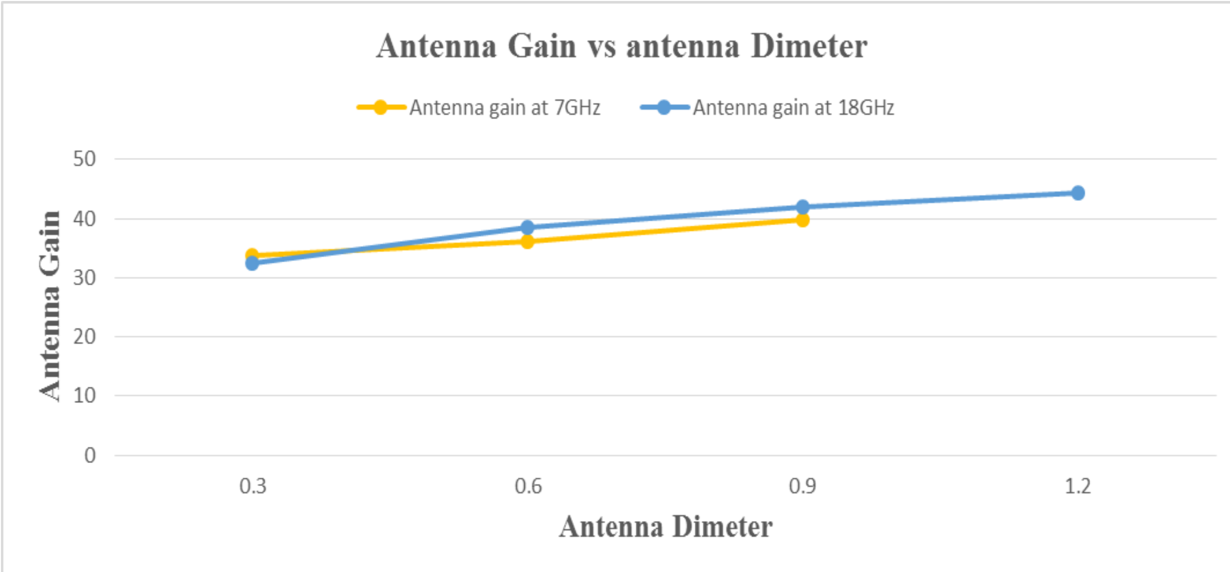


Figure 2.6: Antenna Gain in Different Dimeter at 18 and 7 GHz

Generally, passive relay stations use large-diameter parabolic antennas. If the Diameter of the parabolic antenna is increased to a large extent, the cost of the Passive relay station grows high and the installation and erection become difficult. In Addition, the half-power angle of the beams from the parabolic antenna must be small, which makes the antenna installation complicated and the antenna adjustment Difficult, because the half-power angle of the beams from the parabolic antenna is Reverse to the diameter of the parabolic antenna. Therefore, the parabolic antennas

That have too large diameters are not applicable to common passive microwave relay Stations on the ground.

2.6.2.6 Efficiency

The efficiency of an antenna is generally determined on its capability to emit energy into the air. Antenna can be efficient when during the radiation procedure it dissipate very less energy. On the other hand antenna efficiency is generally referred to the power gain as measured with a regular reference antenna. Whereas, power gain of an antenna is a proportion to the radiated power of reference antenna which is basically dipole antenna, when the energy is radiated both antenna should supply radio frequency energy in same behavior and position. [10].

2.7 Path Loss

Generally radio transmission systems consist of transmitter, antennas and receiver. In radio transmission the most important questions are: how far apart can the transmitter and receiver be in distance while maintaining acceptable performance, and what can be changed to increase this separation distance?

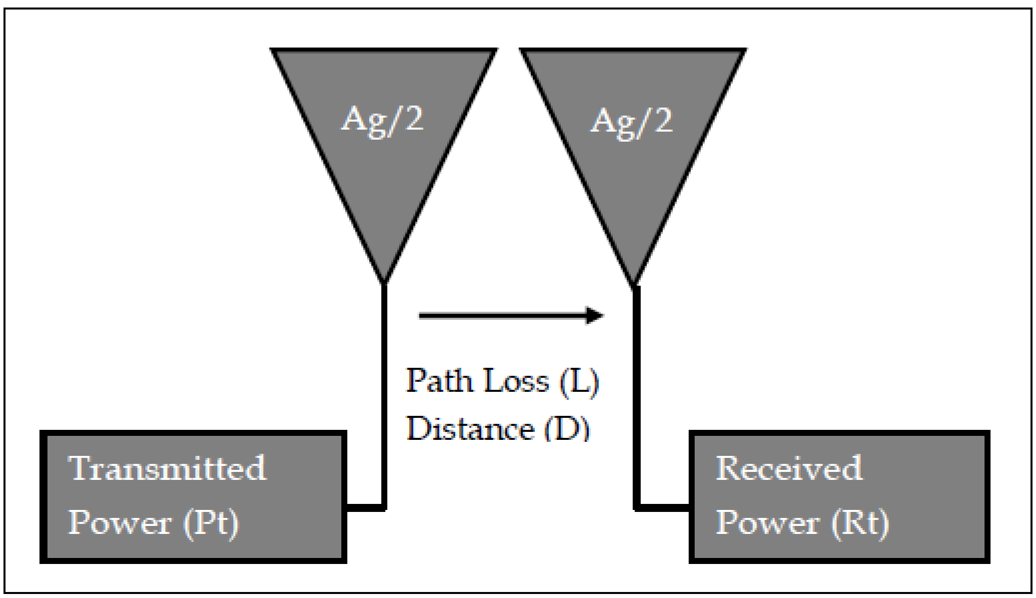


Figure 2.7. Typical RF Transmission System

The simple answer is: Use the Free Space Path Loss model in determining transmitter and receiver separation, and change the transmitter power to increase separation distance.

The following definitions are referring to the equations (2.5) and (2.6):

Pt = Transmitter power in dBm

G tot = (Ag - Cl) Total gain in dB

L = Transmission path loss in dB

R = Receiver sensitivity in dBm

d = Distance between transmitter and receiver in meters

Figure 2.7 shows the typical RF Transmission system. The received signal strength R is equal to:

$$R = Pt + G_{tot} - L \tag{2.5}$$

For a known receiver sensitivity value, the maximum path loss can be derived as:

$$L = Pt + G_{tot} - R \tag{2.6}$$

2.7.1 Path Loss and Distance Calculation

Path Loss depends on many factors such as frequency, antenna height, receive terminal location relative to obstacles and reflectors, and link distance. It is the largest and most variable quantity in the link budget. Usually a statistical path loss model or prediction program is used to estimate the median propagation loss in dB. There are many different path loss models available now based on different condition such as line of sight (LOS) or non-LOS.

The National Institute of Standards and Technology (NIST) have done an excellent job in documenting and comparing several realistic empirical propagation loss models. Based on the NIST study, the remainder of this document examines the following loss models [11].

2.7.2 Free Space Pathloss Model (FSPL)

FSPL is a fundamental factor for numerous radio frequency calculations and it is used in various locations for predicting power of radio signals which probably anticipated in a radio frequency system. FSPL is basically the sort of failure in signal strengths which happens when an electromagnetic wave communicate over a line of sight path in free space. In this condition there is no obstacle that may ground the signal to be refracted of reflected, or that may source of extra attenuation. The signal in FSPL decreases in a manner which is inversely proportional to square of distance among the signal source [11].

$$Signal = {}^{1}/_{distance^2} \qquad (2.7)$$

2.7.2.1 FSPL Equation

The majority radio frequency evaluations and dimensions are achieved in decibels (dB). It provides a simple and steady method to balance the signal levels formed at different positions [11].

We can calculate the free space loss on the path by using the following formula:

FSL = 92.45 + 20lgD + 20lgF (2.8)

Where

FSL: free space loss (unit: dB)

F: operating frequency (unit: MHz)

D: distance in km

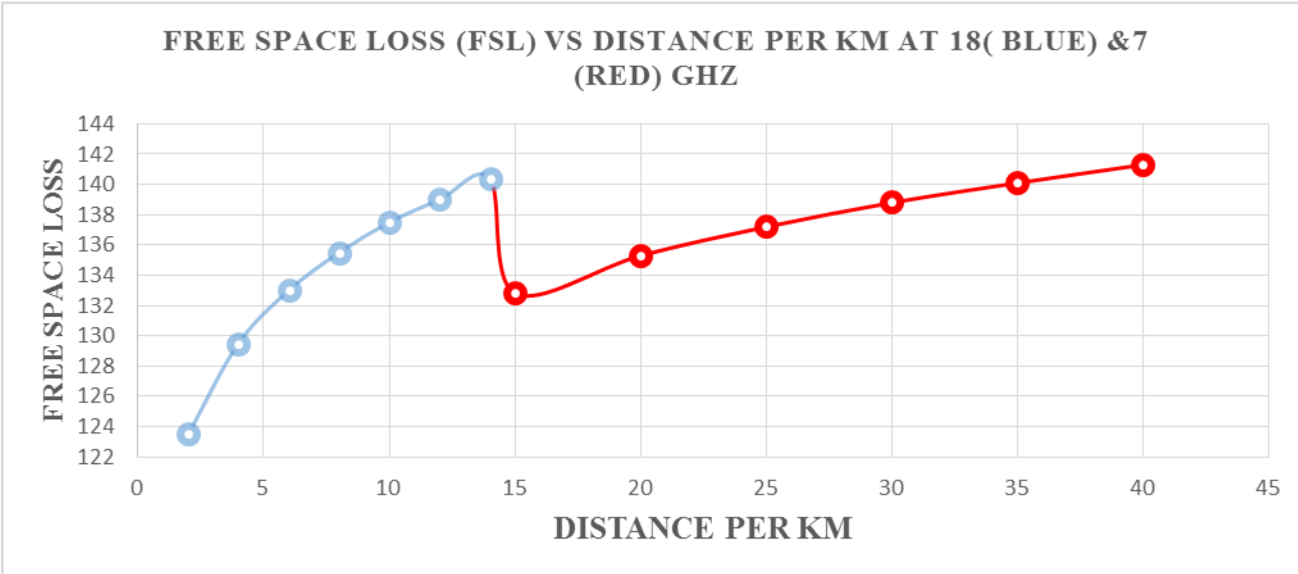


Figure 2.8. Free space loss Vs Distance (from 2Km to 14km in blue) at 18 GHz and (from 15Km to 40km in Red) at 7GHz

2.7.3 Link Budget

Shaping and calculating all the power gain and loss in a transmission system is known as link budget. It identifies the total of power form transmitter that is required to broadcast a signal with a definite Signal to Noise Ratio - SNR and satisfactory Bit Error Rate - BER. Path loss, distortion, failure by rain, connectors, losses, cable losses and antenna gain are the aspects which are obligatory to be taken into the consideration though estimation of link budget. Figure 2.9 illustrates the link budgeting procedure [11].

A microwave engineer starts the microwave link design by doing a link budget analysis. The link budget is a calculation involving the gain and loss factors associated with the antennas, transmitters, receivers, transmission lines, and propagation environment, used to determine the maximum distance at which a transmitter and receiver can successfully operate.

The purposes of the *transmitter* are to generate the carrier frequency that is to be used for the communication, to modulate this carrier frequency with the desired information, and finally, to amplify the signal so that it attains a sufficiently high power level so that it may travel the desired communication distance to the receiver.

The *receiver* amplifies the received signal (which is at this point much weaker than when it was transmitted), filters out any undesirable signals (interfering signals) that the receiver picked up and, finally, detects the existence of information in the carrier frequency.

The purpose of transmission lines is to interconnect the antenna with the transmitter/receiver. Transmission lines between the radio equipment and the antenna may consist of coaxial cabling or a (flexible) waveguide. The *antenna-coupling unit* makes it possible to utilize a common antenna for both the transmitter and receiver. The transmitter and receiver can, for example, be connected to the same antenna either via a duplex filter or a transmitter/receiver switch. Together, feeder cable losses, antenna-coupling losses, and any additional losses (depending on the radio configuration) constitute *branching losses*.

The *antenna* adapts the generated signal to the surrounding environment (to the propagation medium) and directs the radio waves that are to be transmitted towards the receiving station. When receiving, the antenna receives the signal from the desired direction and sends it to the receiver.

Every antenna is typically characterized by its impedance, bandwidth, directivity (radiation pattern), and polarization. Antennas may be more or less an isotropic antenna (it radiates equally in all directions) or an antenna that exhibits extremely high directivity, such as parabolic dish antennas used in microwave point-to-point links.

The *receiver sensitivity threshold* is the signal level at which the radio runs continuous errors at a specified bit rate. Specifications are listed for the 10−3 bit error rate (PDH radios) or 10-6 bit error rate.

System gain (in decibels) is defined as the difference between the transmitter output power and the receiver threshold. Lowering the system gain will reduce the fade margin. System gain can be used to reduce antenna sizes or improve the path availability. A given radio system has a system gain that depends on the design of the radio and the modulation used.

For example, 99.999 percent system availability (five minutes of outage per year) will degrade to 99.980 percent (two hours of outage per year) if the modulation is changed from 16 QAM to 128 QAM without recovering the system gain reduction and all other conditions remaining unchanged.

The gains from the antenna at each end are added to this gain, with larger antennas providing higher gain. The free-space loss of the radio signal as it travels over the air is then subtracted from the system, and the longer the link, the higher the loss. These calculations result in a “fade margin” for the link (see Figure 2.11); *fade margin* is the difference between the received signal and receiver threshold value (or sensitivity) for given BER, typically 10-6 or 10-3.

In most applications, the same duplex radio setup is applied to both stations forming the microwave link. Thus, the calculation of the received signal level is independent of direction. The radio can handle anything that affects the radio signal within the fade margin. If the margin is exceeded, then the link could go down and

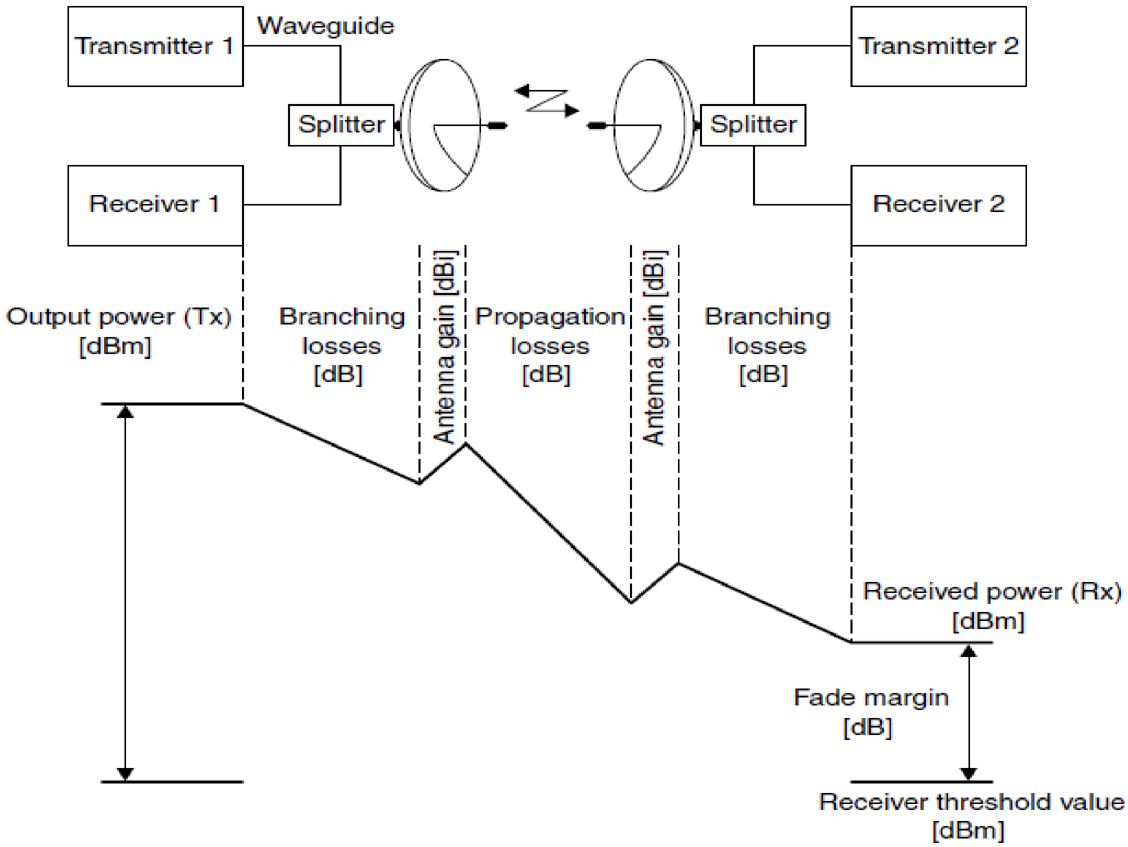


Figure 2.9. Radio path link budget

Therefore become unavailable. The fade margin is calculated with respect to the receiver threshold level for a given bit-error ratio (BER). The threshold level for BER = 10−6 for older microwave equipment used to be about 3 dB higher than the threshold level for BER = 10−3. Consequently, the fade margin was 3 dB lower for BER = 10−6 than for BER = 10−3. For the new generation of microwave radios with power forward error correction schemes, this difference is more in the 1.0 to 1.5 dB range.

After analyzing the link budget, the next step is to analyze rain fading, multipath fading, interference, and other (miscellaneous) losses that could potentially affect the radio signal.

2.7.4 Calculation of Link Budget

In Figure 2.9 once the heights of the transmitting and receiving towers have been established the designer is in a position to select the appropriate antenna, or waveguide, transmitter power and receiver sensitivity to operate the proposed system. The next step is then to calculate the link budget to verify that the design will operate satisfactorily. There is a need to check, on both of the link transmitting frequencies, that sufficient signal arrives at the chosen receiver. This is done by consulting the appropriate data sheets for the chosen items of equipment to determine their appropriate gains and losses.

To starting point of any Link Budget is the equipment parameters of the intended microwave equipment to be used and these are; RF output power usually expressed in dBm or Watts. Receiver sensitivity usually expressed as a Bit Error Rate (BER) against a given RF signal level,

The system Link Budget is then calculated using the following methodology [17].

- The free space loss along the radio path is calculated (FSL)
- The effective power produced by the transmitter is calculated (EIRP)
- The effective gain of the receiving antenna is obtained (GRX)
- The losses o The signal arriving at the receiver is the algebraic sum of all the above gains of all components in the receiving chain is calculated (LRX) and losses can be calculated as follows:

$$\text{Received Signal} = EIRP - LFS + GRX - LRX \text{ dBW} \quad (2.9)$$

This can be compared with its receiver sensitivity limit (RSL) Providing the received signal exceeds the RSL with sufficient fade margin then the system is deemed satisfactory.

2.8 Adaptive Modulation

Adaptive modulation is a way to provide balance between Bit Error Rate (BER) and spectral efficiency. It is possible to make effective use of adaptive modulation in a slowly varying fading channel with noise based on SNR estimation. Phase of high gain of power or lower fading, will improve the SNR, which allow the higher modulation schemes to be worked with less probability of error, on the other hand, phase of higher fading, will deteriorate the SNR and force us to work with lower modulation schemes in order to make transmission more effective.

A sinusoidal electromagnetic wave has three properties: *amplitude*, *frequency*, and *phase*. Any one of these parameters can be modulated to convey information. However, phase and frequency are just different ways to view or measure the same signal change15. In terrestrial radio systems, for example, AM and FM channels represent amplitude and frequency modulation, respectively. In analog signals, the range of values of a modulated parameter is continuous.

Over the past 20 years, a major transition has occurred in communication systems, from simple analog amplitude modulation (AM) and frequency/phase modulation (FM/PM) to new, and more complex, digital modulation techniques. Examples of digital modulation include

QPSK (quadrature phase shift keying)

FSK (frequency shift keying)

QAM (quadrature amplitude modulation)

In digital signals, the modulated parameter takes on a finite number of discrete values to represent digital symbols. The advantage of digital transmission is that signals can be regenerated without any loss or distortion to the baseband information.

To transmit a signal over the air, there are three main steps:

1. A pure carrier is generated at the transmitter.

2. The carrier is modulated with the information to be transmitted.

Any reliably detectable change in signal characteristics can carry information.

3. At the receiver the signal modifications or changes are detected and demodulated.

In *amplitude modulation*, the amplitude of a high-frequency carrier signal is changed in proportion to the instantaneous amplitude of the modulating information signal. In *frequency modulation*, the amplitude of the modulating carrier is kept constant while its frequency (or the phase in phase modulation) is changed by the modulating information signal.

A simple way to view amplitude and phase is with the *polar diagram*, as shown in (Figure 2.10a). The carrier becomes a frequency and phase reference and the signal is interpreted relative to the carrier. The signal can be expressed in polar form as a *magnitude* and a *phase*. The magnitude can be either an absolute or relative value, and both are used in digital communication systems (Figure 2.10b).

Amplitude and phase can be modulated simultaneously and separately, but this is difficult to generate and especially difficult to detect. Instead, in practical systems the signal is separated into another set of independent components: I (in-phase) and Q (quadrature). These components are orthogonal and do not interfere with each other (Figure 2.10c).

Polar diagrams are very common in many displays used in digital communications, although it is common to describe the signal vector by

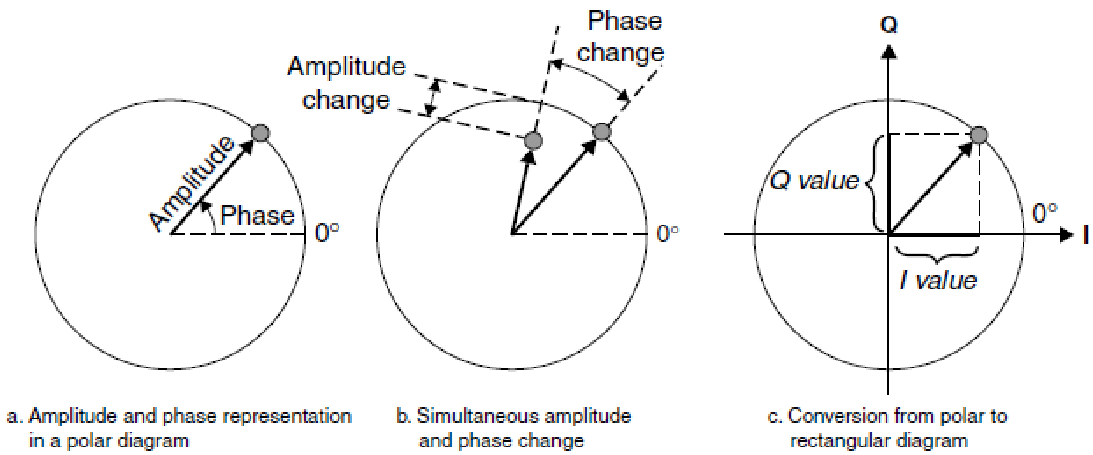


Figure 2.10. Signal changes in polar form

Its rectangular coordinates of I and Q, a rectangular representation of the polar diagram. On a polar diagram, the I axis lies on the zero degree phase reference, and the Q axis is rotated by 90 degrees. The signal vector's projection onto the I axis is its "I" component and the projection onto the Q axis is its "Q" component. I/Q diagrams are particularly useful because they represent the way most digital communications signals are generated using I/Q modulator.

2.8.1 I/Q Modulator/Demodulator

In the transmitter, I and Q signals are mixed with the same local oscillator (LO) (see (Figure 2.11). A 90° phase shifter is placed in one of the LO paths. Signals that are separated by 90° are also known as being orthogonal to each other or *in quadrature*.

Signals that are in quadrature do not interfere with each other. They are two independent components of the same signal. When recombined, they are summed to a composite output signal. There are two independent signals in I and Q that can be sent and received with

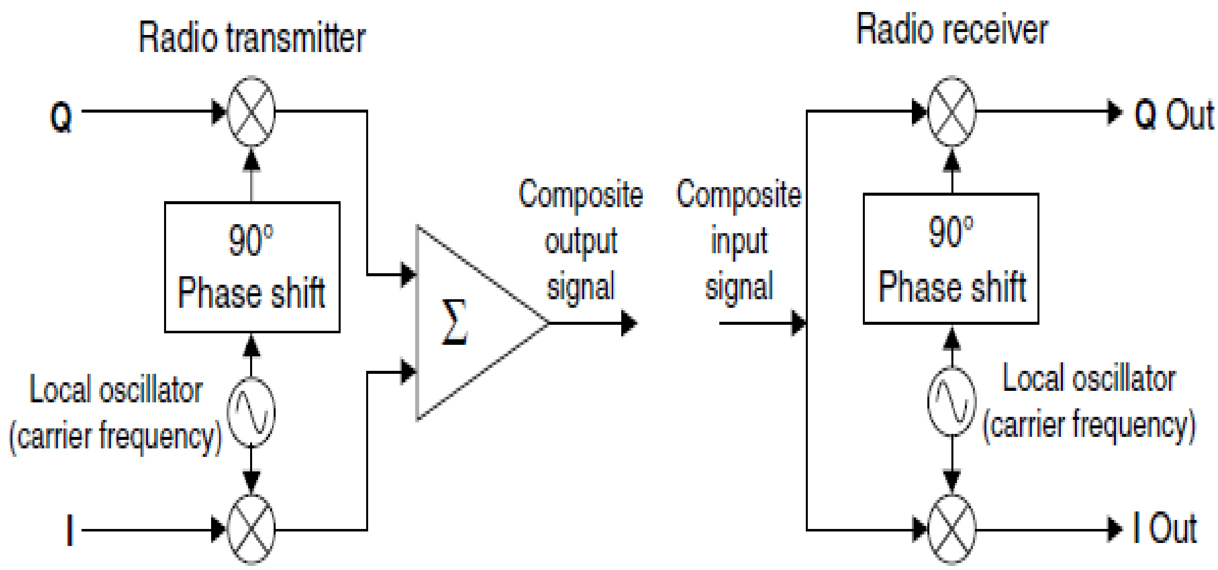


Figure 2.11. I/Q modulator/demodulator

Simple circuits, thus simplifying the design of digital radios. The main advantage of I/Q modulation is the ease of combining independent signal components into a single composite signal and later splitting such a composite signal into its independent component parts.

At the receiver, the input signal is mixed with the local oscillator signal at the carrier frequency in two forms. One is at an arbitrary zero phase while the other has a 90° phase shift. The composite input signal (in terms of magnitude and phase) is thus broken into an in-phase (I) and a quadrature (Q) component. These two components of the signal are independent and orthogonal so one of them can be changed without affecting the other.

Normally, information cannot be plotted in a polar format and reinterpreted as rectangular values without doing a polar-to-rectangular conversion. This conversion is exactly what is done by the in-phase and quadrature mixing processes in a digital radio. A local oscillator, phase shifter, and two mixers can perform the conversion accurately and efficiently.

In order to understand and compare different modulation format efficiencies, it is important to understand the difference between *bit rate* and *symbol rate*. The required signal bandwidth of the communications channel depends on the symbol rate, not on the bit rate.

$$\text{Symbol rate} = \frac{\text{Bit rate}}{\text{Number of bits per symbol}} \qquad (2.10)$$

Symbol rate is sometimes called *baud rate* or *modulation rate* (note that baud rate is not the same as bit rate). If more bits can be sent with each symbol, then the same amount of data can be sent in a narrower spectrum. This is why modulation formats that are more complex and use a higher number of states can send the same information over a narrower piece of the RF spectrum.

Let's say you have an 8-bit sampler, sampling at 10 kHz for voice. The bit rate—the basic bit stream rate—would be 8 bits multiplied by 10,000 samples per second or 80 kbps. (Note that for the moment we will ignore the extra bits required for synchronization, error correction, etc.).

Groups of k bits can then be combined to form new digits, or *symbols*, from a finite symbol set of $M = 2^k$ such symbols. A system using a symbol set size of M is referred to as an *M-ary system*.

If one bit is transmitted per symbol, as with binary phase shift keying (BPSK), then the symbol rate would be the same as the bit rate of 80 kbps. If two bits are transmitted per symbol ($k = 2$), as in QPSK, then the symbol rate would be half of the bit rate or 40 kbps. QPSK is therefore a more band width efficient type of modulation than BPSK, potentially twice as efficient.

QAM is the most widespread digital modulation method in use today for high-capacity terrestrial microwave links, and employs a combination of amplitude and phase modulation. For example, in 16-state quadrature amplitude modulation (16QAM), there are four I values and four Q values. This results in a total of 16 possible states for the signal. It can transition from any state to any other state at every symbol time. Since 16 = 24, four bits per symbol can be sent (k = 4). This consists of two bits for I and two bits for Q. The symbol rate is one-fourth of the bit rate. So, this modulation format produces an even more spectrally efficient transmission; it is more efficient than BPSK, QPSK or 8PSK. *Note that QPSK is the same as 4QAM*.

Due to their spectral efficiency, 32QAM, 128QAM, and 512QAM are commonly used for high-capacity microwave digital radios. Unfortunately, the symbols get closer and closer together and thus more prone to errors due to noise and distortion, as well as interference.

2.8.2 Adaptive Modulation and Coding Scheme (AMC)

In wireless communication AMC or Link Adaption indicates the identification of the coding, modulation and signals and protocol parameters depending on the circumstances of radio link. For more understandings consider the examples of Pathloss, the intrusion due to transmitted signals from different transmitters, receiver sensitivity, and power outskirts of existing transmitter. Let’s consider the example of Enhanced Data rates for GSM Evolution (EDGE) which uses the adaption algorithm of Modulation and Coding Schemes (MCS). It depends on the excellence of radio channel, bit rate and more importantly on data transmission robustness. The link adaption procedure is dynamic but protocol parameters and signal depends on the radio link circumstances. If circumstances change signals and protocol parameters change. As an example, High-Speed

Downlink Packet Access (HSDPA) in Universal Mobile Telecommunications System (UMTS) occurs after every 2ms.

The channel information is frequently required by the adaptive modulation system at the transmitter. It can be assumed in time division duplex systems that the channel from the transmitter to receiver and receiver to transmitter are more or less be same. On the other hand the channel information may also be calculated deliberately at the receiver and gradually pass back to the transmitter. At the transmitter, the adaptive modulation improves the Bit Error Rate (BER) or rate of transmission boldly by exploiting the channel information, especially over fading channels which represents the wireless broadcasting environments. In a result adaptive modulation reveal enormous performance as compared to system which does not exploit channel information at transmitter.

2.8.3 Adaptive Modulation in Microwave Link

In microwave radio systems adaptive modulation is introduced for point to point digital communication to give more capacity to user over air throughout the period of good transmission conditions, where the path conditions will adapt dynamically the modulation level of radio link [8].

Automatic Transmit Power Control – ATPC is an adaptive technique which has been used in microwave radio system to lowers the output power when circumstances are good to lessen power utilization and network interface. If channel is suffering from fading then the power will be automatically increase in order to maintain the required level of performance link. ATPC is taken further by adaptive modulation by scheming of output power and modulation level dynamically, to regulate the link ability to fit with transmission conditions.

2.8.4 Key Benefits

Adaptive Modulation (AM) enables the service providers to easily grow the existing capability of links without increasing the size of antenna, no need of hardware changes and license conditions. Licensed radio links usually designed to carry system availability due to transmission give rise to outages of purely 99.9%, which means that the radio link will not be available for approximately 50 minutes in a year. For rest of the time the fading margin is essentially unexploited. Therefore, it is kept in reserve. The unexploited margin comes at elevated price, requiring radio links to be smaller duration, larger antennas or link capability to be inadequate than required. Whereas, adaptive modulation permit excessive use of fade margins to significantly increase the radio link capability for a smaller or no extra cost [8].

2.8.5 Adaptive Modulation

It is important to discuss about how to change the modulation scheme. In which our system will make a way to decide best suitable modulation scheme for present, future – delayed feedback conditions depending on different SNR level. Dunlop and Pons [18] asserted that BER at receiver level can be good enough to decide switching scheme. In this thesis the rejected metric of Pons and Dunlop is being used in order to estimate the Link SNR. The adaption rate would be restricted because BER estimation is complicated over short periods. Now, the question arises: How and what ranges of SNR can be best to use for which modulation scheme? The answer would be finding in performance of AWGN for each modulation scheme.

The received signal equation,

$$r(t) = c(t) \times s(t) + n(t) \qquad (2.11)$$

Where

r (t) is a received signal,

c(t) is a fading channel which is multiply with transmitted signal

s(t) with addition of noise

n(t). Generally is the signal to noise ratio

Decided by the noise since the signal power usually is restricted. To consider this the transmitted power of the signal is multiplied by fading channel. In result, the direct received signal power can be compare instantaneously with noise, which allows us to put BER in fading or AWGN channel. Now, let's take the BER performance for three modulation schemes which are QPSK, 16 QAM and 64 QAM. Modulate.

2.9 Interference and Anti-Interference Methods

2.9.1 Interference Sources

The interference that functions on the communication system is generated by the following interference sources:

1) Thermal noise of the circuit, which is caused by the thermal disturbance of the electronics in the conductor

2) Internal noise of the electronic component, which is caused by the shot effect of the in continuous movement of the electric charges inside the component

3) Thermal radiation noise of objects (including the absorption noise), which is caused by the thermal radiation of objects

4) Cosmic interference, which is a kind of noise radiation generated by cosmic bodies

5) Atmospheric interference, which is caused by the discharge in the atmosphere and is in the pulse shape

6) Industrial interference, which is caused by the electric radiation from electrical equipment, for example, electric spark interference

7) Radio station interference, which is caused by the signal radiation from other radio stations

8) Various kinds of interference generated inside the receiver, including the back drop, microphonics, noise caused by the phase jitter of the oscillator, and various spurious emissions

2.9.2 Anti-Interference Methods of Communication Systems

The major factors that affect the quality of communication are the defects in the communication equipment and interference. The quality of the communication is improving with the development of science and technology, but interference always exists and increases with the wider application of electronic equipment. The effect of interference on communication continues to increase, and therefore, the anti-interference issue of communication systems becomes more and more important.

The special subject on the anti-interference capability of communication systems has been established and attracts many learners and technical engineers. Currently, the study on communication technologies is the study on anti-interference technologies or the study closely related to anti-interference requirements. The basic ideas of various existing anti-interference methods are as follows:

1) Increase the transmitted power to increase the input signal level at the receive end.

This method has good effects but is limited in many aspects such as size, weight, and power consumption of the equipment in application. In addition, increasing the transmitted power may result in the interference with other radio stations or lines. Therefore, the Radio Management Department imposes strict limitation on the maximum transmitted power of radio stations.

2) Use a directional antenna to select the signal from a certain direction.

It is known that directional antennas can help increase the strength of wanted signals and suppress the high level interferences from other directions. You can also suppress the strength of the interference by using the directional suppression method. To use this method, complicated and large-size antennas are required. Therefore, the method is also limited.

3) Use a narrowband filter to select the frequency.

Currently, this is the basic anti-interference method of communication systems and is used by almost every type of communication systems. Therefore, this method is the most popular anti-interference method. Narrowband filters are complicated in processing. When the operating frequency is high, the fading characteristics are difficult to ensure. Therefore, narrowband filters need to be used with other anti-interference measures to achieve the required anti-interference performance.

4) Use a correlator to select the waveform.

If narrowband filtering is the processing of signals in the frequency domain, correlation receiving is the processing of signals in the time domain. When the levels of the signal and the interference input into the correlator are low, the correlator can work in the linearity state. The anti-interference capability of correlators is stronger than the anti-interference capability of narrowband filters and thus is paid more and more attention to. When the input interference level exceeds the linearity region of the correlator, however, the anti-interference performance of the correlator is degraded. Therefore, correlation receiving is always used together with narrowband filtering.

5) Improve the modulation and demodulation method.

According to the different characteristics of interference, you can use the methods such as narrowband modulation (for example, single sideband modulation), broadband modulation (for example, frequency modulation), spread spectrum, and digital modulation to improve the anti-interference capability. Currently, the modulation and demodulation technologies are developing rapidly.

6) Use the error correction and error detection technologies to control errors.

This is an effective anti-interference measure that is developed in digital communication technologies and has been widely used in the communication systems that require high reliability.

2.10 previse studies

The objective of short term measurement is to compare the measurement with the result of indirect method, experiments have been done in different environments such as Iraq, Sudan and Saudi Arabia using different frequencies and links length

S. I. Ghobrial [12]reported the attenuations is less than 0.5 dB at 2 GHz link during a dust storm in Khartoum with visibility less than 150 meters, The link is Khartoum North Wadi Saidnaa has a path of 18 km flat terrain. Another microwave link that runs from Halfayat El Muluk to the Post office Head Quarters in Khartoum has been studied. The radio path length was around 20 km. The frequency at which the study was made was 7.5 GHz. The Minimum visibility recorded was 0.15 km on 26th August 1985 at 0700. The attenuation caused by the storm is less than 0.5 dB [12].

On the other hand, Ghobrial and Jervase measured in Khartoum a peak attenuation of 6.4 dB observed on a 25-km link at 10.5 GHz affected by dust storm produced a visibility is less than 100 m. The wind speed was recorded as 30 knot and vertically polarized signals were transmitted at a height of 30 m and the receive antenna was at a height of 27 m [13].

Elfatih A. A. Elsheikh, reported the attenuation in two microwave links in Khartoum during a sever dust storm on 21 September 2008where visibility was reduced to 50 meters. Attenuation was recorded by Marconi microwave system. The measured total attenuation for SOBA_MUD link was equal to 32 dB at 13GHz and 15.2 km link. Whereas, the measured total attenuation for SOBA_ JERRAIF link equal to 36 dB at13GHz and 13km link length[14].

On 6 June 2014 Md. Rafiqul Islam reported attenuation during a sever dust storm where visibility was 150 meter the recorded attenuation was13.3dB for MABLOOLJREEF SHAREG link 6.2 km operating at 22.4GHz[15].

Chapter Three

Materials and Methods

3.1Introduction

The effect of precipitating particles on signal attenuation has received considerable attention especially at high frequencies. As most of the work done in this area was carried out in Europe and USA, a significant amount of research has done in developing models to quantify the impact of rain and snow attenuation on communication systems operating in the microwave [16].

In contrast of that, little work has been done to investigate the impact of dust storm on the same propagation paths, rapid development in telecommunication technology and increasing competition in the sector have extended service to new locations and environments especially in Africa and Asia[15].

The basic theory under mathematical model for attenuation is the theory for single particle scattering. The propagation effects may be modeled by volumetric integration of scattering by individual particles. When an object is illuminated by a wave, part of the incident power is scattered out and another part is absorbed by the object. The characteristics of these two phenomena, scattering and absorption, can be expressed most conveniently by assuming an incident plane wave.

3.2 Materials and methods

The propagation of microwave signals in dust storms have found considerable interest recently, due to the increasing number of satellite and terrestrial links as well as many radar applications which operate at frequencies above 10GHz, when microwaves pass through a medium containing precipitations like rain, snow or dust particles, the microwave Signals get attenuated through two phenomena.

1) Absorption of energy by these particles.
2) Scattering of energy out of the beam by these particles.

Microwaves suffer absorption and scattering by the atmosphere especially at higher frequencies
Where the scattering effects become more severe, sensitivity to weather condition like rain, fog, cloud, snow, dust storm and other phenomena can effect quality of telecommunication system especially in 10 GHz frequency bands and higher due to attenuation signal, microwave Attenuation signal due to dust storm one of these potential technical challenges need to be investigate in order to provide reliable wireless communication system with good performance, dust storm occur in many parts of the world, especially in the Middle east, arid parts of Asia ,south west of USA in dray states like Texas and Arizona, dust storms are becoming more frequent in some parts of the world, there is significant correlation between the increased occurrences of dust storm and the climate change phenomenon.

The goal of a short-term measurement is to compare the measurements with the result of indirect methods, experiments conducted in different environments in different city in Sudan such as, Khartoum, Madani and Port Sudan using different link length as shown in figure 3.1.

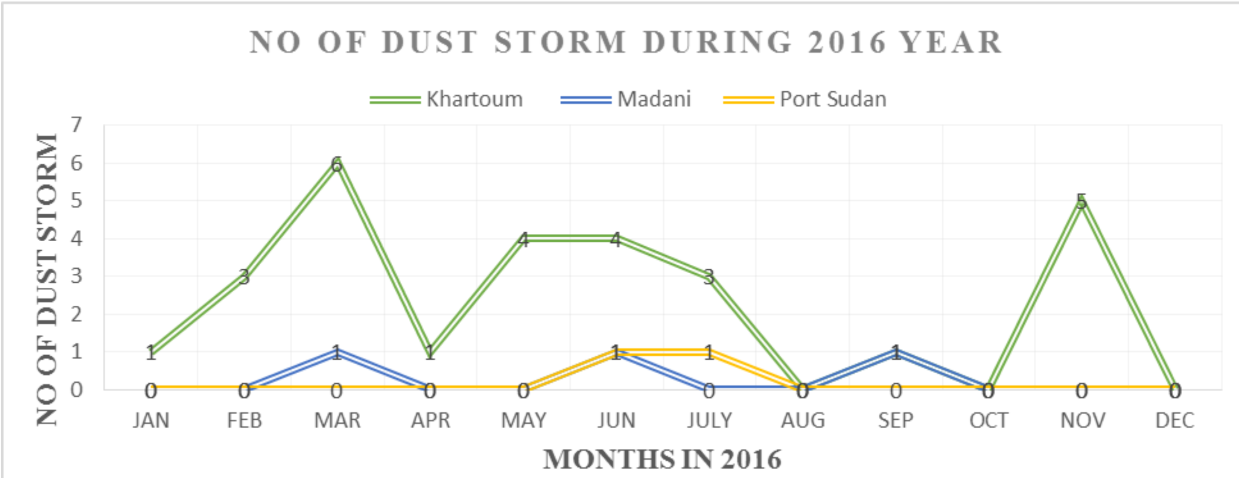


Figure 3.1: Frequency of dust storm occurrence in Khartoum, Madani and Port Sudan (2016) visibility less than 1km.

Dust storms affect the microwave propagation and it is severe in high frequencies, it attenuates the signal and degrades the performance of microwave links especially in arid region in figure 3.1 shows the Frequency of dust storm occurrence in Khartoum, Madani and Port Sudan from 1Jan 2016 to 31Dec 2016 with visibility less than 1km.

18 GHz Microwave Links have been installed in different lengths and different location, tow links in Khartoum, one link in Madani and last one in Port Sudan as shown in figure 3.2, 3.3 and 3.4 and Table 3.1 All links have been monitored by Management system (U2000) and we record all the transmitted and received signal levels for one year, also we collect visibility data for one year from Meteorological department.

Figure 3.2: Geographical details of the Microwave links for Port Sudan Area

Figure 3.3: Geographical details of the Microwave links in Khartoum area

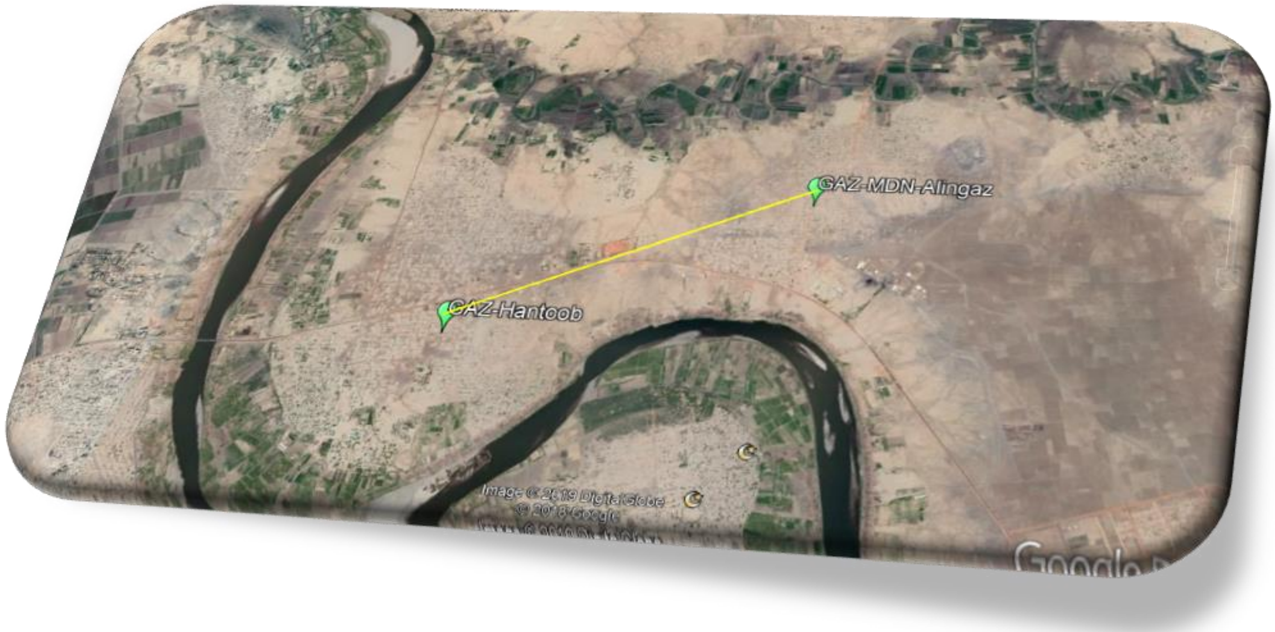


Figure 3.4. Geographical details of the Microwave links in Madani area

Table 3.1. Details of the four terrestrial links that are used for the study

#	Link	Location		Frequency MHZ		Length Km	Region
				up	down		
1	Hantoop	14.430381°	33.531254°	18,981.00	17,971.00	4.36	Madani
	Alingaz	14.449780°	33.566480°				
2	Port sudan-centre	19.617635°	37.221069°	18,910.00	17,900.00	4.84	Port Sudan
	DAR EL NAEEM	19.585830°	37.189500°				
3	Umdawban	15.426000°	32.838800°	18,640.00	17,630.00	6.96	Khartoum
	Alaasilat-01	15.369670°	32.867630°				
4	Eldoroshab	15.727900°	32.581900°	18,810.00	17,800.00	8.06	Khartoum
	Alsamra	15.764940°	32.645740°				

3.2 Data survey

The prophase site survey for a microwave transmission project is the foundation of the later microwave network planning. Site surveys are especially important for the new microwave route that passes cities or residential areas where there are many buildings and the line-of-sight conditions cannot be obtained from the topographic map. The purpose of site surveys is for collecting accurate information of the engineering site and other concerned information to support network planning, Purposes of site surveys are as follows[5].

- The overall network architecture was determined for the microwave transmission project. Draw a network route diagram of the entire microwave network by using the global positioning system (GPS) and 1:50,000 topographic map to accurately locate the microwave stations.
- The types and roughness of the profiles of the microwave transmission relay sections have been determined according to the 1:50,000 topographic map.
- The electromagnetic environment and available frequency resources ware checked around the microwave transmission relay sections and plan the frequencies based on the network route diagram.
- The indoor size of the microwave stations was measured and draw the layouts of the equipment rooms. Determine the routing methods and length of the feeder cables, power cables, and grounding cables. Determine the positions where the microwave equipment is installed. Determine the positions where the stored program control (SPC) switches, cable distribution frames, PCM equipment, ADM equipment, and ATM equipment are installed relative to the microwave equipment.

- Measure the relative positions of the towers and the equipment rooms, and draw the layout of the stations. Determine the positions on the tower where the antennas are installed. Determine the feeder holes through which the feeders are routed into the equipment room. Know the heights and diameters of the existing antennas.

- The operating conditions of frequency bands was learning and frequencies of the existing microwave equipment at the station.

- Acquire the meteorological information at the local place. Especially, learn the rainfall distribution of the local place and whether there are the climate phenomena such as typhoon, hurricane, and flood that can affect microwave transmission.

- The status of the existing power systems was checked at the microwave stations especially, check the supplied voltage and maximum power of the existing power systems, power consumption of the existing equipment, and power consumption of the new equipment.

A site survey consists of three procedures: preparation, site survey, and information collection [5].

3.2.1Preparation before Microwave Site Surveys

The preparation before the site survey is important. The preparation involves making a detailed site survey solution, collecting the information of the existing stations of the customer, and preparing drawings. Those work can greatly improve the efficiency of the site survey. The preparation is made on the customer coordination meeting before the site survey. The major work during the preparation phase is collecting basic information and making the site survey plan.

3.2.2 Information Collection

The Goals of the information collection phase are as follows:

- Understand the requirements specified in the RFQ and confirm the information with the customer.
- The local microwave specifications was collected and learn the specific requirements of the customer.
- The network conditions of the area was learned and obtain concerned drawings.
- Determine the network layout, microwave routes, and site locations according to the 1:50,000 topographic map of the area. Record the data of the profiles of the microwave relay sections.

Information collection and site survey are implemented at the same time. Information collection and verification should be done first for a new deployment. The following parties may be involved:

- Construction party:
    - Collect the information of the existing and planned digital microwave transmission systems, microwave type, capacity, route, schedule, site distribution, and the existing maintenance team from the construction party, Mark the routes related to the project on the map.
    - Collect the questions, requirements, and suggestions for the construction solution of the project

    - Collect the drawings of the existing and planned microwave equipment rooms.
- Radio Management Department:
    - Know the frequency band approved by the Radio Management Department.
    - Learn the frequencies used in the existing microwave circuits and the owners of the existing microwave circuits on the planned routes of the project from the Radio Management Department.
    - Learn the frequencies used in the existing microwave circuits near the planned routes of the project to check whether there are unidirectional microwave routes that do not have blocking between them from the Radio Management department.
    - Submit a frequency application to the Radio Management Department together with the construction party.
- Meteorological department:
  Learn the meteorological information from the local meteorological department.
- Other concerned departments:
  Learn the requirements for the site selection of other concerned departments such as electric power, geologic, petroleum, chemical, coal, metallurgy, mining, and earthquake departments [5].

3.2.3 Tools for Microwave Site Surveys

You need to prepare the following tools:

- GPS: for on-site positioning

- Ground resistance testers: for testing the ground resistance of a new station or office
- Portable forestry compasses and 51 compasses: for locating the obstacles and objects in the communication direction of the office and indicating the direction
- Spectrum analyzers (optional): for testing the interference frequency and level of the location
- Portable infrared ray distance measuring instrument: for measuring the dimension in a small space
- Digital cameras: for recording complicated on-site situations
- Common tools: big and small screwdrivers, electrical knives, hammers, cutting pliers, magnifiers, flashlights, and insulating tapes
- A laptop: for recording and collecting files
- An urban planning drawing of the areas where the project covers and a 1:50,000 topographic map marked with latitude and longitude

3.2.4 Making the Site Survey Plan

- Make the site survey plan, which defines the scope, goal, and schedule of the survey and the involved personnel.
- Make a proper survey route to reduce repetition.
- Contact the management department or owner of the microwave station to which you pay a site survey in advance for obtaining the key to the equipment room.
- Contact a guide if you go to a remote area for the site survey. If you need to stay in the equipment room or the field during the site survey and accommodation is unavailable near the microwave station, prepare a sleeping bag, tent, mosquito repellent, and enough food.

- Prepare the tools including the GPS, digital camera, laptop with concerned electronic documentation and application software, tape, and telescope.

When you make the site survey plan, ensure that you have acquired the support from the owner of the microwave station. That is, the owner has someone accompany with you during the site survey. This can ensure that the survey data is correct and effective [5].

3.2.5 Site Surveys

The site survey is implemented by the team formed by one or two microwave design engineers one or two microwave design engineers from the construction party, and concerned design personnel from the civil work, tower, power, and geologic departments. The following work must be complete during the site survey [5].

1) Check the line-of-sight conditions of the site.
2) If the line-of-sight conditions of the transmission relay section are uncertain because the distance between stations is too long and the topographic map is unavailable or unhelpful (for example, urban transmission), the construction party needs to perform electrical measurement on the route or select the standby route solution.
3) If the microwave relay section does not support line-of-sight transmission, re-plan the route and select the active/passive relay stations, or make a standby route solution.
4) Draw a local route solution diagram.
5) Measure the indoor size of the microwave stations and draw the plane diagrams of the equipment rooms. Determine the routing methods and length of the feeder cables, power cables, and grounding cables.

Determine the positions where the microwave equipment is installed. Determine the positions where the stored program control (SPC) switches, cable distribution frames, PCM equipment, ADM equipment, and ATM equipment are installed relative to the microwave equipment.

6) Measure the positions of the towers and the equipment rooms, and draw the layout of the stations. Determine the boom where the antennas are installed, determine the feeder holes through which the feeders are cabled into the equipment room. Obtain the heights and diameters of existing antennas, determine the positions where the antennas can be installed.
7) Check the status of the existing power systems at the microwave stations. Especially, check the supplied voltage and maximum power of the existing power systems, power consumption of the existing equipment, and power consumption of the new equipment.
8) Make a distinct mark at the positions of the new microwave stations and new towers and take pictures of the surroundings.
9) Record the frequency bands used by the existing microwave equipment running in the equipment room.
10) Select the site locations of the new passive relay stations. The length of the shorter hop must not be more than 5 km.

3.3 Information Collation

After the site survey of the entire network or of part of the network is complete, compare and collate the information collected before the site survey and the information obtained during the site survey. Output the overall solution to microwave transmission that is optimized based on the RFQ, requirements of the customer, and network planning solution.

3.4 Data Collection

The visibility data were collected from Automatic Weather Station, operating at Khartoum International Airport from 1Jan 2016 to 31Dec 2016 with 92% time availability. and Transmitted and Received Signal Levels (TR/SL) were collected from Management system (computerized system) from 1Jan 2016 to 31Dec 2016 with 89% include the measured and calculated attenuation due to dust storms at 18GHz, four Microwave links at 18GHz in different lengths

During the experimental period from 1 Jan 2016 to 31 Dec 2016, more than 28 dust storms were experienced in the city of Khartoum as shown in table 3.2. Metrological parameters as well as transmitted and received signal levels were recorded during the storm events.

Table 3.2. Data collected from Automatic Weather Station from 1Jan 2016 to 31Dec 2016

Khartoum- Dust Storm 2016					
Month	Day	Time	Visibility	Direction	Speed
JAN	24	15:30Z	0300m	350°	18KT
FEB	16	8:40Z	0800m	30°	8KT
FEB	19	05:15Z	0800m	360°	16KT
FEB	20	05:13Z	1500m	360°	10KT
FEB	22	09:00Z	1500m	360°	22KT
MAR	3	18:30Z	0800m	330°	16KT
MAR	13	19:00Z	0800m	320°	20KT
MAR	14	19:15Z	0500m	320°	20KT
MAR	14	06:45Z	0800m	360°	17KT
MAR	15	18:30Z	0500m	360°	21KT
MAR	27	21:30Z	0500m	340°	13KT
APR	NIL	NIL	NIL	NIL	NIL
MAY	6	19:40Z	0400m	360°	23KT
MAY	17	19:10Z	0200m	220°	22KT
MAY	19	19:35Z	0130m	180°	24KT
MAY	21	03:15Z	0800m	210°	11KT
JUN	5	17:20Z	0200m	160°	33KT
JUN	11	19:10Z	0230m	040°	25KT
JUN	21	00:10Z	0200m	140°	20KT
JUN	22	12:20Z	0500m	240°	13KT
July	10	02:15Z	300m	350°	35kt
July	10	03:00Z	500m	220°	23 KT
July	19	14:10Z	500m	300°	9KT
August	NIL	NIL	NIL	NIL	NIL
September	17	03:15Z	500m	260°	23KT
October	NIL	NIL	NIL	NIL	NIL
November	10	04:20Z	800m	320°	31KT
November	11	04:50Z	800m	320°	16KT
November	14	05:00Z	1500m	360°	62KT
November	14	06:00Z	800m	320°	32KT
November	15	05:00Z	200m	280°	30KT

Port Sudan - Dust Storm 2016					
Month	Day	Time	Visibility	Direction	Speed
JUN	18	02:30Z	500m	290°	38KT
july	8	01:00z	140m	350°	22

Madani - Dust Storm 2016					
Month	Day	Time	Visibility	Direction	Speed
MAR	14	14:30Z	200m	250°	6KT
JUN	26	13:10Z	800m	190°	7KT
September	20	21:40Z	500m	320°	19KT

Table 3.3: RSL and TSL Power reading each 15 minutes

RSL: Received signal level (power)

TSL: Transmitted signal level (power)

Monitored Object	Performance Event	Monitor Period	End Time	Power MAX	Power MIN
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 12:3	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 12:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 12:4	-37.10	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	06/05/2016 12:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 13:00	-37.10	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 13:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 13:15	-37.00	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 13:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 13:30	-37.10	-40.10
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 13:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 13:45	-37.00	-39.30
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 13:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 14:00	-37.00	-39.30
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 14:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 14:15	-37.70	-39.10
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 14:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 14:30	-37.70	-39.90
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 14:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 14:45	-37.60	-39.90
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 14:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 15:00	-36.90	-41.20
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 15:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 15:15	-37.60	-40.50
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 15:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 15:30	-37.00	-40.00
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 15:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 15:45	-37.00	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 15:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 16:00	-37.90	-40.10
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 16:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 16:15	-37.90	-39.90
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 16:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 16:30	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 16:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 16:45	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 16:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 17:00	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 17:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 17:15	-37.90	-39.90
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 17:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 17:30	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 17:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 17:45	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 17:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 21:00	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 21:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 21:15	-37.90	-39.90
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 21:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 21:30	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 21:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 21:45	-37.90	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 21:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 22:00	-37.60	-40.50
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 22:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 22:15	-37.60	-40.50
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 22:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 22:30	-37.00	-41.00
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 22:30	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 22:45	-47.00	-50.90
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 22:45	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 23:00	-39.90	-42.10
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 23:00	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 23:15	-37.60	-40.50
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 23:15	23.00	23.00
Umdawan Ban 02 -	RSL_CUR(dbm)	15-Minute	05/06/2016 23:30	-37.00	-39.40
Umdawan Ban 02 -	TSL_CUR(dbm)	15-Minute	05/06/2016 23:30	23.00	23.00

3.5 Data Analysis and Tools

The International Telecommunications Union (ITU) publishes recommendations for the field of telecommunications. Recommendations for telecommunications are published in ITU-T, and recommendations that have been adapted for radio communication are published in ITU-R. The International Organization for Standardization (ISO) and American National Standards Institute (ANSI) are other organizations that promulgate standards, and they are referenced in this book where applicable.

Most microwave network design software tools are developed by radio manufacturers and therefore are biased toward the manufacturers' own equipment. In other cases, the tool may be proprietary and not sold on the open market. These tools are sometimes provided to engineering personnel who are working on the customer's site and performing network design, while some microwave equipment manufacturers insist on using their own software tools, some operators and consultants prefer to use commercially available tools.

One such vendor-independent tools is Pathloss 5.0 (and the older 4.0 version) and Mat lab version 18 .This tools is probably one of the best (and most moderately priced) tools for the complex microwave design, including North American and ITU standards, different diversity schemes, diffraction and reflection (multipath) analysis, rain effects, interference analysis, and others.

Radio equipment parameters for equipment from any vendor, channel tables, antenna diagrams, and so on are defined and stored in the default parameters database for easy retrieval. This tool is widely accepted by microwave system design engineers around the world.

3.6 Dust Storm Prediction Models

Different approaches have been adopted to evaluate microwave signal attenuation due to dust storm in terms of its characteristics such as the number of dust particles per cubic meter, the mass of dust per cubic meter or visibility. Therefore, various investigations showed that the scattering of electromagnetic waves propagating in dust storms is influenced by various factors including incident wave frequency, permittivity, density, geometric scale, distribution of grains, moisture and chemical behavior of dust particles [14].

Attenuation prediction models have been developed based on single scattered theory. However, these models have been based on certain assumptions they rely on some empirical inputs

Three recent attenuation prediction models have been investigated, these models have been based on certain assumptions but rely on some empirical inputs such as particle shape, chemical composition, size and dielectric constant.

3.6.1Elshaikh Model (2008)

Elshaikh. Z. has proposed a prediction model based on Mie scattering which can calculate the specific attenuation in microwave wave band with high reliability. The model has related attenuation coefficient to the visibility, particle size distribution as show in eq (3.1) and figure 3.5 [16].

$$A = \frac{r_e f}{V}\left(x + y r_e^2 f^2 + z r_e^3 f^3\right) \text{ [dB/km]} \quad (3.1)$$

where

r_e = Equivalent particle radius in meter.

V = Visibility in kilometer.

f = Frequency in GHz.

$$x = \frac{1886 \times \varepsilon''}{(\varepsilon'+2)^2 + \varepsilon''^2} \quad (3.2)$$

$$y = 137 \times 10^3 \times \varepsilon'' \left\{ \frac{6\left(7\varepsilon'^2 + 7\varepsilon''^2 + 4\varepsilon' - 20\right)}{5[(\varepsilon'+2)^2 + \varepsilon''^2]^2} + \frac{1}{15} + \frac{5}{3\left[(2\varepsilon'+3)^2 + 4\varepsilon''^2\right]} \right\} \quad (3.3)$$

$$z = 379 \times 10^4 \left\{ \frac{(\varepsilon'-1)^2 . (\varepsilon'+2) + [2.(\varepsilon'-1).(\varepsilon'+2) - 9] + \varepsilon''^4}{[(\varepsilon'+2)^2 + \varepsilon''^2]^2} \right\} \quad (3.4)$$

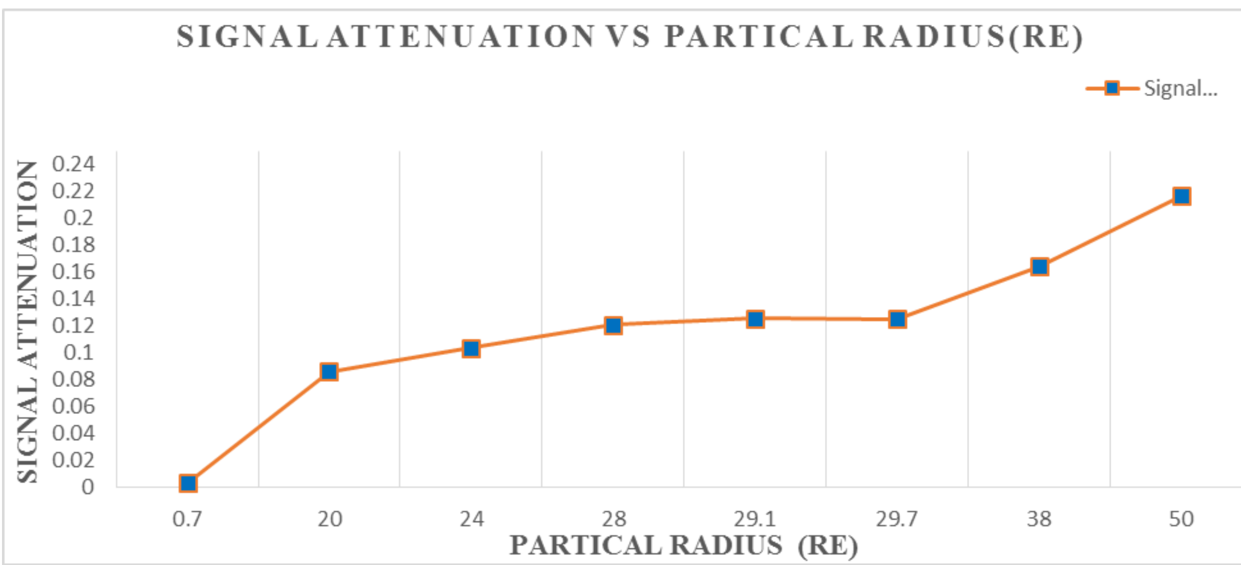


Figure 3.5. Signal Attenuation calculated using Elshaikh model due to dust Storm with different particle radius in ku band at 300m visibility and 18GHz frequency

However, Elshaikh's model has achieved better results it has assumed equal dust particle size distributions (30 μm and 50μm). Elshaikh didn't clearly mention whether he based his particle size distribution on theoretical assumptions or real measurements. In addition, this model loses its reliability as the dust concentration and frequency increase.

3.6.2 D. Ahmed Model

A.S. Ahmed has derived an equation based on Chu's model he has expressed signal attenuation in terms of easily measured dust parameters [17]. Assuming that at optical wavelength the intensity decays exponentially with distance as show in eq (3.5) and figure 3.6

$$A = 566.97\left(\frac{1}{V}\right)\left(\frac{r_a}{\lambda}\right)(G)[dB/km] \quad (3.5)$$

Where:

r_e = Equivalent particle radius in meter.

λ = wavelength in meters.

V = optical visibility in kilometers.

$$G = \left[\frac{\varepsilon''}{(\varepsilon'+2)^2+\varepsilon''^2}\right] \quad (3.6)$$

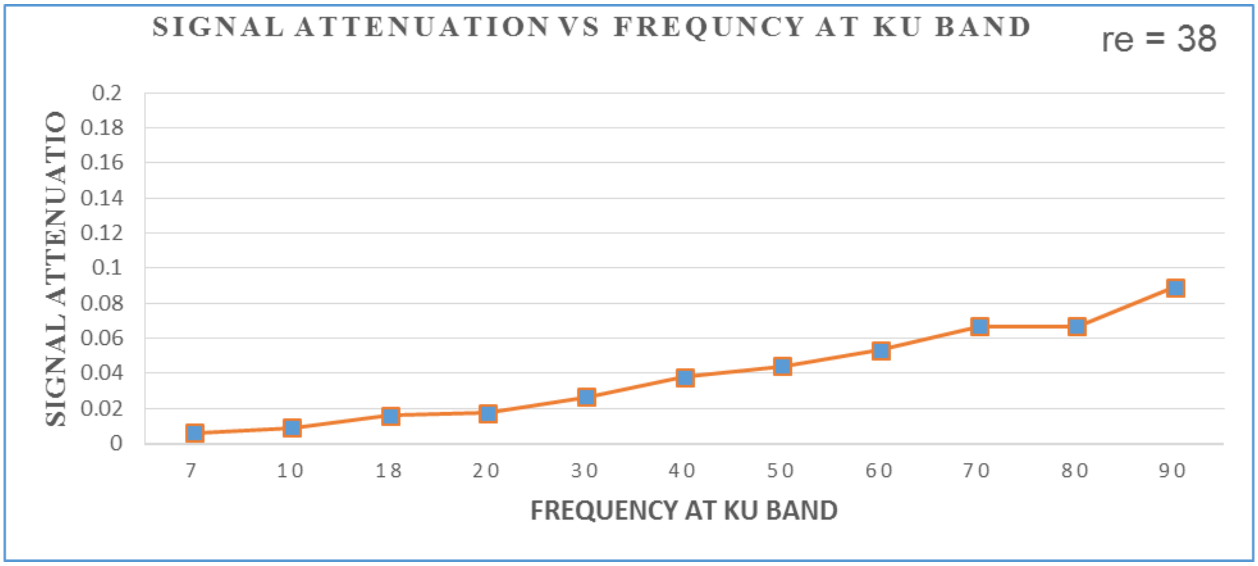


Figure 3.6. Signal Attenuation calculated using D. Ahmed A.S model due to Dust Storm with visibility200 m, at 38 micro meter dust particle radius in ku band.

3.6.3 Goldhirsh Model

Goldhirsh [18] derived an attenuation prediction model for dust storms expressed as show in eq (3.7) and figure 3.7

$$A = \frac{2.317 \cdot 10^{-3} \cdot \varepsilon''}{[(\varepsilon' + 2)^2 + \varepsilon''^2] \cdot \lambda} \cdot \frac{1}{V^{\gamma}} [dB/km] \qquad (3.7)$$

Where:

V is the visibility in kilometers

γ is a constant value equal to 1.07

λ is the wavelength in meters

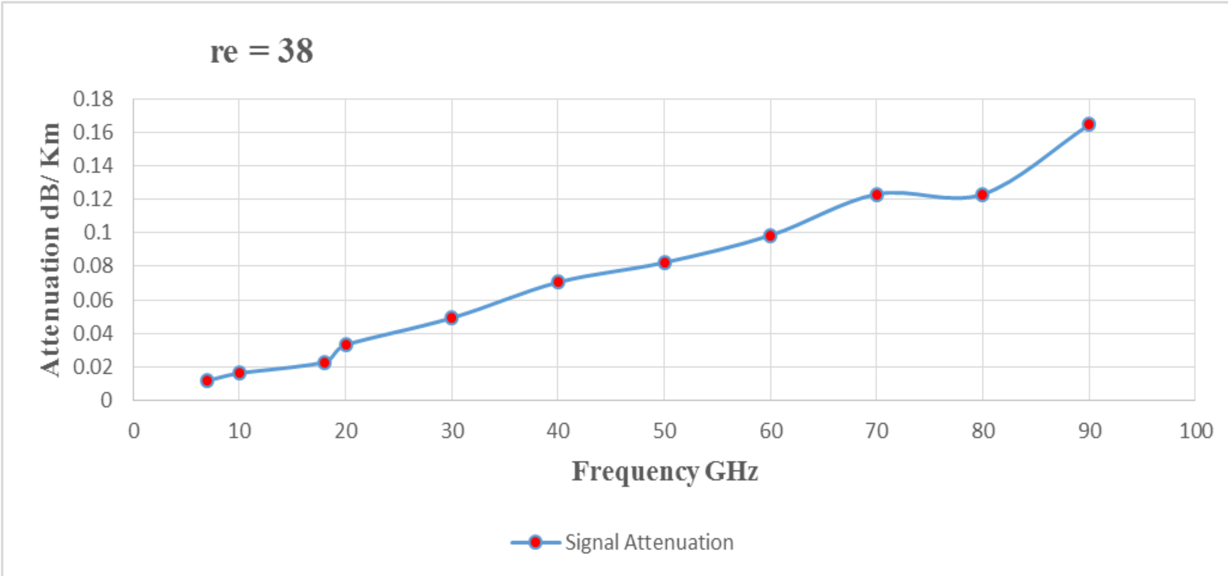
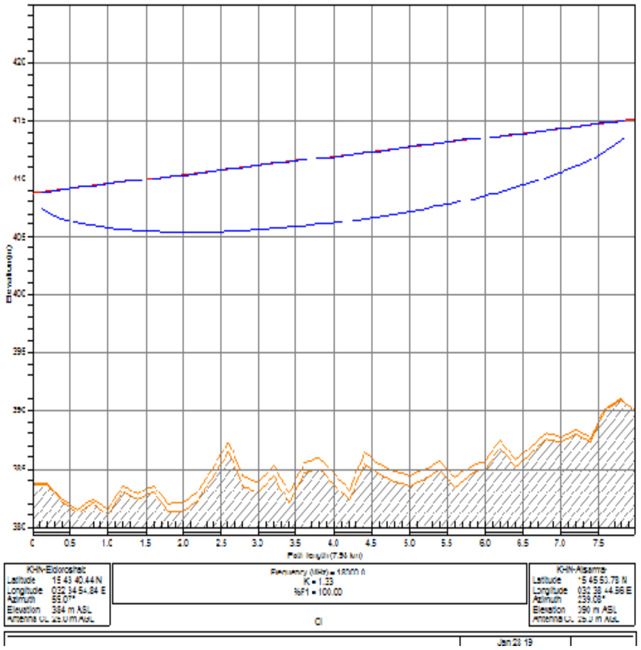
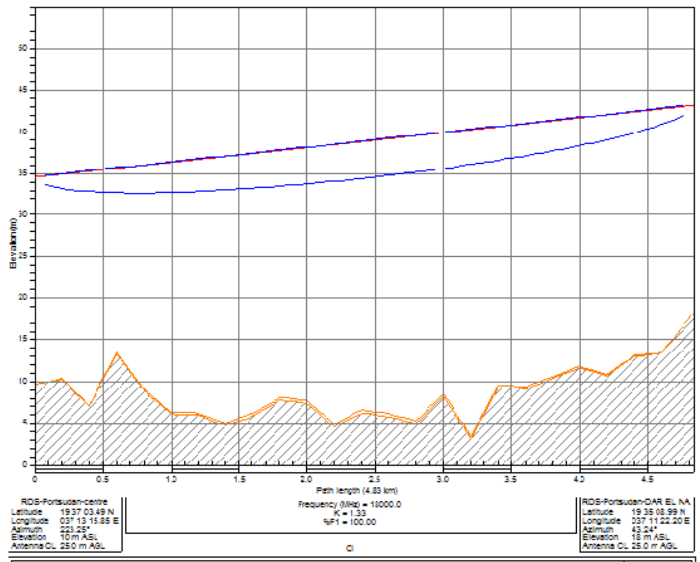


Figure 3.7. Signal Attenuation calculated using Goldhirsh model due to Dust Storm with visibility200 m, at 38 micro meter dust particle radius in ku band

In below table 3.5 and 3.6 shown that the Pathloss design for Microwave links and this tools used to create any new microwave links.

Table 3.5. Data from Pathloss design tools for DROSHAB - ALSAMRA link and PORT SUDAN - DAR ELNAEEM link





	KHN-Eldcroshab	KHN-Alsamra-
Elevation (m)	383.72	390.07
Latitude	15 43 40.44 N	15 45 53.78 N
Longitude	032 34 54.84 E	032 38 44.66 E
True azimuth (°)	59.07	239.08
Vertical angle (°)	0.02	-0.07
Antenna model	A18S06HAC	A18S06HAC
Antenna height (m)	25.00	25.00
Antenna gain (dBi)	38.80	38.80
Frequency (MHz)	18000.00	
Polarization	Vertical	
Path length (km)	7.98	
Free space loss (dB)	135.61	
Atmospheric absorption loss (dB)	0.43	
Net path loss (dB)	58.44	58.44
Radio model	18G_XMC2_128Q_14M 78M	18G_XMC2_128Q_14M 78M
TX power (watts)	0.09	0.09
TX power (dBm)	19.50	19.50
EIRP (dBm)	58.30	58.30
Emission designator	14M0D7W	14M0D7W
RX threshold criteria	BER 10-6	BER 10-6
RX threshold level (dBm)	-71.50	-71.50
Maximum receive signal (dBm)	-20.00	-20.00
RX signal (dBm)	-38.94	-38.94
Thermal fade margin (dB)	32.56	32.56
Geoclimatic factor	8.92E-05	
Path inclination (mr)	0.80	
Fade occurrence factor (Po)	9.07E-03	
Average annual temperature (°C)	25.00	
Worst month - multipath (%)	99.99950	99.99950
(sec)	13.27	13.27
Annual - multipath (%)	99.99981	99.99981
(sec)	59.70	59.70
(% - sec)	99.99962 - 119.39	

	RDS-Portsudan-centre	RDS-Portsudan-DAR EL NA
Elevation (m)	9.63	18.20
Latitude	19 37 03.49 N	19 35 08.99 N
Longitude	037 13 15.85 E	037 11 22.20 E
True azimuth (°)	223.25	43.24
Vertical angle (°)	0.09	-0.12
Antenna model	A18S06HAC	A18S06HAC
Antenna height (m)	25.00	25.00
Antenna gain (dBi)	38.80	38.80
Frequency (MHz)	18000.00	
Polarization	Vertical	
Path length (km)	4.83	
Free space loss (dB)	131.26	
Atmospheric absorption loss (dB)	0.26	
Net path loss (dB)	53.92	53.92
Radio model	18G_XMC2_128Q_14M 78M	18G_XMC2_128Q_14M 78M
TX power (watts)	0.09	0.09
TX power (dBm)	19.50	19.50
EIRP (dBm)	58.30	58.30
Emission designator	14M0D7W	14M0D7W
RX threshold criteria	BER 10-6	BER 10-6
RX threshold level (dBm)	-71.50	-71.50
Maximum receive signal (dBm)	-20.00	-20.00
RX signal (dBm)	-34.42	-34.42
Thermal fade margin (dB)	37.08	37.08
Geoclimatic factor	8.92E-05	
Path inclination (mr)	1.77	
Fade occurrence factor (Po)	8.14E-04	
Average annual temperature (°C)	25.00	
Worst month - multipath (%)	99.99998	99.99998
(sec)	0.42	0.42
Annual - multipath (%)	99.99999	99.99999
(sec)	1.89	1.89
(% - sec)	99.99999 - 3.79	

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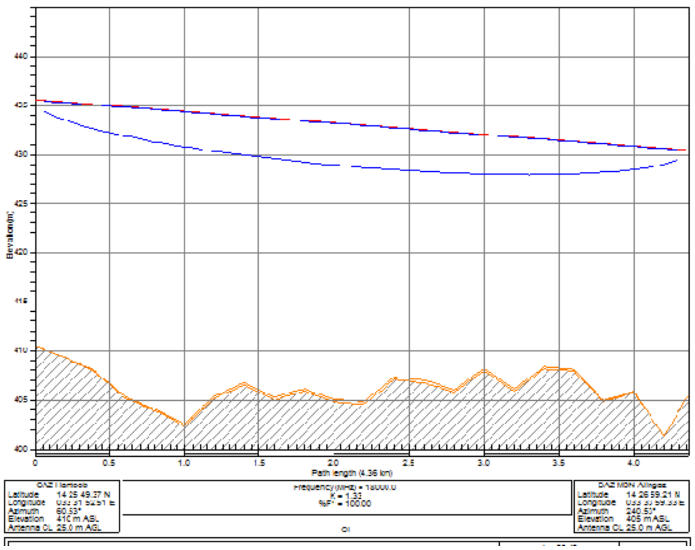
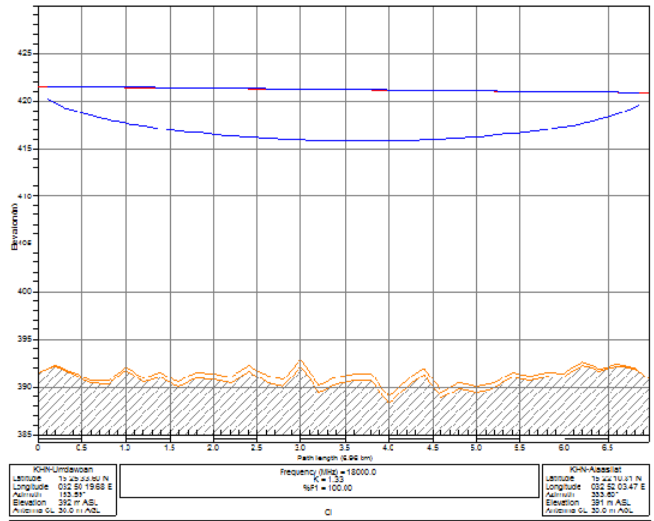
Table 3.6. Data from Pathloss design tools for HANTOOP – MADANI and UMDOBAN – ALASILAT links





	GAZ-Hantoob	GAZ-MDN-Alingaz
Elevation (m)	410.49	405.39
Latitude	14 25 49.37 N	14 26 59.21 N
Longitude	033 31 52.51 E	033 33 59.33 E
True azimuth (°)	60.53	240.53
Vertical angle (°)	-0.08	0.05
Antenna model	A18S06HAC	A18S06HAC
Antenna height (m)	25.00	25.00
Antenna gain (dBi)	38.80	38.80
Frequency (MHz)	18000.00	
Polarization	Vertical	
Path length (km)	4.36	
Free space loss (dB)	130.37	
Atmospheric absorption loss (dB)	0.24	
Net path loss (dB)	53.00	53.00
Radio model	18G_XMC2_128Q_14M 78M	18G_XMC2_128Q_14M 78M
TX power (watts)	0.09	0.09
TX power (dBm)	19.50	19.50
EIRP (dBm)	58.30	58.30
Emission designator	14M0D7W	14M0D7W
RX threshold criteria	BER 10-6	BER 10-6
RX threshold level (dBm)	-71.50	-71.50
Maximum receive signal (dBm)	-20.00	-20.00
RX signal (dBm)	-33.50	-33.50
Thermal fade margin (dB)	38.00	38.00
Geoclimatic factor	8.92E-05	
Path inclination (mr)	1.17	
Fade occurrence factor (Po)	7.94E-04	
Average annual temperature (°C)	25.00	
Worst month - multipath (%)	99.99999	99.99999
(sec)	0.33	0.33
Annual - multipath (%)	100.00000	100.00000
(sec)	1.50	1.50
(% - sec)	99.99999 - 2.99	

	KHN-Umdawban	KHN-Alaasilat
Elevation (m)	391.54	390.92
Latitude	15 25 33.60 N	15 22 10.81 N
Longitude	032 50 19.68 E	032 52 03.47 E
True azimuth (°)	153.59	333.60
Vertical angle (°)	-0.03	-0.02
Antenna model	A18S06HAC	A18S06HAC
Antenna height (m)	30.00	30.00
Antenna gain (dBi)	38.80	38.80
Frequency (MHz)	18000.00	
Polarization	Vertical	
Path length (km)	6.96	
Free space loss (dB)	134.42	
Atmospheric absorption loss (dB)	0.38	
Net path loss (dB)	57.20	57.20
Radio model	18G_XMC2_128Q_14M 78M	18G_XMC2_128Q_14M 78M
TX power (watts)	0.09	0.09
TX power (dBm)	19.50	19.50
EIRP (dBm)	58.30	58.30
Emission designator	14M0D7W	14M0D7W
RX threshold criteria	BER 10-6	BER 10-6
RX threshold level (dBm)	-71.50	-71.50
Maximum receive signal (dBm)	-20.00	-20.00
RX signal (dBm)	-37.70	-37.70
Thermal fade margin (dB)	33.80	33.80
Geoclimatic factor	8.92E-05	
Path inclination (mr)	0.09	
Fade occurrence factor (Po)	1.12E-02	
Average annual temperature (°C)	25.00	
Worst month - multipath (%)	99.99953	99.99953
(sec)	12.28	12.28
Annual - multipath (%)	99.99982	99.99982
(sec)	55.26	55.26
(% - sec)	99.99965 - 110.52	

Chapter Four

Software and Flowchart Diagram

4.1 Frequency Channel Arrangements

Channels are segments (subdivisions) of a frequency range or a portion (frequency band) of the electromagnetic spectrum. Every channel has a specified bandwidth and, depending on the capacity of the link, a certain number of carriers can be accommodated in the band.

For instance, a frequency raster may include four adjacent 28-MHz channels (applicable for 34-Mbps links), but each of these channels can be further divided into four 7-MHz channels (applicable for 8 Mbps). To enable four 7-MHz channels to be included within one 28-MHz channel, the center frequencies of the 28- and the 7-MHz channels cannot coincide. Likewise, each 7-MHz channel may be divided in two 3.5-MHz channels. The available frequency band is subdivided into two equal halves: a lower (go) and an upper (return) duplex half. The frequency separation between the lowest frequency in the lower half and that of the upper half is known as the *duplex spacing* (see Figure 4.1). Each RF channel requires two frequencies (transmit and receive). All transmit frequencies are in one half of the band, and all receive frequencies are in the other half. Frequencies are normally assigned so that all frequencies transmitting from a site are either in the high half or the low half of the band. The duplex spacing is always sufficiently large that the intended radio equipment can operate interference-free under duplex operation

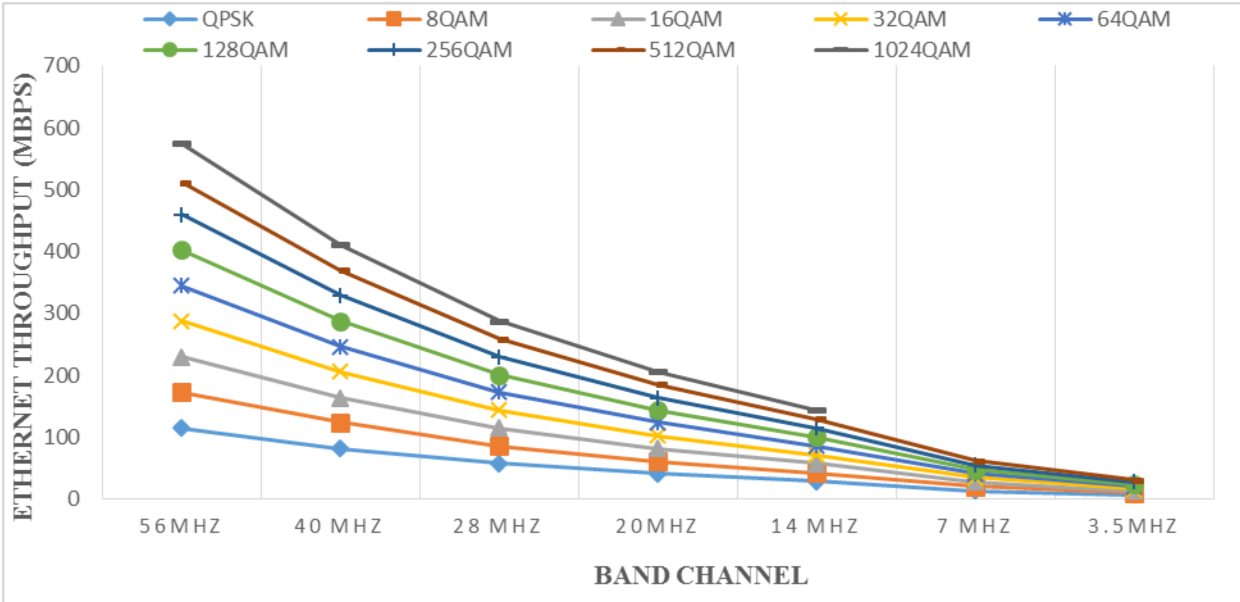


Figure 4.1. Maximum Ethernet throughput (Mbps) Vs Band channel

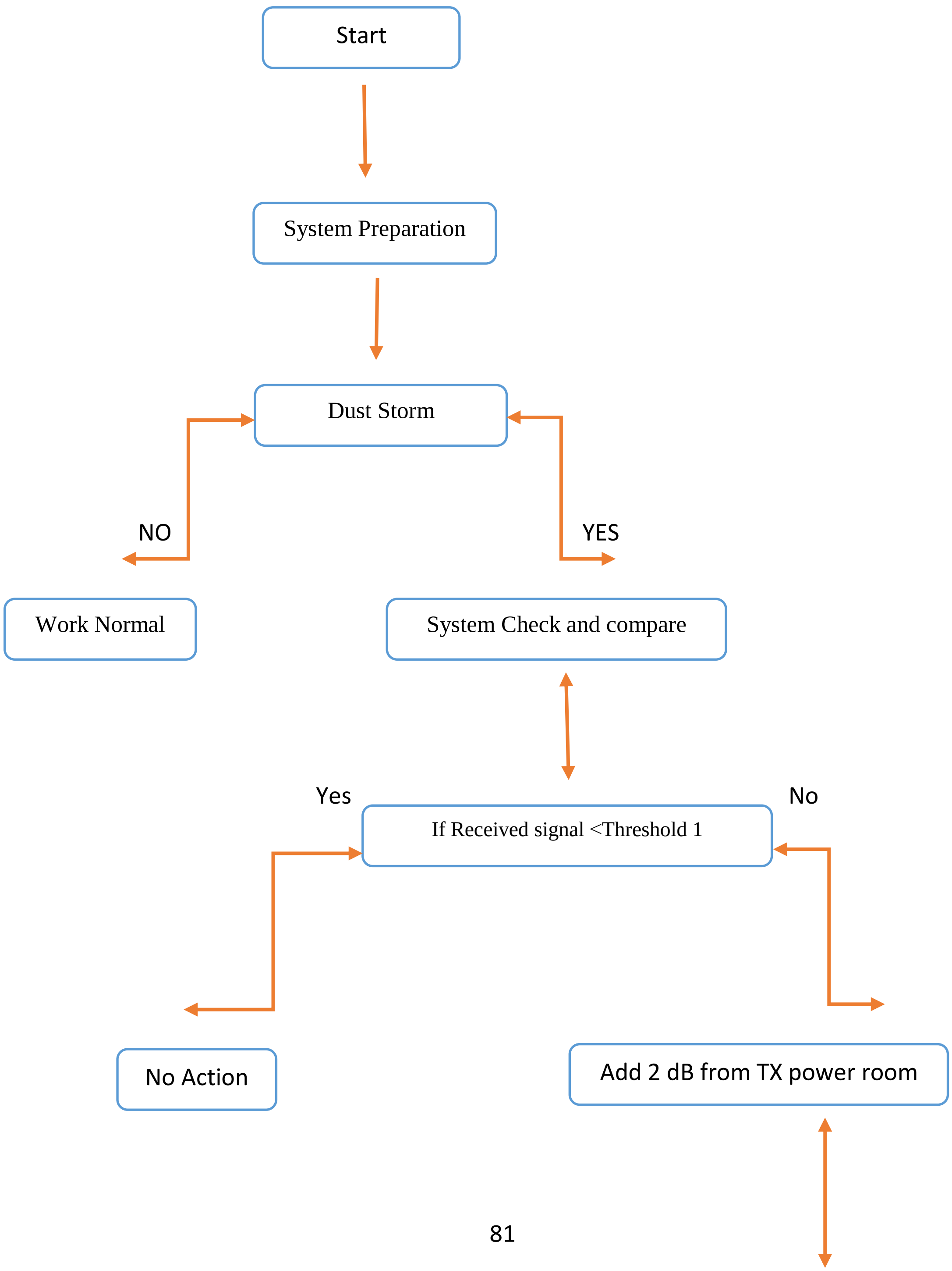
With the growing demand for wireless backhaul capacity usage of advanced modulation is spreading and wider channels are becoming more popular as a result transmission is getting more sensitive to fading and network reliability is strongly affected in figure 4.1 shows the relation between the modulation and microwave band channel with maximum Ethernet throughput (Mbps)

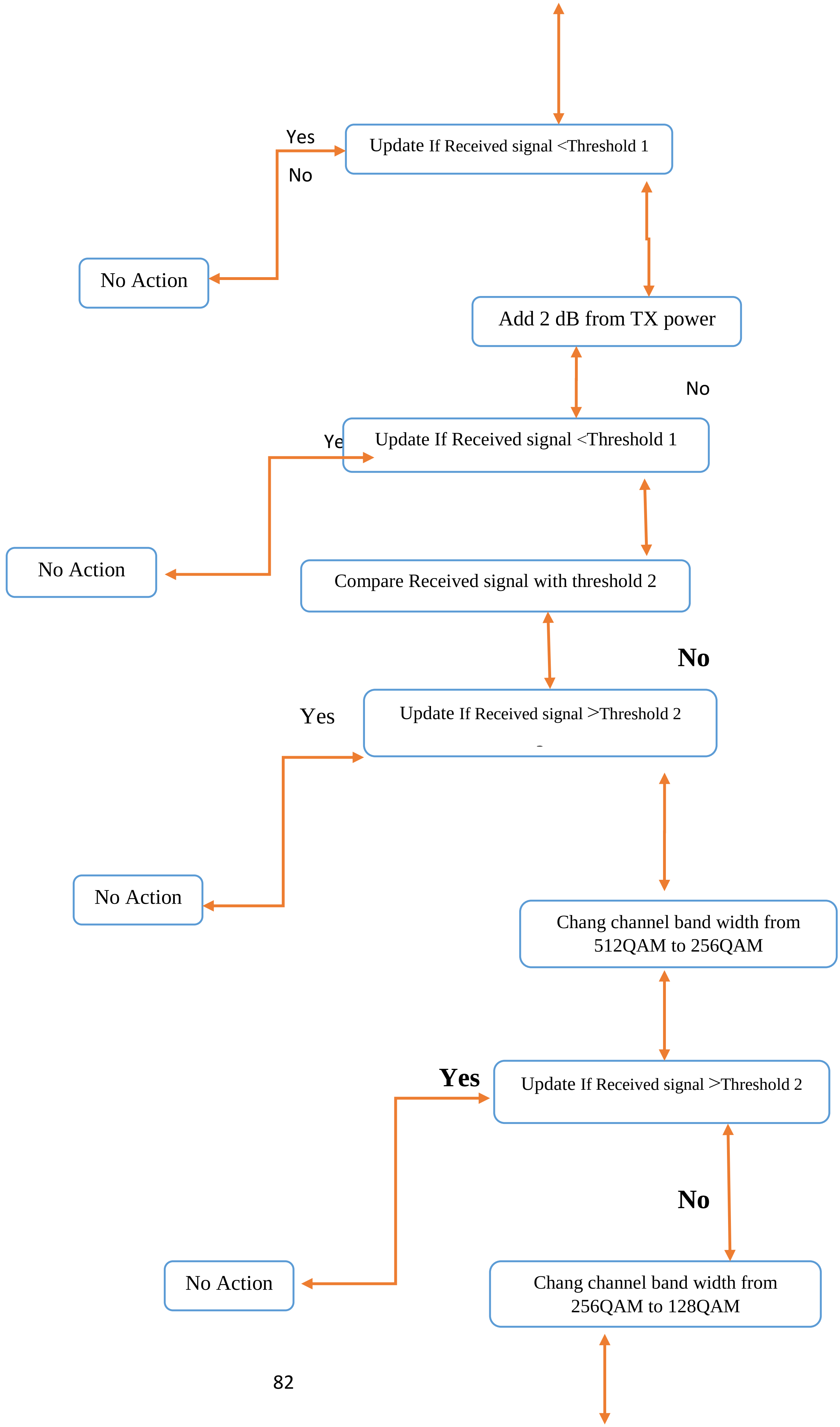
Table 4.1. Maximum Ethernet throughput (Mbps) Vs Band channel

Modulation	Frequency						
	56MHz	40 MHz	28 MHz	20MHz	14 MHz	7 MHz	3.5MHz
QPSK	115	82	58	41	29	14	7
8 QAM	173	124	86	61	43	21	10
16QAM	230	164	115	82	58	28	14
32QAM	288	206	144	103	72	35	17
64QAM	345	246	173	124	86	41	21
128QAM	403	288	201	144	101	48	24
256QAM	460	329	230	164	115	55	28
512QAM	512	370	259	185	129	62	31
1024QAM	575	411	288	206	144		

4.2 Flowchart diagram

The flow diagram of a microwave showing the Software how to work and the software steps as shown in figure 4.2.




Update If Received signal <Threshold 1
Yes
No
No Action
Add 2 dB from TX power
No
Ye
Update If Received signal <Threshold 1
No Action
Compare Received signal with threshold 2
No
Yes
Update If Received signal >Threshold 2
No Action
Chang channel band width from 512QAM to 256QAM
Yes
Update If Received signal >Threshold 2
No
No Action
Chang channel band width from 256QAM to 128QAM

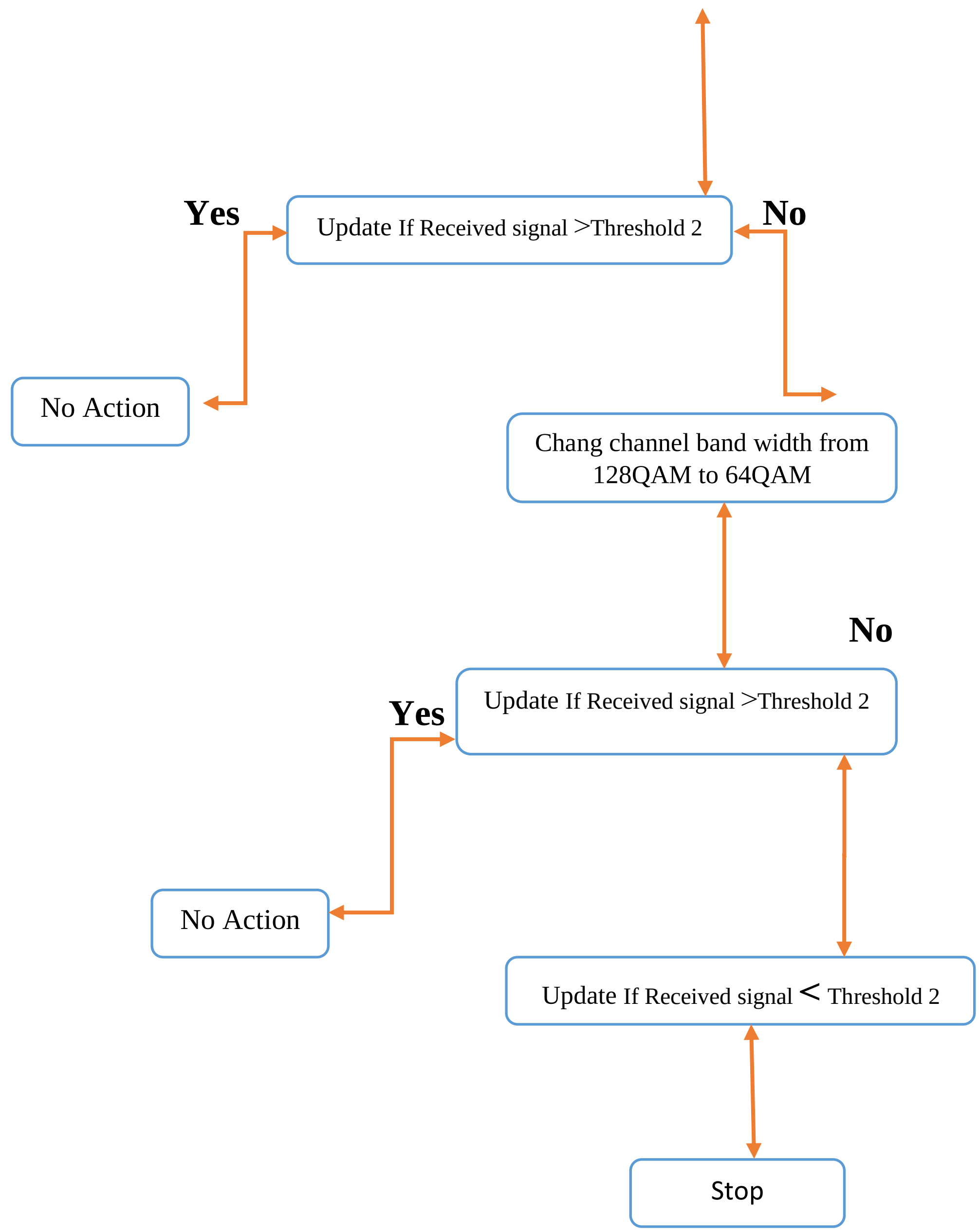


Figure 4.2. Flowchart diagram

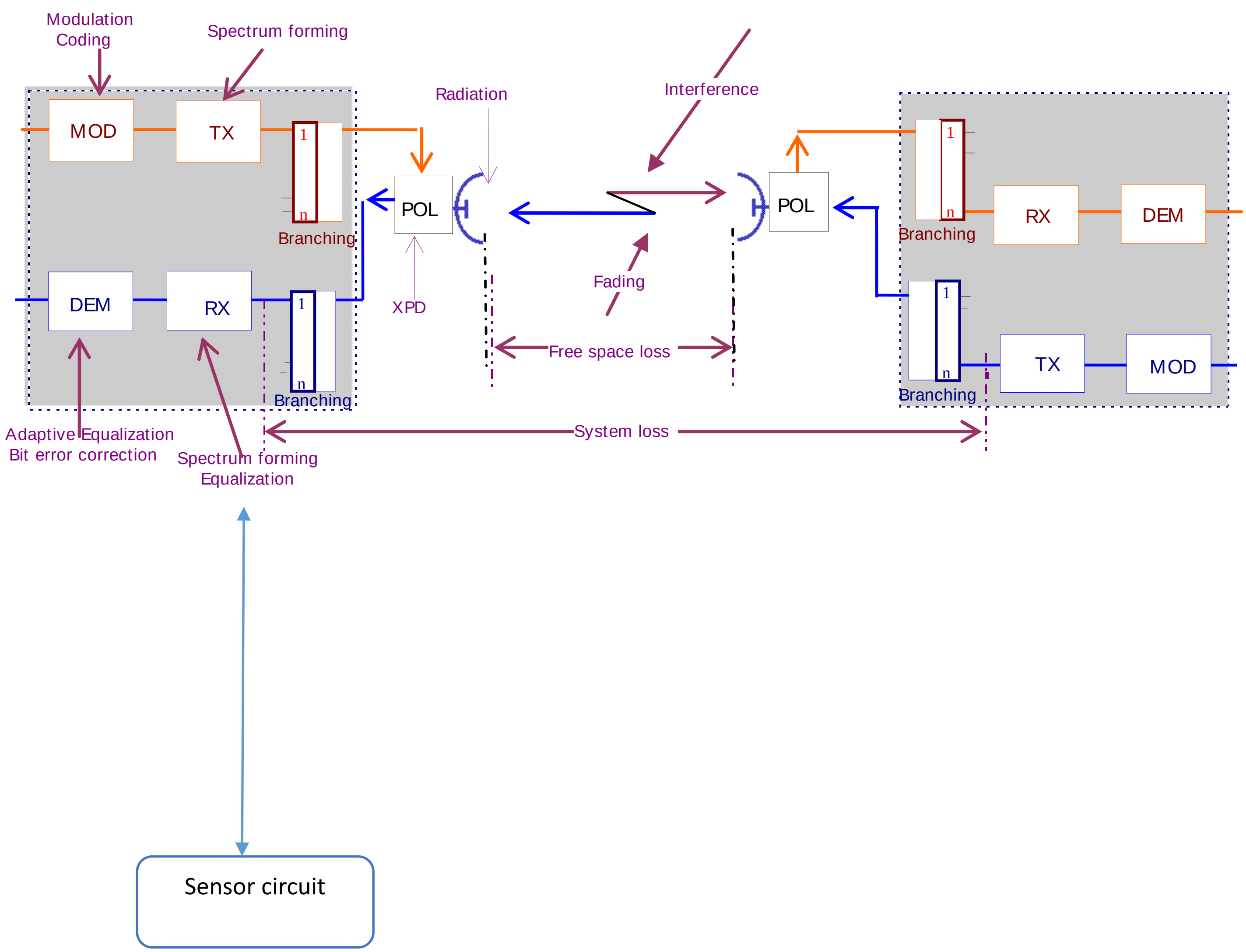
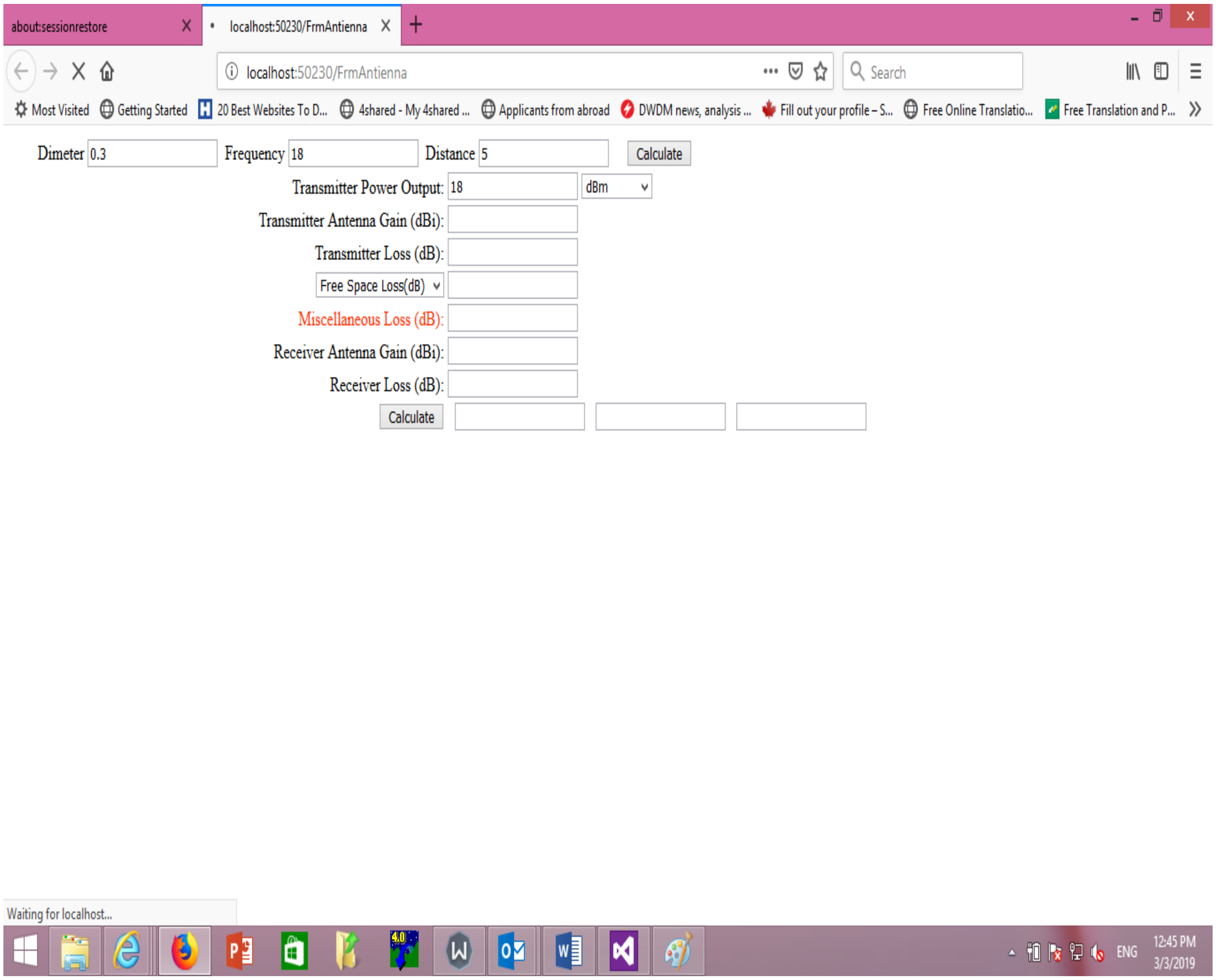
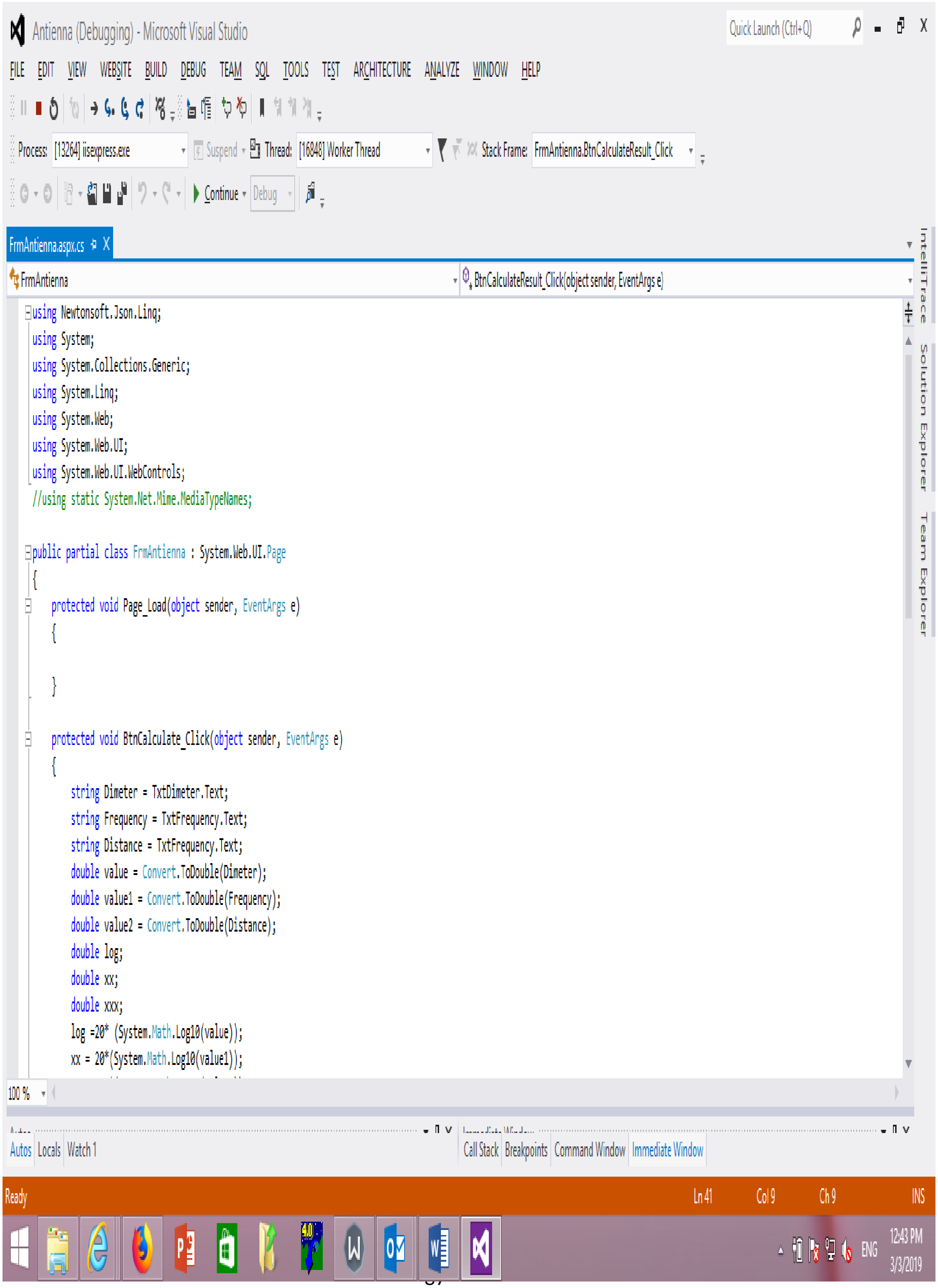


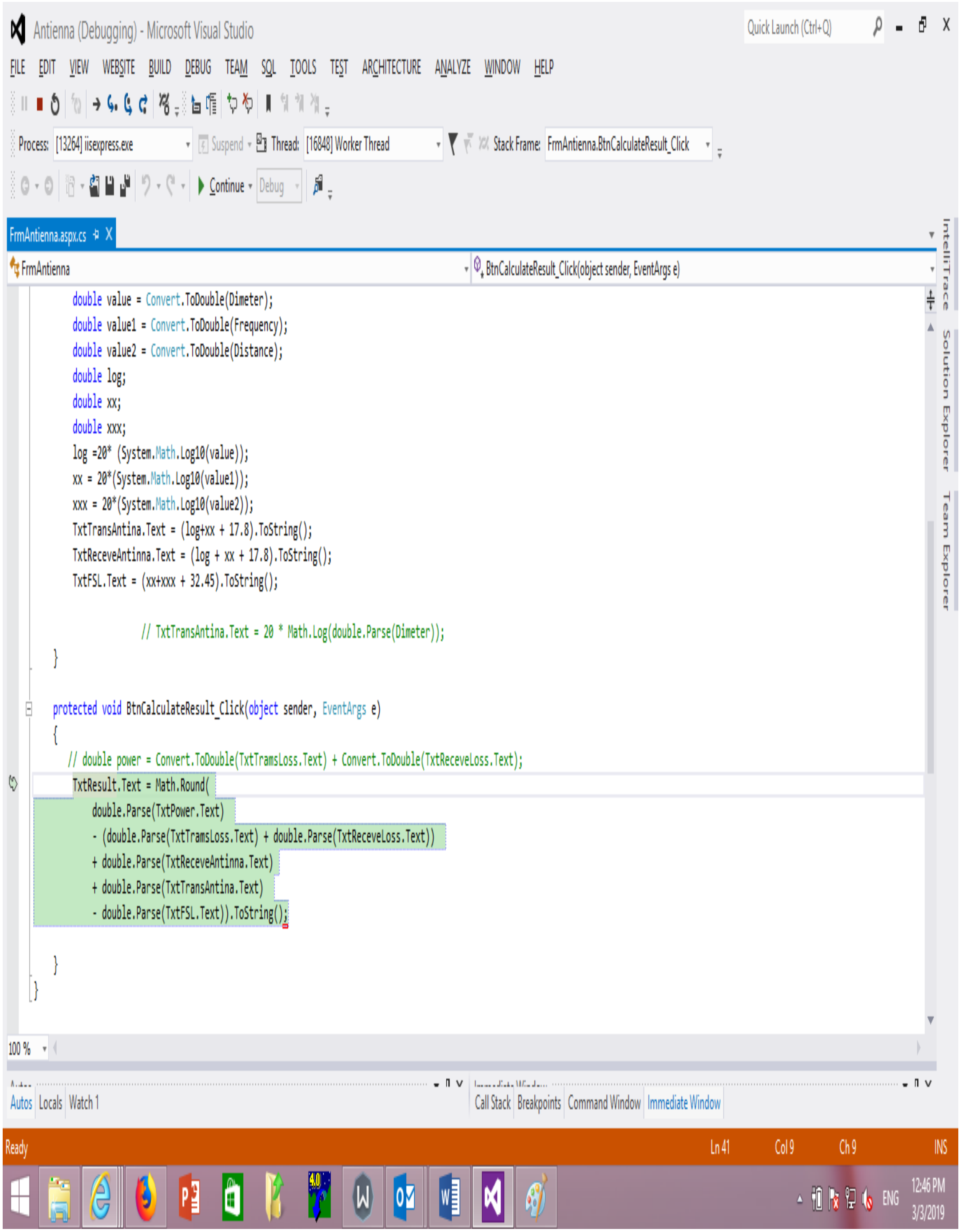
Figure 4.3 Microwave Basic Structure

4.3 Software Program

Visual Studio is a **Integrated Development Environment (IDE)** developed by Microsoft to develop GUI(Graphical User Interface), console, Web applications, web apps, mobile apps, cloud, and web services etc. With the help of this IDE, you can create managed code as well as native code. It uses the various platforms of Microsoft software development software like Windows store, Microsoft Silverlight, and Windows API etc. It is not a language specific IDE as you can use this to write code in C#, C++, VB(Visual Basic), Python, JavaScript, and many more languages. It provides support for 36 different programming languages. It is available for Windows as well as for macOS.


about:sessionrestore
localhost:50230/FrmAntienna
localhost:50230/FrmAntienna
Most Visited
Getting Started
20 Best Websites To D...
4shared - My 4shared ...
Applicants from abroad
DWDM news, analysis ...
Fill out your profile – S...
Free Online Translatio...
Free Translation and P...
Dimeter 0.3
Frequency 18
Distance 5
Calculate
Transmitter Power Output: 18
dBm
Transmitter Antenna Gain (dBi):
Transmitter Loss (dB):
Free Space Loss(dB)
Miscellaneous Loss (dB):
Receiver Antenna Gain (dBi):
Receiver Loss (dB):
Calculate
Waiting for localhost...
ENG
12:45 PM
3/3/2019


Antienna (Debugging) - Microsoft Visual Studio
Quick Launch (Ctrl+Q)
FILE EDIT VIEW WEBSITE BUILD DEBUG TEAM SQL TOOLS TEST ARCHITECTURE ANALYZE WINDOW HELP
Process: [13264] iisexpress.exe
Suspend
Thread: [16848] Worker Thread
Stack Frame: FrmAntienna.BtnCalculateResult_Click
Continue
Debug
FrmAntienna.aspx.cs
FrmAntienna
BtnCalculateResult_Click(object sender, EventArgs e)
using Newtonsoft.Json.Linq;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
//using static System.Net.Mime.MediaTypeNames;
public partial class FrmAntienna : System.Web.UI.Page
{
protected void Page_Load(object sender, EventArgs e)
{
}
protected void BtnCalculate_Click(object sender, EventArgs e)
{
string Dimeter = TxtDimeter.Text;
string Frequency = TxtFrequency.Text;
string Distance = TxtFrequency.Text;
double value = Convert.ToDouble(Dimeter);
double value1 = Convert.ToDouble(Frequency);
double value2 = Convert.ToDouble(Distance);
double log;
double xx;
double xxx;
log =20* (System.Math.Log10(value));
xx = 20*(System.Math.Log10(value1));
IntelliTrace
Solution Explorer
Team Explorer
100 %
Autos Locals Watch 1
Call Stack Breakpoints Command Window Immediate Window
Ready
Ln 41
Col 9
Ch 9
INS
ENG
12:43 PM
3/3/2019


Antienna (Debugging) - Microsoft Visual Studio
Quick Launch (Ctrl+Q)
FILE EDIT VIEW WEBSITE BUILD DEBUG TEAM SQL TOOLS TEST ARCHITECTURE ANALYZE WINDOW HELP
Process: [13264] iisexpress.exe
Suspend
Thread: [16848] Worker Thread
Stack Frame: FrmAntienna.BtnCalculateResult_Click
Continue
Debug
FrmAntienna.aspx.cs
FrmAntienna
BtnCalculateResult_Click(object sender, EventArgs e)
double value = Convert.ToDouble(Dimeter);
double value1 = Convert.ToDouble(Frequency);
double value2 = Convert.ToDouble(Distance);
double log;
double xx;
double xxx;
log =20* (System.Math.Log10(value));
xx = 20*(System.Math.Log10(value1));
xxx = 20*(System.Math.Log10(value2));
TxtTransAntina.Text = (log+xx + 17.8).ToString();
TxtReceveAntinna.Text = (log + xx + 17.8).ToString();
TxtFSL.Text = (xx+xxx + 32.45).ToString();
// TxtTransAntina.Text = 20 * Math.Log(double.Parse(Dimeter));
}
protected void BtnCalculateResult_Click(object sender, EventArgs e)
{
// double power = Convert.ToDouble(TxtTransLoss.Text) + Convert.ToDouble(TxtReceveLoss.Text);
TxtResult.Text = Math.Round(
double.Parse(TxtPower.Text)
- (double.Parse(TxtTransLoss.Text) + double.Parse(TxtReceveLoss.Text))
+ double.Parse(TxtReceveAntinna.Text)
+ double.Parse(TxtTransAntina.Text)
- double.Parse(TxtFSL.Text)).ToString();
}
}
100 %
Autos Locals Watch 1
Call Stack Breakpoints Command Window Immediate Window
Ready
Ln 41 Col 9 Ch 9 INS
ENG
12:46 PM
3/3/2019

Chapter Five

Result, Discussion and Conclusion

5.1 introduction

Although dust storms effects on microwave propagation have been the interest of quite big group of researchers, the systematic observation of dust storm effects are scare.

5.2 Long Term Observations

On the other hand, the objective from the long term observations is twofold. First is to study the effect of dust storms on the link availability in the arid land. The second is to study the behavior of the microwave links due to dust storm in order develop experimental dust storm attenuation models based on the statistical observation.

Four Microwave links at 18GHz in different lengths were under study in Khartoum, Madani and Port Sudan and the signal attenuation for links in this study, as shown in Figure 3.2,3.3 and 3.4, and Table 3.1, The links have been monitored the Transmitted and Received Signal Levels (TRSL) have been recorded for one year from 1 Jan 2016 to 31 Dec 2016 and from Weather Station (AWS) operating at Khartoum International Airport as well the system comprises the four microwave links data acquisition and processing system.

5.3 Comparison of Measured and Calculate Attenuation

There has been growing interest in dust storm effect on microwave signal recently, very limited work has been done in long term observations, this section shows comparisons between measured attenuation due to dust storms at

18GHz, and the Corresponding estimated attenuation using the prediction models.

For four Microwave links operating at18GHz with different link lengths were under study for one year in Madani, Port Sudan and Khartoum, Sudan. The detailed description of the experiment as well as results and analysis of the effect of the dust storms on the links will be presented in this sections.

Different dust particle sizes (re) have been found from the available measurements In addition, the dust particle dielectric constants (ε) have been obtained [19, 20]. Therefore, the attenuation coefficients have been calculated based on the mentioned attenuation prediction models [21, 22].

Table 5.1.MEAN RADIUS AND PDF FOR DIFFERENT DISTRIBUTION FUNCTION.

No	Distribution function	Radius range µm	Mean µm	St dev	$\int pr^3 dr$	$r_e = \left[\int pr^3 dr\right]^{1/3}$	ref
1	Exponential	0.05 - 50	14	14	7.8811e-015	2.0695e-005	[3]
2	Exponential	1 - 250	15	15	2.0150e-014	2.8211e-005	[4]
3	Normal	1- 10	5.7	2.5	3.9898e-019	7.9125e-7	[5]
4	Lognormal	0.1 - 100	1	2	1.2408e-014	2.4039e-5	[6]
5	Lognormal	10 - 100	21	1.7	2.3697e-014	2.9761e-005	[7]
6	Lognormal	1 - 100	2.1	‹ 2	2.2195e-014	2.9125e-005	[8]

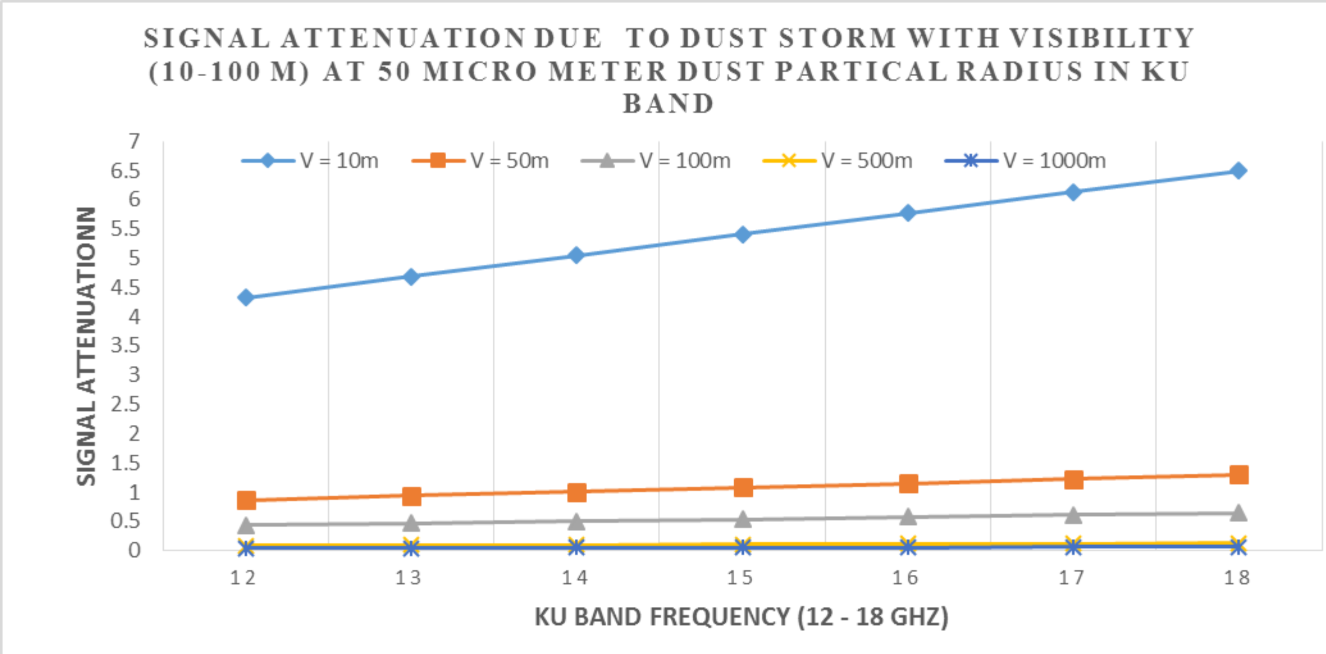


Figure 5.1. Signal attenuation (dB / Km) Vs frequency at Ku band with different Visibility (10 – 1000m)

Signal Attenuation calculated using Elshaikh Model due to Dust Storm with different visibility (10--1000m) and different frequency (12 - 18 GHz), at 50 micro meter dust particle radius in ku band.

5.4 Measured and Calculated Attenuation at 18 GHz in Khartoum

Two Microwave links at 18 GHz with 8.08 Km and 6.6 Km lengths located in DROSHAB-ELSAMRA and UM DOBAN – ASILAT north Khartoum were under study in Khartoum as shown in TABLE 5.2 and 5.3 the terrestrial links have been monitored and the Transmitted and Received Signal Levels (TRSL) have been recorded and also an Automatic Weather Station (AWS) operating at Khartoum International Airport, visibility reduction is measured using the near infrared link recorded for one year from 1 Jan 2016 to 31 Dec 2016.

Table 5.2. Detailed Description of UM DOBAN –ASILAT Link

parameters	UM DOBAN	ASILAT
RX Freq	18640	17630
polarization	Vertical	Vertical
Antenna Dimeter	0.6	0.6
Antenna Gain	38 dBi	38 dBi
Antenna Height	30m	30m
TX Power	19 dB	19 dB
Latitude	15.426	15.36967
Longitude	32.8388	32.86763

Table 5.3. Detailed Description of DROSHAB –ELSAMRA Link

parameters	DROSHAB	ELSAMRA
RX Freq	18810	17800
polarization	Vertical	Vertical
Antenna Dimeter	0.6	0.6
Antenna Gain	38 dBi	38 dBi
Antenna Height	25m	25m
TX Power	15 dBi	15 dBi
Latitude	15.7279	15.76494
Longitude	32.5819	32.64574

Figure.5.2 and TABLE 5.4 compare the measured and calculated attenuation due to dust storms at 18GHz from two Links, with an equivalent particle sizes (*re*) 38μm has been used in D. Ahmed, Elshaikh and Goldhirsh model. The dielectric constants (ε) have been calculated content.

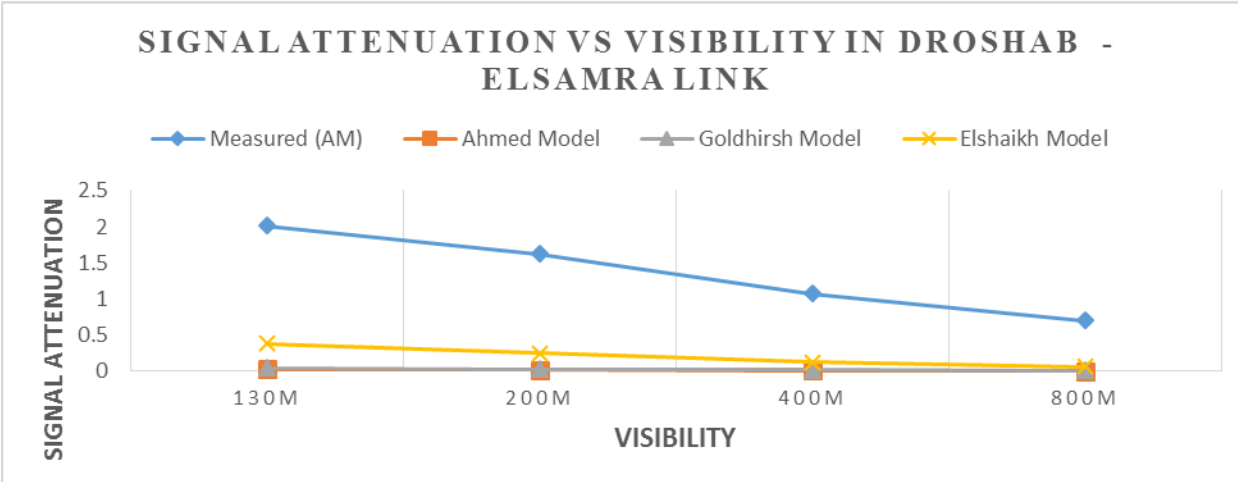


Figure 5.2. Comparison between measured attenuation versus predicted for DROSHAB -ELSAMRA link in May- 2016

Dust storm attenuation was predicted using models proposed by Goldhirsh, D. Ahmed and Elshaikh with the parameters re = 38μm, ε'=4.2 , ε''=1.56, V=(130 ,200,400,800m) and f=18GHz. Equations (3.1) to (3.7) were used to estimate the attenuations and presented in Table 5.4. Measured and predicted attenuation are compared in Table 5.5. It is obvious that the measured attenuation are 13 and 11 dB higher than that predicted by three models for DROSHAB-ELSAMRA and UM DOBAN – ASILAT links respectively.

Table 5.4. Predicted and Measured Attenuation using measured visibility in May 2016

Month	Visibility	Measured AM	Ahmed	Goldhirsh	Elshaikh
19-May	130m	2.01	0.0248	0.047	0.3793
17-May	200m	1.62	0.0161	0.0297	0.2465
6-May	400m	1.07	0.0081	0.0141	0.1233
21-May	800m	0.7	0.0042	0.0067	0.0616

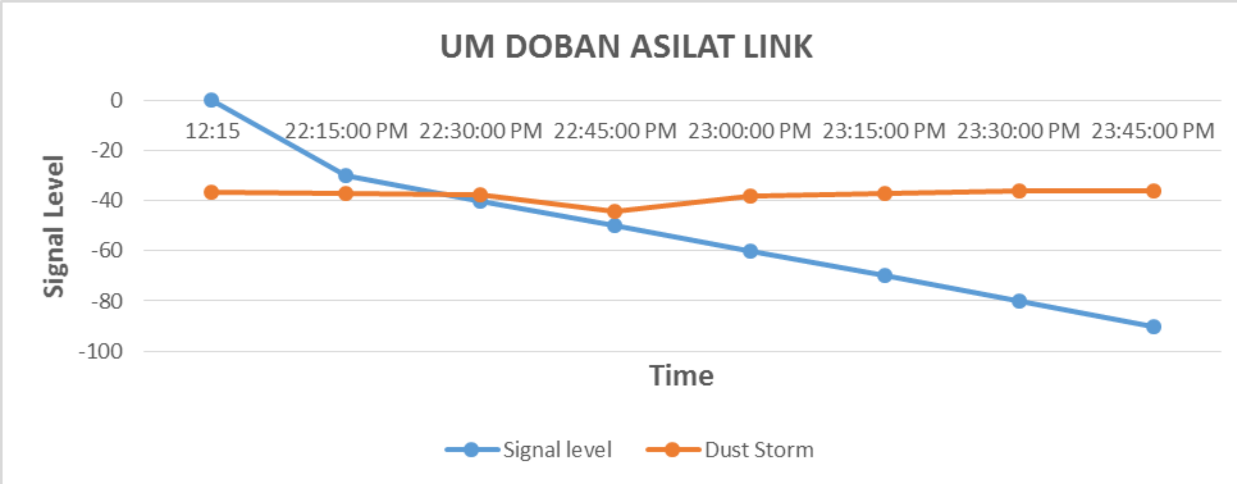


Figure 5.3. Measured signal level for UM DOBAN – ASILAT link on 6st May 2016.

Table 5.5. Comparison between measured and predicted attenuation as total for DROSHAB – ELSAMRA link.

Table 5.5: Length of link between DROSHAB and ELSAMRA

Attenuation per KM (Goldhirsh model) = AG/Km

Attenuation per KM (Elshaikh model) = AE/Km

Attenuation per KM (Ahmed model) = AA/Km

Total attenuation for the Goldhirsh model = AGT

Attenuation per KM (Elshaikh model) = AE/Km

Total attenuation for the Elshaikh model = AET

Link	Visibility	Ahmed	Goldhirsh	Elshaikh	Measured AM	Length Km	Ahmed Total	Goldhirsh Total	Elshaikh Total	Measured AM Total
DROSHAB -ELSAMRA	130m	0.0248	0.047	0.3793	2.01	8.08	0.200384	0.37976	3.064744	16.2408
	200m	0.0161	0.0297	0.2465	1.62	8.08	0.130088	0.239976	1.99172	13.0896
	400m	0.0081	0.0141	0.1233	1.07	8.08	0.065448	0.113928	0.996264	8.6456
	800m	0.0042	0.0067	0.0616	0.7	8.08	0.033936	0.054136	0.497728	5.656

Table 5.6. Comparison between measured and predicted attenuation as total for UMDOBAN – ASILAT link

Table 5.6: Length of link between UMDOBAN and ASILAT

Attenuation per KM (Goldhirsh model) = AG/Km

Attenuation per KM (Elshaikh model) = AE/Km

Attenuation per KM (Ahmed model) = AA/Km

Total attenuation for the Goldhirsh model = AGT

Attenuation per KM (Elshaikh model) = AE/Km

Total attenuation for the Elshaikh model = AET

Link	Visibility	Ahmed	Goldhirsh	Elshaikh	Measured AM	Length Km	Ahmed Total	Goldhirsh Total	Elshaikh Total	Measured AM Total
UM DOBAN -ASILAT	130m	0.0248	0.047	0.3793	2.01	6.6	0.16368	0.3102	2.50338	13.266
	200m	0.0161	0.0297	0.2465	1.62	6.6	0.10626	0.19602	1.6269	10.692
	400m	0.0081	0.0141	0.1233	1.07	6.6	0.05346	0.09306	0.81378	7.062
	800m	0.0042	0.0067	0.0616	0.7	6.6	0.02772	0.04422	0.40656	4.62

Measured and predicted attenuation are compared in Table 5.5and 5.6. It is obvious that the measured attenuation are 13 and 11 dB higher than that predicted by both models for DROSHAB -ELSAMRA and UMDOBAN – ASILAT links respectively with different Visibility at18GHz.

5.5 Measured and Calculated Attenuation at 18 GHz in Region (MADANI and PORT SUDAN)

Two Microwave links at 18 GHz with 4.35 Km and 4.86 Km lengths located in HANTOOP-ALINGAZ and PORT SUDAN – DAR ELNAEEM in middle and east Sudan were under study in Khartoum as shown in Figure 5.4, and TABLE 5.7 the terrestrial links have been monitored and the Transmitted and Received Signal Levels (TRSL) have been recorded and also an Automatic Weather

Station (AWS) operating at Khartoum International Airport, visibility reduction is measured using the near infrared link recorded for one year from 1 Jan 2016 to 31 Dec 2016.

Table 5.7. Detailed Description of HANTOOP –ALINGAZ Link

parameters	HANTOOP	Alingaz
RX Freq	18981	17971
polarization	Vertical	Vertical
Antenna Dimeter	0.6	0.6
Antenna Gain	38 dBi	38 dBi
Antenna Height	25m	25m
TX Power	23 dBi	23 dBi
Latitude	14.430381	14.44978
Longitude	33.531254	33.56648

Table 5.8. Detailed Description of PORT SUDAN –DAE ELNAEEM Link

Parameters	Portsudan Center	Dar Elnaeem
RX Freq	18910	17900
Polarization	Vertical	Vertical
Antenna diameter	0.3 m	0.3 m
Antenna gain	32 dBi	32 dBi
Antenna height	30 m	25 m
TX Power	21 dBi	21 dBi

Dust storm attenuation was predicted using models proposed by Goldhirsh, D. Ahmed and Elshaikh with the parameters re = 38µm, $\varepsilon'=4.2$, $\varepsilon''=1.56$, , V=(140 ,200,500,800m) and f=18GHz. Equations (3.1) to (3.7) were used to estimate the attenuations and presented in Table 5.9. Measured and predicted attenuation are compared in Table 5.12. It is obvious that the measured attenuation are 13 and 11 dB higher than that predicted by three models for HANTOOP-ALINGAZ and PORT SUDAN – DAR ELNAEEM links respectively.

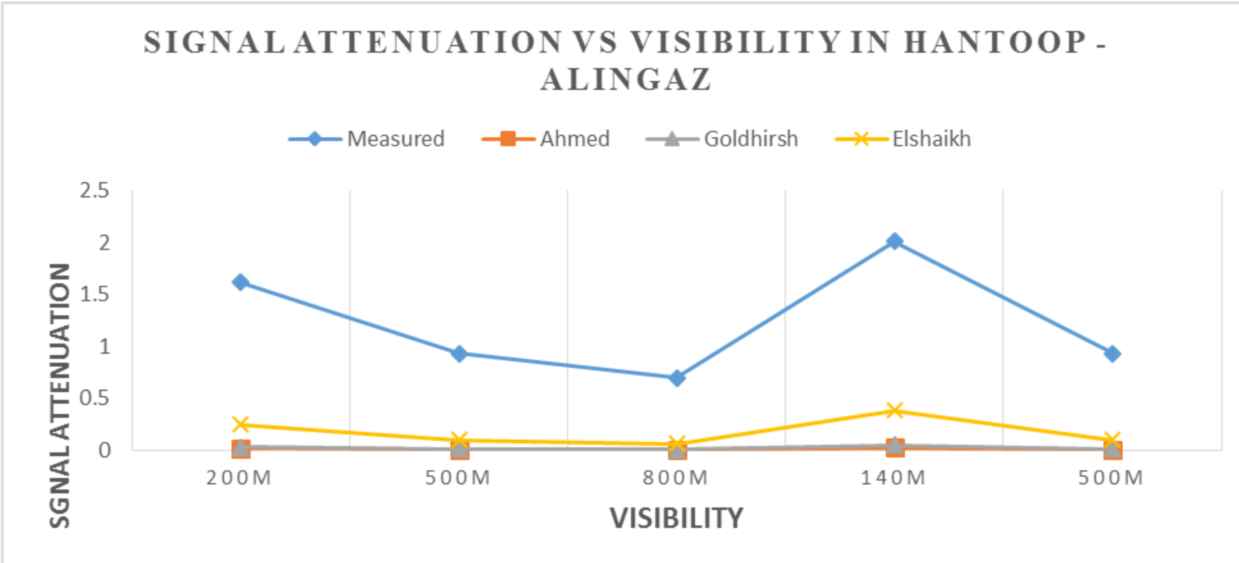


Figure 5.4. Comparison between measured attenuation versus predicted for HANTOOP - ALINGAZ link

Table 5.9. Predicted Model and Measured Attenuation using different measured visibility (200m, 500m& 800m) in Mar, Jun and Sep 2016

Month	Visibility per m	Measured	Ahmed	Goldhirsh	Elshaikh
MAR	200m	1.62	0.0161	0.0297	0.2465
Jun	800m	0.7	0.0042	0.0067	0.0616
Sep	500m	0.93	0.0065	0.0111	0.0986

Table 5.10. Predicted Model and Measured Attenuation using different measured visibility (140m, 500m) in Jun and July 2016

Month	Visibility per m	Measured	Ahmed	Goldhirsh	Mlshaikh
jun	500m	0.93	0.0065	0.0111	0.0986
july	140m	2.01	0.0248	0.047	0.3793

Table 5.11. Comparison between measured and predicted attenuation as total for HANTOOP-ALINGAZ link

Table 5.11: Length of link between HANTOOP and ALINGAZ

Attenuation per KM (Goldhirsh model) = AG/Km

Attenuation per KM (Elshaikh model) = AE/Km

Attenuation per KM (Ahmed model) = AA/Km

Total attenuation for the Goldhirsh model = AGT

Attenuation per KM (Elshaikh model) = AE/Km

Total attenuation for the Elshaikh model = AET

Link	Visibility	Ahmed	Goldhirsh	Elshaikh	Measured AM	Length Km	Ahmed Total	Goldhirsh Total	Elshaikh Total	Measured AM Total
HANTOOP -ALINGAZ	200m	0.0161	0.0297	0.2465	1.62	4.35	0.070035	0.129195	1.072275	7.047
	500m	0.0065	0.0111	0.0986	0.93	4.35	0.028275	0.048285	0.42891	4.0455
	800m	0.0042	0.0067	0.0616	1.07	4.35	0.01827	0.029145	0.26796	4.6545

Table 5.12. Comparison between measured and predicted attenuation as total for PORT SUDAN – DAR ELNAEEM link

Table 5.12: Length of link between PORT SUDAN and DAR ELNAEEM

Attenuation per KM (Goldhirsh model) = AG/Km

Attenuation per KM (Elshaikh model) = AE/Km

Attenuation per KM (Ahmed model) = AA/Km

Total attenuation for the Goldhirsh model = AGT

Attenuation per KM (Elshaikh model) = AE/Km

Total attenuation for the Elshaikh model = AET

Link	Visibility	Ahmed	Goldhirsh	Elshaikh	Measured AM	Length Km	Ahmed Total	Goldhirsh Total	Elshaikh Total	Measured AM Total
)RT SUDAN - DAR ELNAEEI	140m	0.0161	0.0297	0.2465	2.01	4.35	0.070035	0.129195	1.072275	8.7435
	500m	0.0065	0.0111	0.0986	0.93	4.35	0.028275	0.048285	0.42891	4.0455

Measured and predicted attenuation are compared in Table 5.11and 5.12. It is obvious that the measured attenuation are 6 and 7 dB higher than that predicted by both models for HANTOOP-ALINGAZ and PORT SUDAN – DAR ELNAEEM links respectively with different Visibility at18GHz.

5.6 Conclusion and Recommendation

Afield study aimed at studying the effect of Microwave signal in arid land has been done in Khartoum, Madani and Port Sudan for a period of one year. The project presented the results of measuring the signal attenuation caused by the dust storms at 18GHz.Various metrological parameters were simultaneously measured and statistically analyses with direct emphasis on visibility.

It has been concluded from the measurement that, the deviation between the measured and the predicted attenuation is due to the use of the single scattered theory in developing the theoretical models.

The failure of the models to directly include important parameters such as relative humidity, wind speed, temperature and pressure is the additional source deviation between the measured and predicted attenuation. However, dust storms attenuation measurement is costly and time consuming, currently it is the only way available to accurately estimate the dust storm effects on microwave signal.

Dust storms can cause serious attenuation in signal level especially at Ku band and higher frequencies with direct impact on telecommunications system performance. four operational microwave links at 18 GHz in Sudan were monitored during dust storm and observed more than 13 dB for the higher one and 6 dB for the lower one attenuation for about 8.08 and 4.35 Km lengths. Models proposed by Goldhirsh, Ahmed and Elshaikh were used to predict attenuation on both measurements. It is found that all models underestimate the attenuation measured on four microwave links.

The authors recommended to study the variation of attenuation due to visibility, humidity and temperature data will be analyzed to figure out the relation between different parameters can be done, comparison with other types of models can be done.

These findings will be very useful information for microwave link designers at areas affected by dust storms and the optimum radio planning and link budget analysis can be obtained accordingly.

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