CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

In the recent time, mobile communication networks have witnessed series of evolutions ranging from the legacy services of 1G (first generation) through to the 4G (fourth generation) and now the newly launched 5G (fifth generation), (Arun Agarwal et al 2019). Each generation of mobile cellular network has an improvement over the previous ones and also has its challenges. Subscribers have shifted from the generic voice -only communications to data, online gaming, video streaming, machine to machine communication, etc. In figure 1.1, a mobile subscription forecast was carried out in (Rysavy Research, 2009), and it predicted a mobile subscription pattern for different networks from 2010 to 2030. It forecasted that by the end of 2020, Global System for Mobile communication / Enhanced Data for Global Evolution (GSM/EDGE) network operators may not have customers; subscription will be shifted to only Universal Mobile Telecommunications System / High Speed Packet Access (UMTS/HSPA) and Long Term Evolution (LTE) networks. Accordingly, it forecasted that by 2030, there will be a sharp drift to LTE and 5G technologies. This means that by 2030 all network operators must upgrade to LTE and 5G for them to be in business. Between 2010 and 2030, customers are embracing new applications that required huge bandwidth. Unlike the 1G, there are glaring indications that applications from new generation networks are bandwidth-hungry. A demographic presentation of applications' demand for bandwidth from 2G to 3G is shown in (John Tang et al, 2007). Figure 1.2 indicates that applications such as streaming, interactive gaming, and video conferencing have high bandwidth demand.

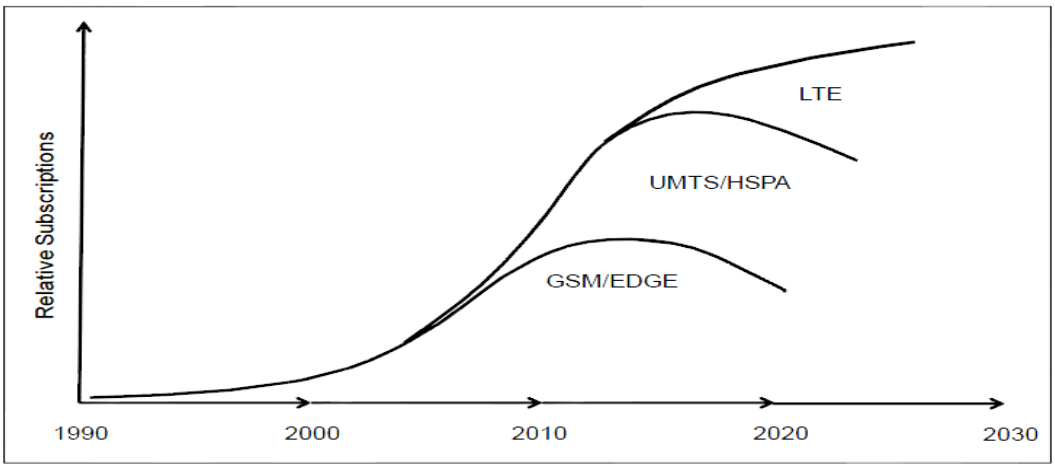


Figure 1.1: Mobile Subscription forecast (Rysavy Research,2009)

Figure 1.3 showed a research carried out by (ABI research team, 2014), it forecasted mobile data traffic for new generation applications from year 2011 to 2019. From their analysis, worldwide video streaming for instance which generated 9840 petabytes (38%) by 2013 was forecasted to generate about 139000 petabytes (65.4%) by 2019.

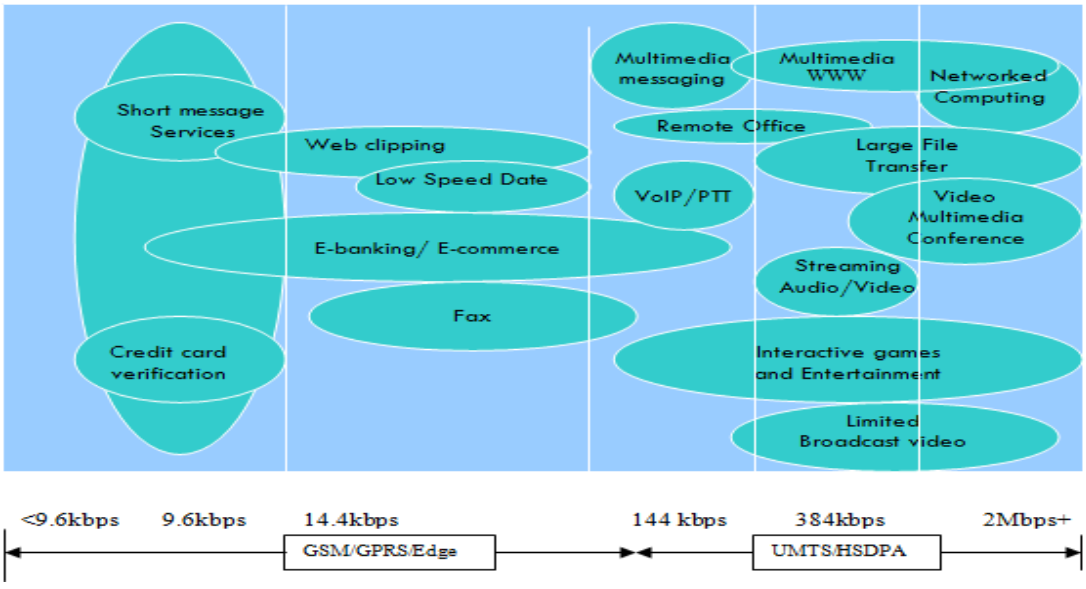


Figure 1.2: High speed wireless multimedia application (John Tang et al, 2007)

From the research, the global average amount of traffic generated per user per day which was at 400 megabytes per day at 2014 was forecasted to be 1800 megabytes per day by 2019. It could be deduced from their work that there is a serious drift from voice-only applications to new generation applications which appear to demand more bandwidth. The subscribers are embracing these new generation applications which generate huge traffic on the backhaul.

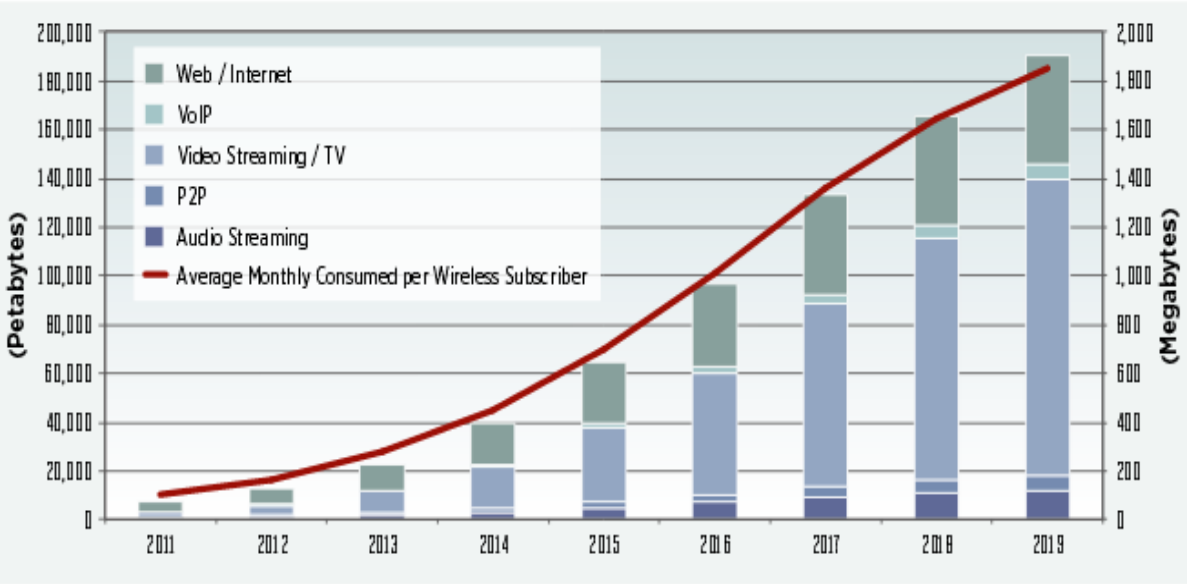


Figure 1.3: Applications' Bandwidth demand forecast from 2011 to 2019 (ABI Research 2014)

Despite the improvements in mobile communication systems as witnessed by the evolutions, there are still short comings in delivering higher speed data and meeting up excellent performance as promised by each generation of evolution. 3GPP which stands for 3rd generation partnership project released LTE technology document in its Release 8 and 9 which is set to provide an increase to both capacity and speed using new techniques for modulation. The standard requirement was specified by the International Telecommunication Union-radio communication sector (ITU-R) and it was named the International Mobile Telecommunication Advanced (IMT-Advanced) specification. Setting peak speed requirement for 4G services at 1 gigabit per second (Gbit/s) for low mobility communication such as pedestrians and stationary users and 100 megabit per second (Mbit/s) for high mobility communication like trains and vehicles (Wikipedia, n.d). Other requirements for this new access network are high spectral efficiency, high peak data rates, short round trip time and also flexibility in frequency and bandwidth. Backhauling (traffic transmission from cell sites, such as base station/eNodeB, to core networks) of this LTE has witnessed some challenges leading to operators not meeting up to LTE promised deliverables. It is likely very unfeasible for the current microwave backhaul systems of the cellular networks to satisfy the Gigabit promised by 4G networks without promoting latency and poor quality of service (

QoS) in the system. Several backhaul technologies like point to point microwave, point to multipoint microwave, free space optics, etc have been adopted by different operators of existing cellular networks with each having its merits and demerits. Nonetheless, point to point fibre optics is backhaul technology that can contend the 4G traffic but is a bit costly. However going by the cost limitations of point to point fibre link, Passive Optical Networks (PON) is considered a potential and cost-effective means of traffic transportation because its scalable, has unlimited capacity, range, reliability and its use of passive components.

1.2 STATEMENT OF PROBLEM

As promised by International Telecommunication Union-radio communication sector (ITU-R), 4G networks would deliver up at 1 gigabit per second (Gbit/s) for low mobility communications such as pedestrians and stationary users and 100 megabit per second (Mbit/s) for high mobility communication like trains and vehicles. It is expected that 4G when fully embraced, will experience exponential increase in data traffic and to backhaul this huge traffic will be a very serious issue of concern if telecom operators are to keep to service level agreements. Present microwave backhaul systems as constituted are faced with some challenges as poor weather conditions, limited capacity, limited range, and latency issues to say the least. To achieve unlimited capacity, lowest latency, scalability, cost effective backhaul, etc, by operators of 4G, Passive Optical Network is viewed as a backhaul technology that can meet the challenges in backhauling of 4G (LTE) traffic.

1.3 AIM AND OBJECTIVES

The aim of this work is to Design a Passive Optical Networks (PON) as backhaul for 4G (LTE) cellular networks using SMILE mobile communications network, Port Harcourt as a case study.

The Specific Objectives of this work are as follows;

i, To Understudy Port Harcourt terrain, identify SMILE network eNBs and their coordinates in Port Harcourt.

ii, To carry out Computation of Optimal splitter location using 'manual' approach and 'automatic/systematic' approach

iii, To determine the effect of Dispersion for both downstream and upstream transmissions with respect to network capacity and further determine the ranging delays for upstream transmissions

iv, To carry out Power budget calculations for both downstream and upstream transmission scenarios.

v, To implement the designed networks for both downstream and upstream transmission in Optisystem simulation environment.

vi, To carry out comparative analysis of the proposed system in terms of performance with existing SMILE backhaul system.

1.4 SIGNIFICANCE OF THE STUDY

Existing backhaul technologies like T1/E1, Microwave, etc used by previous generation of networks will certainly not meet promised deliverables of 4G (LTE). Therefore, 4G technology are expected to deliver 1 gigabit per second (Gbit/s) for low mobility communication such as pedestrians and stationary users and 100 megabit per second (Mbit/s) for high mobility communication like trains and vehicles hence giving high spectral efficiency, required scalable network in case of expansion and of course cost effective backhaul that will reduce the CAPEX of the operators. Based on the foregoing, it is obvious the T1/E1 wire line with maximum bit rate of 155Mbit/s or microwave (with maximum bit rate 620Mbit/s) used for 3G infrastructure are not going to meet the capacity, throughput and support QoS requirement of these 4G networks . To meet the demands of 4G mobile network, a backhaul technology that can support Quality of Service (QoS), cost effective, unlimited capacity is needed. Hence, this work is centered on using Passive Optical Networks (PON) as cellular backhaul for 4G LTE using SMILE Port Harcourt as a case study. The significance of this study is not limited to but includes the following:

(i) To have a backhaul that will help reduce the OPEX of the mobile Operators

(ii) To have a backhaul that has unlimited capacity and as well reliable for 4G networks

(iii) To have a backhaul that will help realise the ambition of fixed-mobile convergence.

(iv) To have a scalable backhaul that will help improve throughput and QoS

(v) To have a backhaul that will help achieve the lowest latency in LTE networks.

1.5 SCOPE OF THE WORK

This dissertation is focused on the design of Passive Optical Networks (PON) as cellular backhaul for 4G LTE networks and SMILE mobile communications network Port Harcourt was used as a case study. The research used SMILE eNB distribution in Port Harcourt to generate coordinates that was used to calculate the fibre requirements for PON backhaul design. It also looked at 4G backhaul network power budget analysis for both downstream and upstream transmissions. Finally, the network was implemented in Optisystem simulation tool.

CHAPTER TWO

LITERATURE REVIEW

This chapter gave a general view of Long Term Evolution (LTE), its standards and architecture, it also reviewed related literature on backhaul with a view to finding the research gap and also gave detailed information about passive optical networks

2.1 LONG TERM EVOLUTION (LTE)

Long Term Evolution (LTE) commonly known as 4G (fourth generation) is a product of the 3rd Generation Partnership Project 3GPP which operates under the European Telecommunication Standard Institute. It is one of the latest standards in the mobile network technology and may also be referred to as Evolved UMTS Terrestrial Radio Access (E-UTRA) and Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) (Lte Encyclopedia, n.d).

2.1.1 LTE STANDARDS AND TARGETS

3GPP set some specific targets for LTE. According to (Lte Encyclopedia, n.d), the under listed targets were set for LTE to ensure an enhancement of the radio access technology, optimization and simplification of radio access network:

(i) Improved spectral efficiency; 5bps/Hz for DL (down link) and 2.5 bps/Hz for UL (up link)

(ii) Reduced latency

(iii) Improved cell edge performance in terms of bit rate

(iv) Increased peak data rate : 100Mbps for DL with 20MHz and 50Mbps for UL with 20MHz

2.1.2 LTE ADVANCE

Most times, LTE is not seen as true 4G standard because it is believed not to fulfill all the ITU 4G requirements of 4G definition. Based on these foreseen shortcomings, International Mobile Telecommunications – Advance (IMT-Advance) at their Radio Communication Assembly (R4-12) in Geneva, 16-20th January 2012 reached a consensus to expand the IMT Radio interface family by establishing the new IMT advanced standard which gave birth to LTE -Advance (ITU, n.d). The LTE Advance has the capacity to provide peak and sustained data rates, corresponding spectral efficiencies, reduced latency, overall complexity and quality-of–service management. Subsequently, some of the system requirements for LTE Advance according to (Wiki LTE World, n.d) are as follows:

(i) Achievement of peak data rate of 1Gbps data by 4x4 MIMO and that the transmission bandwidth wider than approximately 70MHz, hence, 100Mbit/s for high and 1Gbit/s for low mobility as targets for research.

(ii) For peak spectrum efficiency, the DL, that the Rel.8 LTE satisfies IMT –advanced requirement, and UL need to double Release 8 to satisfy IMT- advanced requirement capacity and cell-edge user throughput.

(iii) Support for flexible deployment scenarios including downlink/uplink asymmetric bandwidth allocation.

(iv) The overall U-plane/C-plane latency shall be significantly reduced.

Despite the evolution (upgrade from LTE to LTE Advance), this work shall see the two as 4G (LTE) and shall refer to the capacity and latency of any of the LTE for link budgeting/ capacity calculations for the sake of this research.

2.1.3 4G (LTE) ARCHITECTURE

The architecture of 4G (LTE) is made up of these major components: The user equipment (UE), the evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the evolved packet Core (EPC).

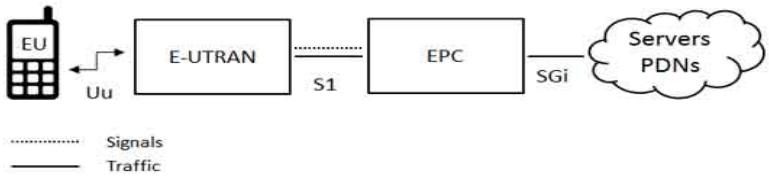


Figure2.1: Simplified LTE 4G Network Architecture (LTE Tutorial Point, n.d)

The interfaces between the different components of the architecture are represented as Uu, Si and SGi as shown in figure 2.1. Uu, Si and SGi are the interfaces between the EU/ E-UTRAN, E-UTRAN/ EPC and EPC/ Servers PDNs respectively. The evolved packet core (EPC) communicates with the outside worlds like the private corporate networks, IP multimedia subsystem or the Internet. The breakdown of each of the components that made up the architecture is as follows:

i, The **User Equipment (UE)**: The user equipment is actually the mobile equipment MT and is comprised of the under listed modules:

(a) Mobile termination; This handles all the communication functions

(b) Terminal Equipment (TE); This terminates the data streams

(c) Universal Integrated circuit Card (UICC); this is sometimes called the SIM Card for LTE equipment. It is responsible for smooth running of Universal Subscriber Identity Module (USIM) application. Like 3G SIM Card, the USIM keeps information about the user's phone number, home network identity and security keys etc.

ii, The **E – UTRAN**: This is referred to as the access network, the core responsibility of the evolved UMTS Terrestrial Radio Access Network (E-UTRAN) is the establishment of radio communication between the mobile and the evolved packet core and it has only one component called the evolved base station (eNodeB or eNB). Each eNB is a base station that controls the mobile in one or more cells. The base station that is communicating with the mobile is known as its serving eNB. Figure 2.2 shows the 4G (LTE) Network Architecture with E-UTRAN as the access network.

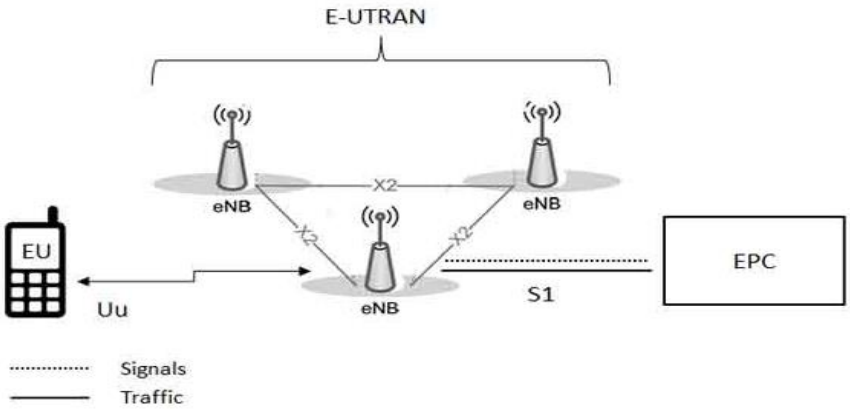


Figure 2.2: LTE 4G Network Architecture with E-UTRAN Access Network (LTE Tutorial Point, n.d)

LTE mobile communicates with one base station and one cell at a time. The eNB supports the following two main functions:

(a) The sending and receiving of radio transmission to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.

(b) The control of low – level operation of all its mobiles, by sending them signaling messages such as handover commands.

As seen from Figure 2.2, each eNB is connected with EPC by Si interface and it is also connected to nearby base station by X2 interface, which is mainly used for signaling and packet forwarding during handover (LTE Tutorial Point, n.d).

iii, **The Evolved Packet CORE (EPC) (The Core Network)**

Simplified architecture of the evolved packet core (EPC) is as shown in Figure 2.3. Each component that made up the diagram is described below;

(a) The Home Subscriber Server (HSS) is a central database that contains information about all the network operator's subscribers.

(b) The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world. The PDN uses SGi interface.

(c) The Serving Gateway (S-GW) forwards data between the base station and the PDN gateway and also acts as a router.

(d) The Mobility Management Entity (MME) controls the high-level operation of the mobile by signaling messages and home subscriber server (HSS).

(e) The Policy Control and Charging Rules Function (PCRF) though not shown in the diagram for the sake of simplicity is responsible for policy control decision making and also for control of flow –based charging functionalities in the Policy Control Enforcement Function (PCEF) which resides in the P-GW.

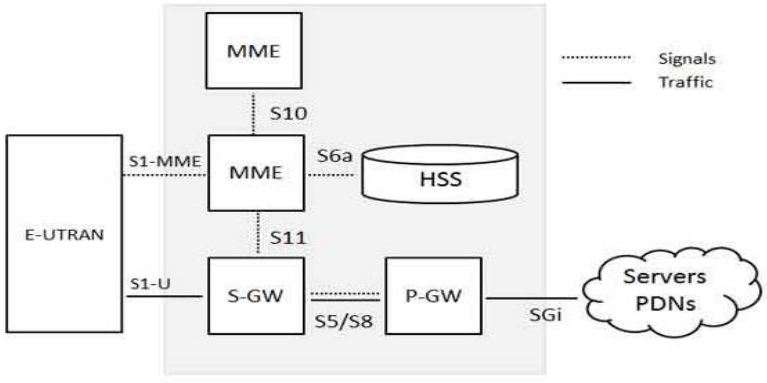


Figure 2.3- Simplified Architecture of Evolved Packet Core (EPC) (LTE Tutorial Point, n.d)

2.2 BACKHAUL AND BACKHAUL TECHNOLOGY

In telecommunication, backhaul refers to traffic transmission from cell sites, such as base station/eNB, to core networks. The backhaul connections could be leased lines such as: E1

interface channeled in a way to carry voice and data, Microwave (PDH and SDH interfaces), optical fibre (SDH interface), among others. For LTE, backhaul link connection is not the same as witnessed in 3G networks; it links eNB to core networks. There is nothing like Radio Network Controller (RNC)/ Mobile Switching Centre (MSC). It is a standalone kind of arrangement with a view to reducing latency. The X2 and Si interfaces of figure 2.2 depict a typical backhaul link of an LTE network. Many factors influence the choice of a backhaul technology by an operator. Some of them are often made based on technical and/or cost considerations. Technical like bandwidth requirements, support for Quality of Service (QoS), among other factors. Other choices may be due to area type (urban, sub-urban or metropolitan) or government policies. However, in as much as cost is imperative care should be taken to ensure a right choice. Bandwidth/ capacity of a backhaul network determine its ability to transport the huge traffic back to the core network at a desired time. Network operators around the globe have employed different backhaul technologies over time. The following section reviews several backhaul technologies that have been in existence and compares them in relation to capacity, reliability and range.

2.2.1 REVIEW OF RELATED WORKS ON BACKHAUL

This section reviews various backhaul technologies from various research persons/teams with a view to finding the strengths and weaknesses of each technology.

2.2.2 POINT-TO-POINT MICROWAVE

Microwave is defined as electromagnetic energy having a frequency higher than 1GHz which corresponds to a wavelength shorter than 30 centimetres (Margaret Rouse, 2006).This part of radio spectrum ranges across frequencies in the neighbourhood of 1.0 GHz to 300GHz. This band of frequency is well situated for wireless transmission of signals having large bandwidth. Figure 2.4 show a typical microwave mounted on a tower to enable line of sight. Microwave signals propagate in straight lines and are said to be affected insignificantly by troposphere.

Figure 2.4: Typical Microwave mounted on a telecommunication tower (Wikipedia, n.d)

Point-to-point microwave is a reliable backhaul system with a good capacity of about 622Mbit/s (Ofcom, 2007).It has range from 4km at 38GHz, 10km at 13GHz and 40km at 6GHz but is highly dependent on the operating frequency. One of the advantages of point-to-point microwave is that it is ideal for a competitive environment as it encourages very fast speed of roll-out especially in a Greenfield lands. However, due to its line of sight suitability, its use is restricted to tower-mounted base stations. Figure 2.5 demonstrates line of sight functionality of Point to point Microwave.

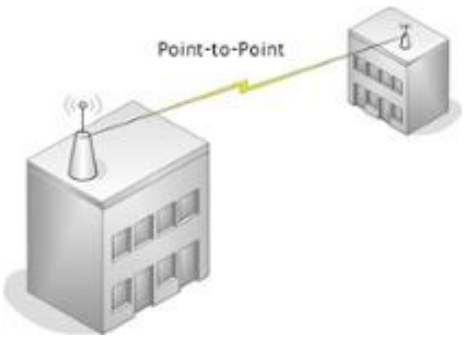


Figure 2.5: Point-to-Point Microwave (Avalan wireless Blog, 2014)

In their work (Manjunath R.K et al, 2014), point to point microwave is viewed as fixed line of sight (LOS) terrestrial links that operates in frequency bands 6GHz to 30 GHz. Accordingly, point to point microwave can transport traffic up to 2 x STMI, SDH (126E1's), can support distances from less than a km to 40 km in a single hop (6Hz to 30GHz) and up to 120km in a mountain to mountain arrangements. Has the capability of ease upgrade but little weather conditions like rain affects its attenuation greatly. In their view, (ABI research, 2014)

sees point to point microwave as a low cost option for mobile backhaul. It sighted its ease of rollout and other innovations like Adaptive Coding Modulation (ACM), High Order Quadrature Amplitude Modulation (QAM), Compression Accelerators, Polarization Interference Cancellation and Multiple Input and Multiple Output (MIMO) as major strengths, however, atmospheric effects or rain which can attenuate the signal and limit its range coupled with high cost of spectrum licensing are its major drawbacks to fulfilling 4G promised deliverables.

2.2.3 POINT –TO-MULTIPOINT MICROWAVE

Point-to-multipoint microwave is often abbreviated as P2MP, PTMP or PMP. Unlike point to point, PMP microwave uses a single hub to create a sector of coverage that can backhaul multiple sites. It uses area licensed spectrum rather than on link to link basis, allowing bandwidth to be shared across all sites in the sector. PMP competes with point-to-point microwave. Although its use is more in the delivering of broadband access, it has a capacity of 155.52Mbit/s per sector and a range of 3km at 26GHz, 10km at 3.5GHz. Like point-to-point (see section 2.2.2), it encourages speedy roll-out in the developing countries. It is a reliable backhaul, however; it does not operate well for street level micro- and pico-base stations and can also be affected by whether changes. According to a research carried out by (CBNL, nd), major advantage of PMP over PTP microwave is that PMP microwave allows sector aggregation which improves spectral efficiency by at least 40% when compared to PTP. Secondly, expansion (sites can be added to PMP sector) can be done without need for additional spectrum. PMP microwave can be used in the following areas;

(i) Wide area (macro) mobile backhaul

(ii) Small cell (metro) mobile backhaul

(iii) Mixed mobile backhaul and access network and

(iv) Enterprise and private access networks

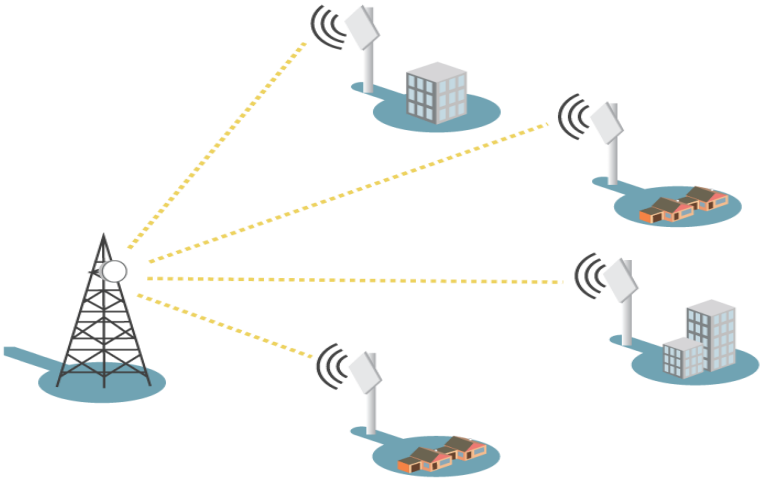


Figure 2.6: Point-to-MultiPoint Microwave (Colombow Consulting, 2015)

2.2.4 MILLIMETER WAVE (MM-WAVE)

Millimeter wave, extremely high frequency (EHF) or very high frequency (VHF) is an International Telecommunication Union (ITU) designation for radio band of frequencies in the electromagnetic spectrum from 30 to 300 gigahertz. Radio wave in this band has wavelengths from ten to one millimeter, giving rise to the name millimeter wave. In their research, (Zhouyue Pi et al, 2011) looked at the propagation and device technology challenges associated with this band and it's unique advantages for mobile communication. Their research introduced millimeter wave mobile broadband system as a technology for next generation mobile communication system and hence demonstrated the feasibility for millimeter wave to achieve gigabit per second data at a distance up to 1km in an urban mobile environment. However, the components (power amplifiers, low noise amplifiers, mixers and antenna) used for the research are not miniaturized and consume so much power, hence not compatible for the next generation mobile communication networks. Secondly, the work discovered that foliage losses for millimeter wave are significant and can be a limiting impairment for propagation. (Sooyoung Hur et al, 2013) proposed the use of outdoor millimeter wave communication for backhaul networking between cells and mobile access

within a cell. Based on their work, it is to overcome the outdoor impairments found in millimeter wave propagation. Their work studies beamforming using large arrays. However, such system may require narrow beams, increasing sensitivity to movement caused by pole sway and other environmental conditions. Their work however proposed an efficient beam alignment techniques using adaptive subspace sampling and hierarchical beam codebook as a corrective measures since it is not possible to use larger arrays without risking a corresponding performance loss from wind induced beam misalignment. According to (Wei Feng et al, 2016), Millimeter wave is a promising technology that has the capability of providing a multi-gigabit transmission rate, offers flexible and cost effective candidate for both 4G and 5G backhauling by taking advantage of highly directional antennas, it becomes practical to cope with explosive traffic demand and to deal with interference issues. Unlike, 2G and 3G, 4G LTE and even the newly lunched 5G goes more on small cells for capacity sake and densification of these small cells produces massive backhaul traffic in the core network. Traditional microwave frequency bands may be limited in achievable gains due to the existing spectrum crunch. It may be difficult for microwave to meet the rapid increase of 4G and even 5G traffic demands. Therefore, millimeter wave is viewed to overcome the above mentioned shortcomings of microwave. Despite the merits of millimeter wave, here are some of the shortcomings;

(i) Difficulty in aligning the beam and narrow beam

(ii) Limited resources for alignment

(iii)Difficulty in deployment and mounting of poles etc.

2.2.5 TV WHITE SPACE (TVWS)

The transition to digital television transmission has made available new spectrum bands often called TV white space (TVWS). Communication regulators in some parts of the world especially in the USA have mandated that the TVWS should open up for unlicensed usage

provided that equipment operating in those bands does not in any way interfere with the services of the primary user. Operators and regulators around the globe are developing geo-location databases to control and manage TVWS operation with the aim of protecting the primary user. TV white Space is likely to be implemented in the frequency range of 470 to 694/8 MHz bands. TVWS availability is location specific and can be used for wireless backhaul for small cells in locations where the TVWS availability is high. One major strength of TVWS as a backhaul network is when it is used in rural areas and even in the places with no pre-existing wired infrastructure. (Cyrus Gerami et al, 2011) proposed a system using fixed towers and directional antennas which could provide backhaul/ or distribution for Internet access in places where its services are needed. In their view, (Ratnesh Kumbhkar et al, 2015) TV white space channels with their desirable radio propagation characteristics can provide an excellent alternative for engineering backhaul networks in area that lack abundant infrastructure. They maintained that TV white space channels can provide "free wireless backhaul pipes" to transport aggregated traffic from broadband sources to fibre access points. In his analysis, (Bill Brown, 2016) sees TVWS as a means of overcoming the dual challenge of maximizing coverage and capacity economically and effectively. However, TVWS has faced some challenges such as poor quality of service for the backhauled traffic (quality of service degraded by interference emanating from co-located participant in the TVWS spectrum), difficulty in vendors to source compatible hardware, ability of the TVWS to protect the licensed primary user, etc (ABI Research, 2014).

2.2.6 WORLD WIDE INTEROPERABILITY FOR MICROWAVE ACCESS (WiMAX)

WiMAX is another form of backhaul technology that comes from the family of wireless communication standards based on IEEE 802.16 set of standards; it comes in two flavours IEEE 802.16-2004 (Fixed WiMAX) and IEEE 802.16e-2005 (mobile WiMAX). Like point-to-point microwave, WiMAX is also a good backhaul for tower-mounted macro-base station.

It uses adaptive modulation and coding (AMC) for its high data rates. It has a range up to 50km and a theoretical capacity of 70Mbit/s which is poor compared to optical fibre and point-to-point microwave. WiMAX operations are very similar to wi-fi but it provides higher speed, greater distance of coverage and accommodates a larger number of users. It has the advantage of providing services in terrains difficult for wired backhauling hence, delivers broadband services in an economical way to both enterprise and residential customers (Hitesh Kumar et al, 2014). In addition to its weakness in providing capacity, the WiMAX technology is seen as an evolutionary one that uses orthogonal frequency division multiplexing and causes transmission resistant to fading and minimizes multipath effect. In his research, (Bhuteswar Jena, 2014) views WiMAX as a technology that is spectral efficient, inherently simple and easy to deploy. He based his claim on its cost effectiveness, its ability in disaster recovery and use in backup of broken wired links. WiMAX suffers drawbacks because of its limited and expensive spectrum (John Tang et al, 2007). Another major problem with the deployment of WiMAX as a backhaul is that it operates on a broad frequency spectrum and this has lead WiMAX into interoperability problems as regulators imposed frequency split on operators (Panagiotis Georgopoulos et al, 2010).

2.2.7 SATELLITE

The use of satellite as backhaul is seen in oil platforms, war prone zones as ad hoc backhaul measures for places where temporal backhaul services are needed. Though high throughput satellites tend to cover the lapses of traditional satellite, its use is predominantly seen in rural and semi-rural environments. Satellite has excellent range and is very reliable but has a poor capacity. This poor capacity of satellite coupled with its high cost makes it not a good backhaul technology (Ofcom, 2007). Satellite backhaul technology is good for small cell deployments especially in the rural areas where wired connectivity is not feasible. Typically, its deployments are not meant for 4G/LTE services but are limited to 2G coverage for voice and minimal data services. Recently, it is recorded that Hughes Networks systems are

working on some of these limitations (ABI Research, 2014). The transmission over satellite links for cellular backhaul is usually on T1/E1 techniques; its use is for locations where other backhaul is not feasible. The advantages of satellite backhaul are short installation times and flexible coverage. However, it is not cost effective and has long propagation delay (Orawan Tipmongkolsilp et al, 2010). Figure 2.7 shows a typical satellite backhaul network

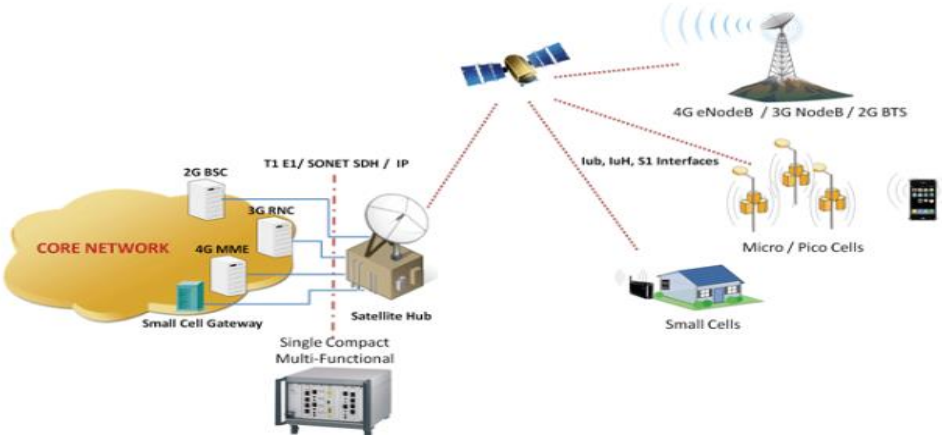


Figure 2.7: Satellite Backhaul Network (Wikipedia, n.d)

2.2.8 FREE SPACE OPTICS (FSO)

Free Space Optics is a type of optical communication in which light propagating in free space is used to establish a wireless link to transmit data/ voice communication. The technology is used in situations where physical connection is not practicable due to certain considerations. FSO as a backhaul technology can be used mostly over a short distances where the line of sight (LOS) can be obtained. It has an excellent capacity that can support data rates up to 10Gbit/s and encourages speedy roll-out because of its low cost; however it is not a reliable backhaul system. In addition to not being reliable, FSO covers only short range of distance, affected by weather change and in all does not meet the technical requirements of a good backhaul (Foundry networks, 2007). Figure 2.8 shows a typical FSO.

Figure 2.8: Free Space Optics (Wikipedia, n.d)

2.2.9 DIGITAL SUBSCRIBER LINE (DSL)

According to the work carried out in (Foundry networks, 2007), DSL as backhaul saves operators some cost instead of using Optical fibre, point to point or even point to multipoint microwaves. DSL has two Varieties, Symmetrical Digital Subscriber Line (SDSL) and Asymmetrical Digital Subscriber line (ADSL). DSL has different capacities and range. Symmetrical High Speed Digital Subscriber Line (SHDSL) which is a type of SDSL has 3km range and 5.6Mbit/s up/down while ADSL has a range of 5km and a capacity of 7Mbit/s down and 800 Kbit/s up; its reliability depends on the copper wires used, in some areas the copper wires get rusted due to water leakages and affects the overall performance of the DSL link. Despite this poor range and capacity when compared to optical fibre, it encourages high speed of roll-out in areas where pairs of copper are readily available. However, research carried out by (Neder et al, 2004) spotted out that impulse noise is a limiting factor in the performance of DSL systems as a backhaul because of its high power demand and burstiness. In a related work, (Ravishankar et al, 2007) noticed the same power limitation of ADSL and proposed bit-loading algorithm with the aim of reducing the power that is required to transmit data in ADSL.

2.2.10 POWER-LINE COMMUNICATIONS (PLC)

The power-line communication (PLC) is a communication system that can use electrical wiring to simultaneously carry both data and alternating current (AC) electric power transmission or electric power distribution. The Power line changed into a data line via the superposition of a low energy information signal to the power wave. Since the electricity is 50 or 60 Hz, data can be transmitted at a minimum of say 3 kHz to ensure that the power wave does not interfere with the data signal. PLC as a backhaul can only deliver a good capacity over a very short distance (less than 20m). Its capacity works in opposite direction with distance, the more the distance lesser the capacity becomes. It failed in the technical aspects like range, reliability, capacity, speed of roll-out hence; it is not a good backhaul technology. It works well in providing communication inside a building by transmitting data over electrical wiring (Foundry networks, 2007).

2.2.11 OPTICAL FIBRE

Optical fibre is a flexible but transparent material that uses glass (or plastic) threads called fibre to transmit data. Fibre optics is the overlap of applied science and engineering concerned with the design and application of optical fibre. Optical fibre is widely used in fibre optic communications, which permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communications. A desirable feature for optical fibre is the ability to process information entirely for the purpose of amplification, multiplexing, de-multiplexing, switching since optical signal processing is more efficient than electrical signal processing (Francis Idachaba et al, 2014). Even more importantly, fibre optic networks are easily upgradable when there is need for greater speed in the future by just upgrading the end point electronics that makes it a good backhaul technology (Bas Van Dongen et al, 2016).

2.2.12 OPTICAL FIBRE BASIC PRINCIPLE

According to (Sanjay Sharma, 2012), fibre optics operated based on the principle of total internal reflection and the Snell's Law. Snell's law describes the relationship between the sine angle of incidence and the sine angle of refraction and says that they are equal to the ratio of the speed of the wave in the first medium and the speed of the wave in the second medium.

Mathematical representation of the law is:

$$n_1.sin\theta_1 = n_2.sin\theta_2 \quad (2.1)$$

Where n_1 = refractive index of first medium;

θ_1= Angle of incidence;

n_2= refractive index of the second medium;

θ_2= angle of refraction.

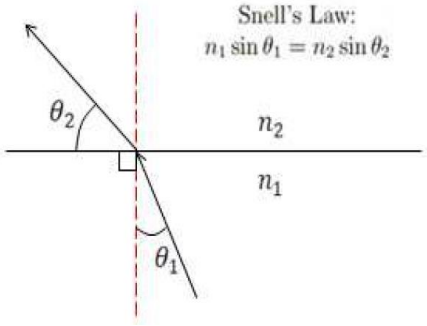


Figure 2.9: Diagram representation of Snell's Law

Total Internal Reflection is a phenomenon that occurs when the angle of incidence is greater than the critical angle, the refractive index of the core is higher than that of the cladding, and therefore all the light is reflected. Critical angle is simply the largest angle of incidence for which refraction can still occur. Thus, when incoming light pulses enter through one end of

the optical fibre, it can be totally reflected along the inner surface linings of the fibre. This same process is repeated again and again throughout the entire length of the cable. And since the angle of incidence and reflection are equal, the beams continue to be reflected and transmitted in a zigzag mode throughout the entire fibre. Figure 2.10 shows total internal reflection

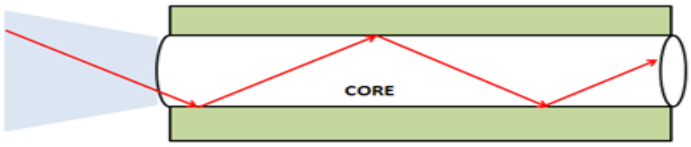


Figure 2.10: Total Internal Reflection

2.2.13 ELEMENTS OF OPTICAL COMMUNICATION SYSTEM

Fibre optics communication system consists mainly of three elements:

(i) Optical Transmitter

(ii) Optical Cable

(iii) Optical Receiver

Depending on the technique, purpose and topology, additional elements such as connectors, switches, couplers, multiplexing devices, amplifiers and splices are also essential in this communication system. Figure 2.11 shows a general fibre optic communication system

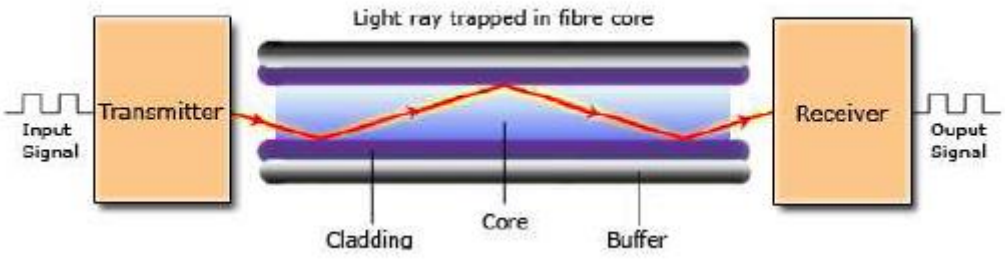


Figure 2.11: General fibre optic communication system (G.Keiser, 2000)

2.2.13.1 OPTICAL TRANSMITTER

Optical transmitters convert the information carried as electrical signals into optical signals and launch/drive the optical signals into an optical fibre. The most common light sources are Light Emitting Diodes (LEDs) and Laser Diodes (LDs). LEDs emit light through spontaneous emission and are used extensively in fibre optic communication systems due to their small size, long lifetime and low cost. They are used in short distance and low bandwidth networks (Hiba, Altahir, 2017). Light amplification by stimulated emission of radiation otherwise known as Laser has a higher output power than LED and so they are capable of transmitting information over longer distances and provide high bandwidth communication (G. Keiser, 2000).

The Optical fibre consists of three major layers according to (Juan Salvador Asensi, 2011), they are:

1. **The Core:** This is the innermost part of the fibre. It is responsible for driving the optical signals from the transmitting device to the receiving device. It is made from high temperature pure quartz, plastic or silicon dioxide. If made with silicon dioxide, it is typically doped with phosphorous oxide (P_2O_5) or germanium oxide (GeO_2) to adjust its refractive index. It has a core diameter ranging between 10 to 300µm. The higher the diameter the greater the amount of light the cable can carry.
2. **The Cladding:** It is the middle layer of the fibre. It surrounds and protects the core. The refractive index of the cladding must be lower than that of the core to ensure total internal reflection throughout the fibre, and keep the light energy within the nucleus/core. It is made from high temperature quartz or plastic, with more thickness in order to absorb the potential impact or shock that the fibre can get and provide extra protection for the core against excessive cable bending.

3. **The Coating/ Buffer:** The coating is the outer part of the fibre. It acts as the shock absorber of the fibre and protects the core and the cladding from damage and external agents. It is made from plastic capable of resisting moisture, crushing force, rodent action, and other environmental hazards. The coating is sometimes divided into 2 layers: The **Buffer (Primary coating)** and the **Jacket (Secondary coating).** The Buffer/Coating may have diameter of 125 to 250µm without secondary coating, and 500 to 900µm with secondary coating. Figure 2.12 shows a fibre cable with various protecting coatings like jacket, buffer, and cladding, also shown in figure 2.12 is the core.

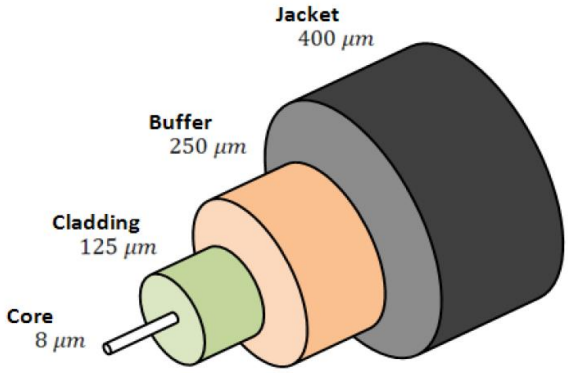


Figure 2.12: Layers of fibre optics cable (G.Keiser, 2000)

According to (G. Keiser, 2000), fibre optics is classified into two categories based on number of modes (single mode, multi-mode) or on the refractive index (step, graded). A mode in an optical fibre corresponds to one of the possible multiple ways in which a wave may propagates through the fibre.

Single mode fibre (SMF) with a relatively narrow diameter, through which only one mode will propagate typically 1310 or 1550nm, carries higher bandwidth than multimode fiber. However, it requires a light source with a narrow spectral width. Also SMF has a narrow core (eight microns) and the index of refraction between the core and the cladding changes less than it does for multimode fibers. Figures 2.13a and 2.13b respectively show single mode and

multimode fibre. A fibre is called multimode fibre (MMF) if more than one mode propagates through it. In general, a larger core diameter or high operating frequency allows a greater number of modes to propagate.

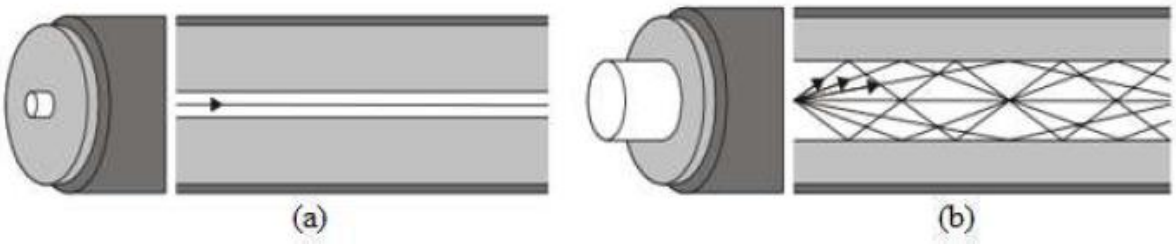


Figure 2.13: Modes of fibre optics

2.2.13.2 OPTICAL RECEIVER

The function of the optical receiver is to detect the incoming optical power and extract from the transmitted signal. The first receiver element is a photodiode which serves as the Optical-electrical converter of the receiver. It is either a Positive Intrinsic Negative diode (PIN) or Avalanche Photo detector Diode (APD), which produces an electrical current proportional to the received power level. Since the electrical current is typically very weak, a Trans-Impedance Amplifier is added to boast it to a level that can be used by the next element. After being amplified the signal passes through a Limiting amplifier/Low Pass Filter (LPF) to reduce the noise that is outside the signal bandwidth. Further signal processing such as clock recovery from data by a phase-locked loop may be applied before data signal passed on, so an integrated signal processing circuit is added to analyze the delivered data.

2.2.13.3 OPTICAL FIBRE TRANSMISSION ARCHITECTURE

The fibre optic transmission channel applies two configurations for its operation.

(i) Point-to-Point architecture
(ii) Point-to-Multiple point architecture

2.2.13.4 POINT-TO-POINT CONFIGURATION

This is specifically a direct link between the central office and exactly one individual end user. Such a network will provide excellent bandwidth but will be very costly due to the fiber and central office machinery in case of configuration to the 'home' users (Dieter Elixmann et al, 2008).

2.2.13.5 POINT-TO-MULTIPLE POINT CONFIGURATION

Also called shared fibre, this configuration entails that each fibre cable leaving the central office is "shared" by many customers. The main fibre cable gets relatively close to the customer neighborhood and then split into individual customer-specific fibre.

Optical fibre as a backhaul technology is seen to provide solution to the increasing bandwidth demand of the new generation networks.

2.2.13.6 STRENGTHS OF THE OPTICAL FIBRE

The following strengths according to (Juan Salvador Asensi 2011) are what make the fibre optic network desirable.

(i) The optical fibre has a greater transmission capacity. They can achieve speeds in Terra bits per seconds (TB/s), since transmission rate increases as frequency increases; the inherently higher bandwidth capacity of optical fibre facilitates the simultaneous transmission of large amounts of information.

(ii) They have total immunity to electromagnetic interference. They are not affected by radiation or nuclear electromagnetic pulse (NEMP)

(iii) Higher throughput (speed of signal transmission). The optical signals travel through the fibre cable at the speed of light ($c = 3\times10^8 m/s$), while the electric signals travel through the cables at a speed between 50-70% the speed of light, depending on the type of cable.

(iv) Problems such as cross-interference reflection that exist in electrical transmission do not affect optical transmission.

(v) Attenuation in optical systems communication increases more slowly than in the case of the electrical cables, allowing greater distance between signal repeaters.

(vi) There are no risks of short circuiting which is a major problem in the electrical transmission.

(vii) Fibre optic cables weigh one-tenth the weight of copper cables. This is a very important consideration for military applications, ships and aircraft building.

(viii) They are suitable for use in a wide range of temperatures, better than cables with metallic origin.

(ix) They are also the best for 100% signal security, since the transmitted signal cannot be drawn from a fibre without tampering it.

(x) They have higher resistance to environmental action and corrosive substances than the electric cables.

(xi) It is possible to increase transmission capacity by adding new data channels using different wavelengths to those already employed (this is the WDM technique).

Fibre offers capacity in range of hundreds of thousands of Gbit/s, in other words, it is seen to have unlimited capacity. It has unlimited range and its excellently reliable. In fact the excellent technical attributes of optical fibre makes it outstanding when it comes to traffic backhauling. However, the cost of extending this service (procuring the link, digging of new trenches, etc) slows down the speed of roll-out. Sometimes, some existing structures may be destroyed for point-to-point fibre links to get to the targeted location; this requires approvals from authorities which takes some couple of time. In the analysis carried out in (Ofcom, 2007), it compared the technical and economic viability of backhaul technologies in terms of cost, reliability, capacity, speed of roll-out and locally availability. From their result, it is observed that fibre optics scores excellently in characteristic like range, capacity and

reliability and scored low in the speed of roll-out due to its high cost. The result of the research is shown in table 2.1.

Table 2.1: Comparison of backhaul technology characteristics (Ofcom, 2007)

	Characteristic					
Technology	**Range**	**Capacity**	**Reliability**	**Cost**	**Local Availability**	**Speed of Rollout**
Optical Fibre	A	A	A	D	B	D
PtP Microwave	D	D	A	C	B	B
PMP Microwave	C	C	A	C	C	B
DSL	D	D	C	A	D	A
WiMAX	C	D	A	C	C	B
Free-Space Optics	E	A	E	B	B	A
Satellite	A	E	B	E	B	B
Power-Line Comms	E	D	D	unknown	D	D

Where A = Excellent

B = Very Good

C = Good

D = Poor

E = Very Poor

Different from the above backhaul technologies, this work looks at passive optical networks (PON) as a backhaul for 4G LTE Cellular Network. **PON technology being fibre optics utilizes the combination of the good attributes of fibre like unlimited range, unlimited capacity and excellent reliability with cost effectiveness.** PON saves the cost of running point –to point fibre (from one node to the other), instead, use a single fibre up to a point where the splitter will split to different Optical Network Units (ONUs), this saves cost and

makes it easier to achieve fibre to the home (FTTH) in the access network. Secondly, the cost of maintaining the active components in a point to-point network contributes heavily to the OPEX of the operators but PON uses passive component that will not require much maintenance thereby saving the operator huge sum. Again, Point to point links requires 2 transceivers (1:1 transceiver), but PON uses one transceiver at the OLT to communicate several transceivers at ONUs (1: N transceiver). To substantiate the claim that PON reduces the cost of fibre deployments, research carried out by (Chathurika Ranaweera et al, 2013), demonstrated that PON deployment can save up to 50% of deployment cost associated with small cell backhauling in comparison to a typical Point to point fibre backhaul approach. Figure 2.14 is the result of their work. The equipment cost increases as the split ratio decreases.

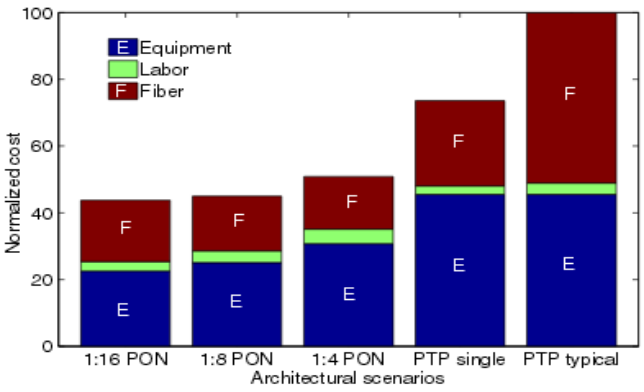


Figure 2.14: Cost –Equipment Analysis, (Chathurika Ranaweera et al, 2013)

Next section of this work gives an in-depth knowledge of passive optical networks, its operation, types and ways of deployments.

2.3.1 PASSIVE OPTICAL NETWORK (PON)

Passive optical network is simply a point-to- multipoint/multipoint-to-point optical network in which information (voice, data, video, etc) is shared optically between one point called the optical line terminal (OLT) and other points called optical network units (ONUs). A typical PON network consists of central node called OLT and a number of ONUs with fibre and

splitters in between them. Optical line terminal is the interface between the PON and the backbone network (core network), likewise ONU is the interface to the end user. In Time Division Multiplexing (TDM) PON, Data/signal is broadcast from OLT to many ONUs in the downstream direction and encryption is used to ensure that information/data meant for a particular ONU is not read by another. In the upstream, data / signal from many ONUs are combined using multiple access protocol like time division multiple access (TDMA) to one OLT. This allows for a two-way traffic on a single optical fibre cable (PON Powerpoint, 2016). The word passive in the PON means that the optical components used in the PON network are non-powered (electrical devices are not used). Figure 2.15 shows a typical PON network; traffic is transported optically between the OLT and several ONUs.

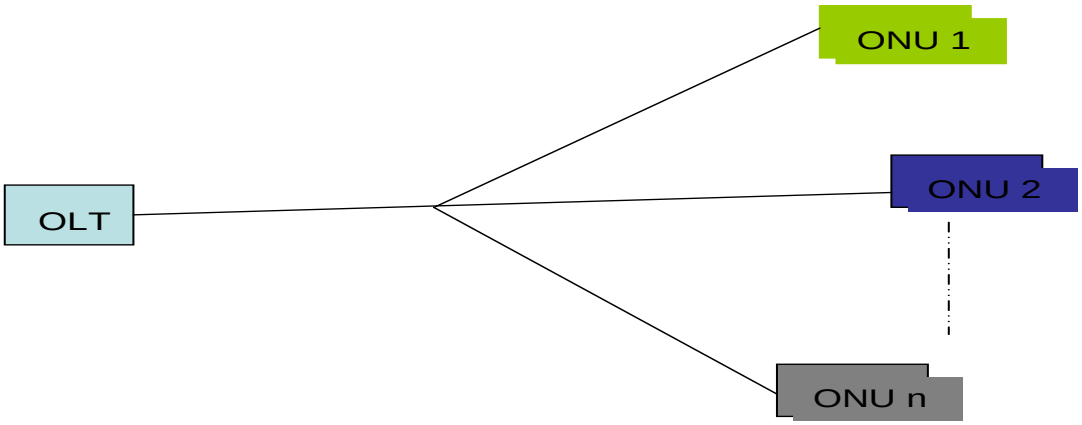


Figure 2.15: Typical PON Network

2.3.2 PON TOPOLOGIES

PON network can be deployed in many different topologies depending on the need an operator intends to meet; some of the topologies may have an extra feature like redundancy in case of failure in the main link. Topologies like Tree, Bus, Ring and Tree with redundant trunk are available in the PON networks. Figure 2.16 shows different topologies that can be used when deploying a PON network.

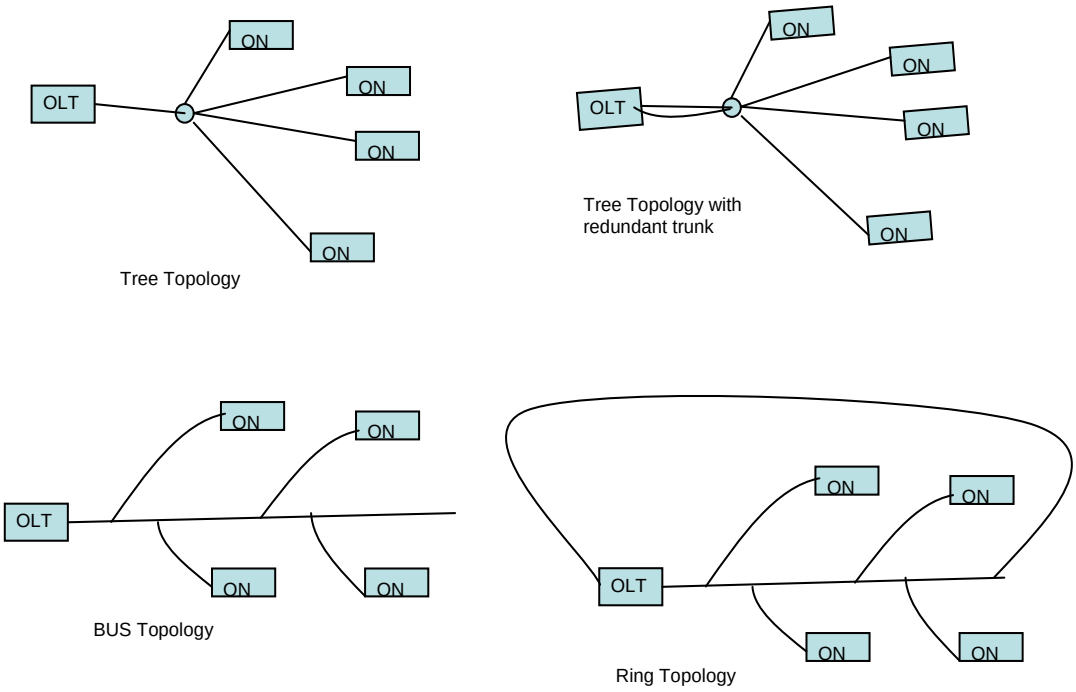


Figure 2.16: PON Topologies

2.3.3 TYPES OF PON

Passive Optical network has been broadly classified into two types based on the type of splitters used; TDM PON and WDM PON.

2.3.4 TIME DIVISION MULTIPLEXING PASSIVE OPTICAL NETWORKS (TDM-PON)

In this arrangement, power splitter is used to separate the signals to different ONUs. The signal/ information from the OLT is sent as a broadcast to different ONUs in the downstream and a label in each signal enables each ONU to identify the signal meant for it. Each ONU reads the address on each frame/cell and only those frames/cells addressed to the ONU are extracted by that particular ONU and the others are left (Peter Ball, 2010). The signals for different ONUs are thus multiplexed into time domain. Figure 2.17 shows a diagram of a TDM-PON

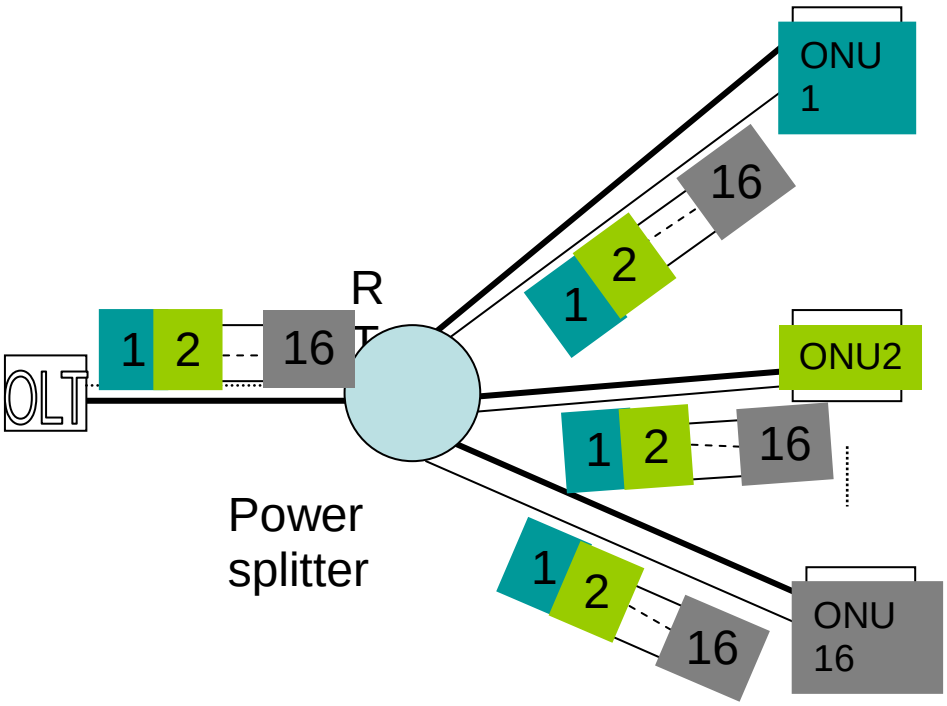


Figure 2.17: TDM-PON

When sending to OLT (upstream), each ONU sends at its allocated time slot. An ONU that is not sending at a particular time slot buffers the data it wish to send then sends it at its allocated time slot.

2.3.4.1 POWER SPLITTING IN TDM-PON

Splitters are passive power dividers that allow communication between the OLT and their respective ONUs. They are Bidirectional in their operation. This means that they are dedicated to multiplexing or demultiplexing optical signals depending on the direction of the signal (Upstream or Downstream). The splitter process is as follows. The downstream signal proceeds from the OLT and divided among multiple output ports, and the upstream signals come from the ONU end of the connection and combined at the entrance of the splitter.

The passive nature of the splitter enables the network to operate without external power in-between the links, thereby reducing cost of deployment, operation and maintenance. They just introduce optical power losses on the communication signal, which are inherent in nature.

The mathematical relationship between the number of outputs (*N*) and the optical power losses (attenuation, α) is:

$$\alpha_{splitter} = 10log\frac{1}{N} \quad (2.\ 2)$$

Different splitting architectures are employed to achieving these objectives. Figures 2.18, 2.19 and 2.20 show the different splitting architectures. Factors like the cost to manage multiple splitters and also the population distribution of users determines the splitting strategy to be used. Figure 2.18 is a simple one-stage splitting strategy whereas Figure 2.19 shows a situation where the splitters are cascaded. Figure 2.20 shows a case where the feeder fibre forms an optical bus and different ONUs are connected at different points on its path using 1:2 optical tap splitters (Cedric Lam, 2007).

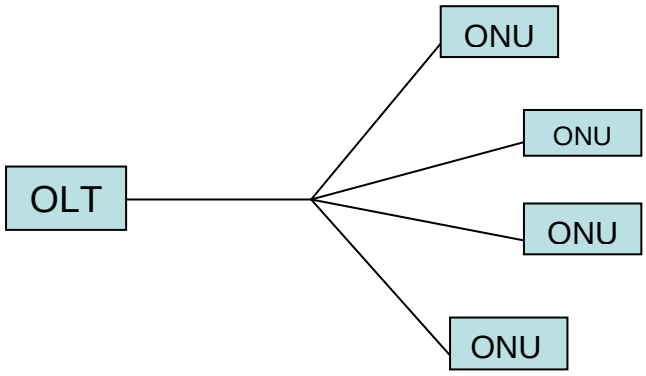


Figure 2.18: A simple one-stage splitting strategy

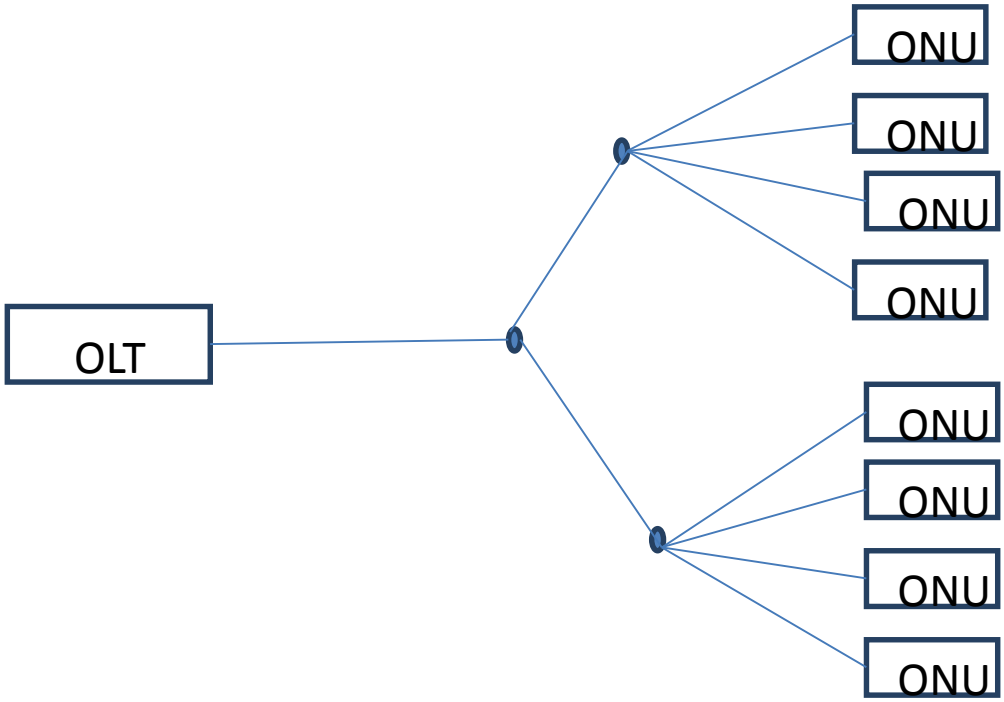


Figure 2.19: Cascaded splitter form

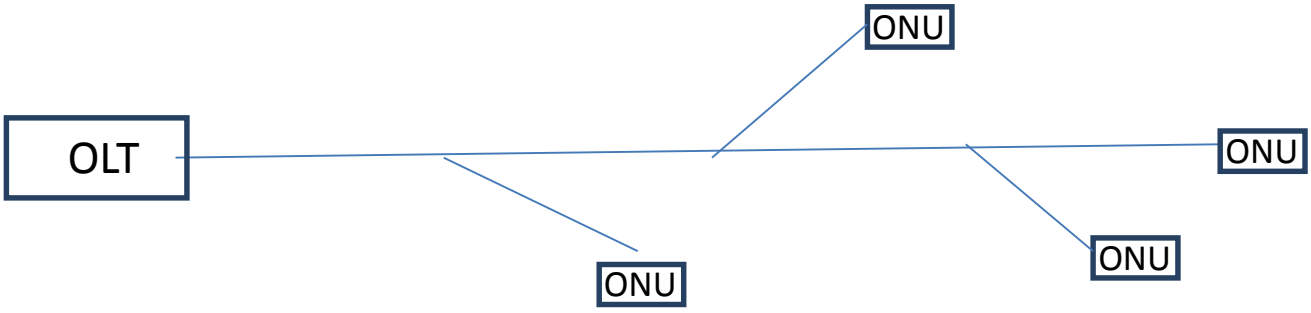


Figure 2.20: Bus method

Single splitter architectures are always easier to manage and it reduces number of connectors to be used and hence reduces splice losses. The bus topology has this problem of the farthest ONU suffering the highest transmission and splitting loss if the splitters have same power splitting ratio.

2.3.4.2 STRUCTURES OF OLT AND ONU IN TDM-PON

In a structure of OLT and ONU of a standard TDM-PON, the MAC (medium access control) layer holds the task of sharing the medium access to different ONUs wishing to send data at different times. This is to avoid the possible contention of access to this shared medium (fibre link) among different ONUs. The MAC layer at the OLT assumes the ‘master’ while that at

the ONU side is the ‘client’; the OLT detects the time a particular ONU should start and stop transmitting data/signal. Figure 2.21 (A and B) show a standard TDM-PON OLT and ONU structures. The physical layer dependent (PMD) in the diagram specify the functionalities of the optical transceiver and wavelength diplexer at OLT and ONU.

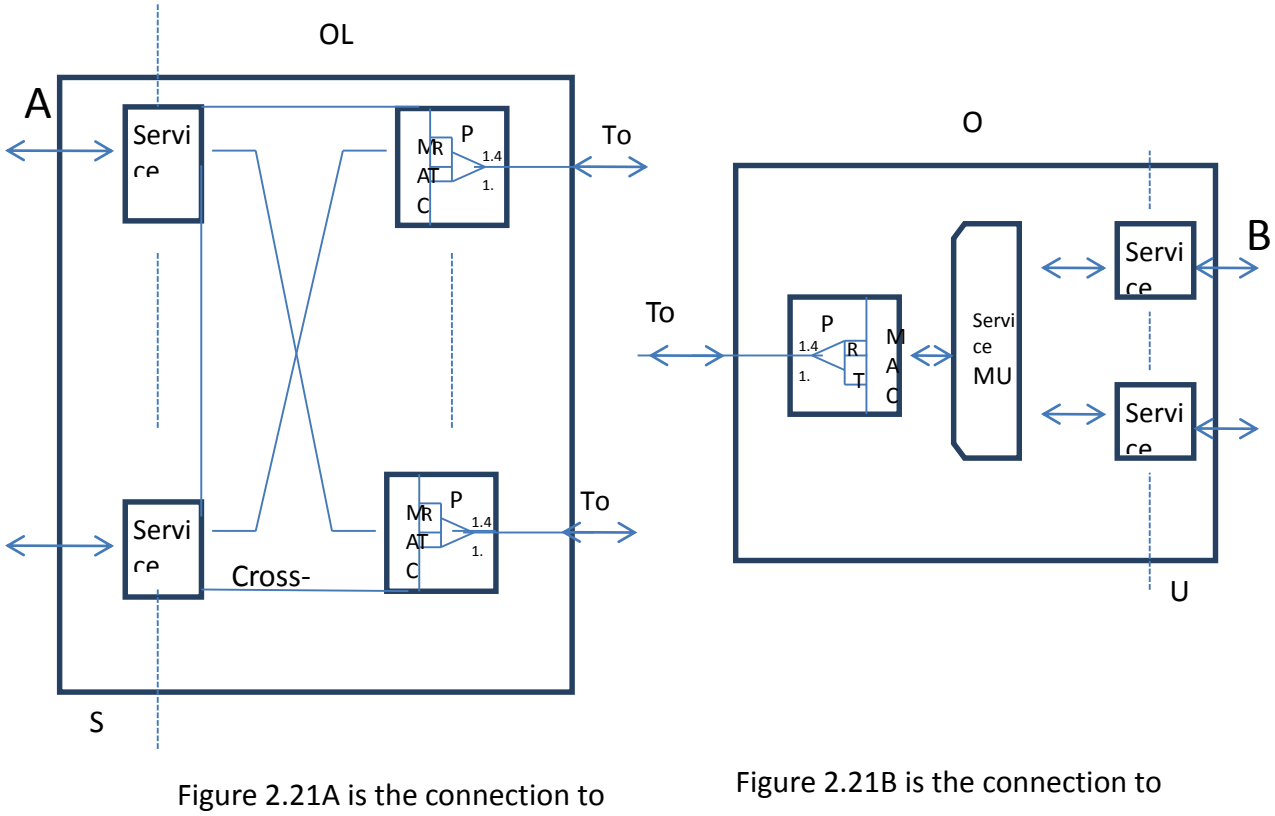


Figure 2.21A is the connection to

Figure 2.21B is the connection to

Figure 2.21: A refers to the OLT structure (Cedric lam, 2007) while B refers to the ONU structure

Multiple MAC and PMD in Figure 2.21A indicate that OLT could accommodate many PON systems. The interconnection between different PON systems, ONUs and the backbone network is called the Service Network Interface (SNI). Signals from the backbone network and PON system needs to be translated to be compactable, hence the service adaptation layer seen in the figure 2.21A brings the translation between the backbone network and PON signals (Cedric Lam, 2007). Figure 2.21B shows the ONU section of the structures, connection is established between the ONU and the OLT through the ONU MAC and PMD. Similar to the OLT section, the service adaption layer provides translation between the signals coming from the client of the network equipment and the PON signal.

2.3.4.3 BURST MODE OPERATION

The distance between each ONU and the OLT is not the same likewise the attenuation between each ONU and OLT. For OLT to have a good detection of signals coming from different ONUs, the burst mode receiver at the OLT must be adjusting its zero-one threshold level as quickly as possible at the beginning of each received time slot (Peter Ball, 2010). For OLT receiver to recover to its initial state before a burst from different ONU, a guard time is reserved.

2.3.4.4 SECURITY IN TDM PON

In PON system, we have both downstream and upstream transmissions, in the downstream, OLT broadcasts to all the ONUs in an interleaved form and each ONU gets the information/data meant for it from the address on the header. However, this OLT broadcast could expose the PON system to risk since the broadcast to all ONU includes their serial number and ID, a malicious ONU may take the advantage of the information for spoofing if there are no security measures like authentication.

2.3.4.5 RANGING IN TDM PON

In the upstream transmission, the OLT has only one receiver to receive signal from different ONUs each with separate transmitter. Since different ONUs are located at different distances from the OLT, signals/data coming from these differently located ONUs experience different propagation delays on getting to the OLT. It became imperative that a timing reference is established to take care of these delays. This will enable the OLT to receive the signals from each ONU at the expected time, thus avoiding possible collision from another ONU that is supposed to transmit at the next time slot irrespective of its distance from the OLT (Cedric Lam, 2007). This process whereby each ONU is allocated a specific delay so that transmission from ONUs to OLT will not experience collision/overlap is called Ranging.

2.3.4.6 BANDWIDTH ALLOCATION

In a PON network with say 32-split splitter, the link between the OLT and the splitter is shared among the 32 ONUs in the network. The technique by which the capacity/ bandwidth of the link is shared among the participating 32 ONUs is called Bandwidth allocation. This bandwidth allocation can be done in two different ways; Fixed or Dynamic bandwidth allocation.

2.3.4.6.1 FIXED BANDWIDTH ALLOCATION

In fixed bandwidth allocation, a deterministic transmission window is assigned to individual ONUs whether or not transmitting. This method is not efficient since bandwidth is consumed even when there is no upstream traffic.

2.3.4.6.2 DYNAMIC BANDWIDTH ALLOCATION (DBA)

This is a method of intelligently allocating the bandwidth to each ONU in a PON system according to the upstream traffic demand and requirements. Unlike the fixed approach, DBA assigns the bandwidth to only ONUs that are transmitting and assigns bandwidth according to demand. This approach gives a better efficiency in a shared link if properly implemented. It is same as TDM statistical multiplexing. It enhances efficient utilization of a shared link.

2.3.5 WAVELENGHT DIVISION MULTIPLEXING PASSIVE OPTICAL NETWORK (WDM-PON)

WDM-PON is seen as the potential technology for the new generation of PON. In extensive work carried out by (Frank Effenberger et al, 2007), it is seen that the capacity of a PON can be increased simply by replacing the optical splitter with a WDM router. Multiple wavelengths in a single fibre can multiply the capacity of the link. These results in each OLT-ONU pairs to have a dedicated or permanent wavelength thereby better the utilization of the fibre bandwidth. It however requires two transmitter/receiver pairs to become a point –to-

point link. WDM-PON uses passive WDM coupler unlike in the case of TDM-PON where passive power splitter is used; this eliminates splitter/combiner losses (Thomas E Stern et al, 2009). OLT send different signals to different ONUs on different wavelength, hence signal for ONU1 is carried on say λ1 and so on. WDM coupler is used to ensure the signal gets to designated ONU, each ONU receives only its own wavelength and this makes the system better in terms of privacy and scalability but a bit more expensive than TDM (Cedric Lam, 2007). Figure 2.22 shows a typical WDM-PON arrangement with 16 ONUs.

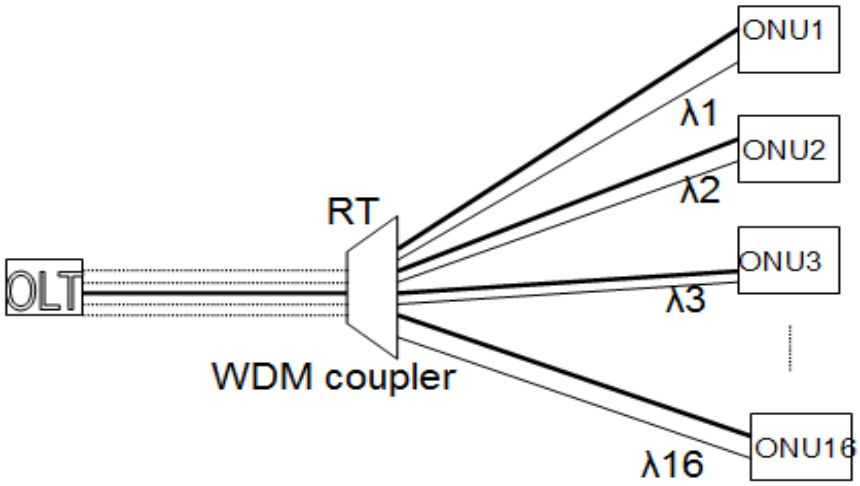


Figure 2.22: WDM-PON

According to (Amitabha Banerjee et al, 2005), several WDM PON architectures were proposed and notable among them are the Composite PON (CPON), Local Access Router Network (LARNET) and Remote Interrogation of Terminal Network (RITENET). CPON solves the scalability problems of traditional PON by employing the concept of Arrayed-waveguide gratings (AWG) on WDM PONs. LARNET tries to resolve the limitations of CPON by employing broad – spectrum source at the ONU. The limitation of LARNET architecture is that the spectrally spliced broad spectrum leads to power loss, hence reducing the distance between OLT and ONU. RITENET helps to reduce end terminal cost at ONU; other advantage of RITENET is that it makes available symmetrical bandwidth in the downstream and upstream directions.

2.4 REVIEW ON ALTERNATIVE WAYS OF PON DEPLOYMENT

PON technology could be deployed using different concepts, below are the available ways and scholarly reviews on deployment of passive optical networks technology based on the transportation scheme and capacity capability.

2.4.1 ATM BASED PASSIVE OPTICAL NETWORKS (ATM-PON/A-PON)

A-PON an acronym for ATM based Passive Optical Networks, is a PON technology that utilises ATM cell for its data/signal transportation. A-PON has its works initially developed by Full Service Access Network (FSAN) working group. Later it was transferred to ITU-TSG15. The ITU-TG.983.1 release specifies some certain functionality like its architecture, range, transceiver characteristics and frame structures of A-PON (Cedric Lam, 2007). A-PON consists of an OLT and ONUs which are connected using optical fibre and optical coupler. In the downstream traffic transmission (OLT to ONU), ONU receives a designated cells from the OLT and the transmission is continuous and based on **Asynchronous Transfer Mode** ATM stream at a bit rate of 155.52Mb/s or 622.08 Mb/s with designated PLOAM (Physical Layer Operation, Administration and Maintenance) cells that are inserted into the data stream. On the side of upstream transmission (ONUs to OLT), traffic is inform of burst mode time division multiple access TDMA. ONUs sends/transmits their data/information based on the time slots allocated to them and these time slots are generated by the OLT (Mitsuhiro Yano et al, 1999). Figure 2.23 shows a schematic diagram of a typical A-PON. It showed clearly that the PLOAM cell conveys the upstream time slot allocation information. The ATM transport scheme can support all multimedia services and a bi-directional transmission is achievable with the aid of WDM. In upstream, a burst mode transmission is employed (Hoyong Kang et al, 2001). It uses a wavelength of 1.31μm, likewise a continuous mode transmission at wavelength of 1.55μm is used in the downstream.

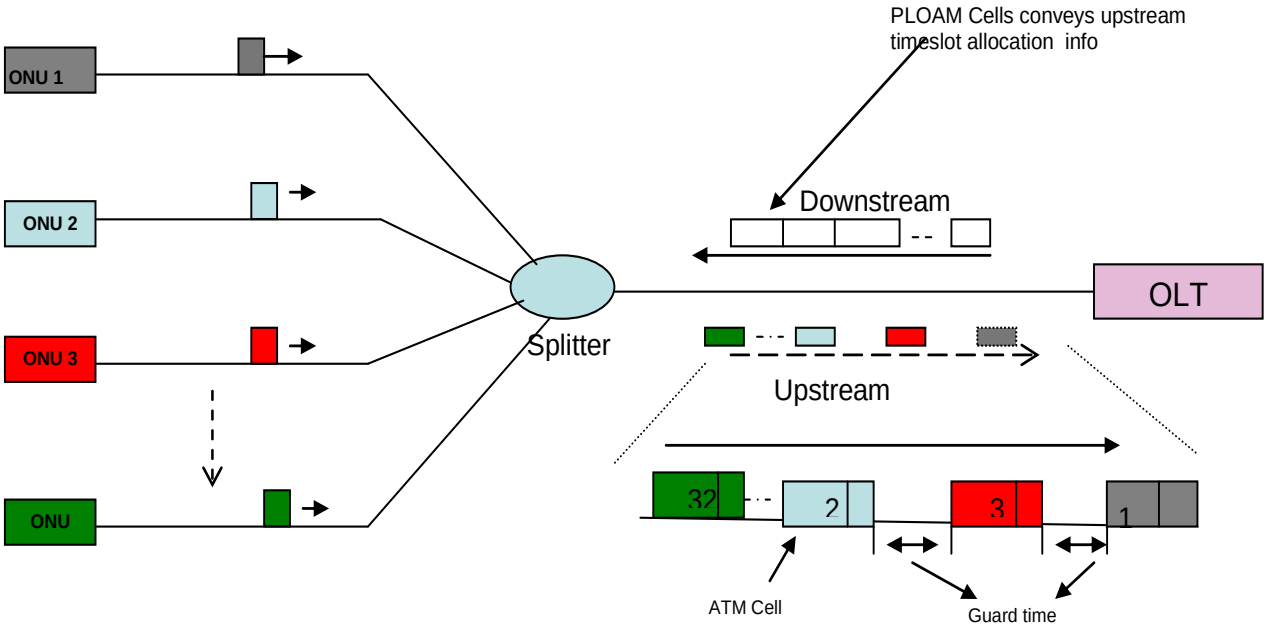


Figure 2.23: Diagram of A-PON (Mitsuhiro Yano et al, 1999)

In (Sami Lallukka et al, 2006), the following upstream and downstream bandwidth were specified for A-PON

155.52 Mbit/s / 155.52 Mbit/s

622.08 Mbit/s / 155.52 Mbit/s

622.08 Mbit/s / 622.08 Mbit/s

1244.16 Mbit/s / 155.52 Mbit/s

1244.16 Mbit/s / 622.08 Mbit/s.

However, ATM- based PON is inefficient for IP traffic (Glen Kramer et al, 2005).

2.4.2 BROADBAND PASSIVE OPTICAL NETWORKS (B-PON)

Broadband Passive Optical Network (B-PON) is another concept of PON defined by ITU-standard (G.983). This concept is used to correct the negative impression that 'ATM-PON support only ATM services'. B-PON is seen to promise the delivery of legacy broadband services and video distribution and is built on the strength of ATM. Like ATM-PON, B-PON

Adopts ATM cells for its transportation and employs the TDM techniques in the downstream and TDMA at the upstream transmission directions. A major limitation is the reach as ITU-T specifies 20km as the maximum distance between the OLT and ONU and also 20km for the distance separating the ONU closest to OLT and that farthest from OLT (Sami Lallukka et al, 2006).

2.4.3 ETHERNET PASSIVE OPTICAL NETWORKS (E-PON)

The concept of Ethernet Passive Optical Network came into being by IEEE 802.3ah in the taskforce called Ethernet in the First Mile (EFM) (Sami Lallukka et al, 2006). For E-PON, Ethernet frame carries all data in encapsulated form and each ONU gets the frame meant for it. The transport protocol in E-PON is based on Ethernet frame and figure 2.24 shows Ethernet frame structure.

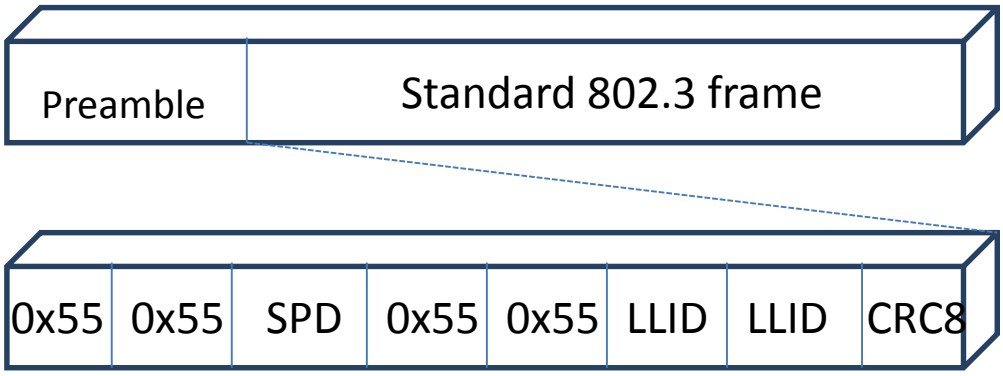


Figure 2.24: E-PON frame structure (Glen Kramer et al, 2002).

In (Sami Lallukka et al, 2006), the speed of E-PON is described as symmetrical and 1Gbit/s with 8B10B block coding and has an operating wavelength of 1490nm downstream and 1310nm upstream for a single fibre and reserving 1550nm wavelength for any expected extensions. A minimum splitting ratio of 1:16 was specified by IEEE 802.3ah. The E-PON supports two different reaches between the OLT and ONU (10km and 20 km). The downstream transmission employs TDM technique while the upstream utilizes TDMA

technique. In the downstream transmission, the Ethernet frame is transmitted by OLT and it goes to 1: N splitter which splits it according to N (N denotes the number of ONU in the network), and the splitting ratio is between 4 and 64. Each ONU extracts the frame meant for it using the destination MAC address and discards the rest. Figure 2.25 shows the downstream traffic in E PON. From the diagram, OLT broadcasts many Ethernet frames, on getting to the optical splitter, it sends the same frames to different ONUs and each ONU uses the destination MAC address on the frame to pick the particular frame meant for it.

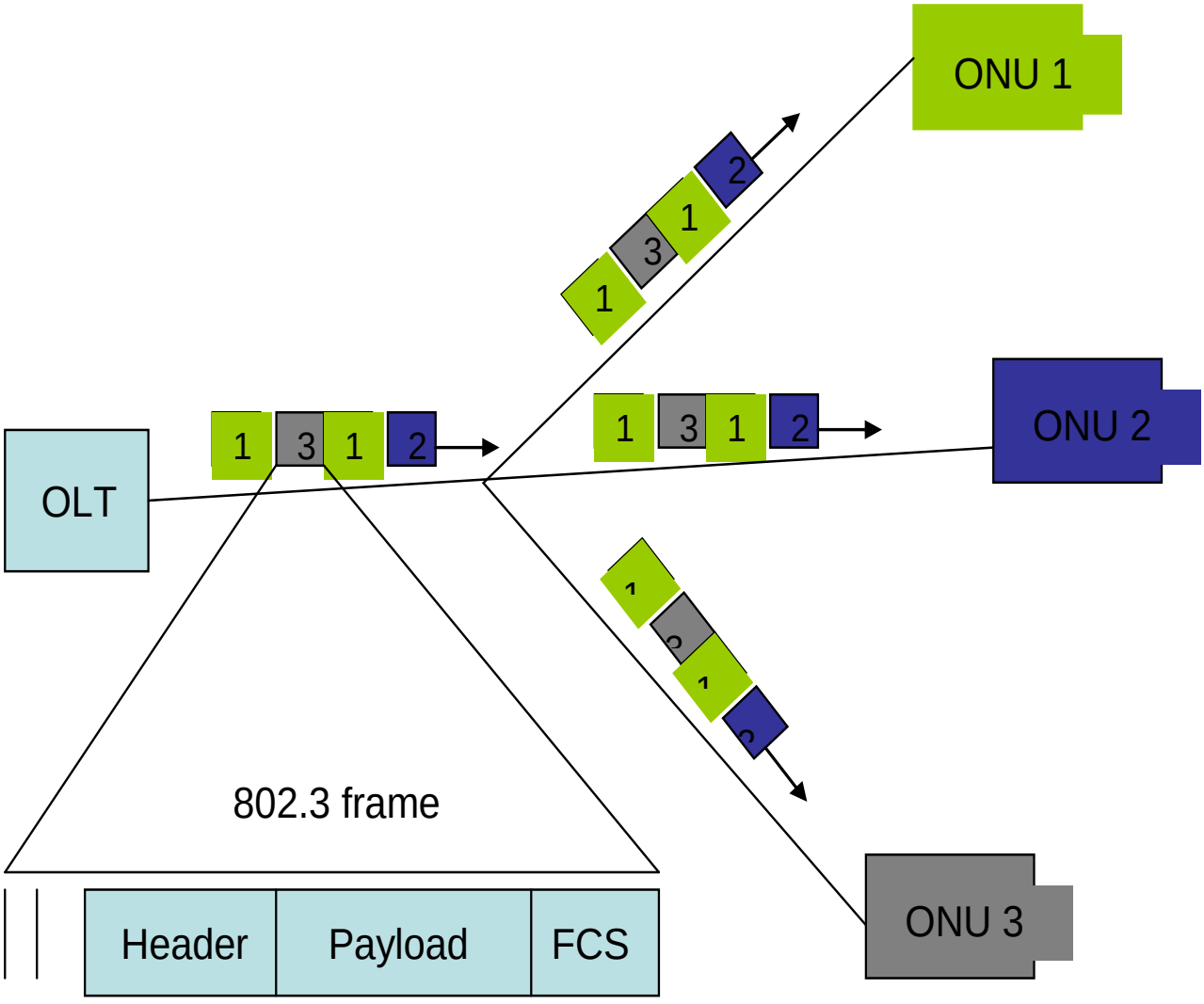


Figure 2.25: Downstream traffic in E-PON

In the upstream, transmission is between different ONUs to OLT simultaneously and sometimes frames from different ONUs may collide. This has resulted in ONUs sharing the link in either time domain (slots) or using WDM. Ethernet networks can support voice, data,

and video and even prioritization and virtual LAN (VLAN) tagging because of its ability to support QoS techniques (Glen Kramer et al, 2002). In PON, multiple users share single fibre and if any failure occurs in feeder, splitter or OLT, entire user suffers connection problems. To solve this problem, (Takashi Nishifani et al, 2015) in their work demonstrated video streaming with N:1 protection of 10G EPON system. Their result showed that uninterrupted service is achievable even during system maintenance using hitless N:1 PON protection scheme. Its interoperability and cost effectiveness is yet another advantage Ethernet networks is using to get more market among other technologies. Despite known for limited reach and split ratios, an improvement was demonstrated by (Takuya Tsutsumi et al, 2015) when 41.3km reach and 128 split 10G EPON system was designed and implemented for commercial broadband access network infrastructure and error free transmission over 130 hours was recorded. Their result proved that N:1 OSU protection with automatic level control semiconductor optical amplifier is a promising approach to practical 10G EPON system that are not only cost effective but also reliable. The major limitation of EPON at the moment is capacity as regards 4G LTE as many researchers in this field are working very hard on the standardization of 100G EPON as shown in the work of (Vincent Houtsma et al, 2017).

2.4.4 GIGABIT- CAPABLE PASSIVE OPTICAL NETWORKS (G-PON)

G-PON is yet another concept of PON developed by ITU-T series G.984 with the intensions of providing high bandwidth requirements for business and residential services. G-PON can utilize either the technology behind Ethernet or ATM in its services, thus, ATM traffics as well as both circuit and packet switched data are being transported by GEM in G-PON frame (Cedric Lam, 2007). In (Frank Effenberger et al, 2007) it specifies that G-PON architecture supports a two WDM wavelength schemes for both the downstream and upstream and a reservation of 1550nm wavelength for extension services like analog video services.

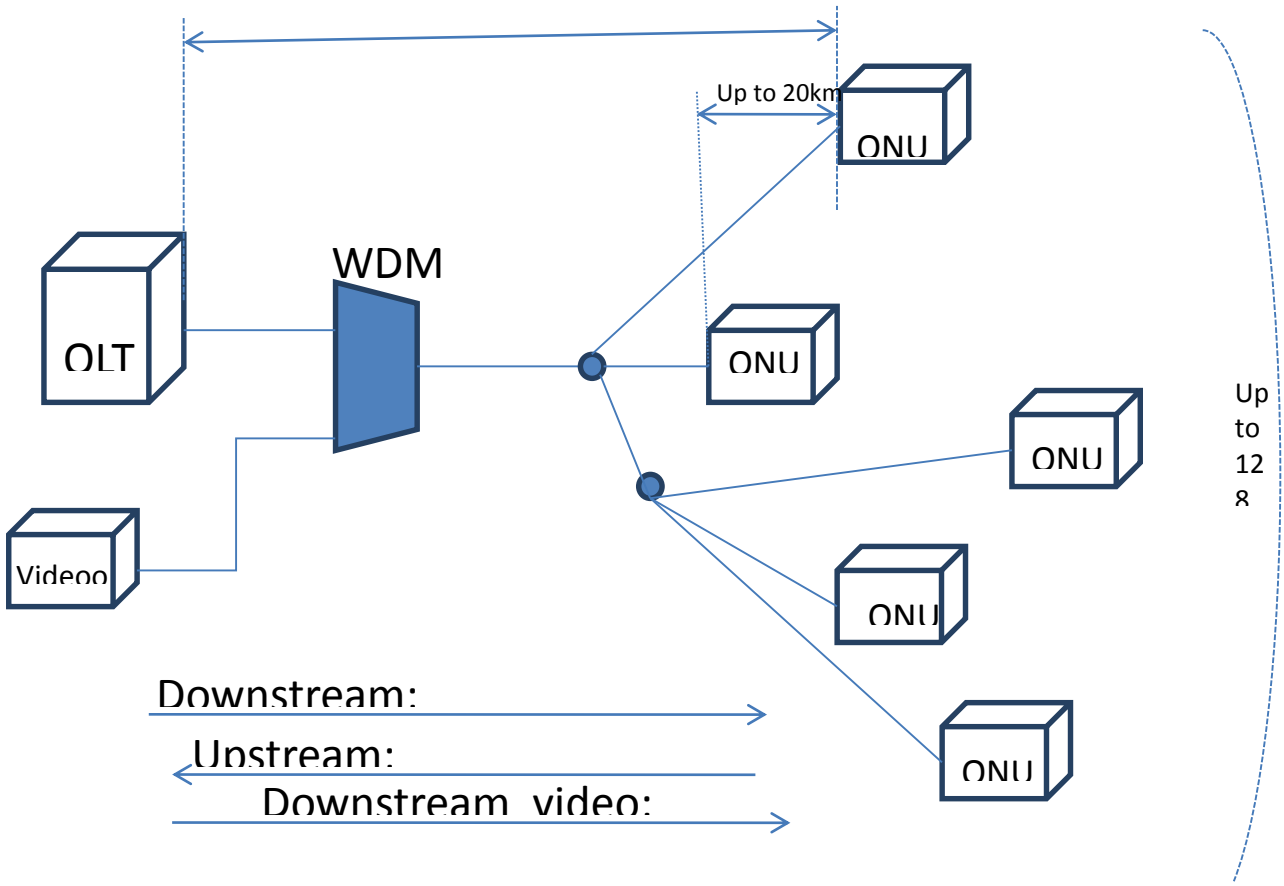


Figure 2.26: Typical G-PON physical architecture

Figure 2.26 specifies the maximum reach of G-PON and also, the reach between two closest and farthest ONUs to the OLT. The diagram also shows the number of splits that can be obtained from G-PON. The G-PON standards specify the following bit rate for downstream and upstream in G-PON (Sami Lallukka et al, 2006).

1244.16 Mbit/s / 155.52 Mbit/s

1244.16 Mbit/s / 622.08 Mbit/s

1244.16 Mbit/s / 1244.16 Mbit/s

2488.32 Mbit/s / 155.52 Mbit/s

2488.32 Mbit/s / 622.08 Mbit/s

2488.32 Mbit/s / 1244.16 Mbit/s

2488.32 Mbit/s / 2488.32 Mbit/s.

The ITU-TG 984.2 standards specify a physical medium dependant layer (PMD) parameters as shown in figure 2.27. The reference points shown in the diagram are as specified by standards

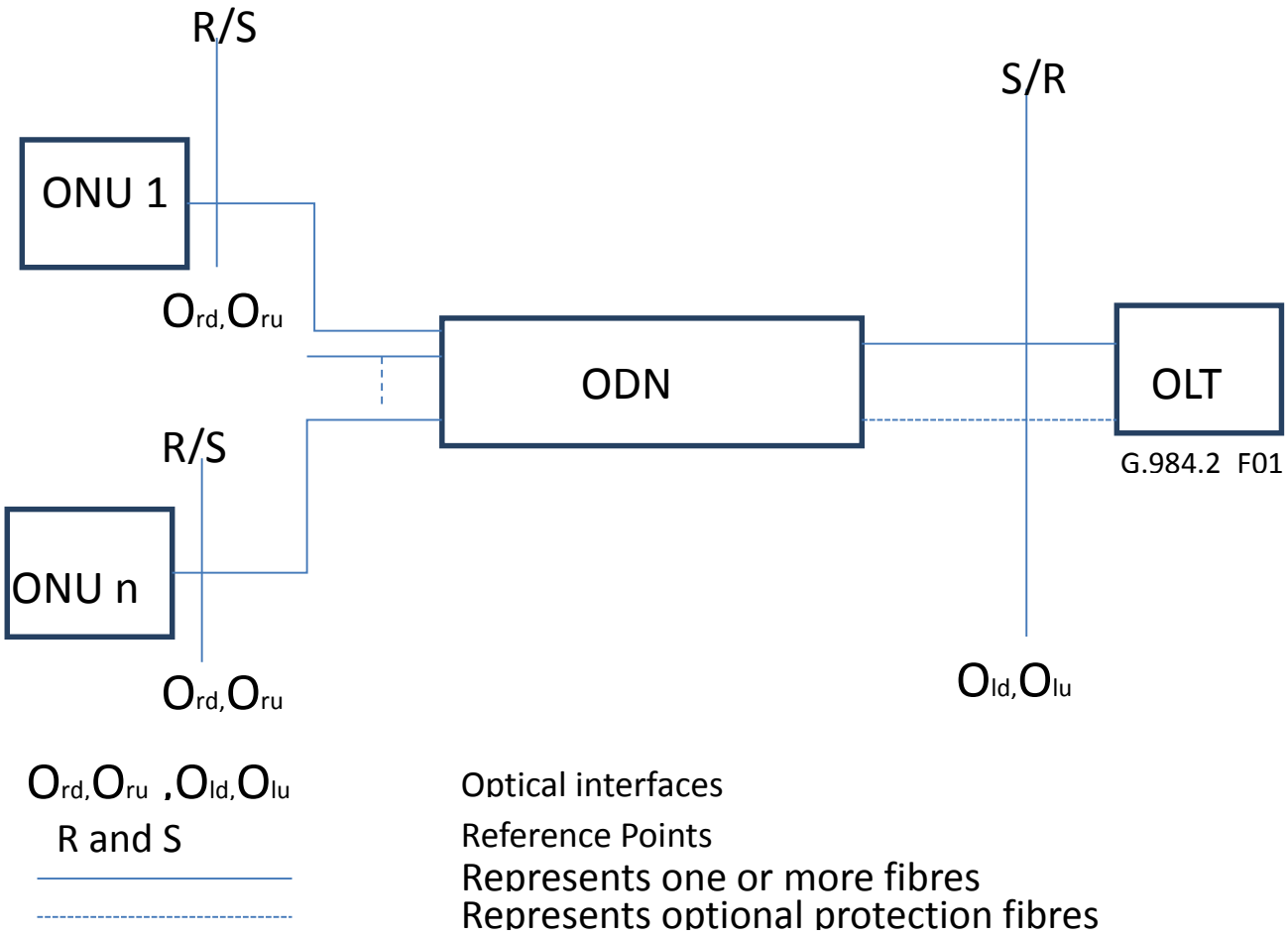


Figure 2.27: Generic physical configuration off optical distribution network

To accommodate the loss budget requirements, G-PON was divided into three classes, class A (5-20dB), class B (10-25dB) and class C (15-30dB) according to their attenuation range. G.984.2 standards specify physical reach of 20km and a split ratio of 1:32 for G-PON.

The table 2.2 shows a summary of the characteristics of various PON concepts described above. In the table 2.2, A-PON and B-PON are considered as same concept as B-PON.

Table 2.2: Summary of characteristics of various PON concepts (Sami Lallukka et al, 2006).

	BPON	EPON	GPON
Bit rates Upstream (max) Downstream (max)	 622 Mbit/s 1244 Mbit/s	 1000 Mbit/s 1000 Mbit/s	 2488 Mbit/s 2488 Mbit/s
Logical split ratio	1:64	1:32768	1:253
Max physical distance OLT-ONU	 10 km / 20 km	 10 km / 20 km	 10 km / 20 km
Max logical distance OLT-ONU ONU-ONU	 N/A 20 km	 Not limited N/A	 60 km 20 km
Max link utilisation[1)] Upstream Downstream	 85,71 % 87,33 %	 98,00 % 98,27 %	 97,44 % 98,53 %
Line coding	Scrambled NRZ	8B10B	Scrambled NRZ
Data priority classes	4	8	5
Security	Churning, AES	Encryption (fs)	AES
ONU TX power adjustment	Yes	N/A	Yes
Protection	APS	N/A	APS
FEC	NO	G.975	G.975

A major limitation of GPON is that it permits only 2.5Gb/s speed for both the upstream and downstream transmission, secondly, its reach is restricted to 60km (OLT to ONU) and 20km max for ONU to ONU (Theodoros, 2015)

2.4.5 SUPER PON

This concept of PONs was proposed to overcome the drawback of reach and split ratio in other PONs described earlier. This proposed idea has some challenges as explained in (Cedric Lam, 2007). Solving those problems may eventually outweigh the benefits of long reach and higher split ratio it may bring because it will involve some advance technologies.

2.4.6 HYBRID PON

Hybrid PON is another Passive Optical Network concept developed with the view of increasing capacity. In this type of PON, there is a combination of WDM and splitter. The WDM carries different wavelengths to a point while the splitter shares those wavelengths in

time domain. The essence is to increase the reach and capacity of GPON. With this method, the reach can get to 40km with 128 way splits.

2.4.7 NEXT GENERATION PON (NG PON)

The standard for NG PON was developed by ITU and detailed an architecture capable of carrying 40 Gbit/s. Good attributes of this PON technology is that it can be compatible with the existing PON networks just by replacing OLT. The architecture is usually time and wave length division multiplexing (TWDM) in both upstream and in downstream directions. This technology can provide up to 10Gbit/s at subscriber premises. The new version is called NG PON2 which has improved reach.

2.5 PON PROTECTION SCHEME

Good backhaul designs have protection mechanisms that provide reliable services. Sequel to large transport capacity this proposed backhaul design intends to carry; failures will cause huge losses of data/information and will affect large number of users. On the part of the operator, huge fortune will be lost during the downtime. To enhance reliability and survivability of this design, one of the protection options as specified by ITU-TG.983.1 in (Cedric Lam, 2007) must be adopted. The specified standard is basically duplicating the fibre links and/ or the components for protection. There are five basic elements that can be protected within the PON network. They are;

i**,** OLT equipment

ii**,** Fibre F1 (from the OLT to the splitter)

iii, Passive Optical splitter/ WDM coupler

iv**,** Fibre F2 (from the splitter to ONU)

v**,** ONU equipment

The choice of which to protect is influenced by many factors like service level agreement, cost implications, competition among the operators, etc. However, there are four protection architectures suggested by ITU-TG983.1 when a tree topology (points to multipoint) is adopted. Figures 2.28 -2.31 show the different protection architectures with different levels of protection.

In Figure 2.28 only the fibre from OLT to splitter is protected. If there is any fibre cut on the active line, the transmission will automatically be switched to the protection line (fibre). In this protection architecture, failures from other components like OLT, splitter, fibre length F2, and the ONU will result in downtime. In a paper presented by (Abhishek Dixit et al, 2016), this class of protection is graded 1/5 representing 20% protection.

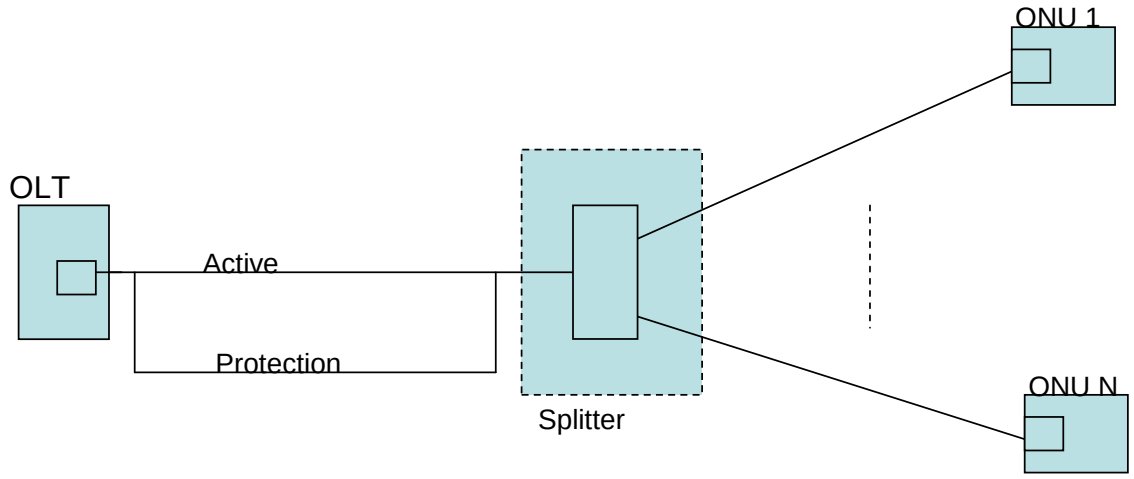


Figure 2.28: Fibre (F1) from OLT to Splitter Protected

Figure 2.29 has two optical transceivers and with duplication of F1 (fibre from OLT to splitter), this represent 40% protection according to (Abhishek Dixit et al, 2016), Failures from either OLT or F1 will not cause downtime to the network, unless in a rear case where the two go down at same time.

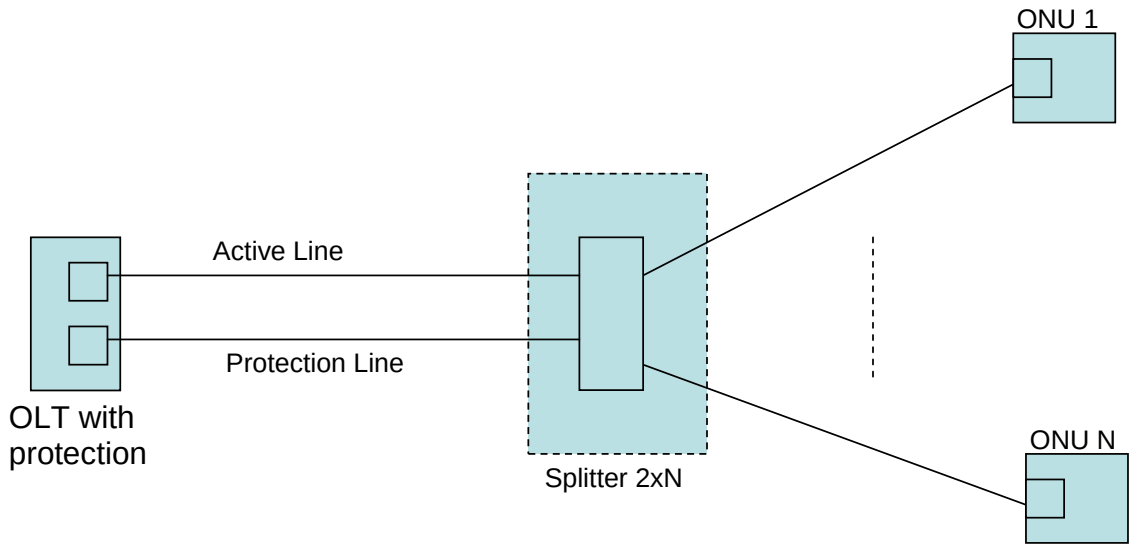


Figure 2.29: OLT, F1 Splitter port Protected

Figure 2.30 shows architecture with protections on OLT, F1, some ONUs transceiver, some F2 and optical splitter, representing about 80% protection. This type of protection will no doubt give better and more reliable network than those in figures 2.28 and 2.29 but will definitely be more expensive as most components are duplicated.

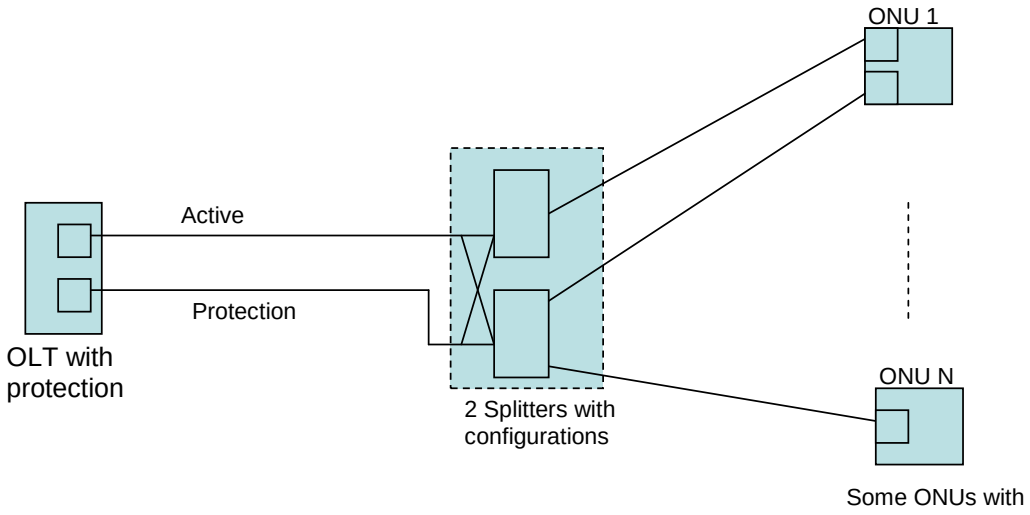


Figure 2.30- OLT, F1 Splitter, some F2, some ONU Protected

In Figure 2.31, the optical transceivers at both OLT and ONU are doubled, F1 and F2 and the splitter are also doubled. The total network is protected representing 100% protection. Failures at any segment of the network will not cause downtime unless if there is natural disaster, causing more than one component to collapse at the same time. This type of

protection would have been ideal for all networks, but considering the cost implications, not too many operators will afford to build it. In the events were the operators put up such formidable protection, the services may go high thereby defeating the initial aims of PON (Cost effectiveness).

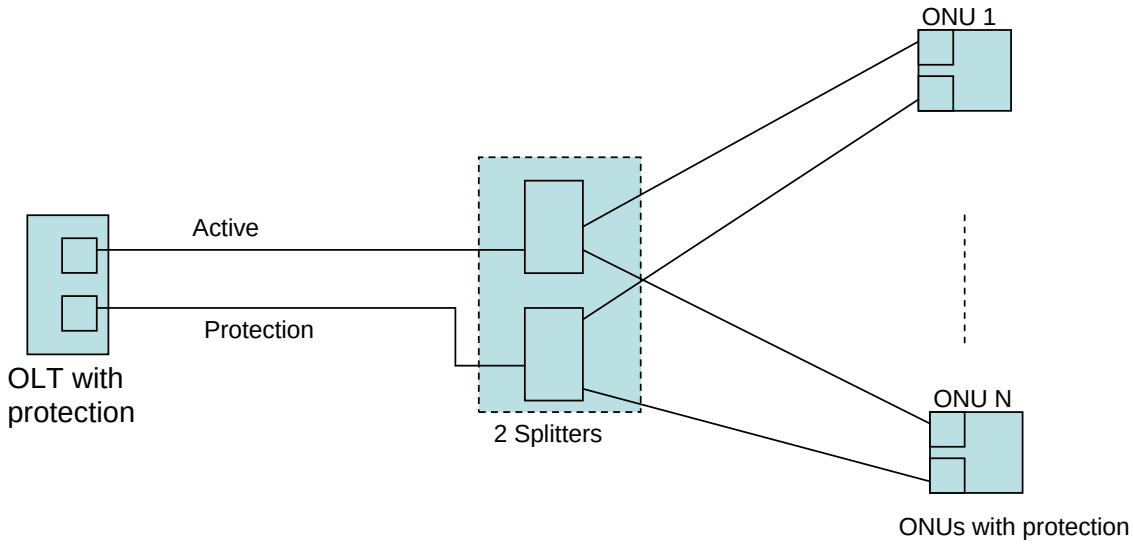


Figure 2.31: All System Protection

In this design, after many considerations such as cost, complexity and reliability of the network, the work has chosen to employ the protection offered in figure 2.29. To capture the market in any business, the operators must consider the cost of rendering the service to its customers. Protection architecture in figure 2.29 will help to bring down the cost of services and at same time provide quality and reliable services needed as optical network equipment like splitters are passive and may not easily develop faults. Coming to the side of ONUs, since Mobile networks like LTE have handover facilities, it may take care of some faults beyond the splitter, as mobiles within the affected eNB will switch over to close by eNBs to continue their conversation.

2.6 SUMMARY OF REVIEWED WORKS

In search of backhaul link that supports quality of service (QoS), unlimited capacity, unlimited range, high reliability and as well cost effective, a good number of researchers have done tremendous works on improving backhaul networks especially for 4G LTE networks.

(i) Many researchers pointed out that microwave transmission links encourage speed of rollout especially in green field areas, however noted that limited capacity, poor weather effects, limited range as well as scarce spectrum were its biggest drawbacks as a quality backhaul for 4G LTE networks

(ii) Researchers also discovered that not only microwave links that are affected by poor weather, limited range and poor capacity, it was noted however from their numerous researches that all radio wave links and all “line of sight” links like WiMAX, mm-wave, Satellite, etc used as backhaul were also having technical some limitations like limited capacity, low range, etc .

(iii) In furtherance, researchers revealed that in all wired backhaul, only fibre optics has all technical attributes like unlimited capacity, unlimited range, reliability, scalability required for a good backhaul system. Regrettably, point to point fibre optics deployments tend to be a bit expensive and hence, slow speed of rollout.

(iv) Researchers also revealed that Passive Optical Networks PON, which is fibre Optics, reduces the cost of fibre deployments by a reasonable percentage, above 70% depending on the split ratio chosen when used in access network.

2.7 RESEARCH GAPS ON REVIEWED RELATED WORKS

The review of related literatures suggest that a great number of research have been carried out in the area of backhaul technology bearing in mind that the importance of backhaul can never be over emphasized in telecommunication networks. However, from numerous related works reviewed, the following gaps were observed:

(i) There is no reported empirical method of determining optimal splitter location for PON deployment in other to achieve efficient and cost effective backhaul deployment.

(ii) Collision avoidance on the upstream transmission was not considered in most reviewed works.

(iii) Pulse spreading effects on PON networks were not determined other reviewed works.

CHAPTER THREE

SYSTEM DESIGN AND METHODS

3.1 METHODOLOGY

In this design of Passive Optical Networks as a cellular Backhaul using SMILE 4G mobile Networks as a case study; many factors were put into considerations towards actualizing the work. The work provided relevant information as regards optimizing the splitter location for PON backhaul, using SMILE mobile communication network provider as a case study for the analysis. The analysis used Port Harcourt as a geographical case study. Analytical data for SMILE 4G mobile network in Port Harcourt is generated from network monitor applications (Net monitor). The methods are as follows:

i, Understudy Port Harcourt terrain, identify SMILE network eNBs and their coordinates in Port Harcourt..

ii, Computation of Optimal splitter location using 'manual' and 'automatic/systematic' approaches

iii, Dispersion determination for both downstream and upstream transmissions with respect to network capacity and further determine the ranging delays for upstream transmissions

iv, Power budget calculations for both downstream and upstream transmission scenarios.

v, Implementation of the designed network for both Downstream and upstream transmission in Optisystem simulation environment.

3.2 LOCATION OF STUDY

The location for this study is Port Harcourt. Port Harcourt is the capital and the largest city of Rivers state in southern Nigeria. It is located along the Bonny River, 41 miles (66 km) upstream from the Gulf of Guinea. Due to oil discovery and subsequent oil explorations and its related businesses, Port Harcourt has witnessed massive inhabitants. Major oil and gas

companies have their bases in Port Harcourt and that has triggered huge commercial activities in the city. According to (Wikipedia, n.d), Port Harcourt is estimated to accommodate 1,865,000 inhabitants. Figure 3.1 shows the satellite view of Port Harcourt along the Bonny River in the upstream of Gulf of Guinea.

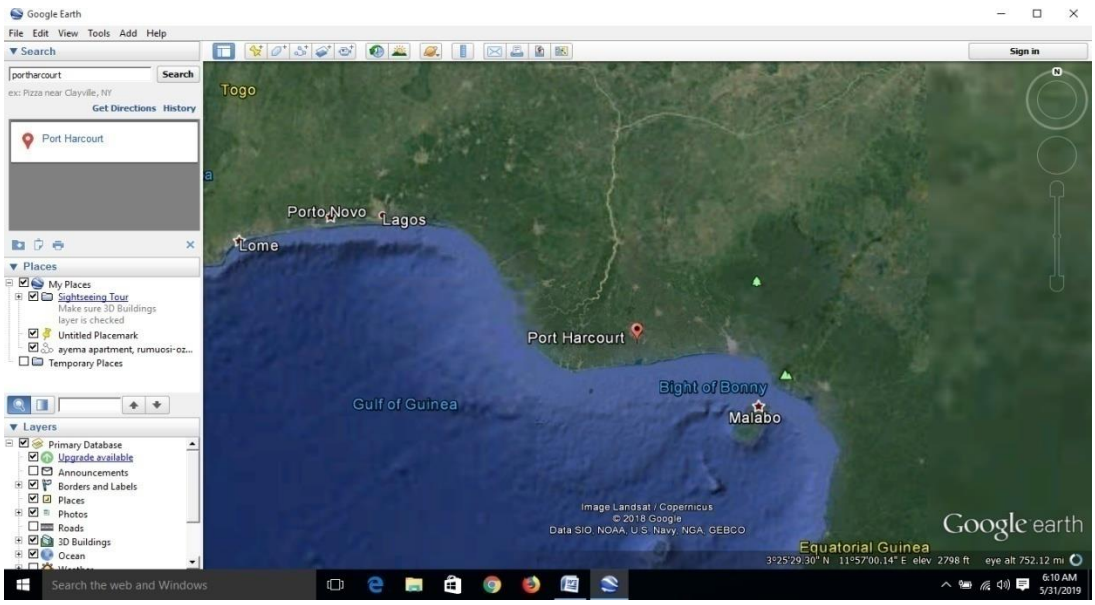


Figure 3.1: Satellite view of Port Harcourt

Population of Port Harcourt can be categorized into 3 sub division: Viz are

(i) Densely populated areas: - The areas under this category have a lot of businesses like schools, hotels, residential, commercials buildings, churches, mosques, multinational companies etc with a lot of people. Areas under this category are D line, GRA phase 1-5, Aba Road, Woji, etc. These areas have businesses like Port Harcourt Pleasure park, Shell residential area, Meridiane Hospital, Agip to mention but a few. Because of it its population, many eNBs are situated in these areas.

(ii) Medium population areas:- The areas under this category also have multiple businesses like banks, schools, churches, multinational companies. Businesses like Rumuokoro market, Choba market, Uniport, etc

(iii)Low population areas:- The area under this category have few businesses. Places like Emeoha, Ndele, and Elele communities fall into this category.

Due to Port Harcourt's dense population, and urbanised setting, Port Harcourt is a major base for many mobile telecommunication network operators in Nigeria constituting quite a huge mobile traffic. However, this research is majorly based on the SMILE 4G network providing company.

The method employed in identifying SMILE eNBs in Portharcourt is as follows:

(i) Data generation for latitude and longitude coordinates for 60eNB stations using network monitor application.
(ii) Data analysis and conversion of coordinates to radian, Great circle and walking distances from one another.

3.2.1 DATA GENERATION

Data assembly will always pose threats, especially in present day Nigeria. Obtaining data for precise coordinates of all base stations (eNB) required is always faced with the challenge of insecurity. However, in the bid to generate accurate data for this analysis, network monitor facility was employed. The network facility provides Cell identification numbers required to correctly obtain the coordinates for base transceiver stations for every network operator in Port Harcourt.

To correctly obtain the coordinates for SMILE base stations, the following tools were useful for the data sourcing.

3.2.2 NET MONITOR TOOL

The Net Monitor tool is a specialized online analytical tool available on apple, windows and android operating systems. The tool grants secondary access to technical parameters of the mobile network. However, this is based on the network card (SIM CARD) available on the mobile device.

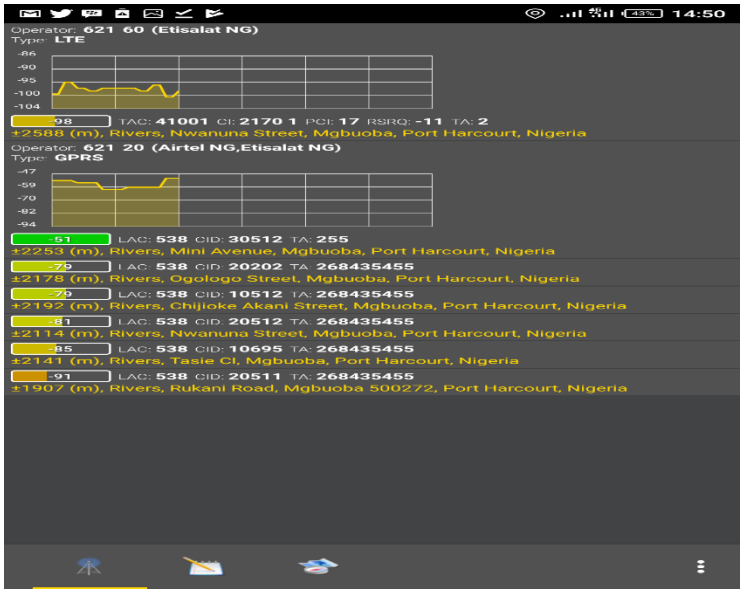


Figure 3.2: a Net Monitor app

3.2.3 CELL FINDER ANALYTICAL TOOL

Cell-finder is a simple analytical tool used in obtaining the location of any base station by employing certain parameters like MCC, MNC, LAC, Cell-id (CID). The cell-finder is an online working environment and can directly provide a Google translation coordinate and even satellite images of the surrounding environment where the base station is situated.

However, to use the cell-finder application successfully would be impossible without the following details:

(i) Mobile Country Code (MCC).

(ii) Mobile Network Code (MNC).

(iii)Location Area Code (LAC).

(iv)CELL-ID.

3.2.3.1 MOBILE COUNTRY CODE

The Mobile Country Code (MCC) is used to identify the particular country where the network provider telecommunication company is situated.

3.2.3.2 MOBILE NETWORK CODE

The Mobile Network Code (MNC) identifies the mobile operator. MNC Values for various mobile operators in West Africa and beyond are also highlighted in the data tables provided.

3.2.3.3 LOCATION AREA CODE

The location area code is a unique number of current location area. A location area in this respect is not defined geographically, instead, a set of eNBs that are grouped together to optimize signaling and are bounded together by one code number can be referred to as a location area.

3.2.3.4 CELL-ID NUMBER

The cell-ID numbers are generally used to identify each eNB or a sector of eNB within a location area code. These parameters are all highlighted in data tables presented below:

Table 3.1: List of MCC and MNC codes for Nigeria

BRAND	**OPERATOR**	**MCC**	MNC
AIRTEL	Bharti Airtel Ltd.	621	20
SPECTRANET	SPECTRANET	621	24
VISAFONE	VISAFONE COMM T LTD	621	25
SMILE	SMILE COM. NIG.	621	27
MTN	MTN NG	621	30
GLO	GLOBACOM LTD	621	50
9ja Mobile	EMERGING MARKETS	621	60

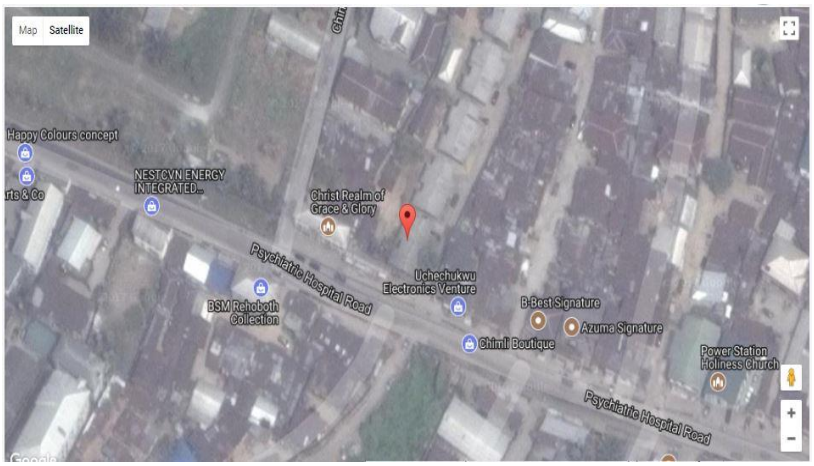


Figure 3.3: Satellite image indicating an eNb from the cell finder analytical tool.

Table 3.2: eNB coordinates in Portharcourt as obtained using Site finder tool

S/N	LAT 1(degree)	LONG 1(degree)	LAT (radian)	LONG1(radian)
eNB 1	4.83656	7.02861	0.084414	0.12267
eNB 2	4.77368	7.01428	0.083316	0.12242
eNB 3	4.799948	6.993902	0.083775	0.12207
eNB 4	4.829351	7.091902	0.084288	0.12378
eNB 5	4.770555	7.022393	0.083262	0.12256
eNB 6	4.874584	6.983038	0.085078	0.12188
eNB 7	4.869227	7.11365	0.084984	0.12416
eNB 8	4.71955	7.15183	0.082372	0.12482
eNB 9	4.855379	7.064134	0.084742	0.12329
eNB 10	4.790941	7.120734	0.083618	0.12428
eNB 11	4.785376	7.008187	0.083521	0.12232
eNB 12	4.832672	7.06854	0.084346	0.12337
eNB 13	4.803861	6.988323	0.083843	0.12197
eNB 14	4.81974	7.06564	0.08412	0.12332
eNB 15	4.743986	7.041728	0.082798	0.1229
eNB 16	4.79387	7.030763	0.083669	0.12271
eNB 17	4.748951	7.098856	0.082885	0.1239
eNB 18	4.777272	7.062001	0.083379	0.12326
eNB 19	4.834117	6.984506	0.084371	0.1219
eNB 20	4.856524	7.040508	0.084762	0.12288
eNB 21	4.806404	7.042423	0.083888	0.12291
eNB 22	4.814565	6.978764	0.08403	0.1218
eNB 23	4.829766	6.958811	0.084295	0.12145
eNB 24	4.892311	6.914281	0.085387	0.12068
eNB 25	4.847984	7.049188	0.084613	0.12303
eNB 26	4.851431	6.983489	0.084673	0.12188
eNB 27	4.808117	6.996657	0.083917	0.12211
eNB 28	4.90283	6.99907	0.085571	0.12216
eNB 29	4.978889	6.961111	0.086898	0.12149
eNB 30	4.62843	7.2701	0.080781	0.12689
eNB 31	4.996944	6.95	0.087213	0.1213
eNB 32	4.953889	7.011111	0.086462	0.12237
eNB 33	4.966944	6.986944	0.08669	0.12195
eNB 34	4.828889	7.021944	0.08428	0.12256
eNB 35	4.81687	7.01119	0.08407	0.12237
eNB 36	4.931694	7.002138	0.086074	0.12221
eNB 37	4.8407	6.96812	0.084486	0.12162
eNB 38	4.8597833	6.9791583	0.084819	0.12181
eNB 39	4.8469444	7.0369444	0.084595	0.12282

eNB 40	4.85847	6.96575	0.084796	0.12158
eNB 41	4.88	7.01	0.085172	0.12235
eNB 42	4.866944	7.03	0.084944	0.1227
eNB 43	4.837774	7.037036	0.084435	0.12282
eNB 44	4.884205	7.137983	0.085245	0.12458
eNB 45	4.781493	7.039845	0.083453	0.12287
eNB 46	4.811602	6.956136	0.083978	0.12141
eNB 47	4.90111	6.92694	0.085541	0.1209
eNB 48	4.90582	6.90656	0.085623	0.12054
eNB 49	4.802444	6.944	0.083818	0.1212
eNB 50	4.8354	7.05281	0.084394	0.12309
eNB 51	4.794722	7.049722	0.083684	0.12304
eNB 52	4.758056	7.011944	0.083044	0.12238
eNB 53	4.8269444	6.9961111	0.084246	0.12211
eNB 54	4.815	7.0419444	0.084038	0.12291
eNB 55	4.71	7.165	0.082205	0.12505
eNB 56	4.8233007	7.0571862	0.084182	0.12317
eNB 57	4.81532	7.06522	0.084043	0.12331
eNB 58	4.89497	7.0153	0.085433	0.12244
eNB 59	4.862628	7.015303	0.084869	0.12244
eNB 60	4.827644	7.01449	0.084258	0.12243

Figure 3.4 shows SMILE eNBs and their locations in Portharcourt map

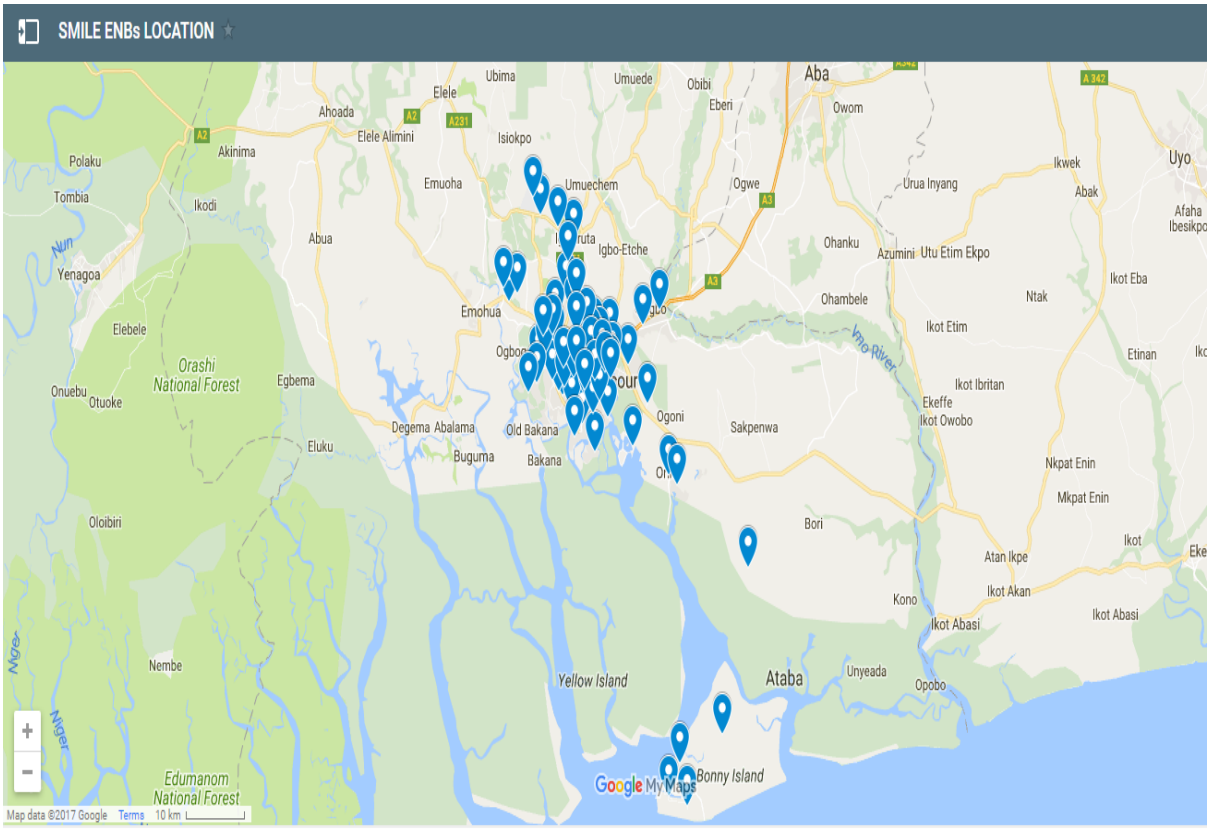


Figure 3.4: SMILE eNB locations in Portharcourt map

3.2.4 SWITCH / EXCHANGE LOCATION

It is very difficult for any operator to disclose its switch locations to outsiders based on security and associated risks. However, for the sake of this research, we were shown the SMILE 4G (LTE) switch in Port Harcourt. The Switch / Exchange location has coordinate 4.808117^0N, 6.996657^0E and it is shown in the Google map image of figure 3.5. For the purpose of this research, the Optical Line Terminal (OLT) is to be housed in this location. The location of the OLT plays a key role as it aids the choice of splitter location since the locations of eNBs are known. It also plays an important role in the choice of topology for the design.

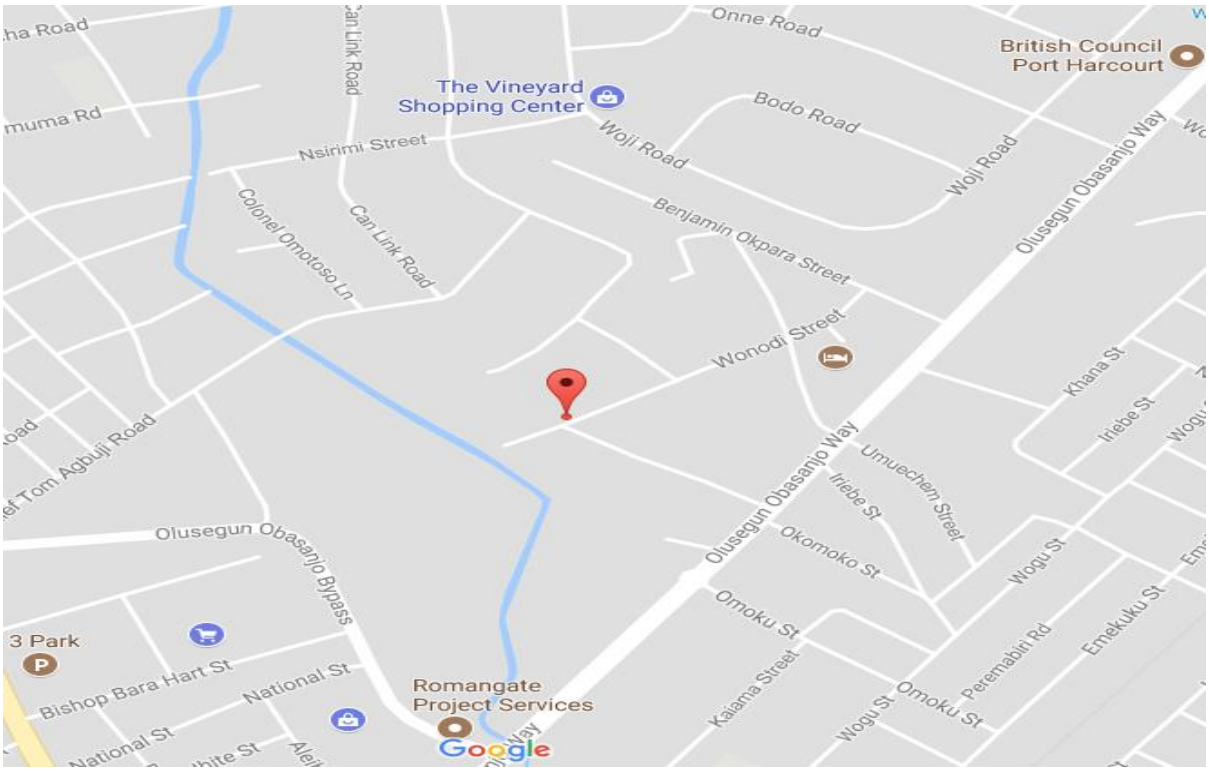


Figure 3.5: Smile Switch/ Exchange location in Portharcourt

3.3 COMPUTATION OF OPTIMAL SPLITTER/ REMOTE NODE LOCATION AND DISTANCES

The coordinates and distribution of eNBs as contained in Table 3.2 is useful in determination of optimum splitter location. Since the switch location is assumed to house the OLT and each eNB serves as ONU, the location of the splitter is imperative in getting minimum fibre cable length, minimal attenuation for a good network design. Figure 3.6 shows a tree topology passive optical network with varying splitter locations and the effect on fibre length of each ONU.

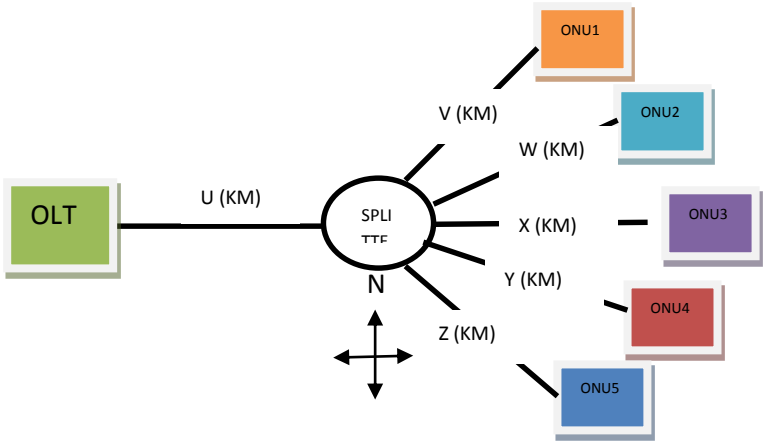


Figure 3.6: PON with Varying Splitter locations

From figure 3.6, the length of fibre for each eNB/ONU is dependent on the position of the splitter. Moving the splitter to any direction in the cardinal point have a resultant increase/ decrease in the length of fibre for each ONU and also on the length between OLT – Splitter. One of the major challenges was how to get the optimal location for the splitter in any geographical environment and still achieve a cost effective PON deployment with minimal attenuation. Placing the splitter/WDM at the optimal location helps in achieving minimum attenuation, minimum fibre length as well as minimal cost for PON deployment. Two

methods (‘Manual’ and ‘Automatic’) were proposed in the determination of optimal splitter location.

3.3.1 MANUAL METHOD

This was done with the intention of analysing different locations for the splitter. For this research, thirty five (35) different sample locations were considered. The interest was to obtain the optimal location considering the fibre length in terms of walking distance, attenuation and cost effective design. This entails obtaining the walking distances (using Google map) from each splitter location to all the eNBs, and the exchange/switch. Summation of these distances becomes the fibre length for the design. The location that has the minimum total distance becomes the optimum location; the location should also give lowest cost and minimum attenuation. To achieve this procedure, one kilometer distance was moved from one base station (eNB point) towards another base station/ (eNB). This pattern was followed to generate up to thirty five (35) test splitter locations, from which the optimal location was chosen based on various great circle and walking distance calculations.

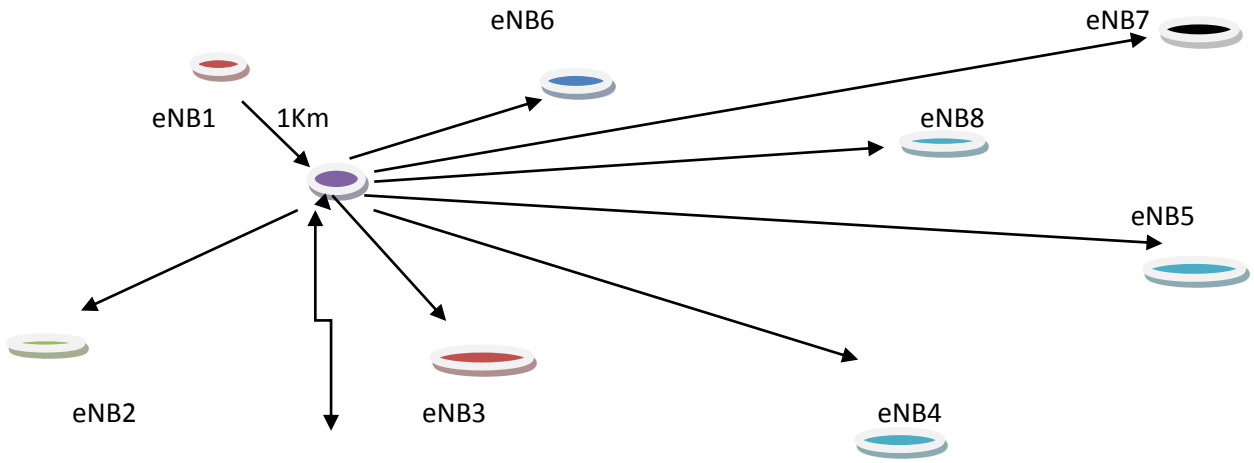


Figure 3.7: Systematic 1km movement to another eNB

To actualize one kilometer distance measurement from any eNB (which is termed a test splitter location), software called GPS VISUALIZER **(**www.gpsvisualizer.com**)** an online platform was greatly used. This approach required that the coordinates of any eNB is

obtained, one kilometer distance from that point say A towards point B, or one kilometer distance from point B towards point A is measured. The coordinate of the new point generated after one kilometer movement was taken as a test splitter location. This procedure was continuously repeated with two random set of base station (eNB) until required number of test splitter locations were generated, which in this case was thirty five (35). Apart from the latitude and longitude coordinates of the two chosen eNBs, one very important parameter that was needed was the "initial angle" between the two eNBs. This parameter (initial angle) was first generated using the GPS VISUALIZER before going ahead to get the test splitter coordinates. Figure 3.8 is a screenshot of GPS VISUALIZER online interface.

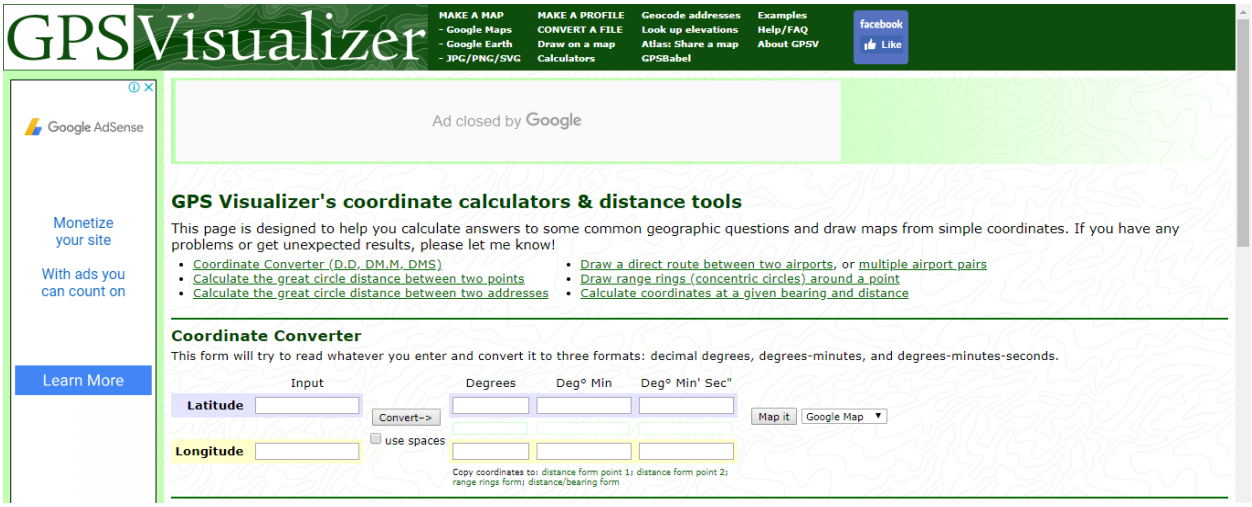


Figure 3.8: Screenshot of GPS Visualizer

To generate one test splitter location, the parameters needed are:

(i) One kilometer distance

(ii) Latitudes of the two eNBs

(iii) Longitudes of the two eNBs

(iv) Initial bearing (angle), which is first generated from the site.

The above listed parameters are as well needed for all other test splitter locations.

To illustrate the steps described above, the coordinates of eNB 5 and eNB 6 of table 3.2 was used to generate a test splitter location coordinate.

The coordinates of the eNBs are: eNB5 = 4.77055^0N, 7.022393^0E and eNB6 = 4.874584^0N, 6.983038^0E.

To get the initial bearing/angle between these two locations using the GPS VISUALIZER platform, coordinates of eNB 5 was keyed in as 'lat.1, lon.1' while coordinates of eNB 6 was keyed in as 'lat.2, lon.2' as shown in figure 3.9. The value of initial angle is 339.348 degrees as obtained from the software.

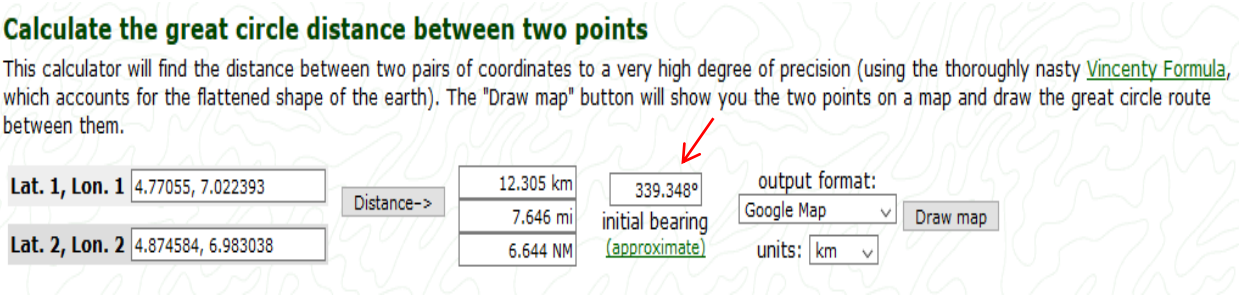


Figure 3.9: Distance between two point and initial Bearing

With this initial angle, together with the coordinates of eNB 5 keyed in as 'Starting Lat.,Lon', the coordinates of the point which equals one kilometer distance from eNB 5 was obtained, it is shown as ' Ending Lat., Lon.'. This point becomes one test splitter location, and is given as 4.779053^0N, 7.019198^0E. Image on figure 3.10 shows the test splitter location.

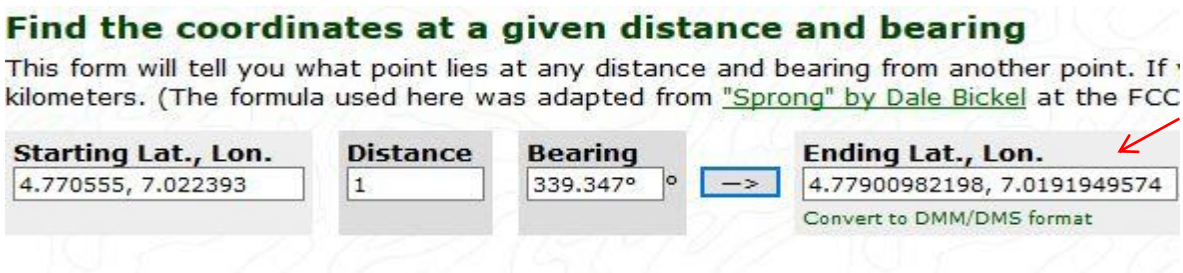


Figure 3.10: Test Splitter Location

Repeating the above procedures, all 35 test splitter location coordinates were obtained and compiled in the table 3.3.

Table 3.3: Test Splitter coordinates

S/N	LATITUDE	LONGITUDE
1	4.81107	7.06291
2	4.779053	7.019198
3	4.78084	7.008668
4	4.874229	6.992008
5	4.72719	7.146899
6	4.848612	7.07006
7	4.790461	7.111696
8	4.790971	7.015301
9	4.829653	7.060012
10	4.805706	6.997133
11	4.8277864	7.026582
12	4.788857	7.038283
13	4.753612	7.091832
14	4.782635	7.054722
15	4.83745	6.992874
16	4.847463	7.040843
17	4.848466	7.040197
18	4.842752	6.986136
19	4.81714	6.99692
20	4.91089	6.994971
21	4.82216	7.01589
22	4.825915	7.010485
23	4.923232	6.998936
24	4.848513	6.97264
25	4.857833	6.987999
26	4.848352	7.028002
27	4.841566	7.045196
28	4.877674	7.131759
29	4.784552	7.031315
30	4.820195	6.953296
31	4.903134	6.918115
32	4.897299	6.909675
33	4.805018	6.952629
34	4.826383	7.052113
35	4.78842	7.043214

Using each sample test location/coordinate to compute for distances between each eNB and the OLT at the switch, lengths in kilometer were obtained. Table 3.4 shows a case when coordinates **4.81107^0N, 7.06291^0E** was used to compute for lengths between each eNB and

the switch/exchange (OLT) and the summed values of lengths in kilometers obtained. Other coordinates in table 3.3 was subsequently used one after the other to compute for lengths between each eNB and the OLT and for the cumulative lengths of fibre. The table with minimal cumulative length was chosen as optimal splitter coordinate. Appendix B showed the results of such computations for 35 sample test coordinates. In table 3.4, great circle distances between two points were obtained using an online distance calculator tool shown in figure 3.9. The latitude and longitude can be in either degrees or radians. Distance between two points in Google map is used for walking distance measurements.

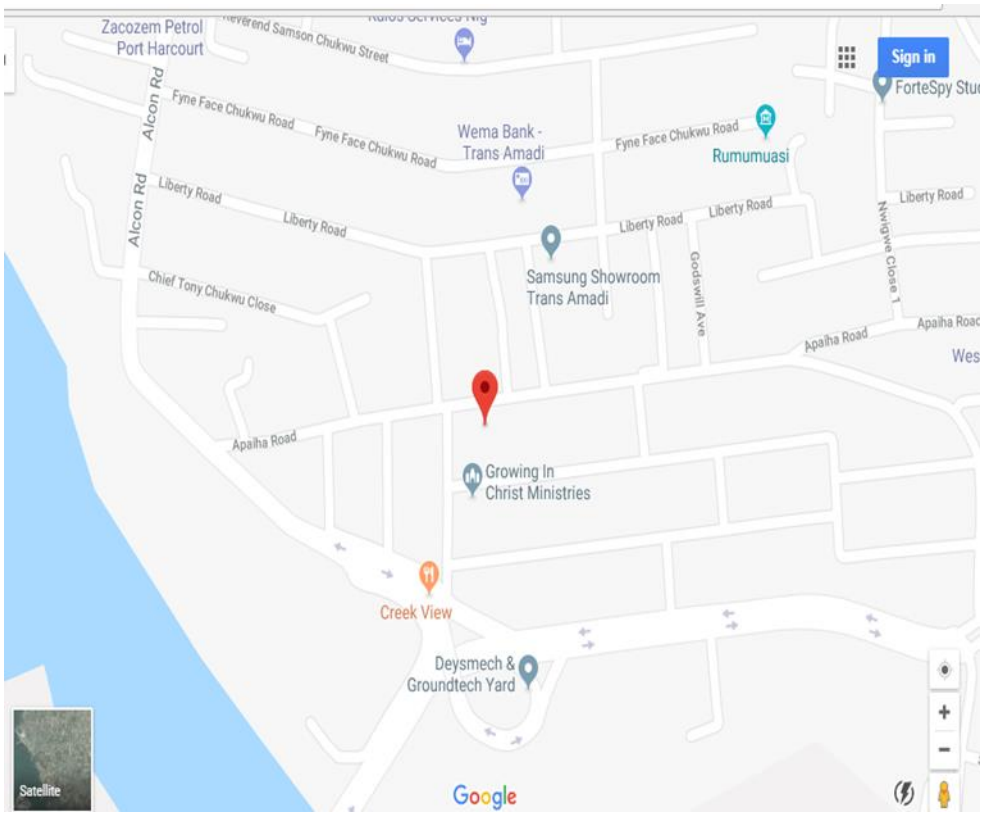


Figure 3.11: Map showing Coordinate **4.81107^{0}N, 7.06291^{0}E**

Table 3.4: Distances between coordinates **4.81107^{0}N, 7.06291^{0}E**, Exchange/ switch and eNBs

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB14 to eNB 15)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.80812	0.08392	6.996657	0.12211	4.81107	0.083969	7.06291	0.123271	7.34838	10.1
eNB 1	4.8366	0.08441	7.0286	0.12267	4.81107	0.083969	7.06291	0.123271	4.744631	7.2
eNB 2	4.7737	0.08332	7.0142	0.12242	4.81107	0.083969	7.06291	0.123271	6.81156	9.9
eNB 3	4.7999	0.08377	6.9939	0.12207	4.81107	0.083969	7.06291	0.123271	7.746772	9.5
eNB 4	4.8294	0.08429	7.0919	0.12378	4.81107	0.083969	7.06291	0.123271	3.804259	6.5
eNB 5	4.7706	0.08326	7.0224	0.12256	4.81107	0.083969	7.06291	0.123271	6.355965	9.3
eNB 6	4.8746	0.08508	6.983	0.12188	4.81107	0.083969	7.06291	0.123271	11.32674	13.5
eNB 7	4.8692	0.08498	7.1137	0.12416	4.81107	0.083969	7.06291	0.123271	8.570252	11.5
eNB 8	4.7196	0.08237	7.1518	0.12482	4.81107	0.083969	7.06291	0.123271	14.15861	20.1
eNB 9	4.8554	0.08474	7.0641	0.12329	4.81107	0.083969	7.06291	0.123271	4.931138	6.7
eNB 10	4.7909	0.08362	7.1207	0.12428	4.81107	0.083969	7.06291	0.123271	6.784737	10.7
eNB 11	4.7854	0.08352	7.0082	0.12232	4.81107	0.083969	7.06291	0.123271	6.700471	8
eNB 12	4.8327	0.08435	7.0685	0.12337	4.81107	0.083969	7.06291	0.123271	2.483724	3.7
eNB 13	4.8039	0.08384	6.9883	0.12197	4.81107	0.083969	7.06291	0.123271	8.305394	10.5
eNB 14	4.8197	0.08412	7.0656	0.12332	4.81107	0.083969	7.06291	0.123271	1.004944	1.7
eNB 15	4.743	0.08278	7.0417	0.1229	4.81107	0.083969	7.06291	0.123271	7.925385	13.8
eNB 16	4.7939	0.08367	7.0308	0.12271	4.81107	0.083969	7.06291	0.123271	4.037762	4.7
eNB 17	4.748	0.08287	7.0989	0.1239	4.81107	0.083969	7.06291	0.123271	8.067511	15.4
eNB 18	4.7773	0.08338	7.062	0.12325	4.81107	0.083969	7.06291	0.123271	3.756268	5.1
eNB 19	4.8341	0.08437	6.9845	0.1219	4.81107	0.083969	7.06291	0.123271	9.057492	11.8
eNB 20	4.8565	0.08476	7.0405	0.12288	4.81107	0.083969	7.06291	0.123271	5.62894	7.2
eNB 21	4.8064	0.08389	7.0424	0.12291	4.81107	0.083969	7.06291	0.123271	2.331133	3.6
eNB 22	4.8146	0.08403	6.9788	0.1218	4.81107	0.083969	7.06291	0.123271	9.327877	12.2
eNB 23	4.8298	0.0843	6.9588	0.12145	4.81107	0.083969	7.06291	0.123271	11.72205	15.1
eNB 24	4.8923	0.08539	6.9143	0.12068	4.81107	0.083969	7.06291	0.123271	18.78018	21
eNB 25	4.848	0.08461	7.0492	0.12303	4.81107	0.083969	7.06291	0.123271	4.378498	5.4
eNB 26	4.8514	0.08467	6.9835	0.12188	4.81107	0.083969	7.06291	0.123271	9.875574	13.5
eNB 27	4.8081	0.08392	6.9967	0.12211	4.81107	0.083969	7.06291	0.123271	7.343705	10.1
eNB 28	4.9028	0.08557	6.999	0.12216	4.81107	0.083969	7.06291	0.123271	12.41691	14.5
eNB 29	4.9789	0.0869	6.9611	0.12149	4.81107	0.083969	7.06291	0.123271	21.80578	26.6
eNB 30	4.9969	0.08721	6.95	0.1213	4.81107	0.083969	7.06291	0.123271	24.15474	27.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.81107	0.083969	7.06291	0.123271	16.8875	20.6
eNB 32	4.9669	0.08669	6.9869	0.12194	4.81107	0.083969	7.06291	0.123271	19.26552	23.4
eNB 33	4.8289	0.08428	7.0219	0.12255	4.81107	0.083969	7.06291	0.123271	4.957712	7.8
eNB 34	4.8169	0.08407	7.0112	0.12237	4.81107	0.083969	7.06291	0.123271	5.766172	8.4
eNB 35	4.9317	0.08607	7.0021	0.12221	4.81107	0.083969	7.06291	0.123271	15.01046	17.5
eNB 36	4.8407	0.08449	6.9681	0.12162	4.81107	0.083969	7.06291	0.123271	11.00957	14.1
eNB 37	4.8598	0.08482	6.9792	0.12181	4.81107	0.083969	7.06291	0.123271	10.74182	14.4
eNB 38	4.8469	0.08459	7.0369	0.12282	4.81107	0.083969	7.06291	0.123271	4.917264	5.7
eNB 39	4.8585	0.0848	6.9658	0.12158	4.81107	0.083969	7.06291	0.123271	11.98277	14.9
eNB 40	4.88	0.08517	7.01	0.12235	4.81107	0.083969	7.06291	0.123271	9.649611	11.1

eNB 41	4.8669	0.08494	7.03	0.1227	4.81107	0.083969	7.06291	0.123271	7.199776	9.7
eNB 42	4.8378	0.08444	7.037	0.12282	4.81107	0.083969	7.06291	0.123271	4.132398	5.4
eNB 43	4.8842	0.08525	7.138	0.12458	4.81107	0.083969	7.06291	0.123271	11.63372	15.5
eNB 44	4.7815	0.08345	7.0398	0.12287	4.81107	0.083969	7.06291	0.123271	4.167442	5.2
eNB 45	4.8116	0.08398	6.9561	0.12141	4.81107	0.083969	7.06291	0.123271	11.835	15.9
eNB 46	4.9011	0.08554	6.9269	0.1209	4.81107	0.083969	7.06291	0.123271	18.09151	21.5
eNB 47	4.9058	0.08562	6.9066	0.12054	4.81107	0.083969	7.06291	0.123271	20.27023	23
eNB 48	4.8024	0.08382	6.944	0.1212	4.81107	0.083969	7.06291	0.123271	13.21087	17.8
eNB 49	4.8354	0.08439	7.0528	0.12309	4.81107	0.083969	7.06291	0.123271	2.92823	4.3
eNB 50	4.7947	0.08368	7.0497	0.12304	4.81107	0.083969	7.06291	0.123271	2.335681	2.8
eNB 51	4.7581	0.08304	7.0119	0.12238	4.81107	0.083969	7.06291	0.123271	8.163247	11.7
eNB 52	4.8269	0.08424	6.9961	0.1221	4.81107	0.083969	7.06291	0.123271	7.609083	10.6
eNB 53	4.815	0.08404	7.0419	0.1229	4.81107	0.083969	7.06291	0.123271	2.368659	3.7
eNB 54	4.71	0.0822	7.165	0.12505	4.81107	0.083969	7.06291	0.123271	15.94603	21.8
eNB 55	4.8233	0.08418	7.0572	0.12317	4.81107	0.083969	7.06291	0.123271	1.499997	1.9
eNB 56	4.815	0.08404	7.0652	0.12331	4.81107	0.083969	7.06291	0.123271	0.505417	0.75
eNB 57	4.894	0.08542	7.0153	0.12244	4.81107	0.083969	7.06291	0.123271	10.62363	13.1
eNB 58	4.8626	0.08487	7.0153	0.12244	4.81107	0.083969	7.06291	0.123271	7.788431	9.3
eNB 59	4.8276	0.08426	7.0145	0.12243	4.81107	0.083969	7.06291	0.123271	5.670133	8.5
									527.8553	686.65

Table 3.5 shows the results obtained from the summed fibre lengths in kilometers when all the thirty five sample test locations were computed. Also shown in table 3.5 is cost of fibre per kilometer and fibre attenuation with attenuation coefficient of 0.25km/dB. Their summed distances from all eNBs and exchange is as obtained using GP Visualizer and Google map. The sum of the distances, cost and attenuation represents the total length of fibre, total fibre cost and total attenuation respectively and so, the table with the smallest sum represents the optimum splitter location.

Table 3.5: Thirty five test splitter coordinates and their cumulative distances

S/N	TEST SPLITTER COORDINATES	GREAT CIRCLE DISTANCE (KM)	Cost per KM of Fibre ($15000)	Fibre Attenuation at coefficient of 0.25km/dB
1	4.81107, 7.06290	527.855	7917825	131.96
2	4.779053, 7.019198	554.338	8315070	138.58
3	4.78084, 7.008668	554.412	8316180	138.60
4	4.874229, 6.992008	539.374	8090610	134.84
5	4.72719, 7.146899	1151.32	17269800	287.83
6	4.848612, 7.07006	554.225	8313375	138.56
7	4.790461, 7.111696	780.446	11706690	195.11
8	4.790971, 7.015301	511.928	7678920	127.98

9	4.829653, 7.060012	502.322	7534830	125.58
10	4.805706, 6.997133	489.956	7349340	122.49
11	4.8277864, 7.026582	440.745	6611171	110.19
12	4.788857, 7.038283	527.233	7908495	131.81
13	4.753612, 7.091832	813.139	12197085	203.28
14	4.782635, 7.054722	580.763	8711445	145.19
15	4.83745, 6.992874	472.145	7082175	118.04
16	4.847463, 7.040843	467.731	7015965	116.93
17	4.848466, 7.040197	468.210	7023150	117.05
18	4.842752, 6.986136	491.087	7366305	122.77
19	4.81714, 6.99692	470.952	7064280	117.74
20	4.91089, 6.994971	674.049	10110735	168.51
21	4.82216, 7.01589	443.611	6654165	110.90
22	4.825915, 7.010485	444.626	6669390	111.16
23	4.923232, 6.998936	727.148	10907220	181.79
24	4.848513, 6.97264	537.156	8057340	134.29
25	4.857833, 6.987999	507.063	7605945	126.77
26	4.848352, 7.028002	455.054	6825810	113.76
27	4.841566, 7.045196	468.762	7031430	117.19
28	4.877674, 7.131759	899.660	13494900	224.92
29	4.784552, 7.0131315	535.772	8036580	133.94
30	4.820195, 6.953296	619.458	9291870	154.86
31	4.903134, 6.918115	891.147	13367205	222.79
32	4.897299, 6.909675	916.504	13747560	229.13
33	4.805018, 6.952629	647.412	9711180	161.85
34	4.826383, 7.052113	480.170	7202550	120.04
35	4.78842, 7.043214	536.057	8040855	134.01

Columns 2, 3, 4 and 5 of table 3.5 represented test splitter coordinates, generated great circle distances in km, fibre cost per km in US dollars, and accrued attenuation per km at attenuation coefficient of 0.25dB/km respectively. Serial numbers 5 and 11 show the highest and lowest values on each column respectively. Using coordinates of test splitter on row 5 (4.72719^0N, 7.146899^0E) results to cumulative fibre length of 1151.32km for the design and which also requires $17269800 US for fibre cable purchase. According to (Amazon.com, nd), on the average, 1km length of single mode fibre is sold at $15000 US. This also introduces a corresponding fibre attenuation of 287.83dB/km. Looking at table 3.5 critically, coordinates of serial number/row 5 represents highest values in terms of cumulative length, fibre cost and total attenuation whereas serial/row 11 represents lowest values for cumulative fibre length,

fibre cost and total attenuation respectively. Hence, coordinate of serial/row 11 (4.8277864^0N, 7.026582^0E) becomes the optimal splitter location for PON deployment. Figure 3.12 shows the coordinates of **4.8277864^0N, 7.026582^0E** on the map, the coordinates produced the lowest fibre length of 577.7km representing the optimal location for manual approach.

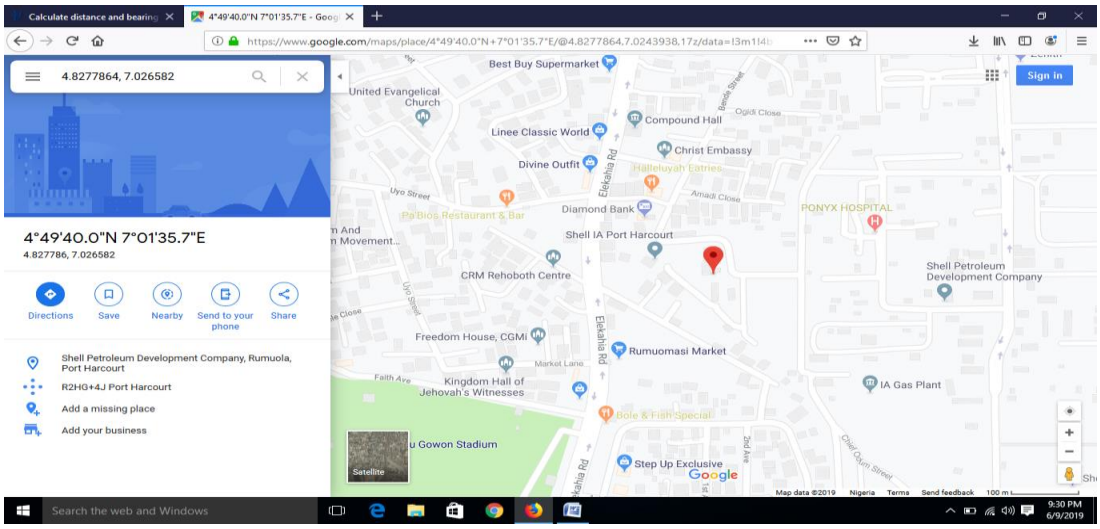


Figure 3.12: Optimal splitter location for Manual approach

Table 3.6 shows the breakdown of distances between the optimal splitter coordinate **4.8277864^0N, 7.026582^0E**, exchange/switch and all other fifty nine eNBs in SMILE network. For great circle, it has a total length of 440.7447km whereas a total length of 577.7km corresponds to its walking distance. Great circle distance is a straight distance between two points on a map and for the fact that great circle distances may not consider obstructions posed a challenge; therefore, it is preferable to take the walking/route length distance as the cumulative minimum length of fiber required for this research.

Table 3.6: Breakdown of distances between coordinate **4.8277864^{0}N, 7.026582^{0}E**, Exchange/ switch and eNBs

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB1 to eNB 2)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.8277864	0.0842604	7.026582	0.1226365	3.97211	6.2
eNB 1	4.8366	0.08441	7.0286	0.12267	4.827786	0.08426	7.026582	0.122636	1.005203	1.6
eNB 2	4.7737	0.08332	7.0142	0.12242	4.827786	0.08426	7.026582	0.122636	6.16862	10.2
eNB 3	4.7999	0.08377	6.9939	0.12207	4.827786	0.08426	7.026582	0.122636	4.767435	6.1
eNB 4	4.8294	0.08429	7.0919	0.12378	4.827786	0.08426	7.026582	0.122636	7.239448	10
eNB 5	4.7706	0.08326	7.0224	0.12256	4.827786	0.08426	7.026582	0.122636	6.375677	8.1
eNB 6	4.8746	0.08508	6.983	0.12188	4.827786	0.08426	7.026582	0.122636	7.100198	10.1
eNB 7	4.8692	0.08498	7.1137	0.12416	4.827786	0.08426	7.026582	0.122636	10.69458	13.7
eNB 8	4.7196	0.08237	7.1518	0.12482	4.827786	0.08426	7.026582	0.122636	18.36402	23.6
eNB 9	4.8554	0.08474	7.0641	0.12329	4.827786	0.08426	7.026582	0.122636	5.167951	6
eNB 10	4.7909	0.08362	7.1207	0.12428	4.827786	0.08426	7.026582	0.122636	11.20614	14.3
eNB 11	4.7854	0.08352	7.0082	0.12232	4.827786	0.08426	7.026582	0.122636	5.13441	6.4
eNB 12	4.8327	0.08435	7.0685	0.12337	4.827786	0.08426	7.026582	0.122636	4.676523	7.2
eNB 13	4.8039	0.08384	6.9883	0.12197	4.827786	0.08426	7.026582	0.122636	5.00467	6.9
eNB 14	4.8197	0.08412	7.0656	0.12332	4.827786	0.08426	7.026582	0.122636	4.415736	6.7
eNB 15	4.743	0.08278	7.0417	0.1229	4.827786	0.08426	7.026582	0.122636	9.575454	12.6
eNB 16	4.7939	0.08367	7.0308	0.12271	4.827786	0.08426	7.026582	0.122636	3.796858	5.5
eNB 17	4.748	0.08287	7.0989	0.1239	4.827786	0.08426	7.026582	0.122636	11.955	18.9
eNB 18	4.7773	0.08338	7.062	0.12325	4.827786	0.08426	7.026582	0.122636	6.849545	8.2
eNB 19	4.8341	0.08437	6.9845	0.1219	4.827786	0.08426	7.026582	0.122636	4.715218	6
eNB 20	4.8565	0.08476	7.0405	0.12288	4.827786	0.08426	7.026582	0.122636	3.545691	4.9
eNB 21	4.8064	0.08389	7.0424	0.12291	4.827786	0.08426	7.026582	0.122636	2.954143	4.3
eNB 22	4.8146	0.08403	6.9788	0.1218	4.827786	0.08426	7.026582	0.122636	5.493586	7.6
eNB 23	4.8298	0.0843	6.9588	0.12145	4.827786	0.08426	7.026582	0.122636	7.51357	9.3
eNB 24	4.8923	0.08539	6.9143	0.12068	4.827786	0.08426	7.026582	0.122636	14.36035	16.5
eNB 25	4.848	0.08461	7.0492	0.12303	4.827786	0.08426	7.026582	0.122636	3.366318	4
eNB 26	4.8514	0.08467	6.9835	0.12188	4.827786	0.08426	7.026582	0.122636	5.447904	7.7
eNB 27	4.8081	0.08392	6.9967	0.12211	4.827786	0.08426	7.026582	0.122636	3.969176	5.3
eNB 28	4.9028	0.08557	6.999	0.12216	4.827786	0.08426	7.026582	0.122636	8.88327	11.5
eNB 29	4.9789	0.0869	6.9611	0.12149	4.827786	0.08426	7.026582	0.122636	18.30218	23.7
eNB 30	4.9969	0.08721	6.95	0.1213	4.827786	0.08426	7.026582	0.122636	20.62986	24.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.827786	0.08426	7.026582	0.122636	14.12764	17.3
eNB 32	4.9669	0.08669	6.9869	0.12194	4.827786	0.08426	7.026582	0.122636	16.08126	20.7
eNB 33	4.8289	0.08428	7.0219	0.12255	4.827786	0.08426	7.026582	0.122636	0.533338	1
eNB 34	4.8169	0.08407	7.0112	0.12237	4.827786	0.08426	7.026582	0.122636	2.09048	3.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.827786	0.08426	7.026582	0.122636	11.86871	14.5
eNB 36	4.8407	0.08449	6.9681	0.12162	4.827786	0.08426	7.026582	0.122636	6.636936	8.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.827786	0.08426	7.026582	0.122636	6.342878	8.6
eNB 38	4.8469	0.08459	7.0369	0.12282	4.827786	0.08426	7.026582	0.122636	2.413286	3.3
eNB 39	4.8585	0.0848	6.9658	0.12158	4.827786	0.08426	7.026582	0.122636	7.550949	9.1
eNB 40	4.88	0.08517	7.01	0.12235	4.827786	0.08426	7.026582	0.122636	6.089612	8.1

eNB 41	4.8669	0.08494	7.03	0.1227	4.827786	0.08426	7.026582	0.122636	4.36567	7.1
eNB 42	4.8378	0.08444	7.037	0.12282	4.827786	0.08426	7.026582	0.122636	1.603808	2.1
eNB 43	4.8842	0.08525	7.138	0.12458	4.827786	0.08426	7.026582	0.122636	13.84695	17.7
eNB 44	4.7815	0.08345	7.0398	0.12287	4.827786	0.08426	7.026582	0.122636	5.351128	6.3
eNB 45	4.8116	0.08398	6.9561	0.12141	4.827786	0.08426	7.026582	0.122636	8.014217	10.6
eNB 46	4.9011	0.08554	6.9269	0.1209	4.827786	0.08426	7.026582	0.122636	13.72697	17
eNB 47	4.9058	0.08562	6.9066	0.12054	4.827786	0.08426	7.026582	0.122636	15.87325	18.4
eNB 48	4.8024	0.08382	6.944	0.1212	4.827786	0.08426	7.026582	0.122636	9.575779	12.4
eNB 49	4.8354	0.08439	7.0528	0.12309	4.827786	0.08426	7.026582	0.122636	3.025785	4.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.827786	0.08426	7.026582	0.122636	4.482936	5.9
eNB 51	4.7581	0.08304	7.0119	0.12238	4.827786	0.08426	7.026582	0.122636	7.917683	10
eNB 52	4.8269	0.08424	6.9961	0.1221	4.827786	0.08426	7.026582	0.122636	3.378845	4.7
eNB 53	4.815	0.08404	7.0419	0.1229	4.827786	0.08426	7.026582	0.122636	2.214073	3.3
eNB 54	4.71	0.0822	7.165	0.12505	4.827786	0.08426	7.026582	0.122636	20.16908	25.3
eNB 55	4.8233	0.08418	7.0572	0.12317	4.827786	0.08426	7.026582	0.122636	3.428968	5.8
eNB 56	4.815	0.08404	7.0652	0.12331	4.827786	0.08426	7.026582	0.122636	4.508943	6.7
eNB 57	4.894	0.08542	7.0153	0.12244	4.827786	0.08426	7.026582	0.122636	7.467938	10
eNB 58	4.8626	0.08487	7.0153	0.12244	4.827786	0.08426	7.026582	0.122636	4.067895	6.3
eNB 59	4.8276	0.08426	7.0145	0.12243	4.827786	0.08426	7.026582	0.122636	1.338846	2.2
									440.7447	577.7

3.3.2 AUTOMATIC / SYSTEMATIC METHOD

This approach uses algorithm and computer programming to achieve the purpose of finding the optimal splitter location that would utilise the least length of fibre for passive optical network deployment. The model automatically generates about 1,200 (20 x N) different test splitter locations using MATLAB programming tool. It generates the splitter locations, calculates and sum the distances between each splitter location and all eNBs, and finally extracts the coordinates of the optimal splitter location. Note that for this model, distances are based on great circle calculations. The model is presented as follows: Assuming the positions of the eNBs, including the exchange/switch, are located on the surface of the earth as depicted in figure 3.13

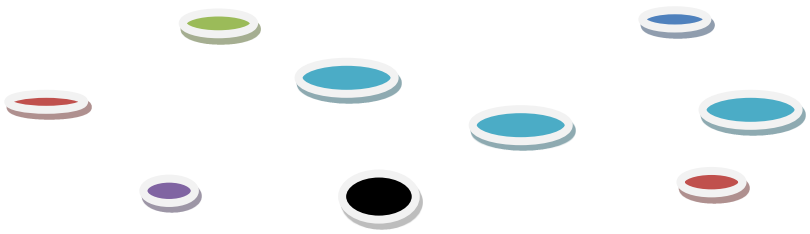


Figure 3.13: Assumed position of eNBs on the surface of the earth

Imagine drawing a square around each eNB, each of the four vertices of each square becomes a test splitter location. Another square is drawn around each of these four vertices and their vertices each also becomes a test splitter location. This whole process in effect produces 20*N test splitter locations, where N is the number of eNBs including the exchange/switch. In this case of SMILE Port Harcourt, it is 20 x 60 eNBs translating to 1200 test splitter locations. This is demonstrated in figure 3.14 using one eNB.

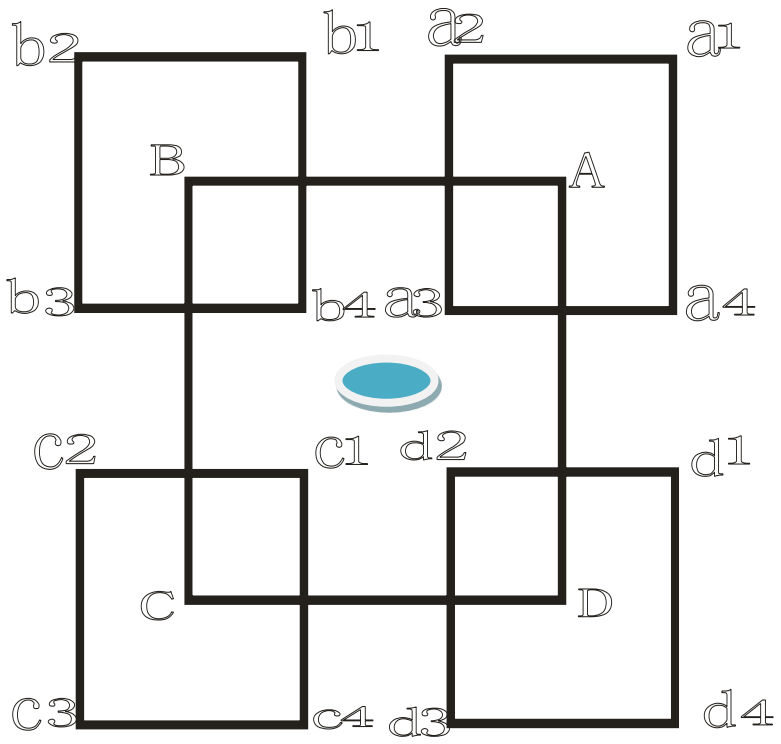


Figure 3.14: 20 Vertices of eNB

The method of obtaining the coordinates of the vertices is as follows:

Considering the earth as ellipsoidal in shape, it is difficult to have a square (of large length values) round a point on the surface of an ellipsoid. But for purpose that involve lengths less than ten miles (16.0934Km), approximations are more than sufficient (stack exchange, n.d). Also, for movement North or South (i.e. to cause a change in the reference latitude value), one degree is equivalent to about 111.1949 km. This is obtained as follows:

$$\left(\frac{\theta}{360}\right).(2\pi R) \qquad (3.1)$$

Where R is the mean radius of the earth, ɵ is the angle in degree achieved when a distance of about 111.1949km is covered in either north or south direction to cause a change in reference latitude.

For movement East or West (i.e. to cause a change in the reference longitude value), one degree is about 111.1949 km multiplied by the cosine of the reference point latitude. The reference latitude is the latitude of the point desired to draw the square around while the reference longitude is the longitude of the same point. From the analysis above, it is demonstrated that;

$$\mathrm{d(lat)} = \frac{r}{111.1949} \qquad (3.2)$$

$$\mathrm{d(lng)} = \frac{r}{(111.1949)} . \cos(lat) \qquad (3.3)$$

Where;

d(lat) = change in latitude.

d(lng) = change in longitude.

r = the distance travelled east, west, north or south.

Since a square is been considered, then r will be half the length of a side of the square.

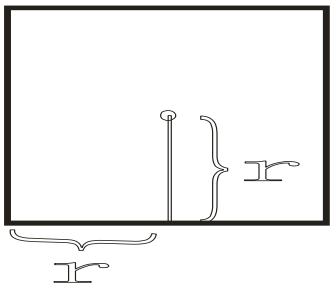


Figure 3.15: Half-length of a square

For this analysis, r is taken to be 2km for the first set of squares and 1km for the second set. This is to ensure that any of the vertices will not overlap. To get the latitude of any vertex, the value of the change in latitude, d(lat) is added to the reference latitude if the vertex point is above the reference point, or subtract the value of the change in latitude, d(lat), from the reference latitude if the vertex point is below the reference point.

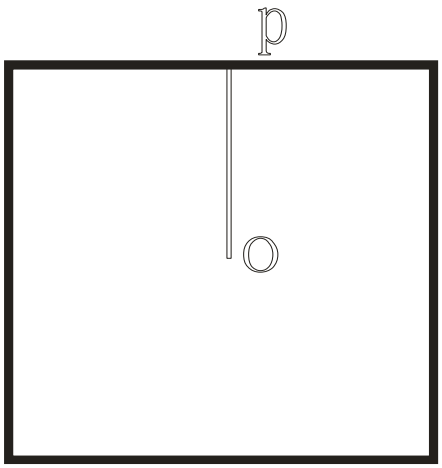


Figure 3.16: Change in latitude

The latitude of the point P is got as the latitude of point O plus the change in latitude, d(lat). This is because point P is above point O

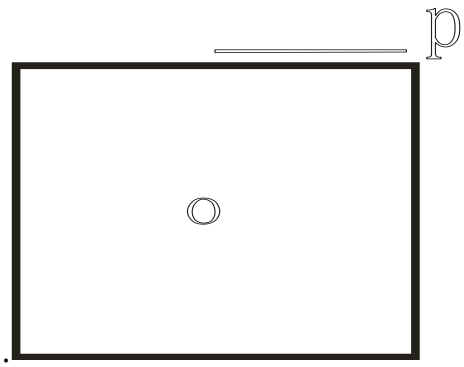


Figure 3.17: Longitude of Vertex

In figure 3.17, the latitude of point P is latitude of P plus the change in latitude. Figure 3.18 shows the pattern followed to move from the reference point to any of the vertex points.

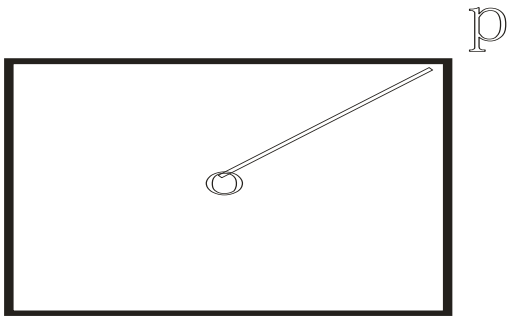


Figure 3.18: Longitude of Point P

Thus the coordinates of the vertices of the square will be obtained as follows, moving from the top right vertex and move anti-clockwise;

$\{[\text{lat} + d(\text{lat}),\ \text{lng} + d(\text{lng})], [\text{lat} + d(\text{lat}), \text{lng} - d(\text{lng})], [\text{lat} - d(\text{lat}), \text{lng} - d(\text{lng})], [\text{lat} - d(\text{lat}), \text{lng} + d(\text{lng})]\}$ (3.4)

Where;

lat = the reference latitude.

lng = the reference longitude.

After using this procedure to obtain the vertices of the squares drawn around each eNB, the same method is also used to obtain the vertices of the squares drawn around each of the already obtained vertices. These are altogether used as test splitter locations.

The distances from each of these test splitter locations to all eNBs including the one at exchange/switch are obtained and summed. To get distance between two points, Vincenty formula and its components shown in equations 3.5- 3.8 are employed.

$d\theta = \tan^{-1}(A|B)$ (3.5)

$A = \sqrt{((\cos(lat2).\sin(dlat))^2 + (\cos(lat1).\sin(lat2) - \sin(lat1.\cos(lat2).\cos(dlng))^2}$ (3.6)

$B = (\sin(lat1).\sin(lat2)) + (\cos(lat1).\cos(lat2).\cos(dlng))$ (3.7)

$L = d\theta.R$ (3.8)

Where

L = distance between two points.

dθ = the angle between the two points

lat1 = latitude of point 1.

lat2 = latitude of point 2.

lng1 = longitude of point 1.

lng2 = longitude of point 2.

dlat = change in latitude.

dlng = change in longitude.

R = mean radius of the earth

The formulae stated in equations 3.1 through 3.8 are performed in a MATLAB environment and the codes shown in appendix C were generated. Figure 3.19 shows the screenshot of the result obtained in a MATLAB environment. The result shows the best coordinate as **4.8276^0N, 7.0254^0E** and a cumulative great circle length of **440.2456km**. The 440.2456km represent total great circle fibre length required for passive optical network deployment. The beauty of this approach is that the MATLAB software is programmed to also show next best five locations and their cumulative fibre lengths. This is to make provisions for second best coordinates in an event the best location is not favoured by topographical problems like swamp, river, hill, etc.

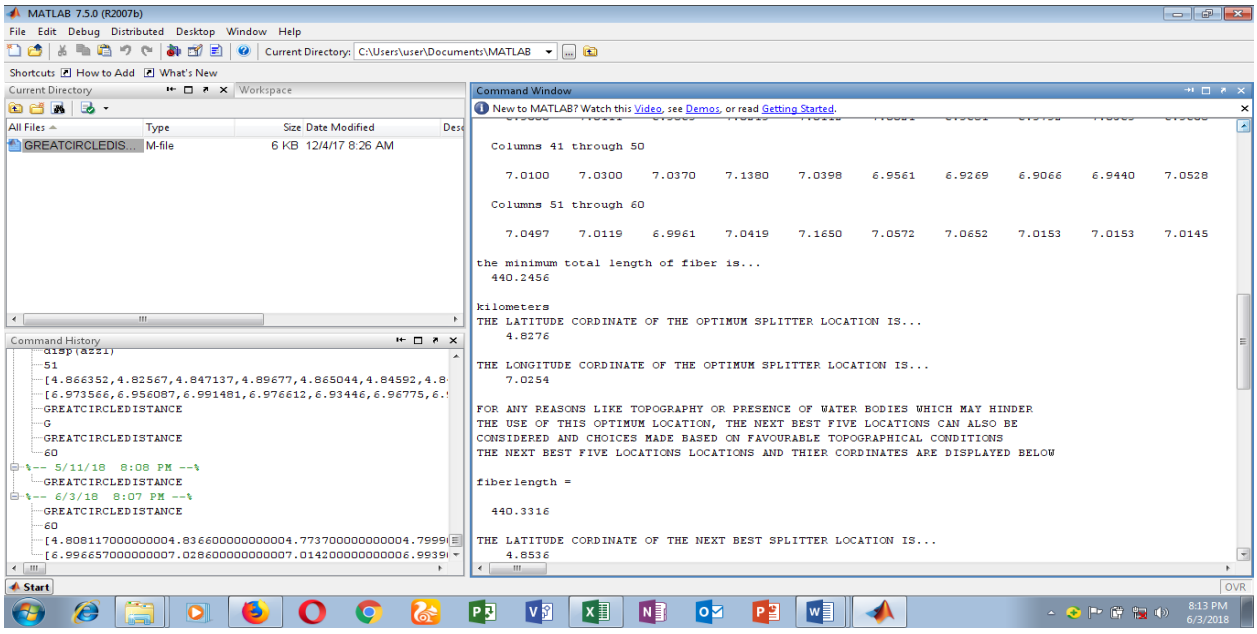


Figure 3.19: Best Splitter coordinates and cumulative fibre length displayed on MATLAB

Figure 3.20 is a map showing the coordinates of splitter location as obtained from Automatic/Systematic approach.

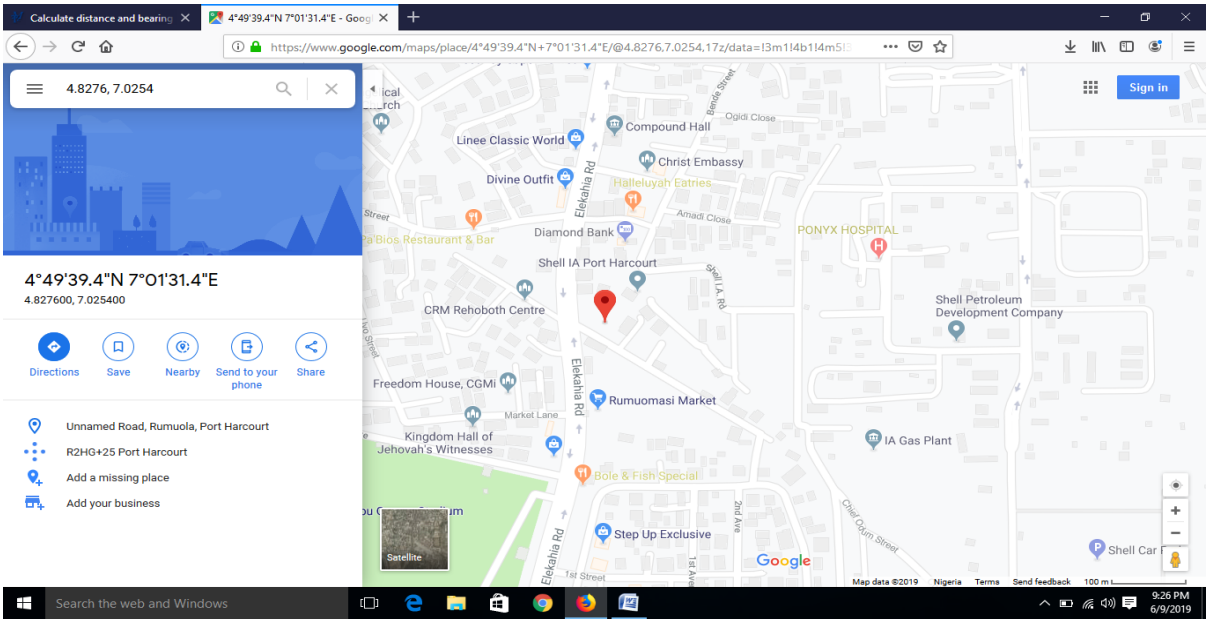


Figure 3.20: Optimal splitter location coordinates from Automatic approach

Table 3.7 shows the breakdown of distances between the chosen coordinate **4.8276^{0}N, 7.0254^{0}E**, exchange/switch and all other fifty nine eNBs in SMILE Port Harcourt network. For great circle, it has a total length of **440.240km** whereas a total length of **564.45km** is for walking distance. As reiterated in the manual method analysis, walking distances are always preferred when applying our results to real life situations, because they take care of obstacles/obstructions. So using the same coordinates obtained from the automatic approach, the total walking distance obtained using the Google map tool is given as 564.45 kilometers.

Table 3.7: Breakdown of distances between coordinate **4.8276^0, 7.0254^0**, Exchange/ switch and eNBs

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (using the authomatic approach)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.8276	0.08426	7.0254	0.12262	3.851776	4.8
eNB 1	4.8366	0.08441	7.0286	0.12267	4.8276	0.08426	7.0254	0.12262	1.061707	1.4
eNB 2	4.7737	0.08332	7.0142	0.12242	4.8276	0.08426	7.0254	0.12262	6.120542	7.8
eNB 3	4.7999	0.08377	6.9939	0.12207	4.8276	0.08426	7.0254	0.12262	4.655009	5.6
eNB 4	4.8294	0.08429	7.0919	0.12378	4.8276	0.08426	7.0254	0.12262	7.370938	10.1
eNB 5	4.7706	0.08326	7.0224	0.12256	4.8276	0.08426	7.0254	0.12262	6.346822	7.7
eNB 6	4.8746	0.08508	6.983	0.12188	4.8276	0.08426	7.0254	0.12262	7.027223	9.7
eNB 7	4.8692	0.08498	7.1137	0.12416	4.8276	0.08426	7.0254	0.12262	10.82182	13.8
eNB 8	4.7196	0.08237	7.1518	0.12482	4.8276	0.08426	7.0254	0.12262	18.44975	23.7
eNB 9	4.8554	0.08474	7.0641	0.12329	4.8276	0.08426	7.0254	0.12262	5.285984	6
eNB 10	4.7909	0.08362	7.1207	0.12428	4.8276	0.08426	7.0254	0.12262	11.32068	14.3
eNB 11	4.7854	0.08352	7.0082	0.12232	4.8276	0.08426	7.0254	0.12262	5.064685	5.9
eNB 12	4.8327	0.08435	7.0685	0.12337	4.8276	0.08426	7.0254	0.12262	4.809035	7.3
eNB 13	4.8039	0.08384	6.9883	0.12197	4.8276	0.08426	7.0254	0.12262	4.882963	6.5
eNB 14	4.8197	0.08412	7.0656	0.12332	4.8276	0.08426	7.0254	0.12262	4.539999	7.1
eNB 15	4.743	0.08278	7.0417	0.1229	4.8276	0.08426	7.0254	0.12262	9.578913	12.1
eNB 16	4.7939	0.08367	7.0308	0.12271	4.8276	0.08426	7.0254	0.12262	3.794737	5
eNB 17	4.748	0.08287	7.0989	0.1239	4.8276	0.08426	7.0254	0.12262	12.02797	19
eNB 18	4.7773	0.08338	7.062	0.12326	4.8276	0.08426	7.0254	0.12262	6.908652	8.1
eNB 19	4.8341	0.08437	6.9845	0.1219	4.8276	0.08426	7.0254	0.12262	4.588992	6
eNB 20	4.8565	0.08476	7.0405	0.12288	4.8276	0.08426	7.0254	0.12262	3.622968	4.8
eNB 21	4.8064	0.08389	7.0424	0.12291	4.8276	0.08426	7.0254	0.12262	3.017467	3.8
eNB 22	4.8146	0.08403	6.9788	0.1218	4.8276	0.08426	7.0254	0.12262	5.36188	7.1
eNB 23	4.8298	0.0843	6.9588	0.12145	4.8276	0.08426	7.0254	0.12262	7.383352	8.9
eNB 24	4.8923	0.08539	6.9143	0.12068	4.8276	0.08426	7.0254	0.12262	14.25756	16.5
eNB 25	4.848	0.08461	7.0492	0.12303	4.8276	0.08426	7.0254	0.12262	3.478413	4
eNB 26	4.8514	0.08467	6.9835	0.12189	4.8276	0.08426	7.0254	0.12262	5.343786	7.8
eNB 27	4.8081	0.08392	6.9967	0.12212	4.8276	0.08426	7.0254	0.12262	3.848902	4.8
eNB 28	4.9028	0.08557	6.999	0.12216	4.8276	0.08426	7.0254	0.12262	8.858675	11.2
eNB 29	4.9789	0.0869	6.9611	0.12149	4.8276	0.08426	7.0254	0.12262	18.26983	23.5
eNB 30	4.9969	0.08721	6.95	0.1213	4.8276	0.08426	7.0254	0.12262	20.59538	24.1
eNB 31	4.9539	0.08646	7.0111	0.12237	4.8276	0.08426	7.0254	0.12262	14.133	17
eNB 32	4.9669	0.08669	6.9869	0.12194	4.8276	0.08426	7.0254	0.12262	16.06601	20.4
eNB 33	4.8289	0.08428	7.0219	0.12256	4.8276	0.08426	7.0254	0.12262	0.413866	0.55
eNB 34	4.8169	0.08407	7.0112	0.12237	4.8276	0.08426	7.0254	0.12262	1.97259	2.6
eNB 35	4.9317	0.08607	7.0021	0.12221	4.8276	0.08426	7.0254	0.12262	11.85975	14.3
eNB 36	4.8407	0.08449	6.9681	0.12162	4.8276	0.08426	7.0254	0.12262	6.513767	8.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.8276	0.08426	7.0254	0.12262	6.246802	8.7
eNB 38	4.8469	0.08459	7.0369	0.12282	4.8276	0.08426	7.0254	0.12262	2.495824	3.1
eNB 39	4.8585	0.0848	6.9658	0.12158	4.8276	0.08426	7.0254	0.12262	7.443959	9.1
eNB 40	4.88	0.08517	7.01	0.12235	4.8276	0.08426	7.0254	0.12262	6.071306	7.8

eNB 41	4.8669	0.08494	7.03	0.1227	4.8276	0.08426	7.0254	0.12262	4.399581	6.9
eNB 42	4.8378	0.08444	7.037	0.12282	4.8276	0.08426	7.0254	0.12262	1.714152	2.2
eNB 43	4.8842	0.08525	7.138	0.12458	4.8276	0.08426	7.0254	0.12262	13.97321	17.8
eNB 44	4.7815	0.08345	7.0398	0.12287	4.8276	0.08426	7.0254	0.12262	5.368672	5.8
eNB 45	4.8116	0.08398	6.9561	0.12141	4.8276	0.08426	7.0254	0.12262	7.881978	10.2
eNB 46	4.9011	0.08554	6.9269	0.1209	4.8276	0.08426	7.0254	0.12262	13.6343	17
eNB 47	4.9058	0.08562	6.9066	0.12054	4.8276	0.08426	7.0254	0.12262	15.77522	18.5
eNB 48	4.8024	0.08382	6.944	0.1212	4.8276	0.08426	7.0254	0.12262	9.444577	12
eNB 49	4.8354	0.08439	7.0528	0.12309	4.8276	0.08426	7.0254	0.12262	3.157376	4.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.8276	0.08426	7.0254	0.12262	4.542345	5.5
eNB 51	4.7581	0.08304	7.0119	0.12238	4.8276	0.08426	7.0254	0.12262	7.871492	9.5
eNB 52	4.8269	0.08425	6.9961	0.1221	4.8276	0.08426	7.0254	0.12262	3.247388	4.2
eNB 53	4.815	0.08404	7.0419	0.1229	4.8276	0.08426	7.0254	0.12262	2.303337	3.8
eNB 54	4.71	0.08221	7.165	0.12505	4.8276	0.08426	7.0254	0.12262	20.25556	25.4
eNB 55	4.8233	0.08418	7.0572	0.12317	4.8276	0.08426	7.0254	0.12262	3.55576	6.2
eNB 56	4.815	0.08404	7.0652	0.12331	4.8276	0.08426	7.0254	0.12262	4.627112	7.1
eNB 57	4.894	0.08542	7.0153	0.12244	4.8276	0.08426	7.0254	0.12262	7.467662	9.8
eNB 58	4.8626	0.08487	7.0153	0.12244	4.8276	0.08426	7.0254	0.12262	4.049514	6.1
eNB 59	4.8276	0.08426	7.0145	0.12243	4.8276	0.08426	7.0254	0.12262	1.207725	1.8
									440.2402	564.45

3.4 CELL CAPACITY/THROUGHPUT DETERMINATION OF A TYPICAL 4G NETWORK

From the research conducted by Rysavy in 2009 and as depicted in table 3.8, it is shown clearly that LTE (2x2 MIMO) and LTE (4x4 MIMO) promised to deliver theoretical capacities of (173Mbps and 58Mbps) and (326Mbps and 86Mbps) respectively for both the downstream and upsream. To design a backhaul for 4G (LTE) technology, theoretical capacity of LTE (4x4 MIMO) is considered as a reference capacity. For this design that has 64 eNBs (4 eNBs were added to take care of possible expansion), a link that will be able to carry 326Mbps by 64 by 6 (125184 Mbit/s) should be considered. 64 by 6 means 64 eNBs multiplied by 6 sectors (some eNBs have up to six sectors). Normally, most eNBs are usually 3 sectored, but to take care of possible expansions, worst case scenario of 6 sectors per eNb is assumed. In the **downstream** consideration, the capacity of the link is 125184Mbit/s or 125.2Gbit/s. Likewise, for **upstream**, 86Mbit/s by 6 will give 516Mbit/s. Considering the fact that there could be possibility of Fibre to the X (FTTX) in near future, allowance for

expansion will be created and hence, the upstream bandwidth per eNB shall be considered to be 2.5Gbit/s.

Table 3.8: Capacity/Throughput of different Technologies (Rysavy Research, 2009)

Technology	**Downlink**		**Uplink**	
	Peak Network Speed	*Typical User Rate*	*Peak Network Speed*	*Typical User Rate*
HSDPA	14.4 Mbps		384 kbps	
HSPA Initial Implementation	7.2 Mbps	> 5 Mbps	2 Mbps	> 1.5 Mbps
HSPA	14.4 Mbps		5.76 Mbps	
HSPA Current Implementation	7.2 Mbps		5.76 Mbps	
HSPA+ (DL64 QAM,UL16 QAM)	21.6 Mbps	1.5 Mbps to 7Mbps 13 Mbps Peak	11.5 Mbps	1 Mbps to 4Mbps
HSPA+ (2X2 MIMO,DL16 QAM,UL 16 QAM)	28 Mbps		11.5 Mbps	
HSPA+ (2X2 MIMO,DL 64 QAM, UL16 QAM	42 Mbps		11.5 Mbps	
HSPA+ (2X2 MIMO,DL 64 QAM,UL16QAM,Dual Carrier)	84 Mbps		23 Mbps	
LTE (2X2 MIMO)	173 Mbps	4 Mbps to 24 Mbps (in 2x 20MHz)	58 Mbps	
LTE (4X4 MIMO)	326 Mbps		86 Mbps	

3.4.1 FIBRE SPECIFICATIONS FOR SMILE 4G (LTE)

For this design, 160Gbit/s shall be used in the downstream instead of the actual 125.2Gbit/s obtained from calculation. This is to give allowance for possible upgrade/expansion. The following fibre specifications shall be put into consideration.

Link capacity = 160Gbit/s downstream and 2.5Gbit/s upstream

Standard Single Mode fibre (SSMF),

Fibre length = 580km (approximated to 580 to take care of unforeseen situations), cumulative walking distance calculated (see table 3.7).

Fibre attenuation = 0.25dB/km at 1550nm (Downstream) and 0.3dB/km at 1310nm (Upstream)

In fibre transmission, the maximum transmission distance of a link is limited by dispersion. The design need to determine the maximum allowable transmission distance that could not be limited by dispersion for each logical OLT – ONU pair. This shall help to know if there is need for dispersion compensation fibre (DCF), Table 3.7 has a breakdown of OLT- splitter and Splitter-ONU distances (in km) of the proposed network.

3.5 DISPERSION LIMITED DISTANCE

For downstream, link capacity is 160Gbit/s (10Gbit/s multiplexed into 16 places)

Single Mode fibre (chromatic dispersion only)

Assumptions

Chromatic dispersion coefficient = 16ps/km.nm

Source; 1550nm Laser, line width = 0.1nm

For maximum bit rate of 160Gbit/s,

Bit Period T = 1/Bit rate (3.9)

$1/160x10^{9} = 6.25 x10^{-12} = 6.25ps$ (3.10)

For survivability and to reduce downtime period in the network due to fibre cut during road construction or earth excavation or total network failure due to faults in the OLT, the entire PON network shall choose 1: 32 splits architecture. This means that there will be two PON networks. The implication is that 1 to 32 eNB will be in one network and 33 to 64 in the second network. Hence, OLT –Splitter region of each of the PON networks will have a total capacity of 80Gbit/s. The network will constitute 2 x 80Gbit/s which still give 160Gbit/s.

Implementing two network architecture of 1:32 split, capacity of each is 80Gbit/s, hence equation 3.10 becomes

$6.25\text{ps} \times 2 = 12.5 \times 10^{-12}\text{ s}$ (3.11)

But maximum tolerable pulse spread to avoid dispersion is τ_{max}

$\tau_{max} = 0.25T$ (3.12)

From equation 3.11, T = bit period = 12.5×10^{-12} s

Hence, $\tau_{max} = 0.25T = 0.25 \times 12.5 \times 10^{-12} = 3.125 \times 10^{-12}$s (3.13)

For Chromatic dispersion, maximum allowable pulse spread is given as
$\tau_{max} = D \cdot L_{max} \Delta\lambda$ (3.14)

Where D = chromatic dispersion coefficient taken as 16ps/km.nm

L_{max} is the max dispersion link length

$\Delta\lambda$ is the line width = 0.1nm

Therefore, $\tau_{max} = 16\text{ps/km.nm} \times L_{max} \times 0.1\text{nm} = 1.6\text{ps } L_{max}$ (3.15)

But from equation 3.13, $\tau_{max} = 3.125 \times 10^{-12}$s .

Comparing equations 3.13 and 3.15,

$$\text{Lmax} = \frac{3.125\text{ps}}{1.6\text{ps}} = 1.953\text{km} \quad (3.16)$$

From equation 3.16, it is clear that dispersion may likely set in immediately a length of 1.953km is achieved. To compensate for the likely dispersion, the following calculations are carried out:

$\tau_{max} = D_c L_{max} \Delta\lambda$ (3.17)

Where Lmax is the max length of dispersion compensation fibre needed

$\Delta\lambda$ is the line width = 0.1nm

D_c is Dispersion compensation coefficient (-80ps/km.nm is obtained from software, Optisystem)

To obtain the length of dispersion compensation fibre, maximum allowable pulse spread for both chromatic dispersion and dispersion compensation equations are compared. In doing that, equations 3.14 and 3.17 are compared as shown in equation 3.18;

$$D L_{max} \Delta\lambda = D_c L_{max} \Delta\lambda \quad (3.18)$$

Substituting values for equation 3.18,

16ps/km.nm x 1.953km x 0.1nm = -80ps/km.nm x L_{max} x 0.1nm

$$Lmax = \frac{3.1248}{-8} = - 0.3906km \quad (3.19)$$

Equation 3.19 shows that a dispersion compensation fibre (DCF) of length 0.3906 km, approximately 0.4km will be needed to compensate for the dispersion in the downstream; the minus sign in equation 3.19 indicates that it is a compensation length.

For Upstream, link capacity is 160Gbit/s (2.5Gbit/s into 64 places)

Since both directions are of the same capacity, 160Gbit/s, the same calculations/ procedures is adopted as in the downstream. Hence;

Length affected by dispersion is 1.953km

Length of DCF needed to compensate for dispersion in the upstream is 0.3906km = 0.4km

3.6 POWER BUDGET CALCULATION

Fibre optics is categorized into classes (Class A, B, B+, C and C+) based on the power budget. Different PON deployment ways are classified into these optics classes based on the split rations and power budget. In white paper presented by ADC telecommunications (ADC, 2006), BPON with maximum split ratio of 32 is classified as Class A, B and C optics if the power budget is 20dB, 25dB and 30dB respectively. GPON with maximum logical split ratio 64 is as well classified into class A, B, B+ and C optics when the power budget is 20dB,

25dB, 28dB and 30dB respectively. In a related work, Calix user group in their conference (Calix, 2016) **,** presented an article that classifies PON and their maximum power budget as class A, class B, class B+, class C and class C+ to 20dB, 25dB, 28dB, 30dB and 32dB respectively. This research adopts class C+ according to (Calix, 2016) for its power budget calculations.

Despite the classes, optical link budgets sometimes are determined by the operator's active components like lasers, receivers and PON chips. Other factor that could contribute to the budget is the kind of protection mechanism employed. The power budget calculations for this work are done in two parts; Downstream and upstream budgets.

In (Peter Ball, 2010) commercially available single mode connectors have losses in the range of less than 0.5dB; splice loss for a single mode fibre is 0.1dB. From National Electrical Contractors association in (Neca, 2016), splice loss for single mode fibre is 0.1dB and in (Transition networks, 2003), a typical distance between two splices is 6km, also minimum value for safety margin is usually from 3dB (vary based on design). Since a typical distance between two splices is 6km; the design will have three splicing (worst case) according to the fibre length for each OLT-ONU distances as obtained in table 3.7.

Table 3.9: Expected losses per component in the system

Components Losses	**Quantity**	**Values (dB)**
Splice	3 x 0.1	0.3
Connectors with insertion loss from OLT, ONU and Switch	(each 0.5dB)	0.5dB each
Fibre Attenuation @ 1560 or 1310	Length x attenuation 0.25dB/km at 1550nm and 0.3dB/km at 1310 nm	
WDM Mux/Dmux	(8x1)/(1x8)	< or = 3.5dB
Margin Power Splitter/Combiner	Protection and other Loss 1 x 4/4 x1	Variable 6.8dB per OLT-ONU pair
DCF attenuation	0.6dB/km	

Table 3.9 shows the expected losses in the system. The design is expected to have connector losses at OLT, ONU, WDM mux, WDM demux, Power Splitter, fibre ends, DCF ends and switch (Switch will be used to transfer transmissions to the protection link in the events of failure), Since a common OLT transmit power is required, variable margin will be used to maintain a common transmit power for each OLT-ONU pair. Margin of (varying values) dB is also used in an event of unaccounted losses and losses from the protection scheme that will be adopted. A maximum loss of 32dB is specified by ITU-T for class C+ optics.

3.6.1 CALCULATING FOR DOWNSTREAM POWER BUDGET

In this backhaul design, the link is 160Gbit/s (2x80Gbit/s) PON network (from the OLT to Splitter). To achieve 80Gbit/s, eight of 10Gibt/s PON is used and 8 x1 multiplexer combines the 8 X 10Gbits. A switch is also used to transfer the traffics in the active link to the protection link when there is fault. These losses from these components were accounted for in the power budget calculations. The losses from each of these equipment are as shown below;

i Connection loss from eight 10Gbit/s OLT = 0.5 x 8 = 4dB (need 80Gbit/s)

ii Connection loss from switch = 0.5dB

iii Connection loss from the ONU =0.5dB

iv Insertion loss from 1 x 8 WDM demultiplexer = 3.5dB

v Insertion loss from 8 x 1 WDM multiplexer = 3.5dB

vi 1x 4 splitter insertion loss = 6.8dB

vii Attenuation at 1550nm =0.25 x fibre length

viii Attenuation at 1310nm = 0.3 x fibre length

ix Attenuation of DCF = 0.6 x DCF length

x Splice loss = 0.1dB

xi Margin = Variable

From the proposed network diagram shown in figure 3.38 (see page 108), outside connection losses due to i, ii and iii above, the network has additional 4 connections in between and that made up a 2dB loss. Total loss due to connections is 4+0.5+0.5+2 = 7dB. Since the losses in the system is established, the transmit power of the OLT in the downstream direction can also be obtained. Equation 3.20 is PON power budget formula used for the OLT transmit power calculation in the downstream direction.

OLT Tx – ONU Rx = {atten x fibre length + atten x DCF length + WDM mux loss + WDM demux loss + Splitter loss + connector losses + splice losses + Margin} (3.20)

Where OLT Tx = OLT transmit Power

ONU Rx = ONU receiver sensitivity

atten x fibre length = loss due to length of fibre cable

atten x DCF length = loss due to dispersion compensation fibre

WDM mux loss = insertion loss due to WDM multiplexer

WDM demux loss = insertion loss due to WDM demultiplexer

Connector losses = losses accrued due to connectors

Splice losses = losses accrued due to splicing

Margin = varying value of loss in the system that will take care for unaccounted losses and as such keep all OLT Tx and all ONU Rx value constant on every OLT-ONU pair

Parameters:

i) Attenuation at 1550nm downstream is 0.25dB/km

ii) Maximum loss for class C+ is 32dB as specified by ITU –T

iii) In downstream, OLT Tx is usually from 3 - 7dBm and ONU Rx is -32dBm maximum while in upstream direction, ONU Tx is always from 0.5 – 5 dBm and OLT Rx is -30dBm worst case.

OLT - ONU1 pair calculation is as shown;

Fibre length = (4.8 +1.4) km = 6.2km (see table 3.7) (3.21)

Attenuation per length = 0.25 x 6.2 = 1.5dB/km (3.22)

Loss due to DCF, atten x DCF length (see eqn 3.19) = 0.6 x 0.4km = 0.24dB/km (3.23)

Loss due to connectors = 4+0.5+0.5+2 = 7dB (3.24)

Loss due to splicing (3 possible splicing) = 0.1x 3 = 0.3dB (3.25)

Insertion loss due to WDM mux =3.5dB

Insertion loss due to WDM demux = 3.5dB

Insertion loss due to 1 x 4 Splitter = 6.8dB

Margin = unknown (varies)

From equation 3.20,

OLT Tx – ONU Rx = (1.5dB/km+0.24dB/km+3.5dB+3.5dB+6.8dB+7dB+0.3dB+M)

OLT Tx – ONU Rx = (22.84+M)dB

Hence, total loss; 32 = 22.84 + M (3.26)

M = 32 – 22.84 = 9.16dB (margin for OLT –ONU1 pair)

Assuming the lowest OLT Tx power (3dBm) for class C+ optics is adopted, OLT Tx power becomes 3dBm

Hence, equation 3.20 becomes 3 – (ONU1 Rx) =22.84+M

ONU1 Rx = -29dBm

The procedure for obtaining the losses, margin and ONU Rx for each OLT Tx - ONU Rx pair as described above is repeated for all the 60 OLT Tx – ONU Rx pairs using spreadsheet and the result is shown in table 3.10. Margin is used to maintain constant losses for all the 60 OLT –ONU pair

Table 3.10: Downstream Power Budget

S/N	OLT TX (dBm)	ONU RX (dBm)	FIBRE LTH (km)	ATTN (db/km)	FIBRE ATTN (db/km)	DCF LTH (km)	ATTN (db/km)	DCF ATTN (db/km)	WDM MUX LOSS (dB)	WDM DEMUX LOSS (dB)	SPT. LOSS (dB)	CONNT. LOSS (dB)	SPL. LOSS (dB)	MARGIN (dB)
eNB1	3	-29	6.2	0.25	1.55	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	9.11
eNB2	3	-29	12.6	0.25	3.15	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.51
eNB3	3	-29	10.4	0.25	2.6	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.06
eNB4	3	-29	14.9	0.25	3.725	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.935
eNB5	3	-29	12.5	0.25	3.125	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.535
eNB6	3	-29	14.5	0.25	3.625	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.035
eNB7	3	-29	18.6	0.25	4.65	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.01
eNB8	3	-29	28.5	0.25	7.125	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.535
eNB9	3	-29	10.8	0.25	2.7	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.96
eNB10	3	-29	19.1	0.25	4.775	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.885
eNB11	3	-29	10.7	0.25	2.675	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.985
eNB12	3	-29	12.1	0.25	3.025	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.635
eNB13	3	-29	11.3	0.25	2.825	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.835
eNB14	3	-29	11.9	0.25	2.975	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.685
eNB15	3	-29	16.9	0.25	4.225	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.435
eNB16	3	-29	9.8	0.25	2.45	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.21
eNB17	3	-29	23.8	0.25	5.95	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.71
eNB18	3	-29	12.9	0.25	3.225	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.435
eNB19	3	-29	10.8	0.25	2.7	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.96
eNB20	3	-29	9.6	0.25	2.4	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.26
eNB21	3	-29	8.6	0.25	2.15	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.51
eNB22	3	-29	11.9	0.25	2.975	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.685
eNB23	3	-29	13.7	0.25	3.425	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.235
eNB24	3	-29	21.3	0.25	5.325	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.335
eNB25	3	-29	8.8	0.25	2.2	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.46
eNB26	3	-29	12.6	0.25	3.15	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.51
eNB27	3	-29	9.6	0.25	2.4	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.26
eNB28	3	-29	16	0.25	4	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.66
eNB29	3	-29	28.3	0.25	7.075	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.585
eNB30	3	-29	28.9	0.25	7.225	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.435
eNB31	3	-29	21.8	0.25	5.45	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.21
eNB32	3	-29	25.2	0.25	6.3	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.36
eNB33	3	-29	5.35	0.25	1.3375	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	9.3225

eNB34	3	-29	7.4	0.25	1.85	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.81
eNB35	3	-29	19.1	0.25	4.775	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.885
eNB36	3	-29	13.1	0.25	3.275	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.385
eNB37	3	-29	13.5	0.25	3.375	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.285
eNB38	3	-29	7.9	0.25	1.975	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.685
eNB39	3	-29	13.9	0.25	3.475	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.185
eNB40	3	-29	12.6	0.25	3.15	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.51
eNB41	3	-29	11.7	0.25	2.925	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.735
eNB42	3	-29	7	0.25	1.75	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.91
eNB43	3	-29	22.6	0.25	5.65	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.01
eNB44	3	-29	10.6	0.25	2.65	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.01
eNB45	3	-29	15	0.25	3.75	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.91
eNB46	3	-29	21.8	0.25	5.45	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.21
eNB47	3	-29	23.3	0.25	5.825	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.835
eNB48	3	-29	16.8	0.25	4.2	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.46
eNB49	3	-29	9.2	0.25	2.3	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.36
eNB50	3	-29	10.3	0.25	2.575	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.085
eNB51	3	-29	14.3	0.25	3.575	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.085
eNB52	3	-29	9	0.25	2.25	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.41
eNB53	3	-29	8.6	0.25	2.15	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.51
eNB54	3	-29	30.2	0.25	7.55	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.11
eNB55	3	-29	11	0.25	2.75	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.91
eNB56	3	-29	11.9	0.25	2.975	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.685
eNB57	3	-29	14.6	0.25	3.65	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.01
eNB58	3	-29	10.9	0.25	2.725	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.935
eNB59	3	-29	6.6	0.25	1.65	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	9.01

The margin is varied in each case to maintain the same loss for the entire OLT – ONU pairs and as such to maintain constant ONU Rx for each. The range of values for the margin is 3.11–9.32dB.

3.6.2 CALCULATING FOR UPSTREAM POWER BUDGET

Calculating for upstream, equation 3.20 is adopted, it is shown below

ONU Tx – OLT Rx = {atten x fibre length + atten x DCF length + WDM mux loss + WDM demux loss + combiner loss + connector losses + splice losses + Margin}

In this case, eNBs (ONUs) are transmitting and the power splitter is replaced by combiners.

Attenuation coefficient at 1310nm window is used and it is 0.3dB/km. Fibre lengths as shown in table 3.7 are used and a worst case OLT Rx (-30dBm) for class C+ optics is adopted.

ONU1 Tx- OLT Rx pair calculation is as shown;

Fibre length = (4.8 +1.4) km = 6.2km (see table 3.7)

Attenuation per length = 0.3 x 6.2 = 1.86dB/km (3.27)

Loss due to DCF, atten x DCF length (see eqn 3.19) = 0.6 x 0.4km = 0.24dB/km

Loss due to connection = 4+0.5+0.5+2 = 7dB

Loss due to splicing (3 possible splicing) = 0.1x 3 = 0.3dB

Insertion loss due to WDM mux =3.5dB

Insertion loss due to WDM demux = 3.5dB

Insertion loss due to 4 x 1 Combiner = 6.8dB

Margin = unknown (varies)

From equation 3.20,

ONU1 Tx – OLT Rx = (1.86dB/km+0.24dB/km+3.5dB+3.5dB+6.8dB+7dB+0.3dB+M)

ONU1 Tx – OLT Rx = (23.2+M)

If a total loss of 32 is adopted because class C+ optics is considered,

M =32-23.2 = 8.8dB

Assuming worst probable OLT Rx (sensitivity) for class C+ optics is adopted, OLT Rx power becomes -30dBm.

ONU1 Tx – (-30dBm) = 32dB (23.2+8.8)

ONU1 Tx = 2dBm

The procedure for obtaining the losses, margin and ONU Tx for each ONU Tx - OLT Rx pair as described above is repeated for all the 59 ONU Tx - OLT Rx pairs using spreadsheet and

the result is shown in table 3.11. Margin is used to maintain constant losses for all the 59 OLT –ONU pair

Table 3.11: Upstream Power Budget

S/N	ONU TX (dBm)	OLT RX (dBm)	FIBRE LTH (km)	ATTN (dB/km)	FIBRE ATTN (dB/km)	DCF LTH (km)	ATTN (dB/km)	DCF ATTN (dB/km)	WDM MUX LOSS (dB)	WDM DEMUX LOSS (dB)	SP.T LOSS (dB)	CONNT. LOSS (dB)	SPL. LOSS (dB)	MARGIN (dB)
eNB1	2	-30	6.2	0.3	1.86	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.8
eNB2	2	-30	12.6	0.3	3.78	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.88
eNB3	2	-30	10.4	0.3	3.12	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.54
eNB4	2	-30	14.9	0.3	4.47	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.19
eNB5	2	-30	12.5	0.3	3.75	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.91
eNB6	2	-30	14.5	0.3	4.35	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.31
eNB7	2	-30	18.6	0.3	5.58	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.08
eNB8	2	-30	28.5	0.3	8.55	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	2.11
eNB9	2	-30	10.8	0.3	3.24	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.42
eNB10	2	-30	19.1	0.3	5.73	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.93
eNB11	2	-30	10.7	0.3	3.21	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.45
eNB12	2	-30	12.1	0.3	3.63	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.03
eNB13	2	-30	11.3	0.3	3.39	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.27
eNB14	2	-30	11.9	0.3	3.57	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.09
eNB15	2	-30	16.9	0.3	5.07	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.59
eNB16	2	-30	9.8	0.3	2.94	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.72
eNB17	2	-30	23.8	0.3	7.14	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.52
eNB18	2	-30	12.9	0.3	3.87	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.79
eNB19	2	-30	10.8	0.3	3.24	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.42
eNB20	2	-30	9.6	0.3	2.88	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.78
eNB21	2	-30	8.6	0.3	2.58	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.08
eNB22	2	-30	11.9	0.3	3.57	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.09
eNB23	2	-30	13.7	0.3	4.11	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.55
eNB24	2	-30	21.3	0.3	6.39	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.27
eNB25	2	-30	8.8	0.3	2.64	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.02
eNB26	2	-30	12.6	0.3	3.78	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.88
eNB27	2	-30	9.6	0.3	2.88	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.78
eNB28	2	-30	16	0.3	4.8	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.86
eNB29	2	-30	28.3	0.3	8.49	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	2.17
eNB30	2	-30	28.9	0.3	8.67	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	1.99
eNB31	2	-30	21.8	0.3	6.54	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.12
eNB32	2	-30	25.2	0.3	7.56	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.1
eNB33	2	-30	5.35	0.3	1.605	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	9.055
eNB34	2	-30	7.4	0.3	2.22	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.44
eNB35	2	-30	19.1	0.3	5.73	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.93
eNB36	2	-30	13.1	0.3	3.93	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.73
eNB37	2	-30	13.5	0.3	4.05	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.61
eNB38	2	-30	7.9	0.3	2.37	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.29

eNB39	2	-30	13.9	0.3	4.17	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.49
eNB40	2	-30	12.6	0.3	3.78	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.88
eNB41	2	-30	11.7	0.3	3.51	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.15
eNB42	2	-30	7	0.3	2.1	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.56
eNB43	2	-30	22.6	0.3	6.78	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.88
eNB44	2	-30	10.6	0.3	3.18	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.48
eNB45	2	-30	15	0.3	4.5	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.16
eNB46	2	-30	21.8	0.3	6.54	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	4.12
eNB47	2	-30	23.3	0.3	6.99	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	3.67
eNB48	2	-30	16.8	0.3	5.04	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	5.62
eNB49	2	-30	9.2	0.3	2.76	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.9
eNB50	2	-30	10.3	0.3	3.09	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.57
eNB51	2	-30	14.3	0.3	4.29	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.37
eNB52	2	-30	9	0.3	2.7	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.96
eNB53	2	-30	8.6	0.3	2.58	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.08
eNB54	2	-30	30.2	0.3	9.06	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	1.6
eNB55	2	-30	11	0.3	3.3	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.36
eNB56	2	-30	11.9	0.3	3.57	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.09
eNB57	2	-30	14.6	0.3	4.38	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	6.28
eNB58	2	-30	10.9	0.3	3.27	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	7.39
eNB59	2	-30	6.6	0.3	1.98	0.4	0.6	0.24	3.5	3.5	6.8	7	0.3	8.68

The margin is also varied in each case to maintain the same loss for the entire OLT – ONU pairs and as such to maintain constant ONU Tx for each. The range of values for the margin is 1.60 – 9.055 dB

3.6.3 RANGING DELAY

This design has both WDM and TDM PON arrangement and hence, it is called a Hybrid PON Network. In TDM-PON arrangement, each ONU transmit its signal to the OLT at different time slot since different ONUs are located differently from the OLT. Signals/data coming from this separately located ONUs experience different propagation delays on getting to the OLT. It became imperative that a timing reference is established to take care of these delays. This enables the OLT to receive the signals from each ONU at the expected time, thus avoid possible collision from another ONU that is supposed to transmit at the next time slot irrespective of its distance from the OLT. Figure 3.21 shows that ONUn has farthest distance to the OLT and if ONUn starts transmission at its allocated time slot, ONU1 that has the

shortest distance to the OLT may likely experience collision with ONUn irrespective of fact that they have different transmission time slots.

To avoid this possible collisions, ranging delay is computed based on each ONU's respective distance to the splitter.

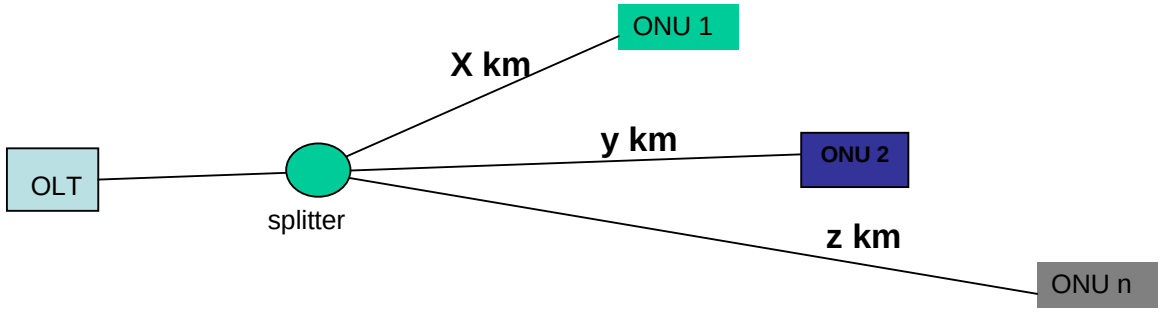


Figure 3.21: ONUs with different Distances to the Splitter

This design assumes a fibre with a refractive index (n) of 1.5 and speed of light 3E8km/s

Ranging delay D $= \frac{X-Y}{2E8}$ (3.28)

Where X = Farthest eNB

Y = eNB under consideration,

2E8 = V= Velocity of light

But $V = \frac{C}{n} = \frac{3E8}{1.5} = 2E8$ (3.29)

Considering farthest eNB and eNB0 (exchange) and Substituting their distances to equation 3.28, D is obtained as follows:

D $= \frac{25.4-4.8}{2E8}$ = 20.6 /2E8 = 1.03E-7 s

From table 3.7, eNB54 has the farthest distance to the Splitter while eNB33 has the shortest distance to the splitter. A distance separating the farthest and each other eNB is established in each row of the fourth column of table 3.12. For the exchange (eNB0), the distance between the farthest eNB (eNB54) and eNB0 is 20.6km (25.4 – 4.8) km. The same procedure was followed to obtain the values in columns 4 and 5 of table 3.12.

Table 3.12: Delay distribution for all the eNB

S/N	IDENTITIES	eNBs FIBRE LENGTH (km)	DISTANCE BTW FARTHEST eNB and EACH eNB	RANGING DELAY (s)
0	Exchange	4.80	20.60	1.03E-07
1	eNB1	1.40	24.00	1.20E-07
2	eNB2	7.80	17.60	8.80E-08
3	eNB3	5.60	19.80	9.90E-08
4	eNB4	10.10	15.30	7.65E-08
5	eNB5	7.70	17.70	8.85E-08
6	eNB6	9.70	15.70	7.85E-08
7	eNB7	13.80	11.60	5.80E-08
8	eNB8	23.70	1.70	8.50E-09
9	eNB9	6.00	19.40	9.70E-08
10	eNB10	14.30	11.10	5.55E-08
11	eNB11	5.90	19.50	9.75E-08
12	eNB12	7.30	18.10	9.05E-08
13	eNB13	6.50	18.90	9.45E-08
14	eNB14	7.10	18.30	9.15E-08
15	eNB15	12.10	13.30	6.65E-08
16	eNB16	5.00	20.40	1.02E-07
17	eNB17	19.00	6.40	3.20E-08
18	eNB18	8.10	17.30	8.65E-08
19	eNB19	6.00	19.40	9.70E-08
20	eNB20	4.80	20.60	1.03E-07
21	eNB21	3.80	21.60	1.08E-07
22	eNB22	7.10	18.30	9.15E-08
23	eNB23	8.90	16.50	8.25E-08
24	eNB24	16.50	8.90	4.45E-08
25	eNB25	4.00	21.40	1.07E-07
26	eNB26	7.80	17.60	8.80E-08
27	eNB27	4.80	20.60	1.03E-07
28	eNB28	11.20	14.20	7.10E-08
29	eNB29	23.50	1.90	9.50E-09
30	eNB30	24.10	1.30	6.50E-09
31	eNB31	17.00	8.40	4.20E-08
32	eNB32	20.40	5.00	2.50E-08

33	eNB33	0.55	24.85	1.24E-07
34	eNB34	2.60	22.80	1.14E-07
35	eNB35	14.30	11.10	5.55E-08
36	eNB36	8.30	17.10	8.55E-08
37	eNB37	8.70	16.70	8.35E-08
38	eNB38	3.10	22.30	1.12E-07
39	eNB39	9.10	16.30	8.15E-08
40	eNB40	7.80	17.60	8.80E-08
41	eNB41	6.90	18.50	9.25E-08
42	eNB42	2.20	23.20	1.16E-07
43	eNB43	17.80	7.60	3.80E-08
44	eNB44	5.80	19.60	9.80E-08
45	eNB45	10.20	15.20	7.60E-08
46	eNB46	17.00	8.40	4.20E-08
47	eNB47	18.50	6.90	3.45E-08
48	eNB48	12.00	13.40	6.70E-08
49	eNB49	4.40	21.00	1.05E-07
50	eNB50	5.50	19.90	9.95E-08
51	eNB51	9.50	15.90	7.95E-08
52	eNB52	4.20	21.20	1.06E-07
53	eNB53	3.80	21.60	1.08E-07
54	eNB54	25.40	0.00	0.00E+00
55	eNB55	6.20	19.20	9.60E-08
56	eNB56	7.10	18.30	9.15E-08
57	eNB57	9.80	15.60	7.80E-08
58	eNB58	6.10	19.30	9.65E-08
59	eNB59	1.80	23.60	1.18E-07

3.7 SIMULATION/VALIDATION OF THE NETWORK DESIGN

This section discusses the validation/simulation of PON backhaul for SMILE 4G LTE network Portharcourt. The simulation is carried out using Optisystem simulation tool and various components like Transmitter section, WDM section, Channel /fibre link and the receiver section of the design will be integrated and simulated with the view to demonstrate the Bit Error Rate (BER), Quality factor (Q-factor), etc of each eNB in the network.

3.7.1 OPTISYSTEM SOFTWARE

Optisystem is computer based simulation software that is very useful in many mathematical and computational modeling for many natural systems and process of engineering

technologies. It is particularly very useful in Optical communication analysis and designs; hence, it is an innovative optical communication systems simulation package saddled with the responsibilities of designing, testing and optimizations of almost all types of optical link in the physical layer.

In this work, Optisystem simulation software was used to demonstrate in a virtual environment what was designed in the previous objectives.

3.7.2 TRANSMISSION SECTIONS ANALYSIS

This section briefly explained the simulation set up. Due to the bulky nature of the design, it is divided into downstream and upstream transmission sections.

3.7.3 DOWNSTREAM TRANSMISSION SECTION

In the downstream section of the transmission, there is transmitter, WDM/splitter, Channel/fibre link, receiver sections. The work takes turn to explain each of the sections starting with the transmitter.

3.7.3.1 TRANSMITTER SECTION

The transmitter is made up of four units:

i) Pseudo Random Bit Sequence Generator (PRBS)

ii) Non – Return -to- Zero (NRZ) Pulse Generator

iii) Light Amplification by Stimulated Emission of Radiation (LASER) Diode

iv) Mach-Zehnder Modulator (MZM)

The data source produces pseudo random bit sequence which represents the information to be transmitted, followed in the section is the NRZ pulse generator which converts binary data into electrical pulses. Third in this section is the Laser, it could also be Light emitting diode (LED) or Vertical cavity surface emitting laser (VCSEL) depending on what is intended to achieve. Any of the sources uses wavelength of either 850nm, 1300nm or 1550 nm infrared

band. Mach-Zehnder modulator (MZM) is the last in the section and it is used to vary the intensity of the light source from the laser in accordance to the NRZ pulse generator output. Figure 3.22 shows the block diagram of the transmitter unit.

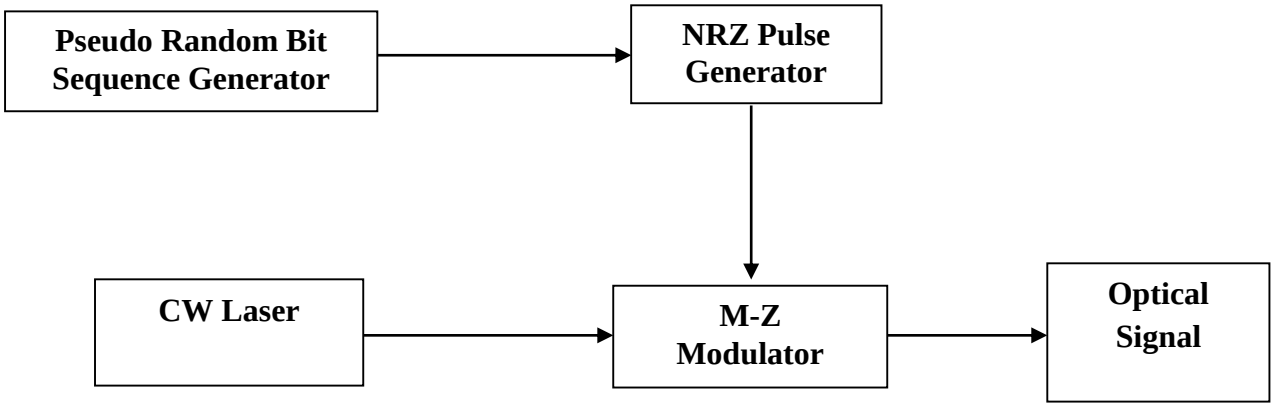


Figure 3.22: Block diagram of Transmitter section

From sections 3.4 through 3.5, the required bit rate is 80GB/s for segment A, then there is 10GB/s on each pseudo random bit sequence generator and 3dBm power is lunched into the laser diode. Each optical signal is allocated a wavelength, its frequency started from 193.1THz through 194.5THz and is spaced 200GHz. Eight of these transmitter units are combined to give 80GB/s in the transmitter section. Figures 3.23 and 3.24 show the optisystem diagram for the transmitter unit and the transmitter section with 8x1 multiplexer respectively.

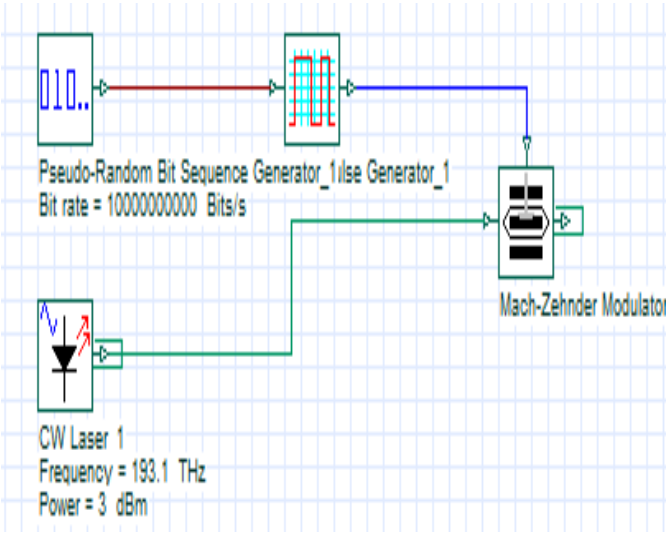


Figure 3.23: Optisystem diagram for the transmitter unit

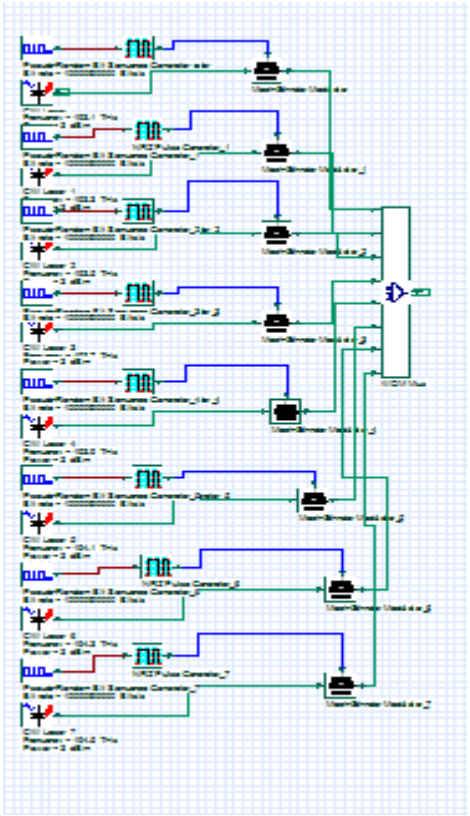


Figure 3.24: Optisystem transmitters with mux

The signals coming out from the 8x1 WDM mux in figure 3.24 (refer to appendix D for clearer image) are allocated dedicated wavelengths, this is displayed in spectrum analyser of figure 3.25

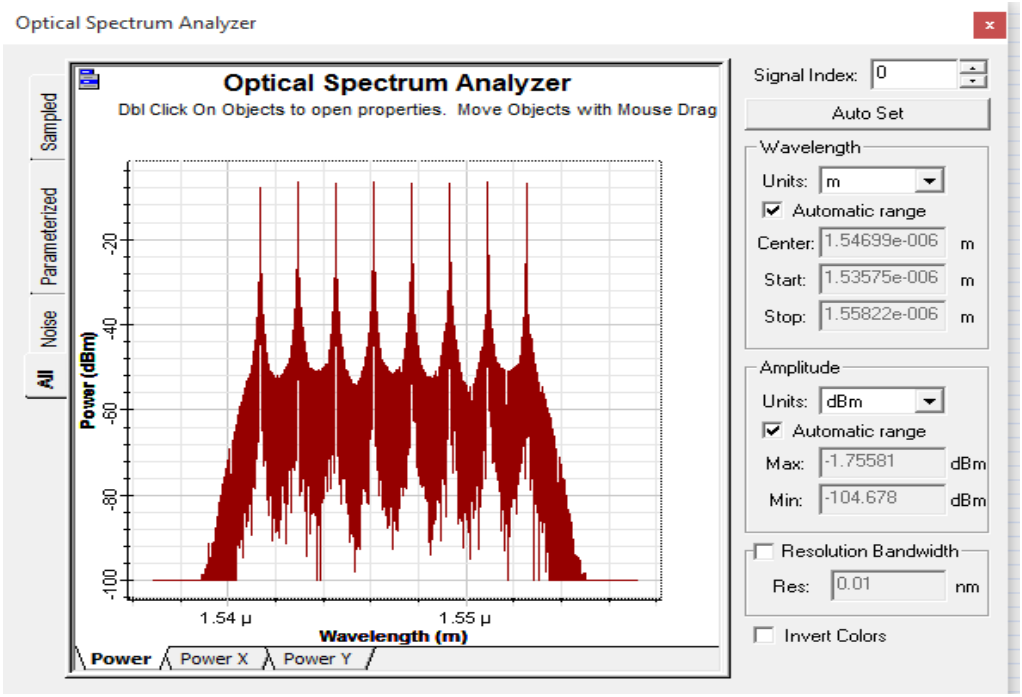


Figure 3.25: Spectrum Analyser

The output of the mux is fed to SMF which is called the channel/fibre link.

3.7.3.2 CHANNEL/FIBRE LINK

The channel in this case is single mode fibre (SMF). The work took time to separate the downstream transmission and the upstream transmission. In each of the transmission directions, SMF is used as the channel. Shared optical fibre length before splitter is 4.8km. Dispersion Compensation Fibre (DCF) was used to compensate for the effect of dispersion in both directions. As stated, attenuation coefficient of 0.25dB was used to multiply each length of fibre in downstream to achieve the recorded attenuation per fibre length measured in dB/km as shown in the downstream power budget of table 3.10

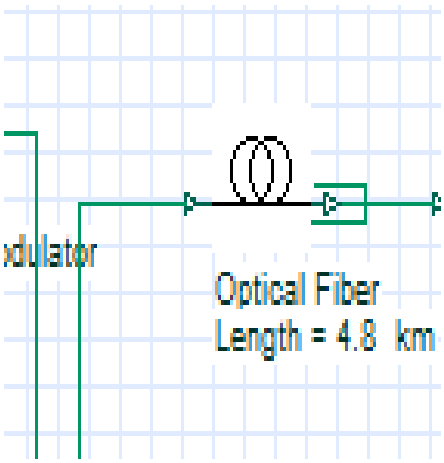


Figure 3.26: Optical fibre with length

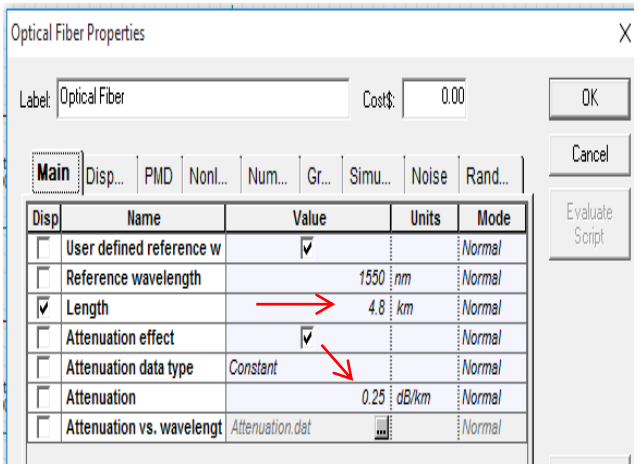


Figure 3.27: Optical fibre properties: attenuation and length

Dispersion could lead to pulse spreading and that could limit transmission distances, a dispersion coefficient of 16ps/km.nm was used for both downstream and upstream directions as could be evidenced in Optisystem image of figure 3.28.

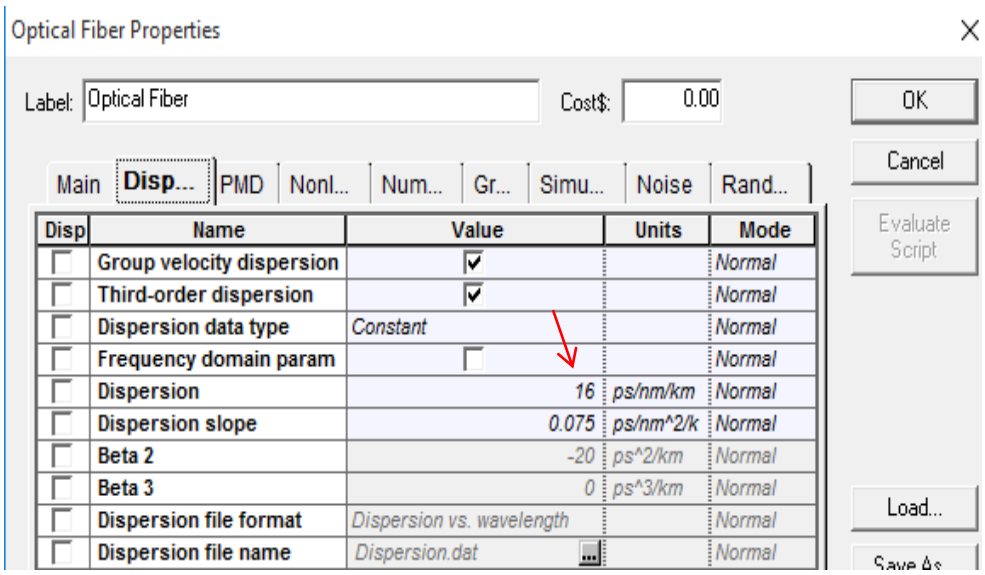


Figure 3.28: Optisystem diagram for dispersion value of 16ps/km.nm

The effect of dispersion was compensated in this design by using a dispersion compensation fibre (DCF) of length 0.4km with attenuation coefficient of 0.6dB. Figure 3.29 showed Optisystem diagram of DCF of length 0.4km and DCF attenuation coefficient of 0.6dB respectively. The DCF has a high dispersion coefficient in the negative domain so as to compensate for the effect of dispersion. Dispersion compensation coefficient of -80ps/km.nm was used as shown in figure 3.30.

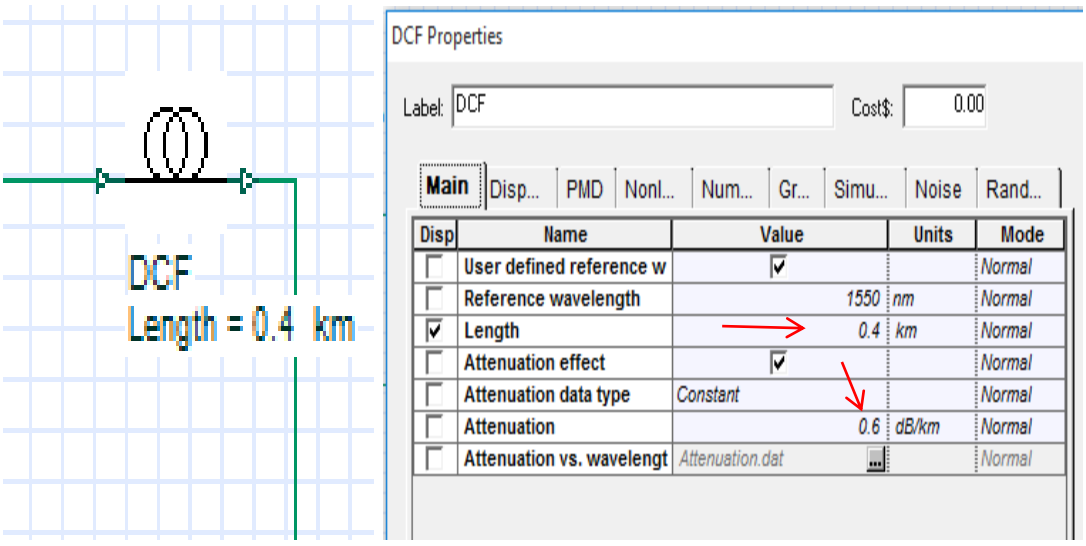


Figure 3.29: DCF of 0.4km and DCF attenuation coefficient of 0.6dB

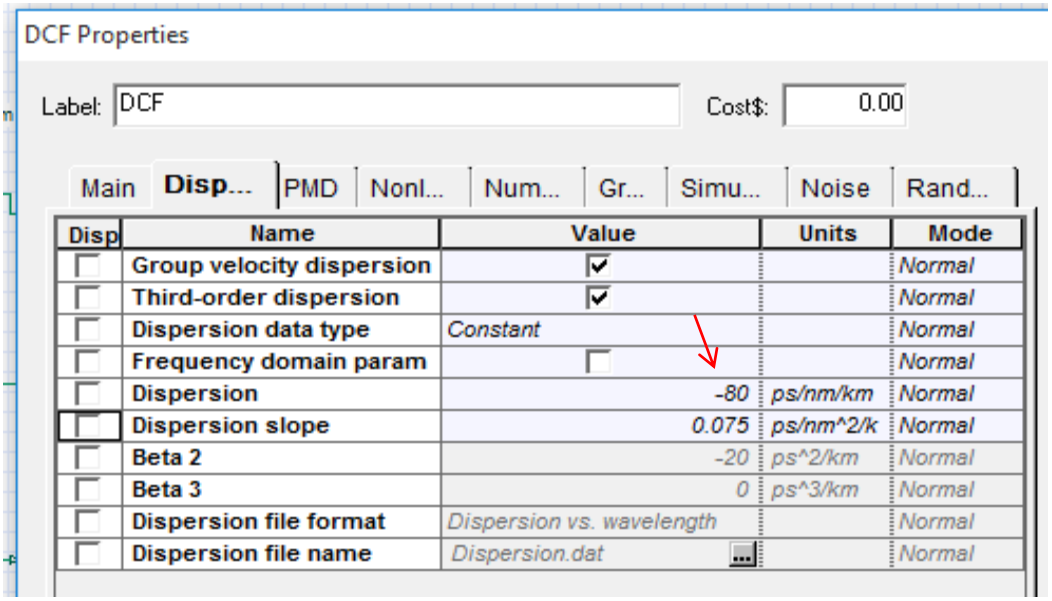


Figure 3.30: DCF dispersion coefficient of -80ps/km.nm

3.7.3.3 WDM/SPLITTER SECTION

The WDM/Splitter section is made up of WDM and Splitter. Some architecture is made up of Arrayed waveguide gratings (AWG) which is also WDM. In some cases, a combination of both WDM and Splitter is used to achieve greater capacity and it is called Hybrid arrangement. The work considers hybrid architecture to achieve an increased capacity. Figure 3.31 shows the WDM/Splitter section of this design.

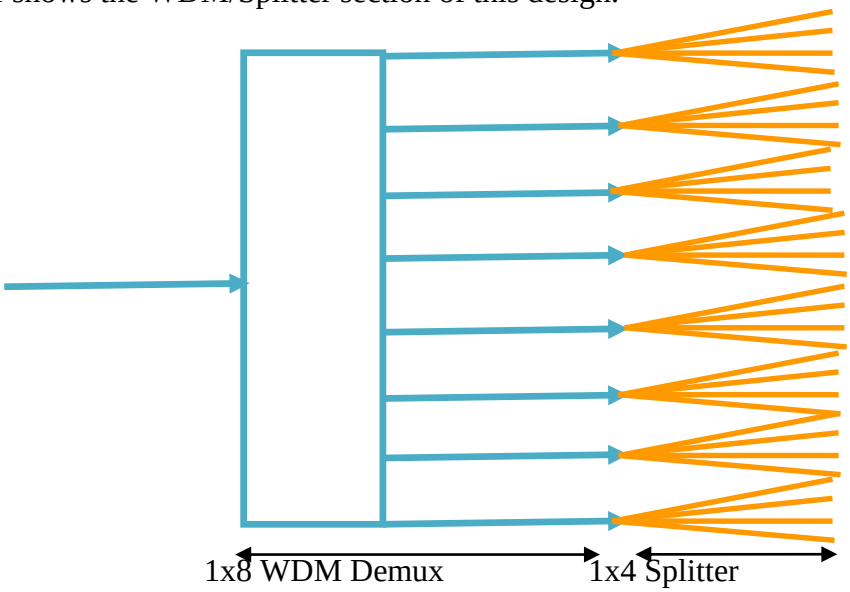


Figure 3.31: Block diagram of WDM/Splitter section

The channel distribution showing the dedicated wavelengths in frequency domain in the WDM demux is shown in figure 3.32. The WDM demux and the optical power splitters used in the design have insertion loss of 3.5dB and 6.8dB respectively. Figure 3.33 and 3.34 show the Optisystem layout of the described losses.

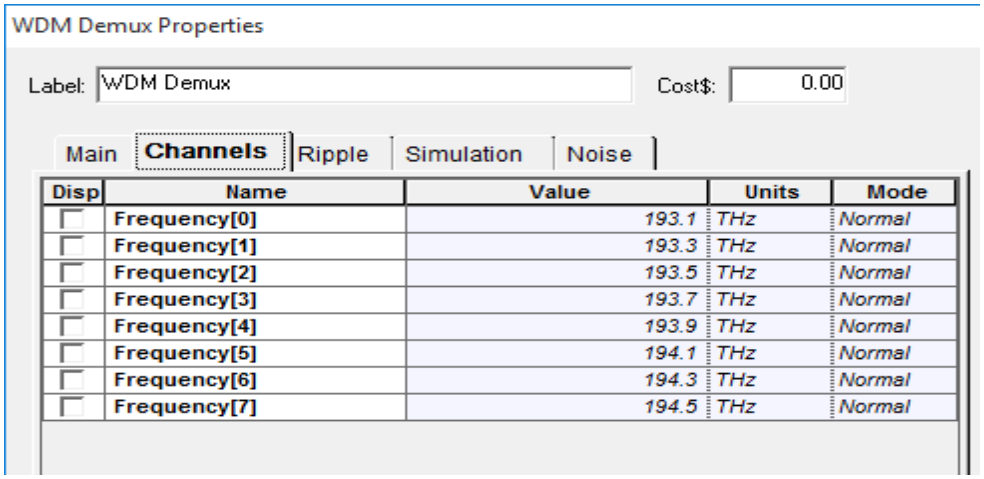


Figure 3.32: WDM demux channel

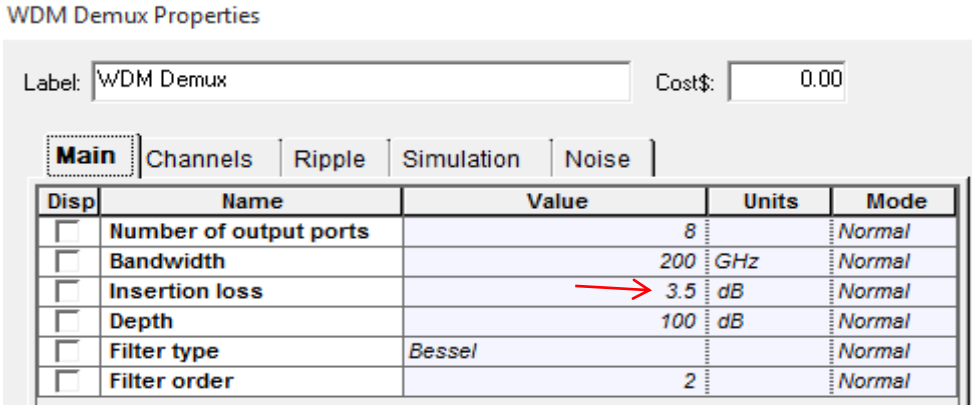


Figure 3.33: WDM mux insertion loss and bandwidth spacing of 200GHz

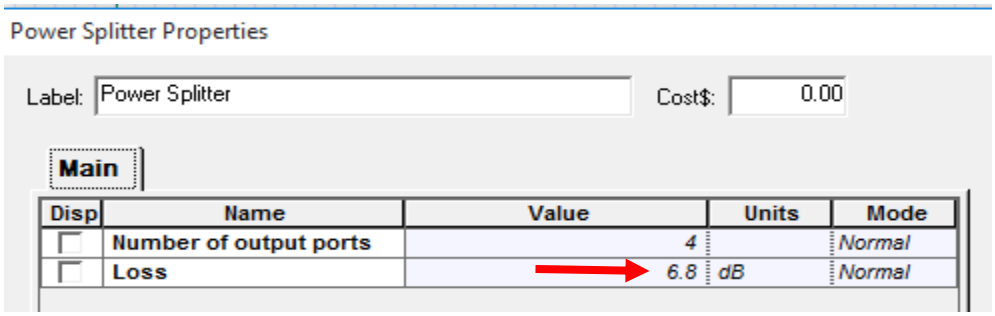


Figure 3.34: Optical splitter insertion loss and number of ports

The output of the WDM mux used in this design consists of eight port numbering ports 1 through 8 and each carries a dedicated wavelength. The signal from each port goes through a 1x4 optical power splitter. Each optical splitter has four output ports. The information coming out from each wavelength of WDM mux is shared in time domain to the four ports of the splitter output.

3.7.3.4 RECEIVER SECTION

The receiver section is made up of Positive Intrinsic Negative diode (PIN), Avalanche photo detector diode (APD) or any diode that produces an electrical signal proportional to the received power level. In some cases, an amplifier is added to take care of attenuation effects by boasting the signal level. Sometimes, regenerators could be used instead of amplifiers, and the job of the regenerator is to boast the signal before being fed to an analyser. Low pass filter separates the noise, also separates wavelengths outside the preferred range. Finally, an integrated signal processing circuit like Bit error rate (BER) analyser is added to analyse the delivered signal. Figure 3.35 shows a block diagram of a typical optical receiver section.

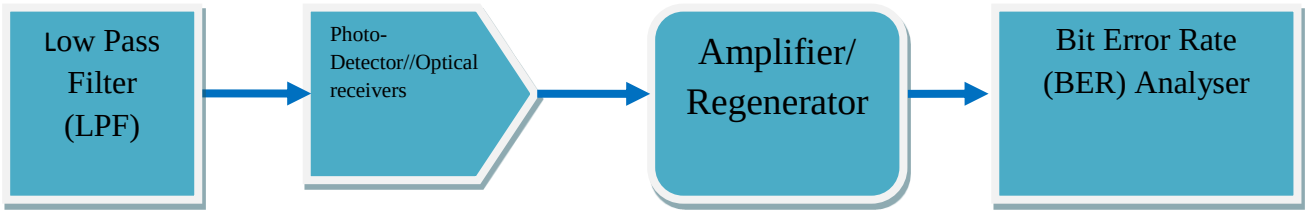


Figure 3.35: Block diagram of optical receiver section

Figure 3.37 shows Optisystem diagram from the receiver section of the work. Low pass filter is used to allow only the desired frequency components at each case. Optical receivers were used. The receiver sensitivity is -29dBm as obtained from the system downstream power budget of table 3.10. Amplifier or regenerators were not used since all loses were accounted

for in the power budget. Figures 3.36 and 3.37 show the frequency allocation in low pass filter and receiver sensitivity of the optical receiver respectively.

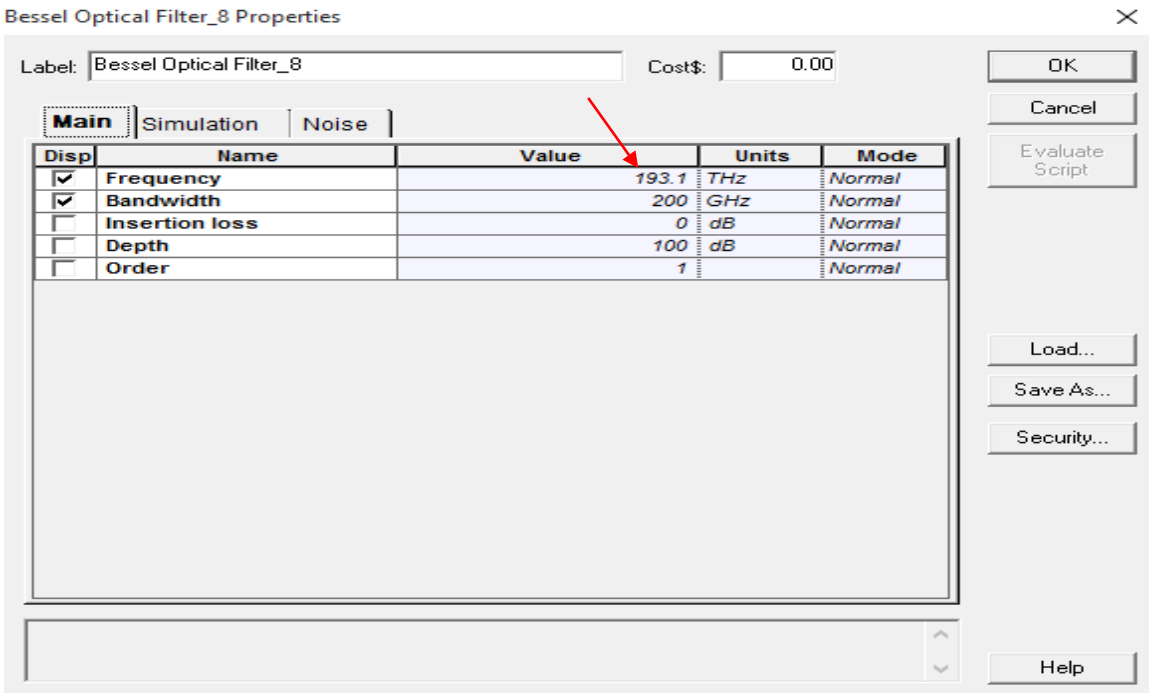


Figure 3.36: Low pass filter showing frequency of 193.1THz.

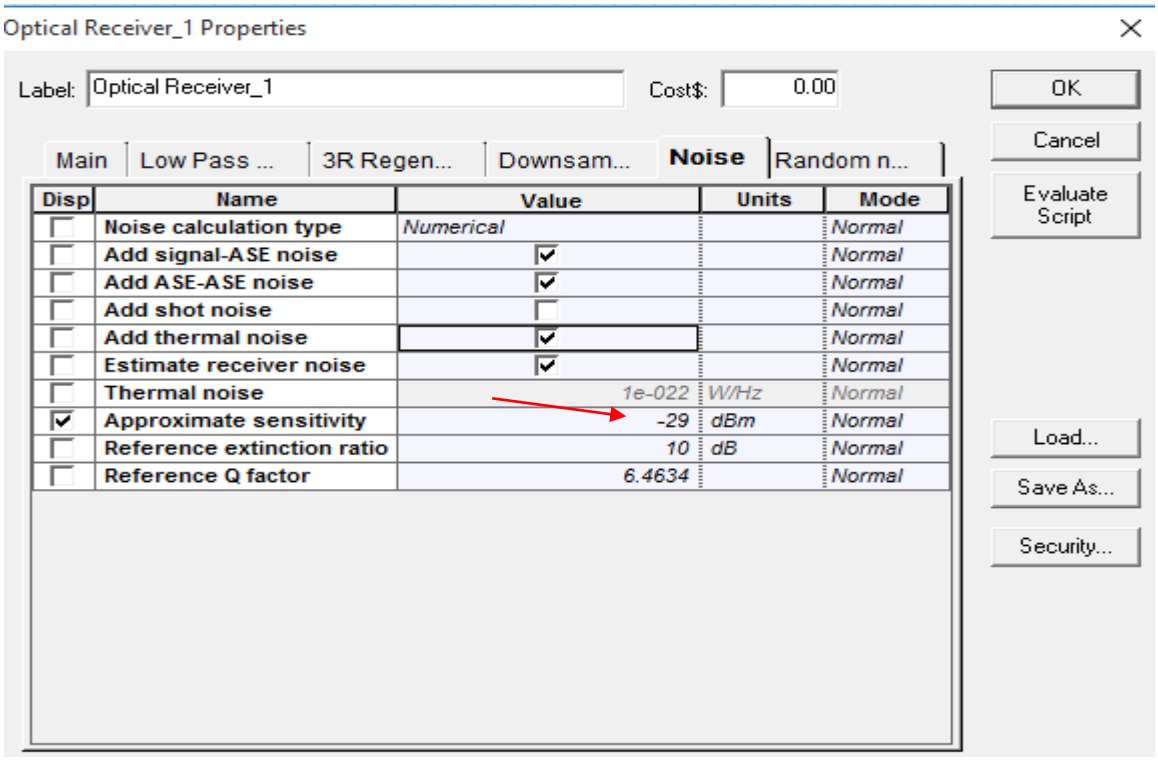


Figure 3.37: Receiver sensitivity of the optical receiver.

Integration of Transmitter, Channel/fibre link, WDM/splitter and receiver sections make up the network. Figures 3.38 and 3.39 gave a block view of all the sections put together in both segments A and B respectively. The exchange/switch houses the OLT (eNB0) and the OLT in turn accommodates the transmitter section, the splitter is seen to represent the spot after the shared fibre, it could be WDM or optical power splitter that distributes/multicasts the signal down to each ONU in the downstream direction. Each ONU represents eNB and BER analyser indicates among other things the bit error rate, Q factor per OLT-ONU pair. Block diagram showing segments A and B of the network is shown in figure 3.38 and 3.39 respectively. It consists of one OLT, a splitter and thirty two ONUs. The parameters of each of the components used in this design is as contained in the downstream power budget of table 3.10 and the system/ network architecture showing full network implementation in Optisystem for segment A and segment B is shown in the figure 3.40 and 3.41 respectively. However, full network diagrams of segment A and B in downstream direction is shown in A3 print out in appendix D and E respectively.

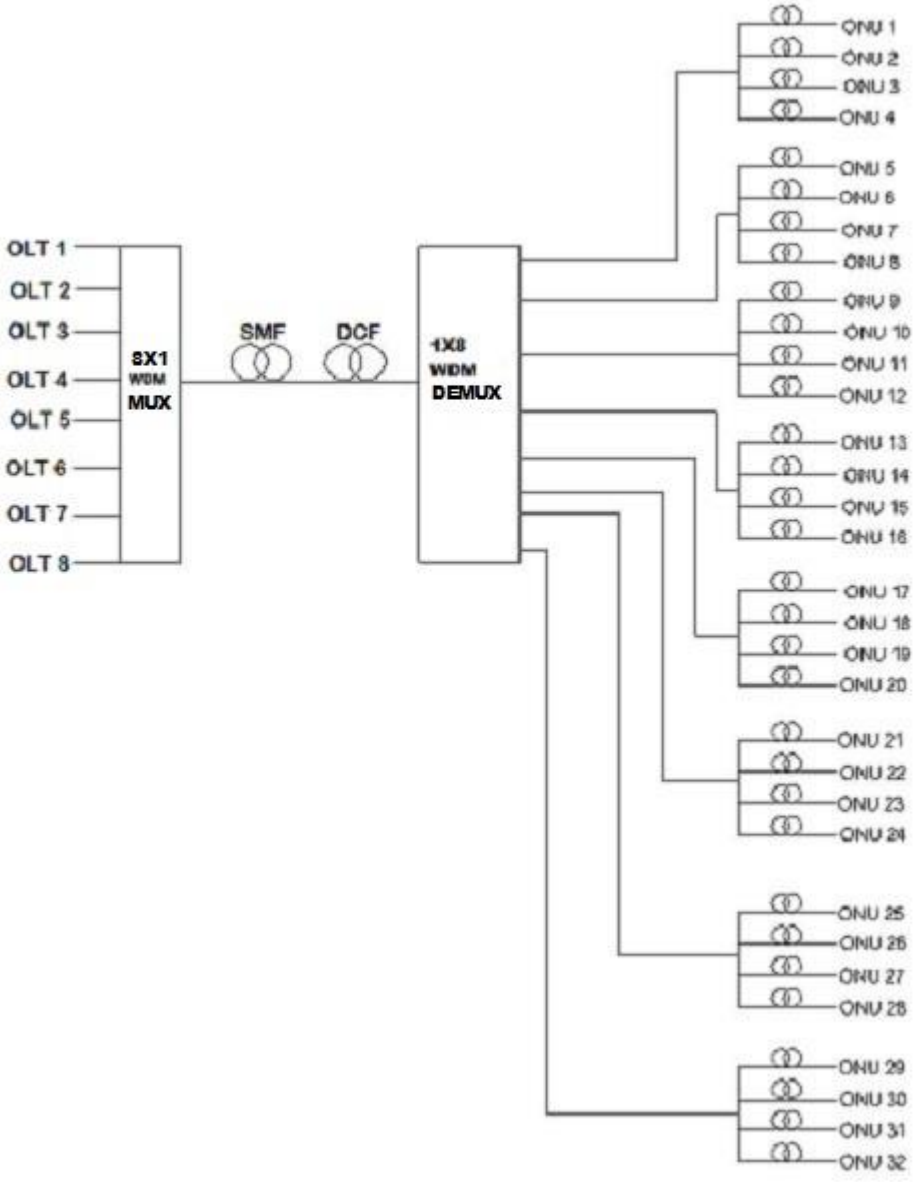


Figure 3.38: Block diagram of segment A of the network

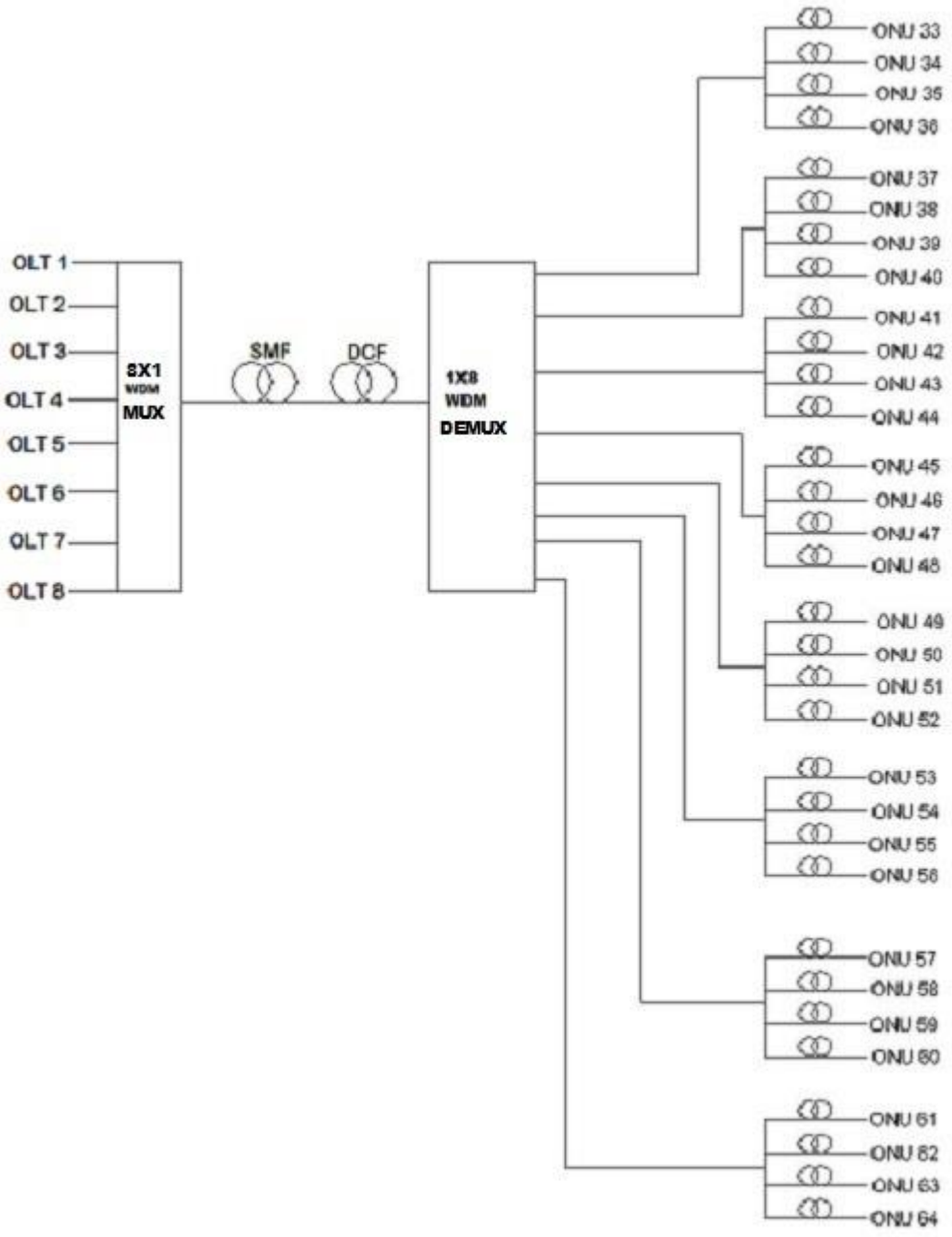
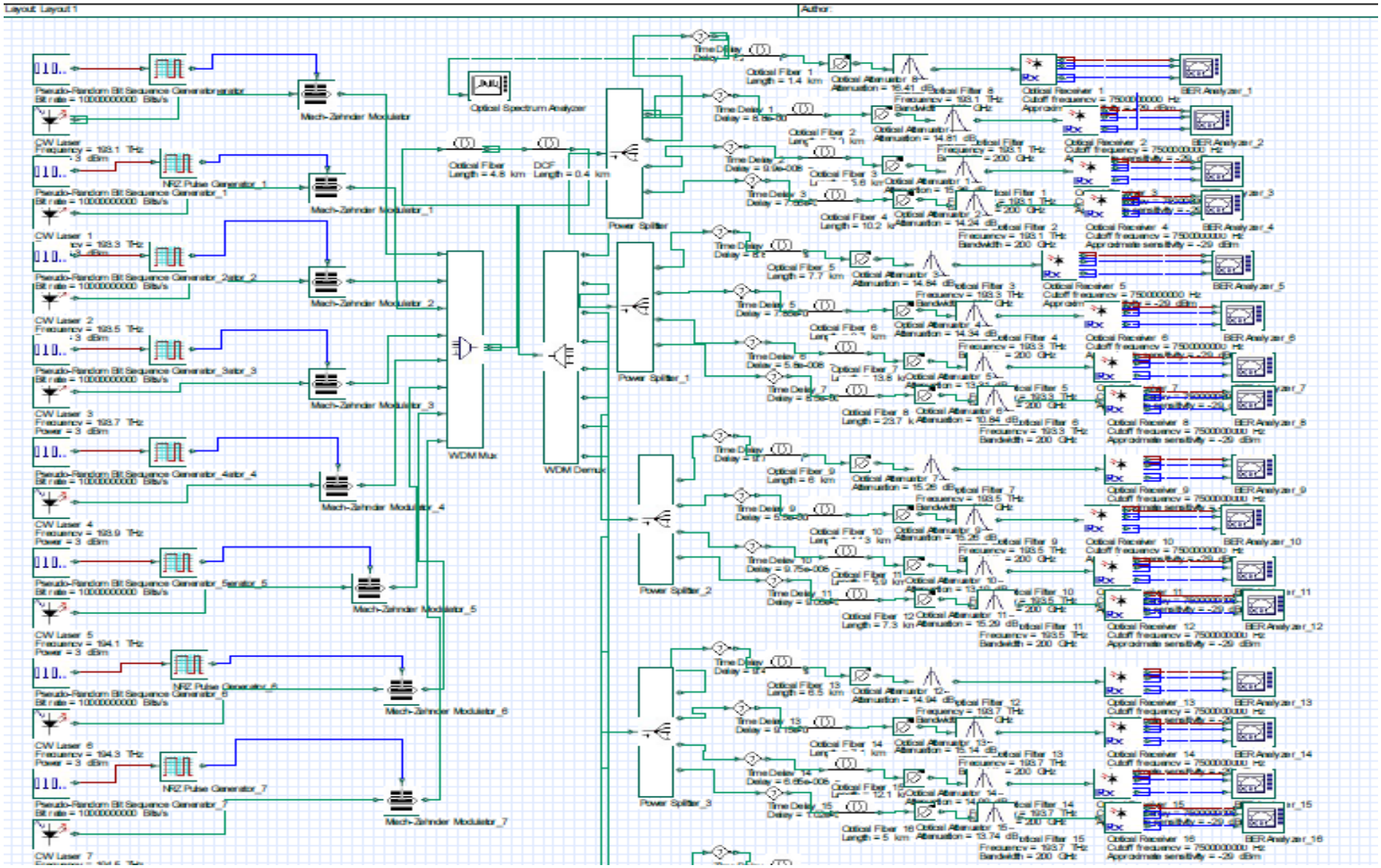


Figure 3.39: Block diagram of segment B of the network


Layout: Layout 1
Author:
Optical Spectrum Analyzer
Optical Fiber
Length = 4.8 km
DCF
Length = 0.4 km
WDM Mux
WDM Demux
Power Splitter
Power Splitter_1
Power Splitter_2
Power Splitter_3
Mach-Zehnder Modulator
Mach-Zehnder Modulator_1
Mach-Zehnder Modulator_2
Mach-Zehnder Modulator_3
Mach-Zehnder Modulator_4
Mach-Zehnder Modulator_5
Mach-Zehnder Modulator_6
Mach-Zehnder Modulator_7
NRZ Pulse Generator_1
NRZ Pulse Generator_7
CW Laser
CW Laser 1
CW Laser 2
CW Laser 3
CW Laser 4
CW Laser 5
CW Laser 6
CW Laser 7
Optical Receiver 1
Optical Receiver 2
Optical Receiver 3
Optical Receiver 4
Optical Receiver 5
Optical Receiver 6
Optical Receiver 7
Optical Receiver 8
Optical Receiver 9
Optical Receiver 10
Optical Receiver 11
Optical Receiver 12
Optical Receiver 13
Optical Receiver 14
Optical Receiver 15
Optical Receiver 16
BER Analyzer_1
BER Analyzer_2
BER Analyzer_3
BER Analyzer_4
BER Analyzer_5
BER Analyzer_6
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BER Analyzer_12
BER Analyzer_13
BER Analyzer_14
BER Analyzer_15
BER Analyzer_16

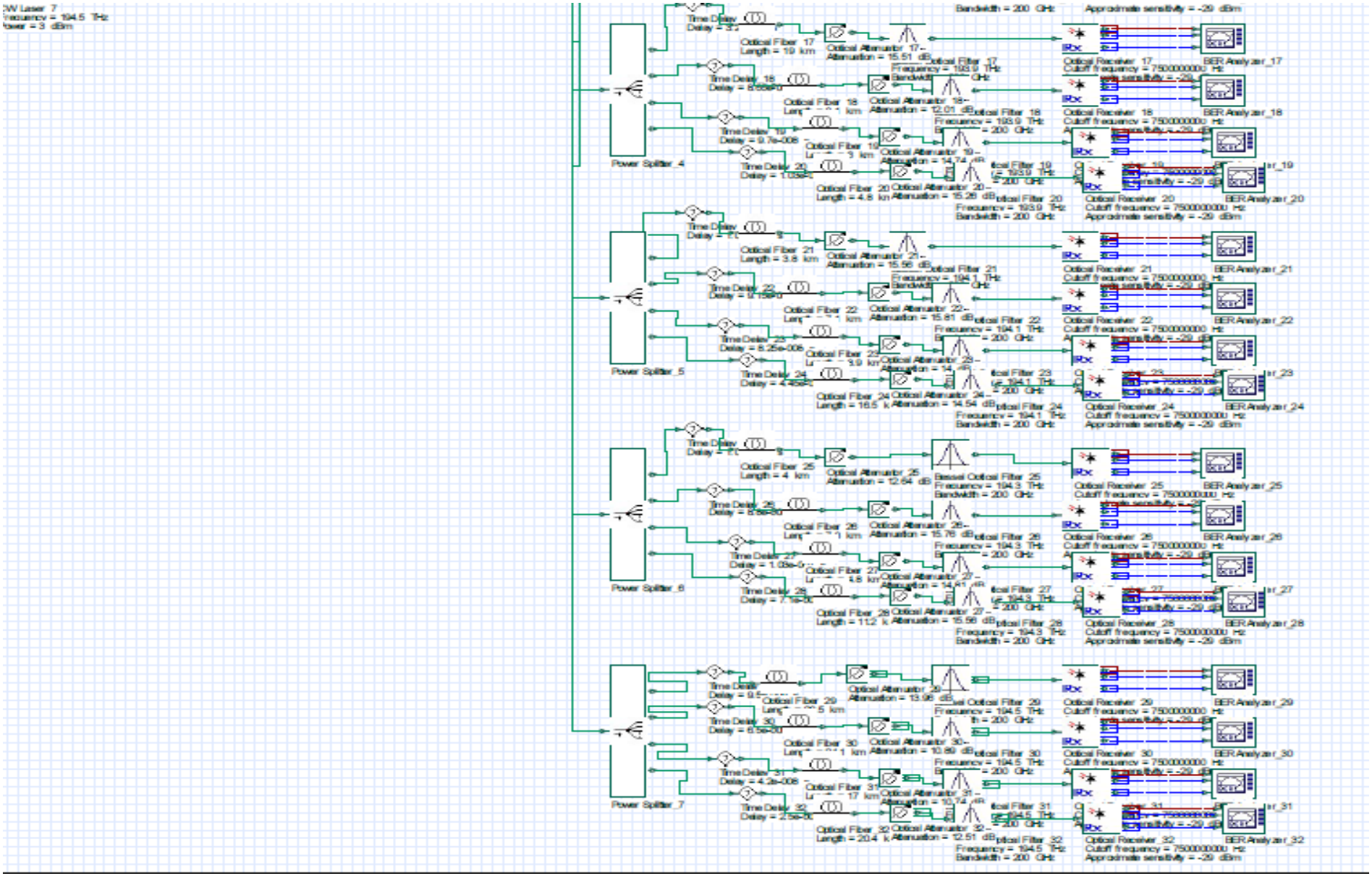
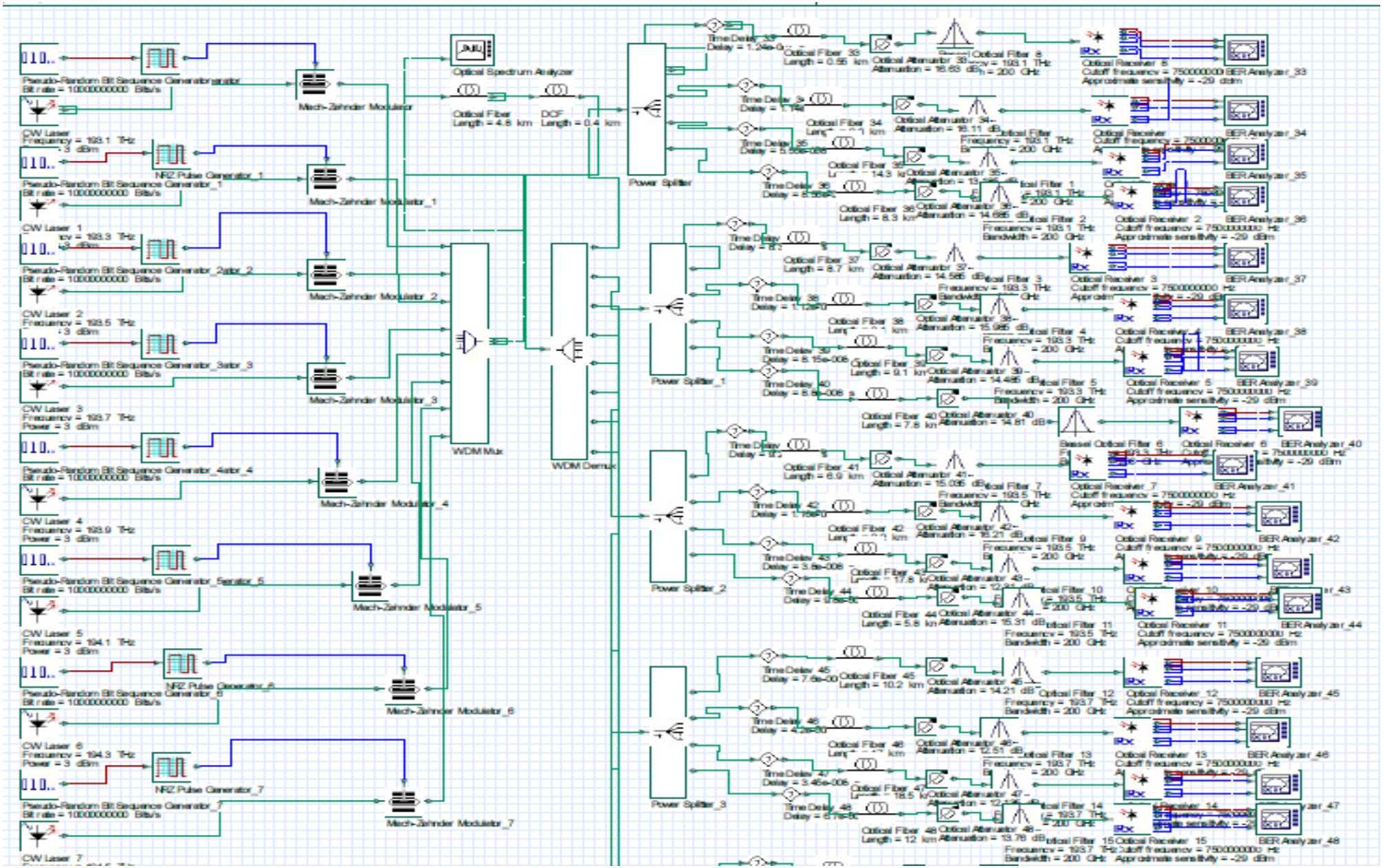


Figure 3.40: Full Network implementation for Segment A


Optical Spectrum Analyzer
Optical Fiber
Length = 4.8 km
DCF
Length = 0.4 km
Power Splitter
Power Splitter_1
Power Splitter_2
Power Splitter_3
WDM Mux
WDM Demux
Mach-Zehnder Modulator
Mach-Zehnder Modulator_1
Mach-Zehnder Modulator_2
Mach-Zehnder Modulator_3
Mach-Zehnder Modulator_4
Mach-Zehnder Modulator_5
Mach-Zehnder Modulator_6
Mach-Zehnder Modulator_7
NRZ Pulse Generator_1
NRZ Pulse Generator_7
CW Laser
CW Laser 1
CW Laser 2
CW Laser 3
CW Laser 4
CW Laser 5
CW Laser 6
CW Laser 7
Optical Attenuator 33
Optical Attenuator 34
Optical Attenuator 35
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Optical Attenuator 46
Optical Attenuator 47
Optical Attenuator 48
Optical Receiver
Optical Receiver 1
Optical Receiver 2
Optical Receiver 3
Optical Receiver 4
Optical Receiver 5
Optical Receiver 6
Optical Receiver 7
Optical Receiver 9
Optical Receiver 10
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BER Analyzer_33
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BER Analyzer_48

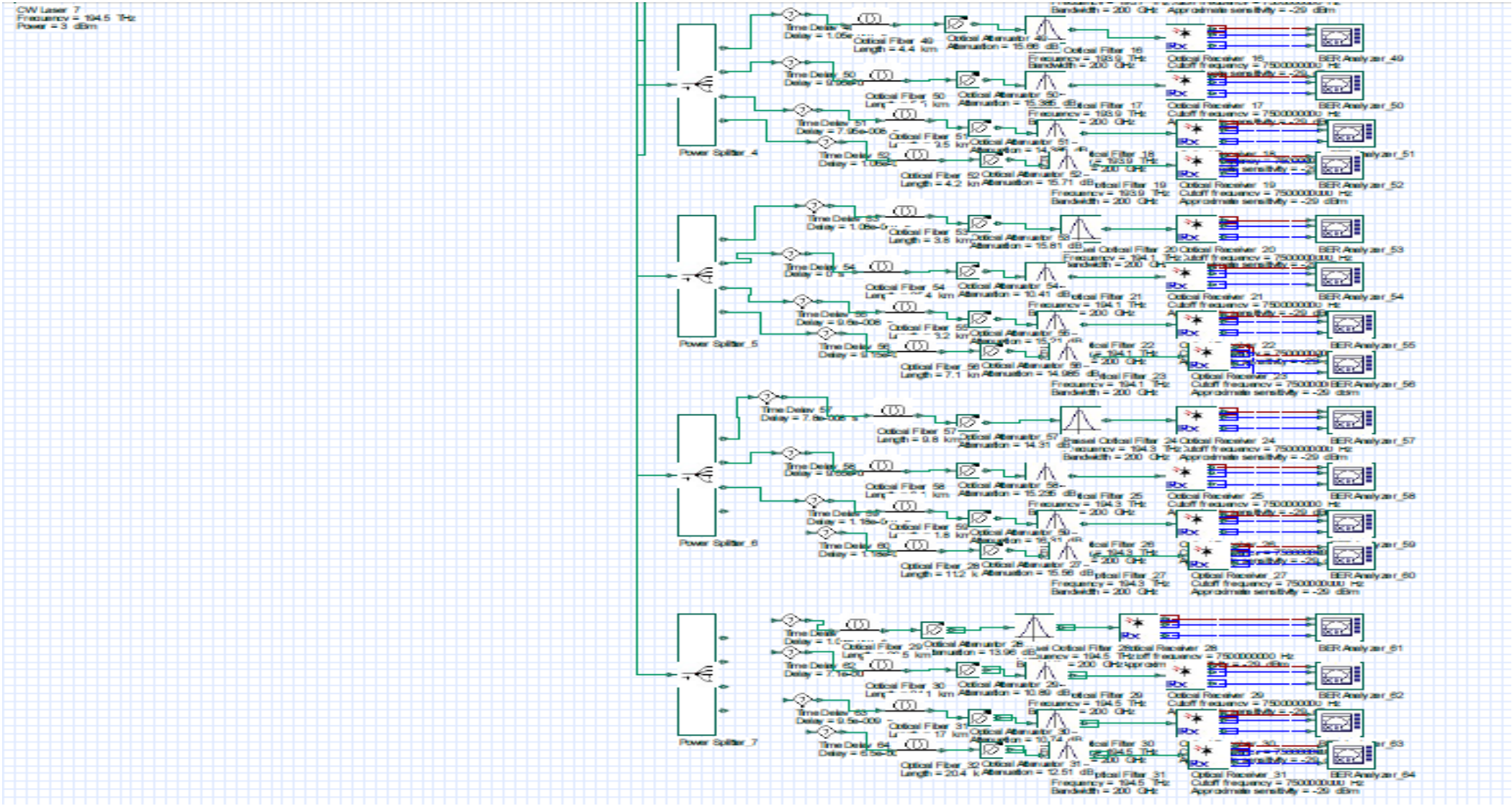


Figure 3.41: Full Network implementation for Segment B

3.7.4 UPSTREAM TRANSMISSION SECTION

In upstream direction, ONUs are transmitting to the OLT whereas the OLT receives the signals from various ONUs. WDM transmitters are used in ONU, each ONU is assigned different wavelength, different frequency. From upstream power budget calculations of table 3.11, ONU transmit power is 2dBm. Figure 3.42 shows different ONU transmitters with different frequencies but same power

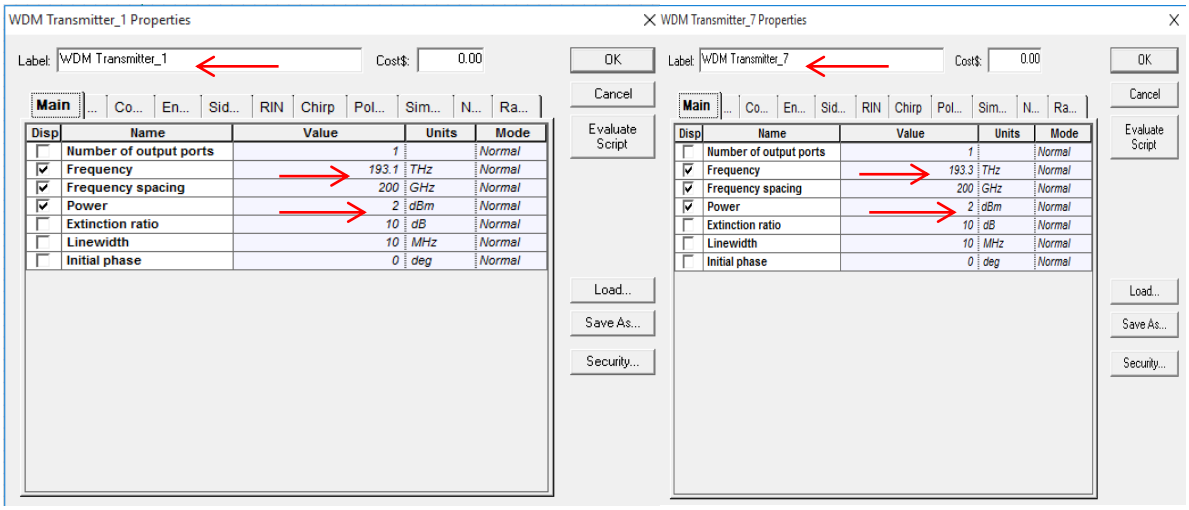


Figure 3.42: Different WDM transmitters with different frequencies but same power

Combiners were used in upstream direction instead of splitters, here; the combiners combine signals transmitted by four ONUs. Each of the combiners combines separate signals from different ONUs using time division principles. 4x1Combiner is used as shown in figure 3.43.

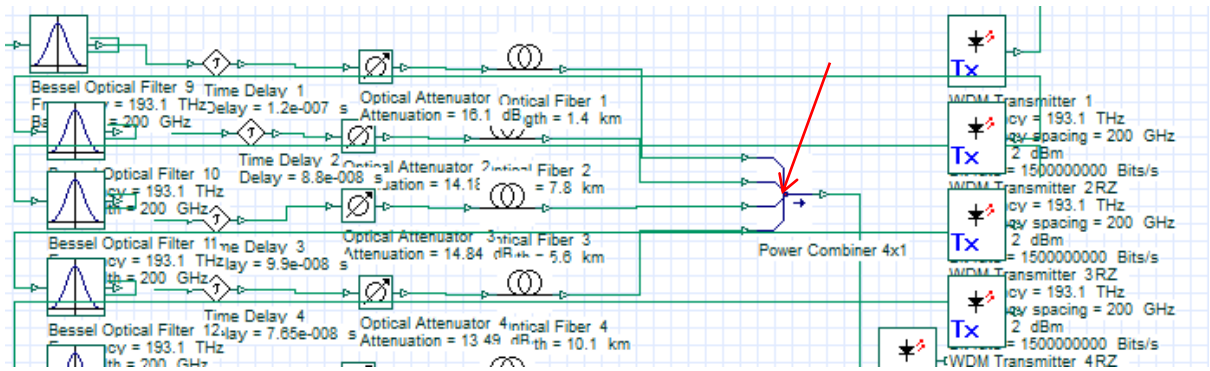


Figure 3.43: 4x 1 Combiner in Optisystem environment

Also shown in figure 3.43 are Bessel filter, time delay, optical attenuator and optical fibres of varying lengths. The filter ensures that only frequency assigned to the transmitter is allowed. Time delay assigns delay to the signal to avoid possible collision in the combiner. The combiner employs time division principles. Hence, signals from the four ONUs are combined as shown in figure 3.43. Just like in the downstream transmission, the upstream is divided into two segments (segments A and B)

Eight number of 4 x 1 combiners were used to combine signals from thirty two (32) ONUs, the output from the 8 combiners constitute the inputs to 8x1 WDM mux as seen in figure 3.44. The output of the WDM mux became input to DCF and in turn feeds the shared fibre of length 4.8km. Output of fibre feeds WDM demux. The outputs of WDM demux are connected to receiver sections.

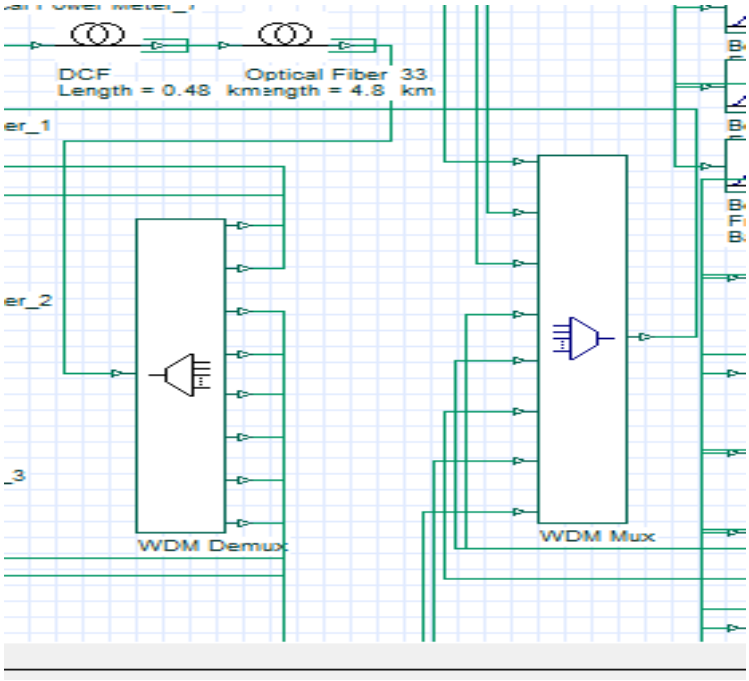


Figure 3.44: DWM mux, WDM demux, Fibre and DCF in optisystem environment

In upstream, 0.3dB attenuation coefficient was used to determine the attenuation per fibre and is measured in dB/km. For DCF, 0.6dB/km was used. Figure 3.45 is an optisystem image showing attenuation in both fibre and DCF, attenuation, also is lengths of fibre and DCF

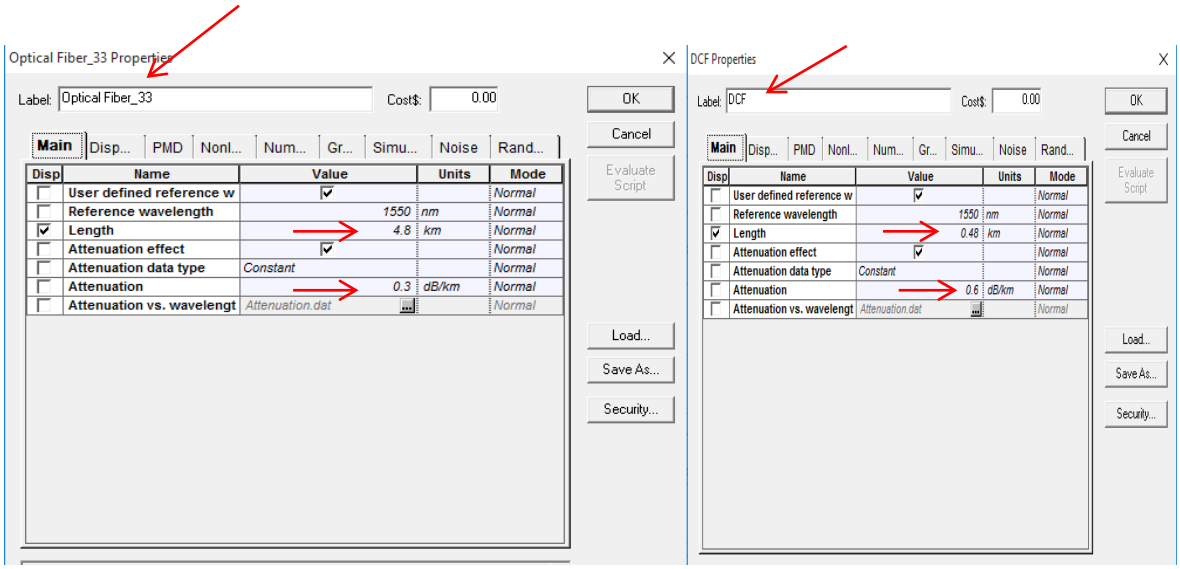


Figure 3.45: Fibre and DCF lenghts and attenuation

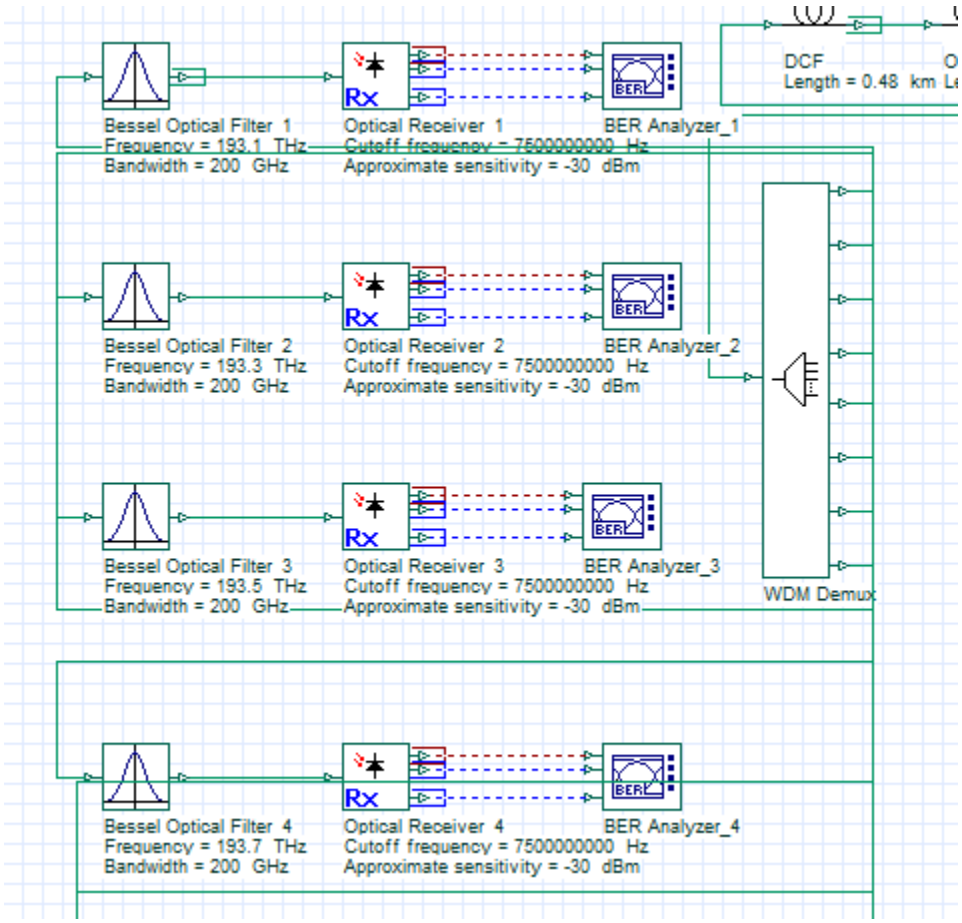
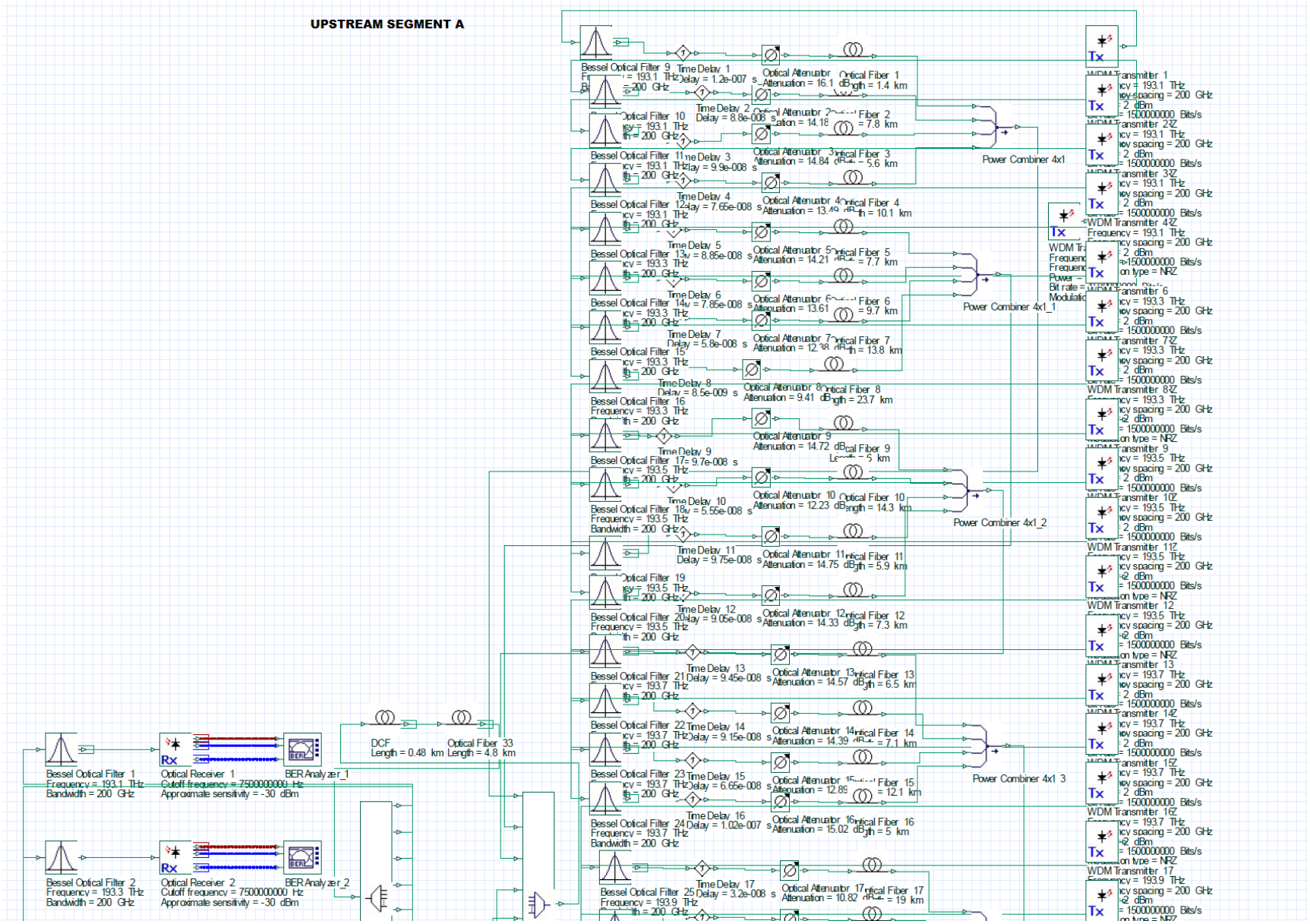


Figure 3.46: WDM demux and Output Port connections

The 1x8 WDM demux has eight ports as output. Each of the eight output ports connects to the receiver section as shown in figure 3.46. The receiver section is made up Bessel filter, optical receiver and BER analyser. The Bessel filter filters unwanted frequencies, hence allows only

assigned frequencies. The optical receiver has sensitivity of -30dBm as provided by upstream power budget of table 3.11. The BER analyser displays the eye diagrams. Figures 3.47 and 3.48 show the complete network diagrams of segment A and B of upstream transmission respectively. However, full network diagrams of segment A and B in upstream direction is shown in A3 print out in appendix F and G respectively


UPSTREAM SEGMENT A
Power Combiner 4x1
Power Combiner 4x1_1
Power Combiner 4x1_2
Power Combiner 4x1_3
DCF
Length = 0.48 km
Optical Fiber 33
Length = 4.8 km
Bessel Optical Filter 1
Frequency = 193.1 THz
Bandwidth = 200 GHz
Optical Receiver 1
Cutoff frequency = 7500000000 Hz
Approximate sensitivity = -30 dBm
BER Analyzer_1
Bessel Optical Filter 2
Frequency = 193.3 THz
Bandwidth = 200 GHz
Optical Receiver 2
Cutoff frequency = 7500000000 Hz
Approximate sensitivity = -30 dBm
BER Analyzer_2

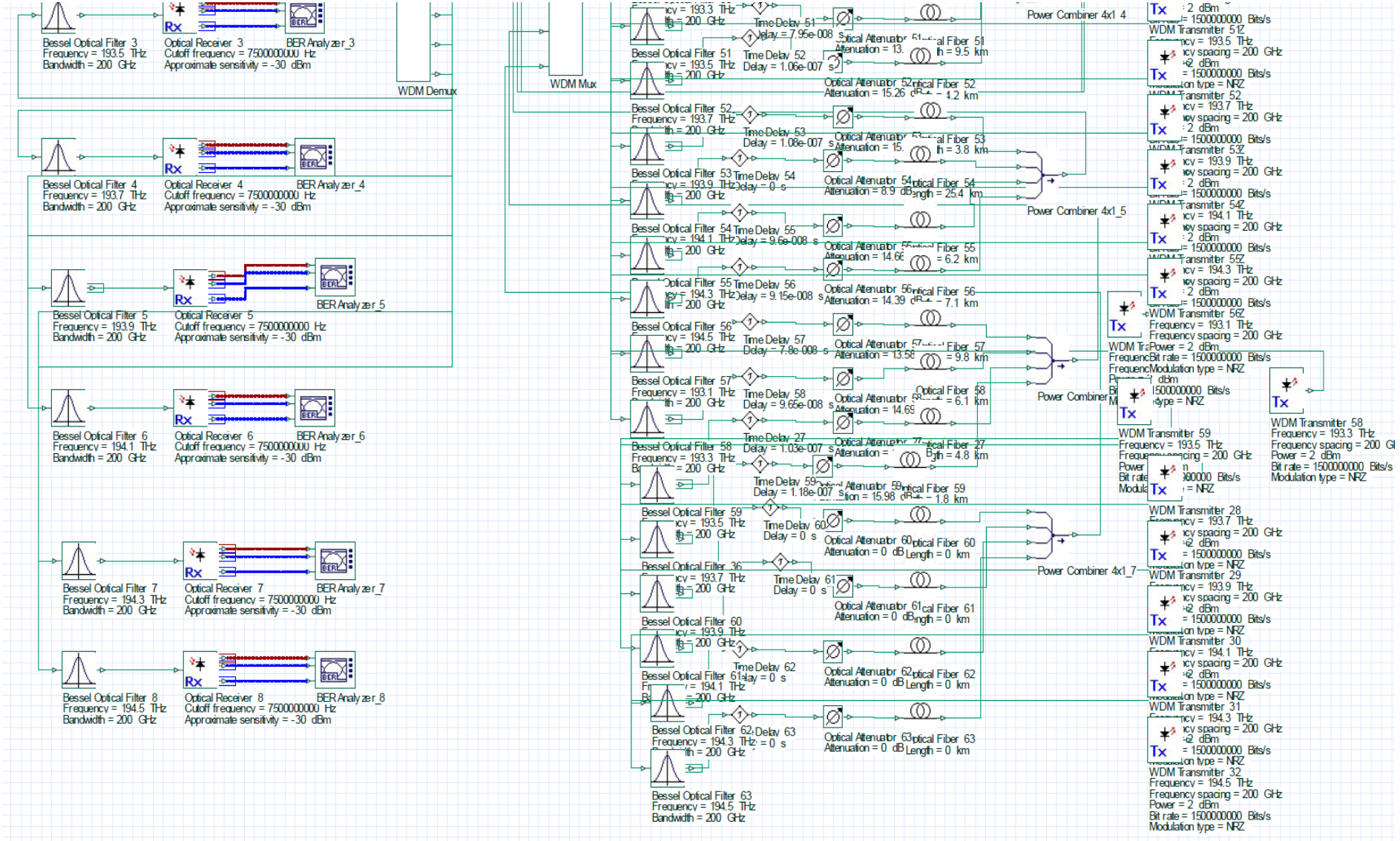
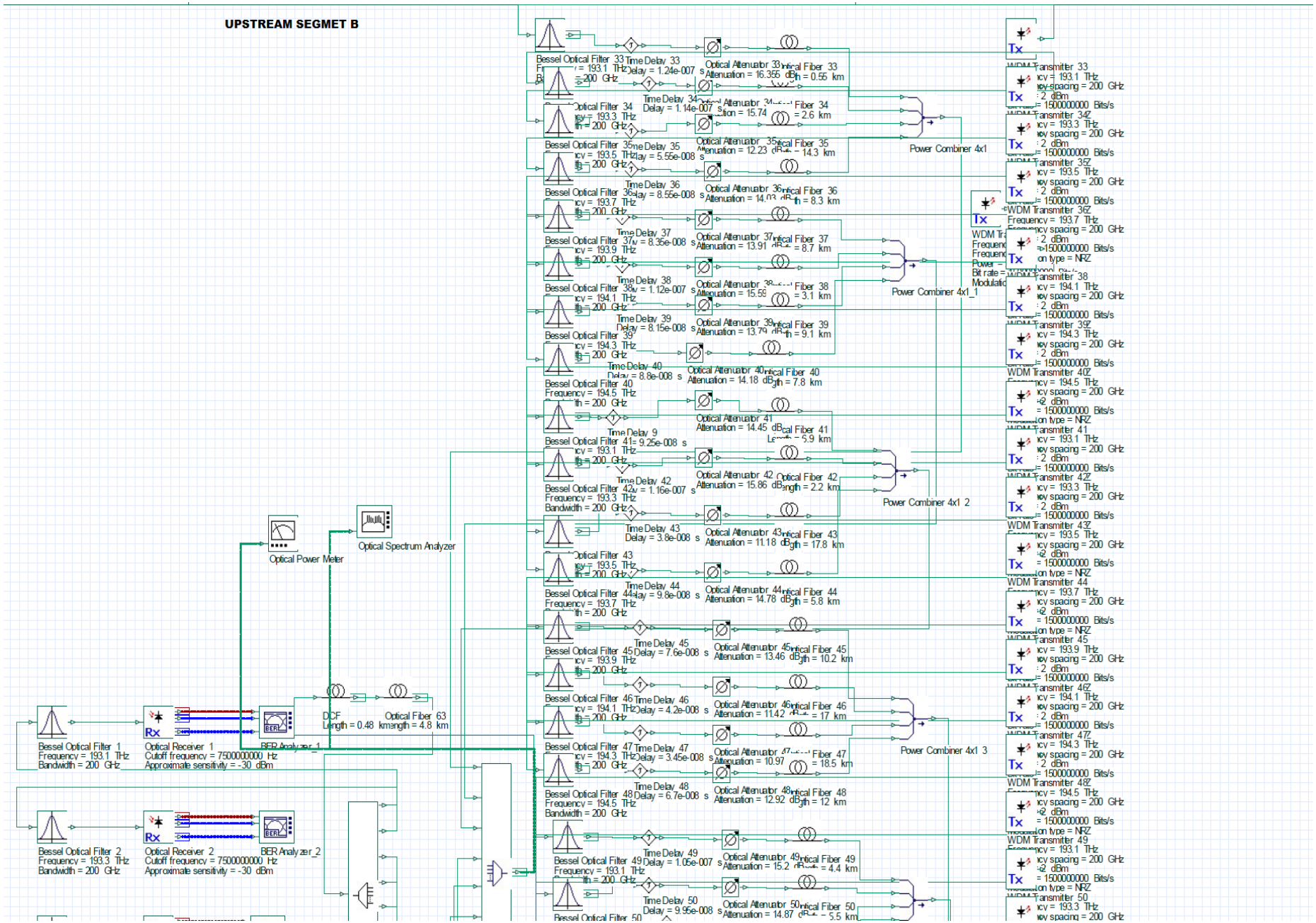


Figure 3.47: Full Network implementation for Upstream Segment A


UPSTREAM SEGMET B
Optical Power Meter
Optical Spectrum Analyzer
DCF
Optical Fiber 63
Bessel Optical Filter 1
Optical Receiver 1
BER Analyzer 1
Bessel Optical Filter 2
Optical Receiver 2
BER Analyzer 2
Power Combiner 4x1
Power Combiner 4x1_1
Power Combiner 4x1 2
Power Combiner 4x1 3

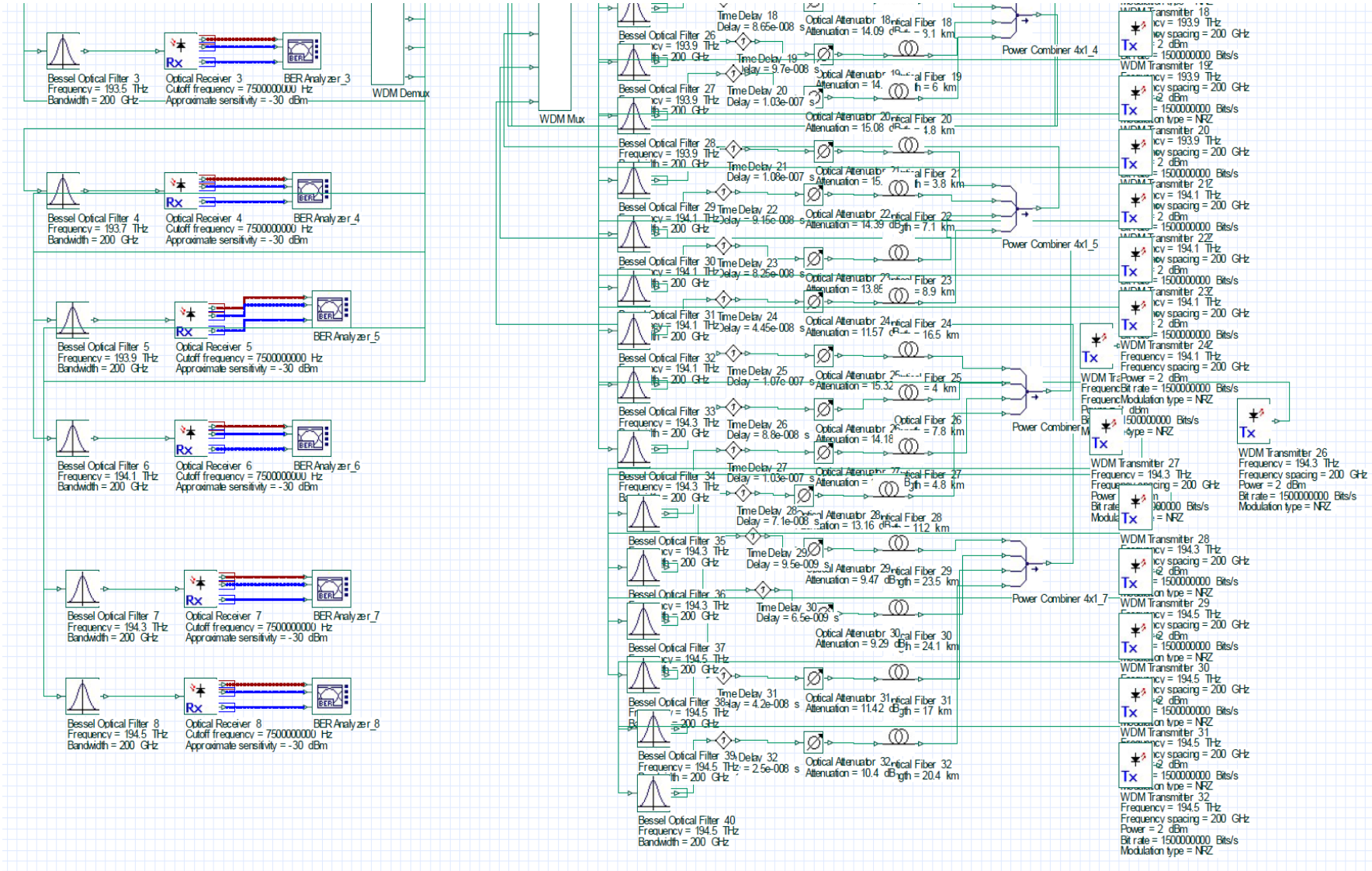


Figure 3.48: Full Network implementation for Upstream Segment B

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter discusses various results obtained from each method used in chapter 3. Results from such methods like optimal Splitter location determination, Power budget analysis for both Downstream and Upstream transmissions, Ranging delay determination, Implementation/validation of the designed network on Optisystem simulation environments, etc were extensively discussed in this chapter.

4.1 OPTIMAL SPLITTER LOCATION DETERMINED

Two methods ('Manual' and 'Automatic') of computing optimal splitter coordinates for Passive Optical Network (PON) deployments were used in the determination of a best/optimal location. Comparing the Optimum splitter coordinates obtained from both methods as shown in table 4.1 indicates that both Manual and Automatic/Systematic methods have similar results for both locations and total distance.

Table 4.1: Coordinates from Manual and Automatic/Systematic Methods

METHOD	LOCATION	GREAT CIRCLE DISTANCE	WALKING DISTANCE
MANUAL	4.8277864, 7.026582	440.7447 KM	577.7 KM
AUTOMATIC	4.8276, 7.0254	440.2402 KM	564.45 KM

From table 4.1, it is observed that both approaches have a very close value for both great circle distance and the walking distance. Also noticed is that the two approaches gave near locations as evidenced in the maps shown in figure 4.1. The great circle distance of both approaches shows a difference of about 0.5045 km length. Considering table 3.5, serial numbers 5 and 11 gave highest and lowest values for fibre length, cost of fibre and attenuation accrued respectively. Adopting the coordinate 4.8277864^0N, 7.026582^0E as optimal location gives total cumulative fibre length to be 440.745km which in turn brings down the cost of fibre purchase and the attenuation in the design. Equation 4.1 shows the percentage value reduction when

considering the highest and lowest values of table 3.5. If cost is considered, equation 4.1 becomes percentage cost reduction whereas it is percentage attenuation reduction if attenuation is considered.

$$\text{Pr} = \frac{Hv - \text{Lv}}{Hv} x100 \qquad (4.1)$$

Where Hv is the highest value and Lv is the lowest value when considering table 3.5

For percentage reduction in cost between the serial/row 5 and 11 of table 3.5, equation 4.1 becomes:

$$\text{Pr} = \frac{17269800 - 6611171}{17269800} x100 \qquad = 61.72\%$$

Considering attenuation reduction, equation 4.1 gives

$$\text{Pr} = \frac{287.83 - 110.19}{287.83} x100 \qquad = 61.72\%$$

From the foregoing, it is evident that the choice of coordinates 4.8277864^0N, 7.026582^0E as optimal splitter location over coordinates 4.72719^0N, 7.146899^0E gives percentage reduction of 61.72% both in cost of fibre purchase and in attenuation. For this research, fibre length of 580km was taken as the total route length. This gave allowance for any unforeseen in the design. For different OLT – ONU pairs, values of walking distances as obtained in Automatic approach of table 3.7 was adopted.

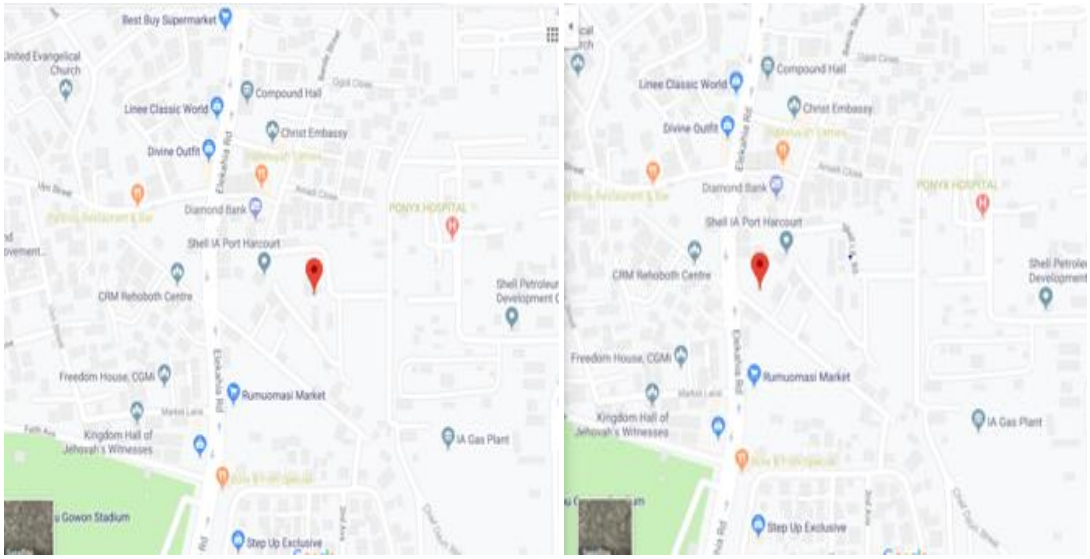


Figure 4.1: Map showing optimal location for both approaches

Figure 4.2 shows graphical representation of both Manual and Automatic/Systematic methods per length in kilometers. The graph shows length in kilometers for each eNB in the PON network for both methods. The blue line shows the systematic/automatic method used in computing optimal splitter location while the red line represents the manual approach of computing optimal splitter location. From the graph, it could be seen that outside exchange to eNB4 where there are very slight variation in the lengths for the both methods, every other segment of the graph is almost same for both approaches. This shows that both methods are very efficient and accurate in the determination of optimal splitter coordinates. They both gave very near/similar results

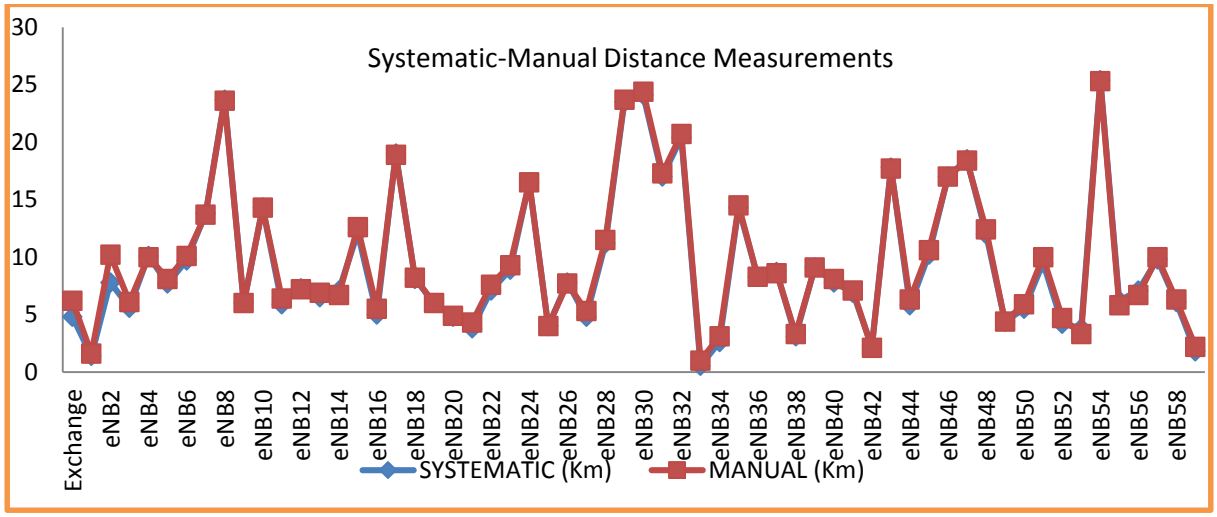


Figure 4.2: Graph for Systematic/Automatic –Manual Distance measurement model

4.2 DOWNSTREAM POWER BUDGET ANALYSIS

In analysing this section, consider the component losses in items (i) to (viii) of section 3.5.1 and also taking note of equation 3.20 in the computation of values obtained in table 3.10. However, from table 3.10, exchange (OLT) –eNB (ONU) pair parameters for the design of downstream PON network is as follows:

(i) OLT Tx to all the eNBs has value of 3dBm

(ii) Receiver sensitivity for all the 59 eNBs in the network is -29dBm

(iii) Attenuation coefficient in downstream is 0.25dB/km

(iv) DCF attenuation coefficient is 0.6dB/km

(v) OLT – eNB1 pair has fibre length of 6.2km

(vi) OLT – eNB1 pair has fibre attenuation of 1.55dB/km

(vii) OLT – eNB1 pair has dispersion compensation fibre (DCF) of length 0.4km

(viii) OLT – eNB1 pair has DCF attenuation of 0.24dB/km

(ix) WDM mux used has insertion loss of 3.5dB

(x) WDM demux used has insertion loss of 3.5dB

(xi) Losses accrued due to connection is 7dB

(xii) Losses accrued due to spicing is 0.3dB

(xiii) Margin of 9.11dB was used to maintain fixed OLT Tx and ONU Rx

The same procedure was used to obtain the above parameters that is, items (i) to (xiii) for all OLT –ONU pairs in the network. In all pairs, margin was used to maintain constant OLT Tx and ONU Rx despite varying fibre lengths and attenuations. Figure 4.3 shows a plot of fibre lengths, fibre attenuations and varying margin for all the 59 eNBs serving as ONUs in the network. It is seen that eNBs with higher fibre cable lengths has corresponding high values for fibre attenuation but lower values for margin. eNB54 with highest fibre cable length of 30.2km has fibre attenuation of 7.55dB and a margin of 3.11dB. Also, eNB33 with least fibre cable length of 5.35km has a fibre attenuation of 1.34dB and a margin of 9.32dB. Similar situation is seen in all the 59eNBs in the network as evidenced in figure 4.3

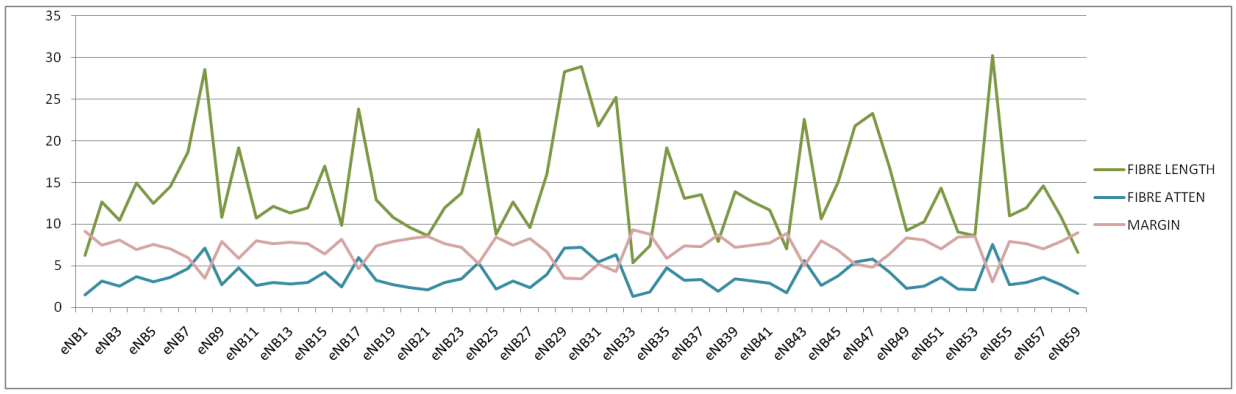


Figure 4.3: downstream power budget graph

4.3 UPSTREAM POWER BUDGET ANALYSIS

In upstream transmission, each eNB transmits to the OLT at the exchange/switch, whereas OLT in turn receives from each ONU. In this section, result of upstream power budget done in section 3.5.2 is discussed. Equation 3.20 was applied in computing table 3.11, ONUs have transmit power 2dBm whereas OLT receiver sensitivity is -30dBm. For ONU1 Tx –OLT Rx pair, the following parameter were obtained in accordance to table 3.11:

(i) All the 59 eNBs (ONU) has transmitter power of value 2dBm

(ii) Receiver sensitivity of the OLT in the network is -30dBm

(iii) Attenuation coefficient in upstream is 0.3dB/km

(iv) DCF attenuation coefficient is 0.6dB/km

(v) OLT – eNB1 pair has fibre length of 6.2km

(vi) OLT – eNB1 pair has fibre attenuation of 1.86dB/km

(vii) OLT – eNB1 pair has dispersion compensation fibre (DCF) of length 0.4km

(viii) OLT – eNB1 pair has DCF attenuation of 0.24dB/km

(ix) WDM mux used has insertion loss of 3.5dB

(x) WDM demux used has insertion loss of 3.5dB

(xi) Losses accrued due to connection is 7dB

(xii) Losses accrued due to spicing is 0.3dB

(xiii) Margin of 8.8dB was used to maintain fixed OLT Rx and ONU Tx

This procedure was used to obtain the above parameters in items (i) to (xiii) for all ONU – OLT pairs in the network. In all pairs , margin was used to maintain fix ONU Tx and OLT Rx despite varying fibre lengths and attenuations. Figure 4.4 shows a plot of fibre lengths, fibre attenuations and varying margin for all the 59 eNBs serving as ONUs in the network. Just like in section 4.2 it is also seen that eNBs with higher fibre cable lengths has corresponding high values for fibre attenuation but lower values for margin. eNB54 with highest fibre cable length of 30.2km has fibre attenuation of 9.06dB and a margin of 1.6dB. Also, eNB33 with least fibre cable length of 5.35km has a fibre attenuation of 1.61dB and a margin of 9.06dB. Similar result is seen in all the 59eNBs in the network as seen in figure 4.4

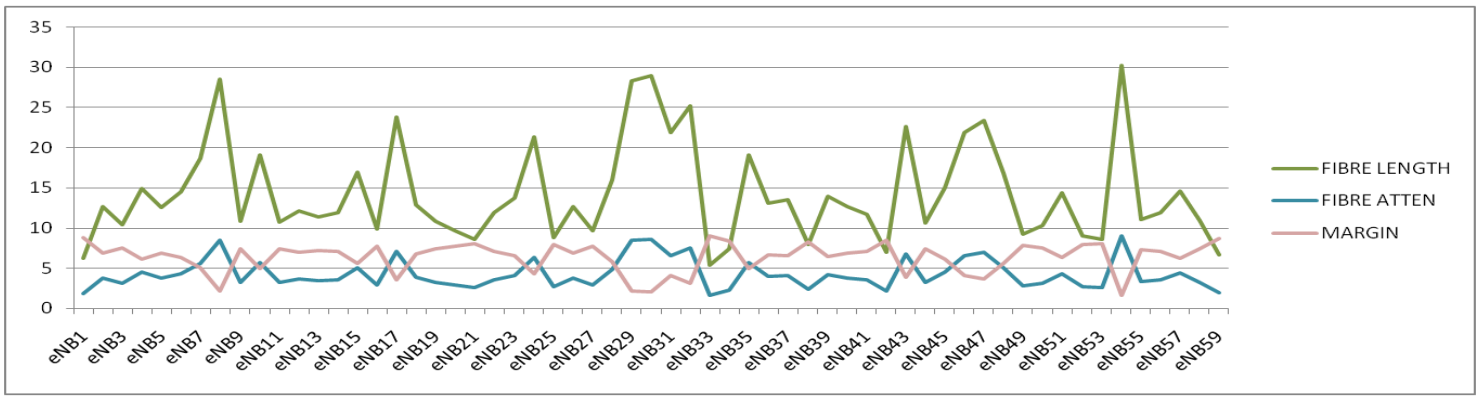


Figure 4.4: upstream power budget graph

4.4 RANGING DELAY ANALYSIS

In upstream transmission, when each eNB (ONU) is transmitting (sending signal to OLT), timing delay is attached to every eNB to avoid collision at the combiner and subsequently at the OLT as explained in figure 3.21 of section 3.5.3. Equations 3.28 and 3.29 were employed in the determination of the delays assigned to individual eNBs as displayed in table 3.12. Figure 4.5 show these delays as assigned to all the eNBs including the exchange (OLT). It is also seen that eNB 54 that has the highest fibre length of 30.2km was assigned no delay (0.0s). This means that eNB 54 transmits without delay since its position is farthest in the network. eNB 33

with least length of 5.35km has the highest delay of 1.24E-7s. All other assigned delays are represented accordingly in the plot of figure 4.5

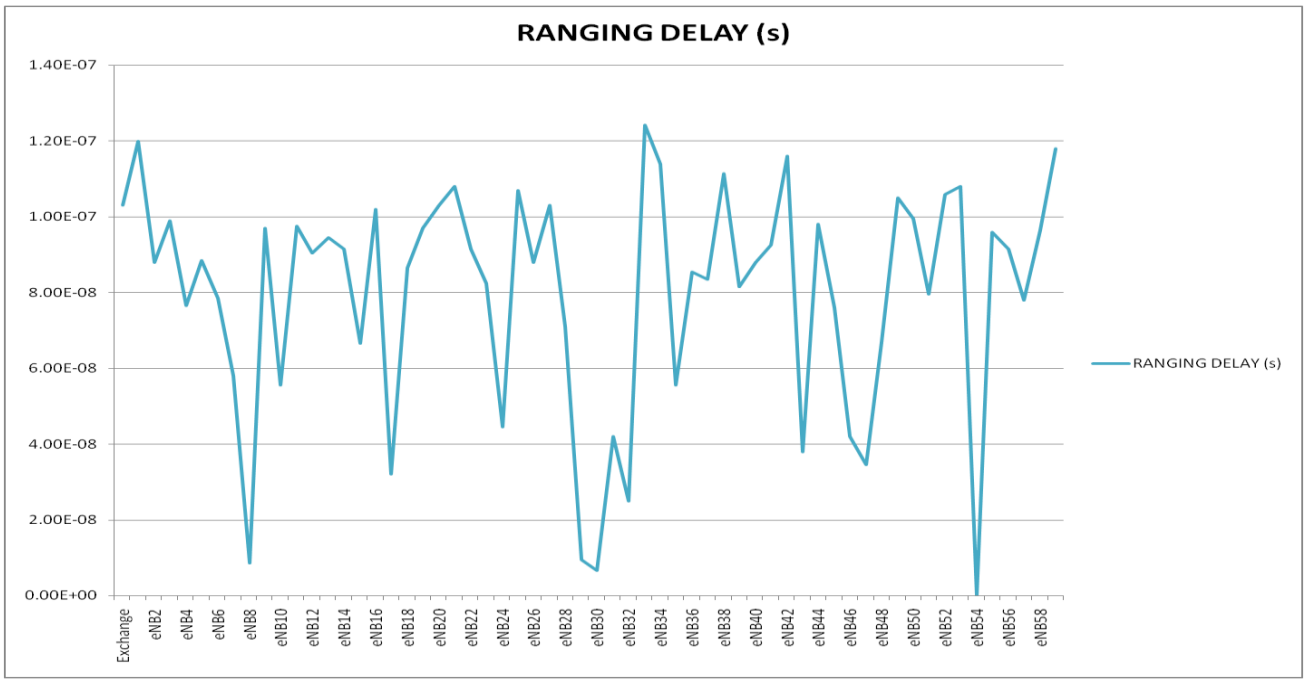


Figure 4.5: Ranging delay

4.5 VALIDATION OF DOWNSTREAM TRANSMISSION

The simulation results for the downstream transmission are divided into segments A and B just as it was done in the network design. Each result shown represents OLT –ONU pair downstream transmission bit error rate (BER) analyser. The analyser used BER and Q factor to analyse the quality of the backhaul link. BER and Q factor are two important parameters that are used to analyse the results obtained in optical communication system. Bit error rate simply called BER is seen as an indicator to measure transmission quality. In Telecommunication, BER represents the percentage of error per bit transmitted relative to total number of bits received. An example is when one million bits is transmitted and only one bit is in error (10^{-6}), The BER so obtained is said to be E-6. Also, Quality factor (Q factor) measures the level of noise in a pulse, in other words, it provides a qualitative description of the receiver performance. The larger the values of Q factor, the freer the pulse (received signal) from noise,

hence, the smaller the value obtained as BER. According to (Peter Ball, 2010), optical transmission links is classified a quality link if it has a minimum BER of E-9, Using the explanations of BER and Q factor to analyse the performance of results obtained in segment A as depicted in figures 4.6 through 4.37 and also as contained in table 4.2, the following deductions were made:

Segment A Simulation Results

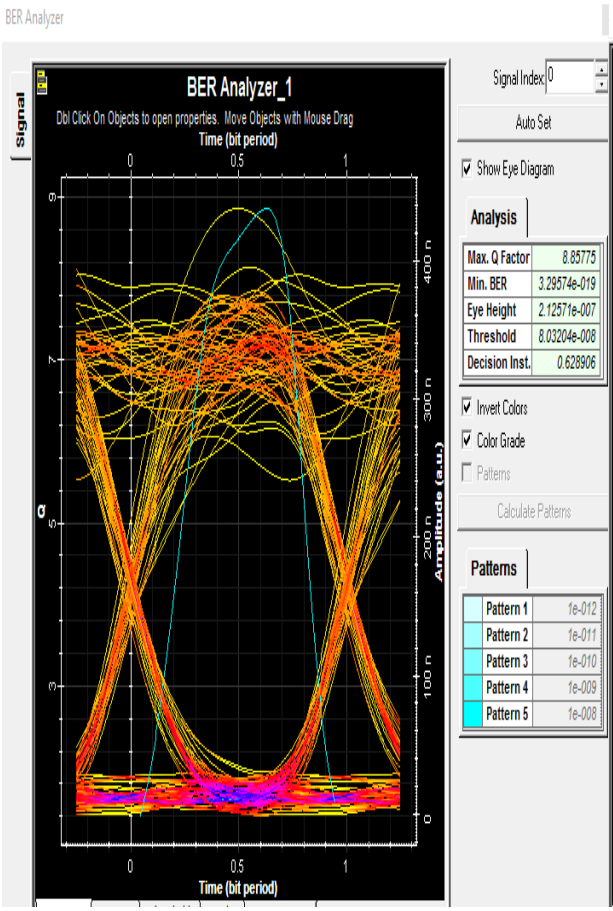


Figure 4.6: eNB1 analyser

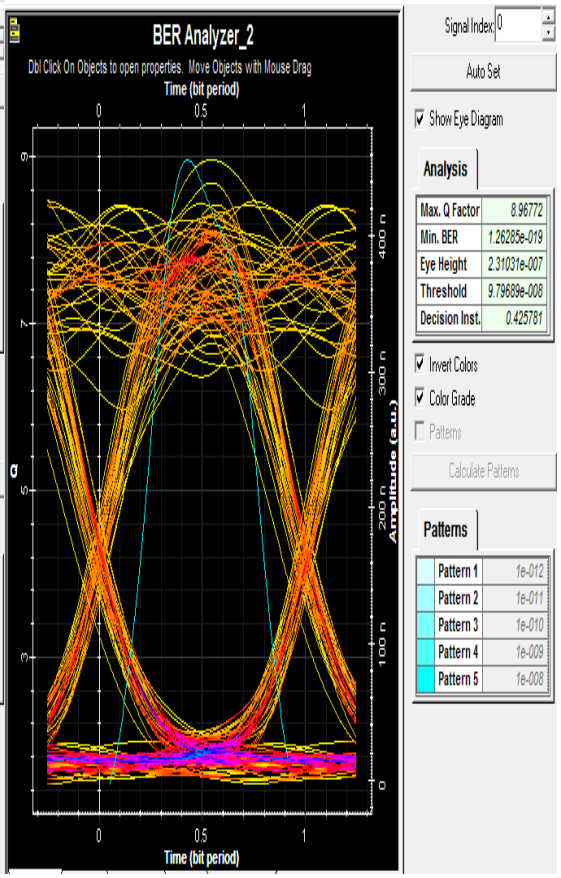


Figure 4.7: eNB2 analyser

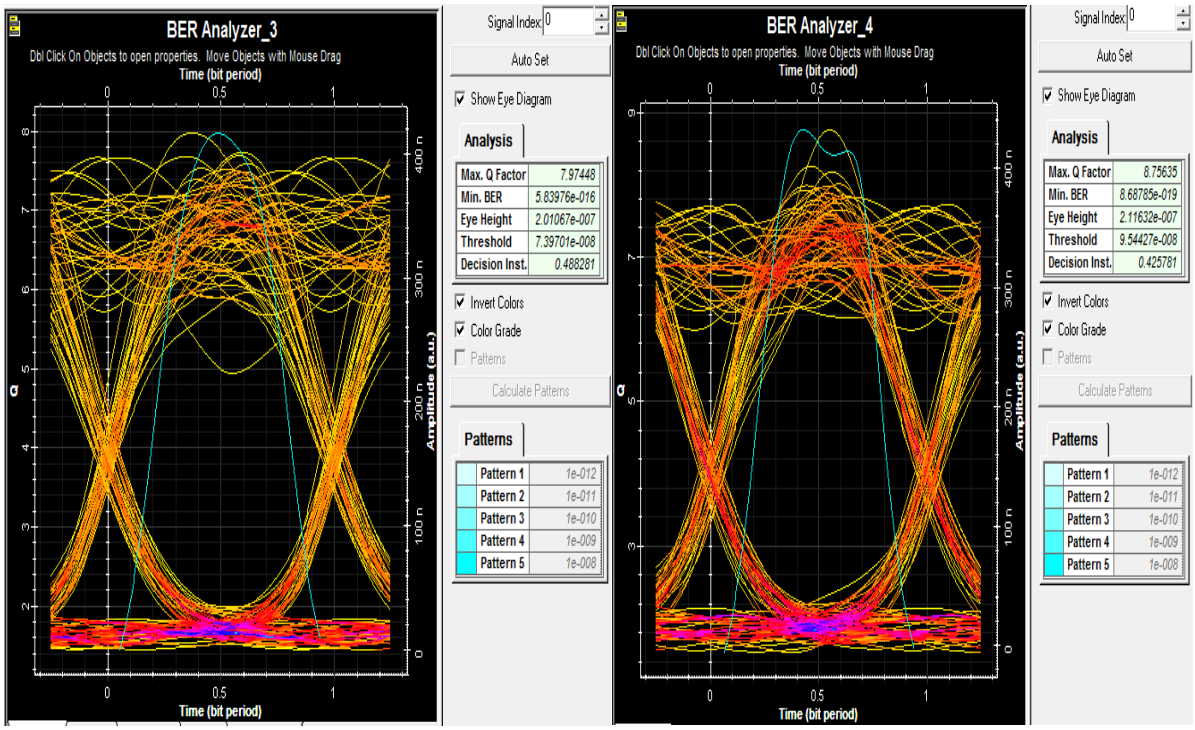


Figure 4.8: eNB3 analyser

Figure 4.9: eNB4 analyser

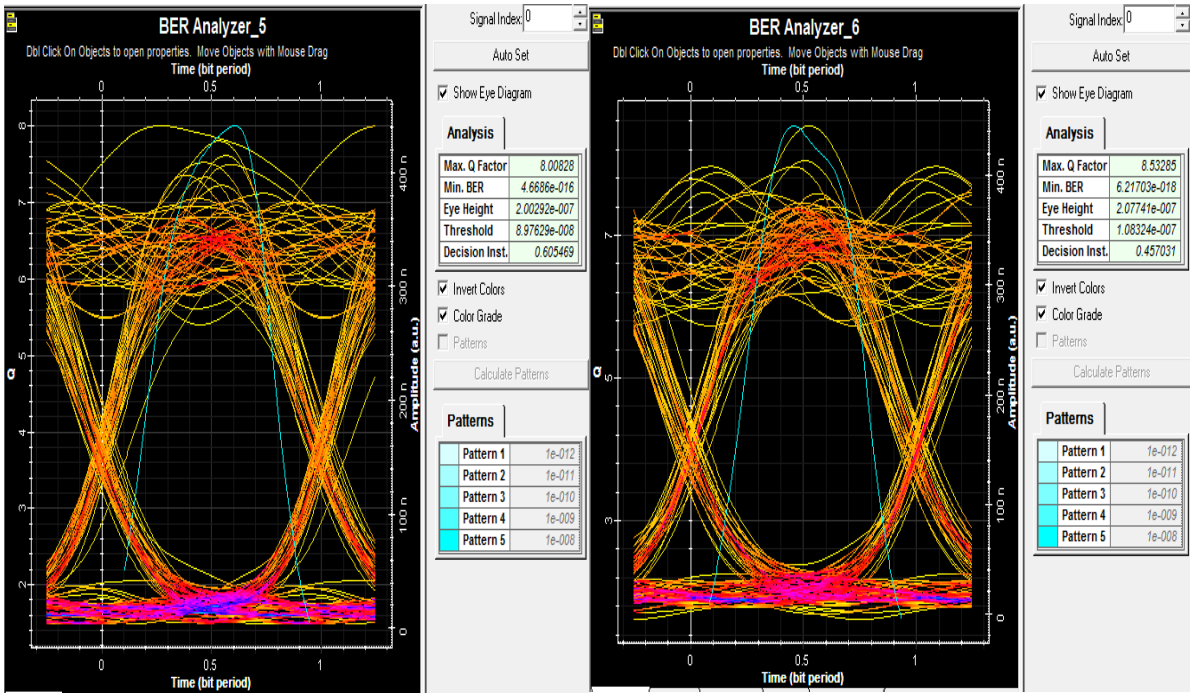


Figure 4.10: eNB5 analyser

Figure 4.11: eNB6 analyser

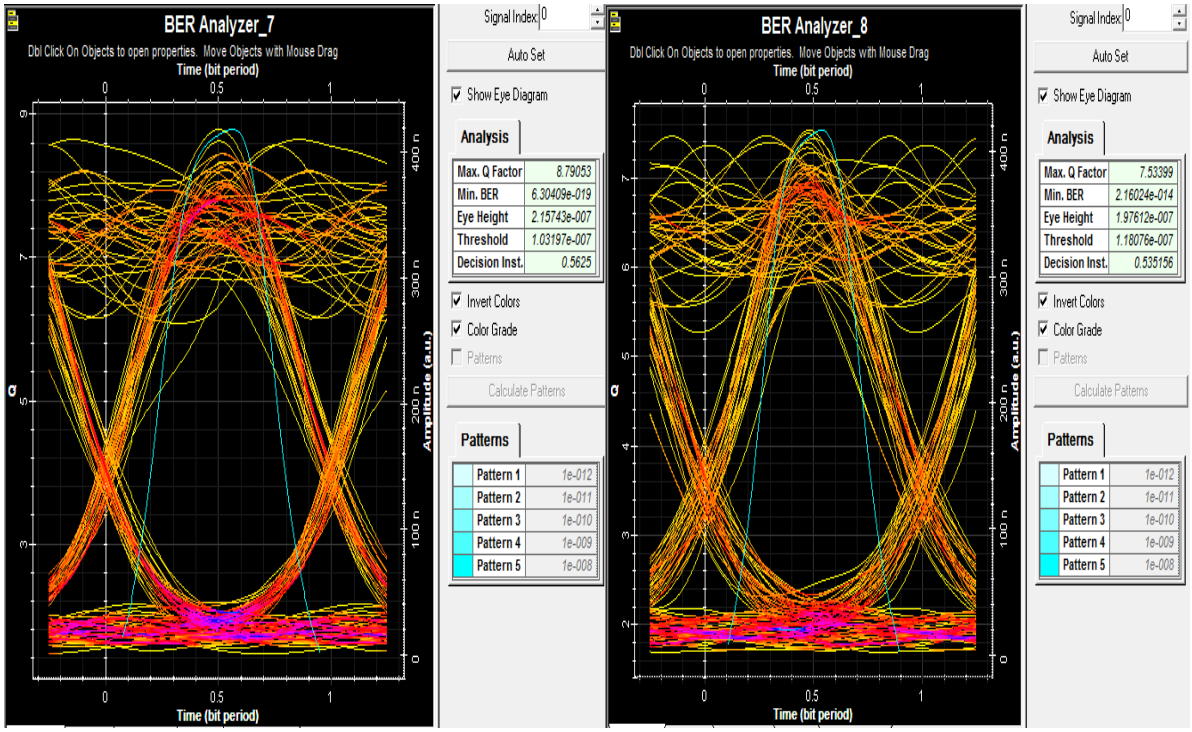


Figure 4.12: eNB7 analyser

Figure 4.13: eNB8 analyser

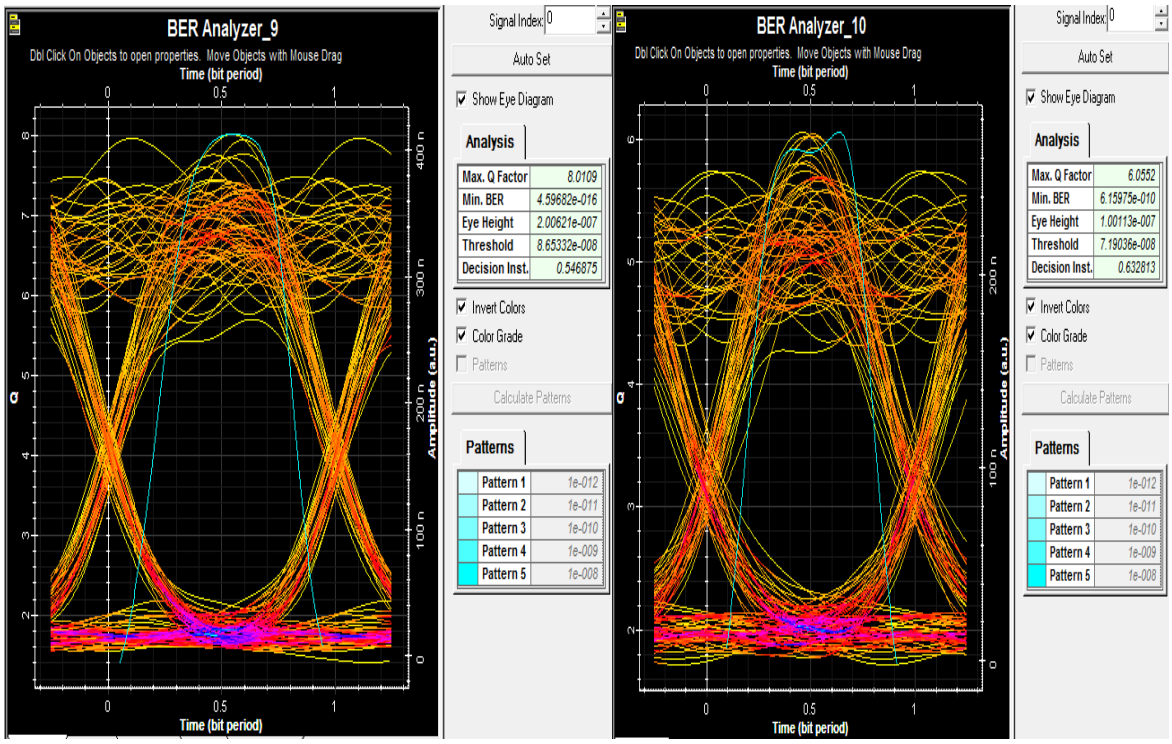


Figure 4.14: eNB9 analyser

Figure 4.15: eNB10 analyser

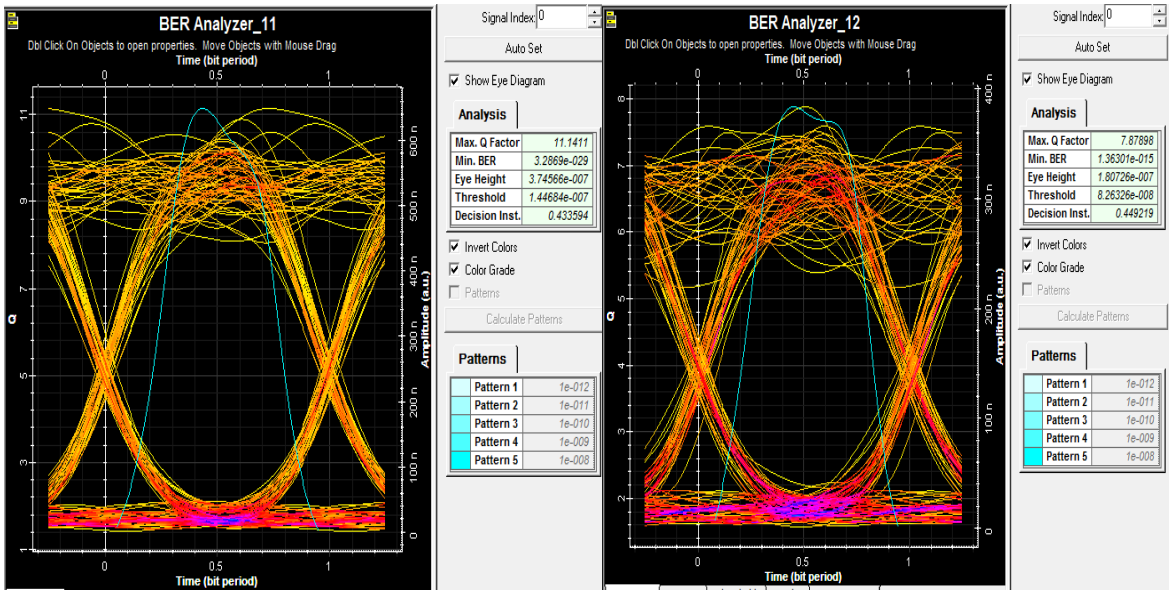


Figure 4.16: eNB11 analyser

Figure 4.17: eNB12 analyser

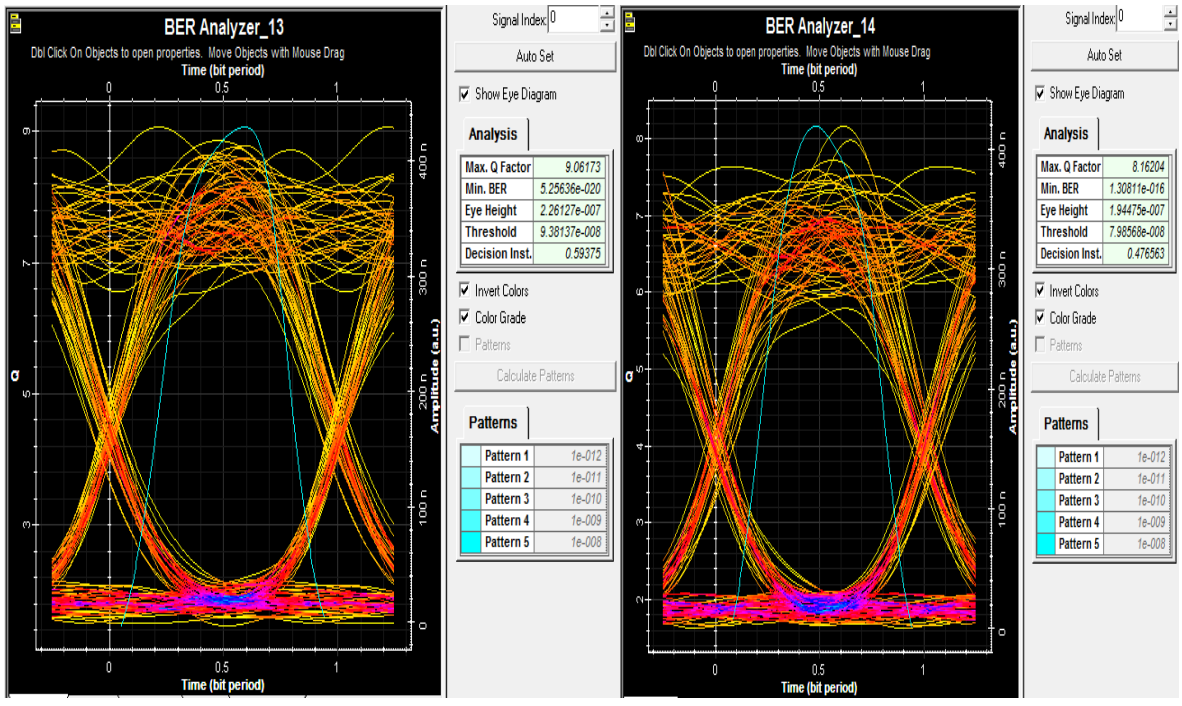


Figure 4.18: eNB13 analyser

Figure 4.19: eNB14 analyser

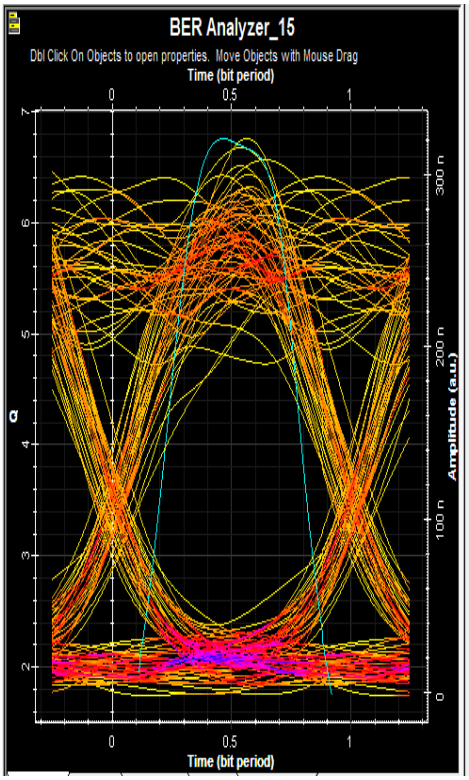


Figure 4.20: eNB15 analyser

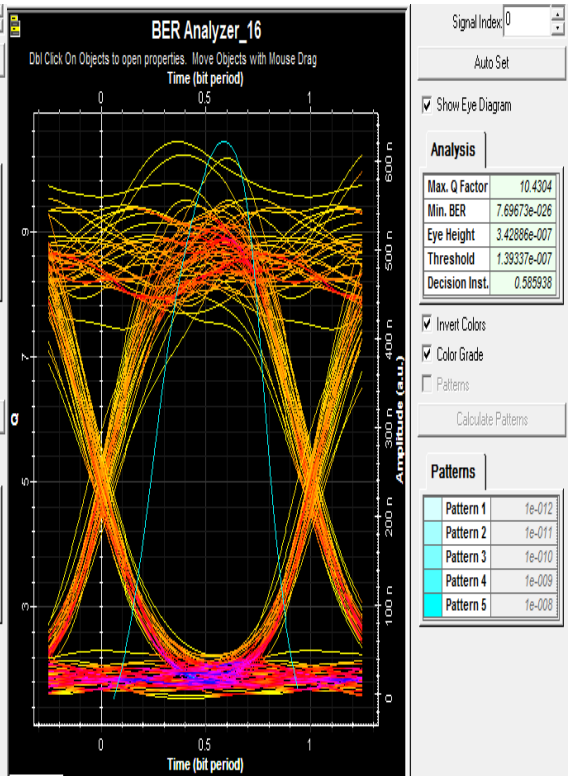


Figure 4.21: eNB16 analyser

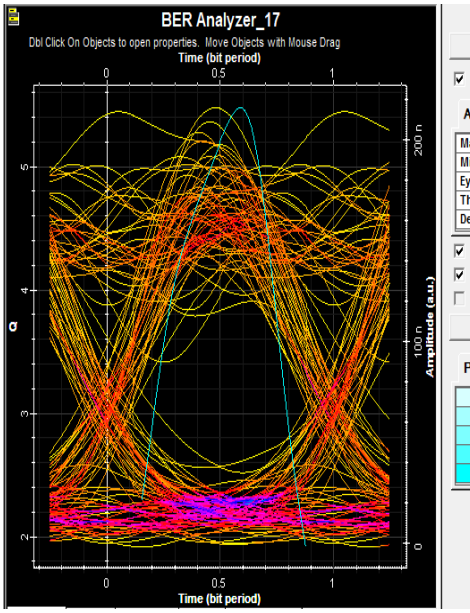


Figure 4.22: eNB17 analyser

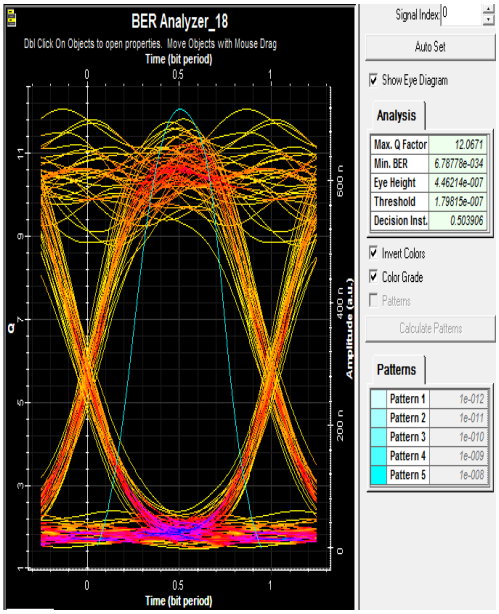


Figure 4.23: eNB18 analyser

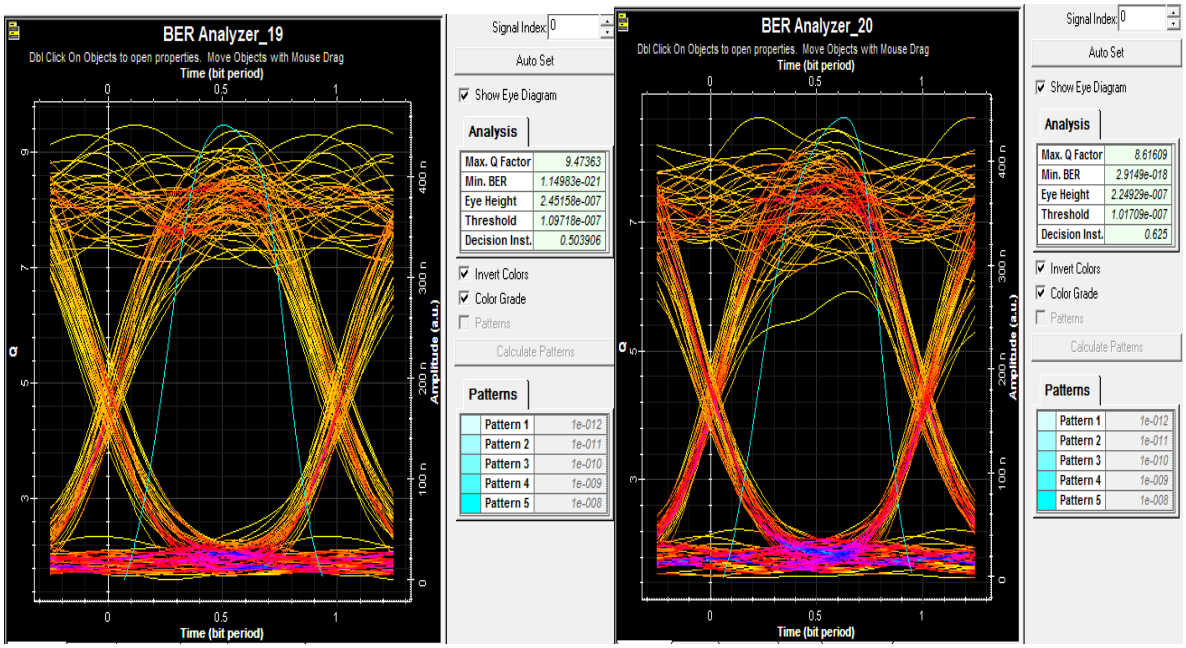


Figure 4.24: eNB19 analyser

Figure 4.25: eNB20 analyser

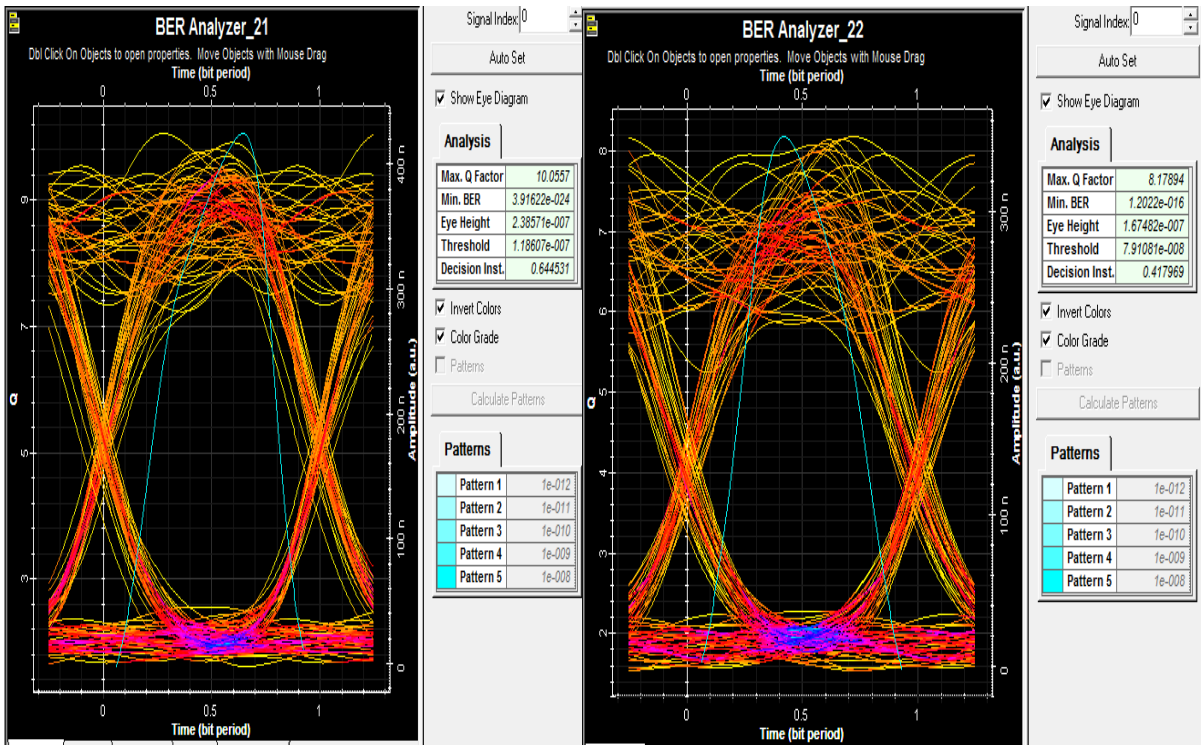


Figure 4.26: eNB21 analyser

Figure 4.27: eNB22 analyser

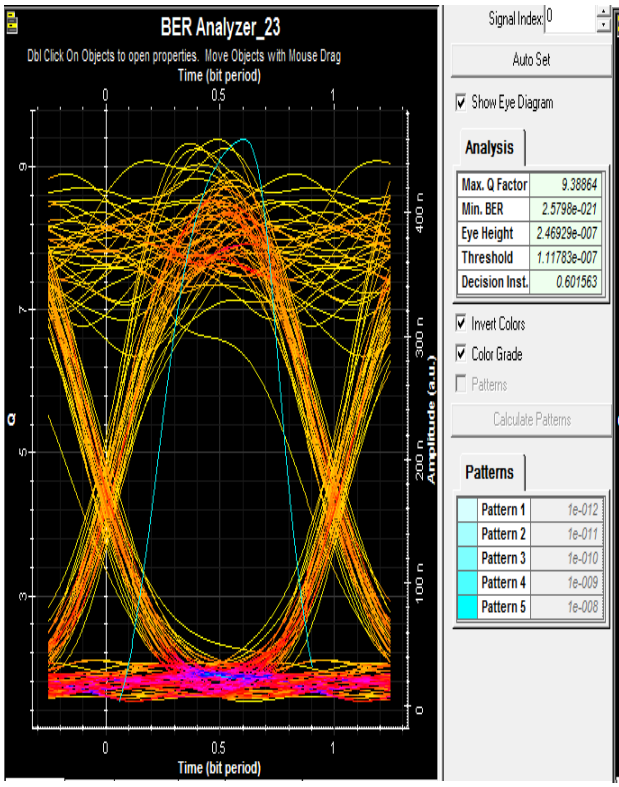


Figure 4.28: eNB23 analyser

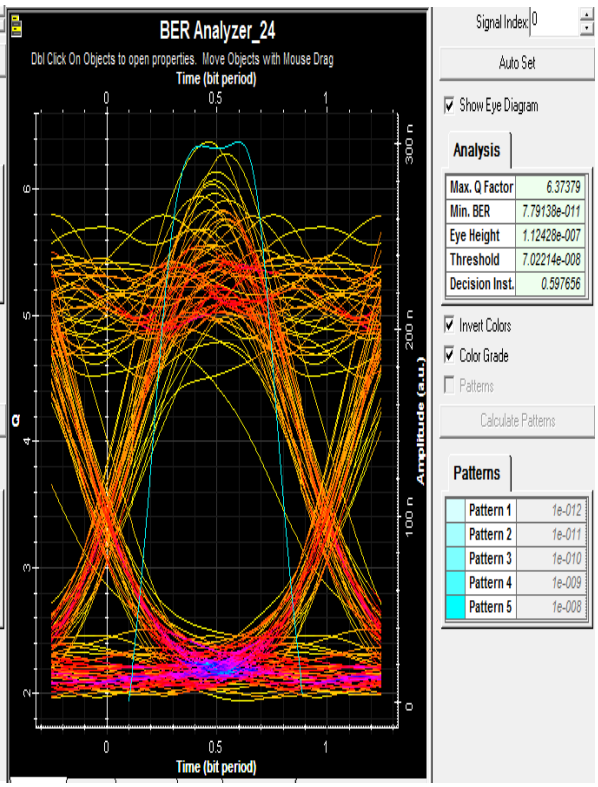


Figure 4.29: eNB24 analyser

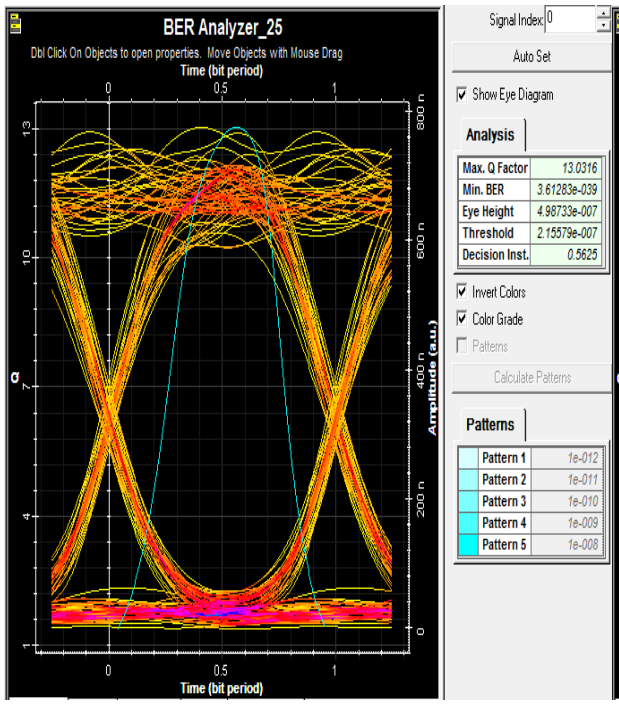


Figure 4.30: eNB25 analyser

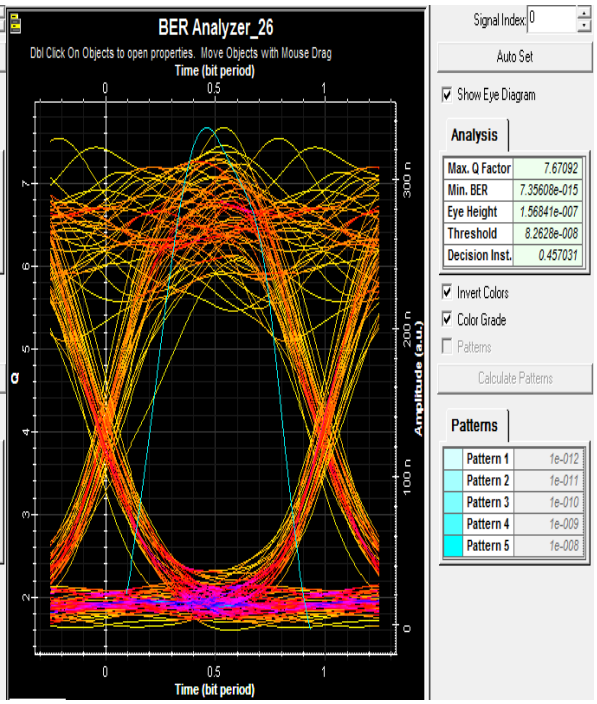


Figure 4.31: eNB26 analyser

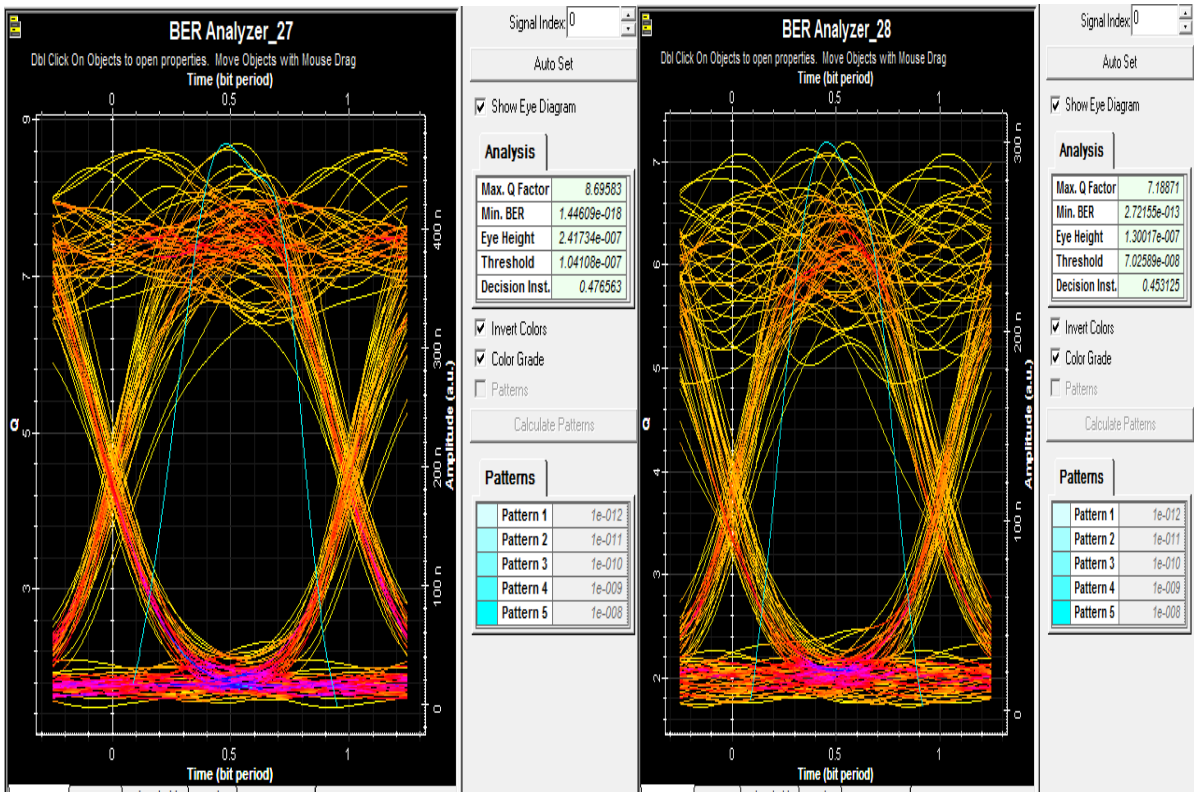


Figure 4.32: eNB27 analyser

Figure 4.33: eNB28 analyser

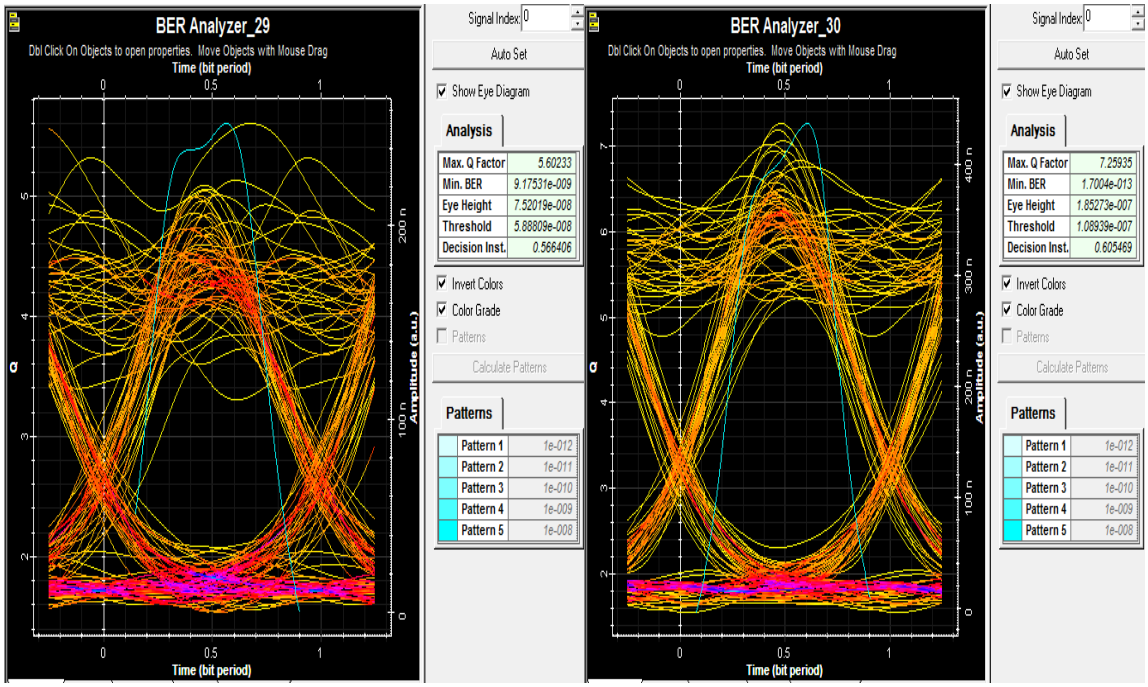


Figure 4.34: eNB29 analyser

Figure 4.35: eNB30 analyser

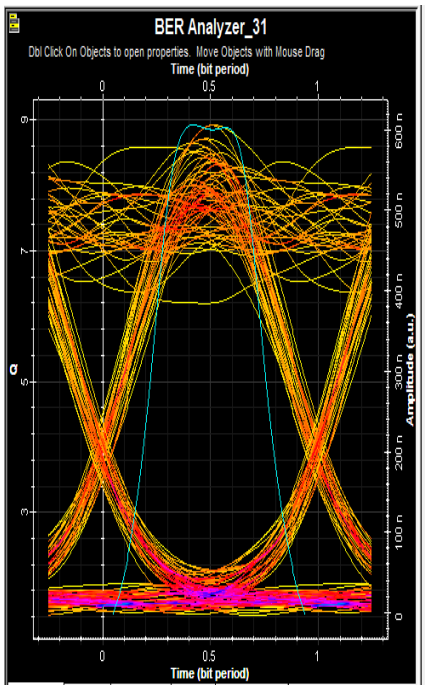


Figure 4.36: eNB31 analyser

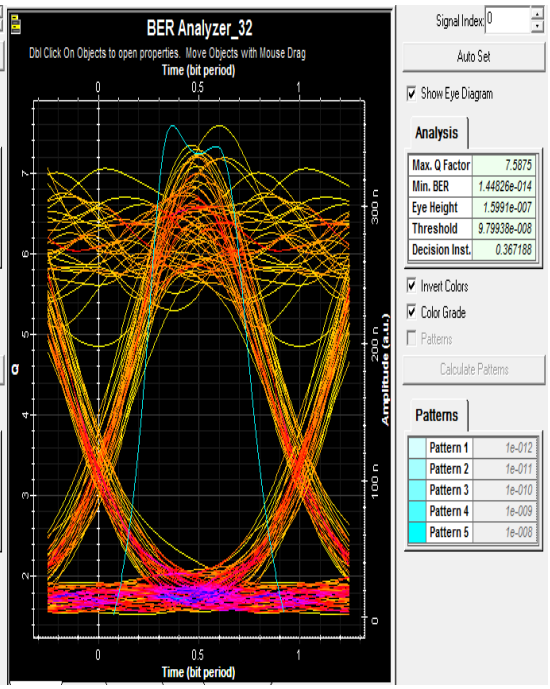


Figure 4.37: eNB32 analyser

eNB1 to eNB32 have very low bit error rates ranging from E-39 to E-8. Representing a range of BER classified as high quality link with very low bit error rate. eNB 25 has the lowest BER E-39 representing a channel with lowest error per bit. In the same vain, eNB 25 has a Q factor of 13.03. The results so obtained showed that segment A of the transmission link has a very good quality of a backhaul link. Table 4.2 gave a breakdown of BER and Q factor for each eNB in segment A.

Table 4.2: BER and Q factor results for segment A

eNBs	BER	Q Factors
eNB 1	3.29E-19	8.86
eNB 2	1.26E-19	8.97
eNB 3	5.84E-16	7.98
eNB 4	8.69E-19	8.76
eNB 5	4.67E-16	8.01
eNB 6	6.22E-18	8.53
eNB 7	6.30E-19	8.79
eNB 8	2.16E-14	7.53
eNB 9	4.60E-16	8.01
eNB 10	6.16E-10	6.06
eNB 11	3.29E-29	11.14
eNB 12	1.36E-15	7.88
eNB 13	5.26E-20	9.06
eNB 14	1.31E-16	8.16
eNB 15	6.10E-12	6.76
eNB 16	7.70E-26	10.43
eNB 17	1.94E-08	5.48
eNB 18	6.79E-34	12.07
eNB 19	1.15E-21	9.47
eNB 20	2.92E-18	8.62
eNB 21	3.92E-24	10.06
eNB 22	1.20E-16	8.18
eNB 23	2.58E-21	9.39
eNB 24	7.79E-11	6.37
eNB 25	3.61E-39	13.03
eNB 26	7.36E-15	7.67
eNB 27	1.45E-18	8.7
eNB 28	2.72E-13	7.19
eNB 29	9.18E-09	5.6
eNB 30	1.70E-13	7.26
eNB 31	1.85E-19	8.93
eNB 32	1.45E-14	7.59

Figures 4.38 and 4.39 are radar and linear plots of BER and Q factor for segment A (eNB1 to eNB32) respectively, the plots represent the results obtained in table 4.2. The blue lines represent BER whereas the red lines represents Q factor. In both graphs, eNB25 shows very high value for Q factor whereas eNB29 gave lowest value for Q factor. None of the results from all the 32 eNB analysers showed a BER value higher than E-8 which translates to a very good backhaul link.

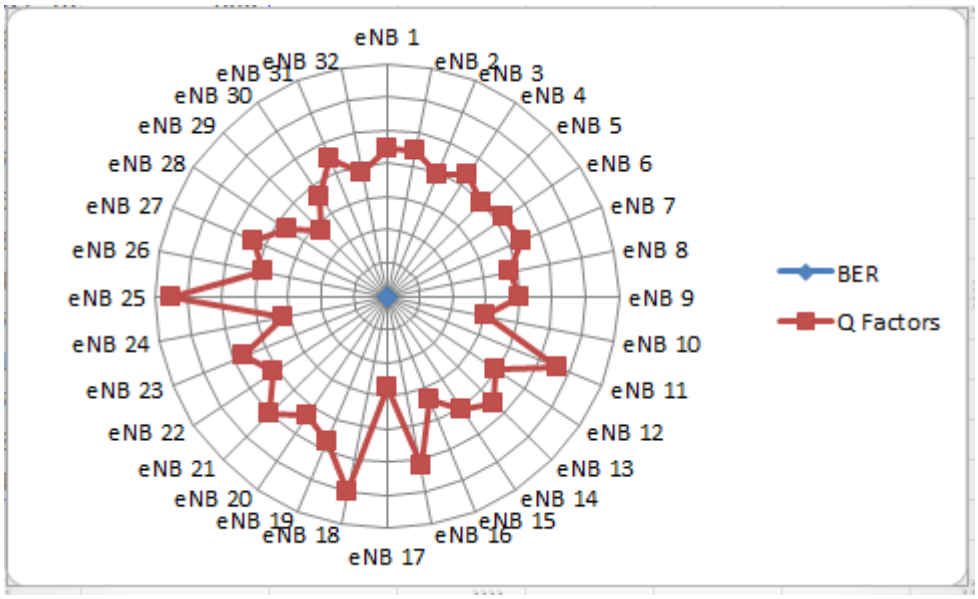


Figure 4.38: BER and Q factor in Radar plot (Segment A)

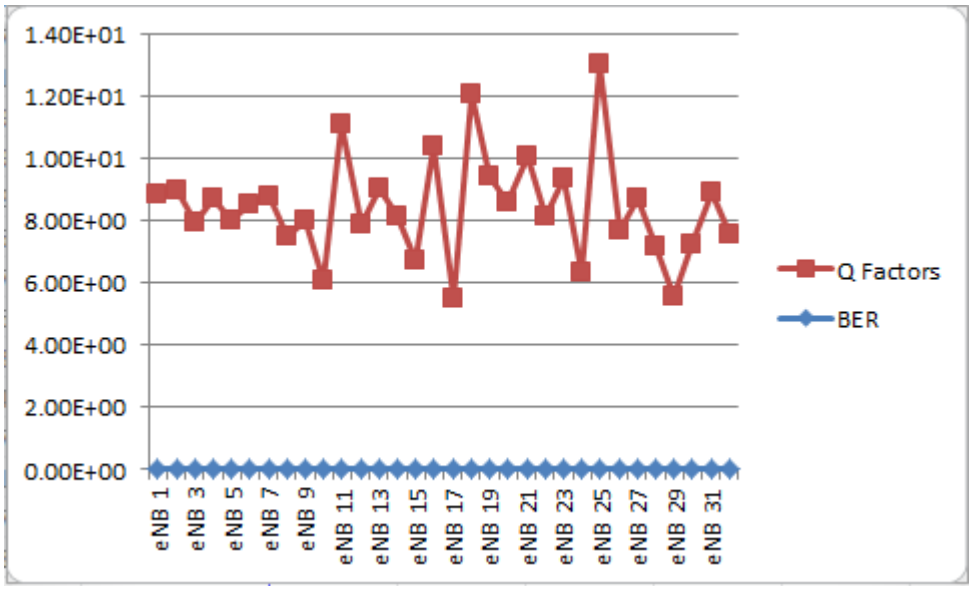


Figure 4.39: BER and Q factor in Linear Plot (Segment A)

DOWNSTREAM SEGMENT B RESULTS

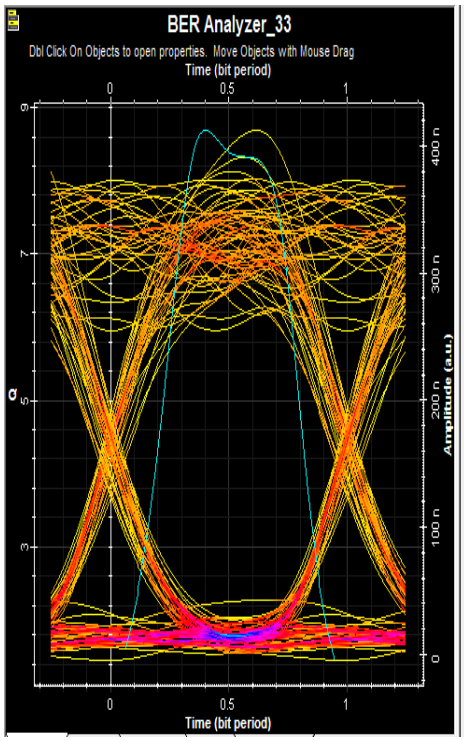


Figure 4.40: eNB33 analyser

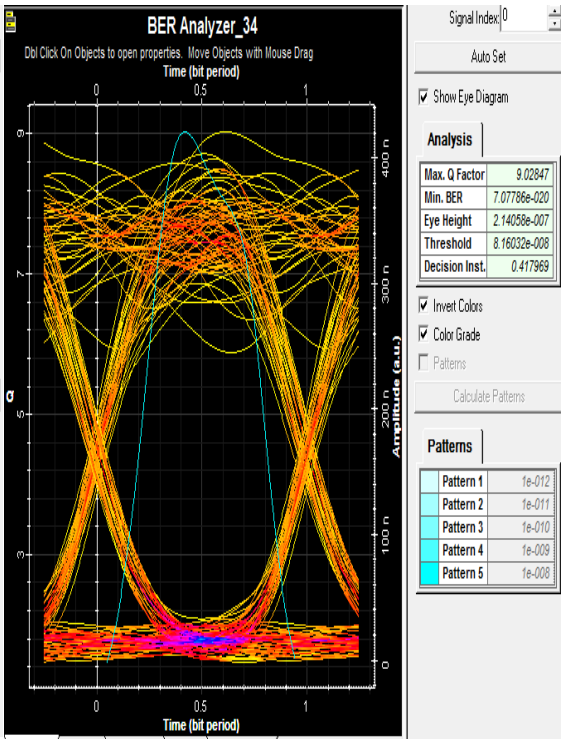


Figure 4.41: eNB34 analyser

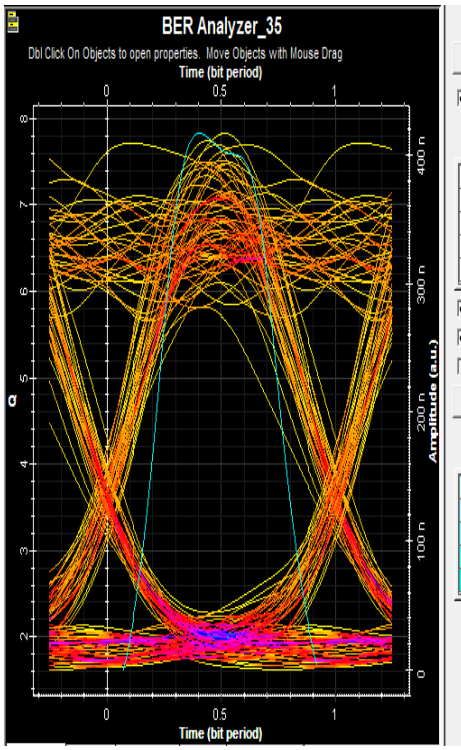


Figure 4.42: eNB35 analyser

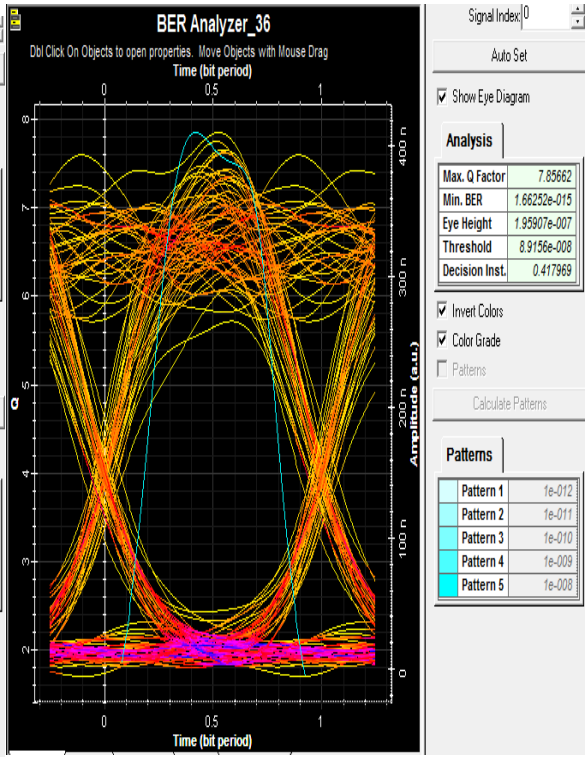


Figure 4.43: eNB36 analyser

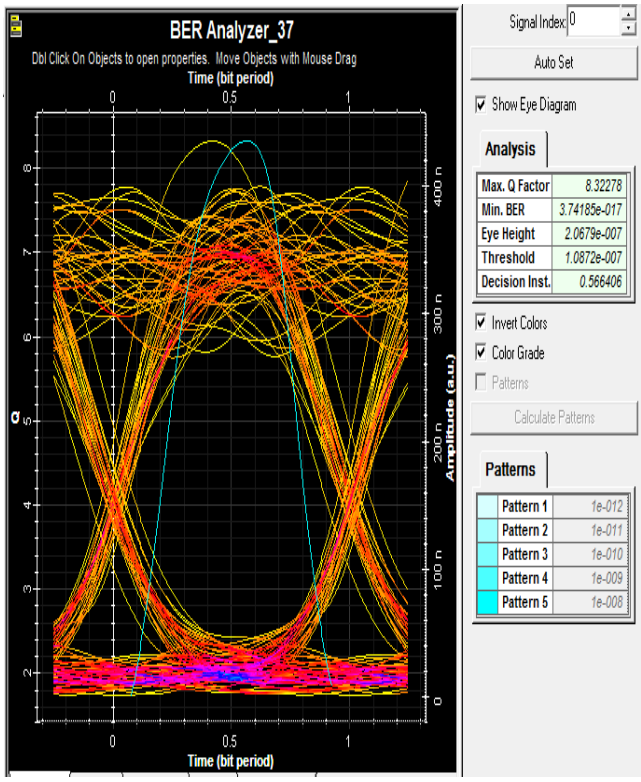


Figure 4.44: eNB37 analyser

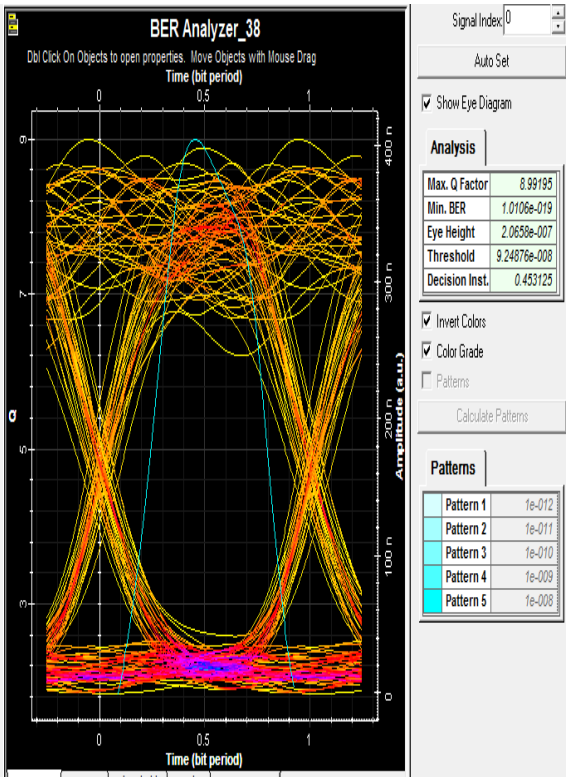


Figure 4.45: eNB38 analyser

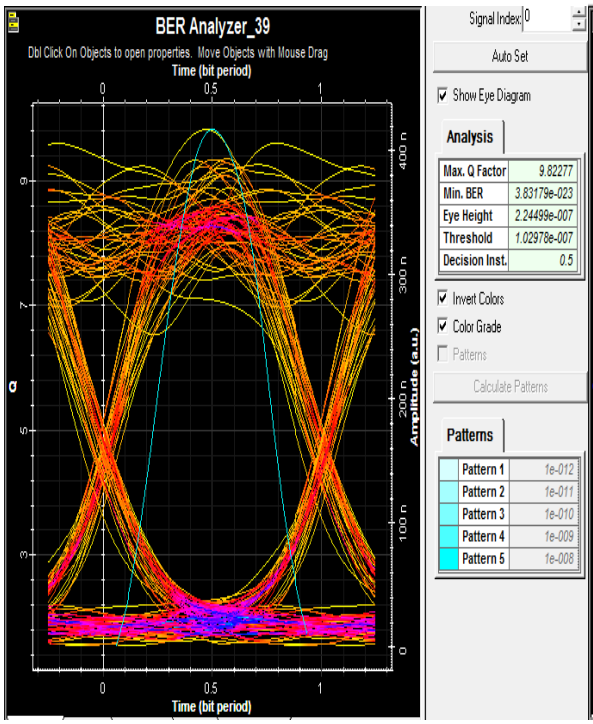


Figure 4.46: eNB39 analyser

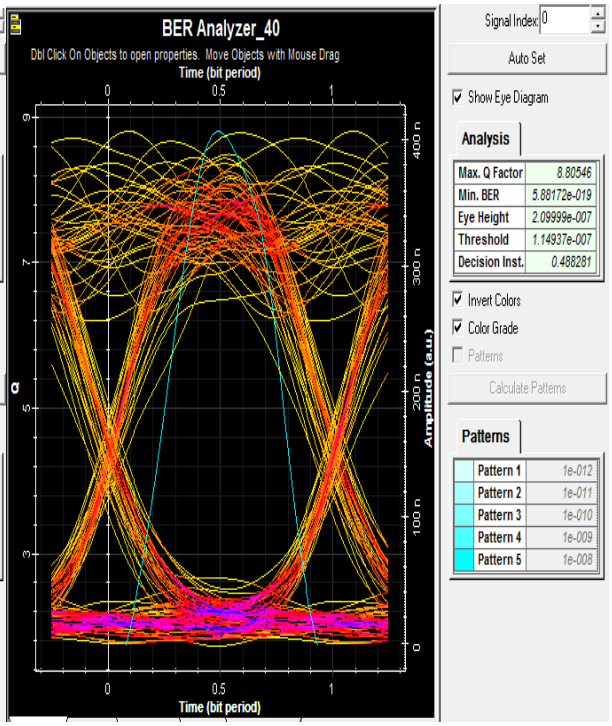


Figure 4.47: eNB40 analyser

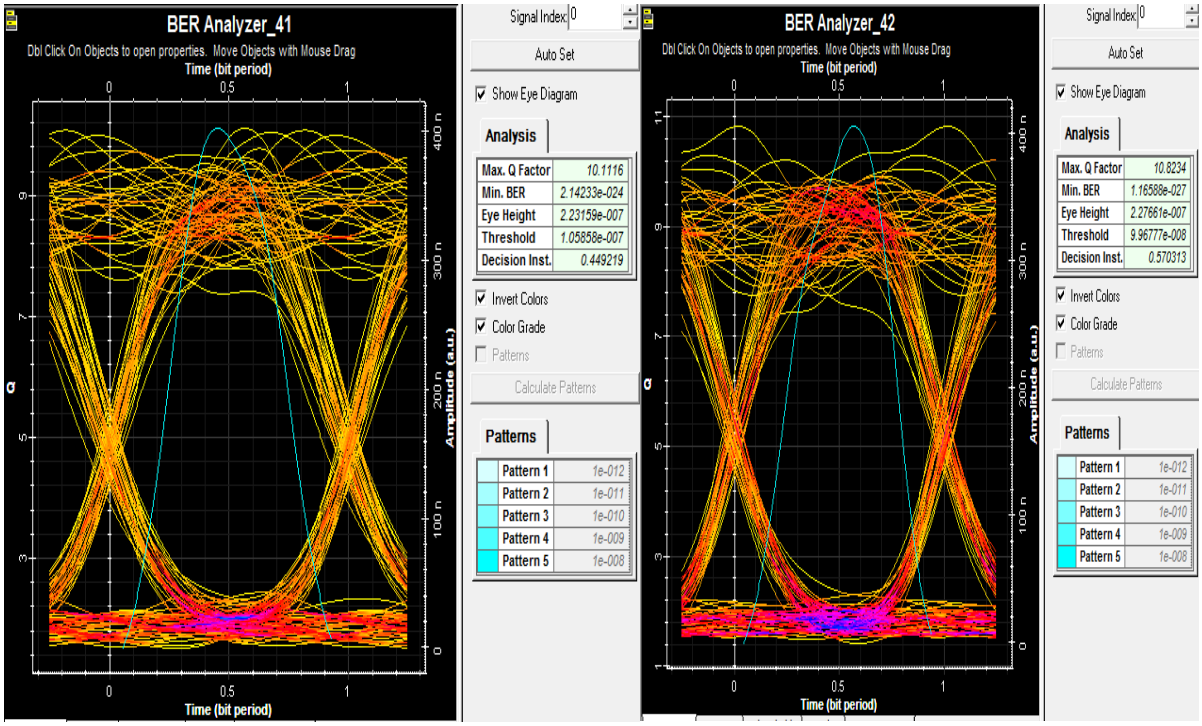


Figure 4.48: eNB41 analyser

Figure 4.49: eNB42 analyser

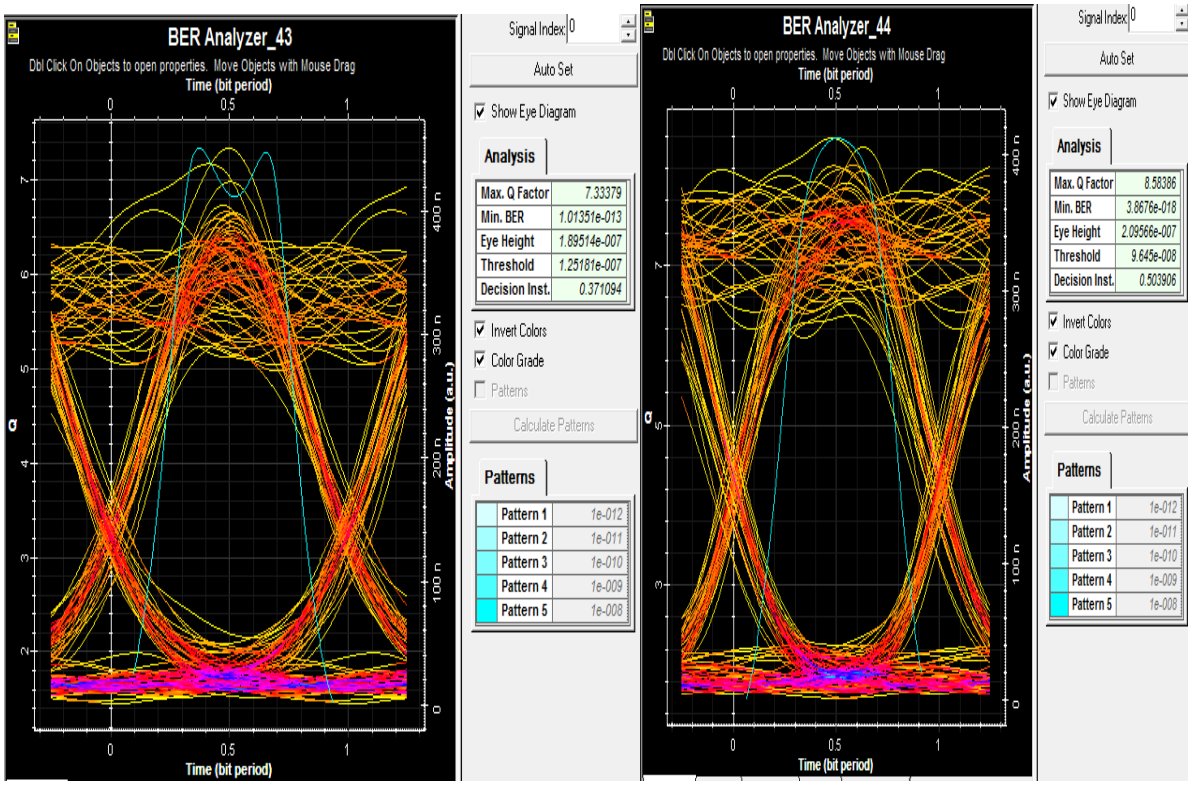


Figure 4.50: eNB43 analyser

Figure 4.51: eNB44 analyser

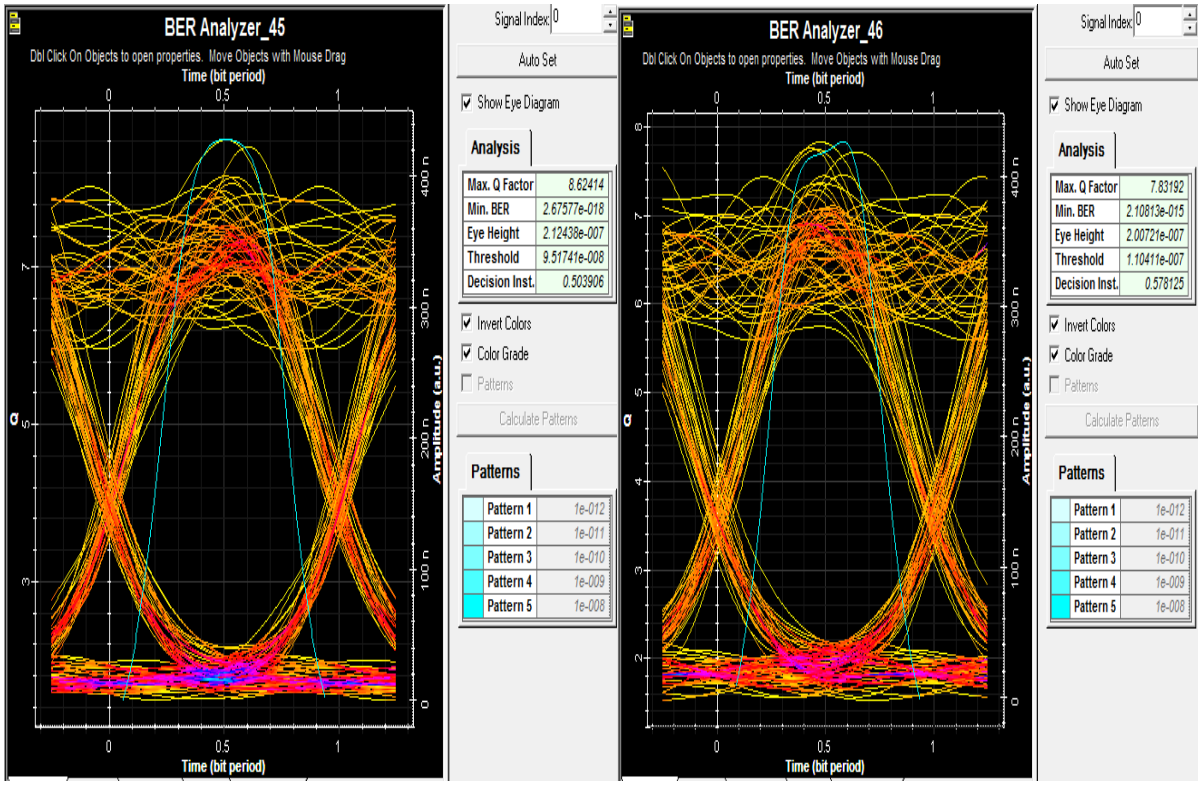


Figure 4.52: eNB45 analyser

Figure 4.53: eNB46 analyser

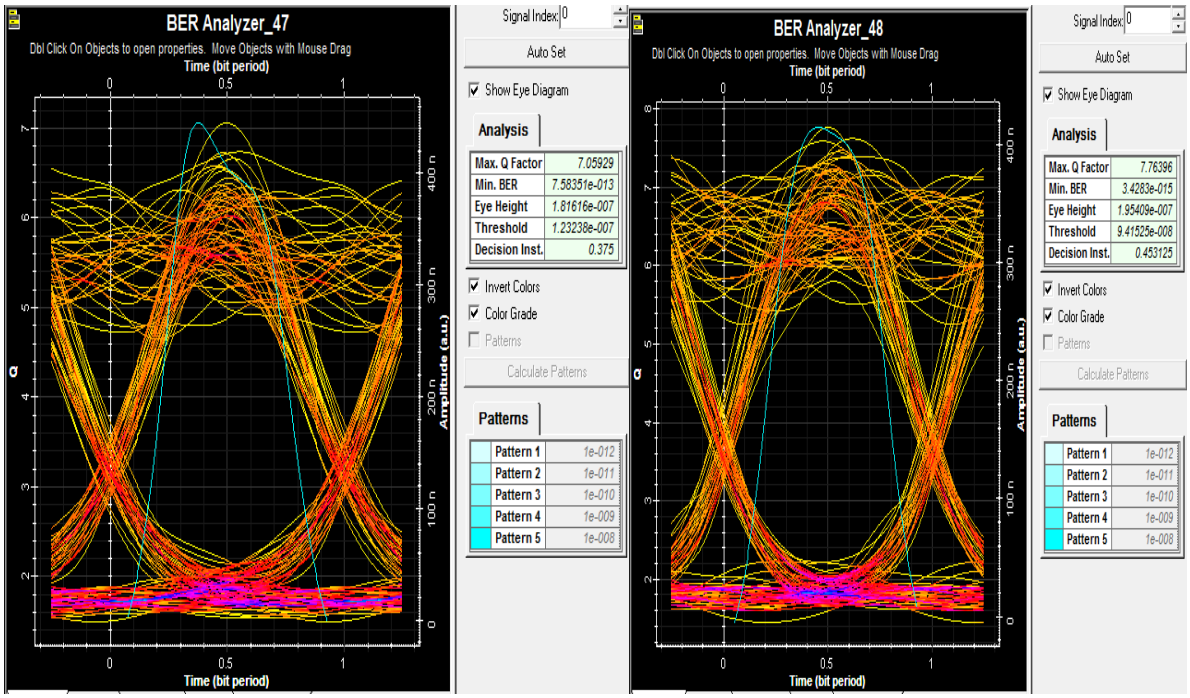


Figure 4.54: eNB47 analyser

Figure 4.55: eNB48 analyser

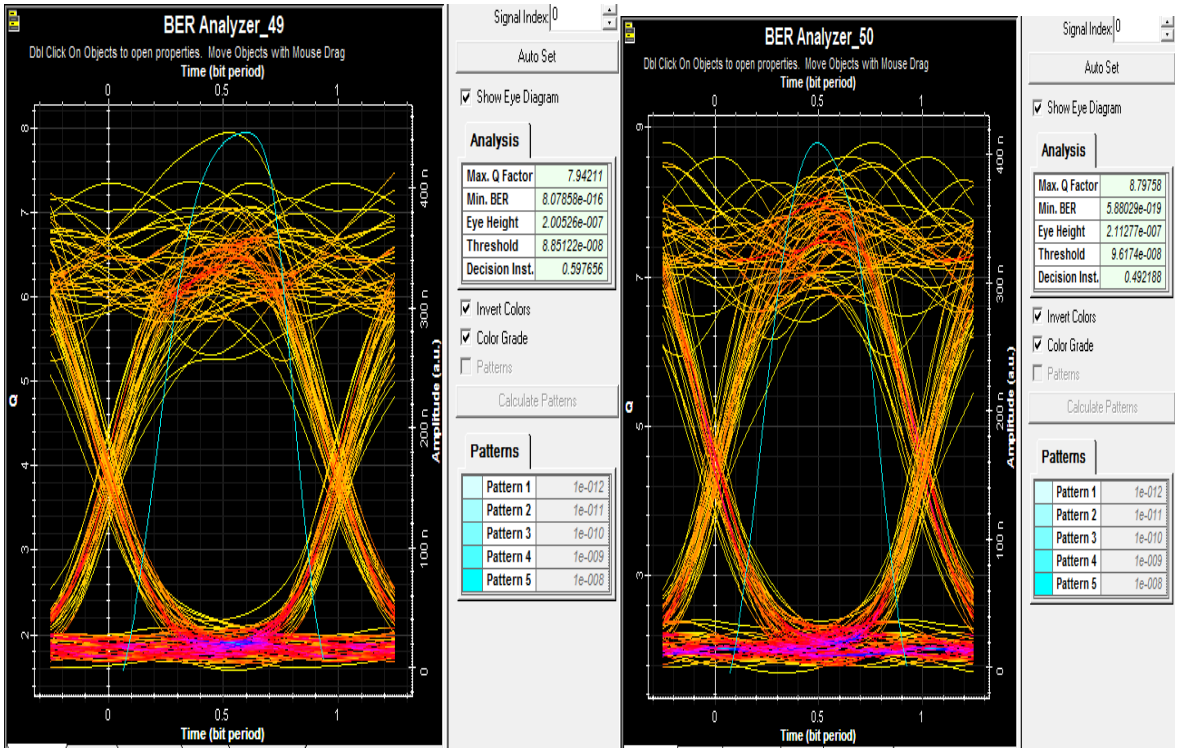


Figure 4.56: eNB49 analyser

Figure 4.57: eNB50 analyser

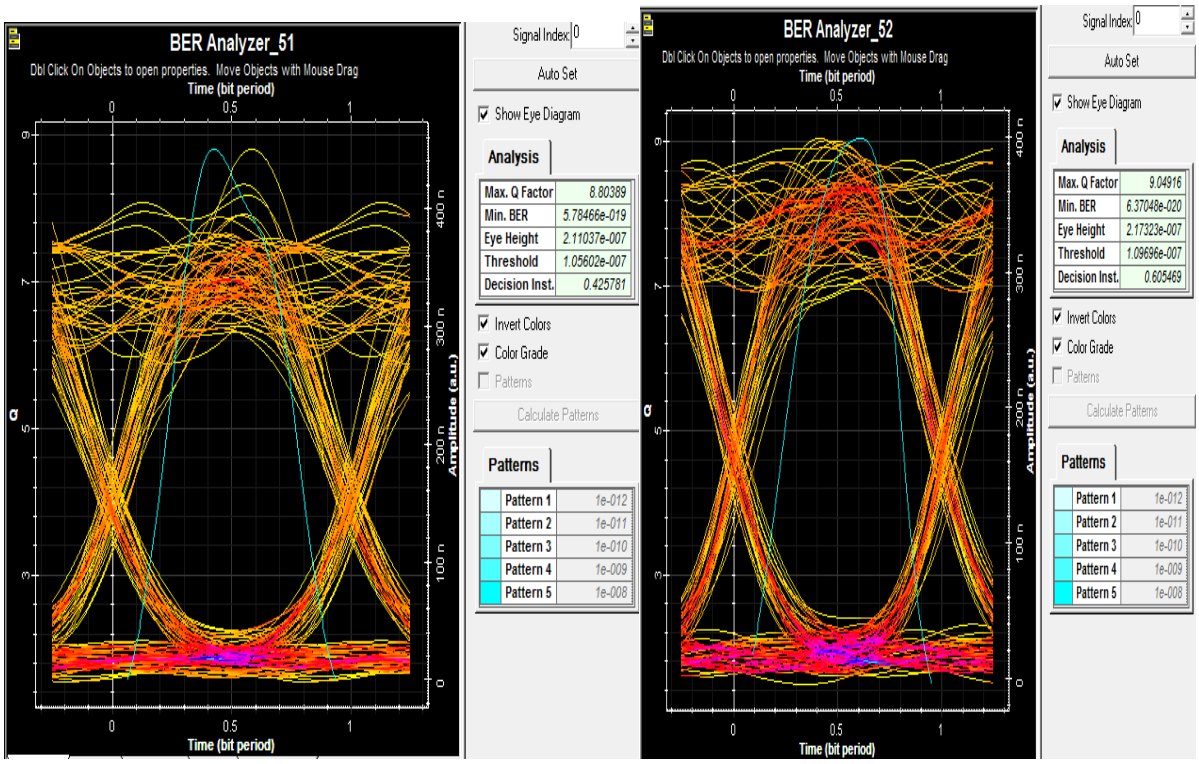


Figure 4.58: eNB51 analyser

Figure 4.59: eNB52 analyser

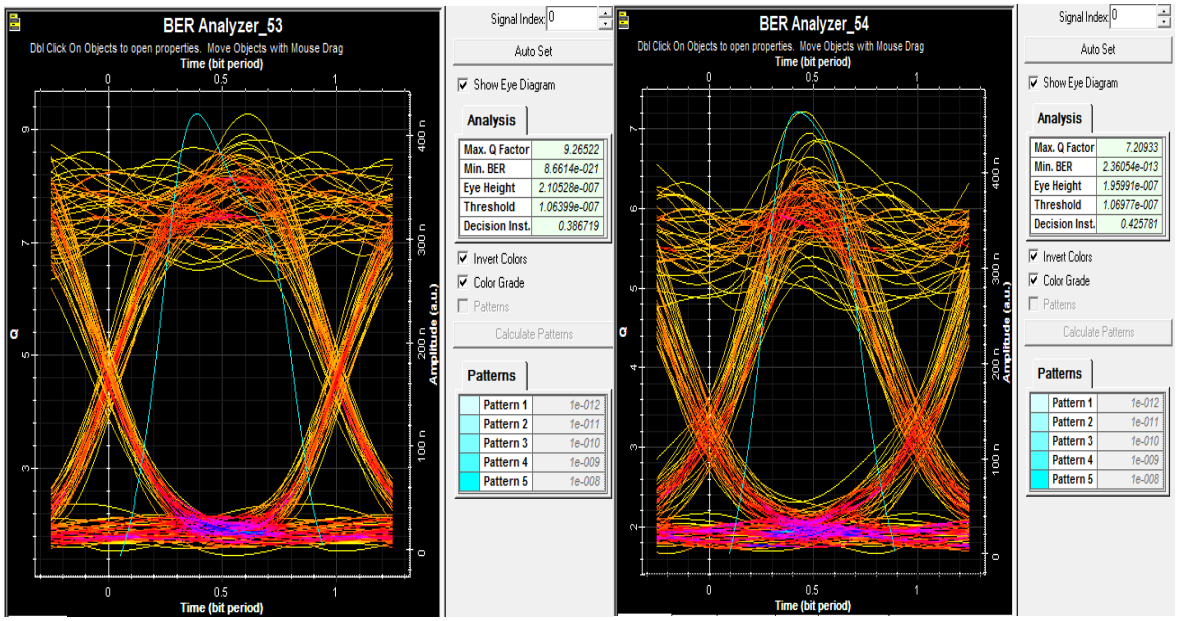


Figure 4.60: eNB53 analyser

Figure 4.61: eNB54 analyser

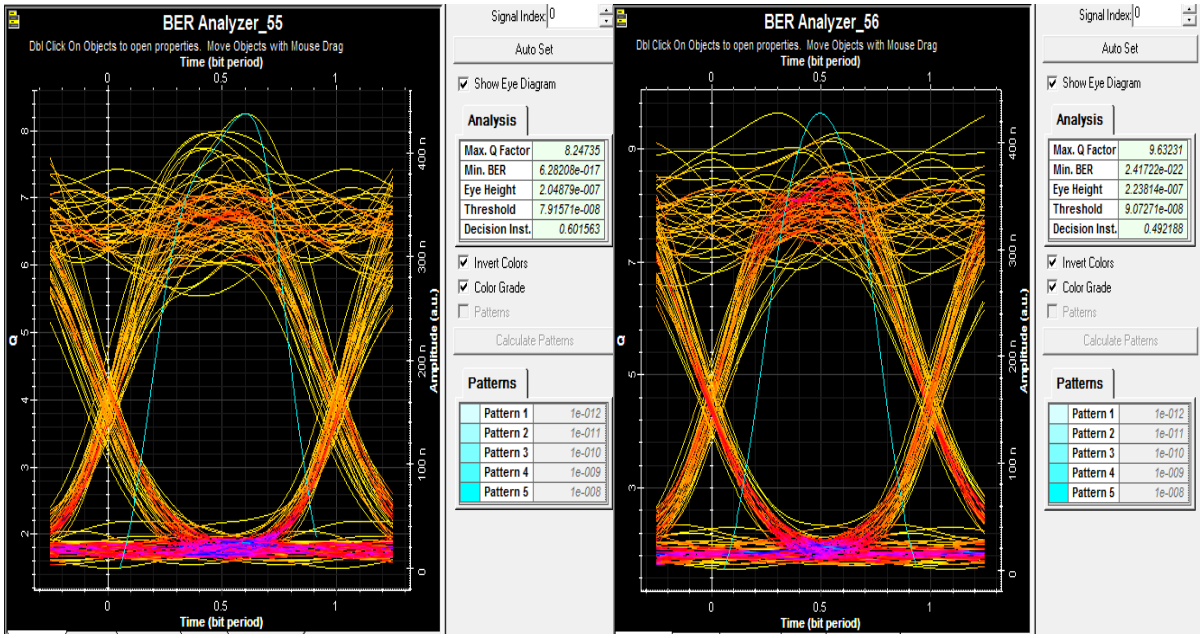


Figure 4.62: eNB55 analyser

Figure 4.63: eNB56 analyser

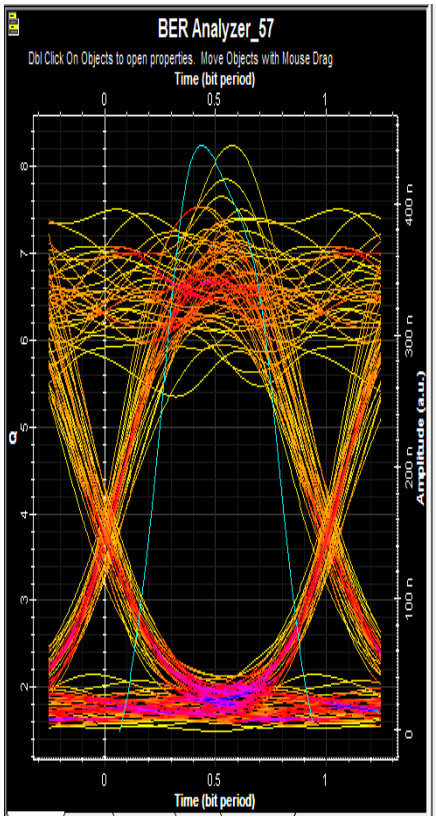


Figure 4.64: eNB57 analyser

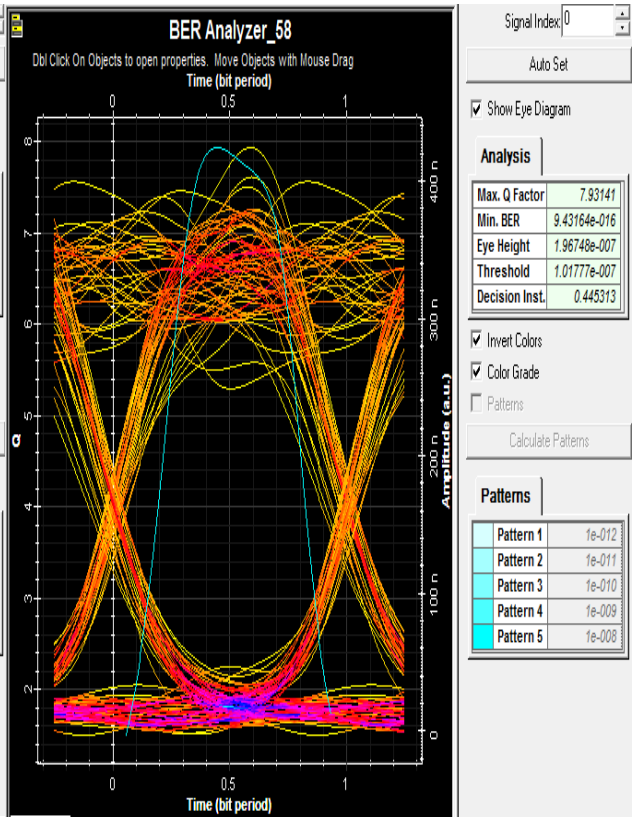


Figure 4.65: eNB58 analyser

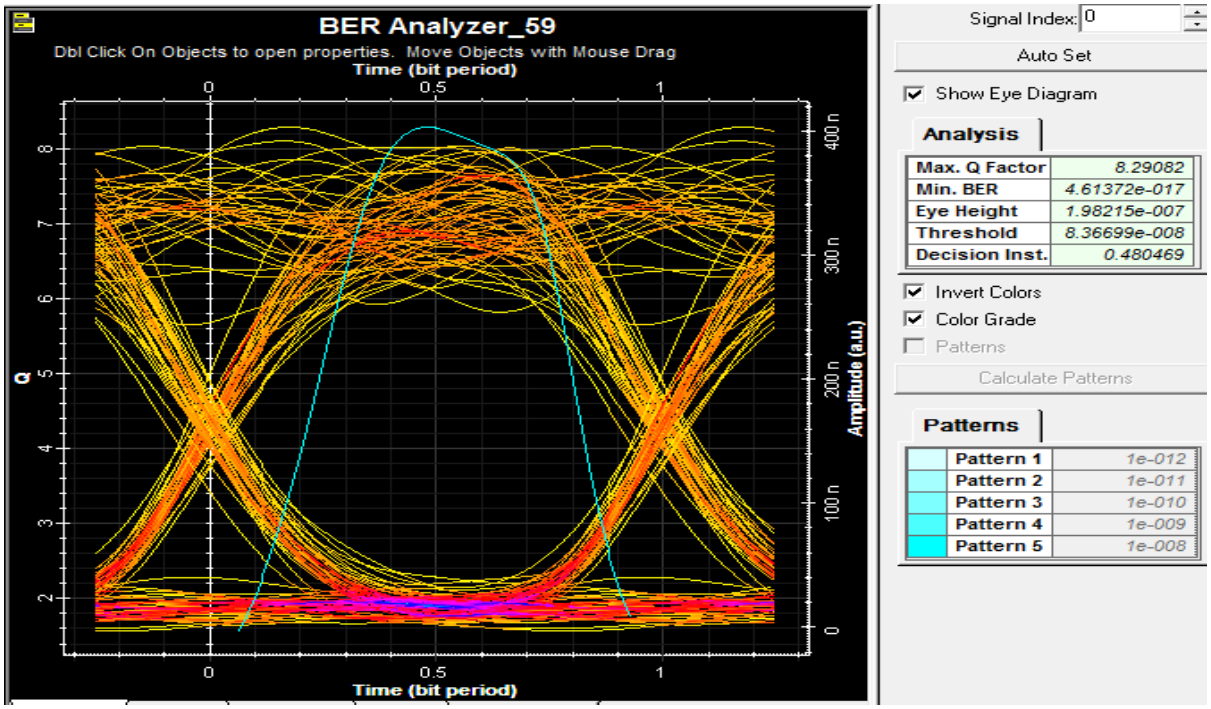


Figure 4.66: eNB59 analyser

Figures 4.40 to 4.66 represents results obtained from BER analysers of segment B. Segment B covers eNB 33 to 59, provisions were made for possible expansion to cover up to 64 eNBs. From the results obtained, none of BER from all the analysers has a BER value higher than E-13. eNB 42 has the lowest bit error rate (1.17E-27) and a Q factor of 10.82 whereas eNB 47 has BER of 7.58 $x10^{-13}$ and a Q factor of 7.06 respectively. The values of BER and Q factor of other eNBs in the downstream segment B is as shown in table 4.3.

Table 4.3: BER and Q factor results for segment B

eNBs	BER	Q Factor
eNB 33	1.47E-18	8.69
eNB 34	7.08E-20	9.03
eNB 35	2.02E-15	7.83
eNB 36	1.66E-15	7.86
eNB 37	3.74E-17	8.32
eNB 38	1.01E-19	8.99
eNB 39	3.83E-23	9.82
eNB 40	5.88E-19	8.81
eNB 41	2.14E-24	10.11
eNB 42	1.17E-27	10.82
eNB 43	1.01E-13	7.33
eNB 44	3.87E-18	8.58
eNB 45	2.68E-18	8.62
eNB 46	2.11E-15	7.83
eNB 47	7.58E-13	7.06
eNB 48	3.43E-15	7.76
eNB 49	8.08E-16	7.94
eNB 50	5.88E-19	8.8
eNB 51	5.79E-19	8.8
eNB 52	6.37E-20	9.05
eNB 53	8.66E-21	9.27
eNB 54	2.36E-13	7.21
eNB 55	6.28E-17	8.25
eNB 56	2.42E-22	9.63
eNB 57	7.43E-17	8.24
eNB 58	9.43E-16	7.93
eNB 59	4.61E-17	8.29

The results as shown in table 4.3 are plotted in figures 4.67 and 4.68. Both figures show the distribution of Q factor and BER per eNB in radar and linear graphs respectively. According to Figures 4.67 and 4.68, all the eNBs have very low bit error rate and corresponding Q factor. eNB 42 showed highest Q factor translating lowest BER. Accordingly, all the BER analysers on this segment B demonstrated qualities of a good backhaul link.

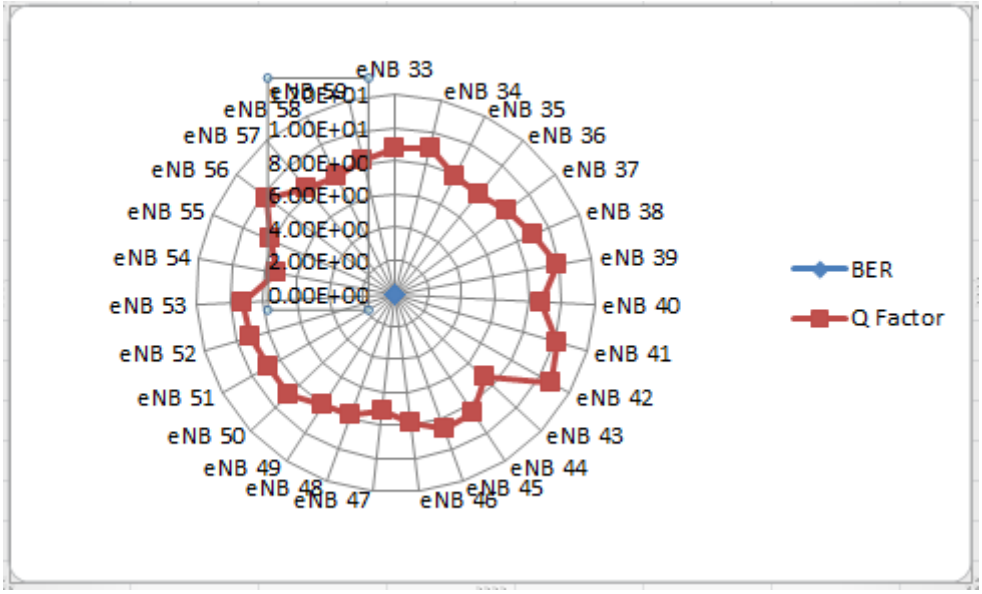


Figure 4.67: BER and Q factor in Radar Plot (Segment B)

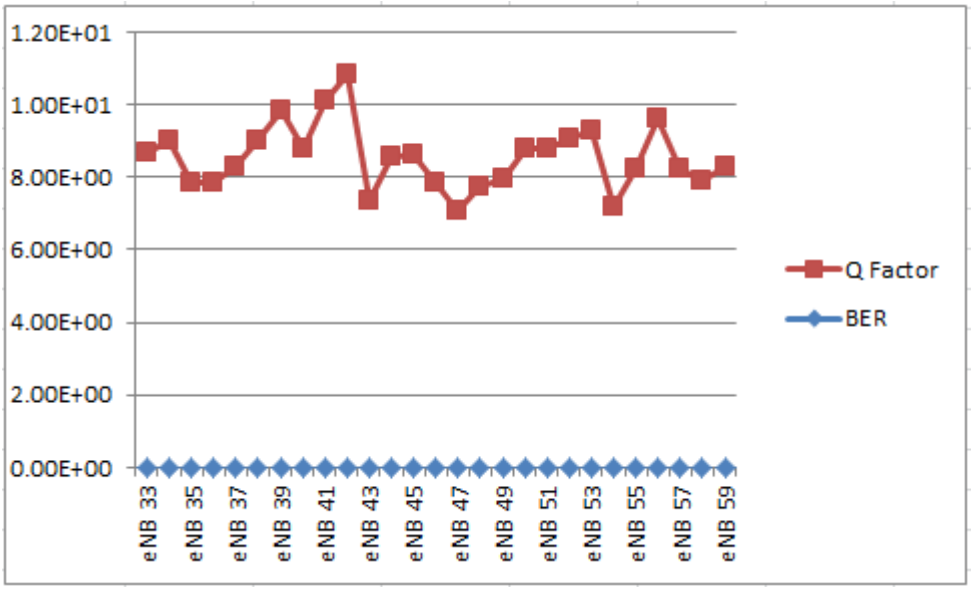


Figure 4.68: BER and Q factor in Linear Plot (Segment B)

4.6 VALIDATION OF UPSTREAM TRANSMISSION

The simulation results for the upstream transmission are also divided into segments A and B just as it was done in the network design. The assigned delays in section 3.5.3 ensured no collision at the OLT since multiple eNBs (ONUs) were sending to OLT. Each analyser used BER and Q factor to analyse the quality of signals coming from multiple eNBs. As said earlier, BER and Q factor are two important parameters that are used to analyse the results obtained in optical communication system. Segment A of the upstream showed BER analysers when ONU 1 to 32 were transmitting.

SEGMENT A RESULTS

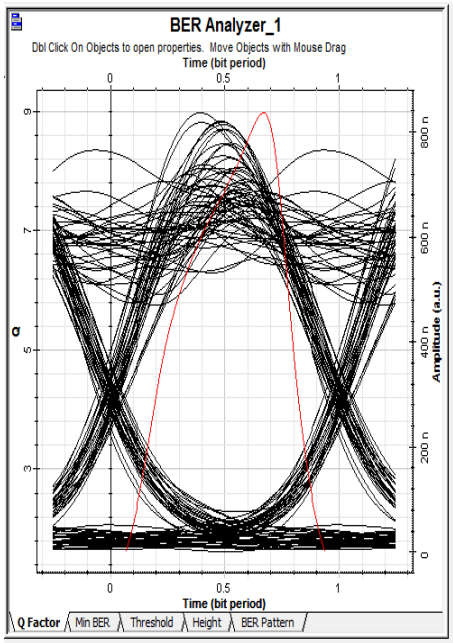


Figure 4.69: BER Analyser 1 (Segment A)

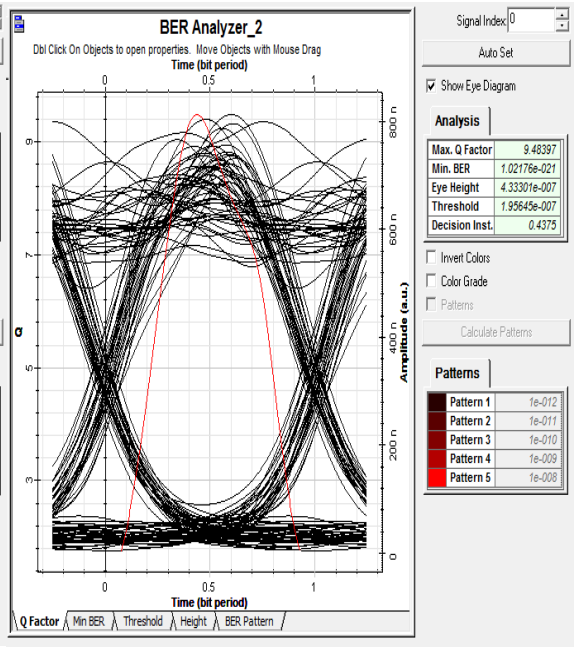


Figure 4.70: BER Analyser 2 (Segment A)

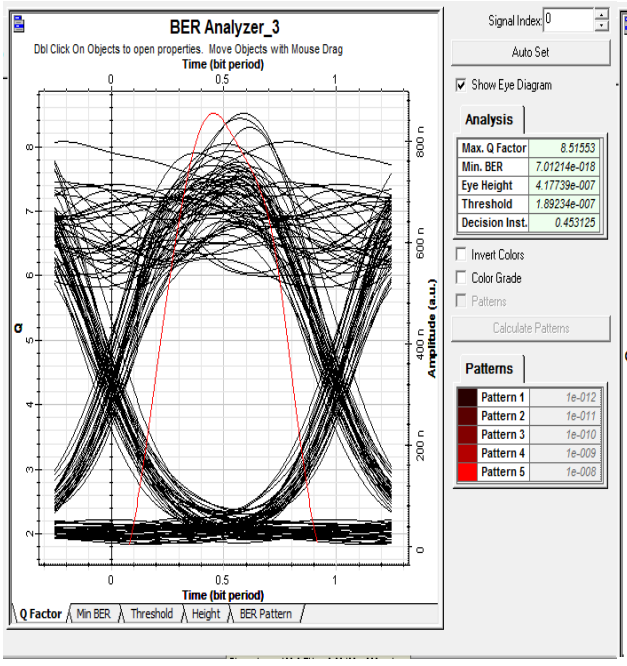


Figure 4.71: BER Analyser 3 (Segment A)

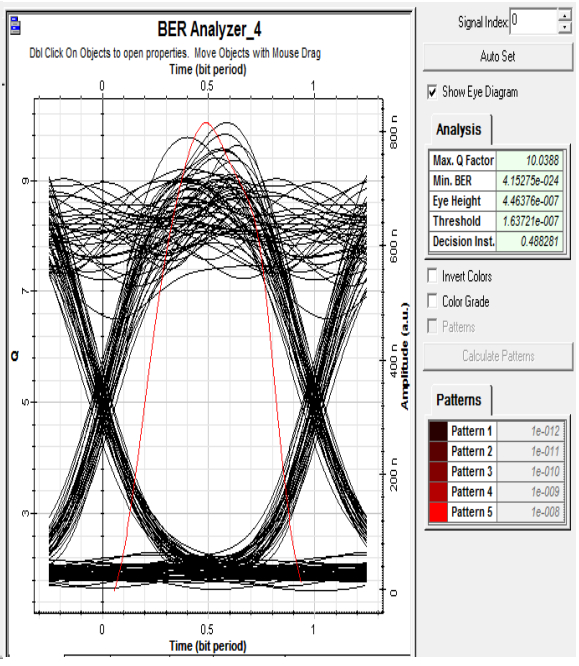


Figure 4.72: BER Analyser 4 (Segment A)

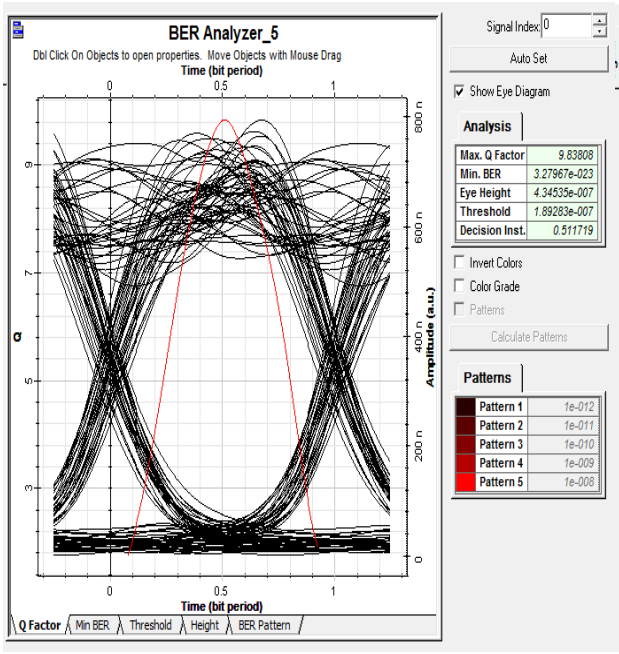


Figure 4.73: BER Analyser 5 (Segment A)

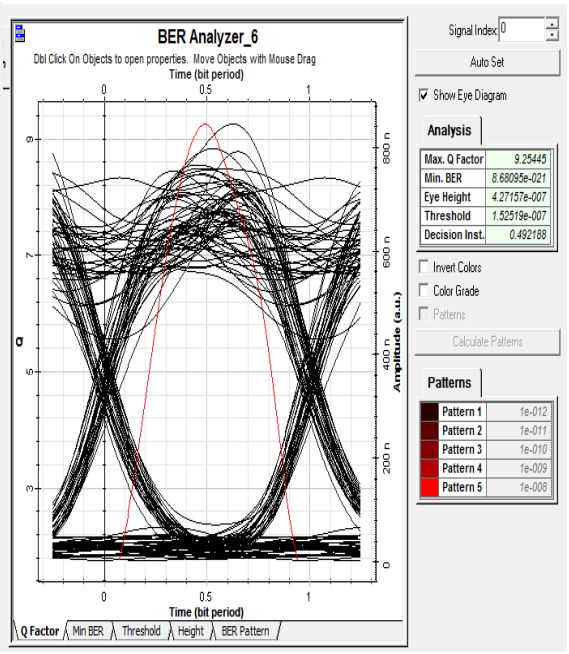


Figure 4.74: BER Analyser 6 (Segment A)

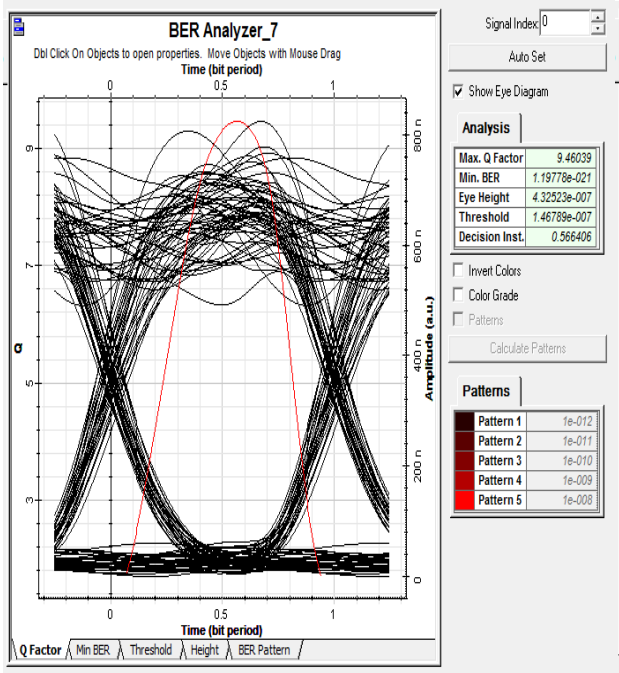


Figure 4.75: BER Analyser 7 (Segment A)

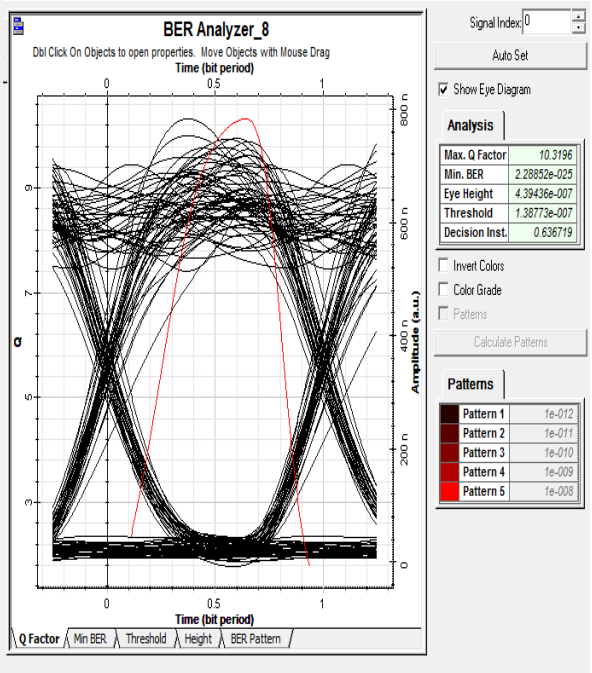


Figure 4.76: BER Analyser 8 (Segment A)

As stated earlier, upstream transmission is when eNBs are transmitting to the OLT. Figures 4.69 to 4.76 shows the results obtained from BER analysers in the OLT of segment A. It shows eye diagrams displaying BER and Q factor for each analyser in the OLT. Table 4.4 showed BER and Q factor values as obtained from the 8 BER analysers. All the eight analysers showed

very low error per bits with values ranging from E-18 to E-25 and Q factors 8.52 to 10.32 respectively. The values of BER and Q factors obtained are typical of a good optical backhaul system.

Table 4.4: BER and Q factor results for segment A (Upstream)

BER ANALYSERS	BER	Q FACTOR
BER ANALYSER 1	1.37E-19	8.97
BER ANALYSER 2	1.02E-21	9.48
BER ANALYSER 3	7.01E-18	8.52
BER ANALYSER 4	4.15E-24	10.04
BER ANALYSER 5	3.28E-23	9.84
BER ANALYSER 6	8.68E-21	9.25
BER ANALYSER 7	1.12E-21	9.46
BER ANALYSER 8	2.29E-25	10.32

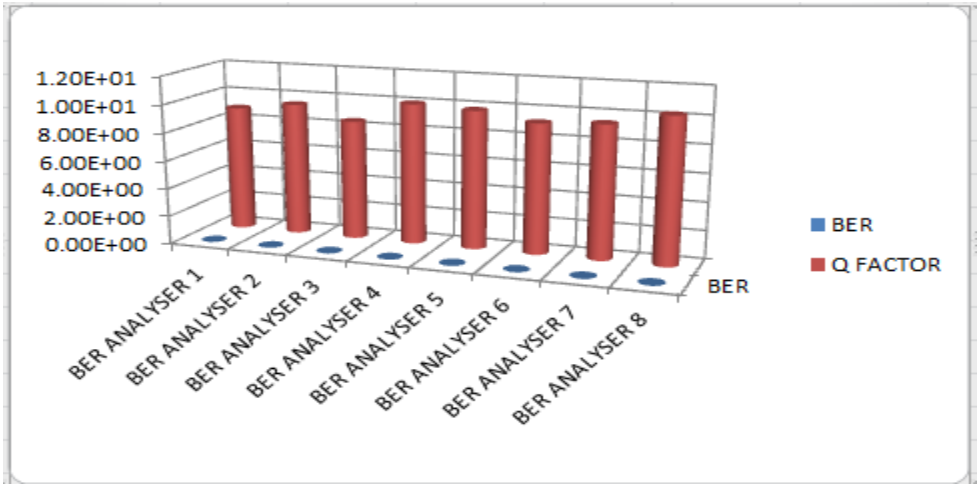


Figure 4.77: BER and Q factor in a bar chart (Upstream Segment A)

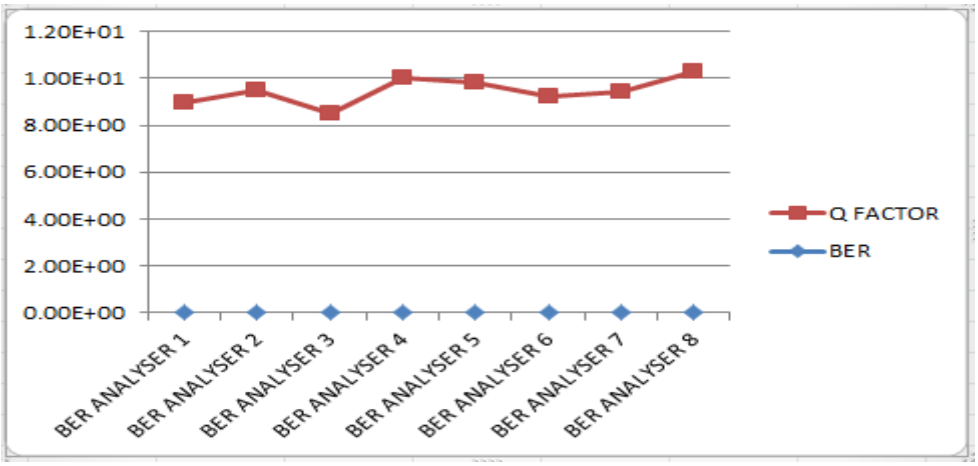


Figure 4.78: BER and Q factor in Linear Plot (Upstream Segment A)

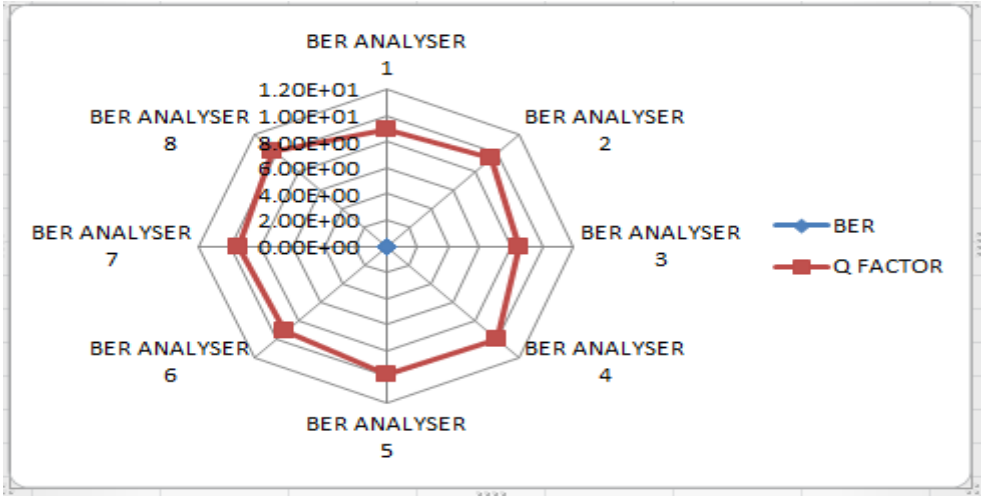


Figure 4.79: BER and Q factor in Radar Plot (Upstream Segment A)

Graphical presentations of results obtained in segment A of the upstream transmission are shown in figures 4.77, 4.78 and 4.79. Figures 4.77 and 4.78 are linear and pictorial relationship between BER and Q factor of table 4.4 respectively and whereas figure 4.79 shows its radar representation. The three graphs clearly showed that error per bit on each analyser is relatively infinitesimal while Q factor values are high. Again, the result showed a good optical backhaul system.

UP STREAM SEGMENT B RESULTS

Segment B results of the upstream as obtained when ONU 33 to 59 are transmitting are as shown in figures 4.80 to 4.87. They are eye diagrams showing both BER and Q factor.

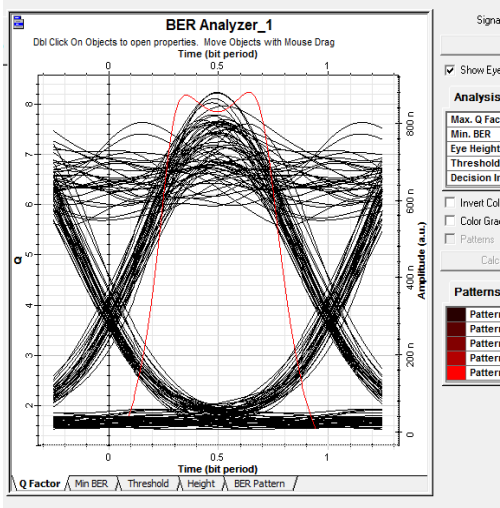


Figure 4.80: BER Analyser 1 (Segment B)

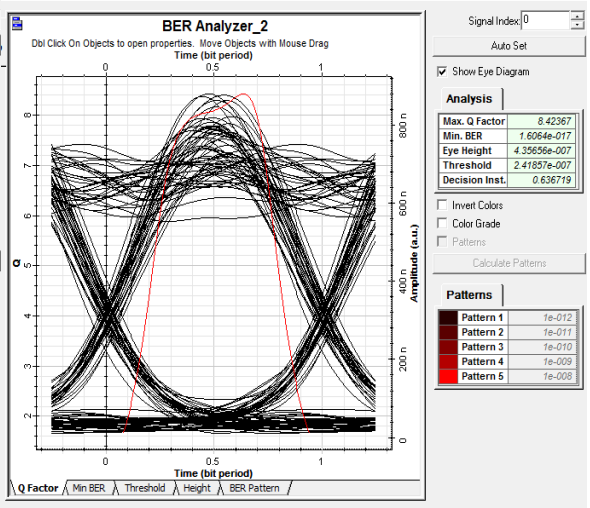


Figure 4.81: BER Analyser 2 (Segment B)

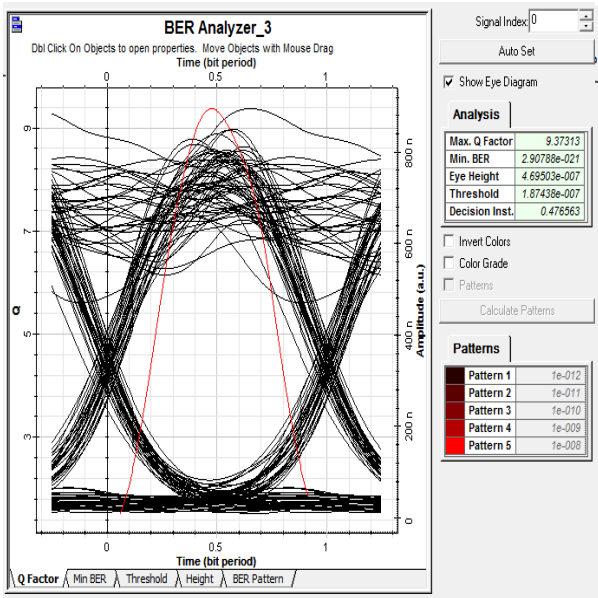


Figure 4.82: BER Analyser 3 (Segment B)

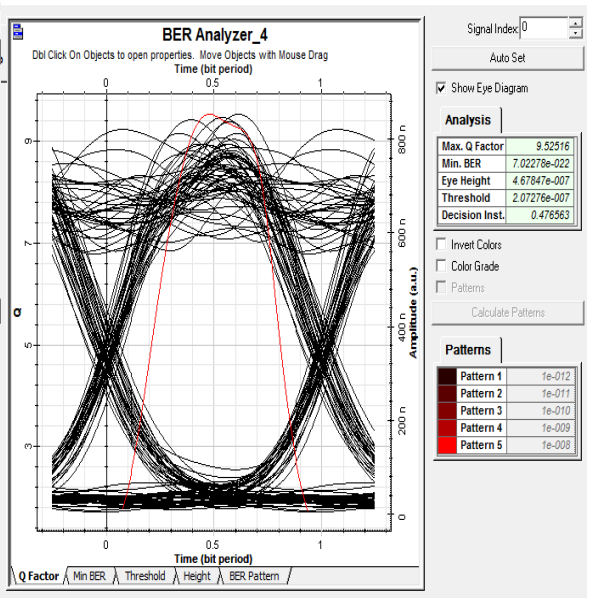


Figure 4.83: BER Analyser 4 (Segment B)

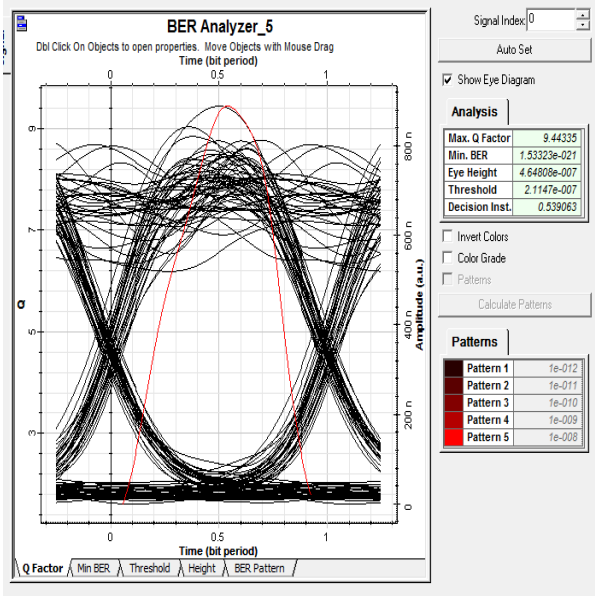


Figure 4.84: BER Analyser 5 (Segment B)

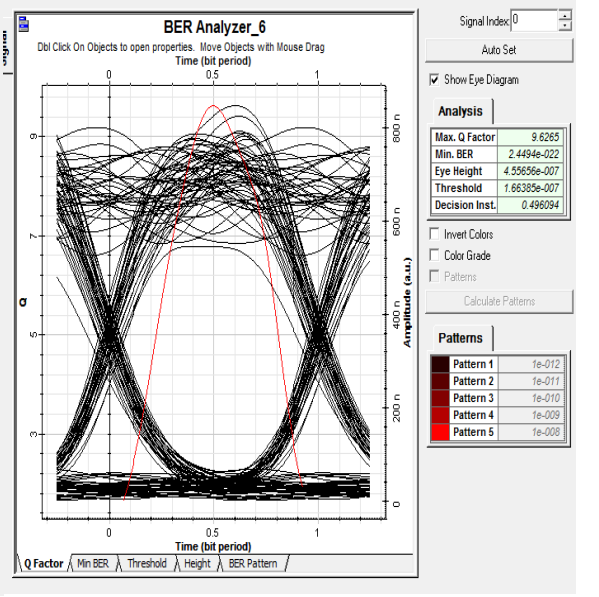


Figure 4.85: BER Analyser 6 (Segment B)

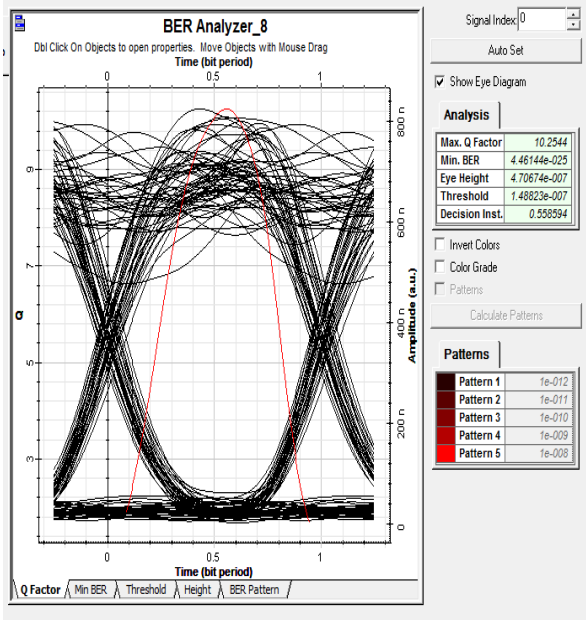


Figure 4.86: BER Analyser 7 (Segment B)

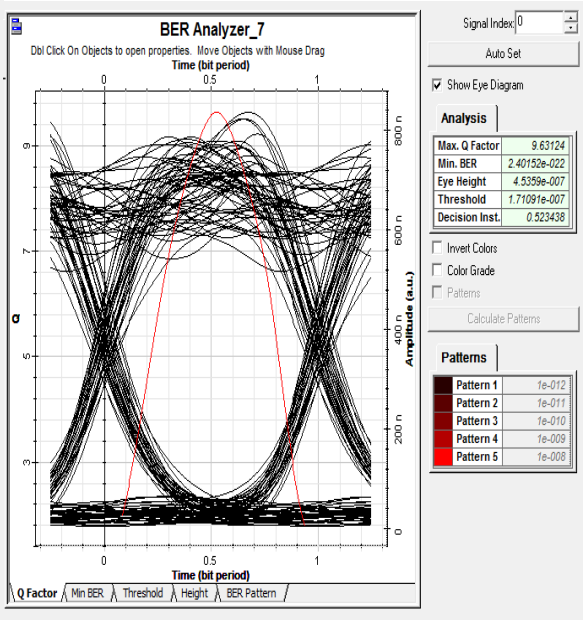


Figure 4.87: BER Analyser 8 (Segment B)

Analysers 1 to 8 showed BER values ranging from 8.30E-17 to 4.46E-25 and Q factor values of range 8.23 to 10.25 respectively. The results from all the eight analysers showed that error per bit from the signals transmitted were very insignificant. Table 4.5 showed BER and Q factor per analyser as obtained from each of the eye diagrams of figures 4.80 through 4.87.

Table 4.5: BER and Q factor results for segment B (Upstream)

BER ANALYSERS	BER	Q FACTOR
ANALYSER 1	8.30E-17	8.23
ANALYSER 2	1.61E-17	8.42
ANALYSER 3	2.91E-21	9.37
ANALYSER 4	7.02E-22	9.53
ANALYSER 5	1.53E-21	9.44
ANALYSER 6	2.45E-22	9.63
ANALYSER 7	2.40E-22	9.63
ANALYSER 8	4.46E-25	10.25

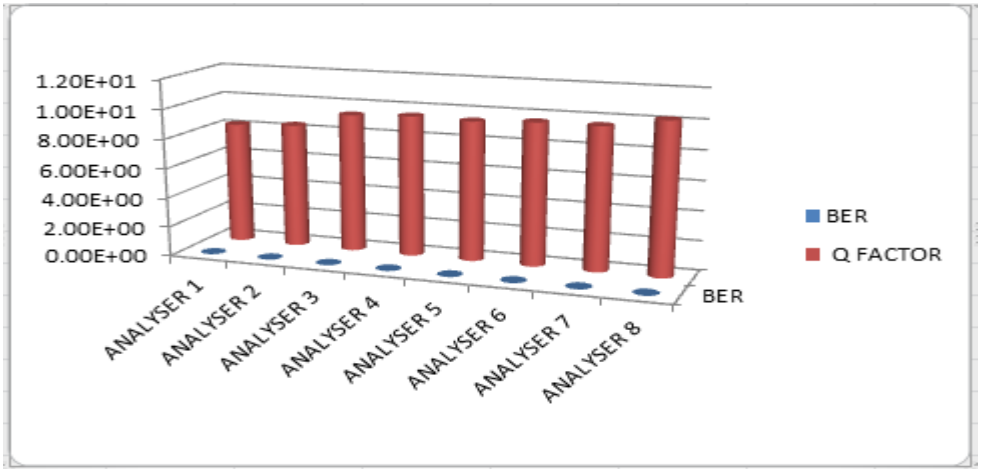


Figure 4.88: BER and Q factor in a bar chart (Upstream Segment B)

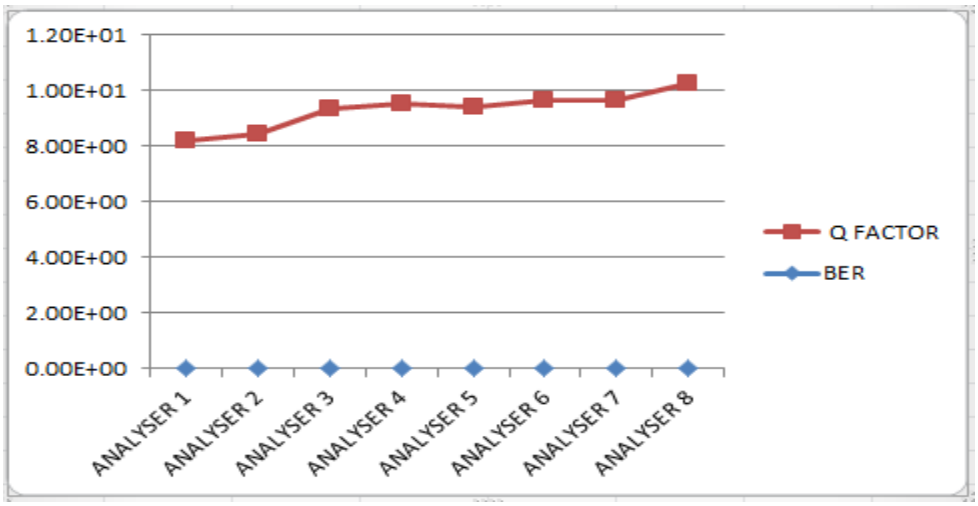


Figure 4.89: BER and Q factor in Linear Plot (Upstream Segment B)

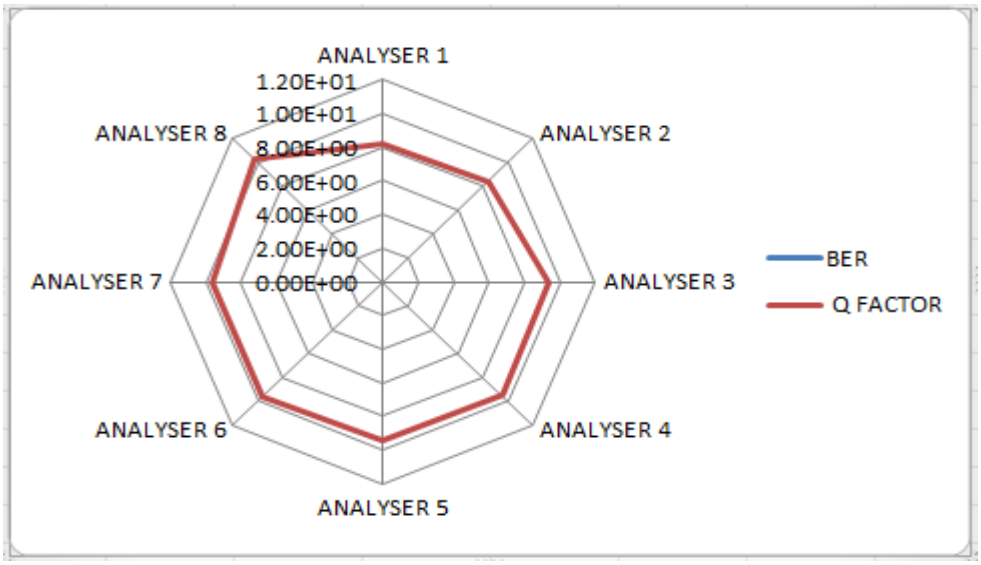


Figure 4.90: BER and Q factor in Radar Plot (Upstream Segment B)

Plots showing the results as obtained from table 4.5 are as shown in figures 4.88, 4.89 and 4.90. In figure 4.88, BER and Q factor for each analyser is linearly represented, the red lines depict the Q factor and Blue lines represent BER for each analyser. Analyser 8 is seen as the link with the least error per bit, this because it has the highest Q factor of value 10.25 and BER value of 4.46E-25, this represents an optical link with infinitesimal error per bit and translates to a high quality backhaul link. Same analyses go to analysers 1 to 7. In the same view, figures 4.89 and 4.90 are pictorial and radar presentation of information in table 4.5, the graphs show distribution of BER and Q factor of table 4.5. They have the same analyses as figure 4.88 and demonstrate a quality backhaul system.

4.7 COMPARATIVE ANALYSIS

This section compares the Bit error rate (BER) performances of existing SMILE Microwave backhaul link with that of the developed PON network system. BER is one of the major key performance indicators to describe the quality of a transmission link. Performance measurement as carried out by SMILE 4G LTE mobile communication network from 13th to 22nd November 2019 are shown in table 4.6.

Table 4.6: SMILE 4G LTE Microwave link Performance

eNBs	**BER on Microwave Link**
eNB 0	7.55E-05
eNB 1	3.25E-05
eNB 2	6.42E-05
eNB 3	8.20E-04
eNB 4	6.38E-05
eNB 5	7.46E-05
eNB 6	4.60E-03
eNB 7	9.36E-04
eNB 8	3.71E-05
eNB 9	8.61E-04
eNB 10	7.24E-05
eNB 11	4.85E-05
eNB 12	6.48E-04
eNB 13	4.72E-04

eNB 14	5.44E-05
eNB 15	9.32E-05
eNB 16	4.47E-05
eNB 17	5.89E-04
eNB 18	7.67E-05
eNB 19	4.81E-03
eNB 20	6.29E-04
eNB 21	6.23E-05
eNB 22	4.84E-04
eNB 23	4.22E-04
eNB 24	8.46E-05
eNB 25	3.54E-04
eNB 26	6.18E-05
eNB 27	7.05E-05
eNB 28	4.49E-05
eNB 29	6.17E-04
eNB 30	3.21E-03
eNB 31	4.33E-05
eNB 32	6.20E-05
eNB 33	3.09E-05
eNB 34	8.16E-05
eNB 35	6.11E-05
eNB 36	5.59E-04
eNB 37	7.02E-05
eNB 38	2.43E-03
eNB 39	3.19E-04
eNB 40	6.15E-05
eNB 41	4.13E-04
eNB 42	8.14E-05
eNB 43	7.34E-05
eNB 44	5.15E-05
eNB 45	7.01E-05
eNB 46	3.36E-04
eNB 47	1.89E-03
eNB 48	4.66E-04
eNB 49	5.12E-04
eNB 50	3.65E-03
eNB 51	7.10E-05
eNB 52	8.31E-05
eNB 53	4.14E-04
eNB 54	7.43E-05
eNB 55	6.02E-05
eNB 56	8.05E-05
eNB 57	4.26E-04
eNB 58	4.88E-05
eNB 59	9.13E-05

Table 4.7: BER for both SMILE Microwave link and that of Developed PON link

eNBs	BER on Microwave Link	BER on the Developed PON Link
eNB 0	7.55E-05	8.95E-19
eNB 1	3.25E-05	3.29E-19
eNB 2	6.42E-05	1.26E-19
eNB 3	8.20E-04	5.84E-16
eNB 4	6.38E-05	8.69E-19
eNB 5	7.46E-05	4.67E-16
eNB 6	4.60E-03	6.22E-18
eNB 7	9.36E-04	6.30E-19
eNB 8	3.71E-05	2.16E-14
eNB 9	8.61E-04	4.60E-16
eNB 10	7.24E-05	6.16E-10
eNB 11	4.85E-05	3.29E-29
eNB 12	6.48E-04	1.36E-15
eNB 13	4.72E-04	5.26E-20
eNB 14	5.44E-05	1.31E-16
eNB 15	9.32E-05	6.10E-12
eNB 16	4.47E-05	7.70E-26
eNB 17	5.89E-04	1.94E-08
eNB 18	7.67E-05	6.79E-34
eNB 19	4.81E-03	1.15E-21
eNB 20	6.29E-04	2.92E-18
eNB 21	6.23E-05	3.92E-24
eNB 22	4.84E-04	1.20E-16
eNB 23	4.22E-04	2.58E-21
eNB 24	8.46E-05	7.79E-11
eNB 25	3.54E-04	3.61E-39
eNB 26	6.18E-05	7.36E-15
eNB 27	7.05E-05	1.45E-18
eNB 28	4.49E-05	2.72E-13
eNB 29	6.17E-04	9.18E-09
eNB 30	3.21E-03	1.70E-13
eNB 31	4.33E-05	1.85E-19
eNB 32	6.20E-05	1.45E-14
eNB 33	3.09E-05	1.47E-18
eNB 34	8.16E-05	7.08E-20
eNB 35	6.11E-05	2.02E-15
eNB 36	5.59E-04	1.66E-15
eNB 37	7.02E-05	3.74E-17
eNB 38	2.43E-03	1.01E-19
eNB 39	3.19E-04	3.83E-23
eNB 40	6.15E-05	5.88E-19
eNB 41	4.13E-04	2.14E-24

eNB 42	8.14E-05	1.17E-27
eNB 43	7.34E-05	1.01E-13
eNB 44	5.15E-05	3.87E-18
eNB 45	7.01E-05	2.68E-18
eNB 46	3.36E-04	2.11E-15
eNB 47	1.89E-03	7.58E-13
eNB 48	4.66E-04	3.43E-15
eNB 49	5.12E-04	8.08E-16
eNB 50	3.65E-03	5.88E-19
eNB 51	7.10E-05	5.79E-19
eNB 52	8.31E-05	6.37E-20
eNB 53	4.14E-04	8.66E-21
eNB 54	7.43E-05	2.36E-13
eNB 55	6.02E-05	6.28E-17
eNB 56	8.05E-05	2.42E-22
eNB 57	4.26E-04	7.43E-17
eNB 58	4.88E-05	9.43E-16
eNB 59	9.13E-05	4.61E-17
AVERAGE BER VALUE	**5.52E-04**	**4.88E-10**

Table 4.7 shows performance of the existing SMILE 4G LTE microwave transmission link and that of the developed Passive Optical Network backhaul system. Also shown on table 4.7 is the average BER value of each of the links. For the microwave, the average BER value is 5.52e-4 whereas, Passive Optical Network backhaul link is 4.88e-10. The average BER value for the microwave indicates that for 10000 bits transmitted, there could be a single error or a single bit loss. However, for the developed PON backhaul system, the average BER of 4.88e-10 indicates that for every 10giga bits (10000000000 bits) transmitted, there is/could be a single bit error. In figure 4.91, a linear distribution of BER on SMILE existing microwave link and that of the developed PON network as contained in table 4.7 is plotted. The graph showed that the BER values of the developed PON network is lower compared to its existing microwave link and hence a better transmission Network. Similarly, figure 4.92 showed a radar representation of BER values of table 4.7. It revealed that BER values for the developed PON network are smaller than that of the existing microwave link and hence, a higher quality backhaul network .

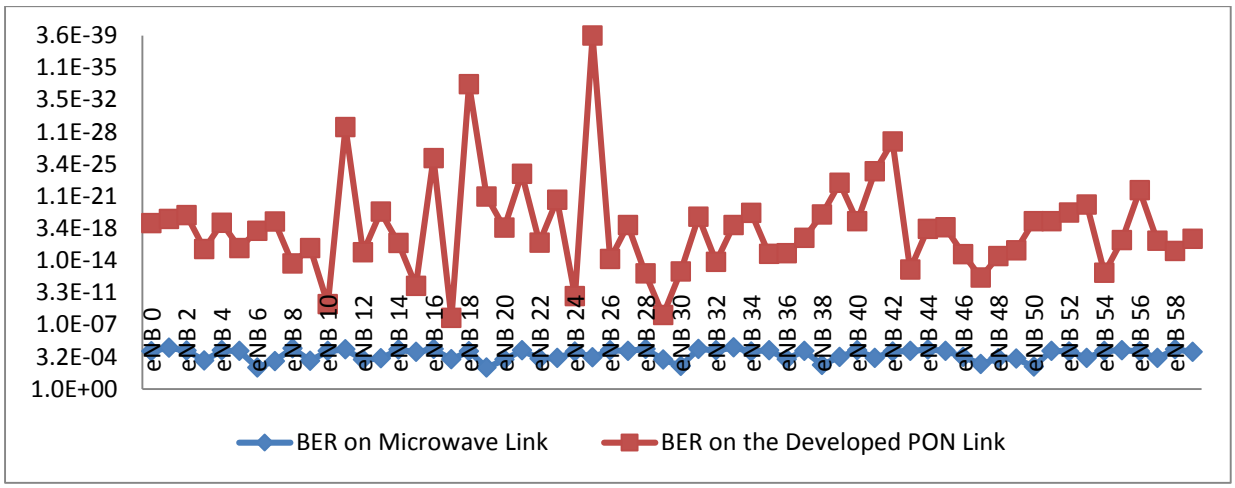


Figure 4.91: BER distribution on existing SMILE network and that of developed PON Network

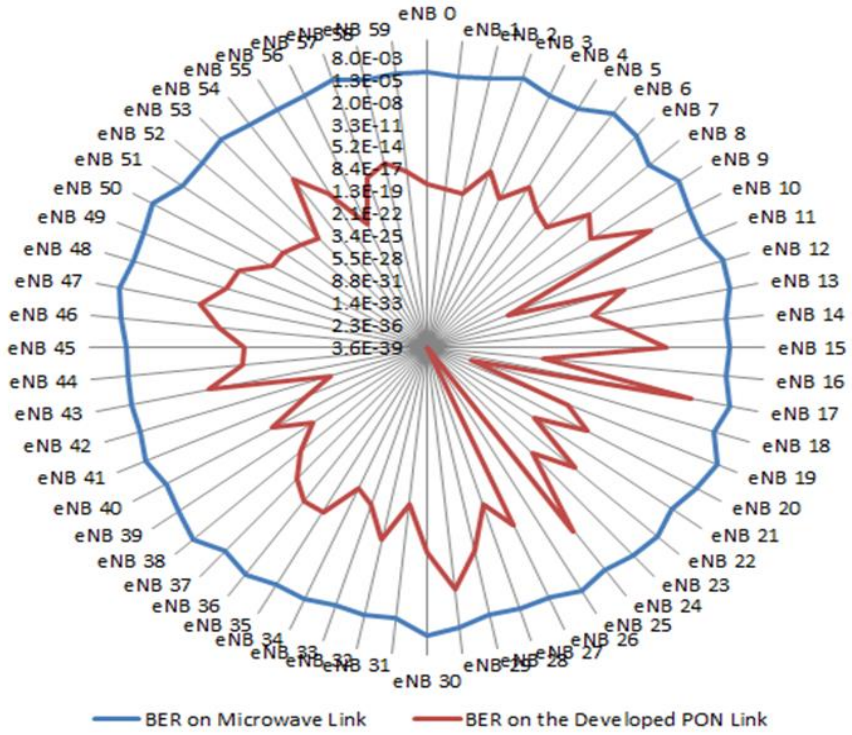


Figure 4.92: Radar representation of BER on SMILE Microwave and the developed PON system

Comparing the average BER for both systems, the performance improvement seen using the developed PON network is calculated as follows:

$$\text{Percentage Performance improvement (Pi)} = \frac{SAB - \text{PAB}}{SAB} x100 \qquad (4.2)$$

Where SAB = SMILE Average BER Value = 5.52e-04

PAB = PON Average BER value = 4.88e-10

Substituting value into equation 4.2,

Pi = $= \frac{5.52\,e-04 - 4.88e-10}{5.52e-04}\ x\ 100$ = 99.99%, hence PON provided 99.99% performance improvement.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

This dissertation employed the use of Passive Optical Network (PON) as a cellular backhaul for 4G LTE network using SMILE 4G networks Port Harcourt Rivers state Nigeria as a case study. The work successfully studied Port Harcourt terrains using a software tool called Cell finder and determined all the SMILE eNB coordinates in Port Harcourt. A total of 60 eNB coordinate references were observed to be configured in the network understudy. Two methods (manual and Automatic) of computing optimal splitter coordinates for PON deployments were developed. In the manual method, online distance calculator tool called GPS Visualiser was employed in the computation, considering one km distance from one eNB to a successive eNB. The pattern was followed to generate up to thirty five (35) test splitter locations, from which the optimal location was chosen based on various great circle and walking distance calculations. However, the Automatic approach adopted Vincenty formula in the computation of optimal splitter coordinates. The results obtained from the Vincenty equations were modelled in MATLAB environment and five best splitter coordinates were determined with respect to topology, cost etc. Again, from the determined optimal splitter coordinate, breakdown and cumulative fibre cable lengths (in km) required for the work was evaluated. Based on the evaluated breakdown of the fibre cable requirements and design parameters, power budget analyses for both downstream and upstream transmissions were achieved for PON network. In furtherance to the power budget analyses, ranging delay computation for upstream transmission was carried out. The computation provided time delay in the upstream transmission to prevent collision from different transmitting eNBs in the PON network. Furthermore, effectiveness of the developed PON network was validated using Optisystem simulation tool. The simulation demonstrated that both downstream and upstream

transmissions are implementable and results displayed in BER analysers showed average BER value of 4.88e-10 and Q factor values obtained were used to characterise the viability of the developed system as a quality backhaul network for 4G LTE. Finally, Performance of the existing SMILE microwave backhaul network was compared with the developed PON model and the developed PON network showed 99.99% improvement over existing SMILE microwave link.

5.2 CONCLUSION

With the increasing demand for higher speed Internet connectivity for Long Term Evolution 4G (LTE) and with the development of bandwidth-hungry applications, most service providers are fast replacing their legacy backhaul infrastructures with new fibre based technologies. The replacement is because some of the existing infrastructures are not capable of meeting 4G (LTE) promised deliverable and hence, have some technical limitations like limited capacity, range, and reliability as well poor weather effects. This work looked at Passive Optical Networks (PON) as cellular backhaul for 4G (LTE) and took SMILE communication networks Port Harcourt as a case study. Furthermore, the work developed two methods of computing optimal splitter coordinates and hence the proposed approaches obtained 4.8277864, 7.026582 and 4.8276, 7.0254 as optimal splitter coordinates for PON deployment in Port Harcourt. In addition, values obtained from both downstream and upstream power budget analyses were used in PON design. In furtherance, the validated network in Optisystem environment produced excellent results in the range of BER of E-8 to E-39 and has average BER value of 4.88e-10. Finally, the results of developed PON network was compared with the existing SMILE microwave link and the developed PON network showed 99.99% improvement. This clearly showed that PON network as a cellular backhaul for 4G (LTE) is practicable and gives a higher quality backhaul.

5.3 RECOMMENDATION

1. Manual and Automatic methods of computing optimal splitter location proposed in this work gave very accurate coordinates (results); however, the process involved is a bit rigorous. It is recommended that further studies in this area should concentrate on the development of online applications that runs on mobile phones and can detect optimal splitter locations of all networks in all cities.

2. It is highly recommended that SMILE communication Networks and other 4G network operators should deploy PON network as backhaul in all their networks for better service delivery.

5.4 CONTRIBUTION TO KNOWLEDGE

The following contributions were made in this work:

1. Manual method of computing optimal splitter coordinate was developed
2. Automatic approach of computing optimal splitter coordinate was developed. This model gives five best coordinates at a glance, the approach encourages the choice of second or third best splitter coordinates in an event best coordinate is affected by topographic conditions.
3. PON network architecture for 4G (LTE) backhaul was developed, the network is capable of delivering 160Gbit/s and still maintains a minimal error per bit in the range of E-8 to E-39.

REFERENCE

ABI Research (2014), Wireless Backhaul Spectrum Policy Recommendation and Analysis.

ADC (2006), GPON Migration (103132AE), Ensuring my Network is Ready to Migrate to GPON

Amitabha B, Youngil P, Frederick C, Haun S, Sunhee Y, Glen K, Kwangjoon K and Biswanath M (2005), Wavelength-division- multiplexed passive optical network (WDM-PON) technologies for broadband access: a review

Arun Agarwal et al (2019), Evolution of Mobile Communication Technology towards 5G Networks and Challenges

Avalan wireless Blog (2014), http://info.avalanwireless.com/blog/topic/radio

Bas Van Dongen (2016), "Fiber Optics: 21st Century communication backbone"

Bhuteswar Jena (2014), Fixed and Mobile WiMAX Networks based on LTE.

Bill Brown (2016), Broadband TV White Space (TVWS) Backhaul Digital Radio system, Technical overview and deployment guide. 2016

Calix (2016), FTTP design Strategies,

https://www.iowaheartlandscte.org/.../2016_october_fttp_design_strategies_bret2.pdf

CBNL White Paper (nd), A guick guide: Modern point-to-multipoint microwave networks. (online)
http://cbnl.com/sites/all/files/userfiles/files/A%20quick%20guide%20to%20PMP%20microwave.pdf Retrieved Jan 2017

Chathurika R, Patrick P, Kostas N, Reichmann K and Sinha R, (2013), Design of cost-optimal Passive Optical Network for small cell Backhaul using installed Fibre.

Cedric Lam (2007), Passive Optical Networks (Principles and Practice)

Colombow Consulting, (2015), http://www.colombow.co.za/network-services/

Cyrus G, Narayan M, and Larry G, (Jan 2011), Backhauling in TV White Spaces, IEEE Xplore 10 Jan 2011

Dieter Elixmann, et al (2008), "The Economics of Next Generation Access-Final Report: Study for the European Competitive Telecommunication Association (ECTA)", WIK-Consult GmbH, 10 September 2008

Dixit, A, Mahloo, M, Lannoo, B, Chen, J, Wosinska L, Colle D, and Pickavet M , (2016), Protection strategies for Next Generation

Passive Optical Networks -2

Ethernet Passive Optical Network (2002), Building a Next- Generation Optical Access Network IEEE Explore (IEEE Communication Magazine, Feb 2002).

Francis I, Dike U and Orovwode H (2014), "Future Trends in Fiber-optics communication", World congress on Engineering: vol. 1, London, U.K.

Frank E, David C, Ohh H, Glen K Ruo D Moshe O and Thomas P (2007), An Introduction to PON Technologies by IEEE Explore (IEEE communication Magazine, March 2007, 0163-6804/07)

Foundry Networks (2007), White Paper; Next-Generation wireless backhaul solutions

G. Keiser, (2000), "Optical Fiber Communications", McGraw-Hill. Pennsylvania, USA

Glen K and Keiji T (2005), Advances in Optical Access Networks

Hitesh Kumar et al, (2014), Performance analysis of LTE and IEEE 802.16 WiMAX in terms of attenuation and BER via MATLAB: Scenario based ROF Amalgamation as backhaul technology. July 2014.

Hiba A.Altahir, (2017), "Performance Evaluation of Gigabit Passive Optical Network (GPON) Access Technology". Department of Electrical and Electronics Engineering, University of Khartoum.

HSPA, (2009), http://www.3gamericas.org/documents/HSPA%20LTE %20Advanced %20 Rysavy%20Powerpoint%20Sept09.pdf

Hoyong Kang, (2001), Architectural Design of an ONU Controller for the ATM-PON,IEEEXplore 2001

(ITU, n.d), http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-adv/Pages/default.aspx,

John Tang et al. (2007), Technology White paper; Backhaul solutions for 3G Networks. Alcatel Lucent 2007

Juan Salvador Asensi (2011), "Design of Passive Optical Networks" Exeter: BRNO University of Technology

LTE Encyclopedia, (n.d), https://sites.google.com/site/lteencyclopedia/home,

LTE World, (n.d), http://lteworld.org/wiki/lte-advanced ,

Manjunath R, Soumya H, Nagabhushan and Manju S. (2014), Design of high capacity microwave link between to cities.

Margaret Rouse,(2006), http://searchnetworking.techtarget.com/definition/microwave,

Mitsuhiro Y, Kazuo Y and Haruo Y (1999), Global Optical Access systems based on ATM-PON, UDC 621.391.6:621.395.3

Movable Type Script: Calculate Distance, Bearing and more between lat/long

http://www.movable-type.co.uk/scripts/latlong.html

Neca (2016), National Electrical Contractors Association, USA https://www.stl.tech/.../optical-fibre/.../Field_Test_Procedure_for_Optical_Fibre_Link

Neder N, McLaughlin S and David L, (2004), Estimating errors in XDSL due to impulse noise. IEEE Xplore: 24 August 2004

Ofcom (2007), Future Options for Efficient Backhaul

Orawan T, Said Z and Admela J, (2010), The Evolution of cellular Backhaul Technologies: Current issues and future trends. 2010.

Panagiotis G, Jose A Rafidah M, Ben M and Christopher E, (2010), Theoretical and Practical Survey of Backhaul Connectivity options. June 2010

Passive Optical Networks PON- Powerpoint PPT Presentation,(online), http://www.powershow.com/view/76ef6-OTllM/Passive_Optical_Networks_PON_powerpoint_ppt_presentation, retrieved August 2016

Peter B, (2010), Optical and Broadband Networks, Module POO336 lecture note, Oxford Brookes University

Portharcourt Population, https://en.wikipedia.org/wiki/Port_Harcourt Retrieved June 2019

Ratnesh K, Muhammad I, Narayan B and Ivan S, (2015), Rate Optimal design of wireless backhaul network using TV white space. 6 May 2015.

Ravishankar S, Padmaja K and Uma B, (2007), Implementation of novel Bit-loading Algorithm with power cut-back in ADSL transmitter on DSP. Dec 2007.

Rysavy Research, (2009), HSPA to LTE Advanced. 3GPP Broadband Evolution to IMT-Advanced 4G, Sept 2009. (Online) Retrieved 14 August 2016

Takashi N, Yukio H and Hiroaki M, (2015), Demonstration of Multicast video streaming with N:1 protection of a 10G EPON system, IEEE Xplore 2015

Sami L and Pertti R, (2006), Passive Optical Networks, Transport concept (VTT Publications 597, ESPOO 2006).

Sooyoung H, Taejoon K, David L James V, Timothy A and Amitava G, (2013), Millimeter wave Beamforming for wireless Backhaul and Acess in small cell Network.

Takuya T, Takeshi S, Yoshihito S, Toshihito F, Hiroshi, O, Yasutaka K, and Ken-ichi S, (2015), Long-Reach and High-Splitting-Ratio 10G-EPON System With Semiconductor Optical Amplifier and N:1 OSU Protection, Journal Of Lightwave Technology, April 15, 2015

Thomas S, Georgios E and Krishna B, (2009), Multiwavelength Optical Networks. Architectures,Design, and Control (second Edition)

Transition networks (2003), (Fibre Optics Basics)

www.synginc.com/docs/Fiber_Optics.pdf

Vincent H, Doutje V and Ed H, (2017), Recent Progress on Standardization of next generation 25,50 and 100G EPON, IEEE Xplore, March, 2017

Wei F, Yong L Depeng J, Li S and Sheng C, (2016), Millimeter wave Backhaul for 5G Networks: Challenges and Solutions.

(Wikipedia, n.d), https://en.wikipedia.org/wiki/4G ,

Zhouyue P and Farooq K, (2011), An introduction to millimetre wave mobile broadband systems, IEEE Communication magazine, June 2011.

APPENDIX A: PUBLICATIONS FROM THE RESEARCH WORK

1. Dispersion effect on Single mode Optical fibre transmission link

Okeke R.O and Idigo V.E

(Published in International Journal of Engineering Trends and Technology (IJETT), 2019,) Volume 67, Issue 11

2. Computational Analysis of Optimal Splitter Coordinates for Passive Optical Network (PON) Deployment

Okeke R.O and Idigo V.E

(Accepted for publication in Journal of Engineering and Applied Sciences (JEAS))

3. Passive Optical Network (PON): A fibre to the 'X' Approach

Okeke R.O, Idigo V.E, Akemi M.O and Ogbuokebe S.K

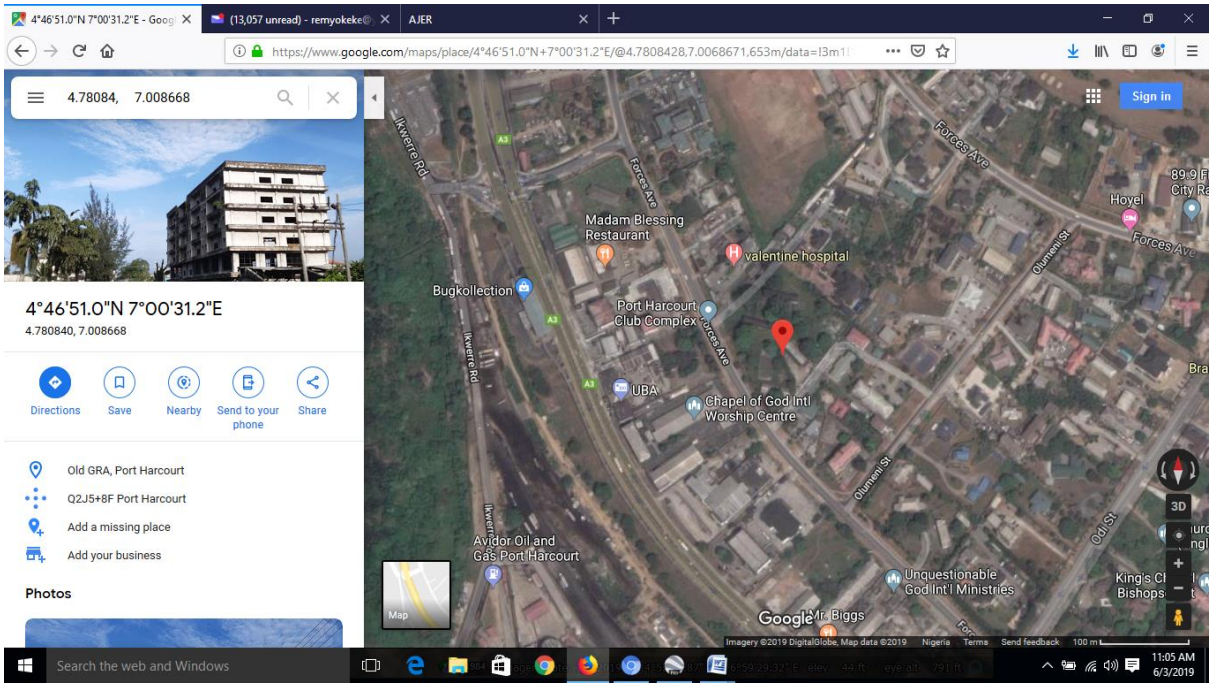
(Accepted for publication in International Journal of Electronic and Telecommunication System Research)

APPENDIX B

*Location 2 (***4.78084, 7.008668***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB5 to eNB 6)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.122114	4.779053	0.08341	7.019198	0.122508	4.084403	5.9
eNB 1	4.8366	0.084414	7.0286	0.122672	4.779053	0.08341	7.019198	0.122508	6.483126	9.1
eNB 2	4.7737	0.083316	7.0142	0.12242	4.779053	0.08341	7.019198	0.122508	0.813044	1.3
eNB 3	4.7999	0.083774	6.9939	0.122066	4.779053	0.08341	7.019198	0.122508	3.637453	5.3
eNB 4	4.8294	0.084289	7.0919	0.123777	4.779053	0.08341	7.019198	0.122508	9.809915	14.7
eNB 5	4.7706	0.083262	7.0224	0.122564	4.779053	0.08341	7.019198	0.122508	1.004698	2.2
eNB 6	4.8746	0.085077	6.983	0.121876	4.779053	0.08341	7.019198	0.122508	11.3561	14.7
eNB 7	4.8692	0.084983	7.1137	0.124157	4.779053	0.08341	7.019198	0.122508	14.49539	19.7
eNB 8	4.7196	0.082372	7.1518	0.124822	4.779053	0.08341	7.019198	0.122508	16.11264	28.3
eNB 9	4.8554	0.084742	7.0641	0.123291	4.779053	0.08341	7.019198	0.122508	9.839798	13.7
eNB 10	4.7909	0.083617	7.1207	0.124279	4.779053	0.08341	7.019198	0.122508	11.32401	19
eNB 11	4.7854	0.083521	7.0082	0.122316	4.779053	0.08341	7.019198	0.122508	1.408245	1.9
eNB 12	4.8327	0.084346	7.0685	0.123368	4.779053	0.08341	7.019198	0.122508	8.088663	11.9
eNB 13	4.8039	0.083844	6.9883	0.121968	4.779053	0.08341	7.019198	0.122508	4.399398	5.9
eNB 14	4.8197	0.084119	7.0656	0.123317	4.779053	0.08341	7.019198	0.122508	6.845674	11.2
eNB 15	4.743	0.082781	7.0417	0.1229	4.779053	0.08341	7.019198	0.122508	4.721112	6.1
eNB 16	4.7939	0.083669	7.0308	0.12271	4.779053	0.08341	7.019198	0.122508	2.092393	5.5
eNB 17	4.748	0.082868	7.0989	0.123899	4.779053	0.08341	7.019198	0.122508	9.482821	23.6
eNB 18	4.7773	0.083379	7.062	0.123255	4.779053	0.08341	7.019198	0.122508	4.746818	9.8
eNB 19	4.8341	0.084371	6.9845	0.121902	4.779053	0.08341	7.019198	0.122508	7.228183	9.4
eNB 20	4.8565	0.084762	7.0405	0.122879	4.779053	0.08341	7.019198	0.122508	8.929248	12.5
eNB 21	4.8064	0.083887	7.0424	0.122913	4.779053	0.08341	7.019198	0.122508	3.981973	7.5
eNB 22	4.8146	0.08403	6.9788	0.121803	4.779053	0.08341	7.019198	0.122508	5.97162	7.6
eNB 23	4.8298	0.084296	6.9588	0.121453	4.779053	0.08341	7.019198	0.122508	8.753732	11.4
eNB 24	4.8923	0.085386	6.9143	0.120677	4.779053	0.08341	7.019198	0.122508	17.13629	20.7
eNB 25	4.848	0.084613	7.0492	0.123031	4.779053	0.08341	7.019198	0.122508	8.356199	11.7
eNB 26	4.8514	0.084673	6.9835	0.121885	4.779053	0.08341	7.019198	0.122508	8.964378	12.1
eNB 27	4.8081	0.083917	6.9967	0.122115	4.779053	0.08341	7.019198	0.122508	4.079995	5.9
eNB 28	4.9028	0.08557	6.999	0.122155	4.779053	0.08341	7.019198	0.122508	13.94075	17.9
eNB 29	4.9789	0.086898	6.9611	0.121494	4.779053	0.08341	7.019198	0.122508	23.13531	29.2
eNB 30	4.9969	0.087212	6.95	0.1213	4.779053	0.08341	7.019198	0.122508	25.40758	29.9
eNB 31	4.9539	0.086462	7.0111	0.122366	4.779053	0.08341	7.019198	0.122508	19.46268	23.7
eNB 32	4.9669	0.086688	6.9869	0.121944	4.779053	0.08341	7.019198	0.122508	21.19182	27.1
eNB 33	4.8289	0.08428	7.0219	0.122555	4.779053	0.08341	7.019198	0.122508	5.550759	8.1
eNB 34	4.8169	0.08407	7.0112	0.122368	4.779053	0.08341	7.019198	0.122508	4.300644	5.9
eNB 35	4.9317	0.086074	7.0021	0.122209	4.779053	0.08341	7.019198	0.122508	17.07886	20.9
eNB 36	4.8407	0.084486	6.9681	0.121616	4.779053	0.08341	7.019198	0.122508	8.890664	11.2
eNB 37	4.8598	0.084819	6.9792	0.12181	4.779053	0.08341	7.019198	0.122508	10.0128	13
eNB 38	4.8469	0.084594	7.0369	0.122817	4.779053	0.08341	7.019198	0.122508	7.794989	10.8
eNB 39	4.8585	0.084796	6.9658	0.121576	4.779053	0.08341	7.019198	0.122508	10.63231	13.1
eNB 40	4.88	0.085172	7.01	0.122347	4.779053	0.08341	7.019198	0.122508	11.27089	14.5

eNB 41	4.8669	0.084943	7.03	0.122696	4.779053	0.08341	7.019198	0.122508	9.841122	13.6
eNB 42	4.8378	0.084435	7.037	0.122818	4.779053	0.08341	7.019198	0.122508	6.823629	9.9
eNB 43	4.8842	0.085245	7.138	0.124581	4.779053	0.08341	7.019198	0.122508	17.60586	23.7
eNB 44	4.7815	0.083453	7.0398	0.122867	4.779053	0.08341	7.019198	0.122508	2.299021	7.2
eNB 45	4.8116	0.083978	6.9561	0.121406	4.779053	0.08341	7.019198	0.122508	7.872707	11.3
eNB 46	4.9011	0.08554	6.9269	0.120897	4.779053	0.08341	7.019198	0.122508	16.99263	21.2
eNB 47	4.9058	0.085622	6.9066	0.120542	4.779053	0.08341	7.019198	0.122508	18.822	22.6
eNB 48	4.8024	0.083817	6.944	0.121195	4.779053	0.08341	7.019198	0.122508	8.727426	13.1
eNB 49	4.8354	0.084393	7.0528	0.123094	4.779053	0.08341	7.019198	0.122508	7.288219	12
eNB 50	4.7947	0.083683	7.0497	0.12304	4.779053	0.08341	7.019198	0.122508	3.801349	7.9
eNB 51	4.7581	0.083044	7.0119	0.12238	4.779053	0.08341	7.019198	0.122508	2.466243	3.3
eNB 52	4.8269	0.084245	6.9961	0.122104	4.779053	0.08341	7.019198	0.122508	5.903874	8.1
eNB 53	4.815	0.084037	7.0419	0.122904	4.779053	0.08341	7.019198	0.122508	4.722749	8.4
eNB 54	4.71	0.082205	7.165	0.125052	4.779053	0.08341	7.019198	0.122508	17.88855	30
eNB 55	4.8233	0.084182	7.0572	0.123171	4.779053	0.08341	7.019198	0.122508	6.475883	10.3
eNB 56	4.815	0.084037	7.0652	0.123311	4.779053	0.08341	7.019198	0.122508	6.477549	10.6
eNB 57	4.894	0.085416	7.0153	0.12244	4.779053	0.08341	7.019198	0.122508	12.78873	16.5
eNB 58	4.8626	0.084868	7.0153	0.12244	4.779053	0.08341	7.019198	0.122508	9.299967	12.7
eNB 59	4.8276	0.084257	7.0145	0.122426	4.779053	0.08341	7.019198	0.122508	5.423167	7.8
									554.338	784.1



*Location 2 (***4.78084, 7.008668***)*

Location 3 (4.874229, 6.992008)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB2 to eNB 3)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.122114	4.78084	0.083441	7.008668	0.12232	3.312205	4.7
eNB 1	4.8366	0.084414	7.0286	0.122672	4.78084	0.083441	7.008668	0.12232	6.581802	8.1
eNB 2	4.7737	0.083316	7.0142	0.12242	4.78084	0.083441	7.008668	0.12232	1.003026	1.4
eNB 3	4.7999	0.083774	6.9939	0.122066	4.78084	0.083441	7.008668	0.12232	2.677595	3.4
eNB 4	4.8294	0.084289	7.0919	0.123777	4.78084	0.083441	7.008668	0.12232	10.68683	13.7
eNB 5	4.7706	0.083262	7.0224	0.122564	4.78084	0.083441	7.008668	0.12232	1.900467	2.9
eNB 6	4.8746	0.085077	6.983	0.121876	4.78084	0.083441	7.008668	0.12232	10.80655	13.1
eNB 7	4.8692	0.084983	7.1137	0.124157	4.78084	0.083441	7.008668	0.12232	15.23046	18.7
eNB 8	4.7196	0.082372	7.1518	0.124822	4.78084	0.083441	7.008668	0.12232	17.2608	27.3
eNB 9	4.8554	0.084742	7.0641	0.123291	4.78084	0.083441	7.008668	0.12232	10.31788	12.7
eNB 10	4.7909	0.083617	7.1207	0.124279	4.78084	0.083441	7.008668	0.12232	12.46419	17.9
eNB 11	4.7854	0.083521	7.0082	0.122316	4.78084	0.083441	7.008668	0.12232	0.509696	0.85
eNB 12	4.8327	0.084346	7.0685	0.123368	4.78084	0.083441	7.008668	0.12232	8.786604	10.8
eNB 13	4.8039	0.083844	6.9883	0.121968	4.78084	0.083441	7.008668	0.12232	3.415913	4
eNB 14	4.8197	0.084119	7.0656	0.123317	4.78084	0.083441	7.008668	0.12232	7.646306	10.1
eNB 15	4.743	0.082781	7.0417	0.1229	4.78084	0.083441	7.008668	0.12232	5.576878	6.9
eNB 16	4.7939	0.083669	7.0308	0.12271	4.78084	0.083441	7.008668	0.12232	2.850082	4.4
eNB 17	4.748	0.082868	7.0989	0.123899	4.78084	0.083441	7.008668	0.12232	10.64457	22.6
eNB 18	4.7773	0.083379	7.062	0.123255	4.78084	0.083441	7.008668	0.12232	5.922691	8.8
eNB 19	4.8341	0.084371	6.9845	0.121902	4.78084	0.083441	7.008668	0.12232	6.499529	7.6
eNB 20	4.8565	0.084762	7.0405	0.122879	4.78084	0.083441	7.008668	0.12232	9.122394	11.5
eNB 21	4.8064	0.083887	7.0424	0.122913	4.78084	0.083441	7.008668	0.12232	4.69553	6.5
eNB 22	4.8146	0.08403	6.9788	0.121803	4.78084	0.083441	7.008668	0.12232	5.004496	5.7
eNB 23	4.8298	0.084296	6.9588	0.121453	4.78084	0.083441	7.008668	0.12232	7.756929	9.6
eNB 24	4.8923	0.085386	6.9143	0.120677	4.78084	0.083441	7.008668	0.12232	16.2151	18.9
eNB 25	4.848	0.084613	7.0492	0.123031	4.78084	0.083441	7.008668	0.12232	8.714224	10.7
eNB 26	4.8514	0.084673	6.9835	0.121885	4.78084	0.083441	7.008668	0.12232	8.326741	10.4
eNB 27	4.8081	0.083917	6.9967	0.122115	4.78084	0.083441	7.008668	0.12232	3.308562	4.7
eNB 28	4.9028	0.08557	6.999	0.122155	4.78084	0.083441	7.008668	0.12232	13.60352	16.2
eNB 29	4.9789	0.086898	6.9611	0.121494	4.78084	0.083441	7.008668	0.12232	22.64497	27.4
eNB 30	4.9969	0.087212	6.95	0.1213	4.78084	0.083441	7.008668	0.12232	24.88841	28
eNB 31	4.9539	0.086462	7.0111	0.122366	4.78084	0.083441	7.008668	0.12232	19.24521	22
eNB 32	4.9669	0.086688	6.9869	0.121944	4.78084	0.083441	7.008668	0.12232	20.82894	25.4
eNB 33	4.8289	0.08428	7.0219	0.122555	4.78084	0.083441	7.008668	0.12232	5.541482	7.1
eNB 34	4.8169	0.08407	7.0112	0.122368	4.78084	0.083441	7.008668	0.12232	4.019479	4.8
eNB 35	4.9317	0.086074	7.0021	0.122209	4.78084	0.083441	7.008668	0.12232	16.79058	19.2
eNB 36	4.8407	0.084486	6.9681	0.121616	4.78084	0.083441	7.008668	0.12232	8.031766	9.4
eNB 37	4.8598	0.084819	6.9792	0.12181	4.78084	0.083441	7.008668	0.12232	9.367383	11.4
eNB 38	4.8469	0.084594	7.0369	0.122817	4.78084	0.083441	7.008668	0.12232	7.983853	9.8
eNB 39	4.8585	0.084796	6.9658	0.121576	4.78084	0.083441	7.008668	0.12232	9.855483	11.3
eNB 40	4.88	0.085172	7.01	0.122347	4.78084	0.083441	7.008668	0.12232	11.02704	13.4

eNB 41	4.8669	0.084943	7.03	0.122696	4.78084	0.083441	7.008668	0.12232	9.856976	12.5
eNB 42	4.8378	0.084435	7.037	0.122818	4.78084	0.083441	7.008668	0.12232	7.068944	8.8
eNB 43	4.8842	0.085245	7.138	0.124581	4.78084	0.083441	7.008668	0.12232	18.36942	22.6
eNB 44	4.7815	0.083453	7.0398	0.122867	4.78084	0.083441	7.008668	0.12232	3.450431	6.2
eNB 45	4.8116	0.083978	6.9561	0.121406	4.78084	0.083441	7.008668	0.12232	6.754792	9.5
eNB 46	4.9011	0.08554	6.9269	0.120897	4.78084	0.083441	7.008668	0.12232	16.15227	19.3
eNB 47	4.9058	0.085622	6.9066	0.120542	4.78084	0.083441	7.008668	0.12232	17.9153	20.8
eNB 48	4.8024	0.083817	6.944	0.121195	4.78084	0.083441	7.008668	0.12232	7.556004	11.3
eNB 49	4.8354	0.084393	7.0528	0.123094	4.78084	0.083441	7.008668	0.12232	7.792138	11
eNB 50	4.7947	0.083683	7.0497	0.12304	4.78084	0.083441	7.008668	0.12232	4.800704	6.9
eNB 51	4.7581	0.083044	7.0119	0.12238	4.78084	0.083441	7.008668	0.12232	2.553794	3
eNB 52	4.8269	0.084245	6.9961	0.122104	4.78084	0.083441	7.008668	0.12232	5.307572	6.9
eNB 53	4.815	0.084037	7.0419	0.122904	4.78084	0.083441	7.008668	0.12232	5.290265	7.4
eNB 54	4.71	0.082205	7.165	0.125052	4.78084	0.083441	7.008668	0.12232	19.03041	29
eNB 55	4.8233	0.084182	7.0572	0.123171	4.78084	0.083441	7.008668	0.12232	7.156031	9.2
eNB 56	4.815	0.084037	7.0652	0.123311	4.78084	0.083441	7.008668	0.12232	7.325688	9.5
eNB 57	4.894	0.085416	7.0153	0.12244	4.78084	0.083441	7.008668	0.12232	12.60421	15.4
eNB 58	4.8626	0.084868	7.0153	0.12244	4.78084	0.083441	7.008668	0.12232	9.120913	11.6
eNB 59	4.8276	0.084257	7.0145	0.122426	4.78084	0.083441	7.008668	0.12232	5.239459	6.7
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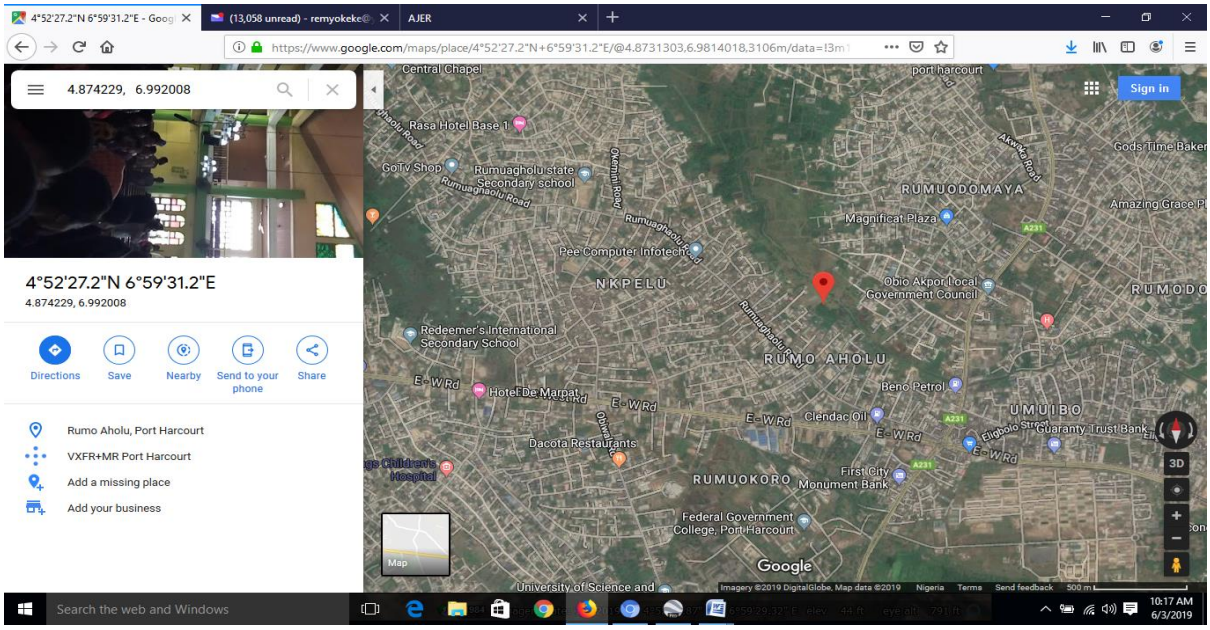
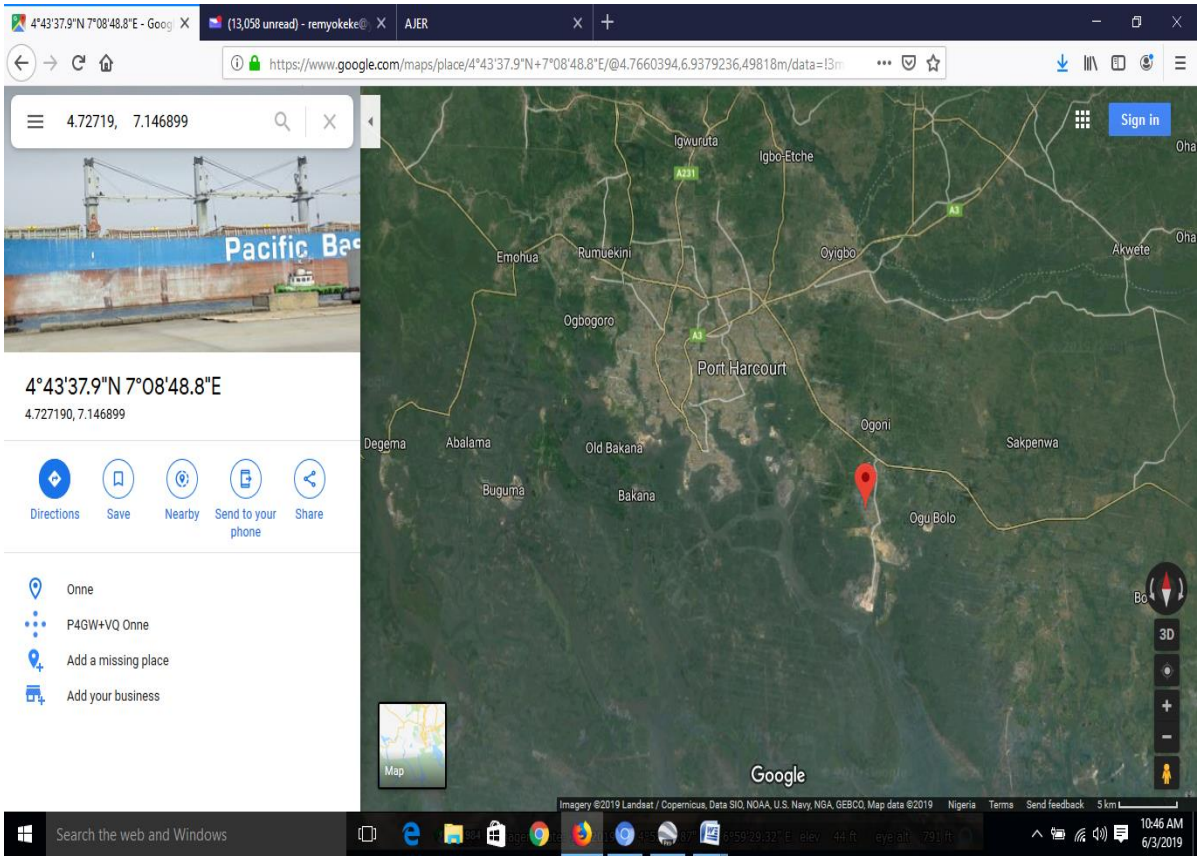


Location 3 (4.874229, 6.992008)

*Location 4 (***4.72719, 7.146899***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB 6 to eNB 7)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.122114	4.874229	0.085071	6.992008	0.122033	7.36927	9
eNB 1	4.8366	0.084414	7.0286	0.122672	4.874229	0.085071	6.992008	0.122033	5.826101	8.8
eNB 2	4.7737	0.083316	7.0142	0.12242	4.874229	0.085071	6.992008	0.122033	11.44547	14
eNB 3	4.7999	0.083774	6.9939	0.122066	4.874229	0.085071	6.992008	0.122033	8.267589	10
eNB 4	4.8294	0.084289	7.0919	0.123777	4.874229	0.085071	6.992008	0.122033	12.13837	14
eNB 5	4.7706	0.083262	7.0224	0.122564	4.874229	0.085071	6.992008	0.122033	12.0049	15
eNB 6	4.8746	0.085077	6.983	0.121876	4.874229	0.085071	6.992008	0.122033	0.998864	1.5
eNB 7	4.8692	0.084983	7.1137	0.124157	4.874229	0.085071	6.992008	0.122033	13.49419	17.2
eNB 8	4.7196	0.082372	7.1518	0.124822	4.874229	0.085071	6.992008	0.122033	24.6804	28.6
eNB 9	4.8554	0.084742	7.0641	0.123291	4.874229	0.085071	6.992008	0.122033	8.257195	10.3
eNB 10	4.7909	0.083617	7.1207	0.124279	4.874229	0.085071	6.992008	0.122033	17.00504	19.3
eNB 11	4.7854	0.083521	7.0082	0.122316	4.874229	0.085071	6.992008	0.122033	10.03886	12.8
eNB 12	4.8327	0.084346	7.0685	0.123368	4.874229	0.085071	6.992008	0.122033	9.651384	12.2
eNB 13	4.8039	0.083844	6.9883	0.121968	4.874229	0.085071	6.992008	0.122033	7.830937	9.2
eNB 14	4.8197	0.084119	7.0656	0.123317	4.874229	0.085071	6.992008	0.122033	10.16107	12.5
eNB 15	4.743	0.082781	7.0417	0.1229	4.874229	0.085071	6.992008	0.122033	15.59615	19.5
eNB 16	4.7939	0.083669	7.0308	0.12271	4.874229	0.085071	6.992008	0.122033	9.912427	13
eNB 17	4.748	0.082868	7.0989	0.123899	4.874229	0.085071	6.992008	0.122033	18.36534	23.9
eNB 18	4.7773	0.083379	7.062	0.123255	4.874229	0.085071	6.992008	0.122033	13.27802	16.1
eNB 19	4.8341	0.084371	6.9845	0.121902	4.874229	0.085071	6.992008	0.122033	4.538956	5.5
eNB 20	4.8565	0.084762	7.0405	0.122879	4.874229	0.085071	6.992008	0.122033	5.722864	6.9
eNB 21	4.8064	0.083887	7.0424	0.122913	4.874229	0.085071	6.992008	0.122033	9.383918	12.6
eNB 22	4.8146	0.08403	6.9788	0.121803	4.874229	0.085071	6.992008	0.122033	6.789947	8.3
eNB 23	4.8298	0.084296	6.9588	0.121453	4.874229	0.085071	6.992008	0.122033	6.159791	8.3
eNB 24	4.8923	0.085386	6.9143	0.120677	4.874229	0.085071	6.992008	0.122033	8.840724	9.6
eNB 25	4.848	0.084613	7.0492	0.123031	4.874229	0.085071	6.992008	0.122033	6.975523	8.6
eNB 26	4.8514	0.084673	6.9835	0.121885	4.874229	0.085071	6.992008	0.122033	2.707786	4
eNB 27	4.8081	0.083917	6.9967	0.122115	4.874229	0.085071	6.992008	0.122033	7.371491	9
eNB 28	4.9028	0.08557	6.999	0.122155	4.874229	0.085071	6.992008	0.122033	3.27006	5.7
eNB 29	4.9789	0.086898	6.9611	0.121494	4.874229	0.085071	6.992008	0.122033	12.13211	16.1
eNB 30	4.9969	0.087212	6.95	0.1213	4.874229	0.085071	6.992008	0.122033	14.4124	16.7
eNB 31	4.9539	0.086462	7.0111	0.122366	4.874229	0.085071	6.992008	0.122033	9.108018	11.4
eNB 32	4.9669	0.086688	6.9869	0.121944	4.874229	0.085071	6.992008	0.122033	10.32007	14.7
eNB 33	4.8289	0.08428	7.0219	0.122555	4.874229	0.085071	6.992008	0.122033	6.031034	8.2
eNB 34	4.8169	0.08407	7.0112	0.122368	4.874229	0.085071	6.992008	0.122033	6.719934	9.5
eNB 35	4.9317	0.086074	7.0021	0.122209	4.874229	0.085071	6.992008	0.122033	6.487573	8.6
eNB 36	4.8407	0.084486	6.9681	0.121616	4.874229	0.085071	6.992008	0.122033	4.573404	6.4
eNB 37	4.8598	0.084819	6.9792	0.12181	4.874229	0.085071	6.992008	0.122033	2.141893	3.7
eNB 38	4.8469	0.084594	7.0369	0.122817	4.874229	0.085071	6.992008	0.122033	5.828629	6.9
eNB 39	4.8585	0.084796	6.9658	0.121576	4.874229	0.085071	6.992008	0.122033	3.389703	4.8
eNB 40	4.88	0.085172	7.01	0.122347	4.874229	0.085071	6.992008	0.122033	2.09413	4

eNB 41	4.8669	0.084943	7.03	0.122696	4.874229	0.085071	6.992008	0.122033	4.287409	6
eNB 42	4.8378	0.084435	7.037	0.122818	4.874229	0.085071	6.992008	0.122033	6.423176	8.1
eNB 43	4.8842	0.085245	7.138	0.124581	4.874229	0.085071	6.992008	0.122033	16.21264	19.6
eNB 44	4.7815	0.083453	7.0398	0.122867	4.874229	0.085071	6.992008	0.122033	11.59119	14.5
eNB 45	4.8116	0.083978	6.9561	0.121406	4.874229	0.085071	6.992008	0.122033	8.0203	10.1
eNB 46	4.9011	0.08554	6.9269	0.120897	4.874229	0.085071	6.992008	0.122033	7.807675	10
eNB 47	4.9058	0.085622	6.9066	0.120542	4.874229	0.085071	6.992008	0.122033	10.09255	11.5
eNB 48	4.8024	0.083817	6.944	0.121195	4.874229	0.085071	6.992008	0.122033	9.596099	11.9
eNB 49	4.8354	0.084393	7.0528	0.123094	4.874229	0.085071	6.992008	0.122033	8.000492	9.4
eNB 50	4.7947	0.083683	7.0497	0.12304	4.874229	0.085071	6.992008	0.122033	10.91153	13.9
eNB 51	4.7581	0.083044	7.0119	0.12238	4.874229	0.085071	6.992008	0.122033	13.09961	16.6
eNB 52	4.8269	0.084245	6.9961	0.122104	4.874229	0.085071	6.992008	0.122033	5.282173	6.8
eNB 53	4.815	0.084037	7.0419	0.122904	4.874229	0.085071	6.992008	0.122033	8.598355	11.2
eNB 54	4.71	0.082205	7.165	0.125052	4.874229	0.085071	6.992008	0.122033	26.47466	30.3
eNB 55	4.8233	0.084182	7.0572	0.123171	4.874229	0.085071	6.992008	0.122033	9.178337	11.5
eNB 56	4.815	0.084037	7.0652	0.123311	4.874229	0.085071	6.992008	0.122033	10.4469	12.4
eNB 57	4.894	0.085416	7.0153	0.12244	4.874229	0.085071	6.992008	0.122033	3.390056	6.5
eNB 58	4.8626	0.084868	7.0153	0.12244	4.874229	0.085071	6.992008	0.122033	2.886428	3.5
eNB 59	4.8276	0.084257	7.0145	0.122426	4.874229	0.085071	6.992008	0.122033	5.752638	7.8
									539.3738	678



Location 4 (**4.72719, 7.146899**)

Location 5 (**4.848612, 7.07006**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB 8 to eNB 9)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.122114	4.72719	0.082505	7.146899	0.124736	18.92466	26.5
eNB 1	4.8366	0.084414	7.0286	0.122672	4.72719	0.082505	7.146899	0.124736	17.88404	22.2
eNB 2	4.7737	0.083316	7.0142	0.12242	4.72719	0.082505	7.146899	0.124736	15.5877	27.4
eNB 3	4.7999	0.083774	6.9939	0.122066	4.72719	0.082505	7.146899	0.124736	18.78304	26.8
eNB 4	4.8294	0.084289	7.0919	0.123777	4.72719	0.082505	7.146899	0.124736	12.89611	14.1
eNB 5	4.7706	0.083262	7.0224	0.122564	4.72719	0.082505	7.146899	0.124736	14.61619	26.8
eNB 6	4.8746	0.085077	6.983	0.121876	4.72719	0.082505	7.146899	0.124736	24.46396	28.5
eNB 7	4.8692	0.084983	7.1137	0.124157	4.72719	0.082505	7.146899	0.124736	16.21359	19.9
eNB 8	4.7196	0.082372	7.1518	0.124822	4.72719	0.082505	7.146899	0.124736	1.003569	1.5
eNB 9	4.8554	0.084742	7.0641	0.123291	4.72719	0.082505	7.146899	0.124736	16.95334	19
eNB 10	4.7909	0.083617	7.1207	0.124279	4.72719	0.082505	7.146899	0.124736	7.656029	8.5
eNB 11	4.7854	0.083521	7.0082	0.122316	4.72719	0.082505	7.146899	0.124736	16.67684	25.4
eNB 12	4.8327	0.084346	7.0685	0.123368	4.72719	0.082505	7.146899	0.124736	14.59836	16.1
eNB 13	4.8039	0.083844	6.9883	0.121968	4.72719	0.082505	7.146899	0.124736	19.53502	27.8
eNB 14	4.8197	0.084119	7.0656	0.123317	4.72719	0.082505	7.146899	0.124736	13.67375	17.7
eNB 15	4.743	0.082781	7.0417	0.1229	4.72719	0.082505	7.146899	0.124736	11.78949	31.3
eNB 16	4.7939	0.083669	7.0308	0.12271	4.72719	0.082505	7.146899	0.124736	14.8504	22.8
eNB 17	4.748	0.082868	7.0989	0.123899	4.72719	0.082505	7.146899	0.124736	5.80058	9
eNB 18	4.7773	0.083379	7.062	0.123255	4.72719	0.082505	7.146899	0.124736	10.93415	23.9
eNB 19	4.8341	0.084371	6.9845	0.121902	4.72719	0.082505	7.146899	0.124736	21.5672	26.9
eNB 20	4.8565	0.084762	7.0405	0.122879	4.72719	0.082505	7.146899	0.124736	18.59409	21.3
eNB 21	4.8064	0.083887	7.0424	0.122913	4.72719	0.082505	7.146899	0.124736	14.54864	20.5
eNB 22	4.8146	0.08403	6.9788	0.121803	4.72719	0.082505	7.146899	0.124736	21.01032	29.1
eNB 23	4.8298	0.084296	6.9588	0.121453	4.72719	0.082505	7.146899	0.124736	23.76149	30.2
eNB 24	4.8923	0.085386	6.9143	0.120677	4.72719	0.082505	7.146899	0.124736	31.64328	36.1
eNB 25	4.848	0.084613	7.0492	0.123031	4.72719	0.082505	7.146899	0.124736	17.25264	19.6
eNB 26	4.8514	0.084673	6.9835	0.121885	4.72719	0.082505	7.146899	0.124736	22.7722	28.6
eNB 27	4.8081	0.083917	6.9967	0.122115	4.72719	0.082505	7.146899	0.124736	18.91957	26.5
eNB 28	4.9028	0.08557	6.999	0.122155	4.72719	0.082505	7.146899	0.124736	25.49219	28
eNB 29	4.9789	0.086898	6.9611	0.121494	4.72719	0.082505	7.146899	0.124736	34.74402	38.1
eNB 30	4.9969	0.087212	6.95	0.1213	4.72719	0.082505	7.146899	0.124736	37.08539	40.6
eNB 31	4.9539	0.086462	7.0111	0.122366	4.72719	0.082505	7.146899	0.124736	29.3578	32.1
eNB 32	4.9669	0.086688	6.9869	0.121944	4.72719	0.082505	7.146899	0.124736	32.01127	34.9
eNB 33	4.8289	0.08428	7.0219	0.122555	4.72719	0.082505	7.146899	0.124736	17.88173	22.9
eNB 34	4.8169	0.08407	7.0112	0.122368	4.72719	0.082505	7.146899	0.124736	18.04465	24.4
eNB 35	4.9317	0.086074	7.0021	0.122209	4.72719	0.082505	7.146899	0.124736	27.83033	30.4
eNB 36	4.8407	0.084486	6.9681	0.121616	4.72719	0.082505	7.146899	0.124736	23.49112	29.1
eNB 37	4.8598	0.084819	6.9792	0.12181	4.72719	0.082505	7.146899	0.124736	23.72177	30.2
eNB 38	4.8469	0.084594	7.0369	0.122817	4.72719	0.082505	7.146899	0.124736	18.04853	20.8
eNB 39	4.8585	0.084796	6.9658	0.121576	4.72719	0.082505	7.146899	0.124736	24.81666	30
eNB 40	4.88	0.085172	7.01	0.122347	4.72719	0.082505	7.146899	0.124736	22.7775	26.1

eNB 41	4.8669	0.084943	7.03	0.122696	4.72719	0.082505	7.146899	0.124736	20.22666	22.8
eNB 42	4.8378	0.084435	7.037	0.122818	4.72719	0.082505	7.146899	0.124736	17.30801	20.5
eNB 43	4.8842	0.085245	7.138	0.124581	4.72719	0.082505	7.146899	0.124736	17.4865	19.9
eNB 44	4.7815	0.083453	7.0398	0.122867	4.72719	0.082505	7.146899	0.124736	13.31602	23.5
eNB 45	4.8116	0.083978	6.9561	0.121406	4.72719	0.082505	7.146899	0.124736	23.13215	31.5
eNB 46	4.9011	0.08554	6.9269	0.120897	4.72719	0.082505	7.146899	0.124736	31.11531	36.6
eNB 47	4.9058	0.085622	6.9066	0.120542	4.72719	0.082505	7.146899	0.124736	33.21688	38
eNB 48	4.8024	0.083817	6.944	0.121195	4.72719	0.082505	7.146899	0.124736	23.98832	33.3
eNB 49	4.8354	0.084393	7.0528	0.123094	4.72719	0.082505	7.146899	0.124736	15.92165	18.5
eNB 50	4.7947	0.083683	7.0497	0.12304	4.72719	0.082505	7.146899	0.124736	13.12862	21.6
eNB 51	4.7581	0.083044	7.0119	0.12238	4.72719	0.082505	7.146899	0.124736	15.34956	29.1
eNB 52	4.8269	0.084245	6.9961	0.122104	4.72719	0.082505	7.146899	0.124736	20.05355	25.7
eNB 53	4.815	0.084037	7.0419	0.122904	4.72719	0.082505	7.146899	0.124736	15.18904	19.7
eNB 54	4.71	0.082205	7.165	0.125052	4.72719	0.082505	7.146899	0.124736	2.770729	3.2
eNB 55	4.8233	0.084182	7.0572	0.123171	4.72719	0.082505	7.146899	0.124736	14.59464	17.5
eNB 56	4.815	0.084037	7.0652	0.123311	4.72719	0.082505	7.146899	0.124736	13.31517	18.9
eNB 57	4.894	0.085416	7.0153	0.12244	4.72719	0.082505	7.146899	0.124736	23.59375	26
eNB 58	4.8626	0.084868	7.0153	0.12244	4.72719	0.082505	7.146899	0.124736	20.96048	24.4
eNB 59	4.8276	0.084257	7.0145	0.122426	4.72719	0.082505	7.146899	0.124736	18.43625	23.9
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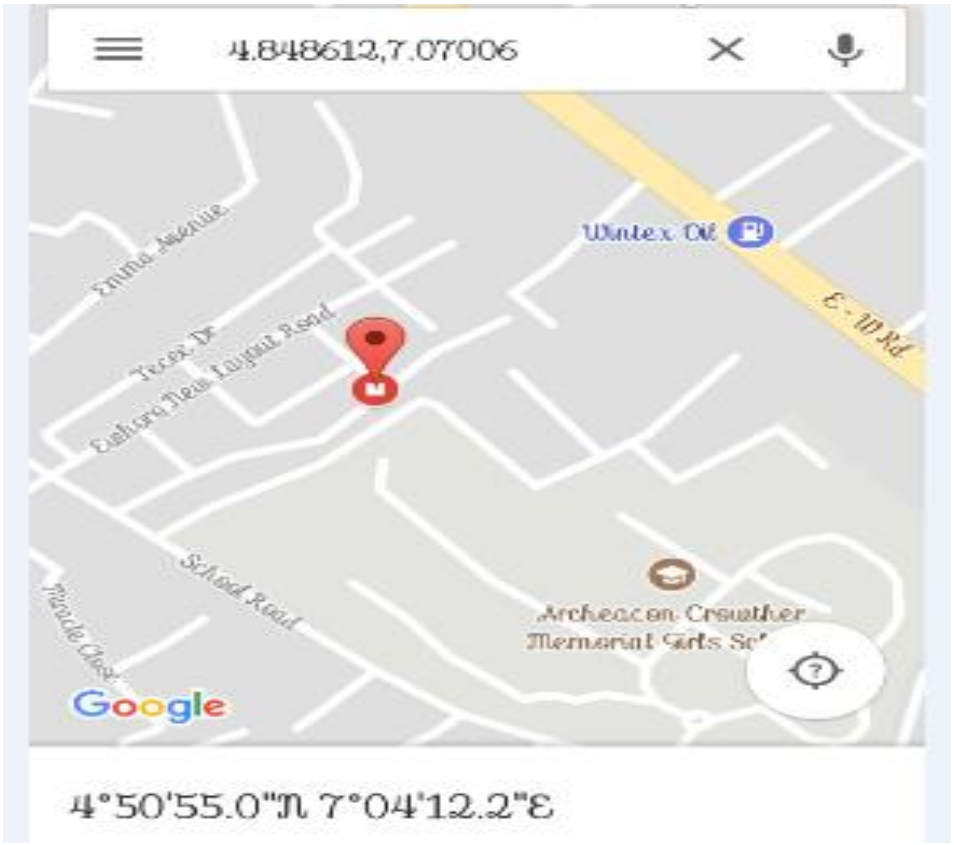
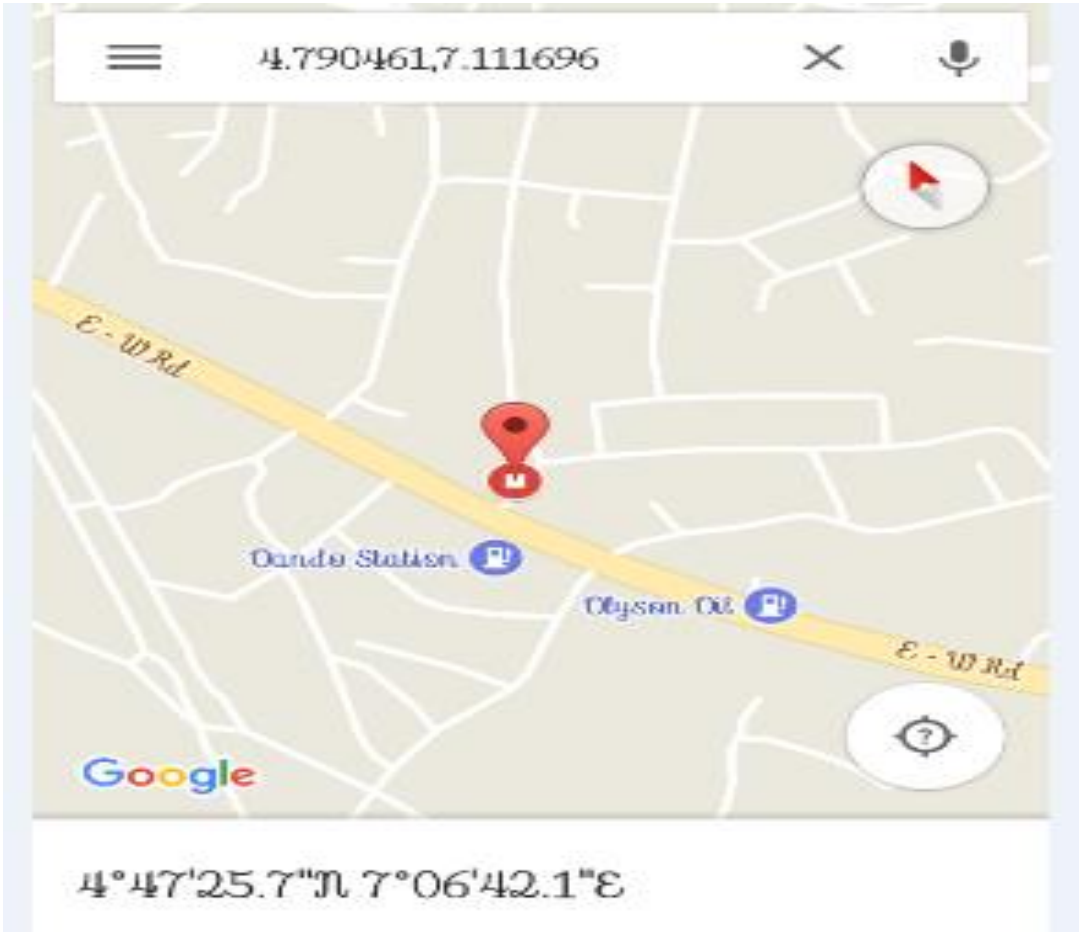


Location 5 *(4.848612, 7.07006)*

Location 6 (**4.790461, 7.111696**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB9 to eNB 10)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.122114	4.848612	0.084624	7.07006	0.123395	9.296055	11.2
eNB 1	4.8366	0.084414	7.0286	0.122672	4.848612	0.084624	7.07006	0.123395	4.783595	5.7
eNB 2	4.7737	0.083316	7.0142	0.12242	4.848612	0.084624	7.07006	0.123395	10.37744	14.2
eNB 3	4.7999	0.083774	6.9939	0.122066	4.848612	0.084624	7.07006	0.123395	10.0271	12
eNB 4	4.8294	0.084289	7.0919	0.123777	4.848612	0.084624	7.07006	0.123395	3.228162	4.2
eNB 5	4.7706	0.083262	7.0224	0.122564	4.848612	0.084624	7.07006	0.123395	10.15538	13.6
eNB 6	4.8746	0.085077	6.983	0.121876	4.848612	0.084624	7.07006	0.123395	10.06899	12.1
eNB 7	4.8692	0.084983	7.1137	0.124157	4.848612	0.084624	7.07006	0.123395	5.349948	7.7
eNB 8	4.7196	0.082372	7.1518	0.124822	4.848612	0.084624	7.07006	0.123395	16.96568	18.8
eNB 9	4.8554	0.084742	7.0641	0.123291	4.848612	0.084624	7.07006	0.123395	1.002624	1.8
eNB 10	4.7909	0.083617	7.1207	0.124279	4.848612	0.084624	7.07006	0.123395	8.524584	9.5
eNB 11	4.7854	0.083521	7.0082	0.122316	4.848612	0.084624	7.07006	0.123395	9.817346	12.3
eNB 12	4.8327	0.084346	7.0685	0.123368	4.848612	0.084624	7.07006	0.123395	1.777755	2.5
eNB 13	4.8039	0.083844	6.9883	0.121968	4.848612	0.084624	7.07006	0.123395	10.33336	12.6
eNB 14	4.8197	0.084119	7.0656	0.123317	4.848612	0.084624	7.07006	0.123395	3.252599	4.6
eNB 15	4.743	0.082781	7.0417	0.1229	4.848612	0.084624	7.07006	0.123395	12.15659	18.1
eNB 16	4.7939	0.083669	7.0308	0.12271	4.848612	0.084624	7.07006	0.123395	7.478738	9.7
eNB 17	4.748	0.082868	7.0989	0.123899	4.848612	0.084624	7.07006	0.123395	11.63508	14.1
eNB 18	4.7773	0.083379	7.062	0.123255	4.848612	0.084624	7.07006	0.123395	7.979634	10.7
eNB 19	4.8341	0.084371	6.9845	0.121902	4.848612	0.084624	7.07006	0.123395	9.615887	10.5
eNB 20	4.8565	0.084762	7.0405	0.122879	4.848612	0.084624	7.07006	0.123395	3.390205	4.6
eNB 21	4.8064	0.083887	7.0424	0.122913	4.848612	0.084624	7.07006	0.123395	5.605538	7.3
eNB 22	4.8146	0.08403	6.9788	0.121803	4.848612	0.084624	7.07006	0.123395	10.79537	12.8
eNB 23	4.8298	0.084296	6.9588	0.121453	4.848612	0.084624	7.07006	0.123395	12.50329	13.8
eNB 24	4.8923	0.085386	6.9143	0.120677	4.848612	0.084624	7.07006	0.123395	17.92749	19.7
eNB 25	4.848	0.084613	7.0492	0.123031	4.848612	0.084624	7.07006	0.123395	2.311882	2.6
eNB 26	4.8514	0.084673	6.9835	0.121885	4.848612	0.084624	7.07006	0.123395	9.595202	12.3
eNB 27	4.8081	0.083917	6.9967	0.122115	4.848612	0.084624	7.07006	0.123395	9.292804	11.2
eNB 28	4.9028	0.08557	6.999	0.122155	4.848612	0.084624	7.07006	0.123395	9.913733	11.5
eNB 29	4.9789	0.086898	6.9611	0.121494	4.848612	0.084624	7.07006	0.123395	18.85702	21.7
eNB 30	4.9969	0.087212	6.95	0.1213	4.848612	0.084624	7.07006	0.123395	21.18445	24.2
eNB 31	4.9539	0.086462	7.0111	0.122366	4.848612	0.084624	7.07006	0.123395	13.40622	15.7
eNB 32	4.9669	0.086688	6.9869	0.121944	4.848612	0.084624	7.07006	0.123395	16.05844	18.5
eNB 33	4.8289	0.08428	7.0219	0.122555	4.848612	0.084624	7.07006	0.123395	5.768377	6.7
eNB 34	4.8169	0.08407	7.0112	0.122368	4.848612	0.084624	7.07006	0.123395	7.413617	9.2
eNB 35	4.9317	0.086074	7.0021	0.122209	4.848612	0.084624	7.07006	0.123395	11.91813	14
eNB 36	4.8407	0.084486	6.9681	0.121616	4.848612	0.084624	7.07006	0.123395	11.33076	12.2
eNB 37	4.8598	0.084819	6.9792	0.12181	4.848612	0.084624	7.07006	0.123395	10.14313	13.2
eNB 38	4.8469	0.084594	7.0369	0.122817	4.848612	0.084624	7.07006	0.123395	3.678612	4.3
eNB 39	4.8585	0.084796	6.9658	0.121576	4.848612	0.084624	7.07006	0.123395	11.60343	13.6
eNB 40	4.88	0.085172	7.01	0.122347	4.848612	0.084624	7.07006	0.123395	7.513726	9.7

eNB 41	4.8669	0.084943	7.03	0.122696	4.848612	0.084624	7.07006	0.123395	4.881794	6.4
eNB 42	4.8378	0.084435	7.037	0.122818	4.848612	0.084624	7.07006	0.123395	3.854905	4.5
eNB 43	4.8842	0.085245	7.138	0.124581	4.848612	0.084624	7.07006	0.123395	8.504392	11.6
eNB 44	4.7815	0.083453	7.0398	0.122867	4.848612	0.084624	7.07006	0.123395	8.180997	10.4
eNB 45	4.8116	0.083978	6.9561	0.121406	4.848612	0.084624	7.07006	0.123395	13.28019	15.1
eNB 46	4.9011	0.08554	6.9269	0.120897	4.848612	0.084624	7.07006	0.123395	16.90042	20.1
eNB 47	4.9058	0.085622	6.9066	0.120542	4.848612	0.084624	7.07006	0.123395	19.19368	21.6
eNB 48	4.8024	0.083817	6.944	0.121195	4.848612	0.084624	7.07006	0.123395	14.88241	17
eNB 49	4.8354	0.084393	7.0528	0.123094	4.848612	0.084624	7.07006	0.123395	2.411271	4.5
eNB 50	4.7947	0.083683	7.0497	0.12304	4.848612	0.084624	7.07006	0.123395	6.405052	8.5
eNB 51	4.7581	0.083044	7.0119	0.12238	4.848612	0.084624	7.07006	0.123395	11.95069	16
eNB 52	4.8269	0.084245	6.9961	0.122104	4.848612	0.084624	7.07006	0.123395	8.54257	9.3
eNB 53	4.815	0.084037	7.0419	0.122904	4.848612	0.084624	7.07006	0.123395	4.868463	6.5
eNB 54	4.71	0.082205	7.165	0.125052	4.848612	0.084624	7.07006	0.123395	18.66113	20.5
eNB 55	4.8233	0.084182	7.0572	0.123171	4.848612	0.084624	7.07006	0.123395	3.154557	4.4
eNB 56	4.815	0.084037	7.0652	0.123311	4.848612	0.084624	7.07006	0.123395	3.776051	5.8
eNB 57	4.894	0.085416	7.0153	0.12244	4.848612	0.084624	7.07006	0.123395	7.891473	9.6
eNB 58	4.8626	0.084868	7.0153	0.12244	4.848612	0.084624	7.07006	0.123395	6.263019	8
eNB 59	4.8276	0.084257	7.0145	0.122426	4.848612	0.084624	7.07006	0.123395	6.58412	7.5
									554.2251	672



Location 6 (4.790461, 7.111696)

Location 7 (**4.790971, 7.015301**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB10 to eNB 11)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.790461	0.083609	7.111696	0.124122	12.89719	17.5
eNB 1	4.8366	0.08441	7.0286	0.122672	4.790461	0.083609	7.111696	0.124122	10.54017	13.3
eNB 2	4.7737	0.08332	7.0142	0.12242	4.790461	0.083609	7.111696	0.124122	10.96288	18.4
eNB 3	4.7999	0.08377	6.9939	0.122066	4.790461	0.083609	7.111696	0.124122	13.09458	17.8
eNB 4	4.8294	0.08429	7.0919	0.123777	4.790461	0.083609	7.111696	0.124122	4.853763	5.1
eNB 5	4.7706	0.08326	7.0224	0.122564	4.790461	0.083609	7.111696	0.124122	10.13815	17.8
eNB 6	4.8746	0.08508	6.983	0.121876	4.790461	0.083609	7.111696	0.124122	17.05472	19.5
eNB 7	4.8692	0.08498	7.1137	0.124157	4.790461	0.083609	7.111696	0.124122	8.758212	10.9
eNB 8	4.7196	0.08237	7.1518	0.124822	4.790461	0.083609	7.111696	0.124122	9.046115	10.1
eNB 9	4.8554	0.08474	7.0641	0.123291	4.790461	0.083609	7.111696	0.124122	8.941671	10.1
eNB 10	4.7909	0.08362	7.1207	0.124279	4.790461	0.083609	7.111696	0.124122	0.99887	1.4
eNB 11	4.7854	0.08352	7.0082	0.122316	4.790461	0.083609	7.111696	0.124122	11.48185	16.5
eNB 12	4.8327	0.08435	7.0685	0.123368	4.790461	0.083609	7.111696	0.124122	6.70583	7.1
eNB 13	4.8039	0.08384	6.9883	0.121968	4.790461	0.083609	7.111696	0.124122	13.75434	18.8
eNB 14	4.8197	0.08412	7.0656	0.123317	4.790461	0.083609	7.111696	0.124122	6.054639	8.8
eNB 15	4.743	0.08278	7.0417	0.1229	4.790461	0.083609	7.111696	0.124122	9.381372	22.3
eNB 16	4.7939	0.08367	7.0308	0.12271	4.790461	0.083609	7.111696	0.124122	8.971923	13.8
eNB 17	4.748	0.08287	7.0989	0.123899	4.790461	0.083609	7.111696	0.124122	4.929698	6.1
eNB 18	4.7773	0.08338	7.062	0.123255	4.790461	0.083609	7.111696	0.124122	5.69782	14.9
eNB 19	4.8341	0.08437	6.9845	0.121902	4.790461	0.083609	7.111696	0.124122	14.90563	17.9
eNB 20	4.8565	0.08476	7.0405	0.122879	4.790461	0.083609	7.111696	0.124122	10.77742	12.3
eNB 21	4.8064	0.08389	7.0424	0.122913	4.790461	0.083609	7.111696	0.124122	7.880255	11.5
eNB 22	4.8146	0.08403	6.9788	0.121803	4.790461	0.083609	7.111696	0.124122	14.96808	20.1
eNB 23	4.8298	0.0843	6.9588	0.121453	4.790461	0.083609	7.111696	0.124122	17.49696	21.2
eNB 24	4.8923	0.08539	6.9143	0.120677	4.790461	0.083609	7.111696	0.124122	24.62876	27.1
eNB 25	4.848	0.08461	7.0492	0.123031	4.790461	0.083609	7.111696	0.124122	9.427957	10.6
eNB 26	4.8514	0.08467	6.9835	0.121885	4.790461	0.083609	7.111696	0.124122	15.73778	19.6
eNB 27	4.8081	0.08392	6.9967	0.122115	4.790461	0.083609	7.111696	0.124122	12.89219	17.5
eNB 28	4.9028	0.08557	6.999	0.122155	4.790461	0.083609	7.111696	0.124122	17.66206	19
eNB 29	4.9789	0.0869	6.9611	0.121494	4.790461	0.083609	7.111696	0.124122	26.78476	29.1
eNB 30	4.9969	0.08721	6.95	0.1213	4.790461	0.083609	7.111696	0.124122	29.11781	31.6
eNB 31	4.9539	0.08646	7.0111	0.122366	4.790461	0.083609	7.111696	0.124122	21.31893	23.1
eNB 32	4.9669	0.08669	6.9869	0.121944	4.790461	0.083609	7.111696	0.124122	24.00162	25.9
eNB 33	4.8289	0.08428	7.0219	0.122555	4.790461	0.083609	7.111696	0.124122	10.82892	13.9
eNB 34	4.8169	0.08407	7.0112	0.122368	4.790461	0.083609	7.111696	0.124122	11.51693	15.4
eNB 35	4.9317	0.08607	7.0021	0.122209	4.790461	0.083609	7.111696	0.124122	19.85177	21.4
eNB 36	4.8407	0.08449	6.9681	0.121616	4.790461	0.083609	7.111696	0.124122	16.86295	20.2
eNB 37	4.8598	0.08482	6.9792	0.12181	4.790461	0.083609	7.111696	0.124122	16.58215	21.2
eNB 38	4.8469	0.08459	7.0369	0.122817	4.790461	0.083609	7.111696	0.124122	10.39559	11.8
eNB 39	4.8585	0.0848	6.9658	0.121576	4.790461	0.083609	7.111696	0.124122	17.84819	21
eNB 40	4.88	0.08517	7.01	0.122347	4.790461	0.083609	7.111696	0.124122	15.03634	17.1

eNB 41	4.8669	0.08494	7.03	0.122696	4.790461	0.083609	7.111696	0.124122	12.41698	13.8
eNB 42	4.8378	0.08444	7.037	0.122818	4.790461	0.083609	7.111696	0.124122	9.808623	11.5
eNB 43	4.8842	0.08525	7.138	0.124581	4.790461	0.083609	7.111696	0.124122	10.82309	12.3
eNB 44	4.7815	0.08345	7.0398	0.122867	4.790461	0.083609	7.111696	0.124122	8.028652	14.5
eNB 45	4.8116	0.08398	6.9561	0.121406	4.790461	0.083609	7.111696	0.124122	17.40024	22.5
eNB 46	4.9011	0.08554	6.9269	0.120897	4.790461	0.083609	7.111696	0.124122	23.88665	27.6
eNB 47	4.9058	0.08562	6.9066	0.120542	4.790461	0.083609	7.111696	0.124122	26.09334	29
eNB 48	4.8024	0.08382	6.944	0.121195	4.790461	0.083609	7.111696	0.124122	18.62896	24.3
eNB 49	4.8354	0.08439	7.0528	0.123094	4.790461	0.083609	7.111696	0.124122	8.219299	9.5
eNB 50	4.7947	0.08368	7.0497	0.12304	4.790461	0.083609	7.111696	0.124122	6.885691	12.6
eNB 51	4.7581	0.08304	7.0119	0.12238	4.790461	0.083609	7.111696	0.124122	11.62899	20.1
eNB 52	4.8269	0.08424	6.9961	0.122104	4.790461	0.083609	7.111696	0.124122	13.43403	16.7
eNB 53	4.815	0.08404	7.0419	0.122904	4.790461	0.083609	7.111696	0.124122	8.20096	10.7
eNB 54	4.71	0.0822	7.165	0.125052	4.790461	0.083609	7.111696	0.124122	10.72073	11.8
eNB 55	4.8233	0.08418	7.0572	0.123171	4.790461	0.083609	7.111696	0.124122	7.056616	8.5
eNB 56	4.815	0.08404	7.0652	0.123311	4.790461	0.083609	7.111696	0.124122	5.829954	10
eNB 57	4.894	0.08542	7.0153	0.12244	4.790461	0.083609	7.111696	0.124122	15.70421	17
eNB 58	4.8626	0.08487	7.0153	0.12244	4.790461	0.083609	7.111696	0.124122	13.35749	15.4
eNB 59	4.8276	0.08426	7.0145	0.122426	4.790461	0.083609	7.111696	0.124122	11.53428	14.9
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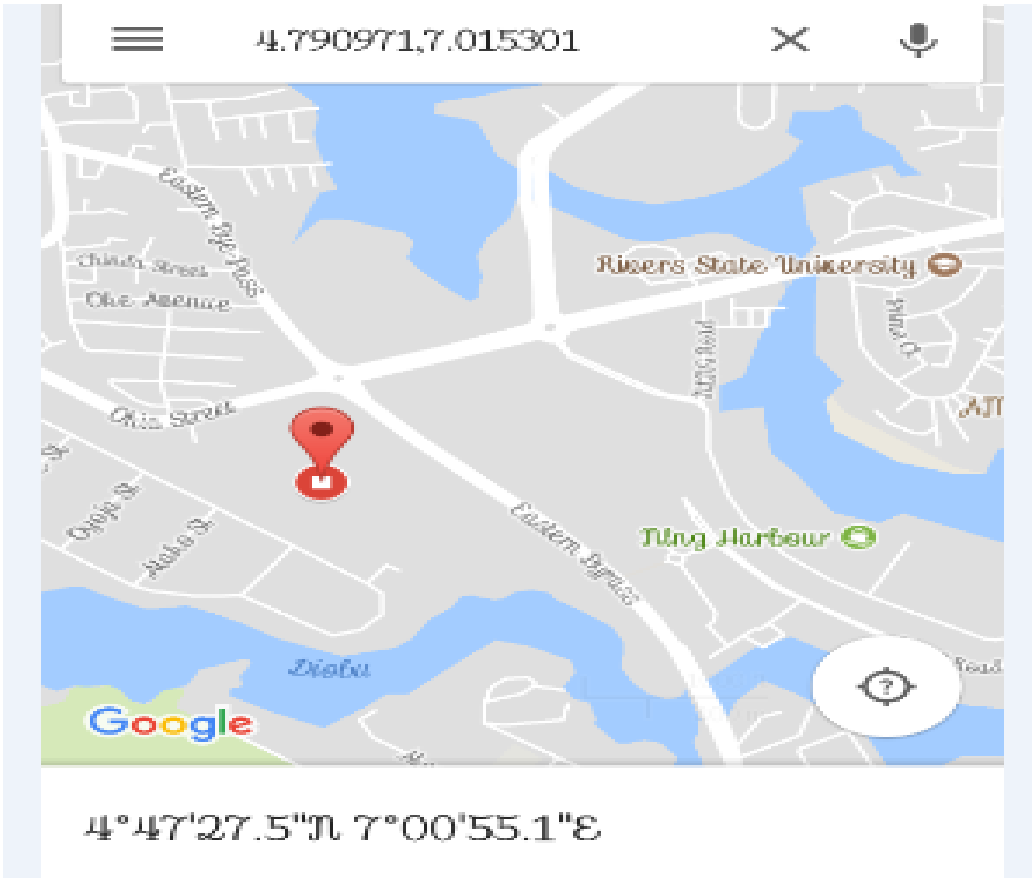
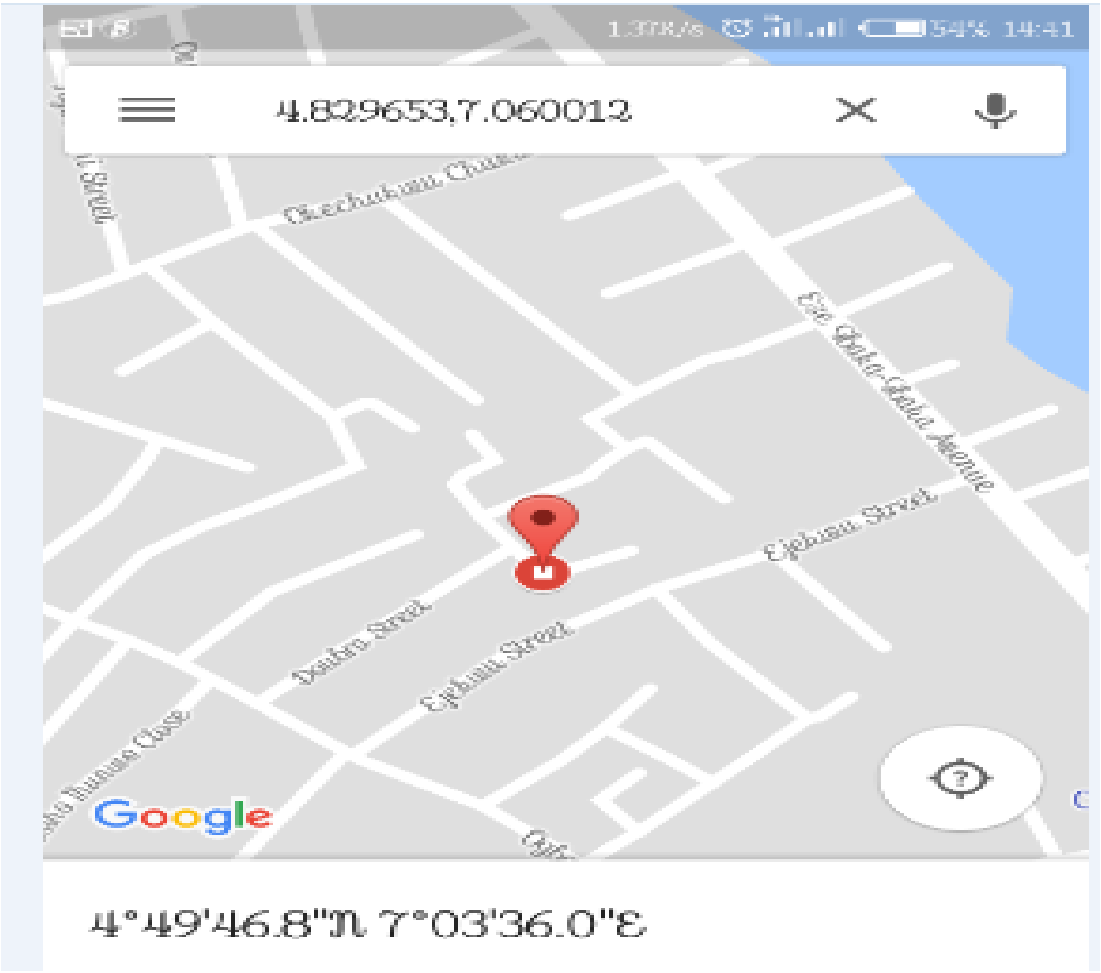


Location 7 (4.790971, 7.015301)

Location 8 (**4.829653, 7.060012**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB11 to eNB 12)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.122114	4.790971	0.08362	7.015301	0.12244	2.811173	3.7
eNB 1	4.8366	0.084414	7.0286	0.122672	4.790971	0.08362	7.015301	0.12244	5.28338	6.8
eNB 2	4.7737	0.083316	7.0142	0.12242	4.790971	0.08362	7.015301	0.12244	1.924276	3.5
eNB 3	4.7999	0.083774	6.9939	0.122066	4.790971	0.08362	7.015301	0.12244	2.57081	3.1
eNB 4	4.8294	0.084289	7.0919	0.123777	4.790971	0.08362	7.015301	0.12244	9.502394	12.4
eNB 5	4.7706	0.083262	7.0224	0.122564	4.790971	0.08362	7.015301	0.12244	2.397812	4.3
eNB 6	4.8746	0.085077	6.983	0.121876	4.790971	0.08362	7.015301	0.12244	9.964047	12.6
eNB 7	4.8692	0.084983	7.1137	0.124157	4.790971	0.08362	7.015301	0.12244	13.94751	17.4
eNB 8	4.7196	0.082372	7.1518	0.124822	4.790971	0.08362	7.015301	0.12244	17.0812	26
eNB 9	4.8554	0.084742	7.0641	0.123291	4.790971	0.08362	7.015301	0.12244	8.975571	11.4
eNB 10	4.7909	0.083617	7.1207	0.124279	4.790971	0.08362	7.015301	0.12244	11.67885	16.6
eNB 11	4.7854	0.083521	7.0082	0.122316	4.790971	0.08362	7.015301	0.12244	1.001396	1.6
eNB 12	4.8327	0.084346	7.0685	0.123368	4.790971	0.08362	7.015301	0.12244	7.501765	9.5
eNB 13	4.8039	0.083844	6.9883	0.121968	4.790971	0.08362	7.015301	0.12244	3.319333	4.1
eNB 14	4.8197	0.084119	7.0656	0.123317	4.790971	0.08362	7.015301	0.12244	6.423938	8.8
eNB 15	4.743	0.082781	7.0417	0.1229	4.790971	0.08362	7.015301	0.12244	6.083552	8.8
eNB 16	4.7939	0.083669	7.0308	0.12271	4.790971	0.08362	7.015301	0.12244	1.748001	3.1
eNB 17	4.748	0.082868	7.0989	0.123899	4.790971	0.08362	7.015301	0.12244	10.42324	21
eNB 18	4.7773	0.083379	7.062	0.123255	4.790971	0.08362	7.015301	0.12244	5.393243	21.3
eNB 19	4.8341	0.084371	6.9845	0.121902	4.790971	0.08362	7.015301	0.12244	5.886125	7.7
eNB 20	4.8565	0.084762	7.0405	0.122879	4.790971	0.08362	7.015301	0.12244	7.803122	10.2
eNB 21	4.8064	0.083887	7.0424	0.122913	4.790971	0.08362	7.015301	0.12244	3.45828	5.2
eNB 22	4.8146	0.08403	6.9788	0.121803	4.790971	0.08362	7.015301	0.12244	4.822974	5.8
eNB 23	4.8298	0.084296	6.9588	0.121453	4.790971	0.08362	7.015301	0.12244	7.604939	9.7
eNB 24	4.8923	0.085386	6.9143	0.120677	4.790971	0.08362	7.015301	0.12244	15.88025	18.8
eNB 25	4.848	0.084613	7.0492	0.123031	4.790971	0.08362	7.015301	0.12244	7.370254	9.4
eNB 26	4.8514	0.084673	6.9835	0.121885	4.790971	0.08362	7.015301	0.12244	7.587227	10
eNB 27	4.8081	0.083917	6.9967	0.122115	4.790971	0.08362	7.015301	0.12244	2.806391	3.7
eNB 28	4.9028	0.08557	6.999	0.122155	4.790971	0.08362	7.015301	0.12244	12.56528	15.5
eNB 29	4.9789	0.086898	6.9611	0.121494	4.790971	0.08362	7.015301	0.12244	21.74239	27.3
eNB 30	4.9969	0.087212	6.95	0.1213	4.790971	0.08362	7.015301	0.12244	24.0139	27.9
eNB 31	4.9539	0.086462	7.0111	0.122366	4.790971	0.08362	7.015301	0.12244	18.12282	21.4
eNB 32	4.9669	0.086688	6.9869	0.121944	4.790971	0.08362	7.015301	0.12244	19.81381	24.7
eNB 33	4.8289	0.08428	7.0219	0.122555	4.790971	0.08362	7.015301	0.12244	4.280444	5.8
eNB 34	4.8169	0.08407	7.0112	0.122368	4.790971	0.08362	7.015301	0.12244	2.918784	3.6
eNB 35	4.9317	0.086074	7.0021	0.122209	4.790971	0.08362	7.015301	0.12244	15.71653	18.6
eNB 36	4.8407	0.084486	6.9681	0.121616	4.790971	0.08362	7.015301	0.12244	7.611122	9.5
eNB 37	4.8598	0.084819	6.9792	0.12181	4.790971	0.08362	7.015301	0.12244	8.635688	10.9
eNB 38	4.8469	0.084594	7.0369	0.122817	4.790971	0.08362	7.015301	0.12244	6.663616	8.5
eNB 39	4.8585	0.084796	6.9658	0.121576	4.790971	0.08362	7.015301	0.12244	9.298688	11.3
eNB 40	4.88	0.085172	7.01	0.122347	4.790971	0.08362	7.015301	0.12244	9.916976	12.2

eNB 41	4.8669	0.084943	7.03	0.122696	4.790971	0.08362	7.015301	0.12244	8.59857	11.2
eNB 42	4.8378	0.084435	7.037	0.122818	4.790971	0.08362	7.015301	0.12244	5.735434	7.5
eNB 43	4.8842	0.085245	7.138	0.124581	4.790971	0.08362	7.015301	0.12244	17.09638	21.3
eNB 44	4.7815	0.083453	7.0398	0.122867	4.790971	0.08362	7.015301	0.12244	2.911766	4.9
eNB 45	4.8116	0.083978	6.9561	0.121406	4.790971	0.08362	7.015301	0.12244	6.949224	9.5
eNB 46	4.9011	0.08554	6.9269	0.120897	4.790971	0.08362	7.015301	0.12244	15.68095	19.2
eNB 47	4.9058	0.085622	6.9066	0.120542	4.790971	0.08362	7.015301	0.12244	17.55227	20.7
eNB 48	4.8024	0.083817	6.944	0.121195	4.790971	0.08362	7.015301	0.12244	8.002067	11.4
eNB 49	4.8354	0.084393	7.0528	0.123094	4.790971	0.08362	7.015301	0.12244	6.455262	9.7
eNB 50	4.7947	0.083683	7.0497	0.12304	4.790971	0.08362	7.015301	0.12244	3.834102	5.6
eNB 51	4.7581	0.083044	7.0119	0.12238	4.790971	0.08362	7.015301	0.12244	3.674416	5.3
eNB 52	4.8269	0.084245	6.9961	0.122104	4.790971	0.08362	7.015301	0.12244	4.526312	5.9
eNB 53	4.815	0.084037	7.0419	0.122904	4.790971	0.08362	7.015301	0.12244	3.978149	6.1
eNB 54	4.71	0.082205	7.165	0.125052	4.790971	0.08362	7.015301	0.12244	18.87438	27.7
eNB 55	4.8233	0.084182	7.0572	0.123171	4.790971	0.08362	7.015301	0.12244	5.871645	7.9
eNB 56	4.815	0.084037	7.0652	0.123311	4.790971	0.08362	7.015301	0.12244	6.140784	8.2
eNB 57	4.894	0.085416	7.0153	0.12244	4.790971	0.08362	7.015301	0.12244	11.45629	14.1
eNB 58	4.8626	0.084868	7.0153	0.12244	4.790971	0.08362	7.015301	0.12244	7.964784	10.4
eNB 59	4.8276	0.084257	7.0145	0.122426	4.790971	0.08362	7.015301	0.12244	4.073944	5.5
									511.9278	685.8

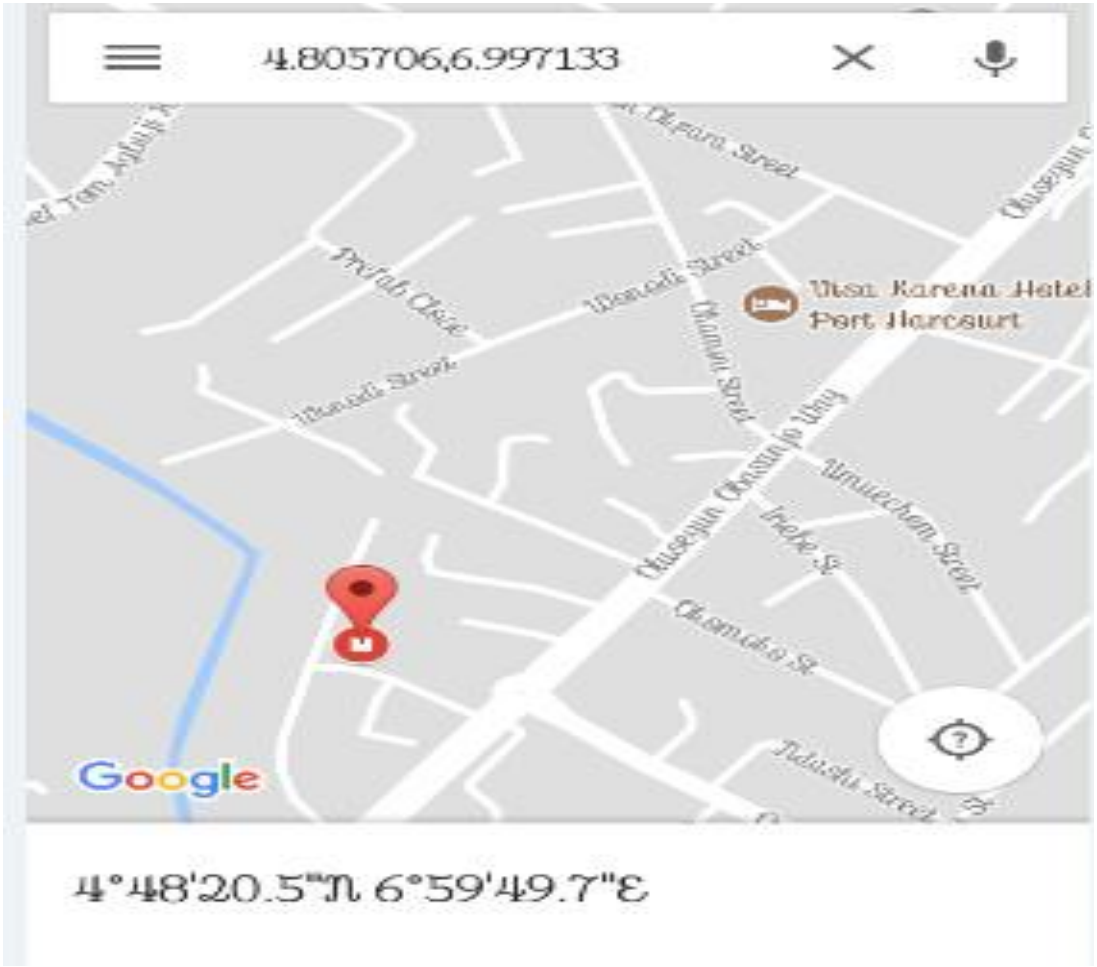


Location 8 (4.829653, 7.060012)

*Location 9 (***4.805706, 6.997133***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB12 to eNB 13)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.829653	0.084293	7.060012	0.12322	7.417058	10
eNB 1	4.8366	0.08441	7.0286	0.122672	4.829653	0.084293	7.060012	0.12322	3.565162	5.4
eNB 2	4.7737	0.08332	7.0142	0.12242	4.829653	0.084293	7.060012	0.12322	8.029715	10.9
eNB 3	4.7999	0.08377	6.9939	0.122066	4.829653	0.084293	7.060012	0.12322	8.037803	10.3
eNB 4	4.8294	0.08429	7.0919	0.123777	4.829653	0.084293	7.060012	0.12322	3.533254	4.8
eNB 5	4.7706	0.08326	7.0224	0.122564	4.829653	0.084293	7.060012	0.12322	7.777246	10.3
eNB 6	4.8746	0.08508	6.983	0.121876	4.829653	0.084293	7.060012	0.12322	9.888648	11.8
eNB 7	4.8692	0.08498	7.1137	0.124157	4.829653	0.084293	7.060012	0.12322	7.397372	9.7
eNB 8	4.7196	0.08237	7.1518	0.124822	4.829653	0.084293	7.060012	0.12322	15.91215	18.4
eNB 9	4.8554	0.08474	7.0641	0.123291	4.829653	0.084293	7.060012	0.12322	2.898576	4.9
eNB 10	4.7909	0.08362	7.1207	0.124279	4.829653	0.084293	7.060012	0.12322	7.986561	9
eNB 11	4.7854	0.08352	7.0082	0.122316	4.829653	0.084293	7.060012	0.12322	7.561185	9
eNB 12	4.8327	0.08435	7.0685	0.123368	4.829653	0.084293	7.060012	0.12322	0.999615	1.9
eNB 13	4.8039	0.08384	6.9883	0.121968	4.829653	0.084293	7.060012	0.12322	8.446093	11.3
eNB 14	4.8197	0.08412	7.0656	0.123317	4.829653	0.084293	7.060012	0.12322	1.268077	2.2
eNB 15	4.743	0.08278	7.0417	0.1229	4.829653	0.084293	7.060012	0.12322	9.846629	14.8
eNB 16	4.7939	0.08367	7.0308	0.12271	4.829653	0.084293	7.060012	0.12322	5.126538	6.4
eNB 17	4.748	0.08287	7.0989	0.123899	4.829653	0.084293	7.060012	0.12322	10.04994	13.7
eNB 18	4.7773	0.08338	7.062	0.123255	4.829653	0.084293	7.060012	0.12322	5.82548	13.7
eNB 19	4.8341	0.08437	6.9845	0.121902	4.829653	0.084293	7.060012	0.12322	8.381318	10
eNB 20	4.8565	0.08476	7.0405	0.122879	4.829653	0.084293	7.060012	0.12322	3.685897	5.5
eNB 21	4.8064	0.08389	7.0424	0.122913	4.829653	0.084293	7.060012	0.12322	3.239345	4
eNB 22	4.8146	0.08403	6.9788	0.121803	4.829653	0.084293	7.060012	0.12322	9.152743	12.4
eNB 23	4.8298	0.0843	6.9588	0.121453	4.829653	0.084293	7.060012	0.12322	11.21431	13.4
eNB 24	4.8923	0.08539	6.9143	0.120677	4.829653	0.084293	7.060012	0.12322	17.58291	19.3
eNB 25	4.848	0.08461	7.0492	0.123031	4.829653	0.084293	7.060012	0.12322	2.365867	3.3
eNB 26	4.8514	0.08467	6.9835	0.121885	4.829653	0.084293	7.060012	0.12322	8.81556	11.8
eNB 27	4.8081	0.08392	6.9967	0.122115	4.829653	0.084293	7.060012	0.12322	7.41316	10
eNB 28	4.9028	0.08557	6.999	0.122155	4.829653	0.084293	7.060012	0.12322	10.57591	12.7
eNB 29	4.9789	0.0869	6.9611	0.121494	4.829653	0.084293	7.060012	0.12322	19.88701	24.5
eNB 30	4.9969	0.08721	6.95	0.1213	4.829653	0.084293	7.060012	0.12322	22.2349	25.6
eNB 31	4.9539	0.08646	7.0111	0.122366	4.829653	0.084293	7.060012	0.12322	14.84038	18.5
eNB 32	4.9669	0.08669	6.9869	0.121944	4.829653	0.084293	7.060012	0.12322	17.27753	21.3
eNB 33	4.8289	0.08428	7.0219	0.122555	4.829653	0.084293	7.060012	0.12322	4.223667	6
eNB 34	4.8169	0.08407	7.0112	0.122368	4.829653	0.084293	7.060012	0.12322	5.591244	8
eNB 35	4.9317	0.08607	7.0021	0.122209	4.829653	0.084293	7.060012	0.12322	13.0355	15.8
eNB 36	4.8407	0.08449	6.9681	0.121616	4.829653	0.084293	7.060012	0.12322	10.2576	12.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.829653	0.084293	7.060012	0.12322	9.560735	12.7
eNB 38	4.8469	0.08459	7.0369	0.122817	4.829653	0.084293	7.060012	0.12322	3.199339	4
eNB 39	4.8585	0.0848	6.9658	0.121576	4.829653	0.084293	7.060012	0.12322	10.92021	13.1
eNB 40	4.88	0.08517	7.01	0.122347	4.829653	0.084293	7.060012	0.12322	7.876922	9.3

eNB 41	4.8669	0.08494	7.03	0.122696	4.829653	0.084293	7.060012	0.12322	5.311418	8
eNB 42	4.8378	0.08444	7.037	0.122818	4.829653	0.084293	7.060012	0.12322	2.70591	3.7
eNB 43	4.8842	0.08525	7.138	0.124581	4.829653	0.084293	7.060012	0.12322	10.55698	13.7
eNB 44	4.7815	0.08345	7.0398	0.122867	4.829653	0.084293	7.060012	0.12322	5.803819	7.1
eNB 45	4.8116	0.08398	6.9561	0.121406	4.829653	0.084293	7.060012	0.12322	11.68728	14.6
eNB 46	4.9011	0.08554	6.9269	0.120897	4.829653	0.084293	7.060012	0.12322	16.75172	19.8
eNB 47	4.9058	0.08562	6.9066	0.120542	4.829653	0.084293	7.060012	0.12322	18.98931	21.2
eNB 48	4.8024	0.08382	6.944	0.121195	4.829653	0.084293	7.060012	0.12322	13.20675	16.5
eNB 49	4.8354	0.08439	7.0528	0.123094	4.829653	0.084293	7.060012	0.12322	1.023242	1.8
eNB 50	4.7947	0.08368	7.0497	0.12304	4.829653	0.084293	7.060012	0.12322	4.051017	5.2
eNB 51	4.7581	0.08304	7.0119	0.12238	4.829653	0.084293	7.060012	0.12322	9.577194	12.7
eNB 52	4.8269	0.08424	6.9961	0.122104	4.829653	0.084293	7.060012	0.12322	7.088093	8.8
eNB 53	4.815	0.08404	7.0419	0.122904	4.829653	0.084293	7.060012	0.12322	2.584969	3.2
eNB 54	4.71	0.0822	7.165	0.125052	4.829653	0.084293	7.060012	0.12322	17.6736	20.1
eNB 55	4.8233	0.08418	7.0572	0.123171	4.829653	0.084293	7.060012	0.12322	0.772047	1.8
eNB 56	4.815	0.08404	7.0652	0.123311	4.829653	0.084293	7.060012	0.12322	1.727702	3
eNB 57	4.894	0.08542	7.0153	0.12244	4.829653	0.084293	7.060012	0.12322	8.702648	11.3
eNB 58	4.8626	0.08487	7.0153	0.12244	4.829653	0.084293	7.060012	0.12322	6.161479	7.6
eNB 59	4.8276	0.08426	7.0145	0.122426	4.829653	0.084293	7.060012	0.12322	5.047923	7.1
									502.3223	639.2

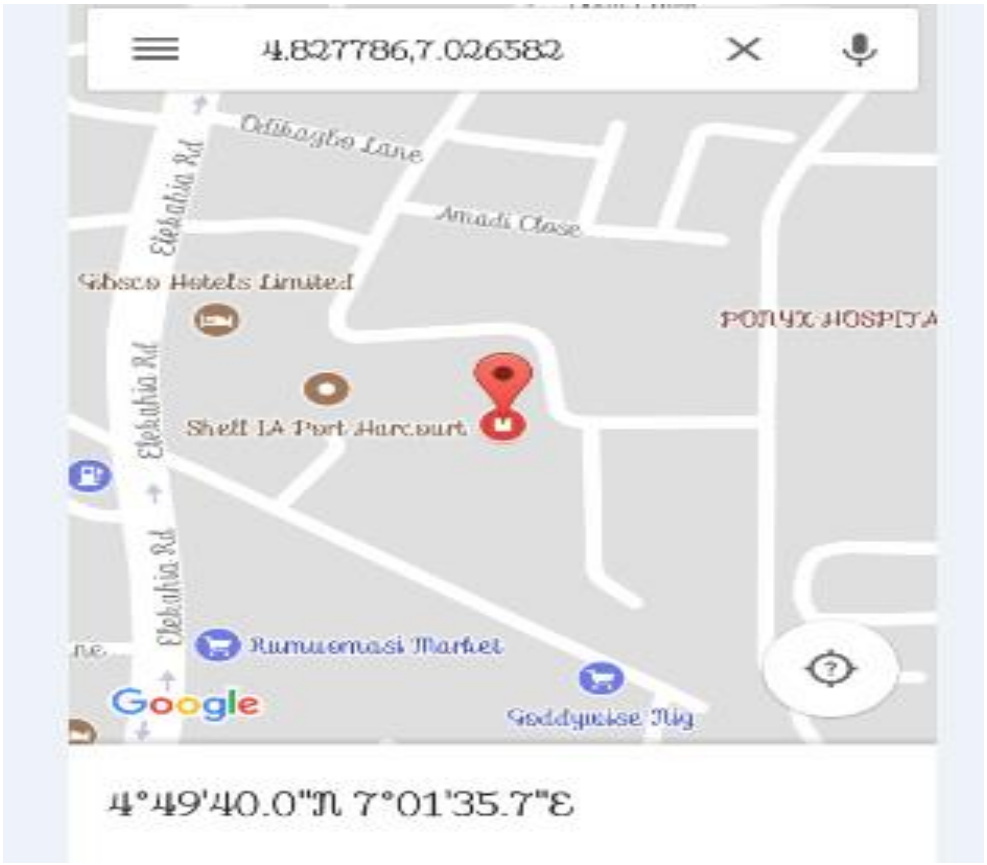


Location 9 (4.805706, 6.997133)

Location 10 (**4.8277864, 7.026582**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB13 to eNB 14)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.805706	0.08388	6.997133	0.122123	0.273236	1.4
eNB 1	4.8366	0.08441	7.0286	0.122672	4.805706	0.08388	6.997133	0.122123	4.894602	6.7
eNB 2	4.7737	0.08332	7.0142	0.12242	4.805706	0.08388	6.997133	0.122123	4.030137	5.2
eNB 3	4.7999	0.08377	6.9939	0.122066	4.805706	0.08388	6.997133	0.122123	0.738319	0.85
eNB 4	4.8294	0.08429	7.0919	0.123777	4.805706	0.08388	6.997133	0.122123	10.82582	14.4
eNB 5	4.7706	0.08326	7.0224	0.122564	4.805706	0.08388	6.997133	0.122123	4.803805	6.5
eNB 6	4.8746	0.08508	6.983	0.121876	4.805706	0.08388	6.997133	0.122123	7.819046	10.2
eNB 7	4.8692	0.08498	7.1137	0.124157	4.805706	0.08388	6.997133	0.122123	14.71919	18.9
eNB 8	4.7196	0.08237	7.1518	0.124822	4.805706	0.08388	6.997133	0.122123	19.63179	28
eNB 9	4.8554	0.08474	7.0641	0.123291	4.805706	0.08388	6.997133	0.122123	9.251403	11.1
eNB 10	4.7909	0.08362	7.1207	0.124279	4.805706	0.08388	6.997133	0.122123	13.79044	18.7
eNB 11	4.7854	0.08352	7.0082	0.122316	4.805706	0.08388	6.997133	0.122123	2.569417	3.6
eNB 12	4.8327	0.08435	7.0685	0.123368	4.805706	0.08388	6.997133	0.122123	8.458075	11.6
eNB 13	4.8039	0.08384	6.9883	0.121968	4.805706	0.08388	6.997133	0.122123	0.999121	1.7
eNB 14	4.8197	0.08412	7.0656	0.123317	4.805706	0.08388	6.997133	0.122123	7.744249	10.9
eNB 15	4.743	0.08278	7.0417	0.1229	4.805706	0.08388	6.997133	0.122123	8.544259	10.6
eNB 16	4.7939	0.08367	7.0308	0.12271	4.805706	0.08388	6.997133	0.122123	3.954694	5.3
eNB 17	4.748	0.08287	7.0989	0.123899	4.805706	0.08388	6.997133	0.122123	12.97439	23.3
eNB 18	4.7773	0.08338	7.062	0.123255	4.805706	0.08388	6.997133	0.122123	7.851041	9.7
eNB 19	4.8341	0.08437	6.9845	0.121902	4.805706	0.08388	6.997133	0.122123	3.45364	5.1
eNB 20	4.8565	0.08476	7.0405	0.122879	4.805706	0.08388	6.997133	0.122123	7.415422	9.9
eNB 21	4.8064	0.08389	7.0424	0.122913	4.805706	0.08388	6.997133	0.122123	5.016333	7.4
eNB 22	4.8146	0.08403	6.9788	0.121803	4.805706	0.08388	6.997133	0.122123	2.259304	3.2
eNB 23	4.8298	0.0843	6.9588	0.121453	4.805706	0.08388	6.997133	0.122123	5.021733	7.1
eNB 24	4.8923	0.08539	6.9143	0.120677	4.805706	0.08388	6.997133	0.122123	13.30195	16.4
eNB 25	4.848	0.08461	7.0492	0.123031	4.805706	0.08388	6.997133	0.122123	7.443025	9.1
eNB 26	4.8514	0.08467	6.9835	0.121885	4.805706	0.08388	6.997133	0.122123	5.300712	7.6
eNB 27	4.8081	0.08392	6.9967	0.122115	4.805706	0.08388	6.997133	0.122123	0.270496	1.4
eNB 28	4.9028	0.08557	6.999	0.122155	4.805706	0.08388	6.997133	0.122123	10.79831	13.2
eNB 29	4.9789	0.0869	6.9611	0.121494	4.805706	0.08388	6.997133	0.122123	19.66763	24.9
eNB 30	4.9969	0.08721	6.95	0.1213	4.805706	0.08388	6.997133	0.122123	21.89161	25.5
eNB 31	4.9539	0.08646	7.0111	0.122366	4.805706	0.08388	6.997133	0.122123	16.55086	19.1
eNB 32	4.9669	0.08669	6.9869	0.121944	4.805706	0.08388	6.997133	0.122123	17.95971	22.4
eNB 33	4.8289	0.08428	7.0219	0.122555	4.805706	0.08388	6.997133	0.122123	3.765934	5.3
eNB 34	4.8169	0.08407	7.0112	0.122368	4.805706	0.08388	6.997133	0.122123	1.994677	2.7
eNB 35	4.9317	0.08607	7.0021	0.122209	4.805706	0.08388	6.997133	0.122123	14.02065	16.3
eNB 36	4.8407	0.08449	6.9681	0.121616	4.805706	0.08388	6.997133	0.122123	5.048698	6.9
eNB 37	4.8598	0.08482	6.9792	0.12181	4.805706	0.08388	6.997133	0.122123	6.33465	8.5
eNB 38	4.8469	0.08459	7.0369	0.122817	4.805706	0.08388	6.997133	0.122123	6.355782	8.2
eNB 39	4.8585	0.0848	6.9658	0.121576	4.805706	0.08388	6.997133	0.122123	6.820135	8.8
eNB 40	4.88	0.08517	7.01	0.122347	4.805706	0.08388	6.997133	0.122123	8.383199	11.1

eNB 41	4.8669	0.08494	7.03	0.122696	4.805706	0.08388	6.997133	0.122123	7.717628	10.2
eNB 42	4.8378	0.08444	7.037	0.122818	4.805706	0.08388	6.997133	0.122123	5.678734	7.4
eNB 43	4.8842	0.08525	7.138	0.124581	4.805706	0.08388	6.997133	0.122123	17.88236	22.9
eNB 44	4.7815	0.08345	7.0398	0.122867	4.805706	0.08388	6.997133	0.122123	5.440223	7.1
eNB 45	4.8116	0.08398	6.9561	0.121406	4.805706	0.08388	6.997133	0.122123	4.593581	7
eNB 46	4.9011	0.08554	6.9269	0.120897	4.805706	0.08388	6.997133	0.122123	13.15548	16.8
eNB 47	4.9058	0.08562	6.9066	0.120542	4.805706	0.08388	6.997133	0.122123	14.98294	18.3
eNB 48	4.8024	0.08382	6.944	0.121195	4.805706	0.08388	6.997133	0.122123	5.89881	8.8
eNB 49	4.8354	0.08439	7.0528	0.123094	4.805706	0.08388	6.997133	0.122123	6.996126	9.7
eNB 50	4.7947	0.08368	7.0497	0.12304	4.805706	0.08388	6.997133	0.122123	5.951831	7.8
eNB 51	4.7581	0.08304	7.0119	0.12238	4.805706	0.08388	6.997133	0.122123	5.540647	6.7
eNB 52	4.8269	0.08424	6.9961	0.122104	4.805706	0.08388	6.997133	0.122123	2.359441	3.6
eNB 53	4.815	0.08404	7.0419	0.122904	4.805706	0.08388	6.997133	0.122123	5.066819	8.2
eNB 54	4.71	0.0822	7.165	0.125052	4.805706	0.08388	6.997133	0.122123	21.43057	29.7
eNB 55	4.8233	0.08418	7.0572	0.123171	4.805706	0.08388	6.997133	0.122123	6.937124	10
eNB 56	4.815	0.08404	7.0652	0.123311	4.805706	0.08388	6.997133	0.122123	7.612487	10.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.805706	0.08388	6.997133	0.122123	10.02202	13.1
eNB 58	4.8626	0.08487	7.0153	0.12244	4.805706	0.08388	6.997133	0.122123	6.638813	9.3
eNB 59	4.8276	0.08426	7.0145	0.122426	4.805706	0.08388	6.997133	0.122123	3.103173	4.2
									489.9563	649.95

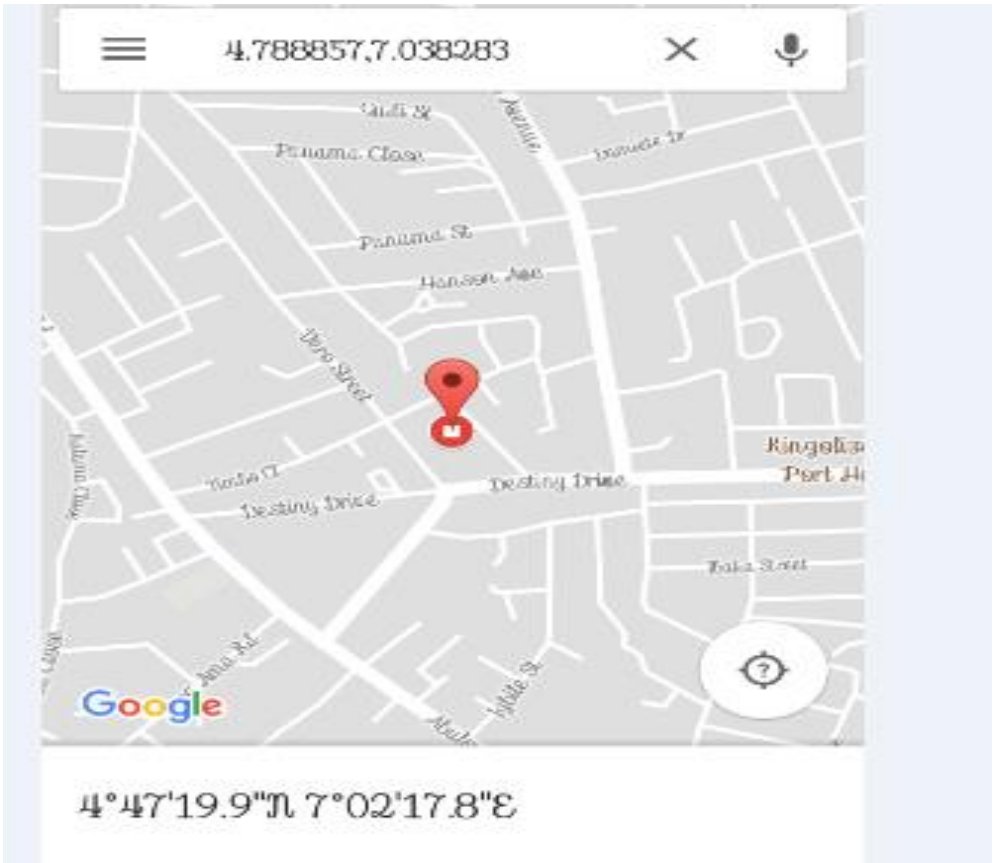


Location 10 (4.8277864, 7.026582)

Location *11* (**4.788857, 7.038283**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB1 to eNB 2)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.8277864	0.0842604	7.026582	0.1226365	3.97211	6.2
eNB 1	4.8366	0.08441	7.0286	0.12267	4.827786	0.08426	7.026582	0.122636	1.005203	1.6
eNB 2	4.7737	0.08332	7.0142	0.12242	4.827786	0.08426	7.026582	0.122636	6.16862	10.2
eNB 3	4.7999	0.08377	6.9939	0.12207	4.827786	0.08426	7.026582	0.122636	4.767435	6.1
eNB 4	4.8294	0.08429	7.0919	0.12378	4.827786	0.08426	7.026582	0.122636	7.239448	10
eNB 5	4.7706	0.08326	7.0224	0.12256	4.827786	0.08426	7.026582	0.122636	6.375677	8.1
eNB 6	4.8746	0.08508	6.983	0.12188	4.827786	0.08426	7.026582	0.122636	7.100198	10.1
eNB 7	4.8692	0.08498	7.1137	0.12416	4.827786	0.08426	7.026582	0.122636	10.69458	13.7
eNB 8	4.7196	0.08237	7.1518	0.12482	4.827786	0.08426	7.026582	0.122636	18.36402	23.6
eNB 9	4.8554	0.08474	7.0641	0.12329	4.827786	0.08426	7.026582	0.122636	5.167951	6
eNB 10	4.7909	0.08362	7.1207	0.12428	4.827786	0.08426	7.026582	0.122636	11.20614	14.3
eNB 11	4.7854	0.08352	7.0082	0.12232	4.827786	0.08426	7.026582	0.122636	5.13441	6.4
eNB 12	4.8327	0.08435	7.0685	0.12337	4.827786	0.08426	7.026582	0.122636	4.676523	7.2
eNB 13	4.8039	0.08384	6.9883	0.12197	4.827786	0.08426	7.026582	0.122636	5.00467	6.9
eNB 14	4.8197	0.08412	7.0656	0.12332	4.827786	0.08426	7.026582	0.122636	4.415736	6.7
eNB 15	4.743	0.08278	7.0417	0.1229	4.827786	0.08426	7.026582	0.122636	9.575454	12.6
eNB 16	4.7939	0.08367	7.0308	0.12271	4.827786	0.08426	7.026582	0.122636	3.796858	5.5
eNB 17	4.748	0.08287	7.0989	0.1239	4.827786	0.08426	7.026582	0.122636	11.955	18.9
eNB 18	4.7773	0.08338	7.062	0.12325	4.827786	0.08426	7.026582	0.122636	6.849545	8.2
eNB 19	4.8341	0.08437	6.9845	0.1219	4.827786	0.08426	7.026582	0.122636	4.715218	6
eNB 20	4.8565	0.08476	7.0405	0.12288	4.827786	0.08426	7.026582	0.122636	3.545691	4.9
eNB 21	4.8064	0.08389	7.0424	0.12291	4.827786	0.08426	7.026582	0.122636	2.954143	4.3
eNB 22	4.8146	0.08403	6.9788	0.1218	4.827786	0.08426	7.026582	0.122636	5.493586	7.6
eNB 23	4.8298	0.0843	6.9588	0.12145	4.827786	0.08426	7.026582	0.122636	7.51357	9.3
eNB 24	4.8923	0.08539	6.9143	0.12068	4.827786	0.08426	7.026582	0.122636	14.36035	16.5
eNB 25	4.848	0.08461	7.0492	0.12303	4.827786	0.08426	7.026582	0.122636	3.366318	4
eNB 26	4.8514	0.08467	6.9835	0.12188	4.827786	0.08426	7.026582	0.122636	5.447904	7.7
eNB 27	4.8081	0.08392	6.9967	0.12211	4.827786	0.08426	7.026582	0.122636	3.969176	5.3
eNB 28	4.9028	0.08557	6.999	0.12216	4.827786	0.08426	7.026582	0.122636	8.88327	11.5
eNB 29	4.9789	0.0869	6.9611	0.12149	4.827786	0.08426	7.026582	0.122636	18.30218	23.7
eNB 30	4.9969	0.08721	6.95	0.1213	4.827786	0.08426	7.026582	0.122636	20.62986	24.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.827786	0.08426	7.026582	0.122636	14.12764	17.3
eNB 32	4.9669	0.08669	6.9869	0.12194	4.827786	0.08426	7.026582	0.122636	16.08126	20.7
eNB 33	4.8289	0.08428	7.0219	0.12255	4.827786	0.08426	7.026582	0.122636	0.533338	1
eNB 34	4.8169	0.08407	7.0112	0.12237	4.827786	0.08426	7.026582	0.122636	2.09048	3.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.827786	0.08426	7.026582	0.122636	11.86871	14.5
eNB 36	4.8407	0.08449	6.9681	0.12162	4.827786	0.08426	7.026582	0.122636	6.636936	8.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.827786	0.08426	7.026582	0.122636	6.342878	8.6
eNB 38	4.8469	0.08459	7.0369	0.12282	4.827786	0.08426	7.026582	0.122636	2.413286	3.3
eNB 39	4.8585	0.0848	6.9658	0.12158	4.827786	0.08426	7.026582	0.122636	7.550949	9.1
eNB 40	4.88	0.08517	7.01	0.12235	4.827786	0.08426	7.026582	0.122636	6.089612	8.1

eNB 41	4.8669	0.08494	7.03	0.1227	4.827786	0.08426	7.026582	0.122636	4.36567	7.1
eNB 42	4.8378	0.08444	7.037	0.12282	4.827786	0.08426	7.026582	0.122636	1.603808	2.1
eNB 43	4.8842	0.08525	7.138	0.12458	4.827786	0.08426	7.026582	0.122636	13.84695	17.7
eNB 44	4.7815	0.08345	7.0398	0.12287	4.827786	0.08426	7.026582	0.122636	5.351128	6.3
eNB 45	4.8116	0.08398	6.9561	0.12141	4.827786	0.08426	7.026582	0.122636	8.014217	10.6
eNB 46	4.9011	0.08554	6.9269	0.1209	4.827786	0.08426	7.026582	0.122636	13.72697	17
eNB 47	4.9058	0.08562	6.9066	0.12054	4.827786	0.08426	7.026582	0.122636	15.87325	18.4
eNB 48	4.8024	0.08382	6.944	0.1212	4.827786	0.08426	7.026582	0.122636	9.575779	12.4
eNB 49	4.8354	0.08439	7.0528	0.12309	4.827786	0.08426	7.026582	0.122636	3.025785	4.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.827786	0.08426	7.026582	0.122636	4.482936	5.9
eNB 51	4.7581	0.08304	7.0119	0.12238	4.827786	0.08426	7.026582	0.122636	7.917683	10
eNB 52	4.8269	0.08424	6.9961	0.1221	4.827786	0.08426	7.026582	0.122636	3.378845	4.7
eNB 53	4.815	0.08404	7.0419	0.1229	4.827786	0.08426	7.026582	0.122636	2.214073	3.3
eNB 54	4.71	0.0822	7.165	0.12505	4.827786	0.08426	7.026582	0.122636	20.16908	25.3
eNB 55	4.8233	0.08418	7.0572	0.12317	4.827786	0.08426	7.026582	0.122636	3.428968	5.8
eNB 56	4.815	0.08404	7.0652	0.12331	4.827786	0.08426	7.026582	0.122636	4.508943	6.7
eNB 57	4.894	0.08542	7.0153	0.12244	4.827786	0.08426	7.026582	0.122636	7.467938	10
eNB 58	4.8626	0.08487	7.0153	0.12244	4.827786	0.08426	7.026582	0.122636	4.067895	6.3
eNB 59	4.8276	0.08426	7.0145	0.12243	4.827786	0.08426	7.026582	0.122636	1.338846	2.2
									440.7447	577.7

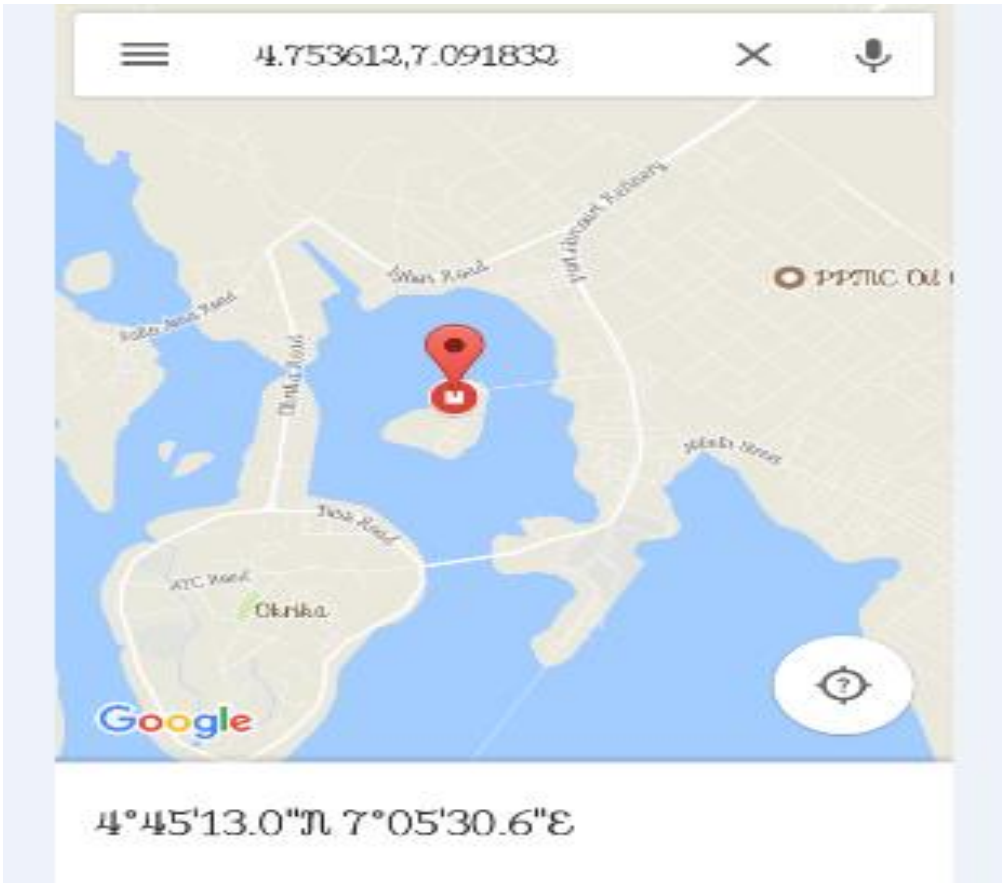


Location 11 (4.788857, 7.038283)

*Location 12 (***4.753612, 7.091832***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB16 to eNB 17)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.788857	0.083581	7.038283	0.12284	5.085266	7
eNB 1	4.8366	0.08441	7.0286	0.122672	4.788857	0.083581	7.038283	0.12284	5.416067	6.4
eNB 2	4.7737	0.08332	7.0142	0.12242	4.788857	0.083581	7.038283	0.12284	3.156209	6.8
eNB 3	4.7999	0.08377	6.9939	0.122066	4.788857	0.083581	7.038283	0.12284	5.068818	6.4
eNB 4	4.8294	0.08429	7.0919	0.123777	4.788857	0.083581	7.038283	0.12284	7.457773	10.2
eNB 5	4.7706	0.08326	7.0224	0.122564	4.788857	0.083581	7.038283	0.12284	2.686747	6.2
eNB 6	4.8746	0.08508	6.983	0.121876	4.788857	0.083581	7.038283	0.12284	11.3322	14.6
eNB 7	4.8692	0.08498	7.1137	0.124157	4.788857	0.083581	7.038283	0.12284	12.23263	15.1
eNB 8	4.7196	0.08237	7.1518	0.124822	4.788857	0.083581	7.038283	0.12284	14.74919	23.7
eNB 9	4.8554	0.08474	7.0641	0.123291	4.788857	0.083581	7.038283	0.12284	7.932911	10.2
eNB 10	4.7909	0.08362	7.1207	0.124279	4.788857	0.083581	7.038283	0.12284	9.135171	14.4
eNB 11	4.7854	0.08352	7.0082	0.122316	4.788857	0.083581	7.038283	0.12284	3.355452	4.9
eNB 12	4.8327	0.08435	7.0685	0.123368	4.788857	0.083581	7.038283	0.12284	5.914105	7.3
eNB 13	4.8039	0.08384	6.9883	0.121968	4.788857	0.083581	7.038283	0.12284	5.785415	7.4
eNB 14	4.8197	0.08412	7.0656	0.123317	4.788857	0.083581	7.038283	0.12284	4.574249	6.2
eNB 15	4.743	0.08278	7.0417	0.1229	4.788857	0.083581	7.038283	0.12284	5.113102	10.7
eNB 16	4.7939	0.08367	7.0308	0.12271	4.788857	0.083581	7.038283	0.12284	1.000937	1.3
eNB 17	4.748	0.08287	7.0989	0.123899	4.788857	0.083581	7.038283	0.12284	8.1091	19
eNB 18	4.7773	0.08338	7.062	0.123255	4.788857	0.083581	7.038283	0.12284	2.925425	3.6
eNB 19	4.8341	0.08437	6.9845	0.121902	4.788857	0.083581	7.038283	0.12284	7.798802	10.4
eNB 20	4.8565	0.08476	7.0405	0.122879	4.788857	0.083581	7.038283	0.12284	7.525524	9.3
eNB 21	4.8064	0.08389	7.0424	0.122913	4.788857	0.083581	7.038283	0.12284	2.003309	2.7
eNB 22	4.8146	0.08403	6.9788	0.121803	4.788857	0.083581	7.038283	0.12284	7.185686	9.1
eNB 23	4.8298	0.0843	6.9588	0.121453	4.788857	0.083581	7.038283	0.12284	9.914038	12.9
eNB 24	4.8923	0.08539	6.9143	0.120677	4.788857	0.083581	7.038283	0.12284	17.9167	21
eNB 25	4.848	0.08461	7.0492	0.123031	4.788857	0.083581	7.038283	0.12284	6.686686	8.3
eNB 26	4.8514	0.08467	6.9835	0.121885	4.788857	0.083581	7.038283	0.12284	9.230857	12.2
eNB 27	4.8081	0.08392	6.9967	0.122115	4.788857	0.083581	7.038283	0.12284	5.080149	7
eNB 28	4.9028	0.08557	6.999	0.122155	4.788857	0.083581	7.038283	0.12284	13.39655	16.2
eNB 29	4.9789	0.0869	6.9611	0.121494	4.788857	0.083581	7.038283	0.12284	22.7963	28.4
eNB 30	4.9969	0.08721	6.95	0.1213	4.788857	0.083581	7.038283	0.12284	25.11592	29.1
eNB 31	4.9539	0.08646	7.0111	0.122366	4.788857	0.083581	7.038283	0.12284	18.59733	22
eNB 32	4.9669	0.08669	6.9869	0.121944	4.788857	0.083581	7.038283	0.12284	20.59961	25.4
eNB 33	4.8289	0.08428	7.0219	0.122555	4.788857	0.083581	7.038283	0.12284	4.808357	5.5
eNB 34	4.8169	0.08407	7.0112	0.122368	4.788857	0.083581	7.038283	0.12284	4.327639	5.6
eNB 35	4.9317	0.08607	7.0021	0.122209	4.788857	0.083581	7.038283	0.12284	16.38143	19.2
eNB 36	4.8407	0.08449	6.9681	0.121616	4.788857	0.083581	7.038283	0.12284	9.680046	12.7
eNB 37	4.8598	0.08482	6.9792	0.12181	4.788857	0.083581	7.038283	0.12284	10.251	13.1
eNB 38	4.8469	0.08459	7.0369	0.122817	4.788857	0.083581	7.038283	0.12284	6.455864	7.7
eNB 39	4.8585	0.0848	6.9658	0.121576	4.788857	0.083581	7.038283	0.12284	11.15648	13.5
eNB 40	4.88	0.08517	7.01	0.122347	4.788857	0.083581	7.038283	0.12284	10.60801	12.8

eNB 41	4.8669	0.08494	7.03	0.122696	4.788857	0.083581	7.038283	0.12284	8.726326	11.7
eNB 42	4.8378	0.08444	7.037	0.122818	4.788857	0.083581	7.038283	0.12284	5.444032	6.4
eNB 43	4.8842	0.08525	7.138	0.124581	4.788857	0.083581	7.038283	0.12284	15.31222	19.1
eNB 44	4.7815	0.08345	7.0398	0.122867	4.788857	0.083581	7.038283	0.12284	0.835171	1.1
eNB 45	4.8116	0.08398	6.9561	0.121406	4.788857	0.083581	7.038283	0.12284	9.450834	12.8
eNB 46	4.9011	0.08554	6.9269	0.120897	4.788857	0.083581	7.038283	0.12284	17.55185	21.4
eNB 47	4.9058	0.08562	6.9066	0.120542	4.788857	0.083581	7.038283	0.12284	19.54372	22.9
eNB 48	4.8024	0.08382	6.944	0.121195	4.788857	0.083581	7.038283	0.12284	10.55499	14.7
eNB 49	4.8354	0.08439	7.0528	0.123094	4.788857	0.083581	7.038283	0.12284	5.419528	7.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.788857	0.083581	7.038283	0.12284	1.42218	2
eNB 51	4.7581	0.08304	7.0119	0.12238	4.788857	0.083581	7.038283	0.12284	4.499225	8.6
eNB 52	4.8269	0.08424	6.9961	0.122104	4.788857	0.083581	7.038283	0.12284	6.303989	8.2
eNB 53	4.815	0.08404	7.0419	0.122904	4.788857	0.083581	7.038283	0.12284	2.934444	3.9
eNB 54	4.71	0.0822	7.165	0.125052	4.788857	0.083581	7.038283	0.12284	16.55478	25.5
eNB 55	4.8233	0.08418	7.0572	0.123171	4.788857	0.083581	7.038283	0.12284	4.365943	5.7
eNB 56	4.815	0.08404	7.0652	0.123311	4.788857	0.083581	7.038283	0.12284	4.164845	5.2
eNB 57	4.894	0.08542	7.0153	0.12244	4.788857	0.083581	7.038283	0.12284	11.96541	14.8
eNB 58	4.8626	0.08487	7.0153	0.12244	4.788857	0.083581	7.038283	0.12284	8.586111	11
eNB 59	4.8276	0.08426	7.0145	0.122426	4.788857	0.083581	7.038283	0.12284	5.050055	6.2
									527.2327	694.1

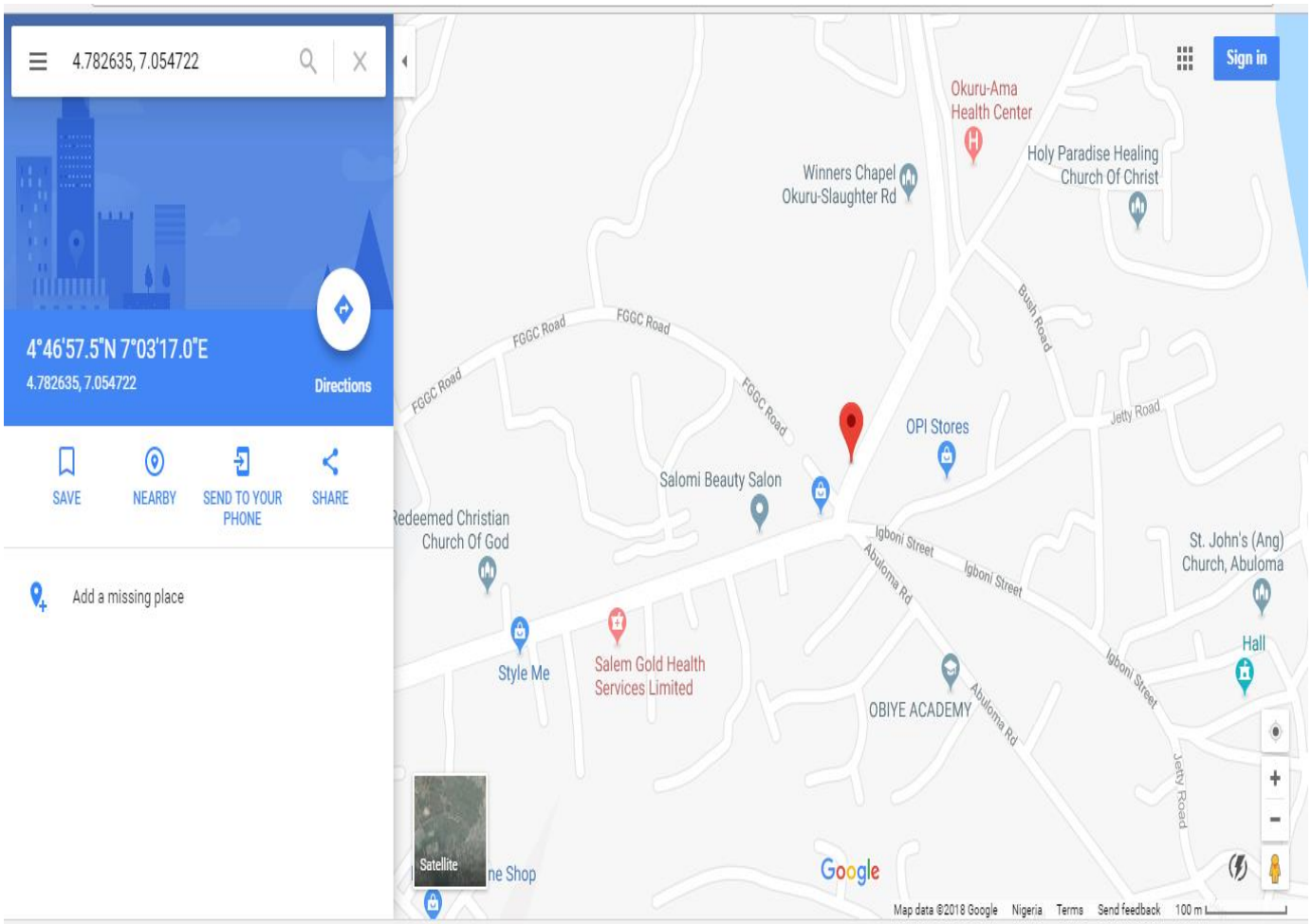


Location 12 (4.753612, 7.091832)

Location *13 (***4.782635, 7.054722***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB17 to eNB 18)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.753612	0.082966	7.091832	0.12378	12.163547	22.7
eNB 1	4.8366	0.08441	7.0286	0.122672	4.753612	0.082966	7.091832	0.12378	11.586287	18.5
eNB 2	4.7737	0.08332	7.0142	0.12242	4.753612	0.082966	7.091832	0.12378	8.8877023	23.6
eNB 3	4.7999	0.08377	6.9939	0.122066	4.753612	0.082966	7.091832	0.12378	12.010416	23
eNB 4	4.8294	0.08429	7.0919	0.123777	4.753612	0.082966	7.091832	0.12378	8.4271641	10.3
eNB 5	4.7706	0.08326	7.0224	0.122564	4.753612	0.082966	7.091832	0.12378	7.9223071	23
eNB 6	4.8746	0.08508	6.983	0.121876	4.753612	0.082966	7.091832	0.12378	18.066626	24.8
eNB 7	4.8692	0.08498	7.1137	0.124157	4.753612	0.082966	7.091832	0.12378	13.079102	16.2
eNB 8	4.7196	0.08237	7.1518	0.124822	4.753612	0.082966	7.091832	0.12378	7.6461583	10.9
eNB 9	4.8554	0.08474	7.0641	0.123291	4.753612	0.082966	7.091832	0.12378	11.727929	15.3
eNB 10	4.7909	0.08362	7.1207	0.124279	4.753612	0.082966	7.091832	0.12378	5.2367139	6.1
eNB 11	4.7854	0.08352	7.0082	0.122316	4.753612	0.082966	7.091832	0.12378	9.9184197	21.7
eNB 12	4.8327	0.08435	7.0685	0.123368	4.753612	0.082966	7.091832	0.12378	9.1662532	12.4
eNB 13	4.8039	0.08384	6.9883	0.121968	4.753612	0.082966	7.091832	0.12378	12.762374	24
eNB 14	4.8197	0.08412	7.0656	0.123317	4.753612	0.082966	7.091832	0.12378	7.9025593	14
eNB 15	4.743	0.08278	7.0417	0.1229	4.753612	0.082966	7.091832	0.12378	5.6792371	27.5
eNB 16	4.7939	0.08367	7.0308	0.12271	4.753612	0.082966	7.091832	0.12378	8.1120293	19.1
eNB 17	4.748	0.08287	7.0989	0.123899	4.753612	0.082966	7.091832	0.12378	1.0014345	1.6
eNB 18	4.7773	0.08338	7.062	0.123255	4.753612	0.082966	7.091832	0.12378	4.2267325	20.1
eNB 19	4.8341	0.08437	6.9845	0.121902	4.753612	0.082966	7.091832	0.12378	14.88428	23.6
eNB 20	4.8565	0.08476	7.0405	0.122879	4.753612	0.082966	7.091832	0.12378	12.776413	17.5
eNB 21	4.8064	0.08389	7.0424	0.122913	4.753612	0.082966	7.091832	0.12378	8.0284419	16.7
eNB 22	4.8146	0.08403	6.9788	0.121803	4.753612	0.082966	7.091832	0.12378	14.242831	25.3
eNB 23	4.8298	0.0843	6.9588	0.121453	4.753612	0.082966	7.091832	0.12378	17.00171	26.9
eNB 24	4.8923	0.08539	6.9143	0.120677	4.753612	0.082966	7.091832	0.12378	24.995051	32.3
eNB 25	4.848	0.08461	7.0492	0.123031	4.753612	0.082966	7.091832	0.12378	11.509454	15.9
eNB 26	4.8514	0.08467	6.9835	0.121885	4.753612	0.082966	7.091832	0.12378	16.196272	26.5
eNB 27	4.8081	0.08392	6.9967	0.122115	4.753612	0.082966	7.091832	0.12378	12.158475	22.7
eNB 28	4.9028	0.08557	6.999	0.122155	4.753612	0.082966	7.091832	0.12378	19.518888	24.2
eNB 29	4.9789	0.0869	6.9611	0.121494	4.753612	0.082966	7.091832	0.12378	28.936723	34.4
eNB 30	4.9969	0.08721	6.95	0.1213	4.753612	0.082966	7.091832	0.12378	31.284975	36.9
eNB 31	4.9539	0.08646	7.0111	0.122366	4.753612	0.082966	7.091832	0.12378	24.000017	28.4
eNB 32	4.9669	0.08669	6.9869	0.121944	4.753612	0.082966	7.091832	0.12378	26.41268	31.2
eNB 33	4.8289	0.08428	7.0219	0.122555	4.753612	0.082966	7.091832	0.12378	11.407388	19.1
eNB 34	4.8169	0.08407	7.0112	0.122368	4.753612	0.082966	7.091832	0.12378	11.3732	20.7
eNB 35	4.9317	0.08607	7.0021	0.122209	4.753612	0.082966	7.091832	0.12378	22.158038	26.6
eNB 36	4.8407	0.08449	6.9681	0.121616	4.753612	0.082966	7.091832	0.12378	16.785146	25.9
eNB 37	4.8598	0.08482	6.9792	0.12181	4.753612	0.082966	7.091832	0.12378	17.180439	26.4
eNB 38	4.8469	0.08459	7.0369	0.122817	4.753612	0.082966	7.091832	0.12378	12.027	17.1
eNB 39	4.8585	0.0848	6.9658	0.121576	4.753612	0.082966	7.091832	0.12378	18.194492	26.7
eNB 40	4.88	0.08517	7.01	0.122347	4.753612	0.082966	7.091832	0.12378	16.724738	22.4

eNB 41	4.8669	0.08494	7.03	0.122696	4.753612	0.082966	7.091832	0.12378	14.339522	19
eNB 42	4.8378	0.08444	7.037	0.122818	4.753612	0.082966	7.091832	0.12378	11.160016	16.7
eNB 43	4.8842	0.08525	7.138	0.124581	4.753612	0.082966	7.091832	0.12378	15.395333	17.1
eNB 44	4.7815	0.08345	7.0398	0.122867	4.753612	0.082966	7.091832	0.12378	6.546666	19.8
eNB 45	4.8116	0.08398	6.9561	0.121406	4.753612	0.082966	7.091832	0.12378	16.364002	28.2
eNB 46	4.9011	0.08554	6.9269	0.120897	4.753612	0.082966	7.091832	0.12378	24.554236	32.8
eNB 47	4.9058	0.08562	6.9066	0.120542	4.753612	0.082966	7.091832	0.12378	26.60054	34.2
eNB 48	4.8024	0.08382	6.944	0.121195	4.753612	0.082966	7.091832	0.12378	17.255918	30.1
eNB 49	4.8354	0.08439	7.0528	0.123094	4.753612	0.082966	7.091832	0.12378	10.070362	14.7
eNB 50	4.7947	0.08368	7.0497	0.12304	4.753612	0.082966	7.091832	0.12378	6.5321556	17.9
eNB 51	4.7581	0.08304	7.0119	0.12238	4.753612	0.082966	7.091832	0.12378	8.8714596	25.4
eNB 52	4.8269	0.08424	6.9961	0.122104	4.753612	0.082966	7.091832	0.12378	13.376565	22.4
eNB 53	4.815	0.08404	7.0419	0.122904	4.753612	0.082966	7.091832	0.12378	8.786695	15.9
eNB 54	4.71	0.0822	7.165	0.125052	4.753612	0.082966	7.091832	0.12378	9.4476998	12.6
eNB 55	4.8233	0.08418	7.0572	0.123171	4.753612	0.082966	7.091832	0.12378	8.6470337	13.7
eNB 56	4.815	0.08404	7.0652	0.123311	4.753612	0.082966	7.091832	0.12378	7.4365532	15.2
eNB 57	4.894	0.08542	7.0153	0.12244	4.753612	0.082966	7.091832	0.12378	17.764836	22.2
eNB 58	4.8626	0.08487	7.0153	0.12244	4.753612	0.082966	7.091832	0.12378	14.791087	20.6
eNB 59	4.8276	0.08426	7.0145	0.122426	4.753612	0.082966	7.091832	0.12378	11.878941	20.1
									813.13927	1280.8



Location 13 (4.782635, 7.054722)

Location 14 **(4.83745, 6.992874)**

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB18 to eNB 19)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.122114	4.782635	0.08347	7.054722	0.123128	7.0301508	9.1
eNB 1	4.8366	0.084414	7.0286	0.122672	4.782635	0.08347	7.054722	0.123128	6.6621653	7.8
eNB 2	4.7737	0.083316	7.0142	0.12242	4.782635	0.08347	7.054722	0.123128	4.5987272	8.9
eNB 3	4.7999	0.083774	6.9939	0.122066	4.782635	0.08347	7.054722	0.123128	7.0074904	8.5
eNB 4	4.8294	0.084289	7.0919	0.123777	4.782635	0.08347	7.054722	0.123128	6.6340207	10.4
eNB 5	4.7706	0.083262	7.0224	0.122564	4.782635	0.08347	7.054722	0.123128	3.8233545	8.3
eNB 6	4.8746	0.085077	6.983	0.121876	4.782635	0.08347	7.054722	0.123128	12.950736	16
eNB 7	4.8692	0.084983	7.1137	0.124157	4.782635	0.08347	7.054722	0.123128	11.634212	15.3
eNB 8	4.7196	0.082372	7.1518	0.124822	4.782635	0.08347	7.054722	0.123128	12.839464	23.9
eNB 9	4.8554	0.084742	7.0641	0.123291	4.782635	0.08347	7.054722	0.123128	8.15751	10.4
eNB 10	4.7909	0.083617	7.1207	0.124279	4.782635	0.08347	7.054722	0.123128	7.3683803	14.6
eNB 11	4.7854	0.083521	7.0082	0.122316	4.782635	0.08347	7.054722	0.123128	5.1640844	7
eNB 12	4.8327	0.084346	7.0685	0.123368	4.782635	0.08347	7.054722	0.123128	5.7724865	7.5
eNB 13	4.8039	0.083844	6.9883	0.121968	4.782635	0.08347	7.054722	0.123128	7.7303925	9.5
eNB 14	4.8197	0.084119	7.0656	0.123317	4.782635	0.08347	7.054722	0.123128	4.2940605	5.8
eNB 15	4.743	0.082781	7.0417	0.1229	4.782635	0.08347	7.054722	0.123128	4.6374031	12.8
eNB 16	4.7939	0.083669	7.0308	0.12271	4.782635	0.08347	7.054722	0.123128	2.9317283	3.3
eNB 17	4.748	0.082868	7.0989	0.123899	4.782635	0.08347	7.054722	0.123128	6.2287284	19.2
eNB 18	4.7773	0.083379	7.062	0.123255	4.782635	0.08347	7.054722	0.123128	1.0011857	1.1
eNB 19	4.8341	0.084371	6.9845	0.121902	4.782635	0.08347	7.054722	0.123128	9.6586101	12.5
eNB 20	4.8565	0.084762	7.0405	0.122879	4.782635	0.08347	7.054722	0.123128	8.363162	9.9
eNB 21	4.8064	0.083887	7.0424	0.122913	4.782635	0.08347	7.054722	0.123128	2.974388	3.5
eNB 22	4.8146	0.08403	6.9788	0.121803	4.782635	0.08347	7.054722	0.123128	9.1325187	11.2
eNB 23	4.8298	0.084296	6.9588	0.121453	4.782635	0.08347	7.054722	0.123128	11.851939	14.9
eNB 24	4.8923	0.085386	6.9143	0.120677	4.782635	0.08347	7.054722	0.123128	19.767735	23.1
eNB 25	4.848	0.084613	7.0492	0.123031	4.782635	0.08347	7.054722	0.123128	7.2939192	8.7
eNB 26	4.8514	0.084673	6.9835	0.121885	4.782635	0.08347	7.054722	0.123128	10.988219	14.3
eNB 27	4.8081	0.083917	6.9967	0.122115	4.782635	0.08347	7.054722	0.123128	7.0250286	9.1
eNB 28	4.9028	0.08557	6.999	0.122155	4.782635	0.08347	7.054722	0.123128	14.719045	17
eNB 29	4.9789	0.086898	6.9611	0.121494	4.782635	0.08347	7.054722	0.123128	24.163114	29.3
eNB 30	4.9969	0.087212	6.95	0.1213	4.782635	0.08347	7.054722	0.123128	26.499855	29.9
eNB 31	4.9539	0.086462	7.0111	0.122366	4.782635	0.08347	7.054722	0.123128	19.647408	22.8
eNB 32	4.9669	0.086688	6.9869	0.121944	4.782635	0.08347	7.054722	0.123128	21.823627	26.2
eNB 33	4.8289	0.08428	7.0219	0.122555	4.782635	0.08347	7.054722	0.123128	6.300065	7.6
eNB 34	4.8169	0.08407	7.0112	0.122368	4.782635	0.08347	7.054722	0.123128	6.1458991	7.6
eNB 35	4.9317	0.086074	7.0021	0.122209	4.782635	0.08347	7.054722	0.123128	17.570671	20.1
eNB 36	4.8407	0.084486	6.9681	0.121616	4.782635	0.08347	7.054722	0.123128	11.567455	14.7
eNB 37	4.8598	0.084819	6.9792	0.12181	4.782635	0.08347	7.054722	0.123128	11.985117	15.2
eNB 38	4.8469	0.084594	7.0369	0.122817	4.782635	0.08347	7.054722	0.123128	7.4137193	8.3
eNB 39	4.8585	0.084796	6.9658	0.121576	4.782635	0.08347	7.054722	0.123128	12.970584	15.6
eNB 40	4.88	0.085172	7.01	0.122347	4.782635	0.08347	7.054722	0.123128	11.906513	13.6

eNB 41	4.8669	0.084943	7.03	0.122696	4.782635	0.08347	7.054722	0.123128	9.7619675	12.3
eNB 42	4.8378	0.084435	7.037	0.122818	4.782635	0.08347	7.054722	0.123128	6.4406588	7
eNB 43	4.8842	0.085245	7.138	0.124581	4.782635	0.08347	7.054722	0.123128	14.583646	19.3
eNB 44	4.7815	0.083453	7.0398	0.122867	4.782635	0.08347	7.054722	0.123128	1.6582355	1.8
eNB 45	4.8116	0.083978	6.9561	0.121406	4.782635	0.08347	7.054722	0.123128	11.392506	14.9
eNB 46	4.9011	0.08554	6.9269	0.120897	4.782635	0.08347	7.054722	0.123128	19.341412	23.5
eNB 47	4.9058	0.085622	6.9066	0.120542	4.782635	0.08347	7.054722	0.123128	21.375135	25
eNB 48	4.8024	0.083817	6.944	0.121195	4.782635	0.08347	7.054722	0.123128	12.463881	16.8
eNB 49	4.8354	0.084393	7.0528	0.123094	4.782635	0.08347	7.054722	0.123128	5.8710269	7.6
eNB 50	4.7947	0.083683	7.0497	0.12304	4.782635	0.08347	7.054722	0.123128	1.4523653	2
eNB 51	4.7581	0.083044	7.0119	0.12238	4.782635	0.08347	7.054722	0.123128	5.473412	10.6
eNB 52	4.8269	0.084245	6.9961	0.122104	4.782635	0.08347	7.054722	0.123128	8.1497011	10.2
eNB 53	4.815	0.084037	7.0419	0.122904	4.782635	0.08347	7.054722	0.123128	3.8690717	4.1
eNB 54	4.71	0.082205	7.165	0.125052	4.782635	0.08347	7.054722	0.123128	14.648123	25.6
eNB 55	4.8233	0.084182	7.0572	0.123171	4.782635	0.08347	7.054722	0.123128	4.5300429	5.9
eNB 56	4.815	0.084037	7.0652	0.123311	4.782635	0.08347	7.054722	0.123128	3.7814535	4.8
eNB 57	4.894	0.085416	7.0153	0.12244	4.782635	0.08347	7.054722	0.123128	13.130908	15.6
eNB 58	4.8626	0.084868	7.0153	0.12244	4.782635	0.08347	7.054722	0.123128	9.9065876	11.9
eNB 59	4.8276	0.084257	7.0145	0.122426	4.782635	0.08347	7.054722	0.123128	6.697811	8.3
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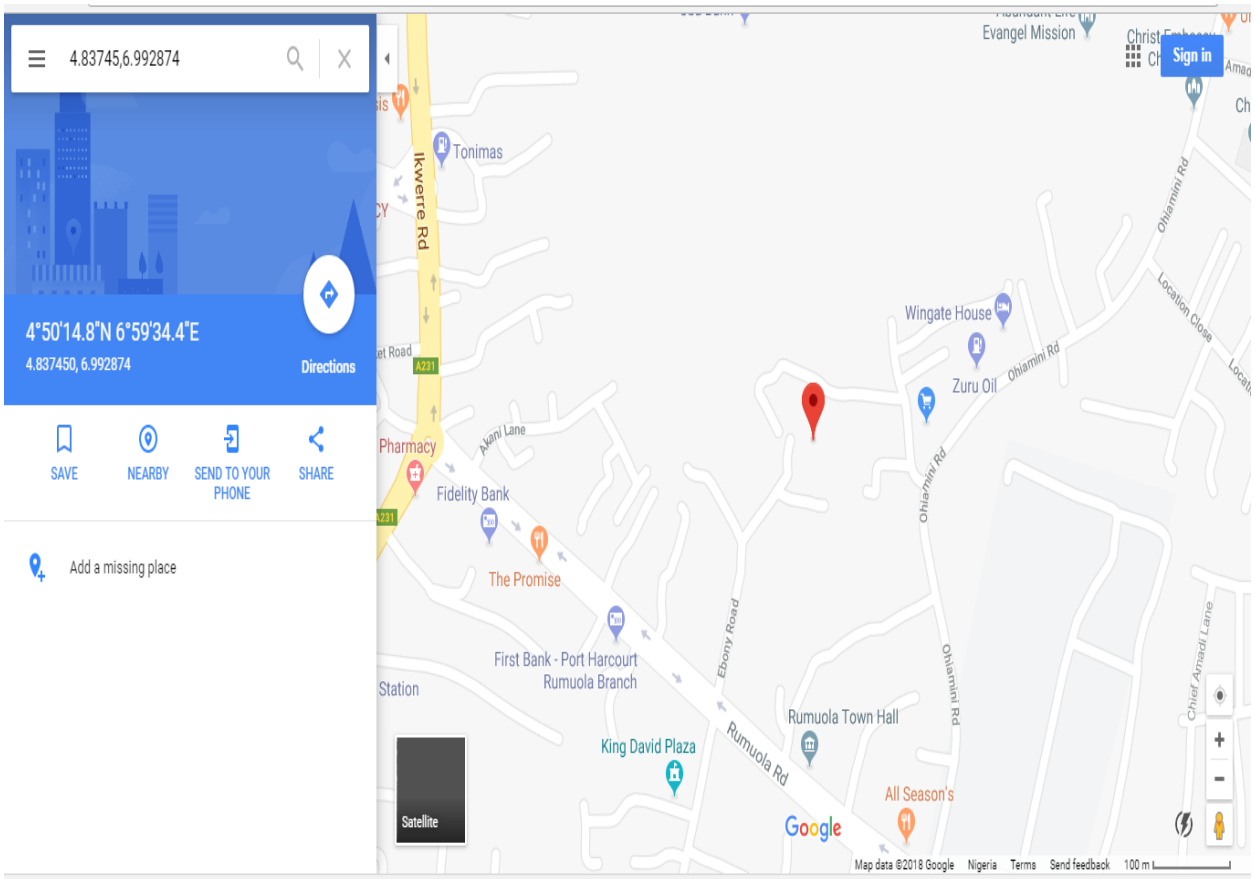
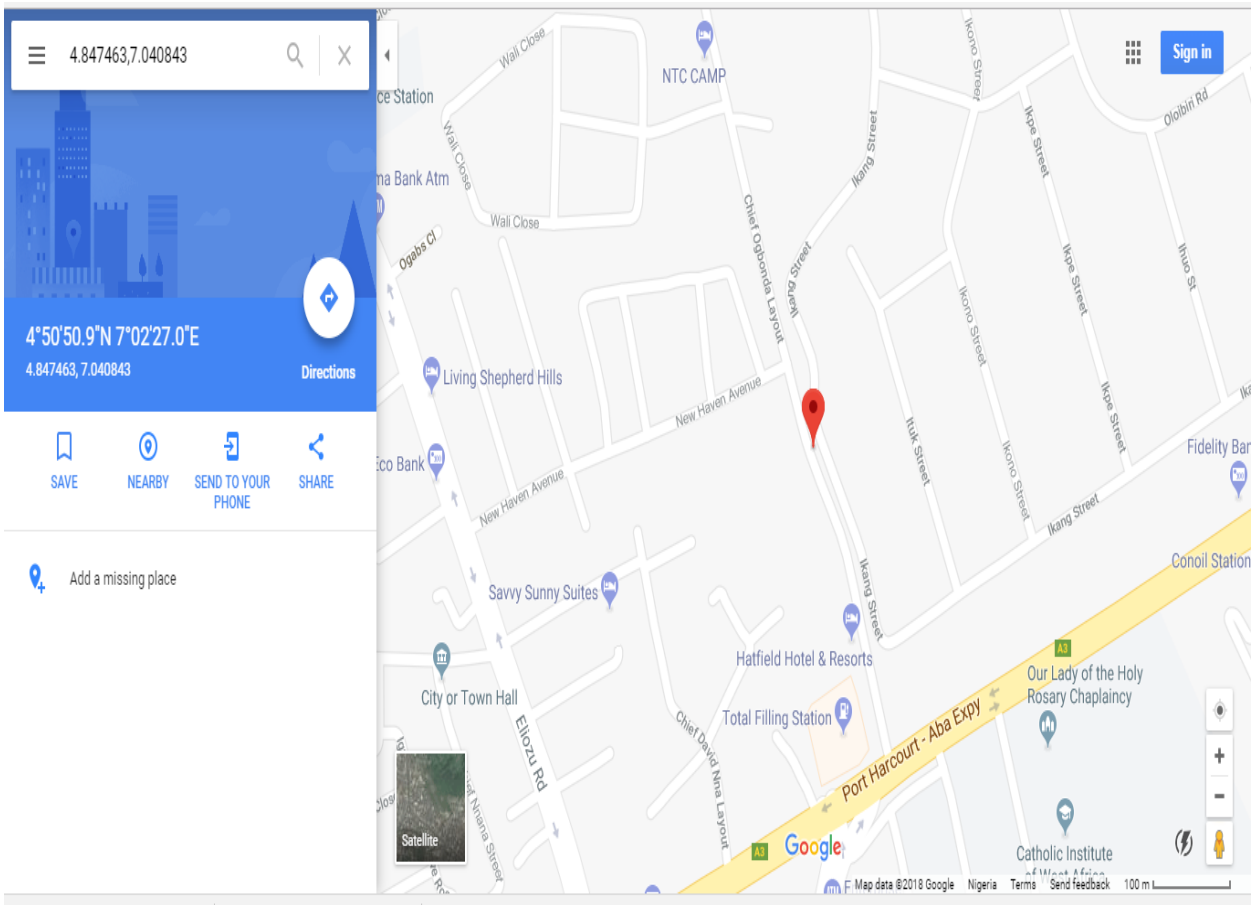


Location 14 (4.83745, 6.992874)

Location *15 (***4.847463, 7.040843***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB19 to eNB 20)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.83745	0.084429	6.992874	0.12205	3.2884831	4.2
eNB 1	4.8366	0.08441	7.0286	0.122672	4.83745	0.084429	6.992874	0.12205	3.9595502	5.3
eNB 2	4.7737	0.08332	7.0142	0.12242	4.83745	0.084429	6.992874	0.12205	7.4721272	9.7
eNB 3	4.7999	0.08377	6.9939	0.122066	4.83745	0.084429	6.992874	0.12205	4.1768888	5.3
eNB 4	4.8294	0.08429	7.0919	0.123777	4.83745	0.084429	6.992874	0.12205	11.008475	13.9
eNB 5	4.7706	0.08326	7.0224	0.122564	4.83745	0.084429	6.992874	0.12205	8.1214586	10
eNB 6	4.8746	0.08508	6.983	0.121876	4.83745	0.084429	6.992874	0.12205	4.2732857	5.7
eNB 7	4.8692	0.08498	7.1137	0.124157	4.83745	0.084429	6.992874	0.12205	13.844749	17.4
eNB 8	4.7196	0.08237	7.1518	0.124822	4.83745	0.084429	6.992874	0.12205	21.950953	27.6
eNB 9	4.8554	0.08474	7.0641	0.123291	4.83745	0.084429	6.992874	0.12205	8.1401536	9.6
eNB 10	4.7909	0.08362	7.1207	0.124279	4.83745	0.084429	6.992874	0.12205	15.079618	18.3
eNB 11	4.7854	0.08352	7.0082	0.122316	4.83745	0.084429	6.992874	0.12205	6.0316571	7.9
eNB 12	4.8327	0.08435	7.0685	0.123368	4.83745	0.084429	6.992874	0.12205	8.3959344	11.2
eNB 13	4.8039	0.08384	6.9883	0.121968	4.83745	0.084429	6.992874	0.12205	3.7648255	5
eNB 14	4.8197	0.08412	7.0656	0.123317	4.83745	0.084429	6.992874	0.12205	8.2962571	11.4
eNB 15	4.743	0.08278	7.0417	0.1229	4.83745	0.084429	6.992874	0.12205	11.813944	14.4
eNB 16	4.7939	0.08367	7.0308	0.12271	4.83745	0.084429	6.992874	0.12205	6.4116531	8.4
eNB 17	4.748	0.08287	7.0989	0.123899	4.83745	0.084429	6.992874	0.12205	15.393263	22.9
eNB 18	4.7773	0.08338	7.062	0.123255	4.83745	0.084429	6.992874	0.12205	10.16861	12.7
eNB 19	4.8341	0.08437	6.9845	0.121902	4.83745	0.084429	6.992874	0.12205	0.9997731	1.3
eNB 20	4.8565	0.08476	7.0405	0.122879	4.83745	0.084429	6.992874	0.12205	5.6861379	8.4
eNB 21	4.8064	0.08389	7.0424	0.122913	4.83745	0.084429	6.992874	0.12205	6.4833351	8.5
eNB 22	4.8146	0.08403	6.9788	0.121803	4.83745	0.084429	6.992874	0.12205	2.9811401	4.1
eNB 23	4.8298	0.0843	6.9588	0.121453	4.83745	0.084429	6.992874	0.12205	3.8699716	4.6
eNB 24	4.8923	0.08539	6.9143	0.120677	4.83745	0.084429	6.992874	0.12205	10.629375	11.8
eNB 25	4.848	0.08461	7.0492	0.123031	4.83745	0.084429	6.992874	0.12205	6.3501188	7.6
eNB 26	4.8514	0.08467	6.9835	0.121885	4.83745	0.084429	6.992874	0.12205	1.8667586	3.1
eNB 27	4.8081	0.08392	6.9967	0.122115	4.83745	0.084429	6.992874	0.12205	3.2909684	4.2
eNB 28	4.9028	0.08557	6.999	0.122155	4.83745	0.084429	6.992874	0.12205	7.298203	8.7
eNB 29	4.9789	0.0869	6.9611	0.121494	4.83745	0.084429	6.992874	0.12205	16.117566	20.4
eNB 30	4.9969	0.08721	6.95	0.1213	4.83745	0.084429	6.992874	0.12205	18.355168	21
eNB 31	4.9539	0.08646	7.0111	0.122366	4.83745	0.084429	6.992874	0.12205	13.105111	14.6
eNB 32	4.9669	0.08669	6.9869	0.121944	4.83745	0.084429	6.992874	0.12205	14.409344	17.9
eNB 33	4.8289	0.08428	7.0219	0.122555	4.83745	0.084429	6.992874	0.12205	3.3536654	4.7
eNB 34	4.8169	0.08407	7.0112	0.122368	4.83745	0.084429	6.992874	0.12205	3.0568855	4.1
eNB 35	4.9317	0.08607	7.0021	0.122209	4.83745	0.084429	6.992874	0.12205	10.529824	11.8
eNB 36	4.8407	0.08449	6.9681	0.121616	4.83745	0.084429	6.992874	0.12205	2.7685655	3.6
eNB 37	4.8598	0.08482	6.9792	0.12181	4.83745	0.084429	6.992874	0.12205	2.9105801	4
eNB 38	4.8469	0.08459	7.0369	0.122817	4.83745	0.084429	6.992874	0.12205	4.9899085	6.7
eNB 39	4.8585	0.0848	6.9658	0.121576	4.83745	0.084429	6.992874	0.12205	3.8048271	4.4
eNB 40	4.88	0.08517	7.01	0.122347	4.83745	0.084429	6.992874	0.12205	5.0976559	6.8

eNB 41	4.8669	0.08494	7.03	0.122696	4.83745	0.084429	6.992874	0.12205	5.2577606	8.6
eNB 42	4.8378	0.08444	7.037	0.122818	4.83745	0.084429	6.992874	0.12205	4.8892801	6.1
eNB 43	4.8842	0.08525	7.138	0.124581	4.83745	0.084429	6.992874	0.12205	16.898634	21.4
eNB 44	4.7815	0.08345	7.0398	0.122867	4.83745	0.084429	6.992874	0.12205	8.1080453	10.2
eNB 45	4.8116	0.08398	6.9561	0.121406	4.83745	0.084429	6.992874	0.12205	4.9863681	5.9
eNB 46	4.9011	0.08554	6.9269	0.120897	4.83745	0.084429	6.992874	0.12205	10.174448	12.3
eNB 47	4.9058	0.08562	6.9066	0.120542	4.83745	0.084429	6.992874	0.12205	12.211768	13.8
eNB 48	4.8024	0.08382	6.944	0.121195	4.83745	0.084429	6.992874	0.12205	6.671916	7.8
eNB 49	4.8354	0.08439	7.0528	0.123094	4.83745	0.084429	6.992874	0.12205	6.6436625	8.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.83745	0.084429	6.992874	0.12205	7.889342	10.1
eNB 51	4.7581	0.08304	7.0119	0.12238	4.83745	0.084429	6.992874	0.12205	9.071639	11.1
eNB 52	4.8269	0.08424	6.9961	0.122104	4.83745	0.084429	6.992874	0.12205	1.226347	1.7
eNB 53	4.815	0.08404	7.0419	0.122904	4.83745	0.084429	6.992874	0.12205	5.9782567	8.2
eNB 54	4.71	0.0822	7.165	0.125052	4.83745	0.084429	6.992874	0.12205	23.761754	29.3
eNB 55	4.8233	0.08418	7.0572	0.123171	4.83745	0.084429	6.992874	0.12205	7.2989292	10.4
eNB 56	4.815	0.08404	7.0652	0.123311	4.83745	0.084429	6.992874	0.12205	8.3935753	11.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.83745	0.084429	6.992874	0.12205	6.7611698	9.4
eNB 58	4.8626	0.08487	7.0153	0.12244	4.83745	0.084429	6.992874	0.12205	3.7409514	6.4
eNB 59	4.8276	0.08426	7.0145	0.122426	4.83745	0.084429	6.992874	0.12205	2.6346266	3.6
									472.14524	599.3



Location 15 (4.847463, 7.040843)

*Location 16 (***4.848466, 7.040197***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB20 to eNB 21)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.847463	0.084604	7.040843	0.12289	6.565835	8
eNB 1	4.8366	0.08441	7.0286	0.12267	4.847463	0.084604	7.040843	0.12289	1.816356	2.6
eNB 2	4.7737	0.08332	7.0142	0.12242	4.847463	0.084604	7.040843	0.12289	8.717173	11.2
eNB 3	4.7999	0.08377	6.9939	0.12207	4.847463	0.084604	7.040843	0.12289	7.417862	8.9
eNB 4	4.8294	0.08429	7.0919	0.12378	4.847463	0.084604	7.040843	0.12289	6.003055	7.5
eNB 5	4.7706	0.08326	7.0224	0.12256	4.847463	0.084604	7.040843	0.12289	8.787697	11
eNB 6	4.8746	0.08508	6.983	0.12188	4.847463	0.084604	7.040843	0.12289	7.083481	8.3
eNB 7	4.8692	0.08498	7.1137	0.12416	4.847463	0.084604	7.040843	0.12289	8.426306	10.9
eNB 8	4.7196	0.08237	7.1518	0.12482	4.847463	0.084604	7.040843	0.12289	18.79647	21.8
eNB 9	4.8554	0.08474	7.0641	0.12329	4.847463	0.084604	7.040843	0.12289	2.723749	3.2
eNB 10	4.7909	0.08362	7.1207	0.12428	4.847463	0.084604	7.040843	0.12289	10.85591	12.5
eNB 11	4.7854	0.08352	7.0082	0.12232	4.847463	0.084604	7.040843	0.12289	7.791479	9.3
eNB 12	4.8327	0.08435	7.0685	0.12337	4.847463	0.084604	7.040843	0.12289	3.476394	5.1
eNB 13	4.8039	0.08384	6.9883	0.12197	4.847463	0.084604	7.040843	0.12289	7.573456	9.4
eNB 14	4.8197	0.08412	7.0656	0.12332	4.847463	0.084604	7.040843	0.12289	4.129771	5.6
eNB 15	4.743	0.08278	7.0417	0.1229	4.847463	0.084604	7.040843	0.12289	11.61615	15.5
eNB 16	4.7939	0.08367	7.0308	0.12271	4.847463	0.084604	7.040843	0.12289	6.059018	7.8
eNB 17	4.748	0.08287	7.0989	0.1239	4.847463	0.084604	7.040843	0.12289	12.79464	17.1
eNB 18	4.7773	0.08338	7.062	0.12325	4.847463	0.084604	7.040843	0.12289	8.146388	9.3
eNB 19	4.8341	0.08437	6.9845	0.1219	4.847463	0.084604	7.040843	0.12289	6.417061	7.8
eNB 20	4.8565	0.08476	7.0405	0.12288	4.847463	0.084604	7.040843	0.12289	1.005527	1.5
eNB 21	4.8064	0.08389	7.0424	0.12291	4.847463	0.084604	7.040843	0.12289	4.569293	5.9
eNB 22	4.8146	0.08403	6.9788	0.1218	4.847463	0.084604	7.040843	0.12289	7.785202	9.8
eNB 23	4.8298	0.0843	6.9588	0.12145	4.847463	0.084604	7.040843	0.12289	9.299946	11.1
eNB 24	4.8923	0.08539	6.9143	0.12068	4.847463	0.084604	7.040843	0.12289	14.88011	15.8
eNB 25	4.848	0.08461	7.0492	0.12303	4.847463	0.084604	7.040843	0.12289	0.927885	1.3
eNB 26	4.8514	0.08467	6.9835	0.12188	4.847463	0.084604	7.040843	0.12289	6.368424	9.1
eNB 27	4.8081	0.08392	6.9967	0.12211	4.847463	0.084604	7.040843	0.12289	6.563543	8
eNB 28	4.9028	0.08557	6.999	0.12216	4.847463	0.084604	7.040843	0.12289	7.704015	9.3
eNB 29	4.9789	0.0869	6.9611	0.12149	4.847463	0.084604	7.040843	0.12289	17.07761	21.6
eNB 30	4.9969	0.08721	6.95	0.1213	4.847463	0.084604	7.040843	0.12289	19.42657	22.2
eNB 31	4.9539	0.08646	7.0111	0.12237	4.847463	0.084604	7.040843	0.12289	12.2853	15.1
eNB 32	4.9669	0.08669	6.9869	0.12194	4.847463	0.084604	7.040843	0.12289	14.56334	18.5
eNB 33	4.8289	0.08428	7.0219	0.12255	4.847463	0.084604	7.040843	0.12289	2.943768	3.6
eNB 34	4.8169	0.08407	7.0112	0.12237	4.847463	0.084604	7.040843	0.12289	4.726196	5.9
eNB 35	4.9317	0.08607	7.0021	0.12221	4.847463	0.084604	7.040843	0.12289	10.30328	12.3
eNB 36	4.8407	0.08449	6.9681	0.12162	4.847463	0.084604	7.040843	0.12289	8.094704	10.1
eNB 37	4.8598	0.08482	6.9792	0.12181	4.847463	0.084604	7.040843	0.12289	6.966142	9.9
eNB 38	4.8469	0.08459	7.0369	0.12282	4.847463	0.084604	7.040843	0.12289	0.441306	0.5
eNB 39	4.8585	0.0848	6.9658	0.12158	4.847463	0.084604	7.040843	0.12289	8.404495	11.1
eNB 40	4.88	0.08517	7.01	0.12235	4.847463	0.084604	7.040843	0.12289	4.976566	5.9

eNB 41	4.8669	0.08494	7.03	0.1227	4.847463	0.084604	7.040843	0.12289	2.472668	4.3
eNB 42	4.8378	0.08444	7.037	0.12282	4.847463	0.084604	7.040843	0.12289	1.155802	1.3
eNB 43	4.8842	0.08525	7.138	0.12458	4.847463	0.084604	7.040843	0.12289	11.51344	15
eNB 44	4.7815	0.08345	7.0398	0.12287	4.847463	0.084604	7.040843	0.12289	7.335686	8.6
eNB 45	4.8116	0.08398	6.9561	0.12141	4.847463	0.084604	7.040843	0.12289	10.20121	12.4
eNB 46	4.9011	0.08554	6.9269	0.1209	4.847463	0.084604	7.040843	0.12289	13.96191	16.3
eNB 47	4.9058	0.08562	6.9066	0.12054	4.847463	0.084604	7.040843	0.12289	16.22602	17.8
eNB 48	4.8024	0.08382	6.944	0.1212	4.847463	0.084604	7.040843	0.12289	11.84254	14.3
eNB 49	4.8354	0.08439	7.0528	0.12309	4.847463	0.084604	7.040843	0.12289	1.885352	2.6
eNB 50	4.7947	0.08368	7.0497	0.12304	4.847463	0.084604	7.040843	0.12289	5.948524	7.1
eNB 51	4.7581	0.08304	7.0119	0.12238	4.847463	0.084604	7.040843	0.12289	10.44142	12.9
eNB 52	4.8269	0.08424	6.9961	0.1221	4.847463	0.084604	7.040843	0.12289	5.45933	6.6
eNB 53	4.815	0.08404	7.0419	0.1229	4.847463	0.084604	7.040843	0.12289	3.611661	4.4
eNB 54	4.71	0.0822	7.165	0.12505	4.847463	0.084604	7.040843	0.12289	20.56475	23.5
eNB 55	4.8233	0.08418	7.0572	0.12317	4.847463	0.084604	7.040843	0.12289	3.240962	4.6
eNB 56	4.815	0.08404	7.0652	0.12331	4.847463	0.084604	7.040843	0.12289	4.507081	5.6
eNB 57	4.894	0.08542	7.0153	0.12244	4.847463	0.084604	7.040843	0.12289	5.897891	7.9
eNB 58	4.8626	0.08487	7.0153	0.12244	4.847463	0.084604	7.040843	0.12289	3.292687	4.2
eNB 59	4.8276	0.08426	7.0145	0.12243	4.847463	0.084604	7.040843	0.12289	3.66024	4.3
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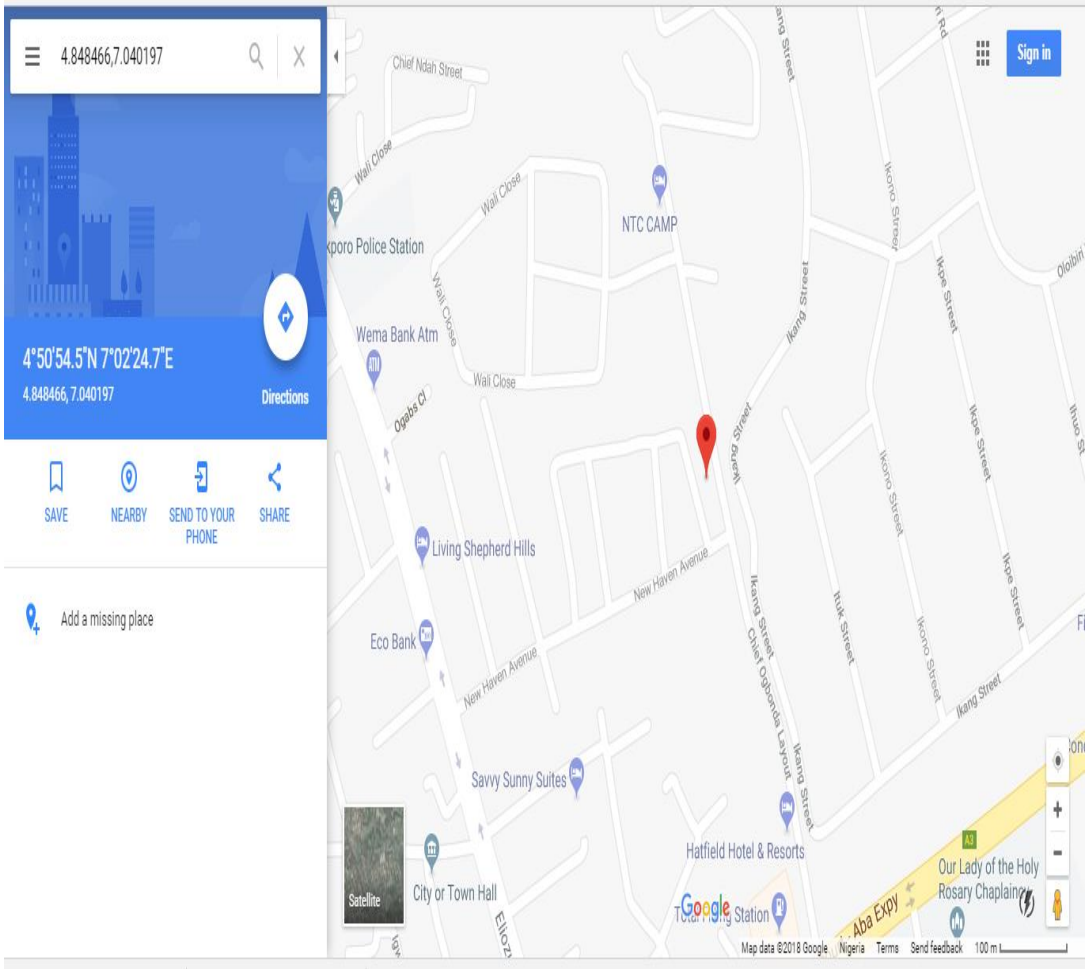
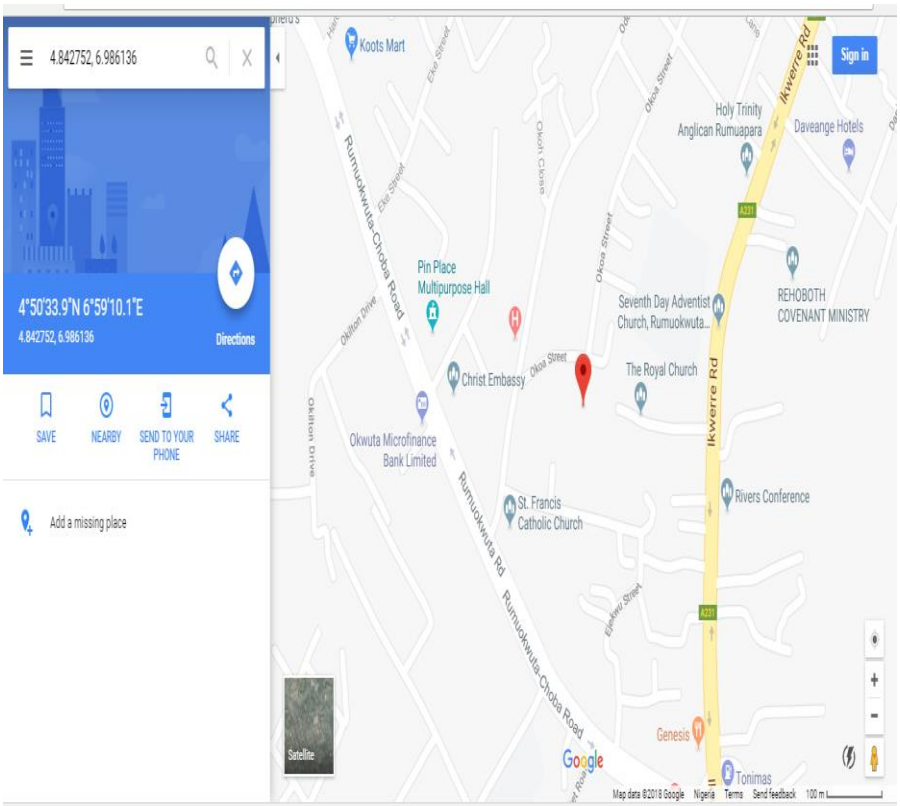


Location 16 (4.848466, 7.040197)

Location 17 (**4.842752, 6.986136**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB25 to eNB 26)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.848466	0.08462	7.040197	0.12287	6.588073	8.2
eNB 1	4.8366	0.08441	7.0286	0.122672	4.848466	0.08462	7.040197	0.12287	1.841725	2.7
eNB 2	4.7737	0.08332	7.0142	0.12242	4.848466	0.08462	7.040197	0.12287	8.798483	11.3
eNB 3	4.7999	0.08377	6.9939	0.122066	4.848466	0.08462	7.040197	0.12287	7.448303	9
eNB 4	4.8294	0.08429	7.0919	0.123777	4.848466	0.08462	7.040197	0.12287	6.108336	7.6
eNB 5	4.7706	0.08326	7.0224	0.122564	4.848466	0.08462	7.040197	0.12287	8.880019	11.2
eNB 6	4.8746	0.08508	6.983	0.121876	4.848466	0.08462	7.040197	0.12287	6.971591	8.2
eNB 7	4.8692	0.08498	7.1137	0.124157	4.848466	0.08462	7.040197	0.12287	8.463826	11.1
eNB 8	4.7196	0.08237	7.1518	0.124822	4.848466	0.08462	7.040197	0.12287	18.92763	21.9
eNB 9	4.8554	0.08474	7.0641	0.123291	4.848466	0.08462	7.040197	0.12287	2.758322	3.3
eNB 10	4.7909	0.08362	7.1207	0.124279	4.848466	0.08462	7.040197	0.12287	10.97895	12.6
eNB 11	4.7854	0.08352	7.0082	0.122316	4.848466	0.08462	7.040197	0.12287	7.857866	9.4
eNB 12	4.8327	0.08435	7.0685	0.123368	4.848466	0.08462	7.040197	0.12287	3.592706	5.2
eNB 13	4.8039	0.08384	6.9883	0.121968	4.848466	0.08462	7.040197	0.12287	7.590901	9.5
eNB 14	4.8197	0.08412	7.0656	0.123317	4.848466	0.08462	7.040197	0.12287	4.260707	5.7
eNB 15	4.743	0.08278	7.0417	0.1229	4.848466	0.08462	7.040197	0.12287	11.72845	15.6
eNB 16	4.7939	0.08367	7.0308	0.12271	4.848466	0.08462	7.040197	0.12287	6.156155	7.9
eNB 17	4.748	0.08287	7.0989	0.123899	4.848466	0.08462	7.040197	0.12287	12.92701	17.2
eNB 18	4.7773	0.08338	7.062	0.123255	4.848466	0.08462	7.040197	0.12287	8.273852	9.5
eNB 19	4.8341	0.08437	6.9845	0.121902	4.848466	0.08462	7.040197	0.12287	6.374488	8
eNB 20	4.8565	0.08476	7.0405	0.122879	4.848466	0.08462	7.040197	0.12287	0.893935	1.4
eNB 21	4.8064	0.08389	7.0424	0.122913	4.848466	0.08462	7.040197	0.12287	4.683905	6
eNB 22	4.8146	0.08403	6.9788	0.121803	4.848466	0.08462	7.040197	0.12287	7.775469	10
eNB 23	4.8298	0.0843	6.9588	0.121453	4.848466	0.08462	7.040197	0.12287	9.254374	11.3
eNB 24	4.8923	0.08539	6.9143	0.120677	4.848466	0.08462	7.040197	0.12287	14.77554	15.8
eNB 25	4.848	0.08461	7.0492	0.123031	4.848466	0.08462	7.040197	0.12287	0.998871	1.5
eNB 26	4.8514	0.08467	6.9835	0.121885	4.848466	0.08462	7.040197	0.12287	6.290263	9
eNB 27	4.8081	0.08392	6.9967	0.122115	4.848466	0.08462	7.040197	0.12287	6.585873	8.2
eNB 28	4.9028	0.08557	6.999	0.122155	4.848466	0.08462	7.040197	0.12287	7.571901	9.2
eNB 29	4.9789	0.0869	6.9611	0.121494	4.848466	0.08462	7.040197	0.12287	16.94516	21.5
eNB 30	4.9969	0.08721	6.95	0.1213	4.848466	0.08462	7.040197	0.12287	19.29412	22.1
eNB 31	4.9539	0.08646	7.0111	0.122366	4.848466	0.08462	7.040197	0.12287	12.15875	15
eNB 32	4.9669	0.08669	6.9869	0.121944	4.848466	0.08462	7.040197	0.12287	14.4323	18.4
eNB 33	4.8289	0.08428	7.0219	0.122555	4.848466	0.08462	7.040197	0.12287	2.973763	3.7
eNB 34	4.8169	0.08407	7.0112	0.122368	4.848466	0.08462	7.040197	0.12287	4.758393	6.1
eNB 35	4.9317	0.08607	7.0021	0.122209	4.848466	0.08462	7.040197	0.12287	10.17212	12.3
eNB 36	4.8407	0.08449	6.9681	0.121616	4.848466	0.08462	7.040197	0.12287	8.034669	10.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.848466	0.08462	7.040197	0.12287	6.87468	9.9
eNB 38	4.8469	0.08459	7.0369	0.122817	4.848466	0.08462	7.040197	0.12287	0.404671	0.45
eNB 39	4.8585	0.0848	6.9658	0.121576	4.848466	0.08462	7.040197	0.12287	8.318014	11
eNB 40	4.88	0.08517	7.01	0.122347	4.848466	0.08462	7.040197	0.12287	4.846428	5.8

eNB 41	4.8669	0.08494	7.03	0.122696	4.848466	0.08462	7.040197	0.12287	2.340454	4.2
eNB 42	4.8378	0.08444	7.037	0.122818	4.848466	0.08462	7.040197	0.12287	1.237792	1.4
eNB 43	4.8842	0.08525	7.138	0.124581	4.848466	0.08462	7.040197	0.12287	11.5415	15.2
eNB 44	4.7815	0.08345	7.0398	0.122867	4.848466	0.08462	7.040197	0.12287	7.446412	8.7
eNB 45	4.8116	0.08398	6.9561	0.121406	4.848466	0.08462	7.040197	0.12287	10.17977	12.6
eNB 46	4.9011	0.08554	6.9269	0.120897	4.848466	0.08462	7.040197	0.12287	13.84975	16.3
eNB 47	4.9058	0.08562	6.9066	0.120542	4.848466	0.08462	7.040197	0.12287	16.11601	17.7
eNB 48	4.8024	0.08382	6.944	0.121195	4.848466	0.08462	7.040197	0.12287	11.8256	14.4
eNB 49	4.8354	0.08439	7.0528	0.123094	4.848466	0.08462	7.040197	0.12287	2.015159	2.7
eNB 50	4.7947	0.08368	7.0497	0.12304	4.848466	0.08462	7.040197	0.12287	6.070533	7.2
eNB 51	4.7581	0.08304	7.0119	0.12238	4.848466	0.08462	7.040197	0.12287	10.52605	13
eNB 52	4.8269	0.08424	6.9961	0.122104	4.848466	0.08462	7.040197	0.12287	5.44263	6.8
eNB 53	4.815	0.08404	7.0419	0.122904	4.848466	0.08462	7.040197	0.12287	3.726049	4.6
eNB 54	4.71	0.0822	7.165	0.125052	4.848466	0.08462	7.040197	0.12287	20.69551	23.7
eNB 55	4.8233	0.08418	7.0572	0.123171	4.848466	0.08462	7.040197	0.12287	3.373422	4.8
eNB 56	4.815	0.08404	7.0652	0.123311	4.848466	0.08462	7.040197	0.12287	4.639246	5.7
eNB 57	4.894	0.08542	7.0153	0.12244	4.848466	0.08462	7.040197	0.12287	5.76573	7.8
eNB 58	4.8626	0.08487	7.0153	0.12244	4.848466	0.08462	7.040197	0.12287	3.174736	4.1
eNB 59	4.8276	0.08426	7.0145	0.122426	4.848466	0.08462	7.040197	0.12287	3.672838	4.5
									468.2098	579.45

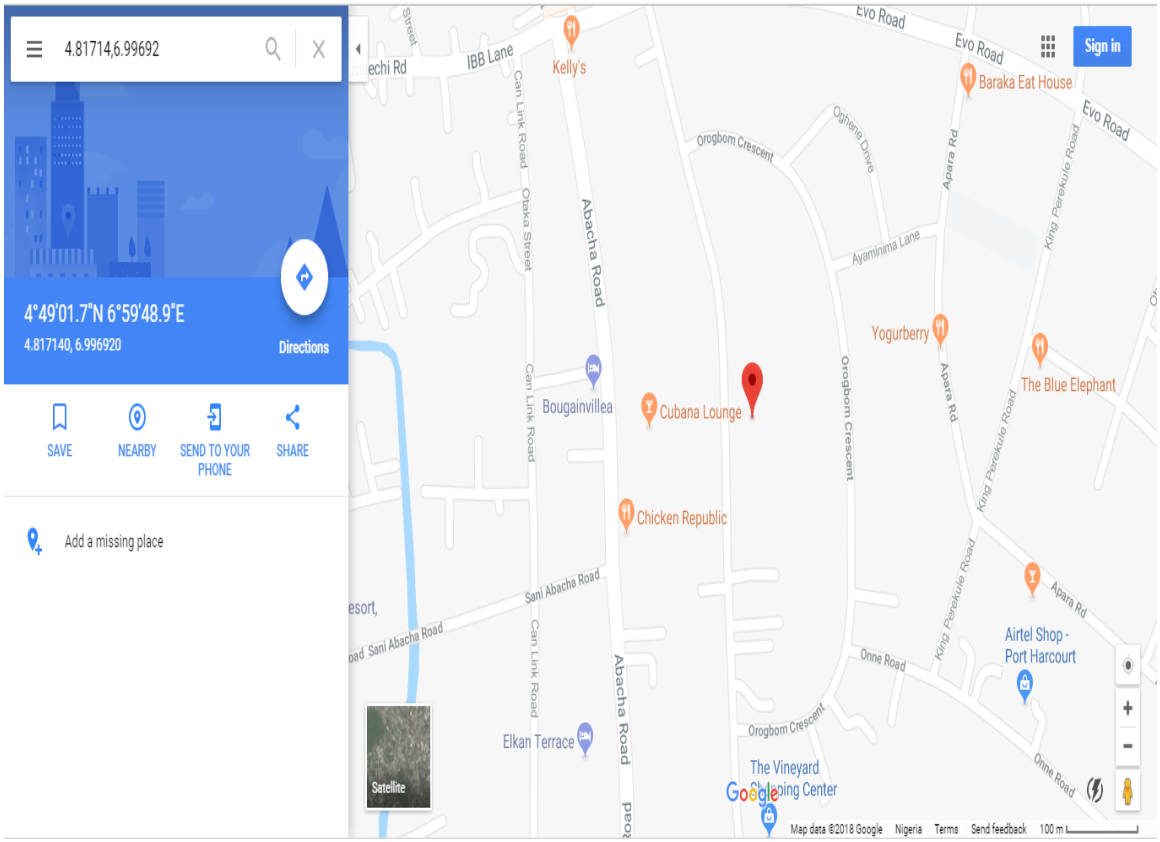


*Location 17 (***4.842752, 6.986136***)*

Location *18 (***4.81714, 6.99692***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB26 to eNB 27)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.842752	0.08452	6.986136	0.12193	4.0238	5.1
eNB 1	4.8366	0.08441	7.0286	0.122672	4.842752	0.08452	6.986136	0.12193	4.75435	6.4
eNB 2	4.7737	0.08332	7.0142	0.12242	4.842752	0.08452	6.986136	0.12193	8.283988	10.1
eNB 3	4.7999	0.08377	6.9939	0.122066	4.842752	0.08452	6.986136	0.12193	4.841963	6.1
eNB 4	4.8294	0.08429	7.0919	0.123777	4.842752	0.08452	6.986136	0.12193	11.81213	15.1
eNB 5	4.7706	0.08326	7.0224	0.122564	4.842752	0.08452	6.986136	0.12193	8.972895	11.1
eNB 6	4.8746	0.08508	6.983	0.121876	4.842752	0.08452	6.986136	0.12193	3.558297	4.5
eNB 7	4.8692	0.08498	7.1137	0.124157	4.842752	0.08452	6.986136	0.12193	14.43616	18.9
eNB 8	4.7196	0.08237	7.1518	0.124822	4.842752	0.08452	6.986136	0.12193	22.9018	28.8
eNB 9	4.8554	0.08474	7.0641	0.123291	4.842752	0.08452	6.986136	0.12193	8.75182	10.8
eNB 10	4.7909	0.08362	7.1207	0.124279	4.842752	0.08452	6.986136	0.12193	15.98586	19.4
eNB 11	4.7854	0.08352	7.0082	0.122316	4.842752	0.08452	6.986136	0.12193	6.829783	8.9
eNB 12	4.8327	0.08435	7.0685	0.123368	4.842752	0.08452	6.986136	0.12193	9.193943	12.3
eNB 13	4.8039	0.08384	6.9883	0.121968	4.842752	0.08452	6.986136	0.12193	4.326807	5.3
eNB 14	4.8197	0.08412	7.0656	0.123317	4.842752	0.08452	6.986136	0.12193	9.170054	12.6
eNB 15	4.743	0.08278	7.0417	0.1229	4.842752	0.08452	6.986136	0.12193	12.68605	15.6
eNB 16	4.7939	0.08367	7.0308	0.12271	4.842752	0.08452	6.986136	0.12193	7.348351	9.6
eNB 17	4.748	0.08287	7.0989	0.123899	4.842752	0.08452	6.986136	0.12193	16.34398	24.1
eNB 18	4.7773	0.08338	7.062	0.123255	4.842752	0.08452	6.986136	0.12193	11.11879	13.9
eNB 19	4.8341	0.08437	6.9845	0.121902	4.842752	0.08452	6.986136	0.12193	0.979025	1.6
eNB 20	4.8565	0.08476	7.0405	0.122879	4.842752	0.08452	6.986136	0.12193	6.214239	8.6
eNB 21	4.8064	0.08389	7.0424	0.122913	4.842752	0.08452	6.986136	0.12193	7.429823	9.7
eNB 22	4.8146	0.08403	6.9788	0.121803	4.842752	0.08452	6.986136	0.12193	3.234201	4.4
eNB 23	4.8298	0.0843	6.9588	0.121453	4.842752	0.08452	6.986136	0.12193	3.353824	4.5
eNB 24	4.8923	0.08539	6.9143	0.120677	4.842752	0.08452	6.986136	0.12193	9.67986	10.7
eNB 25	4.848	0.08461	7.0492	0.123031	4.842752	0.08452	6.986136	0.12193	7.011579	8.8
eNB 26	4.8514	0.08467	6.9835	0.121885	4.842752	0.08452	6.986136	0.12193	1.004967	1.8
eNB 27	4.8081	0.08392	6.9967	0.122115	4.842752	0.08452	6.986136	0.12193	4.026992	5.1
eNB 28	4.9028	0.08557	6.999	0.122155	4.842752	0.08452	6.986136	0.12193	6.827379	7.6
eNB 29	4.9789	0.0869	6.9611	0.121494	4.842752	0.08452	6.986136	0.12193	15.39087	19.3
eNB 30	4.9969	0.08721	6.95	0.1213	4.842752	0.08452	6.986136	0.12193	17.60169	19.9
eNB 31	4.9539	0.08646	7.0111	0.122366	4.842752	0.08452	6.986136	0.12193	12.66468	13.5
eNB 32	4.9669	0.08669	6.9869	0.121944	4.842752	0.08452	6.986136	0.12193	13.8048	16.8
eNB 33	4.8289	0.08428	7.0219	0.122555	4.842752	0.08452	6.986136	0.12193	4.251392	5.9
eNB 34	4.8169	0.08407	7.0112	0.122368	4.842752	0.08452	6.986136	0.12193	3.996925	5.3
eNB 35	4.9317	0.08607	7.0021	0.122209	4.842752	0.08452	6.986136	0.12193	10.04738	10.7
eNB 36	4.8407	0.08449	6.9681	0.121616	4.842752	0.08452	6.986136	0.12193	2.011387	2.7
eNB 37	4.8598	0.08482	6.9792	0.12181	4.842752	0.08452	6.986136	0.12193	2.045478	2.8
eNB 38	4.8469	0.08459	7.0369	0.122817	4.842752	0.08452	6.986136	0.12193	5.643334	7.9
eNB 39	4.8585	0.0848	6.9658	0.121576	4.842752	0.08452	6.986136	0.12193	2.853617	3.3
eNB 40	4.88	0.08517	7.01	0.122347	4.842752	0.08452	6.986136	0.12193	4.9137	5.7

eNB 41	4.8669	0.08494	7.03	0.122696	4.842752	0.08452	6.986136	0.12193	5.552313	7.8
eNB 42	4.8378	0.08444	7.037	0.122818	4.842752	0.08452	6.986136	0.12193	5.662414	7.2
eNB 43	4.8842	0.08525	7.138	0.124581	4.842752	0.08452	6.986136	0.12193	17.44537	21.4
eNB 44	4.7815	0.08345	7.0398	0.122867	4.842752	0.08452	6.986136	0.12193	9.041248	11.3
eNB 45	4.8116	0.08398	6.9561	0.121406	4.842752	0.08452	6.986136	0.12193	4.803636	6.2
eNB 46	4.9011	0.08554	6.9269	0.120897	4.842752	0.08452	6.986136	0.12193	9.228541	11.2
eNB 47	4.9058	0.08562	6.9066	0.120542	4.842752	0.08452	6.986136	0.12193	11.26054	12.6
eNB 48	4.8024	0.08382	6.944	0.121195	4.842752	0.08452	6.986136	0.12193	6.475341	8
eNB 49	4.8354	0.08439	7.0528	0.123094	4.842752	0.08452	6.986136	0.12193	7.431301	9.5
eNB 50	4.7947	0.08368	7.0497	0.12304	4.842752	0.08452	6.986136	0.12193	8.84037	11.3
eNB 51	4.7581	0.08304	7.0119	0.12238	4.842752	0.08452	6.986136	0.12193	9.836233	11.7
eNB 52	4.8269	0.08424	6.9961	0.122104	4.842752	0.08452	6.986136	0.12193	2.079849	2.9
eNB 53	4.815	0.08404	7.0419	0.122904	4.842752	0.08452	6.986136	0.12193	6.906355	9.4
eNB 54	4.71	0.0822	7.165	0.125052	4.842752	0.08452	6.986136	0.12193	24.71258	30.5
eNB 55	4.8233	0.08418	7.0572	0.123171	4.842752	0.08452	6.986136	0.12193	8.165469	11.6
eNB 56	4.815	0.08404	7.0652	0.123311	4.842752	0.08452	6.986136	0.12193	9.287858	12.5
eNB 57	4.894	0.08542	7.0153	0.12244	4.842752	0.08452	6.986136	0.12193	6.550772	8.3
eNB 58	4.8626	0.08487	7.0153	0.12244	4.842752	0.08452	6.986136	0.12193	3.912965	5.3
eNB 59	4.8276	0.08426	7.0145	0.122426	4.842752	0.08452	6.986136	0.12193	3.565801	4.8
									491.0869	618.7

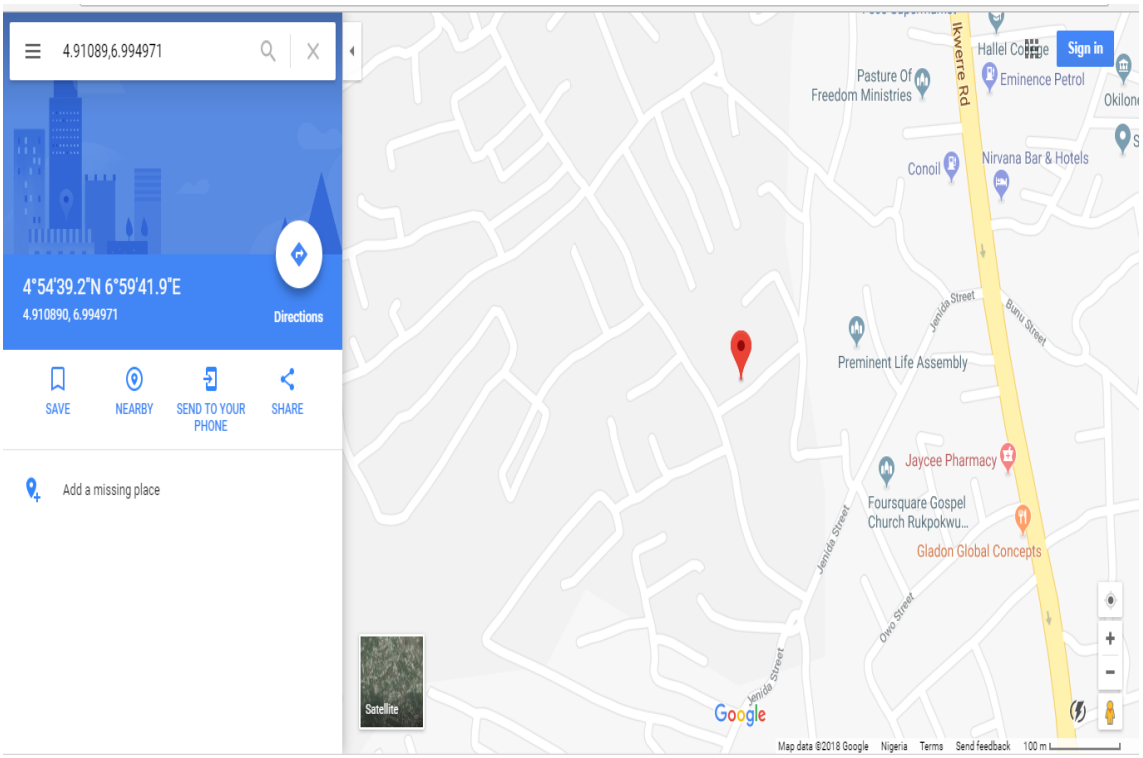


Location *18* (**4.81714, 6.99692**)

*Location 19 (***4.91089, 6.994971***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB27 to eNB 28)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.122114	4.81714	0.08407	6.99692	0.12212	1.003771	1.4
eNB 1	4.8366	0.08441	7.0286	0.122672	4.81714	0.08407	6.99692	0.12212	4.123534	5.7
eNB 2	4.7737	0.08332	7.0142	0.12242	4.81714	0.08407	6.99692	0.12212	5.195999	6.9
eNB 3	4.7999	0.08377	6.9939	0.122066	4.81714	0.08407	6.99692	0.12212	1.946012	2.6
eNB 4	4.8294	0.08429	7.0919	0.123777	4.81714	0.08407	6.99692	0.12212	10.61182	14
eNB 5	4.7706	0.08326	7.0224	0.122564	4.81714	0.08407	6.99692	0.12212	5.895117	7.7
eNB 6	4.8746	0.08508	6.983	0.121876	4.81714	0.08407	6.99692	0.12212	6.572694	8
eNB 7	4.8692	0.08498	7.1137	0.124157	4.81714	0.08407	6.99692	0.12212	14.17486	17.8
eNB 8	4.7196	0.08237	7.1518	0.124822	4.81714	0.08407	6.99692	0.12212	20.30215	27.6
eNB 9	4.8554	0.08474	7.0641	0.123291	4.81714	0.08407	6.99692	0.12212	8.573471	10.1
eNB 10	4.7909	0.08362	7.1207	0.124279	4.81714	0.08407	6.99692	0.12212	14.02228	18.3
eNB 11	4.7854	0.08352	7.0082	0.122316	4.81714	0.08407	6.99692	0.12212	3.744148	5.2
eNB 12	4.8327	0.08435	7.0685	0.123368	4.81714	0.08407	6.99692	0.12212	8.117664	11.2
eNB 13	4.8039	0.08384	6.9883	0.121968	4.81714	0.08407	6.99692	0.12212	1.754907	2.3
eNB 14	4.8197	0.08412	7.0656	0.123317	4.81714	0.08407	6.99692	0.12212	7.615218	10.5
eNB 15	4.743	0.08278	7.0417	0.1229	4.81714	0.08407	6.99692	0.12212	9.622119	12.2
eNB 16	4.7939	0.08367	7.0308	0.12271	4.81714	0.08407	6.99692	0.12212	4.557541	6.5
eNB 17	4.748	0.08287	7.0989	0.123899	4.81714	0.08407	6.99692	0.12212	13.66747	22.9
eNB 18	4.7773	0.08338	7.062	0.123255	4.81714	0.08407	6.99692	0.12212	8.463279	10.8
eNB 19	4.8341	0.08437	6.9845	0.121902	4.81714	0.08407	6.99692	0.12212	2.334509	3.6
eNB 20	4.8565	0.08476	7.0405	0.122879	4.81714	0.08407	6.99692	0.12212	6.516919	8.9
eNB 21	4.8064	0.08389	7.0424	0.122913	4.81714	0.08407	6.99692	0.12212	5.178933	7
eNB 22	4.8146	0.08403	6.9788	0.121803	4.81714	0.08407	6.99692	0.12212	2.027456	3.1
eNB 23	4.8298	0.0843	6.9588	0.121453	4.81714	0.08407	6.99692	0.12212	4.452075	5.9
eNB 24	4.8923	0.08539	6.9143	0.120677	4.81714	0.08407	6.99692	0.12212	12.3951	14.1
eNB 25	4.848	0.08461	7.0492	0.123031	4.81714	0.08407	6.99692	0.12212	6.732698	8.1
eNB 26	4.8514	0.08467	6.9835	0.121885	4.81714	0.08407	6.99692	0.12212	4.089369	5.4
eNB 27	4.8081	0.08392	6.9967	0.122115	4.81714	0.08407	6.99692	0.12212	1.005534	1.4
eNB 28	4.9028	0.08557	6.999	0.122155	4.81714	0.08407	6.99692	0.12212	9.527666	11
eNB 29	4.9789	0.0869	6.9611	0.121494	4.81714	0.08407	6.99692	0.12212	18.41935	22.7
eNB 30	4.9969	0.08721	6.95	0.1213	4.81714	0.08407	6.99692	0.12212	20.65312	23.3
eNB 31	4.9539	0.08646	7.0111	0.122366	4.81714	0.08407	6.99692	0.12212	15.28785	16.9
eNB 32	4.9669	0.08669	6.9869	0.121944	4.81714	0.08407	6.99692	0.12212	16.6894	20.2
eNB 33	4.8289	0.08428	7.0219	0.122555	4.81714	0.08407	6.99692	0.12212	3.061183	4.3
eNB 34	4.8169	0.08407	7.0112	0.122368	4.81714	0.08407	6.99692	0.12212	1.582524	2.3
eNB 35	4.9317	0.08607	7.0021	0.122209	4.81714	0.08407	6.99692	0.12212	12.75132	14.1
eNB 36	4.8407	0.08449	6.9681	0.121616	4.81714	0.08407	6.99692	0.12212	4.130298	5.7
eNB 37	4.8598	0.08482	6.9792	0.12181	4.81714	0.08407	6.99692	0.12212	5.133757	6.3
eNB 38	4.8469	0.08459	7.0369	0.122817	4.81714	0.08407	6.99692	0.12212	5.529318	7.2
eNB 39	4.8585	0.0848	6.9658	0.121576	4.81714	0.08407	6.99692	0.12212	5.747967	6.7
eNB 40	4.88	0.08517	7.01	0.122347	4.81714	0.08407	6.99692	0.12212	7.138312	9.1

eNB 41	4.8669	0.08494	7.03	0.122696	4.81714	0.08407	6.99692	0.12212	6.636866	9.1
eNB 42	4.8378	0.08444	7.037	0.122818	4.81714	0.08407	6.99692	0.12212	4.999902	6.5
eNB 43	4.8842	0.08525	7.138	0.124581	4.81714	0.08407	6.99692	0.12212	17.31865	21.8
eNB 44	4.7815	0.08345	7.0398	0.122867	4.81714	0.08407	6.99692	0.12212	6.187149	8.2
eNB 45	4.8116	0.08398	6.9561	0.121406	4.81714	0.08407	6.99692	0.12212	4.564659	6.9
eNB 46	4.9011	0.08554	6.9269	0.120897	4.81714	0.08407	6.99692	0.12212	12.13843	14.6
eNB 47	4.9058	0.08562	6.9066	0.120542	4.81714	0.08407	6.99692	0.12212	14.04733	16.1
eNB 48	4.8024	0.08382	6.944	0.121195	4.81714	0.08407	6.99692	0.12212	6.088412	8.7
eNB 49	4.8354	0.08439	7.0528	0.123094	4.81714	0.08407	6.99692	0.12212	6.515972	8.8
eNB 50	4.7947	0.08368	7.0497	0.12304	4.81714	0.08407	6.99692	0.12212	6.358333	8.6
eNB 51	4.7581	0.08304	7.0119	0.12238	4.81714	0.08407	6.99692	0.12212	6.771567	8.4
eNB 52	4.8269	0.08424	6.9961	0.122104	4.81714	0.08407	6.99692	0.12212	1.089009	1.2
eNB 53	4.815	0.08404	7.0419	0.122904	4.81714	0.08407	6.99692	0.12212	4.989598	7.8
eNB 54	4.71	0.0822	7.165	0.125052	4.81714	0.08407	6.99692	0.12212	22.10933	29.3
eNB 55	4.8233	0.08418	7.0572	0.123171	4.81714	0.08407	6.99692	0.12212	6.714172	9.6
eNB 56	4.815	0.08404	7.0652	0.123311	4.81714	0.08407	6.99692	0.12212	7.569345	10.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.81714	0.08407	6.99692	0.12212	8.785646	12
eNB 58	4.8626	0.08487	7.0153	0.12244	4.81714	0.08407	6.99692	0.12212	5.449679	8.3
eNB 59	4.8276	0.08426	7.0145	0.122426	4.81714	0.08407	6.99692	0.12212	2.268726	3.2
									470.9515	608.5

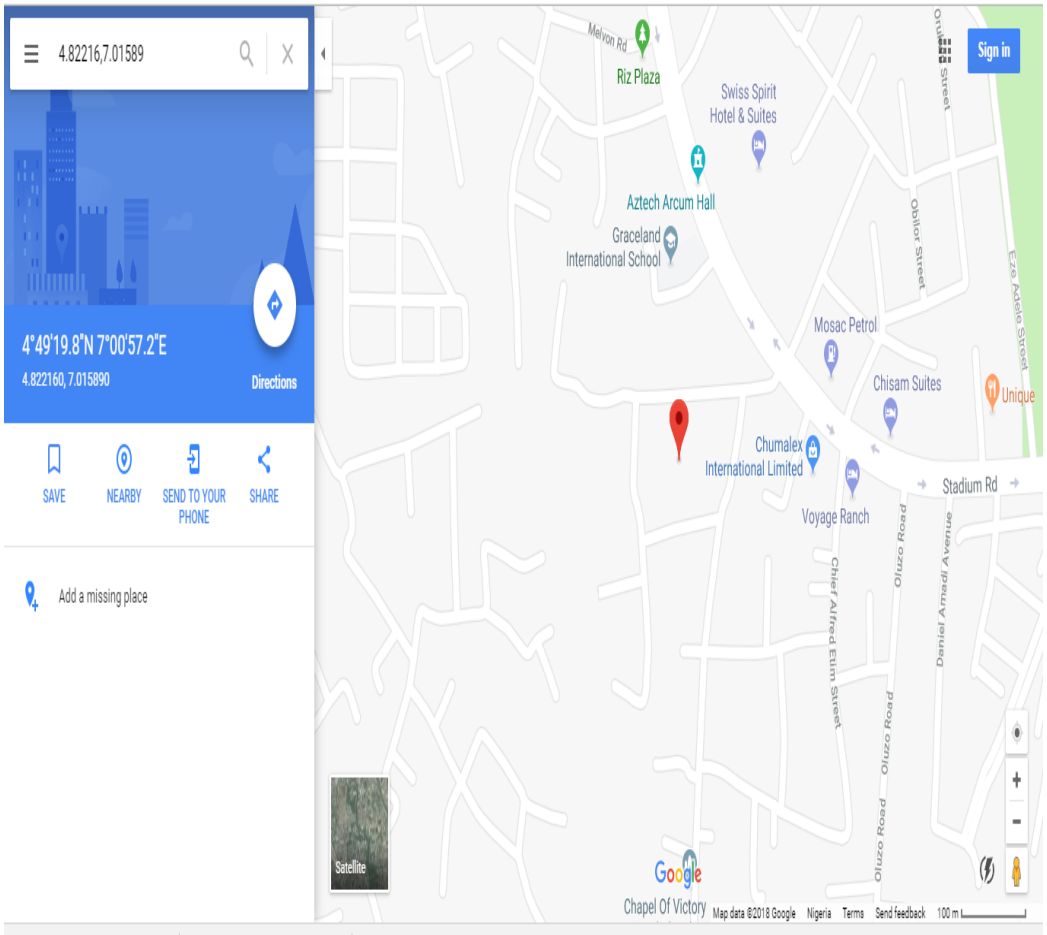


*Location 19 (***4.91089, 6.994971***)*

*Location 20 (***4.82216, 7.01589***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB28 to eNB 29)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.91089	0.085711	6.994971	0.122085	11.42932	13.3
eNB 1	4.8366	0.08441	7.0286	0.12267	4.91089	0.085711	6.994971	0.122085	9.061998	11.9
eNB 2	4.7737	0.08332	7.0142	0.12242	4.91089	0.085711	6.994971	0.122085	15.40283	18.3
eNB 3	4.7999	0.08377	6.9939	0.12207	4.91089	0.085711	6.994971	0.122085	12.34205	14.2
eNB 4	4.8294	0.08429	7.0919	0.12378	4.91089	0.085711	6.994971	0.122085	14.05107	15.2
eNB 5	4.7706	0.08326	7.0224	0.12256	4.91089	0.085711	6.994971	0.122085	15.89275	19
eNB 6	4.8746	0.08508	6.983	0.12188	4.91089	0.085711	6.994971	0.122085	4.247624	5.6
eNB 7	4.8692	0.08498	7.1137	0.12416	4.91089	0.085711	6.994971	0.122085	13.94688	18.3
eNB 8	4.7196	0.08237	7.1518	0.12482	4.91089	0.085711	6.994971	0.122085	27.46611	29.8
eNB 9	4.8554	0.08474	7.0641	0.12329	4.91089	0.085711	6.994971	0.122085	9.835081	11.8
eNB 10	4.7909	0.08362	7.1207	0.12428	4.91089	0.085711	6.994971	0.122085	19.28904	20.4
eNB 11	4.7854	0.08352	7.0082	0.12232	4.91089	0.085711	6.994971	0.122085	14.03056	17.1
eNB 12	4.8327	0.08435	7.0685	0.12337	4.91089	0.085711	6.994971	0.122085	11.9145	14.2
eNB 13	4.8039	0.08384	6.9883	0.12197	4.91089	0.085711	6.994971	0.122085	11.91964	13.4
eNB 14	4.8197	0.08412	7.0656	0.12332	4.91089	0.085711	6.994971	0.122085	12.80821	15.4
eNB 15	4.743	0.08278	7.0417	0.1229	4.91089	0.085711	6.994971	0.122085	19.37312	23.5
eNB 16	4.7939	0.08367	7.0308	0.12271	4.91089	0.085711	6.994971	0.122085	13.60085	16.5
eNB 17	4.748	0.08287	7.0989	0.1239	4.91089	0.085711	6.994971	0.122085	21.46306	25.1
eNB 18	4.7773	0.08338	7.062	0.12325	4.91089	0.085711	6.994971	0.122085	16.60752	19.1
eNB 19	4.8341	0.08437	6.9845	0.1219	4.91089	0.085711	6.994971	0.122085	8.617082	9.7
eNB 20	4.8565	0.08476	7.0405	0.12288	4.91089	0.085711	6.994971	0.122085	7.875295	9.9
eNB 21	4.8064	0.08389	7.0424	0.12291	4.91089	0.085711	6.994971	0.122085	12.75179	15.7
eNB 22	4.8146	0.08403	6.9788	0.1218	4.91089	0.085711	6.994971	0.122085	10.85579	12.5
eNB 23	4.8298	0.0843	6.9588	0.12145	4.91089	0.085711	6.994971	0.122085	9.867234	12.4
eNB 24	4.8923	0.08539	6.9143	0.12068	4.91089	0.085711	6.994971	0.122085	9.173335	12.4
eNB 25	4.848	0.08461	7.0492	0.12303	4.91089	0.085711	6.994971	0.122085	9.21951	11.5
eNB 26	4.8514	0.08467	6.9835	0.12188	4.91089	0.085711	6.994971	0.122085	6.735947	8.8
eNB 27	4.8081	0.08392	6.9967	0.12211	4.91089	0.085711	6.994971	0.122085	11.43129	13.3
eNB 28	4.9028	0.08557	6.999	0.12216	4.91089	0.085711	6.994971	0.122085	1.004204	1.2
eNB 29	4.9789	0.0869	6.9611	0.12149	4.91089	0.085711	6.994971	0.122085	8.442069	11.5
eNB 30	4.9969	0.08721	6.95	0.1213	4.91089	0.085711	6.994971	0.122085	10.7836	12.1
eNB 31	4.9539	0.08646	7.0111	0.12237	4.91089	0.085711	6.994971	0.122085	5.105351	5.7
eNB 32	4.9669	0.08669	6.9869	0.12194	4.91089	0.085711	6.994971	0.122085	6.291859	9.1
eNB 33	4.8289	0.08428	7.0219	0.12255	4.91089	0.085711	6.994971	0.122085	9.592606	11.8
eNB 34	4.8169	0.08407	7.0112	0.12237	4.91089	0.085711	6.994971	0.122085	10.60471	13.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.91089	0.085711	6.994971	0.122085	2.445012	2.9
eNB 36	4.8407	0.08449	6.9681	0.12162	4.91089	0.085711	6.994971	0.122085	8.353283	10.5
eNB 37	4.8598	0.08482	6.9792	0.12181	4.91089	0.085711	6.994971	0.122085	5.943573	7.7
eNB 38	4.8469	0.08459	7.0369	0.12282	4.91089	0.085711	6.994971	0.122085	8.497486	9.9
eNB 39	4.8585	0.0848	6.9658	0.12158	4.91089	0.085711	6.994971	0.122085	6.661943	8.8
eNB 40	4.88	0.08517	7.01	0.12235	4.91089	0.085711	6.994971	0.122085	3.817082	4.5

eNB 41	4.8669	0.08494	7.03	0.1227	4.91089	0.085711	6.994971	0.122085	6.243963	7.9
eNB 42	4.8378	0.08444	7.037	0.12282	4.91089	0.085711	6.994971	0.122085	9.366647	11.1
eNB 43	4.8842	0.08525	7.138	0.12458	4.91089	0.085711	6.994971	0.122085	16.12146	18.5
eNB 44	4.7815	0.08345	7.0398	0.12287	4.91089	0.085711	6.994971	0.122085	15.22067	18.1
eNB 45	4.8116	0.08398	6.9561	0.12141	4.91089	0.085711	6.994971	0.122085	11.85076	14.5
eNB 46	4.9011	0.08554	6.9269	0.1209	4.91089	0.085711	6.994971	0.122085	7.619589	12.4
eNB 47	4.9058	0.08562	6.9066	0.12054	4.91089	0.085711	6.994971	0.122085	9.806715	12.4
eNB 48	4.8024	0.08382	6.944	0.1212	4.91089	0.085711	6.994971	0.122085	13.31994	16.4
eNB 49	4.8354	0.08439	7.0528	0.12309	4.91089	0.085711	6.994971	0.122085	10.55983	12.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.91089	0.085711	6.994971	0.122085	14.27189	16.9
eNB 51	4.7581	0.08304	7.0119	0.12238	4.91089	0.085711	6.994971	0.122085	17.09263	19.9
eNB 52	4.8269	0.08424	6.9961	0.1221	4.91089	0.085711	6.994971	0.122085	9.340065	11
eNB 53	4.815	0.08404	7.0419	0.1229	4.91089	0.085711	6.994971	0.122085	11.86262	14.2
eNB 54	4.71	0.0822	7.165	0.12505	4.91089	0.085711	6.994971	0.122085	29.22178	31.5
eNB 55	4.8233	0.08418	7.0572	0.12317	4.91089	0.085711	6.994971	0.122085	11.93285	14.5
eNB 56	4.815	0.08404	7.0652	0.12331	4.91089	0.085711	6.994971	0.122085	13.19964	15.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.91089	0.085711	6.994971	0.122085	2.932479	3.9
eNB 58	4.8626	0.08487	7.0153	0.12244	4.91089	0.085711	6.994971	0.122085	5.822795	6.8
eNB 59	4.8276	0.08426	7.0145	0.12243	4.91089	0.085711	6.994971	0.122085	9.510769	11.3
									674.0494	806.2

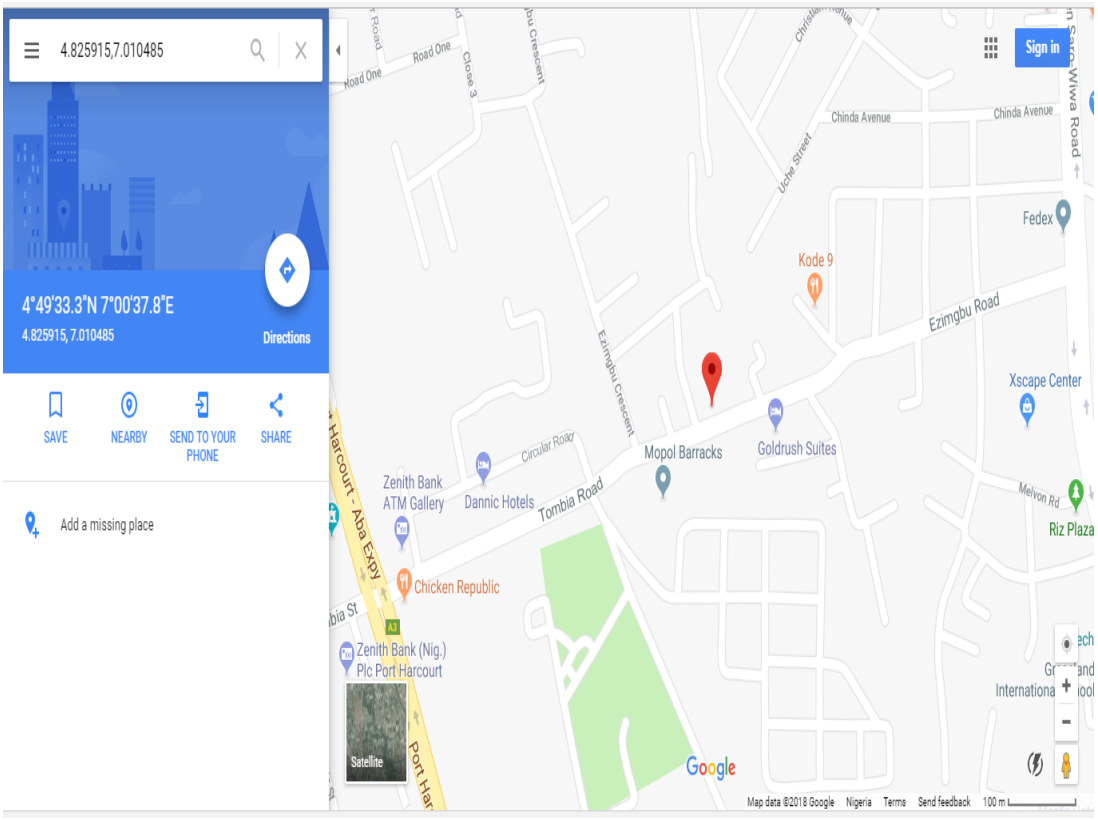


Location *20* (**4.82216, 7.01589**)

*Location 21 (***4.825915, 7.010485***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB33 to eNB 34)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.82216	0.08416	7.01589	0.12245	2.641894	3.4
eNB 1	4.8366	0.08441	7.0286	0.12267	4.82216	0.08416	7.01589	0.12245	2.135743	3
eNB 2	4.7737	0.08332	7.0142	0.12242	4.82216	0.08416	7.01589	0.12245	5.391719	7
eNB 3	4.7999	0.08377	6.9939	0.12207	4.82216	0.08416	7.01589	0.12245	3.473214	4.2
eNB 4	4.8294	0.08429	7.0919	0.12378	4.82216	0.08416	7.01589	0.12245	8.460331	11.5
eNB 5	4.7706	0.08326	7.0224	0.12256	4.82216	0.08416	7.01589	0.12245	5.778371	7
eNB 6	4.8746	0.08508	6.983	0.12188	4.82216	0.08416	7.01589	0.12245	6.876091	9.5
eNB 7	4.8692	0.08498	7.1137	0.12416	4.82216	0.08416	7.01589	0.12245	12.03334	15.3
eNB 8	4.7196	0.08237	7.1518	0.12482	4.82216	0.08416	7.01589	0.12245	18.89072	25.1
eNB 9	4.8554	0.08474	7.0641	0.12329	4.82216	0.08416	7.01589	0.12245	6.495682	7.6
eNB 10	4.7909	0.08362	7.1207	0.12428	4.82216	0.08416	7.01589	0.12245	12.12234	15.7
eNB 11	4.7854	0.08352	7.0082	0.12232	4.82216	0.08416	7.01589	0.12245	4.175357	5.1
eNB 12	4.8327	0.08435	7.0685	0.12337	4.82216	0.08416	7.01589	0.12245	5.945852	8.6
eNB 13	4.8039	0.08384	6.9883	0.12197	4.82216	0.08416	7.01589	0.12245	3.669867	5
eNB 14	4.8197	0.08412	7.0656	0.12332	4.82216	0.08416	7.01589	0.12245	5.514718	7.9
eNB 15	4.743	0.08278	7.0417	0.1229	4.82216	0.08416	7.01589	0.12245	9.255101	11.5
eNB 16	4.7939	0.08367	7.0308	0.12271	4.82216	0.08416	7.01589	0.12245	3.550164	4.5
eNB 17	4.748	0.08287	7.0989	0.1239	4.82216	0.08416	7.01589	0.12245	12.3533	20.4
eNB 18	4.7773	0.08338	7.062	0.12325	4.82216	0.08416	7.01589	0.12245	7.140433	8.9
eNB 19	4.8341	0.08437	6.9845	0.1219	4.82216	0.08416	7.01589	0.12245	3.722799	5.1
eNB 20	4.8565	0.08476	7.0405	0.12288	4.82216	0.08416	7.01589	0.12245	4.69208	6.4
eNB 21	4.8064	0.08389	7.0424	0.12291	4.82216	0.08416	7.01589	0.12245	3.420394	4.6
eNB 22	4.8146	0.08403	6.9788	0.1218	4.82216	0.08416	7.01589	0.12245	4.194712	5.9
eNB 23	4.8298	0.0843	6.9588	0.12145	4.82216	0.08416	7.01589	0.12245	6.382373	8
eNB 24	4.8923	0.08539	6.9143	0.12068	4.82216	0.08416	7.01589	0.12245	13.69371	15.7
eNB 25	4.848	0.08461	7.0492	0.12303	4.82216	0.08416	7.01589	0.12245	4.677301	5.6
eNB 26	4.8514	0.08467	6.9835	0.12188	4.82216	0.08416	7.01589	0.12245	4.842563	6.9
eNB 27	4.8081	0.08392	6.9967	0.12211	4.82216	0.08416	7.01589	0.12245	2.639171	3.4
eNB 28	4.9028	0.08557	6.999	0.12216	4.82216	0.08416	7.01589	0.12245	9.159926	11
eNB 29	4.9789	0.0869	6.9611	0.12149	4.82216	0.08416	7.01589	0.12245	18.45544	23.3
eNB 30	4.9969	0.08721	6.95	0.1213	4.82216	0.08416	7.01589	0.12245	20.75611	23.9
eNB 31	4.9539	0.08646	7.0111	0.12237	4.82216	0.08416	7.01589	0.12245	14.65839	16.8
eNB 32	4.9669	0.08669	6.9869	0.12194	4.82216	0.08416	7.01589	0.12245	16.41165	20.2
eNB 33	4.8289	0.08428	7.0219	0.12255	4.82216	0.08416	7.01589	0.12245	1.002572	1.6
eNB 34	4.8169	0.08407	7.0112	0.12237	4.82216	0.08416	7.01589	0.12245	0.78237	1.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.82216	0.08416	7.01589	0.12245	12.27571	14.1
eNB 36	4.8407	0.08449	6.9681	0.12162	4.82216	0.08416	7.01589	0.12245	5.68226	7.4
eNB 37	4.8598	0.08482	6.9792	0.12181	4.82216	0.08416	7.01589	0.12245	5.834634	7.8
eNB 38	4.8469	0.08459	7.0369	0.12282	4.82216	0.08416	7.01589	0.12245	3.603737	4.7
eNB 39	4.8585	0.0848	6.9658	0.12158	4.82216	0.08416	7.01589	0.12245	6.865073	8.3
eNB 40	4.88	0.08517	7.01	0.12235	4.82216	0.08416	7.01589	0.12245	6.46453	7.6

eNB 41	4.8669	0.08494	7.03	0.1227	4.82216	0.08416	7.01589	0.12245	5.214721	6.7
eNB 42	4.8378	0.08444	7.037	0.12282	4.82216	0.08416	7.01589	0.12245	2.914676	3.8
eNB 43	4.8842	0.08525	7.138	0.12458	4.82216	0.08416	7.01589	0.12245	15.18655	19.3
eNB 44	4.7815	0.08345	7.0398	0.12287	4.82216	0.08416	7.01589	0.12245	5.240207	6.3
eNB 45	4.8116	0.08398	6.9561	0.12141	4.82216	0.08416	7.01589	0.12245	6.728083	9.3
eNB 46	4.9011	0.08554	6.9269	0.1209	4.82216	0.08416	7.01589	0.12245	13.20075	16.2
eNB 47	4.9058	0.08562	6.9066	0.12054	4.82216	0.08416	7.01589	0.12245	15.26814	17.6
eNB 48	4.8024	0.08382	6.944	0.1212	4.82216	0.08416	7.01589	0.12245	8.26306	11.1
eNB 49	4.8354	0.08439	7.0528	0.12309	4.82216	0.08416	7.01589	0.12245	4.346555	6
eNB 50	4.7947	0.08368	7.0497	0.12304	4.82216	0.08416	7.01589	0.12245	4.832972	6.2
eNB 51	4.7581	0.08304	7.0119	0.12238	4.82216	0.08416	7.01589	0.12245	7.136807	8.6
eNB 52	4.8269	0.08424	6.9961	0.1221	4.82216	0.08416	7.01589	0.12245	2.255193	3.3
eNB 53	4.815	0.08404	7.0419	0.1229	4.82216	0.08416	7.01589	0.12245	2.989898	4.8
eNB 54	4.71	0.0822	7.165	0.12505	4.82216	0.08416	7.01589	0.12245	20.70134	26.8
eNB 55	4.8233	0.08418	7.0572	0.12317	4.82216	0.08416	7.01589	0.12245	4.578945	7
eNB 56	4.815	0.08404	7.0652	0.12331	4.82216	0.08416	7.01589	0.12245	5.521329	7.9
eNB 57	4.894	0.08542	7.0153	0.12244	4.82216	0.08416	7.01589	0.12245	7.988497	9.6
eNB 58	4.8626	0.08487	7.0153	0.12244	4.82216	0.08416	7.01589	0.12245	4.497198	5.9
eNB 59	4.8276	0.08426	7.0145	0.12243	4.82216	0.08416	7.01589	0.12245	0.624212	0.95
									443.6109	567.95

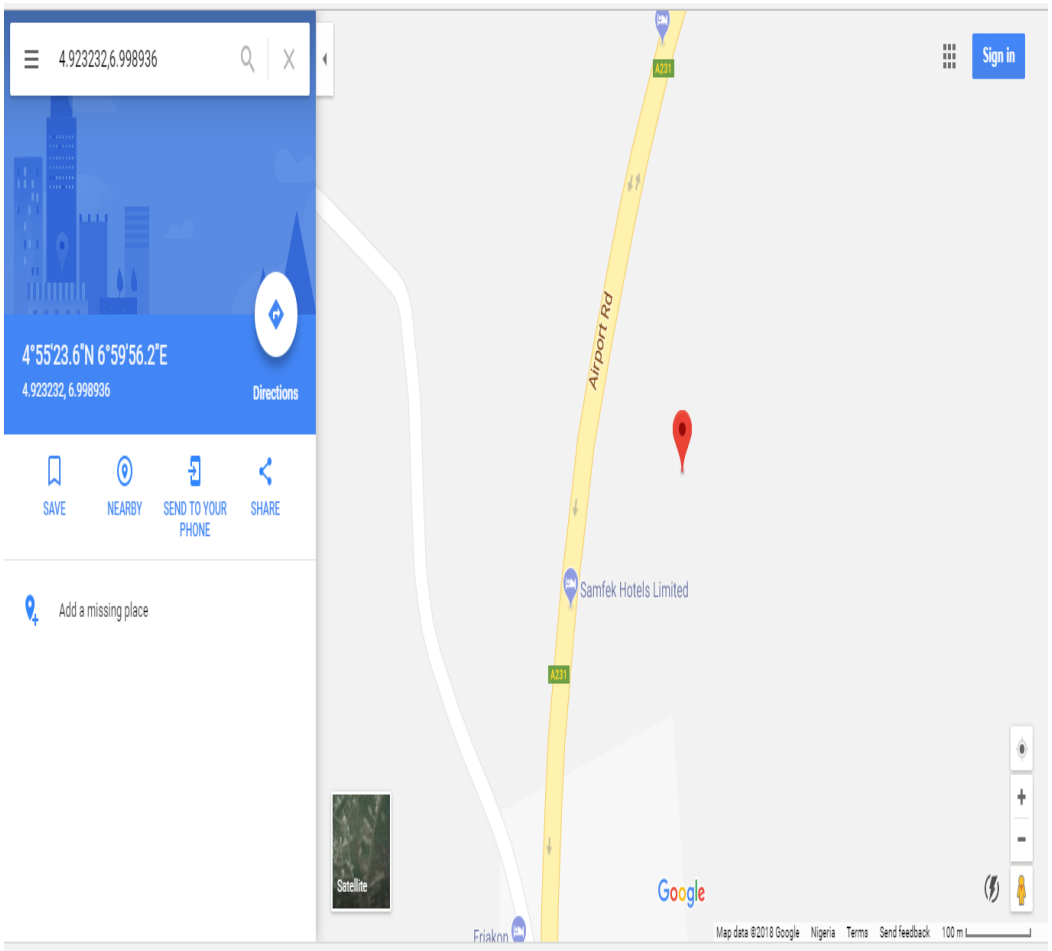


Location *21* (**4.825915, 7.010485**)

Location *22 (***4.923232, 6.998936***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB34 to eNB 35)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.825915	0.08423	7.010485	0.12236	2.502824	3.2
eNB 1	4.8366	0.08441	7.0286	0.12267	4.825915	0.08423	7.010485	0.12236	2.332396	3.1
eNB 2	4.7737	0.08332	7.0142	0.12242	4.825915	0.08423	7.010485	0.12236	5.820546	7.2
eNB 3	4.7999	0.08377	6.9939	0.12207	4.825915	0.08423	7.010485	0.12236	3.427067	4
eNB 4	4.8294	0.08429	7.0919	0.12378	4.825915	0.08423	7.010485	0.12236	9.029048	11.8
eNB 5	4.7706	0.08326	7.0224	0.12256	4.825915	0.08423	7.010485	0.12236	6.290766	7.4
eNB 6	4.8746	0.08508	6.983	0.12188	4.825915	0.08423	7.010485	0.12236	6.211304	8.4
eNB 7	4.8692	0.08498	7.1137	0.12416	4.825915	0.08423	7.010485	0.12236	12.40742	15.2
eNB 8	4.7196	0.08237	7.1518	0.12482	4.825915	0.08423	7.010485	0.12236	19.62018	25.5
eNB 9	4.8554	0.08474	7.0641	0.12329	4.825915	0.08423	7.010485	0.12236	6.785082	7.5
eNB 10	4.7909	0.08362	7.1207	0.12428	4.825915	0.08423	7.010485	0.12236	12.81774	16.1
eNB 11	4.7854	0.08352	7.0082	0.12232	4.825915	0.08423	7.010485	0.12236	4.512113	5.4
eNB 12	4.8327	0.08435	7.0685	0.12337	4.825915	0.08423	7.010485	0.12236	6.47212	9
eNB 13	4.8039	0.08384	6.9883	0.12197	4.825915	0.08423	7.010485	0.12236	3.469146	4.5
eNB 14	4.8197	0.08412	7.0656	0.12332	4.825915	0.08423	7.010485	0.12236	6.145704	8.8
eNB 15	4.743	0.08278	7.0417	0.1229	4.825915	0.08423	7.010485	0.12236	9.847085	11.9
eNB 16	4.7939	0.08367	7.0308	0.12271	4.825915	0.08423	7.010485	0.12236	4.21178	5.5
eNB 17	4.748	0.08287	7.0989	0.1239	4.825915	0.08423	7.010485	0.12236	13.07818	20.8
eNB 18	4.7773	0.08338	7.062	0.12325	4.825915	0.08423	7.010485	0.12236	7.861481	9.9
eNB 19	4.8341	0.08437	6.9845	0.1219	4.825915	0.08423	7.010485	0.12236	3.019621	4
eNB 20	4.8565	0.08476	7.0405	0.12288	4.825915	0.08423	7.010485	0.12236	4.756629	6.3
eNB 21	4.8064	0.08389	7.0424	0.12291	4.825915	0.08423	7.010485	0.12236	4.148874	5.4
eNB 22	4.8146	0.08403	6.9788	0.1218	4.825915	0.08423	7.010485	0.12236	3.729414	4.9
eNB 23	4.8298	0.0843	6.9588	0.12145	4.825915	0.08423	7.010485	0.12236	5.743025	6.7
eNB 24	4.8923	0.08539	6.9143	0.12068	4.825915	0.08423	7.010485	0.12236	12.96372	14.6
eNB 25	4.848	0.08461	7.0492	0.12303	4.825915	0.08423	7.010485	0.12236	4.942743	5.5
eNB 26	4.8514	0.08467	6.9835	0.12188	4.825915	0.08423	7.010485	0.12236	4.119514	5.9
eNB 27	4.8081	0.08392	6.9967	0.12211	4.825915	0.08423	7.010485	0.12236	2.501406	3.2
eNB 28	4.9028	0.08557	6.999	0.12216	4.825915	0.08423	7.010485	0.12236	8.643418	10.8
eNB 29	4.9789	0.0869	6.9611	0.12149	4.825915	0.08423	7.010485	0.12236	17.86935	23.1
eNB 30	4.9969	0.08721	6.95	0.1213	4.825915	0.08423	7.010485	0.12236	20.15894	23.7
eNB 31	4.9539	0.08646	7.0111	0.12237	4.825915	0.08423	7.010485	0.12236	14.23143	16.6
eNB 32	4.9669	0.08669	6.9869	0.12194	4.825915	0.08423	7.010485	0.12236	15.89307	20
eNB 33	4.8289	0.08428	7.0219	0.12255	4.825915	0.08423	7.010485	0.12236	1.307567	1.7
eNB 34	4.8169	0.08407	7.0112	0.12237	4.825915	0.08423	7.010485	0.12236	1.005496	1.4
eNB 35	4.9317	0.08607	7.0021	0.12221	4.825915	0.08423	7.010485	0.12236	11.79938	13.9
eNB 36	4.8407	0.08449	6.9681	0.12162	4.825915	0.08423	7.010485	0.12236	4.975732	6.4
eNB 37	4.8598	0.08482	6.9792	0.12181	4.825915	0.08423	7.010485	0.12236	5.11981	6.7
eNB 38	4.8469	0.08459	7.0369	0.12282	4.825915	0.08423	7.010485	0.12236	3.743066	4.6
eNB 39	4.8585	0.0848	6.9658	0.12158	4.825915	0.08423	7.010485	0.12236	6.135249	7.2
eNB 40	4.88	0.08517	7.01	0.12235	4.825915	0.08423	7.010485	0.12236	6.014238	7.4

eNB 41	4.8669	0.08494	7.03	0.1227	4.825915	0.08423	7.010485	0.12236	5.044236	6.5
eNB 42	4.8378	0.08444	7.037	0.12282	4.825915	0.08423	7.010485	0.12236	3.221367	3.9
eNB 43	4.8842	0.08525	7.138	0.12458	4.825915	0.08423	7.010485	0.12236	15.54364	19.2
eNB 44	4.7815	0.08345	7.0398	0.12287	4.825915	0.08423	7.010485	0.12236	5.911083	7.3
eNB 45	4.8116	0.08398	6.9561	0.12141	4.825915	0.08423	7.010485	0.12236	6.232665	8
eNB 46	4.9011	0.08554	6.9269	0.1209	4.825915	0.08423	7.010485	0.12236	12.47618	15.1
eNB 47	4.9058	0.08562	6.9066	0.12054	4.825915	0.08423	7.010485	0.12236	14.53896	16.5
eNB 48	4.8024	0.08382	6.944	0.1212	4.825915	0.08423	7.010485	0.12236	7.817	9.8
eNB 49	4.8354	0.08439	7.0528	0.12309	4.825915	0.08423	7.010485	0.12236	4.805599	6.2
eNB 50	4.7947	0.08368	7.0497	0.12304	4.825915	0.08423	7.010485	0.12236	5.561186	7.1
eNB 51	4.7581	0.08304	7.0119	0.12238	4.825915	0.08423	7.010485	0.12236	7.542238	8.8
eNB 52	4.8269	0.08424	6.9961	0.1221	4.825915	0.08423	7.010485	0.12236	1.597678	2
eNB 53	4.815	0.08404	7.0419	0.1229	4.825915	0.08423	7.010485	0.12236	3.686278	5.6
eNB 54	4.71	0.0822	7.165	0.12505	4.825915	0.08423	7.010485	0.12236	21.43083	27.2
eNB 55	4.8233	0.08418	7.0572	0.12317	4.825915	0.08423	7.010485	0.12236	5.184149	7.9
eNB 56	4.815	0.08404	7.0652	0.12331	4.825915	0.08423	7.010485	0.12236	6.182718	8.8
eNB 57	4.894	0.08542	7.0153	0.12244	4.825915	0.08423	7.010485	0.12236	7.589489	9.4
eNB 58	4.8626	0.08487	7.0153	0.12244	4.825915	0.08423	7.010485	0.12236	4.113944	5.7
eNB 59	4.8276	0.08426	7.0145	0.12243	4.825915	0.08423	7.010485	0.12236	0.482675	0.55
									444.6256	560.75

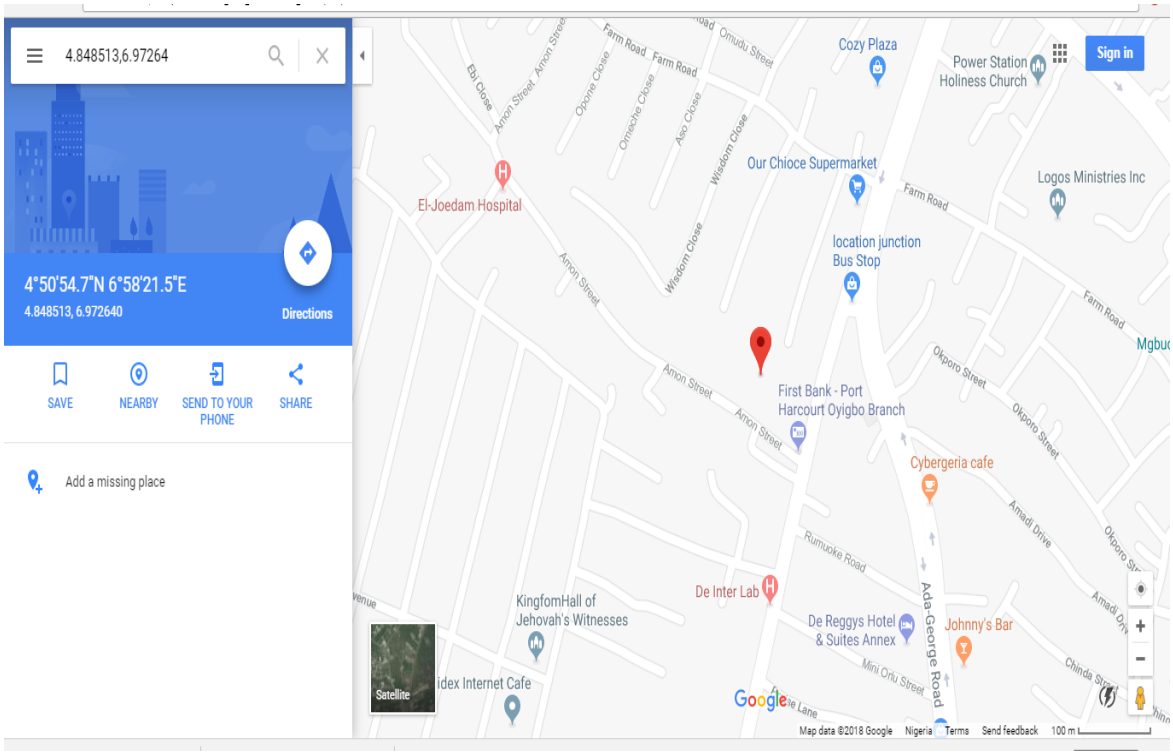


*Location 22 (***4.923232, 6.998936***)*

*Location 23 (***4.848513, 6.97264***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB35 to eNB 36)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.923232	0.08593	6.998936	0.12215	12.80266	14.2
eNB 1	4.8366	0.08441	7.0286	0.12267	4.923232	0.08593	6.998936	0.12215	10.17823	12.8
eNB 2	4.7737	0.08332	7.0142	0.12242	4.923232	0.08593	6.998936	0.12215	16.71294	19.2
eNB 3	4.7999	0.08377	6.9939	0.12207	4.923232	0.08593	6.998936	0.12215	13.7252	15.2
eNB 4	4.8294	0.08429	7.0919	0.12378	4.923232	0.08593	6.998936	0.12215	14.66096	15.7
eNB 5	4.7706	0.08326	7.0224	0.12256	4.923232	0.08593	6.998936	0.12215	17.16981	20
eNB 6	4.8746	0.08508	6.983	0.12188	4.923232	0.08593	6.998936	0.12215	5.688533	7
eNB 7	4.8692	0.08498	7.1137	0.12416	4.923232	0.08593	6.998936	0.12215	14.06262	18.9
eNB 8	4.7196	0.08237	7.1518	0.12482	4.923232	0.08593	6.998936	0.12215	28.27674	30.4
eNB 9	4.8554	0.08474	7.0641	0.12329	4.923232	0.08593	6.998936	0.12215	10.44087	12.3
eNB 10	4.7909	0.08362	7.1207	0.12428	4.923232	0.08593	6.998936	0.12215	19.96305	21
eNB 11	4.7854	0.08352	7.0082	0.12232	4.923232	0.08593	6.998936	0.12215	15.3605	18
eNB 12	4.8327	0.08435	7.0685	0.12337	4.923232	0.08593	6.998936	0.12215	12.67824	14.8
eNB 13	4.8039	0.08384	6.9883	0.12197	4.923232	0.08593	6.998936	0.12215	13.3213	14.4
eNB 14	4.8197	0.08412	7.0656	0.12332	4.923232	0.08593	6.998936	0.12215	13.67781	16.4
eNB 15	4.743	0.08278	7.0417	0.1229	4.923232	0.08593	6.998936	0.12215	20.59333	24.4
eNB 16	4.7939	0.08367	7.0308	0.12271	4.923232	0.08593	6.998936	0.12215	14.80802	17.4
eNB 17	4.748	0.08287	7.0989	0.1239	4.923232	0.08593	6.998936	0.12215	22.41282	25.7
eNB 18	4.7773	0.08338	7.062	0.12325	4.923232	0.08593	6.998936	0.12215	17.66727	20
eNB 19	4.8341	0.08437	6.9845	0.1219	4.923232	0.08593	6.998936	0.12215	10.03922	10.7
eNB 20	4.8565	0.08476	7.0405	0.12288	4.923232	0.08593	6.998936	0.12215	8.732983	10.9
eNB 21	4.8064	0.08389	7.0424	0.12291	4.923232	0.08593	6.998936	0.12215	13.85489	16.6
eNB 22	4.8146	0.08403	6.9788	0.1218	4.923232	0.08593	6.998936	0.12215	12.28358	13.5
eNB 23	4.8298	0.0843	6.9588	0.12145	4.923232	0.08593	6.998936	0.12215	11.30078	13.9
eNB 24	4.8923	0.08539	6.9143	0.12068	4.923232	0.08593	6.998936	0.12215	9.987463	13.5
eNB 25	4.848	0.08461	7.0492	0.12303	4.923232	0.08593	6.998936	0.12215	10.04944	12.5
eNB 26	4.8514	0.08467	6.9835	0.12188	4.923232	0.08593	6.998936	0.12215	8.168361	13.4
eNB 27	4.8081	0.08392	6.9967	0.12211	4.923232	0.08593	6.998936	0.12215	12.80445	14.2
eNB 28	4.9028	0.08557	6.999	0.12216	4.923232	0.08593	6.998936	0.12215	2.271952	2.5
eNB 29	4.9789	0.0869	6.9611	0.12149	4.923232	0.08593	6.998936	0.12215	7.475543	10.4
eNB 30	4.9969	0.08721	6.95	0.1213	4.923232	0.08593	6.998936	0.12215	9.822802	13.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.923232	0.08593	6.998936	0.12215	3.666702	3.8
eNB 32	4.9669	0.08669	6.9869	0.12194	4.923232	0.08593	6.998936	0.12215	5.035364	7.2
eNB 33	4.8289	0.08428	7.0219	0.12255	4.923232	0.08593	6.998936	0.12215	10.79337	12.7
eNB 34	4.8169	0.08407	7.0112	0.12237	4.923232	0.08593	6.998936	0.12215	11.90137	14
eNB 35	4.9317	0.08607	7.0021	0.12221	4.923232	0.08593	6.998936	0.12215	1.004714	3.1
eNB 36	4.8407	0.08449	6.9681	0.12162	4.923232	0.08593	6.998936	0.12215	9.792386	11.9
eNB 37	4.8598	0.08482	6.9792	0.12181	4.923232	0.08593	6.998936	0.12215	7.384441	9.2
eNB 38	4.8469	0.08459	7.0369	0.12282	4.923232	0.08593	6.998936	0.12215	9.472713	10.8
eNB 39	4.8585	0.0848	6.9658	0.12158	4.923232	0.08593	6.998936	0.12215	8.079984	10.3
eNB 40	4.88	0.08517	7.01	0.12235	4.923232	0.08593	6.998936	0.12215	4.960993	5.5

eNB 41	4.8669	0.08494	7.03	0.1227	4.923232	0.08593	6.998936	0.12215	7.147016	8.5
eNB 42	4.8378	0.08444	7.037	0.12282	4.923232	0.08593	6.998936	0.12215	10.39359	12
eNB 43	4.8842	0.08525	7.138	0.12458	4.923232	0.08593	6.998936	0.12215	16.00623	19.1
eNB 44	4.7815	0.08345	7.0398	0.12287	4.923232	0.08593	6.998936	0.12215	16.39729	19
eNB 45	4.8116	0.08398	6.9561	0.12141	4.923232	0.08593	6.998936	0.12215	13.28922	15.3
eNB 46	4.9011	0.08554	6.9269	0.1209	4.923232	0.08593	6.998936	0.12215	8.351397	13.9
eNB 47	4.9058	0.08562	6.9066	0.12054	4.923232	0.08593	6.998936	0.12215	10.41152	13.6
eNB 48	4.8024	0.08382	6.944	0.1212	4.923232	0.08593	6.998936	0.12215	14.75022	17.2
eNB 49	4.8354	0.08439	7.0528	0.12309	4.923232	0.08593	6.998936	0.12215	11.44539	13.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.923232	0.08593	6.998936	0.12215	15.35894	17.8
eNB 51	4.7581	0.08304	7.0119	0.12238	4.923232	0.08593	6.998936	0.12215	18.41788	20.8
eNB 52	4.8269	0.08424	6.9961	0.1221	4.923232	0.08593	6.998936	0.12215	10.71621	11.9
eNB 53	4.815	0.08404	7.0419	0.1229	4.923232	0.08593	6.998936	0.12215	12.94201	15.1
eNB 54	4.71	0.0822	7.165	0.12505	4.923232	0.08593	6.998936	0.12215	30.01237	32.1
eNB 55	4.8233	0.08418	7.0572	0.12317	4.923232	0.08593	6.998936	0.12215	12.85085	15.4
eNB 56	4.815	0.08404	7.0652	0.12331	4.923232	0.08593	6.998936	0.12215	14.09738	16.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.923232	0.08593	6.998936	0.12215	3.721849	4.5
eNB 58	4.8626	0.08487	7.0153	0.12244	4.923232	0.08593	6.998936	0.12215	6.981467	7.7
eNB 59	4.8276	0.08426	7.0145	0.12243	4.923232	0.08593	6.998936	0.12215	10.77267	12.3
									727.1479	857.8

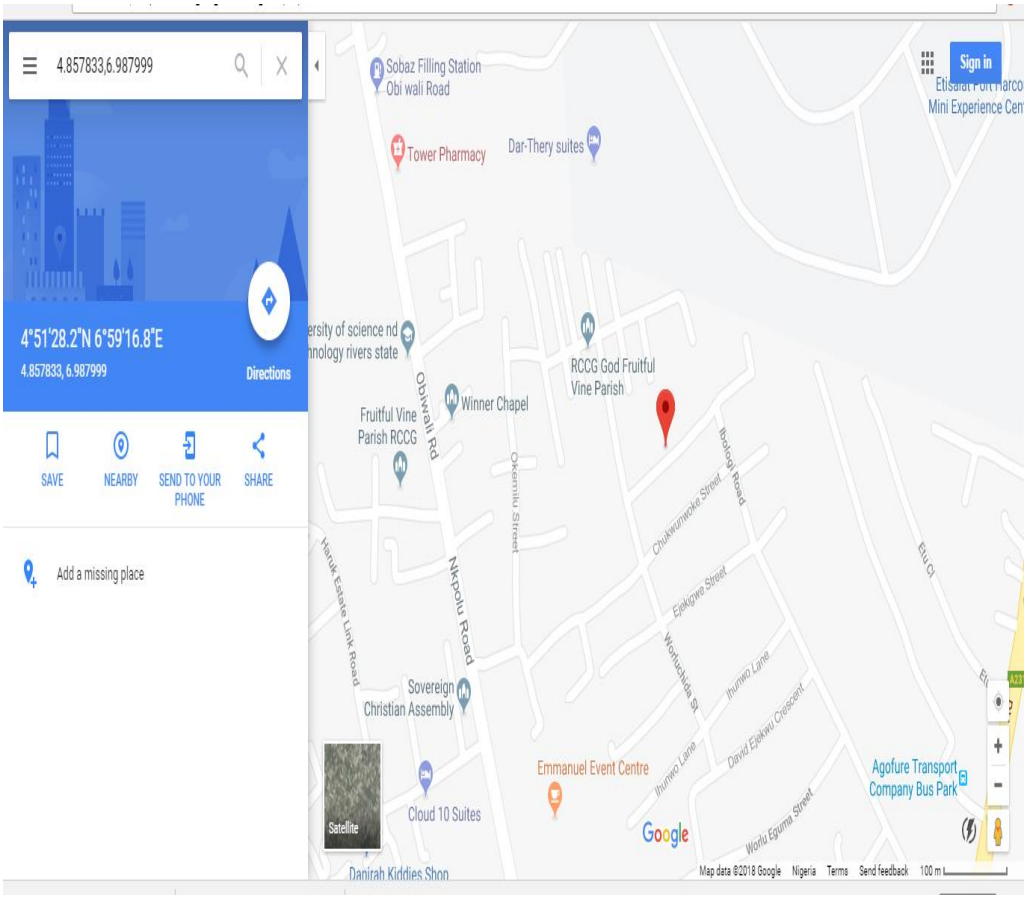


*Location 23 (***4.848513, 6.97264***)*

*Location 24 (***4.857833, 6.987999***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB36 to eNB 37)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.848513	0.08462	6.97264	0.1217	5.220841	6.9
eNB 1	4.8366	0.08441	7.0286	0.12267	4.848513	0.08462	6.97264	0.1217	6.34013	8.2
eNB 2	4.7737	0.08332	7.0142	0.12242	4.848513	0.08462	6.97264	0.1217	9.508258	10.7
eNB 3	4.7999	0.08377	6.9939	0.12207	4.848513	0.08462	6.97264	0.1217	5.896416	6.7
eNB 4	4.8294	0.08429	7.0919	0.12378	4.848513	0.08462	6.97264	0.1217	13.38358	16.9
eNB 5	4.7706	0.08326	7.0224	0.12256	4.848513	0.08462	6.97264	0.1217	10.2691	12.2
eNB 6	4.8746	0.08508	6.983	0.12188	4.848513	0.08462	6.97264	0.1217	3.119616	4.3
eNB 7	4.8692	0.08498	7.1137	0.12416	4.848513	0.08462	6.97264	0.1217	15.79709	20.7
eNB 8	4.7196	0.08237	7.1518	0.12482	4.848513	0.08462	6.97264	0.1217	24.48638	30.5
eNB 9	4.8554	0.08474	7.0641	0.12329	4.848513	0.08462	6.97264	0.1217	10.16229	12.6
eNB 10	4.7909	0.08362	7.1207	0.12428	4.848513	0.08462	6.97264	0.1217	17.61166	21.2
eNB 11	4.7854	0.08352	7.0082	0.12232	4.848513	0.08462	6.97264	0.1217	8.048191	9.6
eNB 12	4.8327	0.08435	7.0685	0.12337	4.848513	0.08462	6.97264	0.1217	10.76562	14.1
eNB 13	4.8039	0.08384	6.9883	0.12197	4.848513	0.08462	6.97264	0.1217	5.255364	5.8
eNB 14	4.8197	0.08412	7.0656	0.12332	4.848513	0.08462	6.97264	0.1217	10.78662	14.3
eNB 15	4.743	0.08278	7.0417	0.1229	4.848513	0.08462	6.97264	0.1217	14.00734	16.2
eNB 16	4.7939	0.08367	7.0308	0.12271	4.848513	0.08462	6.97264	0.1217	8.854602	11.3
eNB 17	4.748	0.08287	7.0989	0.1239	4.848513	0.08462	6.97264	0.1217	17.90638	25.8
eNB 18	4.7773	0.08338	7.062	0.12325	4.848513	0.08462	6.97264	0.1217	12.67822	15.7
eNB 19	4.8341	0.08437	6.9845	0.1219	4.848513	0.08462	6.97264	0.1217	2.072444	2.7
eNB 20	4.8565	0.08476	7.0405	0.12288	4.848513	0.08462	6.97264	0.1217	7.570871	10.4
eNB 21	4.8064	0.08389	7.0424	0.12291	4.848513	0.08462	6.97264	0.1217	9.037202	11.4
eNB 22	4.8146	0.08403	6.9788	0.1218	4.848513	0.08462	6.97264	0.1217	3.832155	4.1
eNB 23	4.8298	0.0843	6.9588	0.12145	4.848513	0.08462	6.97264	0.1217	2.584754	3.2
eNB 24	4.8923	0.08539	6.9143	0.12068	4.848513	0.08462	6.97264	0.1217	8.092316	9.3
eNB 25	4.848	0.08461	7.0492	0.12303	4.848513	0.08462	6.97264	0.1217	8.482764	10.6
eNB 26	4.8514	0.08467	6.9835	0.12188	4.848513	0.08462	6.97264	0.1217	1.245331	1.9
eNB 27	4.8081	0.08392	6.9967	0.12211	4.848513	0.08462	6.97264	0.1217	5.224897	6.9
eNB 28	4.9028	0.08557	6.999	0.12216	4.848513	0.08462	6.97264	0.1217	6.705819	9
eNB 29	4.9789	0.0869	6.9611	0.12149	4.848513	0.08462	6.97264	0.1217	14.55463	17.8
eNB 30	4.9969	0.08721	6.95	0.1213	4.848513	0.08462	6.97264	0.1217	16.68941	18.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.848513	0.08462	6.97264	0.1217	12.4691	14.6
eNB 32	4.9669	0.08669	6.9869	0.12194	4.848513	0.08462	6.97264	0.1217	13.25849	18
eNB 33	4.8289	0.08428	7.0219	0.12255	4.848513	0.08462	6.97264	0.1217	5.877466	7.6
eNB 34	4.8169	0.08407	7.0112	0.12237	4.848513	0.08462	6.97264	0.1217	5.532595	7.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.848513	0.08462	6.97264	0.1217	9.808921	11.8
eNB 36	4.8407	0.08449	6.9681	0.12162	4.848513	0.08462	6.97264	0.1217	1.003846	1.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.848513	0.08462	6.97264	0.1217	1.450353	2.6
eNB 38	4.8469	0.08459	7.0369	0.12282	4.848513	0.08462	6.97264	0.1217	7.122037	9.7
eNB 39	4.8585	0.0848	6.9658	0.12158	4.848513	0.08462	6.97264	0.1217	1.344497	1.7
eNB 40	4.88	0.08517	7.01	0.12235	4.848513	0.08462	6.97264	0.1217	5.421437	7.5

eNB 41	4.8669	0.08494	7.03	0.1227	4.848513	0.08462	6.97264	0.1217	6.675982	9.5
eNB 42	4.8378	0.08444	7.037	0.12282	4.848513	0.08462	6.97264	0.1217	7.229712	9
eNB 43	4.8842	0.08525	7.138	0.12458	4.848513	0.08462	6.97264	0.1217	18.74565	23.1
eNB 44	4.7815	0.08345	7.0398	0.12287	4.848513	0.08462	6.97264	0.1217	10.53085	13.1
eNB 45	4.8116	0.08398	6.9561	0.12141	4.848513	0.08462	6.97264	0.1217	4.495027	5.4
eNB 46	4.9011	0.08554	6.9269	0.1209	4.848513	0.08462	6.97264	0.1217	7.737805	9.8
eNB 47	4.9058	0.08562	6.9066	0.12054	4.848513	0.08462	6.97264	0.1217	9.701124	11.2
eNB 48	4.8024	0.08382	6.944	0.1212	4.848513	0.08462	6.97264	0.1217	6.030003	7.3
eNB 49	4.8354	0.08439	7.0528	0.12309	4.848513	0.08462	6.97264	0.1217	9.000408	11.3
eNB 50	4.7947	0.08368	7.0497	0.12304	4.848513	0.08462	6.97264	0.1217	10.42626	13.1
eNB 51	4.7581	0.08304	7.0119	0.12238	4.848513	0.08462	6.97264	0.1217	10.95418	12.4
eNB 52	4.8269	0.08424	6.9961	0.1221	4.848513	0.08462	6.97264	0.1217	3.540024	4.6
eNB 53	4.815	0.08404	7.0419	0.1229	4.848513	0.08462	6.97264	0.1217	8.530859	11.2
eNB 54	4.71	0.0822	7.165	0.12505	4.848513	0.08462	6.97264	0.1217	26.29724	32.3
eNB 55	4.8233	0.08418	7.0572	0.12317	4.848513	0.08462	6.97264	0.1217	9.779567	13.4
eNB 56	4.815	0.08404	7.0652	0.12331	4.848513	0.08462	6.97264	0.1217	10.91159	14.3
eNB 57	4.894	0.08542	7.0153	0.12244	4.848513	0.08462	6.97264	0.1217	6.922558	10.1
eNB 58	4.8626	0.08487	7.0153	0.12244	4.848513	0.08462	6.97264	0.1217	4.979328	7
eNB 59	4.8276	0.08426	7.0145	0.12243	4.848513	0.08462	6.97264	0.1217	5.188288	6.5
									537.1555	675.9



*Location 24 (***4.857833, 6.987999***)*

*Location 25 (***4.848352, 7.028002***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB37 to eNB 38)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.857833	0.08478	6.987999	0.12196	5.610754	6.8
eNB 1	4.8366	0.08441	7.0286	0.12267	4.857833	0.08478	6.987999	0.12196	5.080351	7.9
eNB 2	4.7737	0.08332	7.0142	0.12242	4.857833	0.08478	6.987999	0.12196	9.795214	11.7
eNB 3	4.7999	0.08377	6.9939	0.12207	4.857833	0.08478	6.987999	0.12196	6.474923	7.7
eNB 4	4.8294	0.08429	7.0919	0.12378	4.857833	0.08478	6.987999	0.12196	11.93816	15
eNB 5	4.7706	0.08326	7.0224	0.12256	4.857833	0.08478	6.987999	0.12196	10.42187	12.7
eNB 6	4.8746	0.08508	6.983	0.12188	4.857833	0.08478	6.987999	0.12196	1.944939	3.1
eNB 7	4.8692	0.08498	7.1137	0.12416	4.857833	0.08478	6.987999	0.12196	13.98412	18.1
eNB 8	4.7196	0.08237	7.1518	0.12482	4.857833	0.08478	6.987999	0.12196	23.78418	29.6
eNB 9	4.8554	0.08474	7.0641	0.12329	4.857833	0.08478	6.987999	0.12196	8.435916	11.1
eNB 10	4.7909	0.08362	7.1207	0.12428	4.857833	0.08478	6.987999	0.12196	16.47965	20.2
eNB 11	4.7854	0.08352	7.0082	0.12232	4.857833	0.08478	6.987999	0.12196	8.35937	10.5
eNB 12	4.8327	0.08435	7.0685	0.12337	4.857833	0.08478	6.987999	0.12196	9.3468	13.2
eNB 13	4.8039	0.08384	6.9883	0.12197	4.857833	0.08478	6.987999	0.12196	5.997147	6.9
eNB 14	4.8197	0.08412	7.0656	0.12332	4.857833	0.08478	6.987999	0.12196	9.586693	13.4
eNB 15	4.743	0.08278	7.0417	0.1229	4.857833	0.08478	6.987999	0.12196	14.08715	17.2
eNB 16	4.7939	0.08367	7.0308	0.12271	4.857833	0.08478	6.987999	0.12196	8.545605	11.2
eNB 17	4.748	0.08287	7.0989	0.1239	4.857833	0.08478	6.987999	0.12196	17.32494	24.9
eNB 18	4.7773	0.08338	7.062	0.12325	4.857833	0.08478	6.987999	0.12196	12.14161	15.4
eNB 19	4.8341	0.08437	6.9845	0.1219	4.857833	0.08478	6.987999	0.12196	2.667313	3.2
eNB 20	4.8565	0.08476	7.0405	0.12288	4.857833	0.08478	6.987999	0.12196	5.818692	7.9
eNB 21	4.8064	0.08389	7.0424	0.12291	4.857833	0.08478	6.987999	0.12196	8.308968	11.2
eNB 22	4.8146	0.08403	6.9788	0.1218	4.857833	0.08478	6.987999	0.12196	4.914146	6
eNB 23	4.8298	0.0843	6.9588	0.12145	4.857833	0.08478	6.987999	0.12196	4.492561	5.7
eNB 24	4.8923	0.08539	6.9143	0.12068	4.857833	0.08478	6.987999	0.12196	9.020031	9.9
eNB 25	4.848	0.08461	7.0492	0.12303	4.857833	0.08478	6.987999	0.12196	6.86835	9.5
eNB 26	4.8514	0.08467	6.9835	0.12188	4.857833	0.08478	6.987999	0.12196	0.871896	1.3
eNB 27	4.8081	0.08392	6.9967	0.12211	4.857833	0.08478	6.987999	0.12196	5.613433	6.8
eNB 28	4.9028	0.08557	6.999	0.12216	4.857833	0.08478	6.987999	0.12196	5.146472	6.9
eNB 29	4.9789	0.0869	6.9611	0.12149	4.857833	0.08478	6.987999	0.12196	13.78788	18.3
eNB 30	4.9969	0.08721	6.95	0.1213	4.857833	0.08478	6.987999	0.12196	16.02626	18.9
eNB 31	4.9539	0.08646	7.0111	0.12237	4.857833	0.08478	6.987999	0.12196	10.98441	12.7
eNB 32	4.9669	0.08669	6.9869	0.12194	4.857833	0.08478	6.987999	0.12196	12.12826	16.1
eNB 33	4.8289	0.08428	7.0219	0.12255	4.857833	0.08478	6.987999	0.12196	4.945558	7.3
eNB 34	4.8169	0.08407	7.0112	0.12237	4.857833	0.08478	6.987999	0.12196	5.227262	6.9
eNB 35	4.9317	0.08607	7.0021	0.12221	4.857833	0.08478	6.987999	0.12196	8.36084	9.9
eNB 36	4.8407	0.08449	6.9681	0.12162	4.857833	0.08478	6.987999	0.12196	2.913847	4
eNB 37	4.8598	0.08482	6.9792	0.12181	4.857833	0.08478	6.987999	0.12196	0.99917	1.6
eNB 38	4.8469	0.08459	7.0369	0.12282	4.857833	0.08478	6.987999	0.12196	5.552694	7.8
eNB 39	4.8585	0.0848	6.9658	0.12158	4.857833	0.08478	6.987999	0.12196	2.46071	3.7
eNB 40	4.88	0.08517	7.01	0.12235	4.857833	0.08478	6.987999	0.12196	3.466542	4.9

eNB 41	4.8669	0.08494	7.03	0.1227	4.857833	0.08478	6.987999	0.12196	4.761383	7
eNB 42	4.8378	0.08444	7.037	0.12282	4.857833	0.08478	6.987999	0.12196	5.868314	8.7
eNB 43	4.8842	0.08525	7.138	0.12458	4.857833	0.08478	6.987999	0.12196	16.87562	20.6
eNB 44	4.7815	0.08345	7.0398	0.12287	4.857833	0.08478	6.987999	0.12196	10.24624	13
eNB 45	4.8116	0.08398	6.9561	0.12141	4.857833	0.08478	6.987999	0.12196	6.238636	7.8
eNB 46	4.9011	0.08554	6.9269	0.1209	4.857833	0.08478	6.987999	0.12196	8.304797	10.4
eNB 47	4.9058	0.08562	6.9066	0.12054	4.857833	0.08478	6.987999	0.12196	10.47752	11.9
eNB 48	4.8024	0.08382	6.944	0.1212	4.857833	0.08478	6.987999	0.12196	7.858743	9.7
eNB 49	4.8354	0.08439	7.0528	0.12309	4.857833	0.08478	6.987999	0.12196	7.600672	10.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.857833	0.08478	6.987999	0.12196	9.798867	12.8
eNB 51	4.7581	0.08304	7.0119	0.12238	4.857833	0.08478	6.987999	0.12196	11.40158	13.4
eNB 52	4.8269	0.08424	6.9961	0.1221	4.857833	0.08478	6.987999	0.12196	3.554751	4.5
eNB 53	4.815	0.08404	7.0419	0.1229	4.857833	0.08478	6.987999	0.12196	7.63873	10.9
eNB 54	4.71	0.0822	7.165	0.12505	4.857833	0.08478	6.987999	0.12196	25.59065	31.3
eNB 55	4.8233	0.08418	7.0572	0.12317	4.857833	0.08478	6.987999	0.12196	8.575065	12.4
eNB 56	4.815	0.08404	7.0652	0.12331	4.857833	0.08478	6.987999	0.12196	9.790307	13.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.857833	0.08478	6.987999	0.12196	5.032068	7.5
eNB 58	4.8626	0.08487	7.0153	0.12244	4.857833	0.08478	6.987999	0.12196	3.070845	4.5
eNB 59	4.8276	0.08426	7.0145	0.12243	4.857833	0.08478	6.987999	0.12196	4.463469	6.3
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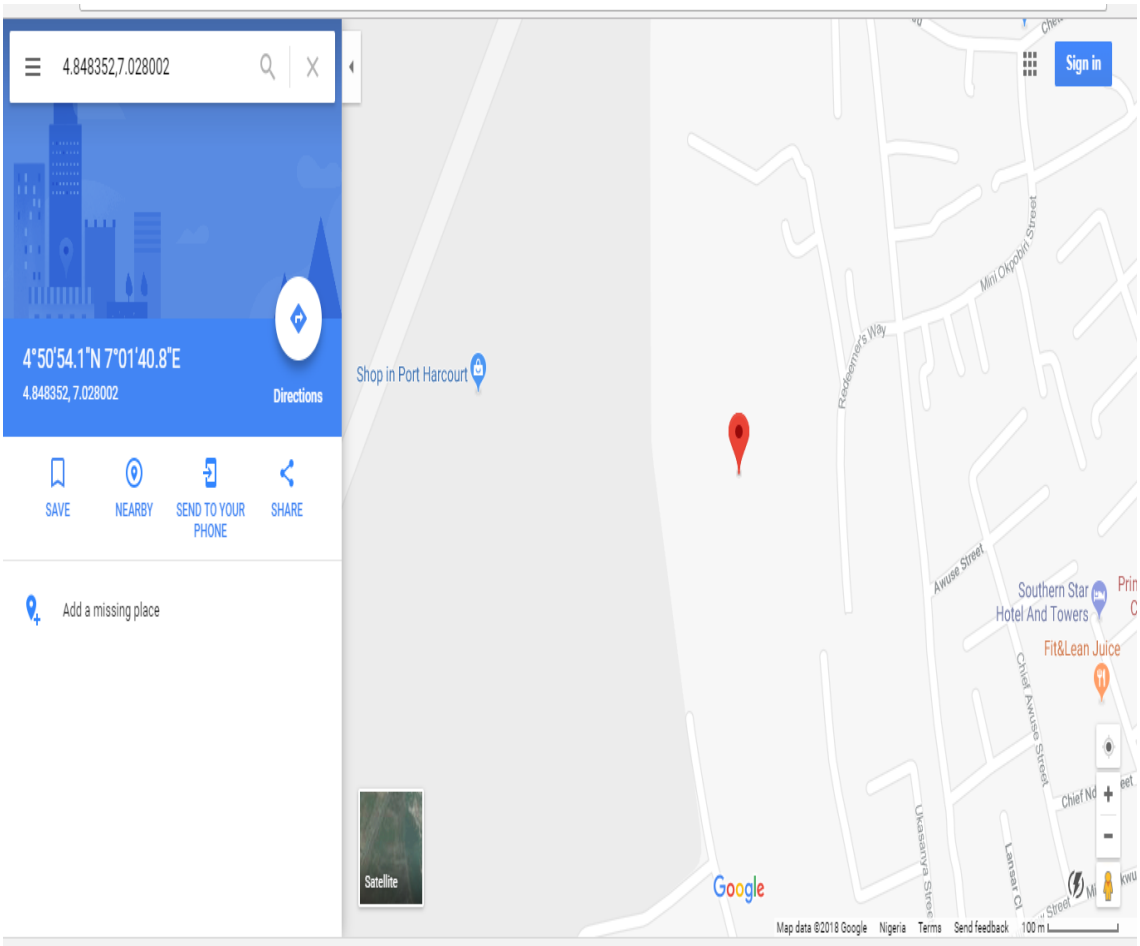
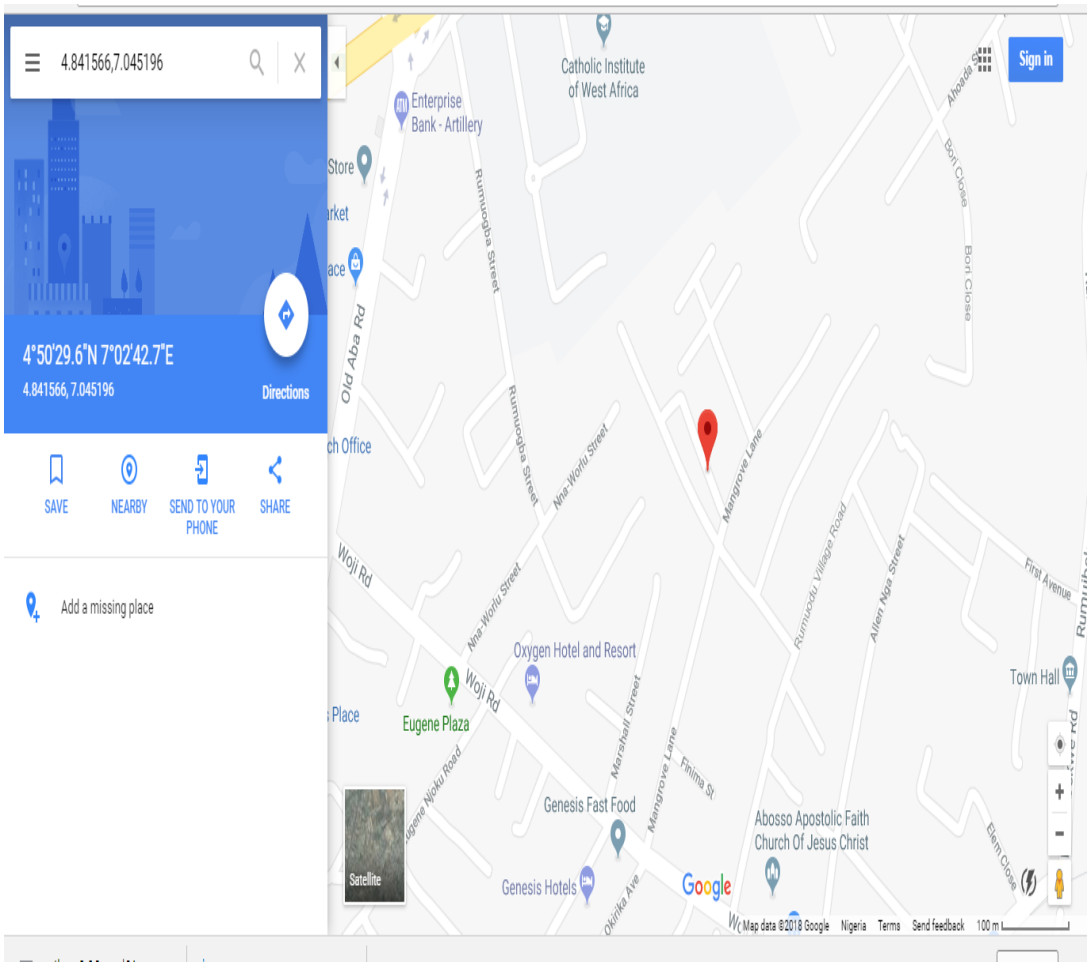


Location *25* (**4.848352, 7.028002**)

*Location 26 (***4.841566, 7.045196***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB38 to eNB 39)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.848352	0.08462	7.028002	0.12266	5.663729	7.9
eNB 1	4.8366	0.08441	7.0286	0.12267	4.848352	0.08462	7.028002	0.12266	1.30846	2.5
eNB 2	4.7737	0.08332	7.0142	0.12242	4.848352	0.08462	7.028002	0.12266	8.440608	11.1
eNB 3	4.7999	0.08377	6.9939	0.12207	4.848352	0.08462	7.028002	0.12266	6.580539	8.7
eNB 4	4.8294	0.08429	7.0919	0.12378	4.848352	0.08462	7.028002	0.12266	7.386788	9.2
eNB 5	4.7706	0.08326	7.0224	0.12256	4.848352	0.08462	7.028002	0.12266	8.667869	10.9
eNB 6	4.8746	0.08508	6.983	0.12188	4.848352	0.08462	7.028002	0.12266	5.77737	7.7
eNB 7	4.8692	0.08498	7.1137	0.12416	4.848352	0.08462	7.028002	0.12266	9.773812	12.7
eNB 8	4.7196	0.08237	7.1518	0.12482	4.848352	0.08462	7.028002	0.12266	19.82773	23.1
eNB 9	4.8554	0.08474	7.0641	0.12329	4.848352	0.08462	7.028002	0.12266	4.07559	4.9
eNB 10	4.7909	0.08362	7.1207	0.12428	4.848352	0.08462	7.028002	0.12266	12.09572	13.7
eNB 11	4.7854	0.08352	7.0082	0.12232	4.848352	0.08462	7.028002	0.12266	7.335742	9.2
eNB 12	4.8327	0.08435	7.0685	0.12337	4.848352	0.08462	7.028002	0.12266	4.812828	6.6
eNB 13	4.8039	0.08384	6.9883	0.12197	4.848352	0.08462	7.028002	0.12266	6.616844	9.3
eNB 14	4.8197	0.08412	7.0656	0.12332	4.848352	0.08462	7.028002	0.12266	5.244483	6.8
eNB 15	4.743	0.08278	7.0417	0.1229	4.848352	0.08462	7.028002	0.12266	11.81251	15.4
eNB 16	4.7939	0.08367	7.0308	0.12271	4.848352	0.08462	7.028002	0.12266	6.062718	8.3
eNB 17	4.748	0.08287	7.0989	0.1239	4.848352	0.08462	7.028002	0.12266	13.64658	18.4
eNB 18	4.7773	0.08338	7.062	0.12325	4.848352	0.08462	7.028002	0.12266	8.752747	10.5
eNB 19	4.8341	0.08437	6.9845	0.1219	4.848352	0.08462	7.028002	0.12266	5.073753	7.7
eNB 20	4.8565	0.08476	7.0405	0.12288	4.848352	0.08462	7.028002	0.12266	1.654794	1.8
eNB 21	4.8064	0.08389	7.0424	0.12291	4.848352	0.08462	7.028002	0.12266	4.930102	7.1
eNB 22	4.8146	0.08403	6.9788	0.1218	4.848352	0.08462	7.028002	0.12266	6.618508	9.7
eNB 23	4.8298	0.0843	6.9588	0.12145	4.848352	0.08462	7.028002	0.12266	7.940094	11
eNB 24	4.8923	0.08539	6.9143	0.12068	4.848352	0.08462	7.028002	0.12266	13.51199	15.2
eNB 25	4.848	0.08461	7.0492	0.12303	4.848352	0.08462	7.028002	0.12266	2.349014	2.9
eNB 26	4.8514	0.08467	6.9835	0.12188	4.848352	0.08462	7.028002	0.12266	4.942273	8.5
eNB 27	4.8081	0.08392	6.9967	0.12211	4.848352	0.08462	7.028002	0.12266	5.662303	7.9
eNB 28	4.9028	0.08557	6.999	0.12216	4.848352	0.08462	7.028002	0.12266	6.85412	8.6
eNB 29	4.9789	0.0869	6.9611	0.12149	4.848352	0.08462	7.028002	0.12266	16.2989	20.9
eNB 30	4.9969	0.08721	6.95	0.1213	4.848352	0.08462	7.028002	0.12266	18.64156	21.6
eNB 31	4.9539	0.08646	7.0111	0.12237	4.848352	0.08462	7.028002	0.12266	11.88477	14.5
eNB 32	4.9669	0.08669	6.9869	0.12194	4.848352	0.08462	7.028002	0.12266	13.94619	17.8
eNB 33	4.8289	0.08428	7.0219	0.12255	4.848352	0.08462	7.028002	0.12266	2.266174	3.4
eNB 34	4.8169	0.08407	7.0112	0.12237	4.848352	0.08462	7.028002	0.12266	3.961925	5.8
eNB 35	4.9317	0.08607	7.0021	0.12221	4.848352	0.08462	7.028002	0.12266	9.701923	11.7
eNB 36	4.8407	0.08449	6.9681	0.12162	4.848352	0.08462	7.028002	0.12266	6.691277	10
eNB 37	4.8598	0.08482	6.9792	0.12181	4.848352	0.08462	7.028002	0.12266	5.554848	9.3
eNB 38	4.8469	0.08459	7.0369	0.12282	4.848352	0.08462	7.028002	0.12266	0.999026	1.4
eNB 39	4.8585	0.0848	6.9658	0.12158	4.848352	0.08462	7.028002	0.12266	6.983463	10.4
eNB 40	4.88	0.08517	7.01	0.12235	4.848352	0.08462	7.028002	0.12266	4.04497	5.3

eNB 41	4.8669	0.08494	7.03	0.1227	4.848352	0.08462	7.028002	0.12266	2.07426	4.1
eNB 42	4.8378	0.08444	7.037	0.12282	4.848352	0.08462	7.028002	0.12266	1.539709	2.5
eNB 43	4.8842	0.08525	7.138	0.12458	4.848352	0.08462	7.028002	0.12266	12.82241	15.8
eNB 44	4.7815	0.08345	7.0398	0.12287	4.848352	0.08462	7.028002	0.12266	7.547668	9.1
eNB 45	4.8116	0.08398	6.9561	0.12141	4.848352	0.08462	7.028002	0.12266	8.953707	12.3
eNB 46	4.9011	0.08554	6.9269	0.1209	4.848352	0.08462	7.028002	0.12266	12.64399	15.7
eNB 47	4.9058	0.08562	6.9066	0.12054	4.848352	0.08462	7.028002	0.12266	14.89015	17.1
eNB 48	4.8024	0.08382	6.944	0.1212	4.848352	0.08462	7.028002	0.12266	10.61775	14.1
eNB 49	4.8354	0.08439	7.0528	0.12309	4.848352	0.08462	7.028002	0.12266	3.102163	3.8
eNB 50	4.7947	0.08368	7.0497	0.12304	4.848352	0.08462	7.028002	0.12266	6.432045	8.2
eNB 51	4.7581	0.08304	7.0119	0.12238	4.848352	0.08462	7.028002	0.12266	10.19291	12.8
eNB 52	4.8269	0.08424	6.9961	0.1221	4.848352	0.08462	7.028002	0.12266	4.264254	6.5
eNB 53	4.815	0.08404	7.0419	0.1229	4.848352	0.08462	7.028002	0.12266	4.015582	5.6
eNB 54	4.71	0.0822	7.165	0.12505	4.848352	0.08462	7.028002	0.12266	21.61283	24.8
eNB 55	4.8233	0.08418	7.0572	0.12317	4.848352	0.08462	7.028002	0.12266	4.269185	5.9
eNB 56	4.815	0.08404	7.0652	0.12331	4.848352	0.08462	7.028002	0.12266	5.544422	6.8
eNB 57	4.894	0.08542	7.0153	0.12244	4.848352	0.08462	7.028002	0.12266	5.267255	7.2
eNB 58	4.8626	0.08487	7.0153	0.12244	4.848352	0.08462	7.028002	0.12266	2.119064	3.5
eNB 59	4.8276	0.08426	7.0145	0.12243	4.848352	0.08462	7.028002	0.12266	2.750028	4.2
									455.054	589.4

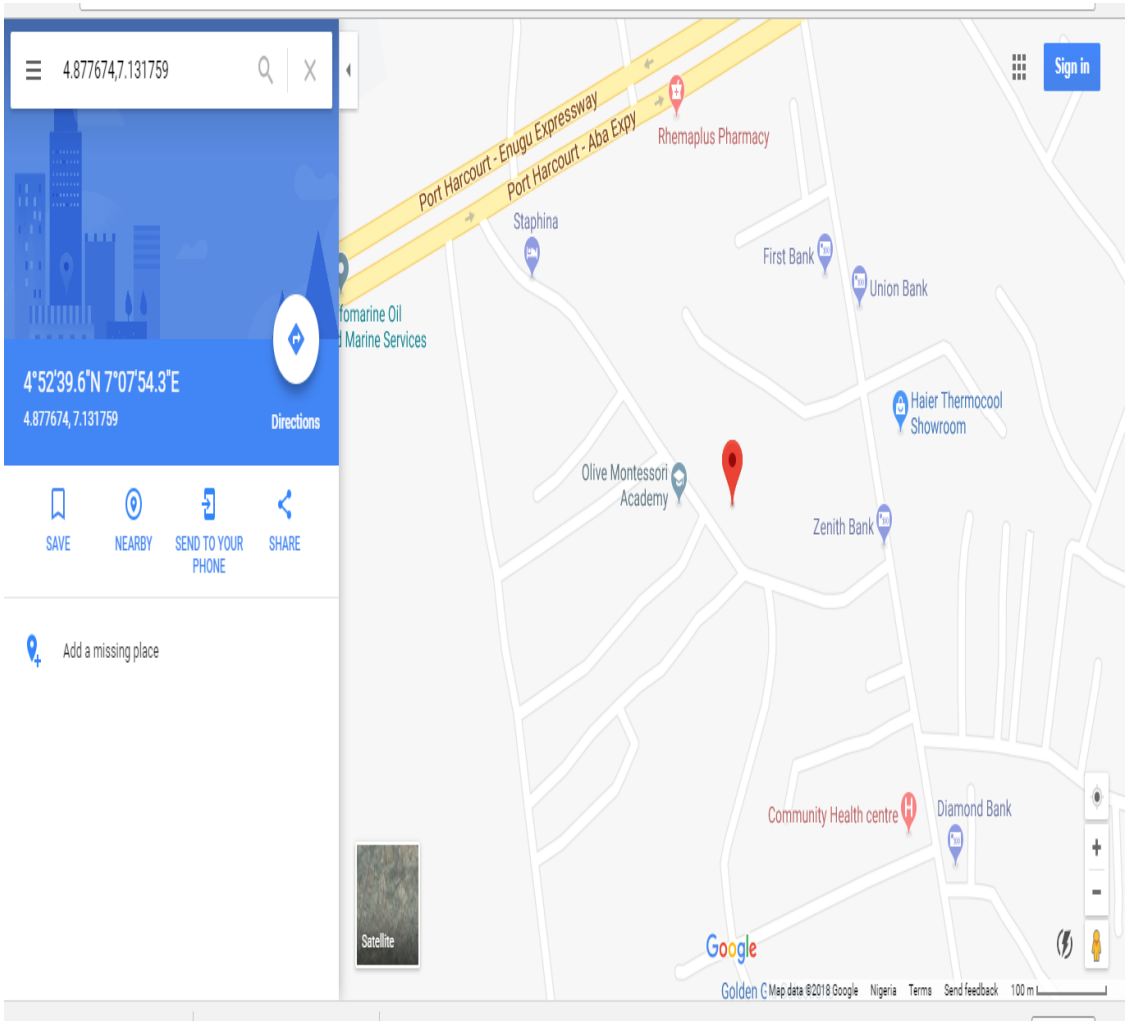


Location *26* (**4.841566, 7.045196**)

Location *27* (**4.877674, 7.131759**)

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB42 to eNB 43)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.841566	0.0845	7.045196	0.122961	6.53897	8.4
eNB 1	4.8366	0.08441	7.0286	0.12267	4.841566	0.0845	7.045196	0.122961	1.91994	3.1
eNB 2	4.7737	0.08332	7.0142	0.12242	4.841566	0.0845	7.045196	0.122961	8.291125	11.3
eNB 3	4.7999	0.08377	6.9939	0.12207	4.841566	0.0845	7.045196	0.122961	7.332742	9.2
eNB 4	4.8294	0.08429	7.0919	0.12378	4.841566	0.0845	7.045196	0.122961	5.348641	7.2
eNB 5	4.7706	0.08326	7.0224	0.12256	4.841566	0.0845	7.045196	0.122961	8.285445	11.2
eNB 6	4.8746	0.08508	6.983	0.12188	4.841566	0.0845	7.045196	0.122961	7.808866	9.5
eNB 7	4.8692	0.08498	7.1137	0.12416	4.841566	0.0845	7.045196	0.122961	8.188324	10.7
eNB 8	4.7196	0.08237	7.1518	0.12482	4.841566	0.0845	7.045196	0.122961	17.98506	20.8
eNB 9	4.8554	0.08474	7.0641	0.12329	4.841566	0.0845	7.045196	0.122961	2.598674	3.5
eNB 10	4.7909	0.08362	7.1207	0.12428	4.841566	0.0845	7.045196	0.122961	10.08609	11.4
eNB 11	4.7854	0.08352	7.0082	0.12232	4.841566	0.0845	7.045196	0.122961	7.470502	9.4
eNB 12	4.8327	0.08435	7.0685	0.12337	4.841566	0.0845	7.045196	0.122961	2.763847	4.3
eNB 13	4.8039	0.08384	6.9883	0.12197	4.841566	0.0845	7.045196	0.122961	7.568594	9.8
eNB 14	4.8197	0.08412	7.0656	0.12332	4.841566	0.0845	7.045196	0.122961	3.320034	4.6
eNB 15	4.743	0.08278	7.0417	0.1229	4.841566	0.0845	7.045196	0.122961	10.96685	15.6
eNB 16	4.7939	0.08367	7.0308	0.12271	4.841566	0.0845	7.045196	0.122961	5.535032	7.9
eNB 17	4.748	0.08287	7.0989	0.1239	4.841566	0.0845	7.045196	0.122961	11.9856	16.1
eNB 18	4.7773	0.08338	7.062	0.12325	4.841566	0.0845	7.045196	0.122961	7.384619	8.9
eNB 19	4.8341	0.08437	6.9845	0.1219	4.841566	0.0845	7.045196	0.122961	6.776074	8.3
eNB 20	4.8565	0.08476	7.0405	0.12288	4.841566	0.0845	7.045196	0.122961	1.740173	3.2
eNB 21	4.8064	0.08389	7.0424	0.12291	4.841566	0.0845	7.045196	0.122961	3.922531	5.5
eNB 22	4.8146	0.08403	6.9788	0.1218	4.841566	0.0845	7.045196	0.122961	7.944284	10.3
eNB 23	4.8298	0.0843	6.9588	0.12145	4.841566	0.0845	7.045196	0.122961	9.661566	11.6
eNB 24	4.8923	0.08539	6.9143	0.12068	4.841566	0.0845	7.045196	0.122961	15.56102	17
eNB 25	4.848	0.08461	7.0492	0.12303	4.841566	0.0845	7.045196	0.122961	0.841794	1.8
eNB 26	4.8514	0.08467	6.9835	0.12188	4.841566	0.0845	7.045196	0.122961	6.922642	10
eNB 27	4.8081	0.08392	6.9967	0.12211	4.841566	0.0845	7.045196	0.122961	6.536128	8.4
eNB 28	4.9028	0.08557	6.999	0.12216	4.841566	0.0845	7.045196	0.122961	8.518014	10.5
eNB 29	4.9789	0.0869	6.9611	0.12149	4.841566	0.0845	7.045196	0.122961	17.88847	22.7
eNB 30	4.9969	0.08721	6.95	0.1213	4.841566	0.0845	7.045196	0.122961	20.23748	23.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.841566	0.0845	7.045196	0.122961	13.0496	16.3
eNB 32	4.9669	0.08669	6.9869	0.12194	4.841566	0.0845	7.045196	0.122961	15.36021	19.8
eNB 33	4.8289	0.08428	7.0219	0.12255	4.841566	0.0845	7.045196	0.122961	2.94042	3.8
eNB 34	4.8169	0.08407	7.0112	0.12237	4.841566	0.0845	7.045196	0.122961	4.659512	6.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.841566	0.0845	7.045196	0.122961	11.10159	13.5
eNB 36	4.8407	0.08449	6.9681	0.12162	4.841566	0.0845	7.045196	0.122961	8.542619	10.6
eNB 37	4.8598	0.08482	6.9792	0.12181	4.841566	0.0845	7.045196	0.122961	7.588006	11.1
eNB 38	4.8469	0.08459	7.0369	0.12282	4.841566	0.0845	7.045196	0.122961	1.093921	1.7
eNB 39	4.8585	0.0848	6.9658	0.12158	4.841566	0.0845	7.045196	0.122961	8.996061	11.4
eNB 40	4.88	0.08517	7.01	0.12235	4.841566	0.0845	7.045196	0.122961	5.785355	7.1

eNB 41	4.8669	0.08494	7.03	0.1227	4.841566	0.0845	7.045196	0.122961	3.281788	5.7
eNB 42	4.8378	0.08444	7.037	0.12282	4.841566	0.0845	7.045196	0.122961	1.000016	1.4
eNB 43	4.8842	0.08525	7.138	0.12458	4.841566	0.0845	7.045196	0.122961	11.32237	14.6
eNB 44	4.7815	0.08345	7.0398	0.12287	4.841566	0.0845	7.045196	0.122961	6.705728	8.6
eNB 45	4.8116	0.08398	6.9561	0.12141	4.841566	0.0845	7.045196	0.122961	10.41904	12.9
eNB 46	4.9011	0.08554	6.9269	0.1209	4.841566	0.0845	7.045196	0.122961	14.68329	17.5
eNB 47	4.9058	0.08562	6.9066	0.12054	4.841566	0.0845	7.045196	0.122961	16.93526	18.9
eNB 48	4.8024	0.08382	6.944	0.1212	4.841566	0.0845	7.045196	0.122961	12.02869	14.7
eNB 49	4.8354	0.08439	7.0528	0.12309	4.841566	0.0845	7.045196	0.122961	1.086235	4.3
eNB 50	4.7947	0.08368	7.0497	0.12304	4.841566	0.0845	7.045196	0.122961	5.235093	6.7
eNB 51	4.7581	0.08304	7.0119	0.12238	4.841566	0.0845	7.045196	0.122961	9.98738	13
eNB 52	4.8269	0.08424	6.9961	0.1221	4.841566	0.0845	7.045196	0.122961	5.678981	7.1
eNB 53	4.815	0.08404	7.0419	0.1229	4.841566	0.0845	7.045196	0.122961	2.976494	4.5
eNB 54	4.71	0.0822	7.165	0.12505	4.841566	0.0845	7.045196	0.122961	19.75483	22.5
eNB 55	4.8233	0.08418	7.0572	0.12317	4.841566	0.0845	7.045196	0.122961	2.427817	3.6
eNB 56	4.815	0.08404	7.0652	0.12331	4.841566	0.0845	7.045196	0.122961	3.693063	4.5
eNB 57	4.894	0.08542	7.0153	0.12244	4.841566	0.0845	7.045196	0.122961	6.705546	9
eNB 58	4.8626	0.08487	7.0153	0.12244	4.841566	0.0845	7.045196	0.122961	4.054874	5.3
eNB 59	4.8276	0.08426	7.0145	0.12243	4.841566	0.0845	7.045196	0.122961	3.738862	4.8
									468.7618	596.6

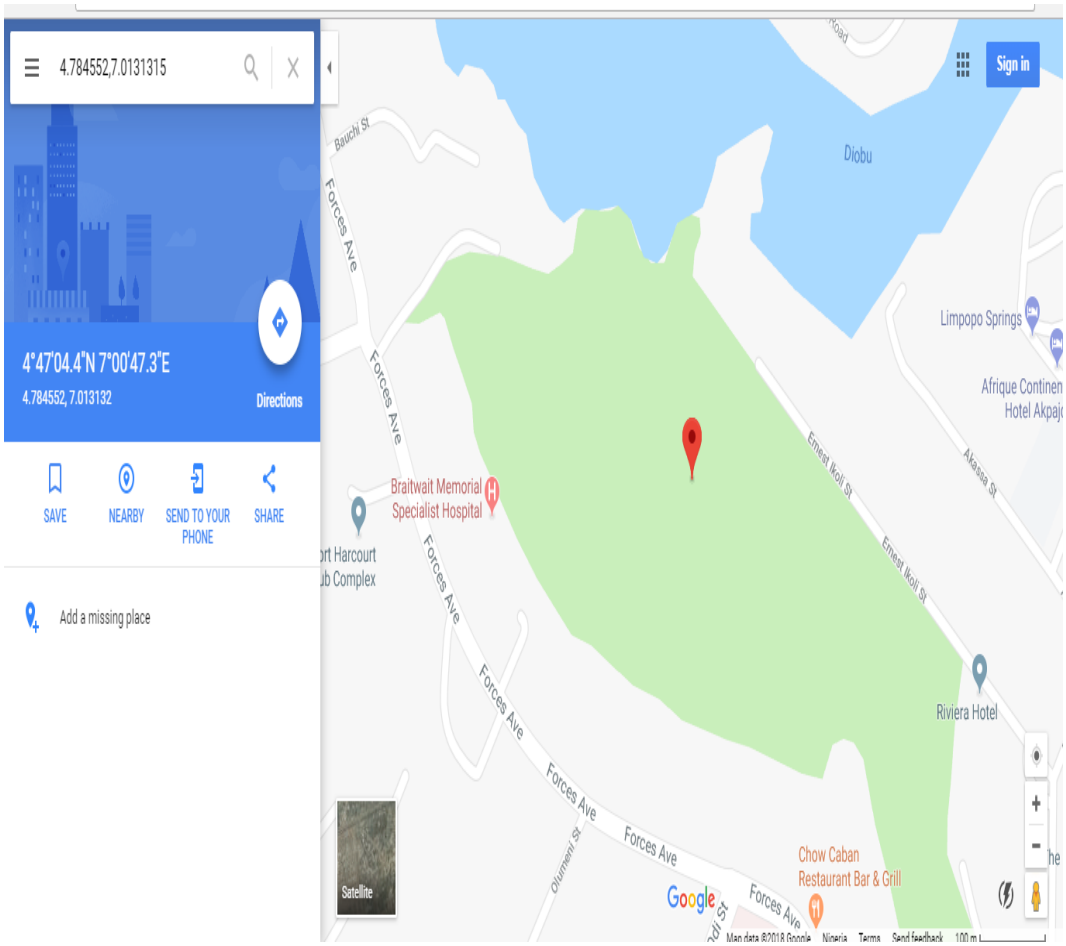


Location *27* (**4.877674, 7.131759**)

*Location 28 (***4.784552, 7.0131315***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB43 to eNB 44)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.877674	0.085131	7.131759	0.12447	16.84903	21.4
eNB 1	4.8366	0.08441	7.0286	0.12267	4.877674	0.085131	7.131759	0.12447	12.30825	15.9
eNB 2	4.7737	0.08332	7.0142	0.12242	4.877674	0.085131	7.131759	0.12447	17.41637	22.8
eNB 3	4.7999	0.08377	6.9939	0.12207	4.877674	0.085131	7.131759	0.12447	17.55276	22.2
eNB 4	4.8294	0.08429	7.0919	0.12378	4.877674	0.085131	7.131759	0.12447	6.950984	8.9
eNB 5	4.7706	0.08326	7.0224	0.12256	4.877674	0.085131	7.131759	0.12447	16.98753	22.2
eNB 6	4.8746	0.08508	6.983	0.12188	4.877674	0.085131	7.131759	0.12447	16.48484	20.9
eNB 7	4.8692	0.08498	7.1137	0.12416	4.877674	0.085131	7.131759	0.12447	2.211563	3.3
eNB 8	4.7196	0.08237	7.1518	0.12482	4.877674	0.085131	7.131759	0.12447	17.71669	20
eNB 9	4.8554	0.08474	7.0641	0.12329	4.877674	0.085131	7.131759	0.12447	7.894735	12
eNB 10	4.7909	0.08362	7.1207	0.12428	4.877674	0.085131	7.131759	0.12447	9.726294	10.4
eNB 11	4.7854	0.08352	7.0082	0.12232	4.877674	0.085131	7.131759	0.12447	17.10842	20.9
eNB 12	4.8327	0.08435	7.0685	0.12337	4.877674	0.085131	7.131759	0.12447	8.609989	11
eNB 13	4.8039	0.08384	6.9883	0.12197	4.877674	0.085131	7.131759	0.12447	17.88694	22.8
eNB 14	4.8197	0.08412	7.0656	0.12332	4.877674	0.085131	7.131759	0.12447	9.761531	13.2
eNB 15	4.743	0.08278	7.0417	0.1229	4.877674	0.085131	7.131759	0.12447	17.9952	26.7
eNB 16	4.7939	0.08367	7.0308	0.12271	4.877674	0.085131	7.131759	0.12447	14.55686	18.3
eNB 17	4.748	0.08287	7.0989	0.1239	4.877674	0.085131	7.131759	0.12447	14.8716	16.2
eNB 18	4.7773	0.08338	7.062	0.12325	4.877674	0.085131	7.131759	0.12447	13.57611	19.3
eNB 19	4.8341	0.08437	6.9845	0.1219	4.877674	0.085131	7.131759	0.12447	17.01983	21.2
eNB 20	4.8565	0.08476	7.0405	0.12288	4.877674	0.085131	7.131759	0.12447	10.3814	13.9
eNB 21	4.8064	0.08389	7.0424	0.12291	4.877674	0.085131	7.131759	0.12447	12.68207	15.9
eNB 22	4.8146	0.08403	6.9788	0.1218	4.877674	0.085131	7.131759	0.12447	18.34128	23.2
eNB 23	4.8298	0.0843	6.9588	0.12145	4.877674	0.085131	7.131759	0.12447	19.88875	24.5
eNB 24	4.8923	0.08539	6.9143	0.12068	4.877674	0.085131	7.131759	0.12447	24.14722	28.4
eNB 25	4.848	0.08461	7.0492	0.12303	4.877674	0.085131	7.131759	0.12447	9.723976	12.8
eNB 26	4.8514	0.08467	6.9835	0.12188	4.877674	0.085131	7.131759	0.12447	16.68397	21.7
eNB 27	4.8081	0.08392	6.9967	0.12211	4.877674	0.085131	7.131759	0.12447	16.84566	21.4
eNB 28	4.9028	0.08557	6.999	0.12216	4.877674	0.085131	7.131759	0.12447	14.97131	18
eNB 29	4.9789	0.0869	6.9611	0.12149	4.877674	0.085131	7.131759	0.12447	22.00307	26.6
eNB 30	4.9969	0.08721	6.95	0.1213	4.877674	0.085131	7.131759	0.12447	24.10802	29.7
eNB 31	4.9539	0.08646	7.0111	0.12237	4.877674	0.085131	7.131759	0.12447	15.82795	20.6
eNB 32	4.9669	0.08669	6.9869	0.12194	4.877674	0.085131	7.131759	0.12447	18.86733	23.4
eNB 33	4.8289	0.08428	7.0219	0.12255	4.877674	0.085131	7.131759	0.12447	13.32548	16.9
eNB 34	4.8169	0.08407	7.0112	0.12237	4.877674	0.085131	7.131759	0.12447	14.96966	19.3
eNB 35	4.9317	0.08607	7.0021	0.12221	4.877674	0.085131	7.131759	0.12447	15.57013	20.4
eNB 36	4.8407	0.08449	6.9681	0.12162	4.877674	0.085131	7.131759	0.12447	18.5928	23.5
eNB 37	4.8598	0.08482	6.9792	0.12181	4.877674	0.085131	7.131759	0.12447	17.01894	22.5
eNB 38	4.8469	0.08459	7.0369	0.12282	4.877674	0.085131	7.131759	0.12447	11.05286	14.5
eNB 39	4.8585	0.0848	6.9658	0.12158	4.877674	0.085131	7.131759	0.12447	18.51033	23.7
eNB 40	4.88	0.08517	7.01	0.12235	4.877674	0.085131	7.131759	0.12447	13.49233	18.5

eNB 41	4.8669	0.08494	7.03	0.1227	4.877674	0.085131	7.131759	0.12447	11.33761	14.4
eNB 42	4.8378	0.08444	7.037	0.12282	4.877674	0.085131	7.131759	0.12447	11.39664	14.7
eNB 43	4.8842	0.08525	7.138	0.12458	4.877674	0.085131	7.131759	0.12447	1.002339	1.5
eNB 44	4.7815	0.08345	7.0398	0.12287	4.877674	0.085131	7.131759	0.12447	14.77086	19
eNB 45	4.8116	0.08398	6.9561	0.12141	4.877674	0.085131	7.131759	0.12447	20.8031	25.8
eNB 46	4.9011	0.08554	6.9269	0.1209	4.877674	0.085131	7.131759	0.12447	22.84527	28.9
eNB 47	4.9058	0.08562	6.9066	0.12054	4.877674	0.085131	7.131759	0.12447	25.14051	30.3
eNB 48	4.8024	0.08382	6.944	0.1212	4.877674	0.085131	7.131759	0.12447	22.42399	27.6
eNB 49	4.8354	0.08439	7.0528	0.12309	4.877674	0.085131	7.131759	0.12447	9.931174	13.9
eNB 50	4.7947	0.08368	7.0497	0.12304	4.877674	0.085131	7.131759	0.12447	12.95332	17.1
eNB 51	4.7581	0.08304	7.0119	0.12238	4.877674	0.085131	7.131759	0.12447	18.79245	24.6
eNB 52	4.8269	0.08424	6.9961	0.1221	4.877674	0.085131	7.131759	0.12447	16.05582	20
eNB 53	4.815	0.08404	7.0419	0.1229	4.877674	0.085131	7.131759	0.12447	12.15281	15.1
eNB 54	4.71	0.0822	7.165	0.12505	4.877674	0.085131	7.131759	0.12447	19.00478	21.5
eNB 55	4.8233	0.08418	7.0572	0.12317	4.877674	0.085131	7.131759	0.12447	10.23703	12.9
eNB 56	4.815	0.08404	7.0652	0.12331	4.877674	0.085131	7.131759	0.12447	10.14646	14.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.877674	0.085131	7.131759	0.12447	13.0296	16.3
eNB 58	4.8626	0.08487	7.0153	0.12244	4.877674	0.085131	7.131759	0.12447	13.01124	16.7
eNB 59	4.8276	0.08426	7.0145	0.12243	4.877674	0.085131	7.131759	0.12447	14.13468	17.7
									899.6597	1141.4

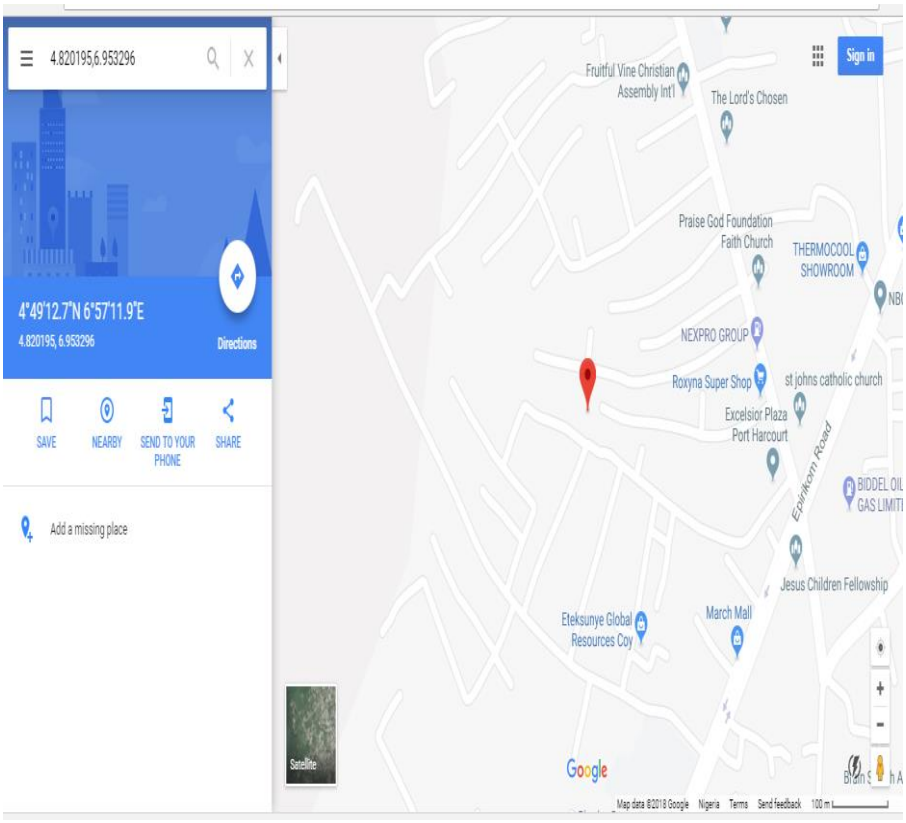


Location *28* (**4.784552, 7.0131315**)

*Location 29 (***4.820195, 6.953296***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB44 to eNB 45)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.784552	0.08351	7.031315	0.12272	4.649016	7.1
eNB 1	4.8366	0.08441	7.0286	0.12267	4.784552	0.08351	7.031315	0.12272	5.795253	7.4
eNB 2	4.7737	0.08332	7.0142	0.12242	4.784552	0.08351	7.031315	0.12272	2.247789	6.9
eNB 3	4.7999	0.08377	6.9939	0.12207	4.784552	0.08351	7.031315	0.12272	4.483276	6.5
eNB 4	4.8294	0.08429	7.0919	0.12378	4.784552	0.08351	7.031315	0.12272	8.362648	11.2
eNB 5	4.7706	0.08326	7.0224	0.12256	4.784552	0.08351	7.031315	0.12272	1.839181	6.3
eNB 6	4.8746	0.08508	6.983	0.12188	4.784552	0.08351	7.031315	0.12272	11.35403	15.2
eNB 7	4.8692	0.08498	7.1137	0.12416	4.784552	0.08351	7.031315	0.12272	13.11179	16.1
eNB 8	4.7196	0.08237	7.1518	0.12482	4.784552	0.08351	7.031315	0.12272	15.17952	24.7
eNB 9	4.8554	0.08474	7.0641	0.12329	4.784552	0.08351	7.031315	0.12272	8.67511	11.2
eNB 10	4.7909	0.08362	7.1207	0.12428	4.784552	0.08351	7.031315	0.12272	9.929604	15.4
eNB 11	4.7854	0.08352	7.0082	0.12232	4.784552	0.08351	7.031315	0.12272	2.562992	5
eNB 12	4.8327	0.08435	7.0685	0.12337	4.784552	0.08351	7.031315	0.12272	6.755704	8.3
eNB 13	4.8039	0.08384	6.9883	0.12197	4.784552	0.08351	7.031315	0.12272	5.229301	7.5
eNB 14	4.8197	0.08412	7.0656	0.12332	4.784552	0.08351	7.031315	0.12272	5.450377	7.1
eNB 15	4.743	0.08278	7.0417	0.1229	4.784552	0.08351	7.031315	0.12272	4.761523	10.8
eNB 16	4.7939	0.08367	7.0308	0.12271	4.784552	0.08351	7.031315	0.12272	1.041001	1.3
eNB 17	4.748	0.08287	7.0989	0.1239	4.784552	0.08351	7.031315	0.12272	8.52094	20
eNB 18	4.7773	0.08338	7.062	0.12325	4.784552	0.08351	7.031315	0.12272	3.494491	3.9
eNB 19	4.8341	0.08437	6.9845	0.1219	4.784552	0.08351	7.031315	0.12272	7.567107	10.6
eNB 20	4.8565	0.08476	7.0405	0.12288	4.784552	0.08351	7.031315	0.12272	8.06469	10.3
eNB 21	4.8064	0.08389	7.0424	0.12291	4.784552	0.08351	7.031315	0.12272	2.722243	3.7
eNB 22	4.8146	0.08403	6.9788	0.1218	4.784552	0.08351	7.031315	0.12272	6.709879	9.2
eNB 23	4.8298	0.0843	6.9588	0.12145	4.784552	0.08351	7.031315	0.12272	9.480144	13
eNB 24	4.8923	0.08539	6.9143	0.12068	4.784552	0.08351	7.031315	0.12272	17.65319	21.2
eNB 25	4.848	0.08461	7.0492	0.12303	4.784552	0.08351	7.031315	0.12272	7.328107	9.3
eNB 26	4.8514	0.08467	6.9835	0.12188	4.784552	0.08351	7.031315	0.12272	9.127944	12.5
eNB 27	4.8081	0.08392	6.9967	0.12211	4.784552	0.08351	7.031315	0.12272	4.644015	7.1
eNB 28	4.9028	0.08557	6.999	0.12216	4.784552	0.08351	7.031315	0.12272	13.62727	16.8
eNB 29	4.9789	0.0869	6.9611	0.12149	4.784552	0.08351	7.031315	0.12272	22.96792	29
eNB 30	4.9969	0.08721	6.95	0.1213	4.784552	0.08351	7.031315	0.12272	25.27214	29.7
eNB 31	4.9539	0.08646	7.0111	0.12237	4.784552	0.08351	7.031315	0.12272	18.96327	22.6
eNB 32	4.9669	0.08669	6.9869	0.12194	4.784552	0.08351	7.031315	0.12272	20.86465	26
eNB 33	4.8289	0.08428	7.0219	0.12255	4.784552	0.08351	7.031315	0.12272	5.040375	6.5
eNB 34	4.8169	0.08407	7.0112	0.12237	4.784552	0.08351	7.031315	0.12272	4.23146	5.7
eNB 35	4.9317	0.08607	7.0021	0.12221	4.784552	0.08351	7.031315	0.12272	16.67913	19.8
eNB 36	4.8407	0.08449	6.9681	0.12162	4.784552	0.08351	7.031315	0.12272	9.382961	12.7
eNB 37	4.8598	0.08482	6.9792	0.12181	4.784552	0.08351	7.031315	0.12272	10.16623	13.3
eNB 38	4.8469	0.08459	7.0369	0.12282	4.784552	0.08351	7.031315	0.12272	6.960314	8.7
eNB 39	4.8585	0.0848	6.9658	0.12158	4.784552	0.08351	7.031315	0.12272	10.96838	13.8
eNB 40	4.88	0.08517	7.01	0.12235	4.784552	0.08351	7.031315	0.12272	10.87286	13.4

eNB 41	4.8669	0.08494	7.03	0.1227	4.784552	0.08351	7.031315	0.12272	9.157794	12.5
eNB 42	4.8378	0.08444	7.037	0.12282	4.784552	0.08351	7.031315	0.12272	5.954294	7.4
eNB 43	4.8842	0.08525	7.138	0.12458	4.784552	0.08351	7.031315	0.12272	16.20186	20.1
eNB 44	4.7815	0.08345	7.0398	0.12287	4.784552	0.08351	7.031315	0.12272	0.999618	1.3
eNB 45	4.8116	0.08398	6.9561	0.12141	4.784552	0.08351	7.031315	0.12272	8.860215	12.9
eNB 46	4.9011	0.08554	6.9269	0.1209	4.784552	0.08351	7.031315	0.12272	17.37202	21.7
eNB 47	4.9058	0.08562	6.9066	0.12054	4.784552	0.08351	7.031315	0.12272	19.30556	23.1
eNB 48	4.8024	0.08382	6.944	0.1212	4.784552	0.08351	7.031315	0.12272	9.876392	14.8
eNB 49	4.8354	0.08439	7.0528	0.12309	4.784552	0.08351	7.031315	0.12272	6.134761	8.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.784552	0.08351	7.031315	0.12272	2.328847	2.9
eNB 51	4.7581	0.08304	7.0119	0.12238	4.784552	0.08351	7.031315	0.12272	3.64411	8.7
eNB 52	4.8269	0.08424	6.9961	0.1221	4.784552	0.08351	7.031315	0.12272	6.115404	8.3
eNB 53	4.815	0.08404	7.0419	0.1229	4.784552	0.08351	7.031315	0.12272	3.583056	4.9
eNB 54	4.71	0.0822	7.165	0.12505	4.784552	0.08351	7.031315	0.12272	16.97579	26.4
eNB 55	4.8233	0.08418	7.0572	0.12317	4.784552	0.08351	7.031315	0.12272	5.175929	6.7
eNB 56	4.815	0.08404	7.0652	0.12331	4.784552	0.08351	7.031315	0.12272	5.055692	6.2
eNB 57	4.894	0.08542	7.0153	0.12244	4.784552	0.08351	7.031315	0.12272	12.29868	15.4
eNB 58	4.8626	0.08487	7.0153	0.12244	4.784552	0.08351	7.031315	0.12272	8.858043	11.6
eNB 59	4.8276	0.08426	7.0145	0.12243	4.784552	0.08351	7.031315	0.12272	5.136499	6.7
									535.7724	726.8

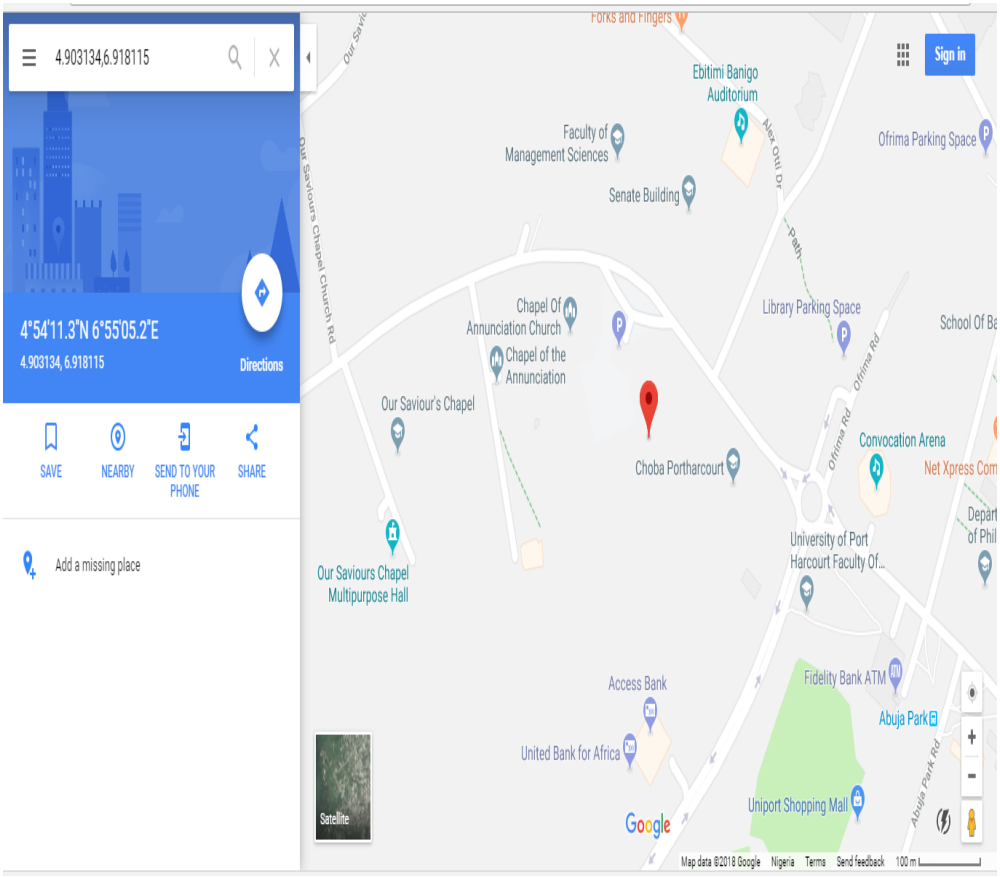


*Location 29 (***4.820195, 6.953296***)*

*Location 30 (***4.903134, 6.918115***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB45 to eNB 46)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.820195	0.08413	6.953296	0.12136	4.988616	7.5
eNB 1	4.8366	0.08441	7.0286	0.12267	4.820195	0.08413	6.953296	0.12136	8.540716	10.1
eNB 2	4.7737	0.08332	7.0142	0.12242	4.820195	0.08413	6.953296	0.12136	8.501149	10.9
eNB 3	4.7999	0.08377	6.9939	0.12207	4.820195	0.08413	6.953296	0.12136	5.033232	6.9
eNB 4	4.8294	0.08429	7.0919	0.12378	4.820195	0.08413	6.953296	0.12136	15.39142	18.8
eNB 5	4.7706	0.08326	7.0224	0.12256	4.820195	0.08413	6.953296	0.12136	9.436186	12.4
eNB 6	4.8746	0.08508	6.983	0.12188	4.820195	0.08413	6.953296	0.12136	6.886836	9
eNB 7	4.8692	0.08498	7.1137	0.12416	4.820195	0.08413	6.953296	0.12136	18.58889	22.3
eNB 8	4.7196	0.08237	7.1518	0.12482	4.820195	0.08413	6.953296	0.12136	24.67678	32.5
eNB 9	4.8554	0.08474	7.0641	0.12329	4.820195	0.08413	6.953296	0.12136	12.88587	14.5
eNB 10	4.7909	0.08362	7.1207	0.12428	4.820195	0.08413	6.953296	0.12136	18.83277	23.1
eNB 11	4.7854	0.08352	7.0082	0.12232	4.820195	0.08413	6.953296	0.12136	7.209604	9.8
eNB 12	4.8327	0.08435	7.0685	0.12337	4.820195	0.08413	6.953296	0.12136	12.8401	16.1
eNB 13	4.8039	0.08384	6.9883	0.12197	4.820195	0.08413	6.953296	0.12136	4.280835	6
eNB 14	4.8197	0.08412	7.0656	0.12332	4.820195	0.08413	6.953296	0.12136	12.4435	16.3
eNB 15	4.743	0.08278	7.0417	0.1229	4.820195	0.08413	6.953296	0.12136	13.02443	16.4
eNB 16	4.7939	0.08367	7.0308	0.12271	4.820195	0.08413	6.953296	0.12136	9.071747	12
eNB 17	4.748	0.08287	7.0989	0.1239	4.820195	0.08413	6.953296	0.12136	18.02071	27.8
eNB 18	4.7773	0.08338	7.062	0.12325	4.820195	0.08413	6.953296	0.12136	12.95486	16.4
eNB 19	4.8341	0.08437	6.9845	0.1219	4.820195	0.08413	6.953296	0.12136	3.78736	4.2
eNB 20	4.8565	0.08476	7.0405	0.12288	4.820195	0.08413	6.953296	0.12136	10.47146	13.3
eNB 21	4.8064	0.08389	7.0424	0.12291	4.820195	0.08413	6.953296	0.12136	9.991332	12.9
eNB 22	4.8146	0.08403	6.9788	0.1218	4.820195	0.08413	6.953296	0.12136	2.893506	4.2
eNB 23	4.8298	0.0843	6.9588	0.12145	4.820195	0.08413	6.953296	0.12136	1.229888	2.1
eNB 24	4.8923	0.08539	6.9143	0.12068	4.820195	0.08413	6.953296	0.12136	9.107777	13.4
eNB 25	4.848	0.08461	7.0492	0.12303	4.820195	0.08413	6.953296	0.12136	11.06669	12.5
eNB 26	4.8514	0.08467	6.9835	0.12188	4.820195	0.08413	6.953296	0.12136	4.820702	6.1
eNB 27	4.8081	0.08392	6.9967	0.12211	4.820195	0.08413	6.953296	0.12136	4.993714	7.5
eNB 28	4.9028	0.08557	6.999	0.12216	4.820195	0.08413	6.953296	0.12136	10.48857	12.8
eNB 29	4.9789	0.0869	6.9611	0.12149	4.820195	0.08413	6.953296	0.12136	17.66833	22.1
eNB 30	4.9969	0.08721	6.95	0.1213	4.820195	0.08413	6.953296	0.12136	19.65206	22.7
eNB 31	4.9539	0.08646	7.0111	0.12237	4.820195	0.08413	6.953296	0.12136	16.18792	18.6
eNB 32	4.9669	0.08669	6.9869	0.12194	4.820195	0.08413	6.953296	0.12136	16.73226	22
eNB 33	4.8289	0.08428	7.0219	0.12255	4.820195	0.08413	6.953296	0.12136	7.662701	9.2
eNB 34	4.8169	0.08407	7.0112	0.12237	4.820195	0.08413	6.953296	0.12136	6.426256	8.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.820195	0.08413	6.953296	0.12136	13.52649	15.8
eNB 36	4.8407	0.08449	6.9681	0.12162	4.820195	0.08413	6.953296	0.12136	2.808764	3.7
eNB 37	4.8598	0.08482	6.9792	0.12181	4.820195	0.08413	6.953296	0.12136	5.25658	7.2
eNB 38	4.8469	0.08459	7.0369	0.12282	4.820195	0.08413	6.953296	0.12136	9.727525	11.6
eNB 39	4.8585	0.0848	6.9658	0.12158	4.820195	0.08413	6.953296	0.12136	4.478986	5.8
eNB 40	4.88	0.08517	7.01	0.12235	4.820195	0.08413	6.953296	0.12136	9.148406	10.8

eNB 41	4.8669	0.08494	7.03	0.1227	4.820195	0.08413	6.953296	0.12136	9.959756	12.9
eNB 42	4.8378	0.08444	7.037	0.12282	4.820195	0.08413	6.953296	0.12136	9.478696	11
eNB 43	4.8842	0.08525	7.138	0.12458	4.820195	0.08413	6.953296	0.12136	21.66667	26.5
eNB 44	4.7815	0.08345	7.0398	0.12287	4.820195	0.08413	6.953296	0.12136	10.5064	13.8
eNB 45	4.8116	0.08398	6.9561	0.12141	4.820195	0.08413	6.953296	0.12136	1.004893	2.4
eNB 46	4.9011	0.08554	6.9269	0.1209	4.820195	0.08413	6.953296	0.12136	9.459671	13.8
eNB 47	4.9058	0.08562	6.9066	0.12054	4.820195	0.08413	6.953296	0.12136	10.834	14.8
eNB 48	4.8024	0.08382	6.944	0.1212	4.820195	0.08413	6.953296	0.12136	2.230726	3.3
eNB 49	4.8354	0.08439	7.0528	0.12309	4.820195	0.08413	6.953296	0.12136	11.15389	13.2
eNB 50	4.7947	0.08368	7.0497	0.12304	4.820195	0.08413	6.953296	0.12136	11.05161	14.6
eNB 51	4.7581	0.08304	7.0119	0.12238	4.820195	0.08413	6.953296	0.12136	9.47843	12.6
eNB 52	4.8269	0.08424	6.9961	0.1221	4.820195	0.08413	6.953296	0.12136	4.800919	5.7
eNB 53	4.815	0.08404	7.0419	0.1229	4.820195	0.08413	6.953296	0.12136	9.834402	13.1
eNB 54	4.71	0.0822	7.165	0.12505	4.820195	0.08413	6.953296	0.12136	26.46615	34.2
eNB 55	4.8233	0.08418	7.0572	0.12317	4.820195	0.08413	6.953296	0.12136	11.5178	15.3
eNB 56	4.815	0.08404	7.0652	0.12331	4.820195	0.08413	6.953296	0.12136	12.41255	16.2
eNB 57	4.894	0.08542	7.0153	0.12244	4.820195	0.08413	6.953296	0.12136	10.7025	13.4
eNB 58	4.8626	0.08487	7.0153	0.12244	4.820195	0.08413	6.953296	0.12136	8.332377	10.4
eNB 59	4.8276	0.08426	7.0145	0.12243	4.820195	0.08413	6.953296	0.12136	6.831207	8.1
									619.4582	790.7

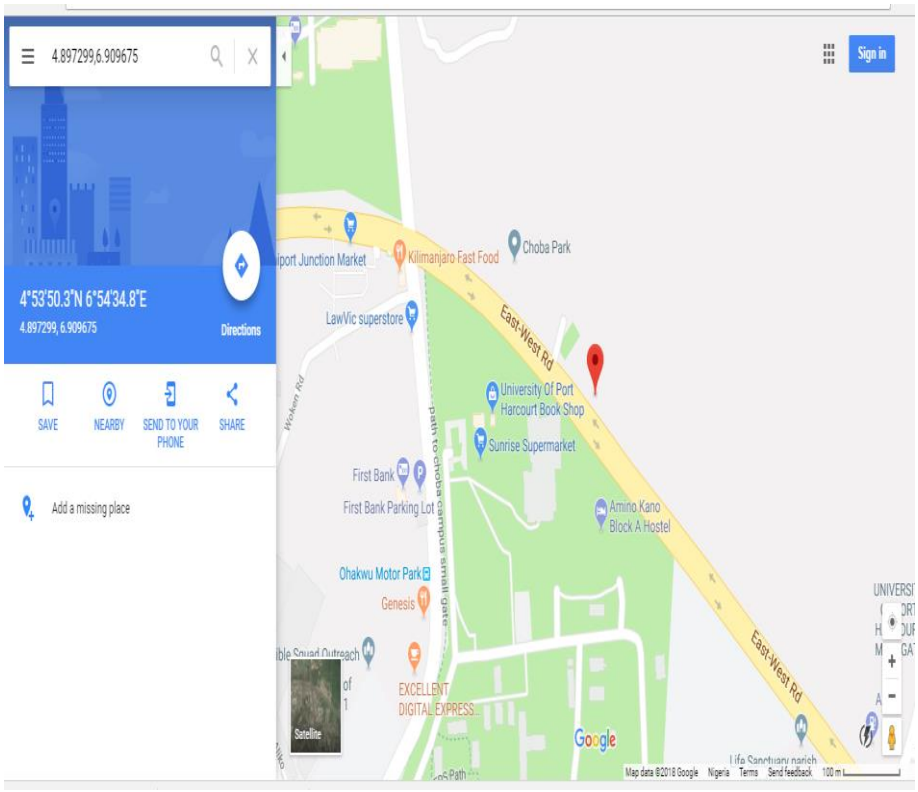


Location *30* (**4.903134, 6.918115**)

*Location 31 (***4.897299, 6.909675***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB46 to eNB 47)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.903134	0.08558	6.918115	0.120743	13.6877	16.7
eNB 1	4.8366	0.08441	7.0286	0.12267	4.903134	0.08558	6.918115	0.120743	14.30296	18
eNB 2	4.7737	0.08332	7.0142	0.12242	4.903134	0.08558	6.918115	0.120743	17.90189	21.3
eNB 3	4.7999	0.08377	6.9939	0.12207	4.903134	0.08558	6.918115	0.120743	14.22226	17.2
eNB 4	4.8294	0.08429	7.0919	0.12378	4.903134	0.08558	6.918115	0.120743	20.92719	23.8
eNB 5	4.7706	0.08326	7.0224	0.12256	4.903134	0.08558	6.918115	0.120743	18.72671	22.7
eNB 6	4.8746	0.08508	6.983	0.12188	4.903134	0.08558	6.918115	0.120743	7.857652	9.9
eNB 7	4.8692	0.08498	7.1137	0.12416	4.903134	0.08558	6.918115	0.120743	21.995	27
eNB 8	4.7196	0.08237	7.1518	0.12482	4.903134	0.08558	6.918115	0.120743	32.96858	38.5
eNB 9	4.8554	0.08474	7.0641	0.12329	4.903134	0.08558	6.918115	0.120743	17.02254	20
eNB 10	4.7909	0.08362	7.1207	0.12428	4.903134	0.08558	6.918115	0.120743	25.68186	29.1
eNB 11	4.7854	0.08352	7.0082	0.12232	4.903134	0.08558	6.918115	0.120743	16.46231	20.2
eNB 12	4.8327	0.08435	7.0685	0.12337	4.903134	0.08558	6.918115	0.120743	18.41057	22.1
eNB 13	4.8039	0.08384	6.9883	0.12197	4.903134	0.08558	6.918115	0.120743	13.49905	16.4
eNB 14	4.8197	0.08412	7.0656	0.12332	4.903134	0.08558	6.918115	0.120743	18.79049	22.3
eNB 15	4.743	0.08278	7.0417	0.1229	4.903134	0.08558	6.918115	0.120743	22.46243	26.7
eNB 16	4.7939	0.08367	7.0308	0.12271	4.903134	0.08558	6.918115	0.120743	17.41862	21.1
eNB 17	4.748	0.08287	7.0989	0.1239	4.903134	0.08558	6.918115	0.120743	26.43494	33.8
eNB 18	4.7773	0.08338	7.062	0.12325	4.903134	0.08558	6.918115	0.120743	21.21154	25.5
eNB 19	4.8341	0.08437	6.9845	0.1219	4.903134	0.08558	6.918115	0.120743	10.63109	13.1
eNB 20	4.8565	0.08476	7.0405	0.12288	4.903134	0.08558	6.918115	0.120743	14.51691	16.8
eNB 21	4.8064	0.08389	7.0424	0.12291	4.903134	0.08558	6.918115	0.120743	17.47331	21.2
eNB 22	4.8146	0.08403	6.9788	0.1218	4.903134	0.08558	6.918115	0.120743	11.92143	14.6
eNB 23	4.8298	0.0843	6.9588	0.12145	4.903134	0.08558	6.918115	0.120743	9.317294	13.4
eNB 24	4.8923	0.08539	6.9143	0.12068	4.903134	0.08558	6.918115	0.120743	1.276683	2
eNB 25	4.848	0.08461	7.0492	0.12303	4.903134	0.08558	6.918115	0.120743	15.7641	18.4
eNB 26	4.8514	0.08467	6.9835	0.12188	4.903134	0.08558	6.918115	0.120743	9.250345	11
eNB 27	4.8081	0.08392	6.9967	0.12211	4.903134	0.08558	6.918115	0.120743	13.69219	16.7
eNB 28	4.9028	0.08557	6.999	0.12216	4.903134	0.08558	6.918115	0.120743	8.961119	12.9
eNB 29	4.9789	0.0869	6.9611	0.12149	4.903134	0.08558	6.918115	0.120743	9.677416	14.5
eNB 30	4.9969	0.08721	6.95	0.1213	4.903134	0.08558	6.918115	0.120743	11.00833	15.1
eNB 31	4.9539	0.08646	7.0111	0.12237	4.903134	0.08558	6.918115	0.120743	11.74645	17.3
eNB 32	4.9669	0.08669	6.9869	0.12194	4.903134	0.08558	6.918115	0.120743	10.40868	17.7
eNB 33	4.8289	0.08428	7.0219	0.12255	4.903134	0.08558	6.918115	0.120743	14.15471	17.4
eNB 34	4.8169	0.08407	7.0112	0.12237	4.903134	0.08558	6.918115	0.120743	14.0822	16.8
eNB 35	4.9317	0.08607	7.0021	0.12221	4.903134	0.08558	6.918115	0.120743	9.831533	14.5
eNB 36	4.8407	0.08449	6.9681	0.12162	4.903134	0.08558	6.918115	0.120743	8.880588	12
eNB 37	4.8598	0.08482	6.9792	0.12181	4.903134	0.08558	6.918115	0.120743	8.307785	10
eNB 38	4.8469	0.08459	7.0369	0.12282	4.903134	0.08558	6.918115	0.120743	14.57039	16.7
eNB 39	4.8585	0.0848	6.9658	0.12158	4.903134	0.08558	6.918115	0.120743	7.248639	9.3
eNB 40	4.88	0.08517	7.01	0.12235	4.903134	0.08558	6.918115	0.120743	10.49986	13.8

eNB 41	4.8669	0.08494	7.03	0.1227	4.903134	0.08558	6.918115	0.120743	13.03413	15.9
eNB 42	4.8378	0.08444	7.037	0.12282	4.903134	0.08558	6.918115	0.120743	15.04222	17.9
eNB 43	4.8842	0.08525	7.138	0.12458	4.903134	0.08558	6.918115	0.120743	24.45167	29.5
eNB 44	4.7815	0.08345	7.0398	0.12287	4.903134	0.08558	6.918115	0.120743	19.09716	22.9
eNB 45	4.8116	0.08398	6.9561	0.12141	4.903134	0.08558	6.918115	0.120743	11.01386	15.7
eNB 46	4.9011	0.08554	6.9269	0.1209	4.903134	0.08558	6.918115	0.120743	0.999192	1.3
eNB 47	4.9058	0.08562	6.9066	0.12054	4.903134	0.08558	6.918115	0.120743	1.309719	2
eNB 48	4.8024	0.08382	6.944	0.1212	4.903134	0.08558	6.918115	0.120743	11.5624	17.4
eNB 49	4.8354	0.08439	7.0528	0.12309	4.903134	0.08558	6.918115	0.120743	16.71517	19.3
eNB 50	4.7947	0.08368	7.0497	0.12304	4.903134	0.08558	6.918115	0.120743	18.91902	22.8
eNB 51	4.7581	0.08304	7.0119	0.12238	4.903134	0.08558	6.918115	0.120743	19.18487	22.9
eNB 52	4.8269	0.08424	6.9961	0.1221	4.903134	0.08558	6.918115	0.120743	12.10413	14.4
eNB 53	4.815	0.08404	7.0419	0.1229	4.903134	0.08558	6.918115	0.120743	16.85628	21.1
eNB 54	4.71	0.0822	7.165	0.12505	4.903134	0.08558	6.918115	0.120743	34.77827	40.2
eNB 55	4.8233	0.08418	7.0572	0.12317	4.903134	0.08558	6.918115	0.120743	17.78383	21.4
eNB 56	4.815	0.08404	7.0652	0.12331	4.903134	0.08558	6.918115	0.120743	19.01599	22.3
eNB 57	4.894	0.08542	7.0153	0.12244	4.903134	0.08558	6.918115	0.120743	10.81475	15.2
eNB 58	4.8626	0.08487	7.0153	0.12244	4.903134	0.08558	6.918115	0.120743	11.6725	13.4
eNB 59	4.8276	0.08426	7.0145	0.12243	4.903134	0.08558	6.918115	0.120743	13.58604	16.3
									891.1465	1099.4

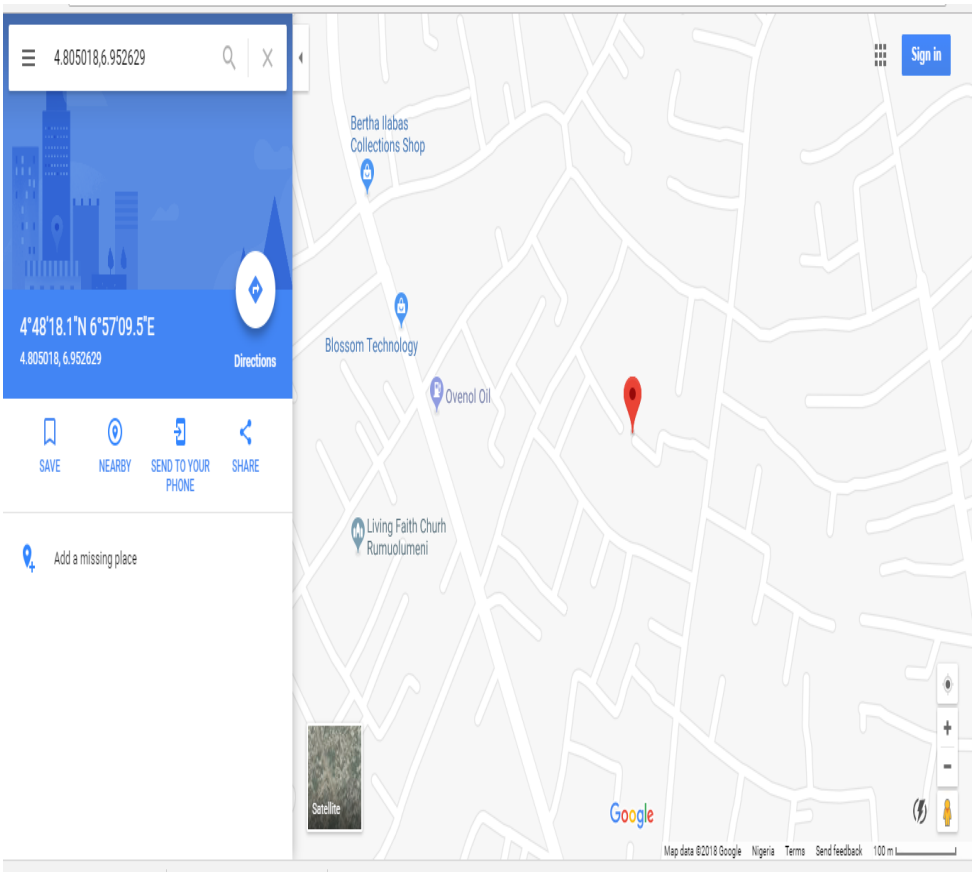


Location *31* (**4.897299, 6.909675**)

*Location 32 (***4.805018, 6.952629***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB47 to eNB 48)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.897299	0.08547	6.909675	0.1206	13.82804	16
eNB 1	4.8366	0.08441	7.0286	0.12267	4.897299	0.08547	6.909675	0.1206	14.8042	17.2
eNB 2	4.7737	0.08332	7.0142	0.12242	4.897299	0.08547	6.909675	0.1206	17.97247	20.6
eNB 3	4.7999	0.08377	6.9939	0.12207	4.897299	0.08547	6.909675	0.1206	14.29606	16.5
eNB 4	4.8294	0.08429	7.0919	0.12378	4.897299	0.08547	6.909675	0.1206	21.55496	23.1
eNB 5	4.7706	0.08326	7.0224	0.12256	4.897299	0.08547	6.909675	0.1206	18.82748	22
eNB 6	4.8746	0.08508	6.983	0.12188	4.897299	0.08547	6.909675	0.1206	8.506763	9.2
eNB 7	4.8692	0.08498	7.1137	0.12416	4.897299	0.08547	6.909675	0.1206	22.81901	26.3
eNB 8	4.7196	0.08237	7.1518	0.12482	4.897299	0.08547	6.909675	0.1206	33.31931	37.8
eNB 9	4.8554	0.08474	7.0641	0.12329	4.897299	0.08547	6.909675	0.1206	17.73203	19.3
eNB 10	4.7909	0.08362	7.1207	0.12428	4.897299	0.08547	6.909675	0.1206	26.20387	28.4
eNB 11	4.7854	0.08352	7.0082	0.12232	4.897299	0.08547	6.909675	0.1206	16.55246	19.4
eNB 12	4.8327	0.08435	7.0685	0.12337	4.897299	0.08547	6.909675	0.1206	19.00643	21.4
eNB 13	4.8039	0.08384	6.9883	0.12197	4.897299	0.08547	6.909675	0.1206	13.55528	15.7
eNB 14	4.8197	0.08412	7.0656	0.12332	4.897299	0.08547	6.909675	0.1206	19.31067	21.6
eNB 15	4.743	0.08278	7.0417	0.1229	4.897299	0.08547	6.909675	0.1206	22.54692	26
eNB 16	4.7939	0.08367	7.0308	0.12271	4.897299	0.08547	6.909675	0.1206	17.67186	20.4
eNB 17	4.748	0.08287	7.0989	0.1239	4.897299	0.08547	6.909675	0.1206	26.74295	33.1
eNB 18	4.7773	0.08338	7.062	0.12325	4.897299	0.08547	6.909675	0.1206	21.51481	24.7
eNB 19	4.8341	0.08437	6.9845	0.1219	4.897299	0.08547	6.909675	0.1206	10.86787	12.4
eNB 20	4.8565	0.08476	7.0405	0.12288	4.897299	0.08547	6.909675	0.1206	15.18772	16.1
eNB 21	4.8064	0.08389	7.0424	0.12291	4.897299	0.08547	6.909675	0.1206	17.84404	20.5
eNB 22	4.8146	0.08403	6.9788	0.1218	4.897299	0.08547	6.909675	0.1206	11.96732	13.9
eNB 23	4.8298	0.0843	6.9588	0.12145	4.897299	0.08547	6.909675	0.1206	9.271279	12.7
eNB 24	4.8923	0.08539	6.9143	0.12068	4.897299	0.08547	6.909675	0.1206	0.756005	0.9
eNB 25	4.848	0.08461	7.0492	0.12303	4.897299	0.08547	6.909675	0.1206	16.40152	17.7
eNB 26	4.8514	0.08467	6.9835	0.12188	4.897299	0.08547	6.909675	0.1206	9.640949	10.3
eNB 27	4.8081	0.08392	6.9967	0.12211	4.897299	0.08547	6.909675	0.1206	13.83271	16
eNB 28	4.9028	0.08557	6.999	0.12216	4.897299	0.08547	6.909675	0.1206	9.915009	12.2
eNB 29	4.9789	0.0869	6.9611	0.12149	4.897299	0.08547	6.909675	0.1206	10.71375	14.8
eNB 30	4.9969	0.08721	6.95	0.1213	4.897299	0.08547	6.909675	0.1206	11.94205	15.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.897299	0.08547	6.909675	0.1206	12.8788	17.6
eNB 32	4.9669	0.08669	6.9869	0.12194	4.897299	0.08547	6.909675	0.1206	11.53631	18
eNB 33	4.8289	0.08428	7.0219	0.12255	4.897299	0.08547	6.909675	0.1206	14.57554	16.7
eNB 34	4.8169	0.08407	7.0112	0.12237	4.897299	0.08547	6.909675	0.1206	14.36839	16.1
eNB 35	4.9317	0.08607	7.0021	0.12221	4.897299	0.08547	6.909675	0.1206	10.93051	14.8
eNB 36	4.8407	0.08449	6.9681	0.12162	4.897299	0.08547	6.909675	0.1206	9.02824	11.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.897299	0.08547	6.909675	0.1206	8.758945	9.3
eNB 38	4.8469	0.08459	7.0369	0.12282	4.897299	0.08547	6.909675	0.1206	15.16877	16
eNB 39	4.8585	0.0848	6.9658	0.12158	4.897299	0.08547	6.909675	0.1206	7.568253	8.6
eNB 40	4.88	0.08517	7.01	0.12235	4.897299	0.08547	6.909675	0.1206	11.2802	13.1

eNB 41	4.8669	0.08494	7.03	0.1227	4.897299	0.08547	6.909675	0.1206	13.75279	15.2
eNB 42	4.8378	0.08444	7.037	0.12282	4.897299	0.08547	6.909675	0.1206	15.58114	17.2
eNB 43	4.8842	0.08525	7.138	0.12458	4.897299	0.08547	6.909675	0.1206	25.33792	28.8
eNB 44	4.7815	0.08345	7.0398	0.12287	4.897299	0.08547	6.909675	0.1206	19.33039	22.2
eNB 45	4.8116	0.08398	6.9561	0.12141	4.897299	0.08547	6.909675	0.1206	10.82888	15
eNB 46	4.9011	0.08554	6.9269	0.1209	4.897299	0.08547	6.909675	0.1206	1.954543	2.9
eNB 47	4.9058	0.08562	6.9066	0.12054	4.897299	0.08547	6.909675	0.1206	1.00476	1.3
eNB 48	4.8024	0.08382	6.944	0.1212	4.897299	0.08547	6.909675	0.1206	11.21667	16.6
eNB 49	4.8354	0.08439	7.0528	0.12309	4.897299	0.08547	6.909675	0.1206	17.28665	18.6
eNB 50	4.7947	0.08368	7.0497	0.12304	4.897299	0.08547	6.909675	0.1206	19.2574	22.1
eNB 51	4.7581	0.08304	7.0119	0.12238	4.897299	0.08547	6.909675	0.1206	19.17978	22.2
eNB 52	4.8269	0.08424	6.9961	0.1221	4.897299	0.08547	6.909675	0.1206	12.36793	13.7
eNB 53	4.815	0.08404	7.0419	0.1229	4.897299	0.08547	6.909675	0.1206	17.27322	20.3
eNB 54	4.71	0.0822	7.165	0.12505	4.897299	0.08547	6.909675	0.1206	35.13016	39.5
eNB 55	4.8233	0.08418	7.0572	0.12317	4.897299	0.08547	6.909675	0.1206	18.29926	20.7
eNB 56	4.815	0.08404	7.0652	0.12331	4.897299	0.08547	6.909675	0.1206	19.51068	21.6
eNB 57	4.894	0.08542	7.0153	0.12244	4.897299	0.08547	6.909675	0.1206	11.7078	14.5
eNB 58	4.8626	0.08487	7.0153	0.12244	4.897299	0.08547	6.909675	0.1206	12.32199	12.7
eNB 59	4.8276	0.08426	7.0145	0.12243	4.897299	0.08547	6.909675	0.1206	13.96245	15.6
									916.5042	1063.8

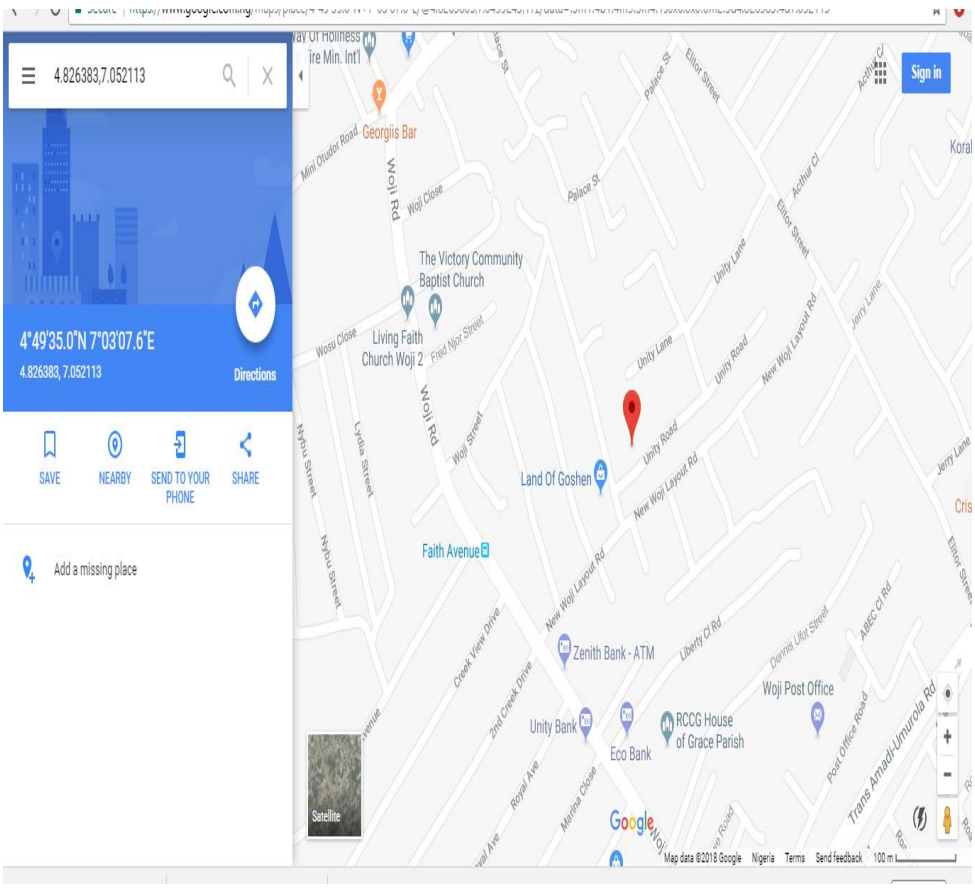


Location *32* (**4.805018, 6.952629**)

*Location 33 (***4.826383, 7.052113***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB48 to eNB 49)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.805018	0.08386	6.952629	0.12135	4.890654	8
eNB 1	4.8366	0.08441	7.0286	0.12267	4.805018	0.08386	6.952629	0.12135	9.120875	11.6
eNB 2	4.7737	0.08332	7.0142	0.12242	4.805018	0.08386	6.952629	0.12135	7.659855	11.4
eNB 3	4.7999	0.08377	6.9939	0.12207	4.805018	0.08386	6.952629	0.12135	4.608313	7.4
eNB 4	4.8294	0.08429	7.0919	0.12378	4.805018	0.08386	6.952629	0.12135	15.66786	20.3
eNB 5	4.7706	0.08326	7.0224	0.12256	4.805018	0.08386	6.952629	0.12135	8.626518	12.9
eNB 6	4.8746	0.08508	6.983	0.12188	4.805018	0.08386	6.952629	0.12135	8.437254	10.5
eNB 7	4.8692	0.08498	7.1137	0.12416	4.805018	0.08386	6.952629	0.12135	19.22053	23.7
eNB 8	4.7196	0.08237	7.1518	0.12482	4.805018	0.08386	6.952629	0.12135	24.02728	33.9
eNB 9	4.8554	0.08474	7.0641	0.12329	4.805018	0.08386	6.952629	0.12135	13.56214	16
eNB 10	4.7909	0.08362	7.1207	0.12428	4.805018	0.08386	6.952629	0.12135	18.68917	24.6
eNB 11	4.7854	0.08352	7.0082	0.12232	4.805018	0.08386	6.952629	0.12135	6.53258	10.3
eNB 12	4.8327	0.08435	7.0685	0.12337	4.805018	0.08386	6.952629	0.12135	13.20255	17.5
eNB 13	4.8039	0.08384	6.9883	0.12197	4.805018	0.08386	6.952629	0.12135	3.95448	17.5
eNB 14	4.8197	0.08412	7.0656	0.12332	4.805018	0.08386	6.952629	0.12135	12.62353	17.7
eNB 15	4.743	0.08278	7.0417	0.1229	4.805018	0.08386	6.952629	0.12135	12.04035	16.9
eNB 16	4.7939	0.08367	7.0308	0.12271	4.805018	0.08386	6.952629	0.12135	8.749527	12.5
eNB 17	4.748	0.08287	7.0989	0.1239	4.805018	0.08386	6.952629	0.12135	17.40398	29.2
eNB 18	4.7773	0.08338	7.062	0.12325	4.805018	0.08386	6.952629	0.12135	12.50477	16.9
eNB 19	4.8341	0.08437	6.9845	0.1219	4.805018	0.08386	6.952629	0.12135	4.788319	5.6
eNB 20	4.8565	0.08476	7.0405	0.12288	4.805018	0.08386	6.952629	0.12135	11.29433	14.7
eNB 21	4.8064	0.08389	7.0424	0.12291	4.805018	0.08386	6.952629	0.12135	9.948179	14.3
eNB 22	4.8146	0.08403	6.9788	0.1218	4.805018	0.08386	6.952629	0.12135	3.089412	4.7
eNB 23	4.8298	0.0843	6.9588	0.12145	4.805018	0.08386	6.952629	0.12135	2.839207	3.7
eNB 24	4.8923	0.08539	6.9143	0.12068	4.805018	0.08386	6.952629	0.12135	10.59372	15.3
eNB 25	4.848	0.08461	7.0492	0.12303	4.805018	0.08386	6.952629	0.12135	11.71901	14
eNB 26	4.8514	0.08467	6.9835	0.12188	4.805018	0.08386	6.952629	0.12135	6.188641	7.7
eNB 27	4.8081	0.08392	6.9967	0.12211	4.805018	0.08386	6.952629	0.12135	4.895274	8
eNB 28	4.9028	0.08557	6.999	0.12216	4.805018	0.08386	6.952629	0.12135	12.02559	14.2
eNB 29	4.9789	0.0869	6.9611	0.12149	4.805018	0.08386	6.952629	0.12135	19.3575	23.7
eNB 30	4.9969	0.08721	6.95	0.1213	4.805018	0.08386	6.952629	0.12135	21.33822	24.4
eNB 31	4.9539	0.08646	7.0111	0.12237	4.805018	0.08386	6.952629	0.12135	17.77723	20
eNB 32	4.9669	0.08669	6.9869	0.12194	4.805018	0.08386	6.952629	0.12135	18.39649	23.4
eNB 33	4.8289	0.08428	7.0219	0.12255	4.805018	0.08386	6.952629	0.12135	8.1218	10.6
eNB 34	4.8169	0.08407	7.0112	0.12237	4.805018	0.08386	6.952629	0.12135	6.622994	9.5
eNB 35	4.9317	0.08607	7.0021	0.12221	4.805018	0.08386	6.952629	0.12135	15.11515	17.3
eNB 36	4.8407	0.08449	6.9681	0.12162	4.805018	0.08386	6.952629	0.12135	4.32214	5.4
eNB 37	4.8598	0.08482	6.9792	0.12181	4.805018	0.08386	6.952629	0.12135	6.765622	8.7
eNB 38	4.8469	0.08459	7.0369	0.12282	4.805018	0.08386	6.952629	0.12135	10.43423	13.1
eNB 39	4.8585	0.0848	6.9658	0.12158	4.805018	0.08386	6.952629	0.12135	6.123364	7.5
eNB 40	4.88	0.08517	7.01	0.12235	4.805018	0.08386	6.952629	0.12135	10.48437	12.3

eNB 41	4.8669	0.08494	7.03	0.1227	4.805018	0.08386	6.952629	0.12135	10.99262	14.3
eNB 42	4.8378	0.08444	7.037	0.12282	4.805018	0.08386	6.952629	0.12135	10.03398	12.4
eNB 43	4.8842	0.08525	7.138	0.12458	4.805018	0.08386	6.952629	0.12135	22.34629	27.9
eNB 44	4.7815	0.08345	7.0398	0.12287	4.805018	0.08386	6.952629	0.12135	10.00681	14.3
eNB 45	4.8116	0.08398	6.9561	0.12141	4.805018	0.08386	6.952629	0.12135	0.826812	1
eNB 46	4.9011	0.08554	6.9269	0.1209	4.805018	0.08386	6.952629	0.12135	11.05756	15.8
eNB 47	4.9058	0.08562	6.9066	0.12054	4.805018	0.08386	6.952629	0.12135	12.31224	17.1
eNB 48	4.8024	0.08382	6.944	0.1212	4.805018	0.08386	6.952629	0.12135	0.999415	1.6
eNB 49	4.8354	0.08439	7.0528	0.12309	4.805018	0.08386	6.952629	0.12135	11.60187	14.7
eNB 50	4.7947	0.08368	7.0497	0.12304	4.805018	0.08386	6.952629	0.12135	10.81697	14.9
eNB 51	4.7581	0.08304	7.0119	0.12238	4.805018	0.08386	6.952629	0.12135	8.387615	13
eNB 52	4.8269	0.08424	6.9961	0.1221	4.805018	0.08386	6.952629	0.12135	5.396392	7.1
eNB 53	4.815	0.08404	7.0419	0.1229	4.805018	0.08386	6.952629	0.12135	9.953608	14.6
eNB 54	4.71	0.0822	7.165	0.12505	4.805018	0.08386	6.952629	0.12135	25.7961	35.7
eNB 55	4.8233	0.08418	7.0572	0.12317	4.805018	0.08386	6.952629	0.12135	11.76372	16.8
eNB 56	4.815	0.08404	7.0652	0.12331	4.805018	0.08386	6.952629	0.12135	12.52252	17.7
eNB 57	4.894	0.08542	7.0153	0.12244	4.805018	0.08386	6.952629	0.12135	12.08774	14.9
eNB 58	4.8626	0.08487	7.0153	0.12244	4.805018	0.08386	6.952629	0.12135	9.445323	11.8
eNB 59	4.8276	0.08426	7.0145	0.12243	4.805018	0.08386	6.952629	0.12135	7.30086	9.5
									647.4115	872



Location *33* (**4.826383, 7.052113**)

*Location 34 (***4.78842, 7.043214***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB49 to eNB 50)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.08392	6.996657	0.12211	4.826383	0.08424	7.052113	0.12308	6.471638	9.6
eNB 1	4.8366	0.08441	7.0286	0.12267	4.826383	0.08424	7.052113	0.12308	2.842177	5
eNB 2	4.7737	0.08332	7.0142	0.12242	4.826383	0.08424	7.052113	0.12308	7.208691	10.3
eNB 3	4.7999	0.08377	6.9939	0.12207	4.826383	0.08424	7.052113	0.12308	7.09059	9.7
eNB 4	4.8294	0.08429	7.0919	0.12378	4.826383	0.08424	7.052113	0.12308	4.421112	5.6
eNB 5	4.7706	0.08326	7.0224	0.12256	4.826383	0.08424	7.052113	0.12308	7.022412	9.7
eNB 6	4.8746	0.08508	6.983	0.12188	4.826383	0.08424	7.052113	0.12308	9.347846	11.3
eNB 7	4.8692	0.08498	7.1137	0.12416	4.826383	0.08424	7.052113	0.12308	8.320373	10.6
eNB 8	4.7196	0.08237	7.1518	0.12482	4.826383	0.08424	7.052113	0.12308	16.21736	19.2
eNB 9	4.8554	0.08474	7.0641	0.12329	4.826383	0.08424	7.052113	0.12308	3.489154	5
eNB 10	4.7909	0.08362	7.1207	0.12428	4.826383	0.08424	7.052113	0.12308	8.562799	9.8
eNB 11	4.7854	0.08352	7.0082	0.12232	4.826383	0.08424	7.052113	0.12308	6.666538	8.4
eNB 12	4.8327	0.08435	7.0685	0.12337	4.826383	0.08424	7.052113	0.12308	1.94677	2.8
eNB 13	4.8039	0.08384	6.9883	0.12197	4.826383	0.08424	7.052113	0.12308	7.499602	10.7
eNB 14	4.8197	0.08412	7.0656	0.12332	4.826383	0.08424	7.052113	0.12308	1.668923	2.4
eNB 15	4.743	0.08278	7.0417	0.1229	4.826383	0.08424	7.052113	0.12308	9.343277	14.2
eNB 16	4.7939	0.08367	7.0308	0.12271	4.826383	0.08424	7.052113	0.12308	4.315466	5.8
eNB 17	4.748	0.08287	7.0989	0.1239	4.826383	0.08424	7.052113	0.12308	10.14108	14.5
eNB 18	4.7773	0.08338	7.062	0.12325	4.826383	0.08424	7.052113	0.12308	5.566642	6.8
eNB 19	4.8341	0.08437	6.9845	0.1219	4.826383	0.08424	7.052113	0.12308	7.540503	10.1
eNB 20	4.8565	0.08476	7.0405	0.12288	4.826383	0.08424	7.052113	0.12308	3.587513	5.1
eNB 21	4.8064	0.08389	7.0424	0.12291	4.826383	0.08424	7.052113	0.12308	2.468948	3.4
eNB 22	4.8146	0.08403	6.9788	0.1218	4.826383	0.08424	7.052113	0.12308	8.228185	12.1
eNB 23	4.8298	0.0843	6.9588	0.12145	4.826383	0.08424	7.052113	0.12308	10.34608	13.4
eNB 24	4.8923	0.08539	6.9143	0.12068	4.826383	0.08424	7.052113	0.12308	16.93709	18.9
eNB 25	4.848	0.08461	7.0492	0.12303	4.826383	0.08424	7.052113	0.12308	2.425243	3.2
eNB 26	4.8514	0.08467	6.9835	0.12188	4.826383	0.08424	7.052113	0.12308	8.095174	11.9
eNB 27	4.8081	0.08392	6.9967	0.12211	4.826383	0.08424	7.052113	0.12308	6.467709	9.6
eNB 28	4.9028	0.08557	6.999	0.12216	4.826383	0.08424	7.052113	0.12308	10.33586	12.3
eNB 29	4.9789	0.0869	6.9611	0.12149	4.826383	0.08424	7.052113	0.12308	19.73014	24.5
eNB 30	4.9969	0.08721	6.95	0.1213	4.826383	0.08424	7.052113	0.12308	22.07894	25.2
eNB 31	4.9539	0.08646	7.0111	0.12237	4.826383	0.08424	7.052113	0.12308	14.88943	18.4
eNB 32	4.9669	0.08669	6.9869	0.12194	4.826383	0.08424	7.052113	0.12308	17.21424	21.2
eNB 33	4.8289	0.08428	7.0219	0.12255	4.826383	0.08424	7.052113	0.12308	3.359308	5.6
eNB 34	4.8169	0.08407	7.0112	0.12237	4.826383	0.08424	7.052113	0.12308	4.654258	7.4
eNB 35	4.9317	0.08607	7.0021	0.12221	4.826383	0.08424	7.052113	0.12308	12.9554	15.4
eNB 36	4.8407	0.08449	6.9681	0.12162	4.826383	0.08424	7.052113	0.12308	9.443736	12.4
eNB 37	4.8598	0.08482	6.9792	0.12181	4.826383	0.08424	7.052113	0.12308	8.892175	13
eNB 38	4.8469	0.08459	7.0369	0.12282	4.826383	0.08424	7.052113	0.12308	2.83652	3.6
eNB 39	4.8585	0.0848	6.9658	0.12158	4.826383	0.08424	7.052113	0.12308	10.20834	13.2
eNB 40	4.88	0.08517	7.01	0.12235	4.826383	0.08424	7.052113	0.12308	7.570697	8.9

eNB 41	4.8669	0.08494	7.03	0.1227	4.826383	0.08424	7.052113	0.12308	5.128363	7.6
eNB 42	4.8378	0.08444	7.037	0.12282	4.826383	0.08424	7.052113	0.12308	2.10135	3.2
eNB 43	4.8842	0.08525	7.138	0.12458	4.826383	0.08424	7.052113	0.12308	11.48401	14.5
eNB 44	4.7815	0.08345	7.0398	0.12287	4.826383	0.08424	7.052113	0.12308	5.173899	6.5
eNB 45	4.8116	0.08398	6.9561	0.12141	4.826383	0.08424	7.052113	0.12308	10.76466	14.7
eNB 46	4.9011	0.08554	6.9269	0.1209	4.826383	0.08424	7.052113	0.12308	16.17039	19.3
eNB 47	4.9058	0.08562	6.9066	0.12054	4.826383	0.08424	7.052113	0.12308	18.38202	20.8
eNB 48	4.8024	0.08382	6.944	0.1212	4.826383	0.08424	7.052113	0.12308	12.27244	16.6
eNB 49	4.8354	0.08439	7.0528	0.12309	4.826383	0.08424	7.052113	0.12308	1.005499	2.2
eNB 50	4.7947	0.08368	7.0497	0.12304	4.826383	0.08424	7.052113	0.12308	3.533133	4.6
eNB 51	4.7581	0.08304	7.0119	0.12238	4.826383	0.08424	7.052113	0.12308	8.80364	12.1
eNB 52	4.8269	0.08424	6.9961	0.1221	4.826383	0.08424	7.052113	0.12308	6.206547	8.9
eNB 53	4.815	0.08404	7.0419	0.1229	4.826383	0.08424	7.052113	0.12308	1.697864	2.6
eNB 54	4.71	0.0822	7.165	0.12505	4.826383	0.08424	7.052113	0.12308	17.99854	20.9
eNB 55	4.8233	0.08418	7.0572	0.12317	4.826383	0.08424	7.052113	0.12308	0.659693	1.5
eNB 56	4.815	0.08404	7.0652	0.12331	4.826383	0.08424	7.052113	0.12308	1.924759	2.4
eNB 57	4.894	0.08542	7.0153	0.12244	4.826383	0.08424	7.052113	0.12308	8.55368	10.9
eNB 58	4.8626	0.08487	7.0153	0.12244	4.826383	0.08424	7.052113	0.12308	5.731864	7.2
eNB 59	4.8276	0.08426	7.0145	0.12243	4.826383	0.08424	7.052113	0.12308	4.169751	6.6
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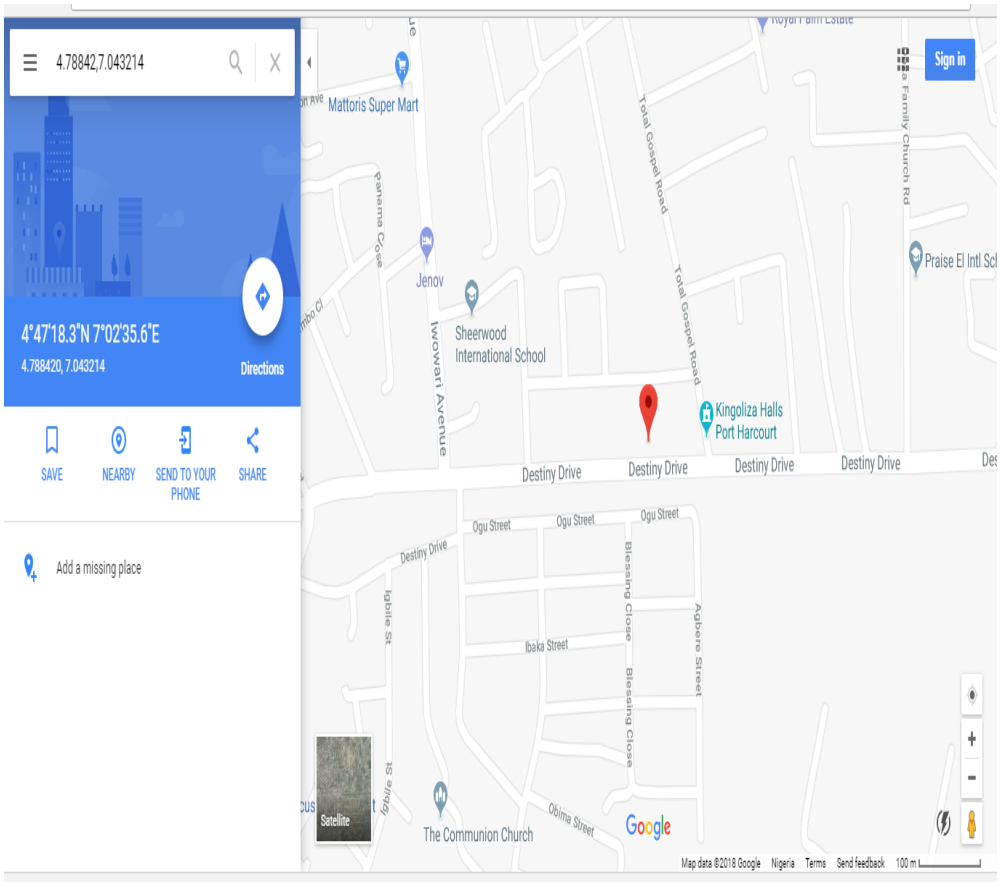

Location *34* (**4.78842, 7.043214**)

Location *35 (***4.78842, 7.043214***)*

EXCHANGE/NODB PARAMETERS					SPLITTER PARAMETERS (1km from eNB50 to eNB 51)				GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)		
exchange	4.808117	0.083917	6.996657	0.12211	4.78842	0.08357	7.043214	0.12293	5.60439	7.5
eNB 1	4.8366	0.084414	7.0286	0.12267	4.78842	0.08357	7.043214	0.12293	5.596699	6.6
eNB 2	4.7737	0.083316	7.0142	0.12242	4.78842	0.08357	7.043214	0.12293	3.607619	7.3
eNB 3	4.7999	0.083774	6.9939	0.12207	4.78842	0.08357	7.043214	0.12293	5.61135	6.9
eNB 4	4.8294	0.084289	7.0919	0.12378	4.78842	0.08357	7.043214	0.12293	7.06155	10.2
eNB 5	4.7706	0.083262	7.0224	0.12256	4.78842	0.08357	7.043214	0.12293	3.040631	6.7
eNB 6	4.8746	0.085077	6.983	0.12188	4.78842	0.08357	7.043214	0.12293	11.67645	14.9
eNB 7	4.8692	0.084983	7.1137	0.12416	4.78842	0.08357	7.043214	0.12293	11.90275	15.1
eNB 8	4.7196	0.082372	7.1518	0.12482	4.78842	0.08357	7.043214	0.12293	14.25988	23.8
eNB 9	4.8554	0.084742	7.0641	0.12329	4.78842	0.08357	7.043214	0.12293	7.799058	10.3
eNB 10	4.7909	0.083617	7.1207	0.12428	4.78842	0.08357	7.043214	0.12293	8.590387	14.4
eNB 11	4.7854	0.083521	7.0082	0.12232	4.78842	0.08357	7.043214	0.12293	3.894258	5.4
eNB 12	4.8327	0.084346	7.0685	0.12337	4.78842	0.08357	7.043214	0.12293	5.665041	7.3
eNB 13	4.8039	0.083844	6.9883	0.12197	4.78842	0.08357	7.043214	0.12293	6.323499	7.9
eNB 14	4.8197	0.084119	7.0656	0.12332	4.78842	0.08357	7.043214	0.12293	4.272046	5.8
eNB 15	4.743	0.082781	7.0417	0.1229	4.78842	0.08357	7.043214	0.12293	5.053246	11.2
eNB 16	4.7939	0.083669	7.0308	0.12271	4.78842	0.08357	7.043214	0.12293	1.504436	1.8
eNB 17	4.748	0.082868	7.0989	0.1239	4.78842	0.08357	7.043214	0.12293	7.633902	19.1
eNB 18	4.7773	0.083379	7.062	0.12325	4.78842	0.08357	7.043214	0.12293	2.4212	3
eNB 19	4.8341	0.084371	6.9845	0.1219	4.78842	0.08357	7.043214	0.12293	8.253675	10.6
eNB 20	4.8565	0.084762	7.0405	0.12288	4.78842	0.08357	7.043214	0.12293	7.576081	9.5
eNB 21	4.8064	0.083887	7.0424	0.12291	4.78842	0.08357	7.043214	0.12293	2.001301	2.6
eNB 22	4.8146	0.08403	6.9788	0.1218	4.78842	0.08357	7.043214	0.12293	7.708147	9.6
eNB 23	4.8298	0.084296	6.9588	0.12145	4.78842	0.08357	7.043214	0.12293	10.42379	13.4
eNB 24	4.8923	0.085386	6.9143	0.12068	4.78842	0.08357	7.043214	0.12293	18.36947	21.2
eNB 25	4.848	0.084613	7.0492	0.12303	4.78842	0.08357	7.043214	0.12293	6.65808	8.5
eNB 26	4.8514	0.084673	6.9835	0.12188	4.78842	0.08357	7.043214	0.12293	9.634233	12.4
eNB 27	4.8081	0.083917	6.9967	0.12211	4.78842	0.08357	7.043214	0.12293	5.599265	7.5
eNB 28	4.9028	0.08557	6.999	0.12216	4.78842	0.08357	7.043214	0.12293	13.62923	16.4
eNB 29	4.9789	0.086898	6.9611	0.12149	4.78842	0.08357	7.043214	0.12293	23.05145	28.7
eNB 30	4.9969	0.087212	6.95	0.1213	4.78842	0.08357	7.043214	0.12293	25.37804	29.3
eNB 31	4.9539	0.086462	7.0111	0.12237	4.78842	0.08357	7.043214	0.12293	18.74129	22.2
eNB 32	4.9669	0.086688	6.9869	0.12194	4.78842	0.08357	7.043214	0.12293	20.80359	25.6
eNB 33	4.8289	0.08428	7.0219	0.12255	4.78842	0.08357	7.043214	0.12293	5.083067	5.8
eNB 34	4.8169	0.08407	7.0112	0.12237	4.78842	0.08357	7.043214	0.12293	4.755173	6.1
eNB 35	4.9317	0.086074	7.0021	0.12221	4.78842	0.08357	7.043214	0.12293	16.57034	19.5
eNB 36	4.8407	0.084486	6.9681	0.12162	4.78842	0.08357	7.043214	0.12293	10.15195	13
eNB 37	4.8598	0.084819	6.9792	0.12181	4.78842	0.08357	7.043214	0.12293	10.64444	13.3
eNB 38	4.8469	0.084594	7.0369	0.12282	4.78842	0.08357	7.043214	0.12293	6.540167	7.9
eNB 39	4.8585	0.084796	6.9658	0.12158	4.78842	0.08357	7.043214	0.12293	11.58863	13.8
eNB 40	4.88	0.085172	7.01	0.12235	4.78842	0.08357	7.043214	0.12293	10.82774	13

eNB 41	4.8669	0.084943	7.03	0.1227	4.78842	0.08357	7.043214	0.12293	8.848499	11.9
eNB 42	4.8378	0.084435	7.037	0.12282	4.78842	0.08357	7.043214	0.12293	5.533772	6.6
eNB 43	4.8842	0.085245	7.138	0.12458	4.78842	0.08357	7.043214	0.12293	14.95736	19.1
eNB 44	4.7815	0.083453	7.0398	0.12287	4.78842	0.08357	7.043214	0.12293	0.857422	1.2
eNB 45	4.8116	0.083978	6.9561	0.12141	4.78842	0.08357	7.043214	0.12293	9.990792	13.3
eNB 46	4.9011	0.08554	6.9269	0.1209	4.78842	0.08357	7.043214	0.12293	17.97404	21.7
eNB 47	4.9058	0.085622	6.9066	0.12054	4.78842	0.08357	7.043214	0.12293	19.9866	23.1
eNB 48	4.8024	0.083817	6.944	0.1212	4.78842	0.08357	7.043214	0.12293	11.10276	15.2
eNB 49	4.8354	0.084393	7.0528	0.12309	4.78842	0.08357	7.043214	0.12293	5.330803	7.4
eNB 50	4.7947	0.083683	7.0497	0.12304	4.78842	0.08357	7.043214	0.12293	1.002083	1.4
eNB 51	4.7581	0.083044	7.0119	0.12238	4.78842	0.08357	7.043214	0.12293	4.838002	9.1
eNB 52	4.8269	0.084245	6.9961	0.1221	4.78842	0.08357	7.043214	0.12293	6.749802	8.7
eNB 53	4.815	0.084037	7.0419	0.1229	4.78842	0.08357	7.043214	0.12293	2.959124	3.9
eNB 54	4.71	0.082205	7.165	0.12505	4.78842	0.08357	7.043214	0.12293	16.06748	25.5
eNB 55	4.8233	0.084182	7.0572	0.12317	4.78842	0.08357	7.043214	0.12293	4.176611	5.7
eNB 56	4.815	0.084037	7.0652	0.12331	4.78842	0.08357	7.043214	0.12293	3.830165	4.8
eNB 57	4.894	0.085416	7.0153	0.12244	4.78842	0.08357	7.043214	0.12293	12.14045	15
eNB 58	4.8626	0.084868	7.0153	0.12244	4.78842	0.08357	7.043214	0.12293	8.809188	11.3
eNB 59	4.8276	0.084257	7.0145	0.12243	4.78842	0.08357	7.043214	0.12293	5.394653	6.5
									536.0572	706.5

APPENDIX C

```
clc
splittercordinateslat=[];
splittercordinateslng=[];
splitdistfrom_exchange=[];
splitterdistfrom_exchange=[];
splitcordlat=[];
splitcordlng=[];
longitude=[];
lattitude=[];
N=input('how many base stations do you have, including the exchange ? ');
disp('')
disp('what are their cordinates, starting with the exchange ?')
disp('')
disp('note that the first cordinates have to be for the exchange location.
')
lat20=input('type or copy the base stations latitude cordinates in  square
brackets')

lattitude=lat20;

lng20=input('type or copy the base stations longitude cordinates in square
brackets')
longitude=lng20;




n=1;
nn=0;
while(n<=N)
    latt1=lattitude(n)-0.017986432118375;
    latt2=lattitude(n)+0.017986432118375;
    latt3=latt2;
    latt4=latt1;

    lng1=longitude(n)-0.017986432118375*cos(lattitude(n));
    lng2=lng1;
    lng3=longitude(n)+0.017986432118375*cos(lattitude(n));
    lng4=lng3;
    ax=4*nn+1;
axx=4*n;
splitcordlat(ax:axx)=[latt1,latt2,latt3,latt4];
splitcordlng(ax:axx)=[lng1,lng2,lng3,lng4];
    n=n+1;
nn=nn+1;
end

n=1; nn=0;
while(n<=(length(splitcordlat)))

    latt1=splitcordlat(n)-0.008993216059187;
    latt2=splitcordlat(n)+0.008993216059187;
    latt3=latt2;
    latt4=latt1;

    lng1=splitcordlng(n)-0.008993216059187*cos(splitcordlat(n));
    lng2=lng1;
    lng3=splitcordlng(n)+0.008993216059187*cos(splitcordlat(n));
    lng4=lng3;
    ax=4*nn+1;
axx=4*n;
    splitcordlat1(ax:axx)=[latt1,latt2,latt3,latt4];
```

```
    splitcordlng1(ax:axx)=[lng1,lng2,lng3,lng4];
    n=n+1;
nn=nn+1;
end

splittercordinateslat(1:(length(splitcordlat)))=splitcordlat;
splittercordinateslat((length(splitcordlat)+1):(length(splitcordlat1)+(lengt
h(splitcordlat))))=splitcordlat1;

splittercordinateslng(1:(length(splitcordlng)))=splitcordlng;
splittercordinateslng((length(splitcordlng)+1):(length(splitcordlng1)+(lengt
h(splitcordlng))))=splitcordlng1;



xx=1;
while(xx<=length(splittercordinateslat))
    xxx=1;
while(xxx<=N)
lt=splittercordinateslat(xx)*(pi/180);
        lg=splittercordinateslng(xx)*(pi/180);
ltt=lattitude(xxx)*(pi/180);
lgg=longitude(xxx)*(pi/180);
        distance1=sqrt(((cos(ltt)*sin(lgg-lg))^2)+(cos(lt)*sin(ltt)-
sin(lt)*cos(ltt)*cos(lgg-lg))^2);
        distance2=(sin(lt)*sin(ltt)+cos(lt)*cos(ltt)*cos(lgg-lg));
anglediff=atan(distance1/distance2);
        distance3=(6371*anglediff);
splitdistfrom_exchange(xxx)=distance3;
        xxx=xxx+1;
end
summ=sum(splitdistfrom_exchange);
splitterdistfrom_exchange(xx)=summ;
    xx=xx+1;
end
fiberlength=min(splitterdistfrom_exchange);
disp('')
qran=splitterdistfrom_exchange;


disp('the minimum total length of fiber is...')

disp(fiberlength)
disp('kilometers')

h=1;
while(splitterdistfrom_exchange(h)~=fiberlength)
   h=h+1;
end
hh=h;


az=splittercordinateslat(h);
azz=splittercordinateslng(h);

disp('THE LATITUDE CORDINATE OF THE OPTIMUM SPLITTER LOCATION IS...')
disp(az)


disp('THE LONGITUDE CORDINATE OF THE OPTIMUM SPLITTER LOCATION IS...')
disp(azz)
```

```
disp('FOR ANY REASONS LIKE TOPOGRAPHY OR PRESENCE OF WATER BODIES WHICH MAY
HINDER  ')
disp('THE USE OF THIS OPTIMUM LOCATION, THE NEXT BEST FIVE LOCATIONS CAN
ALSO BE ')
disp('CONSIDERED AND CHOICES MADE BASED ON FAVOURABLE TOPOGRAPHICAL
CONDITIONS ')

disp('THE NEXT BEST FIVE LOCATIONS LOCATIONS AND THIER CORDINATES ARE
DISPLAYED BELOW')


splitterdistfrom_exchange(h)=[];
fiberlength=min(splitterdistfrom_exchange)
h=1;
while(splitterdistfrom_exchange(h)~=fiberlength)
   h=h+1;
end
hh=h;
       az1=splittercordinateslat(h);
azz1=splittercordinateslng(h);

disp('THE LATITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(az1)


disp('THE LONGITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(azz1)



splitterdistfrom_exchange(h)=[];
fiberlength=min(splitterdistfrom_exchange)
h=1;
while(splitterdistfrom_exchange(h)~=fiberlength)
   h=h+1;
end
hh=h;
       az1=splittercordinateslat(h);
azz1=splittercordinateslng(h);

disp('THE LATITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(az1)


disp('THE LONGITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(azz1)


splitterdistfrom_exchange(h)=[];
fiberlength=min(splitterdistfrom_exchange)
h=1;
while(splitterdistfrom_exchange(h)~=fiberlength)
   h=h+1;
end
hh=h;
       az1=splittercordinateslat(h);
azz1=splittercordinateslng(h);

disp('THE LATITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(az1)
```

```
disp('THE LONGITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(azz1)


splitterdistfrom_exchange(h)=[];
fiberlength=min(splitterdistfrom_exchange)
h=1;
while(splitterdistfrom_exchange(h)~=fiberlength)
   h=h+1;
end
hh=h;
       az1=splittercordinateslat(h);
azz1=splittercordinateslng(h);

disp('THE LATITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(az1)


disp('THE LONGITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(azz1)


splitterdistfrom_exchange(h)=[];
fiberlength=min(splitterdistfrom_exchange)
h=1;
while(splitterdistfrom_exchange(h)~=fiberlength)
   h=h+1;
end
hh=h;
       az1=splittercordinateslat(h);
azz1=splittercordinateslng(h);

disp('THE LATITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(az1)


disp('THE LONGITUDE CORDINATE OF THE NEXT BEST SPLITTER LOCATION IS...')
disp(azz1)
```