# PLANNING AND DESIGN OF FIBER OPTIC DIGITAL TRANSMISSION IN NIGERIAN TELECOMMUNICATION SYSTEM
## OYO STATE AS A CASE STUDY

OLAJIDE, MATTHEW BABATUNDE
EEE/90/2357

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# PLANNING AND DESIGN OF FIBER OPTIC DIGITAL TRANSMISSION IN NIGERIAN TELECOMMUNICATION SYSTEM
# OYO STATE AS A CASE STUDY

BY


**OLAJIDE, MATTHEW BABATUNDE**

**EEE/90/2357**


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SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY
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AKURE, ONDO STATE NIGERIA


AUGUST 2001

## CERTIFICATION

This is to certify that this work was carried out by Mr. OLAJIDE, MATTHEW BABATUNDE (EEE/90/2357) in the Department of Electrical and Electronic Engineering, Federal University of Technology, Akure in partial fulfillment of the requirements for the award of Master Degree in Communication/Electronic Engineering of the Federal University of Technology, Akure.

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# DEDICATION

This project is dedicated to GOD ALMIGHTY, the source and owner of all wisdom and to all who through pursuit of wisdom strive to make the world a better place

# ACKNOWLEDGMENT

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# ABSTRACT

With the Advent of Third - Generation Technology just ahead, wireless terminals and handsets will offer applications that go way beyond basic voice communications. Before this becomes a reality, the technology must pass through various stages of standard development around the world. Design and planning of Digital fiber Optical System in Nigerian Telecommunication was studied on the plesiochronous digital hierarchy design and the upgrade version of it, which is known as synchronous digital hierarchy using a section of the national transmission network of NITEL within Oyo State as a case study.

Both designs were implemented to provide free flow of communication traffics among the local exchanges with their subscribers and other telecommunication stations connected to this network.

The development of digital fibre optic system has proved to be faster, cheaper and easier to acquire, implement, operate and maintain as against other line communication systems. Also, the utilization of this system has been evaluated during the course of study from the annual overall system availability to be more efficient and reliable.

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| | |
|---|---|
| $\mu m$ | micro meter($10^{-6}$) |
| Nm | nano meter($10^{-9}$) |
| Mm | multimode |
| Sm | singlemode |
| GHz | GigaHerzt(109) |
| MHz | Megaherzt(106) |
| E | ElectricField |
| H | MagneticField |
| $\alpha$ | Attenuation constant / absorption coefficient |
| $\beta$ | Phase constant |
| $\delta n$ | Refractive index change |
| $\epsilon_o$ | permittivity of free space($8.854 \times 10^{-12}$ F /m) |
| $\epsilon_r$ | Relative permittivity |
| $D_{mat}$ | Material dispersion coefficient |
| $D_{wg}$ | Waveguide dispersion coefficient |
| $\gamma$ | Propagation coefficient |
| $\lambda$ | Wave length |
| $\mu_o$ | Permeability of free - space (4_x$10^{-7}$ H/m) |
| $\mu_r$ | Relative permeability |
| NA | Numerical Aperture |
| P | Advantage received power |
| Q | Electron charge(1.6x10-19c) |
| σmat | Material Dispersion per unit length |
| σmod | Modal Dispersion per unit length |
| S/N | Signal – to –noise ratio |
| C | Speed of light |

| | |
|---|---|
| F | Frequency |
| E | Photon energy |
| H | Plank,s constant |
| dB | decibels |
| $B_T$ | Total Bandwidth |
| $B_m$ | Overall Modal Bandwidth |
| $B_{mk}$ | Kilometrical Modal Bandwidth of fiber (HZ) |
| L | Link length (KM) |
| R | A constant ( 0.75 ) |
| $B_c$ | overall chromatic bandwidth(HZ) |
| FCl | Fiber cable length |
| NJ | Number of joint |
| $C_L$ | Connector loss |
| $P_r$ | Receiver Sensitivity |
| $P_s$ | Transmit Power |
| EM | Excess Margin |
| Am | Attenuation Measured |
| $F_L$ | Fiber loss from factory |
| $S_L$ | Splice loss |
| $T_L$ | Terminal loss |
| A | Maximum Attenuation |
| SG | System Gain |
| S(km) | Maximum Repeater spacing |

# CHAPTER ONE

# INTRODUCTION

## 1.1 TELECOMMUNICATION DEVELOPMENT IN NIGERIA: AN OVERVIEW

### 1.1. 1 What is Telecommunication?

Telecommunication can be defined as the transfer and delivery of information either in voice, data or video form from one point to another by means of electrical/electromagnetic signals. The medium of transfer can be by cable or wireless technology. Telecommunication provides a fast means of transmitting information over a long distance at a cheap cost compared with the traditional methods of communication - the use of town criers, couriers and post.

Telecommunication media in use include radio, television, and telephone (including telegraph, telex and fax), Satellite Communication and Internet services. [Friday, 1993]

### 1.1.2 Stages of telecommunication development in Nigeria

Telecommunication started in Nigeria in 1895 when the then Colonial government introduced telegraphy, using the electromechanical switch and copper cables, as administration support. Post and Telegraph Department (P & T) were initially offering limited services - telephone, telex and telegraph, by the Public Works Department and later. Telecommunication services and came under one umbrella Clustered Nigeria Telecom (NITEL) in 1985company - NITEL in 1985. The telecommunications industry in Nigeria has grown in leaps and bounds since then, and new technologies and services such as, digital satellite, Integrated Services Digital Network (ISDN), cellular, card-phone and Local Area Network (LAN) have been introduced.

Radio is the next in telecommunication media to come to Nigeria. Introduced by the Colonial administration in 1933, it provided a means of information dissemination and entertainment to the populace. Before the advent of portable wireless, transistor radios, radio broadcasting was through wired loudspeakers (called re-diffusion) located at community receiving centres where large numbers of people gathered to listen to programmes.

The first radio stations started as monitoring and re-broadcast stations for the British Broadcasting Corporation Empire Service. But gradually, local programmes were introduced and the stations soon became full broadcasting houses under the Nigerian Broadcasting Service (NBS), later rename Nigerian Broadcasting Corporation (NBC). Today, there are broadcasting stations owned by the Federal Government under the Federal Radio Corporation of Nigeria (FRCN) Also most State Governments also have their own radio stations. In addition, radio broadcasting has been deregulated and there are a number of private radio stations across the country.

Television was introduced by late Chief Obafemi Awolowo administration in Western region in1959 as the first television medium in Africa. The station situated at Ibadan, is now known as NTA. Other Regions soon followed in establishing their own television stations. At the time the Federal Government took over all television stations in 1976, there were ten television houses in the country. The Nigerian Television Authority was run these stations.

With the deregulation of the communications industry in 1992, States and individuals were allowed to own television and radio broadcasting stations. Most States and some private persons and organisations now own and run their own television and radio stations.

The use of Satellite in communication has made easier international telecommunication, especially data transmission and video coverage of international events. The NITEL owns a number of digital satellite earth stations through which it renders international telecommunication service - telephone, data transmission, broadcast, etc to customers.

Nigeria has also kept abreast of modern developments in information technology, especially of facilities offered by computer technology - Internet. Electronic mail (e-mail) is a very popular and cheap means of telecommunication in the country now while our businessmen and other information users are gradually using the Internet for electronic commerce, as well as to send, receive or obtain information through web-sites

### 1.1.3 Telephone

Telephone is a device for transmitting sound over a distance by means of electrical signal or/and electromagnetic waves. The conventional telephony is the fixed telephone that uses wires but now with the advancement in wireless technology, wireless phones (mobile or cellular phones) are becoming popular.

Telephone can also be used in sending typed or written message. These applications are various known as telegraphy, telex and facsimile.

### 1.1.4 Privatisation of Telecommunication Services

Until 1992, NITEL Limited had the monopoly of telecommunication management, delivery and development. It solely planned, implemented and operated telecommunications network services, and supervised. However, in December 1992, a regulatory agency named "Nigerian Communications Commission" (NCC) was established to regulate, promote, and facilitate the development and operations of the telecommunications industry in Nigeria and protect the rights of users and operators alike. The Decree setting up the NCC also privatised certain areas of telecommunication services, including: installation of terminal or other equipment, provision and operation of pay-phones, provision and operation of private network links employing wire-line communication or satellite within Nigeria, provision and operation of mobile phones etc.

As a follow-up to this privatisation policy, Private Telephone Operators (PTOs) have been licensed to operate telephone services. Seven of these PTOs signed interconnectivity agreements with NITEL between 1997 and 1999. These include Multi-Links Communications Limited, Em-International Systems Limited (EMIS), Intercellular Nigeria Limited, VGG Communications Limited, Bordeaux Telecommunications Limited, Independent Telephone Network (ITN) Limited and Mobitel Nigeria Limited. Each of them was linked to NITEL and allocated various numbers of telephone lines to serve its customers. However the activities of these PTOs are still concentrated in major cities where the demand for their services is high. They are yet to reach the hinterland.

### 1.1.5 Internet

Internet, a modern system of telecommunication via computer network became popular in Nigeria in the late nineties. It involves the telephone, a personal computer (PC) fitted with Internet software, modem and a router. The (PC) is linked with the global Internet via the telephone and information is transmitted to and fro the user's PC via telephone line. The most popular uses are e-mail, electronic commerce and information transmission via the World Wide Web.

### 1.1.6 Satellite

Satellite communication is a system of transmitting information with the aid of a global satellite. NITEL Limited is a signatory to INMARSAT - the global Satellite Company and owns a number of digital satellite earth stations through which it is linked with INMARSAT's global satellite. Through its domestic satellite (DOMSAT) stations, NITEL renders satellite communications services to domestic users. [Ofulue 1993]

## 1.2 FIBRE OPTIC COMMUNICATION SYSTEM

### 1.2.1 Introduction of Fibre Optic Technology

Fibre optic communication is a new era of communication in which instead of electron moving back and forth on metallic wires to carry signals, light waves are guided by tiny glass fibre to accomplish the same purpose.

With information carrying capacity thousands of times greater than that of copper circuits optical communication has a potential to transmit voice, television and data signals or combination of these at an affordable price.

Our current "age of technology" is the result of many brilliant inventions and discoveries, but it is our ability to transmit information, and the media we use to do it, that is perhaps most responsible for its evolution, our increasing ability to transmit more information, more quickly and over longer distances has expanded the frontiers of our technological development in all areas.

Today's low-loss glass fibre optic cable offers wide bandwidth and unique advantages over all previously developed transmission media. The basic point-to-point fibre optic transmission system consists of three basic elements: the optical transmitter, the fibre optic cable and the optical receiver,

The Optical Transmitter: The transmitter converts an electrical analog or digital signal into a corresponding optical signal. The source of the optical signal can be either a light emitting diode, or a solid state laser diode. The most popular wavelengths of operation for optical transmitters are 850, 1300 or 1550 nanometers.

Most of the Fibre Optics transmission equipment manufactured by communication specialists operates at wavelengths of 850 or 1300mm.

The fibre Optic Cable: The cable consists of one or more glass fibbers, which act as waveguides for the optical signal. Fibre optic cable is similar to electrical cable in its construction, but provides special protection for the optical fibre within. For systems requiring transmission over distances of many kilometre, or where two or more fibre optic cables must be joined together, an optical splice is commonly used.

The Optical Receiver: The receiver converts the optical signal back into a replica of the original electrical signal. The detector of the optical signal is either a PIN-type photodiode or avalanche-type photodiode. [Joseph. 1990]

### 1.2.2 Advantage of Fibre Cable over Conventional Copper Cable

Fibre systems are not perfect. They have technical and economical limitations, for any desired system, the relative merits of guided channel versus unguided channel and metallic conduct or versus or fibre must be evaluated. Some generalities about these concerns are worth presenting. For long paths, fibre cables are cheaper to transport and easier to install than metal cables. This is because fibres are smaller and lighter but delicate. One cable design has a fibre of diameter 125um enclosed in a plastic sheath with an outer diameter of 2.5mm. The weight of this cable is 6kg/km; the loss is 5dB/km. Let us compare this cable with the RG - 19/u coaxial cable, which has an attenuation of 22.6dB/km when carrying a 100MHz signal. Its outer diameter is 27.4mm and its weight is 1,110kg/km. Smaller and lighter coaxial cables are available, but they have higher losses than the RG- 19/U.

Maintenance of fibre cables does differ, however, if a line is broken, either as a result of an accident or a system modification, splices must be made or new connectors are used these operations require more time and skill for fibres than for wires. As a result, maintenance cost should be considered when designing a system in which many changes are likely to be made.

The development and application of optical fibre system grew from the combination of semiconductor technology, which provided the necessary light sources and photo detectors and optical wave-guide technology. The result was an information-transmission link that had a certain inherent advantages over conventional copper systems. These advantages are listed below:

#### 1.2.2.1 Low Transmission Loss and Wide Bandwidth

Optical fibres have lower transmission losses and wider bandwidth than copper wires. This means that with optical fibre cable system, more data can be sent over longer distances, thereby decreasing the number of wires and reducing the number of repeaters needed for these spans. This reduction in equipment and components decreases the system cost and complexity.

#### 1.2.2.2. Small Size and Weight

The low weight and the small (hair size) dimension of fibres offer a distinct advantage over heavy, bulky wire cables in Nigeria or in ceiling mounted cable trays. This is also of importance in aircraft, satellites and ships, where small lightweight cables are advantageous and in tactical military applications, .

#### 1.2.2.3. Immunity to Interference

An especially important feature of optical fibres relates to their dielectric nature. This provides wave-guides with immunity to electromagnetic interference (EMI), such as inductive pick up from signal-carrying wires and lighting. It also ensures freedom electromagnetic pulse (EMP) effects, which is of particular interest in military applications.

Fibres have excellent rejection of radio frequency interference (RFI) and of (EMI). RFI refer to interference caused by radio and televisions, radar and other signals. Originating in electronic equipment, EMI include those sources of radiation and those caused by natural phenomena (such as lightning) or caused unintentionally (such as sparking). If not rejected, then these undesired signal could increase the system noise level beyond acceptable limits. The ability of fibre to isolate itself from its environments allows us to pack numerous fibres together in a cable to transmit many channels of information along a single path. No cross talk occurs.

#### 1.2.2.4. Electrical Isolation

Because fibres are insulators, they will not pick up or propagate electromagnetic pulses (EMP) caused by nuclear explosions, which can induce millions of volts in a conducting transmission line.

The voltage pulse can travel many miles along the wire and eventually (because of its strength) destroy the electronics at the end of the path.

The insulating nature of a fibre has several other practical consequences. In an environment in which high-voltage lines are present, a wire communication link could possibly short-circuit the line by falling across them, causing considerable damage, and this problem disappears with fibre.

Fibre offers a degree of security and privacy. Because fibres do not radiate the energy within them, it is difficult for an intruder to detect the signal being transmitted. The fibre would have to be physically violated to obtain the signal. Breaking the fibre, or fusing a new fibre to a transmitting fibre, would provide access to the optic beam. During such modification of the link, the power reaching the receiver would drop. A sensitive receiver can measure this loss, providing knowledge that an intrusion is occurring.

Glass fibre themselves can withstand extreme temperature before deteriorating. Temperatures approaching 800° C leave glass fibre unaffected. Other components of a fibre system are much more sensitive to increase in temperature. Plastic cable sheathing can melt, leaving the fibre unprotected and possibly distorting the fibre. The distortion would increase the fibre loss. Fibre cable with an operating range of - 25° to +65°C are commercially available at moderate costs.

### 1.2.2.5. Signal Security

This makes fibres attractive in applications where information security is important, such as Banking, Computer networks and Military System.

### 1.2.2.6. Abundant Raw Material

The additional importance is the fact that silica is the principal material of which optical fibres are made. This raw material is abundant and inexpensive. Since it is found in ordinary sand.

Some optic fibres are made of transparent plastic, another readily available material.

### 1.2.2.6. High Information Capacity

One of the most important advantages of fibres is their ability to carry large amounts of information in either digital or analogue form. For example, a single fibre of the type developed for telephone service can propagate data at 44.7 Mbps, amounting to 672 voice channels. Fibres with greater capacities than this are available. Although pulse spreading limits the transfer, fibre capabilities meet the requirements of most data-handling systems which far exceed the capabilities of conducting cables. Bit rates up to at least 140Mb/s per fibre can be handled by graded index fibres and potentially in excess of 1Gb/s by mono-mode fibres.

#### 1.2.2.7. Low Attenuation and Dispersion

Fibre attenuation is now generally less than 5dB/km and dispersion can be kept to very low values. In the analogue format, the fibre carry a bandwidths of Megahertz, or more, In digital systems, the rate of data transmission is limited by distortion of the optical signal.

#### 1.2.2.9. Space Saving

The coefficient of information capacity divided by cable cross section is high, therefore efficient use is made of the duct space. This is a very significant advantage in congested city environments.

For instance, in a standard wire telephone cable, the metal cable contains 900 twisted-wire pairs and its diameter is 70mm. Each pair carries 24 voice channels so the cable capacity is 21,600 calls. One fibre cable developed for telephone application has a 12.7mm diameter and contains 144 fibres; each operates at the T3 rate (672 channels). The capacity of this fibre cable has nearly 4.5 times as that of the wire cable and has a cross-sectional area that is 30 times less

#### 1.2.2.10. Long Life Span

Optical cables have a years ranging from 20 to 30 years as compared to 12 to 15 years for conventional cables because glass does not corrode as metal does.

### 1.2.2.11. Ease of Expansion of System Capability

Fibre optic systems can be easily upgraded to expand system capacity by simply changing LED to LASERS, one can upgrade most present day low loss optic system without replacing the original optical cable. Improved Modulation techniques can also be incorporated without difficulty. [Joseph. 1990]

## 1.3 AIM AND OBJECTIVE OF THE PROJECT

The aim and objective of this project is to present and accurate analysis of the design and evaluation of the performance of the digital fibre optic system as it was partially implemented within the Oyo State metropolises for the free flow of communication traffics. Concisely, it covered the various users of the system, interconnectivity and installation of the network elements of the system, the evaluation performance study, system consideration and system availability.

It should be noted that no consideration was given in terms of the design and constructional details of each of the network element of terminal equipment.

This project covered the digital fibre optic system in Nigeria taking Oyo State metropolis as a case study. Although, this system has been partially implemented in some cities in Nigeria, such as, Ibadan, Abuja, Kano, Port Harcourt, Calabar, Kaduna and Enugu. But, a more detailed study and evaluation was carried out on the Oyo State Telecommunication networks, which also have a partially implemented digital fibre optic system.

Limit of the project is the recent upgrade of the existing interconnectivity of all the exchanges (digital and analogue (domestic) satellite earth station, television house, digital and analogue carrier rooms, international gateways, primary centre and secondary centre using the digital optic system.

This project also covered a wide range of theoretical aspect of fibre optic, the splicing technique, basic element of fibre optic communication system which covered multiplexing equipment, line terminal equipment (LTE), fibre optic cable design and repeater housing. Fibre optic characteristic is an important aspect that was not left out, this section covered attenuation, disperses bandwidth requirement.

The design and planning analysis are well explained for the benefit of whosoever want to use this project for educational aid.

## 1.4. BENEFITS OF TELECOMMUNICATION

### 1.4.1 Making the World Smaller:

The world is fast becoming a global village, as they Say. Two people staying thousands of kilometres apart can communicate as easily as if they are in the same room with the aid of telephone or e-mail. The radio and television including satellite communication make it possible for events /activities in one place to be watched in another place. This has obviated the risks and rigours of travelling when these telecommunication media are available and can easily do the job.

### 1.4.2 Improving Information Dissemination:

Transmission of information is much faster with the use of telecommunication. This enables timeliness of decision – making and currency of information. Telecommunication also enhances the flow and circulation of information. Information or message of public interest can be passed to people simultaneously. This can be very helpful, for example in averting disaster when a warning of impending flood or earthquake is given over the radio or television.

### 1.4.3 Public Order and Crime Control:

Telecommunication has made the work of law enforcement agents and security personnel a lot easier. Closed-circuit television is used for surveillance, radio communication is used for net-working with other agents while telephone is handy for contact with the police for help when criminals strike, etc.

### 1.4.4 Education

Telecommunication has also made learning easier. Close-circuit television is used in some institutions with large class student population to teach while one can actually receive tuition for some courses via the Internet. Audio or videocassettes of lectures are also popular.

### 1.4.5 Research and Exchange of Knowledge

With the aid of Internet, research is easy as the researcher can surf web-sites of universities, libraries and scholarly institutions around the world for the required information. It also broadens knowledge through exchange of research findings. This is especially useful in medical science where new discoveries and breakthroughs are displayed on the Internet.

### 1.4.6 Governance:

Telecommunication also makes the work of governance easier. From communicating information on policy and other matters to the citizen on mass media, using telephone. E-mail, internet, etc to co-ordinate and monitor government activities, telecommunication is a necessity for governments all over the world.

### 1.4.7 Trade and Commerce:

Telecommunication has broken the physical barriers to commerce and enhanced international trade. Contacts with suppliers, buyers, financiers and other business partner is made easier via the telephone, fax or E-mail. Telecommunication has broken the physical barriers to Business transactions are initiated and concluded these days on the Internet. Goods and services are advertised on electronic media and sales deals are struck via telephone, telex, fax or E-mail.

### 1.4.8 Space Research and Exploration

Telecommunication is a crucial utility in the research into space. Through it, man has been able to study and learn about our planet as well as other planets around us. As the space ships and rockets are launched, communication is maintained with the earth through powerful telecommunication devices and through them the progress of the space craft is monitored, pictures and properties of the atmosphere are relayed to earth for analysis, etc.

### 1.4.9 Transportation:

The first use of telecommunication actually is in the transport industry - to establish communication with and between ships on the high seas. Telecommunication is the mainstay of air traffic control and navigation of ships. Without telecommunication, it would be impossible to monitor the progress of aircraft in the sky or to guide them in taking off or landing. Telecommunication is also used to schedule and monitor the rail services.

### 1.4.10 Entertainment:

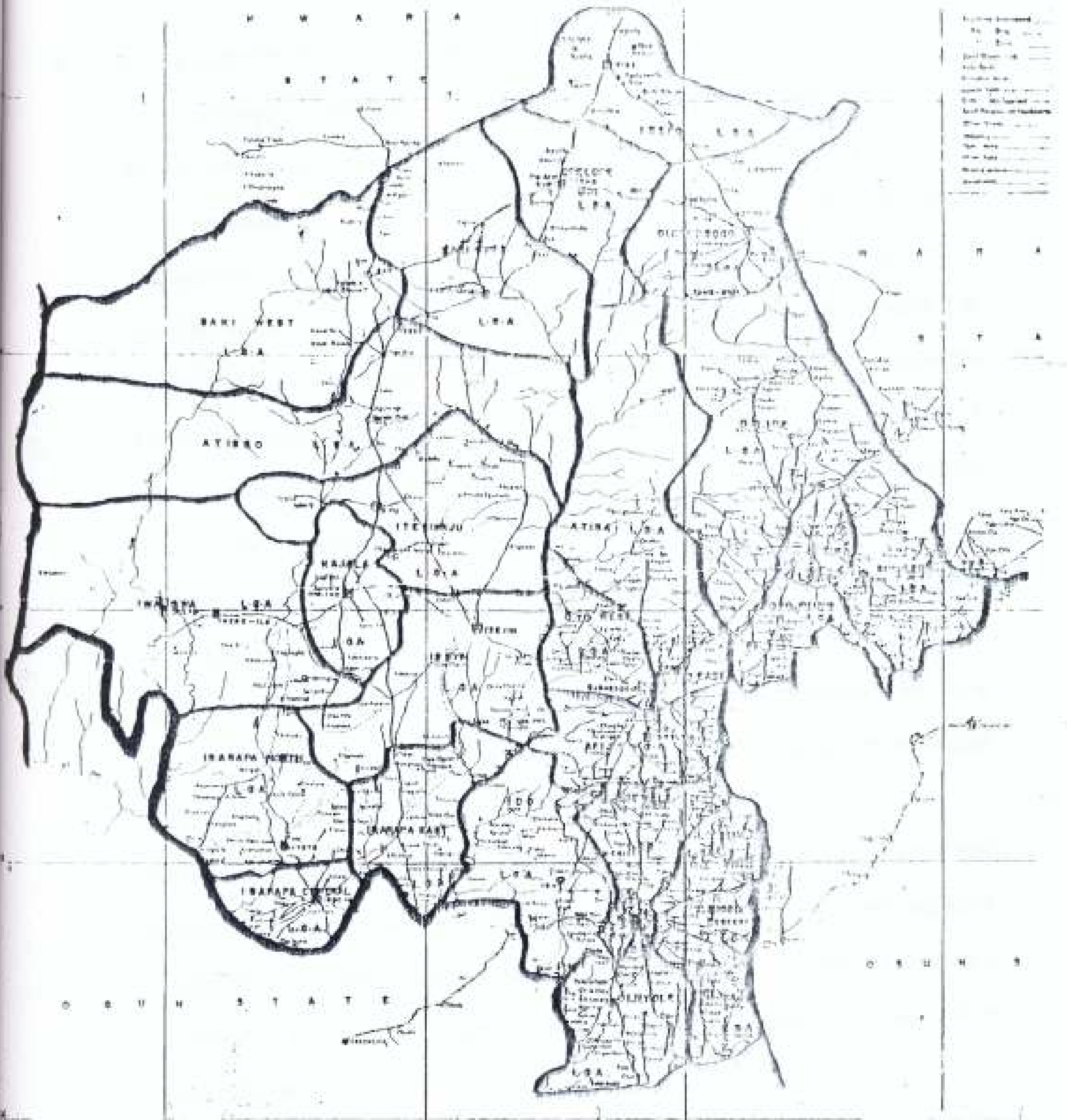
Telecommunication has revolutionised the entertainment world. Radio and television stations daily broadcast hours of drama, quiz, sports and other types of entertainment programmes to audience around the world. Through satellite and cable telecommunication, sport events, beauty contests, music and film award shows, world class social ceremonies etc are transmitted live to millions of homes world-wide from any part of the globe. Without doubt, telecommunication has made the world a much pleasant place to live in.

## 1.5 PROFILE OF OYO STATE

Oyo State is one of the 36 States of the Federal Republic of Nigeria. Oyo state is located on 6.5o N – 9.2o N Latitude and 2.5o E – 4.5o E Longitude .It came into existence with the break-up of the old Western State of Nigeria during the States creation exercises of 1976 and 1991. Ibadan, the capital, which is reputed to be the largest indigenous city in Africa, is as the centre of administration of the old Western Region since the days of the British Colonial rule in Nigeria.

State (State of the Living Spring) was excised out of Oyo State. The State covers a total of 26.249 square kilometres of landmass and it is bounded in the South by Ogun State (Gateway State), in the North by Kwara State. To the West, it is bounded partly by Ogun State and partly by the Republic of Benin while in the East, it is bounded by Osun State .

# MAP OF OYO STATE



# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 THE EVOLUTION OF FIBRE OPTIC SYSTEMS: -

Communication using light occurred early in our development when human beings first communicated by using hand signals. This is obviously a form of optic communication. It does not work in darkness. During the day, the sun is the source of light for this system, the information is carried from sender to receiver on the sun radiation. Hand motion modifies or modulates the light, the eye is the message - detecting device and the brain processes this message. Information transfer for such a system is low, the transmission distance is limited and the chances of error are great. Also light is used in the night for signalling and passing message across

In 1880 Alexander Graham Bell invented a light communication system called photo-phone. This system used sunlight reflected from a thin voice modulated mirror to carry conversation. At the receiver the modulated sunlight fell on a photo conducting selenium cell which converted the message to electrical current. A telephone receiver completed the system.

All the system just described have low information capacities. A major break through was the invention of the laser in 1960. The laser provides a narrow band source of optic radiation suitable for use as a carrier of information. Lasers are comparable to the radio frequency sources used for conventional electronics Communication.

Unguided optic communication systems (non-fibre) were developed shortly after

# MULTI-FIBRE CABLES

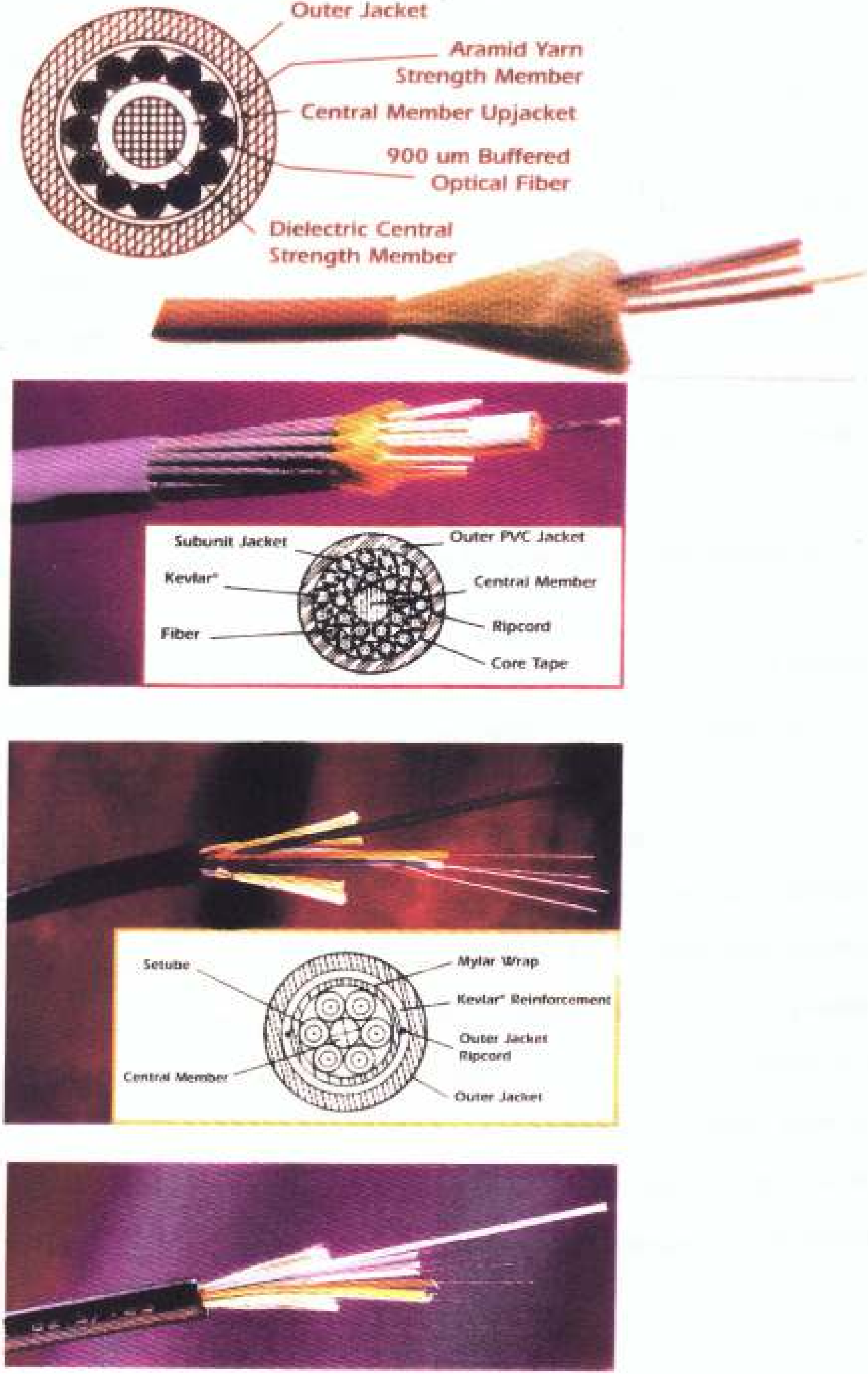



Fig 2.1: Multi-fibre cable

the discovery of the laser. Communication over light beam travelling through the atmosphere was easily accomplished. The disadvantage of these system include dependence on a clear atmosphere, the need for a line - of - sight path between transmitter and receiver and the possibility of eye damage to persons who unknowingly look into the beam. These early applications caused an interest in optic systems that would guide the light beam and thus overcome those disadvantages. In addition, guided beam could be bent around corners and could be buried in the ground. The early work on atmospheric laser systems provided much of the fundamental theory and many of the actual components require for communication over fibres. It is know that laser sources are not required for all fibre systems. In many cases the narrow band light emitting diode is suitable.

Glass produced by the ancient Egyptians was opaque. The artisan of Venice fabricated glass of much greater purity in the middle ages after [Joseph 1986]

## 2.2 HISTORY OF DIGITAL FIBRE OPTIC SYSTEM IN NIGERIA

The history of the digital fibre optic system in Nigeria could be traced to mid-80's when the management of Nigerian National Petroleum Corporation (NNPC) introduced it to her telecommunication network in 1987 to provide interconnectivity among her stations or depots in various location within the country. This interconnectivity supported telecommunication systems such as, the digital private ranch exchange (PABX), micro- wave communication links, VHF and UHF radio and data communication systems. The system was design and implemented by Ericsson telecommunication Company. The Nigerian National Petroleum Corporation's digital fibre optic

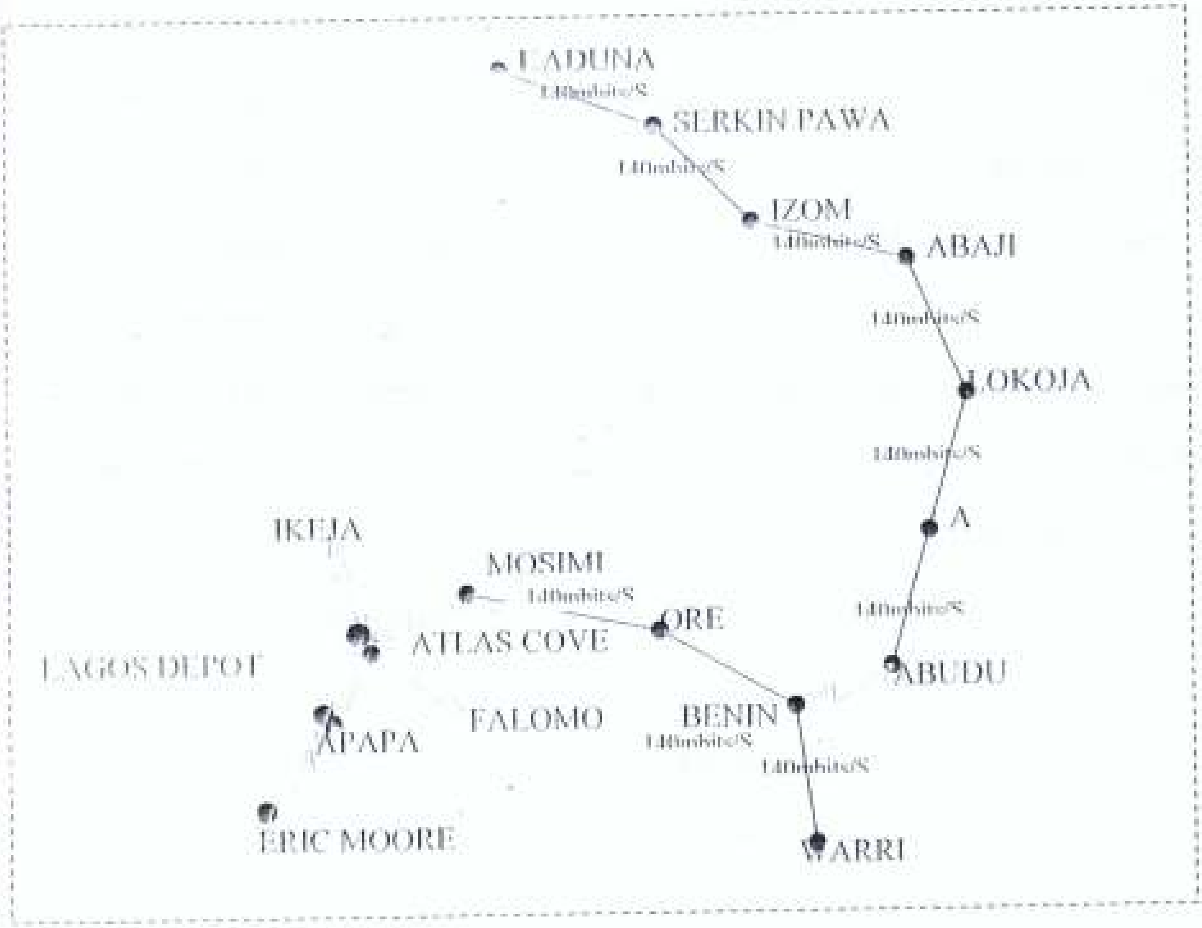



Figure 2.2 Existing fibre network in Nigeria

System as shown in Figure 2.2 is broken into three parts; the first link covered Mosimi, Ore and Benin, the second link included Abudu and Warri while the last link interconnected Abudu, Auchi, Lokoja, Abaji, Izom, Sarkin Bower and finally terminated at Kaduna.

Subsequently, the NITEL management incorporated digital fibre optic system into her national network for the provision of short and long haulage transmission. Its usage in the national network started with the Lagos - Ikorodu optic fibre link under the Abuja Telecommunication Project (ATP) in 1990 complementing the 140 Mbps Plesiochronous Digital Hierarchy PDH radio installed at Ikorodu.

Later, NITEL saw the need to provide transmission flexibility and improve connectivity in the Lagos multi-exchange. Moreover, the Lagos fibre optic ring network was upgraded to a higher capacity of synchronous transport mode 16 (2.48 Gbps) to support the tremendous increase in demand for telecommunication services.

After the Lagos optic fibre ring network, fibre optic cable with associated terminal equipment have been used extensively at different transmission capacities in her network for linking exchanges and carrier rooms. Some of which include:

| | |
|---|---|
| - Kaduna (carrier room) | - Kaduna (secondary centre) |
| - Minna exchange | - Boso exchange |
| - Oniyanrin | - Bawer Hill |
| - Oniyanrin | - Ibadan (Ring road) |
| - Oniyanrin | - Ibadan (Bodija) |
| - Benin (central) | - Benin (Oluku) |
| - Benin (Ugbowo) | - Benin (Central) |
| - Otta | - Lagos (Agege) |

NITEL, responding to the telecommunication requirement of the Nigerian Television Authority (NTA), in 1995 provided transmission facilities for the youth soccer championship. Liberty Stadium was one of the centres for the competition. The fibre cable was laid from liberty Stadium to DOMSAT (Domestic Satellite Station) at Agodi- Gate (Ibadan) where the signal is finally linked to the satellite in space so that other countries will find it easy to view the events at Liberty stadium.

With the rapid growth of operational bases of the oil industries along the riverine and Niger-Delta areas of Nigeria, NITEL had implemented the submarine cable optical fibre transmission project to support various telecommunication services related to these industries. Also, it serves as the backbone for alternative wide-band transmission of traffic to the eastern part of the country from the Oyo State metropolis. Going by the versatility of the digital fibre optic system it is expected that by the close of the next decade. Fibre optic transmission technology, which was created by two technical break-through in 1970, has now been widely accepted to offer both technical and economic advantages for transmitting information.

# CHAPTER THREE

## METHODOLOGY OF THE PROJECT

The methods involved in carrying out the project on Design and Planning of Digital fibre optic Transmission in Nigeria Telecommunication System, Oyo State metropolis as a case study were:

1. Personal Approach Method.
2. Attending a course with NITEL staff on Optical fibre cable splicing.
3. Joining the team of NITEL worker during fibre optic cable installation.
4. Questionnaire administrating method.
5. Literature referencing method.

## 3.1 PERSONAL APPROACH METHOD:

Going from one telephone exchange to the other to get the number of lines coming in and the number of line going out at each exchange. Interviews were conducted with the project monitoring and contracting officer (PMCO) and the Clerk of Work (C/W) to obtain up to date information about the design and implementation of the project. Census office headquarter at Ibadan was visited to get the fact and figure of total population of Oyo State and total number of houses in each local government areas. Map office at Federal Secretariat Ibadan was not left out, the map of Oyo State indicate all the local government areas and their locations was purchased. In this map, major road and minor was also indicated because major roads were used for the installation of fibre cable.

## 3.2 FIBRE SPLICING COURSE

The course was organised by NITEL (Oniyanrin exchange-Ibadan) to enable participants carry out fibre splicing operation when the need arises.

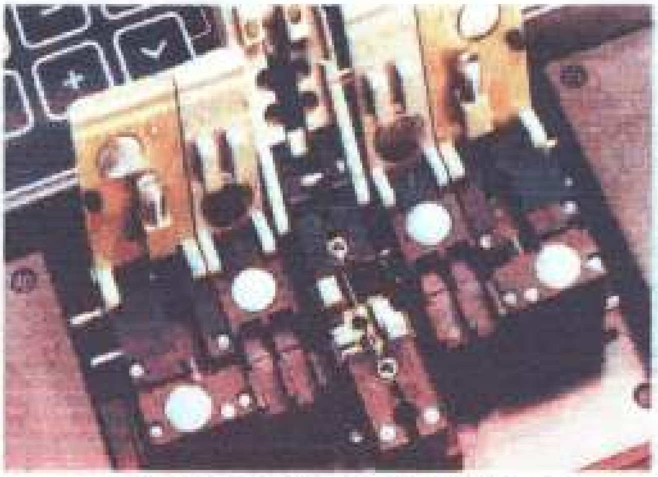
**Methodology of Splicing**

Demonstration method was used. The instructors began by showing the working team, the materials/instruments required for the splicing which include:

1. Arc - Fusion Splicer
2. Sheath clamps
3. Fibre guides
4. Discharge electrode
5. Fibre opener
6. Mastic tape
6. Measuring tape
7. Alogen 51
9. Soldering iron (heavy duty)
10. Heat blower
11. Air-conditioned van
12. Splice box
13. Generator, etc.

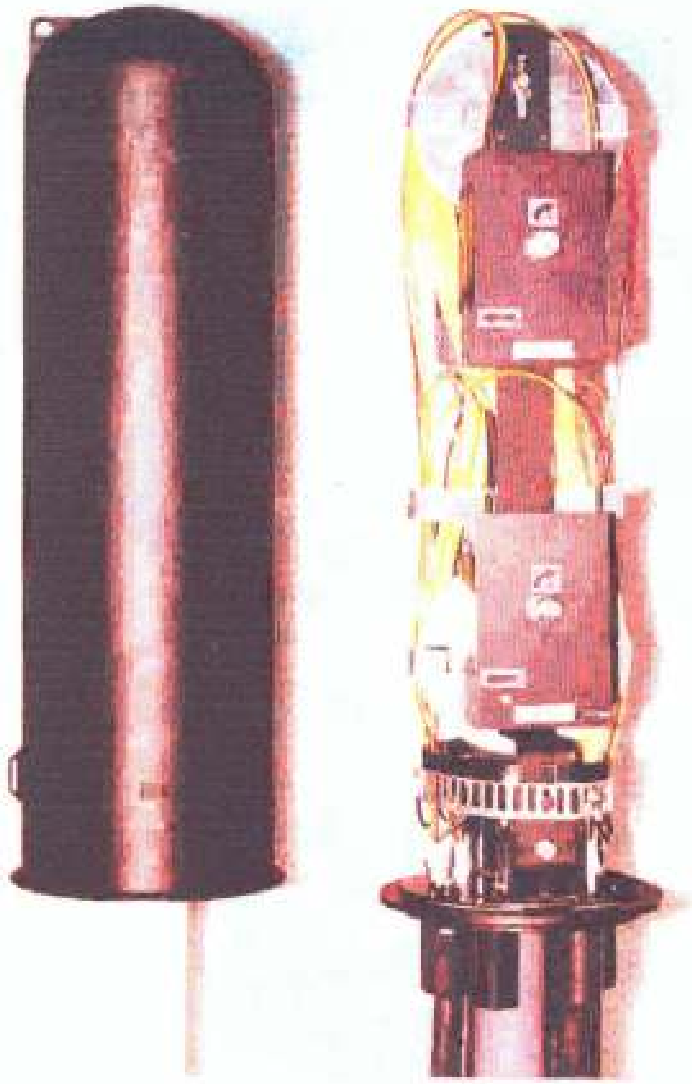
The process proceeded step by step. The first was to prepare the two ends of the fibre to be spliced. 2 meter was measured from the ends of both fibres and mark with a marker. The outer covers were opened using a fibre opener up to 2-meter marks. After removing the outer cover, the fibre was washed or cleaned

**FUSION SPLICER**
**X7 SPLICER**



**FIBRE ALIGNMENT SYSTEM**
**OF X77 SPLICER**

Fig. 3.1.: Splicing Machine



FUNCTION MODULES FOR FIBRE HANDLING ARE PROTECTED BY HOOD CLOSURES WHEN USED OUTSIDE OR IN CABLE DUCTS.

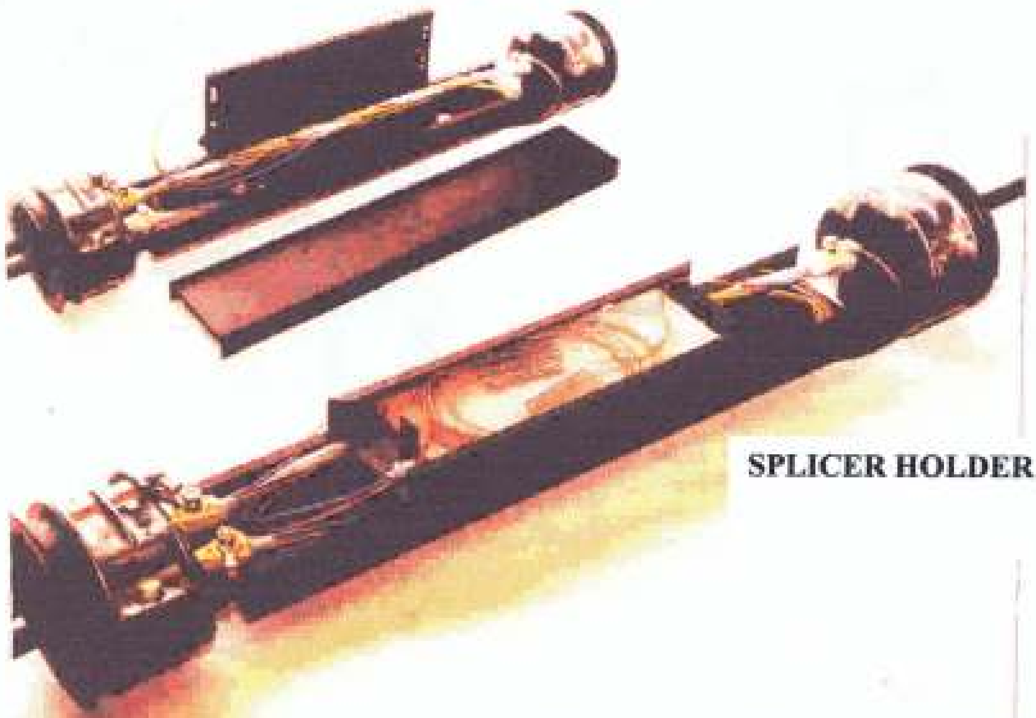



Fig. 3.2: Module for Fibre handling


Fig. 3.3.: Fiber Splcing tools

with appropriate chemicals (alcohol).

The two fibres to be spliced were inserted from one end of the splice box, which at this time must have been mounted on its stand. The work of the splice box is to hold the joint securely. The tray must be removed. The principal cable was marked with red tape to ensure easy identification. The earth cover of the two fibres being spliced was then joined together using earthling cable, before being soldered together. Cover the earth soldering point (joint) with a seal and apply hot air for proper sealing.

The 2$^{nd}$ and 3$^{rd}$ insulation were removed from the fibre. Each time insulation was removed, the fibre was cleaned with appropriate chemical and brushed. After the two ends of the fibre are ready, the appropriate ones (the two to be spliced) were cut to 16 or 20cm depending on size. The sleeve was passed through one end of the fibre. The ends of both fibres were now passed through opposite sides of the Arc fusion splice which by now was powered. An indication of 'proton' shows that the splice is ready for use.

Then press set and the splice is made. The splice was checked by pulling or twisting. If it is not good, it will break and the process has to be repeated.

Finally, the trays were put back and the splicing is protected by inserting the splice box cover after which the holes for the fibre passage was covered with mastic tape and heat applied using heat blower.

## 3.3 JOINING THE TEAM OF NITEL WORKER DURING INSTALLATION

In order for me to have a wide knowledge about this project, I joined the team of workers doing the installation and asked them pertinent questions to acquire more knowledge.

ALCATEL Company from Italy was given the job. During the period of installation, I moved to the project Supervisor in order to get more facts and figures about the implementation of the project. Most of the technical questions raised were well answered. Direct Burial Method was used. This type of installation is normally planned for long distance (trunk) routes linking major cities where frequent excavation is seldom carried out. This method was used throughout the installation from Ibadan to Ogbomoso.

The fibre optic cable sheath should be rodent proof to avoid termite attack. The trench where the cable was laid is 4ft below the earth surface to protect it from bush burning and some other problems. In some cases additional protection was given to the cable by using a protective duct liner (26 mm to 10 mm) already extruded over the fibre optic cable (FOC) in the factory. The usual cable marker was placed at strategic point along the route.

During this period, splicing of the cable was also carried out which gave me more experience about the installation.

## 3.4 QUESTIONNAIRE ADMINISTRATING METHOD

About seventeen questions were drawn to cover all aspect of the project. It was distributed to some NITEL staff at Oniyanrin exchange and DOMSAT in Ibadan, and NITEL Exchange Oyo.

As a matter of fact, this system in Nigeria is completely a new communication system. Hence, only few were able to administer the questionnaires accurately. More so some answers to the questions were referred to the project monitoring and contracting officer for clarity purpose. A sample of the questionnaire is included in the appendix A.

## 3.5 LITERATURE REFERENCING METHOD

A lot of textbooks on fibre optic were consulted Equipment, manuals, NITEL journals and a lot of informative papers pertaining to this project were obtain at NITEL Office and NITEL Library at Oshodi in Lagos.

Diskette containing courses on fibre optic was also obtained from ALCATEL experts handling the installation at Ibadan. The Guardian newspaper was not left out. Tuesday and Wednesday papers are very informative. The column for INFOTECH really helped a lot. Internet was also visited and a lot of information was downloaded from the Internet to get the latest technology about this project. Network plans on topology and operational charts were carefully studied to retrieve related information on this study.

Though various literatures were referenced but the relevant one's within the scope of this project were collated to achieve the aims and objective of this thesis.

# CHAPTER FOUR

# FUNDAMENTALS OF FIBRE OPTICS

## 4.0 INTRODUCTION.

In most optical communication links, it is the Optical fibre that provides the transmission channel. The fibre consists of slid cylinder of transparent materials, the core, surrounded by a cladding of similar material light waves propagate along the core in a series of plane wave fronts, or modes; the simple light ray path used in elementary optics is an example of a mode. For this propagation to occur, the refractive index of the core must be large than that of the cladding, and there be larger than of the cladding, and there is two basic structures which have this property. Step-index fibres, of the step -index types, there are multi-mode MM, fibres (which allow a great many modes to propagate) and single- mode, SM, fibre (which only allow one mode to propagate). Although graded-index is normally MM, some SM fibres are available. The three fibre types, together with their respective index profiles are shown I figure 4.1 (In this figure, n is the refractive index if the material)

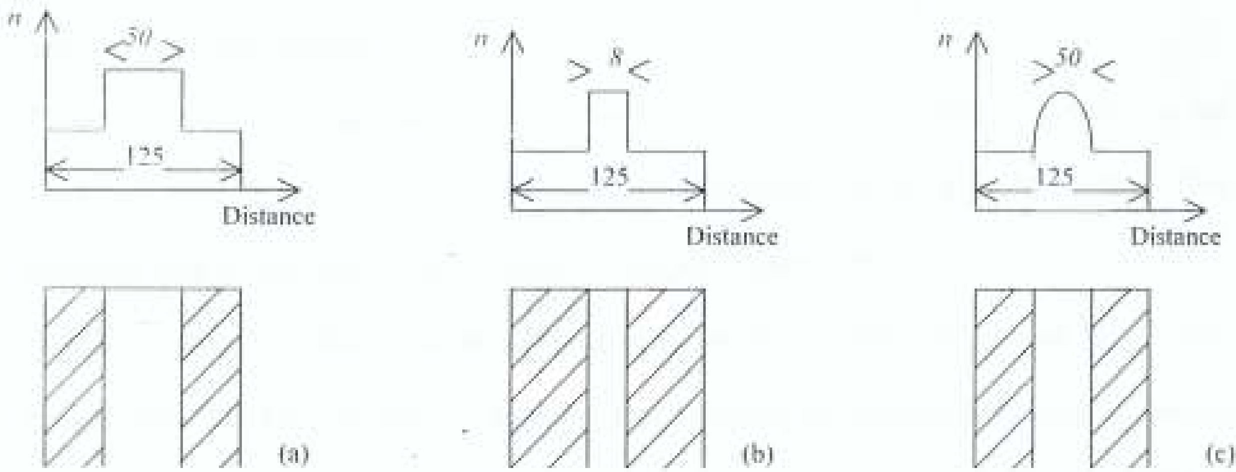



Figure 4.1 Typical refractive index profiles of

(a Step-index multimode

(b Step-index single mode

(c Graded-index multimode fibre (all dimensions are in μm)

The crosshatched area represents the cladding, the diameter of which ranges from 125μm to a typical maximum of 1mm. The core diameter can range from 8μm, for SM fibres, up to typically 500μm for large-core MM fibres.

Optical fibres can be made from two different materials: silica glass ($SiO_2$) and plastic. The addition of certain dopants to the glass will vary the refractive index; all-plastic fibres use different plastic for he core and cladding. All -glass, SM fibres exhibit very low losses and high bandwidths, which make them ideal for use in long-haul telecommunication routes. Unfortunately such fibres are expensive to produce and so are seldom-found in short haul (less than 500m length) industrial links.

The attenuation and bandwidth of an Optical fibre will determine the maximum distance that signals can be sent. Attenuation is usually expressed in dB/km, Attenuation is dependent on impurities in the core and so the fibre must be made from very pure materials.

To some extent the bandwidth also depends on the core impurities, however, as we shall see later, the number of propagating modes usually limits the bandwidth. This explains why single-mode fibres have the largest bandwidth.

In this chapter we shall examine the properties and design of optical fibres. We could study the propagation of light in Optical fibres by solving Maxwells equation applied to a cylindrical wave-guide. However, this involves some rather complicated mathematics. Instead, we will solve Maxwells equations in an infinite block of dielectric, and then apply them to a planar Optical wave-guide. [ Sibley . M . J . N . 1990]

## 4.1 PROPAGATION OF LIGHT IN A DIELECTRIC

In some instances it is convenient to treat light as a stream of particles, or photons; in others as an electromagnetic wave, there we will treat light as a wave, and apply Maxwell's equation to study light wave propagation. We will consider a plane wave front, of arbitrary optical frequency, travelling in an infinite block of dielectric (glass). This will give us valuable insight into certain fibre characteristics, which we cannot easily explain in terms of simple geometric ray optics.

### 4.1.1 The Wave Equation

In order to study the variation of the E and H field in a dielectric, we need to derive the relevant wave equations, we take as our starting point, the following Maxwell's equations.

$$\nabla \times E = -\mu \frac{dH}{dt} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 4.1a$$

and

$$\nabla \times H = \epsilon \frac{dE}{dt} + \sigma E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.1b$$

If E and H vary sinusoidally with time the frequency of the light we are transmitting then we can use the phasor forms of E and H so.

$E = E_x \exp(j\omega t)\, a_x$ and $H = H_y \exp(j\omega t)\, a_y$

where $a_x$ and $a_y$ are the x-and y- axis unit vectors. Thus we can rewrites (4.1a) and (4.1b) as

$$\frac{dE}{dz} = -j\omega\mu H \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.2a$$

and $-\frac{dH}{dz} = j\omega\epsilon E + \sigma E$ ........................4.2b

We can manipulate these two equations to give the wave equations which describe the propagation of a plane wave or transverse electromagnetic (TEM) wave in the material. Thus if we differentiate (4.2a) with respect to z, and substitute from 4.2b we get

$\frac{d^2E}{dz^2} = -\omega^2\mu\epsilon E + j\omega\mu\sigma E$ ....................................4.3

and, if we differentiate (4.2b) with respect to z, and substitute from (4.2a) we get

$\frac{d^2H}{dz^2} = -\omega^2\mu\epsilon H + j\omega\mu\sigma H$....................................4.4

if we now let $\gamma^2 = -\omega^2\mu\epsilon + j\omega\mu\sigma$,

the solution to these equation are

$E = E_{xo} \exp(j\omega t) \exp(-\gamma z)$ ....................................4.5

and

$H = H_{yo} \exp(j\omega t) \exp(-\gamma z)$ ....................................4.6

Where, the subscript o denotes the values of E and H at the Origin of right handed Cartesian co-ordinate set, and $\gamma$ is known as the propagation coefficient. Writing $\gamma = \alpha + j\beta$, Where $\alpha$ and $\beta$ are the attenuation and phase constants respectively, we get

$E = E_{xo} \exp(-\alpha z) \cos(\omega t - \beta z)$ ..........................4.7

and

$H = H_{yo} \exp(-\alpha z) \cos(\omega t - \beta z)$ .......................... 4.8

These equations describe a TEM wave travelling in the positive z direction, undergoing attenuation as exp $(-\alpha z)$. The E and H fields are Orthogonal to each other and, as figure 4.2 shows, perpendicular to the direction of propagation.

### 4.1.2 Propagation Parameters

Equation (4.7) and (4.8) form the starting point for a more detailed study of light wave propagation. However, before we proceed much further, we will find it useful to derive some propagation parameters from the previous section, the propagation coefficient, $\gamma$, is given by

$\gamma = \alpha + j\beta$ and $\gamma^2 = -\omega^2 \mu\epsilon + j\omega\mu\sigma$

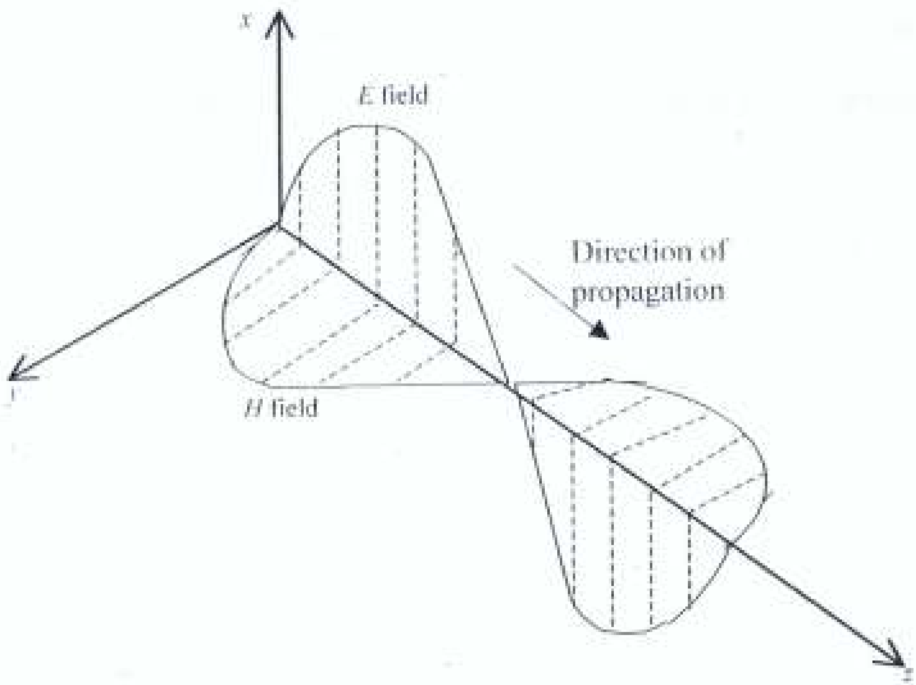



Figure 4.2 variation of E and H for TEM Wave propagating in the z- directions,

Hence it is simple matter to show that $\alpha^2 - \beta^2 = -\omega^2\mu\epsilon$ .......... 4.9

and

$2\alpha\beta = w\sigma\mu$ ..................................................................................4.10

As glass is an insulator, the conductivity is very low and the relative permeability is approximately unity, that is $\sigma$ <<0, and $\mu_r \approx 1$, Over a distance of a few wavelengths, This results in $\alpha \approx 0$, and so we can write the E and H fields as

$E = E_{xo} \cos(\omega t - \beta z)$ ....................................................................4.11

and

$H = H_{yo} \cos(\omega t - \beta z)$ ..................................................................4.12

Where $\beta \approx w\sqrt{(\mu o \varepsilon)}$. We can study the propagation of these fields by considering a point on the travelling wave as t and z change. Figure 4.3 shows the sinusoidal variation of the E field with time and distance. if we consider the point A then at time t = o and distance z = o, the amplitude of the wave is zero. At time $t = t_1$, the point A has moved a distance $z_1$ and, as the amplitude of the wave is still zero, we can write

$\sin(\omega t_1 - \beta z_1) = o$ and so $\omega t_1 = \beta z_1$ ..........................................4.13

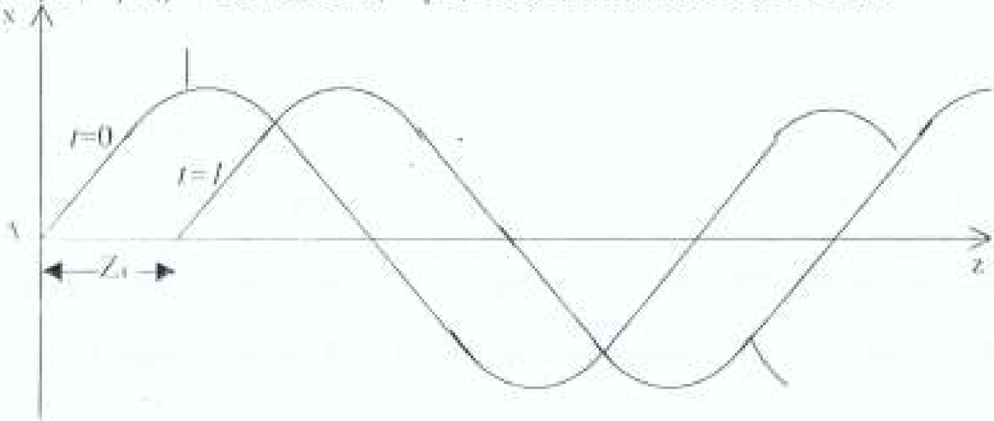



Figure 4.3 Illustrative of the phase velocity of a constant phase point A, on the E field of a TEM wave.

Thus we can see that the constant phase point, A. propagates along the z-axis at a certain velocity. This is the phase velocity, $V_p$ given by

$$V_p = \frac{Z_1}{t_1} = \frac{\omega}{\beta} = \frac{\omega}{\omega\sqrt{(\mu_o\varepsilon)}} = \frac{1}{\sqrt{(\mu_o\varepsilon)}} \quad \text{......... 4.14}$$

If the dielectric is free space, then $V_p$ is $\approx 3 \times 10^8$ $Ms^{-1}$ (the velocity of light in a vacuum, c). This leads us directly on to the definition of refractive index for the dielectric, $\epsilon = \varepsilon_0\varepsilon_r$ and so

$$V_p = \frac{1}{\sqrt{(\mu_o \epsilon_o)}} \times \frac{1}{\sqrt{\epsilon_r}} = \frac{C}{n} \quad \text{......... 4.15}$$

Where n is the refractive index of dielectric. It can be shown that the wavelength $\lambda$ of the light in the dielectric is

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi V_p}{\omega} = \frac{2\pi c}{n\omega} = \frac{\lambda o}{n} \quad \text{......... 4.16}$$

Where $\lambda o$ is the wavelength of the light in free space. This leads us to an alternative definition for $\beta$

$$\beta = \frac{2\pi}{\lambda} \quad \text{......... 4.17}$$

(It is interesting to note that if $\epsilon_r$, and hence n, varies with frequency, then $\beta$ and $V_p$ will also vary. Thus, if we have two light wave of slightly different frequencies, then the two wave will travel at different velocity .The impedance Z of the dielectric of TEM waves, Z equals E/H, and we can find E as a function of H by using equation ( 4. 2a) thus.

$$\frac{dE}{dz} = J\mu_o\omega H \quad \text{become} \quad - J\beta E = - J\mu_o\omega H$$

and so

$Z = \mu_o\omega/B = \sqrt{(\mu_o/\varepsilon_o\varepsilon_r)} = Z_o/n$ ..............................4.18

Where $Z_o$ is the impedance of free space. 377 ohm One final useful parameter is the power flow. If we take the cross product of E and H, then we will get a third vector, acting in direction of propagation, with Unit of $Wm^2$ that is, power flow per unit area. This vector is known as the poynting vector, S, and its instantaneous value is given by

$S = E X H$ ........................................................................................ 4 19

We can find the average power flow, $S_{av}$, by integrating (4.19) over one period, and then dividing by the period. In phasor notation form, $S_{av}$ will be given by

$S_{av} = R_e\,(^1/_2\, E X H^*)$ ........................................................................4.20

Where $R_e$ denote the real part

$H^* = H \exp(-j[\omega t - \phi])$, and $\phi$ is the temporal phase angle between the E and H fields (In geometric Optics, ray paths are drawn in the direction of propagation and normal to the plane of E and H. Thus the ray-path has the direction of power flow). [Sibley . 1990]

## 4.2 BASICS OF OPTICS

The first step in understanding fibre optics is to review the relevant parts of Optics. From a physical standpoint, light can be seen either as electromagnetic waves or as photons or quanta of electromagnetic energy. This is the famous wave-particle duality of modern physics. Both viewpoints are valid and valuable, but the simplest view point for optics often is to consider light as rays travelling in straight lines between or within optical elements, which can reflect or refract (bend) light rays at their surface.

## 4.3 THE ELECTROMAGNETIC SPECTRUM

What we call "light" is only a small part of the spectrum of electromagnetic radiation.

The fundamental nature of all electromagnetic radiation is the same. It can be viewed as photons or waves and travels at the speed of light (c), which is approximately 300,000 kilometre per second (m/s) or 180,000 miles per second (Mi/s). The difference between radiation in different parts of the electromagnetic spectrum is a quality that can be measured in several ways as the length of a wave, as the energy of a photon, or as the oscillation frequency of an electromagnetic field. These three views are compare in figure 4.6 below. Each measurement_ wavelength, energy, or frequency _ has its own characteristic unit. In some parts of the spectrum, frequency is used most; in others, photon energy or wavelength is. The Optical world talks in wavelength, which is measured in metric units meters, micrometers (μm or $10^{-6}$m) and nanometers (nm or $10^{-9}$ m). Wavelength is sometimes measured in angstroms (1Å = $10^{10}$m), but the angstrom is not a standard unit, so it is rarely used. Frequency is measured in cycle per second (cps) or hertz (Hz), with megahertz (MHz) meaning a million hertz and gigahertz GHz) meaning a billion hertz. (The metric system uses the standard prefixes listed in Table 4.1 to provide different units of length, weight, frequency, and other quantities. The prefix makes a unit a multiple of a standard unit. For example, a millimeter is a thousandth ($10^{-3}$) of a meter, and a kilometer is a thousand ($10^{3}$) meters) photon energy can be measured in many ways, but the most convenient here is in electron volts ($_{e}$v) _ the energy that an electron gains in moving through a 1-volt (V) electric field.

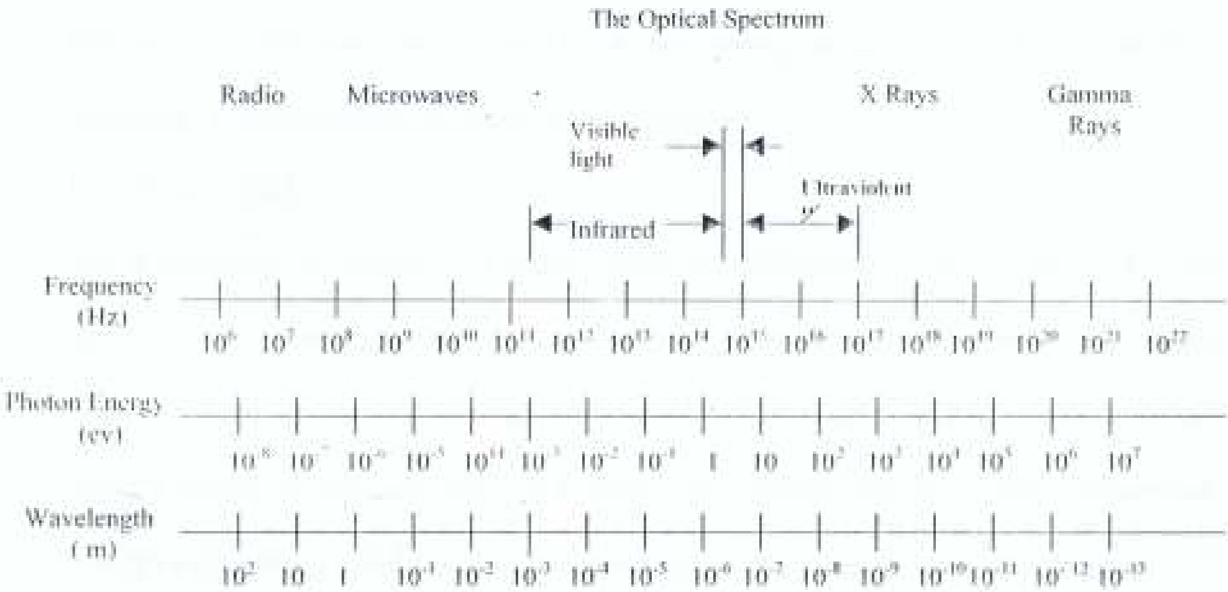



Figure 4.4 Electromagnetic Spectrum.

All the measurement Units shown on the Spectrum Chart are actually different rulers that measure the same thing. There are simple ways to convert between them. Wavelength is inversely proportional to frequency, according to the following formula.

$$\text{Wavelength} = \frac{c}{\text{Frequency}} \qquad \text{or } \lambda = \frac{c}{v}$$

Where c is the speed of light, $\lambda$ is wavelength, and $v$ is frequency. To get the right answer, all terms must be measured in the same units

You can also turn this around to get the frequency if you know the wavelength

$$V = \frac{3 \text{ X } 108 \text{ m/s}}{\lambda}$$

Not many people talk about photon energy (E) in fiber Optics, but a value can be obtained from Plank's law, which states:

$E = hv$ ..........................................................................................(4.21)

Where h is Planck's constant (6.63 X 10-34 J-s or 4.14 eV-s) and v is the frequency. Because most interest in photon energy is in the part of the Spectrum measure in wavelength, a more useful formula is

$$E\ (eV) = \frac{1.2406}{\lambda(\mu m)}$$

We are mainly interested in a small part of the spectrum shown in figure 4.4, the optical region, where optical fibers and other optical devices work. That region includes light visible to the human eye at wavelengths of 400 - 700 nm and nearby parts of the infrared and ultraviolet, which house similar properties. Roughly speaking, (this means wavelengths of 200 - 20,000 nm (0.2-20μm).

The wavelengths normally used for communications through Silica glass Optical fibers are 700 - 1600nm (0.7 - 1.6μm) in the near infrared, where silica is the most transparent. Glass and Silica fibers can transmit visible light over shorter distances and special grades of Silica (often called fused quartz) can transmit near-ultraviolet light over short distances.

Plastic fibers typically transmit better at visible wavelength than in the near infrared, so communication through plastic fibers typically is with visible light. However, plastic fibers are not as transparent as Silica glass. Fiber made from certain other materials can transmit at longer infrared wavelengths than Silica glass fibers. [ Jeff Hecht 1999]

### 4.3.1 Refractive Index.

A critical Optical characteristic for any transparent material is it refractive index (n). the refractive index is the ratio of the speed of light in a vacuum to the speed of light in the medium.

$$n = \frac{c_{vac}}{c_{mat}}$$

Light always travels more slowly in a material than in a vacuum, so the refractive index is always greater than 1.0

Although light rays travel in straight lines through Optical Materials, Something different happened at the surface, light is bent as it passes through a surface were the refractive index changes for example, as it passes from air into glass, The amount of bending depends on the refractive indexes of the two media and the angle at which the light strikes the surface between them. The angle of incidence and refraction are measured not from the plane of the surface but from a line normal (perpendicular) to the surface. The relationship is known as Snell' s law, $n_i$ Sin I = $n_r$ Sin R

where $n_i$ and $n_r$ are the refractive indexes of the initial medium and the medium into which the light is refracted, and I and R are the angles of incidence and refraction, respectively as shown in figure 4.5.

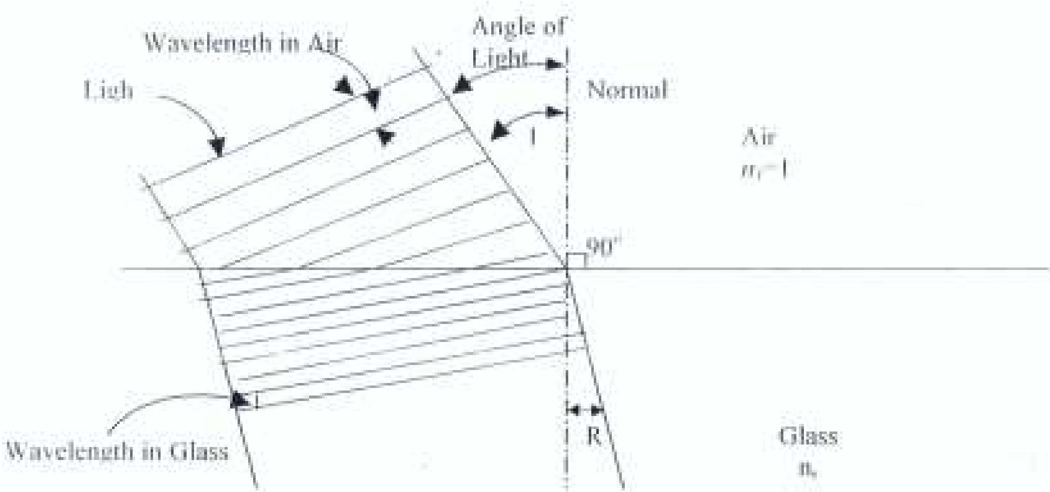



Figure 4.5 Light refraction as it enters glass.

As the light goes into the glass, the frequency of the Wave does not change, but because it shows down in the glass, the wavelength gets shorter, causing the light wave to bend, whether the surface is flat or curved. However, if both front and rear surface are flat, light emerges at the same angle that it entered, and the net refraction is zero, as when you look through a flat window. If one or both surface are curved, you see a net refraction or bending or the light, as if you were looking through a lens.

That is, light rays emerge from the lens at a different angle than they entered. These overall refractive effect are shown is figure 4.6

What does this have to do with fiber Optics? Let us consider what happens when light in a medium with high refractive index (such as glass) come to an interface with a medium having a lower refractive index (such as air). If the glass has a refractive index of 1.5 and the air an index of 1.0, the equation becomes.

$1.5 \text{ Sin } \theta_i = 1 \sin \theta_r$;

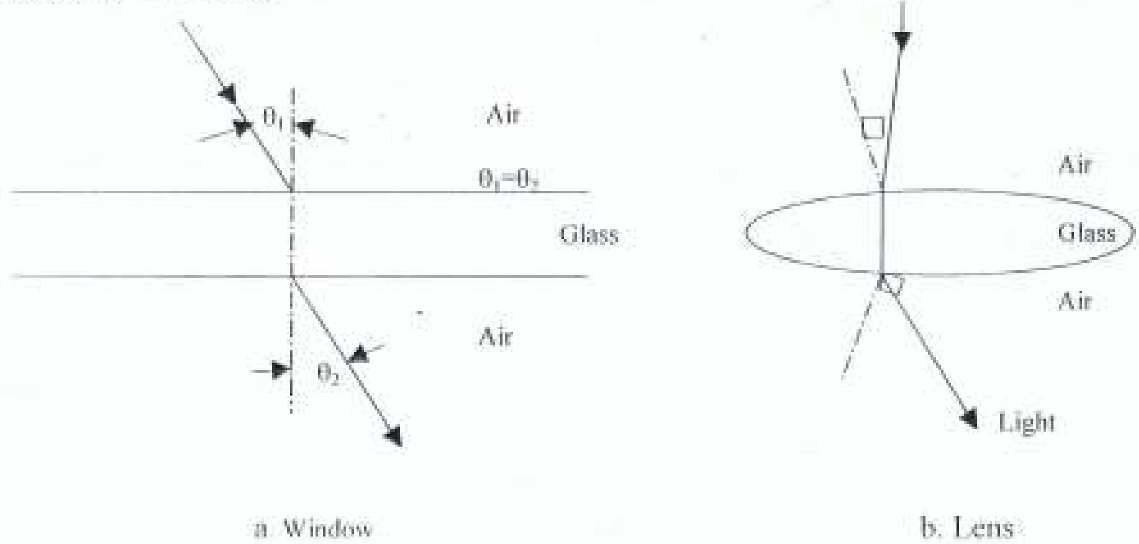



Figure 4.6 light refraction through a window and a lens

That means that instead of being bent closer to the, normal, as in figure 4.5, the light is bent farther form it. this isn't a problem if the angle of incidence is mall.

For $\theta_i$ = 30°, Sin $\theta_i$ = 0.5 and Sin $\theta_r$ = 0.75. but a problem does occur when the angle of incidence becomes too steep. For $\theta_i$ = 60°, Sin $\theta_i$ = 0.866 so Snell's law says that sin $\theta_r$ = 1.299, this is an error. That angle can't exist because the sin c cant be greater than 1.0. Snell law indicate that refraction cant take when the angle of incidence is too large. Light cannot get out of the glass if the angle of incidence exceeds a value called the critical angle, where the sine of the angle of refraction would equal 1.0. Instead, total internal reflection bounces the light back to the glass, obeying the law that the angle of incidence equals the angle of reflection, as shown in figure 4.10. it is this total internal reflection that keeps light confined in Optical fibers, at least to a first approximation, the mechanism of light guiding is more complex in most modern communication fibers.The critical angle above which total internal reflection takes place, θc , can be deduced by turning Snells law around, to give. $\theta_c$ = arc sin ($n_r$/ $n_i$)

The critical angle above which total internal reflection takes place θc, can be deduced by turning Snells law around, to give $\theta_r$ = arcsin ($n_r$ /$n_i$) For the example given, with light trying to emerge from glass with n=15 into air, the critical angle is arcsine (1/1.5), or 41.8°.

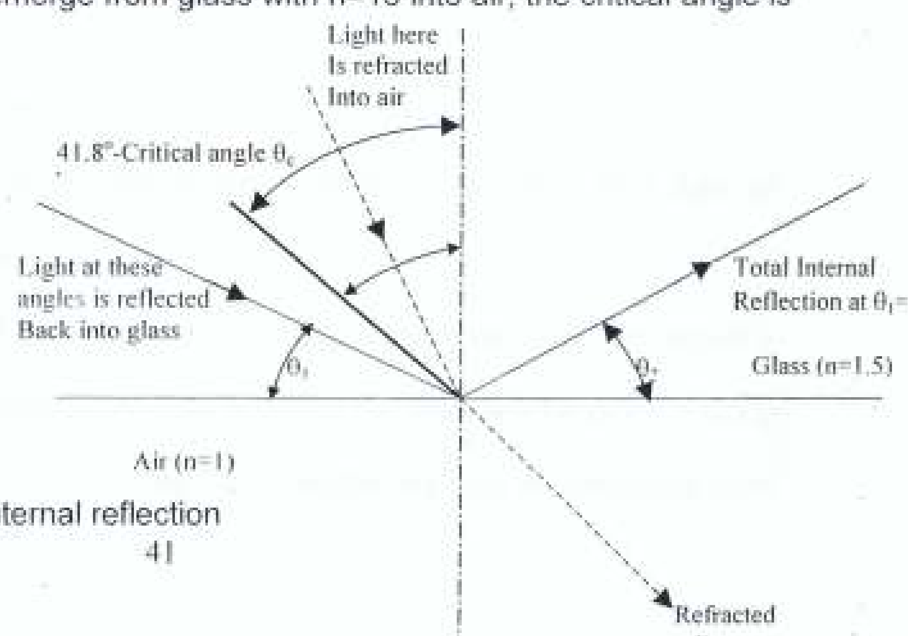



Figure 4.7 Refraction and total internal reflection

## 4.4 LIGHT GUIDING

The two key elements of an optical fiber-from an optical standpoint-are its core and cladding. The core is the inner part of the fiber, through which light is guided, the cladding surrounds it completely. The refractive index of the core is higher than that of the cladding, so light in the core that strikes the boundary with cladding at a glancing angle is confined in the core by total internal reflection, as shown in Figure 4.6.

The difference in refractive index between core and cladding need not be large. In practice, it is only about 1%. This still allows light guiding in fibers. For $n_r/n_i$ =0.99, the critical angle, $\theta$, is about $82^{b}$. Thus, light is confined in the core if it strikes the interface with

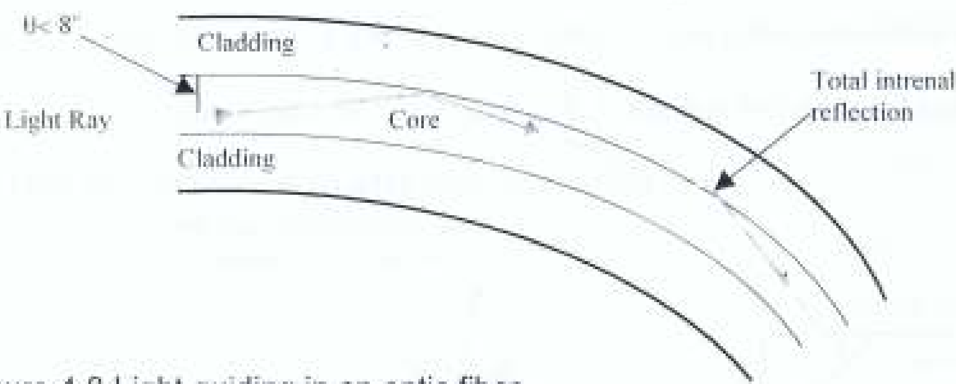



Figure 4.8 Light guiding in an optic fiber

the cladding at angle of $8^{\circ}$ or less to the surface. The upper limit can be considered the confinement angle in the fiber.

Another way to look at light guiding in a fiber is to measure the fibers acceptance angle as the angle over which lights rays entering the fiber will be guided along its core, shown in Figure 4.7. (Because the acceptance angle is measured in air outside the fiber, it differs form the confinement angle in the glass.) The acceptance angle normally is measured as numerical aperture (NA), which for light entering a fiber form air is approximate.

$NA = \sqrt{(n^2_0 - n^2_1)}$

where $n_0$ is the refractive index of the core and $n_1$ is the index of the cladding. For a fiber with core index of 1.50 and cladding index of 1.4485 (a1% difference.), NA = 0.21. An alternative but equivalent definition is the sine of the half angle 90 over which the fiber can accept light ray, 12° in this example (θ in Figure 4.8) Another alternative definition is NA = $n_0$ sinθc, where θc is the confinement angle in the fiber core (8° in this example).

Note that the half acceptance angle is larger than the largest glancing angle at which light rays must strike the cladding interface to be reflected, which earlier was 8°.. The difference is the factor $n_0$, which is the refractive index of the core glass, or 1.5. as you can see in Figure 4.8, refraction bends a light ray entering the fiber so that it is at a smaller angle to the fiber

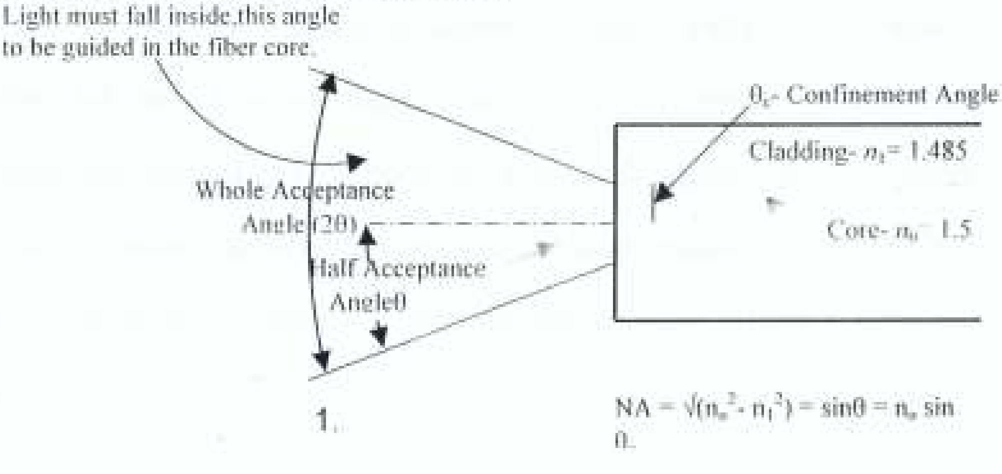



Figure 4.9 Measuring the acceptance angle axis than it was in the air.

The sine of the angle inside the glass equals that of the angle outside the glass, divided by the refractive index of the core($n_0$).

## 4.5 INFORMATION CAPACITY

Information capacity is very important in all types of communications but is measured differently in different types of systems. Where data is transmitted digitally (i.e., in digitized_ bits or units of information), transmission capacity is measured in bits per second. The more bits that can pass through a system in a given time, the more information it can carry. A 100-megabit-per second (Mbit/s) system can carry as much information as a hundred 1-Mbit/s systems. As long as all the information is going between the same two points, it is much cheaper to build on 100-Mbit/s system than a hundred 1-Mbit/s system. The same principle works for analog communications, like the telephone line to your home or most television signals, but we measure capacity by the frequency bandwidth in hertz. In practice, the attenuation of copper wires increases with the frequency of the electrical signals they carry. Electrical power wires have low attenuation only at very low frequencies, including the 60-Hz variation of alternating current. Coaxial cables can transmit higher frequencies, but their loss increases sharply with frequency, as shown in Figure 4.9 however, the loss of optical fibers in essentially independent of signal frequency over their normal operating range. (The scale is measured in loss per kilometer of cable and does not take into account the transfer losses mentioned earlier.) [Jeff Hecht 1999]

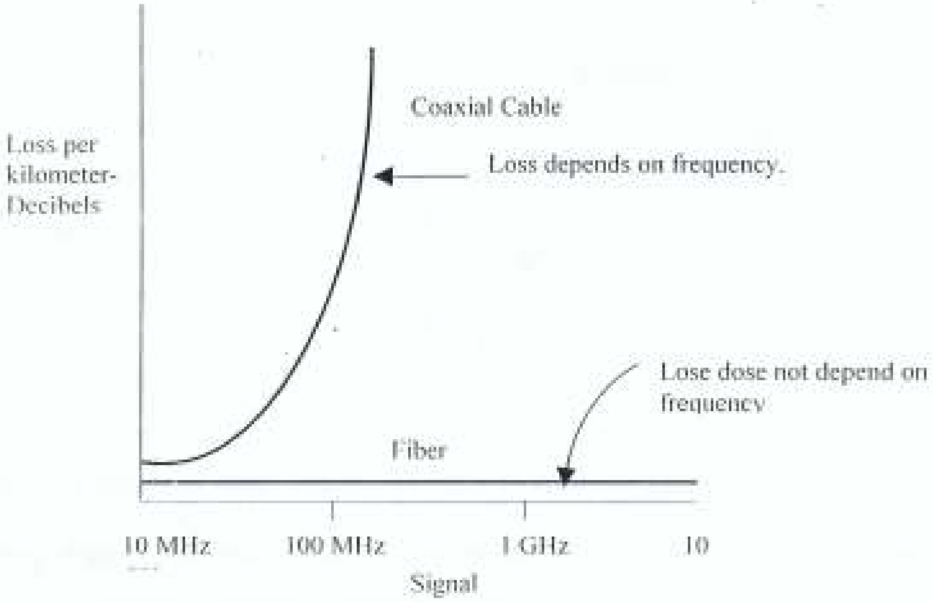



Figure 4.10 loss as a function of frequency

## 4.6 TRANSMISSION SPEED LIMITS

Effects other than loss limit fiber transmission speed. They are best seen by looking at digital transmission, although they also occur for analog transmission. Consider another view of the basic optical fiber shown in Figure 4.10. as long as the fiber has a core diameter much larger than the wavelength of light (i.e, well over 10_m), rays can enter the fiber many different angles to its axis. A ray that bounces back and forth within the core. Many times will travel a slightly greater distance than one that goes straight through. For instance, if one ray travelled straight through a 1-km fiber and another bounced back and forth at a $5^{0}$ angle through a 100-m core through the same fiber, the second ray would travel 3.8 m farther.

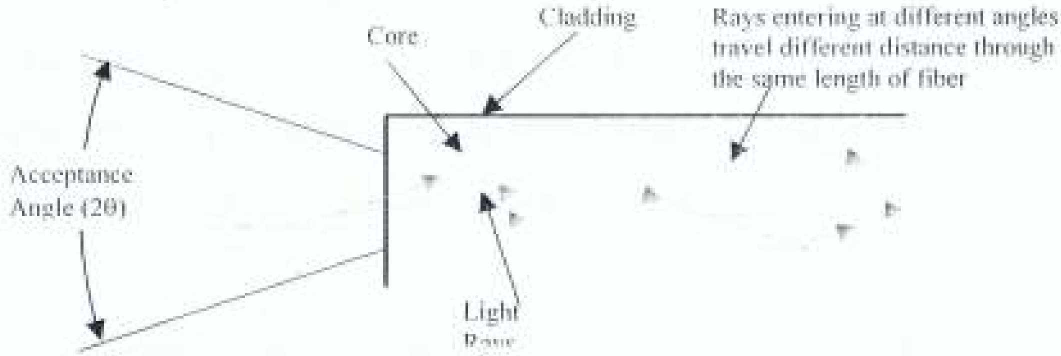



Figure 4.11 light ray take different paths in a fiber core

The one that goes down the centre of the fiber will reach the output end first, 19ns before the ray that bounced back and forth at a 5° angle. Thus an instantaneous pulse at the start of the fiber would spread out to 19ns at the end. This phenomenon is called pulse dispersion. This example gives a rather simplified view of how light travels through the fiber in what are called different modes, other effects can also cause various degrees of pulse dispersion. Dispersion is important because, as the pulses spread, they can overlap and interfere with each other, limiting data transmission speed

## 4.7 SYSTEM CONSIDERATIONS

### 4.7.1 Transmitters and Light Sources

Optical transmitters generate the signal carried by fiber-optic communication system. They use light sources chosen to match the properties of optical fibers. There are several standard configurations, which are used in different circumstances.

Visible red LEDs generally are used with all-plastic fibers, which transmit visible wavelengths better than the near infrared. Distances are short and speeds are modest. Near-infrared LEDs and semiconductor lasers made from gallium arsenide (GaAs) emitting at 750 to 900 nm are used with glass optical fibers for relatively short links and moderate speed systems. This technology was the first developed for commercial fiber-systems and is relatively inexpensive, although it is limited in performance.

The most common system configuration for telecommunications is a semiconductor laser transmitting at 1300 nm through glass fibers, which have loss of 0.35 to 0.5 dB/km at that wavelength. The lasers are made form another semiconductor compound, indium gallium arsenide phoshide (In GaAsP). LEDs can be made form the same material to operate at the same wavelengths, but their power is too low and transmission speeds are too low for most applications. Solid state crystalline lasers containing neodymium also can operate at 1300nm, but they have not been widely used because they are much more complex and hence more costly to operate.

Many long-distance telecommunication systems also transmit signals at wavelengths near 1550nm, where glass fibers have attenuation of only 0.2 to 0.3 dB/km. InGaAsP laser operate at this wavelength ( LEDs are not used because they cannot generate enough light to go long distances). Optical fibers doped with the rare earth erbium also generate light near 1550 nm, but they are used more often to amplify an optical signal that has travelled a long distance than to generate a new optical signal.

### 4.8 SIGNAL FORMAT AND MODULATION

Signals are transmitted by modulating the intensity of a carrier. For radio or television, the carrier is a single frequency transmitted steadily. For optical communication, it is a beam of light. In both cases, the modulation can be digital or analog. Digital modulation turns the carrier signal off and on; analog modulation varies the carrier intensity (or some times its frequency) in a way proportional to the analog input. Most fiber-optic system use the digital transmission technology that has become common in modern telecommunications, but some use analog transmission, particularly for applications such as cable television, where signals are still transmitted in analog form.

Transmitting a fiber-optic signal requires modulating the intensity of a light source. This can be done in two ways: by modulating the input power to directly change source intensity or by changing the intensity of the beam after it leaves the light source. Each approach has its advantages.

Direct modulation is simple, which can be a compelling advantage. It works best for LEDs and semiconductor lasers, because their light output changes with the drive current passing through the semiconductor device, as shown in Figure Current on and off with a digital signal produces a series of light pulses. Analog modulation makes light output rise and fall continuously with variations on the drive current. The current-output curves of optical devices are not perfectly linear, so direct modulation can cause some distortion of analog signals. However, digital signals suffer little form such distortion because the intensity of the signal is less important than its presence or absence.

External modulation is more complex, because it requires an external modulator that changes the intensity the light passing through it, External modulators offer two distinct advantages. One is their ability to modulate the output of certain types of lasers which cannot be modulated directly. A second is somewhat higher performance, because rapid modulation of a semiconductor laser can cause undesired side effects, such as small shifts in its output wavelength.

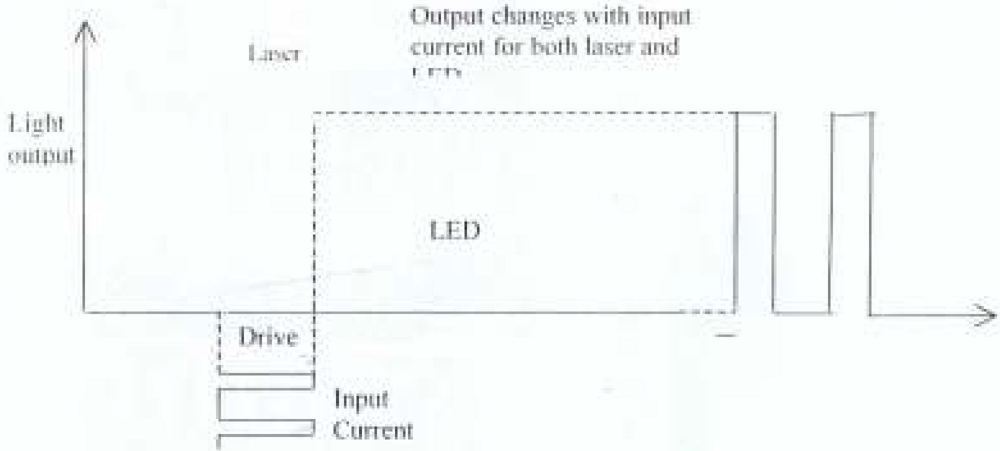
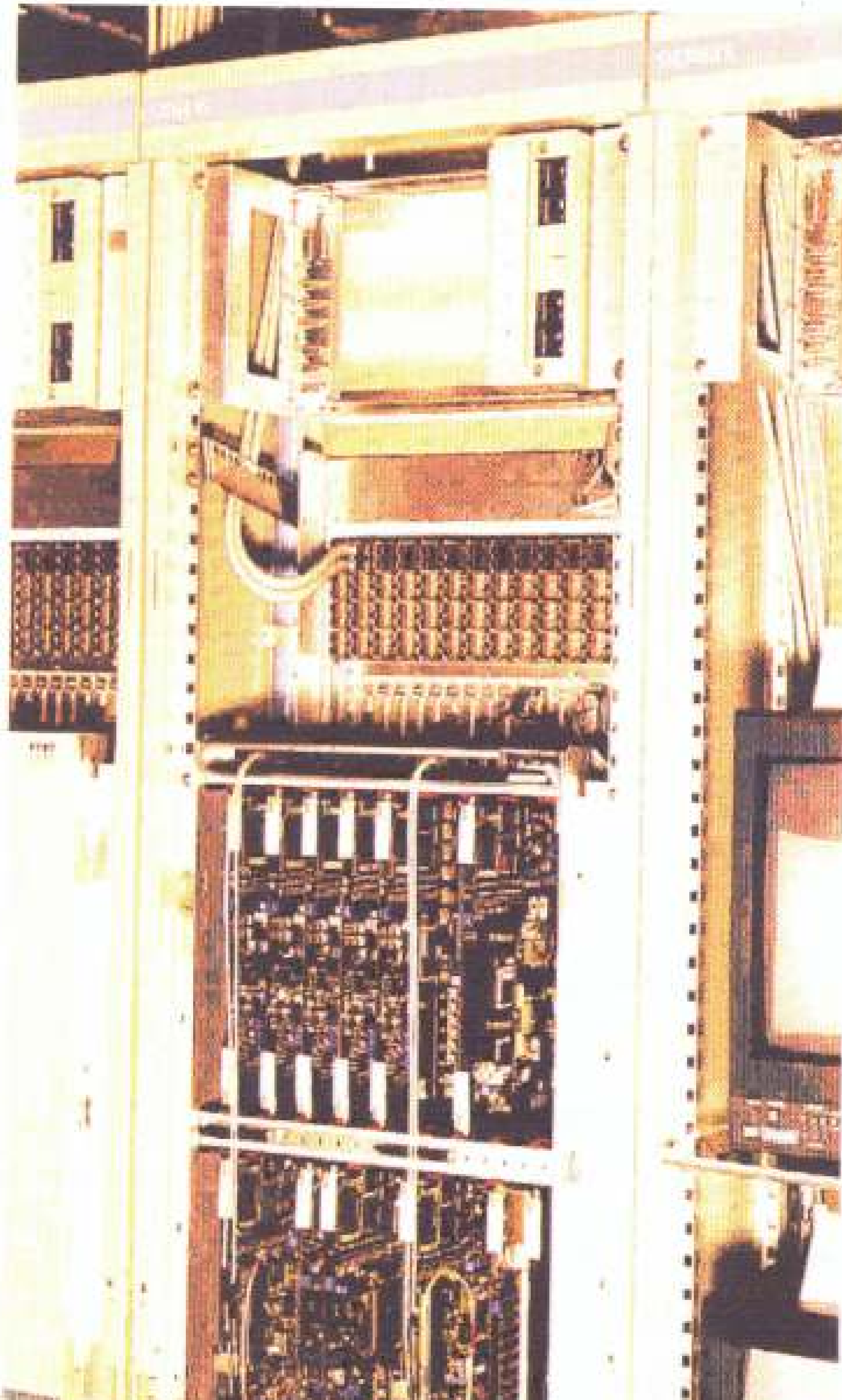



Figure 4.12 Relationship between drive current and optical output

## 4.9 MULTIPLEXING

As with other communication systems, fiber-optic systems often combine, or multiplex, multiple signals that follow the same route. Multiplexing is particularly valuable fiber optics because of its huge potential capacity of individual fibers. Three main types of multiplexing can be used in fiber-optic systems: directional, time-division, and wavelength-division.

It is possible to send signals in opposite directions through the same fiber.



Multiplexers of the STEP program allow access to the 2-Mbit/s level and implementation of add/drop. cross connect and terminal multiplexer configurations in ring chain or meshed network topologies

STEP: SDH products for today and tomorrow

Fig. 4.13: Multiplexing Equipment

However, this is done only rarely because the signal can interact with each other, degrading performance. Directional multiplexing works best if the signals are at different wavelengths.

Time-division multiplexing is the combining of bit streams from several different signals, as shown in Figure 4.12. For example four signals at 10 million bit (megabits) per second can be combined to generate one 40-Mbit/s signal. There is a standard set of time-division multiplexing rates used in telecommunications. They were originally developed for electronic systems but have been adapted and extended for fiber-optic transmission. A demultiplexer separates them at the end for distribution.

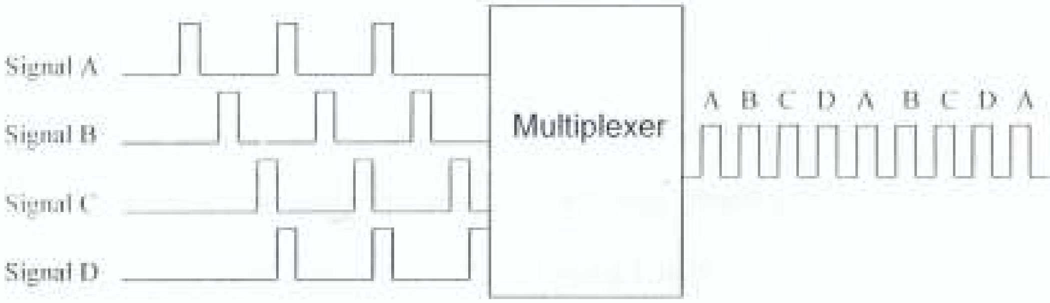



FIGURE 4.14 Time division multiplexing combine several slow signals into a faster one

Wavelength-division multiplexing (WDM) combines signals at different wavelengths to travel through the same fiber, as shown in figure 4.13. Optics combine signals at several different wavelengths, which pass along the same fiber with minimal interaction to a demultiplexer, which splits them apart and routes them to their separate destinations. Wavelength-division multiplexing has become important because it can multiply the transmission capacity of a single fiber without the installation of new cable. WDM sometimes is called frequency-division multiplexing because the various wavelengths have different frequencies, making it analogous to frequency-division multiplexing used in radio and electronic transmission, where many television channels are sent through a coaxial cable at different carrier frequencies.

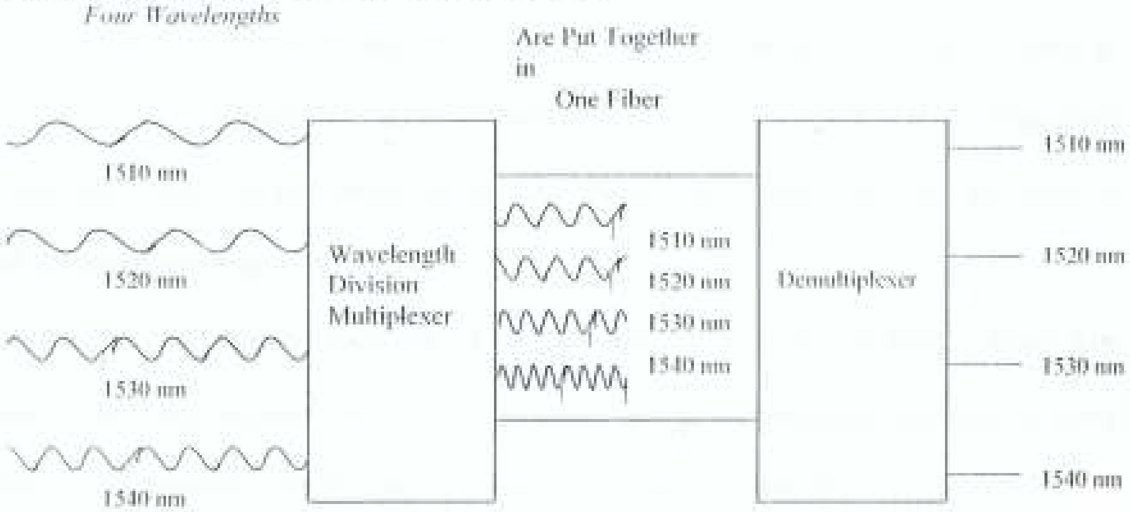



FIGURE 4.14 Wavelength division multiplexing sends separate signals through one fiber at different wavelength. [ Jeff Hecht 1999]

## 4.10 SWITCHING

Switching is an integral part of telecommunication networks. Switches route signals from one point to another in the network. Historically, switching was developed for the telephone network to make temporary connections between pairs of phones so that people could talk with each other. At first, local operators made temporary connections with cords on switchboards, gradually, automated machines took over those functions and expanded automatic dialling around the world. Switches direct signals from your home to a local switching centre and form there to other switching centres around the world.

Electronic switching technology, using special-purpose semiconductor electronics and computers, is much better developed today than optical switching. This partly reflects the greater difficulty in manipulating photons than electrons. It also reflects the investment of much more effort in developing electronic switches over many more years than optical switches have been in development. However, optical switches do exist, and offer important advantages, such as the ability to reroute all signals carried by a single fiber in case of cable failures.

Not all systems require switches. Cables need no switches if they merely run between two points-whether form your home to the phone pole outside or from California to Hawaii. Today, most fiber-optic systems function as point-to-point links, running between nodes where electronic switches can route signals as necessary. This will change as optical switches improve.

### 4.10.1 Detection

The last element in any fiber-optic link is the receiver, which detects the optical signal emerging form the end of the fiber and converts it to electronic form for further transmission or processing. Typically a receiver consists of a semiconductor photodetector and amplifying electronics. Further optical processing may be possible at some point in the future, but at present optical devices to process the light signals emerging form fibers are only in the laboratory stage.

How well the detector does Its job depends on its sensitivity and the signal level reaching it. Sensitivity, in urn, depends on operating conditions, detector design, and how he light-sensitive detector material responds to the signal wavelength. For example, silicon photodiodes work well at 400 to 1000nm but are not sensitive to the longer wavelengths of 1300 and 1550 nm used in most long-distance fiber systems.

Receiver electronics process the electrical signal generated by the detector to replicate the original signal sent through the fiber. You can think of this as cleaning up the signal emerging form the optical information pipeline. The signal itself is amplified. Digital pulse edges, which grow blurred as the signal passes through the system, are sharpened by detecting when the signal strength passes a threshold level. Timing of a series of pulses is checked and corrected.

# CHAPTER FIVE

## 5.0 PLANNING AND DESIGN ANALYSIS.

Optical fiber systems are now widely accepted to offer both technical and economic advantages for transmitting information. The high bandwidth. Low attenuation and potentially low cost of fiber optics makes it an attractive transmission medium for both long haul and short transmission systems. In addition, its immunity to electromagnetic interference and intrinsic safety among others, are added advantages for suitability for data links, particularly in electrically noisy or hazard environments.

The basic elements of àn optical fiber communication system are shown in Figure 5.1 the system can be broadly divided into the following areas:

(a) Baseboard electronics

(b) Optoelectronic devices

(c) Transmission path

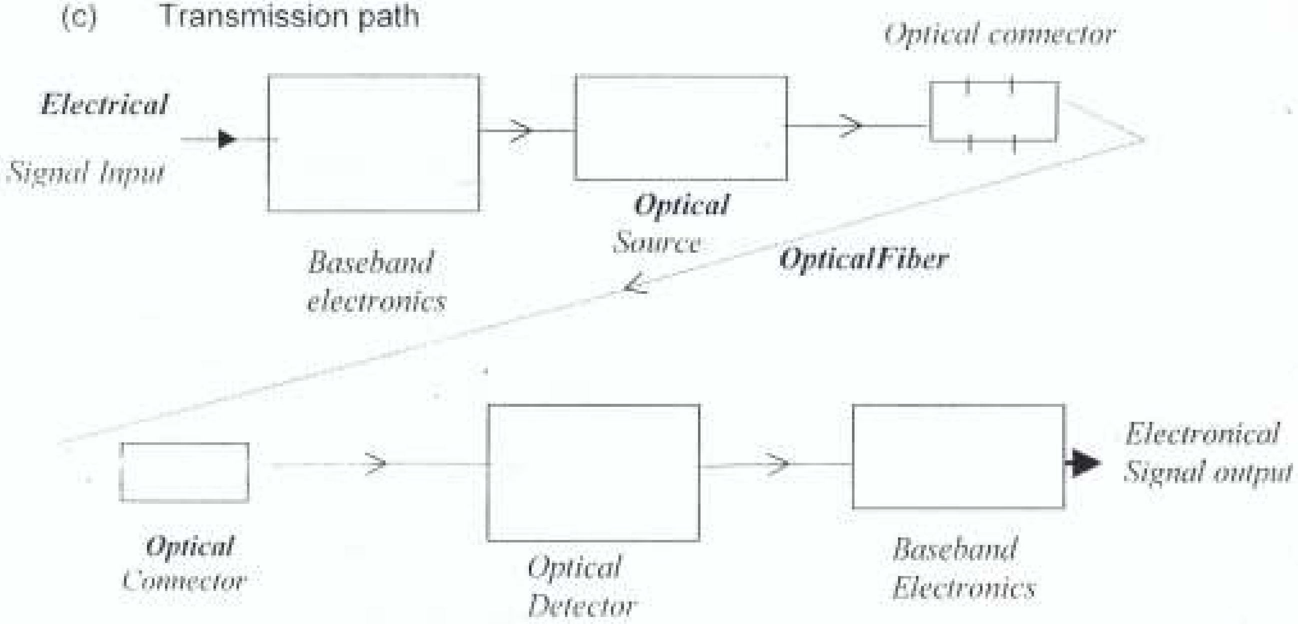



*Fig 5.1 Basic elements of an optical fibre communication system*

The factors which influence the choice of components and the design of circuits for each part of the system and how they relate in a complete system design will be discussed In the following sections, together with design example of a high capacity Optical fiber trunk transmission system and a low cost data link. [Ball, 1997]

The top two technical considerations for communication systems are loss budget and transmission capacity, or bandwidth

In this chapter, we will concentrate on the major goals of achieving specified transmission distance and data rate at reasonable cost. Many design variables can enter into the equation, directly or indirectly. Among them are the following:

- Light source output power (into fiber)
- Coupling losses
- Response time of the light source and transmitter
- Signal coding
- Splice and connector loss
- Type of fiber (single or multi-mode)
- Fiber attenuation and dispersion
- Fiber core diameter
- Fiber NA (Nautical Angle)
- Operating wavelength
- Wavelength-division multiplexing
- Optical amplifiers

- Direct versus indirect modulation of transmitter
- Switching requirements
- Receiver sensitivity
- Bit error rate or signal-to-noise ratio
- Receiver bandwidth
- System configuration
- Number of splices, couplers, and connectors
- Type of couplers
- costs

Many of these variables are interrelated. For example, fiber attenuation and dispersion depend on operation wavelength as well as the fiber type. Coupling losses depend on factors such as fiber NA and core diameter. Some interrelationships limit the choice available. For example, the need to achieve low fiber loss may require operation at 1300 or 1550nm, and the need for optical amplification may dictate 1550nm. [Jeff Hecht 1999]

## 5.1 OYO OPTICAL FIBRE RING NETWORK STATIONS (OFR)

The Oyo Optical fiber ring network station (OFR) located in all the local exchanges and other telecommunication stations along the ring interconnectivity. Although, the OFR fell under the national trunk network section of the long distance communication division, but its activities were restricted within the metropolis.

The activities of the (OFR)) were coordinated from the main stations, which were located at Oniyarin exchange, Ibadan.

The activities on the network include

- Monitoring and controlling the operation of the digital fiber optic system
- The execution of periodic preventive maintenance measures on the system
- The provision of transmission route for leased and dedicated circuits
- The trouble shooting of various fault along the transmission routes.
- The collation and complication of the monthly reports of the system
- The provision of interconnectivity between the NITEL terminal and private telecommunication operator's terminals.

With the implementation of the digital fiber optic system, this will bring in expansion of the switching systems, high degree of information capacity, security and digital integrated services which will lead to the increase in revenue generated.

In order to meet the challenged of this millenium, the design of the optical fiber ring network have to be upgraded from the plesiochronous digital hierarchy to synchronous digital hierarchy's system, which is simpler, more flexible and with greater information carrying capacity.

## 5.2 OBJECTIVE OF OYO STATE DIGITAL OPTICAL FIBER SYSTEM

The following objective of the Oyo state digital fiber optic system resulted from the design's goal; the provision of a new transmission route which has free flow of traffic in and out of the nodal points with new additional telecommunication services, they are:

- To have system that can cope with the increased demand for the telecommunication services.
- To have a technological advanced system, which comply with the International Telecommunication Union[ITU]
- To have a system that can be integrated with both the existing and new systems.
- To have highly reliable system
- To have a software controlled and intelligent network.

At present, the use of fiber optic cable (FOC) transmission in NITEL is limited to trunk and junction applications. However, the deployment of fiber optics into the local network is seriously being looked into by the planning and Development Division.

The operating route covers Ibadan, Oyo town and Ogbomoso while local network covers Oniyanrin, Bodija and Ring Road. Is operating on 140Mb/S.The junction application is however restricted to Ibadan Multi-Exchange Areas with a transmission rate of 140Mb/S (1920 voice channels) on 12 fibres between Host Exchanges; 6 fibers between Host RSU on 140 Mb/s working and RSU on 140 Mb/S Working (1920 voice channels). The FOC design was based on Ring configuration.

The National Optic Fiber Network currently being designed by the planning and Development Division is equally based on Ring concept. This type of network offers a good degree of flexibility such that traffic is never disrupted should the cable be cut.

## 5.3 PLANNING & DESIGNING ASPECT

When designing a fiber optic system, there are many factors that must be considered all of which contribute to the final goal of ensuring that enough light reaches the receiver. Without the right amount of light, the entire system will not operate properly.

The following step-by-step procedure should be followed when designing any system.

1. A study of the map of the Locality, in this cases the map of Oyo State showing all the 33 Local Governments in details.
2. Contacting census office to predict the number of subscriber
3. Calculation of the bandwidth to know the type of cable required
4. Design of optical fiber links
5. Identification of the types of equipment needed.
6. Consulting fiber instrument sales Inc.

## 5.4 IMPORTANCE OF MAP.

The Map provides the following information, which will be helpful for the planning and design of this project.

- It's indicating geographical position of the towns.
- The map makes it easy to link exchange together
- The distance between two towns can also be obtained or read from the map. This will help to get the length of fiber cable and it will also specify, if repeater station will be needed.
- The map also indicates all the major road, which is the most important information for planning and design; as fiber cable installation follows major road.
- The map also indicates where river cross the road and this must be put into consideration because installation at the river side is more tedious than ordinary land and the design is quite different.
- The map also makes it easy to plan for future expansion. It also helped to locate where there is likely fault, on the cable. For example WILCOM FIBER RANGER is an instrument from Fiber Instrument Sales Inc. The Wilcom fiber range fault locator is a rugged, lightweight, hand held, easy to use optical locator for multi-mode and single mode applications. The system is designed to pinpoint faults in optical cable, which can be over 20 kilometers away with amazing accuracy. The system operates at the industry standard wavelength of 1310nm, and can display the distance to the fault in meter or in feet.[Sue Muraca, 2000]

## 5.5 VISITATION TO CENSUS OFFICE

Census head office was visited at Ibadan to acquire certain information and data, which will be needed for the planning and designing of the project.

From the census office, number of household at each 33 Local Governments Area was provided. This information helped to predict the number of likely subscribers. The population of each Local Government was obtained.

One of the aims of this project is to provide telephone line for each house in Oyo State. The number of houses was used for voice channels and the number of voice channel will determine the bandwidth of the fiber optic cable that will be required for this operation.

The population census of 1990 gave the following results, although the people of Oyo State earlier rejected it, but after some amendments it was later adopted. The total population was given to be 3,452,720 and the total number of houses was 769,525. The details of the information were well explained in the table below.

| S/N | Local Government Area | Number of household | Population |
|---|---|---|---|
| 1. | Afijio | 18,580 | 82,792 |
| 2 | Akinyele | 30,257 | 140,118 |
| 3. | Egbeda | 28,087 | 129,461 |
| 4. | Ibarapa Central | 13,212 | 59,197 |
| 5. | Ibadan Northwest | 36,667 | 147,918 |
| 6. | Ido | 12,085 | 53,582 |
| 6. | Saki West | 23,382 | 109,437 |
| 7. | Ibarapa East | 14,665 | 65,897 |

| | | | |
|---|---|---|---|
| 9. | Irepo | 15,051 | 65,897 |
| 10 | Iseyin | 26,984 | 118,667 |
| 11. | Kajola | 24,471 | 112,006 |
| 12. | Lagelu | 14,963 | 68,901 |
| 13. | Ogbomoso North | 23,752 | 104,295 |
| 14. | Ogo – Oluwa | 7,754 | 36,188 |
| 15. | Oluyole | 20,268 | 91,527 |
| 16. | Ona-Ara | 26,976 | 123,048 |
| 16. | Orelope | 14,522 | 68,566 |
| 17. | Orire | 21,457 | 103,611 |
| 19. | Oyo East | 37,098 | 165,068 |
| 20. | Surulere | 12,503 | 64,09 |
| 21. | Ibadan North East | 65,335 | 275,627 |
| 22. | Ibadan South East | 52,278 | 225,800 |
| 23. | Ibadan South West | 64,333 | 227,047 |
| 24. | Ibadan North | 68,464 | 302,271 |
| 25. | Ogbomoso South | 15,157 | 65,959 |
| 26. | Atiba | 3,396 | 11,643 |
| 26. | Atisbo | 11,959 | 58,565 |
| 27. | Ibarapa North | 9,555 | 42,558 |
| 29. | Itesiwaju | 10,327 | 52269 |
| 30. | Iwajowa | 11,348 | 56,254 |
| 31. | Olorunsogo / Iyamapo | 6,961 | 39,298 |
| 32. | Oyo West | 17,631 | 79,187 |
| 33. | Saki West | 10,041 | 51,326 |
| | State total | 769,525 | 3,452,720 |

**Table 5.1 : Local Government Headquarters With Population Census**

## 5.6 TRANSMISSION CAPACITY

The transmission capacity of a communication system measures how much information it can carry. For digital system this is the number of bits per second passing a given point, for analog systems. It is the transmission bandwidth, usually measured in megahertz or gigahertz. Typically it is specified for individual fibers, with a pair of fibers needed to carry two way communications – one transmitting in each direction. The total capacity is the sum of the capacity of the entire fiber Pairs. (It is possible for fiber to carry signals simultaneously in two directions, but there are significant performance drawbacks, so it generally is not done at high speeds, and generally the wavelengths should be well separated. For example, a single fiber might carry signal at 1300 and 1550nm, with the 1550nm signals at a much lower speed.)

We can achieve high speed in various ways. One is to modulate the transmitter at higher and higher speeds. Another is to add other transmitters, and send multiple signals through the fiber at different wavelengths. A third is to add more fibers to the cable or transmission route.

Conversely, various factors can limit transmission speed. We need a light source that can be modulated rapidly. We need low dispersion at the transmitted wavelengths – meaning both low dispersion in the fiber and a narrow spectral width from the lager source. Because total fiber dispersion increases with the distance, We may need to limit transmission distance to achieve high speed. We also need fast, sensitive receiver. [Jeff Hecht 1999]

In designing an optical fiber link, consideration is given to two major factors. The Bandwidth requirement and the loss budget.

To design the system, the bandwidth requirement must first be established. This should give the overall capacity (amount of signal to be transferred) of the link. To establish the total bandwidth ($B_T$). The following parameters are considered for Bandwidth requirement.The total bandwidth required for a system is given by the relationship **(ACHI.1993)**

$B_T$ = (Total Bandwidth)

$$B_T = \sqrt{\left\{\frac{1}{[B_m]^2} + \frac{1}{[B_c]^2}\right\}}$$

Where,

$B_M = B_{mk} / L^r$

$B_M$ = Overall Modal bandwidth (Hz)

$B_{Mk}$ = Kilometric Modal bandwidth of fiber (Hz. KM).

L = Link Length (Km)

r = A constant = 0.75

Where, $Bc = \frac{0.44}{d\lambda.\ \Delta\lambda.L}$

Bc = Overall chromatic bandwidth (Hz)

$d\lambda$ = Dispersion coefficient 3.5ps/nm/km at 13000nm

$\Delta\lambda$ = Spectral width of the source

L = Link length (km)

## 5.7 CALCULATION FOR EXCHANGE LINK BANDWIDTH REQUIREMENT

1. Ring Road exchange – Oniyanrin exchange.

Link length (km) = 6.688km

Jointing plan (Km) = 6.720km

Using the relationship $BT = \sqrt{\frac{1}{(Bm)^2} + \frac{1}{(Bc)^2}}$

For mono mode fiber, modal dispersion is zero. I.e. Bm = 0

∴ The equation will be restricted to

$$B_c = \frac{0.44}{d\lambda \times \Delta\lambda \times L}$$

The spectral width of laser 0.5nm = $\Delta\lambda$

$$B_c = \frac{0.444}{3.5E-12/E-9 \times 0.5E-9 \times 7.720}$$

$$B_c = \frac{0.44}{1.351E-11} = 3.2568E10Hz$$

$$B_c = 32\ GHz$$

Total Bandwidth available = 32 GHz

The total bandwidth required for 140 Mb/s assuming 5B – 6B (Digital codes) is 140 x 6/5 = 168Mb/s

Then Data rate = 168 Mb/s

B/W (Niquist frequency) = $\frac{168}{2} = 84\ MHz$

The above system is quite possible since the total bandwidth available is about 32GHz and we require only 84 MHz.

Calculation for the entire exchange bandwidth requirement was carried out and the result is given in the table 5.2.

Using Ring Road to Oniyanrin with Distance = 6.688km as an example, we can obtain the number of joints. 1.5km was used for spacing to avoid over stressing of the cable so

6.688/1.5 = 5.125 ≈ 5 Joint During the splicing, 2 meter extra must be kept for future splicing incase of any problem.

∴ 2m x 5 = 10m

At the exchange 20m length must be kept while 2m was used for connector into the SDH equipment so this gives total length of 32m

32m = 0.032km

Jointing plan = 6.688 + 0.032

= 6.720km.

This method was used for all other exchange links.

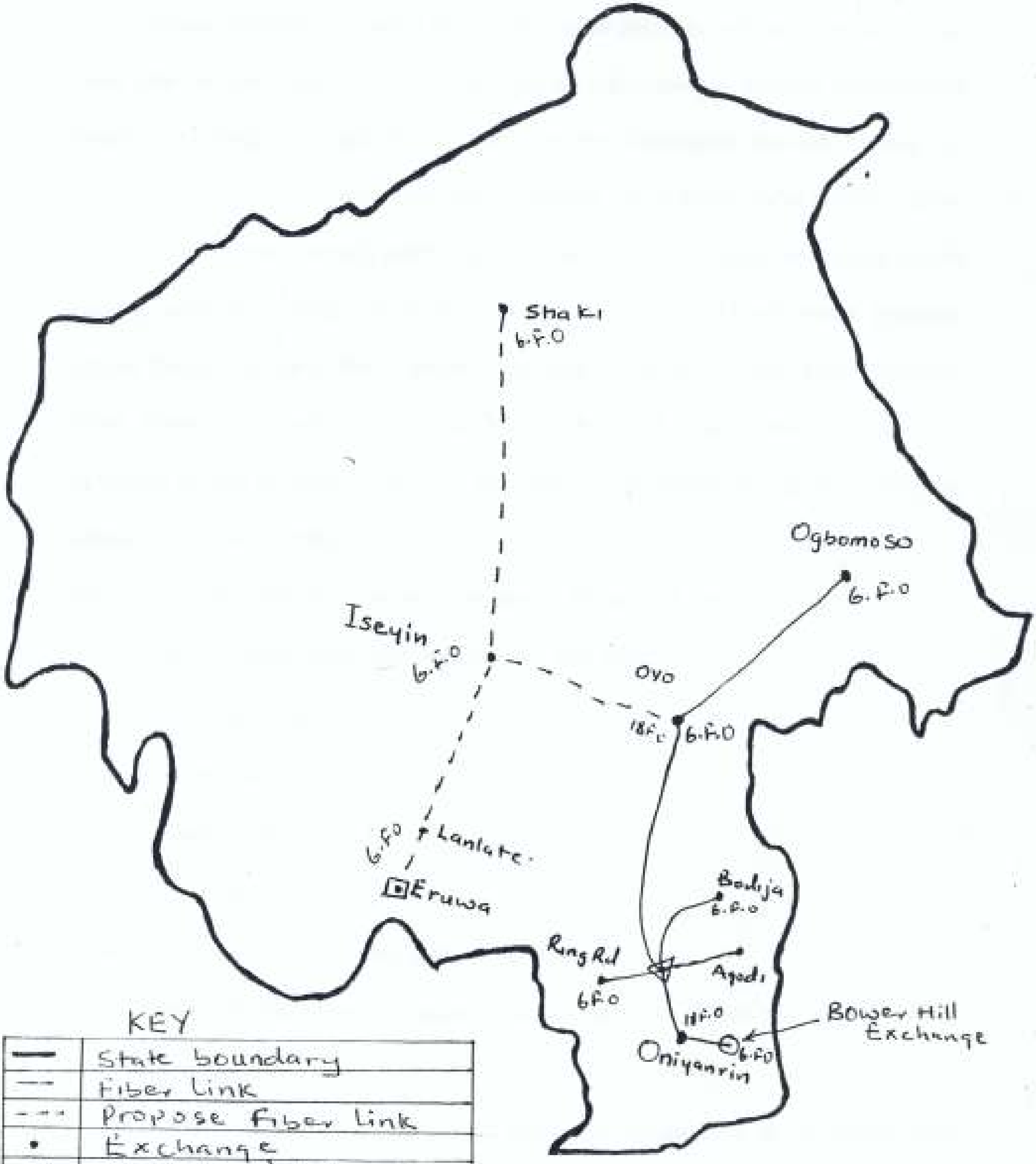
Also 1.8km was used in spacing the splicing for distance above 30km so that the number of splicing can be reduced which will also reduce the losses.

**Table 5.2 Exchange link bandwidth requirement**

| S/N | Exchange Link | Cable laying Plank (Km) | No of Joint (Splicing ) | Jointing Plan Km | Bandwidt h Available Hz | Bandwidth requirement Hz | Splicing Distance (km) |
|---|---|---|---|---|---|---|---|
| 1. | Oniyanrin– Ring Road | 6.688 | 5 | 6.720 | 32GHz | 84MHz | 1.5km |
| 2. | Oniyanrin– Bodija | 5.839 | 4 | 5.869 | 44GHz | 84MHz | 1.5km |
| 3. | Oniyanrin Oyo town | 53.000 | 29 | 53.080 | 4.7GHz | 84MHz | 1.8km |
| 4. | Oyo town Ogbomoso | 56km | 31 | 56.084 | 4.5GHz | 84MHz | 1.8km |
| 5 | Oyo town Iseyin | 4km | 22 | 40.066 | 6.2GHz | 84MHz | 1.8km |
| 6. | Iseyin Shaki | 82km | 22 | 82.066 | 3.1GHz | 84MHz | 3.8km |
| 6. | Oniyanrin Agodi Gate | 4.265 | 3 | 4.293 | 58GHz | 84MHz | 1.5km |
| 7. | Iseyin Eruwa | 65km | 36 | 65.094 | 4.0GHz | 84MHz | 1.8km |

**Note**: - For 140 Mb/s the capacity is 1920 voice channel, that means 1,920 telephone line can communicate at the same time. 34 Mb/s can be used for Tv signals.

MAP OF OYO STATE INDICATING FIBER LINK WITHIN THE EXCHANGE




KEY

| | |
|---|---|
| — | State boundary |
| — | Fiber link |
| - - - | Propose fiber link |
| • | Exchange |
| ⊡ | Propose Exchange |
| ▽ | JD - Distribution joint |
| F.O | fiber optic cable |

## 5.8 POWER BUDGETING/LOSS

Power budgeting is such like making sure you have enough money to pay your bills. In the case, you need enough light to cover all optical transmission losses and deliver enough light to the receiver to achieve the desired sign-to-noise ratio or bit error rate. That design should leave some extra margin above the receiver's minimum requirements to allow for system aging, fluctuations, and repairs, such as splicing a broken cable. However, it should not deliver so much power that it overloads the receiver. One note of warning: make sure you know what power is specified. We can lose 3dB if the transmitter manufacturer specifies output as peak power but the receiver manufacturer specifies average power. [Jeff Hecht 1999]

All losses in the system must be considered. These include

- Loss in transferring light from source into fiber
- Connector loss
- Splice loss
- Coupler loss
- Fiber loss
- Fiber-to-receiver coupling loss
- Some of these losses have been covered in detail earlier, but other deserves more explanation.

A transmitter-receiver section is the basic design unit of an optical fiber cable route. A route may be hundreds of kilometers long and include many sections or be as short as a single section a single receiver and everything in between.

The performance of fiber optic system can therefore be analyzed in form of a "power budget" or "loss budget". This is the apportionment of the various losses of the optical items in a fiber optic system within the limits of launched and receiver power. In other words we can determine the quantities of the various items to be placed between the transmitter and receiver, including allowances for future condition and restoration. These items have a combined loss, which is within the budget. If the loss budget is exceeded, one or more items must be reduced or eliminated until the power budget is met.

The losses between the Transmitter S and the Receiver R are called the Path Loss. This path loss includes the following:

(i) Loss due to Fibre Distribution Frame or Fire Patch Panel, if used.

(ii) Losses on account of splice.

(iii) Loss on the fibre itself.

(iv) Margin due to future splice.

Also, the losses associated with optical equipment (LTE) and accessories are:

(i) The Equipment Margin (to account for aging)

(ii) Dispersion penalty

(iii) Connector loss in the equipment (Pigtails).

(iv) Coupling loss

The power budget for an optical-line system is a detail statement of the optical power levels necessary for correct operation of the system. A manufacturer must submit such a statement when supplying equipment. It is not necessary for maintenance staff to know all the power budget details of a particular system but an appreciation of the general principle can be useful. This project analyzes these general principles and discusses typical optical levels. [ Achi 1993 . 38pp ]

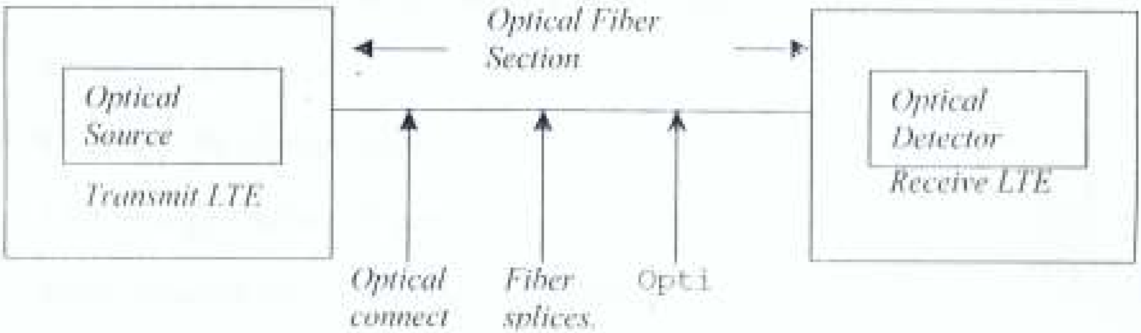



Fig 5.3 Fibre link system

The output of the optical source and the sensitivity of the optical detector are fixed and cannot generally be adjusted. So the power budget is derived from these two limits. Assume, for example, a system using a lager transmitter. The mean emitted power would be typically –3dB. The optical detector sensitivity is defined as the minimum level, which will produce a specified maximum error rate in the signal. A typical sensitivity for a PIN-FET detector would be –50dBm. Thus the system power budget would be

| | | |
|---|---|---|
| Transmit power | - | 3dBm |
| Receiver sensitivity | - - | 50dBm |
| | | 47dBm |

So the total system losses must be less than 47dB if the system is to operate correctly.

### 5.7.1 Sources of Loss:

1. Optical fiber section loss

The main source of loss is the optical fiber. This loss depends upon the fiber type and the wavelength of light that is used.

Typical values are as follows graded index multi-mode:

3.5dB/km @ 850nm

1.5dB/km @ 1300nm (type 1

1.0dB/km @ 1300nm (Type 2)

Single mode 0.1dB to 0.8dB/km @ 1300nm

0.15dB to 0.5dB/km @ 1550nm

As most optical fiber is provided in length of 2km. It has to be jointed (or spliced). The typical loss in a fiber splice is 0.5dB. Although this value vary with the quality of the splice.

Installation specifications should always quote a maximum figure for total jointed section fiber loss. This is necessary because the actual losses of fiber and splices can vary.

The performance of an optical fiber degrades over a period of time, so the figure includes an allowance for this. It also includes a cable maintenance margin to allow for extra splices, which will be necessary in the case of cable repairs. These allowances are typically 2dB for degrading and 4dB for the cable maintenance margin.

For each type of system, the jointing section fiber loss can be found in this system specification. Typical examples are 23dB for 140Mb/s single mode systems and 22dB for 34Mb/s multi-mode.

Excessive high optical levels can over load optical detectors. Because this can cause errors, a minimum figure for jointed section loss is also often quoted. A typical operating range for an optical detector would be –50dB to –32dB. To reduce the receiver level to the required value. Optical attenuation are often fitted in the receive fiber.

2. Connector losses.

The loss of an optical connector will vary with type but an average figure of 1.5dB per connector can be generally assumed. Thus for a typical system, connector losses would be 2 x 1.5 = 3dB. [Ogungbe. 1994]

### 5.8.2 Power Budget Analysis for Exchange Link

Oniyarin - Bodija

(i) Distance = 5.839km

(ii) Transmit power using laser transmitter or Average output power launched in the fiber (Po) = -3dB

(iii) Receiver sensitivity (Pr - -50dB

(iv) Dispersion (chromatic penalty) = 0.5dB

(v) Connector loss = 1dB/connector

(vi) Equipment Margin = 2.0dB

(vii) Cable loss = 0.2 – 0.45dB/km

(viii) Splice loss = 0.5

(ix) Provision for repair splice = 2dB

### 5.7.3 Calculation for power Budget Analysis

System Gain or Maximum allowable loss

(Po - Pr) dB = -3 –(-50) = 47dB.

A. Equipment Losses

(a) Connector losses

2 (connectors) = 2.0dB

(b) Dispersion loss = 0.5dB

(c) Equipment Margin = 2.0dB

4.5dB

B. Path (Line) losses

(d) Loss due to FDFS (2) = 3dB

(e) Cable loss for 5.869km

At 0.2dB/km =1.2dB

(f) 4 splices at

0.05dB/Splice =0.2dB

(g) Provision for repair splice =2dB

Sub Total =6.4dB

Total losses (A + B) = 4.5dB + 6.4dB = 10.9dB

Excess Margin (EM) = 47dB - 10.9dB = 36.1dB

The system can be engineered since the maximum allowable loss is greater than the total losses.

### 5.7.4 Attenuation

In mono mode (single mode) fiber, the attenuation drops from 0.45dB/km (average) at 1300nm to 0.30dB/km (average) at 1550nm Wavelengths.

Some of the sources of loss are: -

(i) Absorption loss: This is due to the impurities in the silica (glass) itself. The impurities are in form of copper, iron etc.

(ii) Raleigh Scattering: This is the scattering of light from micro-irregularities in the fiber.

(iii) Micro-bending: This is the microscopic deformation of the fiber axis. Decreasing the core diameter of the fiber can reduce this effect.

After the installation, attenuation test has to be carried out. The table 5.6.2 below indicates types of test, criteria and types of instrument used for the operation.

Table 5.3

**ACCEPTANCE TEST PROCEDURES**

**TEST CRITERIA: FIBRE OPTICS**

| ITEMS | CRITERIA | MEASURING SYSTEMS |
|---|---|---|
| CONTINUITY | CONTINUITY OK: NO TRANSPOSITIONS | OPTICAL TALK SET |
| WAVEFORM TEST | OPTICAL LENGTH WAVE LENGTH (WL) = 1550NM INDEX OF REFRACTION (IR) = 1.47320 | OTDR (OPTICAL TIME DOMAIN-REFLECTOMETER) |
| CONNECTOR LOSS | WL = 1550 nm: IR = 147320 Av < 1.0Db | OTDR LAUNCHING FIBRE 1000MT |
| SPLICE LOSS | WL = 1550nm: IR = 147320 INDEX OF REFRACTION = 1.4730 MEDIUM VALUE < 0.15DB MAXIMUM VLAUE = 0.50DB | OTDR |
| SECTION (LINK) ATTENUATION | WL = 1550nm: IR = 147320 Am< = A A: MAXIMUM ATTENUATION Am: MEASURED ATTENUATION OR ATTENUATION MEASURED MAX | OTDR/LAUNCHING FIBRE (1000mt) OR OPTICAL ATTENUATORS |

Maximum Attenuation (A) have to be specifies by the manufacturer. While the measured Attenuation (Am) have to be calculated for

A: Maximum Attenuation

Am: Measured Attenuation

For the system to work perfectly

$$Am <= A$$

So measured Attenuation (Am) should not greater than Maximum Attenuation specify by the manufacturer.

### 5.8.5 Attenuation Measured (Am)

The relationship is given by the Am = (FL X L) + (N X SL) + (CL X 2) + (TLX2)

Where

$F_L$ = Fiber Loss from Factory =0.20dB/km

L = Optical length (Distance)

N = Number of Joints (Splices)

$S_L$ = Splice loss

$C_L$ = Connector loss

$T_L$ = Termination Loss

Example: - ONIYANRIN - RING ROAD

Fiber cable length (L) = 6.720km

Number of Splices (N) = 5

Am = (0.20 x 6.720) + (5x0.15) + (1 x 2) + (1 x 2)

= 1.544 + 0.75 + 2 + 2

= 6.294dB

Maximum Attenuation (A) can also be used for Total loss (A + B) calculated earlier i.e. Total loss (A + B) = A

Measured Attenuation ($A_m$) must be less than Maximum Attenuation A and also Maximum Attenuation must be less than system Gain or maximum allowable loss.

$A_m < A < SG$

Where

SG - System Gain.

The splice loss was measured at each point and the average was calculated to get splice loss (SL).

Analysis and Attenuation calculated, for all the Exchange and table 5.4 gives the details.

In order to minimize the number of joints, 4km drum of cable was use to simulate Exchange link between Iseyin and Shaki.

### Table 5.4,m Attenuation measured

| S/N | Exchange | Distance (km) | SG (dB) | No of Joint | Total loss (A + B) or A (dB) | EM (dB) | Am (dB) |
|---|---|---|---|---|---|---|---|
| 1. | Oniyanrin – Ring Road | 6.720 | 47dB | 5 | 11.29 | 35.71 | 6.29 |
| 2. | Oniyanrin – Bodija | 5.869 | 47dB | 4 | 1.37 | 45.63 | 5.77 |
| 3. | Oniyanrin – Agodi-Gate | 4.293 | 47dB | 3 | 10.45 | 36.55 | 5.01 |
| 4. | Oniyanrin – Oyo | 53.080 | 47dB | 29 | 21.55 | 25.45 | 16.05 |
| 5. | Oyo town - Ogbomoso | 56.084 | 47dB | 31 | 22.27 | 24.73 | 16.75 |
| 6. | Oyo town – Iseyin | 40.066 | 47dB | 22 | 17.60 | 27.4 | 13.10 |
| 6. | Iseyin – Shaki | 82.114 | 47dB | 22 | 26.0 | 20.0 | 23.7 |
| 7. | Iseyin – Eruwa | 65.094 | 47dB | 36 | 24.30 | 22.70 | 17.82 |

### 5.7.6 Repeater Spacing

Repeater, regenerators and optical amplifiers all serve to stretch transmission distances. Inserted into fiber system at a point where the original signal is becoming weak, they generate a stronger signal, letting the system operate over much longer distance. Repeater and regenerator convert the signal into electronic form before amplifying it. Optical amplifier work directly on light.

Signal fade away with distance when traveling through any type of cable. The further you go, the fainter they become, until they become too faint to detect reliably. When a digital signal fades below certain level, the bit error rate (BER) rises rapidly. Likewise, an analog signal becomes noisy or distorted, like a distant radio station.

A repeater or amplifier is inserted into the system at a point where the signal has become weak, where it boosts the strength of the signal so it can be transmitted through another length of cable. Many amplifiers or repeater can be placed in sequence, each one taking a weak signal and generating a strong one. However, care must be taken to install them at a point where the signal has not become too weak, distorted, or corrupted by noise because noise and distortion are also amplified. For example, coaxial cable need repeaters every few thousand feet (roughly 1km) to carry hundreds of megabits per second, while fiber system can carry signals at the same speed for 50 to 150km. [ Achi 1993.]

The repeater stations have the following functions;

(1) Receive the signals

(2) Amplifies the signals

(3) Change the frequency

(4) Retransmit the signal.

### 5.7.7 Repeater Spacing Calculation

The maximum repeater spacing is calculated by the following equation.

$$S(km) = \frac{\text{System Gain (dB)} - M(dB) - Dp\ (dB) - Lc\ (dB)}{L\ (dB/km)}$$

Where

S (km) = Maximum Repeater Spacing

L (dB/km) = Cable loss per kilometer

M (dB) = System Margin (due to aging)

Dp(dB) = Loss of internal wiring and connection (FDF, connection etc).

Example

Oniyanrin Exchnge - Oyo town Exchange.

Distance = 53.080km

System Gain (dB) = 47dB

System Margin = 2dB

Dispersion Penalty = 0.5dB

Loss of internal wiring or A = 21.55dB

$$S(km) = \frac{47 - 2 - 0.5 - 21.55}{0.2}$$

$$= \frac{47 - 24.05}{0.2} = 114.75km.$$

Repeater (regenerativé) equipment has to be installed 114.75km from Oniyanrin– Ibadan to Oyo town. But the actual distance between Oyo town and

Ibadan is 53.80km. Therefore, no repeater station will be required between the two locations.

This calculation was used for all the exchange to verify if a repeater station will be needed.

The table below indicates the position of the repeater station but none of the Exchange link requires a repeater station.

**Table 5.5 Repeater spacing**

| S/N | Exchange | Distance (km) | System Gain (dB) | Attenuation measured (A) | Repeater Spacing (km) |
|---|---|---|---|---|---|
| 1. | Oniyanrin – Ring Road | 6.720 | 47 | 11.29 | 166.05 |
| 2. | Oniyanrin – Bodija | 5.869 | 47 | 1.37 | 215.65 |
| 3. | Oniyanrin – Agodi-Gate | 4.293 | 47 | 10.45 | 170.25 |
| 4. | Oniyanrin – Oyo town | 53.080 | 47 | 21.55 | 114.75 |
| 5. | Oyo town - Ogbomoso | 56.084 | 47 | 22.27 | 111.15 |
| 6. | Oyo town – Iseyin | 40.066 | 47 | 17.60 | 129.50 |
| 6. | Iseyin – Shaki | 82.114 | 47 | 23.7 | 104.0 |
| 7. | Iseyin – Eruwa | 65.094 | 47 | 24.30 | 101.0 |

### 5.7.8 Advantages of Fiber Link over Microwave Link.

Thought microwave link has been is still in used in linking exchange nevertheless, with the recent and on going implementation of fiber link in Nigeria Telecom industry, fiber link is bringing to light it's advantages over microwave link Some are discussed below.

#### 5.7.7.1 Terminal Equipment: -

The terminal equipment and associated facilities and infrastructures to make up an exchange is considerably reduced in terms of power consumption installation space and flexibility for fiber link than microwave, For fiber link, a small room is enough for an exchange but with microwave, plots of land. Also for fiber link , the terminal equipment operate on relatively low voltages and currents therefore small battery backups i.e. ups are used for their continuos operation during public power supply failure but with microwave link, generating sets have to be used as backups.

#### 5.7.7.2 Transmission impairments:

In microwave link, proper reception requires line of sight transmission. This means that the sending and the receiving units must be closely aligned and signal path on unobstructed .If the antenna (e) should tilt from its set position reception would suffer . Also adverse atmospheric effects could affect reception.

#### 5.7.7.3 Interference:

microwave link suffers from interference both within the system and from external microwave sources (e.g. microwave oven, microwave radar, maximum sun sport activity) which leads in many cases to cross talk being experience by most telephone users; but in fiber links such problems are eliminated by replacing the plesiochronous Digital Hierarchy technique of multiplexing in microwave link with synchronous Digital Hierarchy in fiber link Also, the carrier of the signals are photons and are confined within the cable.

#### 5.7.7.4 Maintenance:

Though the initial installation cost of fiber link is still very high compare to microwave link, the life –cycle maintenance cost of fiber link is greatly reduced.

# CHAPTER SIX

## MEASUREMENTS, TEST EQUIPMENT AND OPTICAL SAFETY

### 6.1 BASICS OF OPTICAL MEASUREMENT

Most important fibre-optic measurements involve light, in the same way that important **electronic** measurements involve electric fields and currents. There are some exceptions, such as the length and diameter of optical fibres and Cables, the sizes of other components, and the electrical characteristics of transmitter and receiver components. Because this is a project about fiber optics, we will mention such measurements only in passing. However, We will talk about measuring things other than light, because we cannot qualify the properties of optical fibers if you consider only light. For example, to measure the dispersion of light pulses travelling through an optical fiber, we must observe how light intensity varies as a function of time, which requires measuring time as well as light.

When we are working with light, we need to know what can be measured. The most obvious quantity is optical power, which like electrical voltage is a fundamental measuring stick. However, power alone is rarely enough; it usually must be measured as a function of other things, such as time, position, and wavelength. Wavelength itself is important because optical properties of optical components, materials, light sources, and detectors all depend on wavelength. Other quantities that are sometimes important are the phase and polarisation of the light wave. We need to learn a little more about these concepts before getting into more detail on measurement types and procedure. [Jeff Hecht 1999].

### 6.1.1 Optical Power

**Table 6.1 Measurable quantities related to optical power**

| **Quantity and Symbol** | **Meaning** | **Units** |
|---|---|---|
| Energy (Q) | Amount of light energy | Joules |
| Optical power (P or Q) | Flow of light energy past a point at a particular time (dQ/dt) | Watts |
| Intensity (I) | Power per unit solid angle | Watts per steradian |
| Irradiance (E) | Power incident per unit area | $W/cm^2$ |
| Radiance (L) | Power per unit solid angle per unit projected area | $W/stradian\text{-}m^2$ |
| Average power | Power averaged over time | Watts |
| Peak power | Peak power in a pulse | Watts |

Power (P or $\phi$) measures the rate at which electromagnetic waves transfer light energy. It is a function of time, because this rate can vary with time. Mathematically, it is expressed as

$$P = \frac{dQ}{dt} \qquad \text{.......................................... 6.1}$$

or

$$\text{Power} = \frac{d(\text{energy})}{d(\text{time})}$$

Sometimes called radiant flux, this optical power is measured in watts, which is equivalent to joules (a measure of energy) per second. It is the same type of power that you measure electrically in watts. (Note, however, that the power ratings of light bulbs measure how much electrical power they use not the amount of light output, which is much lower). Like electrical power, optical power is a measurable manifestation of more fundamental quantities. In the case of electrical power, those are voltage (V) and current (I):

$$P = VI \quad \text{..............................} 6.2$$

power = volts x amperes. This relationship can also take other forms, using the relationship V = IR (voltage = current x resistance):

$$\text{Power} = I^2R = VI = v^2/R \quad \text{....................} 6.3$$

As we saw earlier, light and other electromagnetic radiation can be described as a wave comprising oscillating electric and magnetic fields. The wave has a characteristic amplitude (A) and oscillates with a particular period or frequency V, as shown in Figure 6.1.. The frequency, in turn, determines the wavelength, λ, which equals the speed of light, c, divided by the frequency, V.

Figure 6.1 Properties of an electromagnetic wave [Jeff Hecht 1999] .

## 6.2 TEST EQUIPMENT

### 6.2.1Hand Held Light Source

The hand held light source offers more flexibility in one unit than other light sources. Available as a dual LED. Dual laser or hybrid LED and Laser combination. LED sources utilise a high performance surface emitting diode, which focuses more light into the fiber core, providing the ability to monitor moult-mode with ease and perform loss measurement on multi-mode applications. The laser source is available in 2 wavelengths, 1310nm and 1550nm which provide Optical Output power of 0dBm (1mω).

**Specification**

Optical Wavelength 850nm and 1300nm (LED) multi-mode , 1310nm & 1550nm (laser), Single mode

Optical power Type:- Laser 0dBm, 1mω

LED - 17dBm

Temperature: -10°C to 50°C

Power Supply: 9V Alkaline Battery. [Sue Muraca 2000]

## 6.3 FIBER OPTIC TALK SET

Talk set is design to allow two party communications over a single optical fibre in an installation environment. The talk set is unaffected by location, electrical noise, shielding and can be used during installation. Talk set offer 20dB Budget on Multi-mode fibre and 25dB budget on single mode and is supplied with a pair of headsets and rugged carry case. The 9 Volt alkaline batteries.

## 7.4 OTDR / FUSION SPLICER

This equipment is of two types FITEL Fusion Splicer and Ericsson fusion splice. Both can be used in an enclosed room or field. It can also be used for multi-mode & single-mode fiber cable. The system can-aligning fiber cables itself, Fast splicing and easy to operate. The system also has ability to analyses the result after splicing. It can be used for both single mode and multi- mode.

**Specification:**

Power Supply: 220 - 240 AC 50Hz

Temperature: -10°C to 50°C [Sue Muraca 2000]

## 6.5 CLEAVER

Cleavers are of different type we have Thomas & Betts cleaver, Alcoa Fujikura cleaver, York cleaver etc Cleaver is designed to provide a light quality cleave when connecting fiber optic connector. It can be used for single mode and multimode. Its very easy to operate this tool requires no power supply. This also determines the good result of splicing.

### 6.6 STRIPPERS

Strippers are of different types for different operation. We have the following stripper Buffer tube strippers, Jacket stripper, Kevlar cutters, Miller stripper, clause striper etc. For example miller strippers is specially designed for fiber optic installers who require a precision stripping tool. This exceptional tool is recommended for stripping 250pm coated loose tube fiber and 900pm buffer tube.

## 6.7 CHEMICAL FOR CLEARING

After the cable has been stripper, the next thing to do is to clean with Forin(F11) and wash with alcohol and tissue paper. This will remove the Jelly from fiber cable and almost before splicing. Any little dust on the cable can cause the cable loss to rise and this may require repeating the splicing process again.

# OPTICAL SAFETY

## 6.8 THE HUMAN EYE

The actual wavelengths used are 850nm, 1300nm and 1550nm.

**Source of Radiation**

A laser will emit an optical power level of typically 0.5mW (-3dBm). This may not appear to be a very high level, but it is concentrated in a very small area producing a very high energy density.

While the optical system is working normally, all of this radiation is contained within the fibre and the system is completely safe. However, when a fibre is broken or when an optical connector is unmated, exposure to the radiation is possible. This must be avoided. Because of its focusing ability, the eye is the organ most susceptible to damage. Since the radiation is invisible, the normal aversion reflexes to bright light do not operate. Therefore, NEVER STARE INTO AN OPEN FIBRE OR OPTICAL CONNECTOR.

Use only approved optical aids to view optical connectors and follow the appropriate instructions for their safe use.

The LEDs used on optical line systems usually emit much lower optical power levels than lasers. Nevertheless, it may be possible under unusual fault conditions for an LED to emit potentially hazardous levels of radiation, therefore the same safety precautions apply to both laser and LED systems.

**[Ogungbe. 1994]**

## 6.9 Safe Working Practices

Although the risk of injury may not be great, it is real. So safe working practice must be adopted at all times. Safety instructions are contained in equipment manual and manufacturers handbooks. All staff must familiarise themselves with the content of current issues of all such instructions.

## 6.10 Safety Training

Training in safe working practices for optical line systems and associated equipment could be considered as mandatory. Do not interfere in any power optical line equipment, optical fibre or optical test equipment (particularly microscopes) until you have completed one of these courses or other approved training. (If you have unconnected fibre tails in your station, do not assume there is no light on them. Acceptance testing could be taking place on the fibres)

## 6.11 Eye Tests

All staff is recommended to have an eye test as specified by a Medical Officer before working on optical fibre line systems. Students are recommended to have the eye test before attending an optical line system course.

## 6.12 Information Sources

Information on specific safe working practises relating to the various manufacturers systems should be included in the system documentation supplied with the Optical systems during installation / hand-cover / final acceptance.

# CHAPTER SEVEN

## CONCLUSION AND RECOMMENDATION

### 7.1 CONCLUSION

The introduction of digital fiber optical system into the public switching telephone network and other telecommunication network has proved very effective and efficient. Also the system is very reliable, flexible and easy to maintain. Thus it can be successfully introduce as transmission link into the communication system of various interested user.

The future holds great promise for fiber optic technology. Increasing use of latest wave-length of 1550nm (nano meter) $3^{rd}$ window is becoming popular because of its low attenuation (about 0.20dB). For this purpose, dispersion shifted mono-mode fibers will be employed. In these fibers by adjusting the refractive index, profile dispersion will be made practically zero. These fibers are sometimes referred to as repeaterless fibers.

Besides development of fibers in the local network has started gaining ground. There is no gainsaying that the potentiality in fiber will be more evident with the integration of telephone, CATV and other services, bi-directional transmission on one fiber with optical wavelength division multiplexing (WDM) techniques is used. This migration of the local network is often referred to as FTTC (fiber-to-the-curb) or FTTH(fiber-to-the-home).

Newly announced splicing techniques and devices which reduces fusion splicing time to about 2 minutes instead of 6 to10 minutes makes fiber system more and more appealing from an installation and maintenance perspective.

The performance of the Oyo State digital fiber optic system which was evaluated from the overall annual system availability indicated that a very high efficient and effective transmission system have been achieved. Equally, it would lead to increase in revenue generation by the Telecommunication management over the years.

## 7.2 RECOMMENDATION

With respect to this dissertation, the following recommendations are made to contribute to the development of the digital fiber optical system in Nigeria. Its highly recommended that the digital fiber optic system should be extended to all the telecommunication network or public switching telephone network in major cities in Nigeria to improve and provide better telephone or telecommunication service at a reasonable cost.

The introduction of digital fiber optic system into other areas of specification, (apart from the telecommunication industry) electronic media, public lectures and workshops in other to promote public awareness. These areas include computer network, video information system, broadcasting, traffic control and supervisory system.

One of the requirements toward the rapid development of the digital fiber optical system in Nigeria is the training development of technical staff to handle the system effectively and efficiently. Therefore technologists and engineers in this field have to be trained both within and outside the country from time to time.

The fundamental knowledge of fiber optic cable is very important to all students of electrical engineering. I will recommend to the nations polytechnic and universities to include fiber optic course in school curriculum, with the collaboration of ALCATEL or SIEMEN Company to assist in the area of practical training especially, splicing technique.

Lastly, the participation of the Federal government in provisions of funds, incentives for research and into the development, the design and the construction of the system. Training of human resources and public enlightenment must be put in-place, so that Nigeria can be involved in the global village in the twenty- first centuries.

of the system, training of human resources and public enlightenment must be put in place, so that Nigeria can be more involved in the global village in the twenty first century.

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