STUDY OF THE TELECOMMUNICATION SYSTEM IN SRI LANKA

by

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Declaration

The work described in this report was carried by me at the Faculty of applied Sciences. Sabaragamuwa university of Sri Lanka under the supervision of Mr. E.K. Pemadasa and Mr. D.A.A. Wikramasinghe. A report of this has not been submitted to any other university to any other degree.

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Abstract

Telecommunication is a very important phenomenological technology. Since we are living in an era of communication explosion. Which is aimed at making this world closer. Sri Lanka telecom has a reputed history as the national telecommunication service provider in the country.

Local telecommunication technology and International telecommunication are major fragments of the Sri Lanka. Telephone that consists transmitter circuit, receiver circuit and local exchanges are the major components of local telecommunication system. The transmitter circuit couples the input massage signal to the channel. While it may some times be possible to couple the input transducer directly to the channel, it is often necessary to process and modify the input signal for efficient transmission over the channel. Signal processing operations performed by the transmitter include amplification. filtering and modulation process and the main function of the receiver is to extract the input message signal from the degraded version of the transmitted signal coming from the channel. The receiver performs this function through the process of demodulation, the reverse of the transmitter's modulation process. Switching technology method can be used to distribute local and international voice signal in exchange equipment. voice signals can propagate Using radio micro waves, pulse code modulation method and multiplex technology method.

The fundamental components of international telecommunication system are telephone, exchanges, ISC (International Switching Center), ITMC (International Transmission Maintenance Center). As well as there are two types of transmission techniques methods to propagate the international voice signals. They are satellite technology method and fiber optic cable technology method which the signal propagate as a light waves. Using these transmission technologies Sri Lanka is able to propagate international voice signals. Therefore every type of voice signals can propagate more efficiency using above methods.

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Acronyms and Abbreviations

2M	2,048 kbps
8M	8,448 kbps
34M	34,368 kbps
140M	139,264 kbps
ADC	Analog to Digital Converter
A/D	Analog to Digital
ADM	Add Drop Multiplexer
ADPCM	Adaptive Differential Pulse Code Modulation
AOR	Atlantic Ocean Region
BHCA	Busy Hour Call Attempts
BJ	Beach Joint
BU	Branching Unit
CFU	Common Function Unit
CLIP	Calling Line Identification Presentation
CODEC	Coder/Decoder
COM	Common
CTB	Cable Terminate Box
DA	Double Armored
DACCS	Digital Access Cross Connection System
D/C	Down Converter
DCM	Digital Circuit Multiplication
DECT	Direct Electric Code Telephone
DSI	Digital Speech Interpolation
DTMF	Dual-Tone Multi-Frequency
DVM	Data Voice Multiplexer
Dx	Demultiplex
E	Earth
EHF	Extremely High Frequency
E/O	Electric to Optical
ETC	Exchange Terminal Circuits
FDM	Frequency Division Multiplexing
IDD	International Direct Dialing
IDR	Intermediate Data Rate
IN	Intelligent Network

Intelsat	International Telecommunications Satellite Organization
IOR	Indian Ocean Region
ISC	International Switching Center
ITMC	International Transmission Maintains Center
LIC	Line Interface Circuits
LNA	Low Noise Amplifier
LRE	Low Rate Encoder
LTU	Line Terminal Unit
LW	Light weight
LWS	Light Weight Screen
Mx	Multiplexer
NE	Equipment Number
NTC	Network Control and Timing
OS	Optical Sender
OW	Order Wise
PAM	Pulse Amplitude Modulated
PC	Personal Computer
PCM	Power Code Modulation
PDH	Plesiochronous Digital Hierarchy
PFE	Power Feeding Equipment
P-MUX	Primary Multiplexer
POR	Pacific Ocean Region
PSTN	Public Switching Telephone Network
RAM	Random Access Memory
RF	Radio Frequency
SAH	Single Armored Heavy
SAL	Single Armored Light
SAM	Single Armored Medium
SDH	Synchronous Digital Hierarchy
SLT	Sri Lanka Telecom
SPC	Stored Program Control
STM	Synchronous Transfer Module
TDM	Time Division Multiplexing
TST	Time-Switch-Time
UHF	Ultra High Frequency

U/P	Up Converter
VBR	Variable Bit Rate
VF	Voice Frequency
VFT	Voice Frequency Telegraph
VHF	Very High Frequency
VLF	Very Low Frequency
WDM	Wavelength Division Multiplexer

CHAPTER 1
INTRODUCTION

1.1 Introduction

Telecommunication service in the Sri Lanka is synonymous with the Sri Lanka Telecom (*SLT*), and it has a reputed history as the National Telecom Service provider in the country. It aims to develop the telecommunication field as a basic infrastructure in the process of economic development and ensure the provision of the best telecommunication services to every customer in the country. It has the largest customer base in telecommunications in Sri Lanka, which is around 800,000 subscribers, and provides public telephones on a nationwide basis.

SLT provides an assortment of services for the domestic and corporate customers. These services are listed below.

- Domestic Voice Services
    - Customer Dialed Calls
    - Operator Assisted Calls
    - Enhanced Services
        - Call Waiting
        - Call Forwarding
        - Abbreviated Dialing
        - Absentee Service
- International Voice Services
    - IDD Calls.
    - International Operator Assisted Calls

- Operator Assisted Services
    - Domestic
        - Local Call Bookings
        - Wakeup Calls
        - Directory Information Services
        - Faults Reporting Services

- International
  - Operator Assistance Service
  - International Directory Service
  - Collect or Reverse Charge Service

- SLT PLUS
  - International Direct Dialing
  - Call Forwarding
  - Call Waiting
  - Conference Calling
  - Hot Line
  - Abbreviated Dialing
  - Absentee Service
- International Direct Dial *(IDD)*
- Globe link Gold Card
- Sri Lanka Directory Service
- Home Country Direct
- Direct Inward Dialing *(DID)*
- SLTNET Internet Services
- ISDN
- Concert Packet Service
- Frame Relay
- Data PAC
- Vision Carrier
- Leased Lines

The Consumer Service Group contains seven sections, which are:

- Billing and Collection
- New Connections
- Maintenance
- Traffic and Interconnection
- Operator Service
- Regulatory Matters
- Information Technology

1.2 objectives

Problem encounter through the periods of 1st of February 2005 – 31st of May 2005.

I. Local communication trouble shooting
II. Satellite station problems
III. Fiber optics cable land station problem.

The approaches adopted in achieving the above mentioned objectives obtained are described in this thesis.

CHAPTER 2
LITRATURE REWIEW

This chapter describes the history of the telephone, introduction of the exchange, transmission techniques and transmission media.

2.1: History of the telephone

In 1876, Alexander Graham Bell applied for a patent for the telephone. The first, simple application consisted of two battery-powered devices placed in separate rooms and connected by one direct line. By turning a crank to generate a current in one of the devices, the user caused a signal to buzz in the other device. One day, Bell's assistant heard not only that signal but also the first words spoken over a telephone: "Mr. Watson, come here; I want you" (Olsson, 2000).

Today, the telephone is powered by the local exchange. The schematic diagram in bellow illustrates the principle of the standard version of the telephone. Somewhat simplified, it can be said to consist of four units:

- The bell and a series capacitor;
- The hook switch;
- The keypad (or dial); and
- The speech circuit with the receiver and microphone.

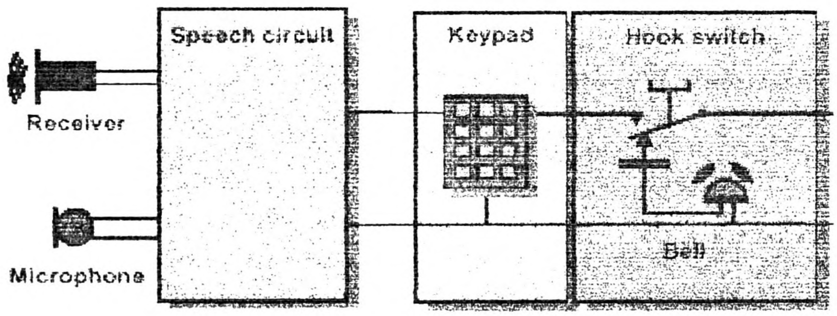

Figure 2.1: Schematic diagram of a keypad telephone

The bell

The bell is connected via the capacitor when the receiver is resting in its cradle (on hook). When a call is placed to the B-subscriber, the bell is energized via the capacitor by an alternating voltage (approximately 90 V, 25 Hz), producing a ringing signal that notifies the subscriber of the incoming call.

The hook switch

When the A-subscriber lifts the receiver to place a call, the speech circuit and keypad are connected (and the bell is disconnected) via the hook function. This alerts the local exchange that a number is about to be dialed: the B-subscriber number. When the B-subscriber lifts the receiver to answer, the hook switch disconnects the bell in his telephone and instead connects the speech circuit and keypad. Since this closes the subscriber line, current from the local exchange can be fed to the line - an indication that the B-subscriber has answered. The parties can commence their conversation.

The keypad

The keypad of a modern telephone is connected to a tone generator, an electronic circuit that translates keyed inputs to tone codes. Each of the digits and each of the "star" (*) and "hash" (#) function keys are represented by a combination of two tones. The frequency of the oscillators is selected whenever a key is pressed to generate the dual-tone combination unique to the digit or function in question.

The bellow diagram illustrates the principle of keypad signaling. The standard is referred to as dual-tone multi-frequency (DTMF). Different combinations of the seven frequencies (the tones) represent the 12 symbols found on an ordinary keypad telephone.

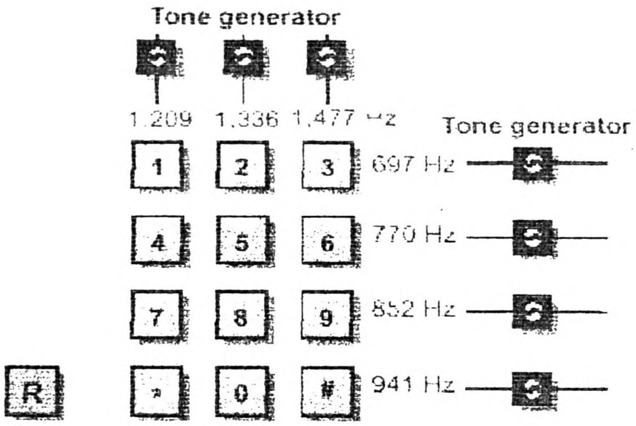

Figure 2.2: Schematic diagram of a keypad and its frequencies

Some modern telephones also have a function key marked with an "R" (register button). Its function (register recall) is to generate a single pulse.

The dial

Older telephones have dials instead of keypads. Although still common in many countries, these telephones represent just a few percent of all telephones sold today. The dial creates a pulse train (signals) containing information to the local exchange. The circuit connecting the exchange and the telephone is closed during the entire digit-sending process, but a contact disconnects the speech circuit during each pulse sequence. (The pulses would otherwise be heard as interference, as "clicks", in the receiver.)

The contact connected to the dial consists of a toothed wheel and two contact tongues. When the dial is released (after being wound up), the wheel starts to rotate, alternately breaking and closing the circuit. Every break results in a pulse, and the number of pulses indicates the digit dialed by the subscriber. Each of the digits forms a pulse train that is detected by the local exchange. Interestingly, Sweden is the only country that has zero as the first digit on the dial. The dials of other countries have zero following the nine.

The speech circuit

The primary function of the speech circuit is to adapt the sound level of incoming voice, outgoing voice and sidetone. The circuit comprises two amplifier blocks (one for amplifying the microphone current and one for feeding the receiver) and a bridge connection that separates voice signals to be sent to the microphone and to the receiver.

Since the degree of amplification is regulated by a control circuit, transmission and reception distortion can be kept low, and amplification can be maintained constant for subscriber line resistances in the interval 0-900 ohms. Line impedance and the sidetone produced by the caller's voice are adapted by the balance circuit.

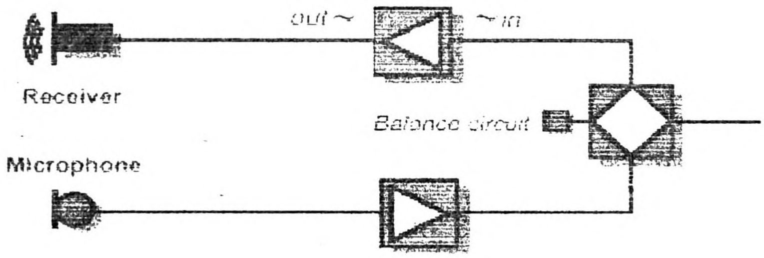

Figure 2.3: Speech circuit

The speech circuit of older telephones was constructed in a simpler fashion, consisting in principle of only a microphone (usually a carbon-type microphone) and a dynamic receiver. Modern speech circuits provide numerous advantages.

- Sound-level attenuation over long-distance connections is counteracted by line-current-controlled regulation of the speech circuit amplifier.
- Accurate bridge balance and speech circuit impedance enhance sidetone characteristics and optimise the impedance of the apparatus.
- Transmission distortion is negligible.

The receiver

In principle, the design of the receiver is still based on traditional techniques. The current generated by the incoming speech passes through an electromagnet that is constructed around a permanent magnet and connected to a membrane. The oscillations, or movement, of the membrane are converted to sound waves that are perceived by the ear.

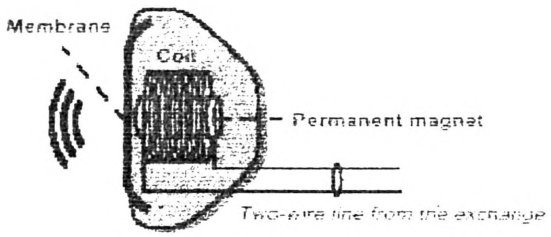

Figure 2.4: The receiver

The microphone

The old carbon microphones are being increasingly replaced by electret microphones. The material upon which these new microphones are based consists of a thin plastic film, similar to Teflon, which is exposed to a strong electrical field. The film retains its negative and positive charges after the external electrical field is removed - somewhat analogous to the poles of a magnet.

The principle of operation of the electret microphone is illustrated in Figure 2.5. The Teflon film (electret material) is stretched over a fixed electrode. The movable electrode consists of a thin metallic layer covering the electret material.

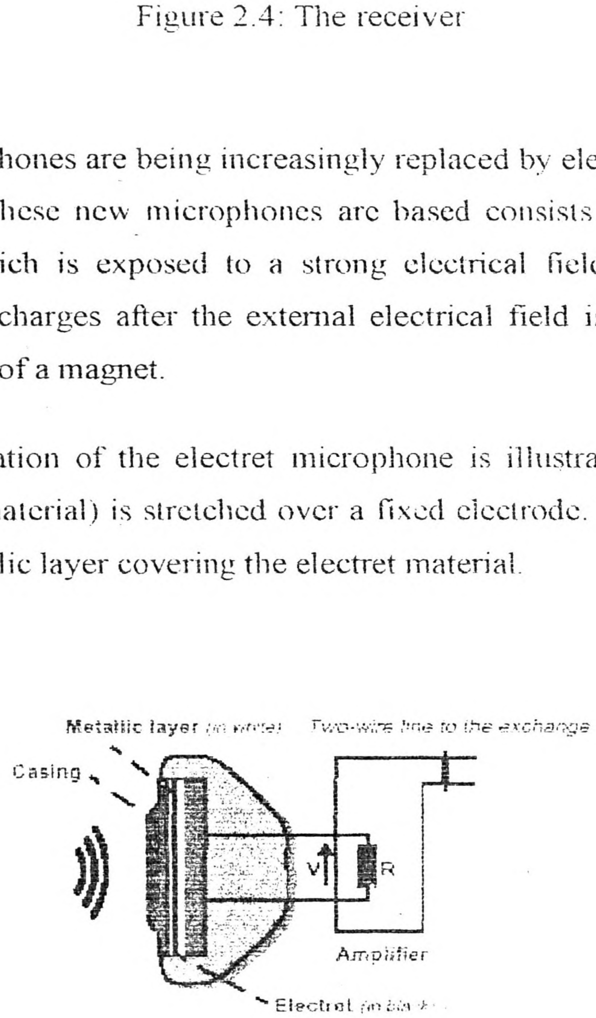

Figure 2.5: Electret microphone

Irregularities in the surface of the fixed electrode cause a number of small air gaps to arise between the electret and the fixed electrode. The electret microphone can therefore be said to consist of a number of small parallel-connected microphones. The electrical field existing in each of the air gaps is generated by the electret's charge. The movements of the membrane change the size of the air gaps and hence their capacitance. These capacitance variations result in voltage variations that appear across the load resistor, R.

Telephone answering machines

Olsson (2000) described the telephone answering machine has a built-in tape recorder that is used by the subscriber to record an announcement to be played back if the call is not answered. As a rule, the caller is also requested to leave a message. The messages can be stored on a variety of storage media, such as standard cassette tapes, microcassette tapes and RAM memory. A common extra feature is the time stamping of incoming calls.

The unit has its own hook function that is normally activated following a couple of ringing signals. After a message has been left, this function automatically breaks and indicates "on hook" to the exchange. The answering function can be set to activate after a number of ringing signals.

Most new telephone answering machines can also be remotely controlled from another telephone. By calling the answering machine, a subscriber can listen to the messages that have been received and, if he so wishes, even record a new announcement.

This remote control functionality involves the transmission of tones from a keypad telephone. When using older telephone models, tone signals can be sent by pressing a small external tone sender against the microphone.

As the price of computer memory has fallen, it has become common since the mid-1990s for operators to offer voice mailbox services; we might call them telephone answering machines in the network.

Calling line identification presentation

Calling line identification presentation (CLIP) makes it possible for the party receiving a call to see the telephone number of the calling party. A user of this service requires a special display connected to his telephone line.

Call meter located at the subscriber

Olsson (2000) mentioned that the A subscriber who wishes to monitor the cost of his calls immediately can have a call meter connected to his telephone line. The subscriber meter registers the same number of unit charged markings as the call meter located in the local exchange, which requires that meter pulses be transmitted over the subscriber line. Many meters are equipped with two counters: one showing the total of unit charged markings and one that can be reset for each call.

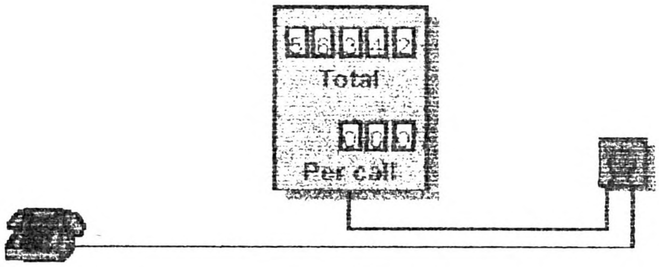

Figure 2.6: Call meter located with a subscriber

Tischler (1995) summarized the Pay phones, Coin-operated pay phones, Card-operated pay phone, and Fax terminals, Codeless Telephones.

2.2: Pay phones

Pay phones (coin-operated and card-operated) are usually owned by the operator running the network. There are also private companies that supply card-operated pay phones.

Emergency numbers can be called from all pay phones free of charge. The same is true for fault reporting and, in some markets, for directory inquiries. Some operators have introduced a service that allows a customer to order a reversed-charge call from a pay phone.

It is also becoming increasingly common that calls can be placed directly to pay phones without the assistance of a telephonist. Pay phones require call charging information to be transmitted from the local exchange.

2.2.1: Coin-operated pay phones

Figure 2.7 is a simplified illustration of a coin-operated pay phone.

Coin-operated pay phones are built around a microprocessor that is programmed to recognize different coins. The telephone also has operation and maintenance programs that check functionality and register any faults detected. A preprogrammed telephone number is used to send scheduled reports to the local exchange on the telephone's status, total amount of money collected, the extent to which the coin box is full, and so forth. Alarms are sent to the local exchange if certain types of fault are detected or if vandalism or theft is indicated .

The exchange contains a special line card connected to the pay phone's subscriber line. This card contains functions that

- detect calls and the B-answer (hook detection);
- generate and receive 12 or 16 kHz pulses (for signaling between the exchange and the pay phone); and
- initiate disconnection in the event of a fault.

Meter pulse information is transmitted, in the form of 12 or 16 kHz pulses, from the charging function located in the local exchange.

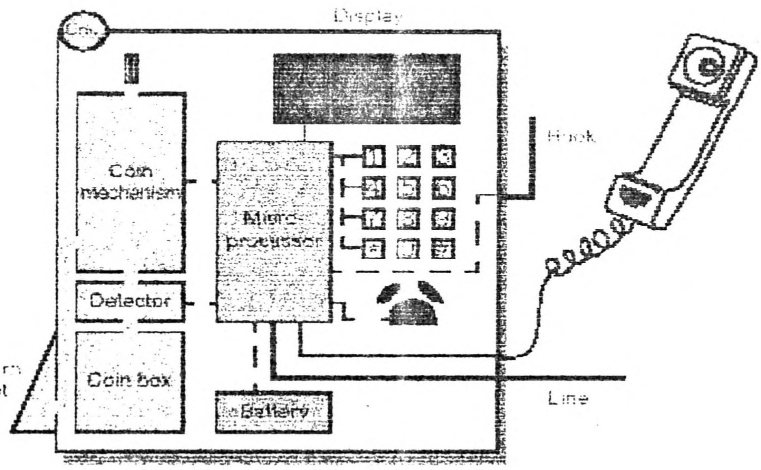

Figure 2.7: Principle of a coin-operated pay phone

2.2.2: Card-operated pay phone

The majority of new pay phones installed nowadays are card-operated. The coin slot has been replaced by a card reader that reads either credit cards or special telephone cards that are preprogrammed for a given number of unit charged markings.when using a credit card, first the user draws the card through the reader, then enters a personal code. Following the completion of the call, the telephone displays the amount that will be charged to the credit card. Credit-card calls in the PSTN are normally implemented with the help of the IN platform.

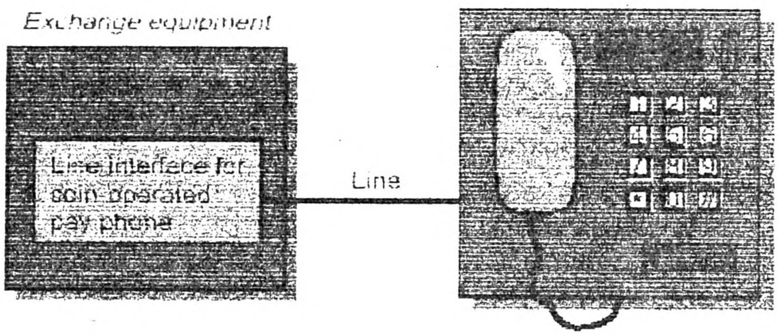

Figure 2.8: Connecting a coin-operated pay phone to the exchange

2.3 : Fax terminals

The term "telefax" (in everyday language "fax") denotes a system for transmitting monochrome images between two telefax terminals. The term also refers to the actual message sent as well as the telefax apparatus . The document to be sent is scanned, point by point, by the fax machine. The resulting information is coded in accordance with an international standard and, after compression, transmitted to the receiving fax via the fax's built-in modem. The receiving unit demodulates the signal, decodes the information and produces a printout. Some systems also produce an acknowledgement on the sending fax; other systems show this acknowledgement on a character display.

The actual terminal contains many extra functions that supplement the basic service: abbreviated dialing, retransmission if the receiving fax is busy and a queuing system for incoming fax messages.

Many residential subscribers and small companies have terminals that combine telephone and fax functionality (even telephone answering functionality) in one and the same unit.

A fax terminal can also be a personal computer running one of the PC fax programs available today. Faxes are created, sent and received in the form of a file instead of on paper. To be able to send a fax of a document that is only available on paper, a user can attach a scanner to his PC.

2.4: Cordless telephones

The following is primarily a study of the DECT terminal. Although the first-generation cordless telephones only offered radio communication between the handset and the telephone set, the DECT terminal has developed into something considerably more intelligent.

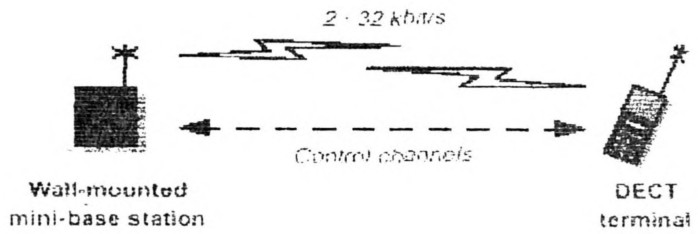

Figure 2.9: DECT terminal functions

DECT terminals contain some special subscriber features that vary for the different manufacturers, and a number of standard functions.

- A keypad, an antenna and a rechargeable battery (like a mobile telephone); battery power consumption is significantly lower in stand-by mode than when a call is in progress.
- Voice coding and encryption/decryption that provide for secure connections of the same quality as that of a fixed-wire connection.
- Functions that handle signalling to and from the base station.
- Functions for mobile-controlled handover (MCHO).

2.5: THE EXCHANGE

In 1878, the first manual exchange was constructed in La Porte, in the United States. At its inception it served 21 subscribers and could connect any two of them together. A ringing signal sounded at the operator's switchboard when any of the subscribers turned the crank of his telephone. Upon answering the signal, the operator was asked to connect the call to one of the other subscribers, which she did manually. She also made a note of who placed the call and when it started and stopped - notes that made it possible to charge for the call (Shanmugam,2004).

Shanmugam(2004) further states that the market forces of the early 1890s prompted the development of the first automatic telephone exchange. It was called the "Strowger switch", after its originator Almon B. Strowger. Strowger was an undertaker from Kansas City who, soon after the advent of the telephone, found himself exposed to a serious form of unfair competition. The woman who operated the manual exchange was the wife of Strowger's competitor, and she connected anyone who asked to speak with an undertaker to her husband.

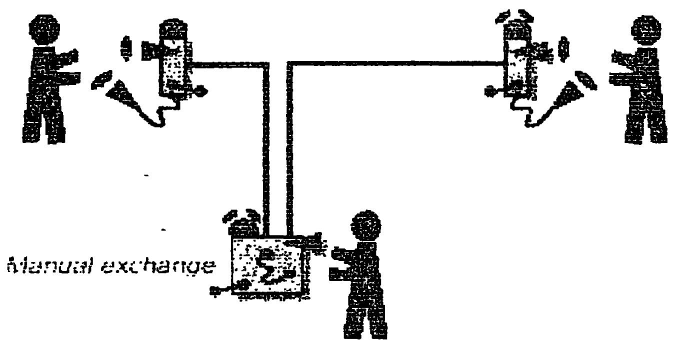

Figure 2.10: A manual exchange

Many years passed during which electromechanical telephone exchanges were developed and improved. The primary objective was still the same as that of the manual exchange: to detect the A-subscriber's call attempt, to connect him to the correct B-subscriber, and to save data about the call for the purpose of billing. The 1960s and 1970s saw the advent of telephone exchanges that were controlled by processors: stored program control (SPC) exchanges . As a result, new functions could be built into the exchanges - of benefit to subscribers and network operators. These functions enabled the introduction of new types of service and facilitated supervision, charging and the gathering of statistics.

2.6: THE TRANSISSION MEDIA:

In the infancy of telephony, metal wires were the only medium available for interconnecting subscribers in the network. Today, the situation is more favorable. Optical fibre cable and different types of radio link, which have very high transmission capacity, are used extensively.

Many telecommunication networks consist of a mixture of different transmission media. In principle, they can all be used to transmit both analog and digital information. However, operators do not select a medium on the basis of technical considerations only -

economic aspects carry a lot of weight too. Previous investments in the network and the economical service life of the equipment must also be taken into account.

In this section we will discuss the following transmission media:

- Copper
- Radio waves and
- Optical fiber.

Olsson (2000) summarized Copper, Paired cable, coaxial cable, Radio waves, Radio spectrum and Radio link.

2.6.1: Copper

Metallic cables (in most cases copper) still constitute a very large part of the telecommunications network, particularly in those parts of the network that connect subscribers. There are two main types of metallic cable: paired cable and coaxial cable. In addition, open wire (metal wire without insulation) is also used in rural areas. Paired cable and coaxial cable are used both for analog and digital transmission; open wire as a rule is only used for analog 3.1 kHz connections.

2.6.2: Paired cable

The simplest form of paired cable is found in our homes. This cable has only two conductors that connect the telephone to the wall socket. Operators have more to choose from in their store rooms: 2-, 10-, 50-, 100- and 500-pair cables, to name a few examples. Paired cable is used mainly in the access network between subscribers and the exchange, and - to some extent - in the trunk network between exchanges.

The paired cable was originally developed for analog connections. A large part of the existing cable network still consists of paper-insulated cables. Plastic is a better insulation material, because it is insensitive to moisture and has lower attenuation at higher frequencies, and that is why newly manufactured paired cable is plastic-insulated. The major part of the paired-cable network is buried under ground.

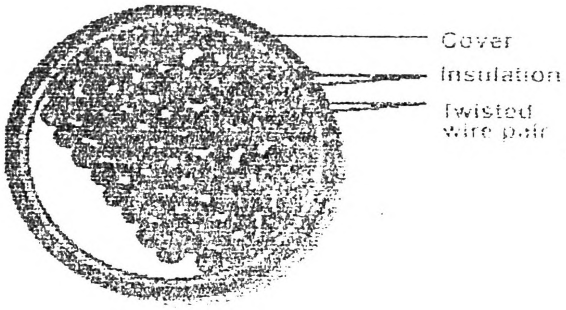

Figure 2.11: Cross-section of a paired cable

Normally, the conducting material is copper, and the conducting wires are manufactured in a number of standardized diameters - the most common diameters are 0.4, 0.5, 0.6 and 0.7 mm. The wires in the cable are twisted together to form pairs (two conductors) or quads (four conductors). The attenuation per kilometer depends on the diameter of the wire and on the frequency.

Figure 2.12: Paired cable and two types of quad

The cable core is often covered with one or more layers of paper or plastic tape to keep the cable pairs together and to protect the cable. The cable sheath may be made of plastic or metal (lead or aluminium) or of a combination of plastic and metal foil. With a suitable choice of material, the sheath can also serve as a shield against electrical and magnetic interference. To further protect the cable from mechanical damage, the sheath is armoured with steel wires or with a tape around the sheath.

2.6.3: Coaxial cable:

Coaxial cable is used in analog (FDM) and digital (TDM) multichannel systems - in local data networks, cable-TV networks, and as a feeder for radio antennas. The cable consists of one or more coaxial tubes, each of which has an inner conductor surrounded by a tube-shaped outer conductor. The coaxial tube has very high transmission capacity (10,800 voice channels in analog multichannel systems). In the trunk network, the tubes are used in pairs, one for each direction of transmission. Today, coaxial cable is no longer installed in the trunk part of the telecommunications network. Instead it is being replaced by optical fiber cable. Nonetheless - apart from being used for cable TV - coaxial cable may come into use in the access part of future broadband networks.

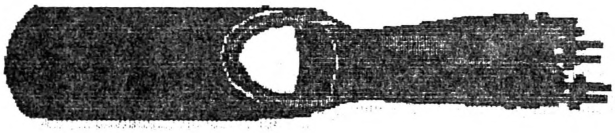

Figure 2.13: Coaxial cable

The tube-shaped outer conductor provides a shielding effect: there is no mutual interference between signals in adjacent tubes.

Normally, the inner conductor consists of a round, solid copper conductor. The outer conductor is made of copper foil which, in certain types of cable, is fused into a tightly sealed tube. The best insulation between the conductors is air, but plastic is also used. The inner conductor must always be centred in the tube; it is kept in position by plastic washers or through compressing the plastic tube slightly at regular length intervals. To improve shielding performance at low frequencies, steel tape may be wound around the tube.

Figure 2.14: Coaxial tube with plastic washers

Some applications require flexible coaxial cable. This cable has a multiwire inner conductor and a twisted multiwire outer conductor. Normally, the insulation material is plastic.

2.6.4: Radio waves

Radio is a transmission medium with a large field of applications, and a medium that provides the user with great flexibility (for example, cordless telephones). Radio can be used locally, intercontinentally, and for fixed as well as mobile communication between network nodes or between users and network nodes. In this subsection, we deal with radio link and satellite connections.

2.6.5: The radio spectrum

The radio spectrum, from 3 kHz to 300 GHz, is one range of the electromagnetic spectrum (infrared, visible and ultraviolet light. and X-ray frequencies are other ranges). The radio spectrum is divided into eight frequency bands as shown by Figure 2.15, from VLF (very low frequency) to EHF (extremely high frequency).

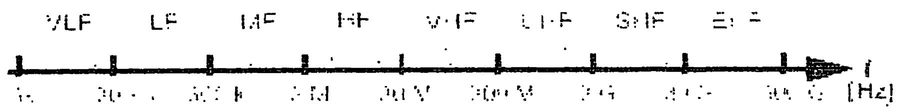

Figure 2.15: The eight frequency bands of the radio spectrum

The propagation of a radio wave depends on its frequency. Radio waves with frequencies below 30 MHz are reflected against different layers of the atmosphere and against the ground. allowing them to be used for maritime radio, telegraphy and telex traffic. The capacity is limited to some tens or hundreds of bit per second.

Above 30 MHz, the frequencies are too high to be reflected by the ionized layers in the atmosphere. The VHF and UHF frequency bands , which are used for TV, broadcasting and mobile telephony, belong to this group. Frequencies above 3 GHz suffer severe attenuation caused by objects (such as buildings) and therefore require a free "line of sight" between the transmitter and the receiver. Radio link systems use frequencies between 2 and 40 GHz, and satellite systems normally use frequencies between 2 and 14 GHz. The capacity is in the magnitude of 10-150 Mbit/s.

2.6.6: Radio link

In radio link connections, transmission is effected via a chain of radio transmitters and radio receivers. The radio link is used for analog as well as for digital transmission.

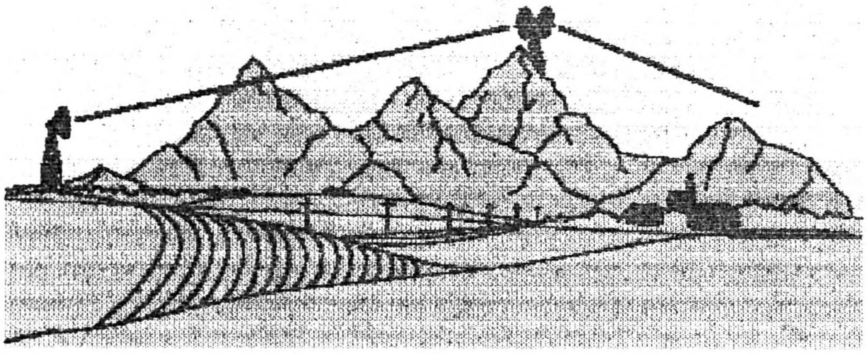

Figure 2.16: Radio link connection

At regular intervals, the signal is received and forwarded to the next link station. See Figure 2.16. The link station may be either active or passive. An active link station amplifies or regenerates the signal. A passive link station generally consists of two directly interconnected parabolic antennas without any amplifying electronics between them.

Each radio link needs two radio channels: one for each direction. A few MHz spacing is needed between the transmitter frequency and the receiver frequency. The same parabolic antenna and waveguide are used for both directions.

The distance between the link stations - also called the hop length - is dependent on output power, antenna type and climate, as well as on the frequency. The higher the carrier frequency, the shorter the range. For example, a 2 GHz system has a range of approximately 50 kilometers, and an 18 GHz system has a range of 5-10 km.

2.7: Satellite

Satellite systems are quite similar to radio link systems; the only real difference being that the intermediate link station is in orbit around earth instead of being set up on the ground. See Figure 2.17. Satellites describe either a polar or a geostationary orbit. Those with a polar orbit pass over the poles at an altitude of about 1,000 km and are used for meteorological and military purposes (Ichihara, 1995).

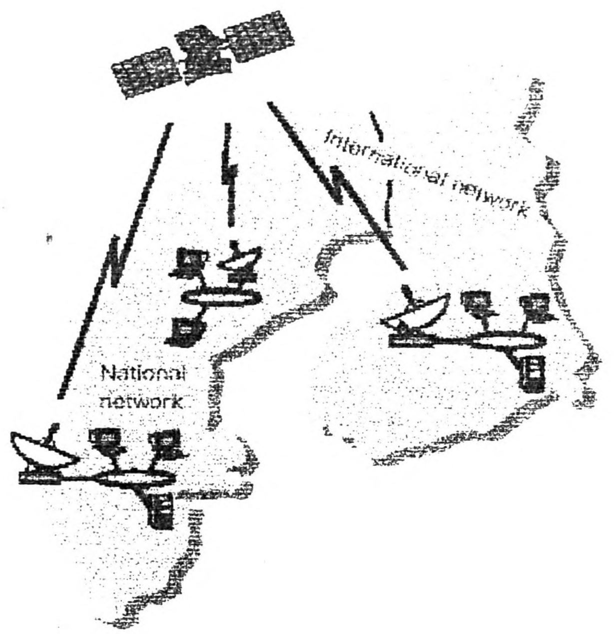

Figure 2.17: Satellite system

Ichihara (1995) further stayed that satellites used for telecommunications are placed in geostationary orbits in the equatorial plane 35,800 km above the earth's surface. They have an orbiting time of 24 hours which, because of the earth's rotation, gives them the appearance of being stationary. Approximately one third of the earth's surface is covered by an antenna with global radiation. Satellite links are used in national as well as international telecommunications networks. Intercontinental use has decreased in favour of optical submarine cables.

The transmission properties of satellite links are excellent and problems are few. However, the long distance between terrestrial stations via the satellite does cause a 240 ms delay, which in itself is troublesome to voice communication and which may give echoes with a propagation time of about 0.5 seconds.

Intelsat (International Telecommunications Satellite Organization) was founded with the aim of financing, developing and running worldwide commercial telecommunication satellite systems. Today, Intelsat, who is responsible for the launching and operation of satellites, has in excess of 100 operators as stakeholders. The individual operators (or an association of operators) manage the terrestrial stations. Intelsat, however, is responsible for the few stations that are required to control and supervise the satellites.

One of Intelsat's satellites is Intelsat VI, which has 80,000 voice channels.

2.8: Optical Fiber

In the 1870s, an Englishman, Tyndall, showed that light can be conducted through a bent jet of water. At the end of the 19th century, Graham Bell designed an optical telephone. The difficulty in finding appropriate light sources, however, made it necessary to wait 100 years before this technology could be used in practice. The first field trials with optical cable were carried out in 1975, and in 1980, the first commercial systems were opened for telephone traffic.

Personick (1995) reported many excellent properties of optical fiber have made the optical cable increasingly important as a transmission medium in telecommunications networks. The fiber is used primarily in urban networks and for long-distance connections, mainly for digital transmission. It has an enormous transmission capacity. Today, there are systems for several Gbit/s - 2.5 Gbit/s approximately corresponds to 32,000 simultaneous telephone calls at 64 kbit/s. The limitations are in the terminal equipment.

The interface between electrical and optical transmission requires E/O converters.

Figure 2.18: E/O converters

The advantages of optical fiber systems can be summarised in the following points:

- Very high capacity
- Long repeater spacing
- Small cable dimensions
- Low weight
- Small bending radius
- No crosstalk and
- Immunity to electromagnetic interference.

2.8.1: Optical cable

Personick (1995) described an optical cable consists of a number of thin glass fibers. See Figure 2.19. The glass is so pure that, were you able to look into a fiber, you would be able to see tens of miles through it. In practice, invisible infrared light is sent through the fiber. Plastic fiber is an alternative to glass fiber for short transmission distances, approximately 100 m. The plastic fiber is cheaper but has much higher attenuation.

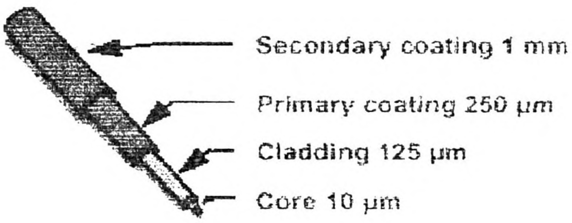

Figure 2.19: An optical fiber

The glass fiber has a glass core with a surrounding glass cladding. The core consists of doped glass with a somewhat higher refractive index than the cladding, which is made of pure quartz glass. Normally, the diameter of the cladding is 125μm. The diameter of the core is different for different types of fiber - 8, 10 or 50 μm.

Figure 2.20 shows the design of an optical cable. The fiber has a primary coating (as a rule consisting of cured acrylate) to provide protection against moisture and chemicals, and an outer - fixed or loose - secondary coating.

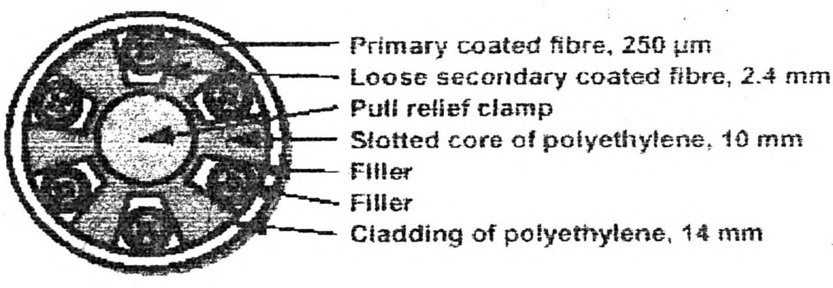

Figure 2.20: Example of optical cable - a slotted core cable with 36 fibers

The optical cable is provided with strength member made of steel or plastic that gives the cable the strength necessary to withstand tensile stress and bending. In addition, the cable contains filling that fixes the fibers and protects them from excessive bending and moisture. The cable cladding is made of plastic, as a rule polyethylene. The number of fibers in a cable varies depending on the field of application - there are, in fact, cables with thousands of fibers.

2.8.2: The properties of light

Light is wave motion whose wavelengths are part of the electromagnetic spectrum. The light we use in optical fiber applications is in the wavelength range 800-1600 nm. See Figure 2.21.

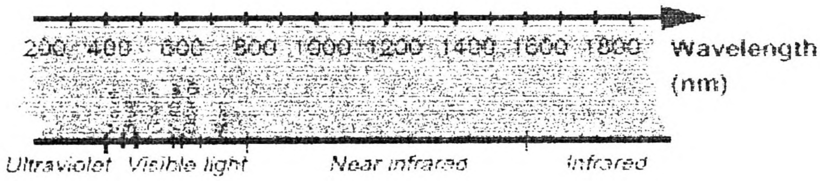

Figure 2.21: The wavelength range of optical fibers

Gowar (1996) mentioned light waves propagate at different speeds in different media. In air, the speed of light is almost equal to its speed in a vacuum; that is, $3 \cdot 10^8$ m/s. In glass, light travels at about 2/3 the speed of light in air. The relationship between the speed of light in air (c) and its speed in another material (v) is called the refractive index (n):

refractive index n = c/v

The term *refractive index* can be explained as follows. A light ray that is propagated through two materials with different refractive indices refracts (changes its angle) in the interface between these materials. The relationship between the angle of incidence alpha and the angle of refraction *beta* is given by Snell's law of refraction:

$n_1 \cdot \sin\alpha = n_2 \cdot \sin\beta$,

where n_1 and n_2 are the refractive indices of the materials. If the angle of incidence *alpha* increases, *beta* increases until it reaches 90°. If *alpha* increases further, total reflection occurs, which means that light is reflected in the interface with the same angle as the angle of incidence ($\alpha=\beta$). See Figure 2.22.

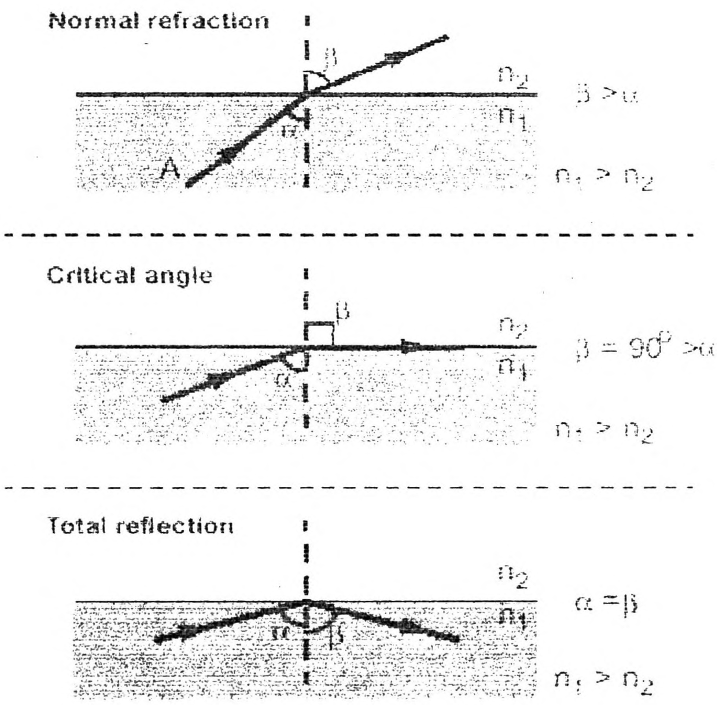

Figure 2.22: Refraction of light

This total reflection is utilized in optical fiber communication. If the angle of incidence is sufficiently large, then the light in the fiber will reflect repeatedly in the interface between the materials(Gowar,1996). The fiber need not be straight but can conduct light even when bent. See Figure 2.23 .

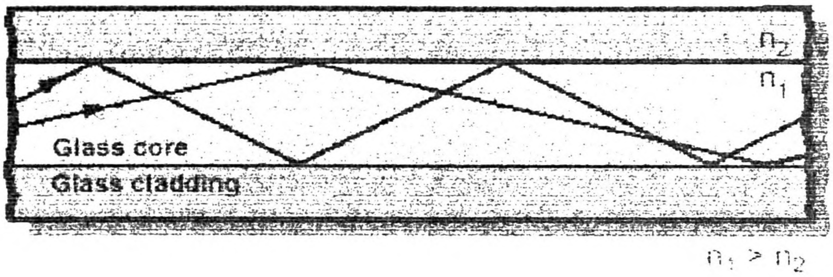

Figure 2.23: Transport of light in an optical fiber

2.8.3: Fiber types

Step index fiber has a bandwidth of 10-50 MHz x km. The core, which is about 70 μm thick, has one refractive index and the cover around it has another. A better result is obtained with the graded index fiber, whose bandwidth is between 300 and 500 MHz x km. The refractive index of this type of fiber decreases gradually from the center of the core towards the outer part of the cover (Personic, 1995).

The step index fiber and the graded index fiber are both multimode fibers; that is, they have many light propagation paths.

The core of the single mode fiber is so thin (3-10 μm) that all light waves travel the same distance(Gowar,1996). The bandwidth is next to unlimited. See Figure 2.24.

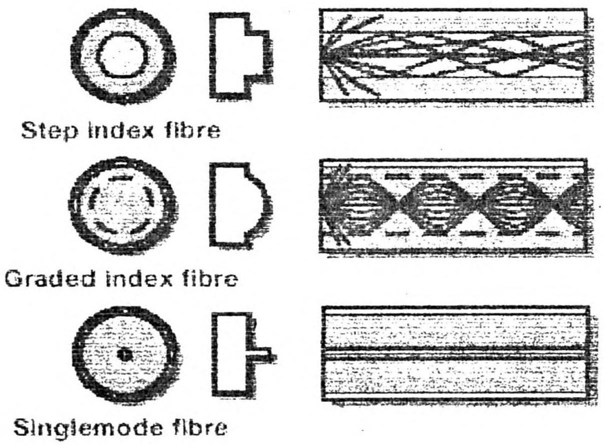

Figure 2.24: Fiber types

CHAPTER3

METHODOLOGY

3.1 REMOVING THE LOCAL TELECOMMUNICATION TROUBLE SHOOTING

Microwave radio links are still famous for point-to-point communication. Therefore, microwave radio links are used to carry the telephone traffic between national exchanges. Different frequency bands have been allocated for use by the common carriers for the transmission of the telephone traffic. Microwave radio beams follow a line of sight path. Sri Lanka Telecom has four main microwave transmission stations, namely Colombo, Galle, Kandy and Anuradapura. Further among these four, the Colombo station is the main one and it has direct microwave links to all other three stations. Between these microwave links there may be several terminal stations and repeater stations and every transmission stations has computerized. Therefore,we can find out which transmission station has trouble shouted using computer.

Every transmission stations has antena tower. Basically cylindrical antena and conical antena are used to propagate the voice signals. Every two antenas should be face to face. Otherwise signal can not propagate correct ways. In my trainnig periods, four antena was fixed in a correct ways in colombo area.

MONITERING THE RADIO LINK STATIONS

↓

FIND THE DAMMAGE ANTENA TOWER

↓

FIXING THE ANTENA

3.2 REMOVING THE SATELLITE STATION PROBLEMS

Satellites stations are the one of the international telecommunication path ways. There are three satellites stations in our country. Two of them are situated in padukka and other one is situated in Colombo. Basically there are two paths of satellite station namely receiving path and transmitting path. Every component of receiving path and transmitting path were computerized. Receiving path has multiplexing equipment that was damaged. It consists of integrated circuits and resisters. In my trainnig periods, multiplexing equipment was rebuilded in a correct way.

MONITERING SATELITESTATIONS

↓

ANALYSED THE PATH

↓

FIND THE DAMGE EQUIPMENT

↓

REBUILD THE EQUIPMENT

3.2 SOLVING THE PROBLEM OF FIBER OPTICS CABLE STATIONS

Fiber optics cable station is anther path of international telecommunication. Fiber optical cables are used to fulfill that purpose. That cables are situated in seabed and these cables are expanded South East Asia - Middle East - Western Europe countries. Optical cables or submarine cable can be divided into ten segments and Sri Lanka is situated in segment four (see Appendix 2) as well as submarine cable can be allocated according to the depth of sea.

Since every cable part of segment four has computerized and the problem can be identified very rapidly.

MONITERING FIBE OPTIC CABLE STATION

↓

ANALYSED THE PATH

↓

FIND THE DAMGE CABLE PART

↓

FIX THE CABLE

CHAPTER 4

RESUL AND DISCUSSION

SLT is the major section of traveling information in Sri Lanka. SLT is provided local telecommunication and international telecommunication.

4.1 LOCAL TELECOMMUNICATION SYSTEM IN SRI LANKA.

In Local telecommunication system. Analogue signal and Digital signal have to propagate. Therefore PCM (power code modulation) technique has to use. Pulse Code Modulation is the common method of converting analogue signals into digital format so that they may be conveyed over a digital line system or digitally processed. The conversion comprises three processes: sampling, quantising and encoding.

Sampling:

Reading the amplitude at regular intervals is called sampling. It is important to take the samples on the voice curve at suitable intervals, which means that the quality obtained should allow us to clearly recognize each other's voices. Taking too many samples is uneconomical: a suitable sampling frequency is 8,000 samples per second. The result will be a pulse amplitude-modulated (PAM) signal where each pulse directly corresponds to the amplitude of the voice curve. See Figure 4.7 .

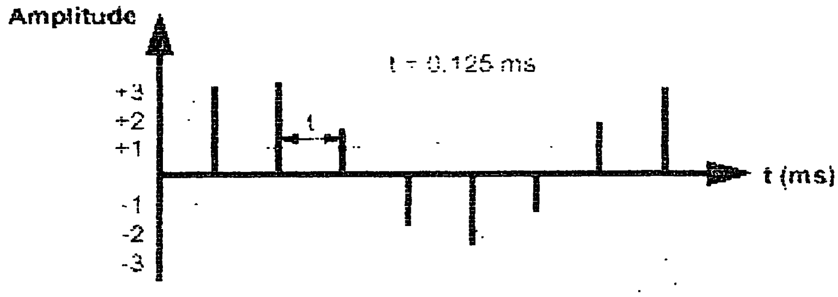

Figure 4.1: Pulse amplitude-modulated signal

Since telephone connections operate in the 300-3,400 Hz band, 8,000 Hz is a sampling - frequency that meets the primary requirement for transmission quality: no information should be lost. The sampling frequency is twice the maximum frequency, which is significantly lower than 8 kHz.

Quantisation

Quantisation means that we measure the amplitude of the pulses in the PAM curve and assign a numerical value to each pulse. To avoid having to handle an infinite number of numerical values, we divide the amplitude levels into intervals and assign the same value to all samples within a given interval. See Figure 4.8. In principle, this is analogous with the way in which a person's age may be viewed.

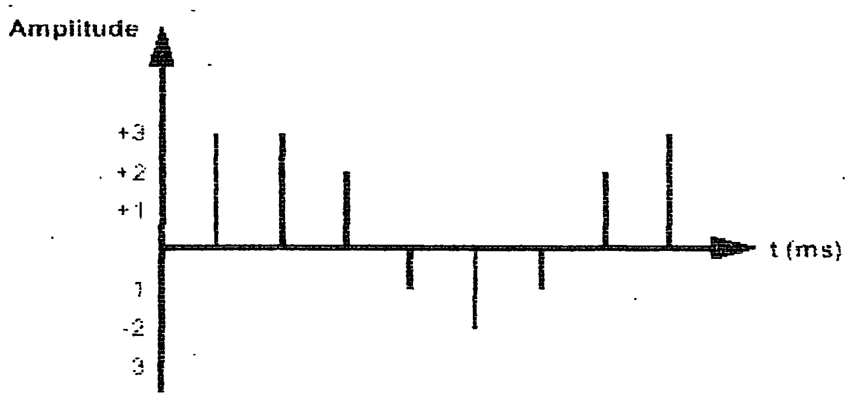

Figure 4.2: Samples with the corresponding quantised values

Quantisation also means that we forgo accuracy: the series of digits is not really the whole truth about the voice curve. We call this deviation quantising distortion. See Figure 4.9. But we will have a limited number of numerical values to transmit, the equipment can be made less complex, and the risk of transmission errors is reduced. In telephony, 256 quantising intervals are used. Consequently, there are 256 values to be transmitted.

Figure 4.9 shows that there are also other problems. In the figure, the quantising intervals are equally large and we will have the same quantising distortion regardless of the amplitude. But if we set distortion in relation to the amplitude, the relationship will vary. A low distortion-to-volume ratio is crucial to audibility. This means that a weak voice will be significantly disturbed if equally large quantising intervals are used.

One way of solving this problem is to make the quantising intervals small enough, so that even low amplitude deviations can be transferred with sufficiently good audibility. Then again, we will have unnecessarily small intervals for the high amplitudes, which also means that there will be an unnecessary amount of numerical values to be transferred.

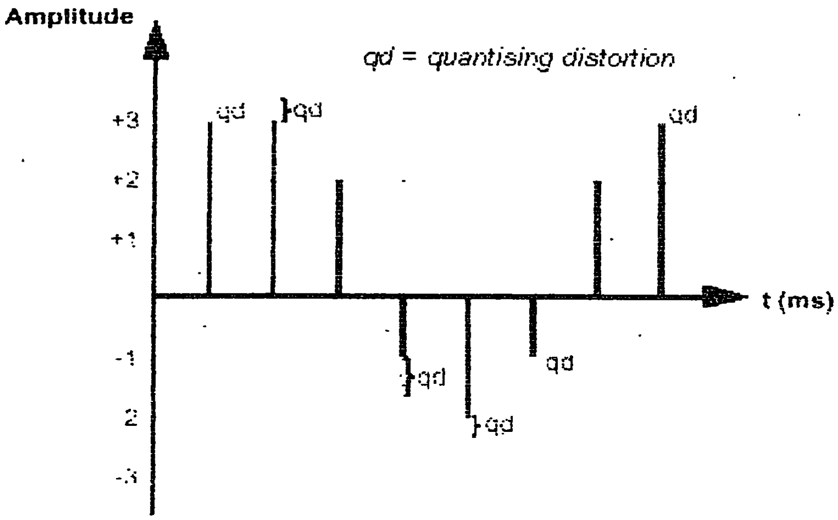

Figure 4.3: Quantising distortion

The ideal thing must be to allow the quantising intervals to increase with amplitude. The amplitude/distortion relationship should preferably be constant. In addition, it is important to find the right relationship between the number of quantising intervals and the desired transmission quality. Here, too, we can refer to the common way of saying or writing a person's age. At the beginning of our lives, we specify age in days - then in weeks and months. Not until a child is two years of age do we start to use "full-year quantising intervals".

Cording:

Now it remains for us to give our 256 possible values a suitable layout for transmission. Let us use binary pulses; that is, pulses with only two levels.

Eight such pulses, or bits, will suffice to form a unique code for each interval value (2^8 - 256). The equipment need only be capable of distinguishing between two pulse levels, and of counting to eight. This technique - the elements of computer technology - is ideally suited for telephony applications.

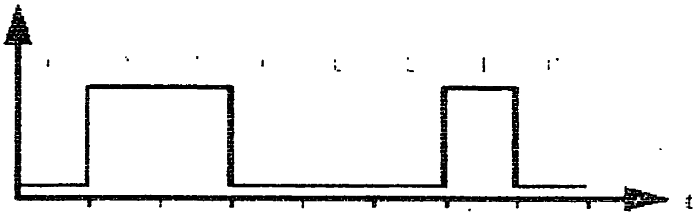

Figure 4.4: Binary pulses.

The ADC (Analog to Digital Converter) will convert the analog signals into digital signals by sampling at 8 kHz and then quantising and encoding them into 8 bit words, resulting in 64 kbps bit streams. Then they are time division multiplexed which enables the use of a common pathway in transmitting them. Thus the output stream is occupied by all the channels but at different time slots. In general a PCM would handle 30 such voice channels to create a so-called 2M.

These 2M streams can be further multiplexed to form higher speed links such as 8M, 34M, 140M,etc. Basically, there are two types of multiplexing technologies. They are Plesiochronous Digital Hierarchy (PDH) and Synchronous Digital Hierarchy (SDH). The benefits of SDH enable individual constituent payloads to be extracted from an aggregate signal, without the need for complete demultiplexing of the entire signal.

4.1.1 Plesiochronous Digital Hierarchy (PDH)

In PDH, multiplexing is done in steps. Each step takes 4 similar speed bit streams and multiplexed them together to form a higher speed stream, as illustrated in Figure 4.11.

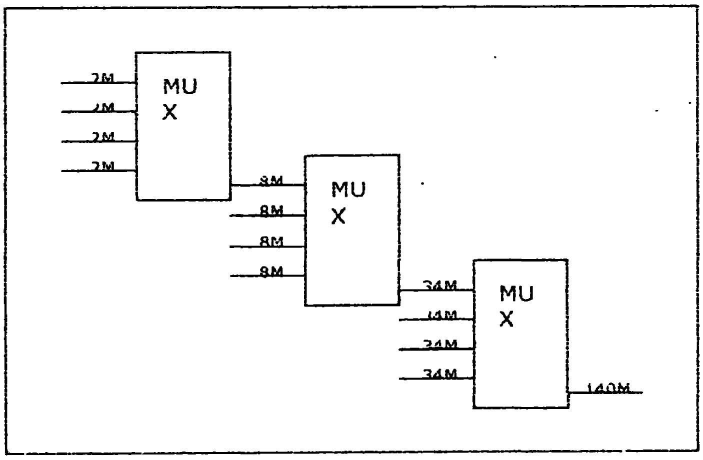

Figure 4.5: PDH Multiplexing.

4.1.2 Synchronous Digital Hierarchy (SDH)

In SDH the multiplexing operation is done in one go as 63 2M streams are multiplexed together to form a 155M stream, called an STM1 (Synchronous Transfer Module). SDH also adds additional bits for pointer overheads and path overheads.
Both PDH and SDH technologies use to propagate the voice signal inside the country.

Radio Transmission Systems basically deals with using microwave links for terrestrial trunk transmissions. These radio systems modulate the signal, up-convert and amplify the signal using power amplifiers. It is then carried to the antenna via wave-guides. This is illustrated in Figure 4.12. On the receiving end, the exact reverse procedure is done.

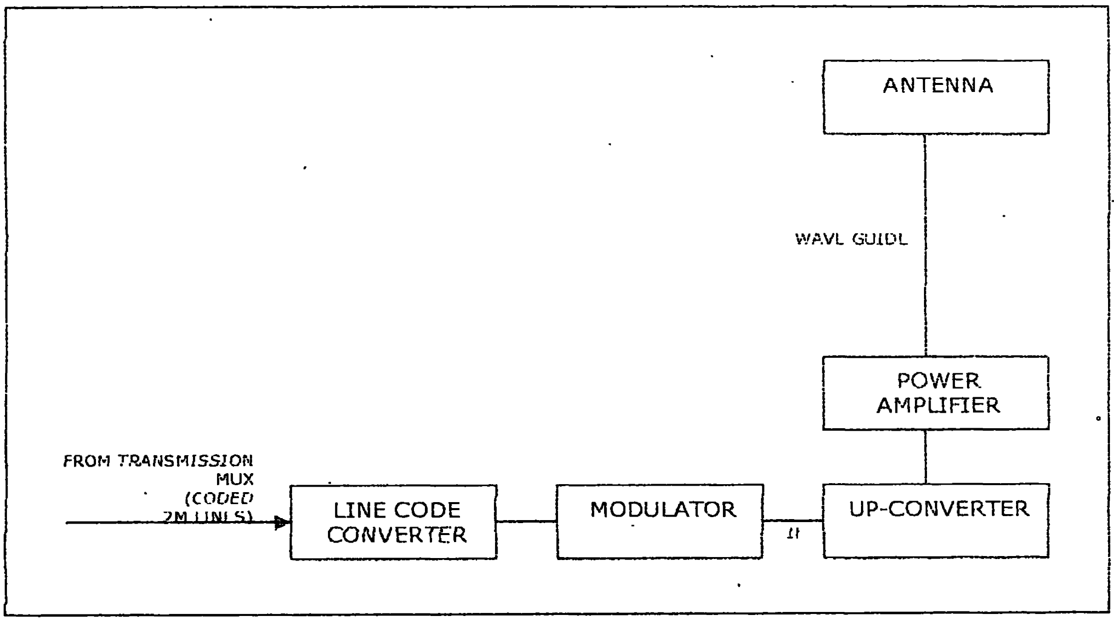

Figure 4.6: Radio Transmitter Arrangement

To make the transmission system more redundant, various diversity techniques are used. The main such methods employed are space diversity, in which several antennas are used for the receiving purpose, and frequency diversity, in which the same signal is repeated on several frequencies.

The main modulation methods employed in these systems are Phase Shift Keying (4PSK, 8PSK and 16PSK), and Quadrature Amplitude Modulation (4QAM and 8QAM). The different types of line codes used are AMI (Alternate Mark Inversion), NRZ (Non Return to Zero), RZ (Return to Zero), CMI (Coded Mark Inversion), and HDB3 (High Density Bipolar 3). The choice of line codes depends on the speed of the data stream.
Using oscillators, the transmitting frequencies and receiving frequencies werecontrolled. And the pressure and humidity were controlled by barometer and copper sulfates solution. Because of the radio waves should be propagated long distances violating attenuations.

The PDH Radio transmission topology and the SDH transmission topology in Sri Lanka are shown bellow diagrams.

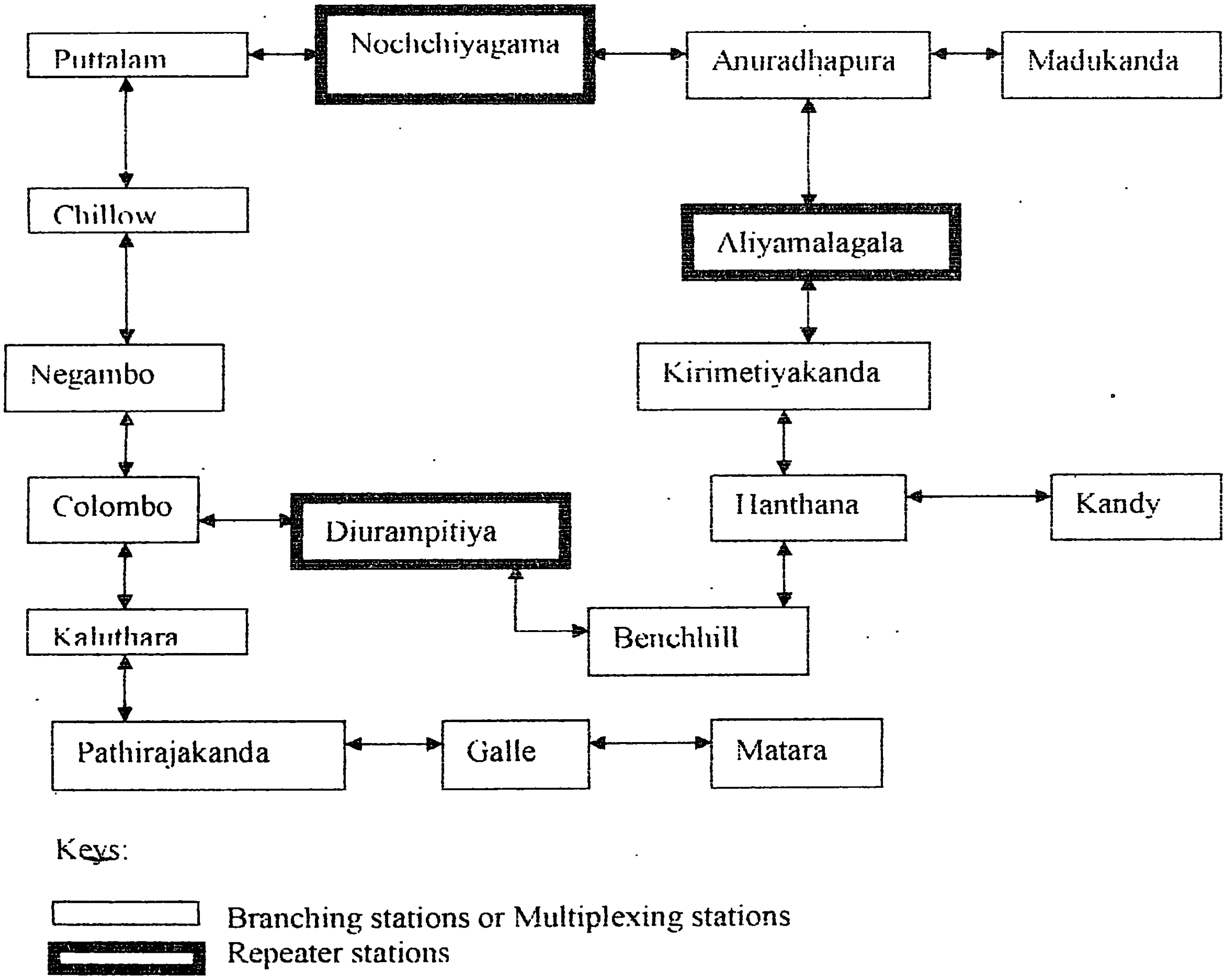

Figure 4.7: SDH transmission network in Sri Lanka.

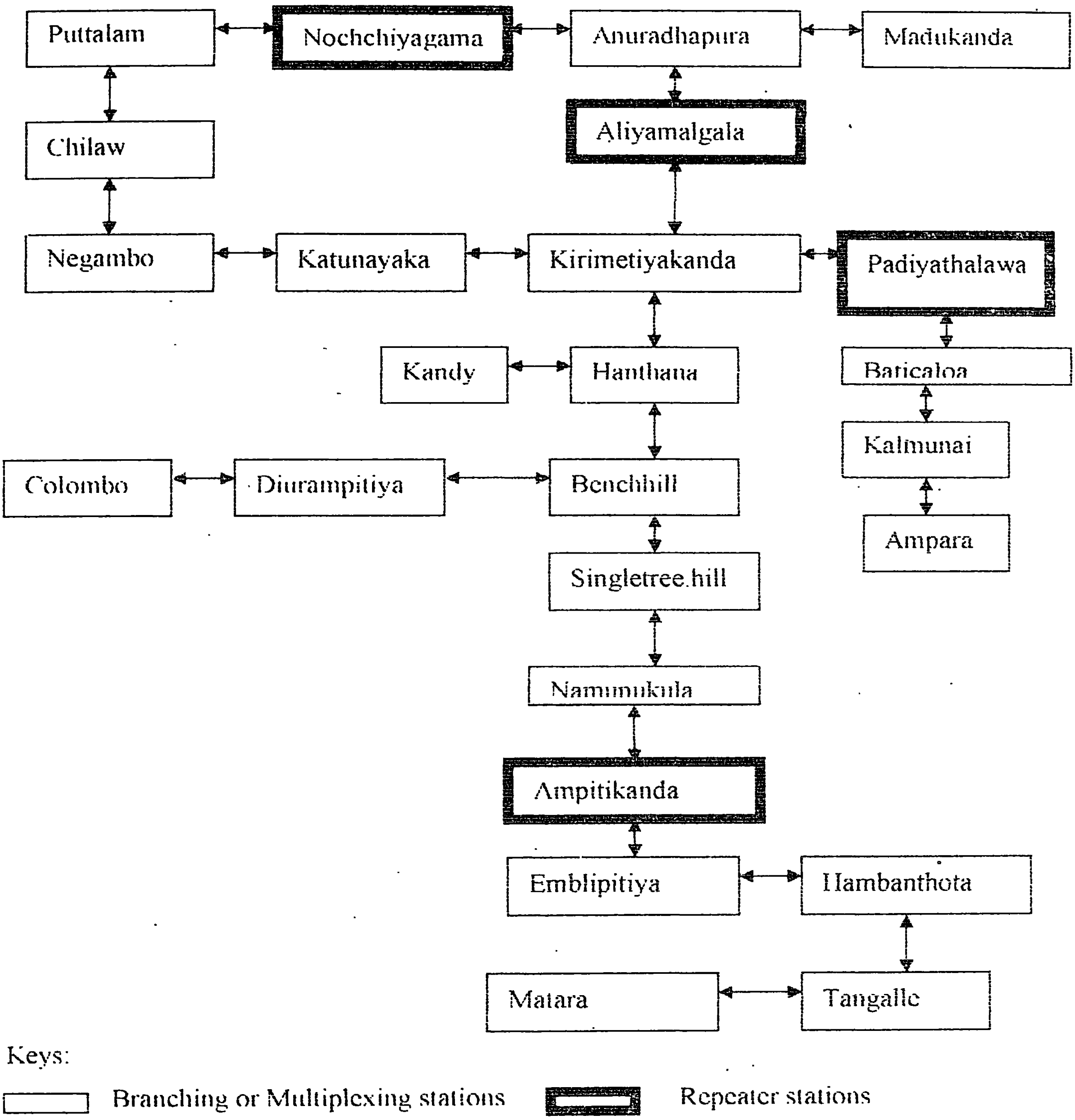

Figure 4.8: PDH Transmission network in Sri Lanka.

4.2 INTERNATIONAL TELECOMMUNICATIONS SYSTEMS IN SRI LANKA

The evolution of the telecommunications made the world a global village and we have to be part and parcel of this village if we want to achieve economic development, therefore we have to keep in contact with the other people in the world. Basically, There are three ISC and ITMC in International telecommunications system. There are two transmission channels to propagate the international telecommunication system. The function of each part can be explained as following.

4.2.1: ISC (International Switching Center):

These are used as gateway switches between domestic network and the international transport network. There are three ISC in Sri Lanka. Two of them are situated in Colombo and other one is situated at welisara. It is a containerized facility, which has its own power generation system and an air-conditioning system together with the switching equipment inside a container.

4.2.2: ITMC (International Transmission Maintenance Center):

International Transmission Maintenance Center (ITMC) acts as the gateway between the local network and the international network. The ITMC provides facilities for monitoring and controlling the quality of signals to and from the international network. The diagram of ITMC and its function will be introduced as shown bellow.

4.2.3: SATELLITE STATIONS

The satellite Earth Station is a place, which transmit and receive signal to and from the satellite. The signal may be either digital or analog. The block diagram of satellite station can be shown bellow.

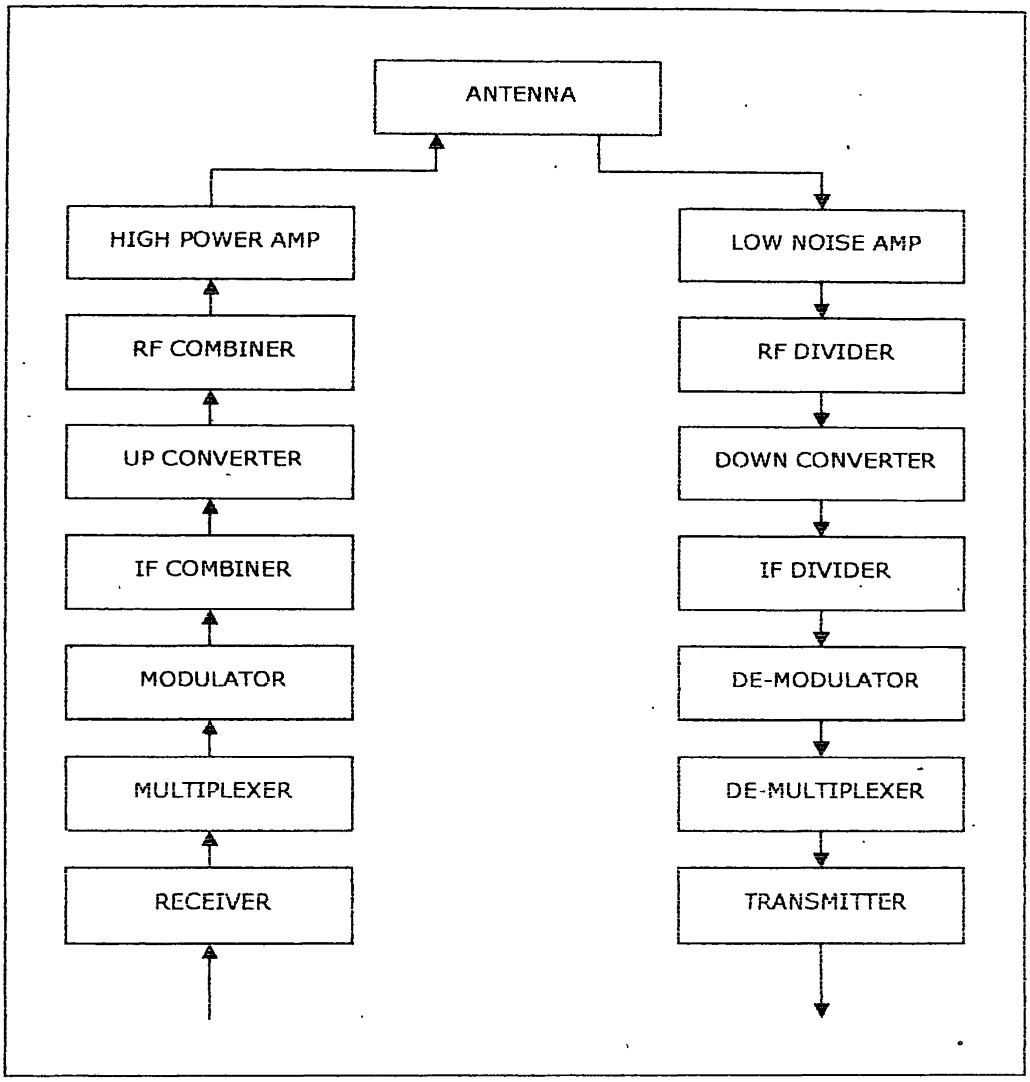

Figure 4.9: Components of a Satellite Earth Station

Transmitting frequencies are in the range of 6 GHz and Receiving frequencies are in the 4 GHz range. First consider receiving path.

Receiving path:

A satellite beam has 500 MHz bandwidth. Within that 500 MHz there are so many RF (Radio Frequency) carriers, but a satellite station do not receive all the carriers. 4118 MHz, 4130 MHz, 4136 MHz, 3925 MHz, 4035 MHz are some RF carriers received. In

satellite communication use circular polarization. Further circular polarization can be divided in to two-part A and B. There for we have to used separate "low noise amplifiers (LNA)" for the A and B. Low noise amplifier is used to prevent the
Amplification of noises included in the receiving signals. In a LNA one is always standby. RF signal coming through the LNA is divided from the RF Divider and pointed to corresponding Down Converter (D/C).

Transmitting path:

Transmitting procedure is opposite to the Receiving procedure. Here also we have to consider about the BW of the Up converter (U/C). For A and B, used separate U/C. In transmitting finally use High power amplifier to amplify the RF to high power range.

These information signals propagate to the satellite. it is a repeater, which is launch on the space. The properties of satellite are35 785 Km above the surface of the earth, directly over the Equator, Circular orbit, Rotating in the same direction as the earth, Rotating in the same velocity of the earth, Illuminate one third (1/3) of the earth surface and Thee satellite for global coverage.

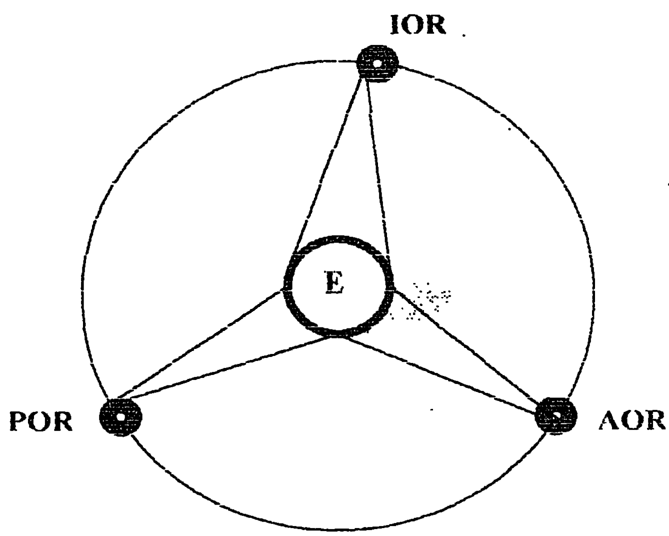

Figure 4.10: the satellite network of the world.

E- Earth
AOR-Atlantic Ocean Region
IOR- Indian Ocean Region
POR-pacific Ocean Region

4.2.4: Fiber optic cable land station:

Other position of international telecommunication is fiber optics land station. The major components of fiber optics land station are ADM, PFE, LTU, CFU, CTB, BJ and BU. The fiber optics cable or submarine cable has to use to fulfill this purpose. The Function of above components can be explained as given bellow.

ADM:

ADM has SDH interconnection equipment and it can convert STM1 electric signal to STM1 optical signal as well as STM1 optical signal to STM1 electric signal.

CTB:

The international information can propagate west side and east side of the country. Therefore CTB can separate the signals of east side of country and the signals of west side of the country.

LTU:

The LTU consists of three major shelves i.e., two optical sender (OS) shelves one common (COM) shelf. The main functions of these shelves are described as bellows.

OS shelf:

The OS shelf receiver STM-16 optical signal from the SDH equipment encodes the signal into the forward error correction code formed 2.6Gbit/s signal, which is transmitted to the CFU. Main functions of this shelf are conversion of the incoming STM-16 optical signal into STM-16 electric signal and its regeneration, encoding of the STM-16 signal by forward error correction rule and forming of the signal with forward error correction overhead, conversion of the 1.6Gbit/s electric signal to the optical signal with turned wave length and extraction of clock signal from the STM-16 signal.

COM shelf:

The COM shelf mainly performs the function of operation, administration and maintenance of the equipment.

CFU:

The CFU consists of major four shelves, i.e. multiplex (Mx) shelf, Demultiplex (Dx) shelf, orderwire (OW) shelf. Mx shelf multiplexes optical 2.6Gbit/s signal from each LTU and Line monitoring equipment dedicated wavelength-by-wavelength division multiplex. The Wave Division Multiplexed optical signals are sent to the submersible plant after amplification by Erbium-doped fiber amplifier.

On the contrary, optical signals incoming from the submersible plant are amplified and sent to DM. This shelf also has the function of high loops loop back for line monitoring and to monitor the input/output optical line signals. Received signal from submersible section is amplified and demultiplexed in this Dx. The OW provides accommodation capability of orderwire interface panels. DCF shelf accommodates dispersion compensation the accumulated chromatic dispersion resulted from long haul transmission through the optical fiber in the submersible potions.

PFE:

The PFE is installed at each terminal station to supply a precisely controlled constant direct current to submerged optical repeaters and Branching Unit (BU).

BJ:

The function of beach joint (BJ) is attaching the submarine cable and the optical fiber that coming from optical cable land station.

BU:

The optical function of Branching Unit is capable of branching the optical signals into each assigned destination by optical Add/Drop filter. The trunk fiber line in the BU has amplifiers, same as the repeaters. It is possible to perform fault localization within one repeater or BU spans by the high loss loop back incorporated in these amplifiers. Properties of BU are given bellow.

Table4.1: properties of BU

Item	Parameter
Dimensions	480mm(diameter)*1520
Weight	1 ton
Pressure strength	More than 800Mpa
Insulation resistance	More than 2000Mega ohm
High voltage pressure	More than 15kv

4.3: Optical Fiber Cables:

Types of fiber cable and characteristics of the cables are given bellow.

Light Weight Cable (LW):

These cables are situated in more than 2500 meter in deep of sea. The characteristics of LW cables are:

Table 4.2: type LW cable

Cable nominal diameter	22.5mm
Cable Weight in air	8.88KN/km
Cable weight in water	4.98KN/km
Minimum braking load	98KN
Minimum bending radius	900mm
Hydrodynamic constant	43.6degree-Knots

Light Weight Screen Cable (LWS):

These cables are situated between 1500 and 2500meter in deep of sea. The characteristics of LWS cables are:

Table 4.3: type LWS cable

Cable nominal diameter	31mm
Cable Weight in air	13.3KN/km
Cable weight in water	5.94KN/km
Minimum braking load	98KN
Minimum bending radius	900mm
Hydrodynamic constant	40.5degree-Knots

Single Armored Medium Cable (SAM):

These cables are situated between 100 and 700meter in deep of sea. The characteristics of SAM cables are:

Table 4.4: type SAM cable

Cable nominal diameter	42mm
Cable Weight in air	41KN/km
Cable weight in water	29.3KN/km
Minimum braking load	295KN
Minimum bending radius	900mm
Hydrodynamic constant	74degree-Knots

Single Armored Light Cable (SAL):

These cables are situated between 700and 1500meter in deep of sea. The characteristics of SAL cables are:

Table 4.5: type SAL cable

Cable nominal diameter	38mm
Cable Weight in air	29.9KN/km
Cable weight in water	19.9 KN/km
Minimum braking load	213KN
Minimum bending radius	900mm
Hydrodynamic constant	64 degree-Knot

Single Armored Heavy cable (SAH)

These cables are situated between 100 and 700meter in deep of sea. The characteristics of SAH cables are:

Table 4.6: type SAH Cable

Cable nominal diameter	46mm
Cable Weight in air	52.9KN/km
Cable weight in water	39.4KN/km
Minimum braking load	379KN
Minimum bending radius	900mm
Hydrodynamic constant	82 degree-Knot

Double Armored Cable (DA):

These cables are situated between 0 to 100meter in deep of sea. The characteristics of DAcables are:

Table 4.7: type DA cable

Cable nominal diameter	60mm
Cable weight in air	107KN
Cable weight in water	82.2KN
Minimum breaking load	434KN
Minimum bending radius	900mm
Hydrodynamic constant	104 degree-Knot

Land Fiber Cable:

It is situated under the strand. The characteristics of these cables are:

Table 4.8: Land Fiber cable

Items	Value
Cable nominal diameter	15mm
Cable weight in air	2KN/km
Cable braking load	2.5KN
Minimum bending radius	300mm

There is the submarine cable in between India (Mumbai) and Singapore (Tuas). Therefore Sri Lanka can joint to this cable from mount lavinia. The profile of submarine cables can be represented as shown bellow.

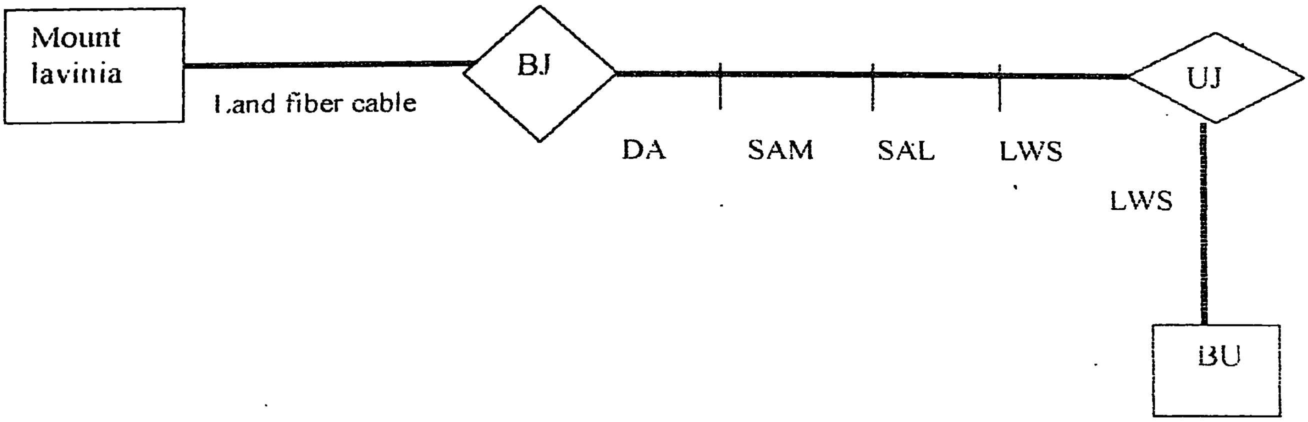

Figure 4.11: structure of submarine cables.

The distance of land fiber cable is 0.825km,distance of DA cable is 28.184km, distance of SAM cable is 6.902km, distance of SAL cable is 8.148km,a and distance of LWS cable is 10.203km. Therefore total length of all types of cable from Mount lavinia to BU is 54.262km.

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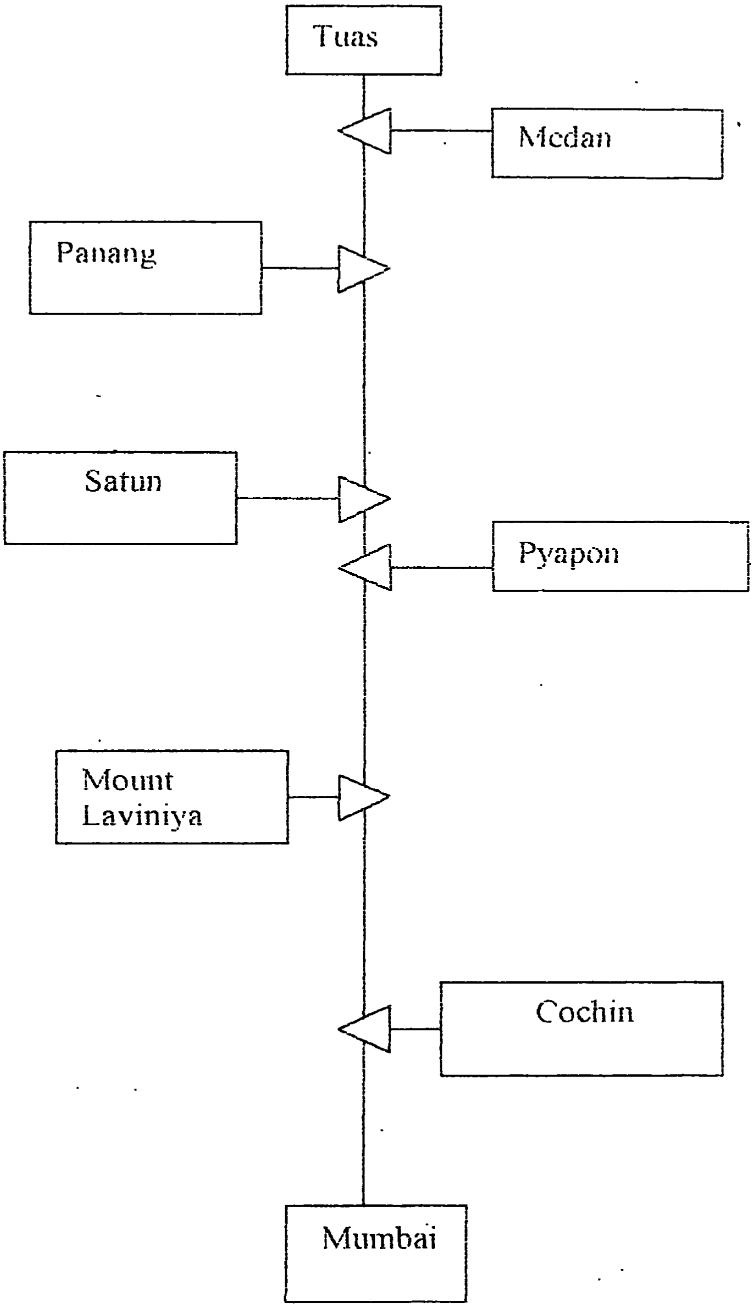
Appendix 1

The area codes used by SLT are listed in bellow table.

Trunk area	Area code	Number of Digits In the Subscriber Number
Ampara	63	5
Anuradhapura	25	5
Avissawella	36	5
Badulla	55	5
Bandarawela	57	5
Baticaloa	65	5
Chillaw	32	5
Colombo	1	5
Galle	9	5
Gampaha	33	5
Hambanthota	47	5
Hatton	51	5
Jaffna	21	5
Kalmunai	67	5
Kaluthara	34	5
Kandy	8	5
Kegolle	35	5
Kurunagala	37	5
Mannar	23	5
Mathale	66	5
Matara	41	5
Nawalapitiya	54	5
Negambo	34	5
Nuwara eliya	52	5
Polonnaruwa	27	5
Rathnapura	45	5
Trincomalee	26	5
Vavunia	24	5

APPENDIX 2



4^{th} Segment of Submarine cable system.

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