AN ISLAND-WIDE SDH TRANSMISSION NETWORK FOR THE CEYLON ELECTRICITY BOARD

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Submitted in partial fulfillment for the Degree of Master of Engineering in Electronic & Telecommunication Engineering to the

Department of Electronic & Telecommunication Engineering
University of Moratuwa
Sri Lanka.

February 2004.

Declaration

This work, presented in this dissertation, has not been submitted for the fulfillment of any other degree.

UOM Verified Signature

M N S Shiraj Sharifdeen
Candidate

UOM Verified Signature

Eng. A T L Kithsiri Samarasinghe
Supervisor

Dedication

This work is dedicated to my father,

Late. M N Sharifdeen (Retd. Principal),

who's dreams, shall reflect on all my successes.

Acknowledgements

I would like to extend my sincere gratitude to my supervisor Eng. A T L Kithsiri Samarasinghe for the invaluable guidance he extended towards the successful completion of this project. Thanks are also due to the M.Eng. Project co-coordinator Prof. J A K S Jayasinghe, for his valuable comments and corrections.

I would like to thank the former Head of the Dept. of Electronic & Telecommunications, Dr. Dileeka Dias for accepting my project proposal for the masters program, for the advices she rendered and for nominating a suitable supervisor for the project.

And finally the Dept. of Electronic & Telecommunications Engineering of University of Moratuwa and my employer, the Ceylon Electricity Board receive big thanks for providing me the opportunity to pursue my master's degree successfully.

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Abstract

Optical fibers are the choice of transmission medium for the high capacity telecommunication transmission systems of today such as Synchronous Digital Hierarchy (SDH), giving a very high yield for the investment made. With the already established highly reliable power transmission infrastructure, together with the advancement of technology, the utilities have a very high potential market in the telecommunication carrier service. By replacing the ground wires of the overhead high tension transmission lines with Optical Ground Wires (OPGW), utilities can build-up a country-wide high capacity transmission network over a relatively very short time frame and a very low investment. This paper analyses the possibility of establishing an island-wide optical fiber transmission network for the Ceylon Electricity Board based on the OPGW technique.

1. Introduction

It is nowadays very common worldwide for the power utilities to enter the telecommunications business. With the massive infrastructure they possess, it is relatively easy to set up and run telecommunication services. The major focus for the power utilities here is to provide long distance carrier services for the telecommunication service providers. The typical customers are wireless operators, cellular operators, data network operators, corporate communication sectors etc. Usually these operators establish their transmission network based on microwave radio links. However, as the network expands the radio transmission systems fail to cope up with the increasing bandwidth requirements. The landline operators usually have the privilege to lay underground optical fiber networks, which offer extremely large bandwidth capacity. However, the operating license of wireless operators usually restricts them from laying underground fiber networks.

Here is where the power utilities have the opportunity to provide carrier services to such operators. Power utilities essentially have the already established highly reliable power transmission network to cover almost the entire nation. These transmission networks can now be used to carry high-speed telecommunication signals. The ground wires of the overhead transmission lines can be replaced by the Optical Ground Wires (OPGW) in which the core of the ground wire contains highly secured optical fibers in large numbers. Since the transmission lines are usually constructed for very high reliability, the resulting optical fiber network is also highly reliable, mechanically. Replacement of the conventional ground wire by the OPGW can be done for both existing lines and new lines. This would give the power utilities extremely large data transmission capacities with the use of advance techniques such as single mode (SM) fibers and Wavelength Division Multiplexing (WDM). With suitable planning the power utilities can build a nation-wide high capacity transmission network in a very short time frame and have quick access to revenue.

This is completely a different case from the conventional fibre cabling, which requires obtaining of right-of-way from relevant authorities to trench roadways, additional expenditures for the trenching and civil works and cumbersome maintenance. The already available right-of-way of power utilities in the form of HT transmission lines is made use of to lay fibres. Hence, the implementation of the OPGW network is relatively cost effective and less time consuming compared to conventional fibre cabling.

In addition to replacing the conventional ground wires with the OPGW, there are several other methods to incorporate optical fibres in to the transmission lines such as All Dielectric Self Supporting (ADSS) fiber cables and Wrap-Around fiber cables. These are presented in the chapter 2.

Once decided on an optical fiber network based on OPGW, the type of transmission technology also should be determined. The most obvious choice will be the Synchronous Digital Hierarchy (SDH) transmission system. The SDH offers numerous benefits over the Plesiochronous Digital Hierarchy (PDH) and other techniques such as high transmission rates (up to 10 Gbps), simplified add and drop functionality, high availability and capacity matching, high reliability (with ring architecture and path/section protection schemes), better interface to other standards, future proof platform for new services etc.

This report analyzes the possibility of establishing an island-wide SDH transmission network for the Ceylon Electricity Board (CEB) based on the OPGW technique. In chapter 2, the SDH transmission hierarchy, the SDH network components, the self healing ring architecture used for the SDH transmission system, SDH network synchronization, the transmission characteristics of optical fibers, the available techniques of incorporating optical fibers in to power transmission lines, and the microwave link design are discussed. In the chapter 3, the network design for the CEB SDH transmission system is presented. The chapter 4 presents the cost analysis for the proposed network, while chapter 5 is devoted for further discussions. Chapter 6 lists the recommendations to the power utility based on the study and in Chapter 7 the drawbacks in the study are discussed. Chapter 8 gives the list of references, which is followed by the relevant technical data from Appendix A to Appendix F.

2. Literature Survey

2.1. Overview of SDH Architecture

2.1.1. SDH Hierarchy

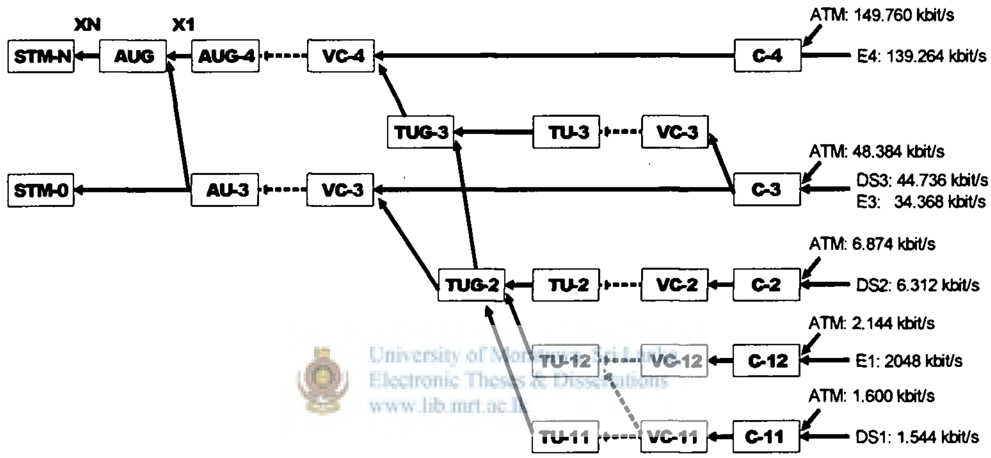


Figure 2.1: SDH Hierarchy.

The structure of the SDH hierarchy is shown in the Figure 1. The SDH standards define a structure which enables plesiochronous signals to be combined together and encapsulated within a standard SDH signal (Ref. 24).

Table 2.1 summarizes the STM-N bit rates of the SDH hierarchy.

Table 2.1: The SDH Bit Rates.

STM-N	Bit Rate (Kbit/sec)
STM-1	155,520
STM-4	622,080
STM-16	2,488,320
STM-64	9,953,280

The STM-N Frame Structure is illustrated in the Figure 2.2.

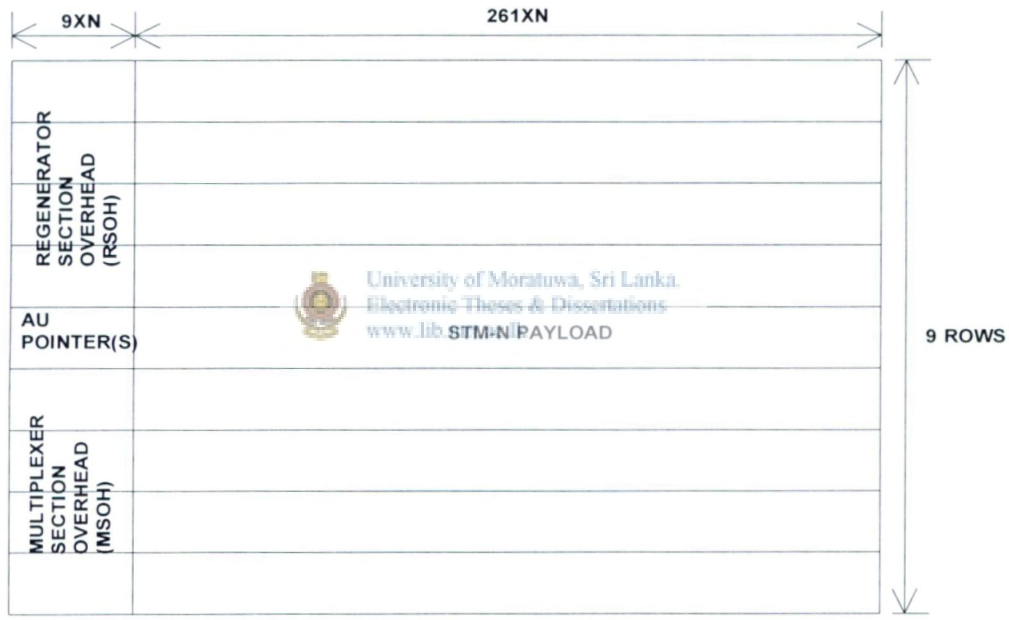


Figure 2.2: SDH Frame for STM - N.

2.1.2. Introduction to SDH Network Components

2.1.2.1. Regenerators

Regenerators, as the name implies, have the function of regenerating the clock and amplitude relationships of the incoming data signals that have been attenuated and distorted by dispersion (typically in a optical link). They derive their clock signals from the incoming data stream (Ref. 24).

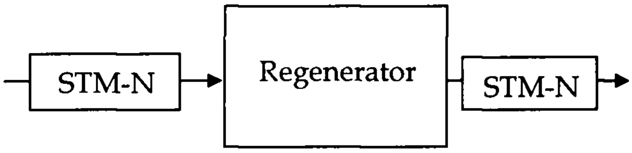


Figure 2.3; The Regenerator

2.1.2.2. Terminal Multiplexers (TMUX)

Terminal Multiplexers are used to combine plesiochronous and synchronous input signals in to higher bit rate STM-N signals (Ref. 24).

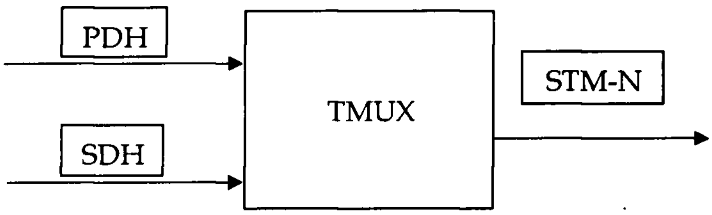


Figure 2.4; The Terminal Multiplexer

2.1.2.3. Add/Drop Multiplexers (ADM)

lesiochronous and lower bit rate synchronous signals can be extracted from or inserted in to high speed SDH bit stream by means of ADMs. This feature makes it possible to set up ring structures, which have the advantage that automatic back up path switching is possible using elements in the ring in the event of a fault (Ref. 24).

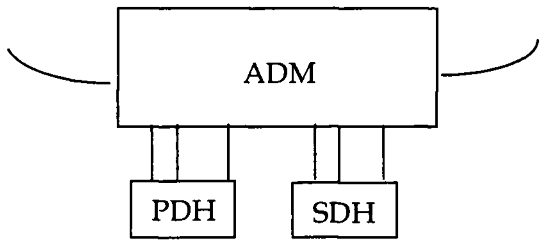


Figure 2.5; The Add-Drop Multiplexer

2.1.2.4. Digital Cross Connect (DXC)

This network element has the widest range of functions. It allows mapping of PDH tributary signals in to virtual containers as well as switching of various containers up to and including VC-4 (Ref.24).

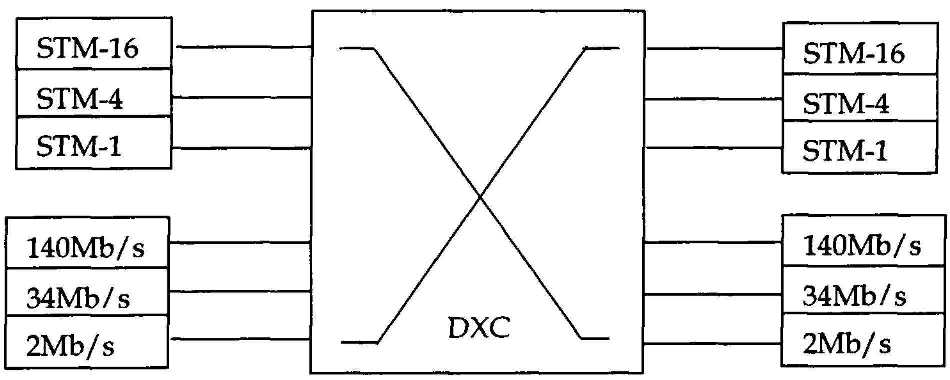
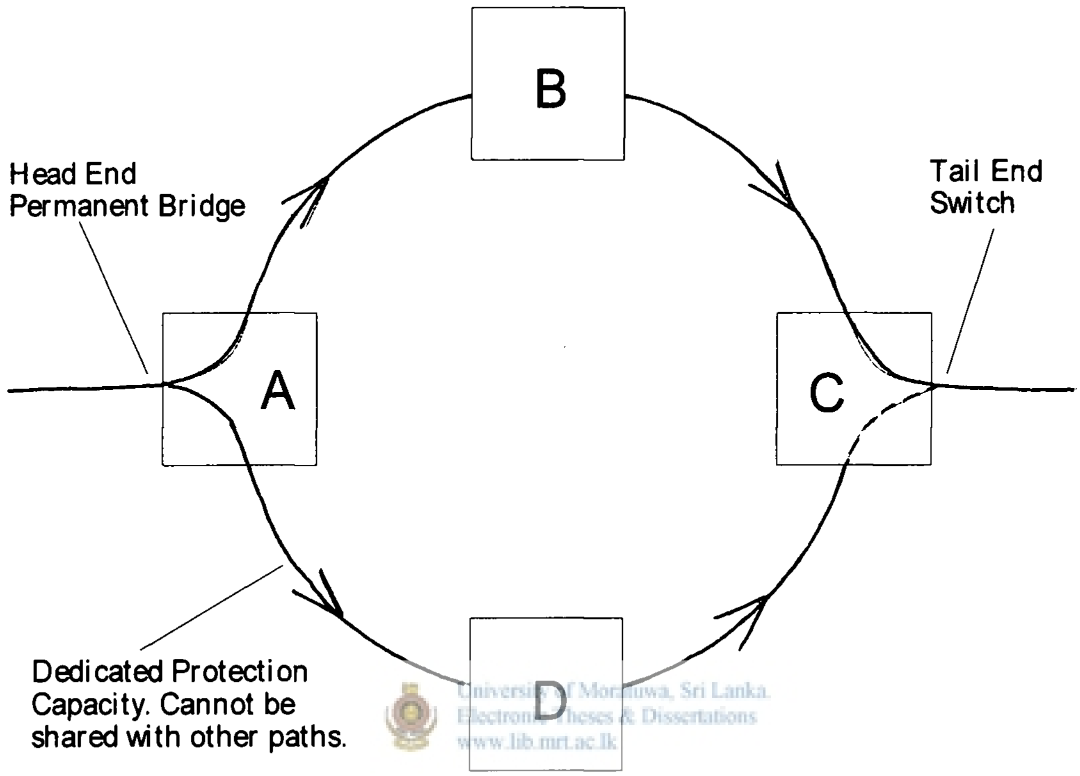


Figure 2.6; The Digital Cross Connect.

2.1.3. SDH Ring Protection



2.1.3.1. Dedicated Protection Ring (DP Ring)

Figure 2.7: The Dedicated Protection Ring.

In this protection scheme the sending node sends the same signal both ways around the ring and the protection mechanism at the receiving node selects the alternate path upon failure detection.

2.1.3.2. Shared Protection Ring (SP Ring)

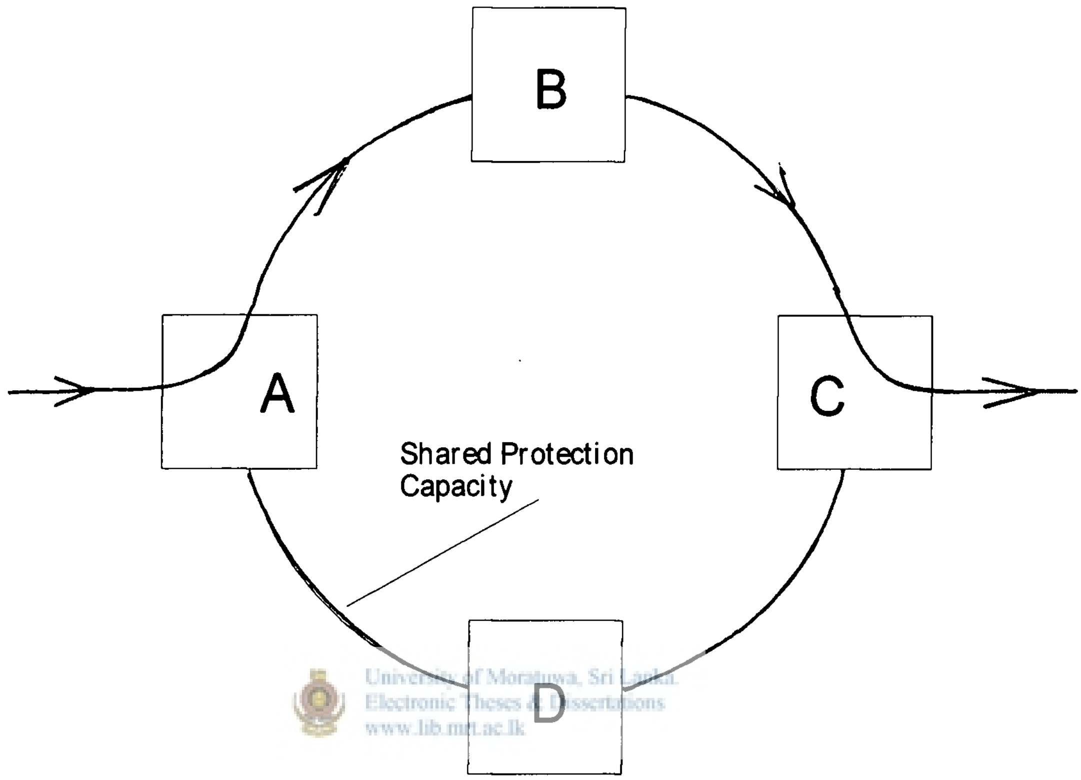


Figure 2.8; The Shared Protection Ring.

This is a shared Multiplex Section (MS) switched ring which is able to share protection capacity, reserved all the around the ring. In the event of a failure the protection switches operate on both sides of the failure to re-route the traffic through the spare capacity.

2.1.3.3. Two Fiber Unidirectional Path Switched (UPS) Ring

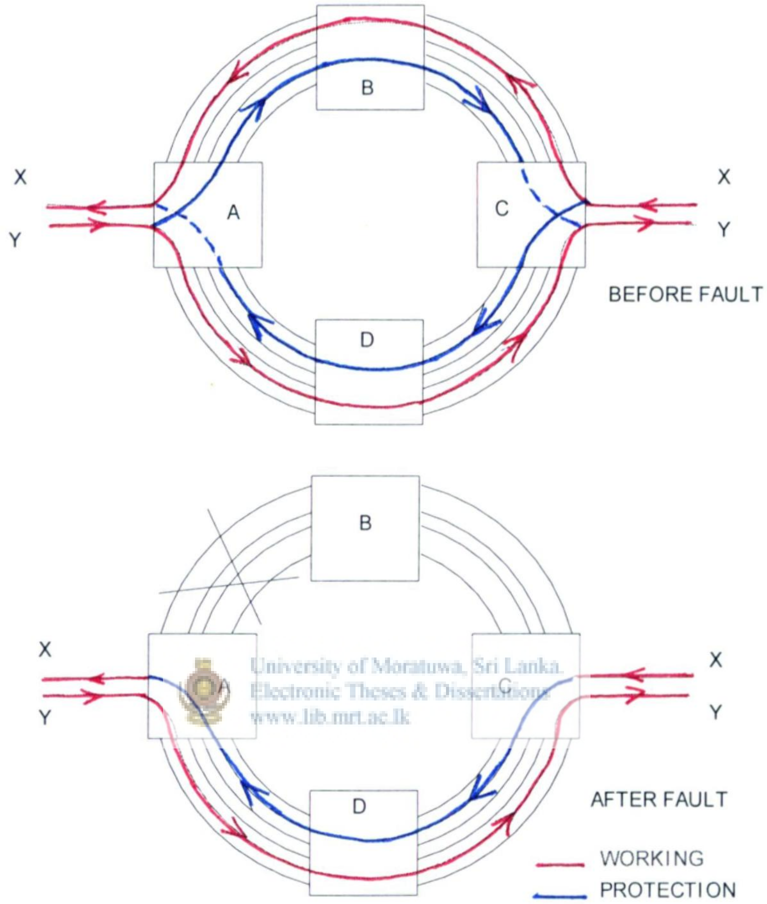


Figure 2.9: The Two FiberUnidirectional Path Switched Ring.

In this type though the transmission is bi-directional for each node, the overall ring transmission is unidirectional and hence, the name unidirectional. Two fibers are used; one for working line and the other for the protection. The transmitting node sends the signal on both working and protection lines and the protection is achieved at the receiver by selecting the better signal (Ref. 24).

2.1.3.4. Two Fiber Bi-directional Line Switched Ring (BLSR)

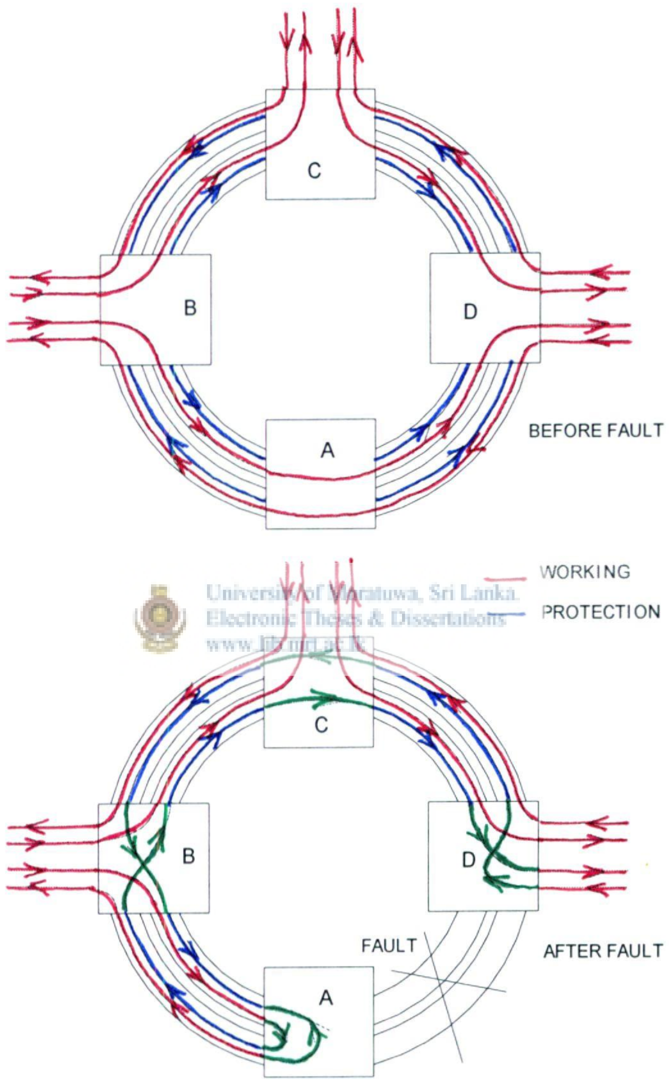


Figure 2.10: The Two Fiber Bi-directional Line Switched Ring.

Here the transmission in the fiber is bi-directional on any point in the ring. However, there are no separate fibers for protection. Each fiber is divided in time slots between working and protection lines. The protection line of any working line is on the opposite side of the ring to provide the route diversity.

Another feature of this ring is that the protection lines are not allocated to any path permanently but are assigned segment by segment, according to the requirement, during a fault condition. The switching is done at nodes at both ends of each multiplex section to route the traffic through the shared protection capacity (Ref. 18).

2.1.3.5. Four Fiber Bi-directional Line Switched Ring

This is similar to the two fiber BLSR, but, instead if sharing the time slots between the working and protection lines, dedicated fibers are reserved for protection lines. Hence, it would be immune against end terminal faults (Ref. 18). This is illustrated in Figure 2.10.

2.1.3.6. Other Methods

Another simple and cost effective method of protection is to split the traffic at each node and transmitting them both ways around the ring. In case of a failure at a given line segment, at least half the transmitting capacity is assured to each node. This does not call for much network management complexity. However, the protection is available only for 50% of the transmission capacity.

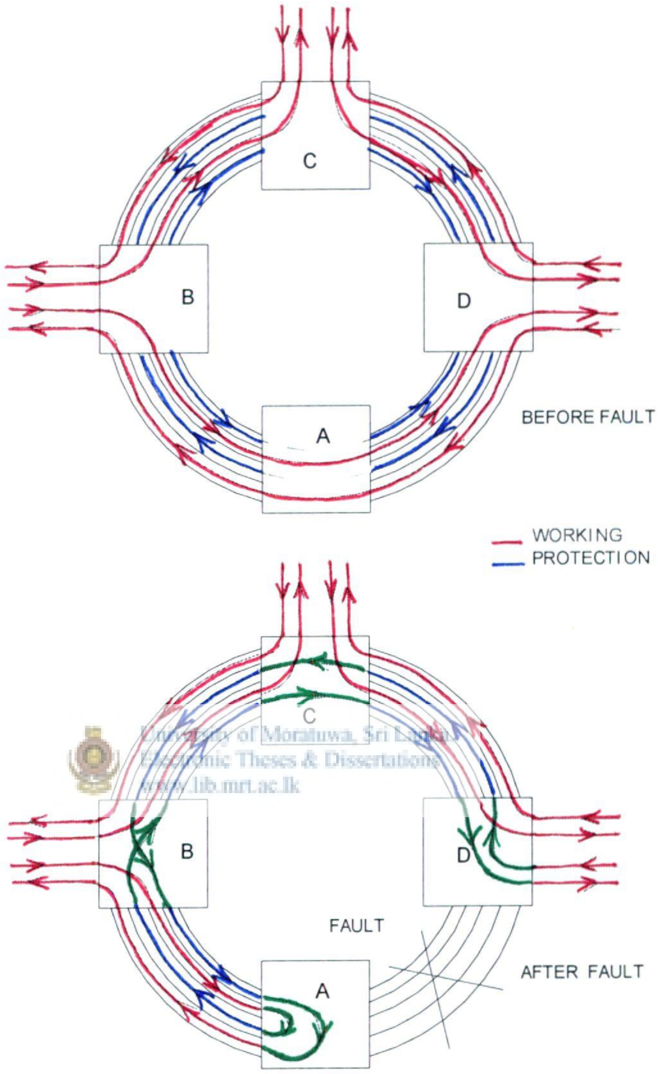


Figure 2.11: The Four Fiber Bi-directional Line Switched Ring.

2.1.4. SDH Network Synchronization

The fundamental requirement of SDH network is synchronization of all network elements to a common highly accurate clock known as the Primary Reference Clock (PRC). This PRC should conform to ITU-T Rec. G.811 with the accuracy of $1*10^{-11}$. This clock signal must be distributed throughout the entire network. A hierarchical structure is used for this; the signal is passed on by the subordinate Synchronization Supply Units (SSUs - G.812) and Synchronous Equipment Clocks (SECs - G.813). The synchronization signal path can be the same as those used for the SDH communications (ref 24.). The clock signal is generated in the SSUs and SECs with the aid of Phase Locked Loops.

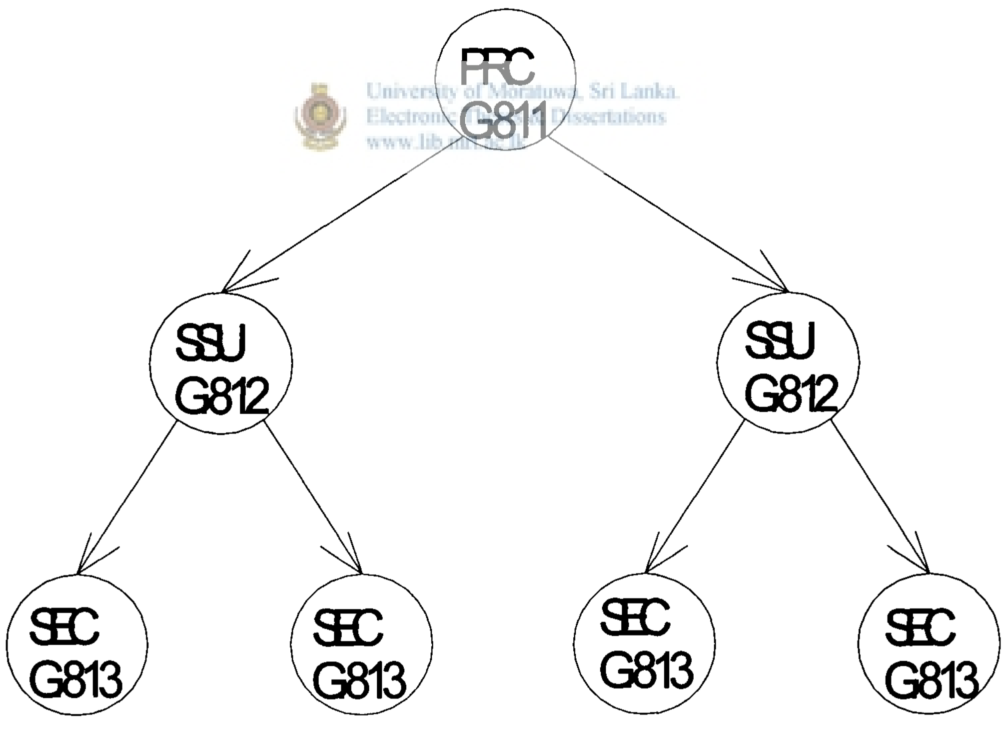


Figure 2.12: Hierarchy of Clock Signal Distribution

The network is organized with a Master-Slave relationship with clocks of the higher-level nodes feeding the timing signals to the clocks of the lower level nodes. All nodes can be traced up to a PRC. The internal clock of an SDH terminal may derive its timing signal from a SSU used by switching systems and other equipment. Thus, this terminal can serve as the Master for the other SDH nodes, providing timing on its outgoing STM-N signal. Other SDH nodes will operate in a Slave mode with their internal clocks timed by the incoming STM-N signal (Ref. 25.).

2.1.4.1. Synchronization Clock Signal Sources for Network Elements

For the proper functioning of the Network Elements (NEs), they should be continuously supplied with the clock signal, which is refered to a PRC. Therefore, protection measures should be taken to ensure that any failure in the network does not affect the continuous supply of the clock signal.

To do this, the NEs are designed so as to select clock signals from various sources. A synchronization source list is SET in each NE so that, in case of a failure of the current source, the NE can switch to the next source in the list.

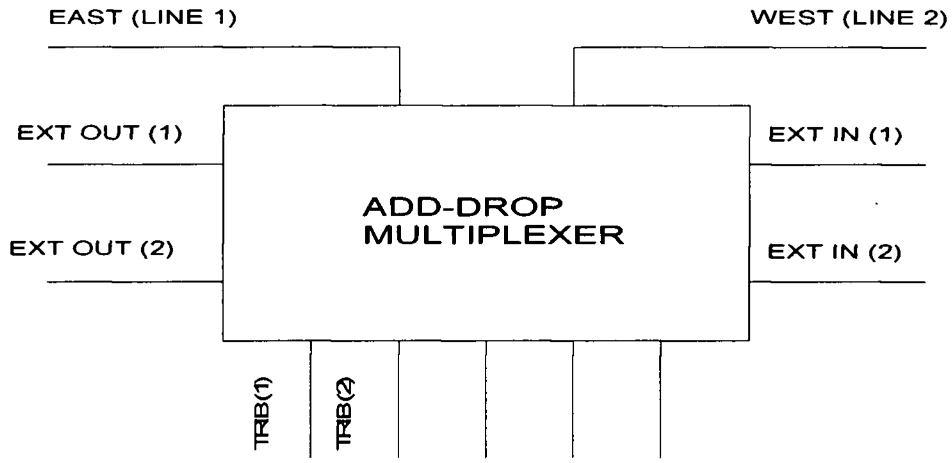


Figure 2.13: Common Sources of Clock Signals

Common sources of clock signals are;

a. Line signals (STM-N)

-East or West

b. Tributaries

-more than one tributary can be selected

c. External Synchronization Input

-such as PRCs, SSUs etc.

d. Internal Clocks

If the clock supply fails, the network element switches over to a clock source of same or lower quality, or if this is not possible, it switches to hold-over mode. In the hold-over mode, the clock signal is supplied by the internal clock. In this situation the clock signal is kept relatively accurate by controlling the oscillator by applying the stored frequency and phase correction values for the previous hours and taking the temperature of the oscillator in to account (Ref 24&27).

Because, the timing source lists at each node can be programmed individually, when the nodes are connected in ring configurations, a potential 'timing loop' or 'clock island' can occur. This must be avoided at all costs, as these would drift out of synchronization with passage of time and the total failure disaster would be the result (Ref 24&27).

2.2. Transmission Characteristics of Optical Fibers

The most important Factors that affect the transmission characteristics of the optical fibers are the attenuation and dispersion mechanisms within the fiber.

2.2.1. Attenuation

The very low attenuation characteristic of today's optical fibers, is one of the most important factors that made them attractive as a transmission medium for the telecommunication signals. The tremendous improvements made in this direction since 1970, after the introduction of the first commercial fiber with an attenuation coefficient of 20dB/km, has led to the production of silica based glass fibers with losses less than 0.2 dB/km (Senior, p.85).

The mechanisms responsible for the signal attenuation within the optical fibers are the material composition, the preparation and purification techniques and the wave guide structures. These irregularities led to several types of signal attenuations such as, material absorption, material scattering, curve and micro-bending losses, mode coupling radiation losses and losses due to leaky modes (Senior, p.88).

These attenuation mechanisms leave three operating regions for optical communications namely the 0.85 μm, the 1.31 μm and the 1.55 μm regions; the 1.55 μm region being the lowest attenuation region having a

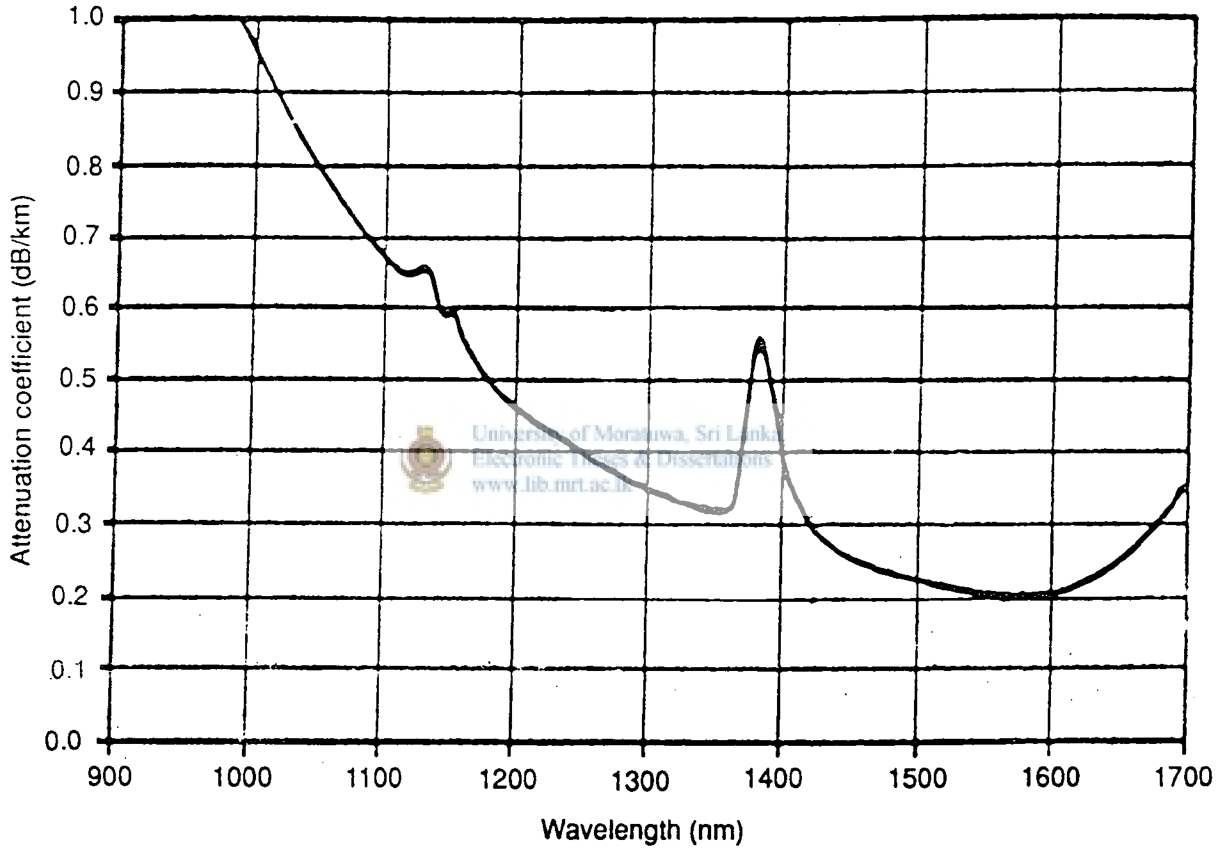


Figure 2.15.Graph of attenuation against wavelength for single-mode silica fiber.

demonstrated attenuation coefficient of 0.2 dB/km which approaches the theoretical minimum limit of 0.16 dB/km for silica fibers (Robert, p.298).

The attenuation characteristic with respect to wavelength for silica fibers is shown in Figure 2.15 (Robert, p.298).

2.2.2. Dispersion

Besides attenuation, dispersion is the most critical parameter that affects the transmission characteristics of optical fibers, as a long haul transmission medium. The dispersion, which is characterized by the broadening of the transmitted pulse, influences both the symbol rate of optical pulses within the fiber as well as the transmission distance. Therefore, the dispersion is represented by a bandwidth–distance product, in the optical fiber system specifications. The dispersion is broadly categorized in to inter-modal and intra-modal dispersions.

With the non-existence of inter-modal dispersion in single mode fibers, the limiting factors of the bandwidth-distance product are the material dispersion (Dm) and the wave-guide dispersion (Dw), which belong to intra-model dispersion. The variations of Dm and Dw with wavelength for silica fibers are illustrated in Figure 2.16 (Senior, p.126; Robert, p.303).

The frequency dependence of the refractive index (and therefore the speed of light) of the fiber material causes the material dispersion. For silica, the material dispersion drops to zero at 1.31 μm, as shown in Figure 2.1.6.

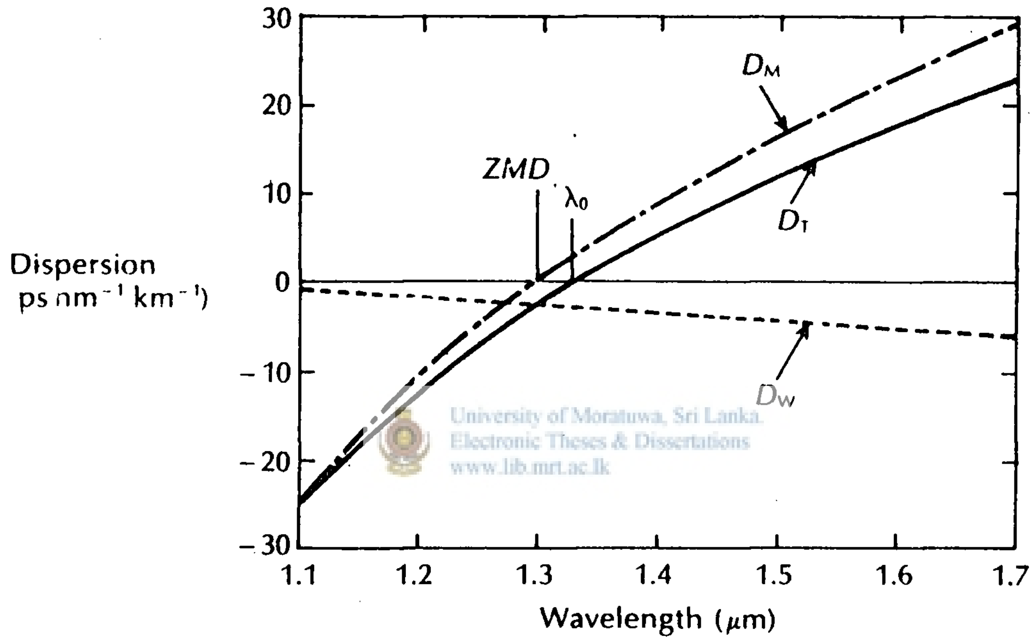


Figure 2.16. The material dispersion parameter (D_M), the waveguide dispersion parameter (D_W) and the total dispersion parameter (D_T) as functions of wavelength for a conventional single-mode fiber.

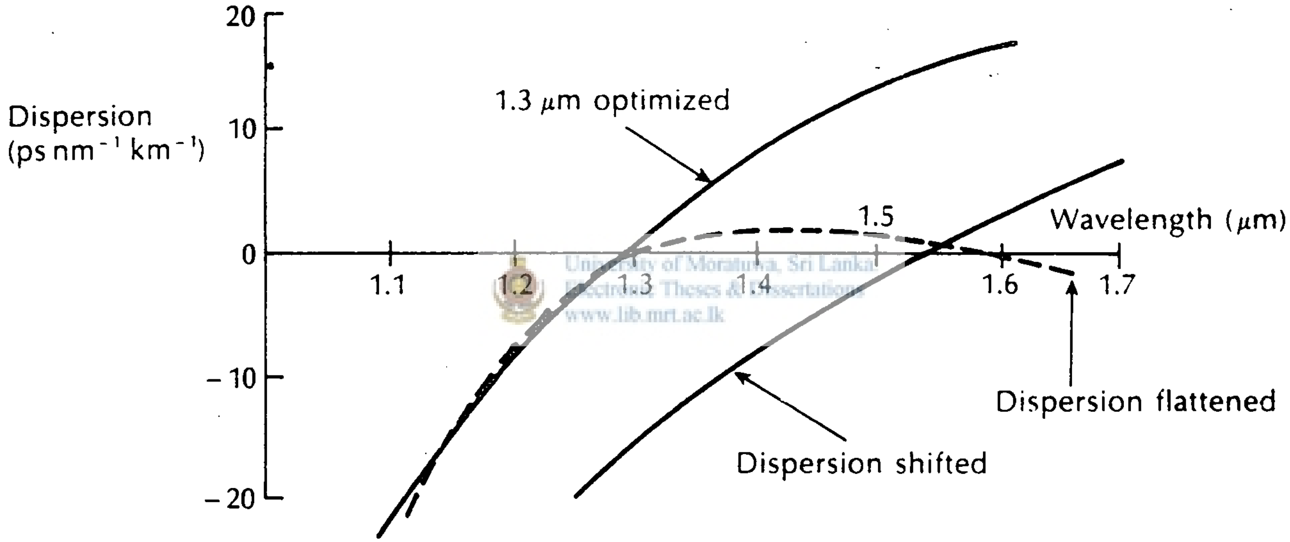


Figure 2.17. Total dispersion characteristics for the various types of single-mode fiber.

Unfortunately, at this wavelength the attenuation is 0.35 dB/km, which is not the minimum attenuation wavelength.

The wave-guide dispersion has a negative slope compared to the positive slope of the material dispersion. By modifying the fiber refractive index profile using precise fabrication techniques to affect the wave-guide dispersion characteristics, the fiber can be designed to have the zero total dispersion wavelength shifted to the lowest attenuation wavelength of 1.55 μm.

Such fibers are known as dispersion shifted fibers and due to manufacturing tolerances will typically have a non-zero dispersion figure of less than 3 $ps.nm^{-1}.km^{-1}$ at 1.55 μm, in practice (Robert, p.303). The dispersion characteristics of various types of single mode fiber are represented by the curves given in Figure 2.17.

The alternative technique to combat dispersion is to periodically introduce Dispersion Compensating Fibers (DCF), which have a dispersion characteristic, opposite to that of the transmitting fiber.

2.2.3. Throughput of Optical Fibers

The two techniques primarily used to increase the throughput of optical fiber systems are;

a. Increasing the bit-rate (symbol rate)

b. Employing Wavelength Division Multiplexing (WDM)

Increasing the bit-rate (bandwidth) is Largely limited by the dispersion characteristics of fibers. In single mode fibers, it is influenced by the chromatic dispersion. With dispersion shifted fibers, which offer the lowest dispersion at the lowest attenuation wavelength, the only avenue left to further improve the bit-rate is to narrow the line-width of the optical sources. The smaller the line-width of the optical source, the lesser the chromatic dispersion.

Among the contestants of light sources for optical fibers, Laser Diode (LD) is found to have the narrower line-width. While Fabry-Perot LDs have a line-width of typically 2nm, the Distributed Feedback LDs offers a line-width of about $5*10^{-6}$ nm. These can be compared with that of LEDs having a line-width of about 40nm (Robert, p.328).

The WDM involves the transmission of a number of different peak wavelength signals in parallel through a single optical fiber. Although, in spectral terms, optical WDM is analogous to electrical Frequency Division Multiplexing, it has the distinction that each WDM channel effectively has access to the entire intensity modulation fiber bandwidth. The next generation Dense Wavelength Division Multiplexing (DWDM) systems will combine hundreds of 40 Gbit/s bit-rate channels to realize multi-terabit throughput in optical fibers (Bigo). Ref. 20 lists the enabling technologies for high capacity point-to-point long distance transmission using optical fibers.

2.3. Methods of Incorporating Optical Fibres in to the Transmission Lines

There are basically three well-established methods of incorporating fibres in to the transmission lines;

a. Optical Ground Wires (OPGW)

Here the conventional ground wires are replaced by OPGWs which has a well secured core containing the optical fibres with very high degree of protection, surrounded by metallic conductors to carry the lightening current. There is adequate protection for the fibre from high temperatures that may exist in the surrounding conductors during a lightening discharge. The specifications for OPGW cables is given in the Ref. 3, which covers the construction, mechanical and electrical performance, installation guidelines, acceptance criteria and test requirements of the same..

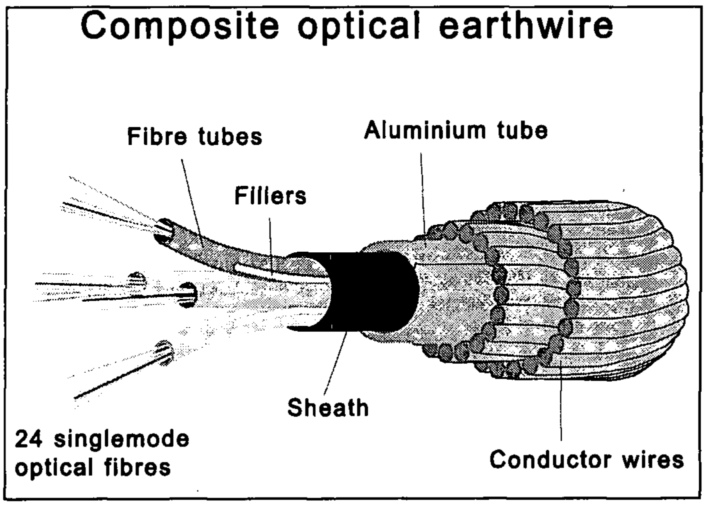


Figure 2.14: OPGW Cable Construction.

b. Wrap-around Cable

Wrap-around cables is suitable for incorporating fibres on existing ground wire in a cost effective way without having to replace them by OPGW. This is a flexible type of optical fibre cable which can be wrapped around the existing ground wire using a special remote controlled wrapping machine, even under energized conditions.

c. All Dielectric Self Supporting (ADSS) Fibre Cable

ADSS cables are manufactured with non-metallic materials to ensure a complete electrical isolation. ADSSs are self-supporting type fibre cables which are strung between transmission towers at a lower elevation than the current carrying conductors of the transmission line.

A comparison of these three techniques is given in the section 5.1. The literature (obtained from the National Grid Company, U.K) pertaining to the installation of fibres by the above techniques is given in Appendix-A.

2.4. Microwave Link Design

♦ The following equation can be used to calculate the size of the first Freznel zone in meters;

$F_1 = 17.3 \sqrt{(d_1 . d_2 / f . d)}$ (2.1)

Where d_1, d_2 – distance to the point of interest from the two ends of the link in km

d _ link length in km

f _ frequency in GHz

♦ The following equations may be used for power budget calculations;

Free Space Loss (FSL) = 32.5 + 20 Log (f) + 20 Log (d) (2.2)

Where f – frequency in MHz and

d– distance in km

Flat Fade Margin (Mf) = $30 \text{ Log}_{10}(d) + 10 \text{ Log}_{10}(6.\delta.Q.f) - 10 \text{ Log}_{10}(1-R) - 70$ (2.3)

Where d- distance in km

δ- factor to convert the worst month fade to the average fade

Q- Terrain Factor

R- Reliability requirement

Selective Fade Margin (Ms)= $102 - 35 \text{ Log}_{10} (L) - 10 \text{ Log}_{10} (S)$ (2.4)

Where L – Length of the link in km

S – Signature of the equipment in MHz

Effective Fade Margin (Me) = $-10 \text{ Log}_{10} \{ 10^{(-Mf/10)} + 10^{(-Ms/10)} \}$ (2.5)

♦ The following equations can be used to calculate the distance to point of reflection;

Distance to point of reflection $= (d/2) + Ad$ (2.6)

Where; d = hop length in km

Ad = Correction

Correction $Ad = 2\sqrt{t} * \mathrm{Cos.}\ \{(\theta+\Pi)/3\}$

Where; $\theta = \mathrm{Cos}^{-1}\ \{T/(t\sqrt{t})\}$

Where; $T = 6.37*(k/4).\ d.\ (h_2-h_1)$

$t = (d^2/12) + 8.5.\ (k/4).\ (h_2-h_1)$

Where h_2 and h_1 are the antenna heights in m.

3. The SDH Network Design

3.1. Identification of Network Nodes

Since, the purpose of laying the fibre network is to provide the transmission capacity to the commercial operators, it is necessary that the nodes of the transmission network be selected in such a way that they are in close proximity to the commercial cities. To do that the power transmission network of the CEB should be matched with the important commercial cities of the country.

Under the first round of investigation the following cities have been selected as important commercial locations;

1. Colombo
2. Kandy
3. Anuradhapura
4. Jaffna
5. Trincomalee
6. Batticaloa
7. Ampara
8. Kurunegala
9. Galle
10. Nuwaraeliya
11. Matale

12. Kalutara
13. Vavuniya
14. Kegalle
15. Badulla
16. Ratnapura
17. Puttalam
18. Matara
19. Hambantota
20. Gampaha
21. Negombo
22. Chilaw

The Figure 3.1 gives the typical power transmission network diagram of the CEB. The table 3.1 gives the matching of the Commercial cities to the network nodes.

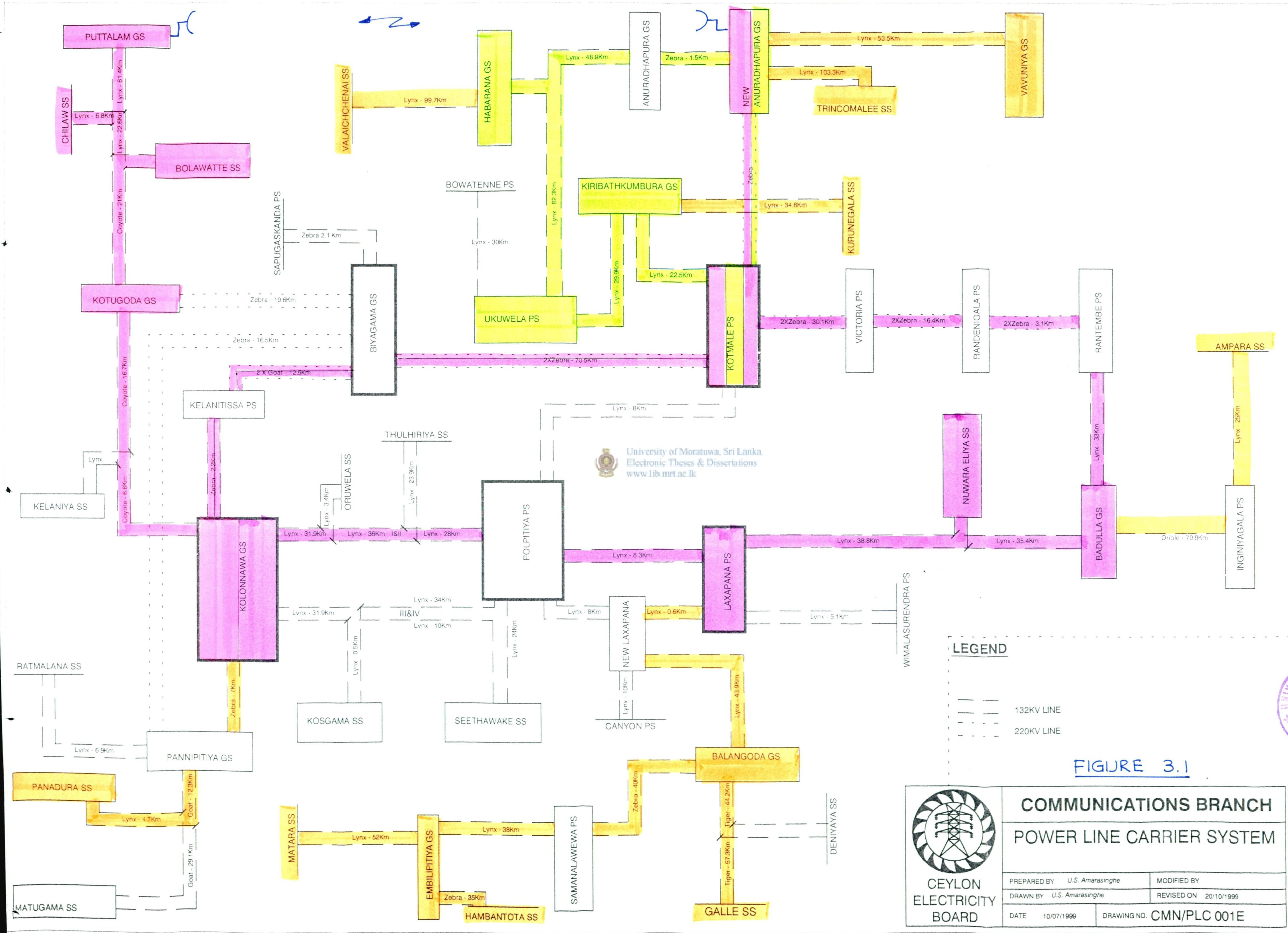

PUTTALAM GS
CHILAW SS
BOLAWATTE SS
KOTUGODA GS
KELANIYA SS
KELANITISSA PS
SAPUGASKANDA PS
BIYAGAMA GS
BOWATENNE PS
VALAICHCHENAI SS
HABARANA GS
ANURADHAPURA GS
NEW ANURADHAPURA GS
VAVUNIYA GS
TRINCOMALEE SS
KIRIBATHKUMBURA GS
KURUNEGALA SS
UKUWELA PS
KOTMALE PS
VICTORIA PS
RANDENIGALA PS
RANTEMBE PS
AMPARA SS
NUWARA ELIYA SS
BADULLA GS
INGINIYAGALA PS
THULHIRIYA SS
ORUWELA SS
POLPITIYA PS
LAXAPANA PS
NEW LAXAPANA
WIMALASURENDRA PS
KOLONNAWA GS
RATMALANA SS
KOSGAMA SS
SEETHAWAKE SS
CANYON PS
PANNIPITIYA GS
PANADURA SS
MATUGAMA SS
BALANGODA GS
DENIYAYA SS
MATARA SS
EMBILIPITIYA GS
SAMANALAWEWA PS
HAMBANTOTA SS
GALLE SS
Lynx - 61.4Km
Lynx - 6.8Km
Lynx - 22.6Km
Coyote - 21Km
Coyote - 16.7Km
Coyote - 6.6Km
Lynx
Zebra 2.1 Km
Zebra - 19.6Km
Zebra - 16.5Km
2 X Goat - 12.5Km
2XZebra - 70.5Km
Zebra - 2.2Km
Lynx - 30Km
Lynx - 99.7Km
Lynx - 48.9Km
Zebra - 1.5Km
Lynx - 53.5Km
Lynx - 103.3Km
Lynx - 82.3Km
Zebra
Lynx - 34.6Km
Lynx - 29.9Km
Lynx - 22.5Km
2XZebra - 30.1Km
2XZebra - 16.4Km
2XZebra - 3.1Km
Lynx - 8Km
Lynx - 33Km
Lynx - 25Km
Lynx - 31.9Km
Lynx - 3.4Km
Lynx - 36Km
I&II
Lynx - 23.9Km
Lynx - 28Km
Lynx - 6.3Km
Lynx - 38.8Km
Lynx - 35.4Km
Oriole - 79.9Km
Lynx - 34Km
III&IV
Lynx - 10Km
Lynx - 0.5Km
Lynx - 24Km
Lynx - 0.6Km
Lynx - 5.1Km
Lynx - 10Km
Lynx - 43.9Km
Zebra - 7Km
Lynx - 6.9Km
Lynx - 4.7Km
Goat - 12.9Km
Goat - 29.1Km
Zebra - 40Km
Tiger - 44.2Km
Tiger - 57.3Km
Lynx - 52Km
Lynx - 38Km
Zebra - 35Km
LEGEND
132KV LINE
220KV LINE
CEYLON ELECTRICITY BOARD
COMMUNICATIONS BRANCH
POWER LINE CARRIER SYSTEM
PREPARED BY U.S. Amarasinghe
MODIFIED BY
DRAWN BY U.S. Amarasinghe
REVISED ON 20/10/1999
DATE 10/07/1999
DRAWING NO. CMN/PLC 001E

FIGURE 3.1

Table 3.1:

No	Commercial Location	Nearest Network Node
1.	Colombo	Kolonnawa GS
2.	Kandy	Kiribathkumbura GS
3.	Anuradhapura	New Anuradhapura GS
4.	Jaffna	Vavuniya GS
5.	Trincomalee	Trincomalee SS
6.	Batticaloa	Valaichenai SS
7.	Ampara	Ampara SS
8.	Kurunegala	Kurunegala SS
9.	Galle	Galle SS
10.	NuwaraEliya	NuwaraEliya SS
11.	Matale	Ukuwela PS
12.	Kalutara	Panadura SS
13.	Vavuniya	Vavuniya GS
14.	Kegalle	Kiribathkumbura GS
15.	Badulla	Badulla GS
16.	Ratnapura	Embilipitiya GS
17.	Puttalam	Puttalam GS
18.	Matara	Matara SS
19.	Hambantota	Hambantota SS
20.	Gampaha	Kotugoda GS
21.	Negombo	Bolawatta SS
22.	Chilaw	Chilaw SS

Key: GS – Grid Sub Station
SS – Sub Station

3.2. Identification of Rings

The capacity of SDH transmission networks is better utilized when ring networks are employed. Therefore the next step is to identify the rings within the existing power network. For this purpose the CEB network is organized in to three rings and number of Spur Links. The rings and Spur Links are illustrated in the figure 3.1.

3.2.1. The Central Ring

The Central ring consists of the nodes given in table 3.2;

Table 3.2.

No.	Nodes
1.	Kolonnawa GS
2.	Kotmale PS
3.	Badulla GS
4.	Nuwara Eliya SS
5.	Laxapana PS

This ring is established via the following installations of the power transmission network;

Table 3.3.

No.	Installation	Remarks
1.	Kolonnawa GS	Node
2.	Kelanitissa PS	By Pass
3.	Biyagama GS	By Pass
4.	Kotmale PS	Node
5.	Victoria PS	By Pass
6.	Randenigala PS	By Pass
7.	Rantambe PS	By Pass
8.	Badulla GS	Node
9.	Nuwara Eliya GS	Node
10.	Laxapana PS	Node
11.	Polpitiya PS	By Pass

The Central ring is illustrated in the figure 3.1 in Blue.

The lengths of line sections in the Central ring are listed in the table 3.4.

Table 3.4.

No.	Inter Node Section	Line Section	Dist. / (km)
1.	Kolonnawa-Kotmale	Kolonnawa-Kelanitissa	2.2
		Kelanitissa-Biyagama	12.5
		Biyagama-Kotmale	70.5
		Total Distance(Sub-Total)	85.2
2.	Kotmale – Badulla	Kotmale-Victoria	30.1
		Victoria-Randenigala	16.4
		Randenigal-Rantambe	3.1
		Rantambe-Badulla	33
		Total Distance(Sub-Total)	82.6
3.	Badulla – Laxapana	Badulla-NuwaraEliya	35.4
		NuwaraEliya-Laxapana	38.8
		Total Distance(Sub-Total)	74.2
4.	Laxapana – Kolonnawa	Laxapana-Polpitiya	8.3
		Polpitiya-Kolonnawa	65.9
		Total Distance(Sub-Total)	74.2
	Total Fibre Distance	(Grand Total)	316.2

3.2.2. North Central Ring

The North Central ring consists of the nodes given in the table 3.5;

Table 3.5.

No.	Nodes
1.	Habarana
2.	New Anuradhapura
3.	Kotmale
4.	Kiribathkumbura
5.	Ukuwela

The ring is established via the following installations of the power transmission network;

Table 3.6.

No.	Installation	Remarks
1.	Habarana	Node
2.	Anuradhapura (old)	By Pass
3.	New Anuradhapura	Node
4.	Kotamle	Node
5.	Kiribathkumbura	Node
6.	Ukuwala	Node

The North Central ring is illustrated in the figure 3.1 in green.

The lengths of line sections in the North Central ring are listed in table 3.7.

Table 3.7.

No.	Inter Node Section	Line Section	Dist. /(km)
1.	Habarana – New Anuradhapura	Habarana – Anuradhapura	48.9
		Anuradhapura – New Anuradhapura	1.5
		Sub Total	50.4
2.	New Anuradhapura - Kotmale		163
3.	Kotmale – Kiribathkumbura		22.5
4.	Kiribathkumbura - Ukuwala		29.9
5.	Ukuwala – Habarana		82.3
	Total Fibre Distance	Grand Total	348.1

3.2.3. North Western Ring

The North Western ring consists of the nodes given in Table 3.8.

Table 3.8.

No.	Nodes
1.	Kolonnawa
2.	Kotugoda
3.	Bolawatta
4.	Chilaw
5.	Puttalam
6.	New Anuradhapura
7.	Kotmale

The segment Puttalam-to-New Anuradhapura has to be established by means of a microwave radio link since there is no transmission line support fibre between these two installations.

The ring is established via the following installations of the power transmission network;

Table 3.9.

No.	Installation	Remarks
1.	Kolonnawa	Node
2.	Kotugoda	Node
3.	Bolawatta	Node
4.	Chilaw	Node
5.	Puttalam	Node
6.	New Anuradhapura	Node
7.	Kotmale	Node
8.	Biyagama	By Pass
9.	Kelanitissa	By Pass

The North Western ring is illustrated in yellow in figure 3.1.

The lengths of line sections in the North Western are listed in the table 3.10.

Table 3.10.

No.	Inter Node Section	Line Section	Dist./ (km)
1.	Kolonnawa – Kotugoda	Kolonnawa- Kelaniya	6.6
		Kelaniya – Kotugoda	16.7
		Sub Total	23.3
2.	Kotugoda – Bolawatta		21
3.	Bolawatta – Chilaw		29.4
4.	Chilaw – Puttalam		68.2
5.	Puttalam–New Anuradhapura		Radio
6.	New Anuradhapura – Kotmale		163
7.	Kotmale – Biyagama		
		Kotmale – Biyagama	70.5
		Biyagama - Kelanitissa	12.5
		Kelanitissa-Kolonnawa	2.2
		Sub Total	85.2
	Total Fibre Distance	Grand Total	390.1

3.2.4. *The Spur Links*

In addition to the three rings, number of Spur Links from the rings have been identified. The Spur Links are shown in the figure 3.1 in orange. There are seven sets of Spur Links.

3.2.4.1. Spur Links - Set 1

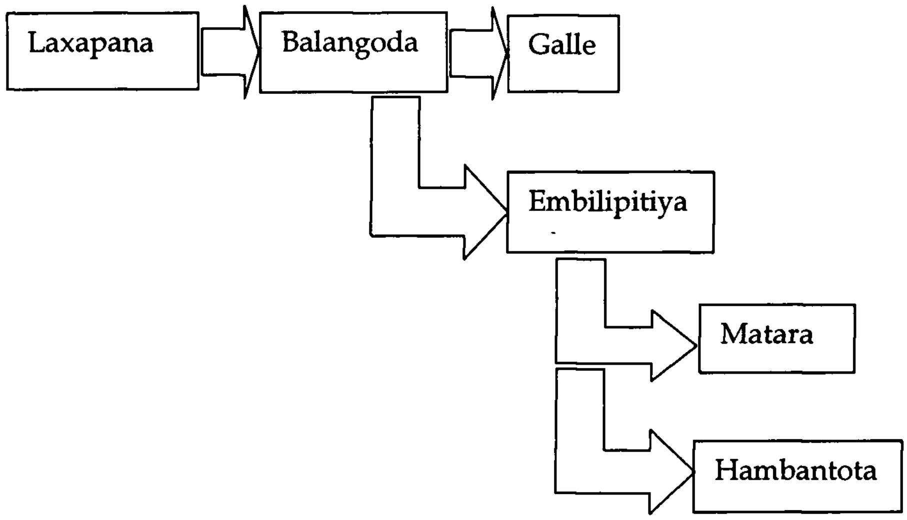


Figure 3.2.

The figure 3.2 gives a set of spur links from the Central ring. The line length of the individual links are listed in the table 3.11.

Table 3.11.

No.	Link Section	Line Section	Dist. / (km)
1.	Laxapana – Balangoda		
		Laxapana – New Laxapana	0.6
		New Laxapana – Balangoda	43.9
		Sub – Total	44.5
2.	Balangoda – Galle		102.5
3.	Balangoda- Embilipitiya		
		Balangoda - Samanalawewa	40
		Samanalawewa-Embilipitiya	38
		Sub – Total	78
4.	Embilipitiya – Matara		52
5.	Embilipitiya-Hambantota		35

3.2.4.2. Spur Links – Set 2

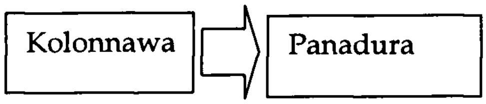


Figure 3.3.

The line lengths are shown in the table 3.12.

Table 3.12.

No.	Link Section	Line Section	Dist. /(km)
1.	Kolonnawa- Panadura		
		Kolonnawa- Pannipitiya	7
		Pannipitiya- Panadura	4.7
		Total	11.7

3.2.4.3. Spur Links – Set3.

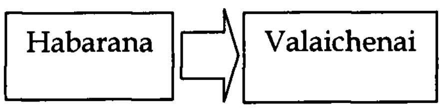


Figure 3.4.

The link length is 99.7 km.

3.2.4.4. Spur Links – Set4

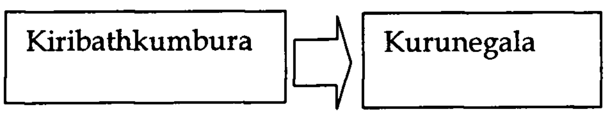


Figure 3.5.

The link length is 34.6 km.

3.2.4.5. Spur Links – Set 5

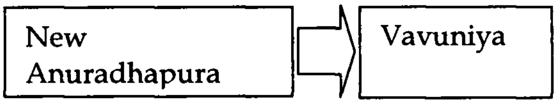


Figure 3.6.

The link Length is 53.5 km.

3.2.4.6. Spur Links - Set 6

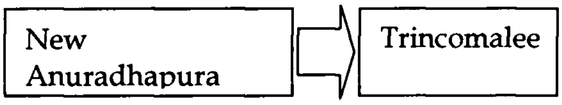


Figure 3.7.

The link length is 103.3 km.

3.2.4.7. Spur Links – Set 7

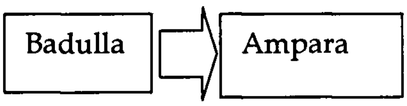
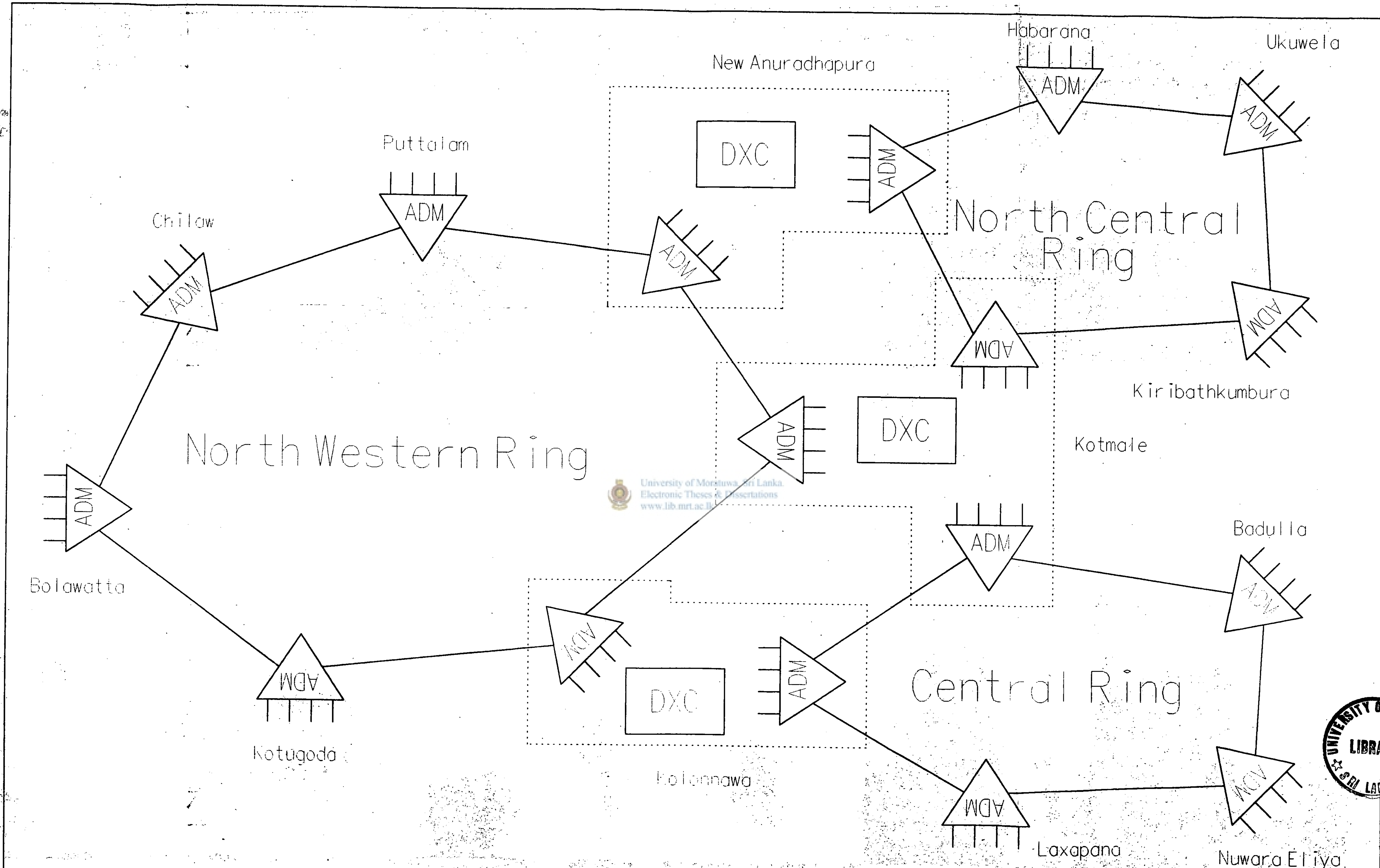


Figure 3.8.

The line lengths are shown in Table 3.13.

Table 3.13.

No.	Link Length	Line Length	Dist. /(km)
1.	Badulla _ Ampara		
		Badulla – Inginiyagala	79.9
		Inginiyagala – Ampara	25
		Total	104.9



Drawing No : 01 THE CONFIGURATION OF THE THREE SDH RINGS

3.3. Network Component Schedule

In this section the network component at each node are identified. The SDH ring network is usually built around multiplexers. In addition to multiplexers, Digital Cross- Connects, Regenerators etc. are also commonly used in network structures. The following abbreviations are used;

ADM Add/Drop Multiplexer

TMUX Terminal Multiplexer

DXC Digital Cross Connect

The configuration of the three ring are illustrated in the Drawing No:01.

3.3.1. Central Ring

The Table 3.14 lists the components at each node that constitute the Central ring.

Table 3.14.

No.	Node	Type of Network Component
1.	Kolonnawa	2 * ADM, DXC (Ring Interconnecting, With Spur Link)
2.	Kotmale	3 * ADM, DXC (Ring Interconnecting)
3.	Badulla	ADM (With Spur Link)
4.	Nuwara Eliya	ADM
5.	Laxapana	ADM (With Spur Links)

3.3.2. North Central Ring

The Table 3.15 lists the components at each site that make – up the North Central ring.

Table 3.15.

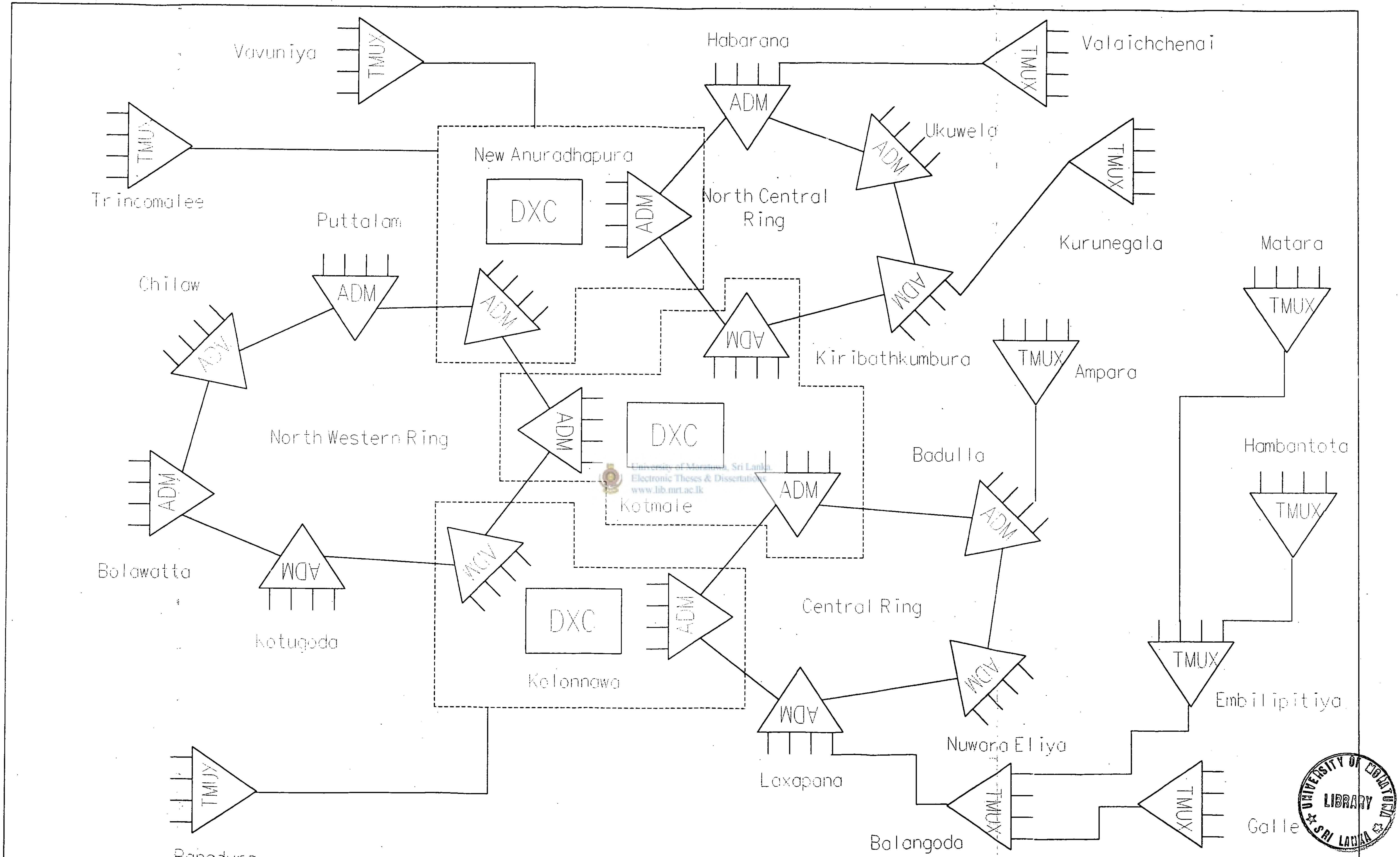
No.	Node	Type of Network Component
1.	Habarana	ADM (With Spur Link)
2.	New Anuradhapura	2 * ADM, DXC (Ring Interconnecting, With Spur Links)
3.	Kotmale	3 * ADM, DXC (Ring Interconnecting)
4.	Kiribathkumbura	ADM (With Spur Link)
5.	Ukuwela	ADM

3.3.3. North Western Ring

The Table 16 lists the components at each site that make – up the North Western ring.

Table 3.16.

No.	Node	Type of Network Component
1.	Kolonnawa	2 * ADM, DXC (Ring Interconnecting, With Spur Link)
2.	Kotmale	3 * ADM, DXC (Ring Interconnecting)
3.	New Anuradhapura	2 * ADM, DXC (Ring Interconnecting, With Spur Links)
4.	Puttalam	ADM
5.	Chilaw	ADM
6.	Bolawatta	ADM
7.	Kotugoda	ADM



Drawing No : 02	ISLAN-WIDE OPGW BASED SDH RING NETWORK FOR THE CEYLON ELECTRICITY BOARD

3.3.4. Spur Links

Table 3.17 shows the network components at each site that make up various spur links.

Table 3.17.

No.	Spur Link Set	Node	Type of Network Component
1.	Set 1	Balangoda	TMUX
		Galle	TMUX
		Embilipitiya	TMUX
		Matara	TMUX
		Hambantota	TMUX
2.	Set 2	Panadura	TMUX
3.	Set 3	Valaichenai	TMUX
4.	Set 4	Kurunegala	TMUX
5.	Set 5	Vavuniya	TMUX
6.	Set 6	Trincomalee	TMUX
7.	Set 7	Ampara	TMUX

3.4. *Determination of Transmission Capacities*

In order to calculate the capacity of each ring and spur links, it is required to assign the traffic requirements for each node. In the assignment of capacity for each node the following should be considered;

a. the ring interconnecting nodes should be assigned with adequate capacity to meet the traffic flow requirements of the ring interconnection.

b. the nodes with spur links should be assigned higher capacity to meet the transportation of traffic from the other connected nodes.

The above applies for the capacity determination of DXCs also.

3.4.1. Traffic Assignment

The actual traffic assignment for a network requires the study of the market demand and additional information. Hence, it is considered beyond the scope of this project. However, for the purpose of demonstration the following traffic flows have been assumed.

3.4.1.1. Central Ring

Table 3.18 lists the traffic assignments for the nodes in the central ring.

Table 3.18.

No.	Node	Type of Node	Capacity / (2Mbps)
1.	Kolonnawa	Ring Interconnecting Node	4000
2.	Kotmale	Ring Interconnecting Node	3000
3.	Badulla	Node with spur link	500
4.	Nuwara Eliya	Node	100
5.	Laxapana	Node with spur link	500

3.4.1.2. North Central Ring

Table 3.19 lists the traffic assignments for the nodes in the North Central Ring.

Table 3.19.

No.	Node	Type of Node	Capacity / (2Mbps)
1.	Kotmale	Ring Interconnecting Node	3000
2.	New Anuradhapura	Ring Interconnecting Node	1500
3.	Habarana	Node with spur link	500
4.	Kiribathkumbura	Node with Spur link	3000
5.	Ukuwela	Node	500

3.4.1.3. North Western Ring

Table 3.20 list the traffic assignments for the nodes in the North Western Ring.

Table 3.20.

No.	Node	Type of Node	Capacity / (2Mbps)
1.	Kolonnawa	Ring Interconnecting Node	3000
2.	Kotmale	Ring Interconnecting Node	2000
3.	New Anuradhapura	Ring Interconnecting Node	1500
4.	Puttalam	Node	100
5.	Chilaw	Node	100
6.	Bolawatta	Node	200
7.	Kotugoda	Node	200

3.4.2. Ring Capacities

In the calculation of the ring capacity, the knowledge of the type of protection system to be employed plays an important role. Assuming that the traffic at each node is split and routed both ways of the ring for protection, the following sample calculations for ring capacities have been made.

3.4.2.1. Central Ring

$$\text{Traffic in the ring} = \frac{\text{Total traffic from all nodes}}{2} \qquad (3.1)$$

$$= \frac{4000+3000+500+100+500}{2}$$

$$= 4050 * 2 \text{ Mbps channels}$$

Hence, the selected SDH capacity is STM-64.

3.4.2.2. North Central Ring

$$\text{Traffic in the ring} = \frac{\text{Total traffic from all nodes}}{2}$$

$$= \underline{3000+1500+500+3000+500}$$

$$= 4250 * 2\text{Mbps channels}$$

Hence the selected SDH capacity is STM-64.

3.4.2.3. *North Western Ring*

$$\text{Traffic in the ring} = \frac{\text{Total traffic from all nodes}}{2}$$

$$= \frac{3000+2000+1500+100+100+200+200}{2}$$

$$= 3550 * 2 \text{ Mbps channels}$$

Hence, the selected SDH capacity is STM-64.

3.5. *Puttalam – Anuradhapura Microwave Link Design*

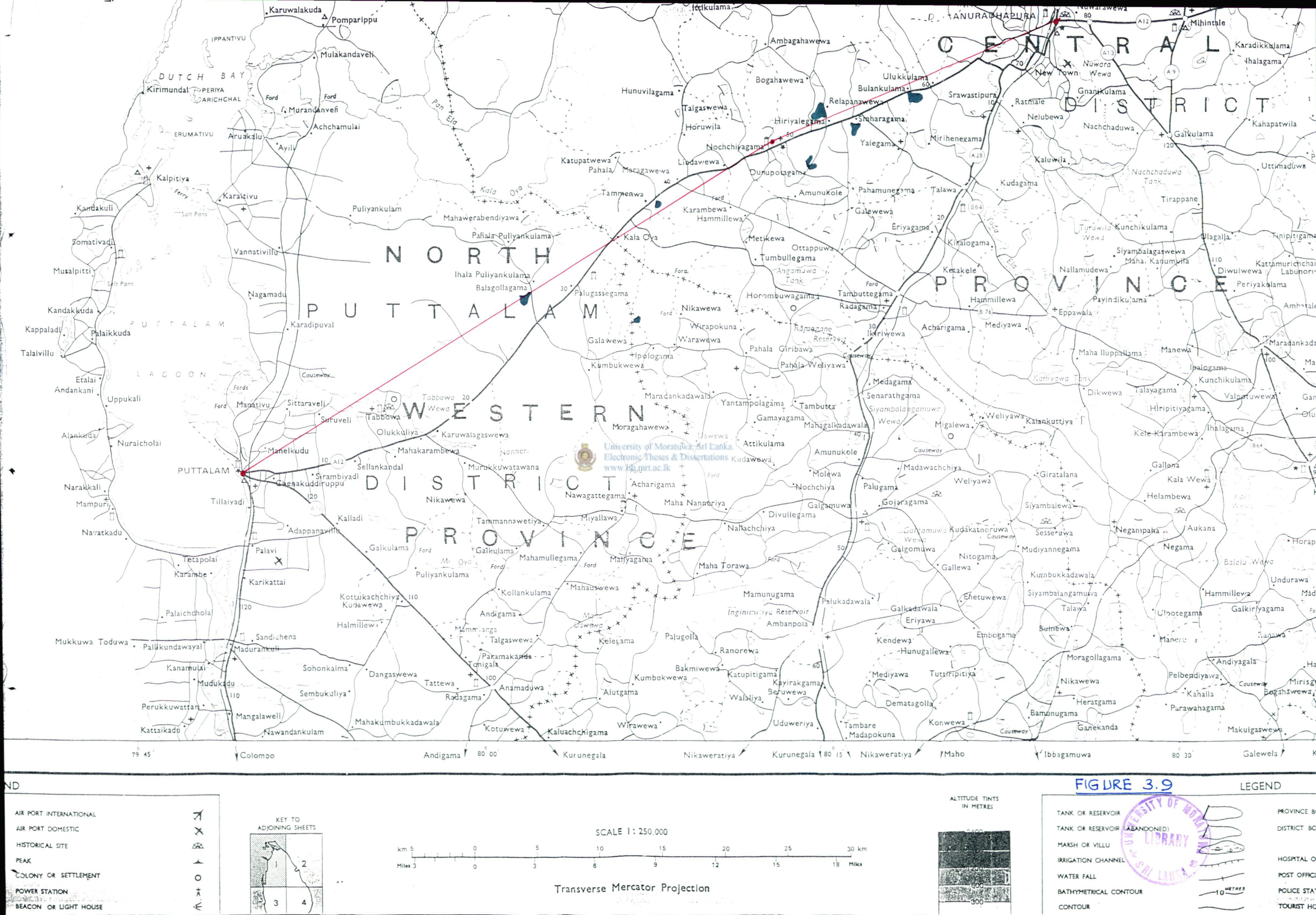
The direct hop length between the two sites is 70 km. As this long link cannot be designed as a single hop, due to the high frequency band of operation (8GHz) and high capacity of transmission (STM-64), it was decided to break the link in to two hops. To do this, an intermediate regenerative repeater was introduced at Nochchiyagama, where a Customer Service Centre had already been set-up. Hence, the hop distances are;

Puttalam – Nochchiyagama	50km
Nochchiyagama – Anuradhapura	25km

The preliminary investigation of the geographical map (1:250,000) reveals that the path profiles of both the hops consist of flat surface throughout their length. However, the Puttala - Nochchiyagama link passes through a water surface (lake) at Balagollagama, situated between 26^{th} – 27^{th} km from Puttalam. Hence, the antenna heights of both ends were adjusted so that the point of reflection falls at 23kms from Puttalam, avoiding the water surface. The point of reflection for both the links were thus considered to be falling on foliage.

3.5.1. Path profile

In order to draw the path profile, the size of the first freznel zone at 8GHz was calculated, at each 5km distance and is tabulated in tables 3.21, 3.22 for both the links.



NORTH WESTERN PROVINCE
PUTTALAM DISTRICT
CENTRAL PROVINCE
ANURADHAPURA DISTRICT
DUTCH BAY
PUTTALAM LAGOON
PUTTALAM
ANURADHAPURA
New Town
Mihintale
Kalpitiya
Nuwara Wewa
Kala Oya
Tabbowa Wewa
Nachchaduwa Tank
Karuwalakuda
Pomparippu
Mulakandaveli
Kirimundal
Vannativillu
Nagamadu
Karadipuval
Manelkudu
Sellankandal
Mahakarambewa
Karuwalagaswewa
Olukkuliya
Suruveli
Sittaraveli
Tammennawetiya
Nochchiyagama
Relapanawewa
Siharagama
Yalegama
Hiriyalegama
Ulukkulama
Bulankulama
Srawastipura
Ratmale
Nelubewa
Galkulama
Tambuttegama
Ikiriwewa
Galgamuwa
Kudakatnoruwa
Sesseruwa
Negampaha
Aukana
Negama
Ambanpola
Maha Torawa
Kaluachchigama
Colombo
Andigama
Kurunegala
Nikaweratiya
Maho
Ibbagamuwa
Galewela
79 45
80 00
80 15
80 30
LEGEND
AIR PORT INTERNATIONAL
AIR PORT DOMESTIC
HISTORICAL SITE
PEAK
COLONY OR SETTLEMENT
POWER STATION
BEACON OR LIGHT HOUSE
KEY TO ADJOINING SHEETS
SCALE 1 : 250,000
Transverse Mercator Projection
ALTITUDE TINTS IN METRES
TANK OR RESERVOIR
TANK OR RESERVOIR (ABANDONED)
MARSH OR VILLU
IRRIGATION CHANNEL
WATER FALL
BATHYMETRICAL CONTOUR
CONTOUR
PROVINCE B
DISTRICT BC
HOSPITAL O
POST OFFIC
POLICE STA
TOURIST HC

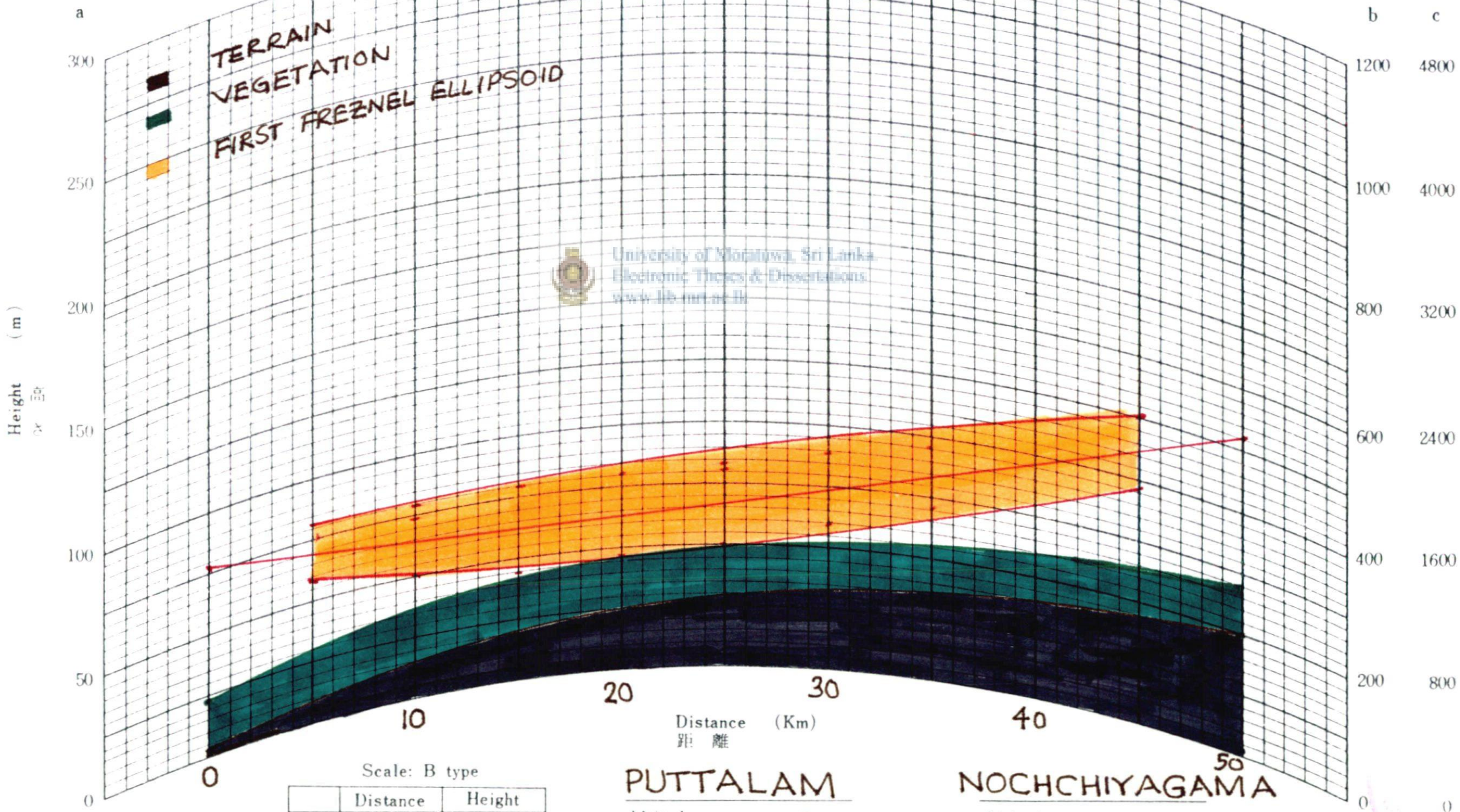
FIGURE 3.9

Note：1）The range of Distance and Height can be selected in the range marks, a, b, c.
2）Encircle one of these range marks, a, b, c, selected.

Terrain Profile 見透図

（K＝4/3）

注1）距離と高さの範囲は、a、b、cの中から選ぶことができます。
2）a、b、cのうち1つを選んで丸で囲む。



Scale: B type

	Distance	Height
a	60 km	300 m
b	120 km	1200 m
c	240 km	4800 m

PUTTALAM

Altitude 標高 3 m

Antenna Height 空中線地上高 77 m

← km →

NOCHCHIYAGAMA

Altitude 標高 50 m

Antenna Height 空中線地上高 80 m

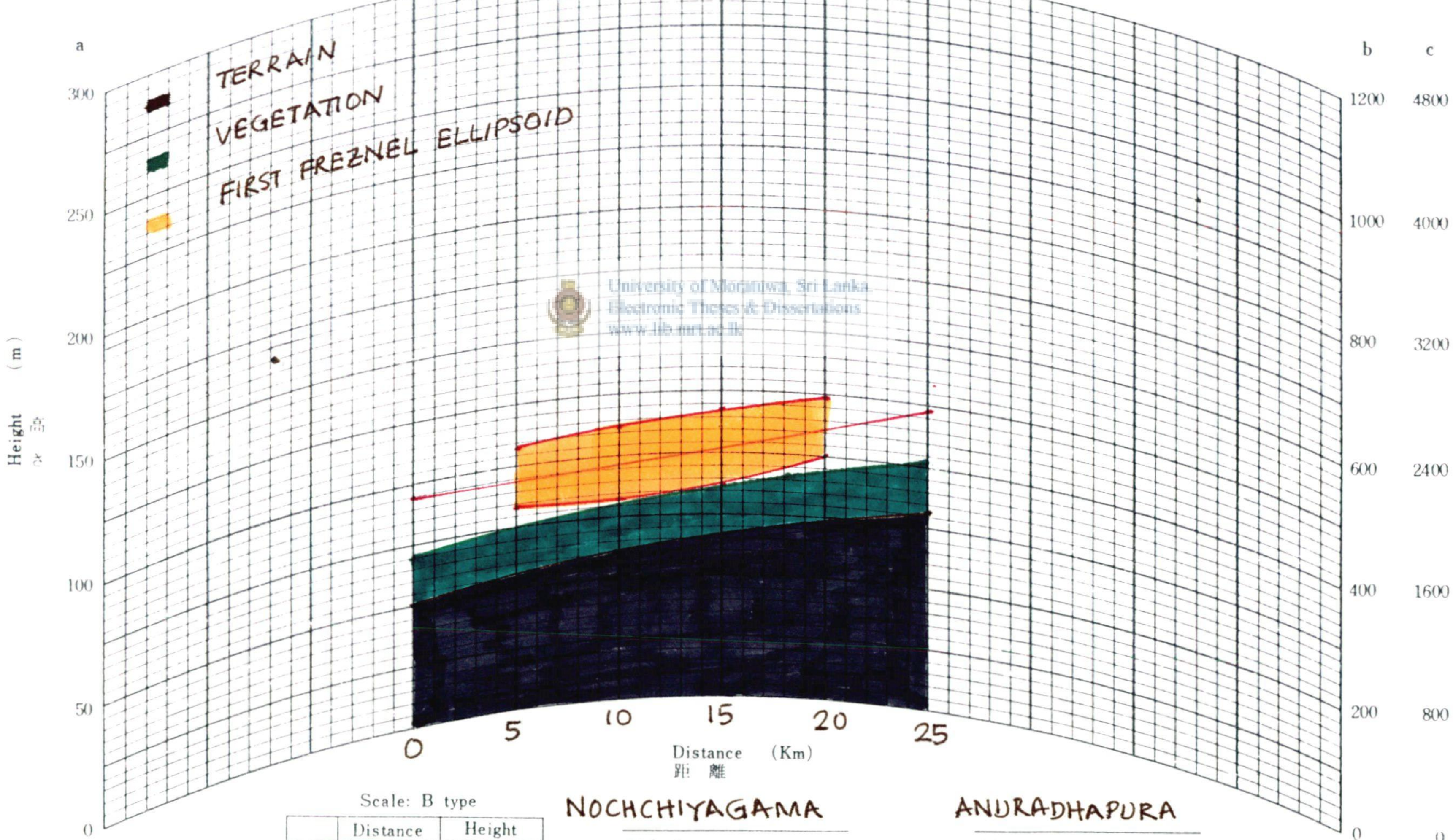
100% CLEARANCE AT 8GHz.

Note：1）The range of Distance and Height can be selected in the range marks, a, b, c.
2）Encircle one of these range marks, a, b, c, selected.

Terrain Profile 見透図

（K＝4/3）

注1）距離と高さの範囲は、a、b、cの中から選ぶことができます。
2）a、b、cのうち1つを選んで丸で囲む。



Scale: B type

	Distance	Height
a	60 km	300 m
b	120 km	1200 m
c	240 km	4800 m

NOCHCHIYAGAMA

Altitude 標高 50 m

Antenna Height 空中線地上高 45 m

←　km　→

ANURADHAPURA

Altitude 標高 82 m

Antenna Height 空中線地上高 48. m

100% CLEARANCE AT 8GHz.

Table 3.21: Puttalam – Nochchiyagama link

Distance d_1/ (km)	Distance d_2/ (km)	Size of Freznel Ellipsoid/ (m)
5	45	13
10	40	18
15	35	20
20	30	21
25	25	22
30	20	21
35	15	20
40	10	18
45	5	13

Table 3.22: Nochchiyagama – Anuradhapura Link

Distance d_1 / (km)	Distance d_2 / (km)	Size of Freznel Ellipsoid / (m)
5	20	13
10	15	15
15	10	15
20	5	13

The following antenna heights were determined from the path profile for the 100% clearance of the first Freznel ellipsoid at 8 GHz frequencies and for the requirements of the distance to point of reflection according to the CCITT recommendations.

Puttalam – Nochchiyagama:	Puttalam	77m
	Nochchiyagama	60m
Nochchiyagama – Anuradhapura:	Nochchiyagama	45m
	Anuradhapura	48m

3.5.2. Power Budget

To determine the power budget, the actual details of the system components are required. Hence, the performance figures of the following commercial products are used in the sample calculations, the specification sheets of which are given in the Appendix B;

a. 8GHz High Performance Antennas (HPX 15-82C) from Andrew Corporation, USA.
b. 8GHZ Elliptical Wave-guides (EWP77) from Andrew Corporation, USA.
c. Microwave Radios from Harris

A Microsoft Excel Power Budget Worksheet is given in Table 3.25 and Table 3.26.

TABLE: 3.25. MICROWAVE POWER BUDGET WORKSHEET

STATION A - to be entered PUTTALAM
STATION B - to be entered NOCHCHIYAGAMA

No.	Parameter	
1	Frequency / (MHz) - to be entered	8000
2	Path Length / (km)- to be entered	50
3	***Free Space Loss / (dB)***	***144.54***
4	Tx Antenna Gain / (dBi)- to be entered	48.7
5	Rx Antenna Gain / (dBi)- to be entered	48.7
6	Tx Feeder Length / (m)- to be entered	77
7	Rx Feeder Length / (m)- to be entered	60
8	Tx Feeder Attenuation / (dB/100m)- to be entered	5.75
9	Rx Feeder Attenuation / (dB/100m)- to be entered	5.75
10	***Tx Feeder Loss / (dB)***	***4.43***
11	***Rx Feeder Loss / (dB)***	***3.45***
12	Branching Loss / (dB) - assume	0.5
13	***Total Losses / (dB)***	***152.92***
14	***Total Gain / (dB)***	***97.4***
15	***System Loss / (dB)***	***55.52***
16	Tx Power / (dBm)- to be entered	30.5
17	***Rx Power / (dBm)***	***-25.02***
18	Rx Threshold (at BER 1E-6) / (dBm)- to be entered	-70
19	***Allowance for Fade Margin / (dB)***	***44.98***
20	Reliability Requirement for CCITT (R)- to be entered	0.9999

21	delta- to be entered	0.5
22	Q- to be entered	4
23	Flat Fade Margin / (dB)	40.79
24	Selective Fade Margin / (dB)	48.00
25	***Effective Fade Margin / (dB)***	***40.04***

TABLE: 3.26. MICROWAVE POWER BUDGET WORKSHEET

STATION A - to be entered NOCHCHIYAGAMA
STATION B - to be entered ANURADHAPURA

No.	Parameter	
1	Frequency / (MHz) - to be entered	8000
2	Path Length / (km)- to be entered	25
3	***Free Space Loss / (dB)***	***138.52***
4	Tx Antenna Gain / (dBi)- to be entered	48.7
5	Rx Antenna Gain / (dBi)- to be entered	48.7
6	Tx Feeder Length / (m)- to be entered	45
7	Rx Feeder Length / (m)- to be entered	48
8	Tx Feeder Attenuation / (dB/100m)- to be entered	5.75
9	Rx Feeder Attenuation / (dB/100m)- to be entered	5.75
10	***Tx Feeder Loss / (dB)***	***2.59***
11	***Rx Feeder Loss / (dB)***	***2.76***
12	Branching Loss / (dB) - assume	0.5
13	***Total Losses / (dB)***	***144.37***
14	***Total Gain / (dB)***	***97.4***
15	***System Loss / (dB)***	***46.97***
16	Tx Power / (dBm)- to be entered	30.5
17	***Rx Power / (dBm)***	***-16.47***
18	Rx Threshold (at BER 1E-6) / (dBm)- to be entered	-70
19	***Allowance for Fade Margin / (dB)***	***53.53***
20	Reliability Requirement for CCITT (R)- to be entered	0.9999

21	delta- to be entered	0.5
22	Q- to be entered	4
23	Flat Fade Margin / (dB)	31.76
24	Selective Fade Margin / (dB)	48.00
25	***Effective Fade Margin / (dB)***	***31.66***

3.6. Optical Links

3.6.1 A Typical OPGW Link

The figure 3.9 shows the typical schematic of an OPGW link, which is comprised of the following;

a. An OPGW line segment

b. Approach cable line segments

c. Fiber patch codes

d. Optical Line Terminating Equipment (OLTE)

e. Terminating Box for the approach cable

f. OPGW to Approach cable splice box

g. Transmission Towers spaced at typically 400m intervals

h. OPGW splice boxes along the transmission line placed at the tower legs.

The optical link design should be primarily focused on the two most important transmission characteristics; the attenuation and dispersion. The attenuation is dealt with a typical power budget calculation that follows this section and it is supplemented by an excel worksheet for the power budget calculation. The generated copies of this worksheet for each link in the network are given under Appendix E. A separate discussion that follows the power budget calculations analyses the dispersion.

For long haul, high capacity applications, where, dispersion is the limiting factor, the Non-Zero Dispersion Shifted Fiber (NZ-DSF/G.655) is preferred by most authorities over ordinary Single Mode Fibers (SMF/G.652) and Dispersion Shifted Fibers (DSF/G.653), owing to its potential to migrate to future multi-terabit DWDM transmission capacities, economically (RRref. 29 and Ref. 30). The G.652 fiber is not preferred due to its unacceptably high dispersion at the lowest attenuation window around 1550nm. The non-linear effects, at higher launched powers and high data rates near zero dispersion wavelength, of the G.653 fiber precludes the use of the same in high capacity DWDM transmission networks.

Considering the long life span (25 to 30 years) of the fibers installed today and their potential to migrate to high capacity DWDM transmission technologies in the very near future, the G.655 fiber is selected for this application.

A sample design for the longest link in the network, the Kotmale – Anuradhapura link of 163 km, below;

The following component specifications are used for this design;

1. *Fiber*

Manufacturer: Corning Inc.

Model: LEAF

Type: NZ-DSF (G.655)

Attenuation at 1550nm: 0.3 dB/km

Dispersion at 1530 – 1565nm: 2.0 to 6.0 ps/(km.nm)

2. *Optical Transceiver 1*

Manufacturer: Juniper Networks

Model: STM-64 PIC

Capacity: STM-64

Wavelength: 1550nm (C band)

Output power: +8 dBm

RX Sensitivity: -22 dBm

RX Saturation: -10 dBm

3. *Optical Transceiver 2*

Manufacturer: NEC Corporation

Model: SMS-2500A

Capacity: STM-16

Wavelength: 1550nm (C band)

Output Power: 0 dBm

Rx Sensitivity: -28 dBm

Source Line Width: <1nm

4. *Dispersion Compensating Module (DCM)-1*

Manufacturer: Avanex Corporation

Model: DCM NZ-DSF-80-336

Wavelength: 1550nm (C band)

Compensation: -336 ps/nm Nominal (Min -353; Max -319)

5. *Dispersion Compensating Module (DCM)-2*

Manufacturer: Avanex Corporation

Model: 60%LC-80-306

Wavelength: 1550nm (C band)

Compensation: -306 ps/nm Nominal (Min -321; Max -291)

6. *EDFA Booster Amplifier*

Manufacturer: Avanex Corporation

Model: PureGain 5500

Wavelength: 1550 nm (C band)

Gain: 30 dB

Output Power: +23 dBm

Input Range: -26 to +10 dBm

7. *EDFA Pre-Amplifier*

Manufacturer: Avanex Corporation

Model: PureGain 1000

Wavelength: 1550 nm (C band)

Gain Range: 13 to 30 dB

Output: +3 dBm

Input Power Range: -30 to -10 dBm

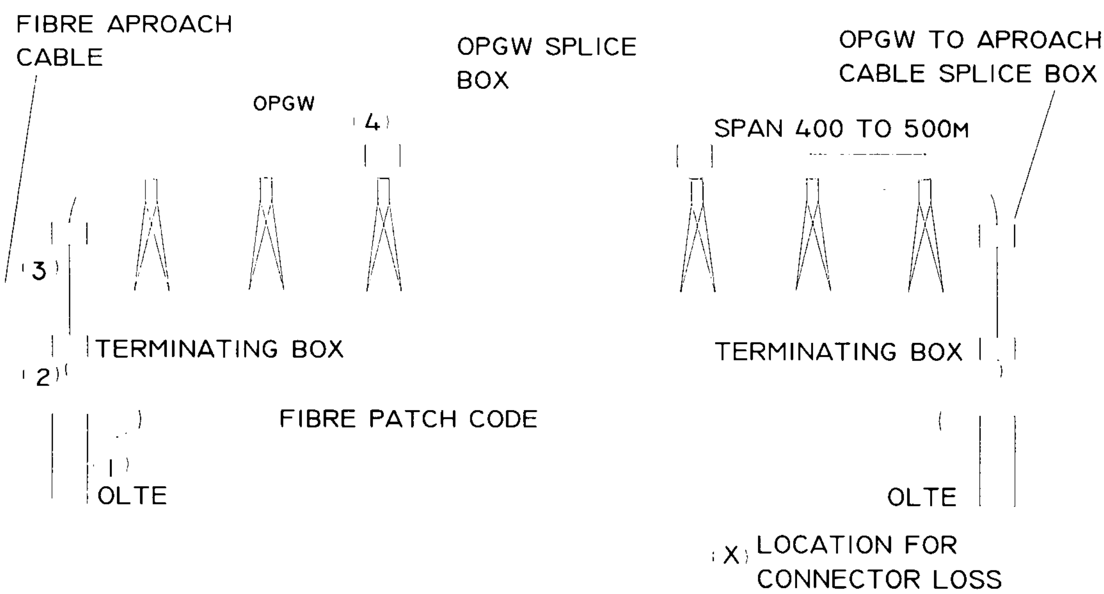


FIGURE 3.9: TYPICAL OPGW LINK

3.6.2. Power Budget Calculation for a Typical OPGW Link

Typical attenuation coefficient for the above G.655 fibre at 1550 nm

= 0.3 dB/ km

The following realistic values are obtained from Appendix C;

Typical single splice loss = 0.04 dB

Typical insertion loss for each pair of matched demountable connecters

= 0.25 dB

Typical splicing interval (Reel Length) of the OPGW cable

= 6 km

Length of the fiber approach cable = 500m

The typical power budget calculations are given below for the longest line in the network, the New Anuradhapura - Kotmale link.

Connector / Splicing Losses

Loss at location (1)	= 2*0.25 (....... demountable connectors)	
	= 0.5 dB	(3.4)
Loss at Location (2)	= 2*0.25 (....... demountable connectors)	
	= 0.5 dB	(3.5)
Loss at Location (3)	= 2*0.04 (........ fusion splicing)	
	=0.08 dB	(3.6)
Length of the line	= 163 km	
Span between the towers	= 400m	
Approximate number of spans	= 163 / 0.4	(3.7)
	= 408 spans (approximately)	
Splicing interval (Reel Length)	= 6 km	

Therefore, the splicing can be done at every 15 spans.

Hence, the number of splices	= (408/15) –1	(3.8)
	= 27 splices (approximately)	
Therefore, the total OPGW splice loss		
	= 27*0.04 (……. Fusion splicing)	
	= 1.08dB	(3.9)
The total connector/splicing losses		
	= 0.5+0.5+0.08+1.08	
	= 2.16dB	(3.10)

<u>Attenuation Losses</u>

Length of the OPGW cable	= 163 km	
Total OPGW attenuation	= 163*0.3	(3.2)
	= 48.9 dB	
Length of the approach cable	=2*0.5	(3.3)
	= 1 km	
Total approach cable attenuation	= 1*0.3	
	= 0.3 dB	(3.4)
Attenuation in the patch cable	= negligible	
Total attenuation loss	= 48.9+0.3	(3.5)
	= 49.2 dB	
Total system loss	= Attenuation Loss +	
	Connector/Splicing Loss	(3.6)
	= 49.2 + 2.16	
	<u>= 51.36 dB.</u>	

In addition, a margin is required for the ageing, fiber cuts (requiring a cable length to be included or a joint to be introduced), change in the physical path etc. and for other uncertainties in the fiber link.

An excel worksheet for power budget calculations, which can be used to calculate power budget for any of the link in the network is attaches in the Appendix E.

3.6.3 Dispersion Analysis

The Dispersion Parameter of the selected fiber	= 4 ps /(nm.km)
Total dispersion	= 4 X 163
	= 652 ps/nm
The maximum allowable dispersion at 10 Gbps	= 0.2/(10E+9)
	(........Senior)
	= 20 ps

Hence, assuming a source line width of 1 nm, the dispersion compensation required = 652 – 20

= 632 ps

Design- 1

Components: Optical Transceiver 1

Dispersion Compensation Module 1 or

Dispersion Compensation Module 2

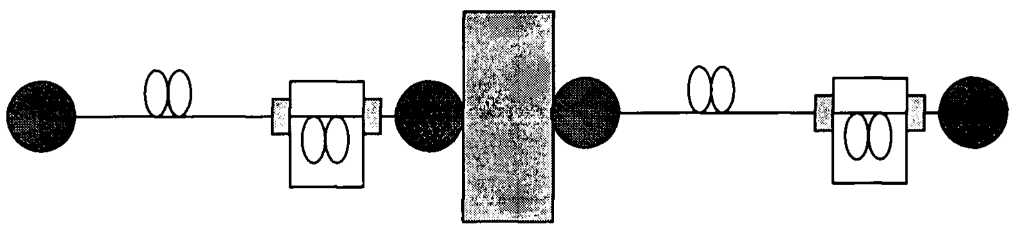
Regenerator

The above specification for Optical Transceiver 1 gives a maximum system gain of 30 dBm. This system gain is sufficient to meet the total system loss of half the link only.

The dispersion compensation requirement of 632 ps can only be compensated by two numbers of either of the compensating modules given above.

From the above attenuation and dispersion analyses, it is evident that the link cannot be established as a single hop and can be designed as two hops of equal length. The specification for the Optical Transceiver 1 also suggests this distance of around 80 km.

Hence, the possible configuration is given below;



TX FIBER DCM REGENERATOR FIBER DCM RX

Out of the twenty four links in the network, six links are much longer than 80km in length and hence, the same above arrangement can be applied to them. For the balance links that are shorter than or around 80 km, a regenerator will not be necessary. However, it will be required to compensate for the dispersion using the dispersion compensating modules.

Design- 2

Components: Optical Transceiver 1

EDFA Booster Amplifier

EDFA Pre Amplifier

Dispersion Compensating Module 1 or

Dispersion Compensating Module 2

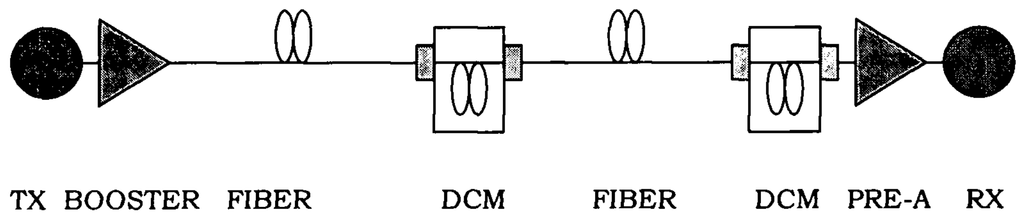
For the links much longer than 80 km, the alternative design is given below;

The combination of EDFA Booster Amplifier and Pre-Amplifier gives a total maximum gain of 60 dB. This gain figure is sufficient to meet the total loss figure calculated above.

The dispersion compensation requirement can be met as described in Design- 1.

Hence, by installing the Booster Amplifier at the transmit end and the Pre-Amplifier at the receive end, and installing one DCM at the mid-span and one at the receive end, the same link can be designed as repeater less link.

The configuration is given below;



3.7. Network Synchronization

Assuming Kolonnawa as the Network Control Centre, a PRC will be located here. Due to the larger geographical spread of the NEs and for the purpose of redundancy, another PRC will be located at Kotmale. However, this PRC will operate on the slave-mode. Synchronization Supply Units (SSUs) will be located at the following locations;

a. Laxapana

b. Badulla

c. New Anuradhapura

d. Kiribathkumbura

e. Habarana

f. Puttalam

g. Trincomalee

h. Vavuniya

i. Balangoda

3.7.1. Synchronization Signal Distribution

The distribution of the synchronization timing signal is shown in the figure 3.10.

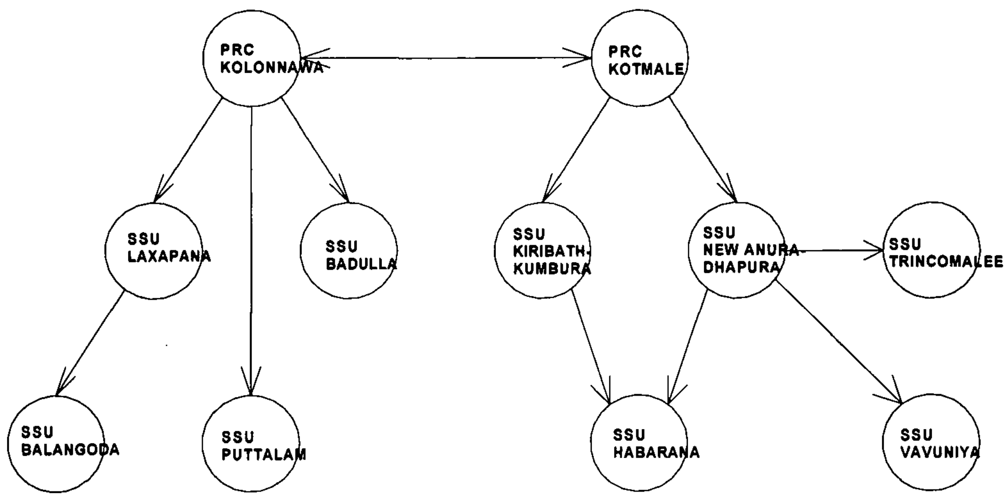


Figure 3.10.

Figure 3.11. shows the typical timing signal distribution arrangement for the Central Ring.

Table 3.27. shows the synchronization source list for the NEs in the Central Ring.

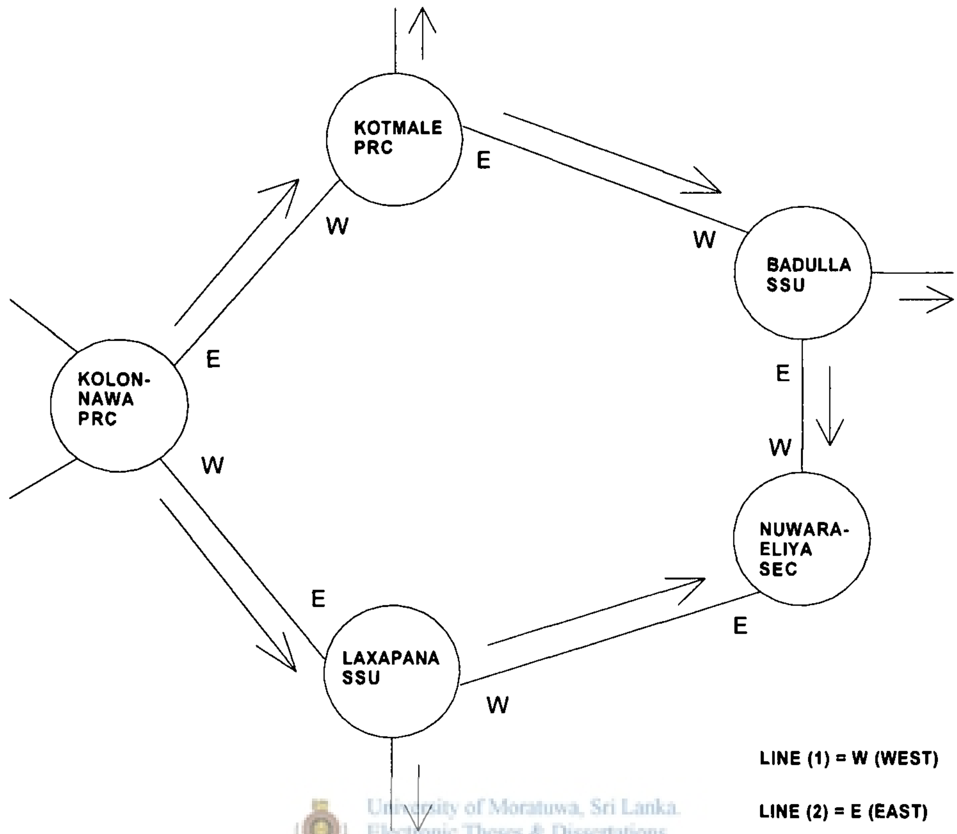


Figure 3.11.

Table 3.27.

Node	Source List
Kolonnawa	1. PRC (G.811) 2. Line (2) 3. Holdover
Kotmale	1. Line (1) 2. PRC 3. Holdover
Badulla	1. Line (1) 2. SSU 3. Holdover
Nuwara Eliya	1. Line (1) 2. Line (2) 3. Holdover
Laxapana	1. Line (2) 2. SSU 3. Holdover

4. Protection Against Lightning

4.1. Fibre Protection

Although optical fibers, naturally, are immune against any Electromagnetic Interferences (EMI), especially the lightening surges, special attention is required with regard to OPGW, as it is meant to carry lightening and earth fault currents, as does an ordinary earth wire. Hence, OPGW specifications restrict variation in optical characteristic, under given fault current conditions (typically 20 kA or more) and duration (typically 0.1 seconds) and lightning currents (typically 200 kA peak).

The IEEE Std 1138-1994 requires that the fiber optic unit and the outer stranded conductors of the OPGW, to serve together as an integral unit to protect the fiber from degradations due to vibration and galloping, wind and ice loadings, wide temperature variations, *lightning and fault currents.* It also calls for a short circuit test to be performed on a sample of the complete cable and specifies the maximum temporary change in attenuation due to lightning, fault current and temperature cycling.

4.2. Equipment Protection

The OPGW cable is grounded at every tower along the line as done with ordinary ground wires, to sink all the lightning currents to earth through tower earth. However, there is the possibility of existence of dangerous induced voltages on the tail end of the OPGW, beyond the last earth point. This problem is addressed by the inclusion of the Fibre Optical Approach

Cable (FOAC) between the equipment end and the OPGW. The FOAC, an essentially all dielectric cable, running between terminating box at the equipment housing and the tower, provides a separation not less than 500m and is spliced with OPGW at the tower leg. Figure 4.1, shows the photograph of OPGW/FOAC splicing and Figure 4.2, shows the photograph of the wall mounted FOAC Terminating Box (CEB, Kelanitissa Power Station).

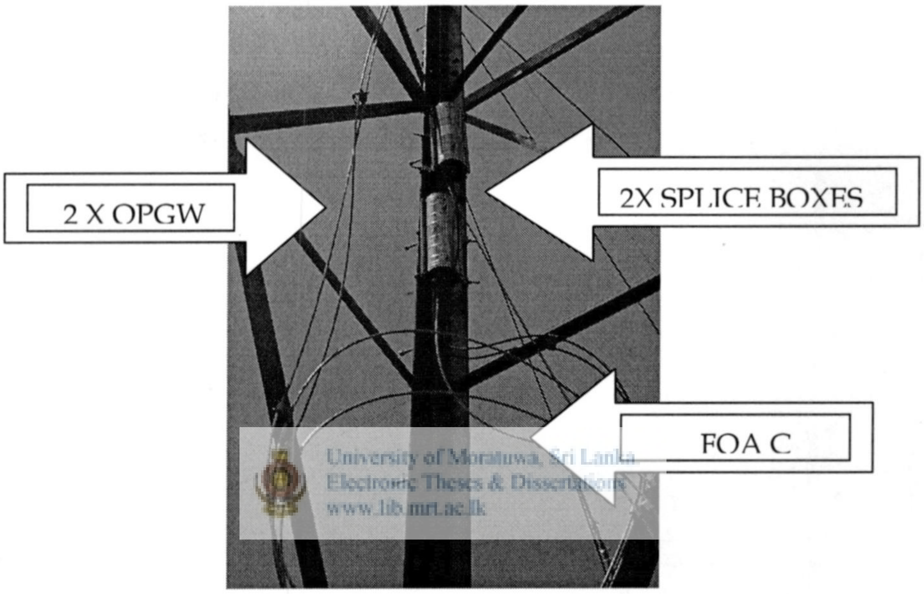


Figure 4.1: OPGW/FOAC Splice Box on the Tower Leg

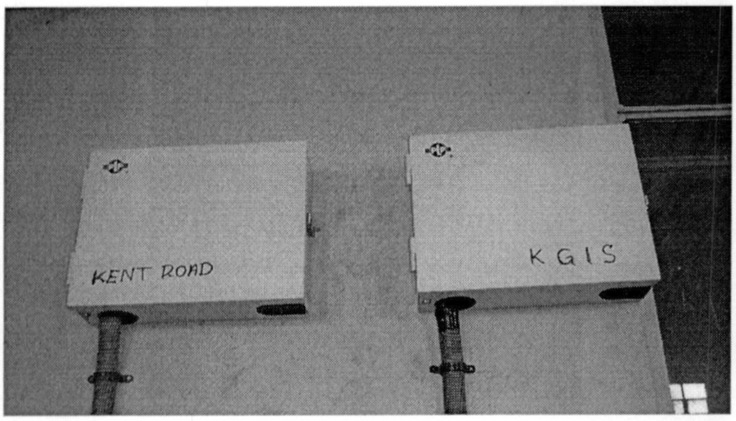


Figure 4.2: Wall Mounted FOAC Terminating Box

5. Cost Analysis

The total network cost basically includes three major components; the cost of the OPGW links, the cost of the end equipment and the civil infrastructure cost. The analysis of the civil infrastructure cost is beyond the scope of this project. The cost of OPGW links and the cost of the end equipment are analyzed here.

The cost of the OPGW links includes the material cost and the erection cost. The erection cost is significant in this case.

The end equipment at each node are the Optical Line Terminal Equipment (OLTE) such as SDH Multiplexers, the Digital Cross Connect (DXC) equipment, Centralized Supervisory Systems, Optical Terminal/Digital Distribution Frames, Power Supplies etc. The costing for power supplies is not included in the analysis as the power supply requirements at each node is different. Many of the latest substations are already equipped with rectified DC power, which are used for the substation control system. As they are very large in capacity it should be possible to make use of them for the communication requirements as well.

The typical cost figures for the cost analysis, were obtained from several local projects recently implemented by local agencies and are given below;

OPGW Links

12 Fiber core OPGW cable	=	US$ 6500.00 /km
24 Fiber core OPGW cable	=	US$ 8500.00 /km
FOAC/ Terminal Box/ Patch Code	=	US$ 2700.00 /Lot
Erection cost	=	US$ 2500.00 /km
Cost of Removal of Existing Earth Wire	=	US$ 850.00 /km

Equipment Cost

STM-64 SDH Multiplexer	=	JP¥ 25,000,000.00
STM-16 SDH Multiplexer	=	JP¥ 10,000,000.00
STM-4 SDH Multiplexer	=	JP¥ 4,500,000.00
DXC	=	JP¥ 25,000,000.00
Optical Terminal/ DDF	=	JP¥ 200,000.00
Centralized Supervisory System	=	JP¥ 25,000,000.00
Local Supervisory System	=	JP¥ 1,000,000.00
STM-64 Regenerator	=	JP¥ 10,000,000.00

The prices given above are FOB (Freight On Board).

5.1. Cost of the OPGW link

Table 4.1 list the cost of each link in the system;

Table 5.1.

No.	Link	Length /(km)	Cost (US$)
1.	Ukuwela –Habarana	82.3	977,955.00
2.	Habarana- New Anuradhapura	50.4	599,940.00
3.	New Anuradhapura – Kotmale	163	1,934,250.00
4.	Kotmale – Kiribathkumbura	22.5	269,325.00
5.	Kiribathkumbura – Ukuwela	29.9	357,015.00
6.	Kolonnawa – Kotmale	85.2	1,012,320.00
7.	Kotmale – Badulla	82.6	981,510.00
8.	Badulla – Laxapana	74.2	881,970.00
9.	Laxapana – Kolonnawa	104.2	1,237,470.00
10.	Kolonnawa – Kotugoda	23.3	278,805.00
11.	Kotugoda Bolawatta	21	251,550.00
12.	Bolawatta – Chilaw	29.4	351,090.00
13.	Chilaw – Puttalam	68.2	810,870.00
14.	Laxapana – Balangoda	44.5	530,025.00
15.	Balangoda – Galle	102.5	1,217,325.00
16.	Balangoda – Embilipitiya	78	927,000.00
17.	Embilipitiya – Matara	52	618,900.00
18.	Embilipitiya - Hambantota	35	417,450.00
19.	Kolonnawa – Panadura	11.7	141,345.00
20.	Habarana – Valaichchenai	99.7	1,184,145.00
21.	Kiribathkumbura – Kurunegala	34.6	412,710.00
22.	New Anuradhapura – Vavuniya	53.5	636,675.00
23.	New Anuradhapura – Trincomalee	103.3	1,226,805.00
24.	Badulla – Ampara	104.9	1,245,765.00
	Total (US$)		16,601,815.00

These link costs were calculated for repeater-less transmission. However, there are six links in the network that are much larger than 80 km. Hence, additional cost should be included for Design-1 and Design-2 to include the cost of Regenerators, Booster Amplifiers, Pre-Amplifiers, DCM etc.

5.2. Cost of End Equipment

Table 4.2 list the cost of each node;

Table 5.2.

No.	Node	Equipment	Cost (JP¥)
	Central Ring (STM-64)		
1.	Kolonnawa	ADM/DDF/DXC	50,200,000.00
2.	Kotmale	ADM/DDF/DXC	50,200,000.00
3.	Badulla	ADM/DDF	25,200,000.00
4.	Nuwara Eliya	ADM/DDF	25,200,000.00
5.	Laxapana	ADM/DDF	25,200,000.00
	North Central Ring (STM-64)		
1.	Kotmale	ADM/DDF	25,200,000.00
2.	New Anuradhapura	ADM/DDF/DXC	50,200,000.00
3.	Habarana	ADM/DDF	25,200,000.00
4.	Kiribathkumbura	ADM/DDF	25,200,000.00
5.	Ukuwela	ADM/DDF	25,200,000.00
	North Western Ring (STM-64)		
1.	Kolonnawa	ADM/DDF	25,200,000.00
2.	Kotmale	ADM/DDF	25,200,000.00
3.	New Anuradhapura	ADM/DDF	25,200,000.00
4.	Puttalam	ADM/DDF	25,200,000.00
5.	Chilaw	ADM/DDF	25,200,000.00
6.	Bolawatta	ADM/DDF	25,200,000.00
7.	Kotugoda	ADM/DDF	25,200,000.00
	Spur Links (STM – 4)		
1.	Vavuniya	TMUX/DDF	4,700,000.00
2.	Trincomalee	TMUX/DDF	4,700,000.00
3.	Valaichchenai	TMUX/DDF	4,700,000.00
4.	Kurunegala	TMUX/DDF	4,700,000.00
5.	Amapara	TMUX/DDF	4,700,000.00
6.	Matara	TMUX/DDF	4,700,000.00
7.	Hambantota	TMUX/DDF	4,700,000.00
8.	Embilipitiya	TMUX/DDF	4,700,000.00
9.	Galle	TMUX/DDF	4,700,000.00
10.	Balangoda	TMUX/DDF	4,700,000.00
11.	Panadura	TMUX/DDF	4,700,000.00
	Total (JP¥)		555,100,000.00

To the above equipment cost the cost of the Supervisory system should be added. Assuming a local supervisory terminal for each node and a Centralized supervisory system for each ring, the cost of the Supervisory system is as follows;

Centralized Supervisory system	=	JP¥	25,000,000.00 X 3
	=	JP¥	75,000,000.00
Local Supervisory system	=	JP¥	1,000,000.00 X 28
	=	JP¥	28,000,000.00
Grand Total (Equipment)	=	JP¥	658,100,000.00

5.3. Total Project Cost

The total project cost is the summation of OPGW link cost and the Equipment cost.

OPGW link cost	=	US$	16,601,815.00
Equipment cost	=	JP¥	658,100,000.00
Grand Total (SLR equivalent)	**=**	**SLR**	**2,024,381,795.00**

Note: 1 US$ = 93 SLR

1 JP¥ = 0.73 SLR

6. Further Discussion

6.1. *Comparison of different methods of incorporating fibers on High Voltage transmission lines*

On new lines the OPGW is the most obvious and economic choice. However, this requires the planning of the OPGW installation with that of the HV transmission line itself. This may not be possible in many circumstances. In order to plan for the OPGW, there should be an overall plan for the complete fibre transmission network before hand and it also requires the knowledge of the terminal equipment and their locations.

On the other hand, technologies have also been developed by many institutions to replace the existing ground wires with OPGW even on a 400kV line under live condition without any service interruptions. (Appendix A).

ADSS is simple to be introduced on an existing live line. As it is strung at a lower elevation, it is relatively easy to be drawn also, without additional precautions for the operator safety. However, ADSS is more prone to shot gun damages by bird hunters. This is a serious issue, as HV transmission lines usually pass forests. Some cable suppliers claim their product to be safe against shotgun damages.

In case the replacement of the existing earth wire by OPGW is considered costly and the ADSS is not preferred, then the next choice is the Wrap-around Cable. Special wrapping tools are also available for wrapping under live line conditions.

6.2. Comparison of project cost

The total project cost of SLR 2,024,381,795.00 is compared with a recently completed island-wide SDH ring project of the Sri Lanka Telecom, based on underground optical fibre network (an unofficial copy of the network diagram is given under Appendix – F). The total contract price of this project (unofficial) JPY 3.5 billion (foreign component) plus SLR 800 million (local component). With the same conversion rate used above the project cost in local currency is SLR 3,355,000,000.00.

The equipment prices used for the analysis are same as those of the equipment used in the Sri Lanka Telecom (SLT) project. Therefore, it is evident that the price difference should largely be due the fiber cabling. In the SLT project the fiber cabling is underground in which the cost of the civil works is very high. Whereas, in this project, we are making use of the already existing civil infrastructure for HV transmission.

In addition, in this project the costing was done for a 24-fiber OPGW cable. However, the proposed network will only make use of four fibers for a Four Fiber BLSR protection system. Therefore, an additional count of eight fibers is available for further development. Hence, it is evident that the use of OPGW for high capacity data transmission is a very efficient and cost effective option for power utilities.

Another factor to consider in the cost analysis is the fiber count. It can be seen from the unit prices that the percentage price difference between 12 core fiber cable and the 24 core fiber cable (doubling the fiber count) is only about 30%. This becomes further insignificant when compared with the total project cost of the transmission line. This is the scenario even with very large fiber count, the reason why many utilities tend to put higher and higher fiber counts, whether they plans to use them in the near future or not.

6.3. A Case Study

The above study was based on assumed traffic for each node and the selection criteria was the coverage of the whole island as much as possible by the information superhighway.

For the purpose of simulation of the above design, a case study of an actual traffic situation is considered here. The forecasted traffic flows between major cities were obtained from Reference 31, which was also a research study for a masters program.

The Table 6.1 below lists the traffic flow between selected major cities;

Table 6.1: Traffic Flow

No.	Link	Accumulated Traffic /(Mbps)
1.	Colombo – Gampaha	10,581
2.	Gampaha – Negombo	6,710
3.	Negombo – Kurunegala	5,678
4.	Kurunegala – Anuradhapura	1,671
5.	Anuradhapura – Jaffana	197
6.	Kurunegala – Kandy	1,814
7.	Kandy – Batticaloa	1,703
8.	Kandy – Matara	5,809
9.	Matara – Galle	5,809
10.	Galle – Kalutara	8,984
11.	Kalutara – Colombo	11,086

These cities should be matched to the nodes in the power transmission network.

The Table 6.2 below lists the nearest nodes.

Table 6.2: Matching of Cities to Nodes

No.	City	Nearest Node
1.	Colombo	Kolonnawa
2.	Gampaha	Kotugoda
3.	Negombo	Bolawatta
4.	Kurunegala	Kurunegala
5.	Anuradhapura	New Anuradhapura
6.	Jaffna	Vavuniya
7.	Kandy	Kribathkumbura
8.	Batticaloa	Valaichchenai
9.	Matara	Matara
10.	Galle	Galle
11.	Kalutara	Panadura

Mapping these nodes on the power transmission network, the optimum network topology was selected by trial and error method.

Considering this topology and the original traffic flow input between cities, we can re-calculate the traffic between the nodes to determine the link capacities.

Table 6.3 lists the traffic flow between nodes and the selected SDH capacity. The links that exceed the STM-64 capacity can be served by a combination of one STM-64 capacity and other low order capacity on separate pairs of fibers, using the surplus fibers in the cable.

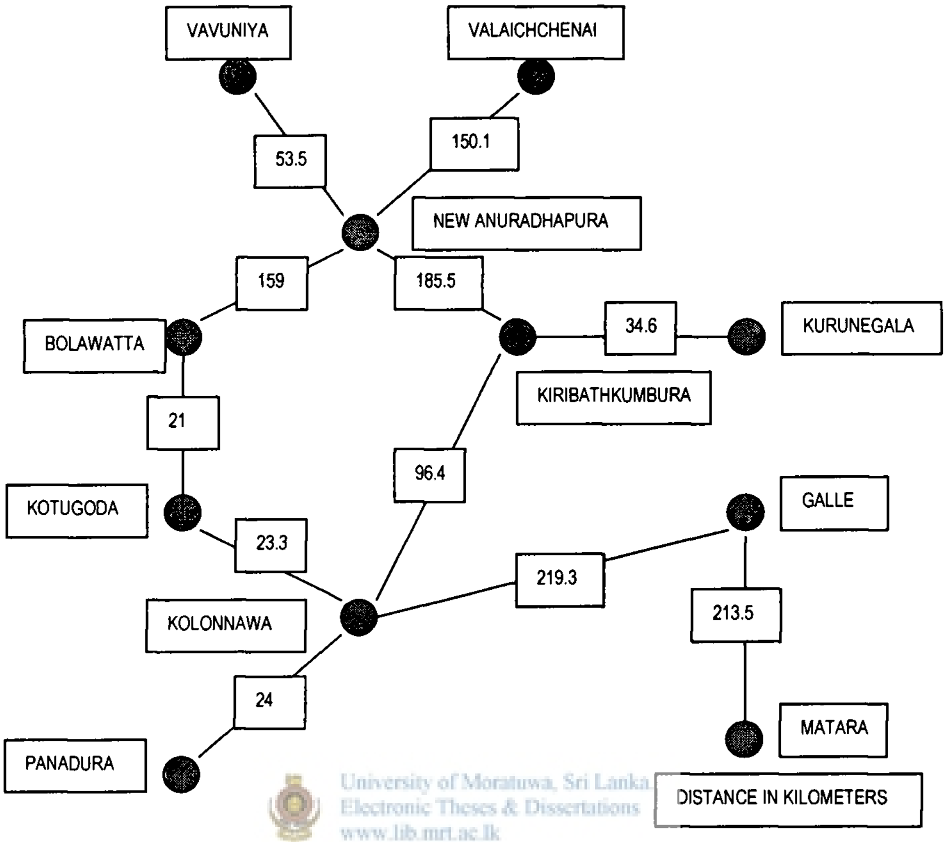


Figure 6.1: Network Topology

Table 6.3: Link Capacity Calculation

No.	Link	Traffic /(Mbps)	STM-N
1.	Kolonnawa – Kotugoda	10,581	STM-64
2.	Kotugoda – Bolawatta	6,710	STM-64
3.	Bolawatta – New Anuradhapura	5,678	STM-64
4.	New Anuradhapura – Kiribathkumbura	9,052	STM-64
5.	Kiribathkumbura – Kolonnawa	5,809	STM-64
6.	Kiribathkumbura – Kurunegala	9.163	STM-64
7.	New Anuradhapura – Vavuniya	197	STM-4
8.	New Anuradhapura – Valaichchenai	1,703	STM-16
9.	Kolonnawa – Panadura	20,070	2X STM-64
10.	Kolonnawa – Galle	14,793	2X STM-64
11.	Galle – Matara	11,618	STM-64 + STM-16

The longest link in the network is the Kolonnawa – Galle link, which is 219.3 km. This link can be designed as follows;

Design –1:

Considering the 80 km Regenerator interval, as above, two Regenerators will be required and they can be installed at New Laxapana and Deniyaya. The dispersion compensation modules also will be required at these locations and at Galle.

Design – 2:

This is a repeater-less transmission design and due to the available system gain limitation even with the Booster-Pre Amplifier combination, cannot be used for this distance, at this link capacity.

Out of the eleven links in the network, six links are much longer than 80 km and would require one or more of the regenerative repeaters.

Table 6.4 gives the line costs including the Regenerator costs;

Table 6.4: Line Cost

No	Link	Distance /(km)	No of Regen.	Line Cost / (US$)	Regen. Cost /(JPY)
1.	Kolonnawa - Kotugoda	23.3	0	278,805.00	0.00
2.	Kotugoda – Bolawatte	21.0	0	251,550.00	0.00
3.	Bolawatte – New Anura.	159.0	1	1,886,850.00	10,000,000.00
4.	New Anura.– Kiribathku.	185.5	2	2,200,875.00	20,000,000.00
5.	Kiribathku. – Kolonnawa	96.4	1	1,145,040.00	10,000,000.00
6.	Kiribathku.– Kurunegala	34.6	0	412,710.00	0.00
7.	Kolonnawa – Panadura	24.0	0	287,100.00	0.00
8.	Kolonnawa – Galle	219.3	2	2,601,405.00	20,000,000.00
9.	Galle - Matara	213.5	2	2,532,675.00	20,000,000.00
10.	New Anura. – Vavuniya	53.5	0	636,675.00	0.00
11.	New Anura. – Valaichen.	150.1	1	1,781,385.00	10,000,000.00
	Grand Total	1180.2		14,015,070.00	90,000,000.00

Table 6.5 gives the End Equipment costs;

Table 6.5: End Equipment Costs

No.	Node	Equipment	Equipment Cost /(JPY)
1.	Kolonnawa	ADM (STM-64)	25,000,000.00
2.	Kotugoda	ADM (STM-64)	25,000,000.00
3.	Bolawatte	ADM (STM-64)	25,000,000.00
4.	New Anuradhapura	ADM (STM-64)	25,000,000.00
5.	Kiribathkumbura	ADM (STM-64)	25,000,000.00
6.	Kurunegala	TMUX (STM-64)	25,000,000.00
7.	Panadura	TMUX (STM-64)	25,000,000.00
8.	Galle	TMUX (STM-64)	25,000,000.00
9.	Matara	TMUX (STM-64)	25,000,000.00
10.	Vavuniya	TMUX (STM-4)	4,500,000.00
11.	Valaichchenai	TMUX (STM-16)	10,000,000.00
	Grand Total		239,500,000.00

With the previous conversion rate, the total cost of the project can be calculated as;

Total Project Cost = Line Cost + Equipment Cost

= SLR 1,543,936,510.00

This is in the same order as that of the previously calculated network cost.

6.4. Marketing Aspects

The optical fiber transmission capacity can be marketed in several ways, depending on the infrastructure, experience and the committed business policy and strategy of the utility company. Some of the commonly practiced ways of marketing the fiber capacity are discussed here;

a. *Leasing the Right of Way*

Under this method the utility leases its right of way to lay fibers in the high-tension lines to other potential company under a lease agreement or enter in to a partnership agreement with a company having the technical and business experience in the field to roll out the fiber network. The revenue is shared among the companies.

b. *Leasing the Dark Fibers*

The utility rolls out the fiber network with sufficiently large fiber counts. The dark fibers can be leased for other operators for a specific period of time under a leased agreement. The operator is free to squeeze the maximum capacity of the fiber using whatever the techniques available them.

c. *Leasing the Wavelength*

The utility employs WDM technology and leases out the capacity in the form of number of wavelengths to other operators. It would be required to impose clear guidelines to avoid any cross talks between wavelengths that originate from different sources of different operators.

d. Leasing Transmission Capacity

The utility can install all the required end equipment and lease out the transmission capacity in Mbps to other operators. Here, the utility has the responsibility of maintaining the reliability of the network, at the committed level.

e. *The Utility as a Service Provider*

The utility can up subsidiaries and become a telecommunication service provider. The possible services may be public telephony, data services, Internet services etc.

From a. to e. above, the technical complexity, business commitment, capital investment and also the revenue increase. Depending on the capacity of the utility, it can select one or combination of more than one business models given above.

Another option is to expand its business in a planned stage-by-stage way, starting from model with lower commitment to higher commitment. It this way the investment risk is avoided while still leaving room for future expansion of the business. This will also give sufficient time for the utility to build up its human resources and technical and marketing expertise, without loosing the opportunities.

7. List of Recommendations

From the findings of this paper, it is recommended that the power utility shall:

1. Make full use of the extremely valuable right-of-way, which is naturally available for her (and which is not easily available for other operators) to quickly and cost effectively establish an island-wide high capacity transmission network and extend these carrier services to other agencies, for the common benefit.

2. Introduce OPGW on all new transmission lines whether it is immediately used or not, as the incremental cost incurred in introducing OPGW in place of conventional ground wires is very minimal compared to the cost of the transmission line project. The cost of the OPGW cabling is a minor fraction when compared with the project cost of the transmission line. Hence, increase the fiber count as much as possible, even if there is no any plan to use them in the near future, considering marginal increase in cost with the fiber count and the very long life time of the fibers installed today.

3. Use SDH as the transmission protocol for such a high capacity transmission network, as this will make full use of the extremely large bandwidth available with optical fibers.

4. Employ ring architectures to increase the reliability of the network.

5. Lease the transmission capacity, rather than the dark fibers, as the former will produce more revenue, in the case of the commercial leasing to outside agencies.

6. Consider the following access technologies to extend the carrier services from grid substations/Substation to commercial customers;

- ♦ Another fiber optic access network based on the medium voltage distribution network
- ♦ Point-to-point microwave links
- ♦ High capacity Multi Access Radio (MAR) systems. (technical details of a typical high capacity multi access radio system is attached in the Appendix-B)

7. Break the total network plan in to number of implementation stages (a separate implementation plan will be required) and execute them in a stage-by stage fashion according to the priorities determined by the market force, so as to save on the capital expenditure and to reduce the investment risk.

8. At the time this project was started the Puttalam – Anuradhapura line was not available and therefore this project attemted to design a microwave link between these nodes. As this line has now been constructed, it is recommended to use OPGW on this line also.

8. Drawbacks

The following drawbacks have been identified in this project;

1. In order to find the capacity requirement of each node, the traffic flow for each node in the ring has been assumed. However, in practice, market surveys have to be conducted among prospective customers, before deciding on the node capacities.

2. In the design of the Puttalam – Anuradhapura radio link, the specification of the radio used was that of a STM-1, 7/8 GHz radio. However, the same data was used for STM-64 capacity, due the difficulty of finding the relevant technical information for STM-64 radios.

3. The prices used in the cost analysis are FOB (Freight On Board) values. To find the actual cost of the project, the freight charges as well as the government taxes should be added to this cost.

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APPENDIX – A:

LITERATURE ON OPGW CABLE STRINGING METHOD

APPENDIX B

CRADLE BLOCK STRINGING OF FIBRE OPTIC EARTHWIRES

Power utilities are under increasing commercial pressure to maintain power connections and reduce outage times when installing Fibre Optic Earthwires.

The technique of live line "Cradle Block' stringing overcomes this problem. This technique has been used in Japan, Canada and others but not under live line conditions. New Zealand has some experience of live line installation but the technique has now been fairly refined and proven in the UK under 400 kV live line conditions.

The technique consists of setting out a number of cradle blocks to enable a new earthwire to be drawn in under live line working conditions. The general arrangement is shown in figure H. For safety reasons a cradle block is required every 10 metres on UK 400 kV lines. This ensures that any breakage of conductor or pulling rope will not contact a live conductor and cause a safety or power system problem.

CRADLE BLOCK AND MACHINERY HANDLING

The key component to this technique is the Cradle Block itself illustrated in figure 5. It is required to have an extremely low rolling resistance to enable up to 6 km drum lengths to be installed as a single section. This will involve some 600 cradle blocks. Earth continuity must be maintained throughout the block to avoid capacitively induced voltage appearing on the long and parallel un-earthed components which will lead to flash over and damage. In addition operator safety would be jeopardised.

To assist in the handling of machinery at tower peaks it is normal to make use of a lifting jib **shown in figure** D. Also **for deployment** of cradle blocks suitable containers are also temporarily mounted near the tower peak and provides for uninterrupted attachment along each span.

CRADLE BLOCK STRINGING METHOD

The following numbers refer to the Process steps shown on 3 **separate diagrams.**

Positioning of cradle blocks - a Pulling Rope and conductor Connecting Rope are deployed using a tug unit along the existing earthwire. Cradle Blocks are attached to the enacting rope every 10 m as the Pulling Rope is deployed.

2 The new optical earthwire is attached to the Pulling Rope using a special high integrity connector shown in figure 7 and drawn in. Thus the cradle blocks and pulling rope are supported by the existing earthwire.

3 When pulling is completed the new earthwire is supported by the cradle blocks. The new earthwire is then sagged using conventional sighting techniques.

5 The final sagging ensures that the new earthwire turns the cradle blocks over and is now supporting the cradle blocks and old earthwire.

6 The old earthwire may readily be drawn OUI on the bottom rollers of the cradle block.

7 A Tail Rope is also drawn through the cradle blocks to control the 'runaway" of the old earthwire.

8 The cradle blocks are then collected by pulling on the "Pulling Rappel and "Runaway" is controlled by a special friction braked roller unit shown in **figure 6**.

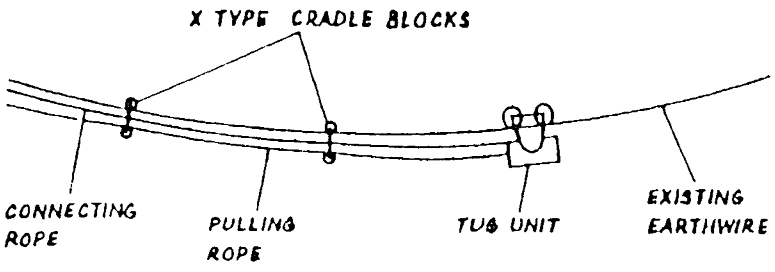
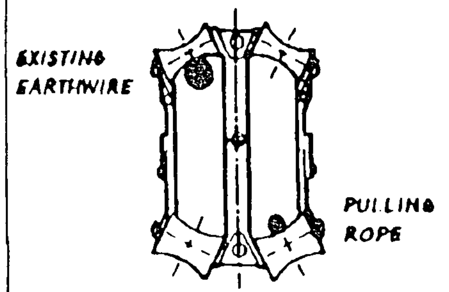
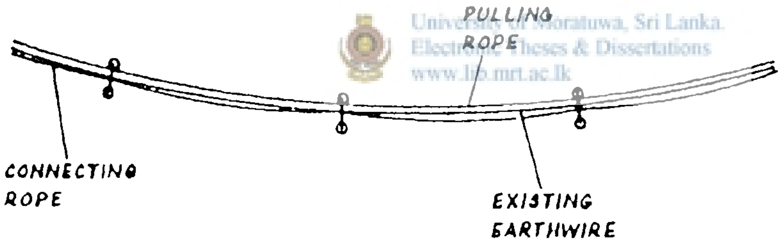
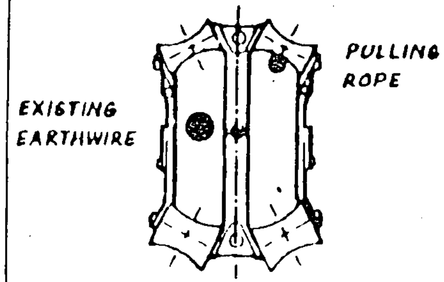
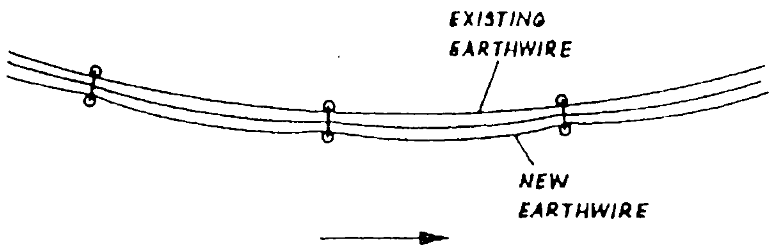
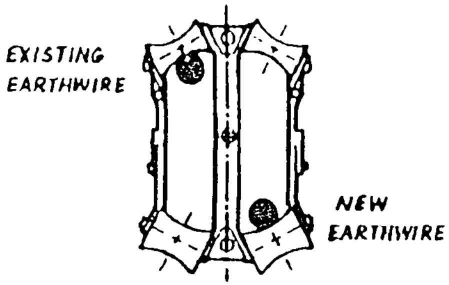
9 Should the hug unit become detective during the initial deployment of Cradle blocks it may be rescued with a second tug unit attached to a Rescue Rope.

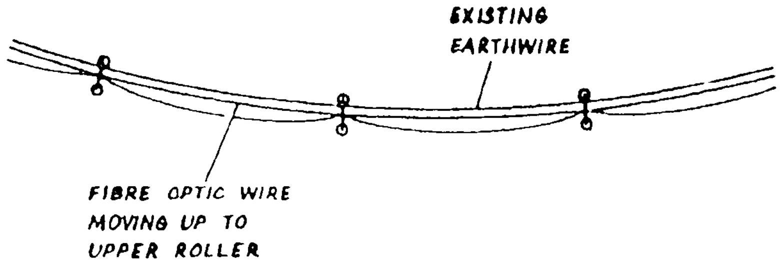
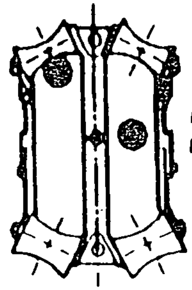
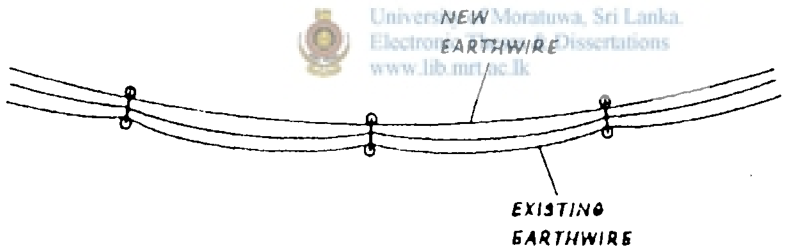
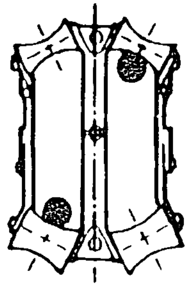
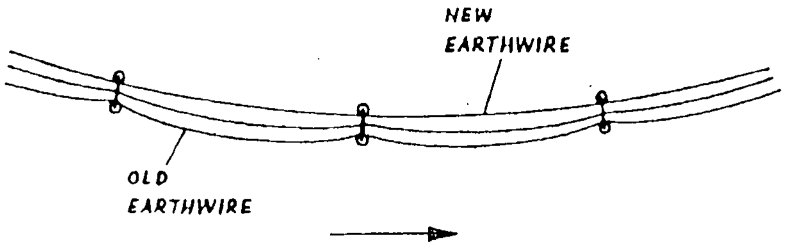
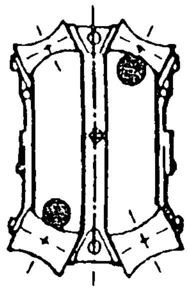
EQUIPOTENTIAL EQUIPMENT ZONES

It is most important for all operators to be working within the equipotential ground plane of the towers and in all circumstances there shall be an effective earth between any operator who may be handling equipment and the source of induced voltage. This is taken care of by deploying special ring fenced earthing mats and bonding all metal parts to the power system earth as shown in the general arrangement sketches of **figure Q1**.

SUMMARY

Cradle block stringing provides rapid deployment of composite conductors on high voltage transmission lines without the need for circuit outages.

PROCESS	METHOD →	CRADLE BLOCK FUNCTION
1. POSITIONING OF CRADLE BLOCKS		
2. TENSIONING PULLING ROPE PRIOR TO NEW EARTHWIRE INSTALLATION		
3. NEW EARTHWIRE INSTALLATION		

PROCESS	METHOD ⟶	CRADLE BLOCK FUNCTION
4. INITIAL TENSIONING (SAGGING)		
5. FINAL SAGGING		
6. REMOVAL OF OLD EARTHWIRE		

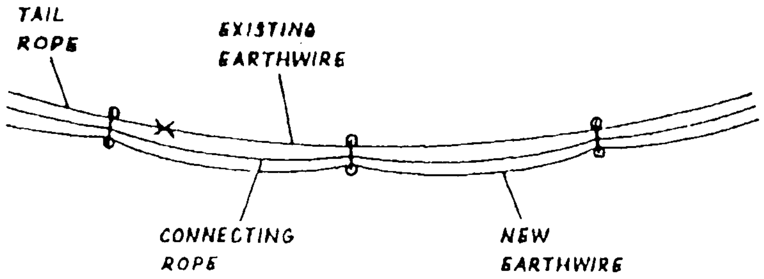
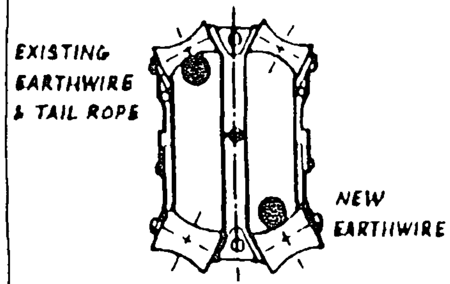
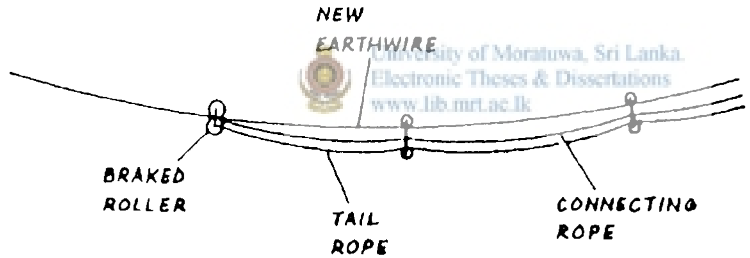
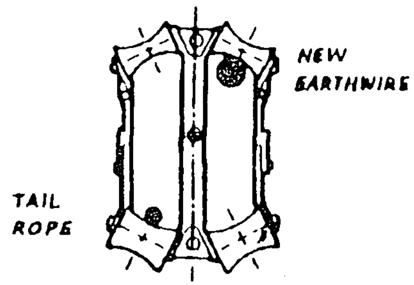
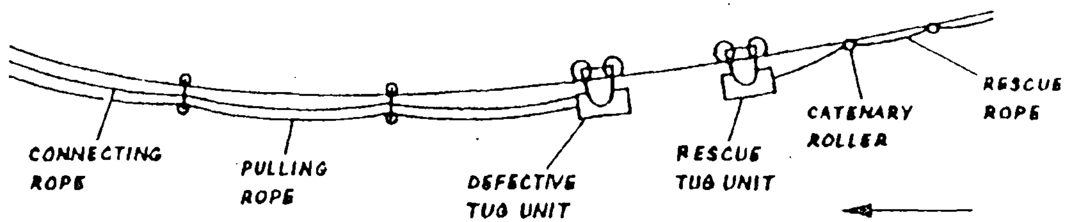
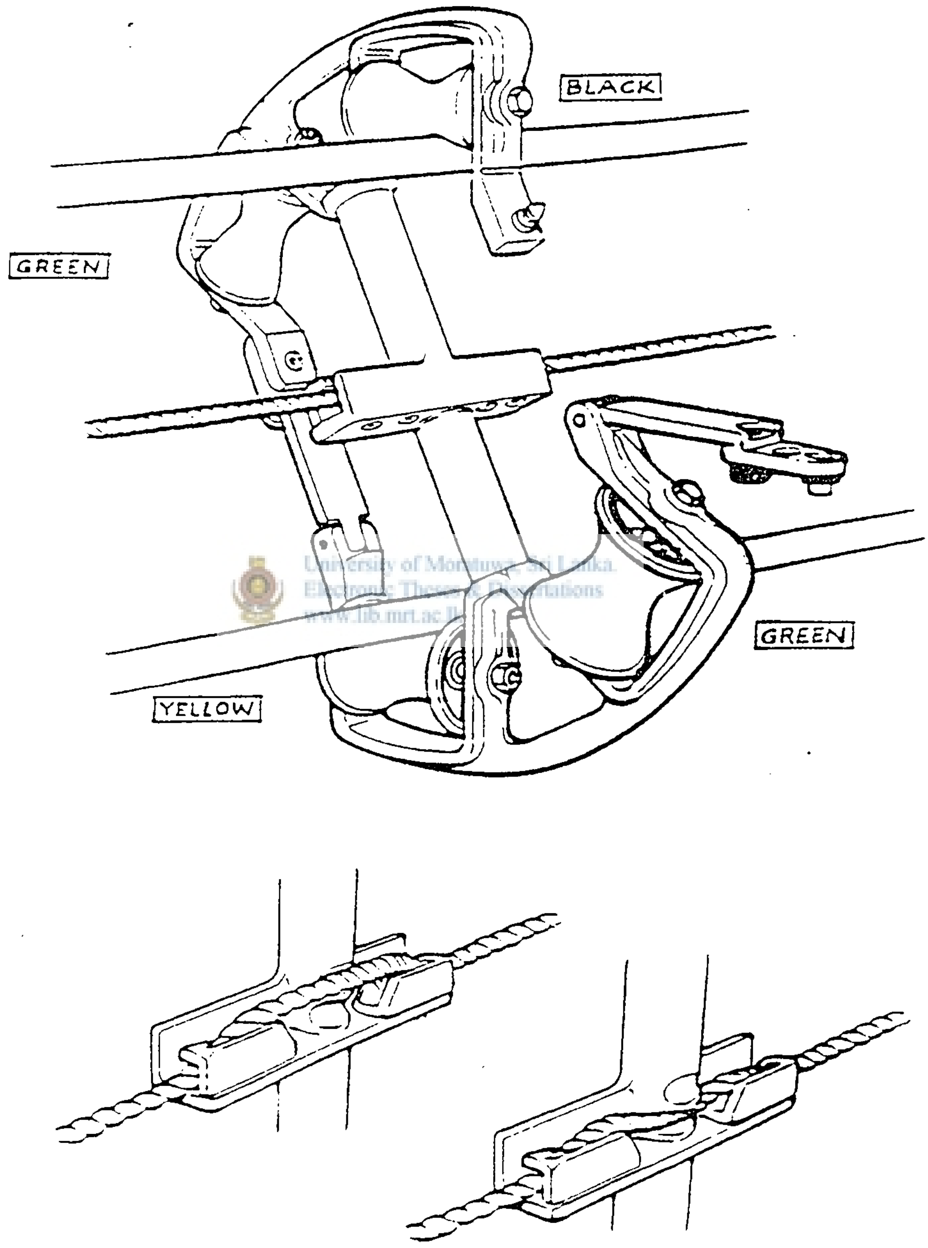
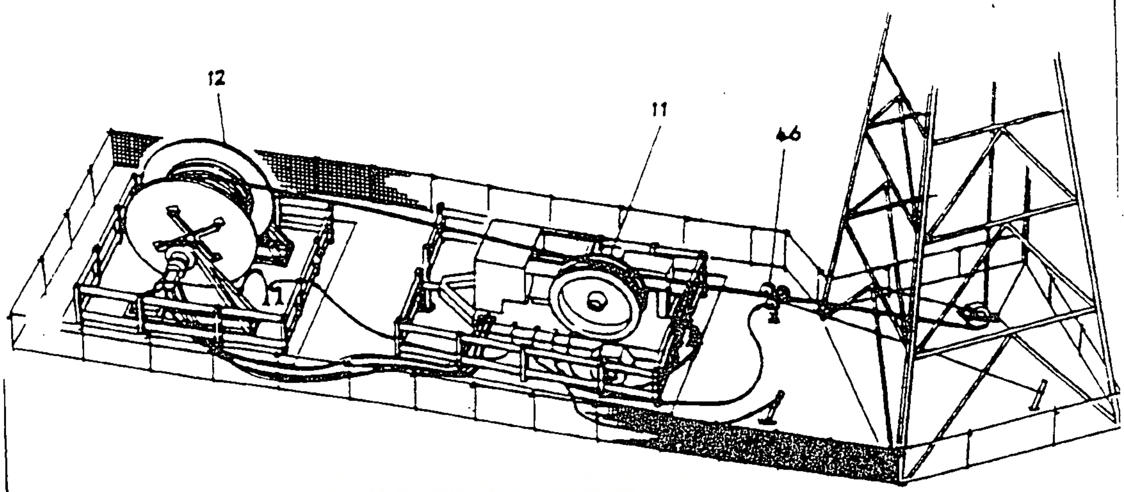
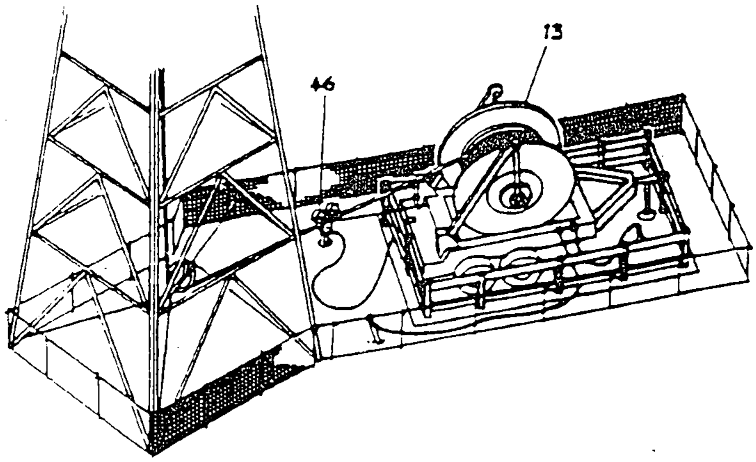
PROCESS	METHOD →	CRADLE BLOCK FUNCTION
7. REMOVAL OF OLD EARTHWIRE AND TAIL ROPE		
8. COLLECTION OF CRADLE BLOCKS AND CONNECTING ROPES		
9. DEFECTIVE TUG RESCUE OPERATION		

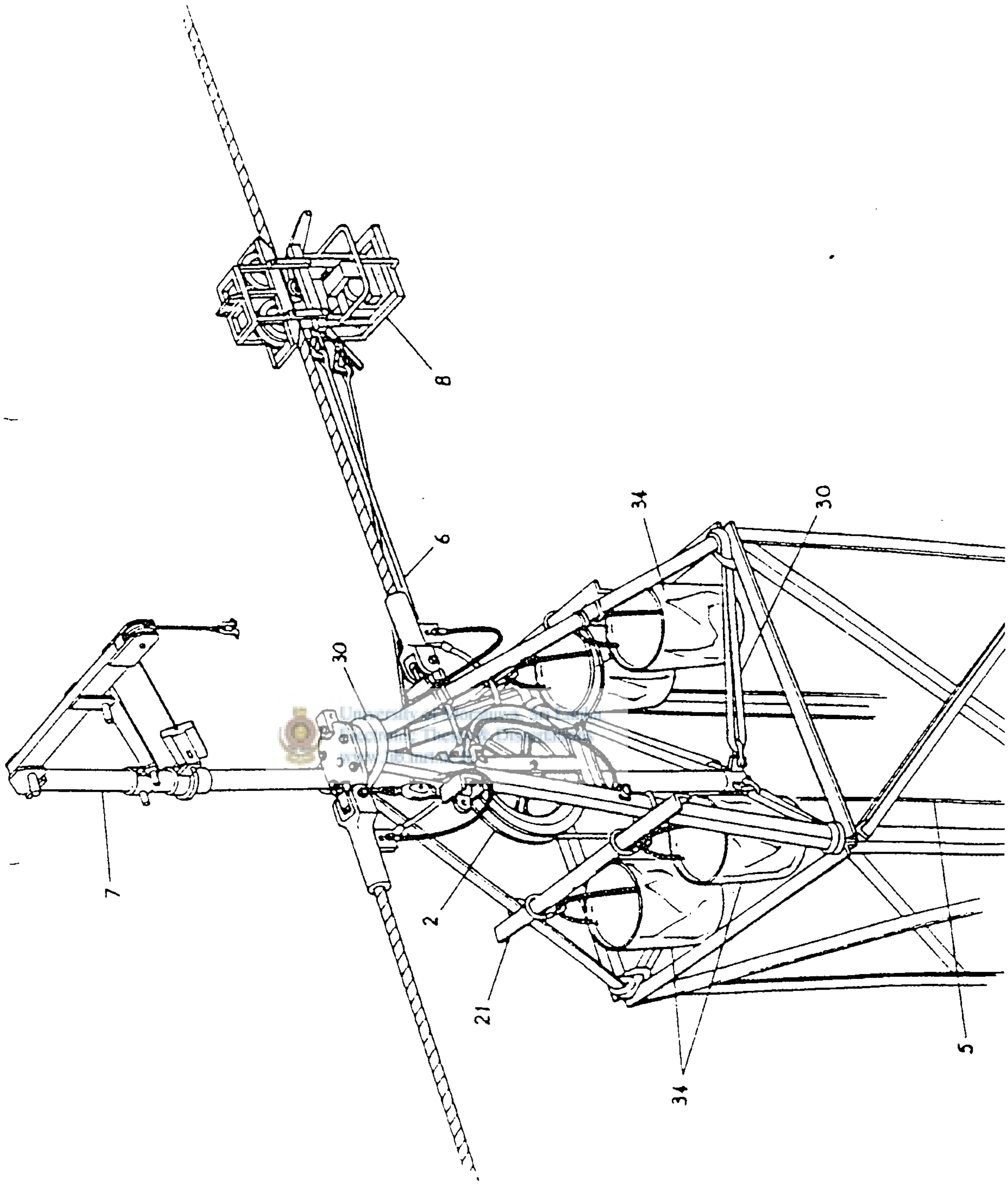
FIG 5 CRADLE BLOCK



EQUIPOTENTIAL ZONES (ITEM 24) FIG Q1



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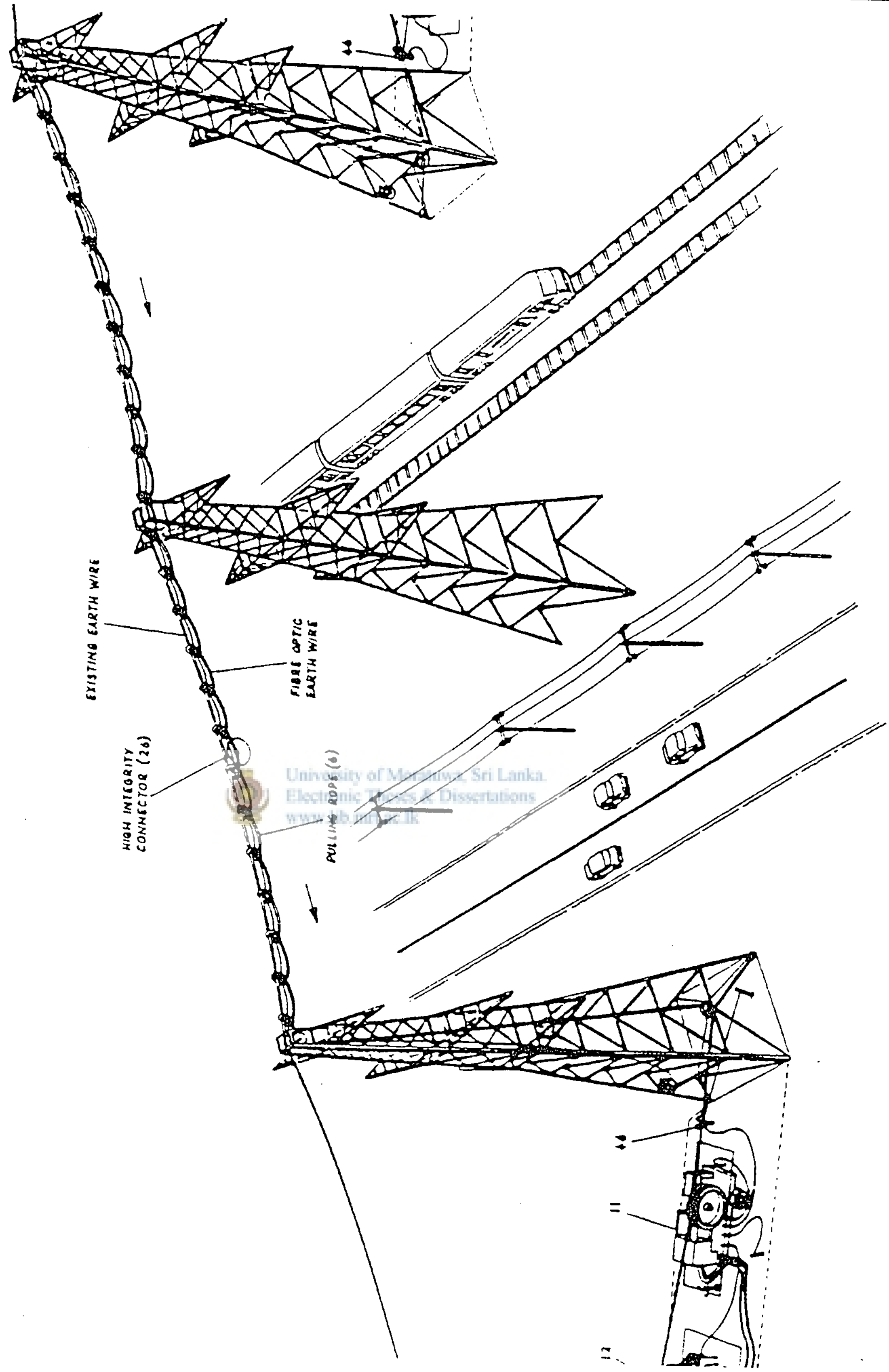


NSTA TION OF FIBRE OPTIC EARTHWIRE
GENE ARRANGEMENT)

FIG 6 BRAKE UNIT

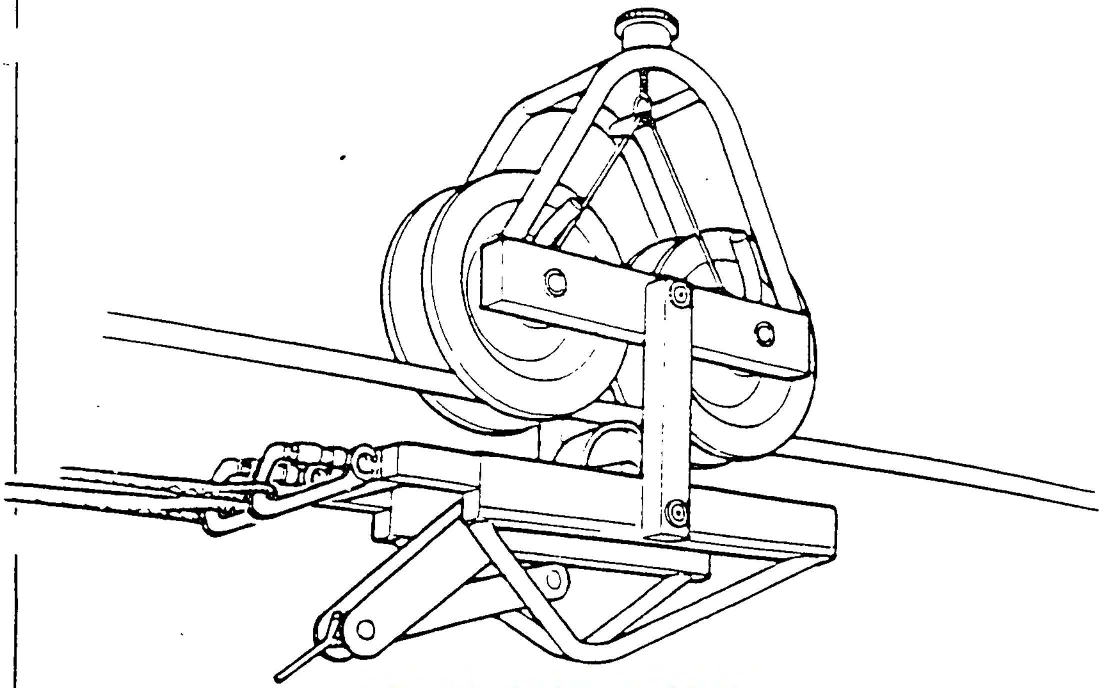
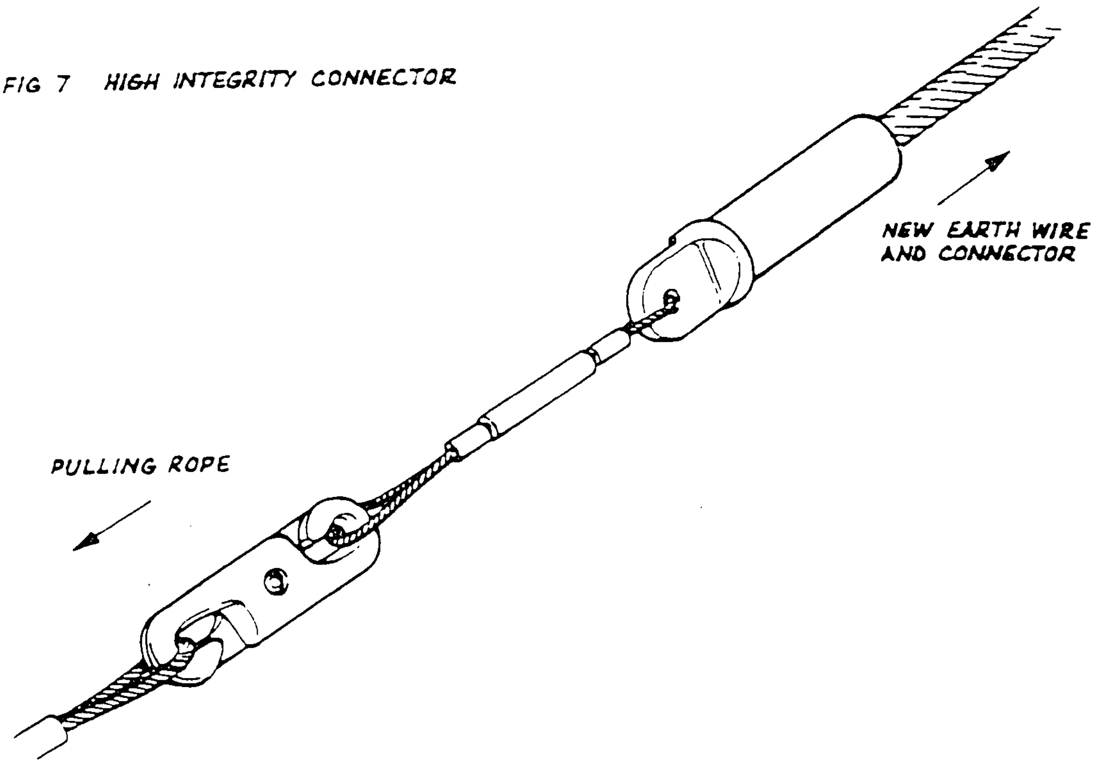


FIG 7 HIGH INTEGRITY CONNECTOR



APPENDIX – B:

SPECIFICATION SHEETS FOR ANTENNAS, FEEDERS AND MICROWAVE RADIOS

. .750-8.4 GHz Antennas - Electrical Characteristics

Frequency GHz	Input Flanges	Type Number	Diameter ft (m)	Gain, dBi Bottom	Gain, dBi Mid-Band	Gain, dBi Top	Beamwidth Degrees	Cross Pol. Disc., dB	F/B Ratio dB	VSWR max. (R.L., dB)
High Performance Antennas - Planar Radome Included										
7.750-8.4* Single Polarized	CPR112G	HP6-77GE	6 (1.8)	40.3	40.8	41.1	1.5	30	68	1.06 (30.7)
		HP8-77GE	8 (2.4)	42.9	43.3	43.6	1.1	30	68	1.04 (34.2)
		HP10-77GE	10 (3.0)	44.8	45.2	45.5	0.9	30	70	1.04 (34.2)
		HP12-77GF	12 (3.7)	46.3	46.7	47.1	0.7	30	71	1.04 (34.2)
		HP15-77GE	15 (4.6)	48.2	48.5	48.9	0.6	30	71	1.04 (34.2)
Low VSWR Standard Antennas										
7.750-8.4* Single Polarized	CPR112G	PL4-77GD	4 (1.2)	36.8	37.2	37.5	2.2	30	45	1.06 (30.7)
		PL6-77GE	6 (1.8)	40.3	40.8	41.1	1.5	30	48	1.06 (30.7)
		PL8-77GE	8 (2.4)	42.9	43.3	43.6	1.1	30	50	1.04 (34.2)
		PL10-77GD	10 (3.0)	44.8	45.2	45.5	0.9	30	58	1.04 (34.2)
		PL12-77GF	12 (3.7)	46.3	46.7	47.1	0.7	30	54	1.04 (34.2)
		PL15-77GD	15 (4.6)	48.2	48.5	48.9	0.6	30	57	1.04 (34.2)

*7.725-8.275 or 7.725-8.5 GHz available on request.

7.125-8.4 GHz Antennas - Electrical Characteristics

Frequency GHz	Input Flanges	Type Number	Diameter ft (m)	Gain, dBi Bottom	Gain, dBi Mid-Band	Gain, dBi Top	Beamwidth Degrees	Cross Pol. Disc., dB	F/B Ratio dB	VSWR max. (R.L., dB)
High Performance Antennas - Planar Radome Included										
7.125-8.4 Single Polarized	CPR112G	HP6-71W	6 (1.8)	39.7	40.3	41.1	1.5	30	66	1.06 (30.7)
		HP8-71W	8 (2.4)	42.3	42.9	43.6	1.1	30	68	1.06 (30.7)
		HP10-71W	10 (3.0)	44.0	44.3	45.5	0.9	30	70	1.06 (30.7)
Standard Antennas										
7.125-8.4 Single Polarized	UG-52B/U	P4-71GD	4 (1.2)	36.2	36.8	37.5	2.2	30	45	1.10 (26.4)
		P6-71GD	6 (1.8)	39.7	40.3	41.1	1.5	30	48	1.10 (26.4)
		P8-71GE	8 (2.4)	42.3	42.9	43.6	1.1	30	50	1.10 (26.4)
		P10-71GE	10 (3.0)	44.0	44.8	45.5	0.9	30	52	1.10 (26.4)
		P12-71GF	12 (3.7)	45.6	46.3	47.1	0.7	30	54	1.10 (26.4)
		P15-71GD	15 (4.6)	47.5	48.2	48.9	0.6	30	57	1.10 (26.4)

7.125 - 7.725 GHz Antennas - Electrical Characteristics

Frequency GHz	Input Flanges	Type Number	Diameter ft (m)	Gain, dBi Bottom	Gain, dBi Mid-Band	Gain, dBi Top	Beamwidth Degrees	Cross Pol. Disc., dB	F/B Ratio dB	VSWR max. (R.L., dB)
Focal Plane Antennas**										
7.125-7.725 Single Polarized	PDR70	FP4-71	4 (1.2)	34.9	35.2	35.4	2.2	25	52	1.10 (26.4)
		FP6-71	6 (1.8)	38.8	39.2	39.5	1.5	25	58	1.07 (29.4)
		FP8-71	8 (2.4)	42.0	42.3	42.4	1.1	26	65	1.06 (30.7)
		FP10-71	10 (3.0)	44.1	44.4	44.5	0.9	26	67	1.04 (34.2)
		FP12-71	12 (3.7)	45.7	46.1	46.2	0.7	28	69	1.04 (34.2)
7.125-7.725 Dual Polarized	PDR70	FPX6-71	6 (1.8)	38.8	39.2	39.5	1.5	25	58	1.08 (28.3)
		FPX8-71	8 (2.4)	41.8	42.1	42.3	1.1	26	65	1.07 (29.4)
		FPX10-71	10 (3.0)	43.9	44.2	44.3	0.9	26	67	1.06 (30.7)
		FPX12-71	12 (3.7)	45.5	45.9	46.0	0.7	28	69	1.06 (30.7)

**Focal plane antennas are manufactured and stocked at our factory in Great Britain and manufactured on special order in Australia. They are not manufactured or stocked in the United States or Canada.

7.425 - 7.900 GHz Antennas - Electrical Characteristics

Frequency GHz	Input Flanges	Type Number	Diameter ft (m)	Gain, dBi Bottom	Gain, dBi Mid-Band	Gain, dBi Top	Beamwidth Degrees	Cross Pol. Disc., dB	F/B Ratio dB	VSWR max. (R.L., dB)
High Performance Antennas - Planar Radome Included										
7.425-7.900	CPR112G	HP4-74G	4 (1.2)	36.5	36.7	37.0	2.3	32	63	1.06 (30.7)
Single		HP6-74G	6 (1.8)	40.1	40.4	40.6	1.5	32	64	1.06 (30.7)
Polarized		HP8-74G	8 (2.4)	42.5	42.8	43.0	1.2	32	71	1.04 (34.2)

7.725-8.275 and 7.725 - 8.5 GHz Antennas - Electrical Characteristics

Frequency GHz	Input Flanges	Type Number	Diameter ft (m)	Gain, dBi Bottom	Gain, dBi Mid-Band	Gain, dBi Top	Beamwidth Degrees	Cross Pol. Disc., dB	F/B Ratio dB	VSWR max. (R.L., dB)
UHX® Ultra High Performance Antennas - Planar Radome Included										
7.725-8.275*	CPR112G	UHX6-77GD	6 (1.8)	40.5	41.0	41.2	1.5	30	67	1.06 (30.7)
Dual		UHX8-77GD	8 (2.4)	43.1	43.5	43.7	1.1	30	68	1.06 (30.7)
Polarized		UHX10-77GD	10 (3.0)	44.9	45.2	45.4	0.9	30	70	1.06 (30.7)
		UHX12-77GD	12 (3.7)	46.4	46.7	46.9	0.7	30	75	1.06 (30.7)
Polarized		UHX15-77GD	15 (4.6)	48.4	48.7	48.9	0.6	30	70	1.06 (30.7)
High XPD Antennas - TEGLAR® Long Life Radome Included										
7.725-8.275*	CPR112G	HXPD6-77GC	6 (1.8)	40.5	40.7	41.0	1.5	35†	70	1.06 (30.7)
Dual		HXPD8-77GC	8 (2.4)	43.1	43.4	43.7	1.1	36†	70	1.06 (30.7)
Polarized		HXPD10-77GC	10 (3.0)	44.9	45.2	45.6	0.9	37†	75	1.06 (30.7)
		HXPD12-77GC	12 (3.7)	46.4	46.7	47.0	0.7	37†	75	1.06 (30.7)
Focal Plane Antennas**										
7.725-8.5	PDR84	FP6-77G	6 (1.8)	40.2	40.6	40.8	1.5	30	60	1.07 (29.4)
Single		FP8-77G	8 (2.4)	42.9	43.3	43.5	1.1	26	64	1.06 (30.7)
Polarized		FP10-77G	10 (3.0)	44.9	45.3	45.4	0.9	30	66	1.04 (34.2)
		FP12-77G	12 (3.7)	46.5	46.9	47.0	0.7	28	68	1.04 (34.2)
7.725-8.5 Dual Polarized	PDR84	FPX6-77G	6 (1.8)	40.2	40.4	40.6	1.5	30	58	1.08 (28.3)

*Meets Canadian DOC Standard SRSP306. VSWR 1.06 (30.7), 7.725-8.5 GHz on request.
†Isolation is 50 dB minimum.

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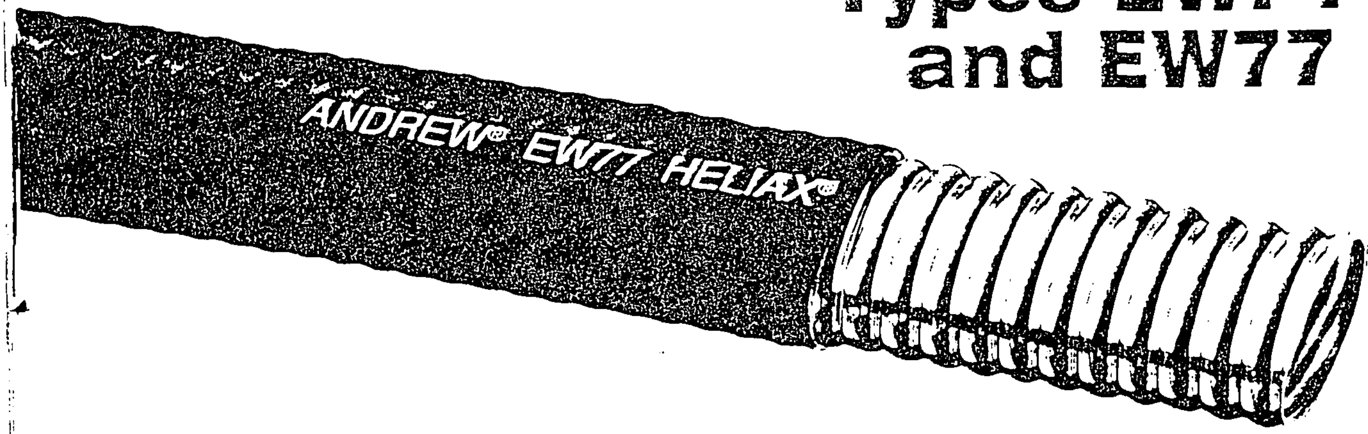
8.2 - 8.5 GHz Antennas - Electrical Characteristics

Frequency GHz	Input Flanges	Type Number	Diameter ft (m)	Gain, dBi Bottom	Gain, dBi Mid-Band	Gain, dBi Top	Beamwidth Degrees	Cross Pol. Disc., dB	F/B Ratio dB	VSWR max. (R.L., dB)
High Performance Antennas - Planar Radome Included										
8.2-8.5	CPR112G	HP6-82C	6 (1.8)	40.6	40.8	41.0	1.5	30	68	1.04 (34.2)
Single		HP8-82C	8 (2.4)	43.4	43.5	43.7	1.1	30	68	1.04 (34.2)
Polarized		HP10-82C	10 (3.0)	45.3	45.5	45.7	0.9	30	70	1.04 (34.2)
		HP12-82C	12 (3.7)	46.8	47.0	47.1	0.7	30	71	1.04 (34.2)
		HP15-82C	15 (4.6)	48.6	48.8	48.9	0.6	30	71	1.04 (34.2)
8.2-8.5	CPR112G	HPX6-82C	6 (1.8)	41.0	41.1	41.2	1.3	30	58	1.06 (30.7)
Dual		HPX8-82C	8 (2.4)	43.5	43.6	43.7	1.0	30	67	1.06 (30.7)
Polarized		HPX10-82C	10 (3.0)	45.5	45.6	45.7	0.8	30	70	1.06 (30.7)
		HPX12-82C	12 (3.7)	47.1	47.2	47.3	0.7	30	70	1.06 (30.7)
		HPX15-82C	15 (4.6)	48.7	48.8	48.9	0.6	30	70	1.06 (30.7)
Low VSWR Standard Antennas										
8.2-8.5	CPR112G	PL6-82C	6 (1.8)	40.6	40.8	41.0	1.5	30	48	1.06 (30.7)
Single		PL8-82C	8 (2.4)	43.4	43.5	43.7	1.1	30	50	1.04 (34.2)
Polarized		PL10-82C	10 (3.0)	45.3	45.5	45.7	0.9	30	58	1.04 (34.2)
		PL12-82C	12 (3.7)	46.8	47.0	47.1	0.7	30	54	1.04 (34.2)
		PL15-82C	15 (4.6)	48.6	48.8	48.9	0.6	30	57	1.04 (34.2)
8.2-8.5	CPR112G	PXL6-82C	6 (1.8)	41.0	41.1	41.2	1.3	30	48	1.06 (30.7)
Dual		PXL8-82C	8 (2.4)	43.7	43.8	43.9	1.0	30	55	1.06 (30.7)
Polarized		PXL10-82C	10 (3.0)	45.7	45.8	45.9	0.8	30	57	1.06 (30.7)
		PXL12-82C	12 (3.7)	47.3	47.4	47.5	0.7	30	63	1.06 (30.7)
		PXL15-82C	15 (4.6)	48.5	48.6	48.7	0.6	30	65	1.06 (30.7)

Microwave Antenna Systems

Types EWP77 and EW77



Flexibility and High Strength

Precision formed and corrugated from high conductivity copper

Long Continuous Lengths

Low installation cost and ease of system planning

Low Attenuation

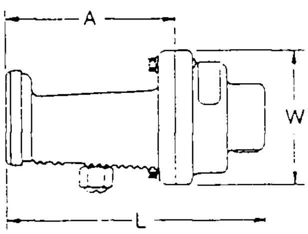
Optimized for specific user band

Advanced Connectors and Accessories

Full line of connectors and accessories designed to simplify system planning and reduce cost of installation

Proven Performer

EWP77 is proven in thousands of demanding microwave systems



Connector Material: Investment Cast Silicon Brass

Connectors

Flange dimensions on pages 179 and 180.

Type No.	L in (mm)	W in (mm)	A in (mm)	Weight lb (kg)
177DC, 177DCT 177DCP	4.8 (122)	2.8 (71)	3.1 (78)	2.8 (1.3)
177DE, 177DET 177DEP	4.8 (122)	2.8 (71)	3.1 (78)	2.8 (1.3)

Characteristics

Type Numbers	
Premium Waveguide	EWP77
Standard Waveguide	EW77
Electrical	
Max. Frequency Range, GHz*	6.1-8.5
TE_{11} Mode Cutoff Frequency, GHz	4.722
Group Delay at 7.8 GHz, ns/100 ft (ns/100 m)	128 (419)
Peak Power Rating at 7.8 GHz, kW	63
Mechanical	
Minimum Bending Radii, without rebending, inches (mm)	
E Plane	7 (180)
H Plane	20 (510)
Minimum Bending Radii, with rebending, inches (mm)	
E Plane	9 (230)
H Plane	25 (635)
Maximum Twist, degrees/foot (m)	1 (3)
Dimensions over Jacket, in (mm)	1.72 x 1.00 (43.6 x 25.4)
Weight, pounds per foot (kg/m)	0.45 (0.67)

*Actual usable range is limited by the connecting rectangular waveguide.

Attenuation, Average Power, Group Velocity

Frequency GHz	Attenuation dB/100 ft (dB/100 m)	Average Power Rating, kW	Group Velocity of Propagation, %
7.1	1.91 (6.28)	3.11	74.7
7.2	1.89 (6.20)	3.15	75.5
7.3	1.87 (6.13)	3.19	76.3
7.4	1.85 (6.06)	3.22	77.0
7.5	1.83 (6.00)	3.26	77.7
7.6	1.81 (5.94)	3.29	78.4
7.7	1.79 (5.89)	3.32	79.0
7.8	1.78 (5.84)	3.35	79.6
7.9	1.77 (5.80)	3.37	80.2
8.0	1.75 (5.75)	3.40	80.7
8.1	1.74 (5.71)	3.42	81.2
8.2	1.73 (5.68)	3.44	81.8
8.3	1.72 (5.64)	3.47	82.2
8.4	1.71 (5.61)	3.49	82.7
8.5	1.70 (5.58)	3.51	83.1

Ordering Information for Waveguide Assemblies

Frequency* Band, GHz	Waveguide Type No.	Connector Type No.	Connector Tuning‡	Connector Mates with Flange Type‡‡ U.S.	IEC	VSWR, max.** (R.L., dB) up to 300 ft (90 m)
Premium Waveguide Assemblies						
7.125-7.750	EWP77	177DCT	Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.06 (30.7)
		177DCP-1	Pre-Tuned	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.06 (30.7)
		177DET	Tunable	CPR112G	PDR84	1.06 (30.7)
		177DEP-1	Pre-Tuned	CPR112G	PDR84	1.06 (30.7)
7.725-8.275	EWP77	177DCT	Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.06 (30.7)
		177DET	Tunable	CPR112G	PDR84	1.06 (30.7)
7.725-8.500	EWP77	177DCT	Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.06 (30.7)
		177DET	Tunable	CPR112G	PDR84	1.06 (30.7)
7.750-8.500	EWP77	177DCT	Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.06 (30.7)
		177DCP-2	Pre-Tuned	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.06 (30.7)
		177DET	Tunable	CPR112G	PDR84	1.06 (30.7)
		177DEP-2	Pre-Tuned	CPR112G	PDR84	1.06 (30.7)
Standard Waveguide Assemblies						
7.125-7.750	EW77	177DC	Non-Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.15 (23.1)
		177DE	Non-Tunable	CPR112G	PDR84	1.15 (23.1)
7.125-7.850	EW77	177DC	Non-Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.15 (23.1)
		177DE	Non-Tunable	CPR112G	PDR84	1.15 (23.1)
7.425-7.725	EW77	177DC	Non-Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.15 (23.1)
		177DE	Non-Tunable	CPR112G	PDR84	1.15 (23.1)
7.425-7.900	EW77	177DC	Non-Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.15 (23.1)
		177DE	Non-Tunable	CPR112G	PDR84	1.15 (23.1)
7.725-8.500	EW77	177DC	Non-Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.15 (23.1)
		177DE	Non-Tunable	CPR112G	PDR84	1.15 (23.1)
7.750-8.500	EW77	177DC	Non-Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.15 (23.1)
		177DE	Non-Tunable	CPR112G	PDR84	1.15 (23.1)
8.2-8.5	EW77	177DC	Non-Tunable	UG-52B/U, UG-51/U	CBR84, UBR84, PBR84	1.15 (23.1)
		177DE	Non-Tunable	CPR112G	PDR84	1.15 (23.1)

*Contact Andrew for information on other frequency bands.
**The indicated maximum VSWR characteristics are guaranteed for factory assemblies and are typical for field assemblies.
‡"Tunable" connectors ordered with factory asemblies are factory tuned. "Pre-tuned" connectors are for field attachment only.
‡‡For detailed information on mating flanges, refer to pages 179 and 180.

Accessories • Photos and detailed descriptions on pages 156-162

Description	Type No.
Hangers and Adaptors	
Hanger Kit of 10, Maximum spacing 4 ft (1.2 m)	42396A-11
Hardware Kit of 10, 3/8" bolts, lock washers, nuts	
3/4" (19 mm) long	31769-5
1" (25 mm) long	31769-1
Angle Adaptor Kit of 10. Stainless steel	31768A
Round Member Adaptor Kit of 10. Stainless steel	
Member Diameter, in (mm)	
1-2 (25-50)	31670-1
2-3 (50-75)	31670-2
3-4 (75-100)	31670-3
4-5 (100-125)	31670-4
5-6 (125-150)	31670-5
45° Adaptor Kit of 10. Galvanized steel	42334
Threaded Rod Support, 3/8" rod, nuts, washers, ceiling bracket	
12 in (305 mm) long, kit of 1	31771
12 in (305 mm) long, kit of 5	31771-4
24 in (610 mm) long, kit of 1	31771-9
24 in (610 mm) long, kit of 5	31771-6
Tower Standoff Kit of 10. 1 in (25 mm) standoff	
Member Diameter, in (mm)	
0.75-1.5 (20-40)	30848-5
1.5-3.0 (40-75)	30848-4
3-4 (75-100)	30848-1
4-5 (100-125)	30848-2
5-6 (125-150)	30848-3

Description	Type No.
Tower Standoff Kit of 10. 2.5 in (60 mm) standoff	
Member Diameter, in (mm)	
3-4 (75-100)	41108A-1
4-5 (100-125)	41108A-2
5-6 (125-150)	41108A-3
Other Accessories	
Flaring Tool for Connector Attachment	202421
Splice	177DZ
Grounding Kit with factory attached lug	204989-3
Grounding Kit with field attachable screw-on lug	204898-33
Grounding Kit with field attachable crimp-on lug	204989-23
Crimping Tool to field attach lug to Grounding Kit	207270
Hoisting Grip	19256B
Bending Tool Kit. One each E and H Plane tool	33586-9
Connector Reattachment Kit	33544-34
Wall-Roof Feed Thru	35849-16
Waveguide Boot for Plates (below), 4 in (102 mm) dia.	204679-77
5 in (127 mm) dia.	48939-77

Feed-Thru Plate for Boots (above)

Openings	For 4 in Boots	For 5 in Boots
1	204673-1	48940-1
1	204673-2	—
2	—	48940-2
3	—	48940-3
4	204673-4	48940-4
6	—	48940-6
8	204673-8	—

To Order

- A sample order is shown on page 273.
- Specify waveguide Type Number, frequency band in GHz and length in feet or metres. See "Waveguide Assemblies" table.
- Specify connector Type Numbers and "attached" or "unattached". See "Waveguide Assemblies" table. When attached connectors on an assembly are different, specify which is "first off" reel.

Further Information

For general information on HELIAX elliptical wavewguide, see pages 120-123.

Section 3
TECHNICAL SPECIFICATIONS

MegaStar Specifications

Frequency Range	5925 - 5425 MHz — U.S. Private/Common Carrier 5915 - 6930 MHz — Canada 7125 - 8500 MHz — U.S. Government 7725 - 8275 MHz — Canada
Frequency Stability	0°C to +50°C: ±3 PPM
Channel Bandwidth	30 MHz
Channel Spacing	29.65 MHz
Transmission Rate	155.52 Mb/s
Modulation Type	128-state non-staggered QAM with Forward Error Correction
Bandwidth Efficiency	> 5.2 b/s Hz
Configurations	The MegaStar radio is available in the following configurations: Terminal Add/Drop Repeater Hubbing Add/Drop Repeater Ring Add/Drop Repeater
Protection	The MegaStar radio is available with the following protection: Hot Standby, Space Diversity Frequency Diversity, Hybrid Diversity Non-Protected Unidirectional Path Switched Ring
Transmitter Power	High, HS: +30.5 dBm Standard, HS: +28.0 dBm Standard, FD, NP: +28.8 dBm
Output Power Stability	Over a 12 month period: ± 0.25 dB at maximum power output ± 1 dB at minimum power output
ATPC Range	10 dB (with HS, FD Transmitter)
Diversity Antenna Delay Equalization (DADE) Range	±480 nsec
Error Floor	One hop basis: 10^{-11} ≤ Five hop system: 10^{-13} (average per hop, measured end to end)

Receiver Threshold	Protection / 10^{-3} BER / 10^{-6} BER NP, SD, FD / -70.0 dBm / -68.5 dBm HS (1) / -69.0 dBm / -67.5 dBm HS (2) / -63 dBm / -61.5 dBm
Receiver Overload Point	At 10^{-6}: $\geq$ -17 dBm
Receiver Switching	Errorless, Stress Initiated
Receiver Image Rejection	> 75 dB
System Gain	High power at BER 10^{-3} is 100.5 dB* High power at BER 10^{-6} is 99.0 dB* * NP, SD, FD receiver only.
Dispersive Fade Margin	48 dB at 10^{-3} BER
Threshold-to-Interference	Cochannel: 37 dB Adjacent channel: 0 dB (±30 MHz)

External Connection Specifications

Payload Interface

STM1 optical

Optical signal specifications:

Parameter	Symbol	Minimum	Typical	Maximum
Receiver specifications				
Optical input sensitivity	P_{IN}	-32.5 dBm	--	-14.0 dBm
Optical wavelength	λ_{IN}	1270 nm	--	1380 nm
Transmitter specifications				
Optical output	P_{OUT}	-19 dBm	--	-14 dBm
Optical wavelength	λ_{OUT}	--	1330 nm	--

SPU Controller

SPUR Connector — Link to other SCAN equipment

CIT Connector — FarScan port

Alarm Display

FarScan Connector — Provides customer access to FarScan

CUSTOMER CONNECT Connector — Provides customer access to nine solid-state on-board Form C relays and eight opto-isolated signal lines:

Five Relays-Alarms	System Major System Minor Major Visible Major Audible Minor	60V DC max, 250mA Strappable for alarm = OPEN or alarm = CLOSED
Four Relays	Site Commands	(Open-collector buffer [use pull-up resistor])
Eight Opto-Isolated	Site Alarms	

SCU Data Orderwire

RS232 Connector — External connection to the two RS232 ports (≤4.8 kb/s asynchronous data channel)

SCU VF Orderwire

4W PORTS Connector

External connection to the four four-wire ports (VF Orderwire with signaling.)

Two four-wire 600 ohm VF ports

VF port 1 has choice of 0 dBm or -16 dBm input levels and 0 dBm or +7 dBm output levels

VF port 2 has choice of 0 dBm or +7 dBm input levels and 0 dBm or -16 dBm output levels.

Antenna Coupling Unit

Antenna Connector CPR-137/UG 344 waveguide flange

Waveguide Connector WR 137

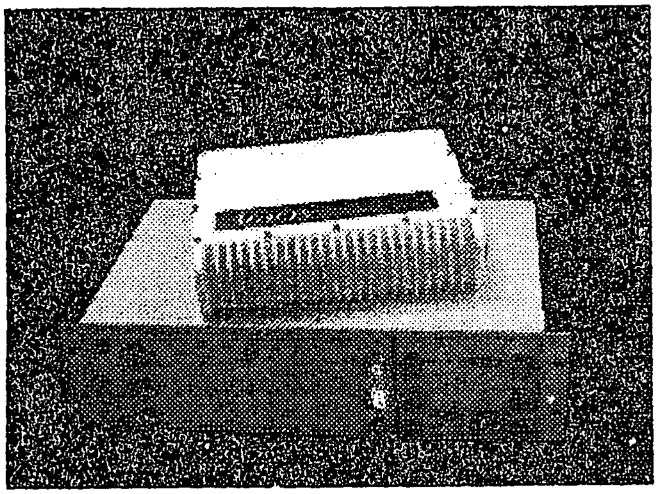
Signal Designations and Pin Assignments

Refer to the schematic drawings in the Appendix.

Environment and Power Characteristics

Ambient Temperature Range	Full performance: 0° C to +50° C No outage, error performance ≤ 10^{-6}: -5° C to +55° C Storage and transportation: -40° C to +65° C
Humidity	5 to 95% non-condensing
Altitude	0 to 4572 m AMSL
Standard Power Source	-56V DC to -21V DC or +21V DC to +56V DC with respect to ground.
Power Consumption	Terminal 425 Watts Linear Add/Drop Repeater 800 Watts Ring Add/Drop Repeater 465 Watts

AGILINK SDH RADIO

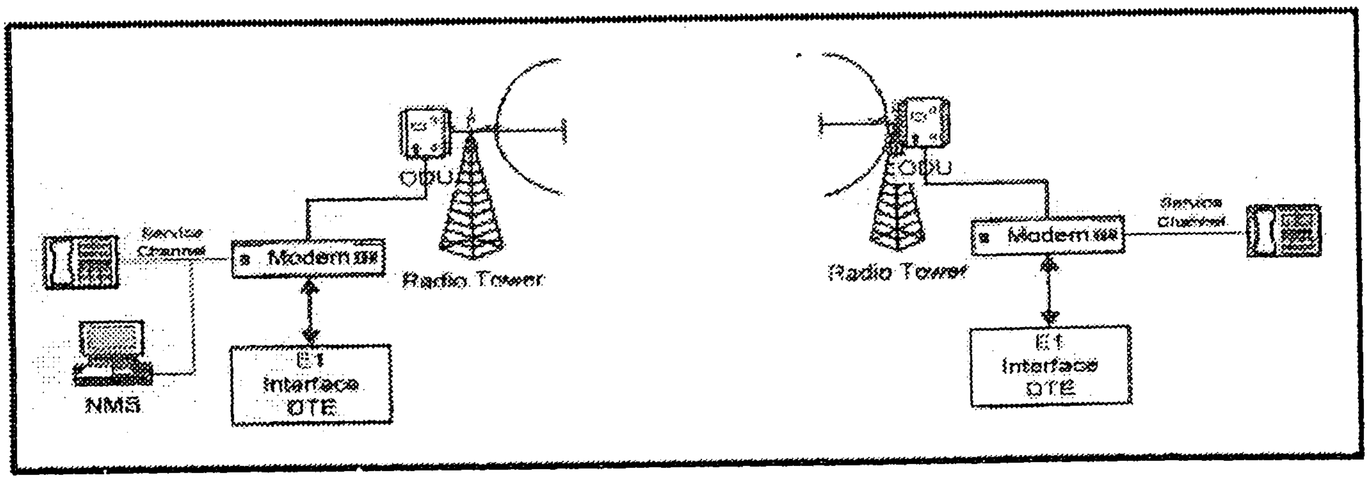


DESCRIPTIONS

ADR series of microwave Radios from Agilis Communication Technologies represents the latest in the high performance Radios that can be used for high capacity wireless solutions. Offered for SDH broadband applications, this series of microwave Radios are designed to be used with high data rate modems with QAM modulations.

FEATURES

- Broad frequency coverage from 7 GHz to 26 GHz
- Low component count and innovative design for flexibility and Reliability
- Conforms to ETSI grade A standards.
- Low Cost
- Competitive Performance
- Support STM0, 21 E1/T1, 16 E1/T1, 8 E1/T1 & 4 E1/T1 Applications
- Stand Alone (1+0) Configuration
- Hot-Standby (1+1) Configuration Protection of Traffic
- Field Proven and Reliable
- Compact and Ruggedized for Outdoor
- Easy and quick Installation
- Remote M&C



Agilis Communication Technologies Pte Ltd

A company of Singapore Technologies Electronics
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Singapore Technologies

POPULAR BANDS	7/8GHz	13GHz	15GHZ	18GHz	23GHz	26GHz
FREQUENCY RANGE (GHz)	7.1-8.5	12.75-13.25	14.4-15.35	17.7-19.7	21.2-23.6	24.5-26.5
FLANGE TYPE	N-Female	WR-62	WR-62	WR-42	WR-42	WR-42
TRANSMITTER	**7/8GHz**	**13GHz**	**15GHZ**	**18GHz**	**23GHz**	**26GHz**
POWER OUTPUT	(Guaranteed at RF Unit antenna port over temperature range)-					
P1dB	+32dBm	+31dBm	+31dBm	+28dBm	+26dBm	+26dBm
STMO - 256QAM - 8MHz	+22dBm	+20dBm	+20dBm	+18dBm	+16dBm	+16dBm
21xE1/T1 - 256QAM - 8MHz	+22dBm	+20dBm	+20dBm	+18dBm	+16dBm	+16dBm
16xE1/T1 - 256QAM - 6MHz	+22dBm	+20dBm	+20dBm	+18dBm	+16dBm	+16dBm
16xE1/T1 - 128QAM - 7MHz	+23dBm	+21dBm	+21dBm	+19dBm	+17dBm	+17dBm
16xE1/T1 - 64QAM - 8MHz	+23dBm	+21dBm	+21dBm	+19dBm	+17dBm	+17dBm
8xE1/T1 - 256QAM - 3.5MHz	+22dBm	+20dBm	+20dBm	+18dBm	+16dBm	+16dBm
8xE1/T1 - 16QAM - 7MHz	+24dBm	+22dBm	+22dBm	+20dBm	+18dBm	+18dBm
4xE/T1 - 16QAM - 3.5MHz	+24dBm	+22dBm	+22dBm	+20dBm	+18dBm	+18dBm
RECEIVER	**7/8GHz**	**13GHz**	**15GHZ**	**18GHz**	**23GHz**	**26GHz**
SENSITIVITY @ 1E-6 BER	(Guaranteed at RF Unit antenna port over temperature range)-					
STMO - 256QAM - 8MHz	-68dBm	-64dBm	-64dBm	-64dBm	-64dBm	-64dBm
21xE1/T1 - 256QAM - 8MHz	-68dBm	-64dBm	-64dBm	-64dBm	-64dBm	-64dBm
16xE1/T1 - 256QAM - 6MHz	-69dBm	-65dBm	-65dBm	-65dBm	-65dBm	-65dBm
16xE1/T1 - 128QAM - 7MHz	-72dBm	-68dBm	-68dBm	-68dBm	-68dBm	-68dBm
16xE1/T1 - 64QAM - 8MHz	-75dBm	-71dBm	-71dBm	-71dBm	-71dBm	-71dBm
8xE1/T1 - 256QAM - 3.5MHz	-72dBm	-68dBm	-68dBm	-68dBm	-68dBm	-68dBm
8xE1/T1 - 16QAM - 7MHz	-81dBm	-77dBm	-77dBm	-77dBm	-77dBm	-77dBm
4xE1/T1 -16QAM - 3.5MHz	-84dBm	-80dBm	-80dBm	-80dBm	-80dBm	-80dBm
FREQUENCY STABILITY	+/- 5ppm	+/- 5ppm	+/- 5ppm	+/- 5ppm	+/- 5ppm	+/- 5ppm
RECEIVER TYPE	Double Conversion					
DYNAMIC RANGE	> 60dB					
RECEIVER UNFADED BER	> 1E-12					
SYSTEM GAIN	**7/8GHz**	**13GHz**	**15GHZ**	**18GHz**	**23GHz**	**26GHz**
SYSTEM GAIN @ Threshold	(Guaranteed at RF Unit antenna port over temperature range)					
STMO - 256QAM - 8MHz	92dB	86dB	86dB	84dB	82dB	82dB
21xE1/T1 - 256QAM - 8MHz	92dB	86dB	86dB	84dB	82dB	82dB
16xE1/T1 - 256QAM - 6MHz	93dB	87dB	87dB	85dB	83dB	83dB
16xE1/T1 - 128QAM - 7MHz	97dB	91dB	91dB	89dB	87dB	87dB
16xE1/T1 - 64QAM - 8MHz	100dB	94dB	94dB	92dB	90dB	90dB
8xE1/T1 - 256QAM - 3.5MHz	96dB	90dB	90dB	96dB	94dB	94dB
8xE1/T1 - 16QAM - 7MHz	107dB	101dB	102dB	99dB	97dB	97dB
4xE1/T1 -16QAM - 3.5MHz	110dB	104dB	104dB	102dB	100dB	100dB

GENERAL

System Configureation	1+0 or 1+1
Modulation Type	QAM
Digital Interface Type	E1 per ITU-T G.703
Digital Line Code	HDB3
Digital I/O Interface	75Ω Unbalance BNC-F (DB-25 Optional)
Intermediate Frequency	Tx:640MHz; Rx:140MHz (User Defined)
Frequency Source	Programmable Sysnthesizer
RF Channel Select	Selected by NMS
RF Power Select	Selected by NMS
Frequency Stability	±5 ppm
Loopbacks	IDU, ODU, Local & Remote
Power Supply	-36 to -72 V DC
Power Consumption	35 Watt for (1+0) 70 Watt for (1+1)

MECHANICAL

IDU	Standard ETSI 3U (19") 130x483x250
Weight	8 Kg
ODU	120x210x210mm (Customisation Possible)
Weight	6 Kg

ENVIRONMENTAL

Temperature Range	ODU	-30 ~ 60°C
	IDU	0 ~ 50°C
Relative Humidity	ODU	0 ~ 100%
	IDU	0 ~ 95%

IDU-ODU INTERCONNECTION

Cable	1
Impedance	50Ω
Max distance	300M
Interconnection	SMA Male- N Male Cable

SERVICE CHANNELS

Code Format	64Kbps PCM
Voice Bandwidth	300~3400Hz
Impedance	600Ω
Signaling	DTMF
Monitor	LED indicate BER(10^{-3},10^{-6}) ODU Alarm IDU Alarm

MONITOR CHANNEL 2 x Ethernet 10BT RG-45

Environment monitor input:	
Type	8 dry contacts + 2 analog
Interface	25 pin D-type
Environment control output:	
Type	4 dry contacts
Interface	25 pin D-type

NETWORK MANAGEMENT

Interface	2 x Ethernet 10BT RG-45
Protocol	SNMP

Note: Customised options available / Specifications subject to change without notice

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Singapore Technologies

System and Equipment Parameters

System Parameters (64QAM)

Radio Frequency	4 GHz	5 GHz	U6 GHz
Frequency Range	3,600 - 4,200 MHz	4,400 - 5,000 MHz	6,430 - 7,110 MHz
Channel Spacing	40 MHz	40 MHz	40 MHz
Modulation Scheme		64QAM MLCM + RS	
TX Output Power (excluding BR CKT Loss)	33 dBm	33 dBm	33 dBm
System Gain at BER=10^{-3} (excluding BR CKT Loss)	109.1 dB	109.1 dB	109.1 dB

Radio Frequency	8 GHz	11 GHz
Frequency Range	7,725 - 8,275 MHz	10,700 - 11,700 MHz
Channel Spacing	40.74 MHz	40 MHz
Modulation Scheme	64QAM MLCM + RS	
TX Output Power (excluding BR CKT Loss)	33 dBm	30 dBm
System Gain at BER=10^{-3} (excluding BR CKT Loss)	108.6 dB	105.6 dB

System Parameters (128QAM)

Radio Frequency	4 GHz	L6 GHz	7 GHz
Frequency Range	3,803.5 - 4,203.5 MHz	5,925 - 6,425 MHz	7,125 - 7,725 MHz
Channel Spacing	29 MHz	29.65 MHz	28MHz
Modulation Scheme		128QAM MLCM	
TX Output Power (excluding BR CKT Loss)	32 dBm	32 dBm	32 dBm
System Gain at BER=10^{-3} (excluding BR CKT Loss)	105.7 dB	105.7 dB	105.2 dB

Radio Frequency	8 GHz
Frequency Range	7,725 - 8,275 MHz
Channel Spacing	29.65 MHz
Modulation Scheme	128QAM MLCM
TX Output Power (excluding BR CKT Loss)	32 dBm
System Gain at BER=10^{-3} (excluding BR CKT Loss)	105.2 dB

System Parameters

Transmission Capacity	STM-1 or OC-3 (155.520 Mbit/s, electrical or optical interface)
Wayside Capacity (in RFCOH)	64QAM System: 2 x 2.048 Mbit/s or 2 x 1.544 Mbit/s 128QAM System: 1 x 2.048 Mbit/s or 2 x 1.544 Mbit/s
Service Channel Capacity (in RFCOH)	1 x (192 or 64 kbit/s) and 4 x 64 kbit/s
Power Supply Requirement	–48V DC (–36 to –72V DC)/–24V DC (–20 to –35V DC)/ +24V DC (+20 to +35V DC)
Total Power Consumption	Approx. 315W (for 4-U6 GHz, 1+1 Terminal, 10W FET type, e/w SD)
Mounting Rack	ETSI - Rack
Dimensions (W x D x H)	600 x 300 x 2,200 mm
Operating Temperature (Guaranteed)	–5°C to +50°C

Specifications are subject to change without notic

NEC

URL: http://www.mesh.nec.co.jp/nec.com/...
Cat. No. SY-001-2 120702 Printed in Japa

Technical Specifications

Frequency Band (MHz)		U4 3803.5-4203.5	L6 5925-6425	L7 7125-7425	U7 7425-7725	L8 7725-8275	13 12750-13250
Modulation Type		128 QAM-MLCM					
ITU-R Series Rec. No.		F.382-6	F.383-5	F.385-6	F.385-6	F.386-4	F.497-4
Channel Spacing (MHz)		29	29.65	28	28	29.65	28
Protection System	Alternated	5+1	7+1	4+1	4+1	7+1	7+1
	Co-channel	2×(5+1)	2×(7+1)	—	—	2×(7+1)	—
RF output power (dBm) (+/−1dB)		32	32	32	32	32	27
System Gain (dB) *		106	106	106	106	105.5	97.5
Wayside		2×N where N is the number of RF channels					

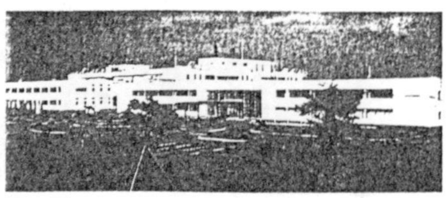
Frequency Band (MHz)		4 3600-4200	5 4400-5000	U6 6430-7110	11 10700-11700
Modulation Type		64 QAM-MLCM			
ITU-R Series Rec. No.		F.635-3 Annex-1	F.1099-1 Annex-1	F.384-6	F.387-7
Channel Spacing (MHz)		40	40	40	40
Protection System	Alternated	6+1	6+1	7+1	7+1
	Co-channel	2×(6+1)	2×(6+1)	2×(7+1)	2×(7+1)
RF output power (dBm) (+/−1dB)		32	32	32	29
System Gain (dB) *		108.5	108.5	108.5	104.5
Wayside		2×N where N is the number of RF channels			

Interface	• SDH: 155.52 Mb/s Electrical, 155.52 Mb/s Optical (Optional) • PDH: 139.264 Mb/s (Optional)
Service Channel	• SOH: 64 kb/s × N (N: Number of RF channels) • RFCOH: 64 kb/s × 2 (Optional)
SDH management network facilities	• Local management interface: V24 • Network management interface: X.25/LAN
Primary input voltage	• −19V to −36V (for −24V input) or −36V to −72V (for −48V input)
Power consumption	• 370 Watts (1+1, STM-1 Electrical interface)
Mechanical dimensions (mm)	• 600(W) × 300(D) × 2200(H) (7+1 Alternated operation system)
Environmental conditions	• Temperature (°C): 0 to +45, Humidity (%): 10 to 95

*: This is a typical figure, excluding losses in the Branching Network Unit.

Kawasaki Research & Manufacturing Facilities

Fujitsu Laboratories, Kawasaki

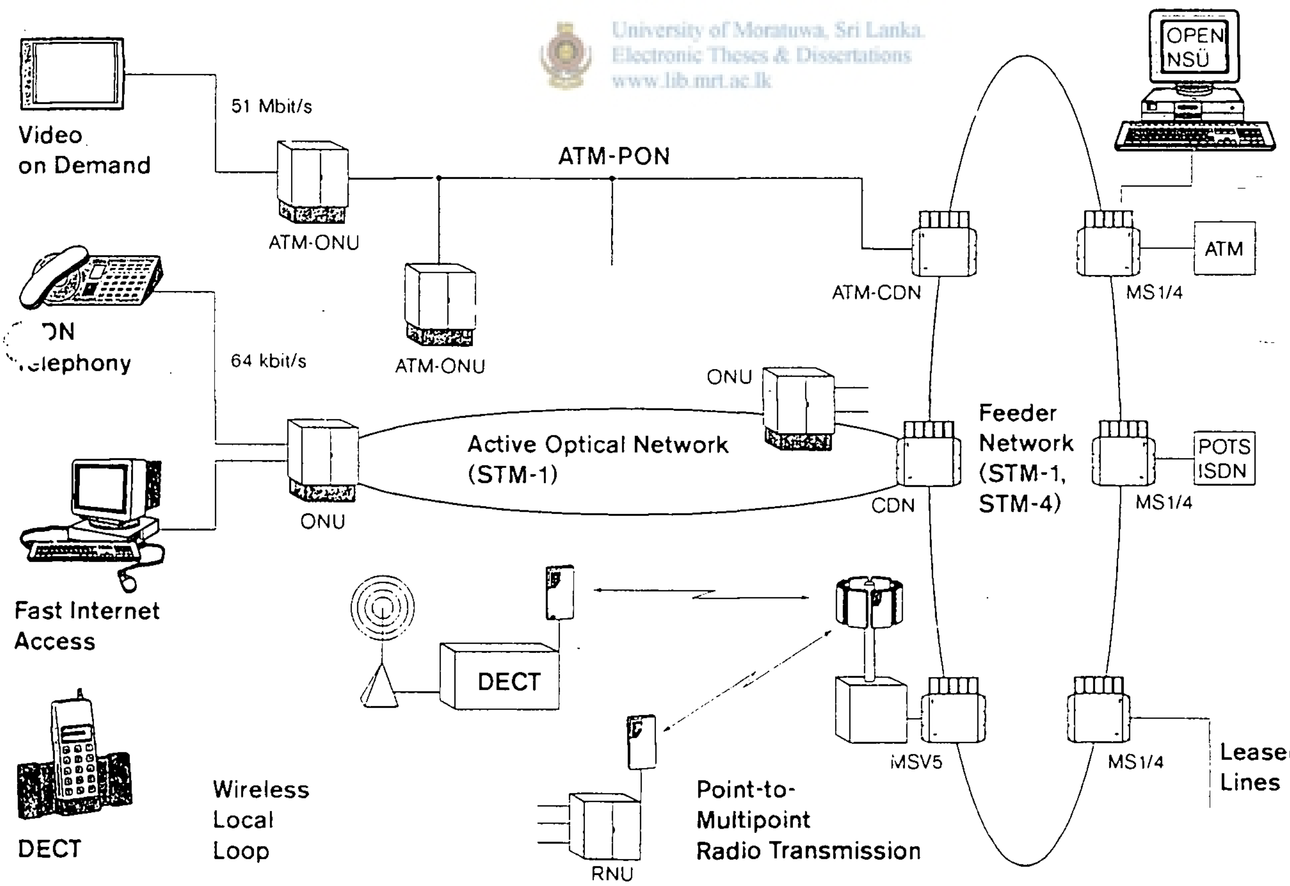


Nasu Plant

General

Access networks are important building blocks used to close the gap between the classical transport (backbone) networks and the end user. The Bosch Access Network is the optimum solution for this purpose as it supports all physical media (fiber, copper, and radio) in one single system and is monitored and configured via one common network management system. Thus, the customer can select any suitable solution (or mixtures thereof) to optimize his specific needs.

As an integral part of the Bosch Access Network, the DMS (Digital Multipoint System) forms the broadband wireless part of the network. This system solution is of special importance, if a quick deployment is required and the installation of a wired network is not possible or too expensive. Consequently, no compromise in quality can be accepted for the wireless solution.

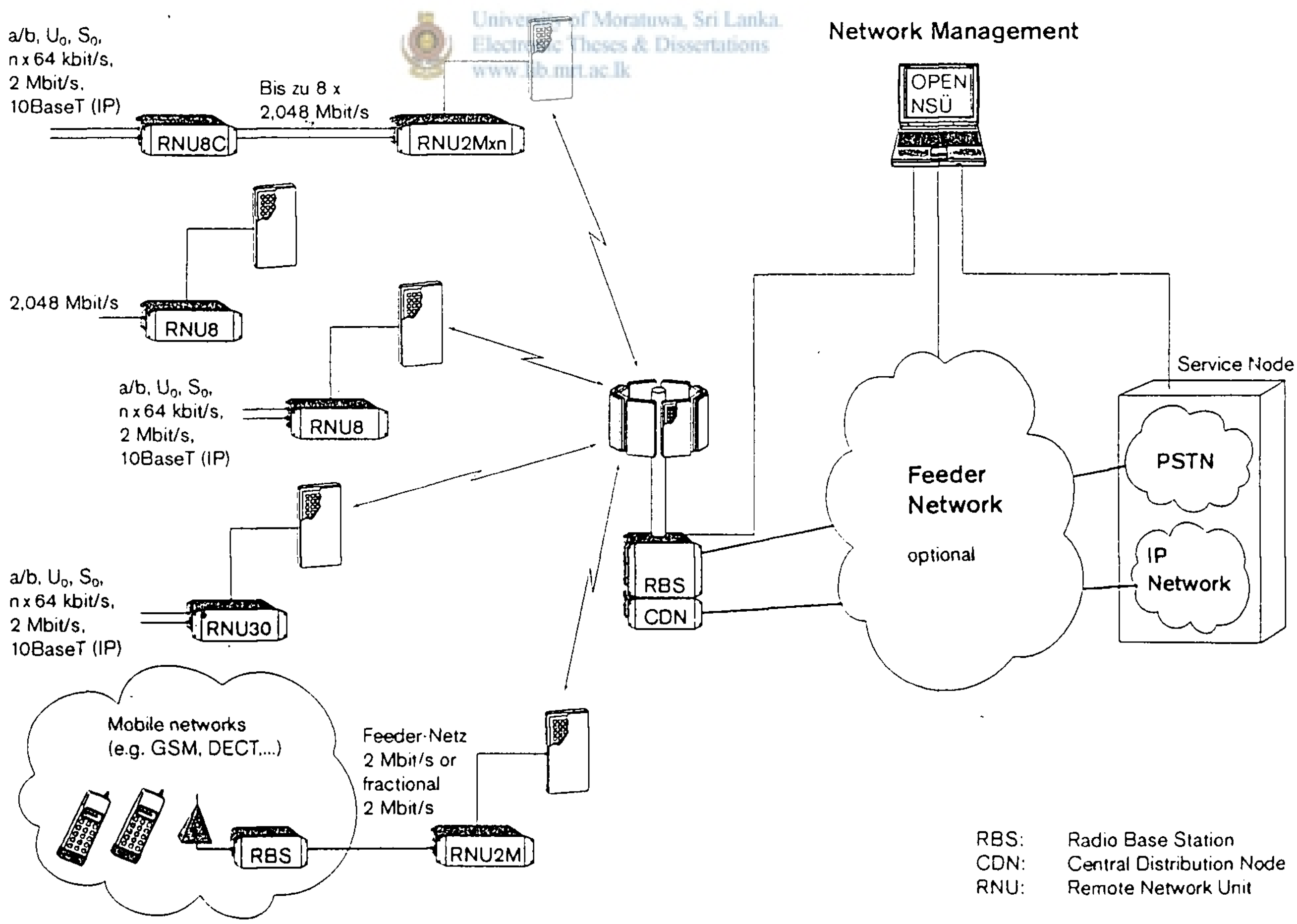


Access Network (all technologies)

DMS – a highly flexible system concept

Main features:

- Point-to-Multipoint system concept
- Single and multiple cell configurations
- Flexible sectorization topologies, overlapping sectors
- Seamless integration into the Bosch Access Network
- Open and standardized interfaces
- Full network management control (OPEN NSÜ)
- Efficient bandwidth utilization
- Dynamic assignment of traffic capacity for voice and data
- High system capacity in cellular environment
- Configurable for business and residential access
- Wide range of RF frequencies
- Fixed network quality and availability
- Advanced adaptive modem technology
- Integrated RF and micro-wave radio technology
- Software-controlled system functions
- Quick and easy installation and setup
- Planning tools for optimum coverage
- Online interference management (OIM) for further capacity optimization



System block diagram

DMS applications and configurations

Typical applications	System configuration Network Interfaces Network units	Customer Services and Interfaces
RTTB/C (Radio to the building/curb) Residential access	FDMA/FBA or DBA STM-1/4, 10 BaseT V5.1, V5.2 RNU 8 RNU 30	Multiple POTS Multiple ISDN (U_0, S_0) Dial-in Internet access (ISDN) High speeed Internet access
RTTB (Radio to the building) Small business access	FDMA/FBA or DBA STM-1/4, 100 BaseT V5.1, V5.2 RNU 8 RNU 30	Multiple POTS Multiple ISDN (U_0, S_0) High speeed Internet access 10 BaseT LAN connectivity
RTTO (Radio to the office) Small business access	FDMA/FBA or DBA STM-1/4, 100 BaseT V5.1, V5.2 RNU 8 RNU 30 RNU 2M	Multiple POTS Multiple ISDN (U_0, S_0) High speeed Internet access 10 BaseT LAN connectivity V.35/X.21 router connections E1/fractional E1 PABX connections
RTTO (Radio to the office) Large business access	FDMA/FBA STM-1/4, 100 BaseT RNU 2M RNU nx2M	10 BaseT LAN connectivity V.35/X.21 router connections E1, fractional E1 PABX connections multiple E1 (up to 8)
Leased lines	FDMA/FBA STM-1/4 RNU 2M RNU nx2M	nx64 kBit/s V.35, X.21 E1, fractional E1 multiple E1 (up to 8)
Microcell networking (GSM, DECT, UMTS)	FDMA/FBA STM-1/4 RNU 2M RNU nx2M	E1, fractional E1 multiple E1 (up to 8)

Example of a radio cell with overlapping sectors (15°, 45°, 2x90°)

DMS system capacity

Switched services mode

	FBA mode			DBA mode		
Frequency range [GHz]	3.5	10.5	24/26/28	3.5	10.5	24/26
RF bandwidth [MHz]	14	30	28	14	30	28
Sectorization [°]	60	45	45	60	45	45
Number of terminals with 4 lines/CPE	282	832	776	534	1760	1640
Total number of lines	1128	3328	3104	2136	7040	6560
Trunk capacity [Mbit/s]	STM-1	2xSTM-1	2xSTM-1	STM-1	2xSTM-1	2xSTM-1
Number of terminals with 30 lines/CPE	72	216	200	138	432	408
Total number of lines	2160	6480	6000	4140	12960	12240
Trunk capacity [Mbit/s]	2xSTM-1	STM-4	STM-4	STM-1	STM-4	STM-4

Boundary conditions for capacity calculation: typical cellular coverage (with interference)
BER < 10^{-7}
for DBA: blocking: < 0.01%
traffic: 0.2 Erl/subscriber

Leased line mode

Frequency range [GHz]	3.5	10.5	24/26
RF bandwidth [MHz]	14	30	28
Sectorization [°]	60	45	45
Number of E1 per sector	12	27	25
Number of E1 per cell (6/8 sectors)	72	216	201
Trunk capacity [Mbit/s]	2xSTM-1	STM-4	STM-4
Total capacity of all channels in the frequency band [Mbit/s] (duplex)	880 Mbit/s	2.6 Gbit/s	7.4 Gbit/s at 26 GHz

Boundary conditions for capacity calculation: typical cellular coverage (with interference)
BER < 10^{-7}
mix of available modulation schemes

Internet traffic

Frequency range [GHz]	3.5	10.5	24/26
RF bandwidth [MHz]	14	30	28
Sectorization [°]	60	45	45
Number of active Internet users per sector	900	3240	3000
Number of active Internet users per cell	5400	25920	24000

Boundary conditions: Peak rate: 2 Mbit/s, duty cycle: 3%, symmetric traffic

Remark: all values are typical

Technical characteristics

Air interface

Frequency band [GHz]	3.4 – 3.6	10.15 – 10.65	24.5 – 26.5
Multiple access scheme	FDMA	FDMA	FDMA
Air interface protocol	FBA and DBA	FBA and DBA	FBA and DBA
Modulation schemes (software-configurable)	QPSK 8-TCM 16-TCM	QPSK 8-TCM 16-TCM	QPSK 8-TCM 16-TCM
Channel coding (software-configurable)	Convolutional Trellis Trellis Reed solomon	Convolutional Trellis Reed solomon	Convolutional Reed solomon
Demodulation	Coherent Viterbi decoder	Coherent Viterbi decoder	Coherent Viterbi decoder
Channel bandwidth [MHz]	14 30	28	
Channel allocation	duplex	duplex	duplex
Compliance with standards	ETSI DEN/TM 04040, CEPT REC T/R 14-03 E	ETSI DEN/TM 04040, CEPT REC T/R 12-05 E	ETSI DEN/TM 04040, CEPT REC T/R 13-02 E

other frequency bands upon request

Base station

Frequency band [GHz]	3.4 – 3.6	10.15 – 10.65	24.5 – 26.5
Architecture	Modular, scaleable, frequency-independent indoor units, frequency-dependent outdoor units		
Antenna sectorization	60° (30°)	15°, 45°, 90°	15°, 45°, 90°
Number of sectors per cell	1 – 6 (12)	1 – 8 (24)	1 – 8 (24)
Antenna type	Planar, sector beam, low sidelobes, low cross-polarization		
Interconnection indoor/outdoor	Single coaxial cable		
Network interfaces	STM-1, STM-4, 34 Mbit/s, 2 Mbit/s, 10/100 Base T		
Network protocols	CAS, V5.1, V5.2, VB5, IP		

User terminal

Frequency band [GHz]	3.4 – 3.6	10.15 – 10.65	24.5 – 26.5
Architecture	Modular, scaleable, frequency-independent indoor units, frequency-dependent outdoor units		
Interconnection indoor/outdoor	Single coaxial cable		
Antennas	Planar, high gain, low sidelobes, low cross-polarization	Planar, high gain, low sidelobes, low cross-polarization	Planar, high gain, low sidelobes, low cross-polarization 30 cm parabolic 60 cm parabolic
User interfaces (depending on network unit)	nxPOTS, nxISDN (Uo, So), V.35/X.21, V.11, nx64 kbit/s, 10BaseT, E1, fractional E1, nxE1(n up to 8), Local PC element manager, remote login		

Link range (cell radius) and availability

Frequency band [GHz]	3.4 – 3.6	10.15 – 10.65	24/26
Rain zone up to E Data rate 2 Mbit/s BER < 10^{-6} Availability 99.995 %	up to 15 km (*)	up to 10 km	3 – 5 km
Rain zone up to K Data rate 2 Mbit/s BER < 10^{-6} Availability 99.99 %	up to 15 km (*)	up to 10 km	3 – 5 km
Rain zone up to P Data rate 2 Mbit/s BER < 10^{-6} Availability 99.95 %	up to 15 km (*)	up to 5 km	1 – 3 km

Remarks: typical average values for standard system configuration, enhanced link ranges with special system configurations

(*) range limited by interference

Environmental specifications

Frequency band [GHz]	3.4 – 3.6; 10.15 – 10.65; 24/26			
Temperature range	Indoor units:	ETS 300 019, Class 3.1		
	Outdoor units:	ETS 300 019, Class 4.1		
Power consumption	Terminal:	depending on the configuration		
	Base station:	depending on the configuration		
Physical dimensions w x h x d [mm]	Terminal:	Outdoor units:	3.5 GHz:	220 x 280 x 70
			10 GHz:	275 x 460 x 60
			26 GHz:	212 x 389 x 83
		Indoor units:	RNU 30 :	435 x 305 x 249
			RNU 8:	268 x 305 x 249
			RNU2M:	19" rack mount 1 HU
			RNU n x 2M:	19" rack mount 7 HU
	Base station:	Outdoor units:	3.5 GHz:	280 x 420 x 70
			10 GHz:	275 x 460 x 110
			26 GHz:	212 x 389 x 94
		Indoor units:		19" rack mounting acc. to system capacity
Wind speed	Operation:	164 km/h		
	Survival:	250 km/h		
Electromagnetic compatibility and safety	ETS 300 385, EN 50081-1, EN 50082-1, EN 55022, DIN VDE 0878, Part 1/3 EN 60950			

Miscellaneous specifications

Frequency band [GHz]	3.4 – 3.6; 10.15 – 10.65; 24.5 – 26.5	
Security, fraud prevention	Standard:	Identification of subscribers via the network management system
	Optional:	SIMM card reader and software control per link authentication
	Optional:	Encryption subsystem (software enabled) DES standard
Alignment tool	Installation and alignment kit	
Planning tools	Planning tools for business and cell/link planning upon request	

APPENDIX – C:

SPECIFICATION SHEETS FOR OPTICAL FIBERS AND CABLES

CORNING CABLE SYSTEMS GENERIC SPECIFICATION FOR SINGLE-MODE OPTICAL FIBER IN LOOSE TUBE AND RIBBON CABLES

April 2003

Revision 8

*Corning Cable Systems reserves the right to update this specification without prior notification. Not all **fiber** types listed below available in every cable design offered. Please see relevant Generic Cable Specification for the available **fiber** types.*

1 General Fiber Specifications

1.1 All fibers in the cable must be usable and meet required **specifications**.

1.2 Each optical **fiber** shall be sufficiently free of surface imperfections and inclusions to meet the optical, mechanical, and environmental requirements of this specification.

1.3 Each optical **fiber** shall consist of a germania-doped silica core surrounded by a concentric glass cladding. The **fiber** shall be a matched clad design.

1.4 Each optical **fiber** shall be proof tested by the **fiber** manufacturer at a minimum of 100 kpsi (0.7 GN/m).

1.5 The **fiber** shall be coated with a dual layer acrylate protective coating. The coating shall be in physical contact with the cladding surface.

1.6 The attenuation specification shall be a maximum value for each cabled **fiber** at 23 5 C on the original shipping reel.

2 **Single-mode (Dispersion Un-shifted)**

The single-mode fiber shall meet EIA/TIA-492CAAA. "Detail Specification for Class IVa Dispersion-Unshifted Single-Mode Optical Fibers." and ITU recommendation G.652, Characteristics of a single-mode optical fibre cable.

Geometry

2.1	Cladding Diameter		(m)	125.0 0.7
2.2	Core-to-Cladding Concentricity		(m)	= 0.5
2.3	Cladding Non-Circularity			= 1.0 %
2.4	Mode Field Diameter		(m)	
		1310 nm		9.2 0.4
		1550 nm		10.4 0.8
2.5	Coating Diameter		(m)	245 5
2.6	Colored **Fiber** Nominal Diameter		(m)	253 - 259
2.7	**Fiber** Curl radius of curvature		(m) = 4.0 m	

PGSF01

Page 2

Corning Cable Systems Generic Specification for Single-Mode Optical Fiber in Loose Tube and Ribbon Cables
April, 2003, Revision 8

Optical

2.8	Cabled **Fiber** Attenuation		(dB/km)	= 0.4
		1310 nm		
		1550 nm		= 0.3
2.9	Point discontinuity		(dB)	= 0.1
		1310 nm		
		1550 nm		= 0.1
2.10	Macrobend Attenuation		(dB)	
		Turns	Mandrel OD	
		1	32 2 mm	< 0.50 at 15:
		100	50 2 mm	< 0.05 at 13
		100	50 2 mm	< 0.10 at 15:
		100	60 2 mm	< 0.05 at 15:
2.11	Cable Cutoff Wavelength (? $_{ccf}$)		(nm)	< 1260
2.12	Zero Dispersion Wavelength (?o)		(nm) 1302	= ?(

2.13 Zero Dispersion Slope (So)		(ps/(nm km))	= 0.092
2.14 Total Dispersion	1285-1330 nm	(ps/(nm km))	= 3.5
	1550 nm		= 18
2.15 Cabled Polarization Mode Dispersion (		ps km)	= 0.5
2.16 IEEE 802.3 GbE - 1300 nm Laser Distance (m)			up to 5000
2.17 Water Peak Attenuation: 1383.3 nm (dB/km)			= 2.1

3 **Single-mode (Dispersion Un-shifted) with Low Water Peak**

The single-mode Low Water Peak **fiber** utilized in the optical **fiber** cable shall meet EIA/TIA-492CAAB, "Detail Specification for Class IVa Dispersion-Unshifted Single-Mode Optical Fibers with Low Water Peak," and ITU recommendation G.652.C, Characteristics of a single-mode optical fibre cable. These fibers shall have the same specified performance and geometry values as standard dispersion un-shifted **fiber** (Section 2) except as noted below.

2.4	Mode Field Diameter		(m)	
		1550 nm		10.4 0.5
2.9	Point discontinuity		(dB)	= 0.05
		1310 nm		
		1550 nm		= 0.05
2.10	Macrobend Attenuation		(dB)	
		Turns Mandrel OD		
	100	60.2 mm		< 0.05 at 16:
2.14	Total Dispersion		(ps/(nm km))	
		1625 nm		= 22
3.1	Cabled **Fiber** Attenuation: 1383.3 nm (dB/km)			= 0.4

4 **Non-zero Dispersion-shifted Fiber for Long-haul Telecommunications Applications**

meet ITU recommendation **G.655**, Characteristics of a Non-Zero Dispersion Shifted Single-Mode Optical Fibre Cable. (Ref Table 1/**G.655**-G.655A)

Geometry

4.1	Cladding Diameter	(m)	125.0 0.7
4.2	Core-to-Cladding Concentricity	(m)	= 0.5
4.3	Cladding Non-Circularity		= 1.0 %
4.4	Mode Field Diameter 1550 nm	(m)	9.2 - 10.0
4.5	Effective Area, A eff (Characterized)	(m)	72
4.6	Coating Diameter	(m)	245 5
4.6	Colored **Fiber** Nominal Diameter	(m)	253 259
4.8	**Fiber** Curl radius of curvature	(m) 4.0 m	

Optical

4.9	Cabled **Fiber** Attenuation 1550 nm		(dB/km)	= 0.3
4.10	Point discontinuity 1550 nm		(dB)	= 0.1
	Macrobend Attenuation		(dB)	
		Turns Mandrel OD		
4.11		1	32 2 mm	< 0.50 at 155
		1	32 2 mm	< 0.50 at 16.
		100	60 2 mm	< 0.05 at 155
		100	60 2 mm	< 0.05 at 16.
4.12	Cable Cutoff Wavelength (? cc)		(nm)	< 1480
			(ps/(nm km))	
4.13	Total Dispersion	1530 - 1565 nm		2.0 to 6.0
		1565 - 1625 nm		4.5 to 11.2
4.14	Cabled Polarization Mode Dispersion (		ps km)	= 0.5

5 Non-zero Dispersion-shifted Fiber for Metropolitan Telecommunications Applications

The non-zero dispersion-shifted single-mode **fiber** utilized in the optical **fiber** cable shall meet ITU recommendation **G.655**, Characteristics of a Non-Zero Dispersion Shifted Single-Mode Optical Fibre Cable. (Ref Table 2. **G.655**-G.655B)

Geometry

5.1	Cladding Diameter	(m)	125.0 1.0
5.2	Core-to-Cladding Concentricity	(m)	= 0.5
5.3	Cladding Non-Circularity		= 1.0 %
5.4	Mode Field Diameter 1550 nm	(m)	7.60 to 8.60
5.5	Coating Diameter	(m)	245 5
5.6	Colored **Fiber** Nominal Diameter	(m)	253 - 259
5.7	**Fiber** Curl radius of curvature	(m) > 4.0 m	

Optical

4.9	Cabled **Fiber** Attenuation 1550 nm		(dB/km)	= 0.3
4.10	Point discontinuity 1550 nm		(dB)	= 0.1
	Macrobend Attenuation		(dB)	
4.11		Turns	Mandrel OD	
		1	32 2 mm	< 0.50 at 15:
		1	32 2 mm	< 0.50 at 16(
		100	60 2 mm	< 0.10 at 15:
		100	60 2 mm	< 0.10 at 16(
4.12	Cable Cutoff Wavelength (? cc)		(nm)	< 1260
4.13	Total Dispersion - 1530 to 1605 nm (ps/(nm km))			-10.0 to -1.0
4.14	Cabled Polarization Mode Dispersion (ps km)			= 0.5

PowerForm™
DCM® Modules for +NZ-DSF Fibers

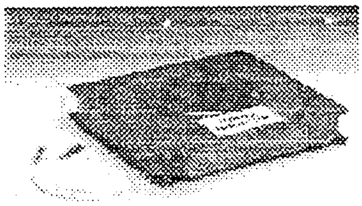
AVANEX

C-Band, Chromatic Dispersion Compensation

Based on negative dispersion compensation fiber technology, these field-proven DCM® Modules for +NZ-DSF fibers efficiently counteract the effects of chromatic dispersion across the C-Band wavelengths and facilitate dispersion compensation for a variety of +NZ-DSF fiber types. Standard modules are available with 1545 nm center wavelength, and dispersion values corresponding to typical +NZ-DSF fiber lengths. Other center wavelength and dispersion values are available upon request.

FEATURES

- Provides Optimized Dispersion Compensation Across the 1525 nm to 1565 nm Passband on Non-Zero Dispersion-Shifted Fibers
- Low Polarization Mode Dispersion
- Enhances DWDM System Performance by Reducing Accumulated Residual Dispersion
- Environmentally Robust and Fully Passive
- Variety of Connector Types and Pigtail Lengths Available



APPLICATIONS

- Systems using LEAF® Fiber or Any Positive Non-Zero Dispersion-Shifted Fiber
- Long-Haul and Ultra-Long-Haul Communications Systems Operating in the 1525 nm to 1565 nm Wavelength Range
- Multi-Channel High-Bit-Rate DWDM Systems
- Longer Reach Metropolitan Networks

DEFINITION OF DISPERSION SLOPE COMPENSATION

To efficiently manage the dispersion and the dispersion slope of a transmission fiber, the dispersion compensating fiber should satisfy the following equation:

$$SC = \frac{K^{1545}_{NZDSF}}{K^{1545}_{DCF}} = \frac{\left(\dfrac{D^{1545}_{NZDSF}}{S^{1545}_{NZDSF}}\right)}{\left(\dfrac{D^{1545}_{DCF}}{S^{1545}_{DCF}}\right)} = 1$$

S^{1545}_{NZDSF} : Dispersion slope of NZ-DCF fiber @ 1545 nm.

D^{1545}_{NZDSF} : Dispersion of NZ-DCF fiber @ 1545 nm.

LEAF® fiber Typical Value of K^{1545}_{NZDSF} equals 45 nm.

POWERED by AVANEX

DC01DC02/04

KEY OPTICAL PARAMETERS FOR COMMON MODULE LENGTHS

Module Description	Approximate Span Length (km)	Nominal Chromatic Dispersion (ps/nm @ 1545 nm)	Measured Dispersion[1] (ps/nm) @1530 nm Min	@1530 nm Max	@1545 nm Min	@1545 nm Max	@1565 nm Min	@1565 nm Max
60% LC-40-153	40 km LEAF® Fiber	-153	-140	-117	-161	-145	-217	-177
NZ-DSF-40-168	40 km NZ-DSF	-168	-154	-129	-176	-160	-237	-196
60% LC-80-306	80 km LEAF® Fiber	-306	-280	-234	-321	-291	-432	-356
NZ-DSF-80-336	80 km NZ-DSF	-336	-308	-256	-353	-319	-475	-390
60% LC-120-459	120 km LEAF® Fiber	-459	-420	-350	-482	-436	-648	-533
NZ-DSF-120-504	120 km NZ-DSF	-504	-461	-385	-529	-479	-711	-588

1. At room temperature.

SPECTRAL CHARACTERISTICS

Module Description	Kappa[1] K^{1545}_{DCM} (nm)	Insertion Loss[2] (dB)	Polarization Mode Dispersion[3] (ps)
60% LC-40-152	< 100	≤ 4.9	0.3
NZ-DSF-40-168	< 100	≤ 5.1	0.3
60% LC-80-304	< 100	≤ 6.3	0.4
NZ-DSF-80-336	< 100	≤ 6.5	0.4
60% LC-120-456	< 100	[illegible]	0.5
NZ-DSF-120-504	< 100	≤ 8.0	0.5

1. Kappa is defined as D_{DCM}/S_{DCM}, where D refers to dispersion and S refers to dispersion slope of the module.
2. This is the maximum optical loss incurred, including one pair of connectors, over wavelength range and temperature range.
3. As measured, average differential group delay over 1510–1565 nm wavelength range using the Jones Matrix method, in 1 nm increments at room temperature.

PowerForm™
DCM® Modules for +NZ-DSF Fibers

AVANEX

NONLINEAR PROPERTIES

Nonlinear Coefficient (n_2/A_{eff})	1.75 x 10^{-9} W^{-1} (Typical)
Effective Area (A_{eff}) @ 1550 nm	15 μm^2 (Typical)

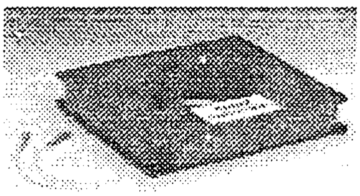
ENVIRONMENTAL CHARACTERISTICS

Operating Temperature Range	-5°C to 55°C
Environmental/Reliability Testing	Telcordia GR-2854 Qualified
Storage Temperature Range	-40°C to 85°C

PACKAGING OPTIONS

Package Type[1]	Nominal Dimensions (mm)	Maximum Dispersion Compensation (ps/nm) @ 1545 nm	Module Interface[2]: Standard Connector	Standard Pigtail Diameter	Standard Pigtail Length
D	267 x 267 x 40	-1360	SC/UPC	3.0 mm	1.5 m

1. Other packaging types available upon request
2. Other pigtail and connector options available



D Package

ORDERING INFORMATION

When ordering, please specify the following:

Module description

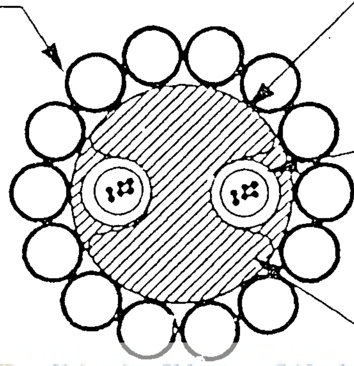
Compensated length (km) and/or requisite compensation (ps/nm)

Package type

Connector type/pigtail length

OPGW + APPROACH CABLE

FOCAS SkyLite™	Title: 0.469" OPGW	Drawn By:
	Design No: F-469N-297T-024	Approved By:
	If RED this is a controlled document. If BLACK it is an uncontrolled copy, check for latest issue	Issue Date: 12/7/99
	Rev. No. 0 / Scale 1" = 1/4"	Rev. Date:



SPECIFICATIONS		
	English	Metric
Cable Diameter:	0.469 in	11.91 mm
Core Diameter:	0.297 in	7.54 mm
Core Area:	0.0468 sq in	30.19 sq mm
Stranding:		
Aluminum Clad Steel Wire No./Dia.	14/0.083 in	14/2.11 mm
Rated Breaking Strength:	13,294 lbs	6,028 kgf
Rated Fault Current @20°C:	40(kA) sq sec	40 (kA) sq sec
Unit Weight:	0.284 lb/ft	0.425 kg/m
Modulus of Elasticity:	18.34 E+6 psi	12,898 kg/sq mm
Coefficient of Thermal Expansion:	8.37 E -6 / Deg F	15.06 E -6/Deg C
Cross Sectional Area:	0.123 sq in	79.06 sq mm
Nominal D.C. Resistance @20°C:	0.189 ohm/kft	0.620 ohm/km
Fiber Count:	2 - 24	2 - 24

SCHEDULE D (Continued....)

D-2

	Unit	Earthwire 7/3.25mm	ACSR $400mm^2$	ACSR $175mm^2$	TACIR Or Equi.
Conductor Jumper Lug Type Number		A4DD4015T	A3DD1454T	A3DD4144T	-
Vibration Damper Type Number		-	A4DD1241T	A3DD4670T	A3DD4670T
Distance from mouth of Suspension or Tension Clamp to Vibration Damper	m		1.37	0.80	1.37
Distance between subsequent Vibration Dampers	m		1.67	0.98	1.67
Details and Type Number of Compression tools -		.... 100 Tons requiered			
Identification Numbers of Compressor Dies to be Supplied -					
Aluminum part - Conductor		-	40A/F	27.5 A/F	40 A/F
Steel part - Conductor		-	17 A/F	16 A/F	17 A/F
Jumper Terminal - Conductor			40 A/F	27.5 A/F	40 A/F
Repair Sleeve - Conductor		-	40 A/F	-	-
Galvanized Steel - Earthwire		19A/F	-	-	-

D 3 - OPGW

Description	**Unit**	
Type of OPGW		SLOTTED CORE
Conforming to standard		IEEE 1138
Construction of OPGW		
1) Overall		
- Number of tubes:		2
- Tube diameter:	mm	1.9
- Tube material:		PBT
- Number of fibre/tube:		6
- Length of each fibre per km of OPGW (km):	km	1.012
- Filling compound:		HYDROCARRON
- Central strength member:		GEL
- Heat resistant barrier:		NONE
- Material of fibre:		NOE
2) Inner layer		SILICA
- Material		

		ALUMINIUM ALLOY
- Number of wires		0
- Diameter of wires		0
- Cross-section	mm^2	30
- Lay ratio		N/A
3) Outer layer		
- Material:		ACS
- Number of wires:		14
- Diameter of wires:	mm	2.11
- Cross-section:		
- Lay ratio:	mm^2	3.5 each
		as per IEEE 1138
Total cross sectional area	mm^2	79
Rated outer diameter	mm	11.9
Nominal weight	kg/km	425
Minimum ultimate tensile strength	kN	59.1
Maximum tensile strength for normal operation	kN	35.5
DC resistance at 20 degree C	ohm/km	0.620
Modulus of elasticity		
- Initial	kg/mm^2	12900
- Final	kg/mm^2	NOT DEFINED
Coefficient of linear expansion	/Deg. C	15×10^{-6}
Method of creep compensation		Calculated using installation program
Minimum bending radius;		
- Short term	mm	240 (STATIC)
- Long term	mm	240 (STATIC)
Strain margin;		
- Nominal	%	No Strain at 60% RBS
- Maximum allowance	%	No Strain at 60% RBS
Maximum allowable temperature and corresponding current;		
- continuous	Deg. C/kA	85
- for short circuit	Deg. C/kA	180
- for lightning stroke	Deg. C/kA	180
Optical Wave Guides;		
1) Number of optical fibres in OPGW		12
2) Mode		SINGLE
3) Optimised wave length	nm	1310 ~ 1550
4) Cut off wave length at;		
measured in 20 m OPGW + 2m optical fibre CC:	nm	< 1190
measured in 2m fibre section C:	nm	< 1260
5) Maximum attenuation per km at;		
1,550nm	dB / km	0.23
1,300nm	dB / km	0.36
6) Chromatic Dispersion at;		
Zero dispersion wave length:	nm	1311.5 +-10
Dispersion slope (So-at o):	$PS / nm^2.km$	<= 0.092
Dispersion D ( ) in the operation window from 1,300nm to 1,575nm	PS / nm.km	3.5 - 18
7) Nominal zero dispersion wavelength :	nm	1311.5
8) Refractive index;		
Core @ 1310 nm		1.4674
Cladding @ 1310 nm		1.4660
9) Material used in;		
Core		Silica
Cladding		Silica
Primary coating		Acrylate
Jacket		

Coating		—
10) Optical attenuation corresponding to		—
crush test		+ 0.05 dB max
impact test		+ 0.05 dB max
bend test		+ 0.05 dB max
sheave test:		
11) Mode field diameter and % deviation	%	9.2
12) Mode field non-circularity		10%
13) Outside (clad) diameter	µm	125+ - 1
14) Tolerance in outside (clad) diameter	µm	
15) Core cladding concentricity error	%	0.5
16) Cladding non-circularity (%):	%	1
17) Screening level/tensile proof test	%	1
18) Loose buffer design or Tight buffer design		Loose Tube
19) Temporary change in attenuation at 20 degree C due to;		
Temperature cycling	dB/km	+ 0.05 dB max
Lightning stroke	dB/km	+ 0.05 dB max
Short circuit current	dB/km	+ 0.05 dB max
20) Splicing loss	dB/splice	+ 0.01 dB max
21) Detail of color coding for fibre identification		EIA 598
22) Expected life time without degradation of characteristics	years	40
23) Maximum allowable short time temperature of fibre	Deg.C for sec.	150 for 1 sec
24) Nominal optical attenuation at 20 degree C over a period of 25 years:	dB / km	<= 0.36
25) Bit error rate:		not determined
26) Optical cross talks		not determined
Filling compound of OPGW:		
Long term effect of protection tube material on optical wave-guide fibre performance:		none
OPGW weight	kg/km	425
Maximum length of OPGW in a drum	km	6.5
Weight of drum with maximum length of OPGW	kg	3100
B. FIBER OPTIC APPROCH CABLE		
Cable type and model number		ALL DOELECTRIC RODENT RESISTANT
Conforming to standard		FDO-12RF6-H
Nominal overall diameter	mm	12.9 + - 0.2 mm
Optical wave-guide fibres similar to fibres in OPGW	yes/no	yes
If answer to item 4. above is no, details of fibres are provided	yes/no	—
Number of fibres in cable		12
Strength member materials	kN	GRP
Tensile strength		3.1
Minimum bending radius	mm	170
Short term	mm	170 statisc
Long term		170 static
Outside jacket		
Material		NYLON 12
Thickness	mm	1.8
Crush resistance (N/cm) at temperature	deg. C	100 N/cm @ 23°C
Method utilized to prevent water migration:		SWELLING YARN

Operating temperature range	deg. C	- 20 to + 60
Maximum variation in optical attenuation within operating temperature in range (item 13. above);		+ 0.1 dB / km
at 1,550nm	dB/km	+ 0.1 dB / km
at 1,300nm	dB/km	40
Cable life expectancy	years	Not determined
Atmospheric and sunlight degradation after	years	
Flexing over 100 cycle +/- 90 with bending radius of		Not determined
(mm) (yes or no):		Not determined
Torsional strength	degree/m	Not determined
Impact resistance at temperature of	deg.C	Not determined
Co-efficient of expansion per degree C		Duct
Suitable for laying in duct/direct burial/for both		I
Length markers on cable in unit length of	m	no
Rodent attack additive provided	yes/no	Sheath meets requirements of BALCORE TR-NWT-000020

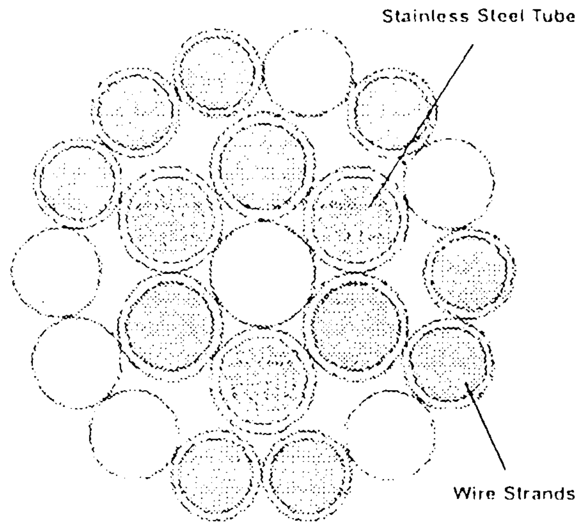
ALCOA

HIGH FIBER COUNT (HFC) OPT-GW DESIGN

DESIGN FEATURES

- High fiber count package with reduced diameter and weight (49 to 288 fibers)
- Laser-welded high grade stainless steel tube provides mechanical and thermal protection and hermetic seal for fibers
- Fiber excess length controlled to provide high load and long span capability
- Each optical fiber and tube is uniquely identified for organization at splice locations
- Stranded wires (type & size) selected to optimize mechanical and electrical properties
- Anti-rotational devices are not required for installation
- 40 year projected life

CABLE CROSS SECTION



DESIGN CRITERIA

- Meets or exceeds test criteria specified in IEEE 1138 and other industry standards
- Test data available upon request

FIBER TYPE & ATTENUATION

- Available fiber types include standard multimode, single-mode, dispersion shifted and non-zero dispersion shifted fibers
- Typical performance of 0.40/0.30 dB/km @ 1310/1550nm for single-mode fiber
- Tighter attenuation fibers available upon request

NOMENCLATURE

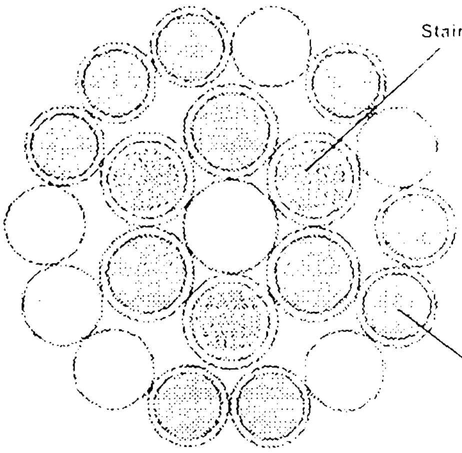
S1 - 29 / 57 / 646

- 646 — Outer Diameter (inch/1000)
- 57 — Aluminum Clad Steel Area (mm^2)
- 29 — Aluminum Alloy Area (mm^2)
- S1 — High Fiber Count Series 1

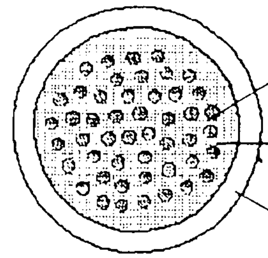
Note. Mechanical and electrical data, cross-sectional and hardware drawings, installation guides, and sag and tension information available upon request

Alcoa Fujikura Ltd.
Telecommunications Division

UP TO 144 FIBER OPT-GW



OPTICAL UNIT CROSS SECTION



SPECIFICATIONS

			INPUT FOR SAG10™ PROGRAM								
Item Number	OPT-GW Size (Strand Area/O.D)	Fault Current (kA)²sec	Total Conductor Area		Overall Diameter		Weight		RBS		Sag10™ Chart Number
			in²	mm²	in	mm	lbs/ft	kg/m	lbs	kg	
HFC7205	S1-60/70/630	107	0 2090	134 87	0.630	16.0	0.4612	0.686	22,534	10,221	1-1444
HFC7215	S1-69/69/646	121	0.2204	142.21	0.646	16.4	0.4723	0.703	22,857	10,368	1-420
HFC7225	S1-75/76/669	145	0.2407	155.29	0.669	17.0	0.5144	0.766	25,109	11,389	1-420
HFC9605	S1-60/70/630	107	0 2090	134 87	0.630	16.0	0.4612	0.686	22,534	10,221	1-1444
HFC9615	S1-69/69/646	121	0 2204	142.21	0.646	16.4	0.4723	0.703	22,857	10,368	1-420
HFC9625	S1-75/76/669	145	0 2407	155 29	0 669	17.0	0.5144	0.766	25,109	11,389	1-420
HFC14405	S1-60/60/630	93	0 1966	126 83	0 630	16.0	0.4316	0.642	19,907	9,030	1-420
HFC14415	S1-69/59/646	106	0.2080	134.17	0.646	16.4	0 4428	0.659	20,230	9,176	1-536
HFC14425	S1-75/66/669	129	0.2282	147 25	0.669	17.0	0.4848	0.722	22,482	10,198	1-536

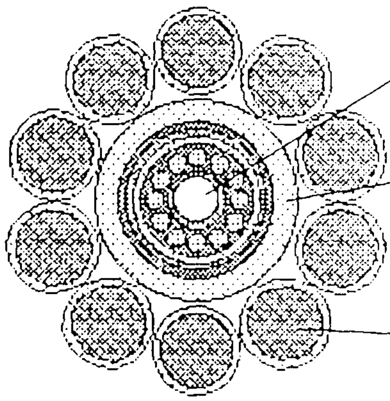
Note: Custom designs available

TYPICAL REEL LENGTHS

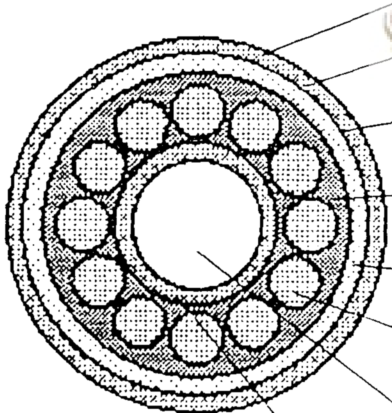
Item Number	NR68.34.35*		NR72.34.35*		NR84.34.35*	
	feet	meters	feet	meters	feet	meters
HFC7205	13,700	4,175	15,900	4,845	15,900	4,845
HFC7215	13,000	3,960	15,300	4,660	15,900	4,845
HFC7225	12,100	3,690	14,250	4,340	15,900	4,845
HFC9605	13,700	4,175	15,900	4,845	15,900	4,845
HFC9615	13,000	3,960	15,300	4,660	15,900	4,845
HFC9625	12,100	3,690	14,250	4,340	15,900	4,845
HFC14405	13,700	4,175	15,900	4,845	15,900	4,845
HFC14415	13,000	3,960	15,300	4,660	15,900	4,845
HFC14425	12,100	3,690	14,250	4,340	15,900	4,845

Longer lengths available upon request.
*Reel nomenclatures and specifications are identified on page 11

TRADITIONAL OPT-GW DESIGN



CABLE CROSS SECTION



OPTICAL UNIT CROSS SECTION

DESIGN FEATURES

- "Tight Structure" optical unit provides optimal mechanical and thermal fiber protection
- Thick wall aluminum pipe provides maximum protection of fiber units with hermetic seal, excellent crush resistance, and low resistivity
- Stranded wires (type & size) selected to optimize mechanical and electrical properties
- 40 year projected life

DESIGN CRITERIA

- Meets or exceeds test criteria specified in IEEE 1138 and other industry standards
- Test data available upon request

FIBER TYPE AND ATTENUATION

- Available fiber types include standard multimode, single-mode, dispersion shifted and non-zero dispersion shifted fibers
- Typical performance of 0.40/0.30 dB/km @ 1310/1550nm or single-mode fiber
- Tighter attenuation fibers available upon request

NOMENCLATURE

34 / 52mm^2 / 646

- 646 — Outer Diameter (inches /1000)
- 52mm^2 — Aluminum Clad Steel Area (mm^2)
- 34 — Aluminum Alloy Area (mm^2)

Note: Mechanical and electrical data, cross-sectional and hardware drawings, installation guides, and sag and tension information available upon request.

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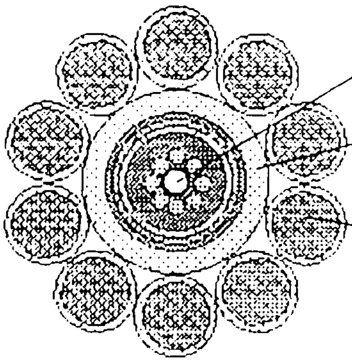
Telecommunications Division

SINGLE OPTICAL UNIT CONSTRUCTION - UP TO 8 FIBERS



SPECIFICATIONS

Item Number	OPT-GW size (Strand Area/O.D.)	Fault Current (kA)²sec	INPUT FOR SAG10™ PROGRAM: Total Conductor Area		Overall Diameter		Weight		RBS		Sag10™ Chart Number
			in²	mm²	in	mm	lbs/ft	kg/m	lbs	kg	
GW0800	53mm²/449	33	0.1166	75.24	0.449	11.4	0.2835	0.4228	0.4228	6,859	1-1453
GW0805	16/37mm²/449	38	0.1166	75.24	0.449	11.4	0.2415	0.3594	11,856	5,378	1-536
GW0810	27/27mm²/449	40	0.1166	75.24	0.449	11.4	0.2131	0.3171	9,679	4,390	1-1439
GW0815	68mm²/448	46	0.1396	90.08	0.488	12.4	0.3512	0.5226	19,158	8,690	1-1423
GW0820	23/45mm²/488	54	0.1396	90.08	0.488	12.4	0.2905	0.4324	14,515	6,584	1-420
GW0825	30/38mm²/488	56	0.1396	90.08	0.488	12.4	0.2703	0.4023	12,967	5,882	1-917
GW0830	86mm²/535	63	0.1677	108.17	0.535	13.6	0.4329	0.6442	22,279	10,106	1-1442
GW0835	32/54mm²/535	77	0.1677	108.17	0.535	13.6	0.3465	0.5157	16,249	7,371	1-536
GW0840	43/43mm²/535	81	0.1677	108.17	0.535	13.6	0.3177	0.4728	14,239	6,459	1-1170
GW0845	111mm²/598	92	0.2069	133.48	0.593	15.2	0.5472	0.8143	26,305	11,932	1-1429
GW0850	32/80mm²/598	110	0.2069	133.48	0.598	15.2	0.4621	0.6876	21,025	9,537	1-1461
GW0855	48/64mm²/598	118	0.2069	133.48	0.598	15.2	0.4195	0.6243	18,385	8,339	1-1460

Note: Customized designs available

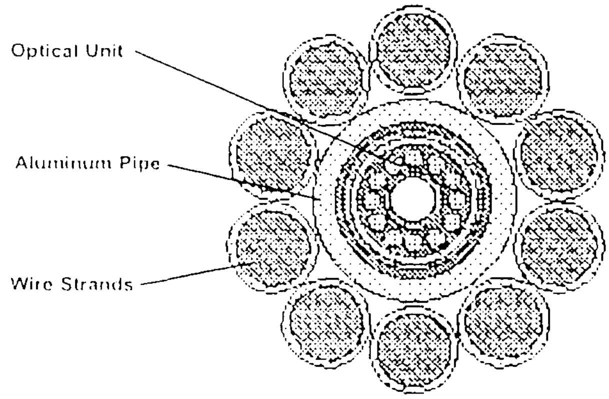
TYPICAL REEL LENGTHS

Item Number	NR60.28.30*		NR68.34.35*		NR72.34.36*	
	feet	meters	feet	meters	feet	meters
GW0800	21,378	6,516	23,000	7,010	23,000	7,010
GW0805	21,378	6,516	23,000	7,010	23,000	7,010
GW0810	21,378	6,516	23,000	7,010	23,000	7,010
GW0815	18,069	5,507	23,000	7,010	23,000	7,010
GW0820	18,069	5,507	23,000	7,010	23,000	7,010
GW0825	18,069	5,507	23,000	7,010	23,000	7,010
GW0830	15,021	4,578	23,000	7,010	23,000	7,010
GW0835	15,021	4,578	23,000	7,010	23,000	7,010
GW0840	15,021	4,578	23,000	7,010	23,000	7,010
GW0845	12,025	3,665	18,649	5,684	19,607	5,976
GW0850	12,025	3,665	18,649	5,684	19,607	5,976
GW0855	12,025	3,665	18,649	5,684	19,607	5,976

Longer lengths available upon request
*Reel nomenclatures and specifications are identified on page 11

ALCOA

SINGLE OPTICAL UNIT CONSTRUCTION - UP TO 24 FIBERS



*12 fiber unit shown

SPECIFICATIONS

Item Number	OPT-GW Size (Strand Area/O.D.)	Fault Current (kA)² sec	INPUT FOR SAG10™ PROGRAM: Total Conductor Area in²	Total Conductor Area mm²	Overall Diameter in	Overall Diameter mm	Weight lbs/ft	Weight kg/m	RBS lbs	RBS kg	Sag10™ Chart Number
GW1200	57mm²/465	35	0.1210	78.08	0.465	11.8	0.3036	0.4517	16,214	7,355	1-1421
GW1205	17/40mm²/465	40	0.1210	78.08	0.465	11.8	0.2576	0.3833	12,692	5,757	1-420
GW1210	23/34mm²/465	42	0.1210	78.08	0.465	11.8	0.2422	0.3604	11,518	5,225	1-1440
GW1215	29/29mm²/465	43	0.1210	78.08	0.465	11.8	0.2269	0.3376	10,344	4,692	1-1439
GW1220	72mm²/504	48	0.1445	93.21	0.504	12.8	0.3718	0.5534	20,329	9,221	1-1442
GW1225	16/56mm²/504	54	0.1445	93.21	0.504	12.8	0.3288	0.4893	17,031	7,725	1-1461
GW1230	24/48mm²/504	57	0.1445	93.21	0.504	12.8	0.3072	0.4572	15,381	6,977	1-420
GW1235	32/40mm²/504	59	0.1445	93.21	0.504	12.8	0.2858	0.4252	13,732	6,229	1-917
GW1240	91mm²/551	66	0.1729	111.56	0.551	14.0	0.4547	0.6767	23,421	10,624	1-1442
GW1245	23/68mm²/551	77	0.1729	111.56	0.551	14.0	0.3939	0.5863	19,181	8,701	1-1461
GW1250	34/57mm²/551	81	0.1729	111.56	0.551	14.0	0.3636	0.5412	17,061	7,739	1-420
GW1255	45/45mm²/551	86	0.1729	111.56	0.551	14.0	0.3333	0.4960	14,941	6,777	1-1170

Note: Custom designs available

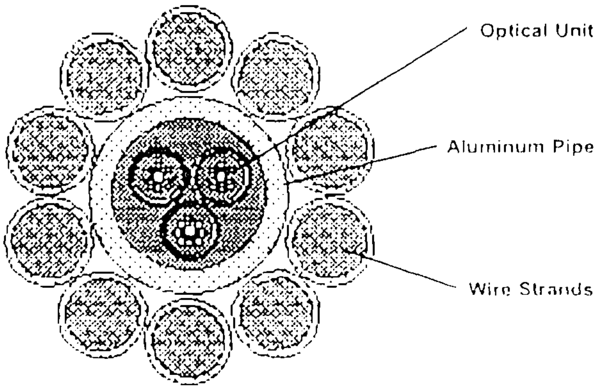
TYPICAL REEL LENGTHS

Item Number	NR60.28.30* feet	NR60.28.30* meters	NR68.34.35* feet	NR68.34.35* meters	NR72.34.35* feet	NR72.34.35* meters
GW1200	19,953	6,081	23,000	7,010	23,000	7,010
GW1205	19,953	6,081	23,000	7,010	23,000	7,010
GW1210	19,953	6,081	23,000	7,010	23,000	7,010
GW1215	19,953	6,081	23,000	7,010	23,000	7,010
GW1220	16,957	5,168	23,000	7,010	23,000	7,010
GW1225	16,957	5,168	23,000	7,010	23,000	7,010
GW1230	16,957	5,168	23,000	7,010	23,000	7,010
GW1235	16,957	5,168	23,000	7,010	23,000	7,010
GW1240	14,175	4,320	21,983	6,700	23,000	7,010
GW1245	14,175	4,320	21,983	6,700	23,000	7,010
GW1250	14,175	4,320	21,983	6,700	23,000	7,010
GW1255	14,175	4,320	21,983	6,700	23,000	7,010

Longer lengths available upon request.
*Reel nomenclatures and specifications are identified on page 11.

Alcoa Fujikura Ltd.
Telecommunications Division

MULTIPLE OPTICAL UNIT CONSTRUCTION - UP TO 24 FIBERS



SPECIFICATIONS

Item Number	OPT-GW Size (Strand Area/O.D.)	Fault Current (kA)² sec	INPUT FOR SAG10™ PROGRAM: Total Conductor Area in²	Total Conductor Area mm²	Overall Diameter in	Overall Diameter mm	Weight lbs/ft	Weight kg/m	RBS lbs	RBS kg	Sag10™ Chart Number
GW2400	64mm²/528	60	0.1531	98.80	0.528	13.4	0.3623	0.5391	18,433	8,361	1-1450
GW2405	25/39mm²/528	69	0.1531	98.80	0.528	13.4	0.2966	0.4413	13,400	6,078	1-1170
GW2410	29/34mm²/528	70	0.1531	98.80	0.528	13.4	0.2833	0.4218	12,393	5,621	1-1438
GW2415	74mm²/551	71	0.1688	108.88	0.551	14.0	0.4078	0.6068	21,174	9,605	1-1453
GW2420	25/49mm²/551	81	0.1688	108.88	0.551	14.0	0.3419	0.5087	16,123	7,313	1-1440
GW2425	37/37mm²/551	85	0.1688	108.88	0.551	14.0	0.3089	0.4597	13,598	6,168	1-1438
GW2430	83mm²/575	82	0.1829	118.01	0.575	14.6	0.4491	0.6682	23,659	10,732	1-1453
GW2435	30/53mm²/575	95	0.1829	118.01	0.575	14.6	0.3682	0.5480	17,468	7,923	1-1440
GW2440	38/45mm²/575	98	0.1829	118.01	0.575	14.6	0.3479	0.5179	15,920	7,221	1-1455
GW2445	96mm²/606	99	0.2034	131.20	0.606	15.4	0.5085	0.7569	25,904	11,750	1-1421
GW2450	29/67mm²/606	114	0.2034	131.20	0.606	15.4	0.4313	0.6419	20,307	9,211	1-420
GW2455	48/48mm²/606	122	0.2034	131.20	0.606	15.4	0.3797	0.5652	16,576	7,519	1-1439

Note: Custom designs available

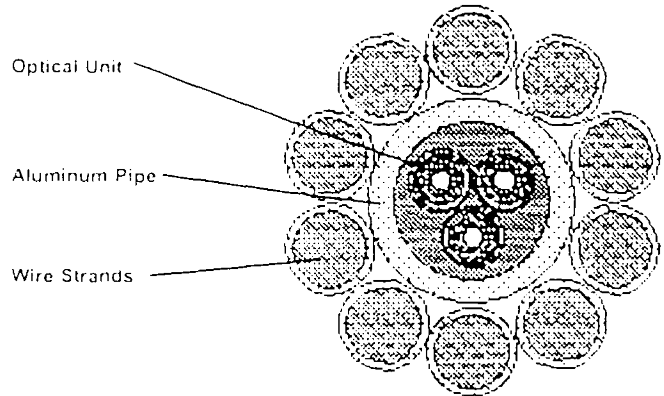
TYPICAL REEL LENGTHS

Item Number	NR60.28.30* feet	NR60.28.30* meters	NR68.34.35* feet	NR68.34.35* meters	NR72.34.35* feet	NR72.34.35* meters
GW2400	15,473	4,716	23,000	7,010	23,000	7,010
GW2405	15,473	4,716	23,000	7,010	23,000	7,010
GW2410	15,473	4,716	23,000	7,010	23,000	7,010
GW2415	14,175	4,320	21,983	6,700	23,000	7,010
GW2420	14,175	4,320	21,983	6,700	23,000	7,010
GW2425	14,175	4,320	21,983	6,700	23,000	7,010
GW2430	13,034	3,972	20,213	6,160	23,000	7,010
GW2435	13,034	3,972	20,213	6,160	23,000	7,010
GW2440	13,034	3,972	20,213	6,160	23,000	7,010
GW2445	11,715	3,570	18,168	5,537	20,803	6,340
GW2450	11,715	3,570	18,168	5,537	20,803	6,340
GW2455	11,715	3,570	18,168	5,537	20,803	6,340

Longer lengths available upon request.
*Reel nomenclatures and specifications are identified on page 11

ALCOA

MULTIPLE OPTICAL UNIT CONSTRUCTION - UP TO 36 FIBERS



SPECIFICATIONS

Item Number	OPT-GW Size (Strand Area/O.D.)	Fault Current (kA)² sec	INPUT FOR SAG10™ PROGRAM: Total Conductor Area in²	Total Conductor Area mm²	Overall Diameter in	Overall Diameter mm	Weight lb/ft	Weight kg/m	RBS lbs	RBS kg	Sag10™ Chart Number
GW3600	65mm²/555	72	0.1646	106.18	0.555	14.1	0.3853	0.5733	18,960	8,600	1-1461
GW3605	26/39mm²/555	81	0.1646	106.18	0.555	14.1	0.3156	0.4697	13,624	6,180	1-1439
GW3610	30/35mm²/555	82	0.1646	106.18	0.555	14.1	0.3040	0.4524	12,734	5,776	1-1438
GW3615	71mm²/571	79	0.1746	112.62	0.571	14.5	0.4144	0.6166	20,712	9,395	1-1450
GW3620	20/51mm²/571	87	0.1746	112.62	0.571	14.5	0.3597	0.5352	16,522	7,494	1-1440
GW3625	36/36mm²/571	93	0.1746	112.62	0.571	14.5	0.3187	0.4742	13,381	6,070	1-355
GW3630	80mm²/591	90	0.1878	121.17	0.591	15.0	0.4530	0.6741	23,037	10,450	1-1457
GW3635	31/49mm²/591	103	0.1878	121.17	0.591	15.0	0.3706	0.5514	16,724	7,586	1-1170
GW3640	37/43mm²/591	105	0.1878	121.17	0.591	15.0	0.3541	0.5269	15,461	7,013	1-1439
GW3645	91mm²/614	104	0.2041	131.70	0.614	15.6	0.5005	0.7448	25,900	11,748	1-1453
GW3650	30/60mm²/614	118	0.2041	131.70	0.614	15.6	0.4197	0.6246	19,709	8,940	1-350
GW3655	45/45mm²/614	125	0.2041	131.70	0.614	15.6	0.3793	0.5644	16,613	7,536	1-1438

Note: Custom designs available

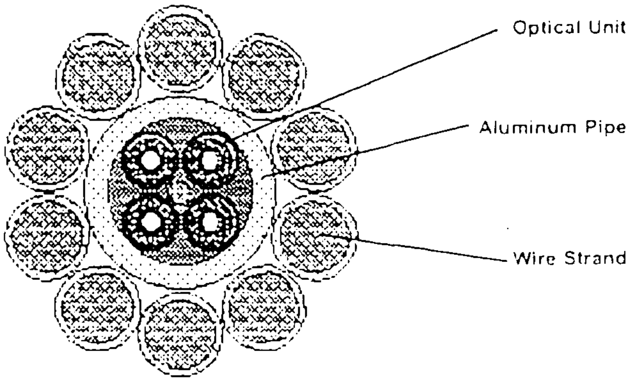
TYPICAL REEL LENGTHS

Item Number	NR60.28.30* feet	NR60.28.30* meters	NR68.34.35* feet	NR68.34.35* meters	NR72.34.35* feet	NR72.34.35* meters
GW3600	13,976	4,260	21,673	6,606	23,000	7,010
GW3605	13,976	4,260	21,673	6,606	23,000	7,010
GW3610	13,976	4,260	21,673	6,606	23,000	7,010
GW3615	13,215	4,028	20,492	6,246	23,000	7,010
GW3620	13,215	4,028	20,492	6,246	23,000	7,010
GW3625	13,215	4,028	20,492	6,246	23,000	7,010
GW3630	12,349	3,764	19,150	5,837	22,572	6,880
GW3635	12,349	3,764	19,150	5,837	22,572	6,880
GW3640	12,349	3,764	19,150	5,837	22,572	6,880
GW3645	11,417	3,480	17,703	5,396	20,869	6,361
GW3650	11,417	3,480	17,703	5,396	20,869	6,361
GW3655	11,417	3,480	17,703	5,396	20,869	6,361

Longer lengths available upon request.
*Reel nomenclatures and specifications are identified on page 11

Alcoa Fujikura Ltd.
Telecommunications Division

MULTIPLE OPTICAL UNIT CONSTRUCTION - UP TO 48 FIBERS



SPECIFICATIONS

			INPUT FOR SAG10™ PROGRAM								
Item Number	OPT-GW Size (Strand Area/O.D.)	Fault Current (kA)² sec	Total Conductor Area		Overall Diameter		Weight		RBS		Sag10™ Chart Number
			in²	mm²	in	mm	lbs/ft	kg/m	lbs	kg	
GW4800	86mm²/646	130	0.2208	142.43	0.646	16.4	0.5139	0.7647	25,098	11,384	1-1461
GW4805	29/57mm²/646	144	0.2208	142.43	0.646	16.4	0.4372	0.6507	19,227	8,721	1-1170
GW4810	34/52mm²/646	146	0.2208	142.43	0.646	16.4	0.4219	0.6279	18,053	8,189	1-1439
GW4815	40/46mm²/646	148	0.2208	142.43	0.646	16.4	0.4066	0.6051	16,879	7,656	1-355
GW4820	99mm²/669	151	0.2410	155.51	0.669	17.0	0.5729	0.8526	28,655	12,998	1-1450
GW4825	21/78mm²/669	163	0.2410	155.51	0.669	17.0	0.5162	0.7682	24,307	11,026	1-536
GW4830	28/71mm²/669	166	0.2410	155.51	0.669	17.0	0.4973	0.7400	22,857	10,368	1-1440
GW4835	49/49mm²/669	176	0.2410	155.51	0.669	17.0	0.4405	0.6555	18,509	8,396	1-355
GW4840	129mm²/724	204	0.2876	185.57	0.724	18.4	0.7088	1.0547	34,134	15,483	1-1453
GW4845	32/97mm²/724	227	0.2876	185.57	0.724	18.4	0.6224	0.9262	28,104	12,748	1-420
GW4850	43/86mm²/724	234	0.2876	185.57	0.724	18.4	0.5936	0.8834	26,094	11,836	1-350
GW4855	65/65mm²/724	247	0.2876	185.57	0.724	18.4	0.5361	0.7977	22,074	10,013	1-1438

Note: Custom designs available

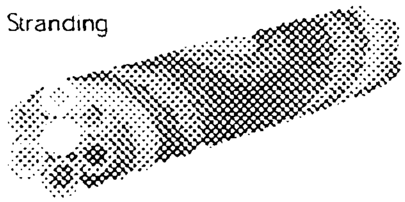
TYPICAL REEL LENGTHS

Item Number	NR60.28.30*		NR68.34.35*		NR72.34.35*	
	feet	meters	feet	meters	feet	meters
GW4800	10,330	3,148	16,020	4,882	18,882	5,755
GW4805	10,330	3,148	16,020	4,882	18,882	5,755
GW4810	10,330	3,148	16,020	4,882	18,882	5,755
GW4815	10,330	3,148	16,020	4,882	18,882	5,755
GW4820	9,613	2,930	14,909	4,544	17,572	5,355
GW4825	9,613	2,930	14,909	4,544	17,572	5,355
GW4830	9,613	2,930	14,909	4,544	17,572	5,355
GW4835	9,613	2,930	14,909	4,544	17,572	5,355
GW4840	8,206	2,501	12,726	3,878	15,000	4,572
GW4845	8,206	2,501	12,726	3,878	15,000	4,572
GW4850	8,206	2,501	12,726	3,878	15,000	4,572
GW4855	8,206	2,501	12,726	3,878	15,000	4,572

Longer lengths available upon request.
*Reel nomenclatures and specifications are identified on page 11

APPLICATION NOTE #018
Issued: 11/99

ADSS Cable Design



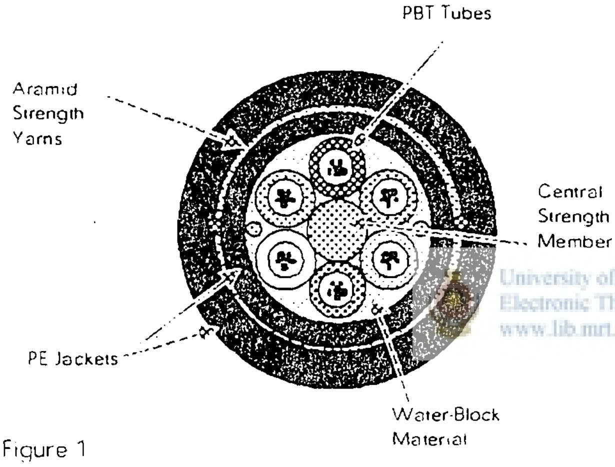


Figure 1

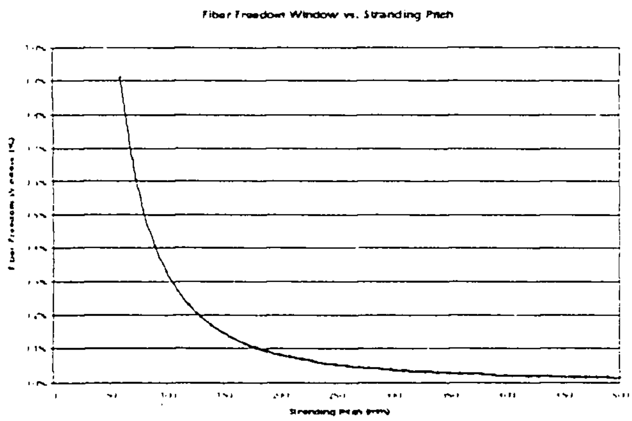


Figure 2: Fiber Freedom Window vs. Pitch

Overview

All Dielectric Self Support (ADSS) cable construction represents a modification of traditional loosetube cable designs which are popular for buried, duct or lashed applications. These modifications allow ADSS cables to endure environmental stresses not typically found in other applications. This Alcatel Application Note describes important similarities and differences between ADSS cables and traditional cables.

Special Design Considerations for ADSS Optical Cables

ADSS cables are, by definition, targeted for aerial installations. Cables that are buried, lashed to other support cables, or installed in ducts are designed with a trade-off between the ability to withstand pulling forces and the ability to handle compressive forces (for example caused by bending around the corner of a duct or caused by ice expansion underground during freezing). The primary design consideration for ADSS is to withstand significant tensile loads as the cables hang between supports. The cables' own weight as well as environmental forces (primarily high winds or ice buildup) apply stress to the cable structure. In addition, ADSS cables have to be designed for installation in "live" electrical power environments, or even to withstand potential stray gunshots from hunters. The requirement for installation in electrical fields and for lighter weight results in designs that are different from conventional optical fiber cables. In conventional cables metallic or other strength members or yarns provide the ability to withstand pulling forces. ADSS cable designs must accomplish this with a lightweight dielectric construction.

continued

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ADSS Cable Designs Compared to Conventional Optical Cables

The fundamental design of virtually all ADSS cable is based on the standard loose tube construction commonly used for most optical fiber cables; however, there are some important differences. The loose tube cable construction, illustrated in **Figure 1**, is designed to allow high tensile loads to be applied to the cable without transferring stress to the optical fibers within. The principle behind this cable design is to place fibers into buffer tubes filled with a gel compound. These tubes house and protect the fibers allowing freedom to move as the cable elongates or contracts. The buffer tubes themselves are spiral wound (stranded) around a central rod (central strength member) which helps to bear the load during cable pulling. The buffer tubes and the fibers within are longer than the cable itself. As the cable elongates under pulling stress, the fibers are free to move within the gel-filled tubes towards the center of the cable without any strain. This creates a 'tensile window' in which there is no fiber elongation or stress to a specified load. For a given central strength member and tube geometry, the shorter the laylength of the stranded tubes, the greater the tensile window available. **Figure 2** illustrates how a decrease in the stranding pitch reduces the coil interval allowing greater cable elongation without straining the fibers. The addition of strength yarns over the buffer tubes provides further protection and torsionally balances the tensile strength along the cable cross section. While most cables undergo tensile stress only during installation, ADSS cables remain continuously under tension once installed. Specificially, it is the tensile load bearing capabilities of the loose tube design that make it a well suited design for ADSS applications.

More recently, ADSS cables have incorporated dry water blocking materials used in conventional loose tube designs. Tests have proven that these materials have excellent resistance to penetration of water into the cable structure. Flooding compound offers excellent water resistance but requires more time in cable preparation for cleaning. Flooding compound also adds to cable weight, another consideration favoring dry water blocking materials.

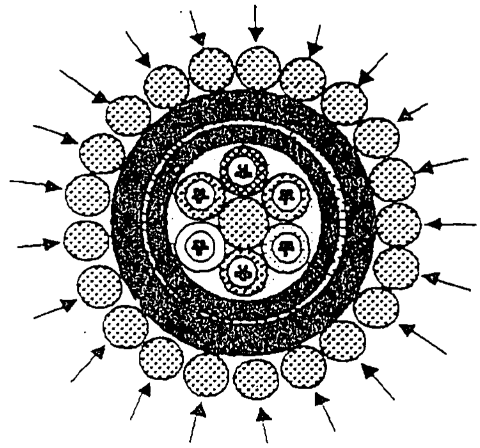


Figure 3: Compressive Forces of Dead End or Suspension Armor Rods

ADSS cables are mounted on poles or towers using hardware to anchor the cable jackets to the structures. Therefore, cable construction must be designed to help support anticipated loads. The cable sheath consists of two layers of polyethylene (inner and outer jackets in Figure 1) with strength yarns sandwiched between them. When anchoring hardware clamps down on the sheath surface, the force is transferred to the strength yarns within (**Figure 3**). The sheath with strength yarns acts like a net holding the bundles of buffer tubes and fibers within the cable length.

The Selection of ADSS Cable Materials of Construction

The primary design challenges for ADSS cables arise from the need to have high strength cables, which are at the same time lightweight and electrically non-conductive. Glass-reinforced plastics (GRPs) and aramid yarns are used to meet all three of these requirements. Aramid yarns are wrapped around the inner jacket over the cable core. Aramid yarns offer excellent strength-to-weight ratios (**Figure 4**) and provide added protection against potential jacket punctures. Aramid yarns are generally lighter than steel strength members, although at a cost premium.

ADSS cables require special outer jacket materials for protection against damage from electrical dry band

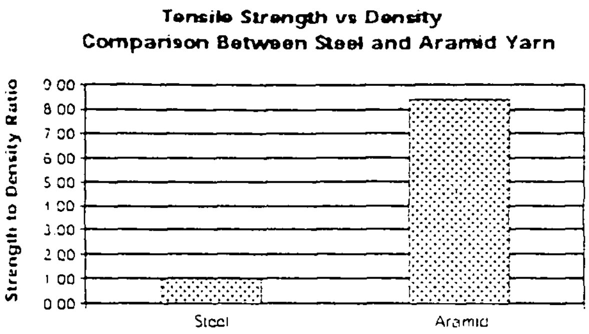


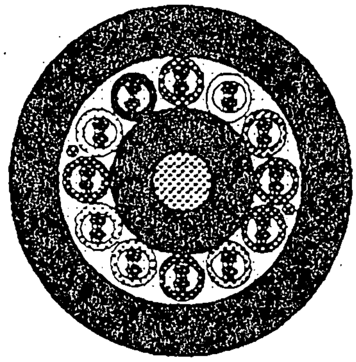
Figure 4: Tensile Strength vs Density

arcing (track resistant jackets). Alcatels' Trackguard™ jacket provides dry band arcing protection in high voltage applications as well as superior abrasion resistance. ADSS jacket requirements for electric fields are detailed in Alcatel's Application Note #017.

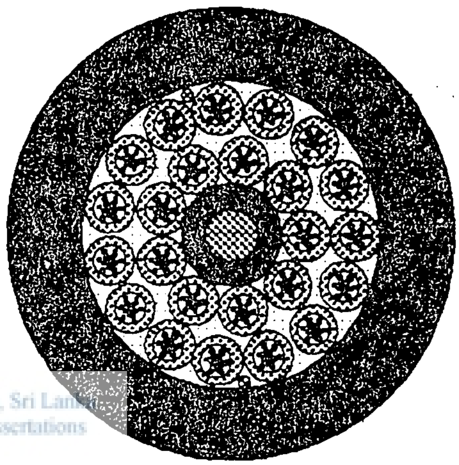
Cable Design for Emerging Bandwidth Needs

Individual ADSS cables must suit installation in a variety of different settings as well as meet demands for a wide range of fiber counts. The physical setting of the installation determines the tensile load requirement for the cable. To accomodate the sometimes enormous tensile loads placed on the cable by high winds or heavy ice, more or thicker strength yarns are wrapped around the cable core. Each installation must be considered carefully for selection of the proper strength yarn 'content' based on distance between poles or towers, obstacles in the area, changes in elevation, changes in temperature as well as local loading conditions due to wind and ice. Alcatel advises on proper selection during the initial quotation for each installation project to make sure that the appropriate cable design is specified for all of these factors.

Traditionally, ADSS cables have been supplied with up to 96 or 144 fibers. Recent growth in bandwidth requirements have resulted in demand for higher fiber counts. Two approaches can be taken to achieve cable designs with higher fiber counts. First, additional buffer tubes may be added which requires an additional outer layer of tubes overlapping an inner layer (multi-layer design). Second, additional fibers may be used within existing buffer tubes (single



12@1 Design with 24 fibers per tube



15@9@1 Design with 12 fibers per tube

Figure 5

layer design). Figure 5 illustrates these two approaches for a 288 fiber cable. Increasing the quantity of fibers within each buffer tube is preferred for several reasons. First, the addition of more buffer tubes adds to the cable weight in several ways. The buffer tubes themselves add weight, and the cable diameter increases requiring more jacket materials. The smaller diameter of the single layer design also reduces the wind and ice load on the cable and support structure by offering a smaller cross section against which these loads are placed.

The Product of Choice for Aerial Deployment

The design of ADSS optical fiber cables produces an optimal product for aerial systems. The design combines features widely accepted with traditional cables while also incorporating innovations ideally suited for installation in utility rights-of-way. The key features are:

- Use of the traditional loose tube optical cable design combined with aramid yarns provides a product that has proven reliability and is economical, durable, and easy to install and maintain
- Aerial applications favor lightweight constructions such as single layer buffer tube designs and use of aramid yarns for strength
- All dielectric construction allows installation on live systems without electrical hazard risks
- *Special jacket materials prevent jacket damage due* to dry-band electrical arcing damage from utility electric fields
- *For each application, the cable construction should* be customized for specific installation structures, climatic conditions, and local topography. Consult the supplier to ensure proper selection.

ALCOA

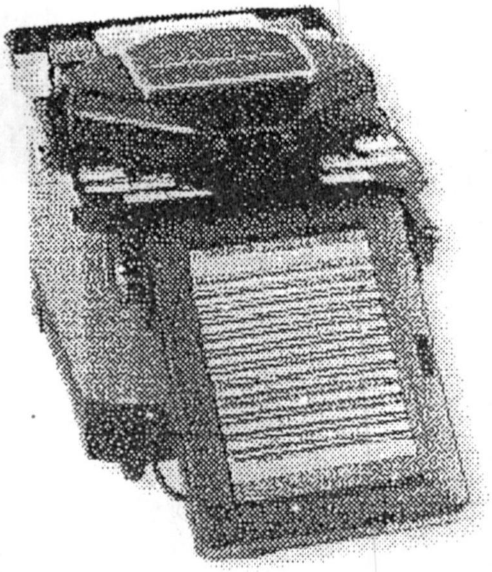
SINGLE-MODE CONNECTOR PERFORMANCE SPECIFICATIONS

Type	Polish	Repeatability Maximum (dB)	Insertion Loss Maximum (dB)	Return Loss	Ferrule Material
SC	Super PC	0.2	0.25	-45	Zirconia Ceramic
SC	Angled PC	0.2	0.5	-60	Zirconia Ceramic
SC	Ultra PC	0.2	0.25	-50	Zirconia Ceramic
FC	Super PC	0.2	0.25	-45	Zirconia Ceramic
FC	Angled PC	0.2	0.5	-60	Zirconia Ceramic
FC	Ultra PC	0.2	0.25	-50	Zirconia Ceramic
ST®	Super PC	0.2	0.5	-45	Zirconia Ceramic
D4	Super PC	0.2	0.25	-45	Ceramic Stainless Steel
D4	Ultra PC	0.2	0.25	-50	Ceramic Stainless Steel
SMA	Flat	0.5	1.5	n/a	Ceramic Stainless Steel
Biconic	Flat	0.3	1	-30	Thermoset Epoxyl
MU	Super PC	0.2	0.25	-45	Zirconia Ceramic
MTP	Flat	0.2	1	n/a	Thermoset Epoxyl
MTP	Angled	0.2	1	-60	Thermoset Epoxyl
ESCON®	Super PC	0.2	0.5	-45	Zirconia Ceramic
FDDI	Super PC	0.2	0.5	-45	Zirconia Ceramic

Test Parameter	Specification	Test Condition
Temperature Cycle	<0.2dB	40 cycles - 40°C too + 80°C
Humidity	<0.2dB	<0.2dB FOTP - 5 + 60°C at 95% RH for 504 hrs.
Thermal Shock	<0.2dB	10 cycles, - 40°C to + 60°C
Twist Test	<0.2dB	<0.2dB FOTP - 36, 10 cycles, 1.5kg (3.3 lbs)
Impact Test	<0.2dB	<0.2dB FOTP - 2, 8 cycles
Connector Durability	<0.2dB	<0.2dB FOTP - 21, 500 insertions
Vibration	<0.2dB	<0.2dB FOTP - 11, Condition II
Flex Test	<0.2dB	<0.2dB FOTP - 1, 300 cycles 0.5kg (1.1 lbs)
Cable Retention	<0.2dB	<0.2dB FOTP - 6, 89 Newton's (20 lbs)

Alcoa Fujikura Ltd.
Telecommunications Division

FSM-30R12 MINI MASS FUSION SPLICER



The new Fujikura FSM-30R12 brings a new level of productivity and capability to mass fusion splicing. The well-proven and market leading mass fusion splicing technology of previous Fujikura mass splicers is now provided in an extremely small and light weight mini-splicer. Improved immunity to ambient conditions and slide-in modular powering units (including battery) provide unprecedented mass fusion splicing capability in remote and outdoor splicing locations. The FSM-30R12 takes mass fusion splicing productivity to a new plateau with 12 fiber splicing time cut to one third that of previous generation mass splicers. The tube heater for heat shrink splice protection sleeves is twice as fast as the previous generation. The FSM-30R12 is the ideal mass fusion splicer for any application.

FEATURES & BENEFITS

- Best mass fusion splice loss performance in the industry, including splicing non-zero dispersion-shifted (NZ-DS) fibers
- Maximum productivity with much faster splicing than previous mass fusion splicer: 30 second splicing time
- New wind protector design withstands 30mph cross wind; unprecedented utility in exposed conditions

- Splices up to 12 fibers simultaneously
- Ultra small and light weight design; ideal for remote/outdoor splicing scenarios
- Built-in programmable tube heater
- Slide-in power modules include AC adapter, battery, or camcorder battery adapter
- Automatically adjusts fusion arc to compensate for differences in atmospheric pressure or altitude
- Simultaneous focus on all 12 fibers and large image magnification on low-glare 5" color LCD monitor provides great fiber visibility
- Great mass fusion splicer capacity under battery power

ALCOA

FSM-30R12 MINI MASS FUSION SPLICER

SPECIFICATIONS

Fiber Splicing Capability	SM, MM, NZ-DS (non-zero dispersion-shifted) & DS fibers (capable of splicing 2, 4, 6, 8, 10, or 12 fibers simultaneously, as well as single fiber splicing)
Splice Loss	0.04dB for SM, 0.02dB for MM, 0.07dB for NZ-DS fiber (typical)
Return Loss	< -60dB
Fusion Splices Per Battery Charge	~30 (includes use of splice protection tube heater & hot jacket ribbon stripping tool)
Splice Sleeve Capability	40mm mass splice sleeves, both 40mm & 60mm single fiber splice sleeves, and micro/mini sleeves (10 programmable tube heater modes)
Altitude Compensation Function	Fully automatic up to 3,500 meters (11,500 feet)
Viewing Method	5" LCD color monitor with 40X magnification
Operating Temperature	-10°C to +50°C
Storage Temperature	-40°C to +80°C
Power Supply	Modular bay accepts slide-in 12V 2.0 amp-hour battery pack or slide-in AC adapter. AC adapter accepts 100 to 240 VAC (50/60Hz). Optional slide-in adapter for 12V 2.0 amp-hour camcorder battery.
Dimensions (W x D x H)	150mm x 150mm x 150mm (5.9" x 5.9" x 5.9")
Weight	2.8 kg (6.2 lbs) with AC adapter installed; 3.2 kg (7.0 lbs) with battery installed

ORDERING INFORMATION

Item Description	Item Number
FSM-30R12 Mass Fusion Splicer Kit Fiber Holders (1 set) HJS-02 Hot Jacket Stripper CT-100B Cleaver Base FAT-02 or FAT-04 Fiber Arrangement Tool BTR-04 Field Replaceable Battery ADC-07 AC Adapter/Battery Charger FP-5 Splice Protection Sleeves	S010208
BTR-04 Spare Battery	S010236
ADC-07 Adapter/Battery Charger	S010240
HJS-02 Hot Jacket Stripper	S010340
BTA-02 Camcorder Battery Adapter	S010232
Camcorder Battery, 12V 2.0 amp-hour (5.65" length)	S010324
FAT-02 Fiber Arrangement Tool	S002111
FAT-04 Fiber Arrangement Tool	S010212
FAA-03 Ribbon Forming Adhesive (4 oz. bottle)	S008720
ST-3 Splice Tray Holder	S010860
Fiber Holders:	
FH-12 (12 fibers)	S010220
FH-10 (10 fibers)	S010348
FH-8 (8 fibers)	S010352
FH-6 (6 fibers)	S010356
FH-4 (4 fibers)	S010360
FH-2 (2 fibers)	S010364
FH-250 (250μm coated single fiber)	S010368
FH-900 (900μm jacketed single fiber)	S010372
Electrodes (pair)	S010216

APPENDIX – D:

SPECIFICATION SHEETS FOR OPTICAL LINE TERMINAL EQUIPMENT

Juniper NETWORKS

Search : This Section Whole Site

Products — Transform Best-Effort into Assured Experience

IP INFRASTRUCTURE

SONET/SDH PICS : DATASHEET

• Advantages • Description • Port Density and Flexibility • Key Features • Specifications • Ordering Information

SONET/SDH PICs

SONET/SDH is a widely deployed, mature enabling technology used in providing high-speed, large-scale IP networks This dependable technology combines high-bandwidth capacity with efficient link utilization, making it a major building block for accommodating a fast growing IP infrastructure both in the core and on the edge

As demand for more bandwidth increases, so does the demand to build out new, state-of-the-art, IP infrastructures to achieve greater backbone throughput and faster network response times. Juniper Networks is at the forefront of IP infrastructure build-out, offering a complete range of SONET/SDH Physical Interface Cards (PICs) and supporting speeds from OC-3c/STM-1 through OC-192c/STM-64.

M-series and T-series SONET/SDH PICs support rich packet processing, multiple IP services, and uncompromising performance, while offering market-leading port density and flexibility. They also provide IP-over-SONET optical connectivity to backbone and access circuits. Juniper Networks platforms support both concatenated and non-concatenated SONET/SDH interfaces, as well as channelized versions

Advantages

Features	Benefits
Predictable performance and consistent service-enabling features across all M-series and T-series PICs	Supports rich IP service deployment across all interfaces Increases service reliability Simplifies configuration Accelerates deployment time

	■ Reduces operational complexity ■ Decreases operational costs ■ Minimizes training time for operational staff
■ High-density interfaces with the ability to mix and match up to four PICs within a single Flexible PIC Concentrator (FPC) slot	■ Improves edge concentration and scalability of the core ■ Increases configuration flexibility by enabling service providers to mix different speeds, technologies, and IP services ■ Enables service providers to add uplink interfaces without wholly consuming an FPC slot ■ Reduces operational costs by maximizing ■ POP space
■ Broad range of connectivity speeds	■ Enables service providers to offer a wide range of IP services in diverse environments ■ Enhances service definition richness by increasing configuration flexibility ■ Ensures scalability for both subscriber and uplink interfaces
■ SONET APS, SDH MSP and MPLS fast reroute protection mechanisms	■ Increases network reliability with under 50-ms failover
■ Link aggregation	■ Increases performance by multiplying available bandwidth ■ Increases network reliability ■ Provides link redundancy ■ Increases scalability using existing SONET/SDH technology to provide additional bandwidth

Descriptions

2-port, 4-port OC-3c/STM-1	The OC-3c/STM-1 PIC provides an ideal solution for building backbones using high-speed OC-3c/STM-1 access circuits. This PIC delivers per-port 155-Mbps throughput for an aggregate PIC throughput of up to 622 Mbps ■ 2-port available on M5 and M10 Routers

	▪ 4-port available on all M-series routers, T320 routers, and the T640 routing node ▪ MM and SMIR optics ▪ Operates in concatenated mode only

1-port, 4-port OC-12c/STM-4	The one-port OC-12c/STM-4 PIC is ideal for migrating backbones to higher speeds while preserving the option for redundant circuits. This PIC delivers up to 622-Mbps clear channel throughput and can also provide four 155-Mbps OC-3/STM-1 circuits over a single optical interface.
	
	The four-port OC-12c/STM-4 PIC is well suited for high-bandwidth intra-POP connections, offering a lower cost per connection than OC-48c/STM-16 interfaces. It is also well fitted for applications where high-bandwidth intracampus connections are needed. This PIC delivers per-port 622-Mbps throughput for an aggregate PIC throughput of up to 2.5 Gbps
	
	▪ 1-port
	  ▪ Available on all M-series routers
	  ▪ Operates in both concatenated and nonconcatenated modes
	  ▪ MM and SMIR optics
	▪ 4-port
	  ▪ Available on M40e, M160, and T320 routers, and the T640 routing node
	  ▪ Operates in concatenated mode only
	  ▪ MM and SMIR optics

1-port, 4-port OC-48c/STM-16	The OC-48c/STM-16 SONET/SDH PIC is ideal for meeting the bandwidth demands at the Internet core with its uncompromising performance. It delivers true 2.5-Gbps throughput with IP services enabled
	
	▪ 1-port SFP
	  ▪ Small form factor pluggable (SFP) optics (SMIR, SMLR, and SMSR options)
	  ▪ Available on M20, M40e, M160, T320, and T640 platforms
	▪ 1-port
	  ▪ Quad wide available on M10 router
	  ▪ SMLR and SMSR optics
	  ▪ Operates in both concatenated and nonconcatenated modes
	▪ 4-port SFP
	  ▪ Small form factor pluggable (SFP) optics (SMIR, SMLR, and SMSR options)
	  ▪ Available on the T320 and T640 platforms

	■ Operates in concatenated mode only
1-port OC-192c/STM-64	The OC-192c/STM-64 SONET/SDH PIC, delivering up to 10-Gbps throughput, is advantageous for offering high bandwidth for inter- and intra-POP connections. This PIC can also provide four 2.5-Gbps OC-48/STM-16 circuits over a single optical interface. The VSR optics, in particular, offer a more cost-effective option than longer reach optics, and are very suitable when coupled with a DWDM system (for long haul connections). ■ Quad wide available on the M160 router ■ Single wide available on T-series platforms ■ SMLR, SMSR, and VSR optics ■ Operates in both concatenated and nonconcatenated modes

Port Density and Flexibility

Platform	OC-3c/STM-1		OC-12c/STM-4		OC-48c/STM-16		OC-192c/STM-64
	2-port	4-port	1-port	4-port	1-port	4-port	1-port
M5/M7i							
Per chassis	8	16	4	—	—	—	—
Per rack	120	240	60	—	—	—	—
M10/M10i							
Per chassis	16	32	8	—	2 M10 only	—	—
Per rack	240	480	120	—	30 M10 only	—	—
M20							
Per chassis	—	64	16	—	4	—	—
Per rack	—	320	80	—	20	—	—
M40e							

Per chassis	—	128	32	32	8	—	—
Per rack	—	256	64	64	16	—	—
M160							
Per chassis	—	128	32	128	32	—	8
Per rack	—	256	64	256	64	—	16
T320							
Per chassis	—	64	—	64	16	64	16
Per rack	—	192	—	192	48	192	48
T640							
Per chassis	—	128	—	128	32	128	32
Per rack	—	256	—	256	64	256	64

— = Not applicable

Key Features

A few of the key features supported by SONET/SDH PICs include SONET APS, SDH MSP, MPLS fast reroute, and link aggregation. Additionally, SONET/SDH PICs support filtering, sampling, load balancing, rate limiting, class of service, and other key features necessary for deploying secure, dependable, high-performance IP services

Automatic Protection Switching

The SONET/SDH PICs support APS 1+1 switching (bidirectional), which enables two routers and a SONET ADM to communicate. This functionality ensures a secondary path in the case of a router-to-ADM circuit failure, interface failure, or router failure. This functionality is interoperable with any ADM that uses GR-253-CORE-style signaling (K1/K2). In addition to the automatic switchover, service providers can manually initiate the switchover

MPLS Fast Reroute

MPLS fast reroute provides fast recovery if any circuit or router along a predetermined MPLS path, known as the label-switched path (LSP), fails. Each router along the LSP computes a standby detour path that avoids its downstream hop. If a circuit fails, the nearest upstream router automatically activates the detour paths

Link Aggregation

Link aggregation is the ability to bundle together a set of ports configured with the same speed in full-duplex mode into a virtual link, thereby supporting simultaneous parallel physical links between Juniper Networks platforms. Service providers can configure up to 16 groups per router, and each group supports up to 8 ports. If a link goes down, the traffic is redistributed among the remaining links, thereby improving network reliability

Specifications

Specification	Description

General	■ 9,192-byte MTU
	■ Encapsulations
	  ■ Frame Relay
	  ■ HDLC
	  ■ MPLS Circuit Cross-connect
	  ■ PPP

Interfaces	OC-3c/STM-1 PICs
	■ MM optical interface
	  ■ Connector: SC duplex connector
	  ■ Length: 1.2 miles / 2 km
	  ■ Wavelength: 1,270 to 1,380 nm
	  ■ Average launch power: -20 to -14 dBm
	  ■ Receiver saturation: -14 dBm
	  ■ Receiver sensitivity: -30 dBm
	■ SMIR optical interface (Bellcore GR-253-CORE compliant)
	  ■ Connector: SC duplex connector
	  ■ Length: 9.3 miles / 15 km
	  ■ Wavelength: 1,260 to 1,360 nm
	  ■ Average launch power: -15 to -8 dBm
	  ■ Receiver saturation: -8 dBm
	  ■ Receiver sensitivity: -28 dBm
	
	OC-12c/STM-4 PICs
	■ MM optical interface
	  ■ Connector: SC duplex connector
	  ■ Length: 546.80 yards / 500 m
	  ■ Wavelength: 1,270 to 1,380 nm
	  ■ Average Launch Power: -20 to -14 dBm
	  ■ Receiver Saturation: -14 dBm
	  ■ Receiver Sensitivity: -26 dBm

- SMIR optical interface (Bellcore GR-253-CORE compliant)
  - Connector: SC duplex connector
  - Length: 9.3 miles / 15 km
  - Wavelength: 1,274 to 1,356 nm
  - Average launch power: -15 to -8 dBm
  - Receiver saturation: -8 dBm
  - Receiver sensitivity: -28 dBm

1-port and 4-port OC-48c/STM-16 PICs with SFP

- Small form-factor pluggable (SFP) optics (SMIR, SMLR, and SMSR options)
- SMIR optical interface (Bellcore GR-253-CORE compliant)
  - Connector: LC duplex connector
  - Length: 9.3 miles / 15 km
  - Wavelength: 1,260 to 1,360 nm
  - Average launch power: -5 to -0 dBm
  - Receiver saturation: -0 dBm
  - Receiver sensitivity: -18 dBm
- SMLR optical interface (Bellcore GR-253-CORE compliant), compatible with 1,550 nm single-mode long reach
  - Connector: LC duplex connector
  - Length: 49.71 miles / 80 km
  - Wavelength: 1,500 to 1,580 nm
  - Average launch power: -2 to +3 dBm
  - Receiver saturation: -9 dBm
  - Receiver sensitivity: -28 dBm
- SMSR optical interface (Bellcore GR-253-CORE compliant)
  - Connectors: LC duplex connector
  - Length: 1.24 miles / 2 km
  - Wavelength: 1,266 to 1,360 nm
  - Average launch power: -10 to -3 dBm
  - Receiver saturation: -3 dBm
  - Receiver sensitivity: -18 dBm

1-port OC-48c/STM-16 PICs

- SMLR optical interface (Bellcore GR-253-CORE compliant); compatible with 1,550 nm single-mode long reach
  - Connector: SC duplex connector
  - Length: 49.71 miles / 80 km
  - Wavelength: 1,500 to 1,580 nm
  - Average launch power: -2 to +3 dBm
  - Receiver saturation: -9 dBm

- SMSR optical interface (Bellcore GR-253-CORE compliant)
  - Connector: SC duplex connector
  - Length: 1.24 miles / 2 km
  - Wavelength: 1,266 to 1,360 nm
  - Average launch power: -10 to -3 dBm
  - Receiver saturation: -3 dBm
  - Receiver sensitivity: -18 dBm

OC-192c/STM-64 PICs

- SMLR optical interface (Bellcore GR-253-CORE compliant), compatible with 1,550 nm single-mode long reach
  - Connector: SC duplex connector
  - Length: 49.71 miles / 80 km
  - Wavelength: 1,530 to 1,565 nm
  - Average launch power: +6 dBm to +8 dBm
  - Receiver saturation: -10 dBm
  - Receiver sensitivity: -22 dBm
- SMSR2 optical interface (Bellcore GR-253-CORE compliant); compatible with 1,550 nm single-mode short reach 2
  - Connector: SC duplex connector
  - Length: 15.5 miles / 25 km
  - Wavelength: 1,530 to 1,565 nm
  - Average launch power: -4 to -0 dBm
  - Receiver saturation: -3 dB
  - Receiver sensitivity: -14 dBm
- VSR optical interface; compatible with 12-ribbon multimode fiber
  - Connector: MTP connector
  - Length: 984.25 ft / 300 m
  - Wavelength: 830 nm to 860 nm
  - Average launch power: -10 to -3 dBm
  - Receiver saturation: -3 dB
  - Receiver sensitivity: -16 dBm

LEDs

One tricolor LED per port

Green	Port is online with no alarms or failures
Amber	Port is online with alarms or remote failures
Red	Port is active with a local alarm; failure detected
Off	Port is not enabled

Agency Approvals		
	Safety	■ CAN/CSA-C22.2 No. 60950-00/UL 60950—Third Edition, Safety of Information Technology Equipment ■ EN 60825-1 Safety of Laser Products—Part 1 Equipment Classification, Requirements and User's Guide ■ EN 60825-2 Safety of Laser Products—Part 2 Safety of Optical Fibre Communication Systems ■ EN 60950, Safety of Information Technology Equipment
	EMC	■ AS/NZS 3548 Class A (Australia / New Zealand) ■ BSMI Class A (Taiwan) ■ EN 55022 Class A Emissions (Europe) ■ FCC Part 15 Class A (USA) ■ VCCI Class A (Japan)
	Immunity	■ EN 61000-3-2 Power Line Harmonics ■ EN 61000-4-2 ESD ■ EN 61000-4-3 Radiated Immunity ■ EN 61000-4-4 EFT ■ EN 61000-4-5 Surge ■ EN 61000-4-6 Low Frequency Common Immunity ■ EN 61000-4-11 Voltage Dips and Sags
	NEBS	Designed to meet these standards ■ GR-63-CORE NEBS, Physical Protection ■ GR-1089-CORE EMC and Electrical Safety for Network Telecommunications Equipment ■ SR-3580 NEBS Criteria Levels (Level 3 Compliance)
	ETSI	■ ETS-300386-2 Telecommunication Network Equipment Electromagnetic Compatibility Requirements

Ordering Information

PIC	Platform	Model Number
OC-3c/STM-1 SONET/SDH		

Multimode, 2-port	M5, M7i, M10, M10i	PE-2OC3-SON-MM
Multimode, 4-port	M5, M7i, M10, M10i	PE-4OC3-SON-MM
	M20	P-4OC3-SON-MM
	M40e, M160, T320	PB-4OC3-SON-MM
Single-mode, intermediate reach, 2-port	M5, M7i, M10, M10i	PE-2OC3-SON-SMIR
Single-mode, intermediate reach, 4-port	M5, M7i, M10, M10i	PE-4OC3-SON-SMIR
	M20	P-4OC3-SON-SMIR
	M40e, M160, T320	PB-4OC3-SON-SMIR
	T320, T640	PC-4OC3-SON-SMIR
OC-12c/STM-4 SONET/SDH		
Multimode, 1-port	M5, M7i, M10, M10i	PE-1OC12-SON-MM
	M20	P-1OC12-SON-MM
	M40e, M160	PB-1OC12-SON-MM
Multimode, 4-port	M40e, M160, T320, T640	PB-4OC12-SON-MM
Single-mode, intermediate reach, 1-port	M5, M7i, M10, M10i	PE-1OC12-SON-SMIR
	M20	P-1OC12-SON-SMIR
	M40e, M160	PB-1OC12-SON-SMIR
Single-mode, intermediate reach, 4-port	M40e, M160, T320, T640	PB-4OC12-SON-SMIR
OC-48c/STM-16 SONET/SDH		
1-port SFP (Requires pluggable SFP Optics Modules: SMIR, SMLR, and SMSR)	M20	P-1OC48-SON-SFP
	M40e, M160, T320, T640	PB-1OC48-SON-SFP
Single-mode, long reach, 1-port	M10	PE-1OC48-SON-SMLR
Single-mode, short reach, 1-port	M10	PE-1OC48-SON-SMSR
4-port SFP (Requires pluggable SFP Optics Modules: SMIR, SMLR, and SMSR)	T320, T640	PC-4OC48-SON-SFP
OC-192c/STM-64		
Single-mode, long reach, 1-port	M160	IB-OC192-SON-LR-E
	T320, T640	PC-1OC192-SON-LR
Single-mode, short reach 2, 1-port	M160	IB-OC192-SON-SR2-E

Very short reach 1, 1-port	M160	IB-OC192-SON-VSR-E
	T320, T640	PC-1OC192-SON-VSR
Pluggable Optic Modules		
Small Form-Factor Pluggable Optic Module Single Mode Short Reach	NA	SFP-1OC48-SR
Small Form-Factor Pluggable Optic Module Single Mode Intermediate Reach	NA	SFP-1OC48-IR
Small Form-Factor Pluggable Optic Module Single Mode Long Reach	NA	SFP-1OC48-LR

How to Buy

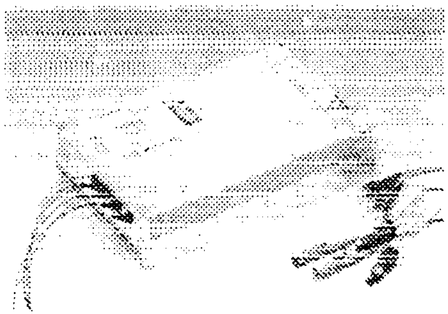
Feedback

PureGain™
Variable Gain EDFA for Long-Haul Networks

AVANEX

PureGain™ 5500

The PureGain™ 5500 Optical Amplifier Series is a family of variable gain amplifiers with mid-stage access (MSA). The amplifier's on-board electronics offer transient control that enables wavelength versatility and dynamic provisioning throughout the network. This high-performance control system allows add/drop of more than 75 percent of channels with minimal impact on system performance. Available for the C- and L-Bands with up to 23 dBm of output power, low ripple and noise figure, these amplifiers are ideal for metro regional, long-haul or ultra long-haul networks. PureGain™ 5500 amplifiers support long-reach, high channel count systems, including up to 4000 km ULH systems when used in conjunction with PureGain™ 5500 Raman Gain Modules.



FEATURES

- Variable Gain Design Provides Flat Gain Across a Wide Range of Operating Conditions
- 12 dB Mid-Stage Access for DC Modules, OADMs and Other High-Loss Optical Components
- Fully Integrated Control Electronics, Including State-of-the-Art Transient Control
- C-Band (1528 – 1565 nm) or L-Band (1570 – 1605 nm)
- Available as a Booster, Line or Pre-Amplifier
- RS-232 Command Interface with Monitoring, Alarms and Safety Shut-Downs
- Optional Optical Supervisory Channel Add/Drop
- 200 x 130 x 29 mm Size

APPLICATIONS

- Metro Regional, Long-Haul and Ultra Long-Haul DWDM Communications Networks
- Protocol, Bit-Rate and Channel-Count Independent, Supporting up to 10 Gb/s Signals

CONTENTS

POWERED by AVANEX

PureGain™
Variable Gain EDFA for Long-Haul Networks

AVANEX

KEY OPTICAL SPECIFICATIONS[1]

	Min	Typ	Max	Unit
C-Band Wavelength Range	1528	1530 – 1562	1565	nm
L-Band Wavelength Range	1568	1570 – 1605	1608	nm
OSC C-Band Wavelength Range		1505 – 1515		nm
OSC L-Band Wavelength Range		1620 – 1630		nm
Total Output Power (P_{out})			+23.0	dBm
Total Input Power Range (P_{in})	-26.0		+10.0	dBm
Mid-Stage Total Power			+16.0	dBm
Gain			30.0	dB
Gain Flatness (0 to +70°C)		0.8	1.0	dB
Mid-Stage Loss	[illegible]	10.0	12.5	dB
Noise Figure (P_{in} = 0 dBm), C-Band		5.8	6.0	dB
Noise Figure (P_{in} = 0 dBm), L-Band		6.5	7.0	dB
Polarization Dependent Gain (PDG)		0.4		dB
Polarization Mode Dispersion (PMD)[2]		0.5		ps/nm

1. Optical specifications show possible parameter ranges, depending on configuration.
2. The ranges depend on wavelength band. Shown for C-Band EDFA.

KEY ENVIRONMENTAL SPECIFICATIONS

	Min	Typ	Max	Units
Operating Case Temperature Range	0		70	°C
Storage Temperature Range	-40		85	°C
Operating Humidity Range[1]	5		95	% RH

1. Non-condensing.

KEY CONTROL[1] AND ELECTRICAL SPECIFICATIONS

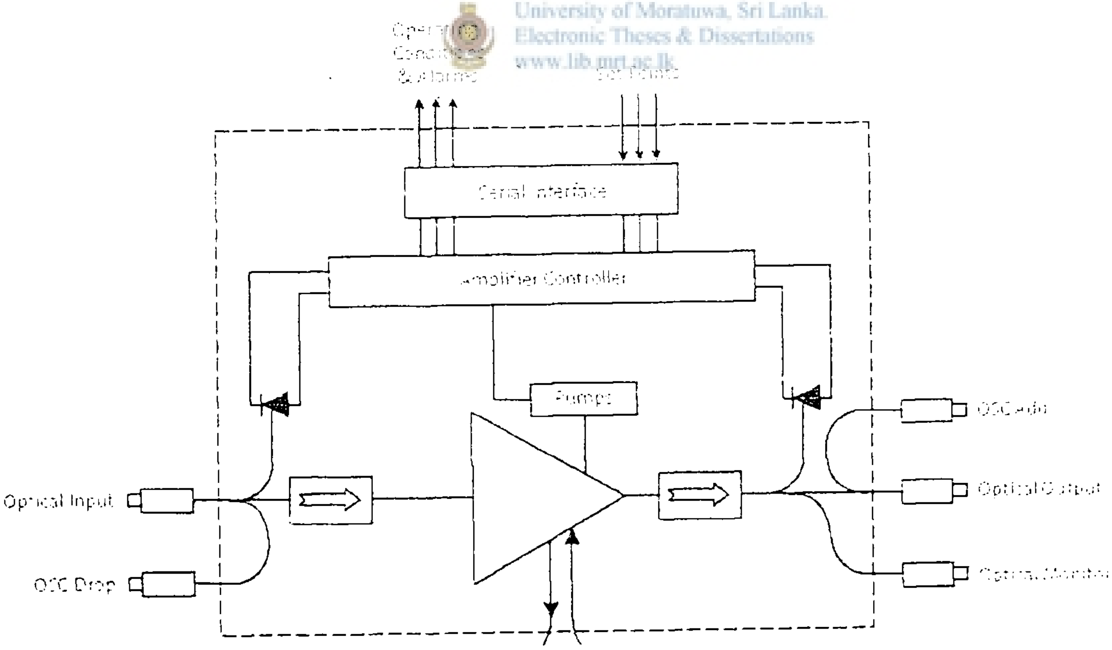
	Min	Typ	Max	Units
Transient Settling Time	10	50[2]	200[3]	µs
Transient Over/Undershoot	0.25	0.5[2]	1.0[3]	dB
Transient Offset			0.2[3]	dB
Cold Start Settling Time			1	s
Warm Start Settling Time			10	ms
Power Supply Voltage	+4.75	+5.0	5.25	VDC
Power Consumption		20	50	W

1. Software Copyright 2000 – 2002, All Rights Reserved.
2. Assumes 50% (3 dB) add/drop event.
3. Assumes 75% (6 dB) add/drop event.

SOFTWARE FUNCTIONS, MONITORS AND ALARMS

		C-Band	L-Band
Functions	In-Service Firmware Upgrades	✓	✓
	Auto Shut Down	✓	✓
	Set Pump Powers	✓	✓
	Fixed Gain Profile	✓	✓
	Gain Tilt Control	✓	✓
	Eye Safety Power Mode	✓	✓
Monitors	Total Output Power	✓	✓
	Case Temperature	✓	✓
	Coil Temperature	✓	✓
	Shut Down Alarm	✓	✓
	Low Input Power Alarm	✓	✓
	Low Output Power Alarm	✓	✓
	Signal Loss Alarm	✓	✓
Alarms	Case Temperature Alarm	✓	✓
	Pump Temperature Alarm	✓	✓
	Pump Bias Alarm	✓	✓

OPTICAL/ELECTRICAL SCHEMATIC



OSC = Optical Supervisory Channel

OPTICAL PIGTAILS

	Standard	Optional
Fiber Type	Corning SMF-28™ Fiber	
Pigtail Material	900 μm	3 mm, 2.0 mm, 2.4 mm and 2.9 mm
Pigtail Length	1 m ± 25 mm	Other Lengths Available
Pigtail Colors	Yellow	Others Available
Connector Type	SC	FC, LC, MU, E2000, Others
Connector Polish	UPC (RFL < -55 dB)	APC (RFL < -65 dB)

Optional pigtail materials may change the boot protrusion from the module and the pigtail bend radius.

STANDARD PRODUCTION TESTS

Total Output Power

Gain, Gain Variation and Gain Control Accuracy

Noise Figure

Transient Suppression (Settling Time, Over/Undershoot, Offset, as required)

1. All measurements are taken outside of the connectors.
2. Avanex measures radiated power.
3. Measurement temperature locations specified by Avanex.

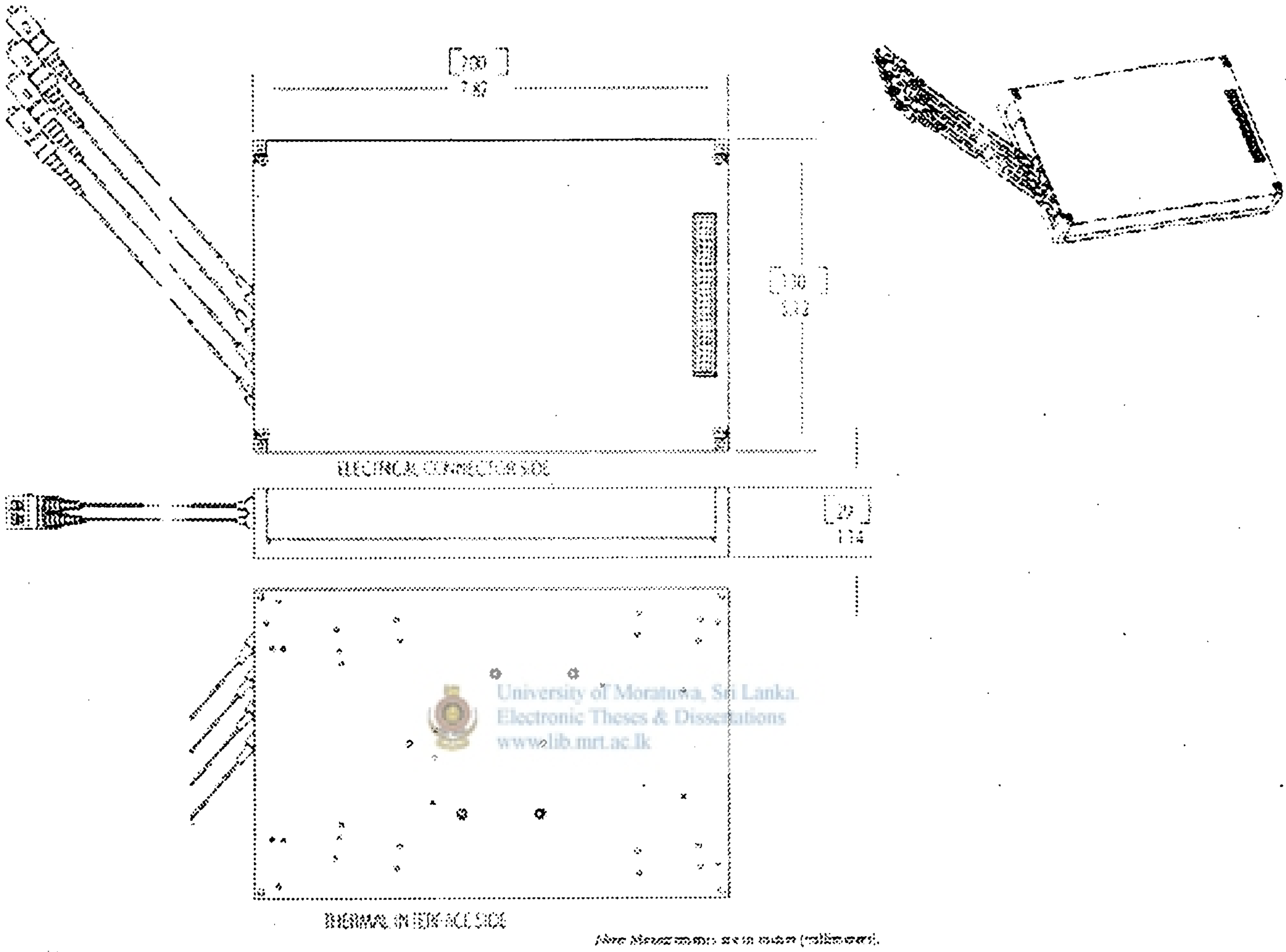
ELECTRICAL PIN ASSIGNMENTS

The electrical interface is via one 2-millimeter pitch socket with the following pin-outs:

50 Pin Connector (Samtec p/n: SQT-125-01-L-D)

Pins	Description	Pins	Description
1	+5 V Supply	2	+5 V Supply
3	+5 V Supply	4	+5 V Supply
5	+5 V Supply	6	+5 V Supply
7	Ground	8	Ground
9	Ground	10	Ground
11	NC	12	NC
13	Ground	14	Reset Input (Active Low)
15	Serial Input	16	Serial Output
17	Pump Current Alarm	18	Loss of Signal Alarm
19	Ground	20	Ground
21	Power Monitor Output 1	22	Power Monitor 1 Ground
23	Power Monitor Output 2	24	Power Monitor 2 Ground
25	Ground	26	Ground
27	Power Monitor Output 3	28	Power Monitor 3 Ground
29	Power Monitor Output 4	30	Power Monitor 4 Ground
31	Ground	32	Ground
33	High Temperature Alarm	34	Output Power Alarm
35	Pump Temperature Alarm	36	NC
37	Amplifier Disable Input	38	Output Power Mute Input
39	NC	40	NC
41	Ground	42	Ground
43	Ground	44	Ground
45	+5 V Supply	46	+5 V Supply
47	+5 V Supply	48	+5 V Supply
49	+5 V Supply	50	+5 V Supply

MECHANICAL FOOTPRINT



COMPLEMENTARY AMPLIFIER PRODUCTS

PureGain™ 5500R Raman Pump Module for Long-Haul Networks
PureGain™ 2600 Variable Gain EDFA for Metropolitan Networks
PureGain™ 1500 Fixed Gain, Compact EDFA with Control Electronics
PureGain™ 1000 Fixed Gain, Compact EDFA Booster Amplifier
PureGain™ 1000 Compact EDFA Pre-Amplifier

AVANEX
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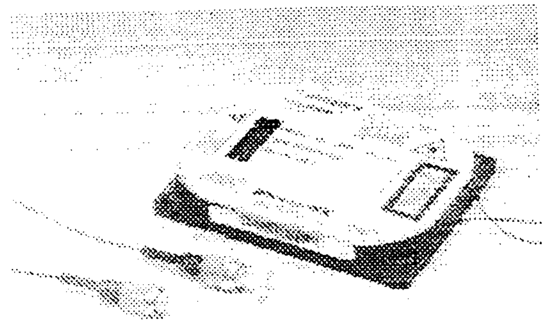
PureGain™
Compact EDFA Pre-Amplifier

AVANEX²

PureGain™ 1000

The PureGain™ 1000 Pre-amplifier provides high gain, high reliability, and superior noise figure performance in an industry-standard, compact form factor. This product enables deployment of flexible, high-density optical networks, while reducing capital and operating expenditures and offering best-in-class optical performance scaled to meet various applications' requirements. The PureGain™ 1000 Pre-amplifier has a proven deployment record in worldwide optical networks.



FEATURES

- Industry Standard Compact Form Factor (70 x 90 x 12 mm)
- Gain up to 30 dB
- Internal Photodiodes to Monitor Input and Output Power

APPLICATIONS

- Long-Haul and Metro Networks
- Single-Channel (SDH/SONET) or DWDM Networks
- Wavelength Add/Drop and Optical Cross Connect Power Equalization
- Transmitter and Receiver Amplification

CONTENTS

POWERED by AVANEX

PureGain™
Compact EDFA Pre-Amplifier

AVANEX

KEY OPTICAL SPECIFICATIONS

Parameters		Units
Wavelength Range	1530 - 1565	nm
Input Power Range	-30 ~ -10	dBm
Gain Range	13 ~ 30	dB
Maximum Output Power	3	dBm
Noise Figure (Typical) @ P_{in} = -20 dBm, P_{out} = 3 dBm	5.0	dB
Noise Figure (Maximum), @ P_{in} = -20 dBm, P_{out} = 3 dBm	5.5	dB
Polarization Dependent Gain (Maximum)	0.4	dB
Polarization Mode Dispersion (Maximum)	0.3	ps

KEY ENVIRONMENTAL SPECIFICATIONS

Parameters	Min.	Typ.	Max.	Units
Operating Case Temperature	0		70	°C
Storage Temperature	-40		85	°C
Operating Humidity[1]	5		95	% RH

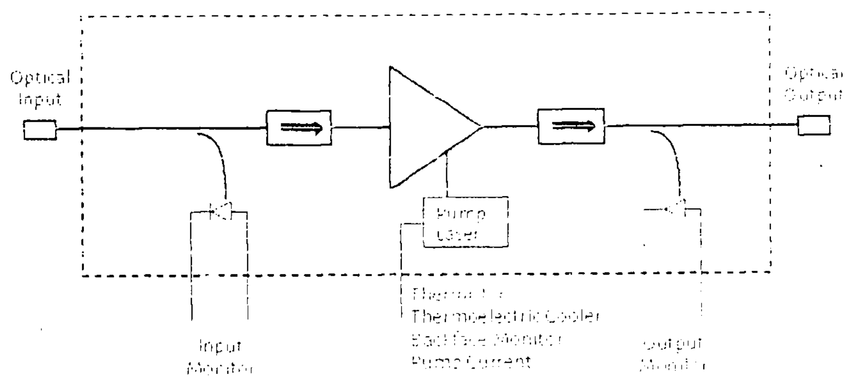
1. Non-condensing.

KEY ELECTRICAL SPECIFICATIONS

Parameter	Min.	Typ.	Max.	Units
Total Power Consumption, With Thermoelectric Cooler		3.0	4.0[1]	W
Total Power Consumption, Uncooled			1.5	W

1. Worst-case, end-of-life operating condition.

OPTICAL SCHEMATIC



ELECTRICAL PIN ASSIGNMENTS

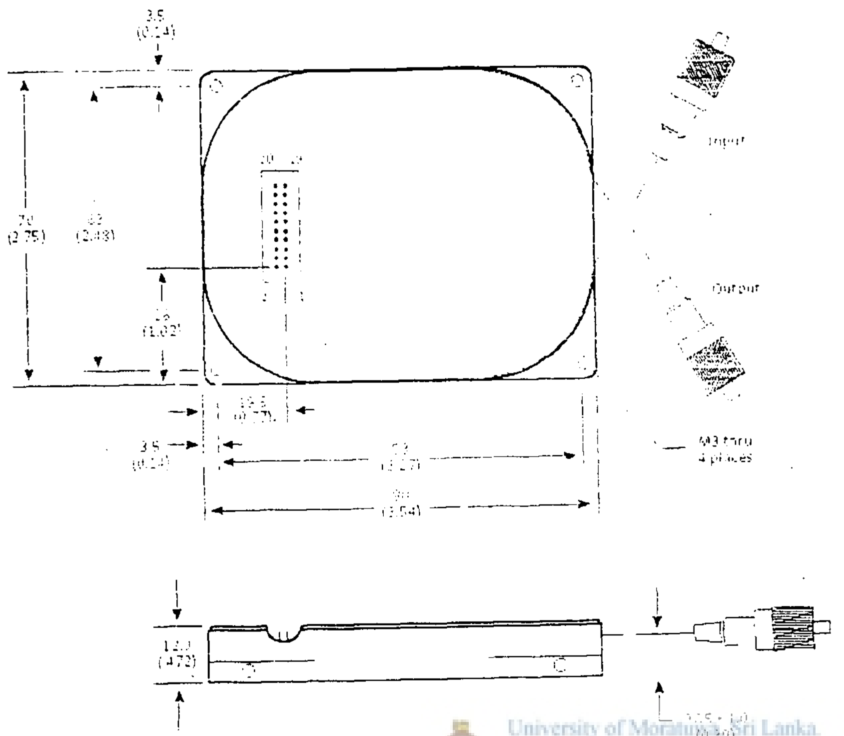
The standard electrical connector is a 20-pin male connector (Samtec MTMM-110-05-S-D-205) with the pin out shown below. An optional 16-pin connector is available upon request.

Pin #	Description
1	Ground Input and Output Photodiodes
2	Input Monitor Cathode
3	Input Monitor Anode
4	Output Monitor Cathode
5	Output Monitor Anode
6	Thermistor
7	Laser Diode Anode
8	Laser Diode Anode
9	Backface Monitor Cathode
10	Backface Monitor Anode
11	Thermoelectric Cooler, Positive
12	Thermoelectric Cooler, Positive
13	Thermoelectric Cooler, Positive
14	Thermoelectric Cooler, Negative
15	Thermoelectric Cooler, Negative
16	Thermoelectric Cooler, Negative
17	Ground Pump Laser
18	Thermistor
19	Laser Cathode
20	Laser Cathode

PureGain™
Compact EDFA Pre-Amplifier

AVANEX²

MECHANICAL FOOTPRINT



1. Dimensions are in millimeters. (Dimensions in parentheses are in inches).
2. Optional integrated or stand-alone heat sink available upon request.

STANDARD PRODUCTION TESTS[1]

Input Power

Output Power

Pump Drive Current

Gain

Noise Figure

Responsivity

1. All measurements are performed outside the connectors and are measured as radiated power.

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APPENDIX – E:

MS EXCEL WORKSHEETS OF OPTICAL POWER BUDGET CALCULATIONS

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: New Anuradhapura - Kotmale	
Link Length /(km):	163

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	168

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	27
OPGW Splice Loss	1.08
Total Connector / Splice Losses	2.16

3 Attenuation Losses

OPGW Attenuation / (dB)	48.9
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	49.2

4 Total System Loss / (dB) — 51.36

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kotmale - Kiribathkumbura

Link Length /(km):	22.5

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	24

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	3
OPGW Splice Loss	0.12
Total Connector / Splice Losses	1.2

3 Attenuation Losses

OPGW Attenuation / (dB)	6.75
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	7.05

4 Total System Loss / (dB) — 8.25

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kiribathkumbura - Ukuwela	
Link Length /(km):	29.9

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	30

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	4
OPGW Splice Loss	0.16
Total Connector / Splice Losses	1.24

3 Attenuation Losses

OPGW Attenuation / (dB)	8.97
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	9.27

4 Total System Loss / (dB) 10.51

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kolonnawa - Kotmale

Link Length /(km):	85.2

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	90

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	14
OPGW Splice Loss	0.56
Total Connector / Splice Losses	1.64

3 Attenuation Losses

OPGW Attenuation / (dB)	25.56
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	25.86

4 Total System Loss / (dB) — 27.5

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kotmale - Badulla	
Link Length /(km):	82.6

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	84

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	13
OPGW Splice Loss	0.52
Total Connector / Splice Losses	1.6

3 Attenuation Losses

OPGW Attenuation / (dB)	24.78
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	25.08

4 Total System Loss / (dB) — 26.68

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Badulla - Laxapana

Link Length /(km):	74.2

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	78

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	12
OPGW Splice Loss	0.48
Total Connector / Splice Losses	1.56

3 Attenuation Losses

OPGW Attenuation / (dB)	22.26
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	22.56

4 Total System Loss / (dB) 24.12

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Laxapana - Kolonnawa

Link Length /(km):	104.2

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	108

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	17
OPGW Splice Loss	0.68
Total Connector / Splice Losses	1.76

3 Attenuation Losses

OPGW Attenuation / (dB)	31.26
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	31.56

4 Total System Loss / (dB) — 33.32

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kolonnawa - Kotugoda

Link Length /(km):	23.3

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	24

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	3
OPGW Splice Loss	0.12
Total Connector / Splice Losses	1.2

3 Attenuation Losses

OPGW Attenuation / (dB)	6.99
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	7.29

4 Total System Loss / (dB) 8.49

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kotugoda - Bolawatta	
Link Length /(km):	21

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	24

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	3
OPGW Splice Loss	0.12
Total Connector / Splice Losses	1.2

3 Attenuation Losses

OPGW Attenuation / (dB)	6.3
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	6.6

4 Total System Loss / (dB) 7.8

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Bolawatta - Chilaw

Link Length /(km):	29.4

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	30

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	4
OPGW Splice Loss	0.16
Total Connector / Splice Losses	1.24

3 Attenuation Losses

OPGW Attenuation / (dB)	8.82
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	9.12

4 Total System Loss / (dB) — 10.36

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Chilaw - Puttalam
Link Length /(km): 68.2

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	72

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	11
OPGW Splice Loss	0.44
Total Connector / Splice Losses	1.52

3 Attenuation Losses

OPGW Attenuation / (dB)	20.46
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	20.76

4 Total System Loss / (dB) **22.28**

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Laxapana - Balangoda

Link Length /(km):	44.5

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	48

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	7
OPGW Splice Loss	0.28
Total Connector / Splice Losses	1.36

3 Attenuation Losses

OPGW Attenuation / (dB)	13.35
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	13.65

4 Total System Loss / (dB) 15.01

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Balangoda - Galle	
Link Length /(km):	102.5

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	108

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	17
OPGW Splice Loss	0.68
Total Connector / Splice Losses	1.76

3 Attenuation Losses

OPGW Attenuation / (dB)	30.75
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	31.05

4 Total System Loss / (dB) **32.81**

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Balangoda - Embilipitiya	
Link Length /(km):	78

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	78

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	12
OPGW Splice Loss	0.48
Total Connector / Splice Losses	1.56

3 Attenuation Losses

OPGW Attenuation / (dB)	23.4
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	23.7

4 Total System Loss / (dB) **25.26**

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Embilipitiya - Matara
Link Length /(km): 52

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	54

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	8
OPGW Splice Loss	0.32
Total Connector / Splice Losses	1.4

3 Attenuation Losses

OPGW Attenuation / (dB)	15.6
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	15.9

4 Total System Loss / (dB) 17.3

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Embilipitiya -Hambantota

Link Length /(km):	35

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	36

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	5
OPGW Splice Loss	0.2
Total Connector / Splice Losses	1.28

3 Attenuation Losses

OPGW Attenuation / (dB)	10.5
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	10.8

4 Total System Loss / (dB) **12.08**

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kolonnawa - Panadura
Link Length /(km): 11.7

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	12

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	1
OPGW Splice Loss	0.04
Total Connector / Splice Losses	1.12

3 Attenuation Losses

OPGW Attenuation / (dB)	3.51
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	3.81

4 Total System Loss / (dB) — 4.93

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Habarana - Valaichchenai	
Link Length /(km):	99.7

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	102

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	16
OPGW Splice Loss	0.64
Total Connector / Splice Losses	1.72

3 Attenuation Losses

OPGW Attenuation / (dB)	29.91
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	30.21

4 Total System Loss / (dB) — 31.93

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Kiribathkumbura - Kurunegala

Link Length /(km):	34.6

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	36

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	5
OPGW Splice Loss	0.2
Total Connector / Splice Losses	1.28

3 Attenuation Losses

OPGW Attenuation / (dB)	10.38
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	10.68

4 Total System Loss / (dB) 11.96

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: New Anuradhapura - Vavuniya

Link Length /(km):	53.5

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	54

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	8
OPGW Splice Loss	0.32
Total Connector / Splice Losses	1.4

3 Attenuation Losses

OPGW Attenuation / (dB)	16.05
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	16.35

4 Total System Loss / (dB) 17.75

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: New Anuradhapura -Trincomalee
Link Length /(km): 103.3

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	108

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	17
OPGW Splice Loss	0.68
Total Connector / Splice Losses	1.76

3 Attenuation Losses

OPGW Attenuation / (dB)	30.99
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	31.29

4 Total System Loss / (dB) **33.05**

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Badulla - Ampara

Link Length /(km):	104.9

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	108

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	17
OPGW Splice Loss	0.68
Total Connector / Splice Losses	1.76

3 Attenuation Losses

OPGW Attenuation / (dB)	31.47
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	31.77

4 Total System Loss / (dB) — 33.53

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Ukuwela - Habarana	
Link Length /(km):	82.3

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	84

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	13
OPGW Splice Loss	0.52
Total Connector / Splice Losses	1.6

3 Attenuation Losses

OPGW Attenuation / (dB)	24.69
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	24.99

4 Total System Loss / (dB) **26.59**

5 Total System Gain / (dB)

6 Margin / (dB)

Appendix E: OPTICAL POWER BUDGET WORKSHEET

LINK: Habarana - New Anuradhapura	
Link Length /(km):	50.4

1 SYSTEM FIGURES

Single splice loss / (dB)	0.04
Attenuation coefficient / (dB/km)	0.3
Insertion Loss for pair of Demountable Connectors / (dB)	0.25
Length of Optical Fiber Approach Cable / (km)	0.5
Span between tower / (km)	0.4
Splicing Interval for OPGW / (km) - to be given in the nearest multiple of span)	6
Approximated Link Length: (to be given in the nearest multiple of splicing interval)	54

2 Connector / Splicing Losses

Loss at Location (1)	0.5
Loss at Location (2)	0.5
Loss at Location (3)	0.08
Number of Splices	8
OPGW Splice Loss	0.32
Total Connector / Splice Losses	1.4

3 Attenuation Losses

OPGW Attenuation / (dB)	15.12
OFAC Attenuation / (dB)	0.3
Total Attenuation Losses / (dB)	15.42

4 Total System Loss / (dB) **16.82**

5 Total System Gain / (dB)

6 Margin / (dB)

APPENDIX – F:

COMPARISON WITH SIMILAR NETWORKS

SYSTEM CONFIGURATION FOR TRANSMISSION SYSTEM
SLTL ATOP-1 (OECF-III) PROJECT

ISSUE NO. : 01 / REV.00
ISSUE DATE : 14TH JANUARY 2000
ISSUED BY : TOSHIYA MATSUMOTO (PM FOR ATOP-1 P/J)

NOTE:
1. THIS SYSTEM CONFIGURATION IS PRODUCED ACCORDING TO THE TECHNICAL DOCUMENT OF THE ORIGINAL CONTRACT. NUMBER OF 2M CH IS ACCORDING TO
2. THE CONCLUSION IN THE TECHNICAL MEETING HELD ON 14TH JAN. 2000.
3. THIS DOCUMENT IS FOR REFERENCE ONLY BUT NOT FOR OFFICIAL USAGE.