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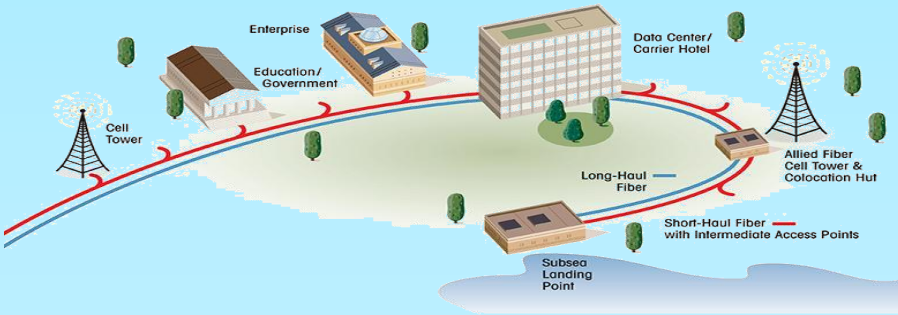
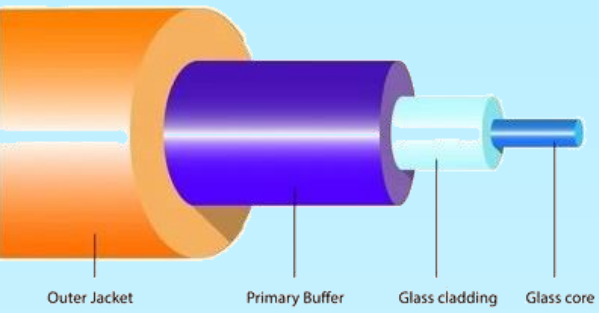
Concept Paper on Optical Fibre and Cable in Indian Telecom Network

TEC 02008:2021





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TELECOMMUNICATION ENGINEERING CENTRE
DEPARTMENT OF TELECOMMUNICATIONS
MINISTRY OF COMMUNICATIONS
GOVERNMENT OF INDIA

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Any comment/suggestions may please be sent to: ofcconcept.tec@gov.in

Methodology of preparation of the document

A number of experienced field engineers, manufacturers, planners and researchers were contacted to get as close a picture of technology, practices, challenges and opportunities as possible. However, consultations were not exhaustive. Many stakeholders may be doing field deployment of OFC and equipment in their own best possible manner which may be different from what is presented in this paper and, therefore, the practices depicted in this paper are illustrative and not representative of all existing deployments.

Disclaimer:

Every care has been taken to provide the correct and up to date information along with references thereof. However, neither TEC nor the authors shall be liable for any loss or damage whatsoever, including incidental or consequential loss or damage, arising out of, or in connection with any use of or reliance on the information in this document. In case of any doubt or query, readers are requested to kindly refer to the detailed relevant documents.

के. राजारामन, भा. प्र. से.
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Government of India
Ministry of Communications
Department of Telecommunications

आज़ादी का अमृत महोत्सव

MESSAGE

I am happy to learn that Telecommunication Engineering Centre (TEC) has prepared a Technical Report on the topic "Concept paper on Optical Fibre and Cable in Indian Telecommunication Network" which is being released as a document for guidance of all stakeholders.

The sudden jump in demand for high speed data in the post-pandemic era has forced the Service providers to upgrade their network in order to provide the very high bandwidth telecom connectivity to both, the retail and enterprise customers. Optical fibre has the capability to provide very high bandwidth to meet this demand.

Therefore, TEC has done a commendable job by bringing this concept paper on Optical Fibre Cable in India Telecommunication Network at this opportune time. I am sure, this paper will be of immense help for Standardization of use of OFC in the Indian Telecom network thereby improving the quality of service.

My best wishes to TEC for the success of their endeavour to disseminate the expert knowledge and guidance on optical fibre and cables. I also hope that emerging standards and new age optical fibresmentioned in the report are researched, designed and manufactured in India soon.

My best wishes.

11/11/2021

(K.Rajaraman)

दीपक चतुर्वेदी
सदस्य (सेवाएँ)
Deepak Chaturvedi
Member (Services) &
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सत्यमेव जयते

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Message

I am delighted to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on topic "Concept paper on Optical Fibre and Cable in Indian Telecommunication Network".

TEC has continued the excellent work in the various aspects of Telecommunications Technologies. Bringing out this paper on OFC, is another more important effort in that direction. It is well known that OFC forms the backbone of the Information Highway and, therefore, knowledge of OFC is very important & prime requirement of present time when we strive for Make in India.

I appreciate the effort of TEC in bringing out this technical concept paper on OFC which, I am sure, shall be useful for all the prospective & existing user/ organizations in building a robust and high quality backbone of Digital India as well as last mile access using OFC in achieving Connecting India.

I extend my best wishes to the team of TEC and wish them success in their efforts in bringing the standardization and helping in the development of world class infrastructure in the field of telecommunication in Emerging India.

With Best Wishes,

10/11/2021

(Deepak Chaturvedi)

ए. के. तिवारी
सदस्य (प्रौद्योगिकी)
A. K. Tiwari
Member (Technology)

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Message

I am pleased to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on the topic "Concept paper on Optical Fibre and Cable in Indian Telecommunication Network".

As we all know that Government has planned to provide the Broadband connectivity to every villages in the country and to achieve this goal, Optical Fibre Cable are being laid on a war footing basis.

Know how on Optical Fibre deployment is very much the need-of- the-hour to realize the goals set in the NDCP-2018 of giving every citizen 50 Mbps and every Gram Panchayat 10 GPs broadband connectivity.

Therefore, this concept paper on OFC is definitely going to be very useful for all the stakeholders involved in providing OFC connectivity.

I appreciate the efforts of Telecommunication Engineering Centre for bringing out this technical report. I wish them success in all their future endeavours.

Best Wishes,

(A. K. Tiwari)

दीपा त्यागी
DEEPA TYAGI
वरिष्ठ उप महानिदेशक एवं प्रमुख
Sr. Deputy Director General & Head

सत्यमेव जयते

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Foreword

It gives me immense pleasure to present this document titled "The Concept paper on Optical fibre and Cable in Indian Telecom network". The document presents a landscape of Indian Telecom network and the very important role being played by OFC in this. The types of OFC being used in Indian Telecom Network have been presented in the document. Examples have been chosen from the actual commercial deployment use cases of OFC.

TEC has issued notification dated 22-09-2021 regarding schedule for Mandatory Testing and Certification of Telecom Equipment (MTCTE) under Phase-III and IV. Optical Fibre (Single Mode) and Optical Fibre Cable are the two products covered under Phase-IV of the above said notification which will be implemented in phased manner and the certification will become mandatory with effect from 01-07-2022. The applications for certifications will be accepted from 01-01-2022. The release of this concept paper at this crucial juncture will be very useful for all stakeholders connected with the task of framing ER (Essential Requirement). The document will also be very useful for all stakeholders connected with the provisioning of telecom services as OFC is integral to all networks.

The new Digital Communication Policy 2018 envisages provisioning of 50 Mbps broadband connectivity to every citizen and enabling fixed line broadband to 50% of households to be achieved by the year 2022. The release of this comprehensive concept paper will help in accelerating this growth. Standardization of Optical Fibre Cable in Indian Telecommunication Network will be of immense help in providing a stable and self-reliant telecom infrastructure.

I congratulate the entire team involved in preparation of this very relevant document especially the RTECs who have put in a lot of effort in preparing this document.

With Best wishes,

(Deepa Tyagi)

Acknowledgement

This paper is a cumulative effort of several engineers and researchers who are involved with the work of optical fibre and optical fibre cable in some capacity or the other. First of all, authors wish to give profuse thanks to Smt. Deepa Tyagi, Head and Sr. DDG, TEC who developed the idea of presenting a paper dealing with all aspects of OFC at one place. She further continued with monitoring the project to bring it to a presentable level. We are thankful to Shri Ashwini Salwan, DDG (TX), TEC for arranging important inputs for the paper. We are thankful to Ms. Ratna Thakur, Director, TEC; Ms. Kamla Pargai, ADG, TEC and Ms. Divya Sharma, ADG, TEC for their valuable contribution in making of the paper. We are thankful to Shri A S Verma, DDG(MT), TEC for enlightening us about 5G mobile system. We are thankful to Shri Sudhir Bhandari, DDG TEC and Shri Rajmohan Meena, ADG TEC for making available the IEEE papers relate to OF. We are thankful to Shri Sushil Kumar, DDG IoT for guidance in making of the paper. We are thankful to Shri Brajendra Kumar of BMRCL and ex- Director (SR), TEC for his valuable contribution in preparation of the paper.

We are thankful to prof. Shri Vikram Gadre, Department of Electrical Engineering, IIT Bombay; Prof Shri Appaya Kumar, Department of Electrical Engineering, IIT Bombay and Prof. Shri Deepak Jain, Department of Electrical Engineering, IIT Bombay for giving us the time to discuss the project and for giving vital inputs about latest technological development in the field of optical fibre technology.

We are thankful to Shri Atul Kumar Chaudhary, DDG DS, DoT; Shri S B Singh, DDG AS DoT; and Shri Sharad Trivedi DDG CS, DoT for giving us vital inputs about provision of services and licensing conditions. Shri Atul Kumar Chaudhary provided very useful data and also guided about other relevant sources of information. We are thankful to Shri Subodh Kumar Gupta DDG, Delhi LSA for giving us vital inputs about the transmission system. We are thankful to Shri Syed Taushif Abbas, Advisor TRAI for giving us vital inputs on wide range of issues from technology to implementation of licensing conditions. We are thankful to Shri B Sunil Kumar DDG NTIPRIT for giving us vital inputs on 5G mobile technology.

We are thankful to many senior officers of BSNL specially Shri Nitin Chhayande, PGM CN-Tx(W), Shri D. Thamizhmani, PGM CN-Tx(S), Shri Vivek Jaiswal, GM BSNL Bangalore and Shri Sanjeev Verma GMTD, Jamshedpur for making available useful information about optical fibre cable and transmission network. We are thankful to Shri A K Singh, CGM BBNL New Delhi, Shri K P Verma, CGM BBNL New Delhi and Shri Sanjay Kumar, CGM BBNL Jharkhand for their kind support and valuable inputs about OFC deployment.

We are thankful to all OF manufactures and OFC manufacturers in India who gave us inputs about their production and testing infrastructure.

We are thankful to Shri Venkatesh Murthy, Head Optical fibre Cable Operations, M/s STL; Shri Sudipta Bhaumik, Head-Applications and Standards Engineering, M/s STL and Shri Hanumant Rao, Chief Manager (Quality), M/s STL for providing key insight about optical fibre and industry trends of OF and OFC. Shri Sudipta Bhaumik has given very useful insight about industry trends in the field of optical fibre and cables. We are thankful to Shri Harsh Pagay, Executive President, OFC business, M/s HFCL and Shri Neeraj Ahuja, AVP (Operations), M/s HFCL for providing insight about optical fibre and drawing of OF. We are thankful to Shri Sunil Upmanyu, President Optical Fibre business, M/s Finolex for providing vital input about OF and OF cable. We are thankful to Shri Kapil Mehta, CEO, M/s Birla Furukawa for giving vital input about fibres. We are thankful to Shri R K Pawar, Sr. DGM(Technical), M/s APAR Industries and Shri Sanjay Bharti DGM (QA & Design), M/s UM Cables for giving us vital inputs about cable manufacturing and deployments. We are thankful to Shri Ashish Jain, Executive President and COO, Telecom M/s Polycab India Ltd. for giving us vital inputs about installation of ribbon fibres.

We are thankful to Shri Kartik Parikh CEO, Fastech India for introducing OTDR. We are thankful to Shri Santosh Shetty of M/s Airtel and Shri Bhaumin Shah of M/s Jio for giving vital inputs about working of FTTH. We are thankful to Shri Deepak D Shah CEO, M/s Tikona, Shri Sunil Yajanan, CEO, ACT; Shri Prasanna Gokhale, CTO, ACT and Shri Sudhir Shetye, CEO of M/s Hathway for giving us vital inputs about working of Cable TV and FTTX.

We are thankful to officers of MTNL for giving us vital inputs about OFC deployment.

We are thankful to Shri Ajay Kamal, DDG Mumbai LSA; Shri C P Samant, DDG Mumbai LSA; Shri Sanjay Sethi, Director, Mumbai LSA and Shri Hemant Borale, Director Mumbai LSA for giving us vital technological inputs about system deployment.

We are thankful to Shri T V Venkatram, ex-CGM BSNL QA and Mrs. G. Geetha, DGM CACT for giving inputs about CACT. We are thankful to Mrs Mamata N K, DGM QA, Bengaluru for giving vital inputs about testing of OF and OFC and production capacities. We are thankful to Shri Dipak Pardesi, SDE BSNL QA; Shri G S Konde, DE BSNL QA and Shri Suhas Shinde, JTO BSNL QA for apprising us about actual testing methods and representative values. They also gave us various specifications, test methods and many other related documents. We are thankful to Shri Sham sunder Joshi, Retd. DE(QA), BSNL, Shri S S Rajput, Retd. DGM(QA), BSNL and Shri K R Pandya, Retd. DE(QA), BSNL for their valuable contribution of giving technical details of actual deployments.

We are thankful to Mr. Shubham Keni and Mr. Ramesh Mane both interns working with TEC Mumbai for giving all help in making of this report.

The lead author Ashok Kumar Jha wants to thank his daughter Shubhra for getting first-hand knowledge from her about converting long interviews into written words. He also wants to thank his daughter Archana who always encouraged him to complete the office work in time.

We may be missing many names whom we should have extended thanks and sincerely apologise if some names have been missed.

Saurabh Gupta, DDG(NR), TEC
K. Hanumanth Rao, DDG(SR), TEC
November 10, 2021 Ashok Kumar Jha, DDG(WR), TEC
Prashant Pati Singh, Dir (WR), TEC
Sushil Kumar, Dir (NR), TEC

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Abbreviations

ADSS: All Die-electric Self-Supporting

AI: Artificial Intelligence

AS: Access Service

BBNL: Bharat Broadband Nigam Limited

BSNL: Bharat Sanchar Nigam Limited

CACT: Component Approval Centre Telecommunications Bengaluru

CD: Chromatic Dispersion

CS: Carrier Service

CUG: Close User Group

DOT: Department Of Telecommunication

DS: Data Service

DSL: Digital Subscriber Line

DWDM: Dense Wavelength Division Multiplexing

EDFA: Erbium-Doped Fibre Amplifier

EPON: Ethernet Passive Optical Network

ER: Essential Requirement

EVA: ethylene-vinyl acetate

FDMS: Fibre Distribution Management

FRP: Fibre Reinforced Plastic

FTTH: Fibre to the home

FWA: Fix Wireless Access

GFGNL: Gujarat Fibre Grid Nigam Limited

GMPCS: Global Mobile Personal Communication by Satellite

GPON: Gigabit Ethernet Passive Optical Network

GPR: Ground Penetrating

GPS: Global Positioning System

GR: Generic Requirement

HDD: Horizontal Directional Drilling

HDPE: High Density Polyethylene

HSN: Harmonized System Nomenclature

IEEE: Institute of Electrical and Electronics Engineers

IL/RL: Insertion Loss/Return Loss

ILD: International Long Distance

IMPCS: Indian Mobile Personal Communication System

INSAT-MSS: INSAT Mobile Satellite System

IP: Infrastructure Provider

IPLC: International Private Leased Circuit

ISP: Internet Service Provider

ITU-T: International Telecommunication Union - Telecommunication

LASER: Light amplification by stimulated emission of radiation

LED: Light Emitting Diode

LSA: Licensed Switching Area

LSZH: Low-Smoke Zero-Halogen

MahaIT: Maharashtra Information Technolgy Corporation Ltd.

MFD: Mode Field Diameter

ML: Machine Learning

MMF: Multimode Fibre

MTNL: Mahanagar Telephone Nigam Limited

NDCP: National Digital Communication Policy

NHAI: National Highway Authority of India

NLD: National Long Distance

OFC: Optical Fibre Cable

OLT: Optical Line Terminal

ONT: Optical Netwrok Termination

OPGW: Optical Fibre Groung Wire

OSA: Optical Spectrum Analyser

OSP: Other Service Provider

OTDR: Optical Time Domain Reflectometer

PLB: Permanently Lubricated Duct

PLMN: Public Land Mobile Network

PMD: Polarization Mode Dispersion

PMRTS: Public Mobile Radio Trunk Service

PON: Passive Optical Netwrok

PSTN: Public Switched Telephone Netwrok

RFTS: Remote Fibre Test System

RoW: Right of Way

SMF: Single Mode Fibre

SSA: Secondary Switching Area

TEC: Telecom Engineering Centre,

TSP: Telecom Service Provider

TWAD: Tamilnadu Water Supply and Drainage Board

UL: Unified Licensing

VDSL: Very high bit rate digital subscriber line

VNO: Virtual Netwrok Operators

VSAT: Very Small Aperture Terminal

Objective of the paper

This paper aims at presenting a review of the types of most widely used optical fibre cables deployed by different organisations in India to meet their connectivity need. We are also presenting the TEC standards for optical fibre cables, typical challenges faced by telecom service providers, opportunities for improvement in telecom network, testing methods of optical fibre cables, tools and accessories being used and raw materials being used in manufacturing of optical fibre cable.

The objective is to present a unified picture of various important aspects related to optical fibre and cable relevant to the Indian telecom network. Effort has been made to present actual deployment scenarios, real opportunities available for improvement and actual challenges faced by Telecom service providers. It is expected that the telecom users and professionals may find some relevant idea, concept or practices mentioned in the paper suitable for implementation and improvement.

We wish to reach as much useful information to stakeholders as possible so that there is a scope of improvement from all stakeholders including users. It is pertinent to mention one example of improvement being caused by users (subscribers). The subscribers who have been availing broadband and TV signal over coaxial cable have been pressing the cable TV providers to switch over to optical fibre for provision of broadband and cable TV in order to get higher bandwidth. Thus, the improvement in telecom network is taking place by virtue of effort by various stakeholders.

This paper, therefore, will be an introductory guide to the concept of optical fibre cables deployed in Indian Telecom network with an anticipation of improvement of network through dissemination of knowledge to all stakeholders.

Abstract

It was originally envisaged that TEC would publish a concept paper on OFC which contains important details of OFC like types of cables deployed in India, tools used for various installations and testing infrastructure among others. However, many interesting and useful facts emerged while the paper was under preparation. It was found that Broadband on FTTH is growing at a very fast pace and, therefore, the OFC used for giving Fibre to the Home (FTTH) connectivity drew most attention. It was found that different service providers are using different types of cables for the last mile FTTH connections and some of these deployments are very good but some have deficiencies in terms of strength. The ITU-T standard G.657 series of fibres are universally used in OFC for FTTH purposes but the OFC being deployed has different types of sheathing and protection mechanism and, therefore, different strengths. A clear opportunity was identified to strengthen the network by setting minimum technical requirement for the OFC. This concept has been highlighted in the paper.

The aspects of growth of broadband connections, technology used for providing broadband, telecom service provisioning framework in terms of licenses and authorisations issued have been discussed in the paper. The strengthening of last mile connectivity by suitable technological intervention has been discussed in detail. The important types of cables used in Indian Telecom network and their design have been discussed. The testing parameters, testing infrastructure and test equipment have been discussed in detail. The raw material used for manufacture of cable has also been discussed.

The latest technological advances in the field of OF and OFC have been discussed in the paper.

2009 Nobel Prize in Physics for ground-breaking achievements concerning the transmission of light in fibres for optical communication

In 1966, Charles K. Kao made a discovery that led to a breakthrough in fibre optics. He was awarded Nobel Prize in 2009. Following is the illustrated information from the Prize foundation.

"The masters of light

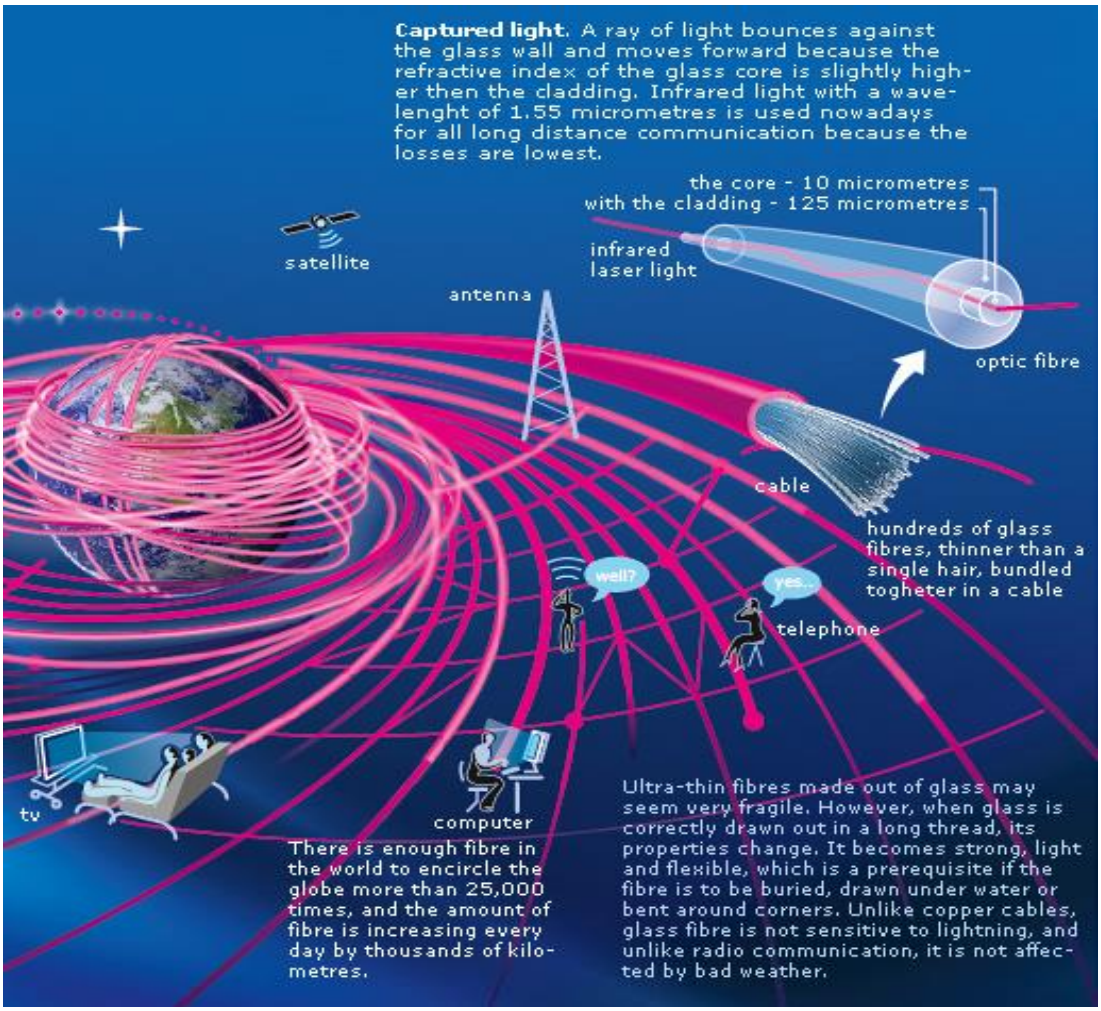
This year's (2009) Nobel Prize in Physics is awarded for two scientific achievements that have helped to shape the foundations of today's networked societies. They have created many practical innovations for everyday life and provided new tools for scientific exploration.

Charles K. Kao

Source: https://www.nobelprize.org

Half of the prize was awarded to Charles Kao who made a discovery that led to a breakthrough for fibre-optic communication. Today optical fibres make up the circulatory system that nourishes our information society. Light flows in threads of glass, as thin as a hair, which carries almost all of the telephony and data traffic in each and every direction. Without optical fibres there would be neither internet nor broadband. A large share of the traffic is made up of digital images, which constitute the second part of the award. In 1969 Willard S. Boyle and

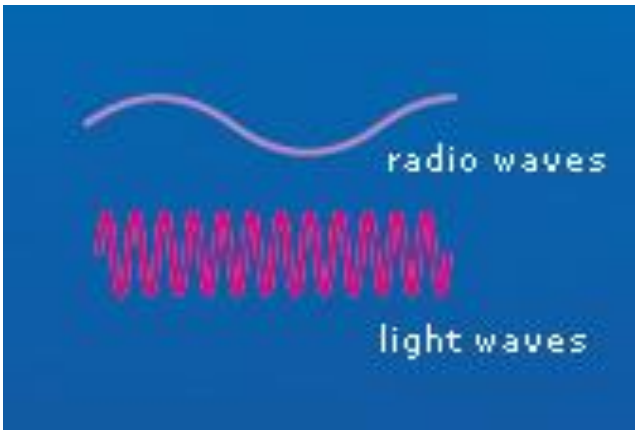
George E. Smith invented the first successful imaging technology using a digital sensor, a CCD (Charge-Coupled Device). The CCD revolutionized photography, as light could now be captured electronically instead of on film…."



Source: https://www.nobelprize.org

Figure 1: Artistic view of global communication

Compared to radio waves, light carries tens of thousands of times more information because of its much higher frequencies. But ways to transmit light signals over longer distances were still not known in the first half of the 1960's. After just 20 metres, only 1 percent of the light that had entered a glass fibre remained. Reducing this loss of light became a challenge for a visionary like Charles Kao.



Source: https://www.nobelprize.org

Figure 2: Depiction of frequency of radio waves and Light waves

Following is the press release for the award of Nobel Prize [1]:

"In 1966, Charles K. Kao made a discovery that led to a breakthrough in fibre optics. He carefully calculated how to transmit light over long distances via optical glass fibres. With a fibre of purest glass, it would be possible to transmit light signals over 100 kilometres, compared to only 20 meters for the fibres available in the 1960s. Kao's enthusiasm inspired other researchers to share his vision of the future potential of fibre optics. The first ultrapure fibre was successfully fabricated just four years later, in 1970.

If we were to unravel all of the glass fibres that wind around the globe, we would get a single thread over one billion kilometres long – which is enough to encircle the globe more than 25 000 times – and is increasing by thousands of kilometres every hour.

A large share of the traffic is made up of digital images, which constitute the second part of the award. In 1969 Willard S. Boyle and George E. Smith invented the first successful imaging technology using a digital sensor, a CCD (Charge-Coupled Device). The CCD technology makes use of the photoelectric effect, as theorized by Albert Einstein and for which he was awarded the 1921 year's Nobel Prize. By this effect, light is transformed into electric signals. The challenge when designing an image sensor was to gather and read out the signals in a large number of image points, pixels, in a short time."

In the same context, it would be necessary to point out the contribution made by an Indian scientist and entrepreneur Late Narinder Singh Kapany (1926-

[1] Source: https://www.nobelprize.org/prizes/physics/2009/press-release/

2020). He had been able to use a bundle of optical fibres as image dissector capable of converting a rectangular image format to a linear strip.[2] The transmitted image could be assembled back at the other end.

Late Narinder Singh Kapany is considered by many as the unsung hero and father of fibre optics, with his diverse pioneering achievements. Ever since his schooldays, Kapany had been curious about the idea of bending the propagation of light and using it for imaging and medical applications. His interests resonated well with his PhD supervisor in London, Harold Hopkins, who advised him to experiment with a bundle of glass cylinders. Kapany worked tirelessly to assemble a coherent bundle of hundreds of glass fibres with a diameter of a few tens of micrometres and used them to build a flexible *fibrescope* for transmitting images that was described in a paper published with Hopkins in Nature on 2nd January 1954.[3] Advanced fibrescope is used today in many medical applications e.g., for colonoscopy.

Narinder Singh Kapany

Source: Tribune India

[2] "Role of Fibre optics in ultra-high speed photography" by N S Kapany in the "journal of the Society of Motion Picture and Television Engineer "Vol 71 No.2 year 1962

[3] Hopkins, H. & Kapany, N. S. Nature 173, 39–41 (1954)

Chapter 1

1 Introduction

Internet and broadband have changed the world and are ever changing it. High speed telecommunication networks are the assets desired by every nation to bring about higher productivity and prosperity to their vast population. There is an ever-growing importance of the telecommunication system in the current world. The optical fibre has become the backbone of the present day high speed digital telecommunication network due to very high bandwidth and very low loss offered by it as compared to another physical medium.

1.1 Recent advances in OF technology

Optical communication technology has been advancing rapidly for several decades and much of this progress has been in finding innovative ways to increase the data-carrying capacity of a single optical fibre. The multiplexing in time, wavelength, polarization and phase has already been achieved and commercial systems now utilize all four dimensions to send more information through a single fibre. New research work in the field of optical fibre is constantly in progress globally on the topics of “Space Division multiplexing of fibre”, “hollow core fibres” and “few mode fibres” which have the potential to further increase the bandwidth of a single fibre many times along with several other enhanced features like ultralow optical nonlinearity, excellent power handling capabilities and low latency. SDM fibres will be extremely useful for internal wiring of, say, large data centres, and also for long distance submarine applications requiring high international bandwidth. SDM fibres can be very useful for applications requiring ultra-high fibre count cable. The hollow core fibres have the potential to offer ultra-low latency and very less “crosstalk”.

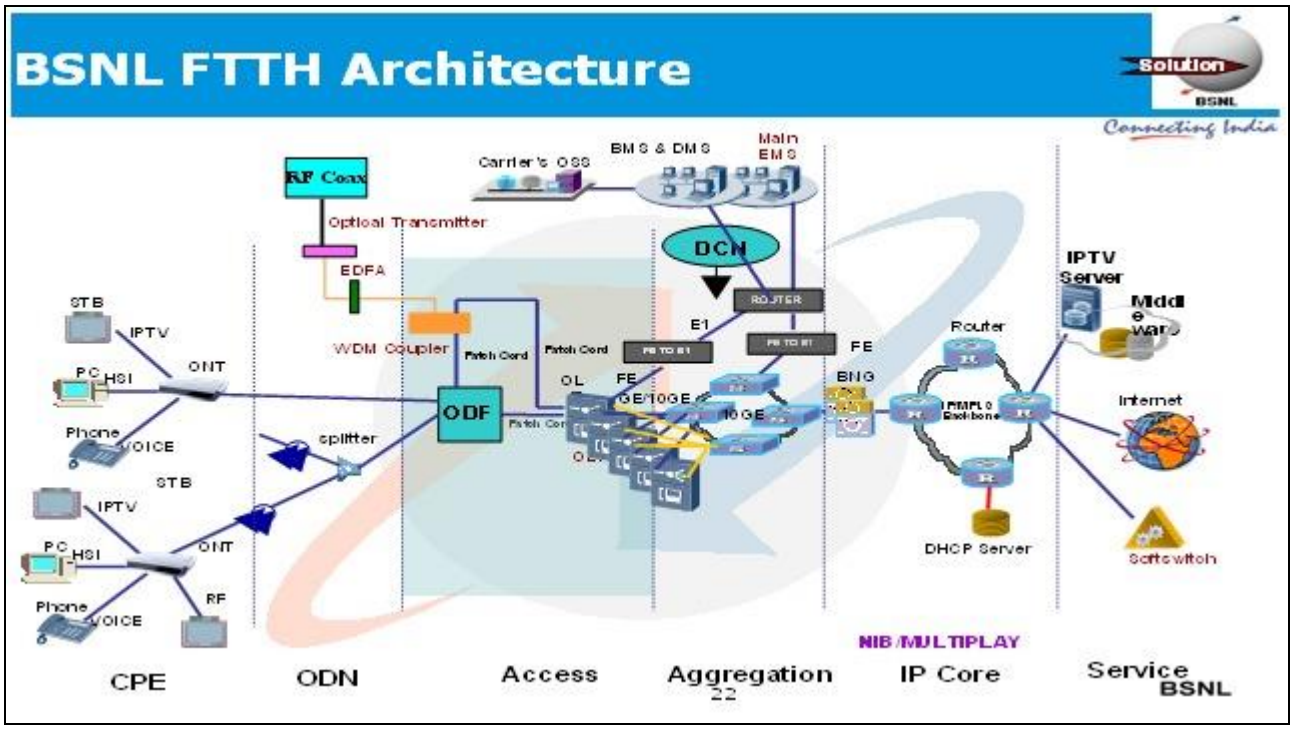
It has also been found that different hardware for different purposes is used by many ISPs. One example is OFC splitters which are used for distributing light energy. Usually 1:4, 1:16 etc. symmetric splitters are used in which light energy is equally divided among all outlets but some ISPs are using 5: 95 % splitters also called couplers. When the ISPs were asked whether they also use

5:95 % segregation, they said such splitters do not exist. It is; thus, clear that practices depicted in this paper may look different to some service providers/ ISPs.

1.2 The great opportunity for network improvement

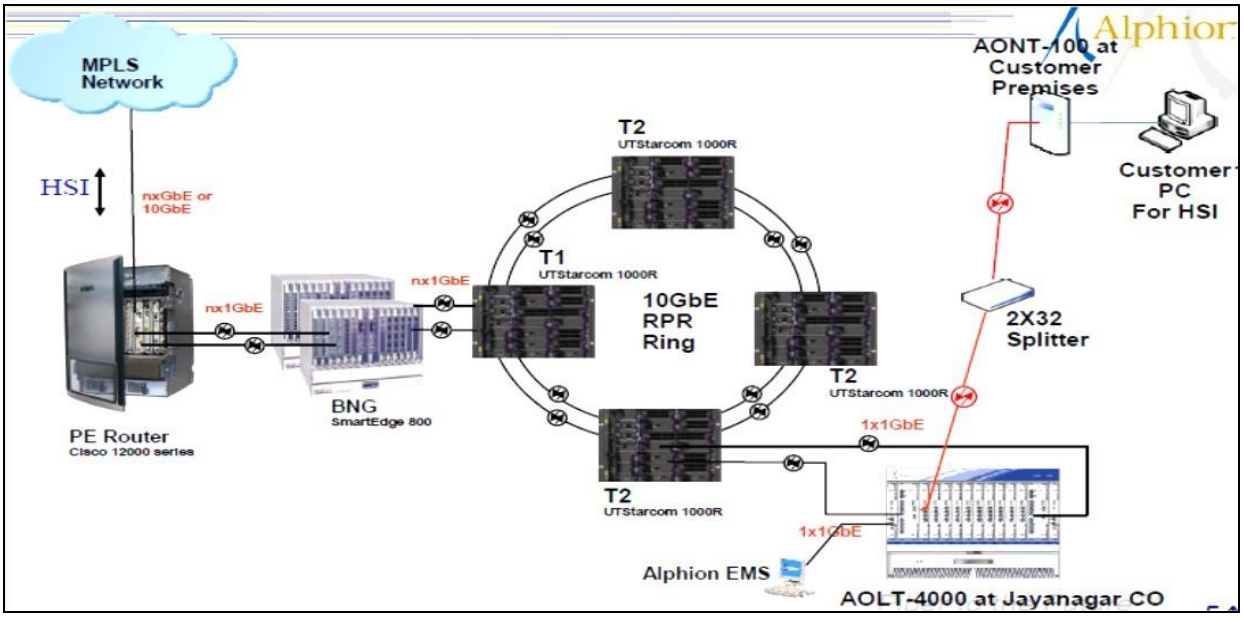
A very important fact has emerged during the review that there is a great scope for improvement of telecom network through technological intervention which includes finding a good suitable design of OFC appropriate to a specific need followed by standardising that design of OFC for use in telecom network. The standardisation of design will mean the minimum performance/design criterion to be met and the service providers will have full liberty to further innovate and deploy cable with better design as long as they meet the minimum criterion of performance.

The design need of an underground cable used for trunk route connectivity will be different from OFC used in bringing Fibre to The Home (FTTH). The OFC for FTTH may have roughly three parts. First part may be the cable from equipment to building premises. Second part may be "riser cable" which rises from ground floor of building till the last floor of the building. Third part may be the OFC used for internal wiring inside the house. The OFC used for internal wiring inside the house has to be fire proof. Low Smoke Zero Halogen (LSZH) compound is, therefore, used in manufacture of such OFC. The number of fibres entering house is also limited to 2 or 4 in most applications and, therefore, the cable is inherently weak. This requires special arrangements to be made to achieve strength of cable. It is obvious that no such special care needs to be taken for OFC used in trunk route. The trunk routes are having high count fibre cables and the cables are heavier. The cable construction of such OFC is inherently rugged. A concept diagram of FTTH is shown below:



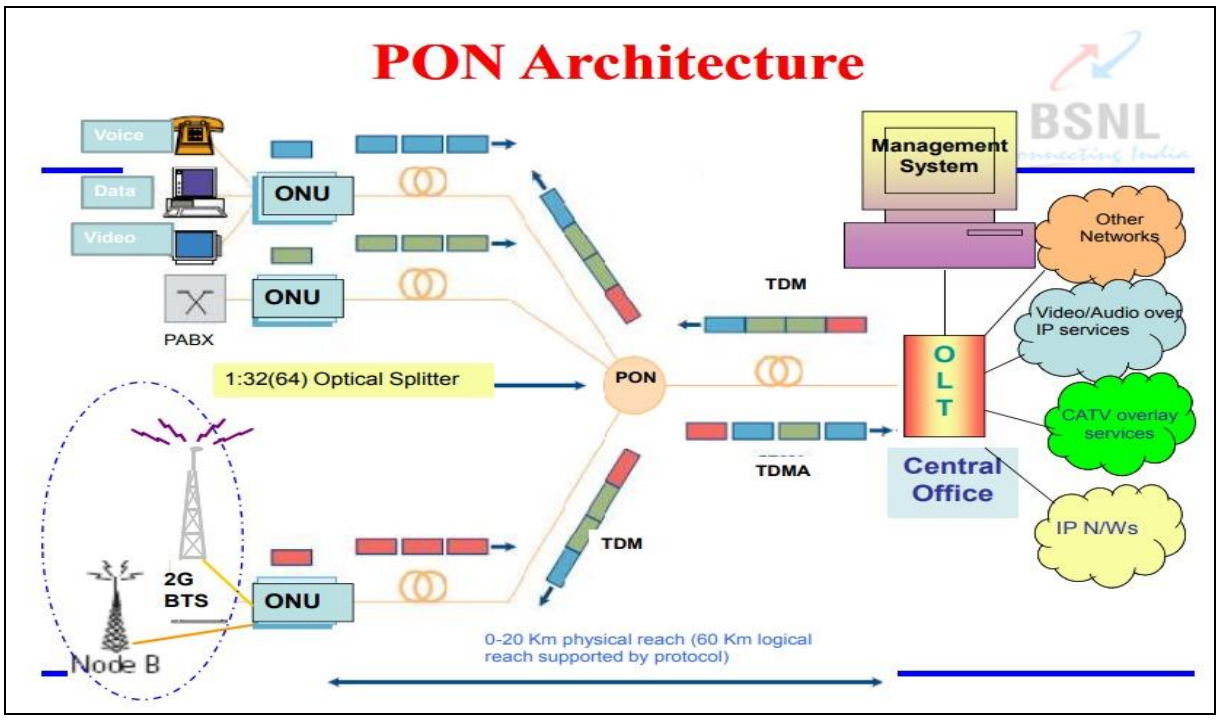
Source: BSNL Bengaluru

Figure 3: Architecture of BSNL FTTH



Source: BSNL Bengaluru

Figure 4: BSNL FTTH Core and Access Network



Source: BSNL Bengaluru

Figure 5: PON Architecture of BSNL FTTH

It is, thus, clear that different OFC applications would require different cable designs. The cable design of trunk routes is almost stable; however, so many different OFC constructions are being used for FTTX applications by different ISPs. Some of these cables are definitely weak and need improvement while some others may be very good and strong. There is, thus, an opportunity for improvement in OFC used for FTTH applications. A detailed analysis has, therefore, been done for this specific case of "Fibre to the X (FTTX where X= (Home/Premises/Building/Node/Curb/Cabinet))" applications. The reason for specially choosing FTTX applications is that the number of FTTX deployment instances will be much more as compared to other deployments, for example, OFC deployment in core metro network. However, the standardisation of OFC would be needed for other deployments too. This can be seen by simple extension of logic presented for standardisation of OFC for FTTX applications which is detailed in the following chapter. The topic has been found so important that it is being presented as a separate chapter. The standardisation would also be required for other most important elements of OFC installation like splice closure, splitters, fibre distribution frame and other such necessary items which are part and parcel of the OFC installation.

1.3 Telecom service provisioning framework

Telecom services are being provided by various Telecom service providers and, therefore, it is important to get an introduction about service providers engaged in telecom service provisioning. These service providers only will ultimately deploy the OFC. Telecom service provisioning framework in India has, therefore, been briefly introduced in the paper.

1.4 Knowledge of tools and testers

Further, a large number of skilled manpower would be required to be the part of this great revolution in connectivity and they need to be well versed with tools and measuring instruments used in OFC installation and testing. We have given details of testing methods, tools and testing instruments also in this paper.

1.5 New Digital Communication Policy

NDCP 2018-Connect India Program has been presented in the paper.

Chapter 2

2 NDCP 2018-Connect India Program

The new Digital Communication Policy 2018 envisages provisioning of 50 Mbps broadband connectivity to every citizen and enable fixed line broadband to 50% of households to be achieved by the year 2022. 4G wireless service and 5G wireless service will be the main means of providing desired data rate to vast number of Indians. However, the use of fixed line broadband is growing at a very high rate since Jan'19. We present a brief of NDCP in reference to Connect India Program below:

2.1 Goals

As per NDCP, following goals are set to be achieved by the year 2022 under Connect India program for creating a robust Digital Communication Infrastructure:

a) Provide Universal broadband connectivity at 50Mbps to every citizen.
b) Provide 1Gbps connectivity to all Gram Panchayats of India by 2020 and 10Gbps by 2022.
c) Enable100 Mbps broadband on demand to all key development institutions; including all educational institutions.
d) Enable fixed line broadband access to 50% of households.
e) Achieve 'unique mobile subscriber density' of 55 by 2020 and 65 by 2022.
f) Enable deployment of public Wi-Fi Hotspots; to reach 5 million by 2020 and 10 million by 2022.
g) Ensure connectivity to all uncovered areas.

2.2 Strategy

Following strategy has been suggested to achieve above goals:

a) Establishing a 'National Broadband Mission – 'Rashtriya Broadband Abhiyan' to secure universal broadband access
b) Implementation of the following broadband initiatives, to be funded through USOF and Public Private Partnerships:

i. BharatNet – Providing 1 Gbps to Gram Panchayats upgradeable to 10 Gbps
ii. GramNet – Connecting all key rural development institutions with 10 Mbps upgradeable to 100 Mbps
iii. NagarNet – Establishing 1 million public Wi-Fi Hotspots in urban areas
iv. JanWiFi – Establishing 2 million Wi-Fi Hotspots in rural areas

c) Implementing a '**Fibre First Initiative'** to take fibre to the home, to enterprises and to key development institutions in Tier I, II and III towns and to rural clusters:
   i. According Telecom Optic Fibre cables the status of public utility promoting collaboration models involving state, local bodies and private sector as necessary for provision of shared duct infrastructure in municipalities, rural areas and national highways
   ii. Facilitating Fibre-to-the-tower programme to enable fibrisation of at least 60% of telecom towers thereby accelerating migration to 4G/5G.
   iii. Leveraging existing assets of the broadcasting and power sector to improve connectivity, affordability and sustainability.
   iv. Incentivising and promoting fibre connectivity for all new developmental construction
   v. By making requirement for telecom installations and the associated cabling and in-building solutions mandatory in all commercial, residential and office spaces by amending National Building Code of India (NBC), through Bureau of Indian Standards (BIS).
d) Establishment of a National Digital Grid by:
   i. Creating National Fibre Authority.
   ii. Establishing Common Service Ducts and utility corridors in all new city and highway road projects, and related elements.
   iii. Creating a collaborative institutional mechanism between Centre, States and Local Bodies for Common Rights of Way, standardisation of costs and timelines; and removal of barriers to approvals
   iv. Facilitating development of Open Access Next Generation Networks
e) Facilitate the establishment of Mobile Tower Infrastructure by:
   i. Extending incentives and exemptions for the construction of telecom towers

ii. According accelerated Rights of Way permissions for telecom towers in government premises. Recently, Department of Telecommunications, GoI has amended the Indian Telegraph Act by issuing of Gazette notification dated 21-10-2021 regarding Right of Way (amendment) Rules, 2021, which is given at Annexure-II.

iii. Promoting and incentivizing deployment of solar and green energy for telecom towers

f) Improve international connectivity and reduce the cost of international bandwidth by facilitating setting up of International Cable Landing Stations by rationalising access charges and removing regulatory hurdles; and by benchmarking international bandwidth to global trends.

g) Encourage and facilitate sharing of active infrastructure by enhancing the scope of Infrastructure Providers (IP) and promoting and incentivizing deployment of common sharable, passive as well as active, infrastructure.

h) Enabling Infrastructure Convergence of IT, telecom and broadcasting:

i. Amending the Indian Telegraph Act, 1885 and other relevant acts for the purpose of convergence in coordination with respective ministries.

ii. Establishing a unified policy framework and spectrum management regime for broadcast and broadband technologies.

iii. Restructuring of legal, licensing and regulatory frameworks for reaping the benefits of convergence iv. Allowing benefits of convergence in areas such as IP-PSTN switching.

i) Creating a Broadband Readiness Index for States/ UTs to attract investments and address RoW challenges.

j) Encouraging investment in broadband infrastructure through fiscal incentives, including accelerated depreciation and tax incentives; and incentivizing fixed line broadband.

k) By encouraging innovative approaches to infrastructure creation and access including through resale and Virtual Network Operators (VNO).

l) Promoting broadband connectivity through innovative and alternative technologies.

It is clear that a strong Fibre backbone has been envisaged in New Digital Communication policy and accordingly optical fibre cable and optical fibre will play a very big role in Indian communication system and Indian economy.

Therefore, it is utmost necessary that a robust quality of cable, supply, installation and testing arrangement of optical fibres are put in place for success of the NDCP 2018.

Chapter 3

3 High growth of Wireline Broadband connection on FTTX

There is a very high growth of broadband connections on FTTX. Following paragraphs deal with this important aspect of growth of broadband connections on FTTX.

3.1 Growth of Wired Vs Wireless Broadband Internet Subscriber base

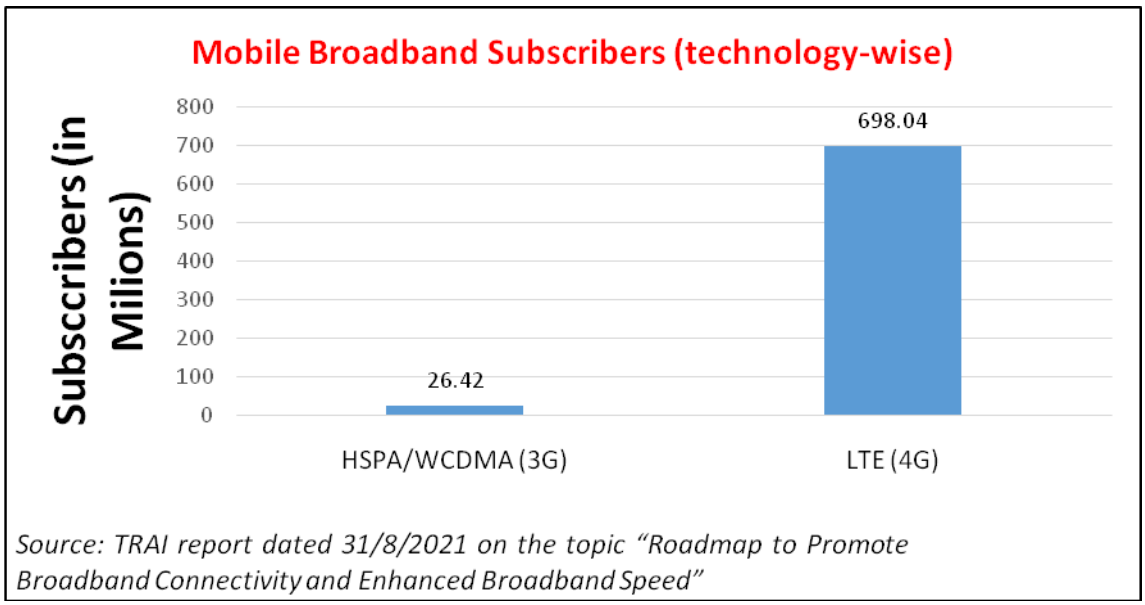
As present, about 26 million fixed line internet subscribers are in India out of which 22.7 million are connected with broadband[4] and this figure has to increase to more than 123 million (246.7 million is the number of households in India as per 2011 census and 50% households are to connected with fixed line broadband) to meet the targets of NDCP 2018. The number of broadband connections (wireline + wireless) stands at 778 million which not only needs to be increased to 1012 million customers but also the bandwidth of 50 Mbps is to be made available to the user. Many subscribers in India are availing broadband at lower speed and their connection speed needs to be upgraded to 50 Mbps. The table below gives the breakup of broadband connections in India.

Table 1: Current status of Broadband subscribers in the country

Segment	**Mode of Access**				**Total Subscribers** (in million)
	Fixed Line Subscribers (in million)	**Wireless Subscribers** (in million)			
		Fixed Wireless (Wi-Fi, Wi-Max, Radio & VSAT)	Mobile Wireless (Phone + Dongle)	**Total Wireless**	
Broadband	22.749	0.671	754.674	755.345	778.095
Narrowband	3.246	0.006	43.955	43.961	47.207
Total	**25.995**	**0.677**	**798.629**	**799.306**	**825.301**
Source: TRAI report dated 31/8/2021 on the topic "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed"					

[4] TRAI report dated 31/8/2021 on the topic "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed".
https://www.trai.gov.in/sites/default/files/Recommendations_31082021.pdf

The current distribution of 3G and 4G subscribers is as given below in Figure.



Source: TRAI report dated 31/8/2021 on the topic "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed"

Figure 6: Mobile Broadband Subscribers (Technology-wise)

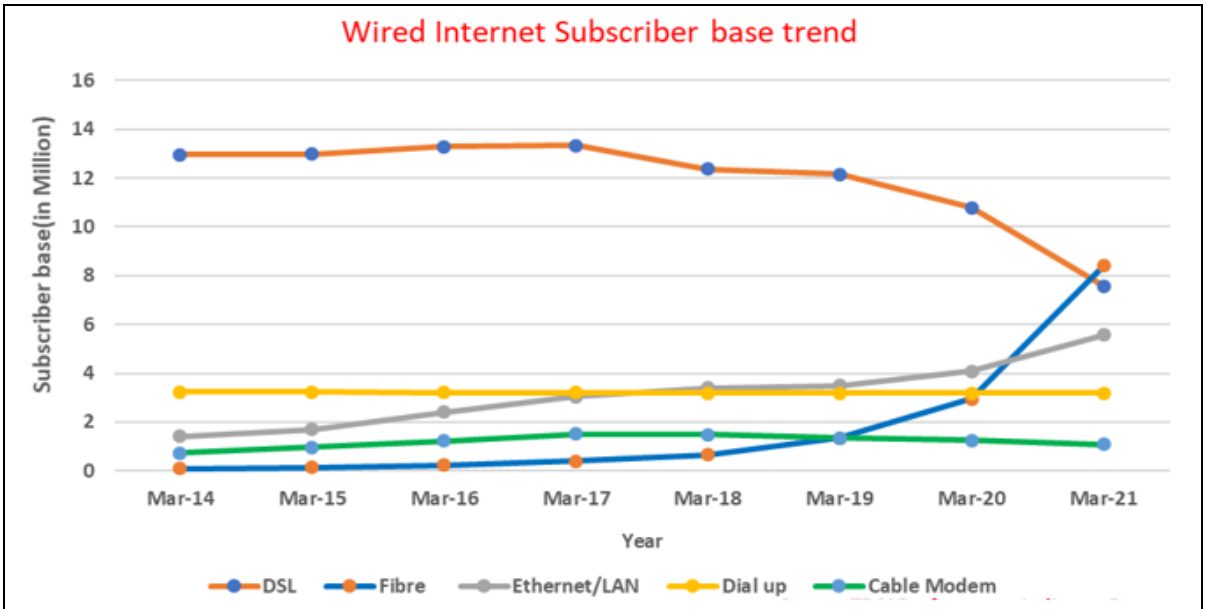
Top 10 ISP providers provide more than 99% of broadband connections and they are listed below.

Table 2: Subscriber base of Top 10 ISP providers as on March'2021

S/N	Internet Service Provider	Subscriber base (In Million) (QE March-21)	Share (%)
1	Reliance Jio Infocom Ltd.	425.51	51.56
2	Bharti Airtel	216.30	26.21
3	Vodafone / Vodafone Idea Ltd.	139.87	16.95
4	Bharat Sanchar Nigam Ltd. (BSNL)	32.45	3.93
5	Atria Convergence Technology Pvt. Ltd.	1.85	0.22
6	Hathway Cable & Datacom Pvt. Ltd.	1.07	0.13
7	You Broadband Pvt. Ltd.	0.83	0.10
8	Mahanagar Telephone Nigam Ltd. (MTNL)	0.77	0.09
9	ONEOTT Entertainment Ltd.	0.62	0.07
10	GTPL Broadband Pvt. Ltd.	0.56	0.07
Total of Top 10 ISPs		**819.83**	**99.34**
Others		**5.47**	**0.66**
Grand Total		**825.30**	**100**

Source: The Indian Telecom Services Performance Indicator Report January-March, 2021 published Online on TRAI dated 27/08/2021

The broadband connections on wired line can be provided on fibre (FTTH), DSL, cable modem and LAN /Ethernet. The trend for broadband connections technology wise is shown in the following figure:



Source: TRAI Performance Indicator Report from Mar-14 to Mar-21

Figure 7: Trend of Wired Internet Subscriber base in India

It can be seen from the above figure that broadband connections on copper cable (DSL) is reducing at a fast rate since March 2019 which coincides with the start of sharp rise in the connections on fibre. It can be seen that the percentage growth for FTTH is maximum.

3.2 Fibre to the home (FTTH) - A preferred mode of internet in post-pandemic scenario

The broadband connections on DSL have limitation of bandwidth and limitation of distance up to which required bandwidth can be provided. A high speed VDSL connection of 50 Mbps working on copper cable would work up to limited distance, say just 1 KM from central office in a typical MTNL outdoor plant. On the other hand, a typical FTTH connection can work over large distances from a GPON OLT. The optical fibre cable from OLT to building premises introduces very little loss of power.

The number of internet connections existing in Mumbai LSA and the growth trend of internet connections over FTTH and on non-FTTH media in Mumbai LSA was analysed from 2014 onwards and the graph is plotted below in Figure 8 for FTTH and Figure 9 for non-FTTH. The trend clearly revealed that the growth of FTTH connections is very high since March 2019 onwards whereas growth of non-FTTH connections is almost stagnant.

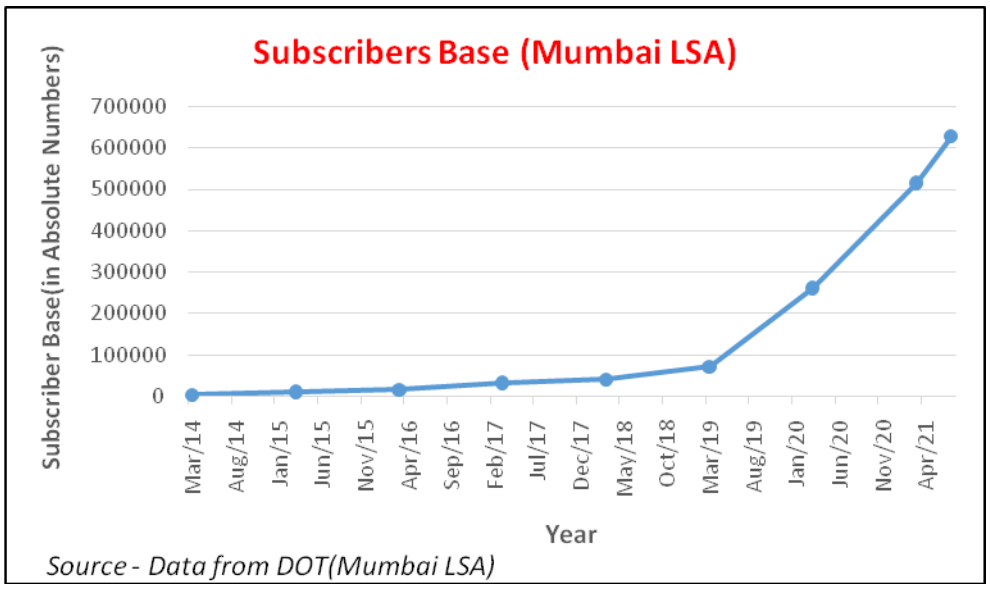


Figure 8: FTTH Subscriber base (Mumbai LSA)

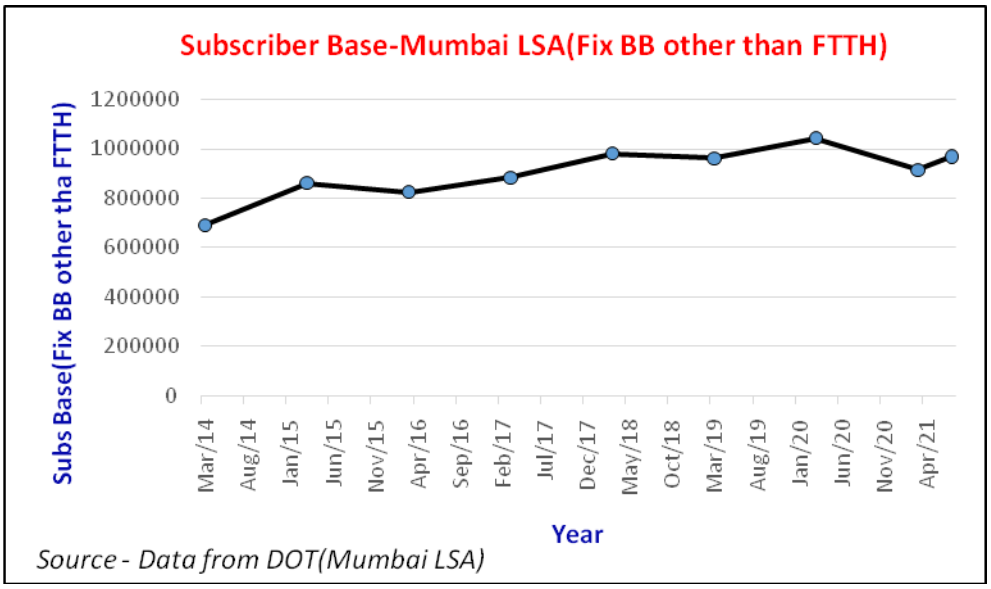


Figure 9: Fix Broadband Subscriber base (other than FTTH) - Mumbai LSA

A discussion with some ISPs in Mumbai has revealed that people are no more satisfied with internet on non-fibre technologies, say, internet on cable modem and are demanding high speed internet connections on fibre. The current technology used for providing internet on cable modem, in Mumbai, is compliant with DOCSIS-2.0 (data-over-cable Service interface specifications) which can give maximum bandwidth of approximately 40 Mbps in downstream which is to be divided among different subscribers. DOCSIS3.0 may also be in use in some parts of India. The provision of broadband over cable modem has no more remained attractive either from user's point of view, who are in need of high speed data or from operator's point of view, who find the provisioning and maintenance of FTTH connections very easy. In fact, Cable TV operators are also deploying FTTH in

replacement of the existing coaxial cable used for providing cable TV connections. The need of high speed data may also be attributed partially to the onset of Covid-19 as work from home has become new normal and people need stable high speed internet connection. The conventional technology of providing internet viz. DSL and cable modem are losing ground to FTTH because of immense power of "light" being transmitted through optical fibre.

It is clear from above discussions that the FTTH is the dominant solution as compared to cable modem and DSL and the growth of FTTH is waiting to explode and the only deterrent in this explosion may be difficulty faced by operators, e.g., ROW permission etc., in laying of OFC in cities in order to cover all the households. The vast provision of fixed line broadband to homes on FTTH is, therefore, imminent in case the difficulties in laying OFC are resolved. The vast deployment of access network through FTTH would cause high consumption of optical fibre cables. The vast rollout of FTTH network would also require the matching access network, aggregation network and Core network interconnected on fibre and so the consumption of OFC is likely to grow at a fast pace.

It can be seen that the LTE 4G is the dominant technology in wireless broadband. Further, the eNodeB/gNodeB of 4G/5G mobile system would also be needed to be connected on fibre to cater to enhanced mobile broadband requirement. The backhaul would have to increase in order to provide 4G/5G wireless broadband to all Indians. It is known that multiple gNodeBs in close vicinity would be required in 5G rollout and all the gNodeBs would also be needed to be connected on fibre. In fact, the Fibre connectivity would be so widespread that easy methods of stripping the fibre and subsequent splicing would be needed to be devised to bring ease of connectivity.

3.3 Deployment of Optical Fibre Cable in Aggregation and Core Network

The optical fibre would also be required for core and aggregation network. It is known that BSNL (which was erstwhile DoT) has been laying cables of different sizes like 24F/48F, since about 1980s and about 30% of cables in most important trunk routes have outlived their life of 20-25 years. As these cables have outlived their life, the attenuation has increased manifold on them. In typical cases, the

attenuation of 1 to 1.25dB/km has become common in life expired cables as opposed to the common standard of 0.2-0.25 dB/km loss. The repair of fault in OFC is already posing tremendous challenge due to various reasons, one of which is also that fibre has become brittle. The brittleness has posed a challenge to BSNL never experienced before. It is illustrated with atypical example. Let us say, 12 fibres are to be spliced and the technician/engineer splices 5 fibres. While splicing the sixth fibre, the sixth fibre gets broken due to brittleness. Then the cable is cut fresh to prepare for fresh joint and all the 5 previous splices also go in vain as they have to be redone. This has posed extreme pressure on maintenance staff and overall effect is degradation in restoration time.

The other difficulties faced during restoration of OFC faults are also listed here among many others: -

- Many OF cables have been covered by highways/roads and digging such highways to restore the fault is impossible now.
- Recognising the correct PLBE pipe has been very difficult due to the existence of many PLBE pipes from different operators in the same trench. There is a strong need of replacing such old cables.

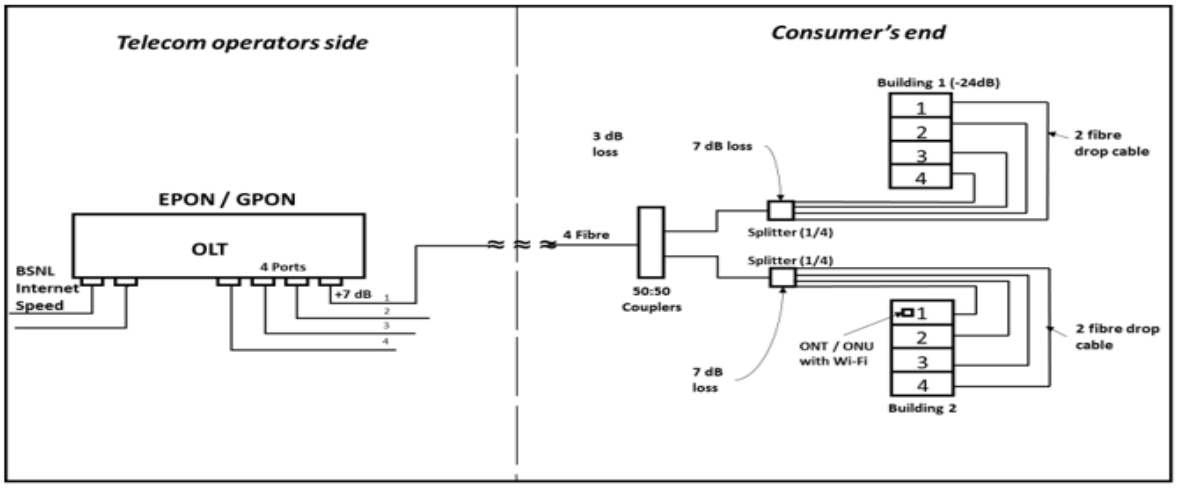
It is clear in view of aforesaid discussions that vast length of OFC would be needed to be deployed in the trunk routes also.

Chapter 4

4 Need of standardisation of OFC in telecom network

It was pointed out in Chapter 1 that there is a strong need of standardisation of OFC and accessories in Telecom network. This chapter presents the current OFC deployment scenario and the need of standardisation of OFC in detail.

4.1 The strengthening of FTTX and 5G gNodeBs network by suitable standardisation



Source: Prepared by Author after consultation with BSNL

Figure 10: Typical FTTX connection diagram of BSNL

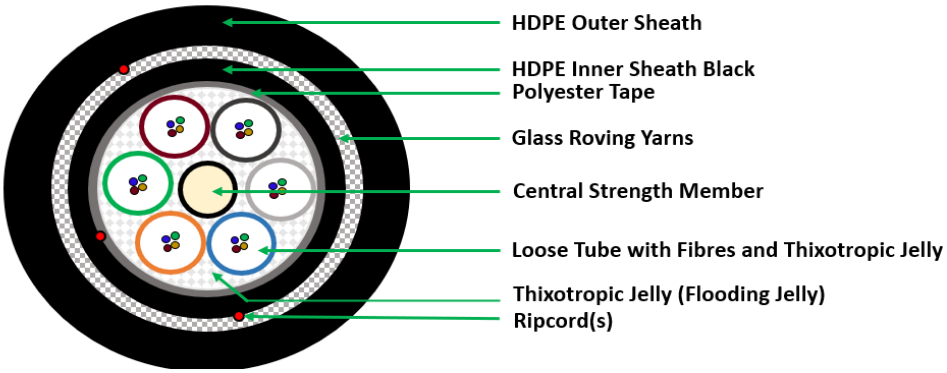
FTTX will be serving homes, premises, buildings, nodes and curbs. The large number of deployment instances automatically demands that these last mile installations should be as rugged as possible to reduce the fault liability. No service provider will have so much manpower to attend to the large number of likely faults which may occur in case of weaker OFC and installations, say, after big storm or when OFC has expired its life. Similar will be the case when 5G gNodeBs would have to be connected through optical fibre. These 5G gNodeBs OFC installations would also be large in number and only limited fault liability would be permitted which may be achieved only by ensuring proper OFC and installation. 5G gNodeBs have the option of getting backhaul on 'mm-wave' also from other near gNodeBs in case of OFC failure. Thus, they may be secure from

reliability viewpoint but the OFC needs to be maintained properly for smooth operation of gNodeBs.

There is a great scope for strengthening such last mile optical fibre cable installation used for FTTX and also the cable used for future 5G gNodeBs by carefully choosing right design and by standardising such right design for OFC. At the same time standardisation would also be needed for other most important components of OFC installation like splice closure, splitters and other necessary items. The robustness of OFC installation can be ensured by ensuring both the minimum standard of OFC and minimum standard of accessories like splice closure etc. It is again emphasized that the standard design would mean the design meeting the basic minimum criterion and any improvement over and above such basic minimum design would be welcome and permissible. An example is the OFC used for internal wiring by some ISPs in which the red light starts glowing at the fibre puncture point thus making it extremely easy for maintenance staff to take prompt action for repair. Such state of the art innovations in design of cable are most refreshing and welcome in creating a self-reliant network.

4.2 The case of underground OFC: already standard OFC being used by Telecom Operators

It is a fact that OFC for underground applications has been more or less conforming to some standards whether of TEC or user's own specification. Mostly, the design of such underground OFC consists of double HDPE sheath with IGFR as strength member and outer sheath having anti-rodent doping. The cable core consists mostly of loose tubes containing fibres and filling jelly. The loose tubes themselves are immersed in flooding jelly. A typical design diagram of such OFC is shown below:



Source: NIT floated by BBNL for Andaman Tender No. BBNL/MM/PIA

Figure 11: Structural diagram of loose tube 24 F OFC used in Bharatnet Phase-I

The other type of core consists of ribbon fibres and may have filling jelly and flooding jelly both in case of wet core or only filling jelly and no flooding jelly in case of wet dry core. The design of underground OFC has thus been conforming to some standards.

The design details of commercially deployed underground OFC have been studied in the report. However, any OFC that is laid beyond such underground applications such as aerial OFC, riser cable or OFC for FTTH and internal wiring needs attention as the main protection mechanism of OFC, i.e., HDPE pipe is not being used for such applications. The TEC standards exist for all such applications namely aerial OFC, riser cable and OFC for FTTH, however, use of the OFC confirming to TEC standard is not mandatory. The same is the case with underground applications too but the operators, themselves, adopted either TEC standard or their own standard (which was actually very close to TEC specification) to ensure that their trunk routes have longer life and best performance. However, fixing of minimum standard of OFC would be definitely helpful in ensuring robust infrastructure.

The accessories like splice closures etc. being used in trunk routes also confirm to TEC standard in almost all cases, however, fixing of minimum standard for these items would also be required to ensure robust infrastructure

4.3 Special attention needed for OFC for FTTX applications

The fault incidence, in case of FTTH, affects only individual subscribers; however, the cumulative burden of likely fault incidences which may occur in case of weak installations is quite high. We have seen in Chapter 3 that there is a very high growth rate of FTTX connections which proves that there is a vast latent demand for FTTX connections. This may be partly due to the increasing WFH (Work from Home) culture. Many ISPs/IP-1 have installed OFC for FTTH in which OFC specifications are as per service provider's own specification. The fibre of ITU-T Standard G.657 has been used for cables for FTTH applications. The G.657 series of fibres (e.g., G.657.A1, G.657.A2 etc.) are bend insensitive fibres and degree of bend insensitivity increases with later innovations e.g., bend insensitivity of G.657.A2 is more than bend insensitivity of G.657.A1. But beyond this minimum similarity in all FTTH OFC (used by different operators), there are many differences in OFC deployed for the purpose of FTTH. Some of these OFCs are really weak. The OFC used in last mile applications, therefore, need special attention. This includes the OFC used for connecting 5G gNodeB also. The underground OFC has been confirming with some standard, however, specifying such conformance formally in the form of minimum requirement will also be helpful for the network.

4.4 Perils of non-standard OFC in FTTX

Presently, FTTX connections will continue to grow at fast pace. It is a fact that different types of OFC are being deployed by various operators including Infrastructure Service providers (IP1). Some of these OFCs may last longer but some others may not last longer. This will cause a mixed network in which the fault liability cannot be estimated and operators would have to do the replacement/repair only as and when the fault has developed. The lack of intelligence on this important task would also truly make India self-non-reliant in provisioning of a robust telecom infrastructure rather than being self-reliant. Needless to say, such situation does not fit in the goal of "*Atmanirbhar Bharat*". Therefore, standardisation of OFC and accessories is the minimum that we can do for ensuring self-reliant network.

4.5 Last mile connectivity has remained an age old problem

Last mile connectivity has always remained a tedious problem in telecommunication network in India since the starting of telecom services. Earlier only voice telephony connections were being provided on copper cable through PSTN network. The last mile connectivity was provided through the use of drop wire. These drop wires gradually exhausted their life span over a period of time and became life expired. They were then replaced by new drop wires so that telephony services could continue to be provided with the desired quality of service. A lot of time had elapsed for individual customers between the arising of need of replacement and actual replacement of drop wires. But we cannot afford any time lag between the need of replacement and actual replacement of OFC used in FTTH applications today as the productivity of user would be hugely impacted. A typical old telephone network having drop wires is shown below.

Source: Google.com

Figure 12: Representative old telephone network having drop wires as last mile connectivity

4.6 Existing case of life expired OFC in TSP's network

We have more precedence for the above situation. DoT /BSNL had laid large length of OFC which have outlived their life may be 4 to 5 years ago i.e., in 2016. More cable installations have been adding up to the list of life expired cables as

the life of OFC is maximum 20 to 25 years which further gets reduced due to multiple cuts and joints in OFC. It is estimated that 30% of OFC in BSNL network has outlived its life as on 2021. The figure can also be easily arrived by making a table of installed OFC up to the year 2001 i.e., 20 years back from today. Of course, it will be theoretical life and practical life will be still less and may cover cable laid up to, say the year 2005. The signal losses have increased manifold on these cables. These cables are also offering great difficulty in their maintenance. This has highly deteriorated the quality of service in terms of restoration time also. The same may also be true for some other operators who laid the OFC very early. This example also proves that life of newly laid FTTH should also be known which is possible only by standardisation else different ISPs would all be having cables of different life some of which may be really low.

4.7 Productivity vs. network quality

We, therefore, have to be more prudent for the quality of last mile FTTX OFC and future 5G gNodeB connectivity such that we don't again land into the problem of poor quality of service in near future. The consequences of such poor quality will directly affect productivity of millions of Indians who are dependent on FTTX. The number of such persons who depend upon FTTH/5G gNodeBs will keep on increasing with time. If there is one wish of these vast numbers of people then it would be that their FTTX should not fail. We have to try to at least partly fulfil that desire of millions of consumers by this action of standardisation of OF cable and accessories.

4.8 Power of Technological intervention in terms of standardisation of OFC

Currently, telecom service providers are able to provide FTTH connection typically within half an hour of work if the junction box containing splitter etc. is already installed in the building premises. The ease of providing FTTH connection is really making the provisioning very easy and fast causing customer delight. But the design and strength of OFC including protection of FTTX/FTTH OFC may be very different for each TSP/ISP/IP1. Some of the FTTH cables may be of appropriate standard to match the life of rest of the OFC network (typical life of OFC is 20 to 25 years) but some FTTH cables are not meeting the appropriate

standards and their life is definitely much less. There is, therefore, a strong need to standardise the OFC for FTTX and, by analogy, for other applications too. At the same time, there is a need to standardise the most important accessories used in making OFC link like splice closures etc. A well laid FTTX network will serve as a good foundation for enabling fault free service over a longer period of time.

4.9 Multiple advantages of standardisation

There would be multiple advantages if the cables confirm to suitable standard developed by TEC for example the life of the OFC installation would increase and life expiry date would be known. The fibre is being provided by a large number of stakeholders like TSPs, ISPs, IP-1 etc. and standardisation would help in providing a uniform type of cable irrespective of providers. This will raise the standard of telecom network itself as the network would be comprised of known cables and maintenance would be so easy. This is especially needed as maintenance personnel would have different capabilities. Similarly, ensuring the standard of OFC accessories would also help in improving standard of telecom network.

4.10 The advantage of standardisation is sustainable under all installation conditions

There is always a chance to improve installation practices in such a way that the installation time does not increase much. Currently, the installation of ONT by extending fibre to the home is completed typically in about just half an hour of work. The advancements in installations may perhaps be achieved by deploying possible state of the art connectors and other suitable mechanisms; however, these have not been discussed in this paper. We may imagine a FTTX cable which when thrown from ground floor may rise up to any desired floor like phoenix. Of course, this is a wish only. Usually, the OFC contributes to just 1% of the total cost of OFC installation but we can increase that ratio by offering much better cable in the interest of robust FTTX infrastructure.

Opportunity has been identified in improving the FTTX cable itself so that it has longer life and can provide desired quality of service. It is known that the field installers would comprise of so many workmen with so different work styles but

the minimum standard of cable and accessories, once fixed, would remain the same irrespective of installers. The improvement in standard of OFC and accessories, thus, has the potential to ensure good quality of service even in the face of say, untrained installers. The available TEC standards for OFC and accessories are available in Chapter 7. Types of cables being deployed in India has been discussed in Chapter 6.

4.11 Technological intervention in the form of standardisation of OFC will help the vast FTTX network and 5G gNodeB the most

Usually, the optical fibre cables deployed to connect large equipment are being maintained properly as they are under regular observation by TSPs but it is not possible to monitor the last mile cables in the same manner and, therefore, there is a need to strengthen this last mile by suitable uniform long life cable and proper installation so that these cables have less fault propensity. At present OFC of varying strength and design are being laid in last mile and at least some of them are weak and may not conform to the desired life of the installation. As the number of such installations will gradually increase, the fault propensity will be adding to the potential maintenance burden on the operator and subscribers may face the quality of service issues later.

4.12 Fixed wireless access through 5G vs FTTH connection

The FWA use case is one of the most useful use cases of 5G. The beam from 5G gNodeB will reach up to 5G antenna mounted on the destination building and the antenna feed will be coming to modem kept inside different flats in that building. The bandwidth can then be distributed inside the flat through, say, Ethernet cables. Thus, the user can get high bandwidth through FWA application of 5G.

This scheme has the potential to compete with FTTX. However, a careful scrutiny will show that FTTH and 5G can be complementary to each other and both can coexist. The subscriber can have both options so that he can choose any one or both. This will give him the redundancy to get the internet always even in the case of failure of one system. Many efforts have been made in the core

network to give uninterrupted service and the redundancy of FTTH vs 5G FWA would give similar assurance of service to the end consumer.

There is one more important aspect related to service provisioning dealt in chapter 9. The number of ISPs and access service providers who can provide FTTH are much more in number than the service providers who can provide mobile broadband. The mobile broadband can be provided by those access service providers who are having authorisation for access services and also are having wireless spectrum. At present only five access service providers are having wireless spectrum and, therefore, mobile broadband can be provided by these five service providers only. On the other hand, FTTH connections can be provided by access service providers as well as by ISPs which together stand at 2249 (Ref Table 14). Thus, the number of operators engaged with provisioning of FTTH will be much more than operators providing mobile broadband. In view of the large number of providers of FTTH, there is an absolute need to make fixed standards of minimum requirement for OFC and accessories. This will greatly help in achieving a robust telecom infrastructure.

It is pertinent to mention here that Unified Licensing terms and conditions issued by DoT also has the clauses which mandate use of standard equipment by the Licensee (TSPs). One such extract from the UL agreement in respect of Access Service is reproduced below. Same clauses are there for ISPs and other types of providers too: -

4.13 Provision of use of standard Product/Equipment in the Unified Licensing Agreement

Unified Licensing Agreement says "The LICENSEE shall provide the details of the technology, proposed to be deployed for operation of the service, to the Licensor. For providing the Service the Licensee shall utilize any type of equipment and product that meet TEC standards, wherever made mandatory by the Licensor from time to time. In the absence of mandatory TEC standard, the Licensee may utilize only those equipment and products which meet the relevant standards set by international standardization bodies, such as, ITU, ETSI, IEEE, ISO, IEC etc., or set by International Forum, such as 3GPP, 3GPP-2, IETF, MEF,

WiMAX, Wi-Fi, IPTV, IPv6, etc. as recognized by TEC and subject to modifications/adaptation, if any, as may be prescribed by TEC from to time."

OFC is automatically covered under above clause as "… any type of equipment and product ….". TEC has issued notification no 5-2/2021-TC/TEC/93 dated 22/9/2021 to bring the Optical Fibre and Optical Fibre Cable under Mandatory Testing and Certification of Telecom Equipment (MTCTE) and the copy of notification is enclosed as Annexure-I. The mandatory conformance to essential requirement for OFC will come into force w.e.f. 1/7/2022 and the applications for testing would be accepted from 1/1/2022.

Chapter 5

5 Broadband Provisioning using FTTX

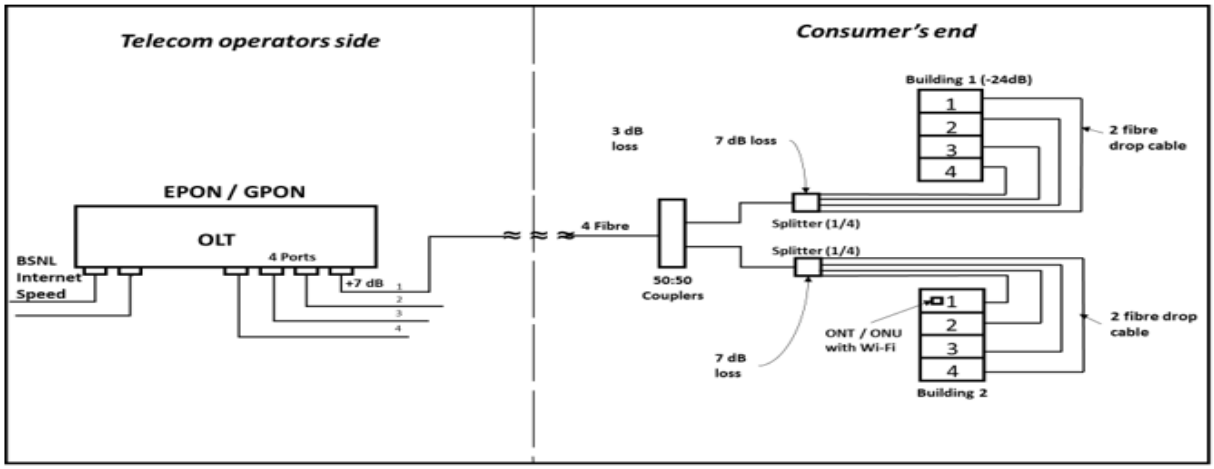
The broadband is provided through one of the two methods:

i. Use of GPON/EPON OLT and ONT.

ii. Metro Ethernet.

Fibre needs to be taken to the home in both the cases.

A typical FTTH connection working in BSNL is shown below in Figure 13. It can be seen that OLT is feeding power of 7dBm which is equivalent to about 5mW of power at the output port. The receiver sensitivity in a typical PON ONT is about (-25) dBm which corresponds to 0.003mW and the allowed end to end dB loss would be 10*log (0.003 mW/5mW) = -32dB which nearly matches with the known figures in dBm i.e.(5dBm-(-25dBm) = 30 dB). The allowed loss margin is so big that energy in fibre can be split into various streams. Assuming a total of 5db loss for OF cable (usually 0.2dB/km), splice loss of about 0.05db/joint, the dB loss that can be allowed is about 27dB. Usually, GPON technology allows division of power to 128 ports which amounts to 5mW/128= 0.039mW and the value is about 8 to 9 times more than the receiver sensitivity of about 0.003 mW. It can be seen that FTTH provides great advantage over copper as the signal can be transported over large distances without much loss of power and as many as up to 128 subscribers can be fed high speed internet with one port of OLT.



Source: Prepared by Author after consultation with BSNL

Figure 13: Typical FTTX connection diagram of BSNL

FTTH is very effective way of providing fibre to the home and providing broadband connectivity. OLT in above figure is giving output of 0 dBm to 7dBm[5] depending upon the optical link budget which is nearly equivalent to1mW to 5mW of power. The table below describes the limits for different classes of optical budget.

Table 3: GPON Power Budget Table

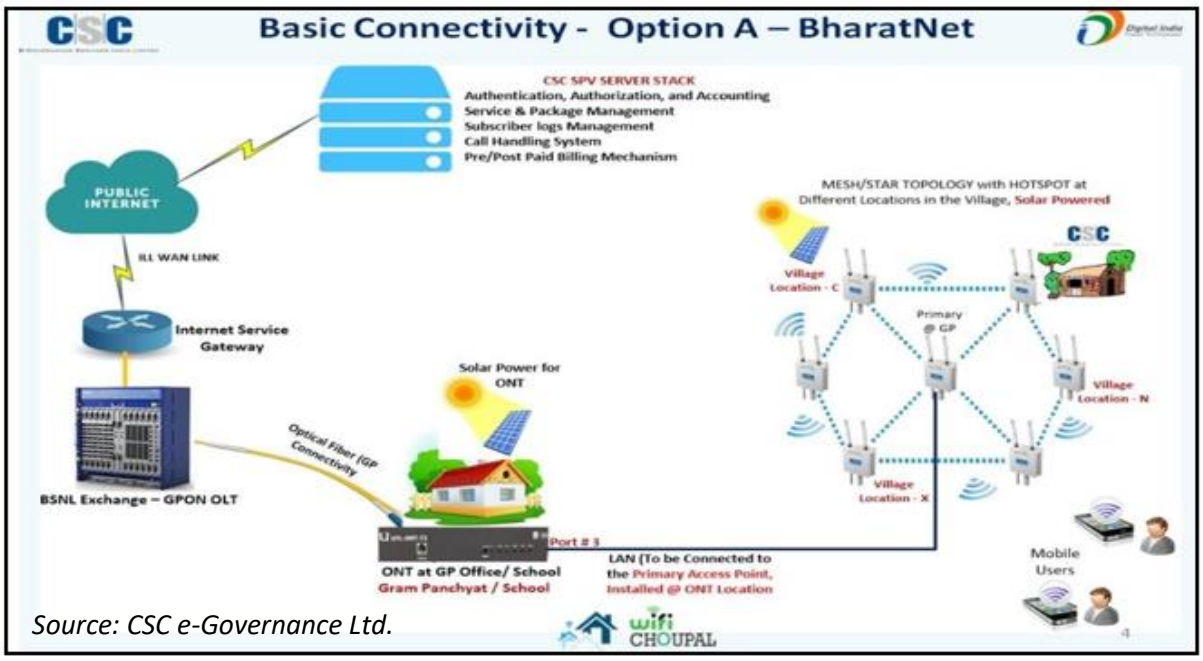
Optical Link Budget Class	Optical Output Power at OLT	Receiver Sensitivity at ONT	Optical Power Margin
A	0 to +4 dBm	-21 dBm (minimum)	+21 to +25 dBm
B	+5.0 to +9.0 dBm	-21 dBm (minimum)	+26 to +30 dBm
B+	+1.5 to +5.0 dBm	-27 dBm (minimum)	+28.5 to +32 dBm
C	+3.0 to +7.0 dBm	-28 dBm (minimum)	+31 to +35 dBm
C+	+3.0 to +7.0 dBm	-30 dBm (minimum)	+33 to +37 dBm
D	+6.0 to +10.0 dBm	-30 dBm (minimum)	+36 to +40 dBm
Source: ER No.: TEC14761911available on TEC website			

As the margin can be assumed to be about 25dB, the planner gets this margin to design the network. We may assume the fibre loss to be 0.2dB/km and joint loss to be 0.1dB per splice. It can be seen that fibre and joint introduce minimal loss and that's almost all the input power is available for distribution to homes. In the above case, the 50: 50 splitter divides the light energy into two streams. As the power in each stream becomes half, the new power coming out of 50:50 splitters are P0/2. Let us assume P0 is 1 mw. Then, the power in output in terms of dBm becomes = 10*Log (P0/2/P0) = 10 Log (0.5) = -3.01dBm. Therefore, the 50:50 coupler shows a loss of 3dBm.

5.1 Broadband Internet connectivity at Gram Panchayat Level using Bharatnet Network by service provider-CSC E-Governance Ltd.

BBNL project of providing connectivity to villages also deploys GPON technology as shown below: -

[5] ITU-T recommendation G984.2



Source: CSC e-Governance Ltd.

Figure 14: Internet connectivity diagram at Gram Panchayat level in Maharashtra

Source: CSC e-Governance Ltd.

Figure 15: Picture of WiFi Chaupal setup by CSC e-Gov at Gram Panchayat level

5.2 Commonly used Fibre and cable for FTTX application

For indoor use, the TEC specification no. TEC 85110:2021 exists. Two types of cables Type A and Type B for indoor FTTH have been specified. The key features of this cable are as follows:

1) Tight buffering of LSZH acrylic material is provided over the fibre. The (core +cladding + primary coating+ secondary coating) diameter of about 240-245 micrometre is tight buffered using primary coating of UV cured acrylate and secondary coating of LSZH material up to a diameter of 900 micrometre. It

not only gives strength to fibre but also the LSZH material protects it from unlikely event of fire hazards.

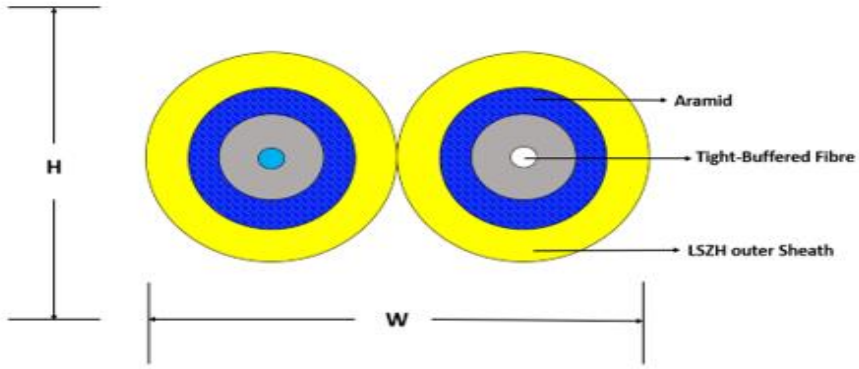
2) The twin fibres would be covered with Aramid yarn reinforcement and outer sheath material would be LSZH. The quantity of the Fibre reinforcement material (Aramid yarn Reinforcement) used per Km length, is indicated by the manufacturer.
3) Type B cable would be having 4/6/8/12 fibres. The fibres would be prepared in the same manner as detailed above. The Aramid yarn reinforcement would be covered by outer sheath of LSZH.

   It may be noted that manufactures have been provided with lot of flexibility in choice of quantity of aramid yarn reinforcement being issued in the cable. The service providers get these cables from manufactures and use them to get connectivity from OLT onwards in their FTTH network.

The most widely used fibre for FTTH application is of ITU-T Standard G.657.

5.3 Technological intervention required in standardisation of OF Cable

For indoor use, TEC specification no. TEC 85110:2021 exists and cable diagram is shown below. Two types of cables Type A and Type B have been specified. Type A, also called duplex, has only two fibres as shown below: -

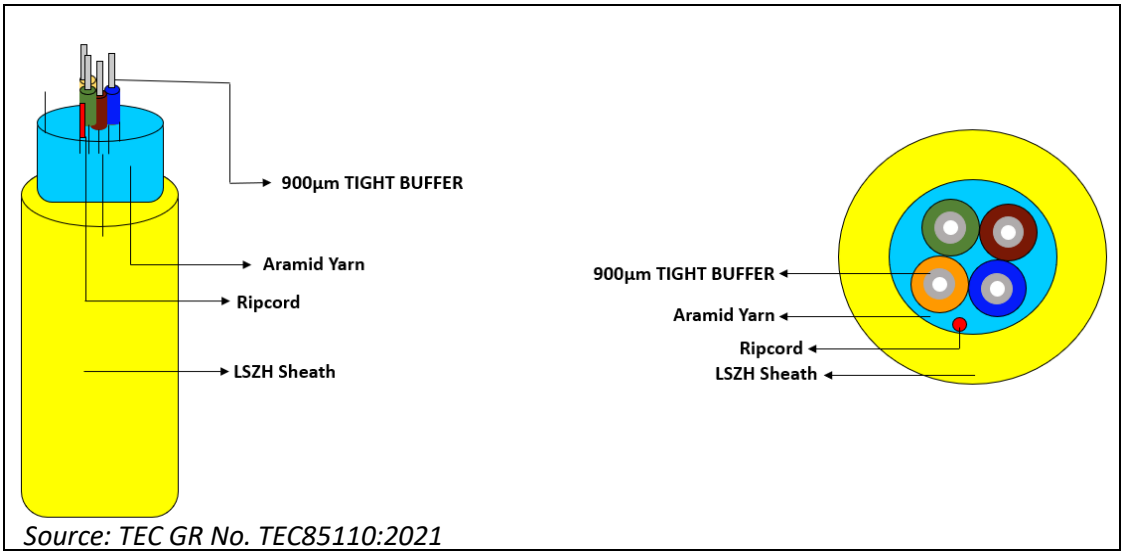


Source: TEC GR No. TEC85110:2021

Figure 16: Construction Diagram of Flexible (Duplex) Optical Fibre Cable (Type-A)

The twin fibres are covered with Aramid yarn reinforcement and outer sheath material is LSZH. The quantity of the Fibre reinforcement material (Aramid yarn Reinforcement) used per Km length, is to be indicated by the manufacturer.

Type B may have 4, 6, 8 or 12 fibres as shown below:



Source: TEC GR No. TEC85110:2021

Figure 17: Construction Diagram of Flexible Indoor Optical Fibre Cable (Type-B)

However, manufacturers are also using UV cured acrylate material for tight buffering. The (core+cladding+primarycoating+secondary coating) diameter of about 240-245 micrometre is tight buffered using primary coating of UV cured acrylate and secondary coating of LSZH material up to the diameter of 900 micrometre. It not only gives strength to fibre but also the LSZH material protects it from unlikely event of fire hazards.

The other two types of cable for indoor FTTH applications are also being consumed in the country:

1) Drop cable in which loose tube with jelly inside is protected by aramid yarn and HDPE sheath.
2) Only tube contains the fibre and jelly.

The production and use of these two types of cables may create future issues of degradation of their quality due to adverse environmental and physical condition.

Further, none of the above three types of OFC have anti rodent dopant as OFC is to be used in homes. The anti-rodent property of OFC also needs to be brought into the design not by adding chemical but through mechanical design means, say, by adding more FRP rods to protect the fibres from all sides

The cables used in Core and metro network are always under observation for fault incidences as they carry very high traffic, however, the last mile subscriber premises cable carries much less traffic and the fault incidences may not be always monitored. If the above two types of FTTX cables are used in last mile applications, their life may be limited and the life will not be in tune with the core or metro cable.

It has been observed, as in the case of BSNL, that the slow deterioration in quality of life expired cables has created huge maintenance problem. The problem will be much more aggravated in case of last mile indoor cable as their sheer numbers are much more.

These last mile cables also do not have rodent protection and some incidences of rat cutting have already been observed.

In view of aforesaid facts, it is utmost necessary that the last mile cables be standardised i.e., minimum design/performance criteria be fixed so that a robust telecommunication infra is available to all citizens.

5.4 ADSL/VDSL connection

ADSL/VDSL broadband connection over copper cable has largely been deployed by BSNL and MTNL and is not being discussed in detail in this paper.

5.5 Data over cable

Internet over cable service interface specifications (DOCSIS) 2.0 & 3.0 version is being used to supply internet through coaxial cable used for cable TV. There is a Cable Modem Termination system at the cable TV operator's end and the cable modem is also there at subscriber's building premises. The data is carried over coaxial cable. The bandwidth is further divided to many customers. The cable modems of DOCSIS3.0 (data over cable Service Interface Standards) standard are also used in India and provide speed up to 150Mbps which gets distributed to 40 0r 50 customers. DOCSIS3.1 has high speed of up to 1 Gbps but it is not yet deployed in India.

5.6 Fixed Wireless Access (FWA)

This mode of broadband service provisioning has already been deployed by many ISPs. In this scheme, the ISP transports the desired bandwidth on fibre and radiates through antenna in unlicensed band. Another antenna in line of sight is installed on the destination building. This destination antenna receives signal from main antenna (i.e., the backhaul) and distributes the signal through the use of LAN switch to the homes in the building. The antenna is installed on top of the building. BSNL has also launched similar service in the name of air fibre scheme.

5.6.1 Case: Bharat Air Fibre Services planned by BSNL

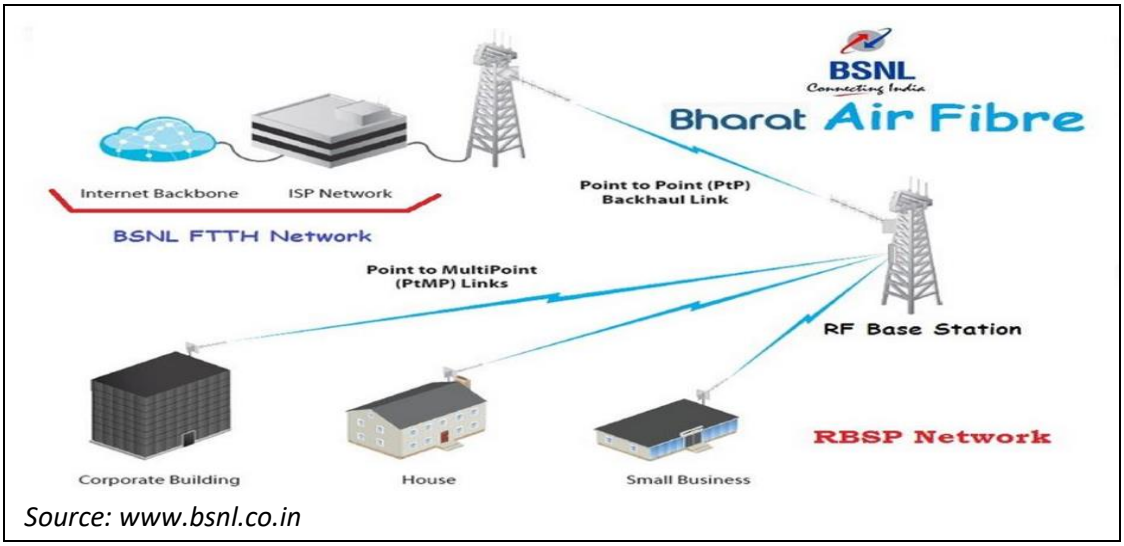
The Bharat Air Fibre services are being introduced by Bharat Sanchar Nigam Limited (BSNL) as a part of the Digital India initiative by the Government of India. It is being scaled pan-India. Aim is to provide BSNL fibre-to-the-home (FTTH) wireless connectivity up to a range of 20 km from the BSNL points of presence.

a. Features

The connectivity speed is 100 Mbps and BSNL is offering various broadband plans in wireline and wireless segments. There is a huge demand for high-speed broadband service in the present situation as there is the migration of people from metro cities to rural areas due to the Covid-19 pandemic. The service is becoming popular due to Work from Home (WFH), e-learning, online shopping, gaming and entertainment, etc. amidst lockdowns. BSNL is also providing unlimited free voice calling.

b. Mechanism:

It provides high-speed broadband to subscribers of remote areas by bridging the gap of last-mile connectivity through radio waves. A vast network of Optical Fibre has been laid by BSNL up to nearest Telephone Exchange or Mobile Tower and from there the connectivity is provided to subscribers over wireless.



Source: www.bsnl.co.in

Figure 18: BSNL Air fibre Fixed Wireless Access Internet Services connectivity diagram

c. Benefits:

- Customers at remote locations will be benefitted with the support of Telecom Infrastructure Partners (TIPs).
- These services are wireless and there are very low chances of interruption in services locally.

5.6.2 Broadband Internet Services on FWA

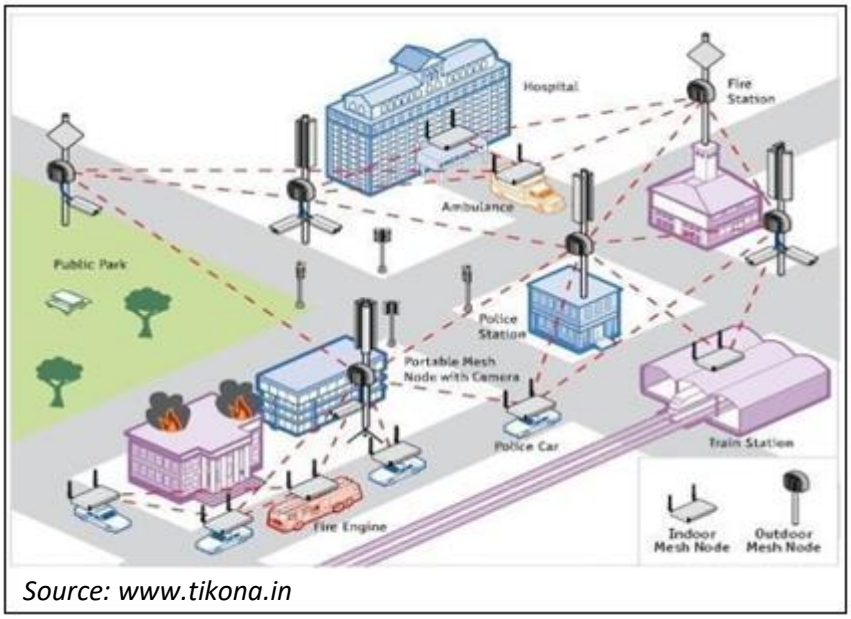
The details of provision of broadband on FWA are described below:

a. The method/technology of providing broadband to homes/subscribers**: -** In each city of operation there is one ISP node where ILL bandwidth is sourced from Upstream Service Provider. Thereafter, below it, first level of access network has been built up by sourcing local loop bandwidth from Infrastructure Service (IP) provider and then last mile to customer premises has been built through network on wireless using Radio and Access Point.

b. The maximum/average speed of broadband connection**: -** 200 Mbps at select building. Popular and most feasible plans are 30 and 60 Mbps.

c. The method/source of the backhaul bandwidth**:** - First level of access network by sourcing local loop bandwidth from IP service provider which is provider Fibre network and below that we build backhaul network on wireless using Radio and Access Point.

d. ISPs don't lay OFC. They source their bandwidth requirement from other Internet Service Providers. Their access network is mostly wireless from first node onwards.



Source: www.tikona.in

Figure 19: Typical pictorial representation of Fixed Wireless Access Internet Service provisioning

5.7 Wireless access over 4G and future 5G mobile technologies

The wireless access service being provided on 4G and future 5G would require high expansion of optical fibre to connect the eNodeB/gNodeB on fibre. Currently, about 30% of towers only are connected on optical fibre. The provision of Fibre connectivity to all eNodeB/gNodeB will require vast deployment of optical fibres.

Chapter 6

6 Brief of Optical Fibre cable used in India

The OFC deployed in Indian Telecom Network can be categorised on following basis:

A) Deployment based

1) Outdoor deployment: Underground and Overhead
2) Indoor Deployment: Within building premises

B) Construction of OFC based:

1) Armoured and unarmoured
2) Loose tube and ribbon type

C) Special application based:

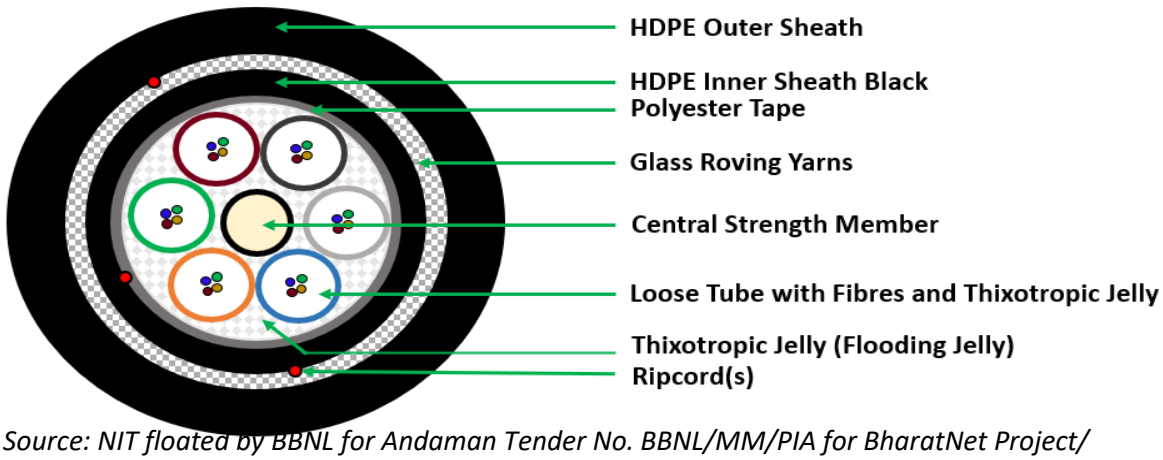
1) Optical Ground Wire (OPGW) cables
2) Submarine cables

Following are the most commonly used various types of OFC in Indian Telecom Network:

6.1 Loose Tube Optical Fibre Cable - most commonly used OFC (Bharatnet Project)

We start our discussion with the most commonly used optical fibre cables in India. DoT was among the first organisation to lay OFC and the cables of 6F were laid initially. Then cables of 12F/24F were laid. Presently, the most common structure of 12F/24F/48F cable resembles something like below figure which has been taken from the cable specification used by BBNL in Andaman and Nicobar Island[6] .

[6]http://bbnl.nic.in/ViewTenderFile.aspx?filetype=file&id=1842



Source: NIT floated by BBNL for Andaman Tender No. BBNL/MM/PIA for BharatNet Project/ Andaman & Nicobar/2020/004 issued on 18/05/2020

Figure 20: Structural diagram of loose tube 24 F OFC used in Bharatnet Phase-I

The basic element in OFC is fibre and whole of the cable construction is done with twin purpose of safeguarding the Fibre and keeping the design suitable and easy for splicing of fibres. It is known that the cable drums are generally of the length of 1KM to 2 KM and the cables have to be joined using splice closures at regular distances to get a sizeable OFC link of about 40 to 50 KM.

In the above diagram, four numbers of fibres are in one loose tube and thixotropic jelly is maintained in the tube. The jelly keeps the fibre safe and healthy inside the loose tube. The non-hygroscopic properties of jelly also protect the fibre from moisture. It can be seen that there are six such loose tubes making the total fibre count to 24. The FRP rod is used in the centre to give strength to the fibres and loose tubes. The structure consisting of tubes, fibres and FRP rod may be called core of the cable which is flooded with flooding jelly and the same is wound by polyester tape. The non-hygroscopic properties of jelly protect the cable from ingress of moisture. The core along with flooding jelly is wrapped by polyester tape and binder thread. The binder thread will be such that no kink mark is left on loose tubes. The core wrapped in polyester tape and wound with binder thread is protected by tough weather resistant High Density Polyethylene (HDPE) sheath, black in colour (UV Stabilized) and this HDPE layer is called inner sheath.

Impregnated Glass Fibre Reinforcement (IGFR) is used over and above the inner sheath to achieve the required tensile strength of the optic fibre cables. It

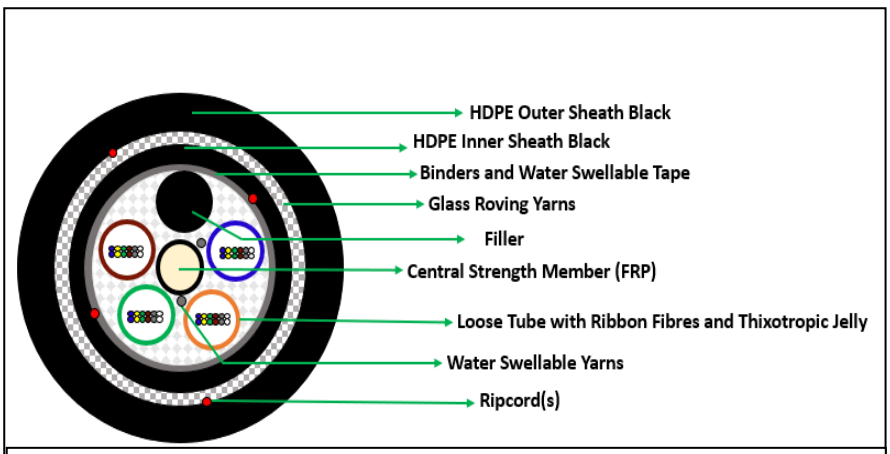
provides peripheral reinforcement and works very nicely along with Solid Rigid FRP Rod to give strength and flexibility to cable. The FRP rod at the centre and IGFR on the periphery over and above inner sheath provide all required strength and reinforcement of cable.

A black coloured non-metallic moisture barrier sheath has been applied over the IGFR which itself is wound helically over inner sheath. The outer sheath material is tough weather resistant made High Density Polyethylene compound (HDPE) and anti-termite. The outer sheath is UV stabilized.

Three suitable ripcords have been provided in the cable, which will be used to open both HDPE sheath of the cable. Two ripcords have been placed diametrically opposite each other below the outer Jacket & one ripcord has been placed below inner sheath. It shall be capable of consistently slitting the sheath.

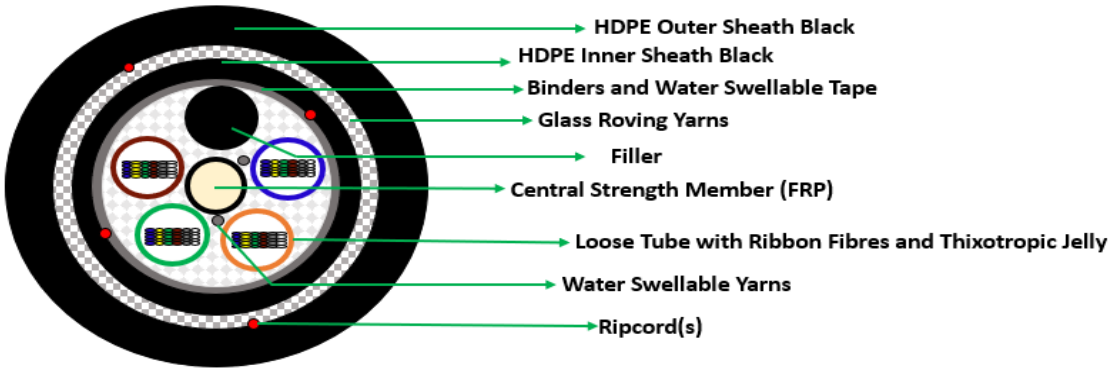
6.2 Ribbon-type OFC (Bharatnet Project)

Another cable design is the design of ribbon fibre cable. An example of the same is the requirement of cable given by MahaIT (Maharashtra Information Technology Corporation Limited) in their NIT No. MahaIT.CNI/001/01/2018 dated 31/1/2018.MahaIT has given the requirement of three types of cables 1) 24F/48F OF cables whose design is exactly same as the OF Cable discussed above. 2) Aerial OF 48F/24F ADSS and 3) 96F/48F OF cable Ribbon type. We will discuss below the ribbon type cable and ADSS cable. The construction diagram of 96F and 48F is given below: -



Source: MahaIT (Govt of MH) Tender No. MahaIT/CNI/001/01/2018 Dated: 31/01/2018

Figure 21: Typical Structural Drawing for 48 Fibre of Dry Core Cable used in Maharashtra Bharatnet Project



Source: MahaIT (Govt of MH) Tender No. MahaIT/CNI/001/01/2018 Dated: 31/01/2018

Figure 22: Typical Structural Drawing for 48 Fibre of Dry Core Cable used in Maharashtra Bharatnet Project

Both the cables above are dry core cable. These two ribbon fibre cables differ from each other in only one respect that there are 4 numbers of 6 Fibre ribbon in each loose tube in the case of 96Fibre dry core cable as compared to only 2 numbers 6 Fibre ribbon in 48F cable.

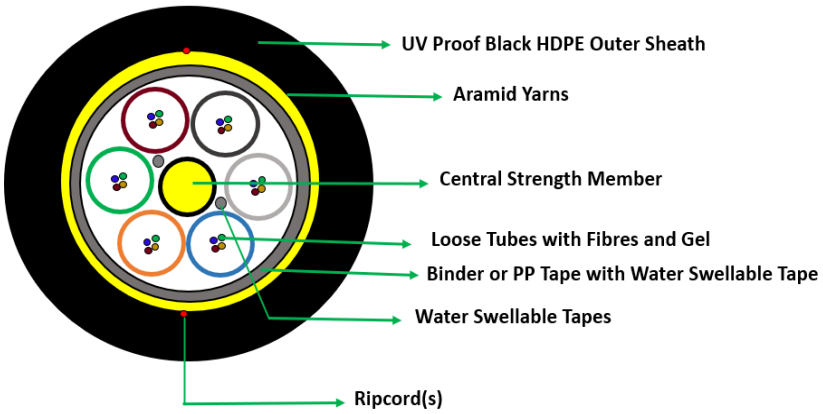
These ribbon cable differs from the loose tube cables in two respects:

i. Fibres in loose tubes are in arranged in the shape of ribbon in ribbon cable whereas fibres in loose tubes are loose in thixotropic jelly in the case of loose tube cables.
ii. The core does not have jelly as protection of moisture rather the core is protected from moisture ingress by the use of water swellable yarn and water swellable tape. The yarns and tape expand in volume as soon as any moisture comes into their contact, say, by puncture of cable.

However, ribbon cables with jelly are also used.

6.3 ADSS (All Die-electric self-supporting) Aerial OFC

Another cable used in MahaIT (Maharashtra) tender is ADSS cable whose diagram is given below:



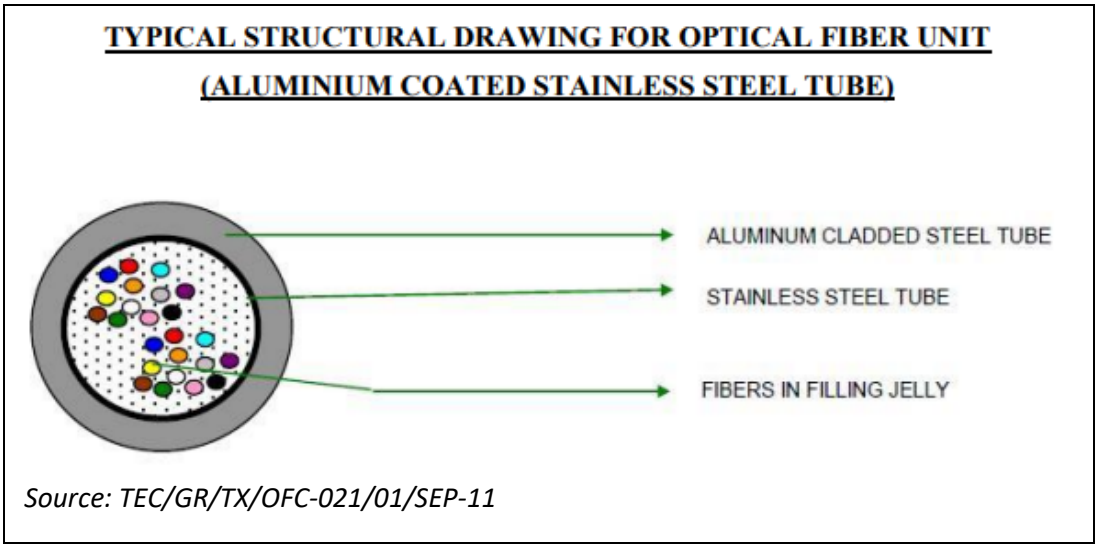
Source: TEC GR No. TEC/GR/TX/OFC-022/02/MAR-17

Figure 23: Cross-Sectional View of ADSS Aerial Optical Fibre

In the above case also, the aramid yarns have been used as peripheral strength member and there is only one layer of HDPE outer Sheath. Water swellable yarns and water swellable tape has been used as protection against water ingress.

6.4 OPGW (Optical Ground Wire) OFC

Another type of cable is OPGW cable which is being used by POWERGRID Corporation Ltd. The basic construction of the cable is as below:



Source: TEC/GR/TX/OFC-021/01/SEP-11

Figure 24: Typical structural drawing for OPGW OFC

The POWERGRID floated NIT no. CC-CS-892-NER/OPGW-4223/3/G4 opened on 5/4/2021 vide which detailed requirement of OPGW cable has been outlined. The cable would meet the requirement as per IEEE-1138, 2009. The

fibres would be in buffer tubes with jelly and one buffer tube can't have more than 12 fibres. The fibre to be used is G.652D and the fibres would be inside the aluminium cladded stainless-steel tube. The cable would be used as ground wire of765/400/220/132kV transmission lines and the minimum guaranteed life would be 25 years. The fibre cannot have strain of more than 0.05%.

6.5 OFC used in FTTX

FTTH cables are being produced of mainly of three types:

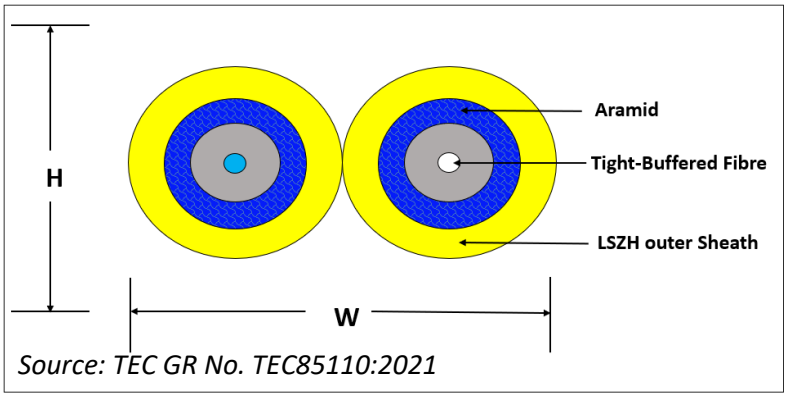
i. Flat drop cable in which two fibres conforming to G.657 A1 /A2 standard are put in a loose tube and two FRP rods are placed on each side of tube. The fibre used is tight buffered fibre of 900-micrometer diameter and the tight buffering is done by UV cured acrylate and LSZH material. Aramid yarn is used for strength.

ii. Drop cable in which loose tube with jelly inside is protected by aramid yarn and HDPE sheath.

iii. Only tube contains the fibre and jelly.

6.5.1 Aerial drop cable

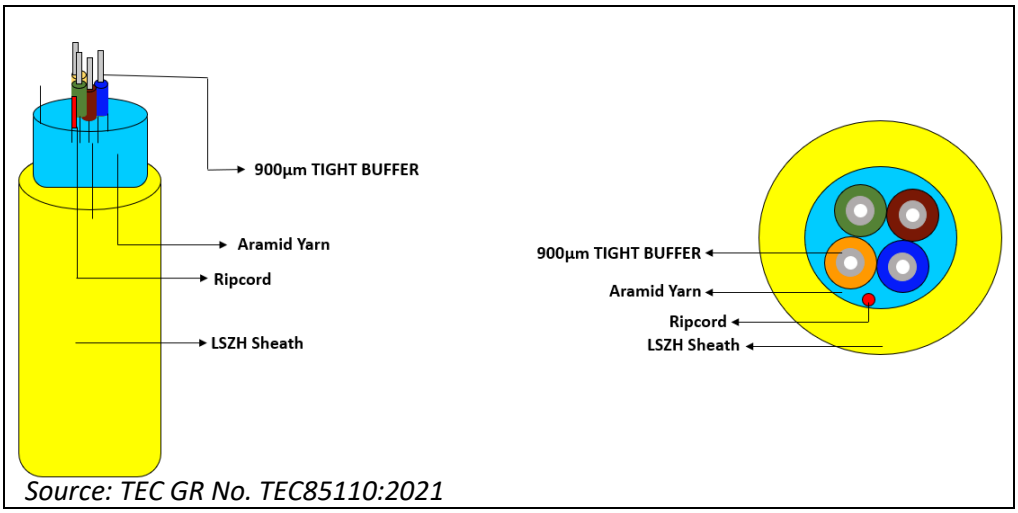
Typical diagrams of OF cable used in indoor application for FTTH are shown below. The cable has only two numbers of fibres. Each fibre is tight buffered by LSZH material to save the fibre from fire in case fire hazard takes place. Further, the outer material is also of LSZH so that the cable does not catch fire. The tight buffered fibres have diameter of 900 micrometre and the fibres are protected by aramid yarn. The LSZH sheath protects the cable from catching fire in case of fire hazards.



Source: TEC GR No. TEC85110:2021

Figure 25: Construction Diagram of Flexible (Duplex) Optical Fibre Cable (Type-A)

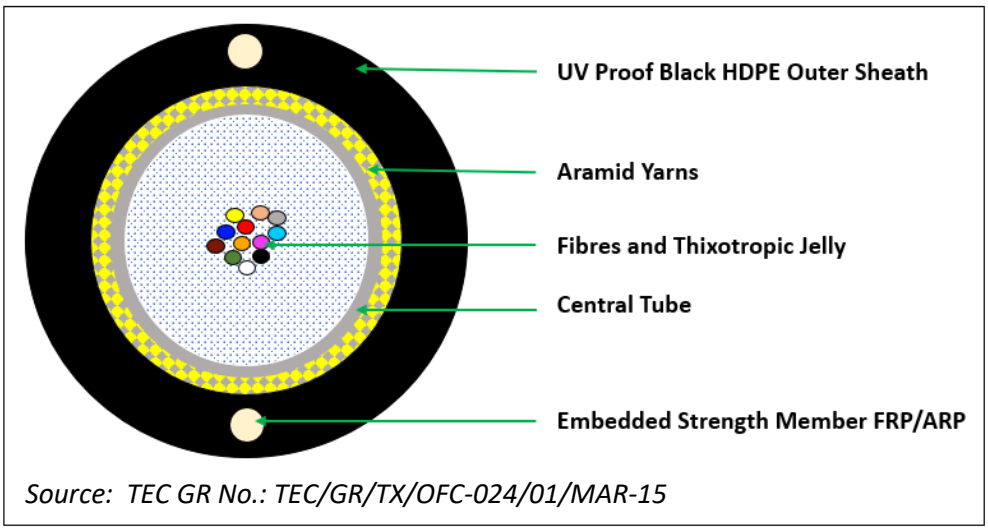
The number of fibres may be more than2, say, 4F, 6F, 8F or 12F. In such case a rip cord is introduced and the design would mostly be round.



Source: TEC GR No. TEC85110:2021

Figure 26: Construction Diagram of Flexible Indoor Optical Fibre Cable (Type-B)

Another cable used as per GR is aerial drop optical Fibre cable as per GR No. TEC/GR/TX/OFC-024/01/MAR-15. The diagram is given below. The FRP rod strength members have been provided on both sides of cable.



Source: TEC GR No.: TEC/GR/TX/OFC-024/01/MAR-15

Figure 27: Aerial Drop Optical Fibre Cable with Installation Accessories (For Last Mile Applications)

It can be seen that the outer sheath of cables meant for FTTH do not have anti rodent properties. The use of LSZH material for tight buffering of fibre and for outer sheath are mandatory and other design aspects can be negotiated to meet

the exact technical requirement. FRP rods may be placed more than two in number in order to cover the fibre in such a way that rats cannot cut the fibre.

6.6 OFC used in Submarine applications

Chennai Andaman Nicobar submarine cable link has been commissioned recently on 25th June 2020. The details are as follows:

Table 4: Chennai-Andaman Submarine OFC Sea link particulars

S/N	Particular	Description
1	Total cable length	2308 KM (total 8 segments)
2	Number of Fibre in the OFC	4 Fibre Pair (FP) cable system out of which 2 fibre pairs are lit initially
3	Fibre Pair designated use	Fibre pair1: Normal path Fibre pair2: Protection path Fibre Pair3: Defence purpose Fibre Pair4: Spare
4	Ultimate bandwidth capacity	• 64 Channels (64X100G=6.4 TB) per Fibre pair for mainland connectivity • 16 channels (16X100G= 1.6TB) for inter-island connectivity.
5	Equipped bandwidth capacity	• 2 channels (2X100G) per Fibre pair for mainland • 1 channel (1X100G) per fibre pair for inter-island connectivity.
6	Type of Fibre used	G.655
7	Repeater/regenerator spacing	80 KM spacing. Total 12 repeaters/regenerators are installed
Source: DPR dated May'2015 of Submarine Optical Fibre Connectivity to Andaman &Nicobar Islands by TCIL		

The entire route is connected using different combinations of cables depending upon the water depths and sea-bed conditions. The level of armouring is increased in case of shallow water where the chances of fibre cuts due to man-made activities like anchoring is more.

The submarine cable, i.e., armoured and non-armoured shall depend on the depth from the seabed. More protection is needed at lower depth of water as more elements are present in shallow water zones. Less protection is required in deep

sea zones as there are very fewer disturbing substances in deep sea. The type of protection used at different depth in the sea is give in the Table below: -

Table 5: Types of protection used in Chennai-Andaman Sea link

Type of Protection	Water Depth Down in sea (meters)
Light weight (LW)	8000 m
Light Weight Protected (LWP)	1500m to 2000 m
Single Armoured (SA)	1000m to 2000m
Double Armoured (DA)	400m
Rock Armoured (RA)	200m
Source: DPR Dated May 2015 for Optical Fibre Connectivity to Andaman & Nicobar Islands by TCIL	

Source: DPR Dated May 2015 for Optical Fibre Connectivity to Andaman & Nicobar Islands by TCIL

Figure 28: Diagrams of different types of Submarine cable used in Chennai-Andaman Sea link

Further details about the various types of Submarine OF Cable being used is given at Annexure-III.

6.7 Example of different types of OFC used along utility corridor

6.7.1 Installation of optical fibre ground wire (OPGW) cable

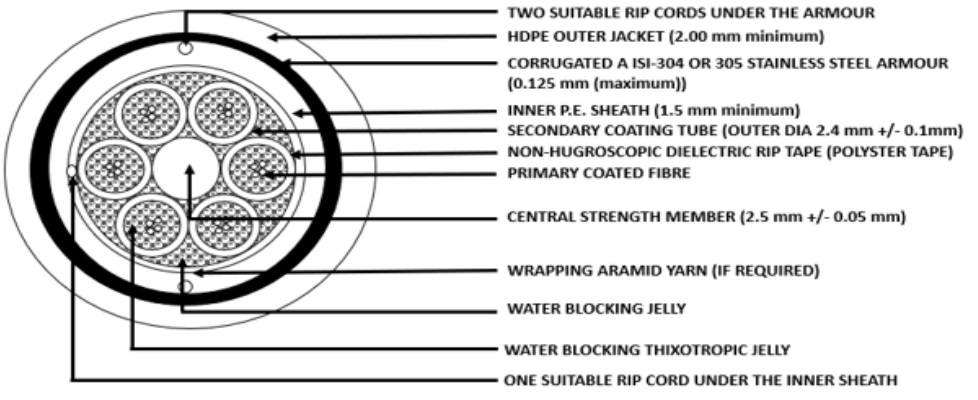
Optical fibres are particularly suitable for use on the aerial power lines in high-voltage networks, because they are immune by electromagnetic influences. There are several types of cable and installation technology. Among them, Optical

Fibre Ground Wire (OPGW) cable technology is specifically designed for high voltage power line installations. OPGW has the advantage of using the ground wire of a power line also for communications. However, users of OPGW need to be aware that if the cable fails it may not be repaired quickly. Therefore, an alternative routing for the optical circuits needs to be considered. These cables consist of a nucleus containing optical fibres and an armour, generally composed of one or more layers of aluminium wire, steel wire or aluminium-coated steel wire.

The additional features of these cables compared to others types of cable are basically as follows:

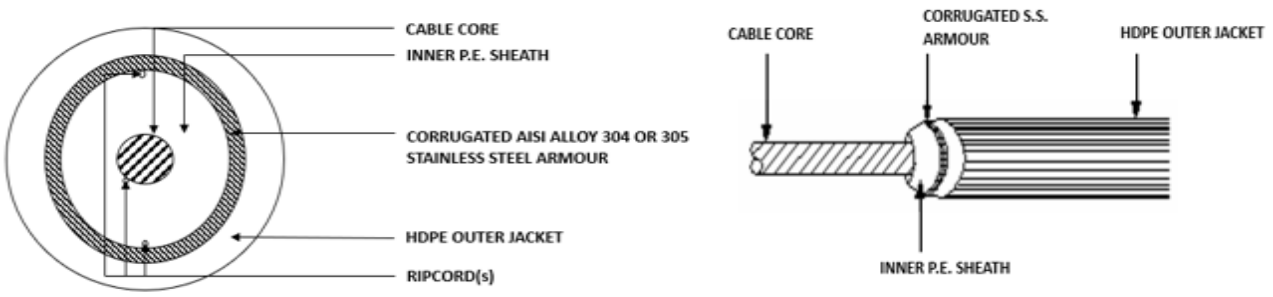
i. Greater tensile strength.
ii. Protection of fibres against excessively high temperatures when high current densities occur in the cable.
iii. Sag of the phase conductors.
iv. Spans.
v. Positions in relation to poles.
vi. Maximum wind speed.
vii. Maximum ice load.
viii. Other aspects such as risk of atmospheric discharge, fire, discharge of bird-shot, saline fog, aggressive chemical agents in the atmosphere.

6.7.2 Installation of optical cables along railways



Source: Indian Railway Standard SPECIFICATION NO. IRS: TC 55-2006

Figure 29: Constructional diagram of 24 Fibre armoured OFC used by RailTel, India



Source: Indian Railway Standard SPECIFICATION NO. IRS: TC 55-2006

Figure 30: Cross-Sectional view of armoured OFC used by RailTel, India

Railway companies have become interested in laying optical cables along their own infrastructures. These installations could be used for internal communications of the railway companies, or be offered to other customers for public telecommunications. Moreover, telecommunication companies could use the railway facilities to provide telecommunication services to their clients. Types of cable and infrastructures used in these installations can be very different.

The cable core may have different configurations: tight tube, loose fibre in tube, loose fibre in groove and ribbon. Usually, the most common configuration is loose fibre in tube.

The type of sheath and armouring of the cables depends on several factors: design of the cable, method of installation and kinds of infrastructures to be used. Generally, totally dielectric cables or armoured cables with corrugates steel tapes, can be used in direct burying and in ducts installations.

6.8 Compilation of different types of OF cable procured in Bharatnet Project

Bharatnet is the flagship project of Govt. of India to connect each Village Panchayat and village on fibre. It will be instructive to study the types of cables being procured for Bharatnet Project. The table containing list of tenders and types of OF cable procured is presented below and the brief of the Technical Specifications is given at Annexure-IV.

Table 6: Types of OF cable procured in Bharatnet Project

S/N	State	Phase I/II	Name of Tendering Agency	Date of Issue/ Publishing of the RFP	Types of Optical Fibre Cable in Tender		OFC Route Length in Km			
					Type I	Type II	48F	96F	24 F	Total Length
1	All India	I	BBNL	20/03/2017	24F OFC metal free				39668	39668
2	Gujarat	Phase II	GFGNL	2018	96/48 Core (Ribbon) UG	24 F Aerial				
3	BIHAR	Phase II	BBNL	15/12/2017	48 F		11574		200	11774
4	PUNJAB	Phase II	BBNL	15/12/2017	48 F, 96 F	ADSS OFC 24 F	10438	2659	200	13297
5	Chhattisgarh	Phase II	Chhattisgarh InfoTech Promotion Society (CHiPS)	31/01/2018	48 F		32466			32466

S/N	State	Phase I/II	Name of Tendering Agency	Date of Issue/ Publishing of the RFP	Types of Optical Fibre Cable in Tender		OFC Route Length in Km			
					Type I	Type II	48F	96F	24 F	Total Length
6	ASSAM	Phase II	BSNL	29/12/2017	288F/96F/48F/24F					6882
7	MADHYA PRADESH	Phase II	BSNL	29/12/2017	288F/96F/48F/24F					24485
8	RAJASTHAN	Phase II	BSNL	29/12/2017	288F/96F/48F/24F					7483
9	UTTAR PRADESH	Phase II	BSNL	29/12/2017	288F/96F/48F/24F					27343
10	WEST BENGAL	Phase II	BSNL	29/12/2017	288F/96F/48F/24F					5171
11	Maharashtra	Phase II	Maharashtra IT Corporation Ltd, Govt of Maharashtra	31/01/2018	48F/96F Ribbon	24F/48F ADSS	(1356 for Ribbon), (17395 for ADSS)	(18984 for Ribbon)	(6780 for Loose), (5798 for ADSS)	50313
12	Andaman & Nicobar	Phase II	BBNL	18/05/2020	24F Loose Type				400	400

Source: Various tender documents of BBNL and States

Chapter 7

7 TEC Standards for OF Cable

TEC has released various standards for OF cables which are listed below:

7.1 List of TEC Standards for OFC

Table 7: List of TEC Standards for OFC

S/N	Sub-Category	Type of OF Cable	GR No.	ITU Standard	Applications
1. Optical Fibre Cables for Underground Applications (Duct and Direct Buried, Micro-Duct)					
1	Underground Duct	Metal free Optical Fibre Cable	TEC-GR-TX-OFC-017-01-JUN-07	G652D	Access/Core network
2	Underground Duct	Armoured OFC for underground duct (Type-I and II)	TEC-GR-TX-OFC-020-01-MAR-11	G652D	Underground Application
3	Direct burial	Armoured Optical Fibre for direct underground burial	TEC-GR-TX-OFC-002-03-SEP-03	G652	Direct UG burial
4	Underground Duct	High count metal free Ribbon type OFC for access network	TEC-GR-TX-OFC-005-02-MAR-06	G652D	Access Network
5	Underground Duct	Non-zero dispersion shifted OFC for wideband optical Transport network	TEC-GR-TX-OFC-018-01-NOV-08	G656	High bit rate wide band long haul link
6	Underground Duct	Non-zero dispersion shifted single mode metal free OFC (Type-1 and II)	TEC-GR-TX-OFC-007-03-DEC-15	G655C	High bit rate for inter office and long distance use
7	Direct burial	Non-zero dispersion shifted armoured single mode OFC	TEC-GR-TX-OFC-008-01-AUG-01	G655	Direct burial high bit rate for inter office and long distance application. Low weight, small volume and high flexibility

S/N	Sub-Category	Type of OF Cable	GR No.	ITU Standard	Applications
8	Micro-duct	Micro duct OFC	TEC- GR/OFC - 16/01. JULY 2005	G652D	Low weight, small volume and high flexibility for micro-duct application
9	Underground Duct	High count armoured OFC for access network	TEC-GR-TX-OFC-006-01-JAN-01	G652	Access Network
10	Direct burial	OFC for concrete surface	TEC-GR-TX-OFC-009-01-MAY-04	G652	For direct buried installation by slitting Concrete / Metal roads, pavements or foot paths. It is required to be used in narrow and congested areas and highways where trenching or digging is not permitted and the work is required to be completed in short period of time.
11	Underground Duct	OFC for coastal area with high sub soil water	TEC-GR-TX-OFC-010-01-FEB-04	G652	For underground installation for coastal areas and sub soil water conditions in ducts.
2. Optical Fibre Cables for Aerial Applications (ADSS over Power line, ADSS on Aerial alignment, Lashed Aerial Cable, OPGW)					
12	ADSS	ADSS OFC For Laying along Power Line Alignments	TEC-GR-TX-OFC-022-02-MAR-17	G652D	Along overhead power distribution network up to 33KV.
13	OPGW	Optical Ground wire cable (OPGW)	TEC/GR/TX/OFC-021/01/SEP-11	G652D/G655	Along EHV Transmission lines up to 400 KV. The cable shall perform the dual function of the Earth wire and Optical Fibre cable
14	Aerial	Aerial Drop Optical Fibre Cable with Installation Accessories (For Last Mile Applications)	TEC-GR-TX-OFC-024-01-MAR-15	G657A1	FTTH network for last mile application.
15	Aerial	Aerial Optical Fibre Drop cable for FTTH Application (for short Span)	TEC-GR-TX-OFC-026-01-APR-18	G657A1	Last mile connectivity to FTTH customer on the Aerial route up to 30 meters of span length
16	ADSS Aerial	Self-Supporting Metal free Aerial OFC (For URBAN areas)	TEC/GR/TX/OFC-012/02/APR-18	G652D	For installing between two points on the Aerial alignment between the poles or pole to building in the Urban areas.

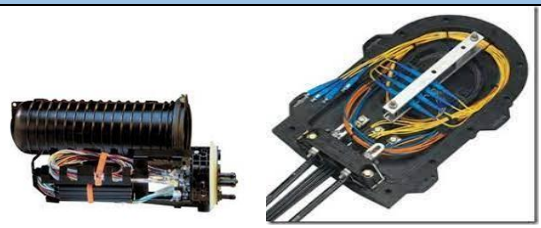
S/N	Sub-Category	Type of OF Cable	GR No.	ITU Standard	Applications
17	ADSS Aerial	Self-supporting metal free aerial OFC (Hilly and Rural Areas)	TEC-GR-TX-OFC-003-04-APR-18	G652D	For installation between two points on the Aerial alignment in Hilly & Rural areas.
3. Optical Fibre Cables for FTTX Drop Applications (Indoor Cable, Outdoor Cable, Riser Cable, Indoor/Outdoor Cable)					
18	Indoor	OFC drop cable with installation accessories (Figure Eight type)	TEC-GR-TX-OFC-015-01-AUG-05	G652D	Suitable for installation between two poles and inside homes.
19	Riser	RISER OPTICAL FIBRE CABLE indoor use (Type-1 and II)	TEC-GR-TX-OFC-025-01-MAR-17	G657A1/A2	These cables are suitable for interconnecting/drop/distribution cabling purpose within the high rise building and have an excellent flexibility required for routing through various turns/curves ensuring fast and easy installation.
20	Outdoor	OFC for FTTH	TEC-GR-TX-OFC-019-01-FEB-09	G657A	This cable is envisaged to be installed inside the premises/buildings and meant to carry high bit rate optical signals to the end user. The optical fibre being used is bending loss insensitive which is suitable for fibre to the home application purpose
21	Outdoor	Outdoor drop OFC with installation accessories	TEC-GR-TX-OFC-013-01-SEP-05	G652D	Suitable for installing between two poles and a pole to building. The cable shall be light weight and flexible
22	Indoor	Flexible Optical Fibre cable for indoor use	TEC 85110:2021	G652D	This cable is suitable for interconnecting /drop/ distribution cabling purpose within the high rise building and shall have an excellent flexibility required for routing through various turns/curves ensuring fast and easy installation

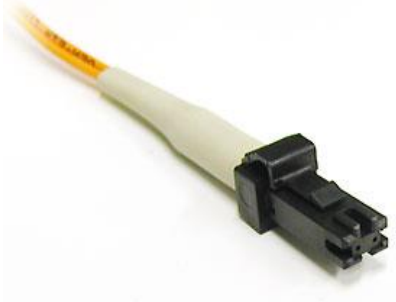
Source: https://tec.gov.in

7.2 Most essential accessories for OFC installations and its TEC Standard

Apart for OFC, there are other essential accessories items being used in installation of OFC which are also equally critical for achieving good quality of network. The list of such items along with corresponding TEC standard and brief function is given below in the Table.

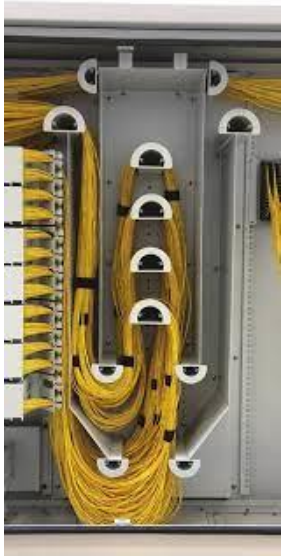
Table 8: Essential Accessories items used in OFC Installation and its TEC Standard

S/N	Item	TEC GR No.	Brief Function	Figure
1	Splice Closure for OFC	TEC/GR/TX/OJC-002/03/APR-2010	Optical Fibre splice closure is used in the outside plant network and houses the spliced optical fibre cables and its fibres in secured conditions. It shall be possible to use it for both Armoured & Metal Free type of Optical Fibre Cables and also compatible for different types of installation practices of cable installations viz. duct, aerial & directly buried. It provides mechanical protection and environmental sealing (by mechanical sealing method only) to the spliced cables and fibres etc. It is also possible to branch out the cable from the splice closure as and when required without damaging the existing cables.	 Source: Corning.com/ Fibreoptic4sale.com  Source: Community.fs.com

S/N	Item	TEC GR No.	Brief Function	Figure
2	Patch Cord Optical Fibre Jumpers	TEC GR TX/OFJ-01/05 NOV 2009	Single mode Optical Fibre Jumpers (Patch cords and Pigtails) (Type-I to Type-IV), Adapters (Type-I to Type-IV), Hybrid Jumpers (Type-I to Type-VI). These are used for terminations, connecting the Optical Line Systems to outdoor / Indoor optical fibre cables and other optical measurement purposes.	 Source: http://www.fibre-optic-components.com/
3	Fibre Termination Box	TEC/GR/TX/FTB-02/02/APR-2010	The Fibre Termination and Distribution Box (FTDB) shall provide management of optical fibres of a cable or number of cables and optical splitter assemblies, with flexibility and reliability for an FTTX application. It shall provide management of fibres in a consistent and in a structured manner. It shall also provide facilities for reconfiguration of fibres, network expansion (through branching) and testing and shall be able to store extra length of pigtails and fibres for rearranging, in case the need arises. The box shall have provision for cable termination and sealing requirements.	 Source: fibrelinktech.com

S/N	Item	TEC GR No.	Brief Function	Figure
4	PLB HDPE Duct	TEC/GR/FA/CDS-008/04/AUG-19	Permanently Lubricated High Density Polyethylene ducts (PLB HDPE ducts) for use as underground cable conduits for optical fibre cables, suitable for cable installation by blowing technique. The PLB HDPE duct shall consist of two concentric layers, the outer layer being HDPE; co-extruded with an inner layer of solid permanently lubricant, to reduce the Internal Co-efficient of Friction (ICF). The lubricant shall be of a solid layer of uniform thickness so formulated to provide a permanent, low friction boundary layer between the inner surface of the duct and OF cable. The lubricant layer shall be clearly visible in cross-section, concentric with the outer layer.	 Source: Indiamart.com
5	PLB HDPE Duct Accessories Push-fit Coupler	TEC/GR/FA/CDS-008/04/AUG-19	Push Fit couplers shall be used for coupling PLB HDPE ducts/coils.	 Source: Indiamart.com
6	End Cap	TEC/GR/FA/CDS-008/04/AUG-19	End Cap, made of hard rubber/suitable plastic material and shall be fitted onto both ends of the duct coil after manufacturing the duct. This shall avoid entry of dust, mud and rain water into the duct during the transit and storage.	 Source: Indiamart.com

S/N	Item	TEC GR No.	Brief Function	Figure
7	Fibre Distribution Management System (FDMS) (Indoor) Type 1, Type 3	GR/FDM-01/02 APR 2007	FDMS shall provide management of a large volume of optical fibres of a cable or number of cables, with flexibility and reliability, in all environment of Access Network. Exchange (Type 1) is in Indoor location in the central office, having a controlled environment. The location has multiple cables converging and hence requires a system to handle a large number of Fibres. The cable is routed through race ways either from the bottom (under floor) or overhead. This FDMS shall be termed as FDMS Exchange. Building Premises (Type 3) is located in premises of the subscriber in an uncontrolled environment and typically, could be fixed in the basement, under the staircase, or, on the roof. The unit would be exposed to direct rain or splashing water, but not submersion. This unit would provide splicing Fibres of a cable to Fibres of another cable, and /or splicing the Fibres of a cable to pigtails and distribution on a patch panel. In most cases only one cable would terminate in this unit, however this unit could also be used for convergence of two or three cables while simultaneously providing patching to the Fibres "dropped" at the location.	 Source: Indiamart.com

S/N	Item	TEC GR No.	Brief Function	Figure
8	Fibre Distribution Management System (FDMS) (Outdoor)	TEC/GR/TX/FDM-003/01 MAR 2012	Fibre Distribution Management System (Outdoor) suitable for all types of optical fibre cables including Ribbon type cables used in telecom network. It is used in the Outside plant network and houses the spliced optical fibre cables and its fibres in secured conditions. It shall be possible to use it for both Armoured & Metal Free type of Optical Fibre Cables and also compatible for different types of installation practices of cable installations viz. duct, aerial & directly buried. Outdoor location is in the outside plant in an uncontrolled environment and may be buried underground, mounted on walls, poles or other structures. The unit must be capable of being submerged in water for extended periods without deterioration.	 Source: commscope.com
9	SPLITTERS	TEC GR No. TEC/GR/TX/OPT-001/01/ APRIL-12	Optical Splitter is a passive component of PON Technology for the application of FTTH to cater the demand of Customer for Broad Band, Voice, Data, and Video Services etc., It will be installed in the Central Office / Remote Office/ Cabinet/ MDU/ MTU/ Optical splitters capable of providing up-to 1: 128 optical splits, on end-to-end basis, per PON interface on OLT, are envisaged. There shall be various options provided to purchasers such as m:N where m = 1 or 2 and N = 2,4, 8, 16, 32,64 and 128.	 Source: opelink.com

S/N	Item	TEC GR No.	Brief Function	Figure
10	Splice Protection Sleeves for Optical Fibre	TEC/GR/TX/PTS-01/03/JAN-2011	The Splice Protection Sleeves is used to provide protection and reinforcement to the Spliced bare ribbon fibres. Since the fibres to be spliced are initially stripped off the UV resins, the inner EVA tube of heat protection sleeve provides a cushioning effect forming a layer on the bare ribbon fibres. The Ceramic rod in the splice protection sleeve provides reinforcement.	 Source: opticfibre-cable.com
11	OF Splice Protection Sleeve for optical fibre ribbon	TEC/GR/TX/PTS-02/03 JAN 2011	The Splice Protection Sleeves is used to provide protection and reinforcement to the spliced bare ribbon fibre having 2 to 12 fibres in a ribbon. Since the fibres to be spliced are initially stripped off the UV resins, the inner EVA tube of heat protection sleeve provides a cushioning effect forming a layer on the bare ribbon fibres. The Ceramic rod in the splice protection sleeve provides reinforcement.	 Source: indiamart.com
Source: Various TEC Standards of OFC Accessories and the Figures have been taken from different websites mentioned above through Google.com				

7.3 Key parameters listed under Essential Requirement (ER) issued by TEC for Optical Fibre under Mandatory Testing and Certification of Telecom Equipment (MTCTE) regime

TEC Essential Requirement(ER) prescribes the Limits/values of the key characteristics of the Optical Fibre (OF). The ER of Optical fibre has been published and Optical Fibre has been brought under MTCTE-Phase-IV with effect from 01/7/2022 as per TEC notification No. 5-2/2021-TC/TEC/93 dated 22/9/2021(Annexure-I).

The following parameters would be checked for fibre as per the Essential Requirement issued by TEC:

Table 9: List of key parameters of OF as per TEC ER No TEC70012008

S/N	Broad category	Individual Parameter Name
1	Geometrical Characteristics	Mode Field Diameter at 1310 nm
		Cladding Diameter
		Cladding Non-circularity
		Core Clad concentricity error
		Coating diameter
		Coating /Cladding concentricity
2	Transmission Characteristics (Attenuation of uncabled fibre)	At 1310 nm
		At 1550 nm
		At 1490 nm
		At 1270 nm
		At 1625 nm
		Water peak attenuation at 1380 to 1390 nm
		Sudden irregularity in attenuation
3	Transmission Characteristics (Chromatic Dispersion)	At 1550nm
		At 1625nm
		In 1285-1330nm band
		In 1270-1340nm band
		Zero Dispersion slope
		Zero Dispersion wavelength range
4	Transmission Characteristics (Polarization mode dispersion)	Uncabled Fibre
		Link design value for un-cabled Fibre
5	Transmission Characteristics (Cut-off wavelength)	Cable cut-off wavelength
6	Transmission Characteristics (Fibre Macro bend loss)	Change in attenuation when fibre is coiled with 100 turns on 60 ±1.0 mm diameter mandrel
		Change in attenuation when fibre is coiled with 1 turn around 32 ± 0.5 mm diameter mandrel

S/N	Broad category	Individual Parameter Name
		Change in attenuation when fibre is coiled with 100 turns on 50 ±0.5 mm diameter mandrel
7	Mechanical Characteristics	Proof test for minimum strain level
		Peak Stripability force to remove primary coating of the fibre (Unaged, Water aged, Damp heat aged
		Dynamic Tensile Strength Un aged)
		Dynamic Tensile Strength Aged (Damp heat aged)
		Dynamic Fatigue (Unaged and Damp heat aged)
		Fibre Curl
8	Environmental Characteristics of Fibre for both coloured and uncoloured fibres	Temperature Cycle Test: Temperature Dependence of Attenuation: Induced Attenuation at 1550 nm and 1625 nm at -60°C to +85°C
		Temperature-Humidity Cycle Test: Induced attenuation at 1550 nm and 1625 nm at -10C TO +85°C and 95% relative humidity
		Water Immersion Test: Induced attenuation at 1550 nm and 1625 nm due to water immersion at 23 ± 2°C
		Accelerated Aging (Dry Heat) Test: Induced attenuation at 1550 nm and 1625 nm due to Temperature aging at 85 ± 2° C
		Retention of Coating Color: Coated fibre aged for 30 days at 85℃temperature with 95% Humidity and then 20 days in 85℃ dry heat
		High Temperature and High Humidity (Damp Heat) Test: Induced attenuation at 1550 nm & 1625 nm at 85℃ temperature and 85% Relative Humidity for 30 days
		Cable Material Compatibility test for fibre: Fibre to be aged with filling compound for 30 days at 85℃ temperature and 85% Relative Humidity
9	Colour qualification for coloured fibres	MEK RUB Test (Methyl Ethyl Ketone)
10	Material Properties	Fibre Materials: The substances of which the fibres are made
Source: TEC ER No.- TEC70012008		

7.4 Status of coverage of all ITU Standard for Optical Fibre in the Standard of TEC for Optical Raw Material (ORM) No. - TEC/GR/TX/ORM-001/05/DEC-17

Table 10: Coverage of ITU Standards for optical Fibre in TEC Standard for Raw Material of Optical Fibre (ORM) No. - TEC/GR/TX/ORM-001/05/DEC-17

Sr No.	ITU-T Standard of Fibre	Whether mentioned in ORM Standard of TEC (Yes / No)	Whether mentioned in ER no. TEC70012008 of TEC (Yes / No)	Remarks
1	G. 651.1	No	No	
2	G.652.A	No	No	
3	G.652.B	**Yes**	No	It is likely to be removed from new ORM under preparation.
4	G.652.C	No	No	
5	G.652.D	**Yes**	**Yes**	It has been most widely used fibre.
6	G.653.A	No	No	
7	G.653.B	No	No	
8	G.654.A	No	No	
9	G.654.B	No	No	
10	G.654.C	No	No	
11	G.654.D	No	**Yes**	
12	G.654.E	No	**Yes**	
13	G.655.C	**Yes**	**Yes**	In TEC ORM and in TEC ER only G.655 is mentioned. It has low Chromatic Dispersion and is suitable for long haul applications like submarine cable.
14	G.655.D			
15	G.655.E			
16	G.656	**Yes**	**Yes**	
17	G.657.A	**Yes**	**Yes** G.657A1 and G.657.A2 are mentioned	Bend insensitive fibre
18	G.657.B	**Yes**	**Yes** G.657 B3 is mentioned	Bend insensitive fibre which allows even lower bend radius than G.657.A

Source: ITU-T and TEC Standard TEC/GR/TX/ORM-001/05/DEC 2017

Chapter 8

8 Technical brief of Optical Fibre

In the 1960s, copper cables were the main medium of transmission. The loss was typically in the range of 20 dB/km. In 1966, a paper was published by K.C. Kao and G. K. Hockham[7] in which it was predicted that a fibre of glassy material constructed in a cladded structure can transmit light pulses and the attenuation can be brought down to 20dB/km by removing impurity from the glass. The refractive index of the core needs to be about 1 % higher than that of the cladding. K.C. Kao and G. K. Hockham won the Nobel Prize in the year 2009 for their work of 1966.

In the early 70's the loss was actually brought down to 5 dB/km. Today, we have installed fibre loss of 0.2 dB/km. This loss figure is achievable in 800 nm, 1300 nm and 1550 nm ranges of optical wavelength.

Low loss, large bandwidth and very little delay are the three most important parameters which are to be achieved for optical fibres in order to get high bandwidth low latency communication.

The associated electronics like light source, modulator, photo detector, demodulator and digital signal processing equipment also play a vital role. For example, the multi-mode fibres which are very suitable for short distance communication e.g., LAN networking, require only LED as light source. The LEDs are cheap. The light pulses coming out of LED are not sharp due to which the pulse width is more and only less number of bits can be sent per unit time. This reduces the bandwidth of transmission. On the other hand, light pulses coming out of laser are very sharp and many pulses can be sent per second. Thus, a higher bandwidth is possible. But the laser sources are very costly as compared to LED sources.

Earlier, the source of optical carrier used to be ruby lasers which were very bulky and had to be continuously cooled by water due to high heat that was being

[7]Dielectric Fibre surface waveguides for optical frequencies by K.C. Kao and G. K. Hockham 1966

generated in their operation. However latest technology permits the laser to operate at room temperature.

8.1 Important fibre parameters

a) Numerical aperture

The Numerical Aperture (NA) of a fibre is defined as the largest angle an incident ray can have for total internal reflectance in the core.

b) The V number of a fibre

The V number of a fibre = 2 π*NA*(a/λ) where 'NA' is the numerical aperture, 'a' is the core radius and λ is the wavelength under consideration. The figure of V < 2.405 ensures single mode transmission.

c) Number of modes

The modes are possible patterns of E and H waves. The number of modes in a fibre is approximately given by $V^2/2$ where v is the wave number of fibres. For a single mode fibre, the V number should be less than 2.405.

d) The Mode Field Diameter:

When the light travels in core, some part of light travels in cladding also and the diameter (including core and part of cladding) in which the power falls to 1/e i.e., 90% of power is concentrated in that region is called Mode Field Diameter. The MFD is most important figure to determine the transmission characteristic of light transmission.

e) The BL equation

BL < C(n1/n2-1) *n1 where n1 is the refractive index of core, n2 is the refractive index of cladding and C is the speed of light in free space.
The BL product imposes the limit of bit rate in multi-mode fibre. If we want to increase bit rate, we have to reduce L.

f) Dispersion

1) PMD: Polarisation mode dispersion (PMD) is due to parallel and perpendicular fields travelling together and reaching a bit late to end

point with respect to one another. PMD is the main parameter that limits the high speed in single mode fibres.

2) Material dispersion: Material dispersion arises due to material. Fibres are made of glass materials. This glass material is doped with appropriate dopants in order to increase or decrease refractive indexes. These dopants and the glass material itself have refractive index which is the function of wavelength or frequency. Since the refractive index varies with frequency, the pulse which has some bandwidth, spreads due to different group velocities.
3) Waveguide dispersion (also called intra-modal dispersion) : Waveguide dispersion is in SMF due to waveguide effect.
4) Intermodal dispersion is in multi-mode fibres due to different modes in the MMF.

g) Attenuation:

Causes of attenuation: 1) Intrinsic e.g., absorption. 2) Scattering of light. 3) Extrinsic e.g., bending

In UV region the wavelength is smaller and frequency is higher. There is a lot of absorption due to breaking of bonds with high energy photon. In infrared zone also, attenuation is high due to intrinsic absorption. In between the UV and infrared regions, the wavelengths are suitable for optical communication. The 800nm, 1300nm and 1550 nm bands have least attenuation.

A lot of information about the current usage and industry trend can be had from the excerpts of interview conducted with Mr. Sudipta Bhaumik Head- Applications and Standards Engineering of M/s STL available in this report.

8.2 Brief about ITU-T G.657 Fibre used in FTTX

The ITU-T information about G.657 is reproduced below:

a) Bend-insensitive single-mode fibres for access networks and customer premises

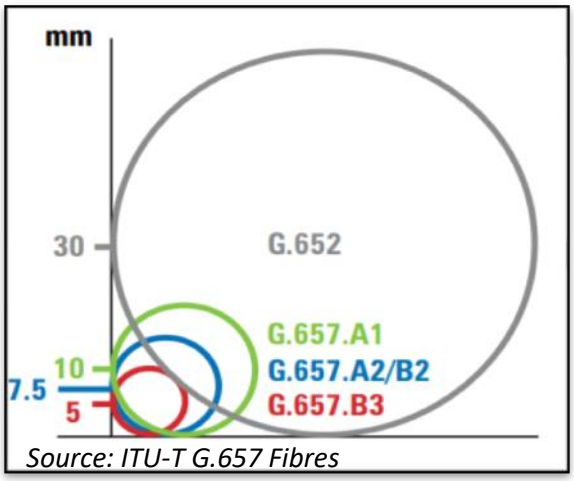


Figure 31: Relevant specified bending radii for ITU-T G.652 and ITU-T G.657

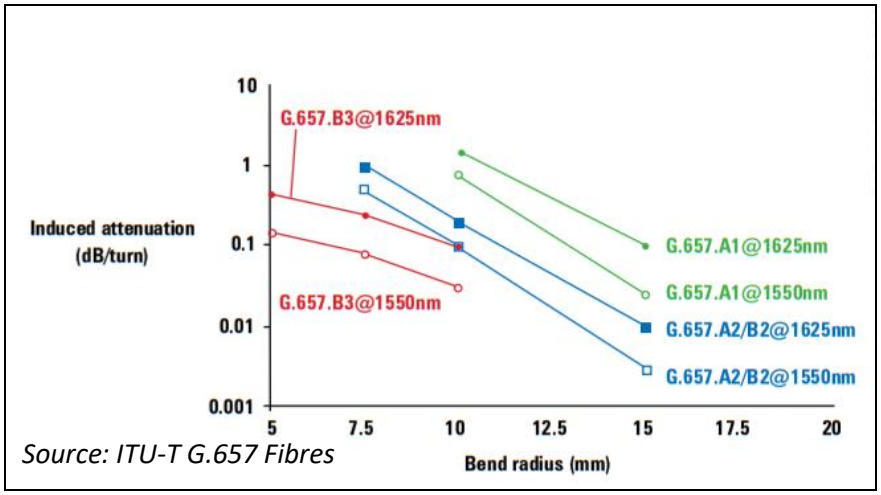


Figure 32: Macro-bending loss limits for ITU-T G.657 fibres

b) Background and history:

- The roll out of fibre-to-the-home (FTTH) networks has been of global importance since the early 2000s, requiring a dedicated single-mode fibre cable Recommendation.
- Operators and manufacturers jointly worked on swift introduction of this Recommendation in 2006 and its updates in 2009 and 2012.
- Since its introduction, ITU-T G.657 optical fibre cables have seen a steady increase in the total optical fibre cable market. Benefits:

- ITU-T G.657 optical fibre cable offers flexible characteristics for easier deployment in streets, buildings, and homes.
- ITU-T G.657 optical fibre cable reduces the roll-out cost for operators and the total cost of ownership (TCO) of an FTTH network.
    - Increased flexibility in optical fibre cables, allowing improved installation in tight corners of buildings.
    - Smaller cabinets, pedestals, enclosures, and terminations, which are important where space is at a premium. (e.g., in apartment buildings).
    - More engineer-friendly installation leading to less re-work.

c) Main aspects / attributes:

- ITU-T G.657 is split into two main parts A and B:
- Each category (A and B) is divided into two sub-categories:
    - **G.657.A1** and **G.657.A2**
    - **G.657.B2** and **G.657.B3**
- These sub-categories have the following minimum specified bending radii:
    - **G.657.A1**: 10 mm
    - **G.657.A2** and **G.657.B2**: 7.5 mm
    - **G.657.B3**: 5 mm
- ITU-T G.657.A1 and ITU-T G.657.A2 fibres are fully compliant with ITU-T G.652.D fibres.
    - Compliance here means adherence to the referenced Recommendation **(ITU-T G.652, category D)** meeting or exceeding the values of the specified attributes.
- ITU-T G.657.B2 and ITU-T G.657.B3 fibres are fully compatible with ITU-T G.652.D fibres (only small differences in chromatic dispersion and polarization mode dispersion (PMD).
    - Compatibility here means that these fibres will introduce negligible system impairment or deployment issues but may not be compliant to the referenced Recommendation **(ITU-T G.652.D)**.

- Additionally, another favoured application is in central offices where ITU-T G.657 fibres mitigate the risk of communication failure and/or high-power damage under inadvertent bending. Care needs to be taken to not impact long-term reliability. Examples of the relationship between minimum bend radius and maximum power can be found in IEC TR62547.

Table 11: Structure of ITU-T G.657 (2012)

G.657 (2012)	
For access networks G.652.D compliant all bands 1260-1625nm	**For end of Access networks (e.g., in/near buildings) G.652.D compatible all bands 1260-1625nm**
A1 Rmin = 10 mm	B2 Rmin = 7.5 mm
A2 Rmin = 7.5 mm	B3 Rmin = 5 mm
Source: ITU-T G.657 Fibres	

8.3 Industry trends of use of OF and OFC

Picture: Courtesy STL

The key features of industry trends have been obtained through interaction with various stakeholders and the industry trends can be easily seen in the excerpts of interview done with Mr. Sudipta Bhaumik, Head-Applications and Standards Engineering, M/s STL described below. The complete text of questions and answer session done during interaction is available at Annexure-V.

1) Centre of Excellence (CoE)

M/s Sterlite Technology Limited, major Optical Fibre and OFC manufacturer in India, has Centre of Excellence (CoE) located at Aurangabad, Maharashtra where following three important work related to Optical Fibre/OFC manufacturing are being carried out: -

I. **Design and Manufacturing**: This unit deals with the following activities: -
   a. Photonics - Study and implementation on attenuation, dispersion, cut off wavelength, material science and precise manufacturing.
   b. Material science - What kind of dopant should be used, types of glass (silica), plastic fibre etc. Plastic fibre production is less and it is used in medical field.
   c. Precision in manufacturing - This is very important aspect. The diameter is of the order of few micrometres only and the tolerance is very less. Therefore, it is very important to ensure precision in manufacturing and lot of effort goes in that. Capturing and quarantine the defective parts in high speed manufacturing process as well.

II. **Application:** The customers give different requirements based on their need and all research is to be done to decide the core, cladding and protective part i.e., jacketing etc., process setting, specified parameters, OFC installation practices, etc.

III. **Testing of Fibres and Simulation method of testing to develop quality product:** It is most important to test the characteristic of fibres before vetting it for production. CoE has all the equipment to test the fibre and in fact, it has got more than the required purpose and many equipment are kept for doing analytical studies.

There is a special team for simulation method of testing the Fibre in CoE. They do mathematical modelling. The physical test has the limitation is that we have to actually produce the fibre and then test it. But simulation has no such limitation. Simulation is very important to reduce time of new product/ process development.

M/s Sterlite is a member in 6 to 7 Standardisation Organizations worldwide. The list includes IEC, ITU, TIA, TSDSI, TEC, BIS, and IEEE.

2) The usual dopants being used in OFC

GeO2 in core for increasing the refractive index and only SiO2 is there in cladding. Sometimes, SiO2 is used in core and Fluorine is used in cladding. Fluorine reduces the refractive index.

3) Important Types of Fibres manufactured

Following are the major types of Optical fibres being manufactured: -

- **G.652.D** – Most commonly used OF so far but due to its bend sensitivity losses its use is being restricted to mostly Trunk routes now. This type of fibre is popular because of it is cheaper cost.

- **G.657.A1/A2/B3** – Due to its bend insensitive characteristics, this type of fibres is being used now in Access Network as well as in Trunk routes. They are however costlier.

A2 type is having lesser bend loss then A1 and B3 type has still lesser bend loss then A2 but cost of manufacturing is higher.

4) Quantum of manufacturing by Fibre types

G.652.D constitutes 60% of supply. From 2016 onwards, G.657 constitute about 30 to 40% of the total production.G.652.D and G.657.A1 constitute 80% of supply. G.652.D, G.657.A1, G.657.A2 together constitute 95% of supply.

5) Key component to decide about cost of Fibre

A2 supports 10 times more bend than A1. B3 is still better bust cost of B3 is still higher. The cost of A1 is now just 5 to 10% more than the cost of G.652.D. The cost of a product depends upon

a) Time taken to produce
b) Accuracy required in production
c) Cost and availability of raw material
d) Volume of manufacturing
e) Design complexity
f) Testing and qualification process.
g) When volume of production increases, cost decreases.

6) The life of OFC network

Life of OFC network was supposed to be 25 years but it is 8 to 10 years in India due to more cable cuts. Splice loss and bend loss disturb the link budget. The OTDR measures splice loss and bend loss together because the

bend is so close to splice. The splice loss is not frequency sensitive but bend loss is frequency sensitive i.e., we get different bend losses for 1310, 1550, 1625 nm. This principle is used to segregate bend loss and splice loss.

Once bend insensitive fibres are introduced, the network will become robust. Even a skilled labourer can do the splicing without bothering about bend losses. The network will run much better as the prime source of deterioration will be gone.

7) Various types of Losses in Optical Fibre

There are mainly 3 types of losses in Optical Fibre, they are: -

a. Bend loss - From 2016 onwards, there were a lot of FTTH applications for which bend insensitive fibre was required. G 657.A1, A2 and B3 are serving that purpose very well. Bend loss is also very high in trunk network and therefore G.657.A2 is coming up in trunk routes also in addition to being used inside house. France and UK have already adopted G.657.A2 for trunk as well as for customer premises because bend loss is so prominent in trunk also. The fibre which is jacketed inside the cable, gives no bend loss but fibre in splice tray, for example, can give lot of bend loss if it is not properly maintained.
b. insertion loss
c. splice loss

8) Key characteristic of Fibre affecting losses

Mode Field Diameter is directly related to bend loss, higher the MFD, higher will be the loss.

Initially, the G.657.A2 fibre core was having marginally lower diameter say 8.6 micrometre as compared to 9.1 or 9.2 micrometre for G.652.D fibre. But gradually, with betterment of technology, the core diameter has now become same as standard fibre and there is no problem in splicing between the fibres in network and G.657.A2. Gradually, 80% of fibres will become G.657.A2. Airtel is using only one fibre G.657.A1 for all trunk and A2 for inside the house (FTTH). VIL is using G.657.A1.

9) Use of Optical Fibre in 5G Mobile applications

More towers will be there in 5G. The fibres have to be reached to all towers and fibrisation will be much more.

i. There will be more cable terminations.
ii. Fibre count will be much more.

iii. Bend loss will be much more important.

So, cable terminations will have to be user friendly. This can be achieved if i) you can strip the fibre just by fingertip. ii) The cable is semi dry from inside so that handling is so easy. iii) Ribbons will be there for increasing fibre count.

A ribbon cable has been produced of more than 6000 fibres which is round in size and has a radius of just 30 mm. The earlier ribbon was flat in shape and cable radius was much more for comparatively much less fibre count of 288 (as used by Jio).

10) Latest development in Optical Fibre Technology

Multi core fibre is in research stage. If successful, then one fibre will have multicore and very high bandwidth can be transmitted on them. At present, submarine cables are required to carry very high bandwidth and they are of 48 Fibres say. But, with multicore technology, only a few fibres will be able to carry very high bandwidth.

11) Single Mode Vs Multimode Optical Fibre

Multi-mode fibres are suitable for LAN or short distance applications. The cost of associated electronics is very less for MMF. LED is used as light source instead of laser required for SMF. LED is much cheaper than laser though now cost of laser source is also reducing. The photodetectors used for MMF are less costly. But the attenuation of multi-mode fibres is very high and it is suitable only for less distance like in LAN applications.

8.4 Specification of the optical fibre characteristics

The optical fibres characteristics in terms of Fibre, Cable and Link attributes are specified in ITU-T with reference to the geometrical, optical, transmission and mechanical attributes and the same listed in the Annexure-VI. However, there is no value or limits set by ITU-T for some of the parameters.

Fibre attributes are those that are retained throughout cabling and installation. Among the fibre attributes, only those providing a minimum essential design framework for fibre manufacture are recommended (e.g., mode field diameter, cladding diameter, cut-off wavelength, macro bending loss). Chromatic dispersion coefficient is also included in these attributes.

Cable attributes are recommended for cables in factory lengths as they are delivered. The attenuation coefficient and the polarization mode dispersion (PMD) coefficient are included among the cable attributes since they can be affected by the cabling process.

Link attributes are the characteristic of concatenated cables. A concatenated link usually includes a number of spliced factory lengths of optical fibre cable. The transmission parameters for concatenated links must take into account not only the performance of the individual cable factory lengths, but also the statistics of concatenation. The transmission characteristics of the factory length optical fibre cables will have a certain probability distribution which often needs to be taken into account if the most economic designs are to be obtained. Link attributes are affected by factors other than optical fibre cables by such things as splices, connectors and installation.

ITU-T specifications for different types of Optical Fibre are enclosed at Annexure-VII.

Chapter 9

9 Telecom service provisioning framework in India

Ever service provider, whether it is desirous of providing voice or data connections has to obtain license and service authorisations for providing the service.

The essential features of policy of DoT is given below:

i. The acquisition of spectrum has been delinked from provision of services and has to be obtained separately as per prescribed procedure. At present, spectrum is allocated through bidding process.
ii. Any company/operator can get only one unified license. The operator has to get at least one service out of following services at the time of application. The operator can get one or more service authorisations from the services listed below.

9.1 List and brief scope of Telecom Service Authorization

Any Telecom Service Provider can get only one unified license and the TSP can get authorisation for service in any of the following categories. DoT is the licensor and all service providers who sign agreement for license and for authorisation are licensees.

Table 12: Types of Service Authorization issued by DOT

S/N	Type of service authorisation	Brief Scope of service
1	Unified License (All Services)	Access Service in all Service Areas, ISP Cat A with All India jurisdiction, NLD, ILD, GMPCS, PMRTS, VSAT CUG, MSS-R, IPLC
2	Access Service (Service Area wise)	i. The Access Service under this authorization covers collection, carriage, transmission and delivery of voice and/or non-voice messages over Licensee's network in the designated Service Area. ii. The Licensee can also provide Internet Telephony, Internet Services including IPTV, Broadband Services and triple play i.e., voice, video and data. While providing Internet Telephony service, the Licensee may interconnect Internet Telephony network with PSTN/PLMN/GMPCS network. iii. The Licensee may provide access service, which could be on wireline and / or wireless media with full mobility, limited mobility and fixed wireless access.

S/N	Type of service authorisation	Brief Scope of service
3	Internet Service (Cat A with all India jurisdiction)	i. The Licensee may provide Internet access including IPTV. ii. The Licensee may provide Internet Telephony subject to conditions prescribed by DoT. iii. For carrying originating and terminating traffic of its subscribers, the licensee may establish its own transmission links within its service area. For this purpose, the Licensee may also establish 'Last Mile' linkages within the service area either on Fibre optic cable or radio communication or underground copper cable. iv. Unified Messaging Services (UMS) within the scope of (i) to (ii) above can be provided by the Licensee. v. Internet Service to any VSAT Service subscriber can be provided, if the VSAT is located within the Service area of the Licensee. For this purpose, a direct interconnection of VSAT Network Hub through leased line obtained from an authorized service provider to the Licensee's node/server shall be permitted only for the Internet traffic. The VSAT Hub, however, need not be located in the service area of the Licensee. vi. The Licensee may provide internet service by using the Cable Network of authorized Cable Operator, as last mile linkage, subject to applicable Cable Laws (The Cable Television Networks (Regulation) Act, 1995) as modified from time to time. vii. Licensee may install operate and commission International Internet Gateway in the service area using satellite or submarine cable as medium after obtaining security clearance/approval from Licensor. viii. Licensee with International internet gateway is allowed to sell international internet bandwidth to other licensed internet service providers. Provision of IPLC service is not covered under the scope of this authorization. ix. The Licensee may share "passive" infrastructure namely building, tower, dark Fibre, duct space, Right of Way owned, established and operated by it under the scope of this Authorization with other Licensees.
4	Internet Service (Cat B with jurisdiction in Service Area)	Same as above except that the licensee can provide the services in its licensed area only.
5	Internet Service (Cat C with jurisdiction in SSA)	Same as above except that the licensee can provide the services in its licensed area only.
6	National Long Distance (NLD)	Provision of bandwidth between Service Areas i.e., carries the inter-circle traffic and provision of lease line anywhere in India. They can provide leased circuit and VPN service
7	International Long Distance (ILD)	Provision of international bandwidth and international lease circuit but the local leads have to be taken from concerned service providers.

S/N	Type of service authorisation	Brief Scope of service
8	Global Mobile Personal Communication by satellite (GMPCS)	All types of mobile services including voice and non-voice messages, data services by establishing GMPCS Gateway
9	Public Mobile Radio Trunking Service (PMRTS)	● At two way land mobile service in which users communicate among themselves through a pair of radio frequencies out of a pool in a designated frequency band, assigned to the system using pair of radio frequencies. ● The pair of frequencies is allocated on placement of call request and returned to the pool on completion of call. ● The communication usually takes place through repeater station (also called base station). Once user is assigned a channel (a pair of frequencies) by the system, no one else can interfere with the communication
10	VSAT Closed User Group Service	The scope of service is to provide data connectivity between various sites scattered within territorial boundary of India using VSATs**.** The users of the service should belong to a Closed User Group (CUG). However, the VSAT licensee after obtaining ISP license may use same Hub station and VSAT (remote station) to provide Internet service directly to the subscribers, and in this case VSAT (remote station) may be used as a distribution point to provide Internet service to multiple independent subscribers. Now, with latest amendment dated 23/9/2021, they can provide backhaul connectivity for cellular mobile services through satellite using VSAT to Access Service Providers. Similarly backhaul can also be provided to Access Service Providers for establishing Wi Fi hotspots.
11	INSAT MSS - Reporting Service	● The scope of service is to provide INSAT- Mobile Satellite System Reporting service, which is a one-way Satellite based messaging service available through INSAT. The basic nature of this service is to provide a reporting channel via Satellite to the group of people, who by virtue of their nature of work are operating from remote locations without any telecom facilities and need to send short textual message or short data occasionally to a central station. The service provides one-way message reporting (Transmit only) facility from anywhere in India (Restricted to Geographical boundaries of India). INSAT-MSS Reporting Service is a low speed data service with the maximum capacity limited to 300 bps. ● The Indian national Satellite System or INSAT is a series of multipurpose geostationary satellites launched by ISRO to satisfy telecommunication and broadcasting needs.
12	Resale of International Private Leased Circuit Service	With a view to promote competition and affordability in International Private Leased Circuits (IPLC) Segment, Government has permitted the Resale of IPLC and introduced a new category of License called as Resale of IPLC Service License with effect from 24th September 2008. The Reseller shall provide end-to-end IPLC between India and country of destination for any capacity denomination. For providing the IPLC service, the Reseller shall take the IPLC from licensed International Long Distance (ILD) Service. Resellers shall be permitted to enter into an arrangement for

S/N	Type of service authorisation	Brief Scope of service
		leased line with Access Providers, National Long Distance Service Providers and International Long Distance Service Providers for provision of IPLC to end customers.
Source: dot.gov.in		

9.2 Other Categories of Telecom Service Providers

In addition to above there are following categories of service providers:

Table 13: List of categories of Licenses issued/ registration done by DOT

S/N	Type	Description	Remark
1	VNO (Virtual Network operator)	VNOs are treated as extensions of NSOs (Network Service Operator) or TSPs and they would not be allowed to install equipment interconnecting with the network of other NSOs. They can apply for licenses for all services as mentioned in above table as for regular licensees. VNOs can install BTS, BSC, MSC but they won't be able to install gateway mobile switching centre, soft switches or TAX equivalent for connecting to other NSOs.	UL-VNO License is to be obtained from DoT.
2	Infrastructure Provider Category I	provide assets such as Dark Fibre, Right of Way, Duct space and Tower	Registration needs to be done with DoT.
3	Other Service Providers	They provide Applications Services which mean providing services like tele-banking, tele-medicine, tele-education, tele-trading, e-commerce, call centre, network operation centre and other IT Enabled Services, by using Telecom Resources provided by Authorised Telecom Service Providers.	The registration of OSPs was being done by DoT TERM cells which has now been discontinued.
Source: dot.gov.in			

9.3 Summary of Count of Service Authorization issued by DOT

Following number of Service authorisations has been issued by DoT.

Table 14: Summary of Telecom Service Authorization issued by DOT

Type of License			UL	UL (VNO)	UL	UL (VNO)	UL	UL (VNO)	
Service Authorization issuing wing of DOT			AS Wing	AS Wing	DS Wing	DS Wing	CS Wing	CS Wing	**Total**
No. of Companies to whom authorization issued			23	133					**156**
1	Type of Service Authorization	Access Services (All India)	2	2					**4**
2		Access Services (State wise)	49	22					**71**
3		Access Services Category-B	0	221					**221**
4		ISP Category-A	12	6	58	34			**110**
5		ISP Category-B	1	2	547	244			**794**
6		ISP Category-C	0	0	984	65			**1049**
7		NLD*	11	4			38	5	**58**
8		ILD*	6	3			25	2	**36**
9		GMPCS	0	0			0	0	**0**
10		PMRTS All India	2	2					**4**
11		PMRTS (Telecom Circle/ Metro)	0	0			40	1	**41**
12		VSAT	1	2					**3**
13		VSAT CUG Commercial*	3		10	1			**14**
14		VSAT CUG Captive			23				**23**
15		INSAT MSS-R**	2	2			1		**5**
16		Resale of IPLC	1	1					**2**
Total Number of Authorizations			**90**	**267**	**1622**	**344**	**104**	**8**	**2435**
Date of issue of Authorization			30-06-21	30-06-21	All except VSAT)-30-06-21 VSAT-31-03-19	All except VSAT)-30-06-21 VSAT-31-03-19	30-06-21	30-06-21	
* The figures given in the DS/CS wing are total no. of authorization issued before and after UL regime.									
** The authorization is inoperative due to non-issue of space segment by ISRO									
Source: dot.gov.in									

It is quite clear from above discussion that a large number of operators are contributing to the growth of telecom services in India. Many operators are themselves TSPs and they have taken licence of VNO also as it suits them to

satisfy customer needs. Let us say, one operator X has provided a data centre connectivity to a customer and the customer demands that the data centre should have connectivity with links from other operators too so that the data centre availability is always secure. In this case, the operator X will hire the connectivity from operator Y and pay him charges. The operator X can also hire from Infrastructure providers (IP1) the dark fibre etc. Operator X can also create a VNO and sign agreement with other TSPs for availing telecom services.

Registration only is required to register as IP1 and so large numbers of operators are working as IP1 providers. At present, following number of companies are registered under IP1:

Table 15: Summary of Infrastructure Provide (IP) Service Authorization issued by Carrier Services (CS) Service Wing, DOT

Total Number of Registered Companies	Type of License	Remark
1156	IP-I	Authorization issued as on 30-06-2021
Source: dot.gov.in		

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Chapter 10

10 Installation Practices and Challenges of various Telecom Service Providers

Feedback could be obtained from some of the service providers to know their OFC Installation practices, types of cables deployed, challenges faced and the suggestions for improvement. The feedback is presented below: -

10.1 Installation Practices of TSPs

A. Airtel

a. Most frequently used type of OFC and the Fibre for core network and for access network

96 Core Armoured Fibre Cable for both Core & Access networks is the widely used OFC. This is as per guidelines and network requirement. Following table lists the type of OFC used in Airtel network: -

Table 16: List of types of OFC deployed by Airtel

Type	Category	Specification	Remarks
Inter	Route	depth -1.65m, ducts -2, Chamber -2km, Cable - 96F	Rural/intercity
Inter	Low last mile	depth -1.65m, ducts -2, Chamber -2km, Cable - 96F	Rural / inter city
Inter	Fib max	depth -1.65m, ducts -1, Chamber -2km, Cable - 96F	Rural / inter city
Intra	Access/S mart City	depth -1.2, ducts -3, Chamber -150m, Cable - 2x96F	Urban / intra city
Intra	Low last mile	depth -1.2, ducts -3, Chamber -150m, Cable - 96F	Urban / intra city
Intra	Fib max	depth -1.2, ducts -3, Chamber -150m, Cable - 96F	Urban / intra city
Source: Airtel			

b. Key features of OFC installation and maintenance practices generally followed

- Fibre Execution with 100% ROW permissions
- Depth -1.2 Mater
- 40 mm ducts -3
- Chamber –every after 150m
- Cable - 96F

B. MTNL Mumbai

i. OF Cables used in core network and access network should be of maximum size available as this would reduce the laying costs per Fibre. (In MTNL max size used is of 96F)

ii. Junction Fibres (Core network) and Access Fibres should always be laid in Ring Formation through different routes to provide redundancy and reliability.

iii. The terminations should always be done with Square Connector (SC) pigtails and this should be standardized. Square connectors are very easy to use and reliable and provide higher Fibre density per Fibre Distribution Frame (FDF).

iv. Use of Maxell in sub ducts should be made mandatory so that the sub-duct can be utilized fully. Use of Maxell increases the Fibre density three folds per sub-duct.

10.2 Challenges faced in OFC Installation

A. Airtel

- Apart from MCGM no other Authority is having Online ROW portal which leads to delay in DN & ROW permissions.
- For ROW permissions no TAT followed by any Authority as per ROW Policy 2016, some Authority takes 3-4 months for giving permissions post DN payment.
- Very High Access charges.
- Some Roads are end to end CC roads till Footpath edge due to which no corridor available for Open Trenching, therefore respective applications are rejected by Authority

B. BSNL

a) **Absence of uniform reinstatement charges** being levied by State and National Highway Authorities.

b) **Tedious process of seeking Permissions from Highway authorities:** At present, permissions are required for laying new Optical Fibre Cable as well as for attending the fault along the Highway. There are two major issues while seeking permissions from Highway Authority, they are: -

- **Delay in granting permission:** Due to absence of online approval system. Nowadays for laying new OFC, it is difficult to get permission from Municipality, Corporation, NHAI, Forest dept., Railways dept. etc.
- **Permission for Attending Fault:** There should not be permissions required to attend the already laid OFC as it delays the removal of fault significantly causing customer dissatisfaction.

c) Difficulties in identification of Cable/Duct due to absence of identification marking system for different TSPs: At present, OFC has been laid by all TSPs along Highway/Roads and there is no guideline for unique identification of Cable/Duct of a particular TSP which causes great difficulties in distinguishing the Cable/Duct of TSP while attending the fault. Therefore, there must be guidelines for putting identification mark on the Cable/Duct of the TSPs to enable unique identification for example assigning unique colour to the Cable/Duct for each TSPs.

d) Absence of uniform Trenching/HDD method of laying OFC-

- At present, there is no standard practice of laying utilities in allotted utility corridor, during project implementation and during maintenance, each of the executing agency damages others utilities which causes loss and unnecessary issues between agencies. Therefore, there is need to prescribe uniform trenching methods and also introduce utility corridor along every Roads with pre-installed duct, similar to what is being done in some other advance countries.
- As almost all private operators have laid OFC, due to water pipe already available in the route, EB cable available in the route, it is difficult to attend the fault and difficult to take trench or HDD to lay new cable. Finding the PLB / cable is very difficult, as so many utility pipes are going on altogether in the same route.
- After cable is laid, two lane expansion / four lane expansion work is coming during which cable gets damaged mostly. Cable goes below the tar road which makes it difficult to attend any fibre break if at all anything in future.
- Drainage work of Water Supply department is being done along our route, just above our cable or sometimes below cable during which cable gets damaged.

- Co-operation from Water Supply Department/Highway Authority is very little during last quarter of Financial Year i.e., Jan to April of every year. They rush the work and never take care of our installed OFC.
- In many places, cable is lot laid in straight line but in zig zag fashion which causes maximum damages during trenching by Water authorities, Drainage authorities and Road works. Many faults happened in cable crossing locations only.

e) **Absence of Anti-rodent measures in the installed OFC** - This causes damages to the OFC due to Ant/Rat bite. There should be suitable pesticide in the unarmoured OFC to avoid such bites or use Armoured Cable.

f) **Track Rent:** Municipality/corporations are demanding track rent for already laid OFC. Track rent is to be paid for the past as well as for future period. Otherwise, they are not permitting to lay new cable or to attend the cable fault.

C. MTNL

MTNL is saddled with typical problem that they need to remove the existing OFC laid over Railway overbridges. BMC has declared the bridges as overloaded and the huge number of MTNL OFC has to be removed from above the overbridges.

10.3 Suggestions for improvement in OFC Installation and Maintenance practices

A. BSNL

a) Uniform OFC Laying method

- Formulation of broad Installation/Trenching Guidelines to achieve uniformity along with Cable/Duct identification system. There should be OFC Joint chambers along highway/roads to facilitate attending the fault.
- Warning tape should be laid in trench during laying of cable. Mostly cable faults are occurring in culvert and bridges along State Highway.

So, if we plan to lay our cable in 5 meters depth in culverts and bridges through HDD, most of the faults would not occur.

- Cable should not be laid in private land and also in some places, cable has been laid in private land of VDC-VPR (Village Development Committee) for 200m.

b) Introduction of online approval system

Online approval system for seeking permission to lay OFC is not available everywhere. It is hard to get permission to attend the cable fault from NHAI / NH / Corporation depts. Permission is not granted in one day. It usually takes two or three days till which time our cable cannot be attended. Therefore, online approval system for laying OFC should be introduced across India at National/State level.

c) Introduction of uniform reinstatement charges

All Highway/Road Authorities (National/State) should levy uniform reinstatement charges.

d) Introduction of Utility Corridor

- Separate cable duct may be planned along NH for Telecom purpose.
- OF cables should be laid in consultation with NHAI / NH / TWAD well in advance and it is better to ask to allot some utility pipes at the extreme end of a side which may be maintained by NHAI itself. In that case NHAI will take care of it and no road work will be done damaging the cables as we are paying some rent to them depending on our income.
- NHAI has started laying PLB pipes in the median of the NH (Work is in progress in Madurai-Tirunelveli section). Possibility of hiring of PLB duct for OTN routes may be explored which will reduce the expenditure for maintenance and our cable will be fault free.

e) Use of Armoured OFC

As far as possible, armoured OFC should be laid to facilitate the feeding of signal and locating the cable using cable locator. No ribbon cables should be laid, as it requires separate type of splicing machine and fault in single Fibres needs the ribbon to be spliced

f) Use of Drones for Route Patrolling

Unmanned drone network can be utilized for route patrolling by all the cable locators instead of engaging so many route patrollers by each operator.

g) Use of Cable Locater/OTDR/GPS/GPR

While attending the cable fault Cable locator, High resolution GPS instruments with highest accuracy, OTDR to locate fault, Ground Penetrating sensors to scan the underground utilities and locating them during activities should be used.

Chapter 11

11 OFC Installation Tools and Accessories

It is necessary to know about the tools and accessories required for installing OFC. The details are given in Annexure-VIII. It can be seen that the most important tools for installation and maintenance of OFC network is Splicing machine which is used for splicing of cable to make a joint. Joint closure, FTB, splitter and FDMS are the most important accessories. Brief of each of them is given below: -

11.1 Important OFC Installation Tools

A. Optical Fibre Splicing Machine

There are three types of Splicing Machines for which TEC has formulated the specifications, they are: -

i. **The Optical Fibre Splicing Machine** is designed to splice fibres by fusing the fibres together using localized heating at the interface of the butted fibres. An electric arc is generated by the electrodes contained in the unit. The splicing consists of fusion cycles resulting in permanently jointing of the optical fibres with minimum splice loss and low reflection.

ii. **The Ribbon Optical Fibre Splice Machine** is designed to splice fibres by fusing the fibres together using localized heating at the interface of the butted fibres. An electric arc is generated by the electrodes contained in the unit. The fusion splicing of the ribbon consists of fusion cycles resulting in permanently jointing of the optical fibres with minimum splice loss and low reflection.

iii. **Optical Fibre Splicing Machine (Portable) (Type-I & Type-II)** used for splicing the optical fibres with minimum splice loss and low reflection. The Type-I machine shall be capable of splicing single fibre and Type-II machine shall be capable of splicing ribbon fibres. It shall be very compact and light weight. It shall enable the precision splicing at the close proximity of the joint location or a pole or any place in the building premises.

11.2 Important OFC Installation Accessories

i. **Optical Fibre splice closure** is used in the outside plant network and houses the spliced optical fibre cables and its fibres in secured conditions. It shall be possible to use it for both Armoured& Metal Free type of Optical Fibre Cables and also compatible for different types of installation practices of cable installations viz. duct, aerial & directly buried. It provides mechanical protection and environmental sealing (by mechanical sealing method only) to the spliced cables and fibres etc. It is also possible to branch out the cable from the splice closure as and when required without damaging the existing cables.

ii. **The Fibre Termination and Distribution Box (FTDB)** shall provide management of optical fibres of a cable or number of cables and optical splitter assemblies, with flexibility and reliability for an FTTX application. It shall provide management of fibres in a consistent and in a structured manner. It shall also provide facilities for reconfiguration of fibres, network expansion (through branching) and testing and shall able to store extra length of pigtails and fibres for rearranging, in case the need arises. The box shall have provision for cable termination and sealing requirements.

iii. **Optical Splitter** is a passive component of PON Technology for the application of FTTH to cater the demand of Customer for Broad Band, Voice, Data, and Video Services etc., It will be installed in the Central Office / Remote Office/Cabinet/MDU/MTU/Optical splitters capable of providing up-to 1: 128 optical splits, on end-to-end basis, per PON interface on OLT, are envisaged. There shall be various options provided to purchaser such as m:N where m = 1 or 2 and N = 2,4, 8, 16, 32,64 and 128.

iv. **Fibre Distribution Management System**

- **Fibre Distribution Management System (Outdoor) for Optical Fibre Cables (Ribbon & Non–Ribbon)**- (Outdoor) suitable for all types of optical fibre cables including Ribbon type cables used in telecom network. It is used in the Outside plant network and houses the spliced optical fibre cables and its fibres in secured conditions. It shall be possible to use it for both Armoured& Metal Free type of Optical Fibre Cables and also compatible for different types of installation practices of cable installations

viz. duct, aerial & directly buried. Outdoor location is in the outside plant in uncontrolled environment and may be buried underground, mounted on walls, poles or other structures. The unit must be capable of being submerged in water for extended periods without deterioration.

- **Fibre Distribution Management System (Exchange) Type-I** - Exchange is in Indoor location in the central office, having controlled environment. The location has multiple cables converging and hence requires a system to handle a large number of Fibres. The cable is routed through race ways either from the bottom (under floor) or overhead. This FDMS shall be termed as FDMS Exchange.
- **Fibre distribution management system Type-III- (Indoor for GP)** Building Premises is located in premises of the subscriber in uncontrolled environment and typically, could be fixed in the basement, under the staircase, or, on the roof. The unit would be exposed to direct rain or splashing water, but not submersion. This unit would provide splicing Fibres of a cable to Fibres of another cable, and /or splicing the Fibres of a cable to pigtails and distribution on a patch panel. In most cases only one cable would terminate in this unit, however this unit could also be used for convergence of two or three cables while simultaneously providing patching to the Fibres “dropped” at the location.

Chapter 12

12 Testing of OFC

Testing of OF is first done by OF manufacturers. Similarly, testing of OFC is first done by OFC manufacturer. Subsequently, the purchasers of OF and OFC also carry out the tests on OF and on OFC to ensure that the OF and OFC indeed meet all the requirement. TEC standard of OFC and TEC standard of ORM (raw material) is usually followed for testing of OF and OFC.

12.1 Test Parameters of OFC

At present BSNL QA does the testing of cables which are offered for acceptance testing and one sample actual list of tests performed by BSNL QA is submitted below. The tests are done at fibre plant location, cable plant location and at neutral lab CACT. The tests are done to ensure geometrical characteristic of Fibre, transmission characteristic of Fibre and cable and environmental characteristic of Fibre. The sample list of tests is given at Annexure-IX.

12.2 Testing Lab Infrastructure in India

Presently OFC testing facilities in India are available at the premises of almost all the OF cable manufacturers which they use for their own purpose and the same in-house facility is also used by BSNL QA wing to test the cables and raw material. The testing facility is also used for other development activities. However, most of the labs are not NABL accredited. The Status of NABL accreditation of in-house testing lab of OFC Manufacturers in India is given in the Table below: -

Table 17: Status of NABL accreditation of in-house testing lab of OFC Manufacturers in India

S/N	Name of Manufacturer	Whether NABL accredited
1	Aksh Opticfibre Ltd.	No
2	Paramount Communication Ltd.	No
3	Paramount Wires and Cable Pvt. Ltd.	No
4	Orient cables India Pvt. Ltd.	No

S/N	Name of Manufacturer	Whether NABL accredited
5	ITI ltd. Raebareli	No
6	Himalaya Communications Pvt. Ltd., Solan, H.P.	No
7	HFCL Ltd. Hyderabad Manufacturing Plant	No
8	HTL, Chennai (a subsidiary of HFCL)	No
9	West Coast Optilinks	No
10	West Coast Opticable Limited	No
11	KEC RPG	No
12	ZTT cable	No
13	Sterlite Technologies Limited	Partial
14	Finolex Cables Ltd.	No
15	Birla Furukawa Fibre Optics Private Limited (BFFOPL)	No
16	APAR Industries	Yes
17	Polycab India Ltd.	No
18	OM Optel	No
19	Vindhya Telelink	No
20	Pratap Group	No
21	Kataria Wires Pvt. Ltd.	No
22	Universal Cable	No
Source: OFC manufacturers		

12.3 International Testing Facilities for OFC

The ILAC signatory accredited OF and OFC testing facilities which are available globally are detailed as below:

Table 18: List of ILAC signatory accredited OF and OFC testing facilities

S/N	Country	ILAC Signatories	No. of Labs for OF & OFC
1 (a)	United States of America	American Association for Laboratory Accreditation	4
(b)		ANSI National Accreditation Board	46
(c)		International Accreditation Service Inc.	59
(d)		National Voluntary Laboratory Accreditation Program	69
2	Canada	Standards Council of Canada	43
3	China	China National Accreditation Service for Conformity Assessment	66
4	India	National Accreditation Board for Testing and Calibration Laboratories	3
5	Taiwan	Taiwan Accreditation Service Foundation	9
6	France	Committee Francais d' Accreditation	4
Source: Optical Fibre Cable Market in India 2020			

12.4 Brief overview of BSNL Component Approval Centre Telecom (CACT) Bengaluru

Source: CACT, BSNL, Bengaluru

Figure 33: Picture of building of CACT, Bengaluru

Component Approval Centre Telecommunications (CACT) is located at CACT Complex, Dooravaninagar, Bengaluru – 560016 (India). CACT is a Testing

Laboratory functioning under Quality Assurance & Inspection Circle of Bharat Sanchar Nigam Limited (BSNL), a Government of India undertaking having its headquarters at New Delhi.

Department of Telecommunications (DOT) under Ministry of Communications and Information Technology (including all its earlier forms) has been providing telecom services to its customers for over 163 years. The Quality Assurance & Inspection Circle plays a key role in ensuring quality and reliability of the equipment/ products used for providing telecom services by BSNL. The reliability of any telecom system or product largely depends on the reliability of components or quality of raw materials that go into the building of the system/product. To ensure the reliability of Components and the quality of Raw Materials that are to be used in the equipment/ products to be inducted into field for providing service, CACT was set up by DOT in the year 1985 with the help of M/s SOFRECOM, French Telecom Company.

BSNL was formed as a result of corporatisation of Department of Telecom Services (DTS) of DOT on 1st October 2000 for providing Telecom services to its customers. Since then, Telecom Quality Assurance circle (TQAC), later reformed as Quality Assurance & Inspection Circle (after the merger of TQAC and Inspection circle on 01.04.2017) and CACT are part of BSNL.

Component Approval Centre Telecom (CACT) is one of the NABL accredited lab in India.

12.4.1 Scope and Field of Application

CACT, a part of Quality Assurance & Inspection Circle under BSNL, plays an important role in testing of components/ raw materials/ telecom items which are used in telecom equipment/ products that go into BSNL telecom network. In addition, CACT caters to the testing requirements of external agencies for components/ raw materials / products that need not necessarily be used for BSNL purposes. CACT is also involved in issuing approvals for components/ raw materials/ telecom items. Critical components used in EPBT, SMPS, UPS, Invertors and similar products which are inducted into BSNL network are covered under CACT approvals. CACT has in its laid down Management System

procedures covers only the testing activities of CACT. And also provides Source approval certificates to raw materials, components and optic Fibres.

The following are the different laboratories at CACT to test different material.

i. Material Testing Laboratory.
ii. Optical Fibre Cable Laboratory.
iii. Components Testing Laboratory.
iv. Climatic lab (supporting lab).

12.4.2 Quality policy

To provide test services that conform to the customer requirements using measurement practices based on National/International standards.

CACT is committed to ensure accuracy, reliability, impartiality, confidentiality and customer satisfaction through timely service in testing area. CACT services will meet the requirements of the organisation, regulatory authorities (National Accreditation Board for Laboratories) and of IS/ISO/IEC 17025:2017 standard."

CACT Optical Fibre Cable Laboratory is entrusted with giving source approval of Single mode optical fibres, Patch Cord and Pigtails, Simplex cables, Adapters and Splice Protection Sleeves as per TEC GR.

12.4.3 Details of Optic Fibre test instruments and tests done at Optical Fibre lab.

Table 19: List of Optic Fibre test instruments and tests done at CACT Optical Fibre lab

S/N	Name of the test Equipment	Name of the test done
1	OTDR	Fibre Length and attenuation
2	Chromatic Dispersion Analyser	Chromatic dispersion
3	Polarization Dispersion Measurement System	Polarization mode dispersion

S/N	Name of the test Equipment	Name of the test done
4	Optical Fibre Analyser	Spectral Attenuation Cut off wave length Mode Field diameter
5	OF Geometrical Analyser	Core/Clad diameter, Concentricity, Coating Diameter and Fibre Curl
6	Splicing Machine	Fibre, patch cord splicing
7	IL/RL Meter	Insertion loss, return loss for patch cord, pig tail and adaptors
8	Optical Spectrum Analyser	To analyse optical source
9	Ribbon fibre analyser	Ribbon width, height and planarity, Fibre spacing, adjacent and extreme, 4, 8, 12, Fibre ribbon matrix can be used.
Source: CACT, BSNL, Bengaluru		

All the above tests are conducted by expert personnel trained in NABL ISO 17025:2005 and follow all the norms as per NABL. These personnel also conduct infrastructure assessment at cable manufacture, validate the process of their system and quality of production of finished product. Most of the tests conducted are covered under various GR like TEC/GR/TX/ORM-001/05/DEC 2017 and have through knowledge of various ISO/IEC test methods.

Raw materials samples, optic Fibre samples are received from all over India for approval testing / surveillance testing. Surveillance Test are conducted and reports released in a timely manner. External customer's samples are also tested on quotation basis. Quality control practices are done on a regular basis and also the samples are sent for inter lab comparison and Z score is maintained < 2. Feedback from customers is collected regularly. Regular internal audits are conducted half yearly. Regular management review meeting held for continual improvement.

For getting quotations and testing of various products, contact mail id is decact@gmail.com contact number 08025611116, Officer address Deputy General

Manager (CACT), O/o DGM CACT complex Dooravaninagar, near K.R Puram railway station, Bengaluru 560016.

Chapter 13

13 Test Instruments used in testing of OFC

Many test instruments are used in testing of OF and OFC. OTDR is the most widely used instrument in locating the fault of OFC etc. A brief write-up contributed by Shri Kartik Parikh, CEO, Fastech Telecommunication India Pvt. Ltd. About OTDR concept and its uses is enclosed at Annexure-X. The list of TEC Standards for OTDR is enclosed at Annexure-XI.

13.1 Comprehensive list of OF and OFC Test Equipment

The comprehensive list of OF/OFC test equipment containing TEC Standard No., their brief functions and latest development is given in the Table below :-

Table 20: List of OF and OFC TEST EQUIPMENT

S/N	Name of Test Equipment	Function	TEC GR No.	Latest Development
Section-I (Optical Testing equipment)				
1	OTDR	An optical time domain reflectometer (OTDR) is a precision instrument used to locate events or faults along a Fibre link, typically within an optical communications network. OTDR has various functions such as measuring splice loss, measuring length and find faults in optical cables. OTDRs can also be used to confirm the quality of the Fibres, connections and splices. OTDR traces are also used for troubleshooting, since they can show where breaks are in the installed Fibre.	TEC/GR/TX/OTD-03/02/APR-2010 &TEC/GR/TX/OTD-001/05/SEP-19	An OTDR contains a laser diode source, a photodiode detector and a highly accurate timing circuit (or time base). The laser emits a pulse of light at a specific wavelength, this pulse of light travels along the Fibre being tested, as the pulse moves down the Fibre portions of the transmitted light are reflected/refracted or scattered back down the Fibre to the photo detector in the OTDR. The intensity of this returning light and the time taken for it to arrive back at the detector tells us the loss value (insertion and reflection), type and location of an event in the Fibre link.

S/N	Name of Test Equipment	Function	TEC GR No.	Latest Development
2	PMD	PMD (Polarization Mode Dispersion) is the differential arrival time of the different polarization components of an input light pulse, transmitted by an optical Fibre.	TEC/GR/ODA-01/01. MAR 2007	Technique based on Michelson interferometer
3	Strain Gauge / CD 400	Strain is measured to determine the degree of wear and thus the tension of a material through mechanical stress. Strain Gauge it used to measure the strain capacity of the optical cable.		A Strain gauge (sometimes referred to as a Strain gage) is a sensor whose resistance varies with applied force; It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured
4	CD-Analyser	CD-Analyser measures chromatic dispersion in single mode optical Fibres and it consists of optical transmitter with stabilized laser diodes generating optical signals in the given wavelength range, and optical receiver receiving and processing optical signals transmitted through the optical Fibre under test. Chromatic dispersion is measured in ps/nm/km, meaning that for every km of Fibre travelled through, a pulse with a 1 nm spread of wavelengths will disperse by 1 ps for a dispersion of 1 ps/nm/km.	TEC/GR/ODA-01/01. MAR 2007	Delay is created between optical pulses of various wavelengths, using a multiple wavelength transmitter at one end of the Fibre and a receiver at the other end for by CD Analyser
5	Spectral Analyser	An Optical Spectrum Analyser (or OSA) is a precision instrument designed to measure and display the distribution of power of an optical source over a specified wavelength span. An OSA trace displays power in the vertical scale and the wavelength in the horizontal scale.	TEC/GR/OSA-01/02. AUG 2007	

S/N	Name of Test Equipment	Function	TEC GR No.	Latest Development
6	Fibre Geometry Analyser	Fibre Geometry Analyser is used to measure the optical end surface geometry of optical cables such as the core diameter, the non-circuitry of the cladding and core-to-cladding concentricity.		The instrument can obtain the boundary of Fibre cladding and diameter of core, at the same time it can provide all the geometry parameters of the Fibre
7	Coating Unit	Coating Unit is used for coating the optical cables. Cable coatings provide mechanical protection or electrical protection.		
8	Vision Microscopy	Visual Microscopy is used for checking continuity of the optical cable.		A laser is beam is passed through the Fibre to check the continuity.
9	Profile Projector	Profile Projector or Optical Comparator is commonly used for complex shape stamping gears, cams, and threads and comparing the contour model. It is used for inspection of the manufactured optical parts.		
10	Optical Power Meter	It is used to check the losses such as Power Loss, Insertion Loss, Optical Loss. This device has 2 parts, first part is the light source, and second part is the meter where it shows the reading.	TEC/GR/TX/OPM-001/04/NOV-13	The major types of semiconductor sensor used in power meter are Silicon (Si), Germanium (Ge) and Indium Gallium Arsenide (InGaAs). Additionally, these may be used with attenuating elements for high optical power testing, or wavelength selective elements so they only respond to particular wavelengths.

Source: tec.gov.in

S/N	Name of Test Equipment	Description
Section-II (OFC Mechanical Testing Equipment)		
1	Tensile Tester (5 Ton)	This machine is used to test the actual tensile strength of the Cable which is to be installed.
2	Tensile Tester (20 Ton)	
3	Mini Tensile Machine	
4	Crush Tester	This machine is used to test the crushing capacity of the cable
5	Dumb bell cutting machine	It is an extremely accurate testing device which is used to cut the sample in dumble shape for various tests such as tensile, compression, etc.
6	Tensile and other mechanical test setups	This machine is used to test the actual tensile strength of the Cable which is to be installed.
7	Mechanical Test Set up for Ribbon	This machine is used to test the tensile strength of the sample
8	Aeolian Vibration Tester	It is used to test the sample at low vibrations and high amplitude
9	Impact test equipment	It is used to check the ability of the cable to withstand a particular weight or pressure which is applied perpendicular to the cable.
10	Torsion	This test is done to determine the torsion capacity of the cable. The cable is twisted gradually to determine the torsion capacity of the cable
11	Repeated bend test set up	Cable Repeated Bending Testing Machine is intended to establish the ability of a Fibre optic cable to withstand repeated bending (cyclic flexing). It allows a cable sample to be bent backwards and forwards through at an angle of 180°, the two extreme positions making an angle of 90°on both sides of vertical, while the sample is subjected to a tensile load.
12	Galloping Tester	Galloping Test Machine is used for Cable to check its strength towards different types of Vibration generated such as vertical motion, horizontal motion and approximate circular motion.
13	Sheave Tester	Sheave or pulley wheel is used for bending tests as well as galloping test
14	Crip Tester	Crimp testers are specialized for tension / tensile strength of the crimped terminals

S/N	Name of Test Equipment	Description
Section-III (OFC Raw Material Testing Equipment)		
1	Carbon Black Content Tester	Determination of black content in Oldefin materials like polyethylene or polypropylene. This test is done for quality control measurement for black polyolefins. Carbon Black is used to prevent degradation of plastic by UV radiation
2	Cone Petro meter	This test is done to evaluate the consistency of lubricating greases over the full ranges, also, to evaluate the consistency of stiff grease having penetration numbers less than 85.
3	Digital Weighing Balance	To compare the weight of the cables or other materials before / after test with precision.
4	Melt Flow Index Tester	Melt Flow Index Tester is used to calculate the Melt Flow Index (MFI). MFI is used to determine whether the molten polymer can easily be fabricated into desired article such that the mechanical strength of the final article can be sustained for a long time
5	Laboratory Oven	This is used to study the effects of different temperatures (extremely high / extremely low) on the raw materials
6	ESCR Tester	Environmental Stress Crack Resistance (ESCR) is a routine test and is used to determine whether the polyethylene plastics can sustain under different levels of strain and stress.
7	Compression Moulding Press	It is process of moulding in which a feeding material is placed in an open heated mould cavity. The mould is then closed and compressed with large hydraulic press to ensure proper moulding
8	Computerized Tensile Tester	This machine is used to test the actual tensile strength of the Cable which is to be installed. This machine is full computerized, the weight on the cable can be varied using a software on the computer which is connected to the machine
9	Digital Micrometre	This is used to determine the diameter tolerance of the cable.
10	THERMOMETER	It is used to measure the temperature for different tests.
11	Electronic Weighing Scale	To measure the cable or raw material's weight before / after tests.
12	Vernier Calliper	To measure inner / outer dimensions of different types of cables
13	Laboratory Oven	The sample which are to tested at higher temperatures are placed in ovens for testing for a particular period of time
14	Differential Scanning Calorimeter	Differential Scanning Calorimeter (DSC) is used for direct assessment of the heat energy uptake, which occurs when a sample is placed in regulated environmental conditions

S/N	Name of Test Equipment	Description
15	Thermohydrometer	It is used to determine the temperature of the liquid under test
16	Meter Scale	It is used to measure the length of the different types of sample or Raw materials to be tested
17	Deep Freezer	Raw materials which are to be tested under lower temperatures are placed in deep freezers
18	Chemical Solvent Tester	The raw material to be tested is suspended in the solvent. The raw material must remain undissolved in the solvent
19	Pyknometer	It is used to measure the density or specific gravity of an object or a liquid
Section-IV (OFC Environmental and UV Testing Equipment)		
1	Environmental Chamber	This chamber is used to test the effects of specific environmental conditions such as on different types of cables to test the endurance, and stability.
2	UV Chamber	Raw materials which are tested under UV light are placed in this chamber for testing purposes for a particular period of time
3	Humidity Chamber	Raw materials which are to be tested for heat are placed in this chamber for testing purposes for a particular period of time. To determine the effects of temperature on different Raw materials
4	Ultra Violet Light Detector	This is used to check the continuity of the cable. Also used for WPT to check for remains of water on the sample
Section-V (OFC Common Testing Equipment)		
1	Stop Watch	To keep a track on the time intervals between the test or for test durations.
2	Tracking Erosion Tester	This equipment is used for evaluating the tracking and erosion resistance by subjecting the materials to a combination of voltage stress
3	WPT Setup	Water Penetration Test (WPT) is done to check whether the cable or the raw material is immune to water when exposed to longer period of time
4	Mandrel	This machine is used for routine check-up which shows whether the cable is bent due to the pressure and stress.
5	Multimeter	Multimeter is used to check the current, resistance, voltage etc., in different raw materials or the cable
Source: tec.gov.in		

Chapter 14

14 Raw materials used in manufacture of OFC

The raw materials used in manufacturing of different components of OFC is covered in TEC GR No.: TEC/GR/TX/ORM-001/05/DEC-17. The list of those raw materials and its brief application & nature is given in the table below: -

Table 21: Raw Materials used in different components of OFC as per TEC GR No.: TEC/GR/TX/ORM-001/05/DEC-17

S/N	Name of the Component & Material	Application	Nature of the Material
1	Central Strength Member Fibre reinforced Plastic rod (FRP)	The Fibre Reinforced Plastic (FRP) rod is used as strength member for optical fibre cables. It can be used as a central strength member or used in sheath.	The FRP is of smooth and even surface, free from defects (absolutely free from glass resin accumulation) and manufactured from electrical insulating non-alkali glass roving/yarn (E-glass) and resin by continuous moulding method. The material does not offer any health hazards. The FRP is compatible with standard cable material used in optical fibre cables. The FRP rod is coated with Ethylene Acrylic Acid.
2	Sheath material [Polyethylene HDPE (Black)]	HDPE Is used as sheathing for optical fibre cables and may be used for filler also	HDPE is resistant to cracking and swelling, caused by contact with cable filling compounds and other material used in the cable. The material shall have the ability to give smooth and even surface after processing and shall have antioxidant properties.
3	Outer Jacket-material (Polyamide – 12)	The material Polyamide-12 of orange colour is to be used as anti-termite for external jacket for optical fibre cable. Polyamide-12 of any colour may be used for tubing, buffering & fillers.	It has necessary amount of antioxidant and protective ingredients to enable it to fulfil the requirements of aging. It has the ability to give a smooth and even surface after processing.

S/N	Name of the Component & Material	Application	Nature of the Material
4	Outer Jacket-material (Polyamide –11) (Alternative material for Polyamide-12)	The material Polyamide-11 orange in colour shall be used as anti-termite for external jacket (outer sheath) of optical fibre cables. Polyamide-11 of any colour may be used for tubing, buffering & fillers in manufacturing of optical fibre cables.	It has necessary amount of antioxidant and protective ingredients to enable it to fulfil the requirements of aging. It has the ability to give a smooth and even surface after processing.
5	Polypropylene and Polybutylene Terephthalate (PBTP) material.	The above material is to be used for buffering (Loose Tube) profile of optical fibre cables and may also be used for filler/dummy	
6	Filling compound for Loose Tube	The secondary filling compound (Jelly) is used for filling, water blocking and buffering of loose tubes.	It is Highly Purified without filter, Thixotropic, Air bubble free, Anti-Toxic, Odourless, Hydrophobic/ Water blocking, Non-Tacky, Non-Melting, and Free from Health Hazards
7	Cable Flooding Compound	The material cable flooding compound (Jelly) is used for interspatial flooding and water blocking and water blocking for optical fibre cable	It is highly purified, Soft, Non-Toxic, Hydrophobic/ Water Blocking, and Thixotropic
8	Binder tape & Nylon/Polyester Binder Thread	The polypropylene binder tape is used for assembly of optical fibre cable and to give covering to the core of the cable. Nylon/Polyester Binder Thread is used for assembly of Optical Fibre Cables	It consists of multifilament nylon yarn untwined, non-wicking, and uniform in diameter throughout the length.
9	Polyester foil/ tape (Natural)	The Polyester foil tape is used around the optical fibre cable core	It is made up of pure polyethylene terephthalate and have uniform thickness. It is e free from dust and any apparent fault such as pinhole, looseness.

S/N	Name of the Component & Material	Application	Nature of the Material
10	Impregnated Semi Rigid Fibre Reinforced Plastic Rod	The Semi Rigid Fibre Reinforced Plastic Rod (FRP) is used as strength member (tension and compressive resistive member) for optical fibre cables in conjunction with Solid Rigid FRP Rods in fibre optic cable design requiring peripheral reinforcement (Embedded/un-embedded).	The Impregnated Semi Rigid Fibre Reinforced Plastic rod is of smooth and even surface, free from defects (absolutely free from glass resign accumulation) and manufactured from electrical insulating non alkali glass roving/yarn (E-glass) and thermo-set resin by continuous pultrusion method. It contributes to the required tensile properties without sacrificing flexibility or adding bulk.
11	Impregnated Glass Fibre Reinforcement	The Impregnated Glass Fibre Reinforced shall be for use as flexible strength member (tension and compressive resistive member) for optical fibre cables in conjunction with Solid Rigid FRP Rods in fibre optic cable design requiring peripheral reinforcement.	The Impregnated Glass Fibre Roving is of smooth and even surface, free from defects (absolutely free from glass resign accumulation) and manufactured from electrical insulating non alkali glass roving/yarn (E-glass) by an impregnation process. The Impregnated Glass Fibre Roving contributes to the required tensile properties. The Impregnated Glass Fibre Roving may be of water blocking or non-water blocking type. It shall have polymer coating styrene Butadiene Rubber or Polyurethane. A super absorbent polymer (SAP) shall also be used for water blocking type.
12	Co-Polymer Aluminium Tape	The Co-Polymer Aluminium Tape is used as moisture barrier for optical cables	The material has smooth surface and be free from wrinkle and other defects. The aluminium shall be polyethylene or copolymer backed on both the sides, having uniform thickness, smooth edges throughout the length and there are no cracks
13	Water Blocking Tape	The Water Blocking Tape is used to prevent water penetration in the optical fibre cables. IT is suitable for pure water, manhole water, ocean water and diluted water solutions	Its compositions are: Polyester non-woven fabrics, Super absorbent polymer (SAP), Water soluble binder, and Corrosion inhibitor.

S/N	Name of the Component & Material	Application	Nature of the Material
14	Co-polymer Coated Stainless Steel (SS) Tape &Electrolytically Chrome coated Steel (ECCS) Tape	The co-polymer coated stainless steel is used for armouring of optical fibre to make the cable rodent and termite proof.	The Electrolytically Chrome Coated mild steel tape is used for armouring of optical fibre cables to use in the direct buried type of application. The tape shall be both side copolymers coated. The copolymer shall be such as to bond the inner & outer sheath made up of high-density polyethylene.
15	Aramid Reinforced Plastic Rod (ARP Rod)	The ARP rod is used as strength member for optical fibre cable.	
16	Aramid Yarn	The Aramid fibre roving shall be used as flexible strength member (tension and compressive resistive member) for optical fibre cables design requiring peripheral strength reinforcement	
17	Polyester Rip cord	Polyester Ripcord is used in a cable for the easy removal of the cable jacket to access the cable core without damaging the other delicate substance. It has different functions like consistently slitting the sheathing. It is placed under the cable jacket which enables easy removal of the jacket and opening of the cable.	Ripcord is manufactured from High Tenacity polyester continuous filament fibre and are twisted and coated with a non-wick material.
18	Water Swellable (WS) Yarn	The Water Swellable (WS) yarn is used in the optical fibre cable to absorb the water. Basic function of this material is to block the path of water through the cable.	Water swellable yarn is manufactured from polyester fibre and water blocking pulp or any suitable chemicals, other than powder
19	LSZH Material	The material Fire Retardant non-corrosive / zero halogen low smoke flame retardant compound is used as sheathing material for optical fibre	The material is resistant to cracking and swelling. In the extrusion, the material must show good processing properties as regards the yield (extrusion speed) and ability to give smooth and

S/N	Name of the Component & Material	Application	Nature of the Material
		cables.	even surface.
20	Anti-Tracking Polyethylene for ADSS		
21	Filling Jelly for OPGW cable		
22	Stainless Steel Tape	This Stainless-steel tape is used for making the loose tube of the OPGW Cable	
23	Aluminium Rod	Aluminium rod is used for coating the stainless-steel tube and cladding the steel wires (ACS Wires) for OPGW cable.	
24	Aluminium Cladded Steel Wire	Aluminium clad steel (ACS) wire is used as strength member and power conductor in OPGW Cables.	
25	Low-Smoke Zero-Halogen (LSZH) Material for Tight Buffer/ Micro module Buffer	The material Fire Retardant Non-Corrosive/Zero Halogen Low Smoke Flame Retardant compound is used as tight buffering or micro-module buffering	The material must show good processing as regards the yield (extrusion speed) and ability to give smooth and even surface. The surface finish of the extruded material is smooth.
26	Polyamide-12/Polyamide-11 Material for Tight Buffer	Alternate Material for Tight Buffer	
27	Polyamide 10, 10 for Outer jacket Material	Alternate material for Polyamide (PA)-12	
28	Thermoplastic Polyurethane (TPU) for Outer jacket Material (Alternative material for Polyamide-12)	The Thermoplastic Polyurethane (TPU) is to be used as anti-termite Sheathing material for optical fibre cable. TPU can also be used as a tight buffering material for OFC cable.	
Source: TEC GR No.: TEC/GR/TX/ORM-001/05/DEC-17			

Chapter 15

15 Ongoing Research in OFC

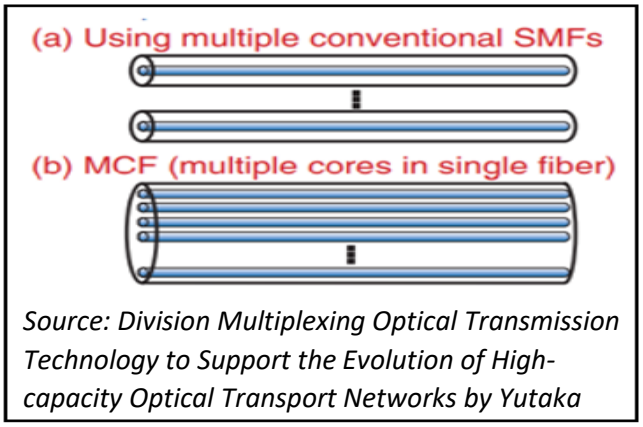
The constant research work in the field of optical fibre is in progress globally on the topics of “Space Division multiplexing of fibre”, “hollow core fibres” and “few mode fibres” and these innovations have the potential to further increase the bandwidth of a single fibre many times along with several other enhanced features. Such fibres will be extremely useful for internal wiring of, say, large data centres and also for long distance submarine applications requiring high international bandwidth.

Here we briefly discuss about space division multiplexing in optical fibres and hollow core fibres.

15.1 Space Division Multiplexing in optical fibres

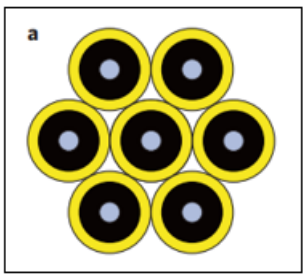
Optical communication technology has been advancing rapidly for several decades and much of this progress has been in finding innovative ways to increase the data-carrying capacity of a single optical fibre. The multiplexing in time, wavelength, polarization and phase have already been achieved and commercial systems now utilize all four dimensions to send more information through a single fibre.

The spatial dimension has, however, remained untapped in single fibres. It is possible to manufacture fibres supporting hundreds of spatial modes or containing multiple cores, which could be exploited as parallel channels for independent signals.

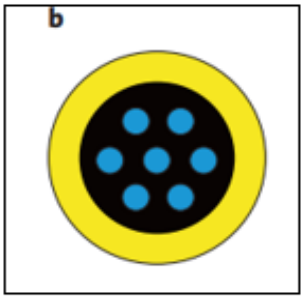


Source: Division Multiplexing Optical Transmission Technology to Support the Evolution of High-capacity Optical Transport Networks by Yutaka

Figure 34: Representation of SDM (Multi Core) Fibre

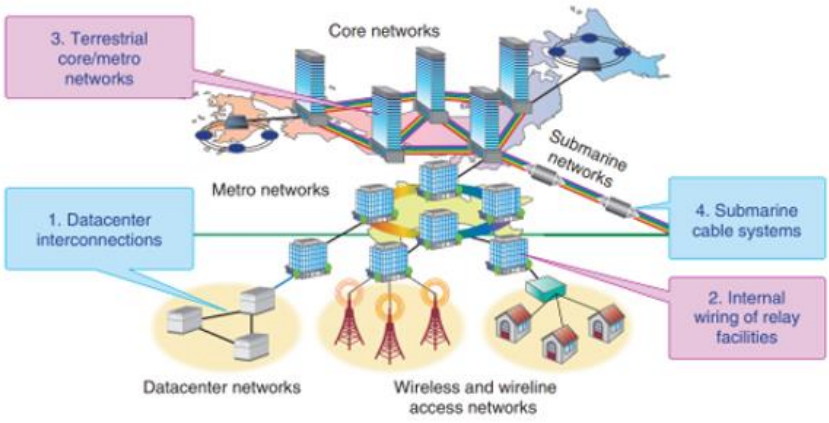


A: Fibre bundles composed of physically independent SMFs with reduced cladding thickness could provide increased core packing densities relative to current fibre cables. However, 'in-fibre' SDM is required to achieve the higher core densities and integration levels ultimately desired.



B: MCF containing multiple independent cores with sufficiently large spacing to limit crosstalk. Fibres with up to 19 cores have been demonstrated for long-haul transmission. Higher core counts are possible for short-haul applications (for example, data communications) for which higher levels of crosstalk per unit length can be tolerated.

Source: Space-division multiplexing in optical fibres by D. J. Richardson, J. M. Fini and L. E. Nelson published online on 29th April 2013.



Source: Space Division Multiplexing Optical Transmission Technology to Support the Evolution of High-capacity Optical Transport Networks by Yutaka Miyamoto and Ryutaro Kawamura

Figure 35: Typical Space Division Multiplexing Network Diagram

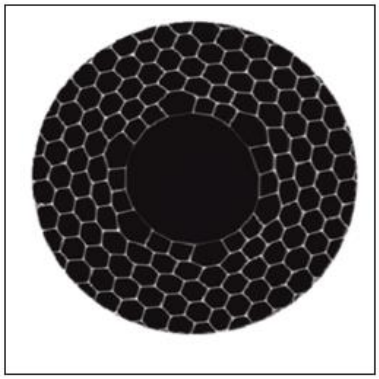
There are many application areas where the future Space Division Multiplexed optical fibres would be used. There is strong demand for short distance applications such as datacentre interconnections and the internal wiring in terms of compactness and low-power operation.

The use of high-capacity SDM optical fibre cable is expected to support the implementation of economical core/metro high-capacity optical networks with a

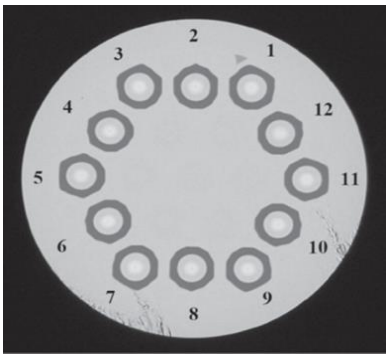
capacity of more than 1 Pbit/s. In ultra-long-haul submarine cable systems that must accommodate the traffic growth of international communications, SDM optical communication technology is expected to offset the capacity crunch of conventional Single Mode Fibre based systems and power supply constraints both of which are critical constraints in ultra-long-haul submarine cable systems.

15.2 Hollow Core Fibre

Single mode optical fibre (SMF) has been the key building block of long-haul optical transmission networks developed and installed. In recent years however, the telecom community has become acutely aware that, at the current data traffic growth rates, SMF based networks will reach their practical capacity limits within the next decade or so and will therefore be unable to support future traffic demands, leaving little options beyond costly deployment of ever more fibre .Much activity has been devoted to fibre designs enabling the incorporation of multiple spatial channels within the same fibres (including for instance multicore and few-mode fibres, as well as combinations of the two) – an approach which is termed spatial division multiplexing. However, there are other ways in which transmission capacity could be boosted such as hollow core photonic bandgap fibres (HC-PBGFs) [3].



Source: Development of Large Core Hollow Core Photonic Bandgap Fibres for Telecommunications Applications by M. N. Petrovich, Senior Member, IEEE, N. K. Baddela, S. R. Sandoghchi, N.V. Wheeler, J. R. Hayes, Y. Jung, E. NumkamFokoua, F. Poletti, and D. J. Richardson; in the year 2014.



Source: Space-division multiplexing in optical fibres by D. J. Richardson, J. M. Fini and L. E. Nelson; published online on 29th April 2013.

Figure 36: Microscope image of cross section of the one-ring, 12-core fibre

Following news item about hollow core fibre is worth reading.

Source: https://newsroom.bt.com/bt-conducts-worlds-first-trial-of-quantum-secure-communications-over-hollow-core-fibre-cable/

Figure 37: Luminosity's hollow core NANF(R) fibre in manufacturing

BT announced that it has achieved a new milestone in the development of quantum-secure communications by conducting the world's first trial of Quantum Key Distribution (QKD), a method of ultra-secure communications, over hollow core fibre cable, from Southampton University spin out, Lumenisity® Limited.

This summer, BT kicked off trials of a new type of optical fibre – Nested Anti-Resonant Nodeless Fibre (NANF) hollow core fibre – at the BT Labs in Ipswich to test the potential benefits of deploying this technology for a variety of scenarios, including secure communications. The trials used cable developed and manufactured by Luminosity to address the need for high-speed transactions and bandwidth increases in advanced communications systems, which has also been used for applications such as Data Centre Interconnects (DCIs), Edge and 5G xHaul.

In the latest trial, BT researchers successfully operated a state-of-the-art QKD system* using commercial equipment over a 6-kilometre-long Luminosity CoreSmart® cable with a hollow, air-filled centre, revealing potential benefits such

as reduced latency and no appreciable crosstalk – the effect of a transmitted signal interfering with the transmission of another signal.

In most optical fibre communications, high-speed signals are sent over a solid piece of glass using different wavelengths of light to deliver high capacity transmissions. In QKD systems, quantum light is transmitted on a single photon channel, traditionally necessitating use of a separate fibre, due to 'crosstalk' an effect that causes the light from high-speed data channels to spread their wavelengths, interfering with a quantum signal carried over the same fibre, as the change in frequency can cause channels of light to leak into other channels. The effect is similar to having a whispered conversation next to an orchestra – it can be hard to hear the other person's voice over the music.

Hollow core fibre doesn't have internal material – it's filled with only air – so there is less light scattering and less crosstalk between channels, even at a single photon level. This clearer separation – similar to a wall between the two speakers and the orchestra - makes it easier to deliver both a high-speed encrypted data stream, and the faint quantum signal that carries the encryption key, over the same fibre.

Luminosity's cable also demonstrated further benefits for the deployment of QKD, as commercial telecommunications equipment will not need to be optimised in order to send a data-encrypted key. This is critically important because the equipment can be used normally without modifications, an issue that creates added complications for sending secure signals over standard fibre.

Professor Andrew Lord, BT's Head of Optical Network Research, said: "This is an exciting milestone for BT, accelerating the UK's lead in quantum technologies that will play an important role in future communications systems globally. We've proven a range of benefits that can be realised by deploying hollow core fibre for quantum-secure communication. Hollow core fibre's low latency and ability to send QKD over a single fibre with other signals is a critical advancement for the future of secure communications."

Tony Pearson, VP Sales and Marketing at Luminosity, said: "We are excited to be identifying new applications for our field deployable CoreSmart cable solutions and working with the BT team on the first trial in the world of this kind.

This milestone further accentuates not just the capability of our hollow core cable solutions, offering low latency and high bandwidth, but also demonstrating the potential CoreSmart has in new applications thanks to ultra-low non-linearity and dispersion across a broad spectrum, perfect for networks operated by our Carrier partners."

*The QKD system was provided on loan by the EU Open QKD project.

15.2.1 About BT

BT Group is the UK's leading telecommunications and network provider and a leading provider of global communications services and solutions, serving customers in 180 countries. Its principal activities in the UK include the provision of fixed voice, mobile, broadband and TV (including Sport) and a range of products and services over converged fixed and mobile networks to consumer, business and public sector customers. For its global customers, BT provides managed services, security and network and IT infrastructure services to support their operations all over the world. BT consists of four customer-facing units: Consumer, Enterprise, Global and its wholly-owned subsidiary, Openreach, which provides access network services to over 650 communications provider customers who sell phone, broadband and Ethernet services to homes and businesses across the UK.

For the year ended 31 March 2021, BT Group's reported revenue was £21,331m with reported profit before taxation of £1,804m.

British Telecommunications plc is a wholly-owned subsidiary of BT Group plc and encompasses virtually all businesses and assets of the BT Group. BT Group plc is listed on the London Stock Exchange.

15.2.2 About Luminosity® Limited

Luminosity was formed in early 2017 as a spin out from the University of Southampton to commercialise breakthroughs in the development of hollow core optical fibre. The company has built a team of industry leaders and experts to realise their goal to be the world's premier high-performance hollow core fibre optic cable solutions provider offering their customers reliable, deployable, low latency and high bandwidth connections that unlock new capabilities in

communication networks. Luminosity, NANF, Hollow coreTrade Smart and Core Smart are registered trademarks of Luminosity Limited

website: www.lumenisity.com

Luminosity contact: hollowcore@lumenisity.com

The hollow core fibre, as reproduced above, has the distinct advantage of reduced “crosstalk” giving it a large edge above all other fibres.

The SDM (multicore) fibres, hollow core fibres and few mode fibres are creating a big hope for communication system which is no less than the excitement when the OF was invented for the first time. The light and its colours are indeed fascinating[8].

[8]https://newsroom.bt.com/bt-conducts-worlds-first-trial-of-quantum-secure-communications-over-hollow-core-fibre-cable/

Chapter 16

16 OFC Market Snapshot

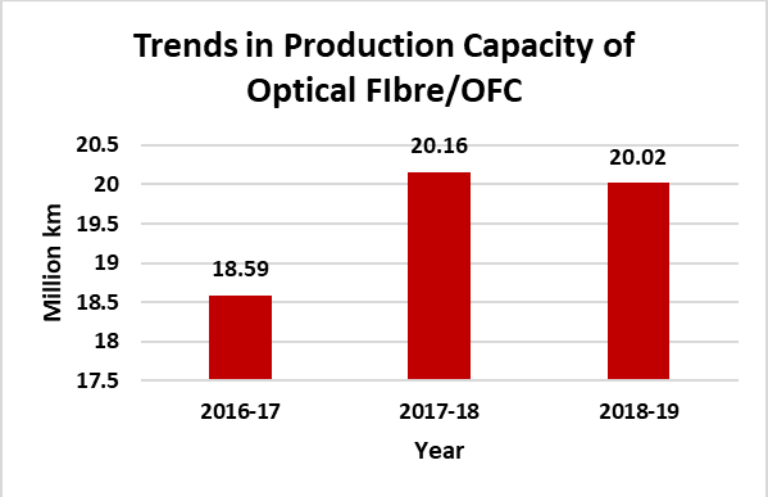
16.1 Optical Fibre Manufacturing Capacity in India

Table 22: Status of Fibre Manufacturing Capacity in India

S/N	Name of Manufacturer	Capacity (Fibre KMs/Annum)
1	M/s Sterlite Technologies limited	50 million Fibre KMs
2	M/s Birla Furukawa Fibre Optics Private Limited (BFFOPL)	12 million Fibre KMs
3	M/s Finolex Cables Ltd	3.5 MN Fibre KMs
4	M/s HFCL Ltd.	10 MN Fibre Kms
5	M/s ZTT Cable	5.8 MN Fibre Kms
6	M/s AKSH Optifibre	4 MN Fibre KMs
Source: OFC Cable Market in India 2020, May2020 by India Infrastructure Research		

16.2 Growth in Production capacity of OFC in India

The production of Optical fibre and OFC has been growing at phenomenal rate in India. The production has increased from 18.59 million km in 2016-17 to 20.02 million km in 2018-19. However, it declined marginally between 2017-18 and 2018-19.

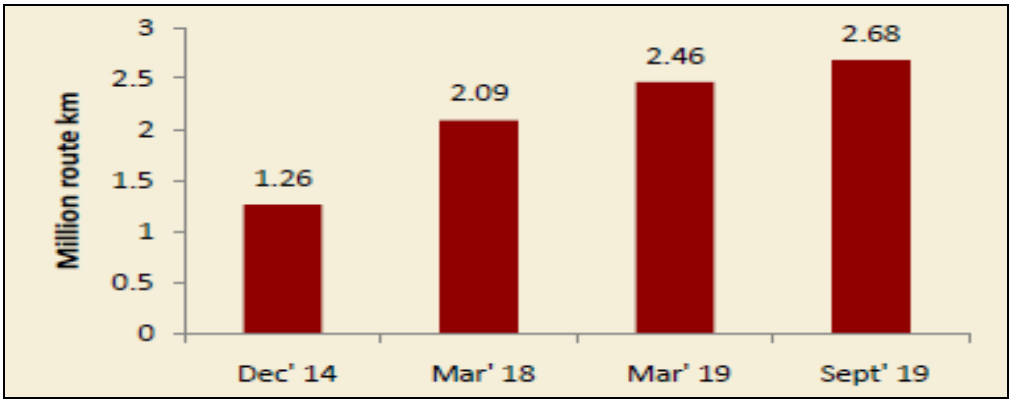


Source: OFC Cable Market in India 2020, May2020 by India Infrastructure Research

Figure 38: Trend in growth of production capacity of Optical Fibre/OFC in India

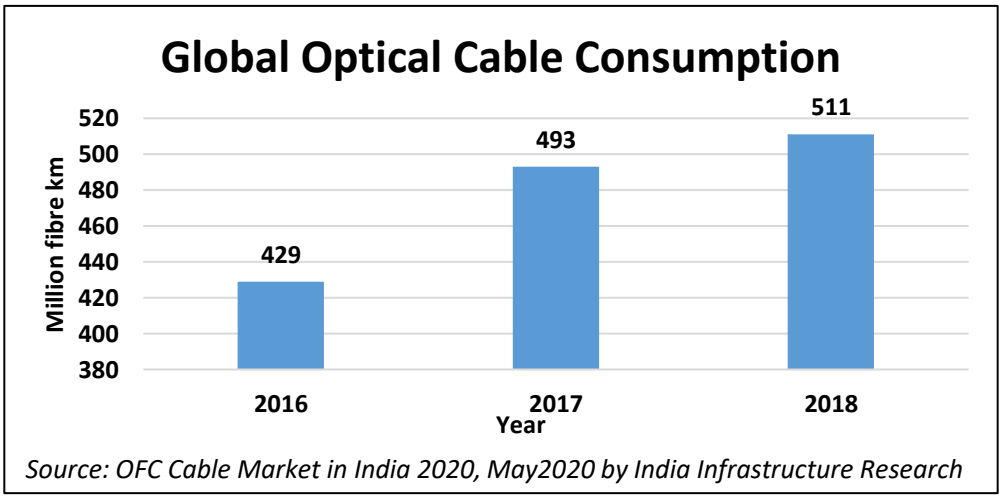
16.3 Growth in Fibre Network in India

Most recently the outbreak of Covid-19 and the subsequent lockdown worldwide has brought high bandwidth fixed line broadband into spotlight. The ongoing pandemic, though as unfortunate as it is, has given a new stimulus to solutions, such as FTTH and Wi-Fi hotspots inside buildings. Post Covid there is going to be clear shift towards indoor coverage which in turn would require huge investments in rollout inside buildings. The utilities in sectors such as power, gas, water and railways which are already deploying OFC networks can also act as neutral providers for Telcos.



Source: OFC Cable Market in India 2020, May2020 by India Infrastructure Research

Figure 39: Growth in Fibre Network in India



Source: OFC Cable Market in India 2020, May2020 by India Infrastructure Research

Figure 40: Global Optical Cable Consumption trend

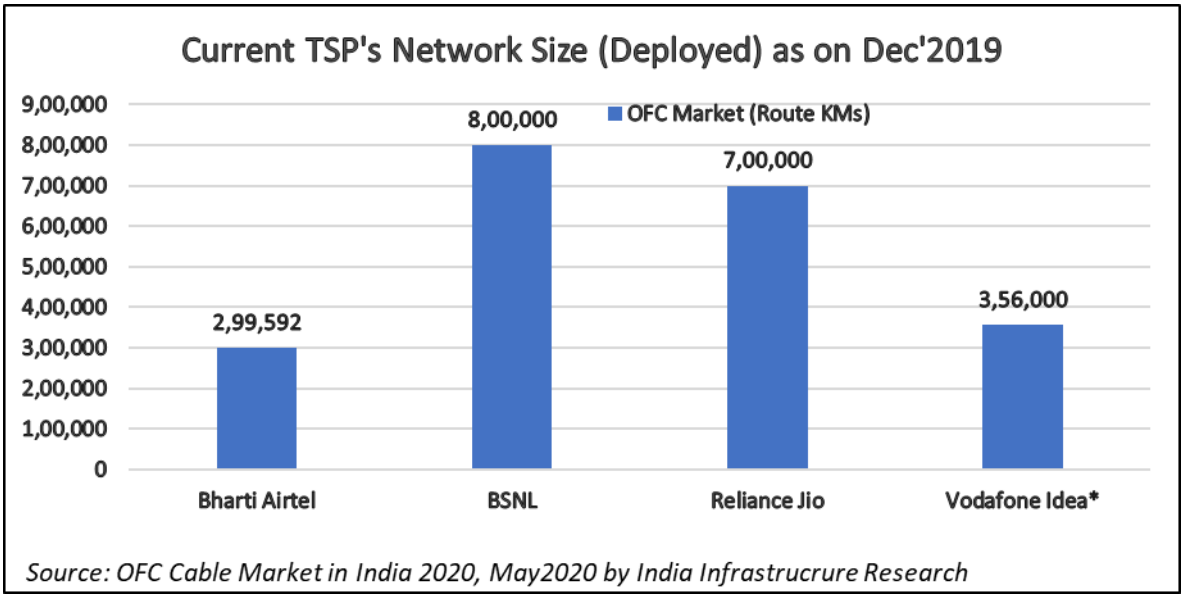


Figure 41: Deployed OFC network size of major TSPs in India

16.4 Export/Import of Optical Fibre Products

Table 23: Export/Import Figures of Optical fibre and Optical fibre Cable

S/N	HSN Code	Import / Export	Commodity	2020-2021 (In Lakhs)	%Share	2021-2022 (Apr-Jul) (In lakhs)	%Share
1	90011000	**Import**	OPTCL FIBRS, OPTICAL FIBRE BUNDLES AND CABLES	35,658.28	0.0122	17,632.71	0.0138
2	90011000	**Export**	OPTCL FIBRS, OPTICAL FIBRE BUNDLES AND CABLES	176,657.46	0.0818	93,304.25	0.0963
Source: Website https://commerce.gov.in/ of Government of India, Ministry of Commerce and Industry							

Chapter 17

17 Conclusion

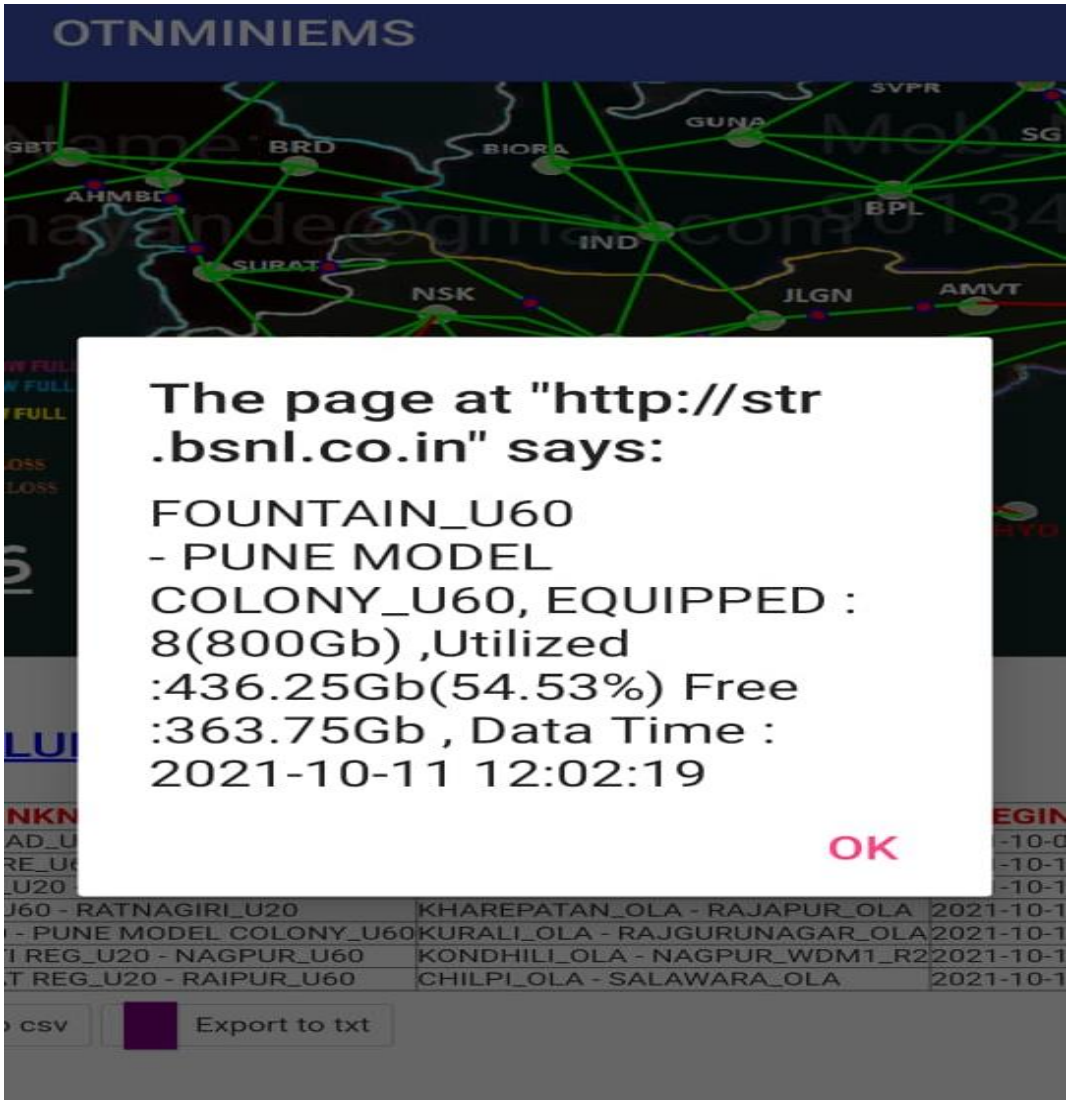
First, we pay our respect to so many scientists and engineers who developed the optical fibre technology along with associated electronics to bring us to this stage of advancement. Enormous lengths of fibres have been laid in the world. The fibres are so much that we can cover the globe 25000 times with them. The OFC route KM deployed in India stands at 2.68 million route KM as on September 2019. The fibre has performed to the best of our satisfaction. We want to cite one example of a single fibre in Pune-Mumbai BSNL route carrying traffic of 436.26Gbps out of equipped capacity of 800Gbps and the route is running fine without any problem. The snapshot is available below as figure 42.

We wish to convey our respect for all cable manufacturers who have produced quality cable, all installers who installed the cables, all testing officers who tested these cables and checked route performances. The performance of cable has so far been very good.

The FTTX connections are growing in India at a fast pace. The future 5G gNodeBs would also be very large in number. Lot of OFC would have to be deployed to meet both these needs. There is a strong need for setting minimum standard for these cables so that we can get robust infrastructure.

We have made out a clear case for standardisation for optical fibre cable in Indian Telecom Network. There are many Telecom Service Providers, Internet Service Providers and a host of Telecom Infrastructure providers. A large number of technicians/engineers will be operating different activities and there can be no fool proof method to ensure that the telecom installations are identical and rugged, however, the technological intervention in terms of standardising the minimum design/performance of OFC can be a very effective tool to achieve comparatively secure last mile connectivity and a robust telecommunication infrastructure.

A unified picture has been presented in the paper about service provisioning framework, place of OFC in Indian telecom network, important types of cables used in India and raw materials used for production of OFC.



Source: BSNL

Figure 42: snapshot of traffic data on one fibre in Mumbai-Pune route

We have discussed the tools and testers required for installation and testing of OFC. We have also discussed the testing methods of OFC. The current advances in fibre technology have been discussed. The Space Division multiplexed fibres (i.e., Multi core fibres) can be very useful in applications requiring ultra-high count fibres. The hollow core fibre has the potential to offer ultra-low latency and very less “crosstalk” making it so useful for secure communication with ultra-low latency.

It would be instructive to summarise the key issues and opportunities highlighted in the paper:

1) 50% of Indian households have to be covered by fixed line broadband as mandated by NDCP 2018. There is a huge growth of fixed line broadband connections using FTTX. Connection through FTTX is most preferred over all other forms of fixed wireline broadband connections. The very high bandwidth is achievable over fibre and there is ease of maintenance of FTTX connections.

2) There is a huge opportunity for ensuring a robust telecom infrastructure by setting minimum strength and performance criterion for OFC and accessories.

3) G.652.D fibre has been most widely used fibre in Indian Telecom network. G.657.A1/A2/B3 fibres offer very high bend insensitivity and their usage is increasing with each passing day. The bend insensitivity feature of G.657 series of optical fibres is causing very less bend losses while splicing as compared to bend losses in G.652.D. The usage of G.657 series of fibres in trunk routes also is increasing due to this low bend loss feature.

4) Large length of OFC laid more than 15 years ago by many TSPs have outlived their life first due to age and second due to enhanced losses caused by multiple cable cuts. The bend loss is most likely to be introduced in addition to splice loss while splicing the fibres in order to repair the fault. The value of bend loss is more than the splice loss. G.657.A1/A2/B3 fibres have the special characteristic of bend insensitivity.

   The life expired cables have been posing a big challenge to TSPs from maintenance point of view.

5) Loose tube double HDPE sheath Optical Fibre Cable is most widely used cable in trunk network.

6) The TSPs are highly burdened with the task of RoW permissions and RoW charges for laying OFC. Enormous length of overhead OFC is likely to be laid for fast rollout of 5G gNodeBs and also for provisioning of FTTX connectivity. GSR 749 (E) dated 21/10/2021 has been issued by DoT vide which maximum charges of Rs 1000/- per Km has been fixed for installing overhead OFC towards RoW charges.

7) Research on OFC is in progress in the field of Space Division multiplexed fibre, hollow core fibres and few mode fibres. They have the potential to further

increase the bandwidth of a single fibre many times along with several other enhanced features like ultralow optical nonlinearity, excellent power handling capabilities and low latency.

A secure OFC network coupled with advances in fibre technology has the potential to give unimaginable benefits to the country.

Annexures

Annexure I: TEC Phase-III&IV Notification dated 22-09-2021 regarding bringing OF and OF Cable under MTCTE-Phase-IV

भारतसरकार
संचारमंत्रालय
दूरसंचारविभाग
दूरसंचारअभियांत्रिकीकेंद्र
खुर्शीदलाल, जनपथ, नईदिल्ली – 110001
https://www.tec.gov.in/

Government of India
Ministry of Communications
Department of Telecommunications
TELECOMMUNICATION ENGINEERING CENTRE
Khurshid Lal Bhawan, Janpath, New Delhi - 110 001
https://www.tec.gov.in/

No. 5-2/2021-TC/TEC/93 Dated: 22.09.2021

Notification

Sub: - Mandatory Testing and Certification of Telecommunications Equipment (MTCTE)

In continuation of this office notification no. TEC/01/2017-TC dated 23rd June, 2020, the testing and certification of telecommunication equipment under Phase-III and Phase-IV of MTCTE regime, as provisioned in Indian Telegraph (Amendment) Rules 2017, is hereby notified as below -

MTCTE **Phase III***		***Acceptance of applications on MTCTE portal : w.e.f : 11.10.2021*** ***Certification becomes Mandatory : w.e.f.: 01.07.2022***
MTCTE **Phase IV***	(i) - **For "EMI/EMC" & "Safety".** (wherever applicable)	***Acceptance of applications on MTCTE portal : w.e.f : 11.10.2021*** ***Certification becomes Mandatory : w.e.f.: 01.02.2022***
	(ii) - **For remaining ER parameters.**	***Acceptance of applications on MTCTE portal : w.e.f : 01.01.2022*** ***Certification becomes Mandatory : w.e.f.: 01.07.2022***

* List of products (Essential Requirements) covered under Phase-III and Phase-IV of MTCTE is given at Annexure-I.

2. Further, in continuation of this office addendum no. 5-2/2017-TC/TEC dated 13/11/2020, the date of acceptance for test results/reports from labs accredited by ILAC signatories, is notified as under -

S. N.	MTCTE Phase	ILAC Relaxation in respect of all Requirements of ER *except Safety and EMI/EMC Requirements.*
1.	Phase-1 & Phase-II	Extended upto - ***30.11.2021***
2.	Phase-III	Extended upto - ***30.06.2022***
3.	Phase-IV	Not Applicable

Page 1 of 2

The test results/reports ***older than two years at the time of submission of the MTCTE applications shall not be acceptable*** in respect of both TEC designated as well as labs accredited by ILAC signatories.

This issues with approval of the competent authority.

Enclc: A/A.

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1. PPS to Secretary (T), DoT, New Delhi
2. PPS to Member(S)/ Member(T)/ Member(F)/ DG(Telecom), DoT, New Delhi
3. Addl. Secretary (T), DoT, New Delhi
4. Sr. DDG TEC New Delhi / Sr. DDG NCCS, Bangalore/ ED C-DoT.
5. All DDGs, TEC.
6. JS (Customs), CBIC.
7. DDG (IC)/ DDG(Security)/ DDG(NT)/ DDG(IT), JS(T) DoT, New Delhi.

List of products (Essential Requirements) covered under Phase-III of MTCTE

Sl. No.	Name of product (Essential requirement)	Category of product (GCS/SCS)#
1.	Base station for cellular network	GCS
2.	Repeater for Cellular Network	GCS
3.	Compact Cellular Network	GCS
4.	Smart /CCTV Camera	GCS
5.	Smart Watch	GCS
6.	Smart Electricity Meter	GCS
7.	Tracking Device	GCS
8.	IoT Gateway	GCS
9.	End Point Device for Environmental Monitoring	GCS
10.	Equipment Operating in 2.4 GHz and 5 GHz Band	GCS

List of products (Essential Requirements) covered under Phase-IV of MTCTE

Sl. No.	Name of product (Essential requirement)	Category of product (GCS/SCS)#
1.	Transmission Terminal Equipment (DWDM, DXC)	GCS
2.	Optical Fibre (Single Mode)	GCS
3.	Satellite Communication Equipment	GCS
4.	Radio Broadcast Receiver	GCS
5.	Mobile Radio Trunking System	GCS
6.	HF Radio	GCS
7.	VHF/UHF Radio System Equipment	GCS
8.	PTP PMP Microwave Fixed Radio Systems	GCS
9.	IP Security Equipment	GCS
10.	Router	GCS
11.	LAN Switch	GCS
12.	Precision Timing Protocol Grand Master Equipment	GCS
13.	IP Multi Media Conferencing Equipment	GCS
14.	Mobility Management Entity (MME)	GCS
15.	Point of Sale Devices	GCS

Sl. No.	Name of product (Essential requirement)	Category of product (GCS/SCS)#
16.	Conferencing Equipment	SCS
17.	Signalling Gateway	GCS
18.	Media Gateway	GCS
19.	Softswitch	GCS
20.	Digital Subscriber Line Equipment	GCS
21.	Session Border Controller	GCS
22.	*Base Station Controller (BSC)/Radio Network controller (RNC)**	GCS
23.	*Mobile Switching Centre (MSC)/MSC- Server (MSC-S)/Gateway MSC (GMSC)/Gateway MSC- Server (GMSC-S)[including Visitor Location Register (VLR)]MSC/ MSC Server**	GCS
24.	*Equipment Identity Register (EIR)**	GCS
25.	*Subscriber Identity Module (SIM)**	GCS
26.	*OTA Platform and Device Manager Platform/FOTA**	GCS
27.	*Home Location Register (HLR) / Home Subscriber Server (HSS)/ Authentication Centre (Auc)**	GCS
28.	*Serving GPRS Support Node (SGSN)/ Gateway GPRS Support Node(GGSN)**	GCS
29.	*Serving Gateway (S-GW) / Packet Gateway (P-GW)**	GCS
30.	*Short Message Service Center (SMSC)**	GCS
31.	*Cell Broadcast Centre (CBC)**	GCS
32.	*Service Control Point (SCP)**	GCS
33.	*Operation Maintenance Center(OMC) / Element Management System (EMS)/ Network Management System (NMS)/ Operation Support Systems (OSS)**	GCS
34.	*Gateway Mobile Location Centre (GMLC)**	GCS
35.	*Serving Mobile Location Centre (SMLC)**	GCS
36.	*Optical Fibre Cable**	GCS
37.	*Infiniband Switch**	GCS

Note-

GCS/SCS category of products are defined in 'Procedure for Mandatory Testing and Certification of Telecom Equipment" Version 2.1 available on MTCTE portal (https://mtcte.tec.gov.in).

* The ERs from Sl. No. 22 to 37 are under process of uploading on MTCTE portal.

Annexure II: Gazette notification dated 21-10-2021 regarding RoW IT (amendment) Rules,2021

रजिस्ट्री सं. डी.एल.- 33004/99 REGD. No. D. L.-33004/99

भारत का राजपत्र
The Gazette of India

सी.जी.-डी.एल.-अ.-21102021-230588
CG-DL-E-21102021-230588

असाधारण
EXTRAORDINARY

भाग II—खण्ड 3—उप-खण्ड (i)
PART II—Section 3—Sub-section (i)

प्राधिकार से प्रकाशित
PUBLISHED BY AUTHORITY

सं. 606] नई दिल्ली, बृहस्पतिवार, अक्तूबर 21, 2021/आश्विन 29, 1943
No. 606] NEW DELHI, THURSDAY, OCTOBER 21, 2021/ASVINA 29, 1943

संचार मंत्रालय

(दूरसंचार विभाग)

अधिसूचना

नई दिल्ली, 21 अक्तूबर, 2021

सा.का.नि. 749(अ).—केंद्र सरकार भारतीय तार अधिनियम, 1885 (1885 का 13) की धारा 10, 12 और 15 के साथ पठित धारा 7 की उप-धारा (1) और उप-धारा (2) के खंड (ड.) द्वारा प्रदत्त शक्तियों का प्रयोग करते हुए, भारतीय तार मार्ग के अधिकार नियम, 2016 को और संशोधित करने के लिए निम्नलिखित नियम बनाती है -

1. **संक्षिप्त नाम और प्रारंभ**:- (1) इन नियमों को भारतीय तार मार्ग के अधिकार (संशोधन) नियम, 2021 कहा जाए।

(2) ये नियम सरकारी राजपत्र में प्रकाशन की तारीख से प्रवृत्त होंगे।

2. भारतीय तार मार्ग के अधिकार नियम, 2016 (जिसे इस अधिसूचना में इसके पश्चात उक्त नियम के रूप में उल्लिखित किया गया है) में, प्रथम पैरा में, "मोबाइल टावर" शब्द के स्थान पर "मोबाइल टावर और तारयंत्र लाइन" शब्द प्रतिस्थापित किए जाएंगे।

3. उक्त नियम में, नियम 6 में, उप-नियम (4) में, "स्थापन" शब्द के स्थान पर "स्थापन, अनुरक्षण, चालन, मरम्मत, अंतरण अथवा स्थानांतरण" शब्द प्रतिस्थापित किए जाएंगे।

4. उक्त नियम में, नियम 9 में, उप-नियम (2) में, खंड (xiv) के बाद निम्नलिखित परन्तुकों को शामिल किया जाएगा:-

"परन्तु यह कि भूमि के ऊपर तारयंत्र लाइन स्थापित करने हेतु किए गए आवेदन के मामले में खंड (ii), (iii), (v), (ix), (x) और (xi) में उल्लिखित दस्तावेज अपेक्षित नहीं होंगे-:

परन्तु यह भी कि अनुज्ञप्तिधारी को भूमि के ऊपर तारयंत्र लाइन स्थापित करने हेतु बनाई गयी मार्ग योजना से संबंधित दस्तावेज भूमि के ऊपर तारयंत्र लाइन स्थापित करने हेतु किए गए आवेदन के साथ प्रस्तुत करने होंगे:".

5. **(i)** उक्त नियम में, नियम 10 में, उप-नियम (1) में, खंड (झ) के बाद, निम्नलिखित परन्तुकों को शामिल किया जाएगा:-

"परन्तु यह कि भूमि के ऊपर तारयंत्र लाइन स्थापित करने हेतु किए गए आवेदन की जांच करने के लिए खंड (क), (ख), (ग), (छ) और (ज) में उल्लिखित प्राचल अनिवार्य नहीं होंगे-:

परन्तु यह भी कि समुचित प्राधिकारी प्रस्तावित भूमि के ऊपर तारयंत्र लाइन के लिए मार्ग योजना की और किसी अन्य लोक अवसंरचना जो इस प्रस्तावित मार्ग के साथ बिछाई जानी है, के साथ ऐसी तारयंत्र लाइन के या तो स्थापन या रख-रखाव में संभाव्य बाधा की जांच करेगा-.";

(ii) उप-नियम (2) में, निम्नलिखित परंतुक शामिल किया जाएगा: -

"परन्तु यह कि जहाँ किसी समुचित प्राधिकारी के नियंत्रण या प्रबंध में निहित या के अधीन किसी स्थावर संपत्ति पर भूमि के ऊपर तारयंत्र लाइन को स्थापित किया जाता है; वहाँ स्थावर संपत्ति के मूल्य के लिए एक बार प्रतिकर स्थापित की गई तारयंत्र लाइन के प्रति किलोमीटर के लिए एक हजार रूपए से अधिक देय नहीं होगा -.";

(iii) उप-नियम (4) में, "स्थापन" शब्द के स्थान पर "स्थापन, अनुरक्षण, चालन, मरम्मत, अंतरण अथवा स्थानांतरण" शब्द प्रतिस्थापित किए जाएंगे।

[फा. सं. 2-41/2020-नीति]

हरि रंजन राव, संयुक्त सचिव

नोट : मूल नियम भारत के राजपत्र, असाधारण, भाग-II, खंड-3, उप-खंड (i) में दिनांक 15 नवम्बर, 2016 की अधिसूचना संख्या सा.का.नि. 1070(अ) के तहत प्रकाशित किए गए थे और दिनांक 21 अप्रैल, 2017 की सा.का.नि. 407(अ) के तहत संशोधित किए गए थे।

MINISTRY OF COMMUNICATIONS
(Department of Telecommunications)

NOTIFICATION

New Delhi, the 21st October, 2021

G.S.R. 749(E).—In exercise of the powers conferred by sub-section (1) and clause (e) of sub-section (2) of section 7 read with sections 10, 12 and 15 of the Indian Telegraph Act, 1885(13 of 1885), the Central Government hereby makes the following rules further to amend the Indian Telegraph Right of Way Rules, 2016, namely:-

1. **Short title and commencement.**-(1) These rules may be called the Indian Telegraph Right of Way (Amendment) Rules, 2021.

(2) They shall come into force on the date of their publication in the Official Gazette.

2. In the Indian Telegraph Right of Way Rules, 2016 (hereinafter referred to as the said rules), in the opening paragraph, for the words "mobile towers", the words "mobile towers and telegraph line" shall be substituted.

3. In the said rules, in rule 6, in sub-rule (4), for the word "establishing", the words "establishing, maintaining, working, repairing, transferring or shifting" shall be substituted.

4. In the said rules, in rule 9, in sub-rule (2), after clause (xiv), the following provisos shall be inserted, namely:–

"Provided that the documents mentioned in clauses (ii), (iii), (v) (ix), (x) and (xi) shall not be required in case of application made for establishment of overground telegraph line:—

Provided further that the documents related to route plan for establishment of overground telegraph line shall be required to be provided by the licensee with the application made for establishment of overground telegraph line:".

5. (i) In the said rules, in rule 10,- in sub-rule (1), after clause (i), the following provisos shall be inserted, namely:–

"Provided that the parameters mentioned in clauses (a), (b), (c), (g) and (h) shall not be necessary for examination of the application made for establishment of overground telegraph line:—

Provided further that the appropriate authority shall examine the route plan for the proposed overground telegraph line and the possible interference in regard to the establishment or maintenance of such overground telegraph line with regard to any other public infrastructure that may have been laid along the proposed route:—";

(ii) in sub-rule (2), the following proviso shall be inserted, namely:–

"Provided that in cases where the overground telegraph line is established over the immovable property, vested in the control or management of any appropriate authority, then in such cases, one time compensation shall be payable for the value of the immovable property, not exceeding one thousand rupees per kilometer of the overground telegraph line established:—";

(iii) in sub-rule (4), for the word "establishing", the words "establishing, maintaining, working, repairing, transferring or shifting" shall be substituted.

[F. No. 2-41/2020-Policy]

HARI RANJAN RAO, Jt. Secy.

Note : The principal rules were published in the Gazette of India, Extraordinary, Part II, Section 3, Sub-section (i) *vide* notification number G.S.R. 1070(E), dated the 15th November, 2016 and further amended *vide* G.S.R. 407(E), dated the 21st April, 2017.

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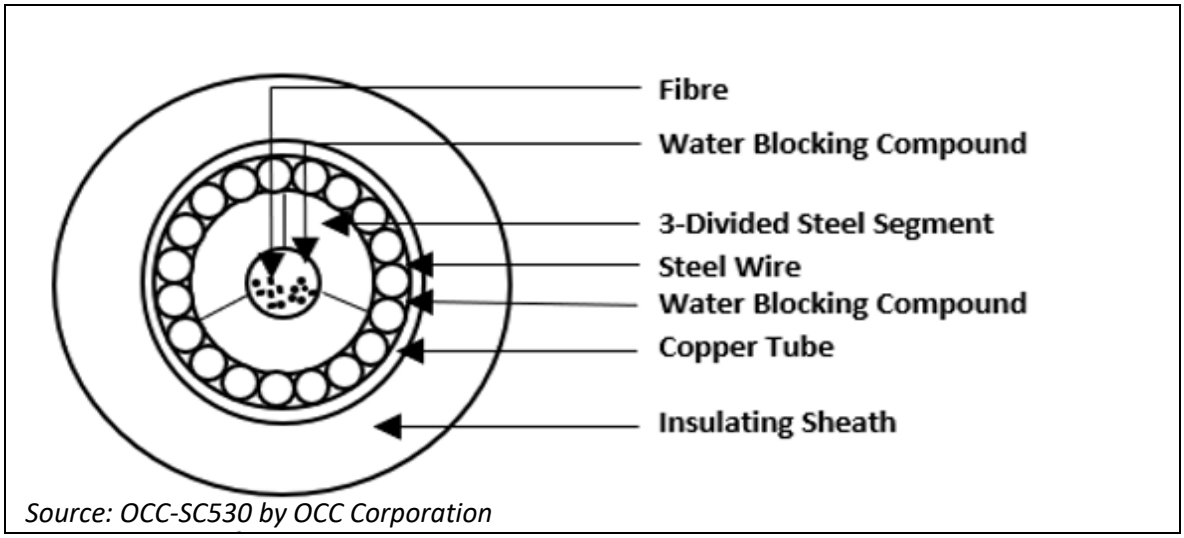
and Published by the Controller of Publications, Delhi-110054. ALOK KUMAR

Annexure III: Brief of various types of submarine cable

A. Light weight (LW) Submarine OF Cable

These are types of cables are used at 8000 meters' depth of sea. This type of cable is suitable for laying, recovery, and operation, where no special protection is required. At such depth the cables are to be protected mainly against strong sea bottom currents, for this purpose the cables are provided with an extra layer of 2 to 3mm diameter steel wires. These cables provide 1000 times abrasion resistance than Light Weight Protected (LWP).



Source: OCC-SC530 by OCC Corporation

Figure 43: A Typical LW Submarine Cable

B. Light Weight Protected (LWP) Submarine OF Cable

These types of cables are deployed at a depth of 1500 to 2000 meters, lightweight protected cable is suitable for laying, recovery, and operation, where special protection is required. This type of cable is made abrasion resistant by providing and additional sheath of polyethylene. These are also protected by a tape to protect the cable form "*Fish bite*" as number of sharks are attracted to such cables because of visible vibration of the cable or acoustic vibration.

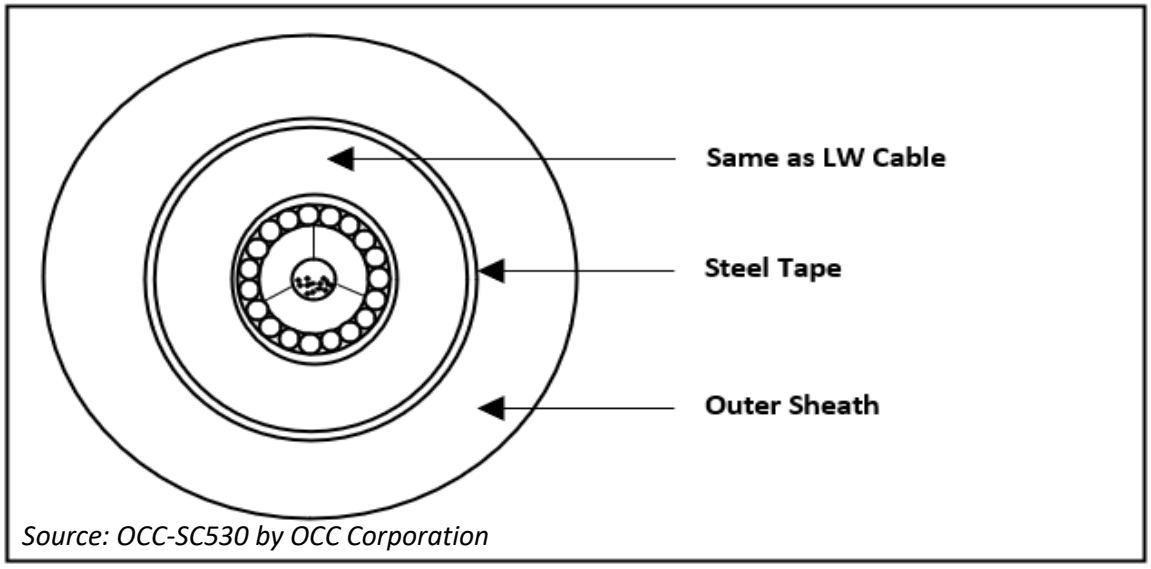


Figure 44: A Typical LWP Submarine Cable

C. Single Armoured Cable (SA) Submarine OF Cable

These types of cables are deployed at a depth of 1000 to 2000 meters, single armoured cable is suitable for laying, burial, recovery, and operation and is suitably protected for specific area in shallow water. These are used in shallower waters where extra protection is needed as it is at the maximum depth of current fishing equipment for edible fishes.

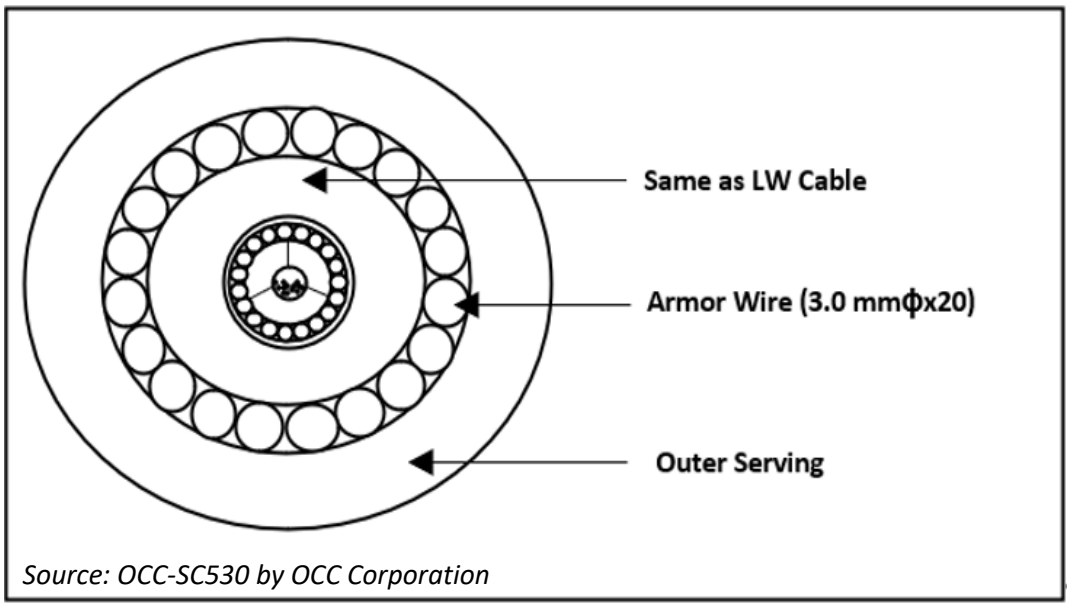


Figure 45: A Typical SA Submarine Cable

D. Double Armoured Cable (DA) Submarine OF Cable

These types of cables are deployed at a depth of around 400 meters, double armoured cable is suitable for laying, burial, recovery, and operation and is suitably protected for specific area in shallow water. Such cables are normally used at a depth of 400 meters where the cables cannot be buried such as rocky regions, pipelines, or area in which other submarine cables are already installed. These cables have more armour as second layer of cables of thickness 3 to 3.5 mm is added.

Table 24: Type-wise Submarine OF cable length of Chennai-Andaman Sea link

S/N	Cable Type	Total (KMs)
1.	Light Weight (LW)	1215.24
2.	Light Weight Protected (LWP)	429.62
3.	Single Armoured (SA)	352.66
4.	Double Armoured (DA)	166.68
5.	Land Cable (BHM to CLS)	48
Total (excluding Land Cable)		**2164.2**

Source: DPR of Submarine Optical Fibre Connectivity to Andaman & Nicobar Islands

Annexure IV: Specification's brief of the OFC deployed in Bharatnet project

Table 25: Specification's brief of the OFC deployed in Bharatnet project

S/N	Type of Cable	TEC GR	Similarities with TEC GR	Differences with TEC GR
1	48F/96F METAL FREE RIBBON OPTICAL FIBRE CABLE WITH DOUBLE HDPE SHEATH (G.652.D Fibre)	**GR No.** GR/OFC - 05/02. MAR 2006	Fibre specifications are as per ITU-T 652.D standard Which is almost same as TEC GR.	**Cable Construction specification are completely different than those given in the TEC GR.** The main difference in Cable constructions parameters is highlighted below: - 1. **Ribbon Structure** – 6 Fibre per ribbon as against 12 in TEC GR and therefore other dimension like width etc are different. 2. **Ribbon optical fibre cable construction** is different than TEC GR, No. of Fibre in a Ribbon (6), No. of ribbon in a tube (2 for 48 F and 4 for 96 F) and No. of loose tube (4 per cable) are all different 3. **Cable dimensions** including weight and diameter are as per Bell Core Document GR-20-Core issue 4, 2013 against GR-20-Core issue 2, July 1998 which is different than the TEC GR. 4. **Cable outer sheath** is made up of HDPE black as against Nylone-12 jacket for TEC GR type cable. 5. **Strength member of the cable** is to be made up of solid RFP non-metallic strength member at centre and Impregnated Glass fibre reinforcement (IGFR) over the periphery of inner sheath for achieving required tensile strength whereas in the TEC GR cable there is no provision of IGFR. 6. **Four suitable ripcords** shall be provided in the

S/N	Type of Cable	TEC GR	Similarities with TEC GR	Differences with TEC GR
				cable, which shall be used to open the both HDPE sheath of the cable. Two ripcords shall be placed diametrically opposite to the each other at below the outer Jacket & two ripcords shall be placed at below inner sheath. In the TEC GR provision for only two RIP CORD is there.
2	24F Metal free optical fibre cable with double HDPE sheath and Glass Yarn Armouring (G.652D Fibre)	**TEC GR No.** GR/OFC-17/01. JUN 2007.	1. Fibre specifications are as per ITU-T 652.D standard which is almost same as TEC GR. 2. No. of Fibre in the tube is 4 which same as TEC GR.	Cable Construction specification are completely different than those given in the above mentioned TEC GR. The main difference in Cable constructions parameters are highlighted below: - 1. **Cable parameter/dimensions including diameter, weight etc** different as compare to TEC GR. 2. **Cable outer sheath** is made up of HDPE black as against Nylon jacket for TEC GR type cable. 3. **Inner Sheath-** The thickness of inner sheath shall not be less than 1.2 mm whereas in TEC GR thickness of inner sheath shall not be less than 1.8 mm. 4. **IGFR are used to achieve tensile strength of the OF Cable over the inner sheath to provide peripheral reinforcement along with Solid Rigid FRP Rod in the centre at cable core whereas in the TEC GR IGFR are used over the core to provide peripheral reinforcement.** 5. **Three suitable ripcords** shall be provided in the cable, which shall be used to open the both HDPE sheath of the cable. Two ripcords shall be placed diametrically opposite to the each other at below

S/N	Type of Cable	TEC GR	Similarities with TEC GR	Differences with TEC GR
				the outer Jacket & one ripcords shall be placed at below inner sheath. In the TEC GR, provision for only two RIP CORD is there. 6. **Dummy Tube provision** is not there whereas it is there in TEC GR.
3	Aerial OF Cable (ADSS Cable): 24 pair ADSS on power lines	TEC GR No. TEC/GR/TX/OFC-022/02/MAR-17 with latest amendments	**Same as TEC GR**	**Own specifications have not been given**
4	Aerial Drop Optical Fibre Cable (For Last Mile Application)	As per TEC GR No.: TEC/GR/TX/OFC-024/01/MAR-15 with latest amendments	**Same as TEC GR**	**Own specifications have not been given**
Source: BBNL/MahaIT/ GFGNL Tenders				

Annexure V: Details of interaction with M/s Sterlite Technology Ltd.

DDG(WR), RTEC Mumbai interacted with Shri Sudipta Bhaumik, Head-Operation, STL to get the idea about the industry trends in use of Optical Fibre and Optical Fibre. The questions and the answers are given below: -

Question: Good afternoon, Shri Sudipta Ji. Thanks a lot for sparing your valuable time. Can we proceed with the discussion?

Answer: Good afternoon. Sure, we can start the discussion.

Question: What are the main targeted activities at the Centre of Excellence (COE) of M/s Sterlite located at Aurangabad?

Answer: Three major things: A) Design and manufacturing – We do work on photonics, material science, and precise manufacturing. B) Application researches suited for needs of the customers like characterization, test beds. C) Testing of materials- Test equipment, testing system, testing methods, reliability models Simulation

A) Design and manufacturing:

i. **Photonics:** Study and implementation on attenuation, dispersion, cut off wavelength.

ii. **Material Science:** What kind of dopant should be used, types of glass (silica), plastic fibre etc. Plastic fibre production is less and it is used in medical field.

iii. **Precision in manufacturing** is very important aspect. The diameter is of the order of few micrometres only and the tolerance is very less. Therefore, it is very important to ensure precision in manufacturing and lot of effort goes in that. Capturing and quarantine the defective parts in high speed manufacturing process as well.

B) Application: The customers give different requirements based on their need and all research is to be done to decide the core, cladding and protective part i.e., jacketing etc., process setting, specified parameters, OFC installation practices, etc.

C) i) **Test methods and equipment:** It is most important to test the characteristic of fibres before vetting it for production. We have all the equipment to test the fibre and in fact, we have more than the required purpose, many equipment is kept for doing analytical studies

ii) **Simulation is another method of testing.** There is a special team for this. They do mathematical modelling. The physical test has the limitation is that we have to actually produce the fibre and then test it. But simulation has no such limitation. Simulation is very important to reduce time of new product/ process development.

M/s Sterlite is a member in 6 to 7 SDOs worldwide. The list includes IEC, ITU, TIA, TSDSI, TEC, BIS, and IEEE.

Question: What are the usual dopants?

Answer: We use GeO2 in core for increasing the refractive index and only SiO2 is there in cladding. Sometimes, SiO2 is used in core and Fluorine is used in cladding. Fluorine reduces the refractive index.

Question: what are the important types of fibres and what are the losses?

Answer: Bend loss, insertion loss, splice loss are important losses. From 2016 onwards, there were a lot of FTTH applications for which bend insensitive fibre was required. G.657.A1, A2 and B3 are serving that purpose very well. Bend loss is also very high in trunk network and therefore G.657.A2 is coming up in trunk routes also in addition to being used inside house. France and UK have already adopted G.657.A2 for trunk as well as for customer premises because bend loss is so prominent in trunk also. The fibre which is jacketed inside the cable, gives no bend loss but fibre in splice tray, for example, can give lot of bend loss if it is not properly maintained.

A2 supports 10 times more bend than A1. B3 is still better bust cost of B3 is still higher. The cost of A1 is now just 5 to 10% more than the cost of G.652.D. The cost of a product depends upon i) time taken to produce it. ii) accuracy required in production iii) cost and availability of raw material. iv) volume of manufacturing v) design complexity vi) testing and qualification process. When volume of production increases, cost decreases.

Question: What are usual losses?

Guest: From 2016 onwards, G.657 is being produces 30 to 40%. Mode Field Diameter is directly related to bend loss. Higher the MFD, higher the loss.

Initially, the G.657.A2 fibre core was having marginally lower diameter say 8.6 micrometer as compared to 9.1 or 9.2 micrometer for SMF. But gradually, with betterment of technology, the core diameter has now become same as standard fibre and there is no problem in splicing between the fibres in network and G.657.A2. Gradually, 80% of fibres will become G.657.A2. Airtel is using only one fibre G.657. A1 for all trunk and A2 for inside the house (FTTH). VIL is using G.657.A1.

Question: What is the life of OFC network?

Answer: Life of OFC network was supposed to be 25 years but it is 8 to 10 years in India due to cable cuts. Splice loss and bend loss disturb the link budget. The OTDR measures splice loss and bend loss together because the bend is so close to splice. The splice loss is not frequency sensitive but bend loss is frequency sensitive i.e., we get different bend losses for 1310, 1550, 1625 nm. This principle is used to segregate bend loss and splice loss.

Once bend insensitive fibres are introduced, the network will become robust. Even a skilled labourer can do the splicing without bothering about bend losses. The network will run much better as the prime source of deterioration will be gone.

Question: How are you prepared for 5G applications?

Answer: More towers will be there in 5G. The fibres have to be reached to all towers and fibrisation will be much more.

i. There will be more cable terminations.
ii. Fibre count will be much more.
iii. Bend loss will be much more important.

So, cable terminations will have to be user friendly. This can be achieved if i) you can strip the fibre just by fingertip. ii) The cable is semi dry from inside so that handling is so easy. iii) Ribbons will be there for increasing fibre count.

A ribbon cable has been produced of more than 6000 fibres which is round in size and has a radius of just 30 mm. The earlier ribbon was flat in shape and cable radius was much more for comparatively much less fibre count of 288 (as used by Jio)

Question: usually we face that some fibres are left with high splicing loss in usual ribbon cables. How the ribbon cable of such huge number will be properly spliced?

Answer: The splicing technology of ribbon cables has improved so much. Now there will not be any difficulty of high splicing loss.

Question: What is latest development of front of fibres?

Answer: Multi core fibre is in research stage. If successful, then one fibre will have multicores and very high bandwidth can be transmitted on them. At present, submarine cables are required to carry very high bandwidth and they are of 48 Fibres say. Bur with multicore technology, only a few fibres will be able to carry very high bandwidth.

Question: What are the most important parameters of optical fibre?

Answer: Attenuation, Dispersion, MFD (Mode field diameter), cut off wavelength are the most important parameters. Additionally, reliability parameters are also important for lifetime.

Question: What are key differences in SMF and MMF?

Answer: Multi-mode fibres are suitable for LAN or short distance applications. The cost of associated electronics is very less for MMF. We LED as light source instead of laser required for SMF. LED is much cheaper than laser though now cost of laser source is also reducing. The photodetectors used for MMF are less costly. But the attenuation of multi-mode fibres is very high and it is suitable only for less distance like in LAN applications.

Question: What are the main fibres being supplied?

Answer: G.652.D constitutes 60% of supply. G.652.D and G.657.A1 constitute 80% of supply. G.652.D, G.657.A1, G.657.A2 together constitute 95% of supply.

Annexure VI: List of Fibre, Cable and Link attributes

Table 26: List of Fibre, Cable and Link attributes

	Unit	Relevant for single-mode fibres (SMF)	Value specified by ITU-T	Relevant for multimode fibre (MMF)	Value specified by ITU-T
Fibre attributes					
Core diameter	µm	-----	-----	Yes	Yes
Core non-circularity	%	-----	-----	Yes	Yes
Mode field diameter	µm	Yes	Yes	----	-----
Effective area	μm^2	Yes	No	----	----
Core concentricity error	µm	Yes	Yes	Yes	Yes
Cladding diameter	µm	Yes	Yes	Yes	Yes
Cladding non-circularity	%	Yes	Yes	Yes	Yes
Cut-off wavelength	nm	Yes	Yes	-----	-----
Numerical aperture		-----	-----	Yes	Yes
Macro bending loss	dB/ turn or dB	Yes	Yes	Yes	Yes
Micro bending loss	dB/km	Yes	No	Yes	No
Fibre and protective materials		Yes	No	Yes	No
Protective materials		Yes	No	Yes	No
Proof stress level	GPa	Yes	Yes	Yes	Yes
Refractive index profile		Yes	No	Yes	No
Modal bandwidth	MHz·km	-----	-----	Yes	Yes
Longitudinal uniformity of chromatic dispersion		Yes	No	-----	-----
Chromatic dispersion co-efficient	ps/(nm·km)	Yes	Yes	Yes	Yes
Cable attributes					
Attenuation coefficient	dB/km	Yes	Yes	Yes	Yes
Polarization mode dispersion coefficient	ps/√km	Yes	Yes	-----	-----
Modal bandwidth	MHz·km	-----	-----	Yes	No
Link attributes					
Attenuation	dB	Yes	No	-----	-----
Chromatic dispersion	ps/nm	Yes	No	-----	-----
Differential group delay	ps	Yes	No	-----	-----
Non-linear coefficient	w^{-1}	Yes	No	-----	-----

Source: ITU-T

Annexure VII: ITU-T specifications for optical fibre

Table 27: Technical Specification of Fibre-ITU-T G.652.D

Fibre attributes		
Attribute	**Detail**	**Value**
Mode field diameter	Wavelength	1310 nm
	Range of nominal values	8.6-9.2 µm
	Tolerance	±0.4 µm
Cladding diameter	Nominal	125.0 µm
	Tolerance	±0.7 µm
Core concentricity error	Maximum	0.6 µm
Cladding noncircularity	Maximum	1.00%
Cable cut-off wavelength	Maximum	1260 nm
Macro bend loss	Radius	30 mm
	Number of turns	100
	Maximum at 1625 nm	0.1 dB
Proof stress	Minimum	0.69 GPa
Chromatic dispersion coefficient	λ_{0min}	1300 nm
	λ_{0max}	1324 nm
	S_{0min}	0.073 ps/(nm² × km)
	S_{0max}	0.092 ps/(nm² × km)
Linear fitting (1460 nm to 1625 nm)	Minimum at 1550 nm	13.3 ps/(nm × km)
	Maximum at 1550 nm	18.6 ps/(nm × km)
	Minimum at 1625 nm	17.2 ps/(nm × km)
	Maximum at 1625 nm	23.7 ps/(nm × km)
Cable attributes		
Attribute	**Detail**	**Value**
Attenuation coefficient (Note 1)	Maximum from 1310 nm to 1625 nm (Note 2)	0.40 dB/km
	Maximum at 1383 nm ±3 nm after hydrogen ageing (Note 3)	0.40 dB/km
	Maximum at 1550-1565 nm	0.30 dB/km
PMD coefficient (Note 4,5)	M	20 cables
	Q	0.01%
	Maximum PMD_Q	0.20 ps/√km

NOTE 1 – The attenuation coefficient values listed in this table should not be applied to short cables such as jumper cables, indoor cables and drop cables. For example, [b-IEC 60794-2-11] specifies the attenuation coefficient of indoor cable as 1.0 dB/km or less at both 1310 and 1550 nm. Attenuation coefficient at a wavelength longer than 1625 nm (for monitoring purpose) is not well known. In general, the attention increases as the wavelength increases, and it may show steep wavelength dependence due to both macro- and microbending losses.
NOTE 2 – This wavelength region can be extended to 1260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1310 nm.
NOTE 3 – The hydrogen ageing is a type test that shall be done to a set of sampled fibres, according to [IEC 60793-2-50] regarding the B1.3 fibre category.
NOTE 4 – According to clause 7.2, a maximum PMDQ value on uncabled fibre is specified in order to support the primary requirement on cable PMD_Q.
NOTE 5 – Optical fibre cables with higher PMD coefficient can be used for systems with less stringent PMD requirements.

Source: ITU-T

Table 28: Technical Specification of Fibre-ITU-T G.654.A

Fibre attributes			
Attribute	**Detail**	**Value**	**Unit**
Mode field diameter	Wavelength	1 550	nm
	Range of nominal values	9.5-10.5	mm
	Tolerance	±0.7	mm
Cladding diameter	Nominal	125	mm
	Tolerance	±1	µm
Core concentricity error	Maximum	0.8	µm
Cladding non-circularity	Maximum	2	%
Cable cut-off wavelength	Maximum	1 530	nm
Macro bending loss	Radius	30	mm
	Number of turns	100	
	Maximum at 1 625 nm	0.5	dB
Proof stress	Minimum	0.69	GPa
Chromatic dispersion parameter	D1 550max	20	ps/(nm · km)
	S1 550 max	0.07	ps/(nm² · km)
Uncabled fibre PMD coefficient	Maximum	(Note 2)	
Cable attributes			
Attribute	**Detail**	**Value**	**Unit**
Attenuation coefficient (Note 1)	Maximum at 1 550 nm	0.22	dB/km
PMD coefficient (Note 2)	M	20	cables
	Q	0.01	%
	Maximum PMD_Q	0.5	ps/√km
NOTE 1 – The attenuation coefficient values listed in this table should not be applied to short cables such as jumper cables. For example, [b-IEC 60794-2-11] specifies the attenuation coefficient of indoor cable as1.0 dB/km or less. NOTE 2 – According to clause 7.2, a maximum PMDQ value on uncabled fibre is specified in order to support the primary requirement on cable PMDQ.			
Source: ITU-T			

Table 29: Technical Specification of Fibre-ITU-T G.655.C

Fibre attributes		
Attribute	**Detail**	**Value**
Mode field diameter	Wavelength	1550 nm
	Range of nominal values	8-11 µm
	Tolerance	± 0.7 µm
Cladding diameter	Nominal	125 µm
	Tolerance	± 1 µm
Core concentricity error	Maximum	0.8 µm
Cladding non-circularity	Maximum	2.00%
Cable cut-off wavelength	Maximum	1450 nm
Macro bend loss	Radius	30 mm
	Number of turns	100
	Maximum at 1625 nm	0.50 dB
Proof stress	Minimum	0.69 GPa
Chromatic dispersion coefficient Wavelength range: 1530-1565 nm	Λ_{min} and λ_{max}	1530 nm and 1565 nm
	Minimum value of D_{min}	1.0 ps/nm·km
	Maximum value of D_{max}	10.0 ps/nm·km
	Sign	Positive or negative
	$D_{max} - D_{min}$	≤5.0 ps/nm·km
Chromatic dispersion coefficient Wavelength range: 1565-1625 nm	Λ_{min} and λ_{max}	TBD
	Minimum value of D_{min}	TBD
	Maximum value of D_{max}	TBD
Uncabled fibre PMD coefficient	Sign	Positive or negative
	Maximum	(Note 1)
Cable attributes		
Attribute	**Detail**	**Value**
Attenuation coefficient (Note 2)	Maximum at 1550 nm	0.35 dB/km
PMD coefficient (Note 3)	M	20 cables
	Q	0.01%
	Maximum PMD_Q	0.20 ps/√km

NOTE 1 – According to clause 6.2, a maximum PMDQ value on uncabled fibre is specified in order to support the primary requirement on cable PMDQ.
NOTE 2 – The attenuation coefficient values listed in this table should not be applied to short cables such as jumper cables, indoor cables and drop cables. For example, [b-IEC 60794-2-11] specifies the attenuation coefficient of indoor cables as 1.0 dB/km or less at both 1310 and 1550 nm.
NOTE 3 - Larger PMDQ values (e.g., ≤ 0.5 ps/√km) can be agreed for particular applications between the manufacturer and user.

Source: ITU-T

Table 30: Technical Specification of Fibre- ITU-T G.656

Fibre attributes		
Attribute	**Detail**	**Value**
Mode field diameter	Wavelength	1550 nm
	Range of nominal values	7.0-11.0 mm
	Tolerance	±0.7 mm
Cladding diameter	Nominal	125.0 mm
	Tolerance	±1 µm
Core concentricity error	Maximum	0.8 µm
Cladding non-circularity	Maximum	2.00%
Cable cut-off wavelength	Maximum	1450 nm
Macro bend loss	Radius	30 mm
	Number of turns	100
	Maximum at 1625 nm	0.50 dB
Proof stress	Minimum	0.69 GPa
Chromatic dispersion coefficient (ps/nm × km) (Note 1)	D_{min}(l): 1460-1550 nm	$\frac{2.60}{1.0090}(\lambda - 1460) +$
	D_{min}(l): 1550-1625 nm	$\frac{0.98}{3.60}(\lambda - 1550) +$ 75
	D_{max}(l): 1460-1550 nm	$\frac{4.68}{4.60}(\lambda - 1460) +$ 90
	D_{max}(l): 1550-1625 nm	$\frac{4.72}{9.28}(\lambda - 1550) +$ 75
Uncabled fibre PMD coefficient	Maximum	(Note 2)
Cable attributes		
Attribute	**Detail**	**Value**
Attenuation coefficient (Note 3)	Maximum at 1460 nm	0.4 dB/km
	Maximum at 1550 nm	0.35 dB/km
	Maximum at 1625 nm	0.4 dB/km
PMD coefficient	M	20 cables
	Q	0.01%
	Maximum PMD_Q	0.20 ps/√km

NOTE 1 – If a Raman pump is used outside this wavelength region, fibre properties must be suitable for accommodating this pump.
NOTE 2 – According to clause 6.2, a maximum PMDQ value on uncabled fibre is specified in order to support the primary requirement on cabled PMDQ.
NOTE 3 – The attenuation coefficient values listed in this table should not be applied to short cables such as jumper cables. For example, [b-IEC 60794-2-11] specifies the attenuation coefficient of indoor cable as 1.0 dB/km or less at both 1310 and 1550 nm.

Source: ITU-T

Table 31: Technical Specification of Fibre- ITU-T G.657.A

Fibre attributes						
Attribute	**Detail**	**Value**				
Mode field diameter	Wavelength	1310 nm				
	Range of nominal values	8.6-9.2 µm				
	Tolerance	±0.4 µm				
Cladding diameter	Nominal	125 µm				
	Tolerance	±0.7 µm				
Core concentricity error	Maximum	0.5 µm				
Cladding non circularity	Maximum	1%				
Cable cut-off wavelength	Maximum	1260 nm				
		ITU-T G.657.A1		**ITU-T G.657.A2**		
Uncabled fibre macro bending loss (Notes 1, 2)	Radius	15nm	10nm	15nm	10 nm	7.5 nm
	Number of turns	10	1	10	1	1
	Max. at 1 550 nm	0.25 dB	0.75 dB	0.03 dB	0.1 dB	0.5 dB
	Maximum at 1625 nm	1 dB	1.5 dB	0.1 dB	0.2 dB	1 dB
Proof stress	Minimum	0.69 Gpa				
Chromatic dispersion coefficient (3-term Sellmeier fitting)	λ0min	1 300 nm				
	λ0max	1 324 nm				
	S0min	0.073 ps/nm2 × km				
	S0max	0.092 ps/nm2 × km				
Chromatic dispersion coefficient (Linear fitting -1460 nm to 1625 nm)	Min. at 1 550 nm	13.3 ps/(nm × km)				
	Max. at 1 550 nm	18.6 ps/(nm × km)				
	Min. at 1 625 nm	17.2 ps/(nm × km)				
	Max. at 1 625 nm	23.7 ps/(nm × km)				
Cable attributes						
Attribute	**Detail**	**Value**				
Attenuation coefficient (Note 3)	Maximum from 1310 nm to 1625 nm (Note 4)	0.4 dB/km				
	Maximum at 1383 nm ±3 nm (Note 5)	0.4 dB/km				
	Maximum at 1530-1550 nm	0.3 dB/km				
PMD coefficient	M	20 cables				
	Q	0.01%				
	Maximum PMD_Q	0.20 ps/√km				

NOTE 1 – ITU-T G.652 fibres deployed at a radius of 15 mm generally can have macro bending losses of several dB per 10 turns at 1 625 nm.
NOTE 2 – The macro bending loss can be evaluated using a mandrel winding method (method A of [IEC 60793-1-47]), substituting the bending radius and the number of turns specified in this table.
NOTE 3 – Due to the lack of accuracy in measuring the attenuation coefficient of a short

cable, its value can be taken from that of the original longer donor cable. NOTE 4 – This wavelength region can be extended to 1 260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm. NOTE 5 – Hydrogen ageing is a type test that shall be done to a set of sampled fibres, according to [IEC 60793-2-50] regarding the B1.3 fibre category.
Source: ITU-T

Table 32: Technical Specification of Fibre- ITU-T G.657.B

Fibre attributes							
Attribute	**Detail**	**Value**					
Mode field diameter	Wavelength	1310 nm					
	Range of nominal values	8.6-9.2 µm					
	Tolerance	±0.4 µm					
Cladding diameter	Nominal	125 µm					
	Tolerance	±0.7 µm					
Core concentricity error	Maximum	0.5 µm					
Cladding non circularity	Maximum	1%					
Cable cut-off wavelength	Maximum	1260 nm					
		ITU-T G.657.B2			**ITU-T G.657.B3**		
Uncabled fibre macro bending loss (Notes 1, 2)	Radius	15 nm	10 nm	7.5 nm	10 nm	7.5 nm	5 nm
	Number of turns	10	1	1	1	1	1
	Max. at 1 550 nm	0.03 dB	0.1 dB	0.5 dB	0.03 dB	0.08 dB	0.15 dB
	Maximum at 1625 nm	0.1 dB	0.2 dB	1 dB	0.1 dB	0.25 dB	0.45 dB
Proof stress	Minimum	0.69 Gpa					
Chromatic dispersion coefficient	λ0min	1250 nm					
	λ0max	1350 nm					
	Nil	Nil					
	S0max	0.11 ps/nm² × km					
Cable attributes							
Attribute	**Detail**	**Value**					
Attenuation coefficient (Note 3,4)	Maximum from 1310 nm to 1625 nm (Note 5)	0.4 dB/km					
	Maximum at 1383 nm ±3 nm (Note 6)	0.4 dB/km					
	Maximum at 1530-1550 nm	0.3 dB/km					
PMD coefficient (Note 4)	M	20 Cables					
	Q	0.01%					
	Maximum PMD_Q	0.5 ps/km					

NOTE 1 – The macro bending loss can be evaluated using a mandrel winding method (method A of [IEC 60793-1-47]), substituting the bending radius and the number of turns specified in this table.

NOTE 2 – While a baseline on macro bending performance can be established for uncabled fibres, the actual design and materials of cable construction can contribute to the resulting performance in the field. The study into the macro bending effects of cabling is ongoing, which may result in the need for any additional cable specifications or parameters in the future.

NOTE 3 – Operators may decide that compliance of ITU-T G.657.B category fibres to spectral attenuation characteristics of [ITU-T G.657]. A category fibre (or ITU-T G.652.D fibres) may

not be necessary in their (particular) networks. For example, small differences in the attenuation coefficient specification around 1380 nm (e.g., as can be found in Figure 10-4 of [b-ITU-T G-Sup.39]) may not introduce system impairments or deployment issues (negligible effect on the total system performance) when applying these fibres at the end of the access network.

NOTE 4 – Due to the lack of accuracy in measuring the attenuation coefficient of a short cable, its value can be taken from that of the original longer donor cable.

NOTE 5 – This wavelength region can be extended to 1 260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm.

NOTE 6 – Hydrogen ageing is a type test that shall be done to a set of sampled fibres, according to [IEC 60793-2-50] regarding the B1.3 fibre category.

Source: ITU-T

Annexure VIII: OFC Installation Tools and Accessories

A. List of OFC Installation Tools along with TEC Standards

Table 33: List of OFC Installation Tools along with TEC Standards

S/N	Name of Tool	TEC Standard	Brief Function
Section-I (Splicing Machines)			
1	Optical Fibre Splicing Machine	TEC/GR/TX/OSM-001/04/SEP-12	The Optical Fibre Splicing Machine is designed to splice fibres by fusing the fibres together using localized heating at the interface of the butted fibres. An electric arc is generated by the electrodes contained in the unit. The splicing consists of fusion cycles resulting in permanently jointing of the optical fibres with minimum splice loss and low reflection.
2	Ribbon Optical Fibre Splice Machine	TEC/GR/TX/OSM-002/03/SEP-12	The Ribbon Optical Fibre Splice Machine is designed to splice fibres by fusing the fibres together using localized heating at the interface of the butted fibres. An electric arc is generated by the electrodes contained in the unit. The fusion splicing of the ribbon consists of fusion cycles resulting in permanently jointing of the optical fibres with minimum splice loss and low reflection.
3	Optical Fibre Splicing Machine (Portable) (Type-I & Type-II)	TEC/GR/TX/OSM-003/03/DEC-16	Optical Fibre Splicing Machine (Portable) (Type-I & Type-II) used for splicing the optical fibres with minimum splice loss and low reflection. The Type-I machine shall be capable of splicing single fibre and Type-II machine shall be capable of splicing ribbon fibres. It shall be very compact and light weight. It shall enable the precision splicing at the close proximity of the joint location or a pole or any place in the building premises.
Section-II (General Purpose Tools)			
4	Ratchet Screw Driver	GR/OFT-01/03.APR.2006	Ratchet Type Screw Driver is used for handling the screws in and outside the joint closures and for any other general purposes. The ratchet type of screw drivers is required to be supplied for slotted head and cross recessed head screws.
5	Measuring Scale		Measuring Scale/Tape is used to measure the length of the optical fibre cable or any other misc. job to be carried out where accurate length is required during installation of the optical fibre cables.
6	Hack Saw (junior) with blades		Hack Saw (junior frame) is used to cut the Optical Fibre cable etc. where the optical fibre cable is being installed or spliced. The blade shall be of 15 cm size to suit the Hacksaw frame

S/N	Name of Tool	TEC Standard	Brief Function
7	Scissor		Scissor is used for cutting tape of optical fibre cable or any other misc. job to be carried out where accurate length is required while installation or splicing of the optical cable.
8	Tweezer		Tweezer is used to handle small items while splicing the Optical Fibre.
9	Cutting Nipper		Cutting Nipper required for handling the delicate work while terminating, installing or splicing of the optical fibres in the termination box or in the splice closures.
10	Snip Nose Plier		Snip Nose Plier required for handling the delicate work while terminating installing or splicing of the optical fibre in the splice closures.
11	Hammer		Hammer required for delicate hammering of the optical fibre closure (if required) and for other general purposes.
12	Adjustable Spanner		The Adjustable Spanner is used for handling the bolts and nuts of the optical fibre termination box and splice closures etc.
Section-III (General purpose tools for optical fibre cables)			
13	Cable Knife	GR/OFT-01/03.APR.2006	The Cable Knife is used for cutting of sheath and jacket, Fibre Reinforced Plastic (FRP) of the optical fibre cable and thermo shrink sleeve etc.
14	Cable Cutter		The Cable Cutter with special cutting edge is used for cutting of the optical fibre cable perpendicular to cable axis.
15	Cable sheath & Jacket Remover		Cable sheath & Jacket Remover tool is used for cutting and removing the HDPE sheath and nylon jacket of the optical fibre cable.
16	Scissor Ceramic Type		Scissor having ceramic blades is used to cut aramid yarn of optical fibre cable and pig tails during the installation or splicing of the optical fibre cables.
17	FRP Cutter		Fibre Reinforced Plastic (FRP) Cutter (with special cutting edge) is used for cutting of the FRP of the optical fibre cable perpendicular to the axis of the FRP rod.
18	Loose Tube Cutter		Loose Tube Cutter is used for the cutting the loose tube of the optical fibre cables, to give a perpendicular cut to the axis of the Loose tube.
19	Stripper Cutter		Stripper Cutter is used for stripping the outer jacket (3 mm. Nominal diameter) of single fibre cable (pigtail or patch cord).

S/N	Name of Tool	TEC Standard	Brief Function
Section-IV (Tools for Optical Fibre)			
20	Fibre Stripper (Primary Coating)	GR/OFT-01/03.APR.2006	Optical Fibre Stripper (primary coating). The fibre stripper (primary coating) is used for removing the primary coating of the Optical Fibres. This is required at the preliminary stage of installation, terminating and splicing of Optical Fibre. It shall be simple to operate without deteriorating any characteristics of the Optical Fibre.
21	Fibre Stripper (Secondary Coating)		The optical fibre Stripper (Secondary coating) is used for removing the secondary coating of the Optical Fibre. This requires at the preliminary stage of installation, terminating and splicing of Optical Fibre. It shall be simple to operate without any degradation in characteristics of the Optical Fibre.
22	Hot Jacket Remover for Ribbon Optical Fibre	TEC/GR/TX/OJR-001/03/DEC-15	The Hot Jacket Remover is used for removing coating (UV acrylate & resin) of the Optical Ribbon Fibre. This is required at the preliminary stage of installation, terminating and splicing of Optical Ribbon Fibre.
23	Fibre Cleaver	GR/OFT-01/03.APR.2006	The optical fibre cleaver (precision) is used for cleaving the bare optical fibre before splicing the two fibres, during installation and maintenance of optical fibre cables. The fibres are cleaved for fusion splicing or mechanical splicing.
24	High Precision Cleaver for Ribbon Optical Fibre	TEC/GR/TX/OCR-001/03/DEC-15	High Precision Cleaver suitable for optical fibre ribbons. The High Precision Cleaver is used for cleaving the bare optical fibre ribbons before splicing the two optical fibre ribbons, during installation and maintenance of optical fibre ribbon cables. The ribbon fibres are cleaved for mechanical splicing also.
Section-V (Consumable items & Tool box)			
25	Consumable Items	GR/OFT-01/03.APR.2006	The Consumable items required for the use during splicing and termination of the optical fibres like Emery Cloth or Emery Paper (zero grade), PVC adhesive tape (5m length of 10 mm width), ISO propane (Lab. Grade, 250 ml, for general cleaning), Hexane (Lab. Grade, 250 ml, for cleaning the jelly), Ethyl alcohol (Lab. Grade 250 ml, for cleaning the fibre), Tissue/Lens Paper - One Packet, Cotton Buds (small size)- One Packet, Torch with cell (Pencil Type)- One etc.
26	Tool Box		The various types of tools are housed in a single tool box (suitable to carry). The tool box shall have the provision to lock the tool box.
Source: tec.gov.in			

B. List of OFC Accessories and their TEC Standards

Table 34: List of OFC Accessories and their TEC Standards

S/N	Name	TEC GR	Brief Function
1	Splice Closures/OF Joint Closures (Straight joints & Branch Joints) for OF Cable	TEC/GR/TX/OJC-002/03/APR-2010	Optical Fibre splice closure is used in the outside plant network and houses the spliced optical fibre cables and its fibres in secured conditions. It shall be possible to use it for both Armoured& Metal Free type of Optical Fibre Cables and also compatible for different types of installation practices of cable installations viz. duct, aerial & directly buried. It provides mechanical protection and environmental sealing (by mechanical sealing method only) to the spliced cables and fibres etc. It is also possible to branch out the cable from the splice closure as and when required without damaging the existing cables.
2	Fibre Termination Box	TEC/GR/TX/FTB-02/02/APR-2010	The Fibre Termination and Distribution Box (FTDB) shall provide management of optical fibres of a cable or number of cables and optical splitter assemblies, with flexibility and reliability for an FTTX application. It shall provide management of fibres in a consistent and in a structured manner. It shall also provide facilities for reconfiguration of fibres, network expansion (through branching) and testing and shall able to store extra length of pigtails and fibres for rearranging, in case the need arises. The box shall have provision for cable termination and sealing requirements.
3	SPLITTERS	TEC GR No. TEC/GR/TX/OPT-001/01/APRIL-12	Optical Splitter is a passive component of PON Technology for the application of FTTH to cater the demand of Customer for Broad Band, Voice, Data, and Video Services etc., It will be installed in the Central Office / Remote Office/Cabinet/MDU/MTU/Optical splitters capable of providing up-to 1: 128 optical splits, on end-to-end basis, per PON interface on OLT, are envisaged. There shall be various options provided to purchaser such as m:N where m = 1 or 2 and N = 2,4, 8, 16, 32,64 and 128.
4	OF Jumpers, Adapters	TEC GR TX/OFJ-01/05 NOV 2009	Single mode Optical Fibre Jumpers (Patch cords and Pigtails) (Type-I to Type-IV), Adapters (Type-I to Type-IV), Hybrid Jumpers (Type-I to Type-VI) and Hybrid Adapters (Type-I to Type-VI). These are used for terminations, connecting the Optical Line Systems to outdoor / Indoor optical fibre cables and other optical measurement purposes.

S/N	Name	TEC GR	Brief Function
5	Fixed Attenuator	TEC/GR/TX/OPA-003/03/OCT-14	The optical fixed attenuators are designed for the use during the measurement of optical power, optical loss, transmission rate and other optical transmission characteristics during installation and maintenance of fibre optical communication equipment and optical fibre links. The Maximum Input power of Type-A Attenuator is +28dBm or more whereas maximum Input power of Type-B Attenuator is +3dBm or more.
6	Drum for Cable ends	G/CBD-01/02 NOV 94	Drum used for supply, transport and storage of telecom cables.
7	Fibre Distribution Frame	TEC/GR/TX/FDF-01/02/MAY-2010	Fibre distribution frame cater for the general functions of organizing the optical fibre pigtails, and Patch cords at distribution nodes in the fibre network. It connects optical line termination box on one side and on other it connects optical line terminal equipment. Fibre distribution frame also permits optical test equipment to be connected to the fibre cable in order to check the transmission lines and terminal equipment. It also provides storing of the excess lengths of pigtails and patch cords.
8	OF Splice Protection Sleeve for optical fibre ribbon	TEC/GR/TX/PTS-02/03 JAN 2011	The Splice Protection Sleeves is used to provide protection and reinforcement to the Spliced bare ribbon fibres. Since the fibres to be spliced are initially stripped off the UV resins, the inner EVA tube of heat protection sleeve provides a cushioning effect forming a layer on the bare ribbon fibres. The Ceramic rod in the splice protection sleeve provides reinforcement.
9	Fibre Distribution Management System (Outdoor) for Optical Fibre Cables (Ribbon & Non–Ribbon)	TEC/GR/TX/FDM-003/01 MAR 2012	Fibre Distribution Management System (Outdoor) suitable for all types of optical fibre cables including Ribbon type cables used in telecom network. It is used in the Outside plant network and houses the spliced optical fibre cables and its fibres in secured conditions. It shall be possible to use it for both Armoured& Metal Free type of Optical Fibre Cables and also compatible for different types of installation practices of cable installations viz. duct, aerial & directly buried. Outdoor location is in the outside plant in uncontrolled environment and may be buried underground, mounted on walls, poles or other structures. The unit must be capable of being submerged in water for extended periods without deterioration.

S/N	Name	TEC GR	Brief Function
10	Fibre Distribution Management System (Exchange) Type – I	GR/FDM-01/02 APR 2007	Exchange is in Indoor location in the central office, having controlled environment. The location has multiple cables converging and hence requires a system to handle a large number of Fibres. The cable is routed through race ways either from the bottom (under floor) or overhead. This FDMS shall be termed as FDMS Exchange.
11	Fibre distribution management system Type-III (Indoor for GP)	GR/FDM-01/02 APR 2007	Building Premises is located in premises of the subscriber in uncontrolled environment and typically, could be fixed in the basement, under the staircase, or, on the roof. The unit would be exposed to direct rain or splashing water, but not submersion. This unit would provide splicing Fibres of a cable to Fibres of another cable, and /or splicing the Fibres of a cable to pigtails and distribution on a patch panel. In most cases only one cable would terminate in this unit, however this unit could also be used for convergence of two or three cables while simultaneously providing patching to the Fibres "dropped" at the location.
Accessory required for installation of Aerial Optical Fibre Cable			
12	FORMED OFC DEAD END AND TERMINATION FITTINGS	TEC/GR/TX/OAF-001/03 Mar 2017	These fittings are used at tension/termination poles (dead end poles), or poles where splices are located and the poles where the overhead alignment takes a turn, (angle exceedingly more than 15 degrees)
13	J-SHAPED TENSION HOOK		J - Shaped tension hook is for the installation on cross arm channel C (C -Bracket) of the poles
14	TURN BUCKLE		Galvanized forged steel turn - buckle is used at the dead end and at tension positions (for adjusting the sag & tension)
15	EXTENSION LINK		Galvanized steel extension link is used along with turn buckle
16	CLEVIS THIMBLE		Aluminium alloy die cast thimble is used to attach the extension link and for accommodating the loop of the helically formed terminating helix at the other and its smooth internal contour
17	PROTECTIVE HELIX (T)		Set of aluminium alloys helically formed protective helix having predetermined spiral shape is used & making them conveniently applied on the optical Fibre cable without excessive clamping pressure at any point.

S/N	Name	TEC GR	Brief Function
18	TERMINATING HELIX		Helically formed terminating helix of Aluminized steel having a prefabricated loop shall be to fit into the grooved contour of the thimble and for fixing over protective helix over the optical Fibre
19	JUMPER CABLE CLAMP		Galvanized steel jumper cable clamp is used to support the through length of optical Fibre cable at the intermediate tension poles m
20	POLE MOUNTED STAY CLAMP (RAIL) OR POLE MOUNTED STAY CLAMP (TUBULAR)		Galvanized mild steel pole mounted stay clamp shall be for use at the pole for the fixing with a twisted eye and turn buckle. The selection of the type of stay clamp shall depend upon the type of poles. (If there are some minor deviations in the size of the stay clamp required depending upon the actual size & type of the poles
21	OFC SUSPENSION FITTINGS		Helically formed suspension fittings along with the elastomeric pad's inserts strapped by a galvanized steel eye-band is used to hang from the twisted eye-link connected to a pole mounted stay clamp or on the tension hook (J-shaped) installed on the C bracket at the intermediate poles.
22	TWISTED EYE LINK		The twisted eye link is used for installing suspension fitting on stay clamp or on tension hook
23	PROTECTIVE HELIX (S)		Set of aluminium alloys helically formed protective helix having predetermined spiral shape is used & making them conveniently applied on the optical Fibre cable without excessive clamping pressure at any point
24	ARMOUR GRIP HELIX		Set of aluminium alloy armour grip helix is used or fixing on the profile shaped elastomer pad for proper strut action, grip & bird caging
25	SPIRAL VIBRATION DAMPER (SVD)		Helically formed spiral vibration dampers are used on both sides of suspension fitting.
26	DEMOUNTABLE PULLEY		Demountable pulleys are used during the installation of aerial optical Fibre cables. These are made from mild steel & the contour of the wheel is coated with rubber or any other suitable material for free movement of cable

S/N	Name	TEC GR	Brief Function
PLB Duct and accessory required for installation of PLB HDPE Duct			
27	PLB HDPE Duct	TEC/GR/TX/CDS-008/03/MAR-11	Permanently Lubricated High Density Polyethylene ducts (PLB HDPE ducts) for use as underground cable conduits for optical fibre cables, suitable for cable installation by blowing technique. The PLB HDPE duct shall consist of two concentric layers, the outer layer being HDPE; co-extruded with an inner layer of solid permanently lubricant, to reduce the Internal Co-efficient of Friction (ICF). The lubricant shall be of a solid layer of uniform thickness so formulated to provide a permanent, low friction boundary layer between the inner surface of the duct and OF cable. The lubricant layer shall be clearly visible in cross-section, concentric with the outer layer.
28	Push fit Coupler	TEC/GR/TX/CDS-008/03/MAR-11	Push Fit couplers shall be used for coupling PLB HDPE ducts/coils.
29	PP Rope		PP ropes drawn through the HDPE/PLB pipes/coils and safely tied to the end caps at either ends with hooks to facilitate pulling of the OF cables at a later stage
30	End Cap		End Cap shall be used for sealing the ends of the empty ducts, prior to installation of the OF Cable and shall be fitted immediately after laying the duct to prevent the entry of any dirt, water, moisture, insects/rodents etc.
31	Cable sealing Plug		This shall be used to seal the end of the ducts perfectly, after the OF cable is pulled in the duct. For pulling the cable through the ducts, it is necessary to provide manholes at that location and also at bends and corners wherever required. The ends of the PLB HDPE ducts/coils are closed with Cable sealing Plugs. The End Plugs used should be suitable for closing40mm/33mm PLB HDPE ducts/coils.
32	Joint Chamber		The Joint chamber shall be provided at every joint location to keep the OF cable joint well protected and also to house extra length of cable which may be required in the event of faults at a later date. The Joint chamber shall be of pre-cast RCC type as per construction specification. Brick chamber can also be made with prior permission of State/SIA.
33	Rubber Bush		To prevent entry of rodents into PLB HDPE DUCTS, the ends of PLB HDPE DUCTS are sealed at every manhole and joint using rodent resistant hard rubber bush (cap) after optical Fibre cable is pulled. The rubber bush should be manufactured from hard rubber

S/N	Name	TEC GR	Brief Function
			with grooves and holes to fit into PLB HDPE DUCTS pipe, so that it should be able to prevent the entry of insects, rodents, mud, and rainwater into the PLB HDPE DUCTS pipe.
34	Route/Joint Indicator		The Route/Joint indicators are co-located with each manhole/joint chamber. In addition, Route indicators are also to be placed were route changes direction like road crossings etc. Either RCC/Pre-cast or Stone based route indicators can be used.
35	Double Walled Corrugated (DWC) HDPE Duct	GR/DWC -34/01 Sep.2007	Double Walled Corrugated Polyethylene Ducts (DWC Duct) for use as under-ground cable conduit for PLB HDPE Ducts as additional protection at places like Road Culverts, Local Area Network. Municipal Limits, water logged area Marshy Lands, Rail/Road crossing and as per existing installation guidelines.
Source: tec.gov.in			

Annexure IX: List of OF Parameters and their limit as per TEC Standard

Table 35: List of OF Parameters and their limit as per TEC Standard

Clause wise compliance statement as per TEC/GR/TX/ORM-001/05/DEC-2017 with amendment no.1 dated 06.07.2020			
Test Specification		TEC/GR/TX/ORM-001/05/DEC-2017 with Amendment no.1 dated 06.07.2020	
Name of product:		SMOF G657A2	
Clause no.	**Requirement/Parameter**	**TEC Specification requirement**	**Location of Testing**
1.0 Single mode optical fibre used in manufacturing optical Fibre cables shall be as per ITU-T Rec. G.657.A1/A2 The specification of optical fibres are mentioned below:			
1.1	**Type of fibre (Wavelength band optimized nominal 1310 nm)**	Single mode Optical fibre conforming to ITU-T Rec G.657. A1/A2	
1.2	**Geometrical Characteristics**		
	MFD At 1310	8.6±0.4 µm	CACT, Fibre Plant & Cable Plant
	Cladding Diameter	125 ± 0.7 µm	CACT, Fibre Plant & Cable Plant
	Cladding noncircularity	≤ 0.8 %	CACT, Fibre Plant & Cable Plant
	Core Clad Concentricity error	≤ 0.5 µm	CACT, Fibre Plant & Cable Plant
	Diameter (uncoloured	242 ± 5 µm	CACT, Fibre Plant & Cable Plant
	Diameter (coloured	252 ± 10 µm	CACT, Fibre Plant & Cable Plant
	Coating cladding Concentricity	≤12 µm	CACT, Fibre Plant & Cable Plant
1.3	**Transmission Characteristics**		
1.3.1	Attenuation.		
a)	**Fibre attenuation before Cabling**		
i)	At 1310 nm	≤ 0.34 dB/km	Fibre Plant & Cable Plant
ii)	Between 1285 to1360 nm	≤ 0.37 dB/km	Fibre Plant & Cable Plant
iii)	Between 1360 to1480 nm	≤ 0.34 dB/km	Fibre Plant & Cable Plant
iv)	Between 1480 to1525 nm	≤ 0.34 dB/km	Fibre Plant & Cable Plant
v)	At 1550 nm	≤ 0.20 dB/km	Fibre Plant & Cable Plant

vi)	Between 1525 to1625 nm	≤ 0.24 dB/km	Fibre Plant & Cable Plant
vii)	At 1270 nm	≤ 0.40 dB/km	Fibre Plant & Cable Plant
viii)	At 1490 nm	≤ 0.24 dB/km	Fibre Plant & Cable Plant
ix)	At 1625 nm	≤ 0.23 dB/km	Fibre Plant & Cable Plant
x)	At 1240 nm	Not specified	Fibre Plant & Cable Plant
b	**Fibre attenuation after Cabling**		
i	At 1310 nm	≤ 0.37 dB/km	Cable Plant
ii	At 1490 nm	≤ 0.26 dB/km	Cable Plant
iii	At 1550 nm	≤ 0.23 dB/km	Cable Plant
iv	At 1625 nm	≤ 0.25 dB/km	Cable Plant
Note			
1	Attenuation in the band 1380-1390nm shall be checked at every 2nm after Hydrogen ageing as per IEC 60793-2-50. Hydrogen aging test to be carried out by CACT, Bengaluru or any recognized laboratory for type test.	Increase in attenuation at 1240 nm >0.03 dB/km	Hydrogen aging test carried out in Fibre Plant
2	Sudden irregularity in attenuation shall be less than 0.1 dB	0.1 dB	Fibre Plant
3	The spectral attenuation in the 1250 nm - 1625 nm band shall be measured at an interval of 10nm and test results shall be submitted.	-	Fibre Plant & Cable Plant
1.3.2	Dispersion		CACT, Fibre Plant & Cable Plant
a	Total Dispersion		CACT, Fibre Plant & Cable Plant
	In 1285 to 1330	≤ 3.5 ps/nm.km	CACT, Fibre Plant & Cable Plant
	In 1270 to 1340	≤ 5.3 ps/nm.km	CACT, Fibre Plant & Cable Plant
	At 1550	≤ 18.0 ps/nm.km	CACT, Fibre Plant & Cable Plant
	At 1625	≤ 22.0 ps/nm.km	CACT, Fibre Plant & Cable Plant
b	PMD		CACT, Fibre Plant & Cable Plant
	i Un-cabled fibre	0.2 ps/km	CACT, Fibre Plant & Cable Plant
	ii cabled Fibre	0.3 ps/km	CACT, Fibre Plant & Cable Plant

	iii Link design value for un cabled Fibre	0.06 ps/km	CACT, Fibre Plant & Cable Plant
c	Zero Dispersion slope	≤ 0.092 ps/(nm².km)	CACT, Fibre Plant & Cable Plant
d	Zero Dispersion wave length range	1300 - 1324 nm	CACT, Fibre Plant & Cable Plant
1.3.3	Cut-off wavelength For Fibres used in patch cards & pig-tails	1260 nm Max.	Fibre Plant & Cable Plant
1.3.4	Cable cut-off wavelength	1260 nm Max.	Fibre Plant & Cable Plant
Note: The above cut-off wavelength is w.r.t. 22m sample length of Fibre.			
1.4	**Mechanical Characteristics**		
1.4.1	Proof test for minimum strain level (Test method IEC-60793-1-30)	1%	Fibre Plant
1.4.2	**Strip force** to remove primary coating of Unaged and Aged fibre (Water aged and Damp Heat aged) (Test method IEC-60793-1-32)		
	Unaged		
a)	Peak strip force	0.4 ≤ N ≤ 8.9 N	Fibre Plant & Cable Plant
b)	Average strip force	0.4 ≤ N ≤ 5 N	Fibre Plant & Cable Plant
	Water aged		
a)	Peak strip force	0.4 ≤ N ≤ 8.9 N	Fibre Plant & Cable Plant
	Damp Heat aged		
a)	Peak strip force	0.4 ≤ N ≤ 8.9 N	Fibre Plant
b)	Average strip force	0.4 ≤ N ≤ 5 N	Fibre Plant
Note:	The force required to remove 30mm ± 3mm of the fibre coating shall not exceed 8.9 N and shall not be less than 1 N for 250µm Fibre and 0.4 N for 200µm Fibre.		
1.4.3	**Dynamic Tensile Strength (Test method IEC-60793-1-31)**		
a)	Un aged	≥ 550 KPSI (3.80Gpa)	Fibre Plant
b)	Aged (Damp Heat aged)	≥ 440 KPSI (3.00Gpa)	Fibre Plant
1.4.4	**Dynamic Fatigue (Test method IEC-60793-1-33)**		
a)	Un aged	≥ 20	Fibre Plant
b)	Aged (Damp Heat aged)	≥ 20	Fibre Plant

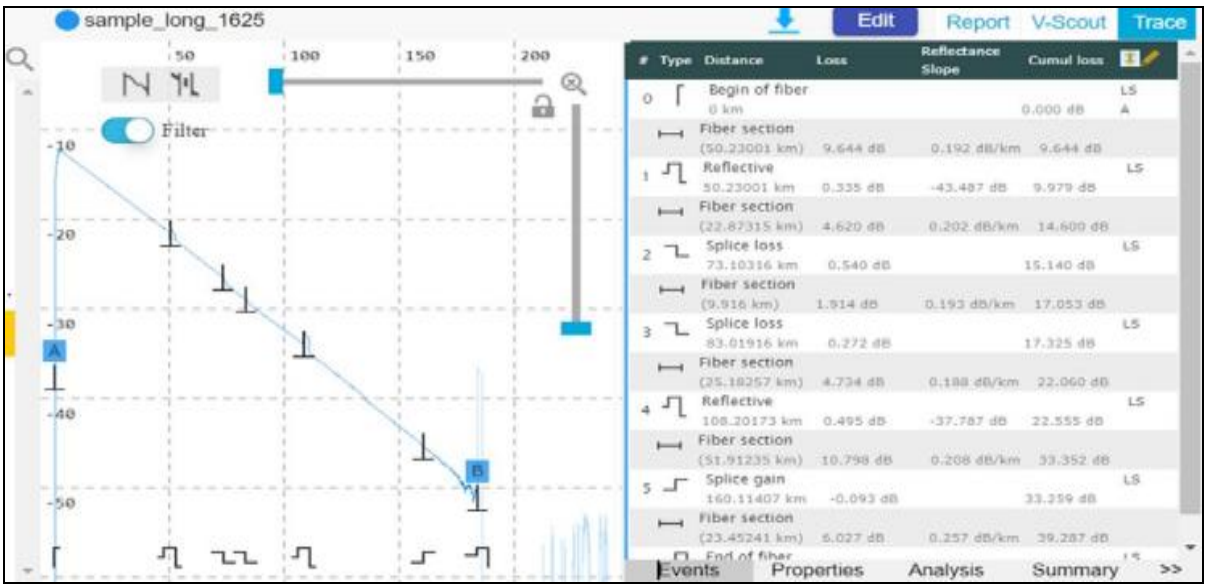
1.4.5	Fibre Macro bend		CACT, Fibre Plant & Cable Plant
1.4.6	Fibre Curl	≥ 4 Meter	CACT, Fibre Plant & Cable Plant
1.5	Material Properties		To be declared by Manufacturer
1.6	**Environmental Characteristics of Fibre (Type test):**		
1.6.1	**Operating Temperature (Test method IEC-60793-1-52)**		
	Temperature Dependence of Attenuation Induced Attenuation at 1550 nm &1625 nm at -60° C to +85° C	-60°C to + 85°C ≤ 0.05 dB/km	Fibre Plant
1.6.2	**Temperature-Humidity Cycling (Test method EIA/TIA 455-73)**		
	Induced attenuation at 1550 nm & 1625 nm at -10°C to +85°C and 95% relative humidity	≤ 0.05 dB/km	Fibre Plant
1.6.3	**Water Immersion 23°C (Test method IEC-60793-1-53)**		
	Induced attenuation at 1550 nm & 1625 nm due to water immersion at 23±2°C	≤ 0.05 dB/km	CACT, Fibre Plant & Cable Plant
1.6.4	**Accelerated Ageing (Temperature 85°C (Test method IEC-60793-1-51)**		
	Induced attenuation at 1550 nm & 1625 nm due to Temperature Ageing at 85±2°(C)	≤ 0.05 dB/km	CACT & Fibre Plant
1.6.5	Retention of Coating colour		
1.6.6	**High Temperature and High Humidity (Damp heat) Test method - IEC 60793-2-50**		
	Induced attenuation at 1550nm and 1625nm at 85°C and 85% Relative Humidity for 30 days	≤ 0.05 dB/km	Fibre Plant
1.7.1	Colour qualification test		
	a MEK Rub Test		CACT, Fibre Plant & Cable Plant
	b Water immersion test		CACT, Fibre Plant & Cable Plant
1.7.2	Primary Coating test		
	a FTIR	CURING LEVEL SHALL BE BETTER THAN 90%	To be declared by Manufacturer
	b Adhesion test		CACT, Fibre Plant & Cable Plant
Source: tec.gov.in			

Annexure X: OTDR Concept and its uses

A brief writeup contributed by Shri Kartik Parikh, CEO, Fastech Telecommunication India Pvt. Ltd. About OTDR concept and its uses is given below: -

OTDR - Most Commonly used Test Equipment

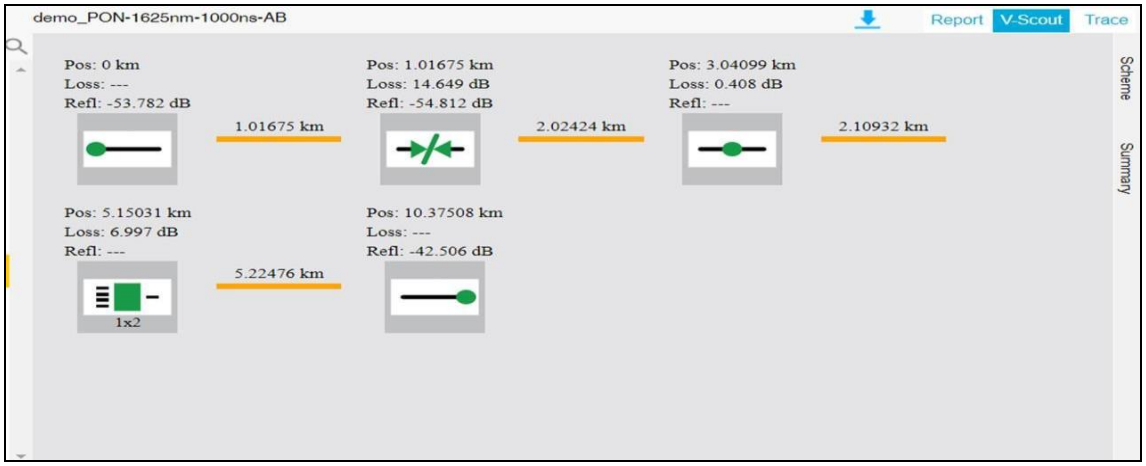
An OTDR (Optical Time Domain Reflectometer) is an instrument used to measure key parameters of an optical Fibre link, such as the length of the Fibre, reflective and refractive losses. It directly provides the distance to the end of the Fibre (or distance to fault) in meters. As optical Fibre links break frequently in the field, OTDRs are used frequently to learn the distance to the fault in meters. Further, as each "splice" (or joint) degrades the Fibre performance, OTDRs are also used to read the loss (or degradation) due to each joint on the Fibre and the accumulated loss until the end of the link. This information helps assess the quality of the Fibre and its' capability to carry new services or traffic.



Source: Actual experimental snapshot taken by M/s Fastech Telecommunication India Pvt. Ltd.

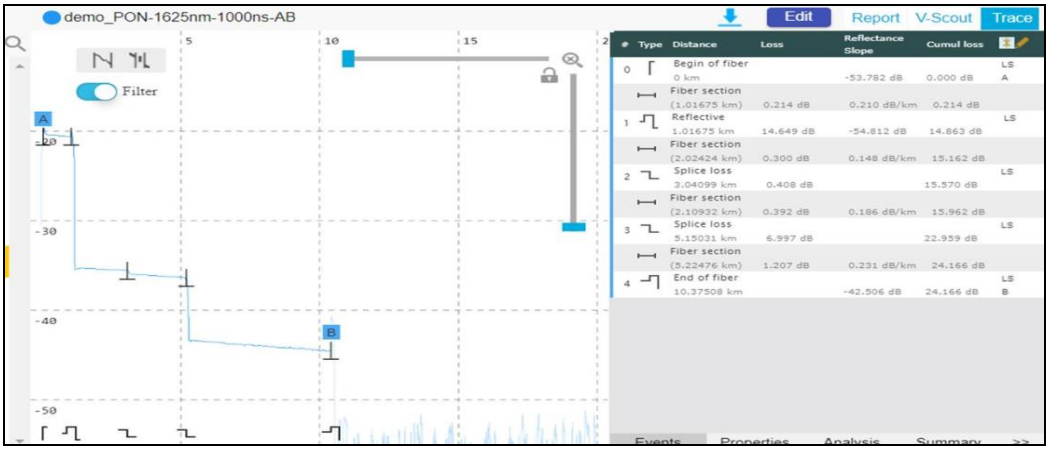
Figure 46: A typical OTDR trace for a point-to-point OFC link

Figure above shows a typical OTDR trace of a 183 kilometre Fibre link with multiple splices (events) and resulting losses. A good splice must have a loss of less than 0.2dB. Today's Passive Optical Networks (PON) require the use of splitters in the Fibre plant. A 16 port splitter may offer a loss of about 15dB drop in optical power. Figures below shows an OTDR trace along with a pictorial representation of an Optical link with two splitters.



Source: M/s Fastech Telecommunication India Pvt. Ltd.

Figure 47: Pictorial View of the PON Fibre link with 2 splitters



Source: Actual experimental snapshot taken by M/s Fastech Telecommunication India Pvt. Ltd.

Figure 48: An OTDR trace for a PON Fibre link with 2 splitters - note the high splitter loss of 14.7dB

Following are the recent advances in OTDRs: -

a) High DR Dynamic Range OTDRs in miniature low priced packages

With the use of faster processors consuming lower power, OTDRs of higher dynamic range (the difference between the power level of the laser and the noise level) in smaller handheld battery operated models are available at lower prices; making them an affordable everyday tool for Fibre technicians even for long Fibre links (such as Figure 47 above) or PON links with high loss splitters (as in Figure 48 above).

b) Remote Control, Cloud Services and Geo-tagging

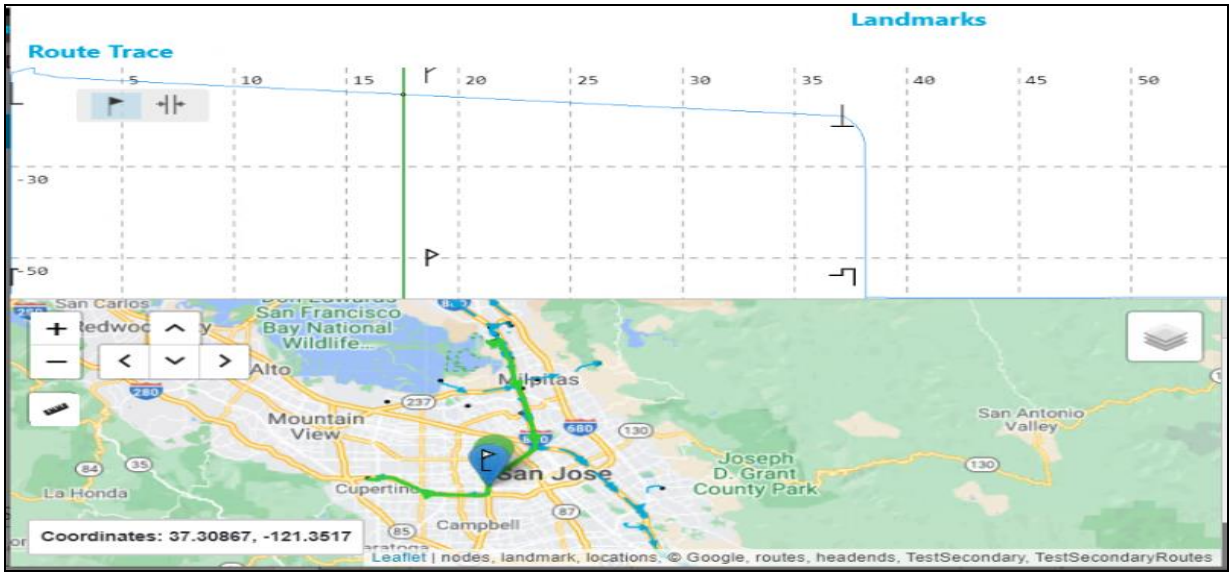
Today's OTDRs are also easy to use, even by technicians who are not qualified or trained to be experts on Fibre performance. Modern day mini-OTDRs such as the VeEX FX150+ have a WiFi connection to a smart-phone which in turn has a GPS and internet connection. As a result, the OTDR in the field is remotely controlled over the internet, so that a trained expert can operate and interpret different remote geo-tagged OTDRs from the network centre while deputing technicians to travel in the field and connect to the suspected Fibre ports. Further, the OTDR results are directly uploaded, saved and tagged in a cloud-based depository with the geo-tag of the location where the measurement was taken.

c) Live Fibre Analysis

An OTDR can be used on a "LIVE" link if it transmits pulses at 1625nm or 1650nm, thereby not interfering with the Fibre communication at 1310nm or 1550nm. Such Liver Fibre OTDRs can be connected to the Fibre for long periods of time for observation without affecting subscriber traffic.

d) Remote Fibre Test Systems (RFTS)

Fibre infrastructure is being recognised as increasingly strategic, so it is necessary to monitor the health of the Fibre continuously rather than only reactively when a fault is suspected. A Remote Fibre Test System (RFTS) consists of OTDR modules connected to switches distributed across the Fibre plant. It keeps measuring each Fibre links sequentially and the results are compared to a "baseline" trace. Any Fibre deterioration, e.g., a Fibre breakage, is immediately detected and localised on a GIS map at the server. These speeds up Fibre resolution as the maintenance crew closest to the fault are automatically alerted with the fault location on their phones. Figure 49 shows a representative view of the output of the VeEX Remote Fibre Test System (RFTS). This system is in use at a BBNL project in Gujarat.



Source: Actual experimental snapshot taken by M/s Fastech Telecommunication India Pvt. Ltd.

Figure 49: RFTS showing the location of a Fibre fault on a GIS map as soon as it occurs

e) Fibre Analytics and AI/ML based Correlation

RFTS solutions are further enhanced with advanced analytics on the Fibre quality with predictions on the available life of the Fibre plant. Furthermore, service level complaints are autonomously and immediately correlated to the Fibre quality so as to quickly arrive at the root cause analysis.

For example, the low throughput or high latency to a key customer may be directly attributed to the quality of the Fibre servicing the network.

(OTDR introduction Courtesy: Shri Kartik Parikh, CEO, Fastech(I) Pvt. Ltd.)

Annexure XI: List of TEC Standards for OTDR

Table 36: List of TEC Standards for OTDR

S/N	Standard Number	Name of Instrument	GR Number	Brief Description
1	TEC 88000:2013	COMPOSITE OPTICAL TEST INSTRUMENT (OTDR, Power Meter & Light Source)	TEC/GR/TX/COI-001/02/NOV-13	The Composite Optical Test instrument is intended for testing and locating faults and irregularities on Optical Fibre Cable and Optical Transmission links during Installation and subsequent maintenance etc. It is used for measuring the output power of active optical devices (except DWDM system & EDFA) and insertion loss / attenuation of passive optical devices, Optical transmission links during installation and maintenance, at all wavelengths (1310nm, 1550nm & 1625nm). It can also be used for installation and testing of Passive Optical Networks (PON) for FTTH applications. Power meter can measure Optical output power ≥ + 3dBm& the Light source has Triple wavelengths (1310nm, 1550nm & 1490nm)
2	TEC 88130:2019	OPTICAL TIME DOMAIN REFLECTOMETER (MINI) (Type-A & Type-B)	TEC/GR/TX/OTD-002/04/AUG-19	The OTDR instrument is intended for use for locating faults and irregularities on single mode optical fibre cable during Installation and subsequent maintenance etc. Type A OTDR is used for analysing the fibre characteristics at 1310nm & 1550nm, whereas Type B OTDR is specifically meant for measuring water peak attenuation of G.652 D fibre at 1383nm in addition to 1310nm & 1550nm.
3	TEC 88120:2019	OPTICAL TIME DOMAIN REFLECTOMETER (For Long Haul Applications) (TYPE-I) (1310nm & 1550nm wavelength)	TEC/GR/TX/OTD-001/05/SEP-19	The OTDR (Type I) instrument is intended for testing and locating faults and irregularities on Optical Fibre Cable during Installation and subsequent maintenance etc. Type I OTDR is used for analysing the fibre characteristics at 1310nm & 1550nm wavelength. This

S/N	Standard Number	Name of Instrument	GR Number	Brief Description
				OTDR having high dynamic range is intended for use in long haul applications.
4	TEC 88140:2010	OPTICAL TIME DOMAIN REFLECTOMETER (For Long Haul Applications) (TYPE-II) (1550nm & 1625nm wavelength)	TEC/GR/TX/OTD-03/02/APR-2010	The OTDR (Type I) instrument is intended for testing and locating faults and irregularities on Optical Fibre Cable during Installation and subsequent maintenance etc. Type II OTDR is used for analysing the fibre characteristics at 1550nm & 1625nm wavelength. This OTDR having high dynamic range is intended for use in long haul applications.
5	TEC 88180:2010	PON OPTICAL TIME DOMAIN REFLECTOMETER (Type- B) (For FTTH Applications)	TEC/GR/TX/OTD-05/01/APR-10	The PON Optical Time Domain Reflectometer Type-B instrument allows the testing of fibre through splitters (1:64). The instrument is specifically meant for troubleshooting & maintenance of live Fibre (in-service troubleshooting) of FTTH networks at 1650nm. The instrument shall have provision of filter port for live fibre testing.
Source: tec.gov.in				

References

[1] Department of Telecommunications, Govt of India [https://dot.gov.in/]

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[4] Common Service Centres Scheme (CSC), MeitY, Govt. of India [https://www.csc.gov.in/]

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Glossary

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