ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

G 652 B Single Mode OFC based Optical Network for Railway Telecommunication System

Prajwalasimha S N

Abstract*— *The paper deals with the establishment of optical network between the waystations. SDH, PDH and control communication are the three equipments provided at each waystation. SDH equipments of each station are interconnected through OFC in the form of ring topology. Fibcom STM-1 is used as SDH equipment in order to split the whole bandwidth into number of individual channels. These channels are assigned to each waystation. Bandwidth of the assigned channels is further split into sub channels by PDH equipment. These sub channels are add/drop multiplexed according to the requirements of each waystation and connected to the Control Communication Equipments.

***Index Terms*— Add/Drop Multiplexing, Bandwidth, Optical Network, Ring Topology.**

I. INTRODUCTION

Transportation plays a very vital role in our day to day life. Only a good communication system can ensure a flawless and ontime transportation. The railway is the largest transportation sector for both goods as well as passengers. A well organized traffic control system which intern plays a very vital role to ensure a flawless transportation service to the general public. For this again a well organized communication network is very much essential. Any delay or advance in departure or arrival time causes inconvenience to the general public. In such cases the communication system must function with a great responsibility. Presently railway's basic communication needed for train operation is Train Control Communication (TCC). TCC is an omnibus circuit connecting all wayside stations to the control office. This type of communication service is not available commercially with any private telecom operators. The continuous availability of required service and round the clock maintenance required to ensure the availability are the speciality of railway control circuits which are not available in telecom market. Further, many private telecom operators will not be willing to provide such services in remote stations and in some of the interior locations, where it will not be economical for them.

In connection oriented communication systems bandwidth plays a major role. More the bandwidth more information can be communicated in short duration. A single-mode OFC is capable of handling 10 Gbps bandwidth [1]. It has capacity to communicate over a distance of 100 km without repeaters at U-band.

STM-1 deals with a bandwidth of 155 Mbps [2]. In early days, railway was using wired communication with coaxial cables as transmitting media. Coaxial cable is capable of handling bandwidth of 0.1 Mbps over a distance of 1 km [3]. The bandwidth reduces if the information is transmitted beyond the range causing information corruption which is undesired. In order to overcome this problem, amplifiers are to be provided at every 1 km range. In order to establish communication between two STM-1 equipments using coaxial cables, more than 155 individual coaxial cables are required for a distance of 1 km range. Beyond this distance, signals of each wire have to be amplified to avoid signal degradation. As the distance increases, number of amplifiers required gets multiplied. Even with this, it is difficult to receive proper information ontime as signal degrades due to RFI and EMI factors. This becomes one of the causes of delayed transportation. One single-mode OFC is just sufficient to connect two STM-1 equipments over a distance of 100 km. In addition, being a non conductor, it is not affected by factors like RFI and EMI.

The paper is organized as follows: Section II deals with literature survey. Section III covers the specifications of G 652 B single-mode OFC. Section IV covers Synchronous Digital Hierarchy principles. Section V covers

Plesiochronous Digital Hierarchy principles. Section VI describes different types of Control Communication Equipments. Section VII concludes the paper.

II. LITERATURE REVIEW

Fibre optic communication network has been implemented in all the connection oriented communication fields due to more information carrying capacity and its environmental immunity. Prachi Shrama, Rohit kumar Arora, Suraj Pradeshi and Mandeep Singh [1] have reviewed the research and development in fibre optic communications. The recent development in the area of fibre optic communication as well as the advances in different fibre types and their properties, optical sources, detectors, system limitations and applications are also discussed in the paper. Gerd Keiser [2] has given an overview of fundamental communication concept and defined the different spectral bands which describes various operational wavelength regions used in optical communication. G. P. Agrawal [3] has described need for optical communication and evolution of light wave systems.

ITU_T G.652 [4] defined the different standards of single-mode optical fibre cable and its characteristics. This Recommendation describes the geometrical and transmission attributes of single-mode optical fibre and cable with chromatic dispersion and cut-off wavelength that are not shifted from the 1310 nm wavelength region. Specification of SFP transceiver is presented by Cisco Systems [5].

H.G. Perros [6] has presented two circuit switching networks, SONET and SDH along with their frame formats. Ninko. B. Radivojevic and Predrag. Z. Micovic [7] has reviewed clock synchronization in 155 Mbps SDH systems. ITU_T G.709 [8] describes the frame structure and bit rates of different optical transport hierarchies. ITU_T G.783 [9] proposed bit rates of different STM levels and characteristics of SDH functional blocks. This Recommendation specifies a library of basic building blocks and a set of rules by which they may be combined in order to describe digital transmission equipment. The library comprises the functional building blocks needed to specify completely the generic functional structure of the Synchronous Digital Hierarchy.

ITU_T G.692 [10] described optical interfaces for multi channel systems with the optical amplifiers. This recommendation defines interface parameters for systems of four, eight and sixteen channels operating at bit rates up to STM-16 on fibres. ITU_T L.35 [11] described installation of optical fibre cables in the access networks. The recommendation gives information about the methodologies recommended to install fibre optic cables in the access network. ITU_T G.707 [12] describes the Network Node Interface specifications for Synchronous Digital Hierarchy. ITU_T G.957 [13] proposed optical interface parameters for SDH equipment operating on single-mode optical fibres. Optical crossconnection in multi channel systems along with the dispersion management in long haul light wave systems are also explained. David Sanchez, Carmen Guerrero and Angel vina [14] has review the frame structure of PDH equipment operating at 2 Mbps. ITU_T G.705 [15] describes the characteristics of Plesiochronous Digital Hierarchy equipment functional blocks.

III. OPTIC FIBRE CABLE

The G 652 B single-mode optical fibres are characterized with a cut-off wave length of 1260 nanometer. The core diameter is around 10 micrometer and cladding diameter of 125 micrometer with the overall coating diameter of 245 micrometer [4].

Fibres produce maximum attenuation in the O-band and minimum in the C-band. Attenuation of 0.5 dB at 1550 nanometer wave length is observed due to fibre bending with a diameter of 32 millimeter and 0.05 dB is observed with a bending diameter of 60 millimeter [4]. The fibre is capable of sustaining 4 GPa tensile force. The fibres undergo elongation of 1% for an elastic force of 0.7 GN/m^2. Table I shows the attenuation at different wavelengths.

TABLE I. Characteristics of G 652 B fibres [4]

Attenuation	Signal degradation
Attenuation @ 1310 nm	$\leq$ 0.35 dB/Km
Attenuation @ 1550 nm	$\leq$ 0.21 dB/Km
Attenuation @ 1625 nm	$\leq$ 0.24 dB/Km
Attenuation between 1285 and	Charge versus attenuation @

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

1330 nm	1310 nm ≤ 0.03 dB/Km
Attenuation slope regularity @ 1310 and 1550 nm	Charge versus attenuation @ 1510 nm ≤ 0.03 dB/Km

A. Small Form Factor Pluggable (SFP)

The Small form factor pluggable (SFP) is a pluggable transceiver used for both telecommunication and data communications.

Fig. 1 SFP transceiver [5]

SFP Gigabit Interface Converter is an input/output device that plugs into a Gigabit Ethernet port, linking the port with the network. The communication over a single-mode fiber is achieved by separating the transmission wavelength of the two devices as depicted in Fig. 2

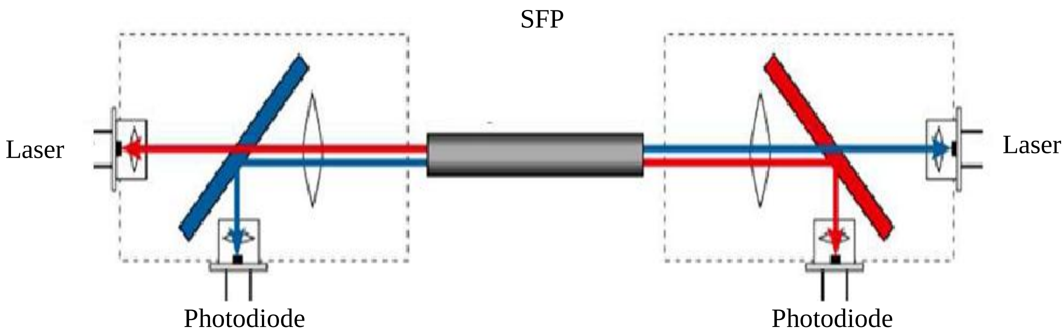

Fig. 2 Bidirectional transmission through SFP [5]

Small form factor pluggable transmits and receives through a GaAlAs laser and GaAs photodiode. Table II provides cabling specifications for the SFP.

TABLE II. SFP Port Cabling Specifications [5]

Product	Wavelength (nm)	Fiber Type	Operating Distance(m)
1000BASE-LX	1310	SMF	10,000
1000BASE-EX	1310	SMF	40,000
1000BASE-ZX	1550	SMF	Approximately 70 km depending on link loss
1000BASE-BXU	1310	SMF	10,000
1000BASE-BXD	1490	SMF	10,000

IV. SYNCHRONOUS DIGITAL HIERARCHY (SDH) EQUIPMENT

Telecommunication is the central nervous system of modern society. North America, Europe, Japan and India all have different communication standards and hierarchies. Digital networks of these nations cannot be freely connected. The technology of these nations competes with each other and remains incompatible. This not only obstructs telecommunications from one country to the other but also slows down the development. SDH multiplexing combines low speed digital signals such as 2, 34 and 140 Mbps signals with required overhead to form a frame called Synchronous Transport Module at level one (STM-1) [6].

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

The first 9 bytes of each segment carry overhead information and the remaining 261 bytes carry payload. When visualized as a block, the STM-1 frame appears as 9 rows by 270 columns of bytes. The STM-1 frame transmits first row. The most significant bit (MSB) of each byte transmitted first. Equation 1 gives bit rate of a framed digital signal.

$$\text{Bit rate} = \text{Frame rate x Frame capacity} \quad (1)$$

In order for SDH to easily integrate existing digital services into its hierarchy, it operates at the basic rate of 8 kHz or 125 microseconds per frame, so the frame rate is 8,000 frames per second. The frame capacity is 19,440 bits/frame. From equation 1, the bit rate of the STM-1 signal is 155.52 Mbps. Five transmission levels (STM-1, 4, 16, 64 and 256) have been defined for the SDH.

A. SDH Multiplexing

SDH is a highly standardized system as Open System Interface by ITU_T such as standardization of optical interface, standardization of frame format, standardization of auxiliary channels and control bits, standardization of multiplexing, standardization with flexible section that be a part of networks LAN, WAN, broad band ISDN, creation of open network structure increasingly required in today's competitive environment.

In SDH system the multiplexing is done by byte interleaving instead of bit interleaving as followed in PDH systems. This maintains the transparency of each bit stream and any bit stream can be dropped from any stage of SDH. For example a 2 Mbps tributary can be dropped even from STM-64, without any necessity of disturbing the other tributaries. ITU_T has standardized E1, E3, E4 of E hierarchy and T1, T2 and T3 of T hierarchy as inputs into SDH [6].

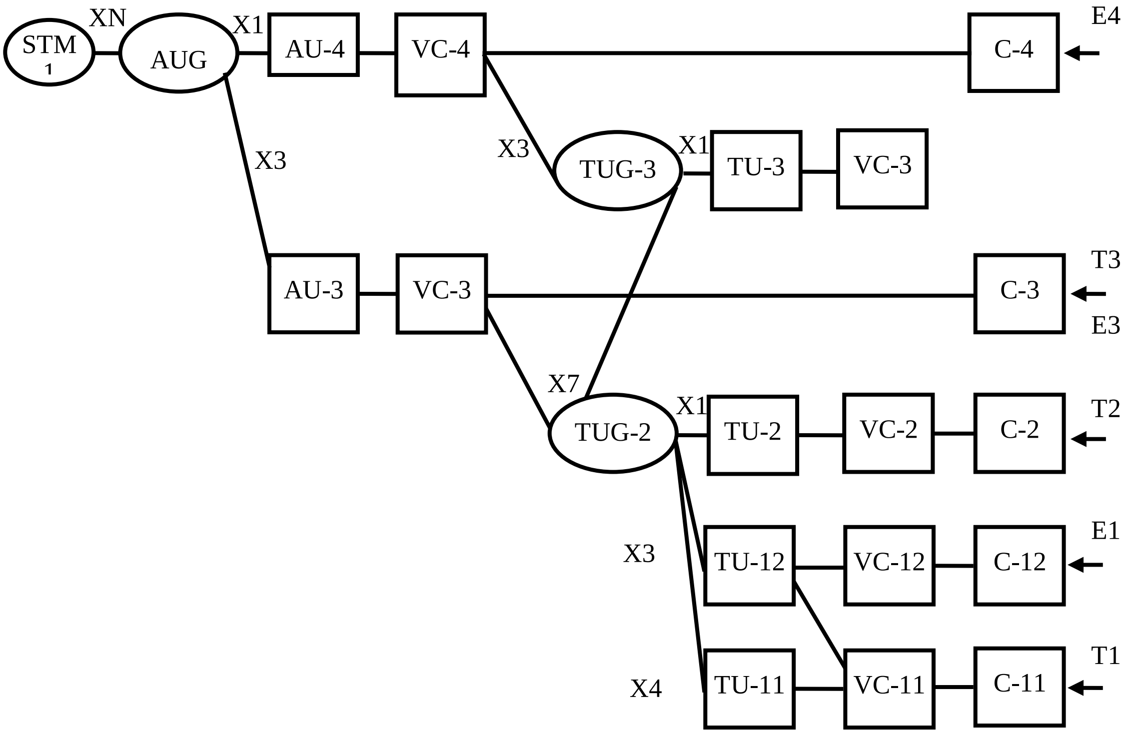

Fig. 3 SDH Multiplexing Structure

Container is the first entry point of the PDH signal. It is the basic packing unit for tributary channels, is filled with the information from a plesiochronous signal. The process is called as mapping. Justification facilities are provided to adapt plesiochronous tributaries to the synchronous network clock [7]. Each container is suitable for the rate of the signal input into it and for the structure of the synchronous frame. Fixed stuffing bits are inserted for synchronous tributaries. Signal is prepared so as to enter into the next stage (virtual container).

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

Containers are classified as Basic Containers and Higher Order Containers. C-11, C-12, C-2, C-3 and C-4 are the containers for PDH bit rates of 1.544 Mbps, 2.048 Mbps, 6.312 Mbps, 34 Mbps or 45 Mbps and 140 Mbps respectively [8]. Each container is added with control information known as Path Over Head (POH), which helps the service provider to achieve end-to-end path monitoring. The container and the path overhead are together called as Virtual Container (VC). The POH is 1 column x 9 rows [9]. In Virtual Container the POH fields are organized in a block frame structure either in 125 microseconds or in 500 microseconds. Basic virtual containers (VC-11, VC-12) and higher order virtual containers (VC-3, VC-4) are the two types of virtual containers.

Tributary unit (TU = VC + Pointer) is an information structure, which provides adaptation between the lower order path layer and the higher order path layer. It consists of information payload of virtual container and the tributary unit pointer (TU-2 for VC-2, TU-3 for VC-3).

One or more tributary units are grouped or multiplexed by byte interleaving to form higher bit stream rate as part of multiplexing structure. TUG-2 is a group of three TU-12s or four TU-11s or one TU-2. TUG-3 consists of homogenous assembly of TUG-2s or TU-3, either seven TUG-2s or one TU-3. Pointer is an indicator whose value defines frame offset of a virtual container with reference to the frame reference of transport entity on which it is supported. It indicates the phase alignment of the virtual containers (VC-n) with respect to the POH of the next higher level VC in which it resides. The tributary Unit Pointer location is fixed with respect to this higher level POH.

The use of pointer to indicate individual multiplex elements is a new feature of SDH. Pointers are not used in asynchronous, especially in PDH. This can take place through indication from the upper level of STM-1 frame to the individual VCs, using the example of a VC-4 as a first step. Within VC-4, four additional pointers are found at fixed locations. The pointers make the beginning of the three VC-3s relative to the VC-4. On one hand it makes possible to insert data signals at any point of time in the form of VCs into the respective higher level frame without a buffer. On the other hand, changes in the phase of the VC with respect to the next higher-level frame can be correlated through a appropriate pointer change. Such changes and phase shifts have caused, such as delay time variations, in the transmission medium or non synchronous branches in the real network. During decomposition of multiplex group, pointer technology makes it possible to directly locate each data channel from every STM-N frame [10]. This considerably simplifies drop and insert mode at network nodes. This is unlike the PDH, where complete demultiplexing is required to be done at each level to access the desired data channel.

Administrative Unit is the information structure, which provides adaptation between higher order path layer and the multiplex section layer [11]. It consists of information payload and Administrative Unit pointer. Administrative Unit location is fixed with respect to STM-frame. Administrative Group Unit consists of a homogenous assembly of AU-3s or AU-4.

B. Fibcom6325 STM-1 System Description

The Fibcom AC1 is a product family where STM- 1 and STM-4 Add/Drop Multiplexers (ADM) and Terminal Multiplexers (TM) are implemented on a single module giving VC-4, VC-3 and VC-12 connectivity.

A Fibcom 6325 node holds modules in a subrack, which is installed in a rack. The actual configuration of the subrack and the modules defines the function and the capacity of the equipment. The subrack consists of 9 slots. SIMX-16, SIMX-4, SPIMX, PIM-1, EMAP are the traffic modules that can be inserted in the slots of Fibcom 6325.

SDH Interface Module-16 (SIMX-16) is a five port module with cross connect. Four of the ports can be equipped with pluggable transceivers for optical STM-1 or STM-4 interfaces. One port can be equipped with a pluggable transceiver for an optical STM-16 interface. The module also contains an interface for external user channels.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

SDH Interface Module-4 (SIMX-4*)* is a four port module with cross connect. Each port can be equipped with a pluggable transceiver for an optical STM-1 or STM-4 interface. The module also contains an interface for external user channels. PIM-1 is a PDH interface module. It provides 21x2 Mbps channels.

SDH Interface Module (SIMX) is a six port module with cross connect. Two ports can be equipped with pluggable transceivers for optical STM-1 or STM-4 interfaces. Four ports provide 2 Mbps (E1) interfaces. It provides 21x2 Mbps channels.

Ethernet Mapping (EMAP) and Central Management and Communications Control (CMCC) is an Ethernet mapping card. CMCC is central management and communications control module that handles the main management tasks in the NE. PS-DC is power supply module. One power supply module is required. But a second PS module may be fitted. This provides power supply equipment protection.

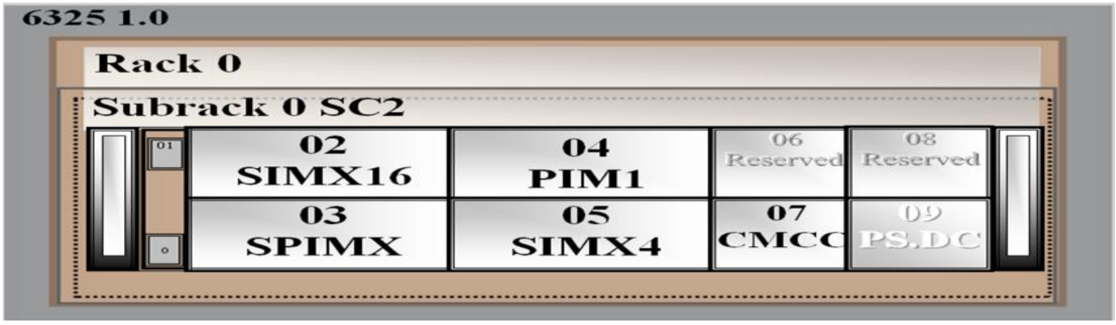

Fig. 5 Slot positions of Fibcom 6325 subrack

V. PLISIOCHRONOUS DIGITAL HIERARCHY (PDH) EQUIPMENT

The plesiochronous digital hierarchy (PDH) is a telecommunications network transmission technology designed for the transport of large data volumes across large scale digital networks [8]. The PDH design allows the streaming of data without having isochronous (clocks running at identical times, perfectly synchronized) to synchronize the signal exchanges. PDH clocks are running very close, but not exactly in time with one another so that when multiplexing, signal arrival times may differ as the transmission rates are directly linked to the clock rate. PDH allows each stream of a multiplexed signal to be bit stuffed to compensate for the timing differences so that the original data stream could be reconstituted exactly as it was sent [9].

A. Webfil Fleximux system description

Fleximux is a versatile 30-channel (2.048 Mbps) digital voice and data multiplexer. Besides, use as terminal equipment, it has the capacity of channel-wise drop and re-insert as a wayside unit with flexible voice interfaces for different adaptations. The design caters for user selectable low and high speed data interface option. The in-built Network Management System (NMS) allows centralized configuration as well as remote status and performance monitoring of the network by a PC. The associated external equipment in the system can also be centrally controlled via NMS.

Analog and digital services are realized with interface specific access units connected to an internal 2 Mbps bus. Each of the access units accommodates one to four channels depending on the complexity of the interface. Each individual service channel consumes one time slot (voice and data up to 64 Kbps) and fractional time slots (low speed data up to 19.2 Kbps) of the 30 time slots available for use with the 2 Mbps stream. The realization concept of the Fleximux is shown in Fig 2.

The Network Interface Module primarily takes care of alarm acquisition function from various network elements. The Network Interface module is used for exchange of information among the Network Manager, the Tributary Module and the various access modules interconnected via the backplane.

The Tributary Module is the heart of the system which interfaces to the 2 Mbps stream and realizes the add/drop function of the channel through digital cross-connect. The Tributary module accepts two 2 Mbps from two directions in NRZ format from PCM channel port. The derived data of the two streams are then presented to frame aligners to locate and synchronize the frame and multi frame boundaries. Each stream of the recorded clock and data then passes through jitter attenuator to the framer which locates frame and multi-frame boundaries and extracts alarms also. Then the data enters into an elastic buffer which absorbs phase and frequency differences between the incoming stream and the master clock of the system as well as network. The stream then undergoes through cross connections as desired. The outgoing stream is transmitted in synchronization with master clock and also synchronized within them.

The ultimate objective of the Fleximux is to add/drop selective time slots from the time multiplexed 2Mb data stream for local access of voice and/or data. Using the flexible channel cross-connect feature, any time slot of 2Mb stream can be mapped to any one of the local channel access module for the necessary interconnection. For voice, normally various types of access interfaces are required to satisfy the user's requirement.

The power supply unit operates from -48V supply. The input power is fed through a surge protector and filter section to protect the system from high voltage spikes and lightning strikes coming along the power line.

PDH equipment is connected to the system for the add/drop programming through RS232 interface module. The 32x64 Kbps channels are provided to the control communication equipments through Data interface module.

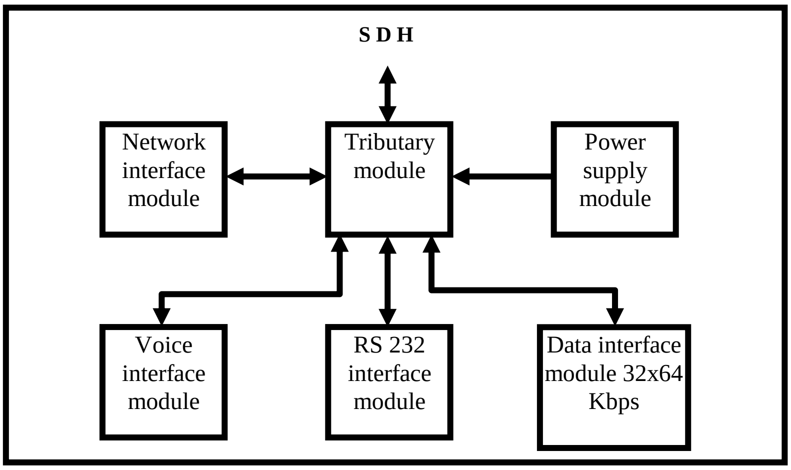

Fig. 6 Block diagram of Fleximux

VI. CONTROL COMMUNICATION EQUIPMENTS

The control communication equipment comes after the PDH equipment in railway telecommunication network transmission technology. The control communication equipment is assigned with a channel out of 30 channels from the PDH equipment.

Control phones are one-way communicating units with only receiving option. Each and every waystation is equipped with control phones. Two out of 30 channels from PDH equipment are assigned to control phone, one as main and another as backup channel. Along the railway track at every kilometer distance a unit called emergency control communication terminal is provided. These units are linked to the control phone channels of waystation. During emergency the loco pilot with his handset can come in contact with control phone through these emergency control communication terminals.

BPAC is fixed to the axil of the engine wheel. It works in such a way that for every rotation of the wheel it produces a pulse confirming the engine motion. Based on this information the location of the engine is traced in the test room. Three out of 28 channels from PDH equipment are assigned to this unit, one as main and other two as backup channels.

Auto phones are two-way communicating equipments. Each and every waystation is provided with this auto phone unit. The remaining 28 channels of PDH equipment are assigned to auto phones.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

VII. CONCLUSION

The paper gives an overview of optical network establishment between the waystations using SDH, PDH and Control Communication Equipments. SPIMX traffic module of Fibcom6325 synchronous transport module level-1 SDH equipment is used to split a portion of available bandwith into 21x2 Mbps channels. Out of 21 channels, each channel is assigned to a waystation and its next immediate station forming a pair. Each 2 Mbps channel is further split into 32x64 Kbps sub channels using Webfil Fleximux PDH equipment. Out of these 32 sub channels, channel 1 and channel 16 are reserved for signaling information. Channel 2, 3 and 4 are connected to control phones. Channel 5 and 6 are assigned to trace the train position in the test room and remaining channels to auto phones of each waystations. The 32x64 Kbps sub channels are add/drop multiplexed as per the requirements of control communication equipments of each waystations.

ACKNOWLEDGMENT

With great affection I thank my parents and society for their wholehearted support in preparing and presenting this paper.

REFERENCES

[1] Prachi Sharma, Rohit Kumar Arrora, Suraj Pradeshi and Mandeep Singh, Fibre Optic Communication: An overview, IJETAE, vol. 3, iss. 5, May 2013.

[2] Gerd Keiser, Optical Fiber Communications, McGraw Hill, 4th edition, 2008.

[3] G. P. Agrawal, Fiber-Optic Communication Systems, Wiley, Hoboken, 3rd edition, 2002.

[4] ITU_T Recommendation G.652, Characteristics of a single mode optical fibre cable, Nov. 2009.

[5] Cisco Systems, Inc., San Jose, California, USA, www.cisco.com.

[6] H.G. Perros, Connection-Oriented Networks: SONET/SDH, ATM, MPLS and Optical networks, Wiley, Hoboken, NJ, 2005.

[7] Ninko. B. Radivojevic and Predrag Z. Micovic, Design and Testing of SDH Equipment Clock (SEC) in SDH 155Mbit/s System, Proc. IEEE, vol.2, pp. 570-573, Oct.1999.

[8] ITU_T Recommendation G.709, Interfaces for the optical transport network, Feb. 2012.

[9] ITU_T Recommendation G.783, Amd.4, Characteristics of a Synchronous Digital Hierarchy (SDH) equipment functional blocks, Aug. 2013.

[10] ITU_T Recommendation G.692, Amd.1, Optical interfaces for multi channel systems with optical amplifiers, Jan. 2005.

[11] ITU_T Recommendation L.35, Amd.1 Installation of optical fibre cables in the access network, Nov.2007.

[12] ITU_T Recommendation G.707, Amd.2 Network-Node Interface for the Synchronous Digital Hierarchy, Nov. 2009.

[13] ITU_T Recommendation G.957, Optical interfaces for equipments and systems relating to the synchronous digital hierarchy, Mar. 2006.

[14] David Sanchez, Carmen Guerrero, Angel Vina, Modeling Legacy PDH equipments. From General Models To Real TMN Solutions, Proc. IEEE, vol.1, pp. 186-195, Apr.1998.

[15] ITU_T Recommendation G.705, Characteristics of plesiochronous digital hierarchy equipment functional blocks. Oct. 2000.

AUTHOR BIOGRAPHY

Mr. Prajwalasimha S N pursued his Bachelor of Engineering in Electronics and Communication from Visvesvaraya Technological University, GEC, Chamarajanagar, Karnataka, India and currently pursuing his Master of Technology in Digital Electronics and Communication Systems from Visvesvaraya Technological University, Department of Post Graduate Studies, Mysore, Karnataka, India.