

Review Of Optical Fiber Communication System- Introduction And Applications

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Abstract— In this paper complete comprehensive analysis of optical fiber communication system has been done. The parameters used in OFC communication system have different laser setup, wavelength bands, power level, modulation formats. An Optical fiber cable deals with examine of light that travels through dielectric medium. With the use of optical fiber cable in considerable parts of the world. In this paper, optical fiber cable (OFC) system with SMF cable is discussed which grants the propagation of light using total internal refraction (TIR) technique. The fiber cable composed of core enclosed by the cladding and both are made of dielectric materials. The single mode fiber cables are ideally suited for maintaining the uniformity of each light pulses which is totally contrary in case of multimode fiber cable. This allows for the transmission of more information per unit of time due to this advantage single mode fiber of boosts of higher bandwidth as compared to multimode fiber cable. The only disadvantage of single mode fiber cable is smaller core diameter, which makes the coupling of light between two single mode fiber cables difficult. This paper contributes the performance evaluation in the form of table collectively with the main characteristics of the modulation formats used in the OFC. These modulated signals are then transmitted through optical fiber cable and received by the optical detector to dictate the overall system performance and then analyzed by the eye detector. This paper closes with the discussion of the different applications of the optical cables used in the transmitting and receiving of data in a variety of industries like telecommunications, broadcasting, lighting and decoration, medical fields etc.

Keywords—Optical Fiber Communication (OFC), Waveguides, Single Mode Fiber (SMF), Total Internal Reflection (TIR), Bit Error Rate (BER).

I. INTRODUCTION

The optical fiber communication is a method of conveying information from transmitter to receiver by transmitting light signals. The OFC system is a fastest and simple method of the communication as compared to any other communication system [1]. This technology is used

to send the signals over the longer distance without repeaters. Usually fiber optic networks are most commonly used as the contact line for hardwired terrestrial previous to the optical fiber cable, the carrier frequency used in conventional systems had the disadvantages of organizing the data transmission [2]. On the contrary optical fiber cable can easily handle the large volume of data transmission in terms of light signals. The higher the wavelength of the transmitter, the greater is the usable bandwidth and the ability to carry information. In several parts of the world, the Fiber to the Home (FTTH) turns into fact, providing broadband capability up to the doorstep of home [2]. The “Fig. 1” optical fiber communication system consists of optical transmitter which is basically used to encode the information. It generally consists of PRBS generator which provides digital data in form of bits/sec. These bits then pass on to MZM modulator through modulation techniques [3]. The laser light is also passing on to MZM modulator which combines both signals and transfer the information further to optical fiber cable.

The Optical fiber cable acts as a medium between transmitter section and receiver section which passes the information to the photo detector. The receiver receives the optical information and converts it into electrical form this electrical information is then analyzed with the help of eye analyzer to check Q factor and BER of converted signal [5]. The Bessel low pass filter is also used prior to the eye analyzer.

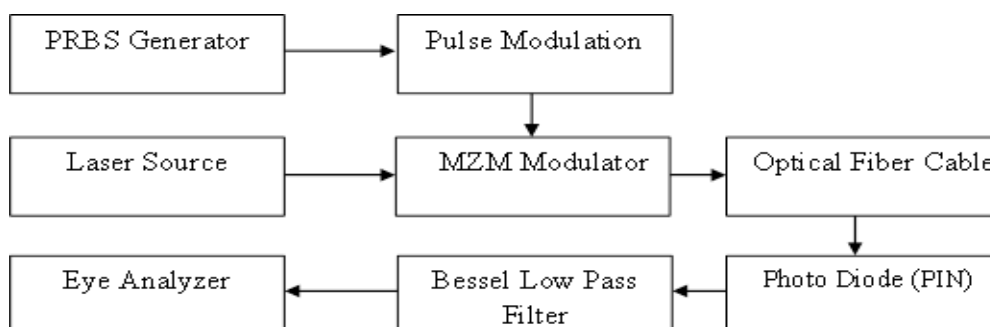


Fig. 1. Optical fiber communication system using single mode fiber

II. DESIGNING AND MANUFACTURING

The optical fiber cable is a very thin glass cable just like human hair extracted from Silica glass. It is chemically purified and has very low absorption loss. Traditional wires are replaced with these optical fiber cables. These cables are used as the transmission medium having higher bandwidth to carry the information in form of light from source to the destination [4].

The optical fiber consists of primarily SiO_2 , while the liquid silicon is the main source for the fiber manufacturing and the process is done by using vapor deposition method. A flame underneath the rods makes the rod walls hot, resulting in the formation of high-purity silicon dioxide. The effect is glassy soot, which is accumulated within the rod in a series of dense layers. This soot will become the core of optical fiber cable. The properties of these layers of soot will vary depending on the chemical vapors used [7].

After the soot has been prepared to the appropriate thickness, the substrate rod is heated again to eliminate any moisture or stuck bubbles in the soot layers and the internal soot layers gets hard in form the balls. The solid soot was then transferred to the vertical fiber drawing device automatically. The machine that prepares a conventional vertical drawing device, which can be two stories high and capable of generating continuous fiber cables [8].

The core consist of (soot) is then enclosed with protective layers of the materials such as Al, polyethylene and kevlar (cladding). Since the core (inner) and the cladding (outing) are constructed of differing materials, light travels through at different speeds [9].

III. THE BASIC OPERATIONAL THEORY

The optical fiber cable consists of non-conducting waveguide that transmit the light signals along the axis based on the effect of TIR. In optical fiber cable, the core is surrounded by cladding, and the refractive index (n_1) of the core must be greater than the refractive index (n_2) of the cladding in order to confine the optical signal in the core [4][5]. The boundary between the core should be instantaneous (step index fiber) or cladding should be progressive (graded index fiber). The optical signal used to transmit data can be taken from either LED or LASER source. The optical fiber cable is immune to interferences especially electrical signal. It is also immune to crosstalk between the signals in different cables [6]. The noise factor is also very negligible in case of optical communication. The fiber cable don't conduct electricity therefore makes it reliable and protective communication equipment because of this property the optical fiber cable can be used as a communication source where likely to explode fumes are present. The only demerit in optical fiber communication is the wire lapping. Further the optical fiber divided into propagation mode which is termed as signal mode or multimode. If there is one direction to follow for optical signal then it is termed as single mode propagation. If there exist in more than one path it is termed as multimode propagation. The single fiber structure is shown in figure 2 below. It is formed by a solid dielectric cylinder. This cylinder is known as fiber heart. The core has dielectric surroundings, called cladding. The core refractive index (glass fiber) is much higher than the cladding refraction index [8]. The optical fiber cable structure is shown in the Fig. 2 below.

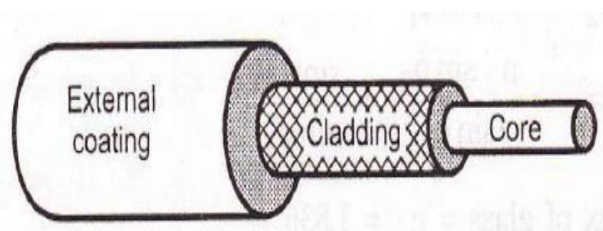


Fig. 2. Optical fiber cable design

The signal degradation is the important property in the optical fiber communication system which leads to the fiber nonlinearities and attenuation [9][10]. Any effect leading to attenuation and dispersion is based on optical wavelength. Where these effects are smallest, there are wavelength bands, and they are the most suitable for transmission [11].

The fiber cables can be categorized according to their mode as well. Light-rays travel through the fiber like an electromagnetic pulse. The two components form patterns throughout

the fiber, the electrical field and the magnetic field. These patterns are called transmission modes. A fiber mode refers to the number of paths within the cable, for the light rays [12][13]. Optical fibers can be classified into two modes which are given below.

- a) Single mode fiber (SMF)
- b) Multi-mode fiber (MMF)

SMF: It supports a single path for light, it can be used for long distances having high bandwidth [12].

MMF: It supports hundreds paths for light. This type of mode is applicable only for the small distance and is having a low bandwidth [13].

IV. LITERATURE REVIEW

Koonen et al. (2010) reviewed that the Fiber to the Home (FTTH) technology capable of providing broadband services up to the door step. SMF (DIY) and CAT- 5E network set up were made while performing the experimental set up. It showed that in a single fiber-based backbone network, which was more flexible and cheaper to build than a CAT-5E network, the combined distribution of wired and wireless networks can be realised with benefit [21].

Chhilar et al. (2011) has analysed the system performance by using the three different digital modulation formats RZ, NRZ and CSRZ. It is found that the CSRZ modulation format gives the minimum ber [31].

Monjur et al. (2011) studied the various forms of dispersion approaches in different kinds of fibres. The test set up configuration consist of DFL operation at 1550 nm generated the CW light of 5 MHz. The simulation had been done using different fibers to find dispersion coefficient of each fiber. Author analyzed that the performance of P-IFM technique was used to find the dispersion compensation and the result obtained in terms of bandwidth and ACF [24].

Ma et al. (2012) investigated the stream signals at 10Gb/s down and 2.5Gb/s up. The Signals from downlink and uplink have SSB spectra, which suffer from fiber dispersion. The full duplex RoF connection had been set and the error vector magnitude (EVM) had been used to test the complete setup efficiency. As the power obtained decreases, the uplink EVM increases and the length of the uplink fibre increases. It demonstrated the complete duplex RoF connection scheme to produce the cheap and realizable high frequency optical wave signal [11].

Igweani and Al-Raweshidy (2013) has experimentally demonstrated their simulation design at low operating wavelengths by using single mode fiber and multi mode fiber to enhance the capacity of transmission over the long distance [41].

Marc and Mathieu (2013) suggested the microwave cable link, which affected the usual airborne random vibration as compared to a direct-modulated optical connection. The direct-modulated optical microwave link was planned with the laser diode distributed Feed-Back and the Modified Unilateral Travelled Photodiode at 1.5 μ m. Direct modulated optical link has been successfully tested [18].

Sharma et al. (2013) reviewed the various papers based on the development in the optical fiber communication system and concluded that due to the low attenuation characteristics and higher bandwidth capabilities optical fiber is used for the higher bit transmission [29].

Yu et al. (2014) studied the sub-system for long haul transmission and fiber Bragg grating to monitor the bridge situation and bridge emergency. The direct-modulated optical microwave communication was designed with the modified unilateral travelled photodiode and distributed feed-back laser diode. The experimental set-up used a narrow wavelength coupler, laser diode, two optical circulators, and Erbium doped fibre. The separate output power levels were reached at the end, between the top and bottom routes less than 1 dB [46].

Rindhe et al. (2014) evaluated the OFDM based system for optical networks. The behaviour of optical network was visualized for frequency domain simulation by using optisim software. The author recorded negligible capacity decay without using any dispersion compensation [42].

Cen et al. (2015) proposed expanding the distance between end-users and central office with the use of Long-Reach Passive Optical Networks. Using TRA-based control technique, fibre split and a bending over a long standard single-mode fibre was implemented at five separate locations. In addition to fibre breakage, experimental bending verifications were also carried out. It investigated the existence of an LR-PON tracking scheme based on TRA by using the "dark fibre." The capacity to identify numerous types of faults in the feeder ring was confirmed [23].

Matsui et al. (2015) suggested that multi-core fibre cladding of 125 μ m would be compatible with single-mode fibre. The Optical communication software was used for the simulation, and analysis of proposed data. The manufactured MCF has been introduced in all communication bands to high-speed SDM transmission, and can be attached to an existing SMF [40].

Yeh et al. (2016) proposed a stable longitudinal single mode (SLM) laser ring structure for the erbium doped fibre (EDF). The complete setup showed good output stability and wavelength tunability on the EDF triple ring laser with SLM efficiency. It demonstrated the wavelength and stable triple ring laser SLM EDF experimentally. The final results showed that output power received on using wavelength in C band [2].

Lu et al. (2017) proposed a bidirectional merging system based two optical sidebands with orthogonal polarization for fibre-IVLLC and fibre-wireless. The Optical communication Software was used for the simulation and analysis of proposed data. The final results from the analysis showed good CNR and BER performance over a long distance using Single mode fiber [7].

Aleshkina et al. (2018) investigated the novel saddle Yb doped fibre with single mode fibre in 976 nm wavelength. The manufactured saddle shaped Yb doped fibre used to provide high efficiency and reliability within the laser scheme. The optimized saddle shaped Yb doped fiber would provide increased pump to signal conversion efficiency [37].

Mishra et al. (2018) have made the comparative analysis of the three modulation schemes CSRZ, NRZ, and RZ at different power levels. The optisim software was used to design eight channel DWDM system using CSRZ, RZ, and NRZ modulation schemes. The author has compared all three modulation schemes and found increased modulation efficiency for CSRZ [33].

Chen et al. (2019) had suggested the broadband and 1300 nm high-power DML used to increase the transmission distance. An Experimental set up was prepared and results were obtained on optisim software. The 1300 nm DML-driven Bit Rate transmission with NRZ and PAM-4 signals over SMF was obtained without additional equaliser or compensator [35].

Mukherjee et al. (2019) had proposed a hybrid transmission method for the bidirectional group radio-over fibre (RoF) antenna based on incoherent light injection and predistortion of radio frequency amplifiers to diminish nonlinearity of the third order. The optical communication system software used to explain the optical free-running FPLD spectrum. It demonstrated the Downlink 10-Gbps and uplink 5-Gbps were successfully transmitted simultaneously [34].

Gonda et al. (2019) had investigated the design of MCFs compatible with standard single mode fibres (SMFs) to minimize the duration time for connections. The four core MCF has a heart with regular cladding diameter of 125 μ m was designed by replacing all the existing SMFs with MCFs. It observed that the optimized bit rate transmitted successfully using MCFs [38].

Mahawar and Khunteta (2019) proposed a system to minimize the effect of chromatic dispersion in fiber cable. The implementation of a new transmission model using optisystem 7.0 software were done by using the 8 channel wavelength division multiplexer (WDM). The analysis provides the best result obtained by using RZ max Quality factor and minimum BER [25].

Rasheed et al. (2020) have proposed an optical fibre communication system to provide the unlimited capacity for transmission to meet the demand for bandwidth. Using optisystem tools, simulations and analyses of full multiplexer system for long distance communication system were performed. The result suggested that pre-distributed amplifier was stronger than post amplifier BER. The Optimized data rate were achieved with the use of optical amplifiers, DCF, Gaussian filters [22].

Sun et al. (2020) have compared the four transmission models (FP, MZ, AR, and MMI) based on the various ID's SMF- Capillary- SMF structure. The fabrication process was carried out using the fiber fusion splicer to splice the capillary short sections between two regular single mode fibres and the air core IDs selected as 10 μ m, 15 μ m and 20 μ m. The result shows that the MZ depends on the capillary ID and AR transmission get stronger as the length of propagation increases over a given range [44].

Kaushik et al. (2020) The author reviewed the compact, faster and user friendly digital technology. With the help of digital signals 0 and 1 the information provided by the OFC

system is encoded. Channel losses must be minimized for the long distance communication [27].

Nandwalkar and Pete (2020) proposed that how the splicing losses can be minimized while relocating the optical fiber communication set up. The author performed two different activities one for short distance and one for longer distance to check the properties of splicing. The splicing loss remains as same as zero at the end but the complete loss is a mixture of additional losses such as bending loss, refractive loss etc. [12].

Shanmugapriya and Raveena (2020) has experimentally demonstrated that the optical fiber cable which is the very important communication channels for transmitting and receiving the signals. In this paper authors compared the performance of the single mode fiber and multimode fiber [30].

TABLE I. COMPARISON BASED ON THE DIGITAL MODULATION SCHEMES USED BY DIFFERENT AUTHORS

Author	Year	Digital modulation technique used	Fiber Used	Laser Used	Operating Wavelength
Yin et al.		NRZ, RZ, CSRZ	SMF, DCF	CW Laser	1550 nm
Chhilar et al.	2011	RZ, NRZ, CSRZ	SMF	_____	_____
Moghaddasi and Rahman		RZ, NRZ	SMF with DCF	CW Laser	_____
Li et al.		NRZ, RZ, CSRZ	SMF with DCF	CW Laser	1550 nm
Sudhakar	2013	RZ	SMF	Laser Diode	1550 nm
Senthamizhselvan et al.	2014	NRZ, RZ	SMF	Stimulated Raman Scattering	1550 nm
Singh et al.	2016	RZ, NRZ	_____	_____	_____
Zhou et al.	2016	PAM	SSMF	DML	C band
Ahmed and Mahmood		PAM	SMF with DCF link	CW Laser	C band
Mishra et al.	2018	NRZ, RZ	SMF	Continuous wave laser	1550 nm
Mahawar et al.	2019	NRZ, RZ	SMF	Continuous wave laser	C band
Chen et al.	2019	NRZ	SMF	DML	1300nm
Shanmugapriya and Raveena	2020	NRZ	SMF	Continuous wave laser	1550nm

Larisch et al.	2020	NRZ	SMF	Continuous wave laser	910nm
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Optical signals were transmitted by using the three modulation formats i.e. the RZ, NRZ and CSRZ through SMF with DCF. The ability of anti nonlinear of the RZ and CSRZ is considered greater than the NRZ [15] [16]. The RZ & NRZ modulation formats are investigated by the electrical & optical dispersion compensation. It is also found that the electrical compensation NRZ give the better performance than the RZ and in optical compensation RZ has given the better performance [16]. The optical signal was transmitted through the SMF with DCF by using the RZ & NRZ modulation formats. The RZ modulation is superior to the NRZ modulation according to researchers [27]. The Figure 3 shows the simulative set up for digital modulation.

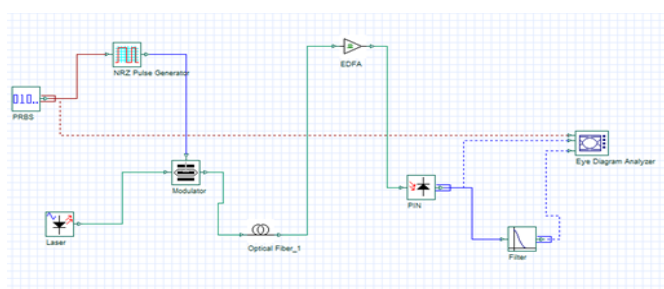


Fig. 3 Simulative set up for NRZ pulse modulation

In addition to the conventional on- off keying (OOK), there are other advanced modulations which are gaining the universal interest due to better performance and higher efficiency [16]. The comparative analysis of the different modulation schemes had made at different power levels and found increased modulation efficiency with the NRZ modulation scheme [27] [28].



Fig. 4 Graphical representation of years Vs modulation formats

As per in the figure 4 and figure 5 different modulation schemes are used to transmit the data at best suited wavelength and it is shown above in the graphical representation of years vs modulation formats and below in the graphical representation of years vs operating wavelength.

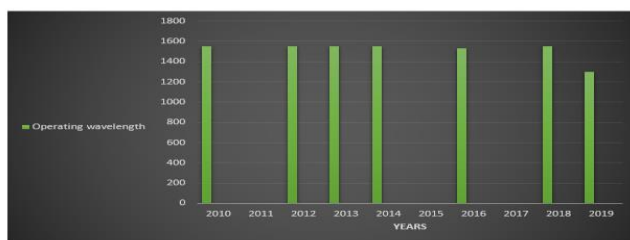


Fig. 5 Graphical representation of years Vs operating wavelength

The photo detector plays very important role in the conversation of the received light signal into an electrical signal. The PIN photodiode is used in Fig. 1 to allow the operation at higher wavelength. At the end of the optical communication system, the eye analyzer is used to analyse the output and the output is analyzed in the terms of BER and Q factor [41] [42] [43] [45].

COURSE OF ACTION

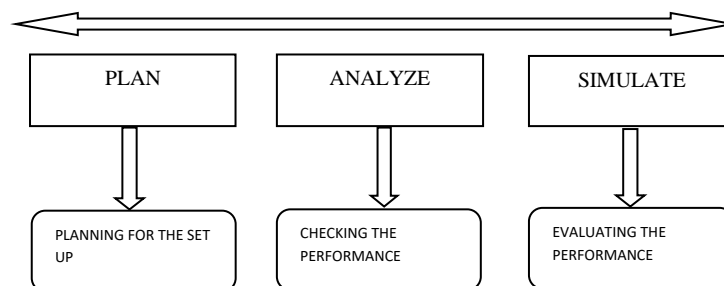


Fig. 6 Course of action to evaluate the system from source to destination

It helps the researcher to understand the facts about the certain issues. Accordingly, to the issues, the required planning is done for suitable set up. The designed set up is then observed for the various parameters used to solve the issues and at last, the performance of the system is assessed to get the improved results.

Conclusion

The researcher provides the comprehensive study of optical fiber cable with its design and encourages further research in the concerned field the collective data from the recent years papers represents how the transmission of optical data is done in form of bits per seconds from transmitter to receiver.

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