ANALYSIS OF DISPERSION REDUCTION IN FIBER OPTIC

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Abstract

Fibre optic has the key to telecommunication of the future, hence it is among the major building block of telecommunication infrastructure due to its high bandwidth capabilities and low attenuation characteristics that make it ideal for gigabit transmission and beyond. However, it is bottle neck by an important characteristics that often cause incorrect transmission of information at it receiving end known as dispersion, characterized by pulse broadening which hinder the amount of information that can be conveyed as well as distance of transmission. This study carryout measurement of dispersion for 650nm to 1800nm wavelength employing Erbium doped fiber amplifier (EDFA) and collating the result obtained with that acquired without EDFA, the collation however gives impressive result in favour of EDFA technique. The results were further validated with simulation analysis and thus, authenticate the technique employed in the study.

Keywords: Fiber optic, Erbium Doped Fiber Amplifier, Dispersion and reduction.

1. Introduction

A communication system conveys information from one place to another, whether separated by a few kilometres or by transoceanic distances. The information is often conveyed by an electromagnetic carrier wave whose frequency can vary from a few megahertz to several hundred terahertz. However, Optical communication systems also called light wave systems employ high carrier frequencies (∼100 THz) in the visible or near-infrared region of the electromagnetic spectrum to convey signal in a medium that transmit information in the form of light called fibre optics [1]. The light wave system can range from simple local area network to extremely intricate and expensive long distance telephone or cable television trunking.

Contrary to other forms of transmission such as copper and the like, fibre optics is not electrical in nature. Basically, a fibre optic system shown in Fig 1, contains an optical transmitting device that transforms an electrical signal into a light signal, an optical fibre cable that conveys the light, and an optical receiver that take in the light signal and transforms it back into the original electrical signal [2].

Fig 1: Block diagram of optical communication system

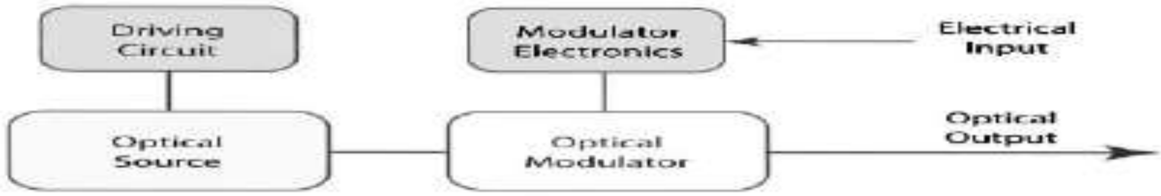


Fig 2: Block diagram of Optical fibre transmitter

2. Literature Review

It is well establish in the literature that fibre optic is a channel through which information can be conveyed through a glass or plastic fiber. However, when dissimilar wavelengths of light pulses are set in motion into an optical fibre, they will moved at entirely different speeds as a result of slight difference of refractive index with wavelength. Hence, the light waves tend to get disperse in time after moving some distance in the optical fibre and this will persists all over the length of the fibre. This phenomenon is known as dispersion and according to [3], it is one of the linear characteristics of fiber optic and it can be lessen by employing core of smaller diameter. Thus, it allows fewer modes and can only be used for short distance.

Additionally, in [4] the dispersion behaviour of single mode fiber was studied by the use of relative refractive index to create dispersion shifted fiber and the result revealed that dispersion null must be at wavelength of minimum attenuation.

moreover, examination of effect of temperature on optical fiber chromatic dispersion and dispersion slop were carried out by [5], this results in mathematically formulating a model expression for the chromatic dispersion slop variation and also validating the model developed by Ghosh et.al for the Silica refractive index temperature dependence which can be employed to define the variation of the dispersion slope within the temperature interval of -40ºC and 60ºC. Thus, inferred that the influence of temperature cannot be disregarded in the design of dispersion compensation devices especially for high bit rate systems.

Further, some measurements on dispersion were carried out in [6] to comprehend the dispersion characteristics and also to ascertain and validate the empirical measurement carryout in the study via the existing conceptual formulation.

In essence quite a large number of studies were carried out on the dispersion, its effects and ways of reducing dispersion in literature, thus [7] carried out critically literature survey on dispersion, highlighting some core causes of dispersion, method of measurement and its effect. Effect such as pulse broadening, degradation of the transmission quality to mention are few were explained in details.

3. Dispersion Generation and its effects

Dispersion in simpler terms is the scattering of information of whatever type (voice, video or data) inform of light pulses as its moves over the length of fiber optic, as established earlier it is produced as a result of variation in the refractive index from cladding to the core of fiber optic. This make the rays striking the boundary at an angle greater than critical angle to be somewhat reflected and partly transmitted throughout the boundary [3]. The consequence is that the information passing via fiber optic arrive at the endpoint at different time due to dissimilarities in fiber optic modes and angle at which the information travels.

Therefore, dispersion is one of the fundamental problem that is confined in optical fiber which is characterized by pulse broadening as presented in Fig 3.

Fig 3: Pulse broadening caused by dispersion

However, dispersion as well discussed in literature are broadly classified into **Modal Dispersion** that arises in multimode optical Fiber, when rays of light that travels at the same speed over different path reaches their destination at different time. Thus, dispersion occurred due to different path length in the fiber [8]. **Material Dispersion** that emerges when different wavelengths travel at different velocities through fiber in same mode, thus different wave change speed differently and refracted differently. **Waveguide Dispersion** that come about in single mode fiber due to different refractive indices in the core and cladding and as a result of differences in refractive indices of the material, the energy travel at different velocities in the core and cladding which distort the internal structure of the fiber that produces waveguide dispersion. **Chromatic Dispersion** that arises as a result of propagation delay of group velocities of different wavelength that make up source spectrum.

4. Proposed Technique for Reducing Dispersion

There are many techniques employed in dispersion reduction such as Fiber Bragg Grating (FBG) technique, Optical Phase Conjugation (OPC) technique, well discussed in [8] and much more. However, Erbium doped fiber amplifier (EDFA) is employed in this study to reduce dispersion. EDFA is an optical device employ to compensate the loss of an optical fibre in primary wavelength band and long wavelength band, in a long distance optical communication. It can directly strengthen the signal of multi-wavelength to effectively extend the transmission distance. In this study two system were considered one with and the other without EDFA device, the system with EDFA device was configured to send data via the device each 5sec with holding period of 2 mins. The study was conducted for period of ten months using MTN Nigeria fiber optic over a distance of 120Km and wavelength ranging from 650nm to 1800nm.

5. Analysis

The results obtained with EDFA depicted in Table 2 was compared with the result found without EDFA device presented in Table 1. Also the variation between these two results is displayed in Table 4, while Table 3 present the effect of dispersion known as pulse broadening.

Table 1: Dispersion in fiber optic without EDFA

S/N	Wave length (nm)	Dispersion (ps/nm-Km)	S/N	Wave length (nm)	Dispersion (ps/nm-Km)
1	650	-152.901	13	1250	12.3858
2	700	-120.313	14	1300	16.8663

3	750	-86.609	15	1350	20.9539
4	800	-64.2077	16	1400	24.7211
5	850	-51.3820	17	1450	28.2268
6	900	-51.9441	18	1500	31.5187
7	950	-20.0577	19	1550	34.6358
8	1000	-15.1214	20	1600	37.2235
9	1050	-1.6951	21	1650	40.5115
10	1100	1.4511	22	1700	42.0110
11	1150	2.1421	23	1750	45.5335
12	1200	8.5787	24	1800	55.6556

However, simulation analysis for dispersion without and with EDFA revealed the extraordinary dip like and linear characteristics depicted in Fig 4(a) and (b) respectively, this clearly signifies how dispersion was well handled by the EDFA and shows the longer the distance of transmission the broader the dispersion. Hence, comparison of the two figures mentioned above illustrates reduced dispersion and better transmission performance for the proposed technique of reducing dispersion. Moreover, some important characteristics of dispersion were evaluated and presented in Fig 5. Fig 5(a) present the effect of wavelength variation against Pulse broadening while Fig 5(b) is a pulse broadening at a distance of 120km, which implied that pulse broadening increases with increasing distance of transmission in fibre optic.

Table 2: Dispersion in fiber optic with EDFA

S/N	Wave length(nm)	Distance (KM)	Dispersion (ps/nm-Km)	S/N	Wave length(nm)	Distance (KM)	Dispersion (ps/nm-Km)
1	650	5	-60.3223	13	1250	65	-1.3609
2	700	10	-50.3130	14	1300	70	5.1509
3	750	15	-43.9060	15	1350	75	9.1969
4	800	20	-41.0727	16	1400	80	12.8925
5	850	25	-35.2083	17	1450	85	16.2979
6	900	30	-28.4149	18	1500	90	19.4617
7	950	35	-23.7507	19	1550	95	22.4242
8	1000	40	-18.1421	20	1600	100	24.2306
9	1050	45	-14.9651	21	1650	105	26.4959
10	1100	50	-10.1154	22	1700	110	28.8172
11	1150	55	-7.4121	23	1750	115	30.1510
12	1200	60	-4.3075	24	1800	120	45.5950

Table 3: Effect of Dispersion

S/N	Distance (Km)	Wavelength variation (nm)	Pulse broadening (ps)	S/N	Distance (Km)	Wavelength variation (nm)	Pulse broadening (ps)
1	5	0.01093	3.29	13	65	0.01063	0.94
2	10	0.01068	5.37	14	70	0.01126	4.06
3	15	0.0108	7.11	15	75	0.01196	8.25
4	20	0.00919	7.55	16	80	0.01273	12.69
5	25	0.00881	7.75	17	85	0.01355	18.77
6	30	0.00862	7.35	18	90	0.01444	25.29
7	35	0.00857	7.12	19	95	0.0150	31.95
8	40	0.00866	6.28	20	100	0.01539	37.29
9	45	0.00887	5.97	21	105	0.01634	45.46
10	50	0.00918	4.64	22	110	0.01729	54.81
11	55	0.00958	3.91	23	115	0.01819	63.07
12	60	0.01006	2.60	24	120	0.02819	154.24

Table 4: Dispersion Variance

S/N	Distance (Km)	Wavelength (nm)	Dispersion Variation (ps/nm-Km)	S/N	Distance (Km)	Wavelength (nm)	Dispersion Variation (ps/nm-Km)
1	5	650	-92.5787	13	65	1250	13.7467
2	10	700	-70.0	14	70	1300	11.7154
3	15	750	-42.703	15	75	1350	11.757
4	20	800	-23.135	16	80	1400	11.8286
5	25	850	-16.1737	17	85	1450	11.9289
6	30	900	-23.5292	18	90	1500	12.057
7	35	950	3.693	19	95	1550	12.2116
8	40	1000	3.0207	20	100	1600	12.9929
9	45	1050	13.27	21	105	1650	14.0156
10	50	1100	11.57	22	110	1700	13.1938
11	55	1150	9.55	23	115	1750	15.3825
12	60	1200	12.89	24	120	1800	10.0606

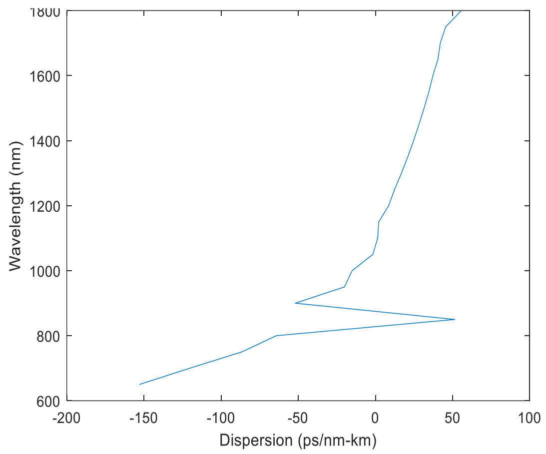


Fig 4: Dispersion without EDFA

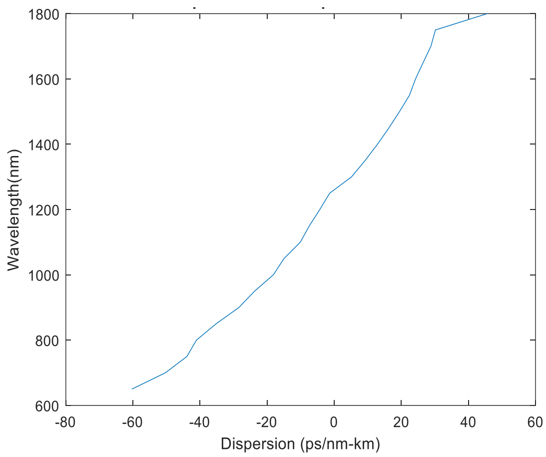
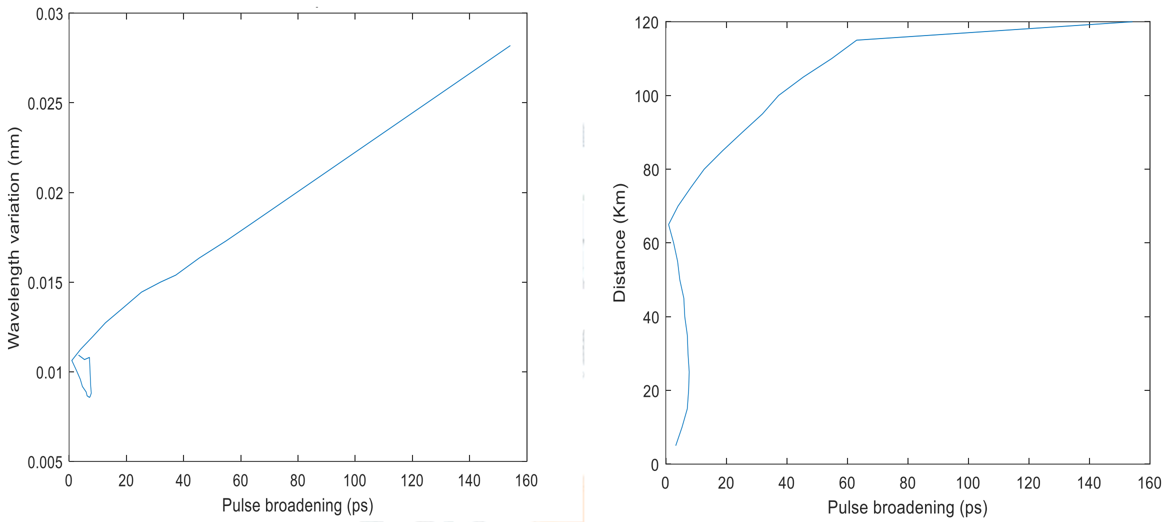


Fig 5: Reduced Dispersion using EDFA



(a) (b)

Fig 5:Demonstrating effect of dispersion with Pulse broadening (a) Wavelength variation (b) Distance

6 Conclusion

The phenomena of dispersion in fibre optic has been well discussed, it effects and some reduction techniques so far applied were also highlighted in this study, specifically this work gives emphases on dispersion generation, effect originating from dispersion generation and assessing an effective reduction technique. Though, an important technique of lessening dispersion known as EDFA was identified and validated as an effective technique of reducing dispersion and improving performance in fibre optics.

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