A Systematic Technique for Attenuation and Dispersion Reduction in Fiber Optics Communication using an Erbium Doped Fiber Amplifier

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***Abstract* —Optical fiber communication system limitations ranges from natural to artificial. In this work, the natural problems were understudied and enhancement solutions proffered using Erbium Doped Fiber Amplifier (EDFA). Experimental characterization was carried out over the period of 15months using MTN Fiber Optic backbone project as a test bed. The result obtained showed that amplification occurred in Erbium Doped Fiber Amplifier (EDFA) at 1550nm with almost zero attenuation and dispersion. With this technique it was observed that optic-electro and electro-optical conversion in normal amplification process which causes data losses was totally eliminated. The percentage of improvement in the research work compared with previous works was found to be 23%. The effectiveness of EDFA scheme deployed in reducing the attenuation and dispersion was shown in simulation result and Excel plots. A simulation validation showed an effective throughput response owing to zero dispersion and attenuation. From the data analysis result, it is feasible to address attenuation/dispersion issues in communication systems to a very minimal level with high electronic amplification.**

***Index Terms*: attenuation, dispersion, Erbium Doped Fiber Amplifier (EDFA), fiber optics, wavelength.**

I INTRODUCTION

Optical fiber technology has advanced rapidly in recent years, today digital optical fiber systems are being installed in numerous telecommunications networks around the world. But its challenges have always being attenuation and dispersion which is regarded as natural problems. Improper design and operating capabilities which requires knowledge of the transmission characteristics of the optical sources, fiber, and interconnection devices such as connectors, couplers, and splices, could be viewed as artificial problems [1]. The transmission criteria that affect the choice of the fiber type used in a system are signal attenuation, information transmission capacity; which is the bandwidth, source coupling and interconnection efficiency [2]. However, as the data rates and fiber lengths increases, limitations due to dispersion and attenuation in the fiber became impossible to avoid. Dispersion was initially a problem when the first optical fibers, multimode step-index fiber, were introduced. Multimode graded-index fiber improved the situation a bit, but it was single-mode fiber that eliminated severe multimode fiber related dispersion and left only chromatic dispersion and polarization mode dispersion to be dealt with by engineers [3]. In this work, an improved technique for reduction of limitations of signal loss as a result of attenuation and dispersion was dealt with deploying real-time approach.

II REVIEW OF RELATED RESEARCH EFFORTS

Research in [4] reported and analyzed the temperature dependence of the bending loss light energy in multimode optical fibers. It showed that the bending losses and the

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temperature measurement range depend on the curvature radius of an optical fiber or waveguide and the kind of the optical waveguide on which the sensing process is implemented. The paper only considered a single source of problem of optic fiber without considering the fact that some losses are inevitable but this work provides a kind of compensator as well as a short cut out of the losses.

In [5] the researchers claimed that modal and chromatic material dispersion in a multimode optical fiber can be reduced by feeding the rays of the light beam into the end of the optical fiber, the angle of each ray relative to the axis of the fiber varied in accordance with the wavelength of the ray. Actually this can reduce these types of dispersion to an extent and worst leaving attenuation and other types of dispersion untouched. Therefore, improvement in this work could provide up to 1000 times gain stability and by this differ to a great extent from [6] which used gain-clamping method to deal with the EDFA stability. Here, EDFA stability was achieved by adding an extra light wave into the gain medium to share upper energy ions together with the signal lights. It proposed a gain-clamped C-band EDFA based on an off-line optical band-pass filter (OBPF) and obtained an optimized C-band EDFA which provides up to 20 times gain stability improvement for multi-wavelength fiber optical transport systems.

III RESEARCH METHODOLOGY

This research work is divided into three parts: the data collection part; data analysis part and validation part. Three different data rate configurations were setup while measuring the values for the outdoor distance of about 140km as shown in Table 1.EDFA was used as optical amplifier in the 1530nm to 1570nm regions of the spectrum. An external laser source of 980nm and 1480nm bands were used to pump light into the EDFA. Two base stations: transmitter and receiver located in Abakaliki and Enugu respectively were used, where the transmitter was configured to send data through the EDFA every 5seconds with retention period of 2minutes. The raw data collated was recorded in excel format and averaged in various cases of data rates as tabulated in table 3 for analysis. Simulation was later carried out to validate the result and ascertain the effectiveness of EDFA used using MATLAB 2009b/Simulink.

IV RESEARCH DESIGN

This research was carried out using MTN fiber optic system (backbone) deployed along Enugu-Abakaliki expressway in eastern region of Nigeria within the period of 15months (January to April, 2013). Abakaliki served as the transmitting station while Enugu the receiver. This environment was characterized as semi-urban with a tropical savanna climate and its mean daily temperature is 26.7˚C (80.1˚F) [7]. It has high altitude and undulating terrain [8]. The test bed architecture was characterized into two parts: the transmission medium and the base stations. Optical fiber cable that covered the distance of 140km passing through bridges, hills, gully, streams etc was used as transmission medium. The base stations also have two components: the transmitter and receiver located at Abakaliki and Enugu respectively. The disphenser in the base station is where the EDFA were customized for measurements and its optimization.

V PROCEDURE FOR DATA COLLECTION

The measurable quantities were the three (3) values for dispersion data rate with specified bandwidth and wavelength. As earlier mentioned, the base station EDFA was configured to send data across from the transmitter to receiver via an optical cable every 5 seconds and left for 2minutes in order to gather enough samples to be averaged. The data sent to the sink in the two occasions at different distances were recorded and saved after 2 minutes and above at data sample size of 20.

VI DATA ANALYSIS

After the measurements, the raw data in the excel file was presented for analysis. In Table 1, the data rate configurations for FP laser, normalized and narrow DFB laser dispersions that was setup while measuring the values for the outdoor distance is shown. Table 3 shows the outdoor parameter values of three different data rates applied to EDFA represented by y1, y2, and y3. The measured wavelength with their corresponding average dispersion is shown in table 2, the variation of its optical power with wavelength was observed. The validation result from the simulation carried out showed the amplification output around 1550nm.

Table 1: Data Rate Dispersion values

Dispersion with a Normalized DFB Laser Data Rates	Dispersion with a FP Laser Data Rates	Dispersion with a Narrow DFB Laser Data Rates
3.1GB/s	780Mb/s	3.11GB/s
1.55GB/s	270Mb/s	1.55GB/s
0.78GB/s	100Mb/s	0.78GB/s

Table 2: Various Spectral Width (Dispersion) against wavelength in EDFA

Avg. Measured Wavelength (nm)	Avg. Dispersion
1250	-6.0363
1300	-1.0249
1350	3.4355
1400	7.4398
1450	11.0639
1500	14.369
1550	17.405
1600	20.2126
1650	22.8253
1700	25.438
1750	28.0507
1800	30.6634
1850	33.2761
1900	35.8888
1950	38.5015
2000	41.1142

In fig.1 shows that as the distance increases from 0 to 20km, the dispersion tends to increase with respect to the data rates. Fig.2 shows that dispersion penalty was gradual form 0 to about 110dB at 5km distance. Data rate of 780Mb/s at 5km recorded the highest attenuation while 270Mb/s at 50km distance has medium attenuation. The data link in these data rates is dispersion limited, but the data rate of 100Mb/s data link was found to be attenuation limited or reduced. The dispersion penalty in fig.3 dropped more than a factor of two as shown in the graph. The one at data rate of 3.11 GB/s never reached 2dB even at 130km. Therefore, EDFA amplification could be said to be high as pump power increases through stimulated emission. When the doped fiber which was used as amplifying medium is optically pumped with a second laser wavelength that is coupled into the line in addition to the signal, both wavelengths of light are transmitted through the doped fiber which transfers energy from the second pump wavelengths to the signal wave. The signal to be amplified and a pump laser were multiplexed into the doped fiber and amplification was achieved through interaction with the doping ions. The overall evaluation showed that the power penalty due to dispersion is optimized at 1550nm, and it relates to the roll-off of a raised cosine receiver response in the base station receiver. It was observed that EDFA offers high polarization-independent gain, high output power, low insertion loss, low noise at the optimized wavelength of 1550nm.

Table 3: three different data rates applied to EDFA at different wavelengths

Y1	Y2	Y3
0	0	0
45.8042	39.7560	33.7926
51.8247	45.7762	39.8118
55.3465	49.2980	43.3334
57.8453	51.7967	45.8321
59.7835	53.7349	47.7702
61.3671	55.3186	49.3538
62.7061	56.6575	50.6928
63.8659	57.8173	51.8526
64.8889	58.8404	52.8756
65.8041	59.7555	53.7908
66.6319	60.5834	54.6186
67.3877	61.3391	55.3744
68.0830	62.0344	56.0697

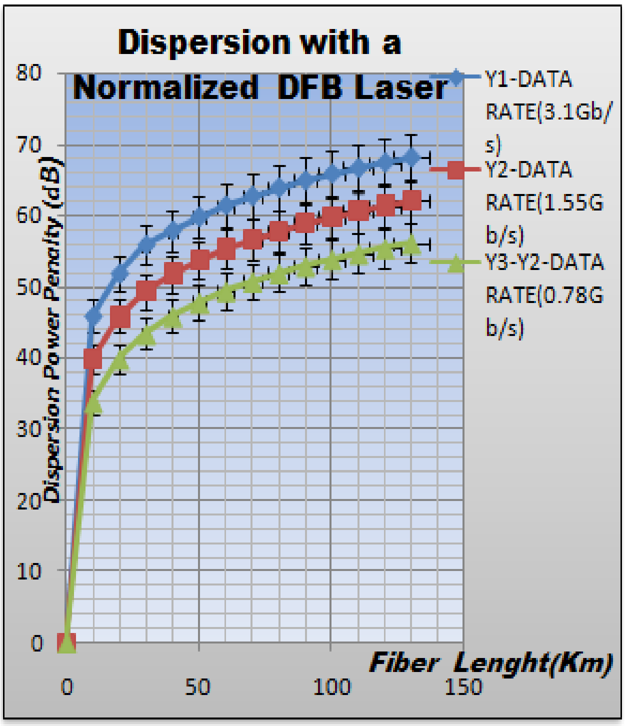

Fig 1 Dispersion penalty for the data link in EDFA operating at three data rates.

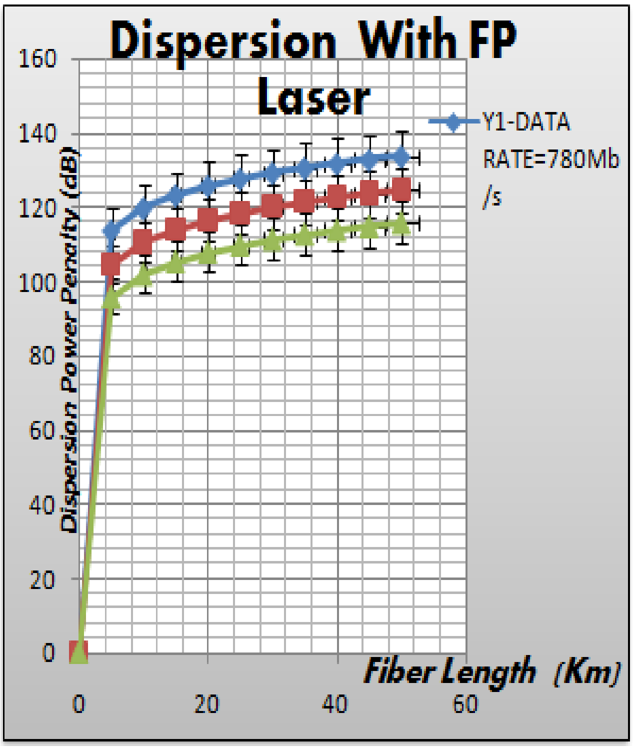

Fig 2 Dispersion penalty power output with three lower data rates in EDFA

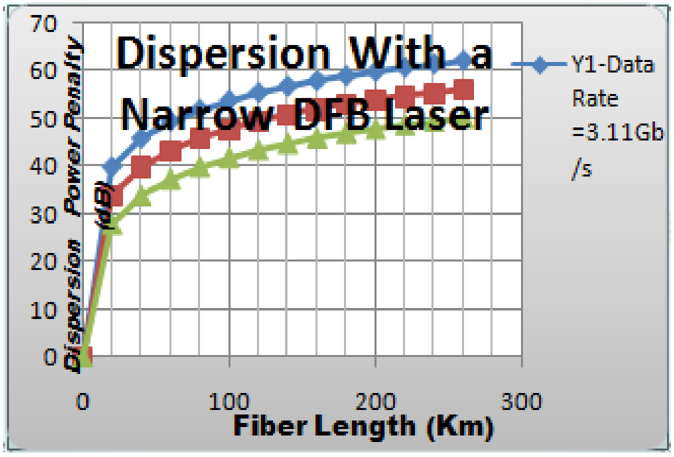

Fig 3 Dispersion penalty of three narrow data rates in EDFA

VII SIMULATION

In this work, simulation was realized using MATLAB 2009b/Simulink. The validation model of [9-11] with components: Bernoulli base station source B_{bs}, Gaussian Minimum Shift Keying (GMSK) modulator, Attenuation/dispersion channel, Amplifier gain (EDFA) and Eye diagram was used. The Bernoulli generates the binary sequence which was modulated by GSMK as shown in fig.5. The choice of GSMK was owing to its merits: constant envelope, spectral efficiency, good BER performance and self-synchronizing capability. This modulated signal changed in this process of modulation in terms of shape, magnitude, phase etc. due to linear and nonlinear effects. EDFA amplifier decodes and bootstraps the signal into a sequence of digital data preparatory for decision making through eye diagram as shown in fig.4. Fig.5 is the simulation validation for EDFA, showing zero dispersion/attenuation responses with the use of gain amplifier. An effective throughput response due to zero attenuation and dispersion was shown in fig.6, while fig.7 depicts a curve fitting response for the attenuation/dispersion.

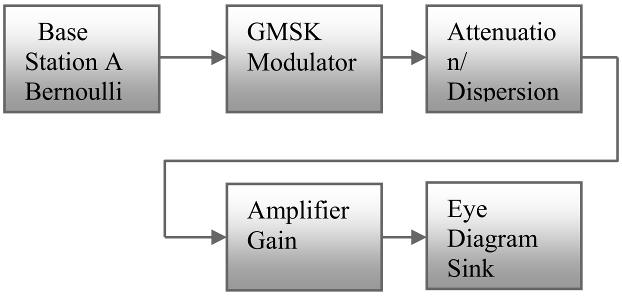

Fig 4: Validation Model for EDFA Optic Fiber Communication.

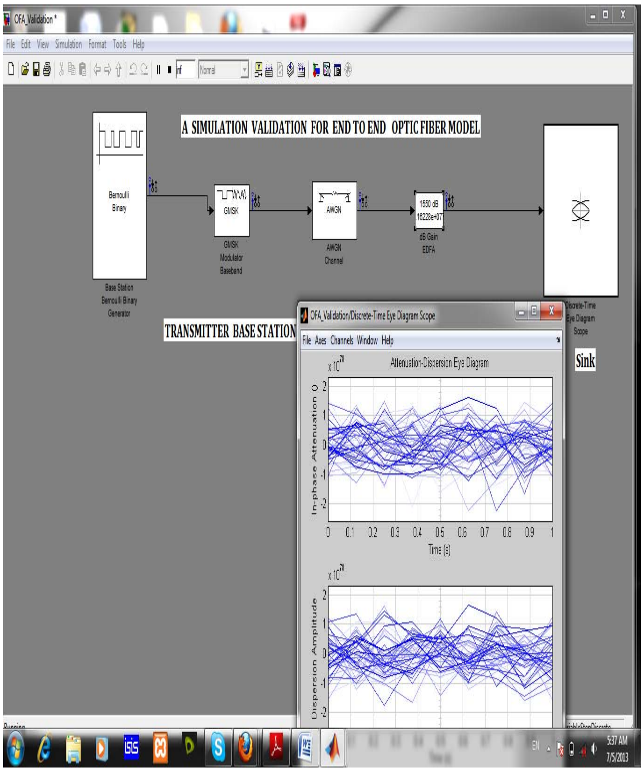

Fig 5 Simulation validation result showing zero attenuation/dispersion responses

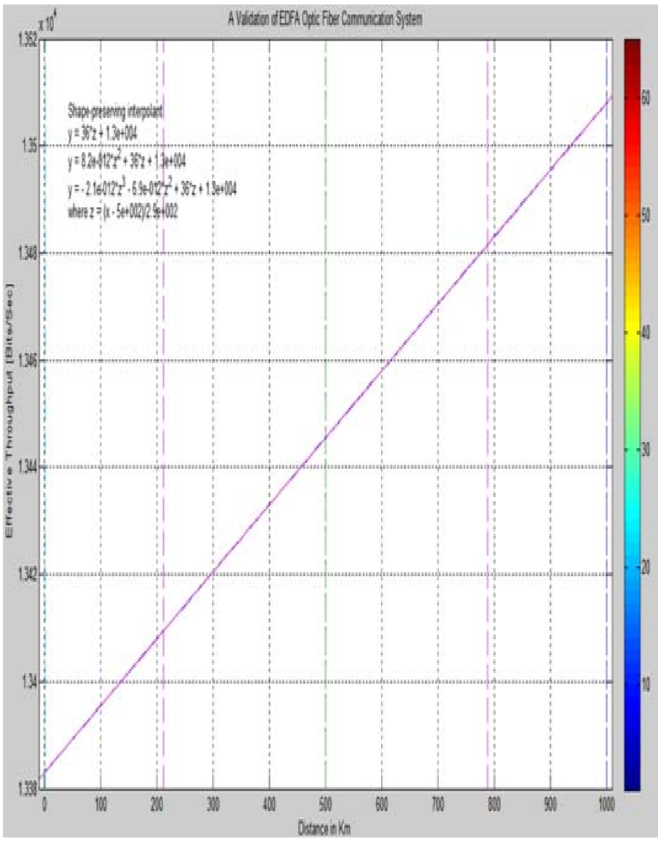

Fig.6 An effective throughput response due to zero attenuation and dispersion

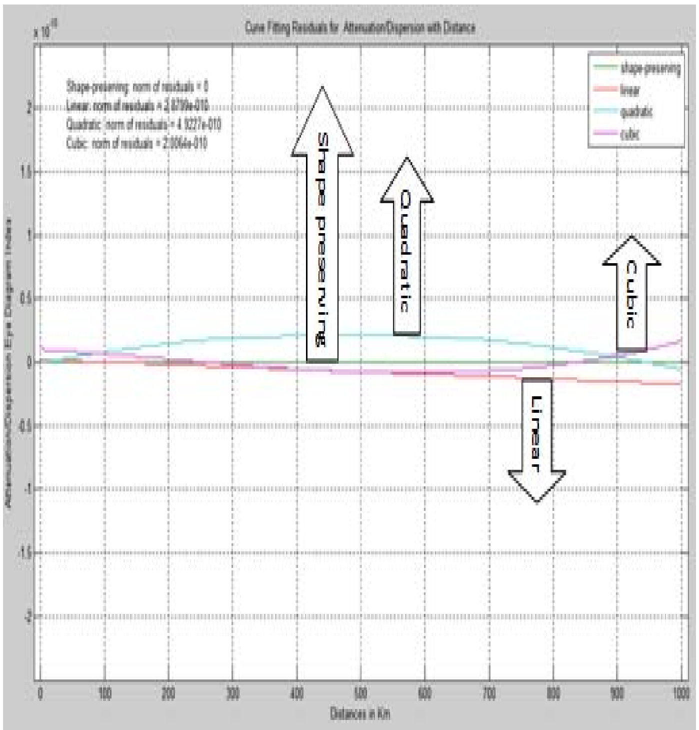

Fig.7 A curve fitting response for attenuation and dispersion

VIII CONCLUSION AND RECOMMENDATION

Based on the findings of this study, the gain of Erbium doped fiber amplifier is high at 1550nm, and that is responsible for its optimum performance in eliminating fiber optic attenuation and dispersion. The research showed that with optimized amplifier in optic fiber communication backbone, curve residuals yields a near zero response and hence offering a high throughput response as well. This implies that the erbium doped fiber amplifier is a promising technique for improving the performance of optic fiber communication systems. The EDFA used for amplification carried out the task regardless of wavelength by splicing a short section of doped fiber into a regular (un-doped) optical fiber line. It also amplifies the optical signals directly without optical-to-electrical conversion. It is therefore imperative to recommend that any organization or firm deploying optics fiber in communication should endeavor to do proper design and operational work plan based on knowledge of transmission characteristics of the optical sources and interconnection devices. Utilizing high performance (low loss and optimal gain) connectivity and fiber cable as well as following industry standardized practices of cable routing (e.g. maintaining bend radius control) are the best ways to minimize signal impairments from excessive optical losses.

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