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Higher Order Approximation for Stimulated Raman Scattering Including Walk-off Effect

Mr. Lokesh Chaudhary
M. Tech Scholar, Digital Communication,
Marudhar Engineering College, Bikaner (Raj.)
prakesh.lokesh@gmail.com

Mr. Gautam Pandit
Assistant Professor, ECE Department
Marudhar Engineering College, Bikaner (Raj.)
gpandit2009@gmail.com

***Abstract*—** The performance of an optical system is reduced by nonlinear effects. It is known that when optical power is very high then non linear effects tend to manifest themselves, so the study became important in DWDM system. The fiber nonlinearities fall into two categories. One is stimulated scattering (Raman and Brillouin), and the second is known as optical Kerr effect. With these effects the results are changed in the refractive index of fiber with optical power. With different input signals kerr-non-linearity manifests itself in three different effects such as Self-Phase Modulation (SPM), Cross-Phase Modulation (CPM) and Four-Wave Mixing (FWM). At high power level, the inelastic scattering phenomenon can induce stimulated effects such as Stimulated Brillouin-Scattering (SBS) and Stimulated Raman-Scattering (SRS). The Brillouin and Raman scattering can be differentiated as the Brillouin generated phonons (acoustic) are coherent and give rise to a macroscopic acoustic wave in fiber, while in Raman scattering the phonons (optical) are incoherent and no macroscopic wave is generated, So SRS is much less problem than SBS. The threshold of SRS is nearly to 1 Watt, more than thousand times higher than SBS. But the real systems are being expanded with EDFAs having output optical powers of 500 mW (+27 dBm), and this will only go higher. A fiber optic link that includes three such optical amplifiers will reach this limit since the limit drops proportionally by the number of optical amplifiers in series.

Keywords- *Walk-off effect, DWDM System, optical system, Brillouin-Scattering,Stimulated Raman Scattering.*

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I. INTRODUCTION

Now in these days in Information Technology and communication systems the immense speed data transmission is one of the biggest needs of the industry. Today, in order to do high speed data transfer optical fibers are used in telecommunication links, Internet and small networks to get large channel bandwidth. In today's world, the advent of erbium-doped fiber amplifier (EDFAs) is one of the most notable breakthroughs in the fiber optical communication technology [1].

The optically amplified transmission lines are deal with as transparent pipe which are transparent to data rates and format of modulation. However, transmission impairments, which are generally not significant in are regenerative system, accumulate along the transmission link when amplifiers are used, so that they cannot be simply ignored, and this puts a new challenge to first order transmission design.

II. LITERATURE SURVEY

M. Arumugam has disposed an overview about the fiber optic communication. This paper deals with the historical development of optical communication systems and their failures initially. Then the different generations in optical fiber communication forward with their features has been discussed. Some aspects of total internal reflection, various types of fibers along with their size and refractive index profile, dispersion and loss mechanisms are also mentioned. Decisively the general system of optical fiber communication is briefly mentioned along with its advantages and limitations. Future soliton situated optical fiber communication is also highlighted. This paper explained that how high quality telecommunication at a lower cost using solitons can be achieved [1].

J. Toulouse, recommended the various kinds of optical nonlinearities encountered in fibers, pointing out the necessary material and fiber parameters that regulate fiber nonlinear effects and describe the effects produced by each kind of nonlinearity, emphasizing their variations for different values of essential parameters on nonlinear effects [2].

S. Bigo, introduced the fast growth of optical fiber communication system in last 30 years, along with the growth of optical linear and nonlinearities make system difficult, it develop into a challenge for system engineers to create the optical fiber with these complexity, dispersion management is one of good technique to make system less complex but it required more time consuming stimulation done optimally. The author described the two rule which provide insight in these matter [3].

Haruo Akimaru et. al., introduced general design deliberations for the broadband Information highway of the future are given in the context of collective broadband services to the home. As potential precursors to this highway the internet, the telephone and cable television networks are verified. Several emerging technologies are also examined as candidates for the future local subscriber loop. For the information highway, classes of network services are proposed that are independent of the specific network technologies used. It has been recommended that the information highway be

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partitioned logically or physically so as to provide a variety of service levels according to the subscriber's cost and quality of service requirements [4].

A.R Chraplyvy, introduced idea about the condition provided by SRS to transmitted power in wavelength division multiplexing optical communication system, This paper gave a general expression for transmitted power assessment for system containing an random number of channels with random channel separation but channel separation should be equal. The expressions are relevant to any WDM system provided the channel separations are roughly constant [5].

Ivan B. Djordjevic, suggested simple expressions appropriate to study the transmission limitations of WDM systems with dispersion compensated links using inline optical amplifiers imposed by fiber nonlinearities are derived in this paper. Two important nonlinear effects, SRS and FWM in the existence of ASE noise are taken into consideration. The maximum possible transmission distance has been discussed in terms of different system parameters such as number of channels, total bandwidth, wavelength spacing, etc. Optimum channel spacing to maximize the transmission distance is found as a compromise between conflicting requirements enforce by FWM and SRS in the presence of ASE noise [6].

S. P. Singhet. al., described the different types of nonlinear effects based on first effect such as self-phase modulation cross-phase modulation and four-wave mixing. The thresholds, managements and applications have been deliberate, and comparative study of these effects has been presented [7].

M.N. Peterson et. al. define the first demonstration of chromatic dispersion monitoring in optical networks having employed all-optical wavelength conversion. Their experimental results proved that dispersion monitoring based on an in-band subcarrier tone combined with wavelength conversion based on four-wave mixing (FWM) render dispersion monitoring possible in an optical network utilizing wavelength conversion [8].

C. A. Brackett et. al. shown an architectural approach for very-high-capacity wide-area optical networks, and described a proposed program of research to address key system and device issues. The network was placed on dense multi-wavelength technology and was scalable in terms of the number of networked users, the geographical range of coverage, and the aggregate network capacity. They employed a distributed optical interconnect that is wavelength-selective and electronically controllable, permitting the same limited set of wavelengths to be reused among other access stations [9].

III. MOTIVATION

According to the literature survey, it has been attended that the most of work has been done in optical nonlinearities effects. The stimulated nonlinearities like SRS and SBS has been studied, SBS threshold is very low but it provide gain in back reflected light so it can be dispose of by using optical isolators whereas in SRS its threshold is very high compare to SBS but in current scenario the use of DWDM system make the threshold level of SRS reach very easily. The SRS model has been studied a lot for development of optical communication system as the forward gain provided by SRS can be used to make distributed amplifiers to increase the efficient use of optical bandwidth. In this paper, the development model of SRS has been studied in detail and taken few observations while calculation of altered power due to SRS indicating almost linear variation of power in channel with respect to each other. During this study different of signal power from 1 to 60 mw was done and number of channels varied from 3 to 99.

IV. PROPOSED APPROACH

The two nonlinearity Kerr effect and stimulated scattering has been considered in with their effects on optical fiber communication. This research work include the development model of SRS and the effects of SRS on transmitted power for four channel. After that the generalized equation of modulated power for N number of channels shown a proposed algorithm is given to negate the SRS effect in DWDM system. At last stimulation results are the considered with some observation gives strength to the result.

V. INTRODUCTION TO NONLINEARTIES & DEVELOPMENT MODEL OF SRS

Nonlinearity effects arose as optical fiber data rates, transmission lengths, number of wavelengths, and optical power levels expanded. The only problems that influence optical fiber in the early time were fiber attenuation and, sometimes, fiber dispersion; however, these issues are easily trade with using a number of dispersion avoidance and cancellation techniques. Fiber nonlinearities give a new domain of obstacle that must be overcome. These nonlinearities earlier arose in specialized applications such as undersea installations. However, the new nonlinearities that need unique attention when designing state-of-the-art fiber optic systems include stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), four wave mixing (FWM), self-phase modulation (SPM), cross-phase modulation (XPM), and intermodulation. Fiber nonlinearities represent the fundamental limiting mechanisms to the amount of data that can be transmitted on a single optic fiber.

The term linear and nonlinear (Figure 1), in optics, mean intensity independent and intensity dependent phenomena respectively. Nonlinear effects in optical fibers (Figure 2) occur due to (1) change in the refractive index of the medium with optical intensity and, (2) inelastic scattering phenomenon. The power dependence of the reflective index is cause for kerr-effect. Depending upon the type of input signal, kerr- non-linearity manifests itself in three different effects such as Self-Phase Modulation (SPM), Cross-Phase Modulation (CPM) and Four-Wave Mixing (FWM) [10].

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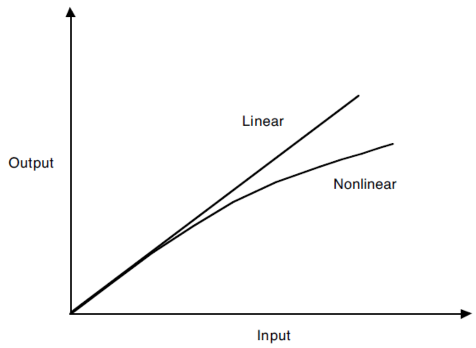

Fig 1. Linear and nonlinear interactions

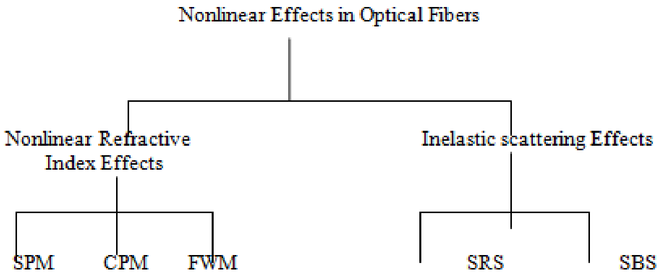

Fig 2. Nonlinear effects in optical fiber

VI. SCATTERING NONLINEARITIES

When light is incident on material it undergoes various scattering process. Most of the scattering is elastic, and the scattered wave has the same frequency as the incident wave. However, this scattered light is, in general, at some arbitrary angle to the forward direction of propagation. Hence, if one measures the transmitted light in the forward direction, there is a reduction in intensity as a result of the scattering into other directions. This loss is admitted as Rayleigh scattering loss. In addition to the elastically scattered component, a small fraction (about 1 to 106) of the incident photons undergo inelastic scattering. The scattered photon develop with a frequency shifted below or above the incident photon frequency. The difference in energy between the incident and scattered photons is deposited in, or extracted from, the scattering medium. The frequency shifts* can be small (approximately 1 cm-1) or large (greater than 100 cm-1). When the frequency shift is small, the process is known as Brillouins cattering. The bigger frequency shifts characterize the regime of Raman scattering

VII. SIMULATION AND RESULTS

SRS causes a distribution of power across all channels linearly. The slope is linearly increases and the intercept linearly decreases for a fixed power transmitted across each channel as the number of channels increases. By using these properties of SRS to transmit power linearly across channels we can set the transmitted power according to eq (1) which provides an approximate constant power across all channels according to the specified power value.

Corrected modulated power =[slope*wavelength + {power+ (slope*wavelength of 3rd channel)}] (1)

The power is varied from 1mW to 60mW, distance take is 2000Km, amplifier distance is 100Km, figure 3 shows the SRS effect on different data format including walk-off effect. The linear approximation algorithm [4] has been implemented on NRZ data format including walk-off effect and the effects of SRS on different data channel is shown in figure 4 and table 1.

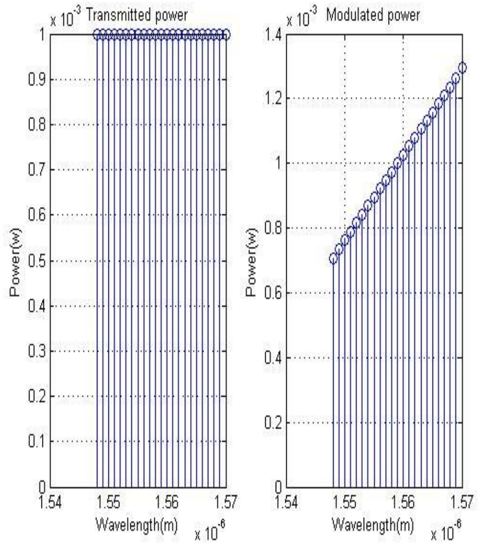

Fig.3. Power transmitted and modulated power due to SRS including walk-off concept

Figure 3 shows 10 channel DWDM system for constant power transmitted across channel. As shown clearly in Figure 1 the constant power across the wavelengths produces a linearly varying modulated channel due to SRS .We can decrease these variation using the power specified by eq. (1).

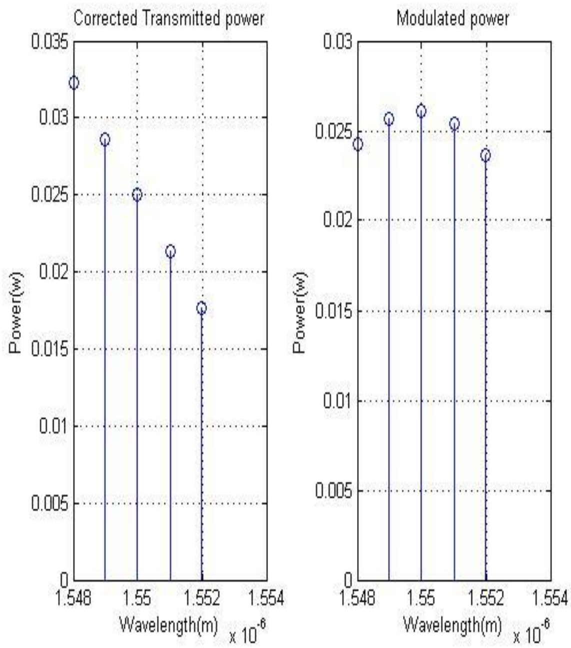

Fig. 4. Corrected power and modulated power for 10 channels

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Figure 4 shows that the modulated power for 10 channels nearly becomes constant as if there is no effect of SRS in the channel.

TABLE 1: NUMBER OF CHANNELS USED FOR NRZ DATA FORMAT

Power (mW)	Amplifier distance(Km)	Channel length (Km)	No. of channel
1	100	2000	23
2	100	2000	17
5	100	2000	12
10	100	2000	9
20	100	2000	7
25	100	2000	5

Table 1 shows the maximum no of channels that can be corrected for a given power value using our algorithm.

VIII. CONCLUSION

The result in Figure 4 and Table 1 show that the use of linear approximation results in almost constant modulated power on given no of channel wavelengths and given power eg. For 1mW of power we can use a 23 channel DWDM system negating the effect of SRS in channel length of 2000 km just by efficient power division. Thus, we can say that using linear approximation on the transmitted side can negate the effect of SRS in DWDM system. It can be said that efficient power division algorithms can help to achieve almost constant power across all the wavelengths.

IX. FUTURE SCOPE

Optical distributed amplifier can be design using Raman gain with proper use of channel separation. Higher order approximation at the transmitter side can improve the result. Fiber loss coefficient used in this dissertation vary linearly because work is done on 1550 nm optical window, further study can be done on nonlinearly varying fiber loss coefficient on 1350 nm window.

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