Analysis of SRS Effects at Different Number of Channels and Power Levels and on the Performance of DWDM System

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Abstract— Stimulated Raman Scattering (SRS) effect is one of the Nonlinear effects in Dense Wavelength Division Multiplexed (DWDM) Fiber Optic Communication System. The effect of Stimulated Raman Scattering causes power to be transferred from the lower wavelength channel to the higher wavelength channel. This will reduce the Optical Signal to Noise Ratio (OSNR) for the high frequency channel or low wavelength channel. SRS effect is studied for different input power and for different number of wavelengths. SRS effect could be reduced by setting optimum optical power in the fiber. Various channel (4,8,11) DWDM system for various power levels of individual channels is stimulated in the sample mode of OPTSIM software for getting the effects of SRS like Power Tilt in the optical spectrum, after the fiber.

Keyword: Ooptical Fiber Communication, Power Tilt, Fiber Nonlinearity, DWDM, SRS, and OSNR.

I. INTRODUCTION

Wavelength Division Multiplexing (WDM) involves the transmission of a number of different peak wavelength optical signals in parallel on a single optical fiber. The WDM standard developed by the International Telecommunication Union (ITU) specifies channel spacing's in terms of frequency. WDM is a method of combining multiple services on a single fiber specified by ITU-T G.692. Many different wavelengths can be sent along a fiber simultaneously in the 1300-1600nm spectrum. This is achieved through WDM. WDM is nothing but N independent optically formatted information streams each transmitted at a different wavelength are combined with optical multiplexer and send over the same fiber. The wavelength in WDM must be properly spaced to avoid inter channel interference. Dense wavelength division multiplexing (DWDM) is a technology that puts data from different sources together on an optical fiber, with each signal carried at the same time on its own separate light wavelength. Using DWDM, up to 80 (and theoretically more) separate wavelengths or channels of data can be multiplexed into a light stream transmitted on a single optical fiber. DWDM has been proven to be one of the most capable technologies for communication systems. Although usually applied to optical networks (ONs), Wavelength Division Multiplexing (WDM), in general, is used to increase the capacity of existing networks by transmitting many channels simultaneously on a single fiber optic line.

In a simple DWDM system (Fig.1), each laser must emit light at a different wavelength, with all the lasers lights multiplexed together and sent into a single optical fiber. After being transmitted through a high bandwidth optical fiber, the combined optical signals must be demultiplexed at the receiving end by distributing the total optical power to each output port and then requiring that each receiver selectively recover only one wavelength by using a tunable optical filter.

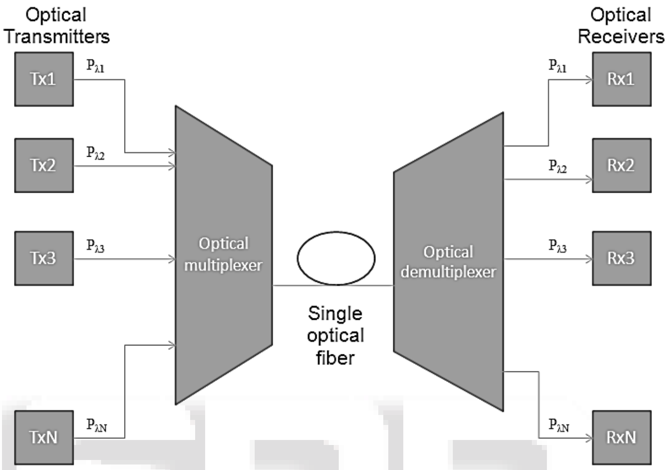

Fig. 1: Dense Wavelength Division Multiplexing

II. FIBER NONLINEARITIES

Fiber nonlinearities become a problem when several channels coexist in the same fiber. Nonlinearity effects arise, when optical fiber data-rates, transmission lengths, number of wavelengths [1,4], and optical power levels are increased.

1. Stimulated Brillouin Scattering (SBS)
2. Stimulated Raman Scattering (SRS)
3. Four-Wave Mixing (FWM)

A. *Stimulated Brillouin Scattering:*

Stimulated Brillouin Scattering occurs when an optical signal power reaches a level sufficient to generate tiny acoustic vibrations in the glass. This can occur at powers as low as a few miliwatts in single-mode fiber. Acoustic waves change the density of a material, and thus alter its refractive index. The resulting refractive-index fluctuations can scatter light, which is called Brillouin scattering.

B. *Stimulated Raman Scattering*

It is the inelastic scattering of a photon. When light is scattered from an atom or molecule, most photons are elastically scattered (Rayleigh scattering), such that the scattered photons have the same energy (frequency) and wavelength as the incident photons [2]. However, a small fraction of the scattered light (approximately 1 in 10 million photons) is scattered by an excitation, with the scattered photons having a frequency different from, and usually lower than, the frequency of the incident photons. In a gas, Raman scattering can occur with a change in vibrational, rotational or electronic energy of a molecule. If two or more signals at different wavelengths are injected into a fiber, SRS causes power to be transferred from the lower-wavelength channels to the higher-wavelength channels. SRS effect is shown in the Figure 2.

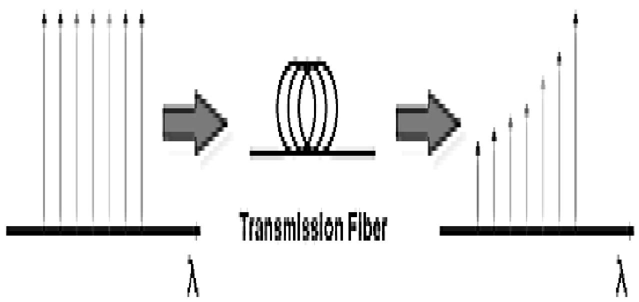

Fig 2: Stimulated Raman Scattering

SRS causes a short signal wavelength to behave as a "pump" for longer wavelengths, either other signal channels or spontaneously scattered Raman-shifted light[3]. The shorter wavelengths are attenuated by this process, which amplifies longer wavelengths. SRS takes place in the transmission fiber. By using suitable Raman Pumps it is possible to implement a Distributed Raman Amplifier into the transmission fiber.

C. Four Wave Mixing

Four-wave mixing is an intermodulation phenomenon in optical systems, whereby interactions between 3 wavelengths produce a 4th wavelength in the signal. It is similar to the third-order intercept point in electrical systems. Four-wave mixing can be compared to the intermodulation distortion in standard electrical systems. FWM is the generation of new optical waves (at frequencies which are the mixing products of the originator signals.

Four-Wave Mixing (FWM) is also present if only three components interact. In this case the term

$f_0 = f_1 + f_1 - f_2$

couples three components, thus generating so-called degenerate four-wave mixing. FWM can be mitigated by using uneven channel spacing or fiber that increases dispersion.

III. ANALYSIS AND SIMULATION

A model of optical communication link is stimulated using OPTISYSTEM software. System which we selected for analysis of SRS consists of CW lasers for input, ideal WDM multiplexer, optical fiber and optical spectrum analyzer to observe the output results. For SRS analysis in optical fiber communication system at various power levels, we vary the number of channels and power by keeping length of fiber unchanged. We design our system such that length of optical fiber which we selected is 10 km. Channel spacing is not constant; it varies from one channel to other.

Here we used 4-channel DWDM system with optical power of 2dBm&-55dbm, the corresponding simulation setup and result is as follows:

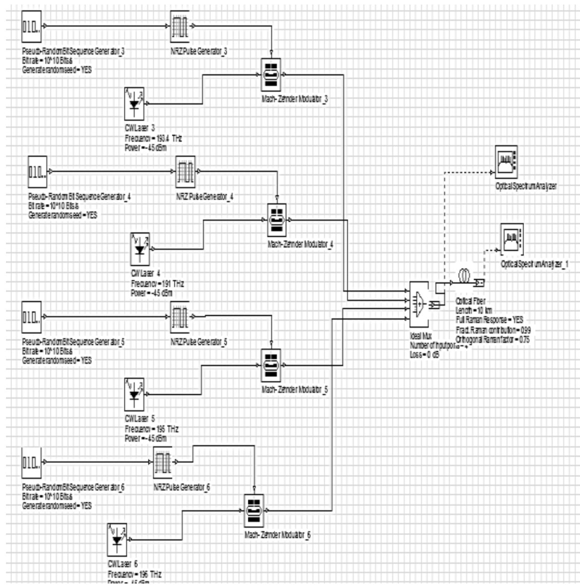

Fig. 3: Generalized Simulation Setup (4 Channels)

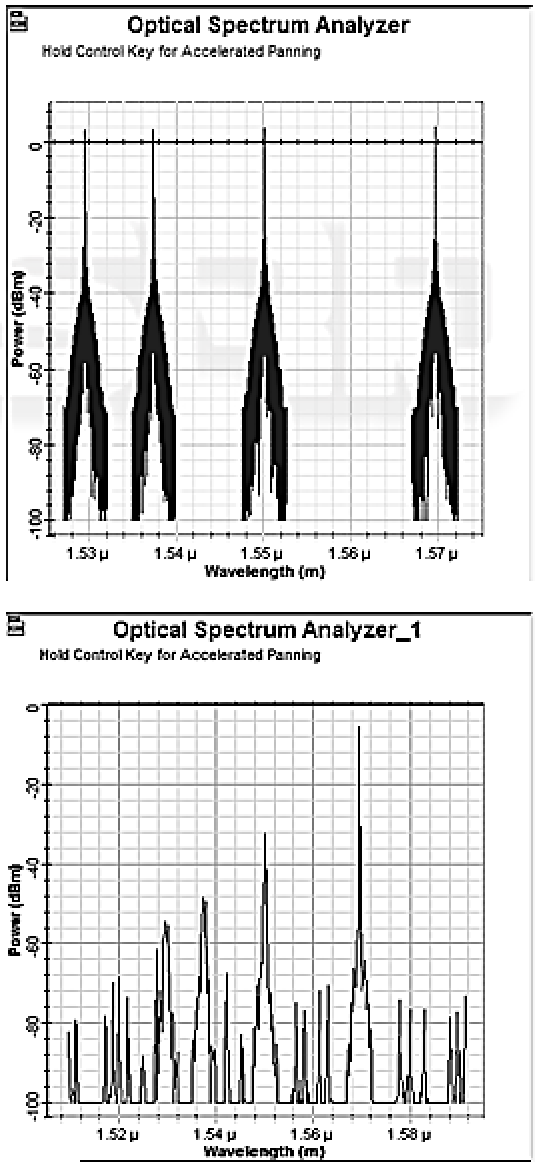

Fig 4: Input &Output of Optical Fiber for 4-Channel DWDM for 2dbm power

PARAMETER SPECIFICATIONS	Output1	Output2
Number of Channels	4	4
Spacing between Channels	Non-uniform	Non-uniform
Input power to each channel	2dbm	-55dbm
Length of the Fiber	10Km	10 Km

Table 1: Parameters for Simulation Setup (4channels)

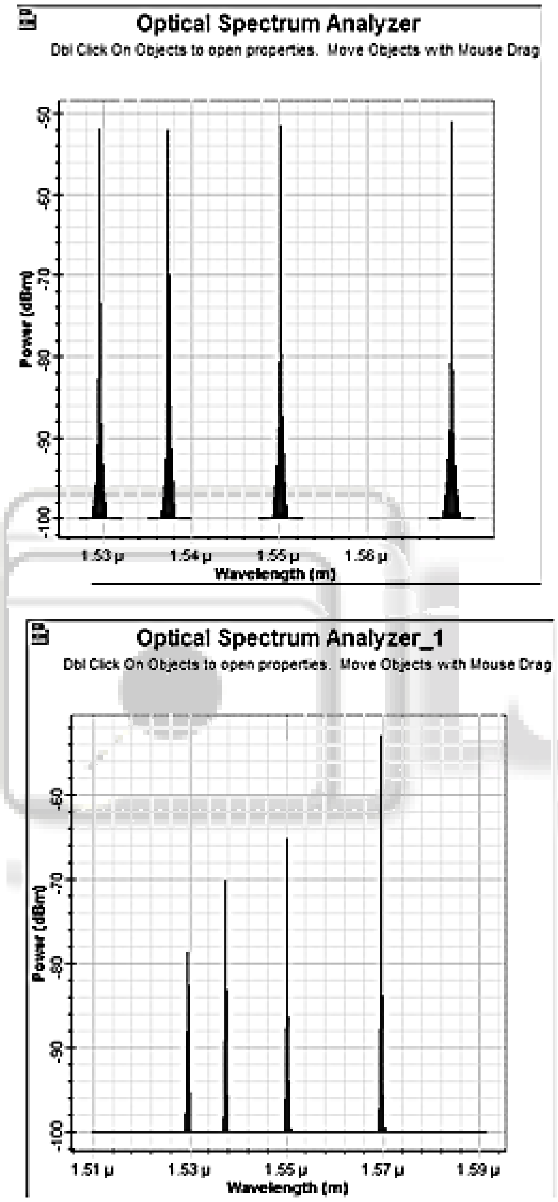

Fig 5: Input &Output of Optical Fiber for 4-Channel DWDM for -55dbm power

PARAMETER SPECIFICATIONS	Output1	Output2
Number of Channels	8	8
Spacing between Channels	Non-uniform	Non-uniform
Input power to each channel	-10dbm	2dbm
Length of the Fiber	10Km	10 Km

Table 2: Parameter for Simulation Setup (8 channels)

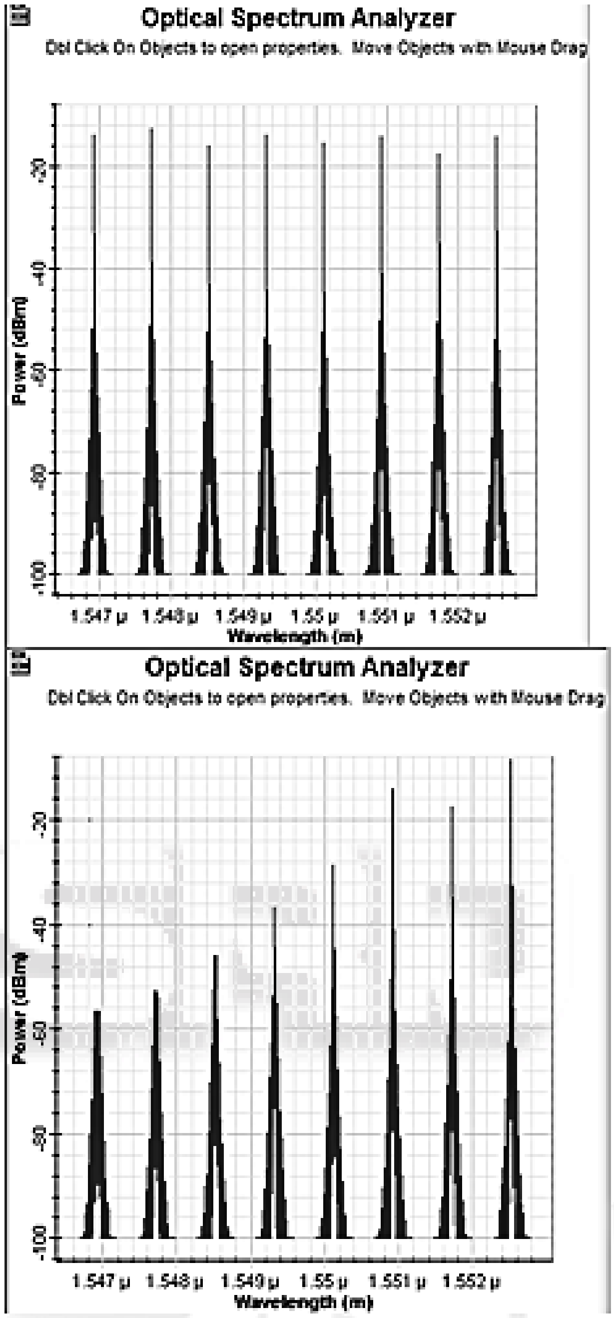

Fig 6: Input &Output of Optical Fiber for 8-Channel DWDM for -10dbm power

PARAMETER SPECIFICATIONS	Output1
Number of Channels	11
Spacing between Channels	Non-uniform
Input power to each channel	-45dbm
Length of the Fiber	10Km

Table 3: Parameter for Simulation Setup 3 (11 channels)

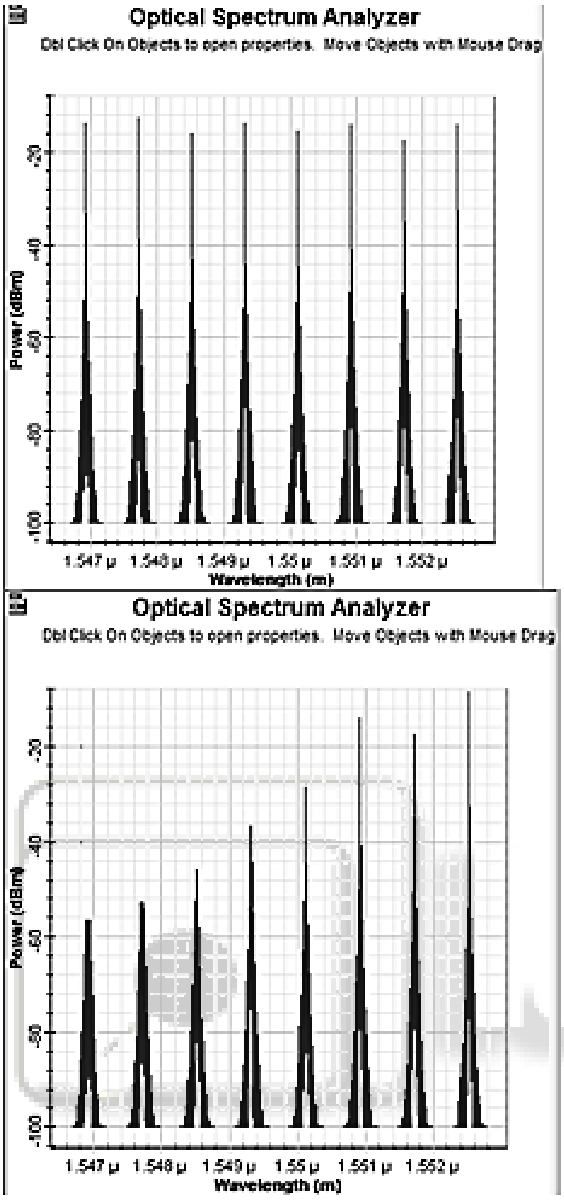

Fig. 7: Input &Output of Optical Fiber for 8-Channel DWDM for 2dbm power

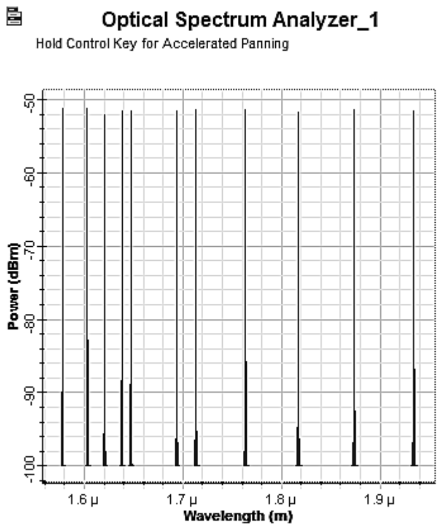

Fig 8: Input of Optical Fiber for 11-Channel DWDM for -45dbm power

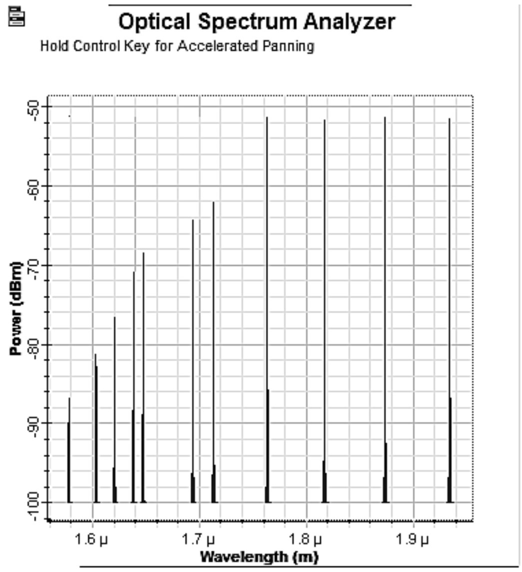

Fig. 9: Input &Output of Optical Fiber for 11-Channel DWDM for -45dbm power

IV. RESULTS AND DISCUSSIONS

When the input optical power in the individual channel is increased, then unwanted power tilt is also getting increased. However if it is decreased, then OSNR is also unnecessarily decreased and it should not be below the sensitivity of the individual photo detector. So input power (P_{in}) should not be too low and should not be too high. For easy interpretation, the results are obtained for 4,8&11 wavelengths. It can be easily scaled up to the required no. of wavelengths like 32 or 64 or128 or even more. Also, the power level could be increased beyond 10 mW.

V. CONCLUSION

Optical fiber exhibits a variety of Nonlinear effects. Nonlinear effects are feared by telecom system designers because they can affect system performance. These nonlinear effects can be managed through proper system design. There are many ways by which these SRS can be reduced. When the Input power is decreased, it is observed that the unwanted optical power tilt is also reduced. However by reducing the input power, number of channels in a DWDM system is reduced. Hence Optimum power level settings in the fiber have to be set for DWDM. The analysis of SRS is done by setting various power levels of individual channels in DWDM system. In Future, the reduction of SRS effect is to be done by setting Inverse Raman effect in the fiber.

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