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ScienceDirect

Procedia Technology 25 (2016) 552 – 559

Procedia Technology

Global Colloquium in Recent Advancement and Effectual Researches in Engineering, Science and Technology (RAEREST 2016)

# A Survey on Dispersion Management using Optical Solitons in Optical Communication System

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**Abstract**

In this paper, the dispersion management in optical communication systems using soliton transmission technique is studied. An optical soliton is a special kind of light pulse that can be transmitted over fibre optic channel due to the exact compensation between nonlinearity and linear broadening due to group velocity dispersion. Since the soliton data looks the same at different distances along the transmission, this technique can be used to overcome the data transmission limitations in Radio over Fibre (RoF) communication systems. This paper investigates the concepts of dispersion management using solitons in optical fibre. It analyses the system with and without soliton parameters in terms of Q-factor, pulse broadening and eye diagram. From the simulation results, it is found that the Q-factor is improved by 77.9751*dB* for the soliton system. The results show that the pulse broadening is less in the output spectrum of dispersion managed system. The eye diagrams also show that the noise is minimal for the system with soliton. The results show that the performance of dispersion managed system with soliton is good.


Peer-review under responsibility of the organizing committee of RAEREST 2016

*Keywords:* Dispersion Management; GVD; optical solitons; SPM

## 1. Introduction

Optical fibre communication systems make use of optical fibre as a media for transmitting light from one end to the other for long distance transmission. The pulses launched into the fibre spread out in time as they propagate along the fibre length; resulting in dispersion. As a result, the peak power of the pulse decreases and the width increases. Dispersion thus limits the transmission capacity and reduces the bandwidth. Therefore, dispersion has

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Peer-review under responsibility of the organizing committee of RAEREST 2016
doi:10.1016/j.protcy.2016.08.144

become a major problem at high bit rates and for long haul optical communication systems. Hence, there is a need to efficiently manage dispersion in optical communication systems. Optical solitons which retain their shape over the propagation distance offer a solution to this problem [1].

Optical solitons are localized solitary waves that occur due to the exact balance between nonlinearity, called self phase modulation (SPM) and linear broadening due to group velocity dispersion (GVD). Solitons are very narrow optical pulses and are so stable that their shape and velocity are preserved as they propagate along the fibre. Thus, even after propagating thousands of kilometres, soliton pulses do not spread within the fibre. The power of the soliton should be retained between specified levels to preserve its dispersion resilient nature in an optical link [2,3].

In the context of nonlinear optics, solitons are classified into two kinds: a) Temporal solitons and b) Spatial solitons. Both types of soliton evolve due to optical Kerr effect. A pulse propagates with no distortion when exact compensation is made between negative GVD and positive SPM. If GVD cancels the phase shift produced by the Kerr effect in the same fibre, the pulse retains its shape and remains undispersed after travelling long distances. Therefore the concept of solitons is a step forward in the field of optical fibre communication and a promising technology for ultra-high bit rate transmission in fibres [4,5].

In this paper, the literature review of optical solitons is done. Also, a basic system is modelled with and without soliton parameters and analysed based on Q-factor, pulse broadening and eye diagram using Optisystem software.

## 2. Formation of soliton pulses

In order to understand the formation of soliton pulses, it is important to know the propagation of optical pulses within the fibre in the presence of dispersion and nonlinearity. Hence, this section deals with GVD and SPM.

### *2.1. Group Velocity Dispersion*

Depending upon the number of channels or information carried, any optical signal contains a number of wavelengths. The group velocity of the signal is a function of wavelength. As the pulse consists of different wavelengths, each travelling at different velocities, a group delay and hence pulse broadening is experienced as the pulse propagates through the fibre. The pulse broadening causes overlapping with the adjacent pulses which further leads to Inter Symbol Interference (ISI) [6,7].

In silica fibres, the zero dispersion wavelength ($\lambda_{ZD}$) is 1.31 μm. When $\lambda < \lambda_{ZD}$, the GVD is positive and the fibre exhibits positive or normal dispersion. When $\lambda > \lambda_{ZD}$, the GVD is negative and the fibre is said to exhibit negative or anomalous dispersion. As a result, higher frequency component of the pulse travels faster than the lower ones and vice versa for normal dispersive medium.

### *2.2. Self Phase Modulation*

SPM is the change in frequency of an optical pulse due to the phase shift induced by the pulse itself. It occurs because the refractive index of the fibre depends upon the intensity component. The leading edge of the pulse attains a positive refractive index gradient, because higher intensity portion of the pulse experiences high refractive index as it propagates through the fibre. Similarly, trailing edge of the pulse attains a negative refractive index gradient. Due to this change in refractive index within the pulse, it also experiences a phase change. Since the pulse itself modulates its own optical phase according to its intensity profile, it is termed as self phase modulation. As frequency is the derivative of phase shift in time domain, the frequency spectrum of the pulse changes due to SPM. That is, the leading edge of the pulse shifts to a lower frequency and trailing edge to a higher frequency. Therefore, the instantaneous frequency linearly increases from leading edge to trailing edge; this phenomenon is termed as upchirp. This chirping generated due to SPM leads to spectral broadening of the pulse retaining its temporal distribution [8].

### *2.3. Propagation of soliton pulses in optical fibre*

An optical soliton can be generated when GVD is balanced by SPM as discussed above. In this regime, the physical length L of the optical fibre is such that: