INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 3)
Available online at: www.ijariit.com

A review article of WDM based optical fiber communication with WDM system evolution

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ABSTRACT

"In the modern world, bandwidth and data rates are two most important parameters under consideration in any communication system. An optical fiber communication system is capable of transmitting the data at high bit rates and has a large bandwidth capacity. This high data rate and bandwidth capacity in an optical fiber communication system are further enhanced by using wavelength division multiplexing (WDM) in conjunction with the information transmission system, in which information from multiple sources are transferred using the same fiber, at the same time, but at different wavelengths. But the high capacity and data rates in optical WDM system is limited by nonlinear effects that occur in optical WDM system, which not only pose a limitation on the channel capacity and data rates but also degrades the performance of the data transmission system. In this paper, analysis has been done to investigate the efficiency of effect under the influence of different system parameters such as chromatic dispersion coefficient, channel spacing, transmission power level, effective area of fiber and fiber length in the form of input signals and output signals frequency spectrums".

Keyword: *OFDM (Frequency Division Multiplexing), QAM, AWGN, etc.*

1. INTRODUCTION

Due to a massive increase in capacity demands inflicted upon the data transmission network by the rapid growth in information transmission rates in communication systems, the total number of channels in Wavelength Division Multiplexing (WDM) optical networks is increased [1]. The EDFA's have limited gain-bandwidth. Hence in order to meet the requirement of increase in a number of channels, the spacing between the channels needs to be very small. A channels spacing of 100 GHz has been specified by current ITU grid, but these days systems with channel spacing of 50 GHz to 25 GHz are being considered. Such close spacing between the channels can give rise to many nonlinear effects such as Four-Wave Mixing (FWM), Cross Phase Modulation (XPM), Self- Phase Modulation (SPM), Stimulated Brillion Scattering (SBS) and Stimulated Raman Scattering (SRS) [3], [7]. These nonlinear effects, not just pose a serious limitation on the data transmission rate and channel capacity of an optical fiber WDM communication system, but also degrade the performance of the communication system. In FWM effect, two or more signals traveling in the same fiber interact with each other to produce new signals whose frequency lie within the same frequency range as that of original information signal [5]. This can lead to severe crosstalk and Intersymbol interference (ISI) and can lead to severe performance degradation of the system. In this paper, analysis has been done to investigate the efficiency of FWM effect at different simulation parameters such as channel spacing, transmission power level, effective area, chromatic dispersion coefficient and fiber length and results have been evaluated in the form of input signals and output signals frequency spectrums.

2. DIGITAL MODULATION TECHNIQUE WDM

Wavelength division multiplexing is a kind of *frequency division multiplexing* – a technique where optical signals with different wavelengths are combined, transmitted together, and separated again. It is mostly used for optical fiber communications to transmit data in several (or even many) channels with slightly different wavelengths. In this way, the transmission capacities of fiber-optic links can be increased strongly, so that most efficient use is made not only of the fibers themselves but also of the active components such as fiber amplifiers. Apart from telecom, wavelength division multiplexing is also used for, e.g., interrogating multiple fiber-optic sensors within a single fiber.

Theoretically, the full data transmission capacity of a fiber could be exploited with a single data channel of very high data rate, corresponding to a very large channel bandwidth. However, given the enormous available bandwidth (tens of terahertz) of the low-loss transmission window of silica single-mode fibers, this would lead to a data rate which is far higher than what can be handled by optoelectronicsenders and receivers. Also, various types of dispersion in the transmission fiber would have very detrimental effects on such wide-bandwidth channels, so that the transmission distance would be strongly restricted. Wavelength division multiplexing solves these problems by keeping the transmission rates of each channel at reasonably low levels (e.g. 10 Gbit/s or 100 Gbit/s) and achieving a high total data rate by combining several or many channels.

Two different versions of WDM, defined by standards of the International Telecommunication Union (ITU), are distinguished:

Coarse wavelength division multiplexing (CWDM, ITU standard G.694.2 [7]) uses a relatively small number of channels, e.g. four or eight, and a large channel spacing of 20 nm. The nominal wavelengths range from 1310 nm to 1610 nm. The wavelength tolerance for the transmitters is fairly large, e.g. ±3 nm, so that unstabilized DFB lasers can be used. The single-channel bit rate is usually between 1 and 3.125 Gbit/s. The resulting total data rates are useful e.g. within metropolitan areas, as long as broadband technologies are not widespread in households (→ *fiber to the home*).

Dense wavelength division multiplexing (DWDM, ITU standard G.694.1 [6]) is the extended method for very large data capacities, as required e.g. in the Internet backbone. It uses a large number of channels (e.g. 40, 80, or 160), and a correspondingly small channel spacing of 12.5, 25, 50 or 100 GHz. All optical channel frequencies refer to a reference frequency which has been fixed at 193.10 THz (1552.5 nm). The transmitters have to meet tight wavelength tolerances. Typically, they are temperature-stabilized DFB lasers. The single-channel bit rate can be between 1 and 100 Gbit/s, and in the future even higher.

Due to the wide amplification bandwidth of erbium-doped fiber amplifiers, all channels can often be amplified in a single device (except in cases where e.g. the full range of CWDM wavelengths is used). However, problems can arise from the variation of gain with wavelength or from the interaction of the data channels (*crosstalk*, *channel interference*) e.g. via fiber nonlinearities. Enormous progress has been achieved with a combination of various techniques, such as the development of very broadband (double-band) fiber amplifiers, gain flattening filters, nonlinear data regeneration and the like. The system parameters such as channel bandwidth, channel spacing, transmitted power levels, fiber and amplifier types, modulation formats, dispersion compensation schemes, etc., need to be well balanced to achieve optimum overall performance.

Even for existing fiber links with only one or a few channels per fiber, it can make sense to replace senders and receivers for operation with more channels, as this can be cheaper than replacing the whole system with a system with a higher transmission capacity. In fact, this approach often eliminates the need to install additional fibers, even though the demand on transmission capacities is increasing enormously.

Apart from increasing the transmission capacity, wavelength division multiplexing also adds flexibility to complex communication systems. In particular, different data channels can be injected at different locations in a system, and other channels can be extracted. For such operations, *add-drop multiplexers* can be used, which allow one to add or drop data channels based on their wavelengths. Reconfigurable add-drop multiplexers make it possible to reconfigure the system flexibly so as to provide data connections between a large number of different stations.

In many cases, *time division multiplexing* (TDM) can be an alternative to wavelength division multiplexing. Here, different channels are distinguished by arrival time rather than by wavelength.

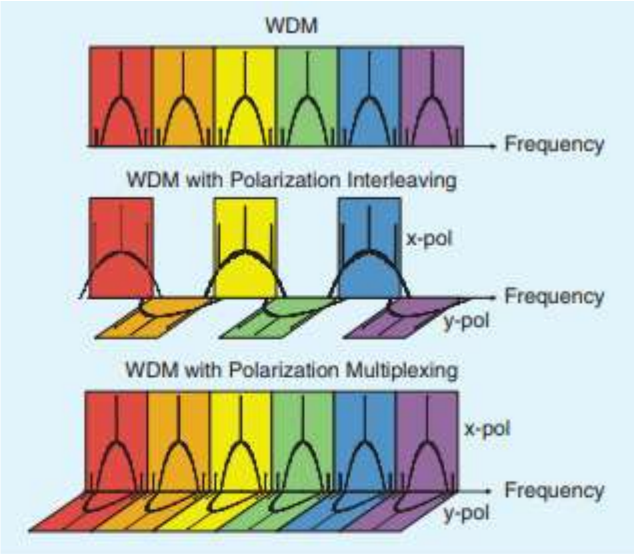

Figure 1. Orthogonality through disjoint frequency bins (WDM) can be combined with orthogonality in the polarization dimension

- **Optical Transmitter:** The main function of this element is to generate optical millimeter waves, which are responsible for carrying radio frequency signals to the base station [3].

- **Fiber Channel:** It is responsible for transporting the radio frequency signals (RF) directly to a point remote radiation according to Figure 2, is the base station in the case of transmitting and receiving radio signals will be provided with electromagnetic transducers better known as antennas. [3].

- **Base Station:** its main function is to perform to electrical Conversion of optical millimeter waves and subsequently power radio signals are sent using an RF amplifier high power [8].

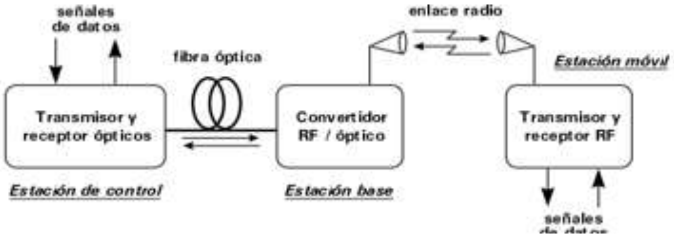

Figure 2. The architecture of a system Radio over Fiber

3. OBJECTIVES

- Identify the basic components of a fiber optic communication system • Discuss light propagation in an optical fiber
- Identify the various types of optical fibers
- Determine the dispersion characteristics for the various types of optical fibers describe the various ROF types.
- Calculate decibel and dBm power
- Calculate the power budget for a fiber optic system
- Calculate the bandwidth of a fiber optic system
- Describe the operation and applications of the various types of fiber optic loss.

4. ISSUES OF OLD ARTICLES

The loss produced as a result of Four-Wave Mixing in optical WDM system degrades the performance of the communication system. This section presents research carried out by different authors to analyze FWM effect in optical WDM communication system.

R.S Kaler et al. [1] presented that as the spacing between the channels is increased and kept unequal, the amount of interference between the signals carrying information is reduced and thus the efficiency of four-wave mixing effect is reduced.

S. JD. Marconi et al. [2] presented an efficient technique of generation of frequency comb having spacing between the channels of the order of hundreds of GHz by use of three pump technique.

K S. Chiang et al. [3] demonstrated the possibility of generation of a distinct frequency-shifted beam by using a distinct optical pump beam and mixing it with the information signal.

Bobby Barua et al. [4] proposed the use of an optical fiber having low chromatic dispersion coefficient which results in higher efficiency of four-wave mixing (FWM) effect.

R. J. F. Fanget et. al. [9] presented channel assignment problem and applied results from coding theory and graph theory. The results are capable of providing an optimal number of frequency plans up to 23 channels.

J. P. Robimson et. al. [8] demonstrated frequency difference triangle set applied to coding theory, a third order intermodulation product free unequally spaced channel allocation scheme for up to 24 channels.

Angel David Torres Palencia [9] Because of the large bandwidth that the optical fiber offers as transmission medium of information and the flexibility of communication of the wireless systems, a new mixed infrastructure called radio over fiber system (Radio over Fiber, RoF) have been developed, these have been characterized for implementing division multiplexing wavelength (WDM) and these work with radio carrier signals in the band of extremely high frequencies (extremely high frequency, EHF.) Nevertheless, this type of communication systems presents linear errors as the dispersion. This article describes the research done and the results obtained from the simulation of a RoF system using multiplexing WDM through the Matlab software, the which it has as main objective to model and simulate a RoF system for to assess the degradations produced by the dispersion that affect the signal in the transmission of information.

*López, [10]*in the last year's big attempts have been performed in the development of networks with division wavelength multiplexing to perform high capability communications between telecommunication nodes in metropolitan areas. Based on the above, it can be said that telecommunications companies must modernize its infrastructure for the implementation of these new technologies, in order to meet the main needs required by the end user of the network of access, which is: bandwidth and flexibility of access to the network at any time and place. Thus has started the interest from telecommunications companies, because these systems are best suited to support the different broadband services requested.

*Fabian Gomez López[11]*the paper focuses on analyzing, modeling and validates a simulation tool for optical communications systems; it has focused in the evaluation of the dispersive effects of linear origin, as are the attenuation and dispersion for a system of radio over fiber based on wavelength-division multiplexing in the computational tool Matlab [5]. For which simulations are performed in the toolbox Simulink for transmission of information with input power not exceeding 10 milliwatts for ignoring the nonlinear phenomena produced by the transmission channel, which appear when there is a high-level power to the channel input [6]. At a transmission rate of 60 Gbps, with channel spacing of 50 GHz and a radio frequency carrier 60 GHz considering the IUT-T G.694.1 recommendation. With lengths of 20 km, 40 km and 60 km standard single-mode optical fiber taking into account the IUT-T G.652 recommendation of the International Telecommunication Union (International Telecommunication Union, IUT.)

5. SIMULATION AND EXPECTED RESULTS

Once implemented the system has been made the corresponding simulations in which is verified the original signal degraded in amplitude in each stage of the system due to the implemented processes. One of the most significant degradations is produced by the attenuation it affects the amplitude of the optical signal in the output by a factor of 0.22 dB/km and implicitly is noted that each 31.5 km of length the signal falls additionally 6 dB, for this is recommended to implement an optical amplification stage in the photoreceptor to adequately recover the signal sent. Furthermore, it has been evidenced how the scattering produced by the transmission channel has widened the pulses in the optical signal, producing the ISIS phenomenon causing distortion of the original signal, while the electrical signal alters the pure sinusoidal signal sent by the transmitter. This deformation is produced by the accumulated dispersion in the channel, which is directly proportional to the length of optical fiber implemented for the transmission, and it increased by a factor of 17 ps/nm*km.

TABLE II. SIMULATION PARAMETERS FOR THE TRANSMISSION CHANNEL IMPLEMENTED IN MATLAB SIMULINK

No.	Simulation Parameters	
	Parameters	*Value*
1	Optical Fiber length (L)	20 , 40 y 60 (km)
2	Dispersion coefficient (β_2)	-17 (ps/nm*km)
3	Attenuation coefficient (α)	0.22 (dB/km)
4	Transmission speed	60 (Gbps)
5	Samples for FFT (N)	1024
6	Sampling factor (n)	16
7	Data frame	64 (bits)

Additionally, is evidenced that for selected distances the receiver is able to capture and properly recognize the transmitted signal allowing a reliable transmission. Thus, it follows that the BER is between values 10-3 to 10-12 with a maximum transmission distance of 60 km. it Allows validating a simulation tool for optical communications systems that are Focused on the assessment of the effects dispersive of origin linear, such as the attenuation and dispersion for a radio fiber optic system based on wavelength division multiplexing technique in the Matlab computing tool.

6. CONCLUSION AND FUTURE SCOPE

In the previous work which was discussed in literature review shows that there is a need for improvement in system in terms of Noise level .as we have seen the results of base paper in terms of simulation model (Fig4.19) and the graph of BER Vs E_b/N_o (Fig4.20), our modified work has enhanced the performance of the newly designed simulation model. Higher level QAM is implemented by which the noise level is decreased. To compare the performance in terms of BER & Packet error Vs. Doppler shift using different modulation schemes on AWGN Channel and Rician Channel, This system model that is presented in this thesis QAM-OFDM in this system model we adopted OFDM, which is advantageous and so shows the better performance.

The performance of WDM networks is strongly influenced by nonlinearity characteristic inside the fiber. Therefore the nonlinearity effects of fiber optics pose an additional limitation in WDM systems. The previous method effect has been investigated analytically and numerically simulated. Simple equations to determine the spectral line width, the previous method power due to channel spacing and the power of the previous method components due to the input power has been deduced. The numerical simulation results obtained have shown the spectral characteristics of the previous method in WDM for ROF where the effects of the previous method are pronounced with decreased channel spacing of wavelengths or at high signal power levels. The previous method can be minimized by ensuring that the phase matching does not occur. This has been achieved by increasing the channel separation and supplying low signal power level. The high effective area is also found to decrease previous method effect. It is noticed that the previous method also causes inter-channel cross talk for equally spaced WDM channels. Thus, the previous method can be mitigated using unequal channel spacing.

7. FUTURE SCOPE

The success of digital information processing over the last century has triggered the demand to transport massive amounts of digital information, ranging from on-chip data buses all the way to inter-planetary distances. Optical communication systems have been replacing electronic and RF techniques starting at the most demanding capacity-constrained and sensitivity-constrained applications and are steadily progressing towards more implementation-constrained shorter-reach systems that require dense integration, low power consumption, and low cost. Modulation and multiplexing techniques are key design elements of sensitivity-constrained and capacity-constrained systems, used to harvest the bandwidth advantages that optical technologies fundamentally offer. Spectrally efficient modulation will stay a key area of research for capacity-constrained systems. As WDM capacities over conventional fibers are approaching their fundamental limits, breakthroughs in fiber design and in complementary multiplexing techniques are expected to further scale capacity [9].

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