OPTICAL SOLITONS IN LONG HAUL TELECOMMUNICATIONS

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OPTICAL SOLITONS IN LONG HAUL TELECOMMUNICATION

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A report submitted in partial fulfillment of the requirements for degree of Electrical Engineering major in Power Electronic and Drives

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" I hereby declare that I have read through this report entitle "*Optical Solitons in Long Haul Telecommunication*" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)

Signature :

Supervisor's Name : Mr Loi Wei Sen

Date : 28 June 2012

I declare that this report entitle "*Optical Solitons in Long Haul Telecommunications"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted of any other degree.

Signature :

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Date : 28 June 2012

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ABSTRACT

This research is to study about the propagation wave of optical solitons in long haul telecommunication. Optical solitons is one types of nonlinear wave in solitons that have dual nature properties such as particle and wavelike. It is currently new technique of telecommunication system used to transmit data with greater bandwidth in optics in the agreement of undistorted signal. It is due to the existence of balance between self-phase modulation (SPM) and group velocity dispersion (GVD). In this research, the propagation of optical pulse will be studied regarding to characteristics of optical pulses. The electrical simulation model will be run by using OptiWave Software and will be comparing for both type of pulse which are Sech hyperbolic pulse and Gaussian pulse. For validity, the simulated results that have obtained from OptiWave Software will be compared with the results of mathematical model which is modeled by forced nonlinear Schrödinger equation (fNLS). By solving fNLS equation numerically, the mathematical result gets the similar results as obtained by simulation.

ABSTRAK

Projek ini adalah untuk mengkaji tentang gelombang penyebaran soliton optik dalam telekomunikasi jarak jauh. Soliton optik merupakan salah satu jenis gelombang tidak linear dalam soliton yang mempunyai ciri-ciri dwi seperti zarah dan gelombang. Buat masa ini ini adalah teknik baru sistem telekomunikasi yang digunakan untuk menghantar data dengan jalur lebar yang lebih besar di dalam optik. Ia adalah disebabkan kewujudan imbangan di antara pemodulatan fasa diri (SPM) dan kumpulan serakan halaju (GVD). Dalam kajian ini, penyebaran denyutan optik akan dikaji mengenai ciri-ciri denyutan optik. Model simulasi elektrik akan dijalankan dengan menggunakan Perisian OptiWave dan akan membandingkan kedua-dua jenis denyutan iaitu denyutan Sech hiperbolik dan denyutan Gaussian. Untuk kesahihan, keputusan simulasi yang telah diperoleh daripada Perisian OptiWave akan dibandingkan dengan keputusan model matematik yang dimodelkan oleh tak linear persamaan Schrödinger (fNLS) paksaan. Dengan menyelesaikan persamaan fNLS berangka, hasil matematik akan mendapat keputusan yang sama seperti yang diperolehi oleh simulasi.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, communication is such as needed things in life. Everyone can connect with one another via modern communication technology like mobile phone, email and others. Meanwhile, of the demand human for the communication system is increasing for the year to year, old ancient telecommunication system no longer applicable their needed.

Hence, the new technology telecommunication system is introduced such that fiber optic communication. It has higher data rate transfer compared to convenient telecommunication system. Besides, it has high bandwidth capabilities and low attenuation characteristics make it ideal for long transmission.

However, the dispersion phenomena is an issue for high bit rate on long haul communication system nowadays. The signal will alternate as the signal propagates in optic systems. Hence, there have easy solutions of this issue by applying optical solitons.

Optical solitons is a pulse that preserves their shape over long distance. This is due the properties of the solutions which has balanced of the nonlinearity effect or known as self phase modulation (SPM) and dispersion effect or known as group velocity dispersion (GVD)and resulted the signal undistorted and symmetric bell shape curve.

1.2 Problem Statement

This research used to study the optical pulses of optical solitons in the fiber optic for long haul communications. In fact, it is hard to study the optical pulses in experimentally due to the cost and some of constrains. Optical pulses in fiber optics were intensively studied recently.

Since it has higher data transmission rates over 20 GB/s in the single mode fiber compared to conventional transmission technique [2]. It is currently area of the interest of all scientists or engineers to achieve for higher transfer rates. The model of the optical pulses in optical fibre was already done by some of the mathematician and gives the model with the equation as below:

$$iu_z + \alpha u|u|^2 + \beta u_{\tau\tau} = 0 \qquad [1.1]$$

The Equation [1.1] is Nonlinear Schrödinger Equation (NLS). Where:

α = the nonlinear coefficient and

β = the dispersion coefficient.

z = as distance in optical solitons.

u = the point at the waveform and

τ = temporal solitons time.

$\alpha u|u|^2$ = the non linearity effect on the waveform or known as self phase modulation (SPM).

Since, there have more than one way to get waveform for the model neither via simulation, hardware or mathematical model. Hence, this is useful for study wave propagation (optical pulses) for optical solitons throughout the optical fibre.

1.3 Objectives

The main objectives for development of this research are to:-

1. Simulate the propagation of the optical solitons in the fiber optic for long haul telecommunication problem
2. Analyze the simulation model of electrical part using OptiSystem software.
3. Compare the waveform from type of the optical sech pulse generator and optical Gaussian pulse generator.
4. Compare the result from electrical simulation model with mathematical simulation model.

1.4 Scope

The scope of this project is use of OptiSystem software to simulate the block diagram of optical pulses then analyze the optical pulses though the simulated block results. Besides, this project started to assume there is no loss in the optical fiber and the signal is perfectly reached to the receiver instead of there have some of the loss reason and scattering.

The main core of this project is using the single mode of optical fiber instead of the multi mode due to it is suitable for transmission of data for a distance. There have two types of optical solitons. There are temporal optical solitons and spatial optical solitons. Here, the temporal solitons are used due to its suitability for long haul communication instead of spatial solitons for short distance communication.

$$iu_z + \alpha u|u|^2 + \beta u_{\tau\tau} = 0 \qquad [1.1]$$

The simulated results from Optiwave Software will be compared with the mathematical models by using the equation 1.1. The mathematical model has been done by some mathematicians in the form of error analysis like mean square error by computing with Matlab software.

1.5 Methodology of Research

The intensive study on literature reviews is an important part for a beginning of a research. Thus, this research is started with literature review for optical solitons communications and its application in optical pulses propagation in optical fiber. The information collection is in form of hard copy such as books, journals and also softcopy like online journal like IEEE explorer and Springer Link, articles in PDF file format and also some literature reviews from webpage.

After understand about theory of optical solitons, and then we will find the experimental setup for doing the simulation. The software that we will use is OptiSystem. Based on simulation results, the properties of optical propagation signal will be studied regarding to characteristic of optical pulses. For validity, the simulated results will compare by the mathematical model.

The propagation of optical pulse in optical fiber can be model into a mathematical equation that is nonlinear Schrödinger equation (NLS) and it can be solve analytically. The effects of dispersive and nonlinearity affect solitons generated has been compared.

1.6 Outline of Thesis

The project consists of 5 chapters. Chapter 1 describe the overview of the project and the purpose in studying about optical solitons. The purpose of the project is to study and analyse the propagation wave of the optical solitons in long haul telecommunication. The simulation of optical solitons will be done using OptiWave Software. Then, the results from Optiwave Software will be compared with the mathematical models by using the equation 1.1. The mathematical model has been done by some mathematicians in the form of error analysis like mean square error by computing with Matlab software, Simbiology package. The objective and the scope of the project are discussed detail in this chapter.

In Chapter 2 discussed detailed the literature review for background of optical solitons in long haul telecommunication. It includes the types of solitons, classification of fiber and its non-linear properties.

Chapter 3 will be discussed the flow and method of the research in completing the project. The research is simulating using Matlab Software and OptiWave Software based on type of pulse which are Sech Pulse and Gaussian Pulse. For Matlab Software, the NLS equation is used to generate the waveform propagation and it is done by some mathematician. For validity of the simulation, the block diagram using OptiWave Software will be creating based on the basic part in optical solitons transmission.

In Chapter 4, the results obtained will be shown in the table with different length of fiber. In this chapter, it will divide into two parts showing the mathematical model and electrical model with different length of fiber and the types of pulse.

The analysis, conclusion and recommendation are discussed detailed in the Chapter 5. This is the last chapter of the project. The waveform of the pulse will be analysed based on its wave shape for different length of fiber. Then, the results from electrical model will be compared with the mathematical models by using the equation 1.1. The mathematical model has been done by some mathematicians using Matlab Software. There are also has some suggestion and recommendation for better future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Optical Fibre Communication

Optical fibre communication is the method of telecommunication technique that transmitting information from one part to another part by sending signal or pulses through a medium optical fibre. This type of communication systems have greater advantage compare to conventional communication system such as microwave system. It is increase the capacity in the transmission due to its high frequency in the fibre carrier. Its carrier frequency can reach up to 200 THz. Besides, it has high bandwidth capabilities and low attenuation characteristics make it ideal for long transmission.

2.1.1 Parts of Optical Fibre

In general, optical fibre communication can classified into 3 major parts such as transmitter, communication channel and receiver. Usually, this system using semiconductor devices such as light-emitting diode (LEDs) and laser diode are use in fibre communication. It

is to convert the electrical signal into optical form and to launch the resulting optical signal into the optical fibre communications. [4]

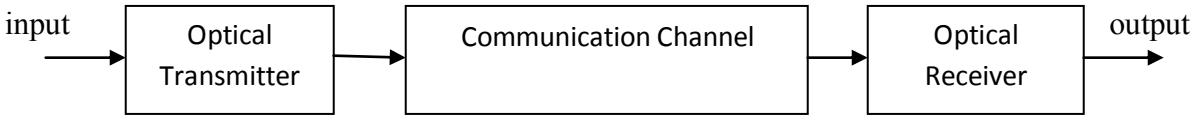


Figure 2.1.1.1 The basic part in optical fibre communications.

Figure 2.1.1.1 shows the basic part of fibre communication. There are optical transmitter, communication channel and optical receiver. The functions of each block are summaries as below:

a. Optical Transmitter

Convert electrical data into optical bit stream which suitable for transmission. The optical source for this block is electrical to optical generator of solitons.

b. Communication Channel

Optical fibres are uses for transmitting optical bit stream in most terrestrial network. This type is use of single mode fibres with low losses that act as communication channel. But the transmission distance is limited by fibre losses. To overcome this problem, the amplifier is used in this system.

c. Optical Receiver

It convert electrical bit stream into the original electrical forms. The photo detector is used in converting from optical to electrical part.

2.1.2 Classification of Fibre Optic Communications

The fibre optic communication can be divided into three modes. Those are multimode step index fibre, multimode gradient index and single mode step index fibre. Figure below will discuss about these three types of mode.

a. Multimode Step-Index Fiber

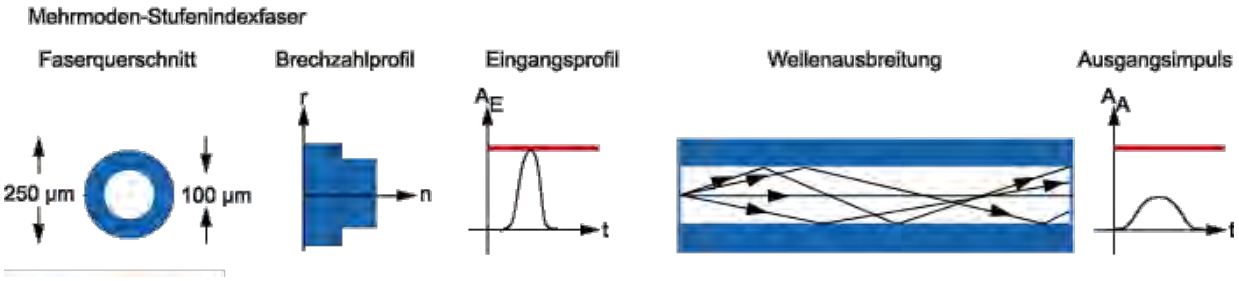


Figure 2.1.2.1 Multimode step index fibre.

Multimode fibres carry many modes of different phase and group velocities. The difference in group velocities of the different modes causes spreading of the temporal envelopes of the individual pulse-excited modes and thus cannot maintain high bit-rate pulse streams(short pulses) over large distances (several kilometres).

Due to its large core, some of the light rays that make up the digital pulse may travel a direct route, whereas others zigzag as they bounce off the cladding. These alternate paths cause the different groups of light rays, referred to as modes, to arrive separately at the receiving point.

The pulse, an aggregate of different modes, begins to spread out, losing its well-defined shape. The need to leave spacing between pulses to prevent overlapping limits the amount of information that can be sent. This type of fiber is best suited for transmission over short distances.

b. Multimode Gradient Index fiber

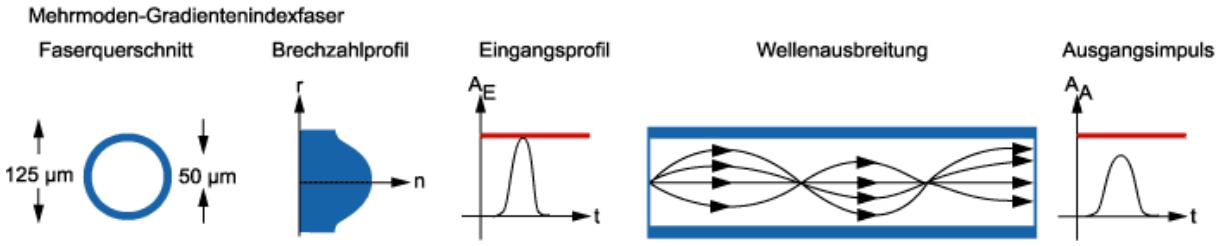


Figure 2.1.2.2 Multimode Gradient Index

This type of mode is also same as the multimode step index fibre. It carries many modes of different phase and group velocities. Contains a core in which the refractive index diminishes gradually from the center axis out toward the cladding. The higher refractive index at the center makes the light rays moving down the axis advance more slowly than those near the cladding as shown in Figure 2.1.2.2

Due to the graded index, light in the core curves helically rather than zigzag off the cladding, reducing its travel distance. The shortened path and the higher speed allow light at the periphery to arrive at a receiver at about the same time as the slow but straight rays in the core axis. For the result, digital pulse suffers less dispersion. This type of fiber is best suited for local area networks.

c. Single Mode Step Index Fiber

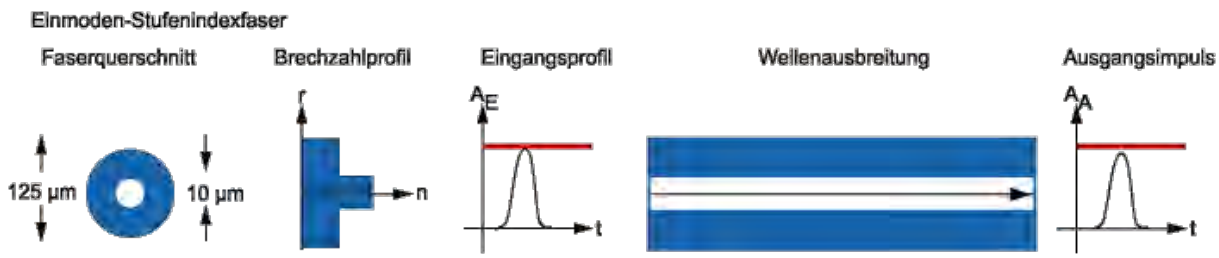


Figure 2.1.2.3 Single mode step index fibre.

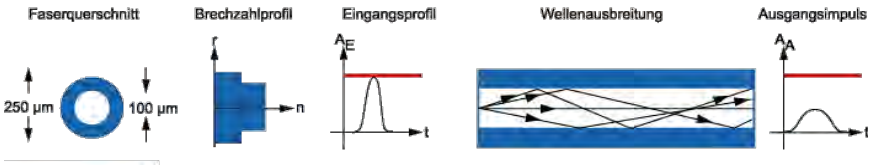
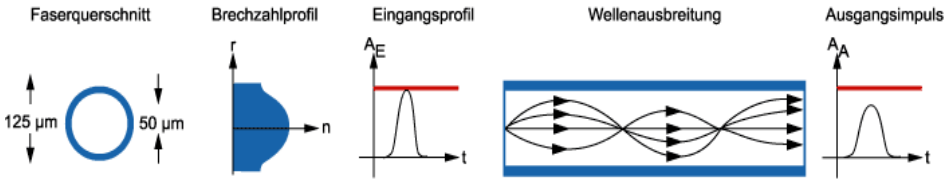
Figure 2.1.2.3 shows the single mode operating in optical fibre communications. The single-mode fibre carries only one mode (of two polarizations). This mode has a definite group velocity at one particular frequency. Single mode fiber optic cable has a small diameter core that allows only one mode of light to propagate.

Because of this, the number of light reflections created as the light passes through the core decreases, lowering attenuation and creating the ability for the signal to travel faster, further. This application is typically used in long distance. In this research only focused on single mode operating due to its advantages over other modes that is most suitable for long haul communications.

2.1.3 Summaries of Classification Type of Fiber Optics

The summaries of classification type of fiber optics are shown in the table below:

Table 2.1.3 Summaries of Classification Type of Fiber optics

Type	Characteristics
Multimode Step Index Fibre	 • Relatively easy to work with • Has larger core size, light is easily coupled to and from it • Coupling losses are less than single index fiber • Suitable for short distance
Multimode Gradient Index	 • Has larger core size, light is easily coupled to and from it • Coupling losses are less than single index fiber • Good compromises between multimode and single mode fiber