INVESTIGATION OF STIMULATED BRILLOUIN SCATTERING FOR THE GENERATION OF MILLIMETER WAVE FOR RADIO OVER FIBER SYSTEM

NORIZAN BINTI MOHAMED NAWAWI

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Universiti Teknologi Malaysia

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ABSTRACT

Radio over fiber (ROF) systems is characterized by having both a fiber optic link and free-space radio path. Such systems are important in a number of applications, including mobile communications, wireless local area networks (LANs), and wireless local loop, etc. However, the growing demand for higher data rates in wireless communication systems requires new frequency bands. The millimeter-wave (mm-wave) range has the highest potential here because it is currently uncluttered and can support high data bandwidth. To ease system complexity in such systems there is growing interest in the exploitation of photonic technologies for the distribution of the mm-waves from a central station to a number of base stations via optical fiber links. Several techniques have been proposed for the optical generation of mm-waves such as direct modulation, external modulation, optical heterodyning and so on. However, in this work we proposed and investigate an alternative to above mention methods, which is based on Stimulated Brillouin Scattering (SBS) in an optical fiber. SBS technique was designed and modeled by performing CW laser in a single mode optical fiber (SMF) through optical Mach-Zehnder modulator (MZM) with two pump lasers for amplification purposes. The analysis was done by determination of the power depletion of generated. SBS performance with the optical fiber loop length up to 100km was analyzed. It has been shown that SBS power is depends on the fiber loop length which is higher and lower at certain length due to natural properties of the fiber. The design shown the RF generation was achieved up to 60 GHz.

ABSTRAK

Sistem radio melalui fiber (ROF) ialah sistem yang mempunyai laluan optik dan laluan radio tanpa ruang. Sistem ini sangat penting dalam banyak aplikasi termasuk perhubungan bergerak, perhubungan kawasan setempat tanpa wayar (LANs), lingkaran setempat tanpa wayar dan sebagainya. Namun, permintaan yang bertambah terhadap kadar pemprosesan data yang tinggi dalam sistem perhubungan tanpa wayar memerlukan jalur frekuensi yang baru. Gelombang millimeter (mm-wave) sangat berpotensi di sini kerana ia tidak berterabur dan boleh manampung lebar jalur yang tinggi. Dalam memudahkan sistem yang komplek, minat untuk mengkaji penggunaan teknologi fotonik dalam mengagihkan gelombang millimeter dari stesen pusat ke beberapa stesen asas melalui rangkaian gentian optik telah bertambah. Beberapa teknik telah dicadangkan untuk menghasilkan gelombang millimeter secara optik seperti modulasi secara terus, modulasi dari luar, pertindihan secara optik dan sebagainya. Namun, dalam projek ini kami telah mencadangkan dan mengkaji satu alternatif kepada teknik-teknik di atas, di mana ia berasaskan kepada rangsangan serakan Brillouin (SBS) di dalam fiber optik. Teknik SBS direka dan dimodel dengan memancarkan laser gelombang terus (CW) ke dalam fiber optik satu mod (SMF) melalui modulasi Mach-Zehnder (MZM) dengan dua laser pam untuk tujuan penguatan. Analisis telah dilakukan dengan menentukan pengurangan kuasa pada signal yang dihasilkan. Prestasi SBS terhadap panjang gentian optik sehingga 100km dianalisis. Ia menunjukkan, kuasa SBS bergantung kepada panjang fiber optik dimana maximum dan minimum disebabkan oleh sifat semulajadi fiber. Rekabentuk menunjukkan penghasilan radio frekuensi (RF) pada 60 GHz telah dicapai.

TABLE OF CONTENTS

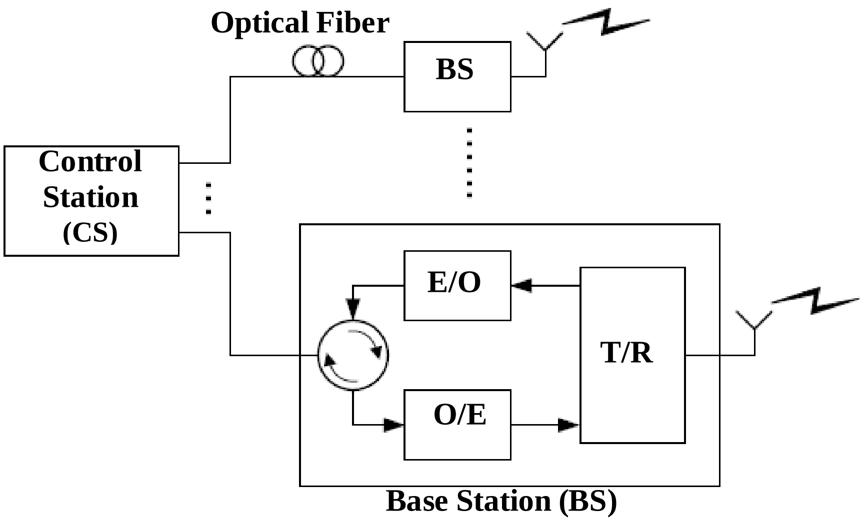
CHAPTER 1

INTRODUCTION

1.1 Project Background

Over the past decade there has been substantial progress in the areas of wireless and optical communications. The driving force behind this advancement has been the growing demand for multimedia services, and hence broadband access. Present consumers are no longer interested in the underlying technology; they simply need reliable and cost effective communication systems that can support anytime, anywhere, any media they want. As a result, broadband radio links will become more prevalent in today's communication systems. Furthermore, new wireless subscribers are signing up at an increasing rate demanding more capacity while the radio spectrum is limited. To satisfy this increasing demand, the high capacity of optical networks should be integrated with the flexibility of radio networks. This leads us to the discussion on the fiber-based wireless access scheme using radio-over-fiber (ROF) technology.

ROF refers to a fiber optic link where the optical signal is modulated at radio frequencies (RF) and transmitted via the optical fiber to the receiving end. At the receiving end, the RF signal is demodulated and transmitted to the corresponding wireless user as shown in Figure 1[1].



E/O: Electric-to-Optic Converter
O/E: Optic-to- Electric Converter
T/R: Transmitter/ Receiver

Figure 1.1 General Radio-over-Fiber (ROF) Systems

ROF is a promising technique in providing broadband wireless access services in the emerging optical-wireless networks. Optical millimeter (mm)-wave generation is a key technique to realize low cost and high transmission performance in the ROF systems [2]. Several techniques have been proposed for the optical generation of mm-waves. One of the simplest methods is the modulation of continuous-wave (CW) laser light by an external modulator is expensive and there are several problems with the group velocity dispersion of the optical transmission systems. Other methods rely on the optical transport of modulated carriers at intermediate frequencies and optical heterodyne techniques. For the first method the mm-wave signal is generated by upconversion in the base station. This requires a high-quality local oscillator or an optically-supported phase-locked loop in the base station. The second method suffers from phase differences between the two superimposed optical signals. To overcome this phenomenon rather complicated setups have been proposed [3].

This thesis reports on an investigation an alternative to above mention methods, which a new proposed technique and very simple that only uses standard components of optical telecommunications. Whereby, the technique relies on the generation of sidebands of a continuous wave (CW) laser by the nonlinear modulation of an optical modulator, which is based on stimulated Brillouin scattering (SBS) in an optical fiber. Two of these sidebands are to be amplified by SBS in an optical fiber whereas the rest are to be attenuated. Then these two sidebands are superimposed in a photodiode. Owing to the fact that both sidebands come from the same source there will be no problem with phase noise. This thesis reports on the work involved in modeling the proposed method using suitable commercial optical system simulator; Optisystem for performance characterization. These efforts resulted in potential to create very stable mm-waves with low noise.

1.2 Problem Statement

ROF system has attracted considerable attention to deliver microwave and millimeter wave signals. It is a system that distributes the radio waveform directly from CS to BS through optical fiber. The growing demand for higher data rates in communication systems requires new frequency bands. The mm-waves range has the highest potential here because it can support high data bandwidth. This project was focused on how to generate radio signal in ROF networks using SBS technique.

1.3 Objectives

The objectives on this project are:

1. To investigate the characteristics and performance of stimulated Brillouin Scattering (SBS) technique in optical fiber for the generation of millimeter waves.
2. To verify the design for the generation of millimeter waves employing Stimulated Brillouin Scattering (SBS).

1.4 Scopes of Project

The scopes of this project are:

1. Understand the basic principle of the SBS technique.
2. Design, model and simulate the SBS for generation of mm-waves for ROF system using Optisystem.

1.5 Methodology

The project focuses on the designation process of the SBS system in generating mm-wave which is very important process before entering the higher process. The corresponding higher process includes prototype system development, measurement and full system integration process. The overall project flow is shown in Figure 1.2.

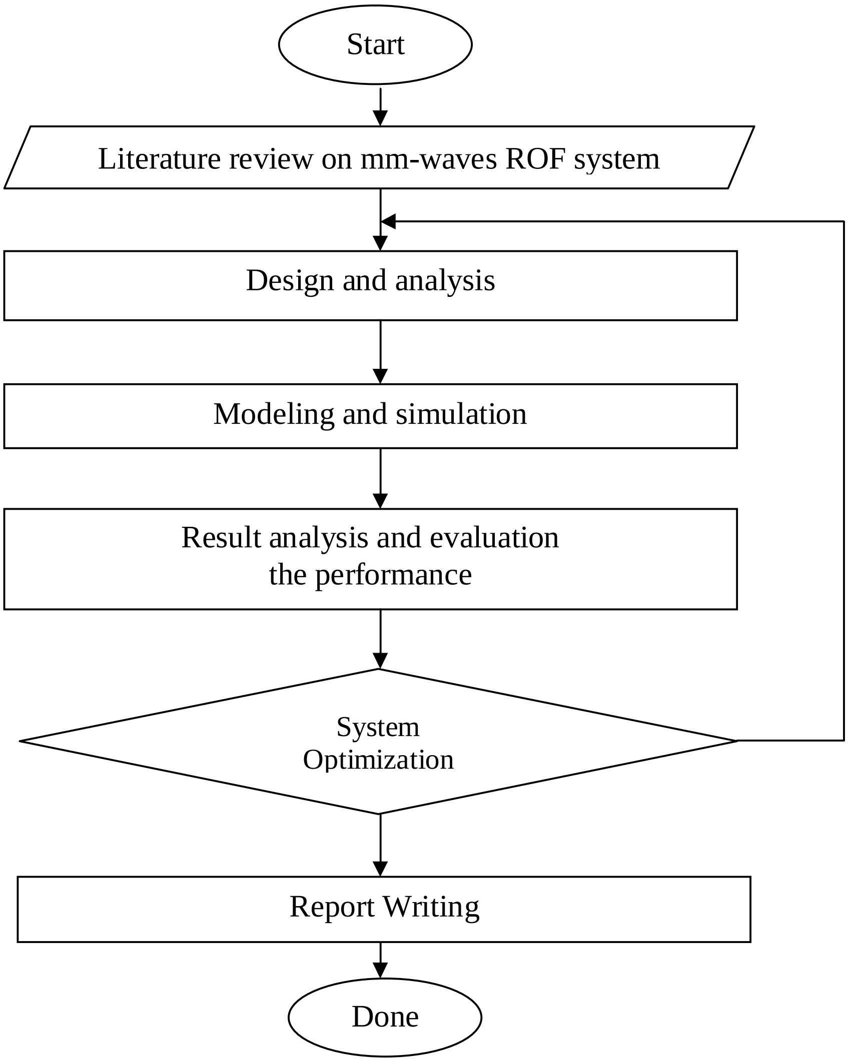


Figure 1.2 Project Flow Chart

The methodology starts with review on current progress on the ROF system especially on the generation of the mm-waves modulated RF. It was followed by investigation SBS for the tunable generation and amplification of mm-waves. The theoretical analysis include SBS technique, basic concepts of ROF system and some review of harmonic generation with a Mach-Zehnder modulator (MZM) and the advantages and limits of SBS for the amplification of the sidebands.

For the system characterization, SBS method has been designed, modeled and simulated. The technique relies on the generation of sidebands of a continuous wave (CW) laser. The numerical simulation will obtained using suitable commercial optical system simulator; OptiSystem.

Optisystem is an innovative optical communication system simulation package that designs, tests, and optimizes virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broadcasting systems to intercontinental backbones. It is a stand-alone product that does not rely on other simulation frameworks. Optisystem is a system level simulator based on the realistic modeling of fiber-optic communication systems. It possesses a powerful new simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be extended easily with the addition of user components, and can be seamlessly interfaced to a wide range of tools.

A comprehensive Graphical User Interface (GUI) controls the optical component layout and netlist, component models, and presentation graphics. The extensive library of active and passive components includes realistic, wavelength-dependent parameters. Parameter sweeps allow you to investigate the effect of particular device specifications on system performance. Created to address the needs of research scientists, optical telecom engineers, system integrators, students, and a wide variety of other users, Optisystem satisfies the demand of the booming photonics market for a powerful and easy-to-use optical system design tool.

The most comprehensive optical communication design suite for optical system design engineers is now even better with the release of new version, Optisystem version 6.0. The latest version of Optisystem features a number of requested enhancements to address the design of passive optic network (PON) based FTTx, optical wireless communication (OWC), and radio over fiber systems (ROF).

Some benefits of Optisystem software as shown below:

- Rapid, low-cost prototyping
- Global insight into system performance
- Straightforward access to extensive sets of system characterization data
- Automatic parameter scanning and optimization
- Assessment of parameter sensitivities aiding design tolerance specifications
- Dramatic reduction of investment risk and time-to-market
- Visual representation of design options and scenarios to present to prospective customers

OptiSystem allows for the design automation of virtually any type of optical link in the physical layer, and the analysis of a broad spectrum of optical networks, from long-haul systems to MANs and LANs.

Optisystem's wide range of applications includes:

- Optical communication system design from component to system level at the physical layer
- CATV or TDM/WDM network design
- Passive optical networks (PON) based FTTx
- Free space optic (FSO) systems
- Radio over fiber (ROF) systems
- SONET/SDH ring design
- Transmitter, channel, amplifier, and receiver design
- Dispersion map design
- Estimation of BER and system penalties with different receiver models
- Amplified system BER and link budget calculations

Finally, compare the results of the simulation with the theoretical analysis and previous work. Improve this method has the potential to create very stable mm-waves with low noise.

1.6 Thesis Outline

This thesis comprises six chapters and is organized as follows:

Chapter 1 discusses the project background, problem statement, objectives, scope of project, followed by methodology and the thesis outline.

Chapter 2 gives an introduction of ROF system, some fundamental theories of optical fiber transmission link and the techniques of generating mm-wave signals. Chapter 3 deals with the theoretical background of nonlinear effects which are focused on physics of SBS effects and the effects in optical fiber.

The SBS system model is described briefly in Chapter 4. The principle operation of the technique and its features are reviewed. The next chapter discusses and analyzes the results obtained from performing SBS simulations. Chapter 6 gives the conclusions for the whole project. Besides, it also provides the suggestion for future recommendation that can be made to make the simulation more practical and continuously.

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