MATEC Web of Conferences **140**, 01020 (2017) DOI: 10.1051/matecconf/201714001020
ICEESI 2017

Optical Generation of 80 GHz Downstream Data in Radio over Fiber System Based on Stimulated Brillouin Scattering

M.M.H Husaini, Mohd Rashidi Che Beson, M.S Anuar, R. Endut and Aljunid Syed A.*

Advanced Communication Engineering, Center of Excellence, School of Computer and Communication Engineering, Universiti Malaysia Perlis (UNIMAP), Perlis, Malaysia

Abstract. In this work, we proposed Stimulated Brillouin Scattering (SBS) in an optical generation of millimeter waves (mm-waves) for radio over fiber (RoF) system with the transmission of 2.5 Gbps data rate. SBS method is achieved by imposing continuous wave (CW) laser in a single mode optical fiber (SMF) via Mach-Zehnder Modulator (MZM) with Erbium-Doped Fiber Amplifier (EDFA) and two pump lasers. Mm-waves signal of 80 GHz was generated from a 40 GHz radio frequency (RF) synthesizer. Simulation result and the analysis comparison of effective light power are investigated with different SMF loop length from 20 km until 120 km. The performance of SBS system is analysed and the generated of millimeter waves signal can be transmit with length up to 120 km based on eye pattern and Bit Error Rate (BER) curve.

1. Introduction

Radio-over-Fiber (RoF) is a fundamental property of communication which light propagates by radio frequency (RF) and transmitted over an optical fiber link [1]. RoF are promising significant advantages such as immune to electromagnetic interference, offers large bandwidth, low attenuation and low cost which these system can be used in various types of application such as Wi-Fi, sensor networks, radar and so on[2]. Optical generation of mm-waves signals is one of the method that would execute the RoF communication system[3]. Mm-waves can be named electromagnetic spectrum that ranges between 30 GHz to 300 GHz which capable to overcome the issue of spectral congestion at lower frequency ranges[4] .

Over the past few years, many optical generation of mm-waves signal approaches have been employed. These approaches comes with advantages and drawbacks as depicted in table 1.

From the table 1, one of the simplest technique based on external modulator has been widely used since it is low cost and high reliability but there are several problem occurs with chromatic dispersion of mm-waves generation signal[5]. Single sideband (SSB), double sideband (DSB) and optical carrier suppression (OCS) are external modulator schemes that have been demonstrated, DSB modulation bear with fading effect which is not suitable for long transmission distance while SSB and OCS requires dual arm MZM to drive optical source. In [6], generate OCS mm-waves signal based on two parallel Dual-Drive MZMs is proposed. However, complicated setup and generated mm-waves produces high BER at 60 km transmission distance.

Table 1. Comparison of technique in mm-waves signal generation

Method	Advantages	Drawbacks
Direct modulation [7]	Low cost and simplest scheme.	Low frequency response and limited by the laser chirp.
External modulation [8][9][10]	High frequency response and scalability	Requires optical filter and larger insertion loss
Optical heterodyne [11]	High spectral purity	Quality of the mm-waves relies on the coherence of the two laser lightwaves.

Thus, an alternative method is proposed which is Stimulated Brillouin Scattering (SBS) to overcome above mention problem. Stimulated Brillouin Scattering (SBS)

* M.M.H Husaini: mhhusaini15@gmail.com

has generally been perceived as one of the causes degrading framework execution in fiber optic systems because of the impact that the signal energy is exchanged to the back scattering signal and SBS has low threshold. In any case, SBS has advantages qualities, for example, frequency selective amplification that can be boost up to microwave and mm-waves photonics applications[12].

1.1 Principle of SBS

SBS is a nonlinear impact due to the measure of light backscattered and the measure of light transmitted by the fiber does not depend directly on the power input to the fiber. In depth, low input power of the backscattering is influence by straightforward Brillouin and Rayleigh scattering which are direct and vary from each other by brillouin shift. When the power increased, the brillouin scattered light is amplified by the output process. The backscattered light slightly increased with the increasing input power until it initiate most of the input light at SBS threshold also known as power level. Hence, the SBS threshold can lie in the span of 6-10 dBm for single mode fiber (SMF) with transmission distance greater than 10 km. Over this threshold, the input power is not independent of the insertion loss of the fiber.

1.2 Proposed of SBS system Model

The optical generation of mm-waves utilizes SBS technique is shown in fig. 1. A Continuous Wave (CW) laser at 1550 nm is intensity-modulated via MZM driven by the electrical sine generator, F_{rf} = 40 GHz. Dual series of MZMs component is used which MZM 1 modulates the optical source and MZM 2 is modulated via pseudo-random bit sequence (PRBS) at 2.5 Gbps NRZ electrical signal to generate baseband data signal. The voltage that is connected on the MZM is sufficiently high so that the laser wave is regulated nonlinearly with the applied frequency of the electrical generator.

A few optical sidebands isolated by frequency of electrical generator from the optical carrier are created by MZM non linearity. The transmission distance are connected into up to 120 km long of Single Mode Fiber (SMF) loop. The optical signal is then amplified using an erbium-doped fiber amplifier (EDFA) before being launched into the optical fiber loop, EDFA act as control power of signal wave which generated sidebands by nonlinear modulation from CW laser will be amplified by SBS in an optical fiber, whereas the rest will be attenuated due to natural attenuation in the fiber[13].

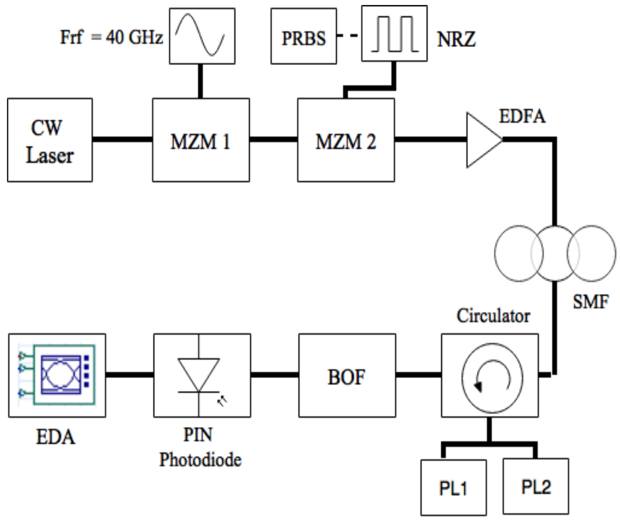


Fig. 1. Experimental setup for optical mm-waves signal generation based on SBS technique.
(CW: Continuous Wave, MZM: Mach-Zehnder Modulator, EDFA: Er.doped Fiber Amplifier, SMF: Single Mode Fiber, PL1 & PL2: Pump Laser, BOF: Bessel Optical Filter, EDA: Eye Diagram Analyzer)

SBS effects gain in the SMF is creating from combined output signal of two pump lasers which pump source driven via an optical circulator that propagates modulate signals through opposite direction. The wavelength of each pump laser is set to 980 nm. Hence, generated mm-waves output
is detected by a photodiode. The execution of this RoF system are utilized by eye diagram analyzer and Bit Error Rate (BER) curve.

Theoretically, the generation of mm-waves frequencies rely on the RF of the electrical generator and on the sidebands that were picked for amplification. The generated mm-waves can be expressed as :

$$f_{mm} = 2nf \qquad [14]$$

where n as the number of the sideband used and f as the RF of the electrical generator. If the f =5 Ghz, generated frequencies will be 10,20,30 and so on can be deploy.

2. Result and Discussion

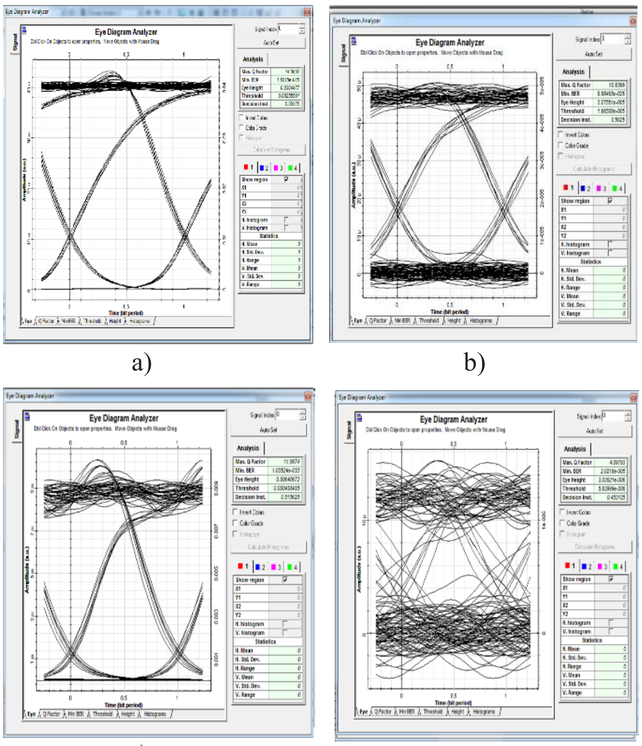
In this section, the generated optical mm-waves for SBS system is validate by using OptiSystem software package. All necessary simulation setup value is shown in the following table.

Table 2. General parameter for simulation

Parameters	Value
Freq. of electrical generator	40 GHz
Reference wavelength of CW laser	1550 nm
Effective light power of CW laser	0,-0.5,5 dBm
Linewidth of CW laser	1 MHz
Samples per bit	64
Bit rate	2.5 Gbps
EDFA	5 m
Optical fiber length	50 KM
Attenuation of Optical Fiber	0.2 db/km
Dispersion of Optical fiber	16.75ps/nm/km
Sensitivity	-100 dBm
Resolution	0.1 nm

The model of SBS system is constructed as shown in table 2, whereas these output signal is measured by the eye diagram analyser that indicate which is best performance of the system can be determine by the wide eye opening.

The demodulation analysis of 2.5 Gbps of the 80 Ghz mm-waves signal are presented when vary SMF loop length within range 20 km until 100 km with EDFA and without EDFA. As can be seen in fig. 2(a-f), for transmitted signal over 20 km, the eye pattern shows both techniques are in good performance but when optical signal mm-waves propagating over 50 km to 100 km distances, the outline of the simulated eye diagram gradually decreases without optical amplifier technique. Hence, the optical amplifier and SBS effect excites the power occur at 20 km then performance degraded over longer fiber transmission.



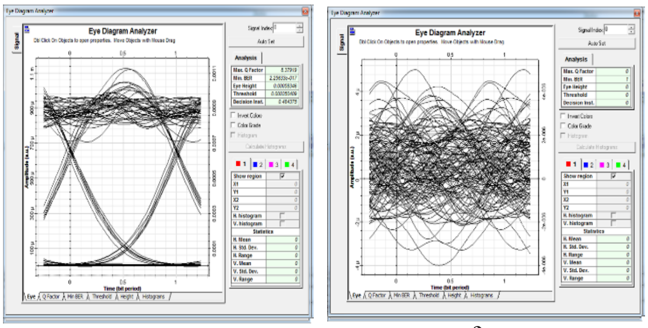


Fig. 2(a-f). Simulated eye diagram at receiver for 2.5 Gbps data rate with different SMF transmission distances a) 20-km with amplifier b) 20-km without amplifier c) 50-km with amplifier d) 50-km without amplifier e) 100-km with amplifier f) 100-km without amplifier.

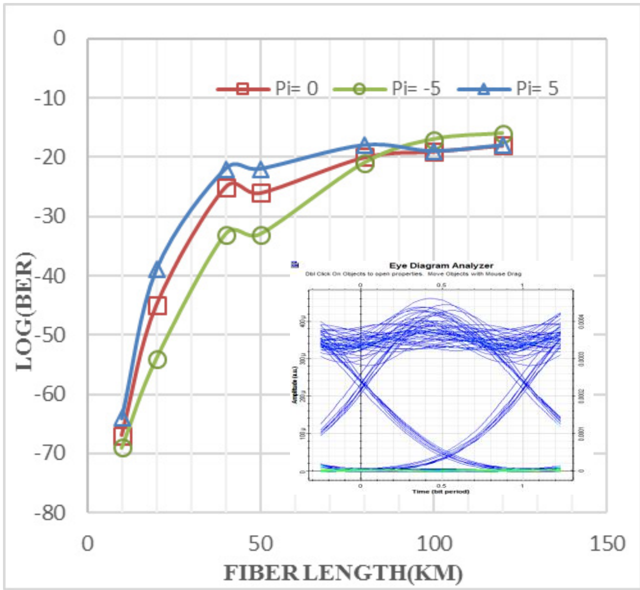


Fig. 3. Measured BER versus fiber length with different transmission distance (inset shows the eye diagram at 120 km for -0.5 dBm of effective light input power).

Fig. 3 compares the experimental data on the effective light power, P_i when varies 0, -0.5 and 5 dBm of the downstream 2.5 Gbps signal with different optical fiber transmission distance. From the graph above, we can see that, the value of BER displays an increasing pattern over longer fiber transmission distance due to attenuation. BER is approximately at (10^{-33}) at 50 km transmission distances with effective light power, P_i= -0.5 dBm. When the effective light power varies to 0 dBm and 0.5 dBm, the system presents high BER with (10^{-25}) and (10^{-20}) respectively. This SBS method capable to perform the system until 120 km transmission distance with the BER is (10^{-19}). Thus, a larger dispersion and attenuation will occur over the longer fiber length as well as increasing the BER.

3. Conclusion

In this paper, we have demonstrated 80 Ghz optical mm-waves signal and transmission of a 2.5 Gbps downlink stream in RoF system based on SBS in SMF. The proposed method of 80 Ghz signal were generated from a 40 Ghz RF oscillator corresponding to theoretical equation. The analysis of the system performance have been made with eye diagram visualizer which eye pattern decreased over long range optical fiber length. This scheme successfully propagates over 120 km in optical fiber length with low BER value at (10^{-19}) from -0.5 dBm of light power. Thus, it is strongly proven that the proposed technique is essential for long range wireless communication networks system.

References

[1] M. S. Transmission and P. C. Systems, "Millimeter-Wave Subcarrier Transmission," no. c, pp. 555–558, 1992.

[2] M. R. C. Beson, S. A. Aljunid, F. Ghani, M. S. Anuar, and H. A. Fadhil, "Alleviation noise effect using flexible cross correlation code in spectral amplitude coding optical code division multiple access systems," *J. Commun.*, vol. **8**, no. 2, pp. 101–109, 2013.

[3] T. A. Chowdhury, M. A. Ghuri, and R. Kibria, "Millimeter Wave Generation Based on Optical Frequency Multiplication in Radio over Fiber Systems," pp. 94–97, 2016.

[4] C. B. M. Rashidi, S. A. Aljunid, F. Ghani, H. A. Fadhil, and M. S. Anuar, "Cardinality enhancement using Flexible Cross Correlation (FCC) code for Spectral Amplitude Coding Optical Code Division Multiple Access systems," *J. Appl. Sci. Res.*, vol. **8**, no. 12, pp. 5614–5626, 2012.

[5] G. H. Smith, "Overcoming chromatic-dispersion effects in fiber-wireless systems incorporating external modulators," *IEEE Trans. Microw. Theory Tech.*, vol. 45, no. 8 PART 2, pp. 1410–1415, 1997.

[6] N. A. Mohammed, S. I. S. Hassan, F. Malek, R. Ngah, and S. A. Abbas, "Optical generation of 60-GHz signal for millimeter wave wireless communication," *RFM 2013 - 2013 IEEE Int. RF Microw. Conf. Proc.*, vol. **0**, no. 1, pp. 437–440, 2013.

[7] H. Shams and J. Zhao, "First Investigation of Fast OFDM Signals at 60GHz using Direct Laser Modulation," *CLEO/Europe-EQEC 2013*, vol. **487**, no. 318415, p. 318415, 2013.

[8] J. Ma, J. Yu, C. Yu, X. Xin, J. Zeng, and L. Chen, "Fiber dispersion influence on transmission of the optical millimeter-waves generated using LN-MZM intensity modulation," *J. Light. Technol.*, vol. **25**, no. 11, pp. 3244–3256, 2007.

[9] N. A. Al-shareefi, S. I. S. Hassan, F. Malek, R. Ngah, and S. A. Abbas, "Optical Generation of 60 GHz Downstream Data in Radio over Fiber Systems Based on Two Parallel Dual-Drive MZMs," vol. 6, no. **2**, pp. 579–587, 2014.

[10] C. Jiang, X. Chen, and Z. Liu, "Effect of Modulation Index of Mach-Zehnder Modulator on Single Sideband Radio over Fiber System," *Proc. 2012 2nd Int. Conf. Comput. Inf. Appl. (ICCIA 2012)*, no. Iccia, pp. 574–577, 2012.

[11] G. J. Simonis and K. G. Purchase, "Optical generation, distribution, and control of microwaves using laser heterodyne," *IEEE Trans. Microw. Theory Tech.*, vol. **38**, no. 5, pp. 667–669, 1990.

[12] N. M. Nawawi and S. M. Idrus, "Investigation of stimulated brillouin scattering for the generation of millimeter waves for radio over fiber system," *Proc. IEEE 2008 6th Natl. Conf. Telecommun. Technol. IEEE 2008 2nd Malaysia Conf. Photonics, NCTT-MCP 2008*, no. August, pp. 33–36, 2008.

[13] M. Junker, T. Schneider, M. J. Ammanno, and A. T. Schwarzbacher, "Carrier Generation in the Millimetre Wave Range based on Stimulated Brillouin Scattering for Radio over Fibre Downlink Systems," pp. 191–195, 2006.

[14] T. Schneider, D. Hannover, and M. Junker, "Investigation of brillouin scattering in optical fibers for the generation of millimeter waves," *J. Light. Technol.*, vol. **24**, no. 1, pp. 295–304, 2006.