Analysis of Advanced Modulation Format Using Gain and Loss Spectrum for Long Range Radio over Fiber System

Shaina Nagpal, Amit Gupta

***Abstract*—**In this work, all optical Stimulated Brillouin Scattering (SBS) generated single sideband with suppressed carrier is presented to provide better efficiency. The generation of single sideband and enhanced carrier power signal using the SBS technique is further used to strengthen the low shifted sideband and to suppress the upshifted sideband. These generated single sideband signals are able to work at high frequency ranges. Also, generated single sideband is validated over 90 km transmission using single mode fiber with acceptable bit error rate. The results for an equivalent are then compared so that the acceptable technique is chosen and also the required quality for the optimum performance of the system is reported.

***Keywords*—**Stimulated Brillouin scattering, radio over fiber, upper side band, quality factor.

I. Introduction

FUTURE generation communication systems including the optical photonics are meant to considerably boost the ability of the transmission system. Its advantages consisting of high speed and extended wide area make it feasible for long distance communication. However, rising figure of users will enforce boundaries to the information transfer [1]-[5]. Now, a lot of developers are trying to solve the current issues by utilizing the new solution that is generation of millimeter waves, that is considered as high range of frequencies ranging from 30 GHz and can be extended up to 300 GHz [6]-[8]. Some other problems come into play by utilizing these solutions [9]. More base stations are required if cell size reduces. Increasing the frequency, motivation contributes to additional equipment, fitting and preservation costs. All optical photonics furnish the approaches to overcome the drawbacks that are existing in optical communication field. Its advantages include high speed and improved range which are integrated in lot of fields such as army, radio astronomy and radio over fiber methods to furnish immunity to interference [10].

Subsequent generation methods require transferring of frequencies to mm-wave region with low false alerts and adjustable advantages that are predominant and intricate. Photonics can overcome these drawbacks via relocating one frequency to more or less frequency. It is also valuable to provide single sideband together with carrier, which plays main role in radio over fiber methods. More application areas like spectroscopy, quantum measurements and optics require frequency relocating or shifting operations of several Ghz [11], [12]. In this work, all optical SBS based on new frequency convertor or shifter is introduced for radio over fiber systems. The principal work is to enhance lower sideband and suppress different sideband to have single sideband suppressed signals. Also, modulator used is biased at minimum point to get single sideband after SBS.

This paper is structured in the following manner: the principle of SBS based frequency down converter is well described in Section II. The detailed description about SBS is also included in this section. Section III reports about the system set up for generating the single side band based in SBS. Results and discussions are explained in Section IV briefly. Section V is followed with the conclusion

II. Working of SBS Based Frequency Down Convertor

All optical frequency shifter for generating single sideband is realized using SBS phenomenon from an optical fiber with two intensity modulators [13], [14]. SBS is very important factor in medium such as optical fiber. There are two effects that mainly exist in this method. When a low power microwave signal is fed into null point operated modulator, a suppressed carrier signal and sidebands are appeared. Low power signal sent to optical fiber, which generate strokes wave in backward direction and rest of the signal to forward direction. Another signal of more power fed to optical fiber from counter direction, which ultimately distributes gain to first signal as shown in Fig. 1. Brillouin gain is shifted to lower frequency due to Brillouin shift introduced by SBS. As a result of this, upper shifted spectrum experienced the loss and is suppressed as compared to low shifted frequency. The considerable use of Brillouin scattering makes it well feasible for providing high bandwidth and high capacity channels and it is also capable of generating the high frequency millimeter waves [6]. Benefits of SBS make it popular because it can be achieved early even at low powers.

From Fig. 1, it is clearly observed that upshifted side band is suppressed with the loss spectrum and downshifted sideband is provided with the gain spectrum. The signal generated is utilized in subcarrier multiplexing. The sidebands are used for upstream data, and the center frequency is utilized for downstream data for transmission in radio over fiber systems.

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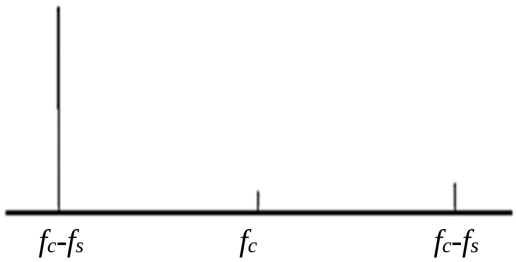


Fig. 1 Down shifted sideband without carrier due to SBS

III. System Setup

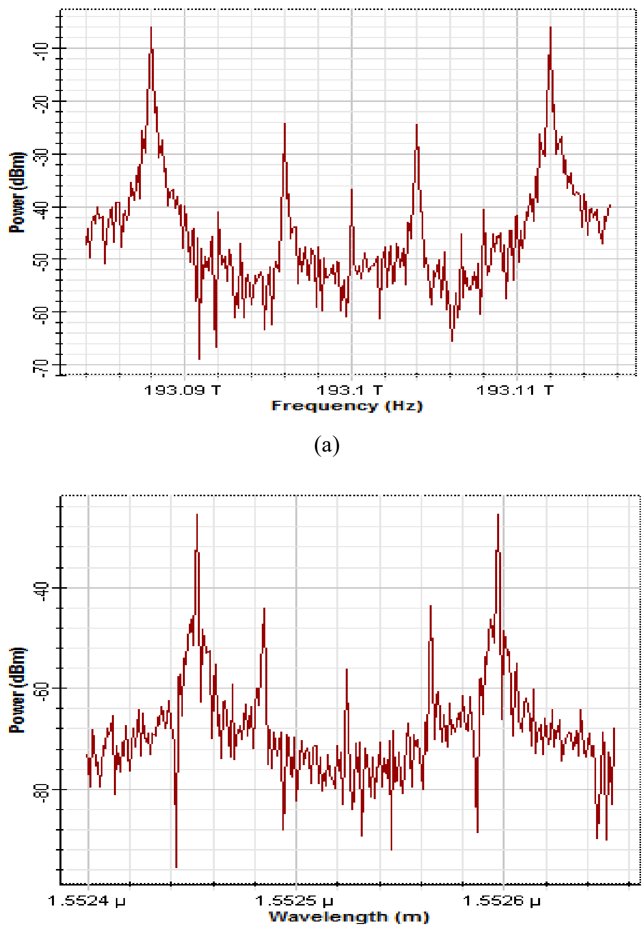
With the help of a power splitter, the continuous wave light is split into two signals, and both the signals are fed into null point biased optical modulator operated at 193.1 THz. The output of both the transmitters have sidebands. The first modulator at power 0 dB receives the radio frequency signal that is having fixed frequency close to the required shift which is 20 GHz. Second modulator is driven by frequency equal to 9 GHz that is the distinction between frequency which is altered and frequency that is related to the Brillouin shift of the fiber. Here another sine wave is also provided and the resultant signals with dual side band after fetching both the modulators are referred as probe signal having low power respectively. Semiconductor amplifier is also used to control the amplitude of upper modulator, and the other modulator is taken into account due to its low cost and less size and provides amplification to lower modulator signal operated at -20 dB input. To generate strokes wave and for the amplification of the wave, two optical signals are fed into bidirectional optical fiber of length 25 km from opposite directions. Eventually, these signals give rise to two phenomena that include loss of the signal and gain of the spectrum. The sideband at upper frequency (193.11 THz) is experience loss because it transfers its energy to another propagating signal at 193.09 THz. This represents that frequency of signal low shifted by stimulated scattering of upper modulator and introduce frequency down shifting operations. Fig. 2 represents the system setup for single side band generation that has been achieved using gain and loss spectrum.

Here, the microwave signal is fed using sine wave that is modulated with the optical signal coming from the laser respectively and transmitted through fiber.

Signal generated from MZM1 is fed into optical fiber from one side and signal generated from MZM2 is fed to opposite side. The signal of MZM1 experiences less SBS due to less power. The part of the signal which is reflected back is called strokes signal. The signal of MZM2 experiences more SBS due to high power and high loss due to transfer of energy to another signal. Now, MZM1 signal gives loss spectrum to MZM2 wave and experiences loss at 193.11 and gain at 193.09 THz. Then, with the help of optical circulator (that works on the principle of n+1 formula), both signals are fed into fiber. The generated signal due to SBS is provided to Mach-Zhender modulator for further communication and validation. A Pseudo Bit random generator is used to generate random bits and this provides NRZ pulse format. Now, signal transmits over optical fiber of 90 km through optical circulator. This system is unidirectional so operated in one direction by using frequency of 193.09 THz due to which SBS is achieved. It is received by using PIN photo-detector having 10 nA dark current followed by Bessel electrical filter to remove noises. A 3R regenerator is incorporated to resample, retime, and reamplify data. BER analyser connected to regenerator to shows eye diagram and also provides Q-factor and error rate.

III. Results and Discussion

In order to achieve the SBS, two signals are given in opposite directions to optical fiber. These signals then, with the help of SBS, give single side band. Fig. 2 depicts single sideband signal at 193.09 THz and is also showing loss at upper frequency. Optical signal is modulated by data with the help of non-return to zero-bit format and transmitted over optical fiber.



(b)

Fig. 2 Output of Optical spectrum analyser for intensity modulators (a) Mach-Zhender modulator 1 (b) Mach-Zhender modulator 2

Fig. 2 clearly depicts the spectrum in optical mode and analyses the optical signals in the frequency domain. It shows the output spectrum of Mach-Zhender modulator 1 that has been used.

TABLE I
SYSTEM SPECIFICATION FOR GENERATING SINGLE SIDE BAND

PARAMETERS	VALUES
Laser Frequency	193.1 THz
Data Rate	10 Gbps
Sine Generator frequency	20 GHz
Gain	3 dB
Injection current (SOA)	0.15 A
Sequence Length	8 bits
Sample Per Bit	32
Photo detector	PIN
Responsivity	1A/W
Dark current	10 nA
(Bi-directional optical fiber) Length	25 km
Reference Wavelength	1550 nm

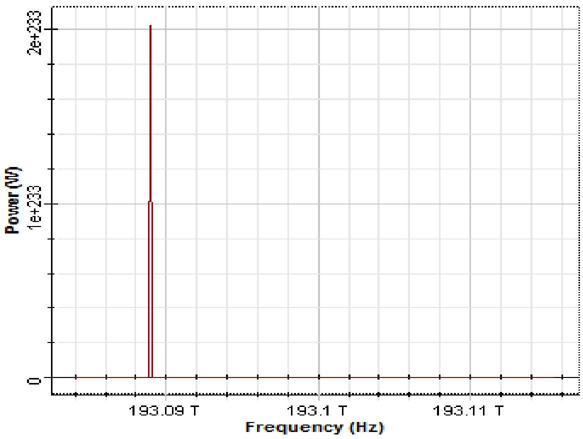


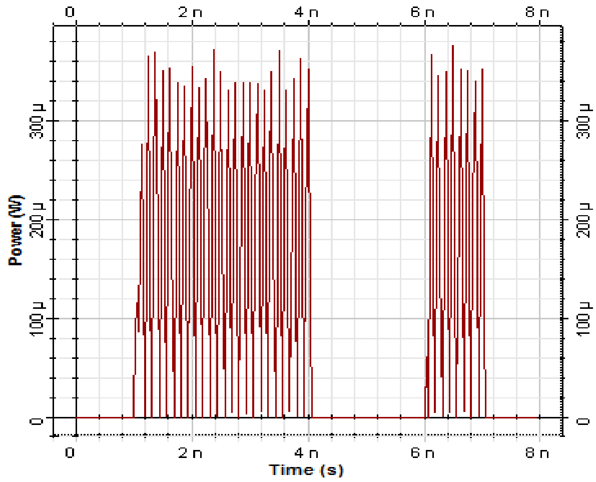
Fig. 3 Single sideband signal after SBS

In Fig. 3, optical domain visualizer has been used in order to visualize the signals in the optical domain. The data have been transmitted over the fiber, and the length of the fiber can be varied accordingly.

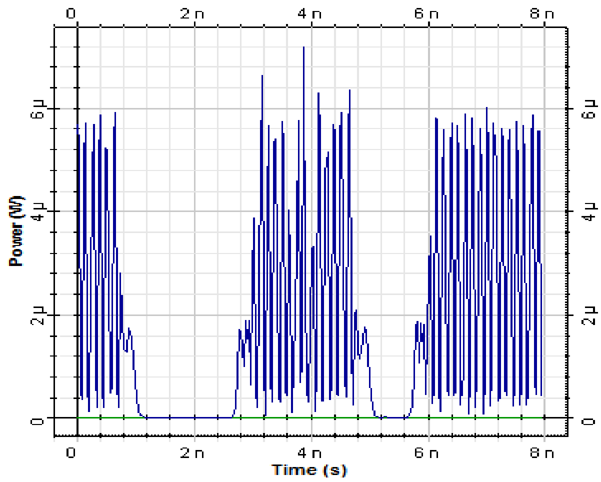
Fig. 4 (b) shows that data bits are distorted after 90 km because of attenuation and dispersion effects. In this work no dispersion compensation fiber has been used. In optical fiber transmission, no amplifier is incorporated.

Only one SOA amplifier is used to amplify low power signal in SBS setup. Also, optical fiber produces less nonlinear effects at low launched power and more effects at high input power. Analysis of system performance is carried out by observing system at different lengths with/without SOA amplifier.

In Fig. 5, eye diagram depicts the Q factor having value 25.9644 with semiconductor amplifier and for 90 km the Q factor comes up to 6.95 with semiconductor amplifier.

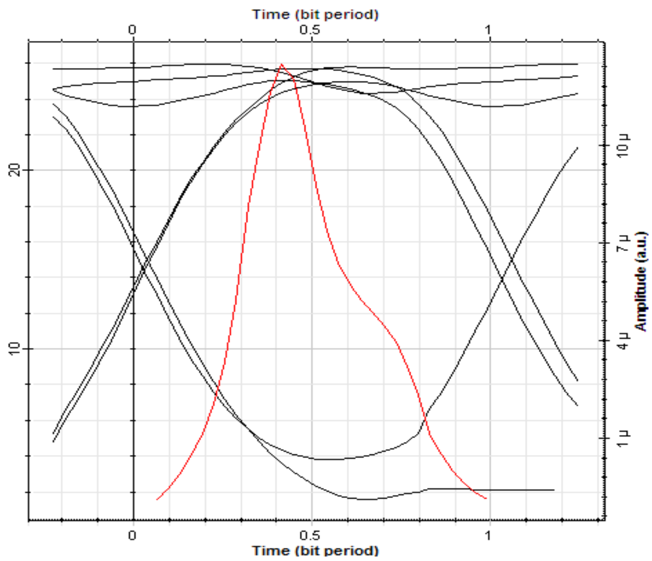


(a)

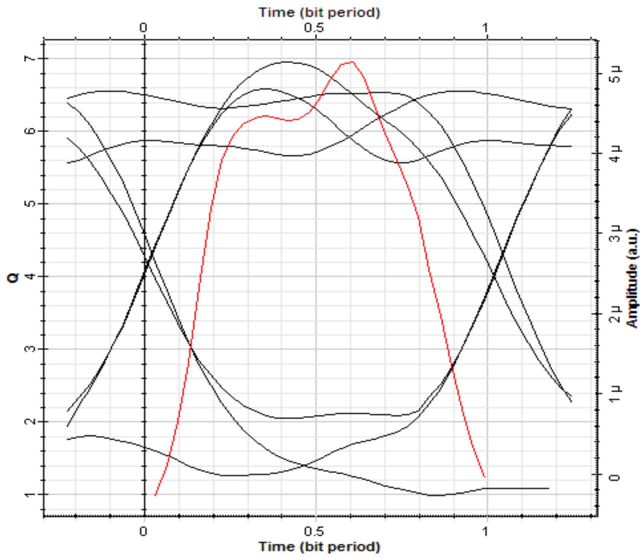


(b)

Fig. 4 Data bits at optical time domain visualizer after (a) transmitter (b) 90 km SMF



(a)



(b)

Fig. 5 Eye diagram at receiver after (a) 50 km (b) 90 km

V. Conclusion

In this work, a new cost effective wavelength shifter has been analysed. A novel frequency mover is proposed that can move signal in millimeter range, i.e. 30 GHz to 300 GHz. The sideband with suppressed carrier created by all optical SBS has provided better efficiency as compared to double sideband with carrier signal over optical medium. System is compared for with and without SOA amplifier in single sideband generation. Results revealed that system acts efficiently with SOA amplifier over different distances. This generation of increased carrier power, and single sideband relies on the SBS which give gain spectrum and loss spectrum in single mode fiber to suppress upshifted sideband and to strengthen low shifted sideband. A single sideband is obtained from SBS phenomenon which is useful in advance modulation formats and requires less bandwidth.

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