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Performance Analysis of Stimulated Brillouin Scattering (SBS) in RoF System

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ABSTRACT: This paper demonstrate the performance analysis of Stimulated Brillouin Scattering in RoF system. The generation of high frequency carrier signals for radio over fiber (RoF) is considered as a promising technique in providing broadband wireless access services. High frequency carriers are generated by Stimulated Brillouin Scattering. The best high frequency carrier can be generated by varying the fiber length, Brillouin linewidth, wavelength of laser source and power of laser source. Modelling and simulation of the SBS system was done for analyzing the system performance and generation of millimeter waves using optical commercial software Optisystem 12.0.

KEYWORDS: Electrostriction, Nonlinearities, Photodiode, Radio over Fiber, RF Spectrum Analyser, Stimulated Brillouin Scattering

I.INTRODUCTION

This project is about characterization of millimeter-wave carrier generation based on Stimulated Brillouin Scattering (SBS) effect. The Stimulated Brillouin scattering effect (SBS) is used to generate the mm – waves that has high carrier frequency which is used to carry signals and data during the transmission in radio over fiber (RoF) system [1].

Although there are several studies in generating mm-waves by utilizing the non-linearity effects of Stimulated Brillouin Scattering (SBS) in an optical fiber [6], further studies could be proposed by varying some of the bidirectional optical fiber parameters and varying CW input power at different fiber length for system performance analysis. This project essentially discusses the non-linear effect such as Stimulated Brillouin Scattering (SBS) to be utilized for generating mm-waves which is obtained by modelling and simulating the proposed design from an experimental set-up for system performance and characterization.

Radio over Fiber (RoF) is a technology that concerns about the light transmission where the light is modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access. However, there are many limitations regarding RoF when using optical communication link [3] and these limitations occur when delivering mm-waves due to its non-linearity effect in the fiber . But the Stimulated Brillouin Scattering can be efficiently used for the generation of high frequency carriers [4].

II.NONLINEARITIES IN FIBER

Optical nonlinearities gives rise to many effects in optical fibers. These effects are interesting in them and can be detrimental in optical communications, but they also have many useful applications, especially for the implementation of all-optical functionalities in optical networks. Nonlinear optics (NLO) is the branch of optics that describes the behavior of light in nonlinear media, that is, media in which the dielectric polarization P responds nonlinear to the electric field E of the light [7]. For intense electromagnetic fields, any dielectric medium behaves like a nonlinear medium. Fundamentally, origin of nonlinearity lies in anharmonic motion of bound electrons under the influence of an applied field. Due to this anharmonic motion, the total polarization P induced by electric dipoles is not linear. The relationship between Polarization (P) and Electric field (E) [9] is given by the eqn. 1,

$$P = \varepsilon_0\chi^0E^0 + \varepsilon_0\chi^1E^1 + \varepsilon_0\chi^2E^2 + \ldots\ldots \quad (1)$$

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Where P is the Polarization, E is the Electric field, ε0 is Permittivity of free space and χ is the susceptibility. The dominant contribution to P is provided by linear susceptibility. The second order susceptibility is responsible for second harmonic generation. A medium, which lacks symmetry at the molecular level, has non-zero second order susceptibility. For a symmetric molecule like silica, second order susceptibility vanishes. Therefore optical fibers do not exhibit second order nonlinear refractive effects. Nonlinear effects in optical fibers occur due to change in the refractive index of the medium with optical intensity and due to the Inelastic scattering phenomenon [5].

SBS is a nonlinear scattering effect involving acoustic phonons [2]. It is the result of an interaction between incident light and the material of optical fiber. Incident light will generate acoustic waves through the process of electrostriction and the sound waves cause vibrations in the glass lattice that makes up the fiber core [8]. Density fluctuations of the material result in a refractive-index modulation that causes the scattering of the incident wave. The refractive index modulation moves away from incident light wave with a relative velocity to it. The incident photon can be converted into a scattered photon of slightly lower energy, usually propagating in the backward direction, and a phonon. This can occur spontaneously even at low optical powers, and can become very strong as a stimulated effect which occurs above a certain threshold power of a light beam in a medium. Above the SBS threshold, parts of the input power launched into the optical fiber will be reflected and the light will be in reverse direction and travel towards the source [10]. An originally weak counter propagating wave at the suitable optical frequency can be strongly amplified. This process involves a strong nonlinear optical gain for the back-reflected wave where the power is converted into backward traveling light which is known as Stokes Wave [4].

III.SBS SYSTEM

The block diagram is shown in Fig. 1, which consists of CW laser which has a narrow line width and a circulator which has three ports. As the signal passes the circulator it goes through the single mode fiber which is 25 km long. After that, it get back through a loopback or a reflector and comes back again to SMF which is connected back to the circulator and then to the photodiode which is directly connected to the RF spectrum analyser. A CW laser is used as a pump source with wavelength of 1550 nm. The pump signal is passed through circulator into the SMF considering the SBS effect is enabled. The three port optical circulator couples the pump signal into the fiber through ports 1 to 2, but directs the backscattered stoke signal through port 3 to 2. Thus, it is possible to measure the reflected or transmitted optical power. The output of circulator at port 3 is in optical domain and is attached to a photodiode followed with RF Spectrum Analyser (RSA) in order to enable the measurement being done in RF domain.

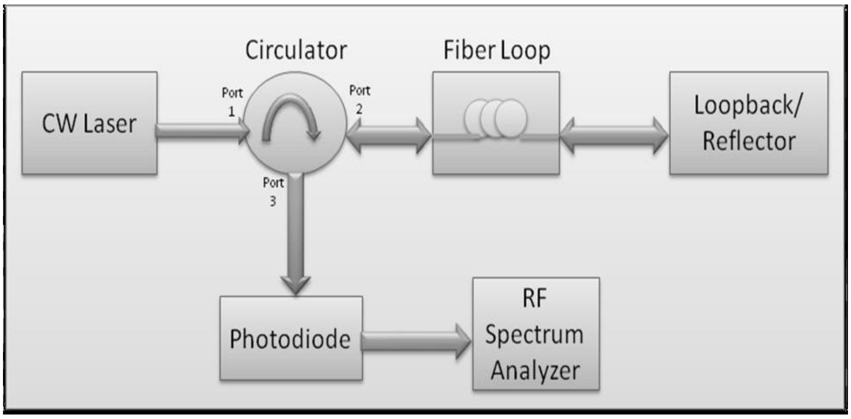

Fig.1 Block diagram of the mm-wave carrier generation based on SBS effect

IV. SYSTEM MODELLING

The designed system is transferred to schematic circuit system as shown in Fig. 2, to investigate the system performance in generating mm-wave carrier using SBS technique. The tools were accepted to simulate the system performance by taking the whole assumption model by the software. However, it was found that there is a slight difference where the function of optical delay and iterations are introduced to support the bidirectional simulation in

Optisystem. This is to prevent the deadlock in the system. Optical delay only generates null signals which bring no effects in the simulation result of the system.

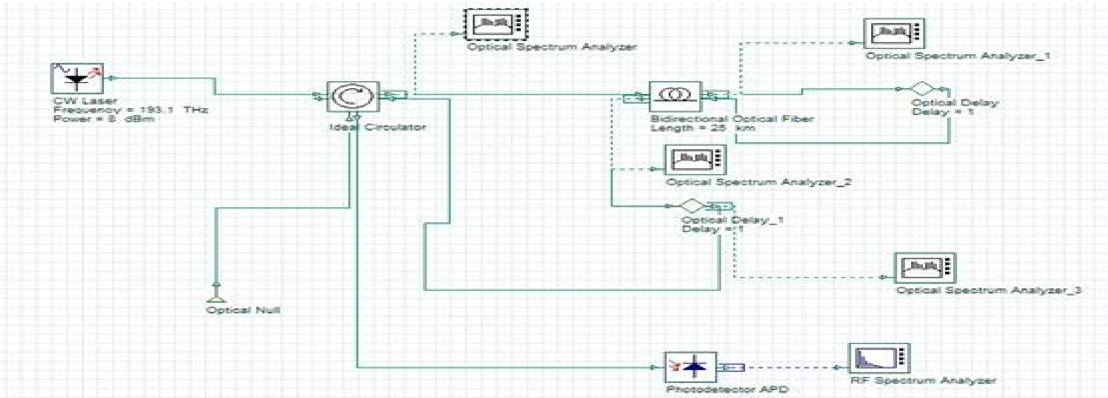

Fig. 2 SBS system model developed in Optisystem

In order to force the signal to circulate several times in the system during simulation, the laser is forced to generate continuous input signals. This is done by setting the iterations parameter in the global parameter setting at the project layout and output at the optical delay can be browsed by changing the signal index parameter from visualiser components such as Optical Spectrum Analyser (OSA) and RSA. It can also prevent deadlock during simulation where there will always be signals at the input ports of the optical fiber and optical delay elements. Stokes wave in SBS interactions in this modelling is produced by both the loopback signal propagating in the opposite direction of the input signal and also signal internally generated when SBS effect is enabled in the modelling parameter of the Optisystem simulation software.

IV. RESULTS AND DISCUSSION

When the power of the incident light exceeds the SBS threshold in the fiber, there is an interaction of the incident light with the acoustic waves in the fiber. The acoustic waves are generated in the fiber as the result of electrostriction process. Light is scattered and some parts of the input power are reflected and generate stokes wave which propagate in opposite direction compared to the input of the optical fiber. However, when the light that goes out of the fiber passes through the loopback and it travels back into the same optical fiber in the opposite direction and it will cause more backscattered light and more stokes wave are generated. Thus the high frequency RF carriers are generated, which is shown in Fig. 3.

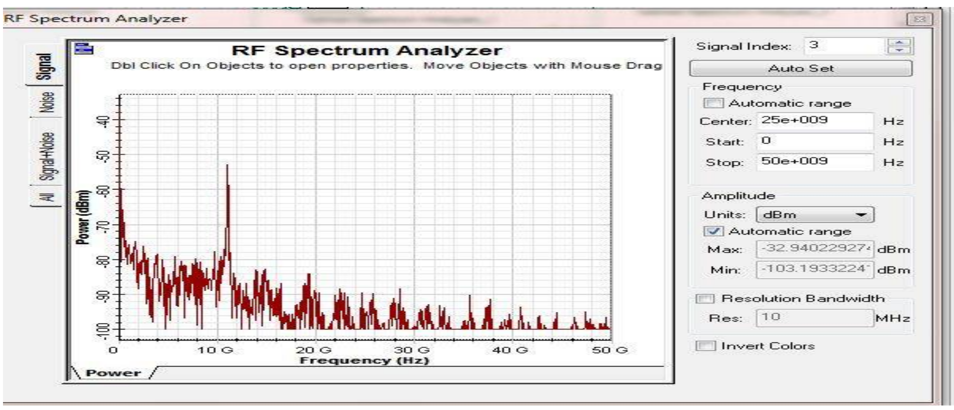

Fig. 3 RF carriers are generated

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The numbers of carriers tend to increase with the rise of laser input power. Simulation has been done for different input power of CW laser where the range of power is between 0 dBm to 10 dBm. Fig. 4 shows the effect of different CW laser power to signal carrier power, when the fiber length is made constant. The output power increases linearly with the input laser power upto 8 dBm and after 8 dBm ,the output power gets reduced. Hence, it is concluded that the SBS threshold is 8dBm.

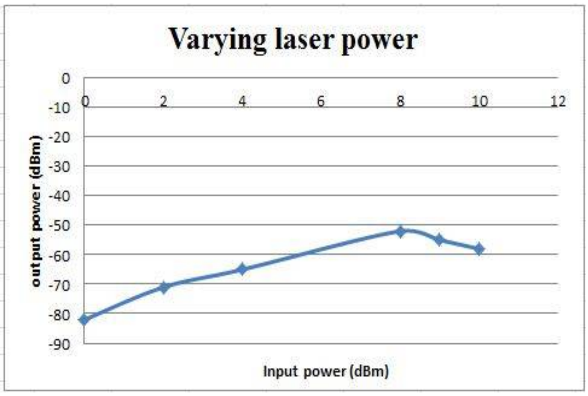

Fig. 4 Intensities of Generated Carrier Power on varying the Laser Power

Analyses are done to obtain the best optical length that gives a high power for the RF carrier generated. Fig. 5 shows that the signal carrier power measured at four different fiber lengths. It is observed that the output power decrease with increase in the fiber length. After 80 km, signal carrier power start to decrease or deplete. However, after a particular length, the carrier power will be reduced.

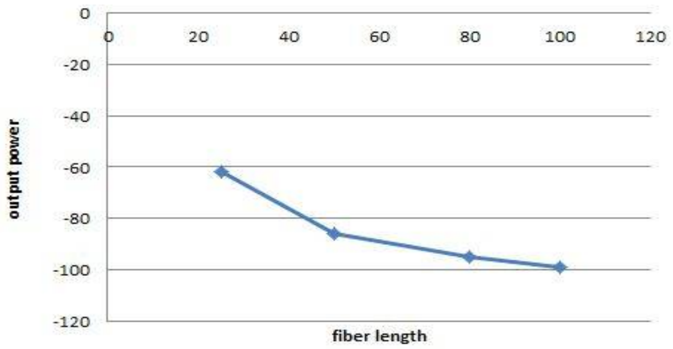

Fig. 5 Intensities of Signal Carrier Power for Different Optical Fiber Length

The Fig. 6 shows the effect of wavelength of CW laser to signal carrier power for the wavelength within the range of 1200 nm to 1600 nm. For this simulation, the optical fiber loop length was fixed at 25 km with laser input power of 8dBm. It shows that the carrier power starts to increase after 1300 nm due to its low attenuation loss. At around 1550 nm the graph is at its highest peak of the output power.

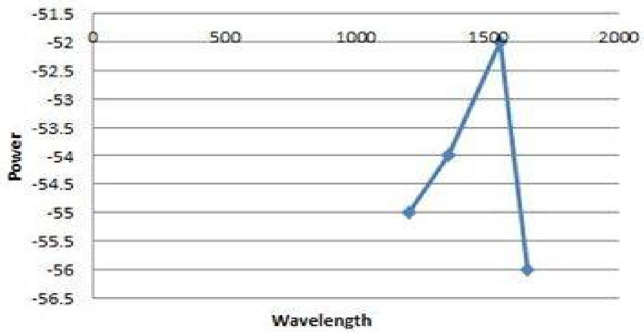

Fig. 6 Intensities of Signal Carrier Power by Varying the Optical Source Wavelength

Fig. 7 shows the effect of different Brillouin linewidth of the bidirectional optical fiber on the generated carrier power. It can be observed that larger the value of Brillouin linewidth, better will be the carrier signal. It can be seen that at 40 MHz, the high carrier signal level can be achieved.

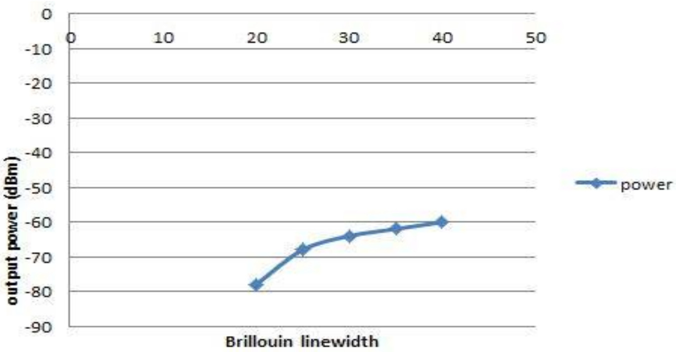

Fig. 7 Intensities of Generated Carrier by varying the Brillouin linewidth

V.CONCLUSION

Performance analysis of Stimulated Brillouin Scattering in RoF system is analysed. In the case of fiber, in which SBS is not enabled, the output power linearly increases with the launched power. But, in the case of fiber, where SBS is enabled, the output power linearly increase and then decreases and SBS threshold is obtained as 8 dBm. .SBS effect is only enabled when the input power is greater than the SBS threshold power. By enabling SBS effect, the system can be used for generation of the high frequency carriers. While disabling the SBS effect in fiber, it is found that no high frequency carriers are generated.

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Biography

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