A review of millimeter wave generation for radio over fiber(ROF) systems

Gulkaran Bajwa[1, a] and Satbir Singh[1, b]

1 Department of electronics and communication engineering, GNDU regional campus, Gurdaspur
E-Mail: [a]bajwagulkaran@gmail.com, [b]satbir1_78@yahoo.co.in

Abstract. In this paper, we investigated the key technology of millimeter wave generation using different schemes such as semiconductor optical amplifier (SOA) and stimulated brillouin Scattering (SBS) based on an external modulator for radio over fiber (ROF) systems which is used for high data bit rate transmission. In these schemes optical signal is modulated with respect to RF signals. The output characteristics of these schemes are compared with simulation results via eye diagram and spectrum analyzers.

Keywords: ROF, SOA, SBS, MZM, EDFA

1. INTRODUCTION

Radio over fiber technology is becoming increasingly important for wireless market in order to support the ever-growing massive data traffic volumes. Optic fibers are perfect to handle gigabits/second speeds that meet the demand of next generation networks. ROF is expected to become a combination two traditional wireless and wire transmission methods effectively for enhancing multi access ability, information capacity as well as transmission distance. The optical signal is modulated by the Radio Frequency signal in the optical transmitter and is then fed to the radio over fiber. At the receiving end the optical receiver coverts the optical signal into RF signal [1]. The basic architectural approach is demonstrated in fig.1.To overcome the high data traffic problems millimeter wave generation is required to provide high bit rate during opto-electro conversions.

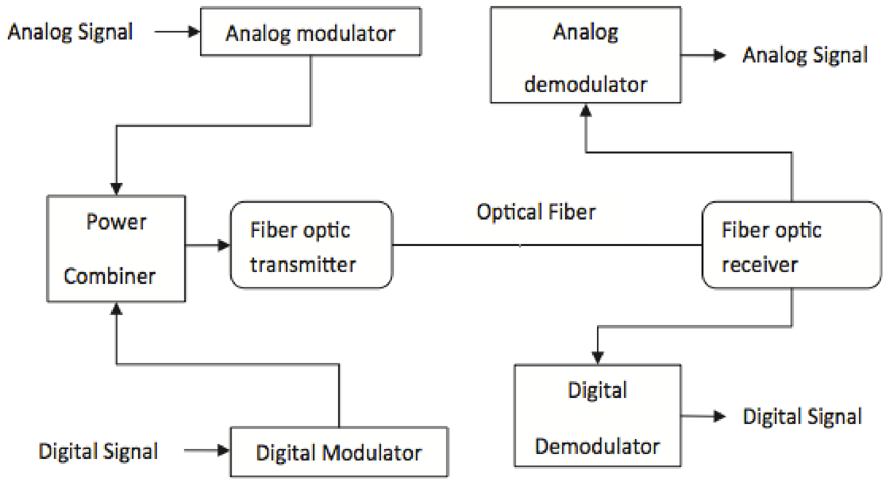

Fig.1. Block diagram of Radio over fiber (ROF).

Many concepts of radio over fiber system have been studied and each of them seems to be attractive because of low loss and extremely wide bandwidth [2]. Optical techniques for microwave generation have gained importance in the recent days, due to its advantage of high speed signal processing [3]. There are many techniques used to for millimeter wave generation such as mode locking methods, optical heterodyning scheme, optical carrier suppression and so on. But we have discussed two methodology experiments for millimeter wave generation using semiconductor optical amplifier and semiconductor optical amplifiers and stimulated brillouin scattering (SBS) performed by Hongjun Zheng et all and M. Baskaran et all respectively [3,4]. Moreover its comparative approach is discussed.

MMW generation principle based on four-wave mixing (FWM) effect in SOAs [4]. This non-linear effect of an optical amplifier is providing fourth wave generation to increase the bit rate of a transmission data. Its span is 50kms up to which signal not degrades .In a similar fashion stimulated brillouin scattering (SBS) effect is implemented by combined effect of harmonics in digital modulation and simultaneous amplification using SBS gain in SMF link [3]. The required RF signal is a result of the harmonics resulting from MZM nonlinearity by amplifying it using SBS effect in the nonlinear fiber link. Mach–Zehnder modulator (MZM) typically use less than 40 GHz and it helps to eliminate the effect of chromatic dispersion in a fiber link [6]. The length of fiber is fixed as mentioned in previous scheme that is 50 km. In last we have discussed the characteristics of millimeter wave generated with different fashion and the litigations come under these schemes results with the help of and eye diagram and spectrum analysers simulated on optisystems version 7.

2. MMW WITH SEMICONDUCTOR OPTICAL AMPLIFIER

The four wave mixing effect is used with semiconductor optical amplifiers for the generations of MMW. In this pump light with fp and signal light fs are input to SOA then with the non linear effect of FWM it generate another waves such as 2fp - fs and idle light 2fs - fp. The phase noise of the system is low because the phase difference between the lights fs and 2fp -fs is stable for the FWM effect.

The setup of the MMW generation for the ROF system by using the SOA is shown in Fig. 2. The values of main parameters used in the simulation. At the central station (CS) of the ROF system, a continuous wave (CW) of LD1 is modulated by non return-to-zero (NRZ) signal with the help of MZM. The modulated optical signal is called the signal light fs after passes through a polarization controller (PC1). Another CW of LD2 which we called the pump light fp when it passes through the PC2.Further, the lights fp and fs are input into a Semiconductor optical amplifier (SOA) by using a WDM. It generates two new components of 2fp - fs and idle light 2fs - fp because of FWM effect in the SOA. The optical MMW is generated between the lights fs and 2fp - fs via the filter.

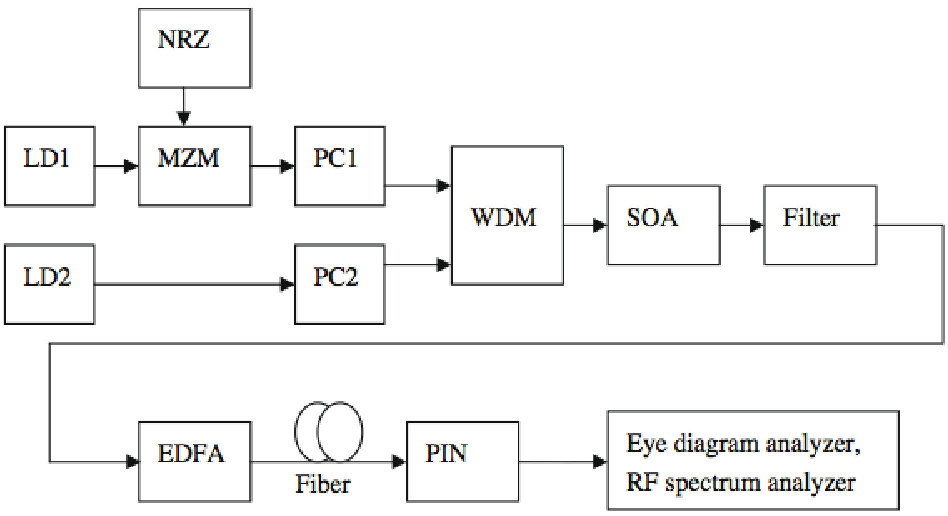

Fig.2. Block diagram of MMW generation with SOA

The optical MMW propagates over a SMF afterwards it is amplified by an erbium doped fiber amplifier (EDFA). On the other side the base station (BS), the optical MMW is going through a conversion from opto-electro process of MMW with the help of PIN diode detector and then transmitted via an antenna at the base station (BS) [3]. After the signal passes through 3R (reshaping, retiming and regenerating) Regenerator and bit-error- ratio (BER) tester, we get the BER and eye diagram of the system [3-7].

Table 1. SOA parameters used in generation.

Name of parameters	Value	Symbols
Injection current	0.15	A
Length	500	um
Width	3	um
Height	0.08	um
Loss	0	1/m
Differential gain	2.78×10^{-20}	m^2
Optical confinement factor	0.3	

The powers of the high-harmonic lights are little as well as the phase of the lights are stable for the FWM effect. The outputs have a high bit rate for transmission of data. The power of millimeter wave is increased via increase of the pump light power and the pump current of the SOA. The propagation characteristics will not change or remain constant and acceptable up to 50km. Afterwards signal start changing with different parameters. The simulation results are given in a fig.4 in which opening of eye is wide which indicate the signal strength is acceptable and RF spectrum of the output.

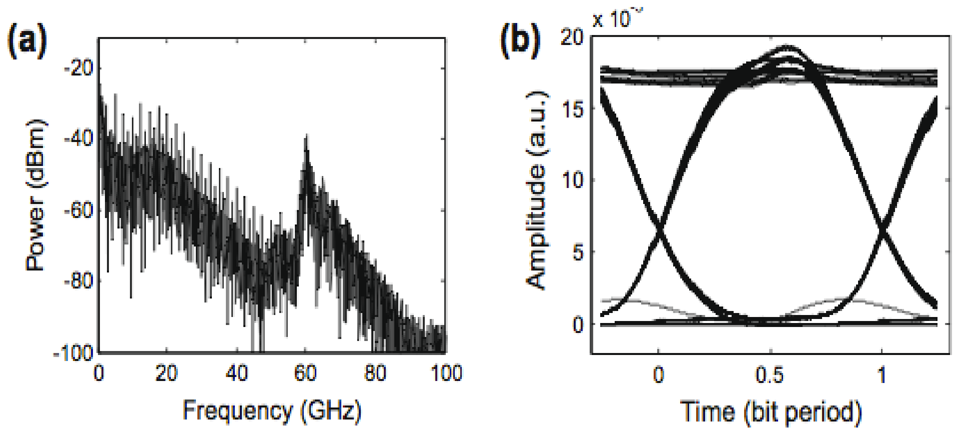

Fig.4. Electrical MMW (a) power spectrum and (b) eye diagram after 50km SOA

3. MMW WITH STIMULATED BRILLOUIN SCATTERING (SBS)

Stimulated Raman and Brillouin scattering can be described as the interaction of several light waves with optical and acoustic-phonon waves, respectively. The coupling parameters can be derived both classically and quantum mechanically. Stimulated Brillouin Scattering (SBS) has been mostly recognized as one of the reason, which causes degrading performance of the system in fiber-optic networks, due to the effect that the signal energy is transferred to the backward scattering signal. It happens due to the generation of a backward propagating Stokes' wave that carries most of the input energy, once the Brillouin threshold is reached. Therefore, SBS imposes limitations on the amount of optical power that can be launched into the fiber without degrading the signal quality. Moreover, SBS has some beneficial characteristics such as frequency selective amplification that can be utilized in millimeter wave photonics applications [4].

The principle behind this scheme is a combining effect of harmonics in digital modulation and simultaneous amplification using SBS gain in single mode fiber link. It is well known that for a data coded in NRZ format of rate N Gbps the nulls occur at N GHz and its harmonic. The optical carrier at x_c is

Table 2. SBS parameters used in generation.

Name of parameters	Value	Symbols
Bit rate	9.95328	Gbps
Sample rate	640	GHz
Optical power of CW laser	2	dBm
Wavelength of CW laser	1550	nm
Fiber length	50	Km
Attenuation of optical fiber	0.2	dB/Km

Neglected because of its small amplitude. The current mainly consists of A2+1 + A2-1, so the top of "1"s becomes narrow and a base appears and intrude in the adjacent "0"s (NRZ) or blank (RZ). In the mean time, the "0" level rises [6,7]. In the case of 10 Gbps standards transmission, the actual data rate is 9.953 Gbps and the nulls correspond to frequency of 9.953 GHz and its harmonics. Hence, it is clear that spectral components of a NRZ data signal are converted to the optical carrier frequency, when it modulates an optical carrier [4,5].

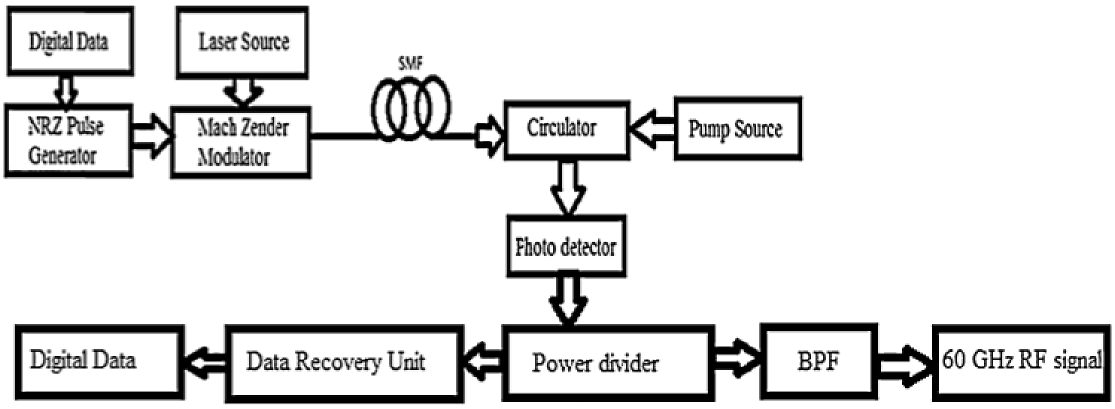

Fig.5. MMW generation with SBS.

A 1550 nm DFB laser diode is used as the optical source. A Mach-Zender Modulator modulates the optical carrier by a 9.953 Gbps NRZ data source. The bias point of the MZM is adjusted so that its nonlinear effects are minimized. The optical spectral output of the MZM shows the optical carrier frequency and harmonics due to pulse modulation. These signals are imposed on a single mode optical fiber link. The output from the optical fiber is an input circulator and a pump laser source is use for creating SBS effect gain in the SMF. The output of the circulator is which is fed into the photo detector. After conversion into electrical signal it is passed through a RF band pass filter with bandwidth of 5 GHz and center frequency of 60 GHz. A regenerator is utilized to generate the digital data to its original form.

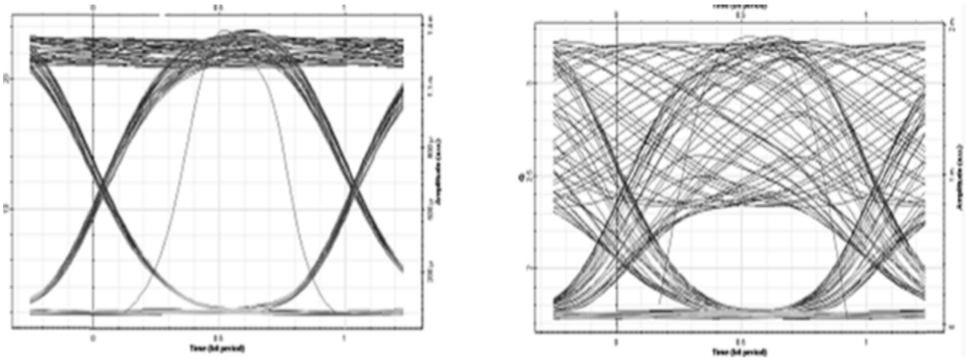

Fig.6. Eye diagram of optical MMW using SBS.

The length of fiber and pump power at the receiver side is fixed as 50 km and 18 dBm respectively. The received eye diagram and optical spectrum after the fiber link is shown in analyzer. It is observed that as the pump power is directly proportional to the amplitude of RF signal.

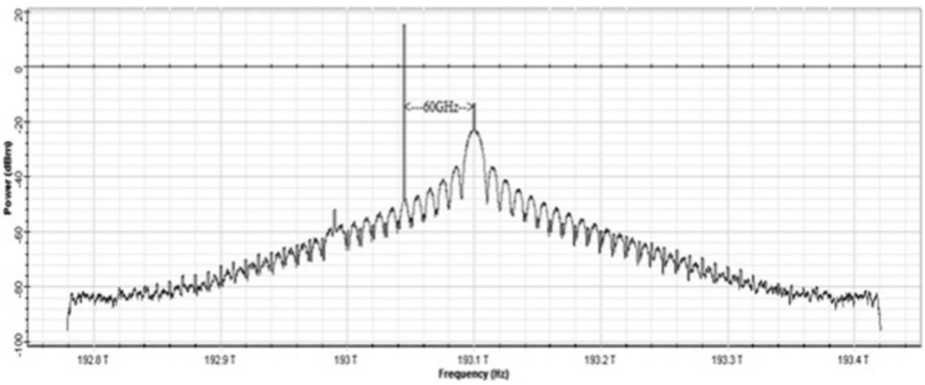

Fig.3. Optical spectrum of 50km fiber link (SBS)

4. CONCLUSIONS

We have investigated the two different schemes of millimeter wave generation by using semiconductor optical amplifier (SOA) and Stimulated Brillouin scattering (SBS) effect produced by MZM for radio over fiber (ROF) schemes. Both approaches provide a acceptable signal up to 50km in single mode fiber (SMF) and provide high bit rate transmission data with MMW at 60GHz. In SOA output MMW have low noise phase effect as compare to SBS but require another optical source for processing. To achieve brillouin threshold value pump laser should have to operate at 15db that stable the effect of SBS cause wastage of pump power.

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