International Journal of Advanced Research in Engineering and Technology (IJARET)
Volume 8, Issue 2, March - April 2017, pp. 17–23, Article ID: IJARET_08_02_003
Available online at http://www.iaeme.com/IJARET/issues.asp?JType=IJARET&VType=8&IType=2
ISSN Print: 0976-6480 and ISSN Online: 0976-6499

A NOVEL SINGLE SIDEBAND SUBCARRIER MULTIPLEXING TECHNIQUE FOR RADIO OVER FIBER COMMUNICATION SYSTEMS

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ABSTRACT

Radio over Fiber (RoF) is an amalgamation of optical communication with wireless access technology. In Radio over Fiber system the radio signal is modulated on to light and distributed over optical fiber cable to various Radio Access Units (RAU). These RAUs to convert the optical signal to an electrical signal, amplify and transmit it. The performance of RoF can be enhanced by using several systems which include Subcarrier Multiplexing System (SCM). Double sideband and Optical single sideband modulation has been done in SCM system and analyzed. A full duplex SCM system using Fiber Bragg Grating (FBG) is proposed. The number of users for this full duplex SCM system is further enhanced by using optical comb techniques. The modulator performance in various configurations is analyzed in this paper.

Key words: over Fiber, Subcarrier Multiplexing, Optical Double sideband modulation, Optical Single sideband modulation.

Cite this Article: R. Pradeep and N. Vijayakumar, A Novel Single Sideband Subcarrier Multiplexing Technique for Radio Over Fiber Communication Systems. *International Journal of Advanced Research in Engineering and Technology,* 8(2), 2017, pp 17–23.
http://www.iaeme.com/IJARET/issues.asp?JType=IJARET&VType=8&IType=2

1. INTRODUCTION

Telecommunication industry experiences unexpected exponential growth in multimedia and internet usage and the demand for data has become insatiable [1]. Not only there has been an increase in the number of users, but the amount of online time spend by the users has also increased. One of the solutions for this dilemma is Radio over Fiber (RoF) which inherently carries much greater bandwidth capacity [2], [3]. Radio over Fiber is a combination of both optics and microwave [6]. It is fundamentally ananalog communication system. In this light is modulated by a radio signal and transmitted over an optical link which facilitates wireless access. RoF system consists of a transmitter and receiver connected by an optical link.

Centralization of radio signal processing is possible using RoF. This optical backbone infrastructure can be scaled by 1000 times to make it more efficient. Subcarrier multiplexing (SCM)[4] is an attractive technology which can be used to accommodate large number of users. Another way of efficient use of the spectrum is Wavelength Division Multiplexing (WDM) [5].This paper analyses the basic double side band SCM system and proposes a technique to improve its performance. Optical single sideband transmission is found to be more effective compared to double sideband system. In this paper a single side band SCM model is proposed using dual drive MZM [5] in phase shifted mode.

The contents of this paper are organized as mentioned below. The session II & III of the paper describe Subcarrier multiplexing (SCM), proposed OSSB SCM system respectively. The session IV of the paper describes the simulation results and then conclusion.

2. SUBCARRIER MULTIPLEXING

Optical Subcarrier Multiplexing (SCM) is a system in which multiple signals are multiplexed in the radio frequency domain and then transmitted by a single wavelength using optical fiber. A significant advantage of SCM is that microwave devices are more mature compared to optical devices. One of the important application of SCM is the analog cable television (CATV) distribution. Due to its simplicity and cost effectiveness SCM has widespread applications [8], [9].

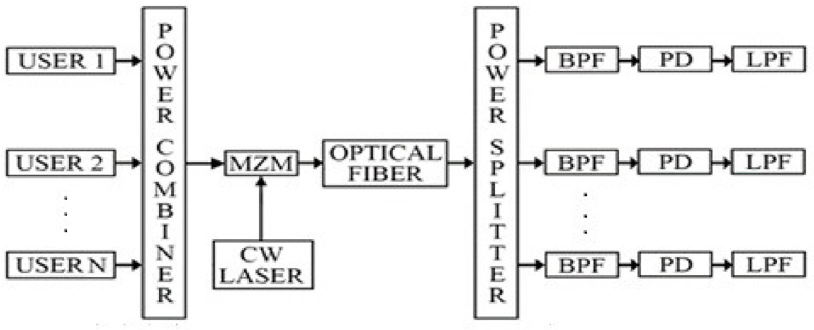


Figure 1 Block Diagram of SCM

Bandwidth available for an optical fiber is far greater than radio signals. Radio signals can be combined and transmitted through optical fiber. Effective utilization of bandwidth is possible in SCM. In this scheme two modulations are done at the transmitter end and two demodulations at the receiver end. A baseband signal modulates an RF signal which is then used to modulate an optical carrier at the transmitter. This signal is then transmitted through an optical fiber and at the receiver end it undergoes two demodulations. The spectral efficiency of SCM is better than Wavelength Division multiplexing (WDM) [11] because SCM uses a single wavelength for transmission through optical fiber.

Radio frequency signals of different frequencies but having suitable separation is added together and then used to modulate the light source. Usually amplitude modulation is done and each RF carrier produces LSB and USB or Double Side Band modulation (DSB). When a number of RF signals are mixed and modulated together chances are there that higher harmonics of a particular signal come in the same frequency range that of another RF signal which cause signal deterioration and affect the overall performance of the system. As a solution to this single side band SCM is proposed.

3. OPTICAL SINGLE SIDEBAND SCM

The basic structure of single sideband generation is illustrated in figure2. Here the modulating signal is fed to two product modulators at 90^0 out of phase. The carrier also fed at each modulator at 90^0 out of phase. The modulated signal is then combined using an adder/subtract or unit which in turn results in single side band modulation.

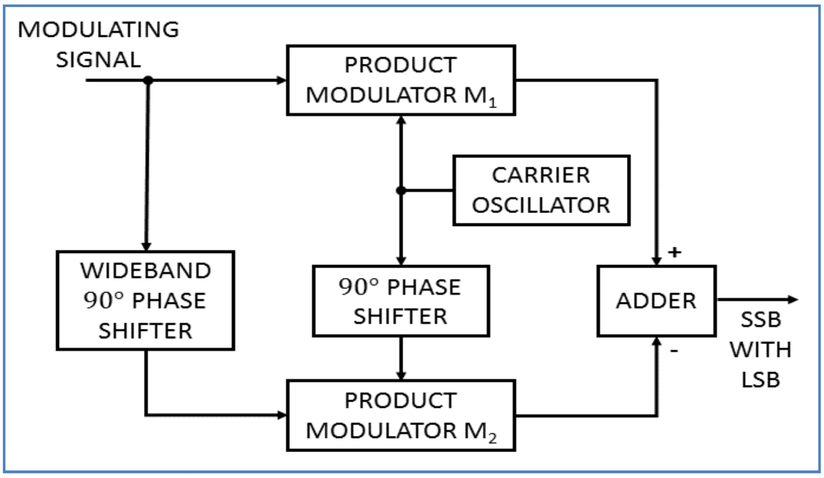


Figure 2 Basic Structure of SSB generation

In the proposed optical single sideband system instead of two product modulators a dual drive Mach-Zehnder Modulator(MZM)[5,8] serve the purpose.

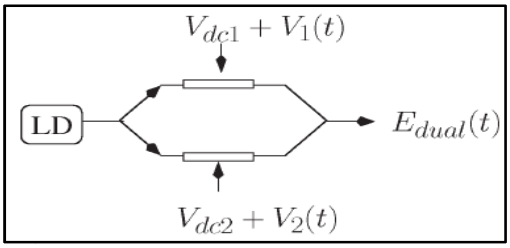


Figure 3 Dual Drive MZM

Here the V_1 and V_2 are RF signal at 90^0 out of phase. The biasing voltages V_{dc1} and V_{dc2} are adjusted to operate in AM modulation. Then the signals of both the arms are combined resulting OSSB using phase shift method [10].

Let the output of the AM modulator is,

$$m(t) = A_c Cos\omega_c t \quad (1)$$

The positive and negative sign denote 1 and 0 baseband binary data stream. If we consider baseband signal as 1, we have,

$$m_1(t) = A_c Cos\omega_c t \quad (2)$$

The signal is applied onto the upper end of MZ modulator and another modulating signal with same amplitude and 90° out of phase as compared to the other signal. $m_1(t)$ is applied onto the lower arm of the MZ modulator [10]

$$m_2(t) = A_c Sin\omega_c t \quad (3)$$

Light signal from laser source is given to the branches of the modulator.

$$n(t) = A_0 Sin\omega_0 t \quad (4)$$

Light wave passing through upper and lower arm can be written as shown below,

$$n_1(t) = A_0 Cos\omega_0 t \qquad (5)$$

$$n_2(t) = A_0 Sin\omega_0 t \qquad (6)$$

Output of MZM modulator is,

$$s(t) = m_1(t)n_1(t) \pm m_2(t)n_2(t) \qquad (7)$$

$$= A_c A_0 Cos\omega_c t Cos\omega_0 t \pm A_c A_0 Sin\omega_c t Sin\omega_0 t$$

$$= \frac{A_c A_0}{2}[Cos(\omega_0 + \omega_c)t + Cos(\omega_0 - \omega_c)t \pm \frac{A_c A_0}{2}[Cos(\omega_0 - \omega_c)t - Cos(\omega_0 + \omega_c)t]$$

$$= A_c A_0 Cos(\omega_0 - \omega_c)t \qquad (8)$$

or

$$= A_c A_0 Cos(\omega_0 + \omega_c)t \ (5)$$

Spectrum of OSSB signal is obtained as,

$$s(f)_{LSB} = \frac{A_c A_0}{2}\{S[\omega - (\omega_0 - \omega_c)] + S[\omega + (\omega_0 - \omega_c)]\} \qquad (9)$$

$$s(f)_{USB} = \frac{A_c A_0}{2}\{S[\omega - (\omega_0 + \omega_c)] + S[\omega + (\omega_0 + \omega_c)]\} \qquad (10)$$

4. SIMULATION RESULTS

The simulative experiments are carried out using Optisystem v13, a high end optical communication simulation package. It can be used for design, testing and optimization of virtually any type of optical link. This tool is very versatile and enables users to test and simulate realistic models of Fiber optic communication system including RoF. It has advanced visualization tools like OSA, Eye diagrams, BER analyzer, constellation diagram etc.

Here a three user scenario is simulated. Each cell has a PRBS generator which generates the data signal. Different electrical carriers are used for modulating these data signals which are then passed through Bessel filters to remove unwanted frequencies. Different electrical carriers are used for modulating these data signals which are then passed through Bessel filters to remove unwanted frequencies. These different signals are combined using electrical 3x1 combiner and are the combined signal is modulated by an optical carrier. This is then transmitted through an optical single mode fiber. Single mode fiber allows only one mode and it has a core size of about 10 micrometre which eliminates intermodal dispersion and makes it suitable for long distance communication.

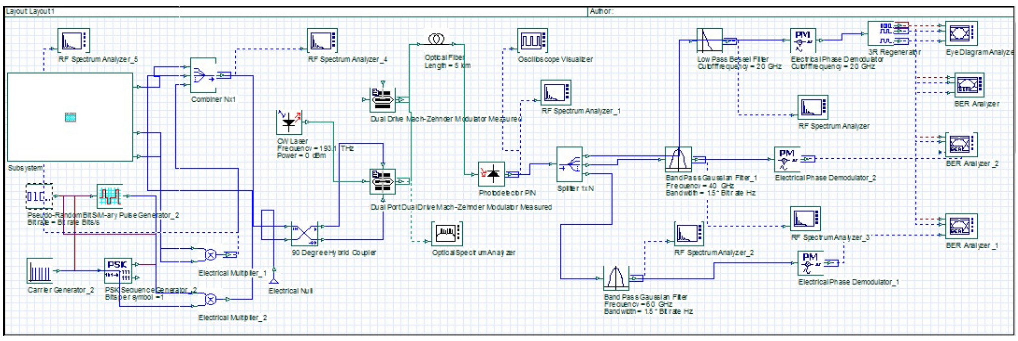


Figure 4 Optisystem Simulation Setup

At the receiver end signal is detected by a PIN photo detector which converts optical signal into electrical signal. It is given to an electrical splitter which is used to split this electrical signal into three signals. These are then passed through band pass filter and then to demodulator of respective frequency bands.

Output spectrum of the modulated light at MZM after enabling OSSB modulation is shown in the Fig.5. It can be observed that the USBs in the spectrum is absent.

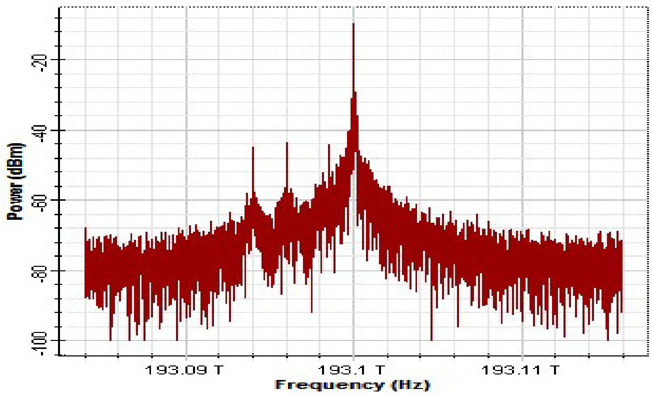


Figure 5 Spectrum of OSSB modulated signal

The DSB and OSSB SCM system are analyzed for different lengths of optical fiber in Optisystem. Observations were taken and graphs were plotted at different distances for BER, power obtained at the receiver and quality factor.

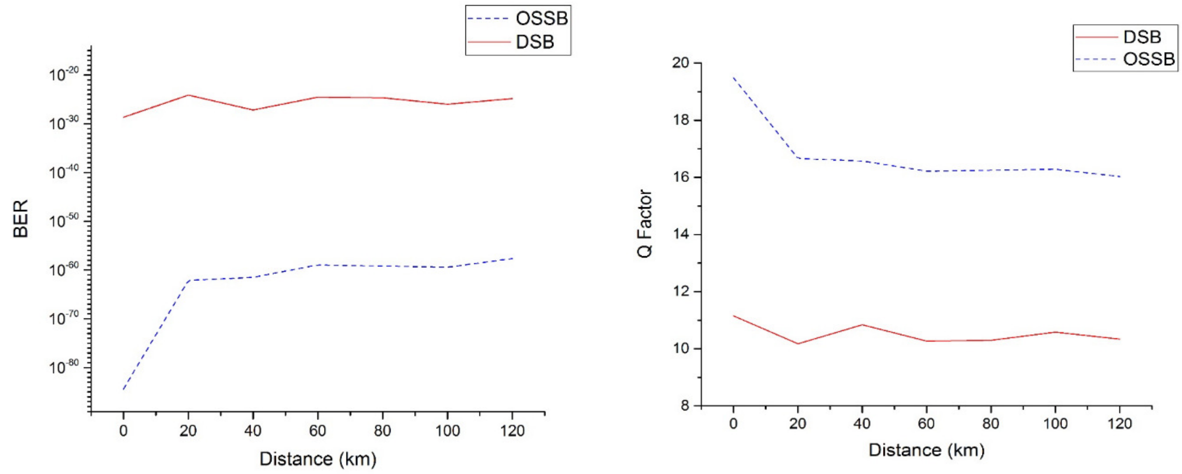
Table 1 Analysis of OSSB for Various Distances

Distance (km)	Power received (dBm)	BER	Quality Factor
20	-23.612	$7.51 \times e^{-63}$	16.662
60	-39.629	$1.10 \times e^{-59}$	16.219
100	-55.607	$3.77 \times e^{-60}$	16.286
120	-63.598	$2.33 \times e^{-58}$	16.031

Table 1. shows the analysis of Optical single side band modulation for various distances. Graphs are plotted based on this table for OSSB. Comparing with Table 2 where DSB parameters are listed SSB technique provides enhanced performance.

Table 2 Analysis of DSB for Various Distances

Distance (km)	Power received (dBm)	BER	Quality Factor
20	-28.786	$7.45 \times e^{-25}$	10.176
60	-44.898	$2.89 \times e^{-25}$	10.268
100	-60.725	$1.06 \times e^{-26}$	10.584
120	-68.942	$1.46 \times e^{-25}$	10.337



(a) (b)

Figure 6 Comparison of BER for DSB and OSSB system (a) BER and (b) QFactor.

From Fig. 6. It is clear that the bit error rate in OSSB is lesser compared to DSB system. The quality factor obtained for optical single side band SCM is much higher as compared to that of double side band SCM. For a distance of 120 km DSB SCM system has a quality factor of 11 where as OSSB SCM system has a quality factor of 17.

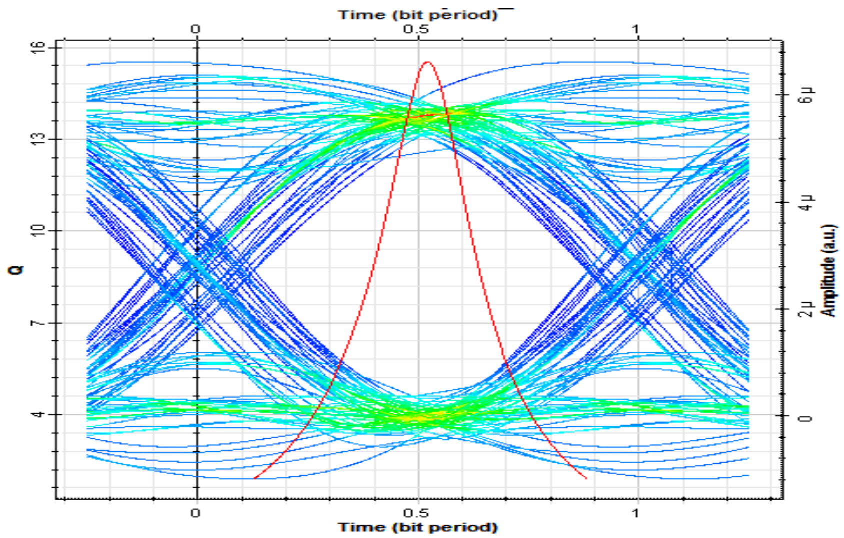


Figure 7 Eye pattern of the received signal

The eye diagram obtained for a distance of 60Km is shown in figure 7 with a clear eye opening.

5. CONCLUSION

The subcarrier multiplexing in Radio over Fiber system is examined. The performance of Normal Double side band SCM can be improved by employing Single Sideband SCM technique. The Single sideband SCM is generated by employing dual drive Mach-Zehnder modulator. The simulative results showing enhanced performance of the proposed system.

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