Multiuser Based on Subcarrier Multiplexing with Spacing of 5Ghz in Radio over Fiber System using Direct Detection Method

K. Sasikala*, D. Helena
Department of Electronic and Communication Engineering, ACCET, Karaikudi, India

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Abstract
In integrating the broadband optical fiber communication and the mobility of wireless communication, ROF has become a promosing wireless access technique for 4G mobile commercial system with improved performance and reduced cost. A novel intensity based modulation on SCM in Radio over Fiber system is introduced to allow a flexible convergence of optical fiber's high capacity and wireless access flexibility. It provides high capacity transmissions at lower costs and enables fiber based wireless access. This paper proposes to reduce the number of electronic components for the detection of baseband signals and also use low power to operate the system. Here baseband signals are directly detected from optical signals without any need of electrical demodulation module. A 6- Gb/s SCM test bed has been set up in which 3 2 Gb/s data streams are combined into 1550nm wavelength. In order to increase the Receiver sensitivity, 5GHz channel spacing is used to reduce the inter-channel crosstalk. The performance of the system can be evaluated by the parameters like, maximum Q-factor, minimum BER, and Eye Diagram.

1. Introduction

With the development of the third generation of mobile communications, IMT 2000, radio over fiber technology will play a significant role in solving problems facing this technology. Envisioning a global village, people could transmit and receive “anytime, anywhere, and anything”. In addition, the explosive growth in Internet applications, such as the World Wide Web, demonstrates the tremendous increase in bandwidth and low power that the coming world of multimedia interactive applications will require from future networks. Radio over fiber systems have many advantages such as enhanced microcellular coverage, higher capacity, lower cost, lower power, and easier installation. Therefore, radio over fiber technology is the most suitable candidate for indoor applications such as airport terminals, shopping centers, and large offices, in addition to outdoor applications such as those underground, tunnels, narrow streets (i.e., dead zone areas), and highways.

The next generation of cellular mobile phone systems will make extensive use of microcells. This will permit a large increase in the numbers of users and will also allow a significant increase in the available channel bandwidth, so that broadband services can be offered, in addition to the voiceband services offered with current systems. The introduction of large numbers of microcells will result in the need to interconnect huge numbers of cells and microcells and this can be carried out effectively using optical fiber, which offers a high transmission capacity at low cost. The transmission of radio signals over fiber, with simple optical-to-electrical conversion, followed by radiation at remote antennas, which are connected to a central station, has been proposed as a method of minimizing costs. The reduction in cost is brought about in two ways. First, the remote antenna or radio distribution point needs to perform only simple functions, and it is small in size and low in cost. Second, the resources provided by the central stations can be shared among many antenna sites. This technique of modulating the RF subcarrier onto an optical carrier for distribution over a fiber network is known as radio over fiber (RoF) technology. In addition to the advantages of potential low cost, RoF technology has the further benefit that transferring the RF frequency allocation to a central station can allow flexible network channel allocation and rapid response to variations in traffic demand. It is very clear that the synergy of wireless and optical fiber communications is an important issue, taking into consideration future requirements for the fourth generation, such as software radio and intelligent networks, in which ROF technology will play a significant role through its macrodiversity.

Corresponding Author,
E-mail address: sasik53@gmail.com

2. Subcarrier Multiplexing

The optical signal emitted by a laser operating in the 1310 or 1550nm wavelength band has a center frequency around 1014Hz. This frequency is the optical carrier frequency. In what we have studied so far, the data modulates this optical carrier. In other words, with an OOK signal, the optical carrier is simply turned on or off, depending on the bit to be transmitted. Instead of modulating the optical carrier directly, we can have the data first modulated an electrical carrier in the microwave frequency range, typically ranging from 10MHz to 10GHz.The upper limit on the carrier frequency is determined by the modulation bandwidth available from the transmitter.

If the transmitter is directly modulated, then changes in the microwave carrier amplitude get reflected as changes in the transmitted optical power envelope. The microwave carrier can itself be modulated in many different ways, including amplitude, phase, and frequency modulation, and both digital and analog modulation techniques can be employed. The microwave carrier is called the subcarrier, with the optical carrier being considered the main carrier. This form of modulation is called subcarrier modulation. The main motivation for using subcarrier modulation is to multiplex multiple data streams onto a single optical signal.

This can be done by combining multiple microwave carriers at different frequencies and modulating the optical transmitter with the combined signal. At the receiver, the signal is detected like any other signal, and the rest of the processing to separate the subcarriers and extract the data from each subcarrier, is done electronically. This form of multiplexing is called subcarrier multiplexing (SCM).

3. Multicarrier Intermodulation

In an SCM system the CIM3 generally decreases with increasing number of carriers. Two classes of third-order products are generated under multicarrier excitation: three-tone third-order intermodulation at $f_i+f_k-f_l$ and two-tone third-order intermodulation at $2f_i-f_k$.The numbers of intermodulation products at frequency $f_1+(r-1)\,\Delta f$ of each of the two classes generated from an equally distributed set of n equidistant carriers separated by Δf from a frequency f_1 up to a frequency $f_1+n\Delta f$ are

$$Z_{2fi-fk}=\tfrac{1}{2}\{n-2-1/2[1-(-1)^n](-1)^r\} \quad (1)$$

$$Z_{fi+fk-fl}=r/2(n-r+1+1/4[n-3)^2-5]-1/8[1-(-1)^n](-1)^{r+n}) \quad (2)$$

The total intermodulation power of products of the two classes at frequency $f_1+(r-1)\,\Delta f$ is found by incoherent addition.$(3/2A^3a_3)Z_{fi+fk-fl}$ for the $f_i+f_k-f_l$ products and $(3/2A^3a_3)\,Z_{fi+fk}$ for the $2f_i-f_k$ products with the coefficient of the third-order nonlinearity a3 and the amplitude per carrier A. For six or more carriers, the $2f_i-f_k$ products can be neglected and only the $f_i+f_k-f_l$ products are significant. For a high number of transmitted carriers, the maximum number of intermodulation products is generated in the center of the band $(r=n/2)$:

$$Z_{fi+fk-fl}\; n^2 \quad (3)$$
$$r=n/2$$

Whereas on the band edges (r = 1 and n)

$$Z_{fi+fk-fl}\; n^2 \quad (4)$$
$$r=n/2$$

If the two-tone intermodulation is known, the multicarrier intermodulation is found by relating the two-tone formulas.

$$IM_{fi+fk-fl}=IM_{2-tone}\_10\log(Z_{fi+fk-fl})-6dB \quad (5)$$

$$IM_{2fi-fk}=IM_{2-tone}\_10\log(Z_{2fi-fk}) \quad (6)$$

From 6th CIM3 in the center of the bend for a high number of carriers is found:

$$CIM3,\ \text{ncarriers}=IM_{2-tone}-10\log(3/2n^2) \quad (7)$$

The same calculation has been done numerically for fifth-order products.

A. Requirements for a Multiband

The fiber optic radio access networks have the potential to be universally used among different kinds of radio services or different providers. The realization of such universal radio access network can reduce the construction time for and investment in infrastructures, thus retaining the advantages of microcellular systems. Different kinds of radio service are ordinarily operated under different frequency bands, and their RCSs are probably located at different locations. To handle such multiple radio services universally, the fiber optic radio access networks need a routing node in the networks, which distinguishes types of radio service and then switches each service signal into its desired RCS. The conventional fiber optic link to transfer radio signal is SCM/optical intensity modulation/direct detection link, which has the advantages of simplicity and cost efficiency in terms of the RBS configuration. However, from the viewpoint of the feasibility of the routing node, the SCM/optical intensity modulation/direct detection link has the primary disadvantage of it being impossible to distinguish among the types of radio service unless the optical signals are photodetected, because optical intensity includes the multiple radio services in subcarrier multiplexing format.

B. Methodology& Simulation Setup

One of the main objectives of this paper is to design a RoF system based on Intensity Modulated Direct Detection (IM-DD) which leads to simple and cost effective system implementation. Fig. 1 depicts the principle and the configuration of the proposed RoF system. Central System (CS) composed of three microwave signal generators of 10 GHz, 15 GHz and 20GHz, one continuous wave (CW) laser, two pulse generators, two pseudo-random binary sequence (PRBS) generators and one Mach-Zehnder Modulator (MZM).

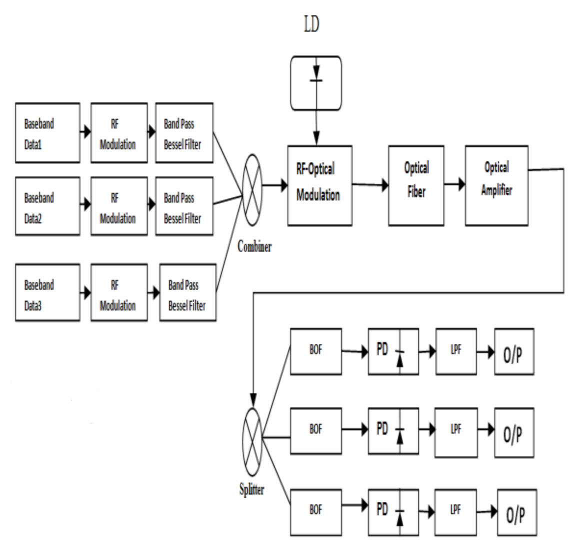

Fig: 1. Simulation Model of our Proposed SCM System

The Reference wavelength of CW laser is 1550 nm. In our proposed system, we have used wavelength which falls under C-Band where attenuation is minimum and hence it achieves the longest range. In this system, 2 GB/s data streams are mixed with 10 GHz, 15 GHz and 20GHz microwave signals and supplied to the MZM along with the optical carrier from the laser diode. Here the frequency spacing was given 5 GHz, to avoid inter- channel crosstalk.

In the first step of transmission pseudo random bit sequence (PRBS) generator is used to generate baseband Signal. This baseband signal is then used to modulate a high frequency RF carrier of frequency f_C using electrical modulation which will shift this spectrum of data signal at frequency f_C. After this shifting lower and upper frequency of this spectrum will become f_C-f_B and f_C+f_B respectively. Electrically modulated signal is then passed through Band Pass Filter (BPF) to remove unwanted frequency components. This filtered signal is used to modulate carrier light of an optical source which is laser diode having frequency *fO* using an external modulator called Mach-Zehnder Modulator (MZM).

This optical modulation will again shift vertical axis of electrically modulated signal at frequency *fO* and the frequency of upper sideband of the optical signal will become *fO+fC* . Now lower and upper frequencies of this upper sideband will become *fO+fC-fB* and *fO+fC+fB* respectively. This optical upper sideband can be filtered using an optical band pass filter (OBPF) having frequency *fO+fC* and bandwidth 1.5*fB. This optical signal is then transmitted through the channel which is a single mode fiber (SMF). At receiving end an optical amplifier is used to amplify attenuated optical signal and then this signal is passed through optical band pass filter (OBPF) to filter the upper sideband of optical signal which is then applied to the PIN photo-detector. This photodetector demodulate filtered optical signal and convert this optical signal directly into a baseband signal. A low pass filter (LPF) is used to remove higher frequency components and at the output of LPF data signal is detected and output is observed.

4. Results and Discussion

The proposed RoF system was successfully modeled and simulated using Optisystem 7. This system has employed the oscilloscope Visualizer, RF spectrum analyzer, BER analyzer and optical spectrum analyzer. RF Spectrum Analyzer allows us to calculate and display electrical signals in the frequency domain. It can also display the signal intensity, power spectral density and phase. Whereas, BER Analyzer displays the eye diagram, Q-factor, Minimum BER, threshold, Eye height and BER pattern of the received signals. Optical Spectrum Analyzer allows us to calculate and display optical signals in the frequency domain. It can display the signal intensity, power spectral density, phase, group delay and dispersion for polarizations X and Y.

Figure 7, 8 and Figure 9 showed the eye diagram of data received at user1, user 2 and user3 respectively. All the three signals or channels are allocated nearby to each other (5GHz spaced channel) and there is no interference or aliasing occur which is shown in figure 2. If there is aliasing, it is important to reallocate the frequency carrier because the effect of aliasing basically on the data recovery at the receiver part.

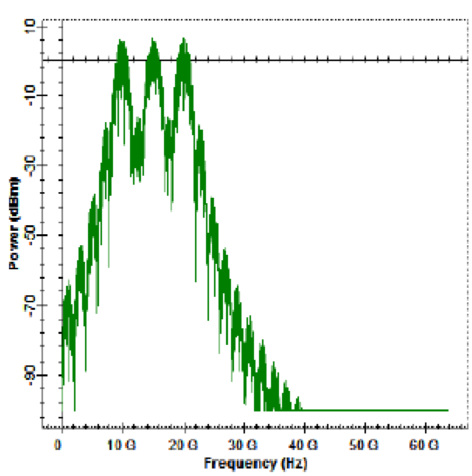

Fig: 2. RF Spectrums for Adding Three Channels at CS

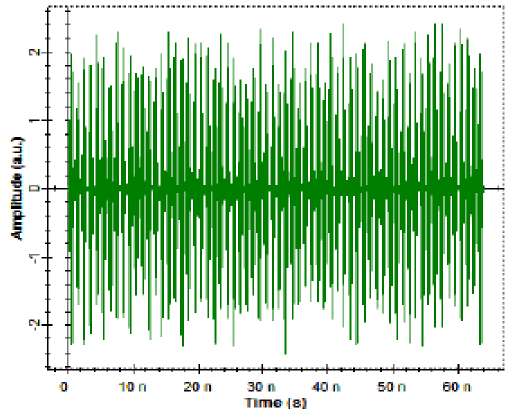

Fig: 3. Output of Oscilloscope Visualizer for 2Gbps

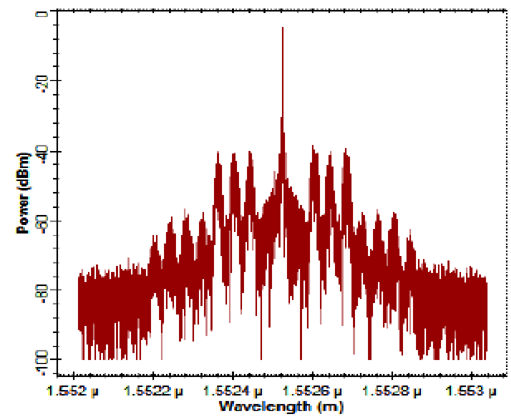

Fig: 4. Transmitted Optical Signal at Central Station

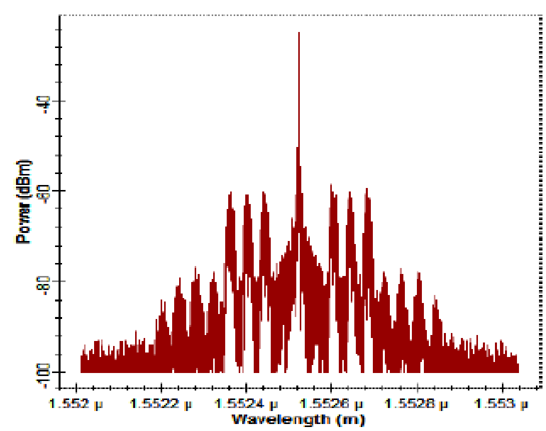

Fig: 5. Received Optical Signal after the Fiber at CS

Oscilloscope visualizer allows us to calculate and display electrical signals in the time domain. It can also display the signal amplitude and autocorrelation. That was shown in fig 3.The combinied three electrical signal is used to modulated an optical carrier of 193.1THz using Mach Zehender Modulator (MZM). That signal spectrum was shown in figure 4. The modulated signal is then transmitted through the single mode fiber, which is shown in fig.5 interm of power vs wavelength. Here signal is consume the power -24dBm at 1552.5nm wavelength.

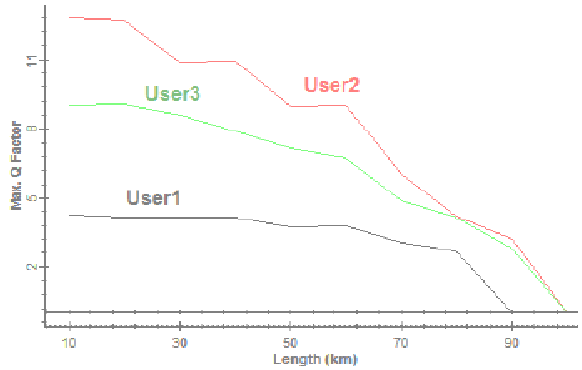

Fig: 6(a).

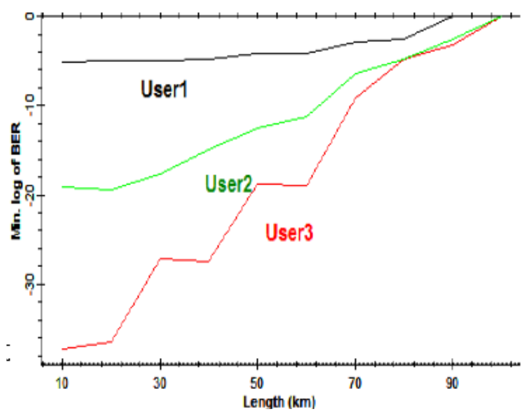

Fig: 6(b).

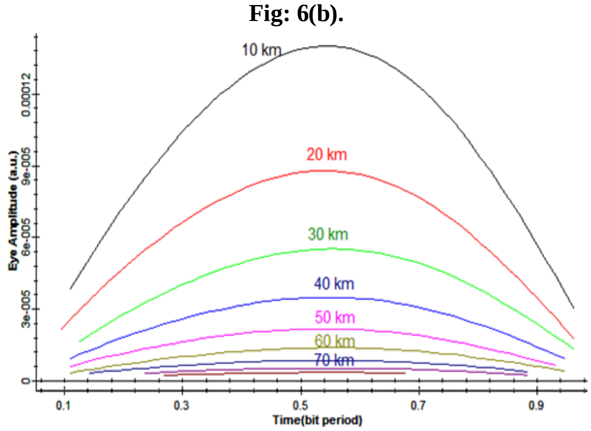

Fig: 6(c).

Fig: 6 (a). The Max.Q Factor for Different Length of Fiber for three users **(b)** The Receiver Sensitivity for Different Length for three users **(c)** Eye amplitude for different length of fiber for user2

Performance metrics should present a precise determination of system's limitation and measurement to improve the performance of the system. The most widely used performance measures are the Q-factor, BER and eye opening. The figure 6 shows that fiber length is varied from 10km to 90km and outputs are compared for nine different values of fiber length for each channel. If the transmission length is increased the Q-factor is decreased and BER is increased and Eye opening is decreased.

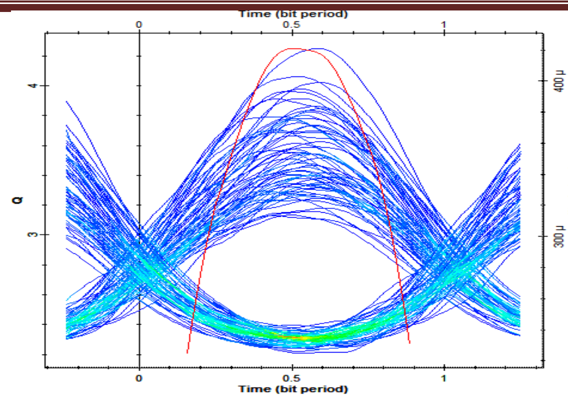

Fig: 7. Eye Diagram for user1

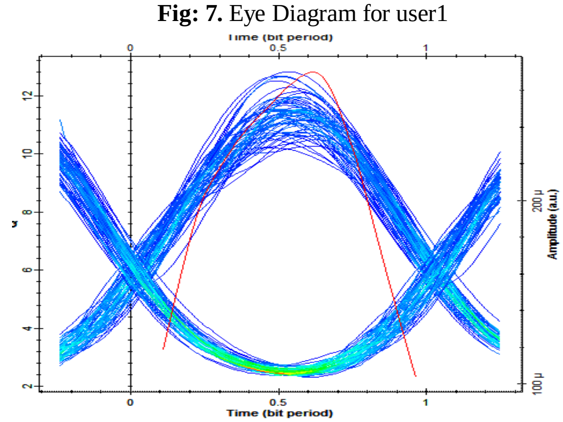

Fig: 8. Eye Diagram for user1

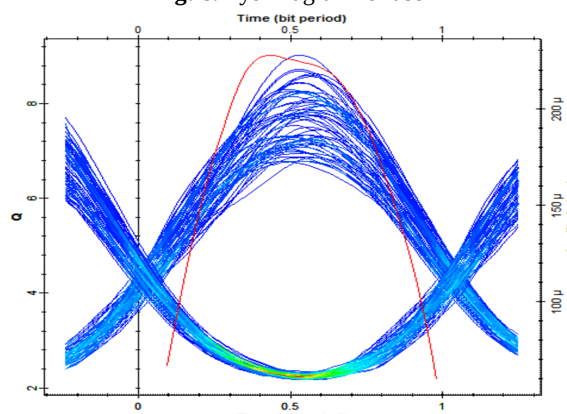

Fig: 9. Eye Diagram for user3

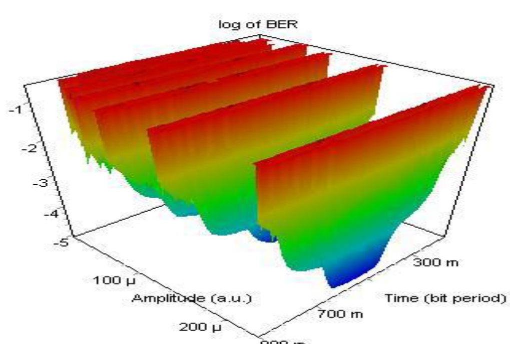

Fig: 10. 3D BER Graph at user1

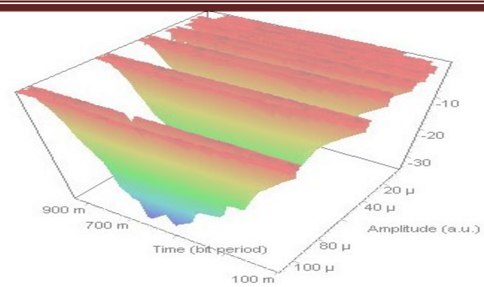

Fig: 11. 3D BER Graph at user2

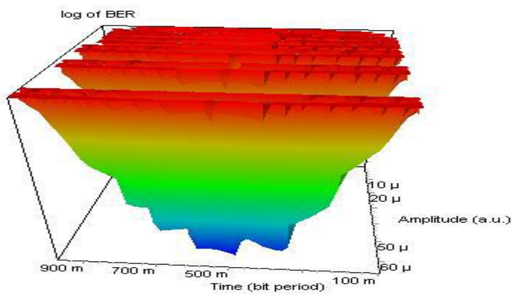

Fig: 12. 3D BER Graph at user3

Eye diagram and 3D BER graph for all three subscribers is shown in figure 7, 8, 9,10,11,12. Eye pattern or diagram is used to visualize how the waveforms used to send multiple bits of data can potentially lead to errors in the interpretation of those bits. Vertical eye opening indicates the amount of difference in signal level that is present to indicate the difference between one bit and zero bits. The bigger the difference the easier it is to discriminate between one and zero. Whereas, horizontal eye opening indicates the amount of jitter present in the signal. An open eye pattern corresponds to minimal signal distortion.

Distortion of the signal waveform due to inter-symbol interference and noise appears as closure of the eye diagram.BER is the number of erroneous bit divided by the total number of transferred bits during a studied time interval. In digital transmission, data stream can be altered due to noise, distortion or synchronization errors. The BER gives the upper limit for the signal because some degradation occurs at the receiver end.

5. Conclusion

The direct detection of base band signal has been simulated and analyzed by numerically. The cost effective and efficient SCM system is made by reducing the electronic components and need for electrical demodulation has been eliminated. Optical signal is directly converted into baseband signal using only one optical demodulation module at receiver. This makes system simpler, cheaper and more broadband. If we increase the power can get high value of Q-factor, but cost of the system is increased. We constructed the SCM system such a way that to operate in power at 0dBm. In the ROF systems, Modulation plays an essential role in amount of fiber nonlinearity and signal impairments such as noise and distortion. So we consider here QAM modulation for better result. The channel one has 16.8% of the desired result among the three users. Then the second channel got 51.2% of the desired result and third channel have 36% of the desired result. From the analysis user2 have the better result than the other channel. There is possibility to increase the number of user, bit rate and any other parameter to further improve the system configuration and its performance.

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