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Effect of Signal Direct Detection on Sub-Carrier Multiplexed Radio over Fiber System

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Abstract: Sub-carrier multiplexing is an emerging technology for Radio over Fiber systems. . It provides high capacity transmissions at lower costs and enables fiber based wireless access. It uses optical components for high performance but limitations of electronic components cause electronic bottleneck which limits the overall system performance. In this paper an attempt has been made to reduce the number of electronic components for the detection of baseband signals. Here baseband signals are directly detected from optical signals without any need of electrical demodulation module. This method overcomes limitations of electronic components and reduces system cost simultaneously. Performance of the system is reported for variation in fiber length and bit rate in form of Max. Q Factor and Min. BER and values of these parameters are plotted on graphs. All the simulations are done on Optisystem v 7.0.

Keywords: Baseband signal, Direct detection, Reduced electronic components, Radio over Fiber, Sub- Carrier Multiplexing, Optisystem.

I. INTRODUCTION

Radio over Fiber (RoF) is a very attractive technology for the future of wireless signals [6]. It uses optical fiber for the distribution of radio frequency signals which provides low attenuation loss, high bandwidth and enables high capacity signal transmission. For RoF technology the variations in Q factor, BER and eye opening with respect to the wavelength, bit rate and fiber length has been investigated [1]. As of April 2012, AT&T had 3000 systems deployed in the USA in places like stadiums, shopping malls and inside buildings. In China, systems are being widely deployed in industrial zones, harbors, hospitals and supermarkets. Plans are in place to expand into rural zones along rail lines, and in new residential and commercial construction spaces.

Sub-carrier multiplexing (SCM) further improves RoF configuration. The modified frequency response of a radio over fiber (RoF) system using a multi-longitudinal laser and dispersive fiber is used for multiplexing data modulated subcarriers [8]. Since the available bandwidth of optical fiber is far larger than the electronic signals, so SCM allows us to combine multiple electronic signals and then use optical fiber to distribute this combined signal which gives improved utilization of optical bandwidth. The investigations of the SCM system are done at different bit rates to report the performance of system in form of various performance metrices like Q factor, BER and Eye diagram [2]. By combining multiple RF signals and then using optical fiber which has low attenuation for the distribution of these combined signals SCM enables high capacity transmission at high data rates. The performance of high-speed digital fiber-optic transmission using subcarrier multiplexing (SCM) is investigated both analytically and numerically [7]. Though SCM allows utilization of optical bandwidth [2], there are many electronic components in these systems which have narrow bandwidth as compare to optical components. These electronic components limit high speed signal processing of optical functions. Reduction of electronic components for wavelength division multiplexed (WDM) systems has also been reported [3]. In this scheme, the subcarriers can be demodulated in the optical domain without any electronic mm-wave devices, thus the electronic bottle-neck could be overcome. Because of the novel configuration of this scheme, all of the subcarriers from different BSs can be demodulated in only one optical demodulation module.

Generally SCM RoF system uses two modulations at transmitter and two demodulations at receiver. For transmission a baseband signal is first used to modulate a RF signal and then this modulated RF signal is used to modulate optical carrier. After these two modulations signal is transmitted through the channel. Similarly at receiver side, first optically modulated signal is demodulated to get RF modulated signal and then this RF modulated signal is again demodulated to get baseband data signal. We have proposed a scheme of direct detection of electrical baseband signal from optical signal for a sub-carrier multiplexed system in which we are getting data signal without any need of electrical demodulation and hence reducing electrical components which indirectly reduces system cost and limitations of narrow electrical bandwidth.

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II. THEORY

In theory analysis we will consider frequency spectrum of a signal at different stages. Fig. 1 shows the frequency domain representation of an amplitude modulated signal [5]. In amplitude modulation, amplitude of a high frequency carrier signal is varied according to the message signal. In this figure x(t) represents the time domain of message signal and X(f) is how this signal x(t) is represented in frequency domain. After amplitude modulation signal is given by g(t) which is the time domain representation of amplitude modulated signal and frequency domain representation of this amplitude modulated signal can be expressed as G(f). This fig. shows message signal before and after modulation and we can see modulation in time domain shifts spectrum of message signal in frequency domain according to carrier frequency at $\pm f_C$.

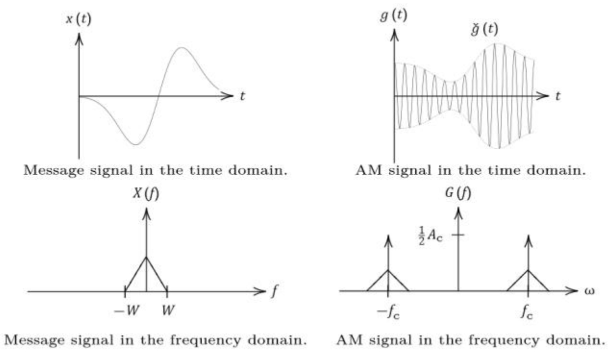

Figure 1: Amplitude modulated signal

This representation can be expressed in mathematical form as well. If X(f) and G(f) are the fourier transforms (FT) of signals x(t) and g(t) respectively, then

$$G(f) = 1/2 * A_C\,[\delta(f-f_C) + \delta(f+f_C)] + 1/2 * \mu * A_C\,[X(f-f_C) + X(f+f_C)]$$

Where μ is the modulation index,

For our work fig. 2(a) shows frequency spectrum of data (baseband) signal having frequency f_B which is used to transmit. 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 frequencies of this spectrum will become f_C-f_B and f_C+f_B respectively, as shown in fig. 2(b). Differential Phase Shift Keying (DPSK) is used for this electrical modulation. DPSK is the non-coherent version of PSK and it eliminates the need for a coherent reference signal at the receiver [4].

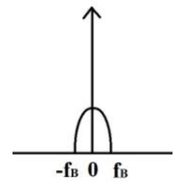

Figure 2 (a): Frequency spectrum of baseband signal

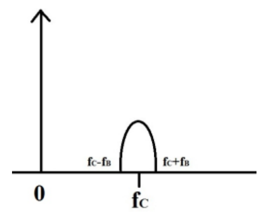

Figure 2 (b): Frequency spectrum after electrical modulation

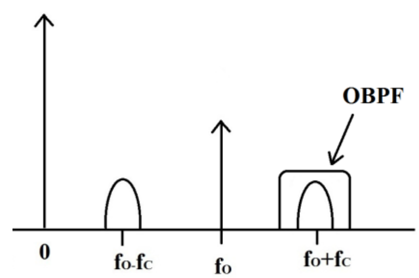

Figure 2 (c): Frequency spectrum after optical modulation

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 f_O using an external modulator called mach zehnder modulator (MZM). This optical modulation will again shift vertical axis of electrically modulated signal at frequency f_O and the frequency of upper sideband of the optical signal will become f_O+f_C as shown in fig. 2(c). Now lower and upper frequencies of this upper sideband will become f_O+f_C-f_B and f_O+f_C+f_B respectively. This optical upper sideband can be filtered using an optical band pass filter (OBPF) having frequency f_O+f_C and bandwidth 1.5*f_B. 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 photo-detector 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.

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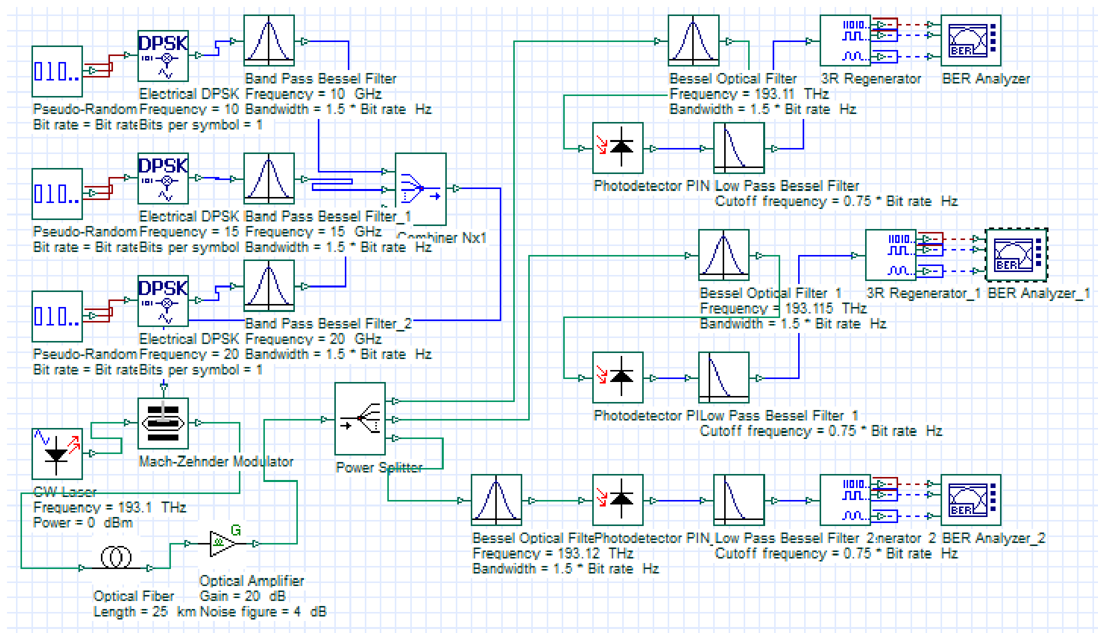

Figure 3: Simulation setup

III. SIMULATION SETUP

Fig. 3 shows the simulation setup for three users. Three pseudo random bit sequence (PRBS) generators are used to generate three different data signals. These data are used to modulate three different electrical carriers having frequencies 10 GHz, 15 GHz and 20 GHz respectively. To remove unwanted frequencies these signals are passed through band pass filters (frequencies same as carrier frequencies and bandwidth= 1.5*Bit Rate). These signals are then combined using electrical power combiner and this combined signal is used to modulate an optical carrier of frequency 193.1 THz using mach zehnder modulator (MZM). This modulated signal is then transmitted through the single mode fiber.

At receiver end signal is amplified using optical amplifier and then an optical power splitter is used to split this optical signal into three signals. These optical signals are then passed through optical band pass filters (frequencies 193.110 THz, 193.115 THz, 193.120 THz respectively and bandwidth= 1.5*Bit Rate). These filtered signals are then applied to photo-detectors which will convert these optical signals directly into baseband signals. Low pass filters (LPFs) are used to filter higher frequency components. And at the outputs of LPFs we will get data which was initially transmitted.

IV. RESULTS AND ANALYSIS

Simulation setup discussed above is simulated for two different cases. In first case number of users and bit rate are kept constant and outputs are observed by varying fiber length. In second case number of users and fiber length are kept constant and outputs are observed with respect to bit rate. The values of Max. Q Factor and Min. BER against fiber length and bit rate are plotted on the graphs.

A. Case 1: 3 Users at 2 Gbps

In this case fiber length is varied from 10 km to 40 km and outputs are compared for four different values of fiber length as shown in table 1. These values are plotted on graphs. From the graphs shown in fig. 4(a) and 4(b) we can observe the value of Max. Q Factor is decreasing and the value of Min. BER is increasing with the increase in fiber length. Maximum variation in output is observed for fiber length 20-30 km and minimum variation is for fiber length 30-40 km.

TABLE 1

Parameter / Fiber Length (km)	Max. Q Factor	Min. BER
10	8.13976	1.94739e-016
20	7.85527	1.96594e-015
30	7.09770	6.22768e-013
40	7.06050	8.24549e-013

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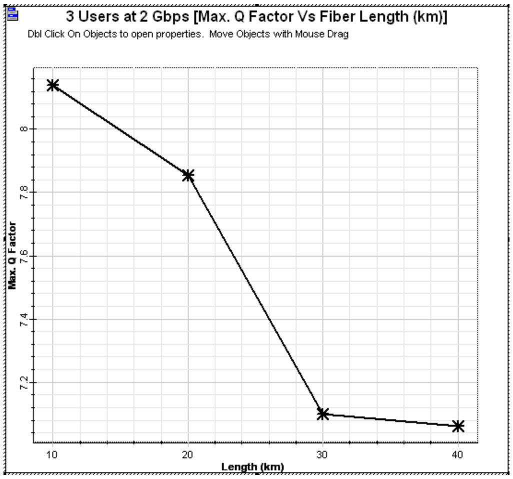

Figure 4 (a): Max. Q Factor Vs Fiber Length

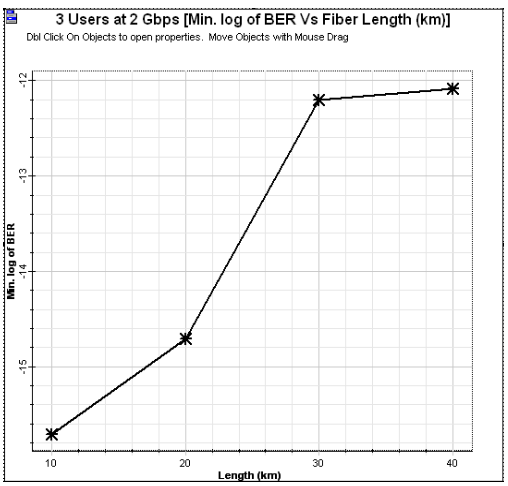

Figure 4 (b): Min. log of BER Vs Fiber Length

B. Case 2: 3 Users for 25 km

Here bit rate is varied from 0.5 Gbps to 2 Gbps and outputs are compared for four different values of bit rate as shown in table 2. These values are plotted on graphs as well.

TABLE 2

Parameter / Bit Rate (Gbps)	Max. Q Factor	Min. BER
0.5	15.05970	1.30903e-051
1	12.18390	1.54376e-034
1.5	9.20464	1.53832e-020
2	8.06464	3.61947e-016

Again from the graphs shown in fig. 5 (a) and 5 (b) we can observe the value of Max. Q Factor is decreasing and the value of Min. BER is increasing with the increase in bit rate. The variations in output for bit rate 0.5-1 Gbps and 1-1.5 Gbps are quite similar but variation in output for 1.5-2 Gbps is less than these two.

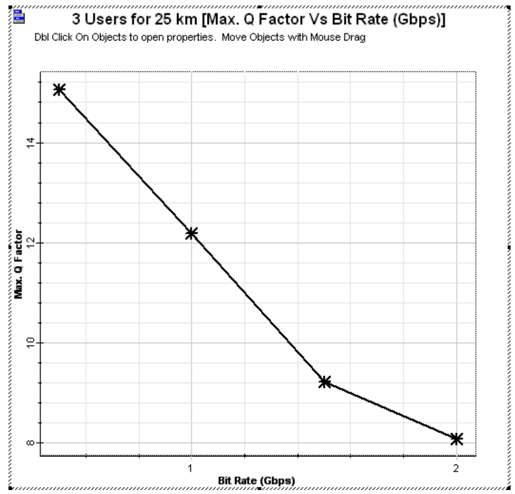

Figure 5 (a): Max. Q Factor Vs Bit Rate

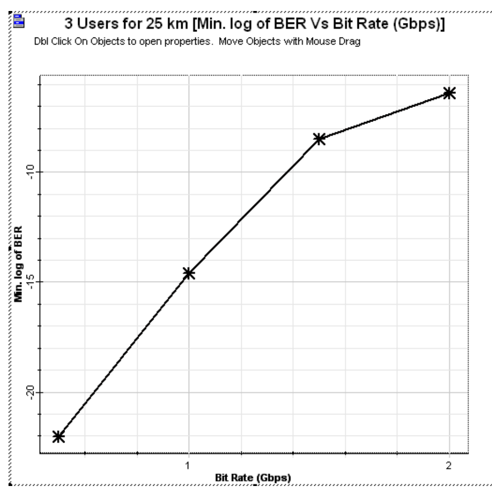

Figure 5 (b): Min. log of BER Vs Bit Rate

V. CONCLUSION

Direct detection of baseband signal has been simulated. Here electronic components are reduced and need for electrical demodulation has been eleminated. Optical signal is directly converted into baseband signal using only one optical demodulation module at receiver. This makes system simpler, cheaper and more broadband. Performance of the

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system is observed and compared by varying fiber length and bit rate. Outputs are still better than required values. So there is a possibility to increase number of users, bit rate, fiber length or other parameter to further improve system configuration and its performance.

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