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Reducing the Effect of Noise for SAC-OCDMA System by using OFDM Modulation

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Abstract

Spectral Amplitude Coding Optical Code Division Multiple Access (SAC-OCDMA) system encounters several challenges because the MultipleAccess Interference (MAI) of the overlapping chips as number of simultaneous users' increases. **Objectives:** Our objective is to develop SAC-OCDMA system with OFDM modulation, based on Flexible Cross Correlation (FCC) code to limit the effect of noises. **Methods/Analysis:** The average received signal to noise ratio (SNR) with the effects of total noise such as Phase Induced Intensity Noise (PIIN), shot noise and nonlinearity of subcarriers is derived. In addition to generated the Numerical analyses of proposed system. **Findings:** The results have been evaluated based on SNR, PIIN, shot noise and number of users as well as the amount of power received. The results show that the proposed system improve the capacity of system performance in term of users and suppress the system impairments, Furthermore, by using FCC code can effectively reduce the effects of total noise and mitigate the Multiple Access Interference (MAI). Therefore the applying of OFDM modulation with SAC-OCDMA system has been proven to be robust against the MAI and surely enhanced the system performance, in term of SNR and high number of user allocated, compare to SubCarrier Multiplexing (SCM)/ SAC-OCDMA system.

Keywords: Noises, OFDM Modulation, SAC-OCDMA System

1. Introduction

Recently, OCDMA technique has getting attention due to it has many features. The first feature of OCDMA technique is supporting high number of users and asynchronously enables to the optical network access simultaneously by define the unique code to each user. However, as the number of users increasing the performance of OCDMA system reduce because the (MAI) interference[1]. Furthermore, the Phase Induced Intensity Noise (PIIN) is created from the (MAI) interference which are both are related to the overlapping of light spectra from different users[2]. Multiple of new techniques have been introduced such as multiple-dimensional codes with PIIN suppression[3]. In order to increase the system performance, the new SubCarrier Multiplexing (SCM) technique is proposed, which demonstrates the benefits of subcarrier multiplexing over OCDMA networks. SAC-OCDMA provides a way for several radio signals to access the OCDMA networks simultaneously. The SCM is envisioned to be able to demonstrate a convenient and efficient technique for transmission of analog or digital information. However, the SCM-OCDMA has the limitation of generating a high scalable number of subcarriers as well as the bandwidth[4,5].

In this work, a new OCDMA with the OFDM technique system is established as an attractive technique where it will provide the limitation of SAC-OCDMA with independency of different channel's allocation. This will provide flexibility in the modulation schemes

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choice. With this technique, the information signals are modulated onto different electrical subcarriers in the radio or microwave domain and combined to modulate the intensity of an optical carrier[6]. Moreover, in the proposed OCDMA_OFDM system is anticipated to enhance the system capacity, produces optimum performance possible through PIIN suppression, shot noise and MAI elimination. The multicarrier transmission OCDMA has the a feature to accommodating a higher number of users. The FCC code used due to it has an advantage of high users and low received power, simple code construction, easy to design the encoder/decoder and has the flexibility in-phase cross-correlation[7]. The SAC has advantages of suppressing the MAI interference. The proposed work is also analyzed the effect of different noises in the system such as PIIN, shot and thermal noises. In addition to that, the InterModulation Distortion (IMD) which is come from OFDM signal is also being analyzed.

2. System Performance Analysis

The OCDMA_OFDM design is based on the AND subtraction technique which can absolutely suppress the effect of the MAI. In Figure 1, it shows the block diagram of the proposed system. In the given system, there are two branches of a Fiber Bragg Grating (FBG) at decoder which is used for each user and follows by one detector for each branch, respectively. This designed format is to eliminate the effect of MAI between the codes. By the matching encoder, the accepted chips are filtered while the undesirable chips are filtered by the subtraction decoder.

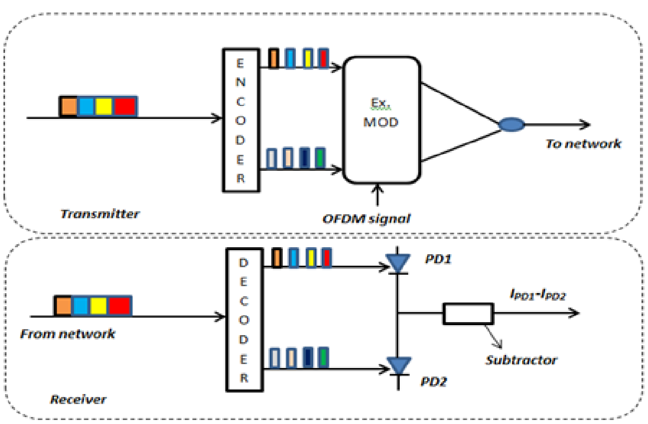

Figure 1. OFDM-SAC-OCDMA Scheme.

In the analysis of the system performance, four types of noises are taken into consideration; the shot noise $\langle I_{sh} \rangle$, thermal noise $\langle I_{th} \rangle$, phase induced intensity noise $\langle I_{PIIN} \rangle$ and the IMD noise which is coming from the intermodulation distortion noise because the subcarrier channels.

The SNR known as the average of the signal-to-noise ratio, $SNR = \left[\frac{I^2}{i^2}\right]$ where i^2 the mean power of noise which is expressed as[8]

$$\langle i^2 \rangle = \langle I_{sh}^2 \rangle + \langle I_{th}^2 \rangle + \langle I_{PIIN}^2 \rangle + \langle I_{IMD}^2 \rangle \qquad (1)$$

From (1) the total noise can then be expressed as[4,8]:

$$i^2 = 2eB\Re\left[\frac{P_{sr}}{N}\right](W+3) + \frac{4K_bT_nB}{R_L} + \frac{P_{sr}^2\ B\Re^2 K\ W\left[\ (W+3\right]}{\Delta V\ N^2} + \frac{9a_3^2}{16N^2} \times P_s^3 \times \left(\sum_{b \neq k} U_3(N,b)\right)^2 \qquad (2)$$

Where:

$$U_3(N,b) = \frac{3}{2}(2bN - 2b^2 + 2b + N^2 - n)$$

The n is defined as the equal spaced frequency points, and b known as the associated frequency index such that $1 \leq b \leq n$. The third order Output Intercept Point (OIP_3) and 1dB compression point (P_{1dB}) are as below[9]:

$$a_3 = -\frac{2}{3}10^{\left(\frac{3G_o}{20} - \frac{OIP_3}{10}\right)}$$

N is defined as the code length of FCC code; P_{sr} is the receiver power; the responsivity of the photo detector, W present the weight of the code sequence. K is the number of users. The photocurrent (I) after OFDM modulator can be found as:

$$I = \frac{\Re P_{sr}(W-1)}{N} \times \sum_{n=1}^{k} C_n . e^{j2\pi f_n t} \qquad (3)$$

The average SNR of the OFDM-SAC-OCDMA system for the FCC code can be written as:

$$SNR = \frac{\left\langle \frac{\Re P_{sr}(W-1)}{N} \times \sum_{n=1}^{k} C_n \times e^{j2\pi fnt} \right\rangle^2}{\frac{P_{sr}\ e\ B\ \Re\left[W+3\right]}{N} + \frac{P_{sr}^2\ B\Re^2 K\ W\left[W+3\right]}{2\,\Delta V\ N^2} + \frac{4K_bT_nB}{R_L} + IMD_3} \qquad (4)$$

The Bit Error Rate (BER) calculated based on Gaussian approximation and can be expressed as [10,11]:

$$BER = \frac{1}{2}\, erfc\left(\sqrt{\frac{SNR}{8}}\right) \quad (5)$$

Table 1 indicates all the parameters and values utilized in the setup.

Table 1. The Parameters used in the theoretical Analysis

Parameters	Values
Line-width Broadband Source (Δv)	3.75 THz
quantum efficiency of Photo detector *(η)*	0.6
Electron charge (e)	1.6×10^{-19}
Noise temperature at receiver(T_n)	300 K
Load resistor at receiver(R_L)	1030 Ω
Planck's constant (h)	6.66×10^{-34}Js
Boltzmann's constant (K_b)	1.38×10^{-23} J/K
Electrical bandwidth (B)	311 MHz
wavelength*(λ)*	1550 nm
Number of subcarriers (N)	256

3. Results and Discussion

The performance of the system is analyzed using the system numerical parameters in Table 1. The mathematical equations of the SNR and BER (Equation 4 and Equation 5) are used in calculation to analyze the proposed system performances.

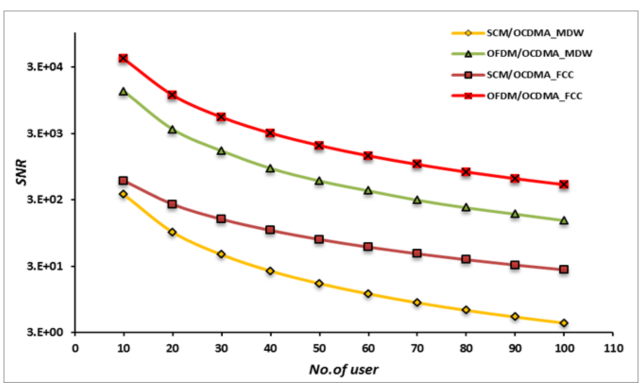

Figure 2. SNR against the Number of User.

In Figure 2, the SNR decreases as the number of users rise when the different codes, such as MDW, and FCC, are used. When the effective light power is fixed at -15 dBm and the number of users in the system increases, the SNR decreases because the high number of users introduces higher noise power and subsequently. The SNR of the OFDM/SAC-OCDMA system based on MDW code remains high as the cardinality reaches 100 (at SNR=$3E^{+02}$) in comparison to SCM/SAC-OCDMA with same number of users (at SNR=$3E^{+00}$). SNR is an important factor for indicating the ability of a receiver to recover the original signal from the corrupted version. In the system designed the code length of the FCC and MDW codes increases as the number of user's increases, which cause a reduction in the SNR value over entire system. The performance of the this system based on FCC code has better performance than with MDW code because the code length of FCC code shorter.

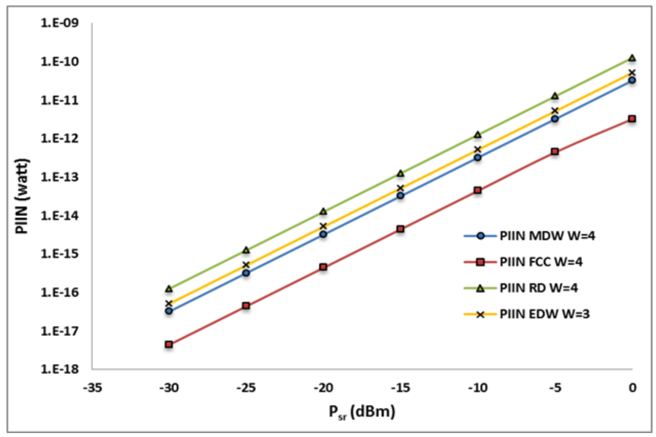

Figure 3. PIIN noise varies with the power receive (Psr).

Figure 3, denote the variation of the PIIN noise against the power received (P_{sr}) as the P_{sr} varies from -35 dBm to 0 dBm when the *B* and *K*values are fixed (B = 311 MHz and K = 50). The result indicates that as the power receive rise the PIIN noise for the MDW, RD, EDW and FCC codes are increasing proportionally. It is shown that the PIIN noise for the FCC code is less in comparison to the other codes. Mathematically, the Equation (2) shows that value of the PIIN noise is decreased with an increase of the code length and the decrease in the code weight.

It can be easily determined from Figure 4, that as the effective power increases, the shot noise will also increase because of the dominance of the shot noise compared to thermal noise and this leads to the degradation of system performance. The FCC code has the lowest shot noise ($1.19E^{-15}$ W) compared to other codes but the MDW code still has lower shot noise ($2.46E^{-15}$ W) than the EDW code ($3.77E^{-15}$ W) and RD code ($1.74E^{-14}$ W).

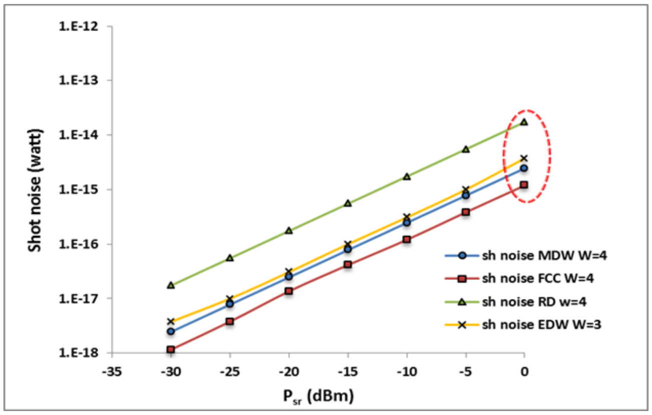

Figure 4. Shot noise versus for various SAC-OCDMA codes using OFDM modulation.

4. Conclusion

In this paper the findings of the new SAC-OCDMA_ OFDM system performance utilizing FCC in comparison to the conventional SCM/SAC-OCDMA system were presented. The findings indicate that the system proposed achieves high SNR with higher number of active users and reduce the PIIN noise and shot noise in comparison to using other codes and SCM/SAC-OCDMA system. The noise performance analysis with the presence of different types of noise; PIIN, shot, thermal noises and IMD, indicates that respectively. This will give a motion in SAC-OCDMA _OFDM system for a better quality and service in the optical transmission systems.

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