مجلة جامعة بني وليد للعلوم الإنسانية والتطبيقية

تصدر عن جامعة بني وليد – ليبيا

Website: https://jhas-bwu.com/index.php/bwjhas/index

العدد التاسع والعشرون، 2023

Performance Enhancement of Orthogonal Frequency Division Multiplexing system for Mitigation of Narrowband Interference over Additive White Gaussian Noise.

Amal A. Salh[1], Mohamed S. Alshulle[2*]

[1]College of Technical Technology, Bani Walid, Libya.

[2]Military Industries Organization, Bani-Walid, Libya.

*Crosspnding author: dr.engineeralshole@gmail.com

تاريخ الاستلام: 17-06-2023 تاريخ القبول: 27-06-2023 تاريخ النشر : 07-09-2023

Abstract: An essential component of multicarrier digital data transmission systems is orthogonal frequency division multiplexing (OFDM), which divides a single data stream into a number of lower-speed subcarrier signals. This new standard for data transmission is the first to use OFDM in a communication system that uses data packets. To achieve high throughput and good transmission quality in wireless communication networks, parallel transmission of data symbols is implemented as an abstraction. A way to handle concurrent transmission is via OFDM.

The performance of the bit error ratio (BER) is improved in this paper when the transmission channel's SNR is altered. Here, SNR is increased while BER is decreased. However, OFDM does not exhibit resilience to narrowband interference (NBI) in its present implementation. It is advised to use an OFDM system with CI to lower the NBI of the OFDM system. Using orthogonal CI spreading codes, the CI code distributes each of the N low-rate symbol streams across all N subcarriers. With little system complexity increases, the high NBI is reduced. Furthermore, the system performs much better than the conventional method in terms of bit error rate (BER). A carrier-interferometry OFDM system's performance has been compared to that of OFDM. It has been found that one of these systems can minimize the symptoms of NBI. The development of a MATLAB software to simulate a basic OFDM system is used to support this work. An completed MATLAB application can be used to explore the characteristics of an OFDM system. This process of development may be used to study the workings of an OFDM system.

Keywords: (Orthogonal Frequency Division Multiplexing (OFDM), Bit Error Ratio (BER), NarrowBand Interference (NBI , Carrier Interferometry (CI)) .

Introduction

In wireless communication systems, it is frequently preferable to permit the subscriber to send data to the base station while simultaneously receiving data from the base station. A cellular system divides any given area into cells where a mobile unit in each cell communicates with a base station. The primary goal in the design of cellular systems is to be able to improve the channel's capacity, or to handle as many calls as feasible in a given bandwidth while maintaining an adequate degree of service quality. It is essential to have a framework in place for several users to access and use wireless communication systems or cellular technologies at once. Different multiple access strategies have been employed as cellular technology has developed. They form the very core of the way in which the radio technology of the cellular system works. There are four main multiple access schemes that are used in cellular systems ranging from the very first analogue cellular technologies to those cellular technologies that are being developed for use in the future. Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Orthogonal Frequency Division Multiplexing (OFDMA) are the four different multiple access systems [1],[2].

OFDM is a method of encoding digital data on multiple carrier frequencies. Since it saves the need for complex equalizers, it is best suited for channels with a non flat frequency response [2]. The OFDM technique enables a base station to bifurcate a bunch of radio spectrum into sub-channels. And the strength of the sub-channels and the no. of channels assigned to different be adjusted as required. The technique enables high data rates, miles away from a transmitter. Hence it suits with the radio interference that is normaly found in urban areas, where signals reflect off walls and generates confusing echoes [2]. The idea of OFDM is derived from Multi-Carrier Modulation (MCM) transmission technique. The principle of MCM is that to divide the input bit stream into several parallel bit streams and then they are used to modulate several sub carriers. Guard band is used to separate the sub-carrier so that they do not overlap with each other. Band pass filters are used at the receiver side, to separate the spectrum of individual sub-carriers. Spectrally efficient MCM techniques, such as OFDM, which use closely spaced orthogonal sub-carriers and overlapping spectrums, are a specific case of MCM. OFDM does not require the use of band pass filters because of the orthogonality of the subcarriers. As a result, the available bandwidth is utilized effectively while preventing ICI.

The fundamental idea behind the OFDM system is introduced and addressed in this work. Including its production and reception, the OFDM communication system This paper's goal is to use OFDM methods to investigate the impact of cyclic prefix on data rate. It has been suggested that the CI techniques [4], such as carrier-interferometry OFDM (CI-OFDM) and pseudo-orthogonal carrier-interferometry OFDM (POCIOFDM), can improve OFDM performance when NaBI is present. The creation of a MATLAB software that simulates a fundamental OFDM system achieves this goal. This work will introduce the CI-OFDM technique, which is thought to lessen the effects of NBI. The following sections stress the CI-OFDM system's primary concept.

1. Transmitter Structure

The CI-OFDM transmitter is shown in Figure 1 (Figure 1(a) and (b)). Each information symbol is modulated onto every N carrier in the CI-OFDM system following the S/P conversion procedure [3],[4]. The transmitter applies a different orthogonal spreading code to each information symbol when spreading is done in the frequency domain in order to ensure the separation of information symbols at the receiver side. These spreading codes line up with how (to the symbol) [3] is applied.

$$C^{(K)}(t) = \sum_{i=0}^{N-1} B_i^{(K)} e^{j2\pi i\Delta f t} . g(t) \quad (1)$$

where Δf is the carrier separation (Δf=1 / T_S to ensure carrier Orthogonality); $g(t)$is a rectangular pulse shape of duration T_S (where T_S is OFDM symbol length); and $B_i^{(K)}$,*i=0,..,N-1* refers to the k^{th} symbol's spreading sequence characterized by

$$\left\{B_0^{(k)}, B_1^{(k)}, \ldots\ldots\ldots, B_{N-1}^{(k)}\right\} = \left\{e^{j\frac{2\pi}{N}.k.0}, \ldots\ldots, e^{j\frac{2\pi}{N}.k.(N-1)}\right\} \quad (2)$$

The CI spreading codes defined in (1) and (2) are orthogonal spreading codes, that is,

$$R\left[\frac{\int c^{(k)}(t)\overline{c^{(l)}(t)dt}}{\int c^{(k)}(t)c^{(k)}(t)dt}\right] = R\left[\frac{1}{N}\cdot\sum_{l=0}^{N-1} e^{j\left(\frac{2\pi}{N}.ki-\frac{2\pi}{N}Li\right)}\right] \qquad (3)$$

where R is the real values.

$$C^{k}(t) = \sum_{i=0}^{N-1} B_i^{(k)} e^{j2\pi i\Delta ft}.g(t) \qquad (4)$$

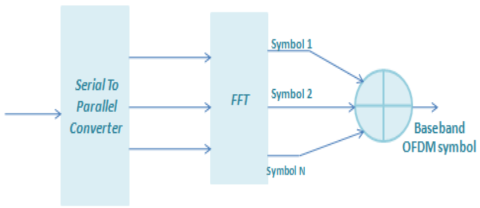
$$\overline{C^{(L)}(t)} = \sum_{i=0}^{N-1} e^{j2\pi i\left(\frac{l}{N}+\Delta f\right)}.g(t) \qquad (5)$$

Multiplied Equation (4) by Equation (5).

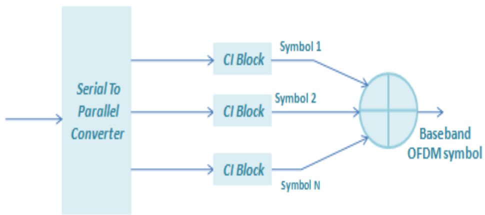
$$c^{(k)}(t)\overline{C^{(l)}}(t) = \sum_{i=0}^{N-1} e^{j2\pi i\left(\frac{k}{N}-\frac{l}{N}\right)}.g^2(t) \qquad (6)$$

And

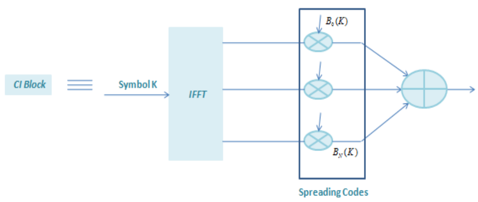
$$c^{(k)}(t)\overline{C^{(k)}(t)} = \sum_{i=0}^{N-1} e^{j2\pi i\left(\frac{k}{N}-\frac{k}{N}\right)} = e^0 = 1 \qquad (7)$$



(a) Traditional OFDM transmitter.



(b) Modified OFDM transmitter with CI blocks.



(c) Detailing the CI block.

Fig. 1: Traditional OFDM and CI-OFDM Transmitters.

In the CI-OFDM system, the sent signal for the kth symbol may be written as:

$$s^{(k)}(t) = R\left[\sum_{i=0}^{N-1} A\,.s^{(k)}.e^{j2\pi i\Delta ft}.e^{j\frac{2\pi}{N}k.i}.e^{j2\pi f_c t}.g(t)\right] \qquad (8)$$

where A is a constant that ensures symbol energy of unity, $s^{(k)}$ is the k^{th} information symbol, an$s^{(k)} \in \{+1,_{'}1\}$, and is the carrier frequency. The total transmitted signal for the CI-OFDM system can be written as:

$$S(t) = R\left[\sum_{k=0}^{N-1}\sum_{i=0}^{N-1} A\,.S^{(k)}.e^{j2\pi i\Delta ft}.e^{j\frac{2\pi}{N}.k.i}.\;e^{j2\pi f_c t}.\,g(t)\right] \quad (9)$$

2. CI-OFDM Receiver Structure

Figure (2) shows the receiver structure for the CI-OFDM kth symbol. The received signal is divided into its N carrier components and recombined in order to reduce both the ISI and the narrowband interference signal in the receiver [4].

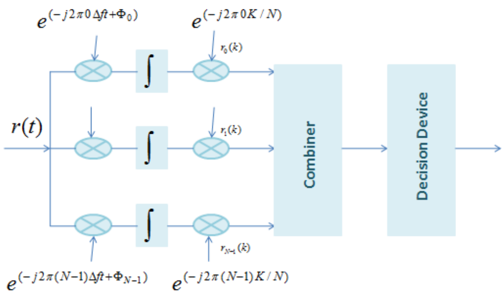


Fig. 2: Receiver Structure for CI-OFDM System for the k^{th} symbol.

$$r(t) = \sum_{k=0}^{N-1}\sum_{0}^{N-1} A\alpha_i S^{(k)} \cos\left(2\pi f_c t + 2\pi\Delta f t + \frac{2\pi}{N}.k.i + \varphi_i\right) g(t) + I(t) + n(t) \quad (10)$$

where the frequency-selective Rayleigh fading channel introduces a fading gain and phase offset (a_i, φ_i) , respectively, into the ith carrier; n(t) is an AWGN with zero mean; and double-sided PSD is equal to $\frac{N_0}{2}$.

In order to reduce interference, the received signal is broken down into its N carrier components and recombined. The symbol estimate's (k) is then created using a hard decision device. By using a single FFT, the frequency decomposition is more effectively (and less expensively) done in practice. Here, we go into further depth about how the receiver works.

To mitigate the effects of narrowband interference (Ii), as well as the presence of both ISI and noise, a well constructed cross-carrier combiner is used. The combiner's standard configuration is

$$R^{(K)} = \sum_{i=0}^{N-1} W_i \,.\, r_i^{(k)} \quad (10)$$

It is simple to demonstrate that [5] and the Ith combining weight obtained using the MMSE criterion are equivalent.

$$W_i = \frac{A\,\alpha_i}{E\left[(r_i^{(k)})^2\right]} \quad (11)$$

when interference is present (i.e., when narrowband interference weakens the i^{th} carrier).

The $r_i^{(k)}$ with and without NBI can be written as:

$$r_i^{(k)} = A\alpha_i S^{(k)} + \sum_{\substack{l=0\\ l\neq k}}^{N-1} A\,\alpha_i S^{(l)} \cos\left[\frac{2\pi}{N}(k-l).i\right] + n_i \quad \text{O.W} \quad (12)$$

where is the NBI and is the AWGN.

$$\therefore W_i = \frac{A\alpha_i}{E\left\{\left(r_i^{(k)}\right)^2\right\}} = \frac{A\alpha_i}{NA^2\alpha_i^2 p_i + \sigma_i^2 + \frac{N_0}{2}} \quad (13)$$

It is important to notice that the combining weights are very closely matched by when the narrowband interference has very high power $\sigma_i^2 \gg NA^2\alpha_i^2$,[[5].

$$\therefore W_i = \begin{cases} 0 & , \; i \in \{m, m+1, \dots, m+M-1\} \\ NA^2\alpha_i^2 p_i + \sigma_i^2 + \frac{N_0}{2} \;, & \text{O.W} \end{cases} \quad (14)$$

3. Performance of OFDM and CI-OFDM with Narrowband Interference in AWGN.

The likelihood of error is first calculated under the assumption that CI-OFDM and OFDM are being transmitted over an AWGN channel with narrowband interference across subcarriers.

For an OFDM signal, the decision variable for the i^{th} symbol is easily shown to be:

$$r_i = \begin{cases} AS^{(i)} + I_i + n_i & , \in \{m, m+1, \dots, m+M-1\} \\ AS^{(i)} + n_i \ , & O.W \end{cases} \quad (15)$$

The probability of error for OFDM in the presence of narrowband interference in an AWGN channel therefore corresponds to:

$$P(e) = \frac{N-M}{N} . Q\left(\sqrt{\frac{2E_b}{N_o}}\right) + \frac{M}{N}\left(\sqrt{\frac{2E_b}{N_o + 2\sigma_I^2}}\right) \quad (16)$$

It is clear that the first term reflects the contribution of "interferred carriers," while the second term indicates the contribution of "carriers that do not experience interference." It is clear that the latter term dominates the typical BER. It has been observed that, for the CI-OFDM system, the impact of narrowband interference is equally dispersed over all information bits and is diffused throughout all sub-carriers. By presenting the decision statistic entering the hard decision device R((K)), we may start to compute the probability of mistake term. Assuming EGC at the combiner (an ideal choice in the AWGN channel), the decision variable $R^{(K)}$ equates to:

$$R^k = \sum_{i=0}^{N-1} r_i^{(k)} = \sum_{i=0}^{N-1} AS^{(K)} + I_i + \sum_{i=0}^{N-1} n_i \quad (17)$$

where the intended signal is the first term, the contribution of interference is the second term, and the AWGN is the third term.Then, for CI-OFDM, the signal-to-interference-plus-noise-ratio (SINR) may be expressed as [6]

$$SINR = \frac{NE_b}{M\sigma_I^2 + N\frac{N_O}{2}} \quad (18)$$

Thus, the probability of error for CI-OFDM corresponds to [6]

$$P(e) = Q\sqrt{SINR} = Q\left(\sqrt{\frac{2E_b}{2\frac{M}{N}\sigma_I^2 + N_O}}\right) \quad (19)$$

4. Result

Extensive simulations are used to validate the BER performances of the OFDM and CI-OFDM systems in the presence of NBI. Assuming that the signal-to-interference ratio (SIR) is equal to -2dB, that the modulation is BPSK, that the channel model is vehicular outdoor channel, and that the number of run 10^3 and 10^4 as indicated in Figures (3).

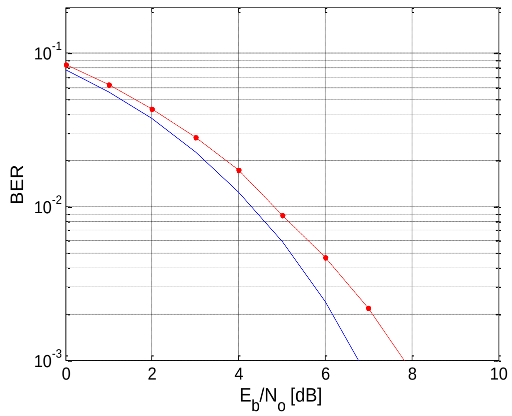


Fig. 3: Depicts the simulation blocks of the CI-OFDM system.

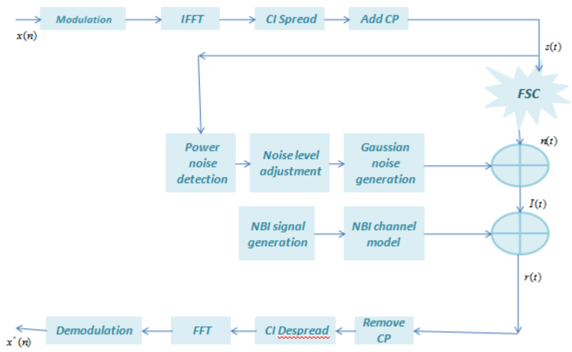


Fig. 4: Simulation blocks of the CI-OFDM system.

where the deterministic number of subcarriers used to form the NBI signal has a normal distribution and SIR.

The 0s and 1s are created at random to create the signal. Each data block is run through a BPSK modulator before being speeded up using CI code and having its symbols translated to the time domain and given subcarriers using IFFT.

5. Simulation results

After adding a cyclic prefix that is longer than the channel's maximum delay spread and serves as a guard interval to ensure circular convolution, the resulting block is broadcast across a wireless multipath channel. After that, the AWGN is added to the signal, and a chosen number of subcarriers interfere with the NBI signal.

The received signal is subsequently distributed using CI dispreading algorithm at the receiver side after the CP has been eliminated. Following the conversion of the received data block to the frequency domain in order to eliminate the ISI and the NBI induced by the channel using MMSE with correction term, the obtained received data block is provided as follows [6].

$$C = \frac{conj(H)}{\left(H * conj(H) + \frac{1}{SNR}\right)} \qquad (19)$$

After that, the demodulation is applied to the produced signal in order to approximate the original signal. the effectiveness of an OFDM system when NBI is present and interference effects are present on subcarriers 1, 2, and 4.

Figure (5) shows how an OFDM system performs when NBI is present and interferes with the 1, 2, and 4 subcarriers.

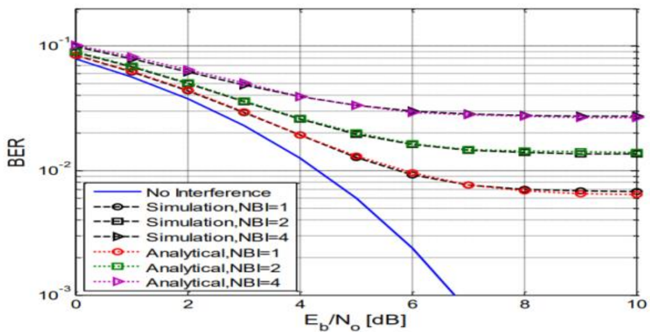


Fig. 5: BER Performance of an BPSK-OFDM system in the presence of NBI in an AWGN, SIR= -2[dB].

Figure (6) shows that the presence of interference significantly reduces an OFDM system's performance, and that this degradation worsens as the number of interference sub-carriers rises. Figure (6) shows the CI-OFDM system's performance when NBI is present for the same values of interference.

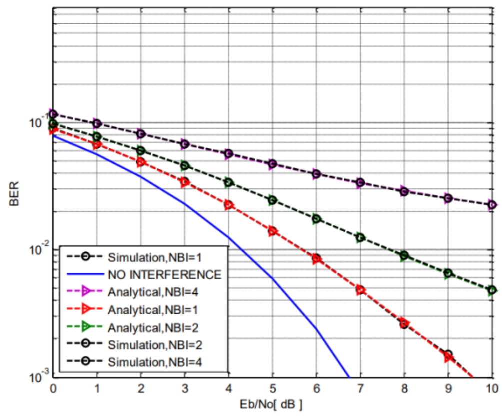


Fig. 6: BER Performance of an BPSK- CI-OFDM system in the presence of NBI in an AWGN, SIR= -2 [dB].

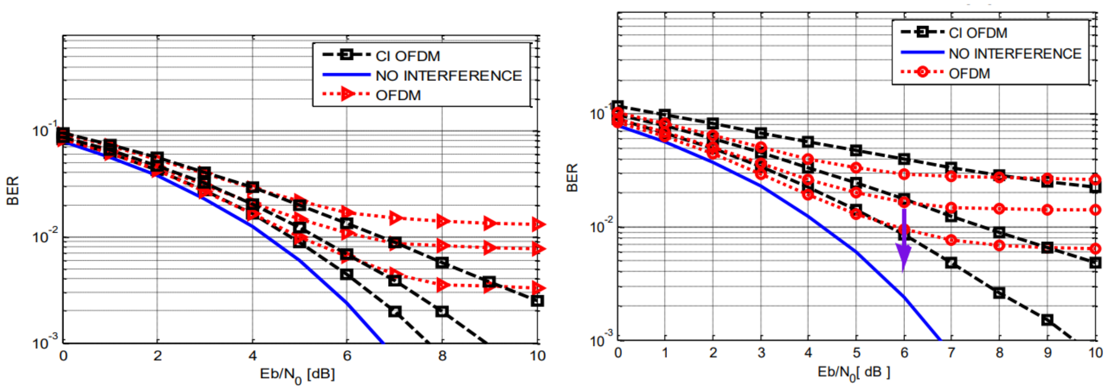


Fig. 7: BER Performance of BPSK- OFDM Vs CI-OFDM systems in the presence of NBI in an AWGN (a) SIR= 2[dB], (b) SIR= -2[dB].

Figure (7) shows that the CI-OFDM system performs better than the OFDM system in the presence of interference because orthogonal codes are used; nevertheless, when the number of interference sub-carriers is increased, the performance of the CI-OFDM system becomes more susceptible to the effects of interference. As a result, although the impact of the NBI has been lessened, the additional complexity introduced to the system has not entirely eliminated it. The performance of the OFDM and CI-OFDM systems in the presence of NBI is shown in Figure (7) for the same values of interference.

6. Conclusion

In wireless networks and mobile communications, OFDM has a bright future. This technology was created in response to the expanding global market for wireless networks and the rising need for massive amounts of bandwidth. OFDM is already a key component of WLAN and will be in MAN as well. It will undoubtedly rule the communication sector in the years to come.

In this study, MATLAB is used to model an OFDM system. The main parts, benefits, and drawbacks of an OFDM system are reviewed. Additionally, the BER performance of OFDM over AWGN channel models in the current NBI has been examined, as well as the OFDM system simulation model.

This study has examined the fundamentals of narrowband interference cancellation methods and OFDM systems. Basic operations and characteristics of the CI and orthogonal systems are discussed. The architecture of the CI system and the justification for using adaptive interference cancellation are also discussed.

A theoretical framework and simulation using the MATLAB program have been used to examine the performance of OFDM Systems utilizing the CI approach. In order to mitigate narrowband interference over additive white gaussian noise and the impact of NBI, the CI-OFDM system is finally introduced. The performance of the orthogonal CI-OFDM system has been proven to be superior to either the OFDM, while both later systems are significantly degraded by the presence of NBI. In light of the previous systems shown, it can be said that the orthogonal CI-OFDM system is the best countermeasure method. When narrowband interference is present, CI-OFDM gives substantially less graceful performance deterioration, according to simulation results of OFDM and CI-OFDM systems over AWGN channel. This is a direct result of the information being spread evenly throughout the whole bandwidth using CI-OFDM.

References

H. Lu, T. Xu and H. Nikookar, "Cooperative Communication over Multi-scale and Multi-lag Wireless Channels", book chapter in "Ultra Wideband", InTech publisher, ISBN 978-953-51-0781-1. Oct. 2012.

A. R. Forouzan, and M. Moone, "Precursor inter-symbol interference removal by block transmission-based time-reversed equalization," EURASIP Journal on Advances in Signal Processing , Dec. 2013.

C. Zhang,"Cognitive Non-Continuous Carrier Interferometry Orthogonal Signal Division Multiplex Transmission In Autonomous Vehicular Communications", IEEE Journal on Selected Areas in Communications, pp.:37-47,Vol.:29, Issue: 1, 2011.

D. Wiegandt, Z. Wu, and C. R. Nassar, "High performance carrier Interferometry OFDM WLANs: RF testing," IEEE International Conference on Communications (ICC), pp.: 203-207, vol. 1, 2003.

A, SALEH,"The Bit Error Rate (BER) Performance in Multi-Carrier (OFDM) and Single-Carrier". Electronic Theses and Dissertations. Paper 744, 2012.

S. Hara and R. Prasad, "Overview of multi-carrier CDMA", IEEE Commun. Mag., pp. 126–133, vol. 35, no. 12, Dec. 1997.