TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 3, June 2020, pp. 1203~1208
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i3.14683

Wireless communication system with frequency selective channel OFDM modulation technique

Hayder Al Ibraheemi[1], Mazen M. A. Al Ibraheemi[2]
[1]Faculty of Technical Engineering, Islamic University, Iraq
[2]Faculty of Engineering, University of Al-Qadisiyah, Iraq

Article Info

Article history:

Received Nov 27, 2019
Revised Jan 18, 2020
Accepted Feb 17, 2020

Keywords:

Equalizer
Fading channels
Frequency selective channels
OFDM
Wireless communication

ABSTRACT

This paper introduces the design and implementation of a wireless communication system with MATLAB based on orthognal frequency division multiplexing technique (OFDM). The constructed system is consisting of transmitter, fading channel and receiver. At the transmitter, the transmitted signal first modulated with PSK modulation, and then multiplexed with OFDM technique to achieve a higher bit rates transmission. The signal was then transmitted through a frequency selective channel with 6 taps. In the receiver parity. The received faded signal processed to be de-multiplexed and de-modulated. Then, a frequency domain equalizer was adopted to remove the fading noise and the inter-symbol interference from the received signal that introduced due to the fading channel. In order to inspect the performance of the frequency equilizer, bit error rate for the overall system was calculated at the receiving point and to recover the original information signal. The simulation results of the designed system as well as the frequency equilizer showed a robustness against the frequency selective faded channel effects. The maximum obtained bit error rate was around 10-5, which means that original signal was effectively recovered.

Corresponding Author:

Hayder Al Ibraheemi,
Department of Electrical and Computer Engineering,
Faculty of Technical Engineering, Islamic University
Kufa Street, Najaf, Iraq.
Email: hayder.mazin@iunajaf.edu.iq

1. INTRODUCTION

Recently, the world has witnessed a massive progress and a huge growth in wireless communication systems (cellular telephony and LAN networks). So, it becomes urgent for applying a modulation method to satisfy a reliable and high data rates communication system characterised by a high bandwidth efficiency. Generally, the signal of wireless communication channels is distributed from the transmitter to the receiver in a multipath fading because of the dynamic environment in the wireless channel [1-4]. Since the multipath takes place in the wireless transmission, this means that the power of transmitted signal will be transformed from the transmission point to the reception point by a huge number of paths. Each path with different power strength and delay. This multipath propagation causes an attenuation at different parts of the signal spectrum, which known as a frequency selective fading [5, 6]. The multipath wireless transmission also leads to a problem of intersymbol interference (ISI). This problem can be solved by increasing the transmitted symbol duration keeping the bandwidth efficiency by adopting the orthogonal frequency division multiplexing OFDM [7].

In the wireless communication system, which is based on the OFDM, the overall data to be transmitted is divided into a sequence of symbols. Then, this sequence is divided into a large number of lower speed symbol streams, where each one is modulated by a different carrier. The spaces between the modulating carriers are equal and their values are selected to make the carriers orthogonal with each other. Moreover, a cyclic prefix is inserted in the beginning of each symbol in order to resist the ISI resulted from the channel effects [6-8].

The OFDM is a digital modulation approach of digital multi-carrier. By this method, the idea of single-subcarrier modulation is extended through utilizing multiple-subcarriers in a certain channel. Thereby, the OFDM permits in parallel-transmitting of a large number of orthogonal subcarriers which are closely spaced. This is to avoid transmitting a high-rate stream of data with a single-subcarrier. The QPSK, 16 QAM is the most popular scheme to modulate each subcarrier at low symbol rate [9]. Therefore, the OFDM represents an efficient method in exploiting an available transmitting channel. The OFDM transceiver communication system can be easily implemented by using fast fourier transform FFT techniques and the inverse of FFT [10].

So, OFDM is a multicarrier modulation, MCM, technique, which becomes a popular method in signals transmitting over wireless paths. It bases on converting a frequency selective channel into frequency flat sub-channels which are parallelly collected. Thereby, the receiver becomes of a simpler implementation. The waveforms of subcarriers are orthogonal in time domain, as well, the signal spectra of the different subcarriers, overlaps in frequency domain. Consequently, for a certain transmission system, the available bandwidth is used very efficiently. By adopting techniques of adaptive bit loading, which exploit the channel estimated dynamic properties, the OFDM transmitting system can adjust its signalling to match the transmission-path conditions. This is to make the transmitting capacity of a specified frequency selective channel approachs, as possible, to the ideal case [11].

Accordingly, the following promising features of OFDM can be determined:

- Good spectral performance
- By aid of FFT, OFDM has a simple implementation.
- The OFDM combining receiver characterises by low difficulty
- A proporite for transmission techniques over a channel of multipath fading with high-data-rate
- In terms of link adaptation, OFDM is of High flexibility
- OFDM has many schemes which all of multiple access Low-complexity (OFDMA)

Due to the above advantages, the target technique, OFDM, has been widely employed in wireless standards. These standards include the wireless local area network (WLAN) standards of the IEEE 802.11a and IEEE 802.16a, terrestrial digital video broadcasting (DVB-T), digital audio broadcasting (DAB), etc. Therefore, for upcoming-generation of mobile wireless systems, the OFDM could be the leading technique [12]. Consequently, the world has witnessed sinifigent efforts in this area of study, OFDM, so as to transmite data streams with high bit rate. References [13-15] adopted a classical OFDM system to build optical systems, as well as the implementation and analyse of OFDM system in visible light communication were investigated. Authors in [16] presented the fundamental aspects of an OFMD based wireless MAN modems implementation, where the proposed wireless MAN modem showed a high-speed communication. The design and implementation scheme of the baseband multimedia communication system, which is currently carried out by automobile, was described by [17]. Refrence [18] introduced a construction for wireless communication system which based on the MIMO and OFDM basic principles. Whereas [19] implemented an OFDM transceiver system FPGA kit for HDTV transmission purpose utilizing two antennas for transmission and one antenna for receiveing. In [20], the FPGA was adopted in order to implement MIMO-OFDM system with 4x2 antennas, which provided 20-meter communication range with 600 Mbps bandwidth. Authors in [21] utilized a frequency selective multipath channel to demonstrate the robustness of the OFMD system at high data rates. Accordingly, an implementation of a high-speed WLAN system based on an asynchronous OFDM, at real-time DSP, has been presented. The implementation of an airborne ultrasonic communication system was proposed by [22], where the OFDM technologh was investigated with different modulation schemes such as BPSK, QPSK and 16-QAM. The work proved that ODFM has a superior behaviour especially with 16-QAM modulation.

In contrast, OFDM system has some disadvantages such as lower single-carrier modulation compared to peak-to-average power ratio (PAPR) and sensitivity to errors of frequency and time synchronization [7, 23, 24]. This article focuses on presenting a wireless communication system, based on OFDM modulation technique, whose receiving part should be capable to recover the original information signal and to eliminate the channel noise. A MATLAB code was exploited to construct a wireless transmitter, wireless faded channel and wireless receiver with frequency domain equilizer. The frequency equilizer has been adopted and tested for the purpose of meeting the articale topic idea. The employed equilizer efficiently satisfid this purpose, where it provided, approximately, 10^{-5}-bit error rate for the overall system.

2. RESEARCH METHOD

OFDM system is a spectrum efficient type of a multicarriers modulation transmission and its basic structure is shown in Figure 1 as given by [25]. A number of linear independent sub-channels, or sub-carriers whose frequency spacing is reversly proportional to the symbol period, are exploited to transmite a single data stream as shown by Figure 2. This means at each channel centre frequency, the crosstalk from other channels will be unnoticeable. The DFT and IDFT (direct and inverse discrete fourier transforms) are respectively employed for the demodulation and modulation processes. Thereby, an efficient replacement to the banks of I/Q-modulators as well as demodulators is performed. Otherwise, those banks would be required in implementing the wireless system.

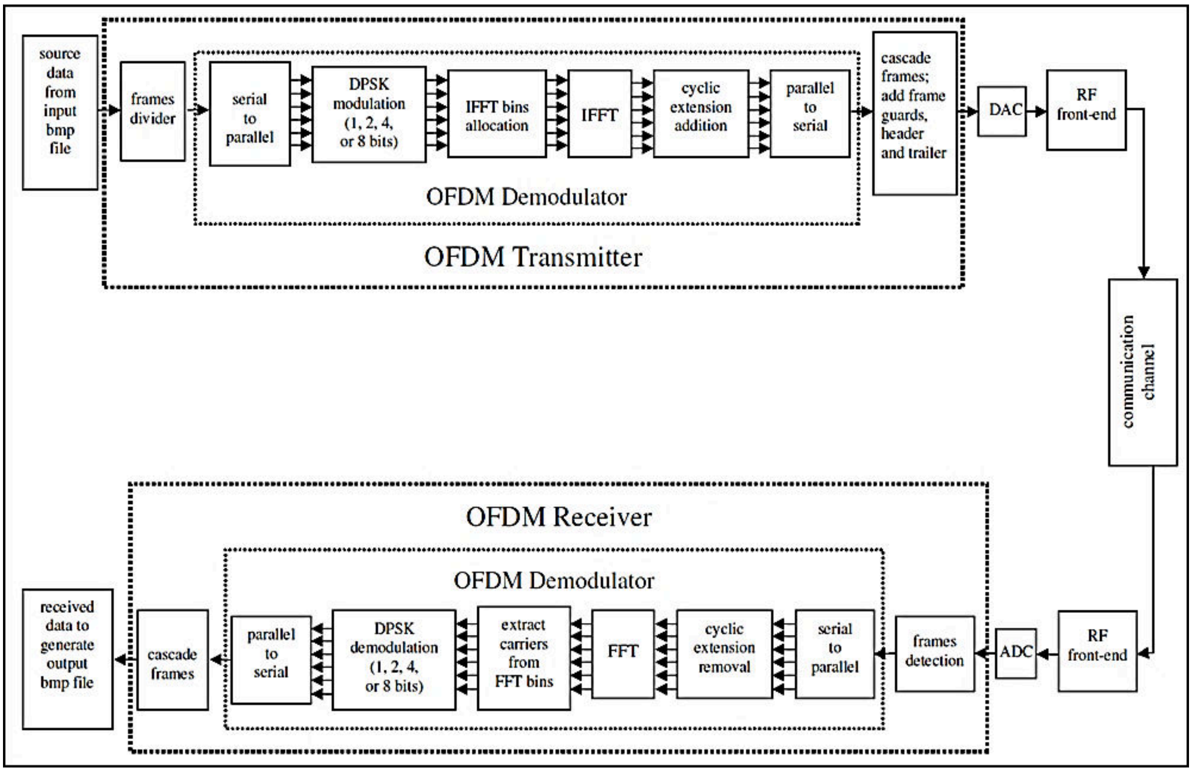

Figure 1. Basic OFDM system

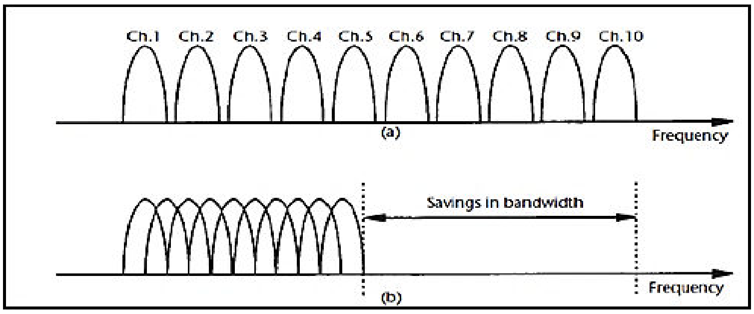

Figure 2. OFDM channels

A forward error correction code has been used, before the IDFT-modulation, to encode the original binary input data. Thereafter the encoded data are interleaved and then mapped to produce the PSK form. On the other side of the transceiving system, receiver side, DFT process is utilized to demodulate the signal samples. Then, obtained sequences are demapped, deinterleaved and lastly decoded to extract the output data in binary form. On the receiving side, the frequency offset and the symbol timing have to be determined. Whereas, a cyclic guard interval in OFDM symbols is introduced to preserve the independence of subsequent and the subcarriers orthogonality, The last part of the OFDM symbol is copied to establish the guard interval, while the duration T_{guard} is adjusted to be larger than the highest value of excess delay in the radio channel. Transmission of the guard interval is done directly before the symbol effective part. Therefore, the process of DFT demodulation, at the receiving side, will not be started before the duration T_{guard} and only for the period T, the original effective symbol time. During this time, and regarding the channel impulse response, the stationary part in the cyclic convolution of the transmitted OFDM symbol can be considered as the received signal.

Then, a roll-off region (transition period) is required before introducing the next symbol. The output-samples establish the OFDM symbol from the IDFT (for the period T, T_{guard}). This action leads to introduce side-lobe effects by the rectangular windowing. Inserting of extra samples after the effective symbol time and before the guard interval can introduce a smoother windowing. Reference [5] determined the total symbol time which is given in Figure 3 by $T_s = T_{DFT} + T_{gurd} + T_w$.

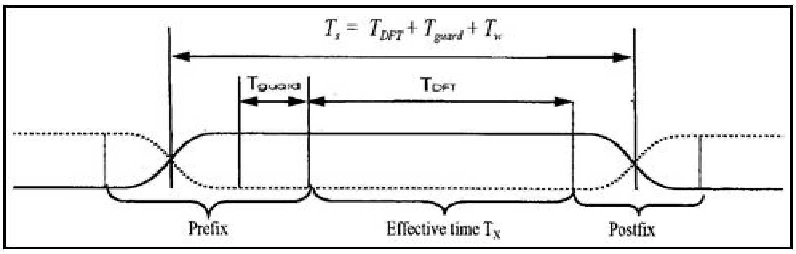

Figure 3. OFDM cyclic periods

Fundamentally, the bit rate, delay spread and bandwidth requirements represent the criterions on which choicing of the OFDM parameters depends upon. Moreover, the delay spread directly decide the T_{guard} T_w. Depending on the PSK modulation and the coding values of T_{guard} T_w should be, approximately, two-to-four times the RMS-value of the delay spread. It is desirable to have a long effective symbol time T_s, compared to T_{guard} and T_w in order to minimize the SNR-loss which always caused by the "wasted time" T_{guard}, T_w. The choice of T_x, is not free because a higher value of symbol time leads to spaced sub-carriers and, consequently, higher sensitivity to frequency offset and phase noise, a larger implementation complexity and an increased peak-to-average power ratio.

In this article, the description of an OFDM system with 6 taps (propagation delays) was investigated. The bit error rate, BER, was calculated accurately by aid of a MATLAB code for this purpose. The proposed communication system based on a PSK modulation with OFDM technique. The number of subcarriers or sub-channels was considered to be 128 channels with a cyclic prefix length of 16. The sampling time was considered to be 1 msec with a negligible Doppler frequency shift (equal to zero). The inverse discrete fourier transform was introduced in the transmitter in order to provide the necessary orthogonality between the subcarriers. This work adopted a frequency selective channel to simulate the overall system with 6 taps (different paths between the transmitter and receiver), the path delays were given by:

$$t = 10^{-6}[0\ 0.1\ 0.3\ 0.5\ 15\ 17\ 17.2] \quad (1)$$

and the average path power gains by:

$$p = [0\ -1.5\ -4.5\ -7.5\ -8\ -17.7] \quad (2)$$

The SNR was calculated so as to calculate the bit error rate of the system at the receiver point. The bit error rate, when just one station has an access to the transmission system, can be calculated based on the following formula [1]:

$$p_e(1) = (\frac{1+J_O(2\pi f_D T_D)(\sigma_d^2/\sigma_n^2)+1}{1-J_O(2\pi f_D T_D)(\sigma_d^2/\sigma_n^2)+1} + 1)^{-1} \exp(-\frac{\zeta\sigma_d^2/\sigma_n^2}{1+\sigma_d^2/\sigma_n^2}) \quad (3)$$

where j_o and f_D stand for zero-order Bessel function and Doppler frequency respectively, σ_d and σ_n are the variances of direct wave and noise respectively and T_b is the bit period. At the receiver side a frequency domain equalizer was adopted. The purpose of an equalizer is to reduce intersymbol interference due to noise and fading effects.

3. RESULTS AND ANALYSIS

Harnessing MATLAB simulation, the designed communication system shows a variant response according to the time, due to the frequency selective, time selective channel and the adopted equilizer. The bit error rate was calculated with respect to the signal to noise ratio, where it showed a good response especially at SNR=30 as shown in Figure 4. The proposed approach generates the information signal which will be distorted randomly after passing it through the faded channel. That means, each time the received signal by the receiver parity will be different. Consequently, the frequency equilizar will provide different result each time, and it is not expected to obtain the same BER distribution with each re-running of the work software. Figure 5 illustrates this topic where the software was run five times. By this figure, it can be noticed that random effect of bit generation becomes noticeable as the signal start having a considerable effect than that of noise, i.e. for SNR greater than 10. To overcome the problem of nonlinearity in sample generations, the average for 100 iterations was taken for each value of SNR. The results for this action are given by Figure 6. Thereby, the obtained results by this article could be summarized by the following points:

- The proposed method successfully manipulated the receiving data and reextracted the transmitted information.
- The transmitting data, and correspondingly the receiving data, may deffer with each iteration due to the random nature of the generated samples and the frequency domain equalizer.
- Signal-to-Noise ratio SNR = 30 is a fair minimum cretrion for success of OFDM system.

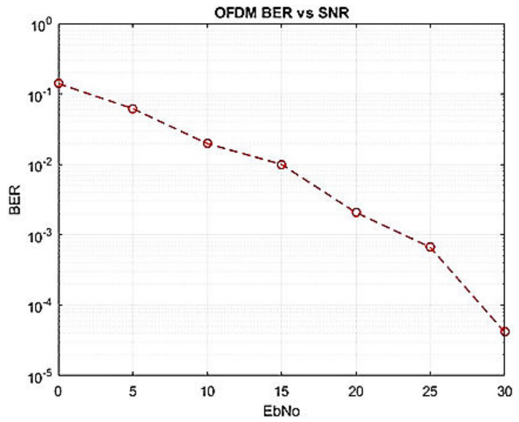

Figure 4. Bit error rate

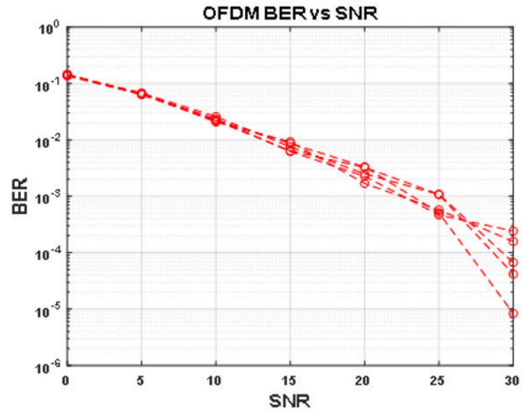

Figure 5. Bit error rate for five times regenerating process

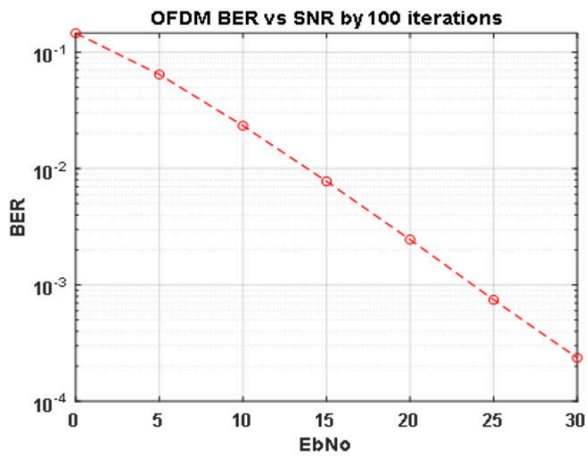

Figure 6. Bit error rate for 100 iterations at each SNR

4. CONCLUSION

Behavior and performance of the frequency domain equilizar has been inspected and examined through the response and the bit error rate calculation of a wireless communication system based on OFDM technique and PSK modulation. OFDM wireless communication system is constructed and examined based on MATLAB coding, it consists of wireless transmitter, receiver and 6 propagation paths (taps) faded channel. The results show that the adopted frequency domain equilizar efficiently can reduce and eliminatethe channel noise and the intersymbol interference. Due to the frequency equilizar minmum bit error rate of 10^{-5} is obtained. The bit error rate is inversely proportional with signal strength or SNR. As shown in Figure 5, best Bit error rate is obtained at the level of SNR = 30.

REFERENCES

[1] F. B. Frederiksen and R. Prasad, "An overview of OFDM and Related Techniques Towards Development of Future Wireless Multimedia Communications," *Proceedings RAWCON 2002. 2002 IEEE Radio and Wireless Conference*, pp. 19-22, 2002.

[2] S. Roy and A. Chandra, "Interpolated Band-pass Method Based Narrow-band FIR Filter : A Prospective Candidate in Filtered-OFDM Technique for the 5G Cellular Network," *TENCON 2019-2019 IEEE Region 10 Conference (TENCON)*, 2019, pp. 311-315.

[3] F. A. P. de Figueiredo and et al, "Comparing f-OFDM and OFDM Performance for MIMO Systems Considering a 5G Scenario," *2019 IEEE 2nd 5G World Forum (5GWF)*, 2019, pp. 532-535.

[4] A. M. Jaradat and J. M. Hamamreh, "Modulation Options for OFDM-Based Waveforms : Classification, Comparison, and Future Directions," *IEEE Access*, vol. 7, pp. 17263-17278, 2019.

[5] F. Sasamorj and F. Takahata, "Theoretical and Approximate Derivation of Bit Error Rate in DS-CDMA Systems under Rician Fading Environment," *IEICE Trans. Fundam. Electron. Commun. Comput. Sci.*, vol. E82-A, no. 12, pp. 2660-2667, 1999.

[6] B. Ahmed and M. A. Matin, "Wireless Channels," in *Coding for MIMO-OFDM in Future Wireless Systems*, Brunei: SpringerBriefs in Electrical and Computer Engineering, 2015, pp. 11-21.

[7] R. J. Hasan and H. N. Abdullah, "Comparative study of selected subcarrier index modulation OFDM schemes," *TELKOMNIKA Telecommun Comput El Control,* vol. 17, no. 1, pp. 15-22, 2019.

[8] J. J. van de Beek and et al, "On channel estimation in OFDM systems," *IEEE Veh. Technol. Conf.*, vol. 2, pp. 815-819, 1995.

[9] Keysight Technologies, Inc., "Concepts of Orthogonal Frequency Division Multiplexing (OFDM) and 802.11 WLAN," [Online]. Available: http://rfmw.em.keysight.com/wireless/helpfiles/89600b/webhelp/subsystems/wlan-ofdm/Content/ofdm_basicprinciplesoverview.htm. [Accessed: 25 November 2019].

[10] Intel Corporation, "Implementing OFDM Modulation and Demodulation." [Online]. Available: https://www.intel.com/content/www/us/en/programmable/support/support-resources/design-examples/design-software/vhdl/vhd-cyclic-prefix-insertion-ofdm.html. Accessed: 25 November 2019.

[11] A. N. Barreto and S. Furrer, "Adaptive bit loading for wireless OFDM systems," *IEEE Int. Symp. Pers. Indoor Mob. Radio Commun. PIMRC*, vol. 2, no. October, 2001.

[12] R. Touhami, D. Slimani, and A. Khelil, "Analysis of an OFDM based Indoor Visible Light Communication System," in *2018 International Conference on Communications and Electrical Engineering (ICCEE)*, 2018, pp. 1-4.

[13] S. Atoui, N. Doghmane, and S. Afifi, "Blind frequency offset estimator for OFDM systems," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 6, pp. 2722-2728, 2019.

[14] R. G. A. Gallo, "Real-DFT Based DCO-OFDM and ACO-OFDM for Optical Communications Systems," *2019 21st International Conference on Transparent Optical Networks (ICTON), Angers, France*, 2019, pp. 1-4.

[15] T. Nguyen and et al, "2D-OFDM for Optical Camera Communication : Principle and Implementation," *IEEE Access*, vol. 7, pp. 29405-29424, 2019.

[16] B. Maham, "DSP Implementation Aspects of an OFDM Based Wireless MAN Modem," in *International Conference on Wireless Communications, Networking and Mobile*, 2006, pp. 1-4.

[17] Y. Wang, J. An, and X. Bu, "The Scheme Design and Implementation of the Baseband Part of a Wireless OFDM System," in *International Conference on Wireless Communications, Networking and Mobile*, 2006, pp. 1-4.

[18] C. Peijiang, "Study and Implementation of MIMO-OFDM System Based on Matlab," in *International* Conference *on Information Technology and Computer Science*, 2009.

[19] L. Henrique and et al, "An FPGA implementation of Alamouti's transmit diversity technique applied to an OFDM system," *IEEE Antennas Propag. Soc. Int. Symp.*, no. 1, pp. 149-152, 2006.

[20] K. N. Tadashi, Y. Nagaot, and A. Teramotot, "Design of 600Mbps 4x2 MIMO-OFDM Wireless LAN System and Its FPGA Implementation," *10th International Conference on Advanced Communication Technology*, pp. 7-10, 2008.

[21] M. F. Tariq and et al, "Development of an OFDM based High Speed Wireless LAN Platform using the TI C6x DSP," *IEEE International Conference on Communications. Conference Proceedings. ICC 2002*, 2002, pp. 522-526.

[22] W. Jiang and W. M. D. Wright, "Indoor Wireless Communication Using Airborne Ultrasound and OFDM Methods," *IEEE International Ultrasonics Symposium (IUS)*, 2016.

[23] S. Nest and et al, "Unscented Particle Filter for Channel Estimation of OFDM Communication Systems," *2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI), Tirunelveli, India*, pp. 600-604, 2019.

[24] A. Hilario-Tacuri, "On the Non-linearity Effects Over the Spectrum of ESIM-OFDM Based Systems," *2019 42nd International Conference on Telecommunications and Signal Processing (TSP), Budapest, Hungary,* pp. 278-281, 2019.

[25] P. Lin, "OFDM Simulation in MATLAB," *Polytechnic State University*, California, 2010.