A New Approach to Mitigating the Effect of Constant Electromagnetic Wave Disturbances in OFDM Systems

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Abstract - Electromagnetic waves are used to transport voice and data over open space. Data exchange between two parties who are not connected by an electrical link is referred to as remote correspondence. The phrase is typically used in the delivered trades industry to refer to media correspondence systems that use some form of energy, such as radio waves and acoustic power, to carry data without the use of wires, such as radio transmitters and receivers and remote controls. Orthogonal frequency division multiple access is a multicarrier modulation method used to transmit the frequencies very quickly. This project proposes a new approach to mitigating the effect of constant electromagnetic wave disturbances in OFDM systems. The Inverse Discrete Fourier Transform (IDFT) technique is used to demodulate the modulated signals. Additive white Gaussian noise (AWGN) is often used as a channel model. An Additive white Gaussian noise channel is the most basic model of a communication system. Some examples of systems operating largely in Additive white Gaussian noise (AWGN) conditions are space communications with highly directional antennas and some point-to-point microwave links. A continuous wave electromagnetic disturbance (CW EMD) represents a signal with constant amplitude, phase and frequency. This project proved its efficiency, so the concept is being used for further improvements. This project is implemented by MATLAB software.

Key Words: IDFT- Inverse Discrete Fourier Transform, AWGN- Additive white Gaussian noise, CW EMD- continuous wave electromagnetic disturbance.

1. INTRODUCTION

Orthogonal frequency division multiplex (OFDM) is used in several modern wireless services. Examples are the mobile technologies 4G [long-term evolution (LTE)] and coming 5G, the wireless local area network standard IEEE 802.11, digital audio broadcasting, and digital video broadcasting. Automobiles and other autonomous systems are both significantly incorporating wireless communication. Orthogonal Frequency Division multiplexing (OFDM), the multi-carrier modulation (MCM) technique, has been seen to be very effective for communication over channels with frequency selective fading. It is very difficult to handle frequency selective fading in conventional communication receivers as the design of the receiver becomes hugely complex. OFDM technique efficiently utilizes the available channel bandwidth by dividing the channel into low bandwidth continuous channels. Instead mitigating frequency selective fading as a whole, OFDM mitigates the problem by converting the entire frequency selective fading channel into number of narrow bandwidth flat fading channels. Flat fading makes the receiver easier to combat channel tracking and Inter Symbol Interference (ISI) by employing simple equalization schemes [1].

Spread spectrum modulation has been the basis for majority of proprietary communication and broadcasting technology including IEEE 802.11 wireless local Area Networks (WLANs), Zig Bee, Ultra Wide Band (UWB) and others. Through the use of frequency hopping and direct sequence, these WLANs provide data rates from 1 to 11 Mbps. Regardless of these relatively high data rates, there has been an increasing demand of higher data rate for wireless broadband Local Area Networks (LANs) and Metropolitan Area Networks (MANs). Because of relatively inefficient use of bandwidth, spread spectrum systems did not satisfy the even higher data rates that multimedia applications required. In addition, multimedia applications operating outdoors or within industrial environments require a wireless network capable of operating more effectively in "RF hostile" areas. Consideration of more efficient and robust OFDM technology became a viable option for high data rate multimedia implementations. OFDM, sometimes referred to as multi-carrier or discrete multi-tone modulation, utilizes multiple sub-carriers to transport information from one user to another [2]. OFDM is a form of signal modulation that divides a high data rate modulating stream to many slowly modulated narrowband close-spaced sub-carrier. In this way narrowband sub-channels, carried by close-spaced sub-carrier, becomes less sensitive to frequency selective fading. In some respects, OFDM is similar to conventional frequency-division multiplexing (FDM). The difference lies in the process in which individual sub-carriers are modulated and demodulated. Priority is also given to minimize the interference and crosstalk among the channels and symbols comprising the data stream. Generally all channels are handled together and individual channels are never handled separately [3].

1.1 OFDM Variants

COFDM: Coded orthogonal frequency division multiplexing. A form of OFDM where error correction coding is incorporated into the signal.

Flash OFDM: This is a variant of OFDM that was developed by Flarion and it is a fast hopped form of OFDM. It uses multiple tones and fast hopping to spread signals over a given spectrum band.

OFDMA: Orthogonal frequency division multiple access. A scheme used to provide a multiple access capability for applications such as cellular telecommunications when using OFDM technologies.

VOFDM: Vector OFDM. This form of OFDM uses the concept of MIMO technology. It is being developed by CISCO Systems. MIMO stands for Multiple Input Multiple output and it uses multiple antennas to transmit and receive the signals so that multi-path effects can be utilised to enhance the signal reception and improve the transmission speeds that can be supported.

WOFDM: Wideband OFDM. The concept of this form of OFDM is that it uses a degree of spacing between the channels that is large enough that any frequency errors between transmitter and receiver do not affect the performance. It is particularly applicable to Wi-Fi systems [4].

1.2 Additive White Gaussian Noise (AWGN)

Additive white Gaussian noise (AWGN) is a basic noise model used in information theory to mimic the effect of many random processes that occur in nature. Some examples of systems operating largely in AWGN conditions are space communications with highly directional antennas and some point-to-point microwave links. The modifiers denote specific characteristics:

1. Additive because it is added to any noise that might be intrinsic to the information system.
2. White refers to the idea that it has uniform power across the frequency band for the information system. It is an analogy to the colour white which has uniform emissions at all frequencies in the visible spectrum. B
3. Gaussian because it has a normal distribution in the time domain with an average time domain value of zero [5].

1.3 Quadrature Amplitude Modulation (QAM)

Quadrature amplitude modulation (QAM) is the name of a family of digital modulation methods and a related family of analog modulation methods widely used in modern telecommunications to transmit information. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme [6]. The two carrier waves are of the same frequency and are out of phase with each other by 90°, a condition known as orthogonally or quadrature. The transmitted signal is created by adding the two carrier waves together. At the receiver, the two waves can be coherently separated (demodulated) because of their orthogonally property. Another key property is that the modulations are low-frequency/low-bandwidth waveforms compared to the carrier frequency, which is known as the narrowband assumption. QAM is used extensively as a modulation scheme for digital telecommunication systems, such as in 802.11 Wi-Fi standards. Arbitrarily high spectral efficiencies can be achieved with QAM by setting a suitable constellation size, limited only by the noise level and linearity of the communications channel [7].

1.4 Phase Shift Keying

Phase Shift Keying (PSK) is the digital modulation technique in which the phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time. PSK technique is widely used for wireless LANs, bio-metric, contactless operations, along with RFID and Bluetooth communications. PSK conveys data by modifying the phase of a signal. Two common PSK types are as follows:

1. Quadrature Phase-Shift Keying (QPSK): Uses four phases to encode two bits per symbol.
2. Binary Phase-Shift Keying (BPSK): Simplest PSK type. Uses two phases separated by 180 degrees [8].

1.5 Inverse Fast Fourier Transform

In principle, the IFFT takes frequency-domain input data (complex numbers representing the modulated subcarriers) and converts it to the time-domain output data (analog OFDM symbol waveform).Thus, the IFFT block provides a simple way to modulate data onto N orthogonal subcarriers. The IFFT output is the summation of all N sinusoids. Thus, the IFFT block provides a simple way to modulate data onto N orthogonal subcarriers. The block of N output samples from the IFFT make up a single OFDM symbol [9].

1.6 Benefits of OFDMA

Spectrum efficiency: Use of closely-spaced overlapping orthogonal sub-carriers enables data transmission with low bandwidth channels and hence it makes efficient use of the available spectrum.

Resilient to ISI: OFDM is very resilient to inter-symbol and inter-frame interference. This is due to the fact that each of the sub-channel carries low data rate data stream.

Resilient to narrow-band effects: Use of adequate channel coding and interleaving make it possible to recover symbols lost due to the frequency selectivity of the channel and narrow band interference.

Simpler channel equalization: In conventional digital communication and spread spectrum communication channel equalization has to be applied across the whole channel bandwidth. So channel equalization complexity increases. In contrast, only a one tap equalizer is required for OFDM channel equalization as it uses multiple sub-channels. This reduces equalization complexity in OFDM. Whilst OFDM has been widely used, there are still a few disadvantages which need to be addressed when considering its use.

Sensitive to carrier offset and drift: OFDM is sensitive to carrier frequency offset and drift compared to single carrier system.

High peak to average power ratio: OFDM signals are characterized by noise like amplitude variation in time domain and have relatively large dynamic range leading to high peak to average power ratio (PAPR). This impacts the RF amplifier efficiency as the amplifiers need to be linear and accommodate the large amplitude swings and these factors mean the amplifier cannot operate with a higher efficiency level.

Receiver complexity: Complexity of the OFDM receiver increases with higher number of sub-channels.

Computational complexity demand: Computational complexity associated with OFDM system increases both at transmitter and receiver by increasing the sub-carrier [10].

2.PROPOSED WORK

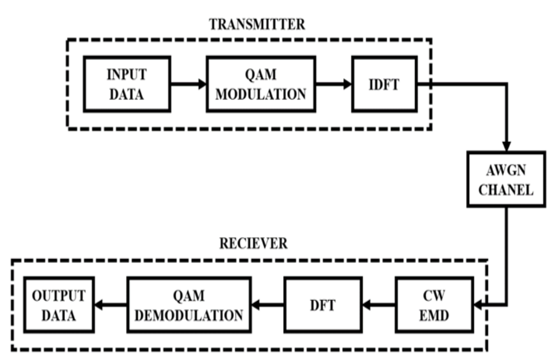

Figure 1. Block Diagram for Proposed System

In the transmitted side, the QAM modulation technique uses input data as its input. The following IDFT technique is permitted for the modulated signals. The signals are then acquired from the transmitter side and sent to the AWGN channel to determine the SNR value. The AWGN channel signal is handled by the CW EMD and DFT processes on the receiver side. Utilizing the QAM modulation technique, the current signal is modulated. High levels of spectrum consumption efficiency are achieved through the use of QAM. Finally, effective, efficient communication is the output of the result.

2.1 Transmitter

The role of the transmitter is to amplify and condition the signal so that it can be relayed over long distances to the control room or to localize devices such as indicators, recorders and controllers without deterioration or interference. The transmitter is the source of the signal, and the receiver is the destination.

2.2 Orthogonal Frequency-Division Multiplexing

OFDM is a method of data transmission where a single information stream is split among several closely spaced narrowband sub channel frequencies instead of a single Wideband channel frequency. Orthogonal frequency-division multiplexing is a method of data transmission where a single information stream is split among several closely spaced narrowband sub channel frequencies instead of a single Wideband channel frequency. Quadrature Amplitude Modulation (QAM) is a method of combining two amplitude modulation (AM) signals into a single channel. This approach helps double its effective bandwidth. QAM is also used with pulse AM (PAM) in digital systems, like wireless applications. AWGN is often used as a channel model.

2.3 Quadrature Amplitude Modulation

Quadrature Amplitude Modulation or QAM is a digital modulation scheme where data is transmitted over the channel by varying both the amplitude and phase of the high-frequency carrier signal. The transmitted signal is represented in a constellation plot that contains two axes namely the in-phase and Quadrature. The in-phase and Quadrature axis are separated from each other by a phase of 90˚. Therefore, these two axes are orthogonal to each other.

In the QAM scheme, two or more bits are grouped together to form a symbol that lies in the constellation plot. Each symbol, also called state, has a unique amplitude and phase level that provides distinction across different points in the constellation.

2.3.1 QAM Modulation

A basic QAM modulator circuit consists of a mixer, local oscillator, a 90˚ phase shifter, and a summer block located close to the output port. A local oscillator generates a clean sinusoidal signal of a fixed amplitude and frequency. The mixer circuit multiplies the incoming signal with the oscillator signal to generate a high frequency carrier signal. While the in-phase signal is a simple mixing of incoming signal and oscillator signal, the Quadrature waveform is formed by shifting the oscillator signal by phase of 90˚, upon which mixing with the data signal is carried out. The resulting two waveforms, the in-phase and Quadrature, are added at the summer circuit to create a QAM modulated signal.

2.3.2 QAM Demodulation

In the QAM demodulation process, a balun is used to split the incoming modulated signal to allow extraction of the in-phase and quadrature components of the signal. The signals can be coherently extracted since the two components are orthogonal to each other. A low-pass filter can be used to filter out the in-phase and quadrature signals separately. To extract the in-phase signal, the received signal is first multiplied with a cosine signal and then passed through a low-pass filter. A sine wave is multiple with received waveform and then passed through the low pass filter to extract the quadrature component.

2.4 Inverse Discrete Fourier Transform

The inverse discrete Fourier transform (IDFT) is defined as the process of finding the discrete-time sequence from its frequency response. An inverse DFT is a Fourier series, using the DTFT samples as coefficients of complex sinusoids at the corresponding DTFT frequencies. It has the same sample-values as the original input sequence.

2.5 Channel

Channel estimation plays an important part in an OFDM system. It is used for increasing the capacity of orthogonal frequency division multiple access (OFDMA) systems by improving the system performance in terms of bit error rate. OFDM is a subset of frequency division multiplexing in which a single channel utilizes multiple sub-carriers on adjacent frequencies. In addition, the sub-carriers in an OFDM system are overlapping to maximize spectral efficiency. Ordinarily, overlapping adjacent channels can interfere with one another.

The process is done as follows.

1. Set a mathematical model to correlate 'transmitted signal' and 'received signal' using 'channel' matrix.

2. Transmit a known signal (we normally called this as 'reference signal' or 'pilot signal') and detect the received signal.

The channel estimation is carried out with conventional Least Square (LS) and Minimum Mean Square (MMSE) estimation algorithms. The performance of MIMO-OFDM system is evaluated on the basis of Bit Error Rate (BER) and Mean Square Error (MSE) level. In telecommunication, equalization is the reversal of distortion incurred by a signal transmitted through a channel. When a channel has been equalized the frequency domain attributes of the signal at the input are faithfully reproduced at the output.

2.5.1 Additive White Gaussian Noise

AWGN is often used as a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The AWGN capacity formula 5.8 can be used to identify the roles of the key resources of power and bandwidth. This formula measures the maximum achievable spectral efficiency through the AWGN channel as a function of the SNR. The random nature of noise can distort signals and the integrity of electrical systems. Therefore, noise generators can help measure a system's response to noise, using an AWGN channel to introduce an average number of errors through the system.

The AWGN channel is a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc. However, for terrestrial path modeling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self-interference that modern radio systems encounter in terrestrial operation.

2.6 Receiver

This practical book is an accessible introduction to orthogonal frequency-division multiplexing (OFDM) receiver design, a technology that allows digitized data to be carried by multiple carriers.

2.7 Continuous Wave Electromagnetic Disturbance

A CW EMD represents a signal with constant amplitude, phase and frequency. The disturbance can be unintentional or intentional. Irrespective of the disturbance's nature, there is a source from which this disturbance originates. This source can disturb other wireless communication protocols constantly or temporarily. Both ITS G5 and C-V2X are using orthogonal frequency division multiplexing (OFDM) methods to transmit signals. The communication can be conditionally split into three parts: transmitter part, communication volume, in which CW EMD is present, and receiver part. The signal is represented in the frequency-domain but during the transmission it has to be represented in the time-domain. This is why there are two transformations in transmitter and receiver which are represented by inverse discrete Fourier transform (IDFT) and discrete Fourier transform (DFT) blocks. The transmitted signal is disturbed with CW EMD and then the disturbed signal ends up at the receiver. The influence of CW EMD in OFDM systems can be dual. It can disturb only one subcarrier or multiple. The former is valid irrespective of CW EMD power but the latter depends on the CW EMD power – the bigger the power value, the more subcarriers are disturbed. This happens due to the phenomenon which is called spectral leakage. It happens when a non-integer number of periods of a signal is sent to the DFT.

2.8 Discrete Fourier Transform

In mathematics, the discrete Fourier transform (DFT) converts a finite sequence of equally-spaced samples of a function into a same-length sequence of equally-spaced samples of the discrete-time Fourier transform (DTFT), which is a complex-valued function of frequency. The interval at which the DTFT is sampled is the reciprocal of the duration of the input sequence. An inverse DFT is a Fourier series, using the DTFT samples as coefficients of complex sinusoids at the corresponding DTFT frequencies. It has the same sample-values as the original input sequence. The DFT is therefore said to be a frequency domain representation of the original input sequence. If the original sequence spans all the non-zero values of a function, its DTFT is continuous (and periodic), and the DFT provides discrete samples of one cycle. If the original sequence is one cycle of a periodic function, the DFT provides all the non-zero values of one DTFT cycle.

The DFT is the most important discrete transform, used to perform Fourier analysis in many practical applications. In digital signal processing, the function is any quantity or signal that varies over time, such as the pressure of a sound wave, a radio signal, or daily temperature readings, sampled over a finite time interval. In image processing, the samples can be the values of pixels along a row or column of a raster image. The DFT is also used to efficiently solve partial differential equations, and to perform other operations such as convolutions or multiplying large integers.

3. RESULT AND DISCUSSION

The proposed work is implemented in MATLAB simulation and the following results are obtained.

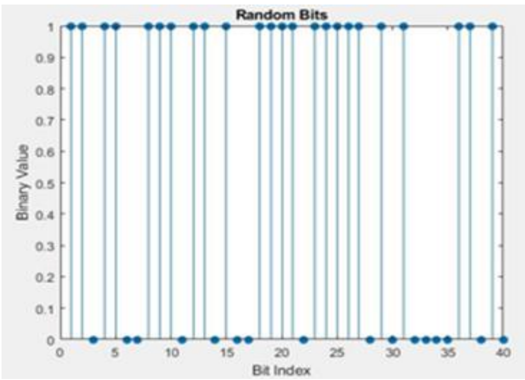

Figure 2. Random bits

Figure 2 shows that the Random bits.

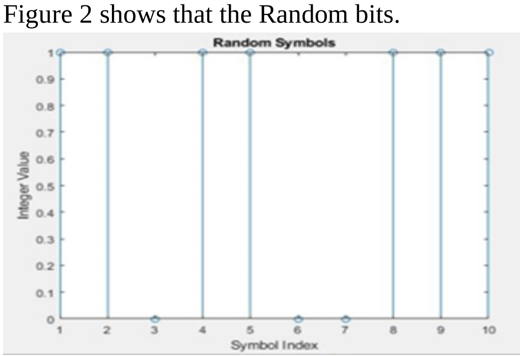

Figure 3 Random symbols

The Random symbols, displayed in Figure 3

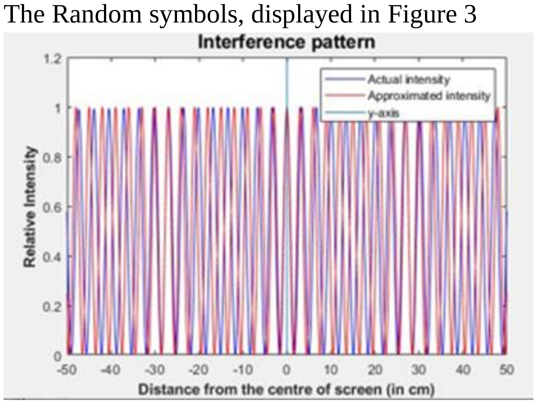

Figure 4 Interference pattern

In Figure 4, the interference pattern system is illustrated.

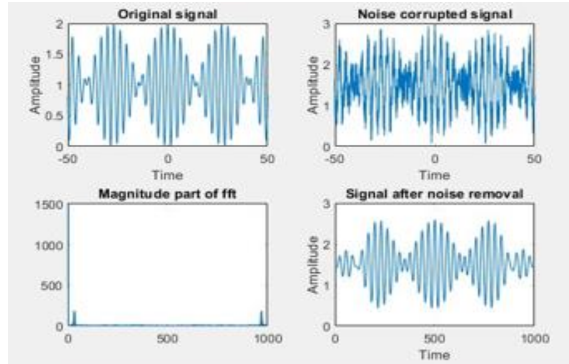

Figure 5. Noise removal

The noise removal procedure is shown in Figure 5. It removes the error when the subcarrier frequency and CW EMD frequency are matched by using the AWGN channel.

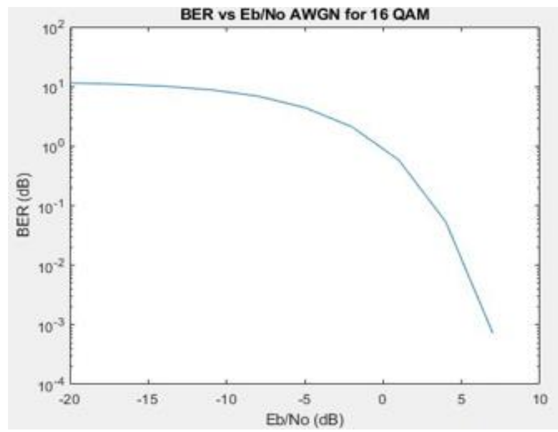

Figure 6. Bit Error Rate (BER)

The findings of the Bit Error Rate for 16 QAM in AWGN channel are displayed in Figure 6. The script for simulating the transmission and reception of QAM modulation. The symbol error rate is found in simulations, and it has been confirmed that the simulated results compare well with the theoretical description.

4. CONCLUSION

Orthogonal frequency division multiplex (OFDM) is used in several modern wireless services. Another advantage of the OFDM technique is that it can easily be implemented by using fast Fourier transform (FFT). The project is based on simulations and a theoretical analysis of a communication system that is subjected to competing CW signals. An innovative method for mitigating the effect of continuous electromagnetic wave disturbances in OFDM systems is proposed in this project. The method is based on an analysis of how a continuous wave electromagnetic disturbance affects spectral leakage in an OFDM system. The BER performance of the system is significantly improved. It removes the error when the subcarrier frequency and CW EMD frequency are matched by using the AWGN channel. The method is put up as a way to enhance OFDM communication, which is currently widely used in digital communication.

REFERENCE

[1] Wenjing Yan, Xiaojun Yuan, 2021, “Frequency Reflection Modulation for Reconfigurable Intelligent Surface Aided OFDM Systems”, pp. 01-28.
[2] Rajeev Kumar Yadav, Abhinav Shukla, 2022, “Analysis of OFDM System using Smoothing Filter”, Research Journal of Engineering Technology and Management, vol. 05, no. 02, pp. 117-122.
[3] Ling Liu, Meihua Bi, Shilin Xiao, Jiafei Fang, Tiancheng Huang, Weisheng Hu, 2018, “OLS based RBF Neural Network for Nonlinear and Linear Impairments Compensation in CO-OFDM System”, IEEE Photonics Journal, PP. 01-06.
[4] Ying Han, Yuanxiang Chen, Yongtao Huang, Jia Fu, Shangjing Lin, Jianguo Yu, 2020, “A Novel Multi-impairment Compensation Scheme Based on Deep Autoencoder for CO-OFDM System”, IEEE Access, pp. 01-03.
[5] Bin Liu, Hongbo Zhu, 2018, “Rotman lens-based two-tier hybrid beam forming for wideband mm Wave MIMO-OFDM system with beam squint”, EURASIP Journal on Wireless Communications and Networking, pp. 01-13.
[6] Do Viet Ha, Nguyen Tien Hoa, Nguyen Van Duc, 2021, “Impact of Inter-Channel Interference on Shallow Underwater Acoustic OFDM Systems”, pp. 01-08.
[7] Tao Jiang, Ming Tang, Rui Lin, Zhenhua Feng, Xi Chen, Lei Deng, Songnian Fu, Xiang Li, Wu Liu, Deming Liu, 2018, “Investigation of DC-Biased Optical OFDM With Precoding Matrix for Visible Light Communications: Theory, Simulations, and Experiments”, IEEE Photonics Journal, vol. 01, no. 05, pp. 01-17.
[8] Jie Lian, Maite Brandt-Pearce, “Clipping-Enhanced Optical OFDM for Visible Light Communication Systems”, journal of light wave technology, pp. 01-09.
[9] Bekawade Nirbhay Naresh Namrataa, Manoj Singh Tomar, 2021, “Introductory Review of Impairments in Optical OFDM Systems”, International Journal of Research Publication and Reviews, vol. 02, no. 12, pp. 1023-1028.
[10] Ling Liu, Meihua Bi, Shilin Xiao, Jiafei Fang, Tiancheng Huang, Weisheng Hu, 2018, “OLS-Based RBF Neural Network for Nonlinear and Linear Impairments Compensation in the CO-OFDM System”, IEEE Photonics Journal, vol. 10, no. 02, pp. 01-09.