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OFDM and its Applications in Multi-Antenna Systems: A Survey

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ABSTRACT

Orthogonal frequency-division multiplexing (OFDM) effectively mitigates intersymbol interference (ISI) caused by the delay spread of wireless channels. Therefore, it has been used in many wireless systems and adopted by various standards. The frequency-selective fading MIMO channel can be transformed into a set of flat-fading MIMO channels by using OFDM. MIMO-OFDM systems are one of the systems which have become the basis of many communication researches nowadays. A system is with several high speed inputs and outputs in sending information or suitable diversity between transmitter and receiver; however the estimation of the channel in this connection is complex. On the other hand, lack of source and target and outbreak of delay by the channel decreases the function of this system. In other words, this kind of system has a high sensitivity toward time and frequency delays. In this paper, we present a comprehensive survey on OFDM for wireless communications. We address basic OFDM and related modulations, as well as techniques to improve the performance of OFDM for wireless communications, including channel estimation and signal detection, time- and frequency-offset estimation and multiple-input–multiple-output (MIMO) techniques.

KEYWORDS: multiple-input multiple-output(MIMO) systems, orthogonal frequency division multiplexing, channel estimation, synchronization, carrier frequency offset(CFO)

INTRODUCTION

Nowadays, increasing efforts are ongoing to achieve wireless telecommunication systems with the ability to send and receive high rate of data. Some limiting factors in this area include: varying nature with fading time channels, variable interference with the time due to existence of different users, limitation of available frequency spectrum, the amount of consuming power, the size limitation, hardware and software complexities especially in mobile terminals, the number of protocols and standards and providing services with acceptable quality. The mentioned challenges have led the research towards finding effective methods of modulation, coding and diversity. Orthogonal frequency dividing multiplexing[1],[2] has been in the focus of research and development in recent decades. Daily growing high-rate demands of users have caused the OFDM development to multi-antenna systems.

Although the known orthogonal frequency division multiplexing concept since 1966 is close to nowadays OFDM, but since the use of analog hardware was not economical for implementing of single systems in the construction of some special military OFDM systems, it was actually being used until the late 1980s. In light of scientific developments and innovations since the early 1990s, this concept came into the focus of attention and became a usable technology in OFDM, electronics and digital processing with the ability to enter the competitive market of telecommunications. But, there were still some other steps to be taken for its practical applications.

The use of multiple antennas at transmitter and receiver seems to be a suitable solution for simultaneous increase in the number of users and data sending rate of each user. The initial works of Telatar and Foschini[3] in this field and predicting that such a method has the capability to increase the spectral efficiency significantly in case of availability of channels with proper dispersion initiated extensive research that has been done on MIMO systems. Recent studies clearly show that using multiple transmitter and receiver antennas increases the channel capacity significantly without any increase in the system working bandwidth or the consuming power. The only price to be paid for utilizing these benefits is increased complexity in communication systems.

Since OFDM converts the frequency-selective fading channels to a number of sub-channels with flat fading, its using in MIMO systems is very useful. In fact, with using OFDM in multi- antenna systems, the possibility for simultaneous exploiting of the advantages of both methods will be provided[4],[5].

Multipath fading channel

Identifying the wireless channel is of the basic requirements of designing wireless telecommunication systems. Several physical factors lead to occurrence of fading phenomenon. In a wireless communication, there is not usually

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a direct path between the transmitter (central station) and receiver (mobile terminal) and as a result, the received signal is a total of several versions of transmitted signal that reaches to the receiver through different routes. Amplitude, phase and arrival angle of these signals are random processes that lead to a change in the received signal power and result in fading occurrence. In addition to fading, the multipath distribution causes increased arrival time of transmitted signal to the receiver that a quantity called the delay spreading represents this time difference. Based on this, two parameters of inherent bandwidth and inherent time are defined for the multipath fading channel[6].

If the transmitted signal rate is selected so that the received different versions can not be distinguished, or in other words, the transmitted signal bandwidth is less than the inherent bandwidth of the channel, the channel is idiomatically called non-frequency selective (flat) fading channel and otherwise is called frequency selective fading channel. If the transmitted signal bandwidth is selected so that its frequency spreading (Doppler's effect) in the receiver can be negligible, or in other words, the time period of the transmitted signal is smaller than the inherent time of the channel, the channel is idiomatically called as slow fading channel and otherwise is called fast fading channel.

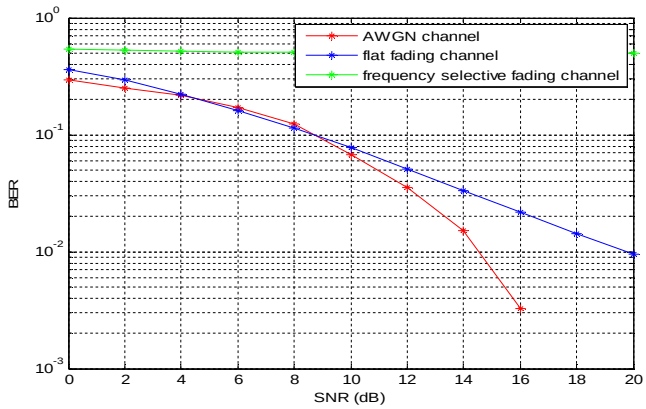

Fig. 1: Effect of types of fadings.

Data transmission technique with multiple orthogonal sub-carriers

The history of OFDM could be traced back to the mid 60's, when Chang presented his idea on the parallel transmissions of bandlimited signals over multi-channels [7]. He developed a principle for transmitting messages simultaneously through orthogonal channel that is free of both inter-channel interference (ICI) and inter-symbol interference (ISI). Five years later, a breakthrough was made by Weinstein and Ebert who used the inverse discrete Fourier transform (IDFT) to perform base band modulation and used discrete Fourier transform (DFT) for the demodulation [8]. This model eliminates the need of subcarrier oscillator banks, and the symbols can be transmitted directly after the IDFT transform rather than being transmitted on different subcarriers. To this end, the physical meaning of OFDM, namely, signals are transmitted through different frequency sub-bands, disappears. Nonetheless, the processing efficiency is greatly enhanced thanks to the development of fast Fourier Transform (FFT) algorithm. To combat ICI and ISI, Weinstein and Ebert used both guard space and raised cosine windowing in the time domain. Unfortunately, such an system could not obtain perfect orthogonality among subcarriers over a multi-path channel.

Another important contribution was made by Peled and Ruiz in 1980 [9], who suggested that a cyclic prefix (CP) that duplicated last portion of an OFDM block be inserted in the front the same OFDM block. This tricky way solves the orthogonality problem in the dispersive channel. In fact, as long as the cyclic extension is longer than the impulse response of the channel, the linear convolution between the channel and the data sequence becomes the cyclic convolution, which implies the perfect orthogonality among sub-channels. Although this CP introduces an energy loss proportional to the length of the CP, the orthogonality among sub-channels normally motivates this loss. Currently, CP based OFDM is enjoying its success in many applications. It is used in European digital audio/video broadcasting (DAB, DVB) [10], [11], high performance local radio area network (HIPERLAN) [12], IEEE 802.11a wireless LAN standards [13], any may others. In fact, OFDM is also a fundamental technique that is adopted in the future fourth generation (4G) wireless communications [14], [15].

The basic idea of OFDM is to divide the frequency band into several over-lapping yet orthogonal sub-bands such that symbols transmitted on each sub-band experiences only flat fading, which brings much lower computational complexity when performing the maximum likelihood (ML) data detection. A modern DFT based OFDM achieves orthogonality among sub-channels directly from the IDFT and the CP insertion. An example of such a block structure is shown in Fig. 2 [16]-[18]. Let K denote the number of the subcarriers in one OFDM block:

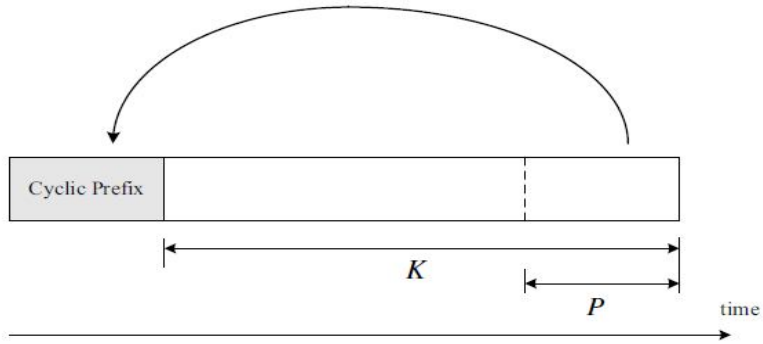

Fig. 2: The OFDM block structure with cyclic prefix.

In case of transmission high rate data in the wireless communication, the fading channel is modeled as an FIR filter that is idiomatically called frequency selective fading channel. Despite the existence of the given channel, there is the destructive phenomenon of inter-symbol interference (ISI) in the receiver. The conventional way to eliminate inter-symbol interference (ISI) included using comparative synchronizers in the receiver, which is associated with high complexity and cost. The new technique is to use OFDM for transmitting data and converting the frequency selective fading channel to flat channel (elimination of ISI). The OFDM technique includes transmission data in multiple orthogonal sub-carriers. As shown below, using this technique, the frequency selective fading channel is converted to multiple flat sub-channels.

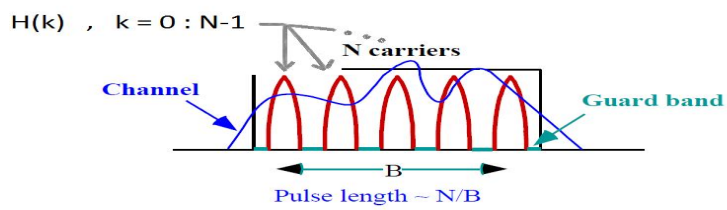

Fig. 3: The characteristic of non-uniform frequency of the wireless channel in the whole band and uniformity in each sub-band.

H (k) (k = 0: N-1) the multiplying values in each sub-carrier data are as the sub-channel coefficient in the frequency domain. The relationship between H (k) and the coefficients of frequency selective fading channel in time domain is discussed using an example. The IDFT is taken in the frequency domain of four data symbols (QPSK ...) on four mounted sub-carriers. A dual-path frequency selective fading channel is assumed; thus, two samples as avoiding prefixes are used to eliminate ISI and the OFDM symbol is formed.

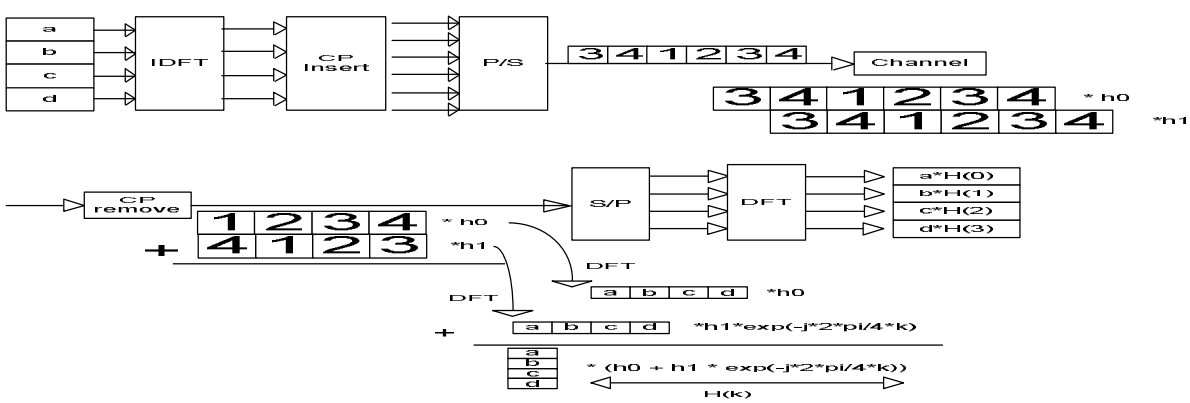

Fig. 4

Then, considering the Figure 4 it is proven that the frequency selective has converted to the flat channel and it becomes clear what a relationship exists between the H (k) coefficients in the frequency domain and the frequency selective channel coefficients.

Introduction of MIMO-OFDM systems

In a traditional wireless communication system, provided that the bandwidth is constant, there is no possibility of increasing the sending rate of information. In this kind of situation, only diversity methods can be used to improve the quality of revealing. In designing communication systems, bandwidth, information sending rate and software-hardware complexities are the important parameters. To expand the new generation of communication systems, methods such as MIMO, OFDM and integrating them together as MIMO-OFDM, are suggested. OFDM is used in numerous wireless transmission standards nowadays (DAB, DVB-T, WiMAX IEEE 802.16, ADSL, WLAN IEEE 802.11a/g, Home Plug AV or DS2 200 aka "Home Bone"). The OFDM modulation transforms a broadband, frequency-selective channel into a multiplicity of parallel narrow-band single channels. A guard interval (called Cyclic Prefix CP) is inserted between the individual symbols. This guard interval must be temporally long enough to compensate for jitter in the transmission channel. Transmitted OFDM symbols experience different delays through the transmission channel. The variation of these delays at the receiving location is called jitter. The appearance of inter-symbol interference (ISI) can thus be prevented. It has been shown in that OFDM can be favourably combined with multiple antennas on the sending side as well as the receiving side to increase diversity gain and/or transmission capacity in time-varying and frequency-selective channels.

The high intrinsic resistance of OFDM against the ISI event and its suitable function against fading destructive event, besides the high rate of information sending of MIMO, creates a very efficient complex in accession toward the fourth generation of wireless communication's demands. Like OFDM systems, the MIMO-OFDM systems have a great deal of sensitivity toward synchronization errors. Again, according to the increase in number of unknowns, estimating the channel in these systems are more complex than estimating channel in one antenna systems [19]. Diagram block of one kind of MIMO-OFDM systems, is shown in the figure5.

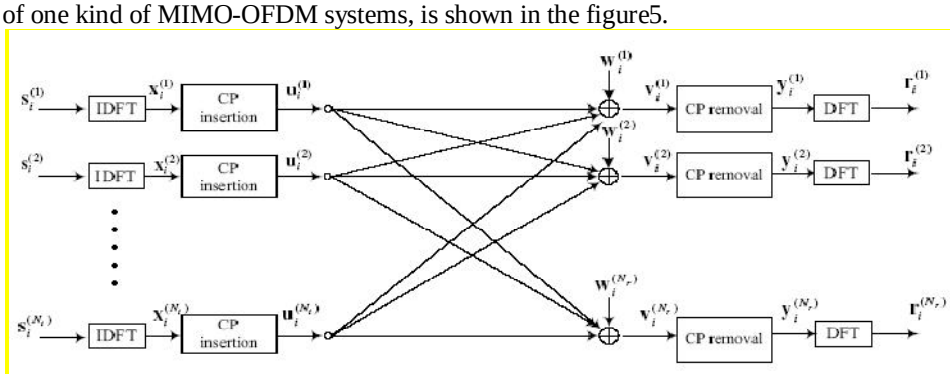

Fig. 5: Displaying a MIMO-OFDM system.

According to the figure, the information in each antenna is sent after IDFT actions and addition of (CP) cyclic prefix. Each receiver antenna receives sum of noises and signals sent by the transmitter's antenna. In each receiver antenna the revealing is done after removing CP and DFT actions.

Synchronization

With random changing in the oscillators phase, their frequency will shift that is considered as phase noise, which causes a frequency shift on the received spectrum of the receiver. Therefore, the first causing factor of non-synchrony is called carrier frequency offset (CFO)[20].

The received signal at one of the receiver antenna, resulted from one of the transmitter antenna, is from OFDM convolution symbol characterized by channel on the "τ" variable. The τ_n (t) and α_n (t) are random processes of the n (th) path that are assumed constant in the length of each symbol with considering the assumption of high transmission rate of symbols, and consequently the slowness of fading channel. The signal sums with its several delays that each of them has involved phase and amplitude distortions. Supposing that the transmitted symbol has N samples, we collect samples from the continuous signal at the provided time with 1/ T' rate and will obtain N samples corresponding to this symbol. Another factor causing non-synchrony is the inequality in transmission and receiving rates of the samples, which is introduced with the SFO (sampling frequency offset) parameter. Each of these symbols has been multiplied by a complex value that the phase of these complex values has caused their spectral shifting. Similarly, if we calculate the L effective paths of channel, L symbols with L different delays will be summed together; also in the general case, the Nt transmitting antennas simultaneously sends Nt different symbols that each of them will be convoluted by its own channel characteristic, and a sum of them reaches to one of the receiver antenna.

Here, with the events occurring on the signal, we witness randomly spectral shifting and amplitude distortion of all symbols that such a spectral shifting will be considered as another part of the CFO for each symbol. The

transmitter sends the symbols serially and the receiver obtains samples according to the expressed details; it should be clear that these samples are corresponding with which transmitted samples. In fact, the beginning of each symbol should be detected that such a factor is expressed as TA (Time Ambiguity). In total, two important factors of non-synchrony were discussed, that one is due to inequality of oscillators' frequencies in addition to the symbols phase delay and the Doppler's effect and the other is the result of inequality in sampling rates (SFO).

According to the surveys which have done until now, the first article with title synchronization in MIMO-OFDM systems has been published by Mody and Stuber in 2001.[21],[22].In those articles, Mody and Stuber generalized synchronization algorithm, proposed by Schmidl , Cox[23],for OFDM systems with one sender antenna and one receiver antenna to MIMO-OFDM. Zelst and Schenk in source[24] with considering all the necessary changes in synchronization algorithm, channel estimation,…,have generalized the OFDM based standard of IEEE-802.11a to MIMO .

The most important intrinsic restriction of the OFDM technique is its high sensitivity toward synchronizing errors. The first creator factor is called the asynchronousity of carrier frequency offset (CFO). This causes the loss of orthogonality between subcarriers and outbreak of interference between carriers. Another factor of asynchronousity is inequality of sending and receiving rate of samples precisely, which is introduced as sampling frequency delay. The proposed synchronizing algorithms for OFDM based systems are categorized to the following two main groups [25]:

Before FFT algorithms

The above-mentioned algorithms are divided to two groups of input based algorithms and non input based algorithms as follows:

Non input based algorithms: this group of algorithms estimates the synchronization parameters using the special structure of OFDM symbols. This group is also called cyclic prefix based methods [26] and [27].

Input based algorithms: this group of algorithms uses the educational symbols sent in information frames to estimate synchronization parameters [28], [29], [30] and [23].

After FFT algorithms

The algorithms of this group are also categorized in two groups of pilot based algorithms and direct decision algorithms. In comparing the two algorithms, before FFT algorithms are faster than after FFT algorithms, but after FFT algorithms has a higher throughput spectral.

One of the principal disadvantages of OFDM is sensitivity to frequency offset in the channel. For example, the coded OFDM system developed by CCETT (Centre Commun. d'Etudes de Telediffusion et Telecommuications) for digital sound broadcasting to mobile receivers incorporates an AFC (automatic frequency control) loop in the receiver to reduce frequency offset caused by tuning oscillator inaccuracies and Doppler shift **.**

Maximum likelihood estimation(MLE) algorithm for carrier frequency offset estimation is formed as following:

The transmitter sends X(K) data for K=0,…,N-1:

$$s(n) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X(k) e^{j\frac{2\pi}{N}kn} \; ; n = 0, \dots, N-1 \qquad (1)$$

Adding the cyclic prefix(cp) and considering carrier frequency offset estimation, the r(n) vector is formed as following:

$$r^{cp}(n) = e^{j2\pi\Delta fn} \times s^{cp}(n) * h(n) + Z(n); \; n = 0, \dots, N_s - 1 \qquad (2)$$

Finally, we remove cp:

$$r(n) = e^{j2\pi\Delta fn} s^{cp}(n) * h(n) + Z(n) \; ; n = Ncp, \dots, N_s - 1 \qquad (3)$$

To estimate the carrier frequency offset of r(n) vector, r1 and r2 vectors are formed as follow:

$$r_1(n) = e^{j2\pi\Delta fNcp} e^{j2\pi\Delta fn}\big(s(n) * h(n)\big) \; ; \; n = 0, \dots, \frac{N}{2} - 1 \qquad (4)$$

And

$$r_2(ń) = e^{j2\pi\Delta fNcp} e^{j2\pi\Delta fń}\big(s(ń) * h(ń)\big) \; ; \; ń = \frac{N}{2}, \dots, N-1 \qquad (5)$$

Assuming d(n)=s(n)*h(n) and performing some calculations we have:

$$r_2^* . r_1 = e^{j2\pi\Delta f\left(-\frac{N}{2}\right)} |d(n)|^2 \qquad (6)$$

$$\Gamma = \frac{r_2^* . r_1}{|r_2^* . r_1|} = e^{j2\pi\Delta f\left(-\frac{N}{2}\right)} = e^{-j\pi\Delta fN} = \cos \pi N\Delta f - j \, sin\pi N\Delta f \qquad (7)$$

Finally the carrier frequency offset estimation is performed as follow:

$$-\tan(\pi N\Delta fT) = \frac{Im\,(\Gamma)}{Re(\Gamma)} \Longrightarrow \widehat{\Delta f} = \frac{1}{\pi} \, tan^{-1}\left(-\frac{Im(\Gamma)}{Re(\Gamma)}\right) \qquad (8)$$

Channel estimation

As was explained at the beginning of the synchronization section, each of a symbol and its delays or offsets are multiplied in random complex numbers and summed together. The phase of these numbers is the causing factor of non-synchrony and their sizes create amplitude distortion on the symbol that the phase distortion and its effects were discussed. In this section, the amplitude distortion issue will be introduced.

Here, we define the subject of obtaining the channel estimation and determining the channel coefficients using an estimator; in other words, we want to determine the degree of amplitude distortion imposed to the symbol using an algorithm, and then, we will use it for detection of the main data.

The major considered estimating channel methods are as follows:

Using educational sequence methods

By putting samples in the sent symbol which are known by the receiver, we can reach the channel's domain which is multiplied by sum symbol and shift results. Now by using the channels reached coefficients, we can reveal the rest of symbol samples which are the desired inputs and the receiver is unaware of them [31].

Blind methods

In this method which has no need of educational samples, using the covariance matrix, the receiver estimates the coefficients of channel and reveals the sent inputs by using them [32].

Half blind methods

In this method the between up between properties of the two previous methods are used [33].

The combination of orthogonal frequency division multiplexing (OFDM) with space-time coding has received much attention recently to combat multipath delay spread and increase system capacity . Channel parameters are needed in order to coherently decode the transmitted signal. Least square (LS) channel estimation for MIMO-OFDM systems has been addressed in . But if the multipaths are not sample-spaced, the well known leakage problem for DFT based channel estimation . induces an irreducible error floor for estimation error. To reduce this error floor, more taps have to be used, which not only increases computational complexity but also makes estimation problem more ill-conditioned and thus enhances noise. As an alternative, channel estimation algorithm based on parametric model has been proposed in and extended to MIMO-OFDM in .

Channel information is required at receiver for signal detection. However, There are different methods of channel estimation such as pilot aided (Li, 2002) and blind (Gao and Nallanathan, 2007) approaches, the first method is chosen as a channel estimation method in this study due to its less complexity. According to sampling theory (Oppenheim and Schafer, 1999), Pilots are inserted equal-spaced among subcarriers in frequency domain at transmitter, which are known at receiver and will be extracted to estimate channel at pilot subcarriers and interpolation is implemented for channel estimation in another subcarriers. In the analysis, channel is estimated with LS (Coleri *et al*., 2002) method at pilots, then linear interpolation is used to complete the estimation (Coleri *et al*., 2002; Hsieh and Wei, 1998). **Receiver designing:** At the receiver, nr × nt sets of extracted received pilot tones are used for channel estimation, which LS method is chosen due to its simplicity. The standard formula for this approach at mth symbol is computed as:

$$H_{LS}(m) = ((x^p(m))^H x^p(m))^{-1}(x^p(m))^H Y^p(m) \quad (9)$$

where, XP(m) and YP(m) respectively show the transmitted and received pilots.

The LS estimate of the channel can be obtained as:

$$H_{LS} = \arg\{\min\{(Y - XH_{LS})^H (Y - XH_{LS})\}\} \quad (10)$$

Set

$$\frac{\partial\{(Y-XH_{LS})^H(Y-XH_{LS})\}}{\partial H_{LS}} \quad (11)$$

Consequently

$$\widehat{H_{LS}} = \frac{Y}{X} = \mathrm{H} + \frac{N}{X} \quad (12)$$

ignore the impact of noise, then

$$\widehat{H_{LS}} = \{H(0)H(1) \dots H(K-1)\}^T \quad (13)$$

Although, LS estimation algorithm is very simple, its performance is sensitive to the noise. The veracity of the estimation is reduced at the low SNR.

In the previous sections, after introducing MIMO-OFDM systems, the subjects of synchronization and channel estimation were separately discussed. The most common method for synchronization and channel estimation is using training sequences. In case of using separate training sequences for channel estimation and synchronization parameters, the spectral efficiency decreases. So, using joint estimation methods that finds the channel coefficients and synchronization parameters with using a training sequence has been suggested.

Joint estimation of the channel coefficients and synchronization parameters

The method is based on the use of common training sequence for estimation of the channel coefficients and synchronization parameters. Although this method will increase the spectral efficiency, but high complexity is its major disadvantage. Confrontation between spectral efficiency and computational complexity in joint estimation techniques has made the experts to provide optimized algorithms with high spectral efficiency and low computational complexity. One of the issues raised in joint estimation is to design suitable training sequences[34].

Joint estimators

The criterion of a maximum aposteriori probability (MAP) is the most common measure in designing the optimized receivers. The mentioned criterion with assuming the uniform distribution of observations is idiomatically called also as the maximum similarity measure. The criterion of a maximum aposteriori probability and the least error squares are the most famous design criteria in joint estimators.

Suppose that the vector w contains the synchronization parameters of (SFO, CFO, and TA) and channel impulse response (CIR). Joint estimation of channel impulse response and synchronization parameters are shown as $\hat{W}$ and defined as following:

$$\widehat{W} = g(r) \tag{14}$$

In the above equation, the g(r) represents a function of the signal observed in the receiver that the estimation is performed based on that.

The received signal at the receiver can be modeled as the following:

$$r = AxB + n \tag{15}$$

In the pervious equation, the x represents the transmitted signal, A and B show the channel resulting distortion and other destructive factors and the "n" is collective Gaussian noise vector. Considering the mentioned criteria, the estimation is as:

$$\widehat{w}_{MAP} = max_w p(w_| r) = max_w \sum_x p(r_| x, w) p(x) p(w) \tag{16}$$

$$\widehat{w}_{MMSE} = E(w_| r) \tag{17}$$

The received signal at the receiver (r) is affected by random factors, including n, x and w. The p (r | x, w) with respect to the Gaussian nature of noise has a Gaussian distribution. The p (w) and p (x) (late probabilities) represents the existing information in the receiver for designing the joint estimation algorithm. According to the mentioned probabilities, the receiver is actually able to design different estimators. Assuming the uniform distribution of the w, the criterion of a maximum aposteriori probability converts to the maximum similarity criterion:

$$\widehat{w}_{ML} = max_w \sum_x p(r_| x, w) p(x) \tag{18}$$

$$\widehat{w}_{MMSE} = E(w_| r) \tag{19}$$

The major joint estimation methods are[35]:

Data-aided methods (DA)

In this case, we have p (x) = δ (x – x pil); such a probability function indicates the complete knowledge of the receiver of the part of the transmitted (pilot) signal. The transmitter sends certain symbols (x pil) among the data symbols and the estimation is performed based on their corresponding received symbols:

$$\widehat{w}_{ML} = max_w \sum_{xpil} p(r_{pil|} x, w) \tag{20}$$

$$\widehat{w}_{MMSE} = E(w_| r_{pil}) \tag{21}$$

In this case, the estimator does not use the existing information in the received signal and only uses the pilot symbols; also, the transmission is done with reduced spectral efficiency and power and the estimator has a closed form as well as good speed and computational complexity.

Non-data-aided methods (NDA)

In this case, data distribution is assumed uniform and the estimation is performed based on the received data symbols. Although this method improves spectral efficiency and power, but due to consideration of all possible scenarios for the estimation, it has high computational complexity and low speed.

$$\widehat{w}_{ML} = max_w \sum_x p(r_| x, w) \tag{22}$$

$$\widehat{w}_{MMSE} = E(w_| r) \tag{23}$$

Code-aided methods (CA)

In this case, the data distribution is an average of the previous modes. The use of coding leads to smaller range of signal distribution compared to the NDA case, and thus limited search space and reduced computational complexity (depending on coding type) and improved spectral efficiency and power.

THE RESEARCH RESULTS

In this chapter, a MIMO-OFDM system with 2 transmitter antennas and 2 receiver ones is used for the simulation. The assumed system has a QPSK modulation. The total number of subcarriers, N, is 64and L is the tap of channel.

The simulations in channel estimation in SISO-OFDM and MIMO-OFDM systems are as follows:

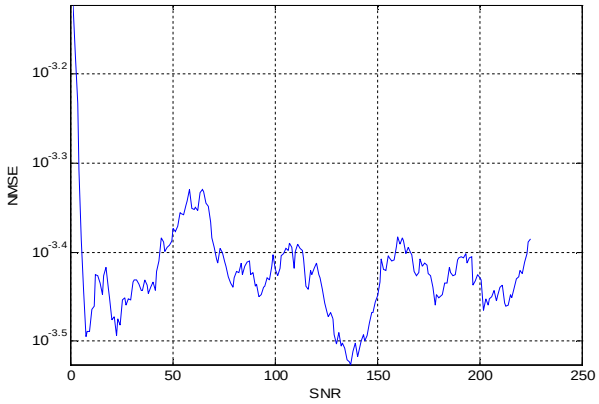

Fig. 6: Channel estimation and synchronization for SISO OFDM System(CFO estimation).

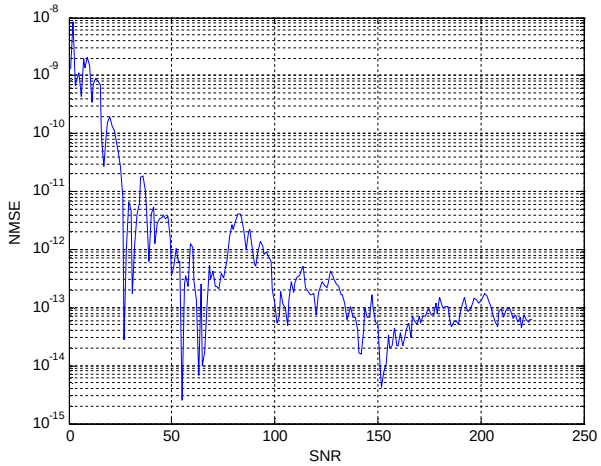

Fig. 7: Channel estimation and synchronization for SISO OFDM System(SFO estimation).

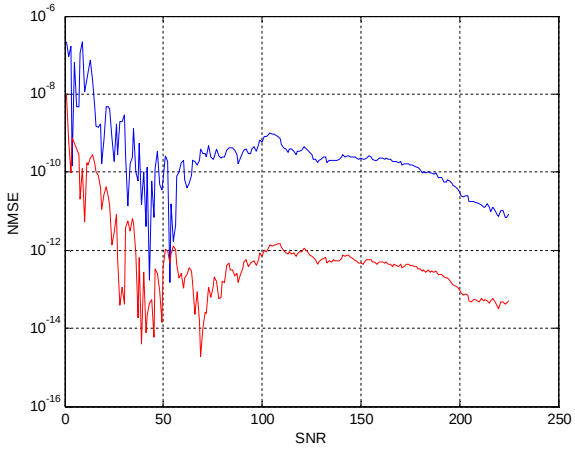

Fig. 8: Channel estimation and synchronization for SISO OFDM System(the red and blue one is SFO and CFO estimation respectively).

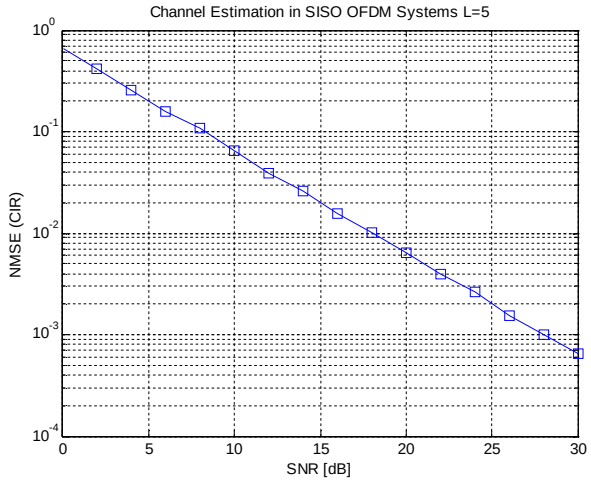

Fig. 9: Channel Estimation in SISO OFDM Systems L=5.

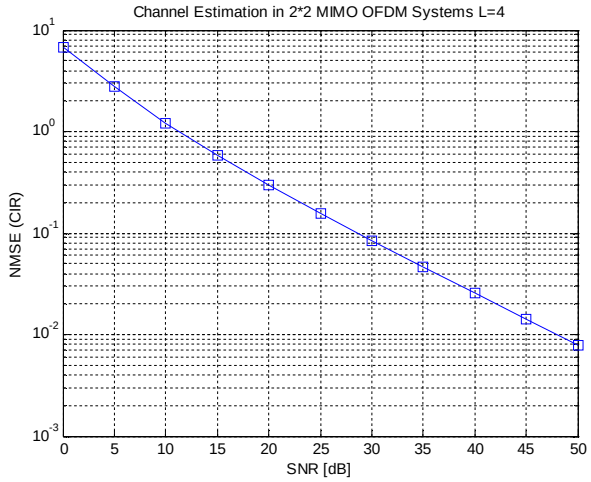

Fig. 10: Channel Estimation in 2*2 MIMO OFDM Systems L=4.

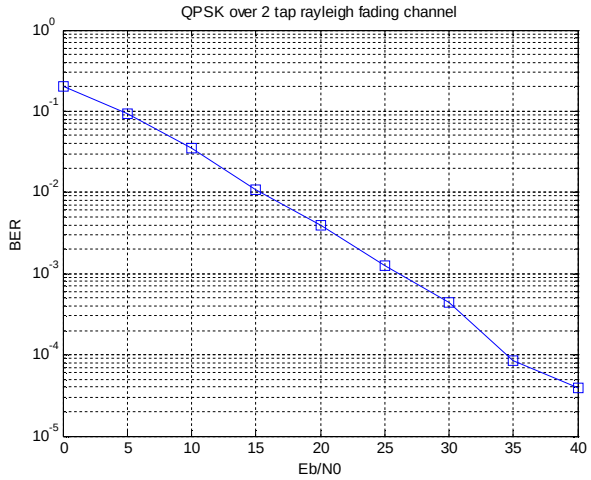

Fig. 11: QPSK over 2 tap rayleigh fading channel(OFDM).

Conclusion

In this paper, I have briefly described OFDM for wireless communications. I start with the basic principle of OFDM and techniques to deal with impairments in wireless systems, The OFDM-related technique has been

invented over 40 years ago. OFDM for wireless communications has intensively been an active research area in the past 10 years. Estimation of channel coefficients and synchronization parameters are two main challenges in realization of MIMO-OFDM systems which are practical. In almost all published references till no, estimation of cannel coefficients is done with the assumption of total frequency synchronously of transmitter and receiver. The created frequency synchronously between transmitter and receiver, in practice, is always exposed to risk due to presence of factors such as Doppler phenomenon and phase noise. Therefore for exact estimation of fading channel status, it's necessary to keep the created frequency synchronously between transmitter and receiver, uninterrupted.

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