Configuration of OFDM Transmission Techniques- Based On Algorithms Developed Using Concept of UML and Matlab

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***Abstract**:This paper proposes the algorithm using concept of UML (Unified Modeling Language) through Matlab, for OFDM (Orthogonal Frequency Division Multiplexing) based system on pilot arrangement. The channel estimation based on pilot symbol has been proposed for estimating channel at pilot frequencies and interpolating the channel. Real time UML can be helpful for developing efficient objects for embedded systems. This paper proposes, using UML constructor, the configuration of an OFDM transmitter and receiver. The broadband WLAN system of the future, using a pilot symbol-assisted OFDM transmission system have been proposed and simulated. These (Pilot symbols) have been inserted at a known period and at the receiver the channel characteristics for every symbol have been estimated for recovering the transmitted data.*

***Keywords:** UML, Orthogonal Frequency Division Multiplexing (OFDM), ISI, Channel Estimation.*

1 INTRODUCTION

A mobile radio channel is characterized by a multipath fading environment. These reflected delayed waves interfere with the direct wave and cause intersymbol interference (ISI), which causes significant degradation of the network performance. A wireless network must be designed in such a way as to minimize these adverse effects. For broadband multimedia mobile communication systems, it is necessary to use high bit rate transmission of at least several megabits per second. However, if digital data are transmitted at a rate of several megabits per second, the delay time of the delayed waves exceeds 1 symbol time. Because the delayed waves interfere with other symbols, the effects of this interference must be eliminated in the received signal. There are several ways to achieve this goal, like; using adaptive equalization techniques at the receiver is one way to equalize the received signal. However, in practice, achieving this equalization at several megabits per second with compact and low cost hardware is quite difficult.

To overcome such a multipath fading environment and achieve a wireless broadband multimedia communication system (WBMCS), it is possible to use an OFDM transmission scheme based on a parallel data transmission scheme that reduces the effects of multipath fading and renders complex equalizers unnecessary.

OFDM has been widely used in broadcast systems. It is being used for Digital Audio Broadcasting (DAB) [1,5,10] and for Digital Video Broadcasting (DVB) in Europe and Australia. It was selected for these systems primarily because of its high spectral efficiency and multipath tolerance. OFDM can be applied in a multi-user application producing a highly flexible, efficient communications system[10,11]. Little work has been previously done on multi-user OFDM [2, 3]. It was first presented by Wahlqvist [6] who suggested one possible implementation.

In this paper a pilot symbol based OFDM modulation technique for OFDM-based WLAN system have been presented using concept of UML, so that efficient embedded systems can be designed in future. Pilot symbols have been inserted at a known period and at the receiver the channel characteristics for every symbol have been estimated for recovering the transmitted data

2. Concept of the Parallel Transmission Scheme

The concept of using parallel data transmission by means of frequency division multiplexing (FDM) was published in mid 60s [3, 4]. A U.S. patent was filled and issued in January, 1970. The idea was to use parallel data streams and FDM with overlapping sub channels to avoid the use of high speed equalization and to combat impulsive noise, and multipath distortion as well as to fully use the available bandwidth. OFDM is an optimal version of multicarrier transmission schemes. The word orthogonal indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. The carriers are linearly independent (i.e., orthogonal) if the carrier spacing is a multiple of 1/T. In addition, by using a guard interval the sensitivity of the system to delay spread can be reduced [7, 9].

To distinguish between the sub channels, frequency division multiplexing (FDM) and code division multiplex (CDM) are often used. In some cases, the first method is called multicarreier transmission, and the second method is called multimode transmission.

2.1 Transmitter Configuration:

The modulated data is fed into an Inverse Fast Fourier transform (IFFT) circuit, and an OFDM signal is generated. This OFDM signal is fed into a guard time insertion circuit to reduce ISI (Inter symbol Interference).The OFDM transmitter is implemented by using UML constructor/concept(using Matlab) as shown in table-1 below.

OFDMTX(OFDM Transmitter)
1)settings
2)Read-rand(n : NumSymb, w: wordsize,c: NumCarr,s :seed):
3)Processes-reshape(s: Seldata, p : Para, n : Nch): Paradata
qpskmod (d : Paradata, p : Para, n: nd, m: ml): ich, qch
cedatagen(i : ich, q : qch, f : fftlen, n :nd): ich2,qch2
ifft(i : ich2, q: qch2): ich3,qch3
giins(i: ich3, q : qch3, f : fftlen, g : gilen, n : nd): ich4, qch4
attn(i : ich4, q : qch4): attn

Table-1-UML Constructor through MATLAB

The OFDM signal is transmitted to the receiver; however, the transmitted data, s’(t), is contaminated by multipath fading and AWGN. Concepts from Unified modeling language (UML) have been used for specifying and visualizing this large object oriented project [12, 13].

2.2 RECEIVER CONFIGURATION:

At the receiver, received signal r(t) is filtered by a band pass filter, which is assumed to have sufficiently wide pass band to introduce only negligible distortion in the signal. An orthogonal detector is then applied to the signal where the signal is down converted to the IF band. Then, an FFT circuit is applied to the signal to obtain Fourier coefficients of the signal in observation periods $[\, iT_{total}\ ,\ i\,T_{total} + T_s\,]$.

Equalization of received data have been performed after estimating the characteristics of the delayed wave, $h_i(k)$, in a multipath fading environment .The BER depends on the level of the receiver’s noise. Here, in this OFDM transmission, the orthogonality is preserved, and the BER performance depends on the modulation scheme in the sub channel. Therefore, if BPSK is used, the BER under AWGN and a one- path Rayleigh fading channel is equal to the theoretical ones.

3. CONFIGURATION BY USING COMPUTER SIMULATION

This section calculates the BER of an OFDM system by using a simple computer simulation program. The parameters, before computer simulation, is shown in table-2 below.

Parameters	Specification
FFT length	128
Number of Parallel channels	128
Modulation	QPSK
Length of Guard Interval	32
Number of carrier	128

Table-2- Parameters settings for computer simulation

The serial data vector, “serial data,” was converted into a parallel data vector, “paradata” was fed into the mapping circuit. In the circuit, the parallel data were converted into the modulated parallel data of two channels, Ich and Qch by a predefined mapping method.
[ich , qch] = qpskmod (paradata, para, nd, ml) ;

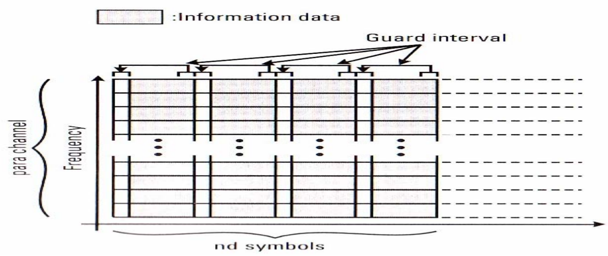

Figure 1- Frame format of the simulation model

The frame format of the simulation model is configured as shown in figure1. Then, these data were increased kmod times, to normalize the data.

After the mapping, these parallel data on the frequency axis were fed into IFFT circuit. In the circuit, the parallel data were converted into serial data on the time axis by using OFDM

Then, ich2 and qch2, guard intervals, were increased to eliminate ISI caused by multipath fading.

At this point, we defined fftlen2 as the length of a symbol including the guard interval. After, that the filtered signal was transmitted to the air. Then, the transmitted signal passed through the radio channel (equivalent low pass system) and was transmitted to the receiver.

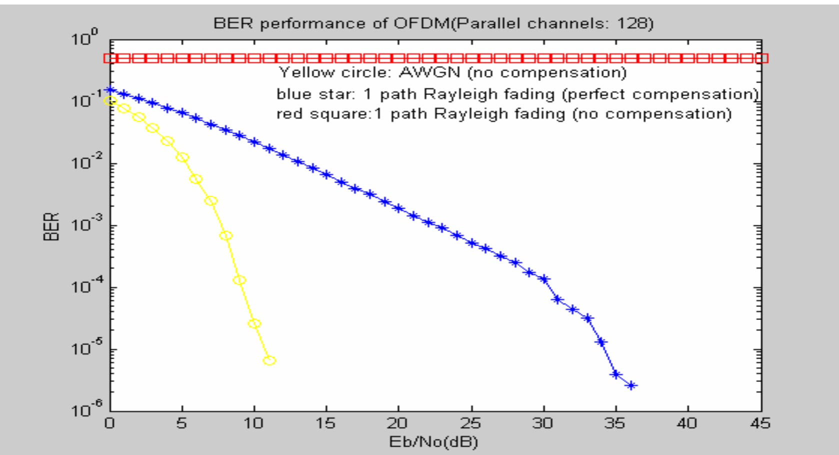

Figure 2: BER performance of OFDM (QPSK modulation) using 128 parallel channels under AWGN and Rayleigh fading environment

Next, we calculated the number of bit errors. At the same time, we calculated the number of packet errors. In this simulation, the transmitted data are referred to as “seridata” and the received data are referred to as “demodata1.”

The BER performance is shown in figure-2, where it is compared with theoretical value. In the simulation result, there was a 0.9691-dB shift from the theoretical value. The Shift was caused by cutting off of the guard interval power from the received signal.

For the BER performance (figure-2) under one-path Rayleigh fading, if we can compensate for amplitude and phase fluctuation caused by propagation characteristics perfectly, we can obtain a 0.969-dbshift from the theoretical value. However if we cannot compensate for fluctuation characteristics, we cannot recover the data. It is important to estimate the propagation characteristics in real time.

One of the estimation methods is *pilot-symbol insertion* in which known pilot symbols are inserted at a known period is now defined. At the receiver we can estimate the channel characteristics for every symbol and recover the transmitted data.

4. A Pilot Symbol-Aided OFDM Modulation Scheme

To compensate for the fluctuation of amplitude and phase due to fading a method called the pilot symbol-aided OFDM modulation scheme is defined. In this method, pilot symbols are inserted at the transmitter at fixed time intervals as shown in figure 3. And at the receiver, we estimate the channel characteristics by using the pilot symbols. Because the level of fluctuation is independent in each sub carrier channel, we can insert pilot carriers in all frequency domains at a known time period. Then, by using the estimated channel characteristics, we can recover the transmitted data. This section shows the configuration of the pilot symbol aided OFDM

Modulation scheme and evaluates the BER performance by computer simulation. A block diagram of the simulation is shown in figure 3.

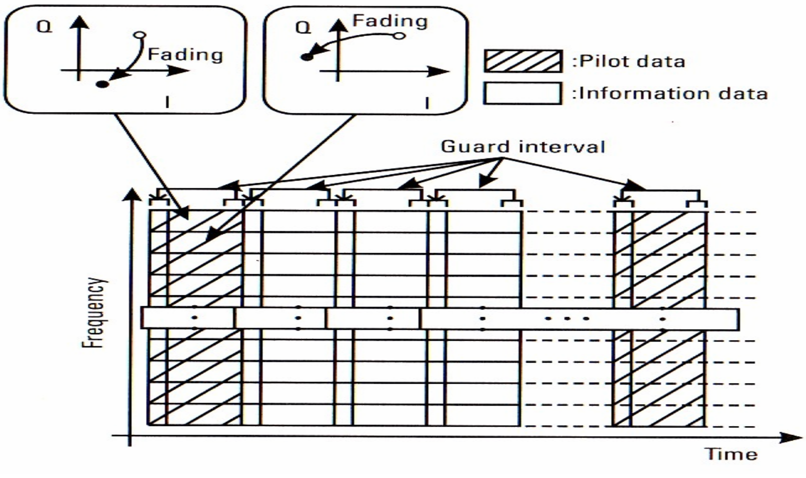

Figure 3: Frame format of the simulation model

Number of subcarriers: Fifty-two sub carriers are adopted and generated by a 64-point FFT circuit. Of the 52 sub carriers, 48 are used for the information data. The rest are used to compensate for the phase noise. We input data into all 52 carriers.

Guard Interval : 800 ns: To avoid the effects of multpath fading where delay time is greater than the symbol length, a cyclically extended signal was inserted before each OFDM signal. We used a guard

Frame Format *:* the frame is divided in to two parts : channel estimation (CE) symbol and transmitted data symbols-figure-4. This method uses one CE symbol and six transmitted symbols as one frame unit . In the CE symbol, the amplitude and phase deviation from the pilot data are measured using the pilot signal. Based on the measured propagation, the deviation of the amplitude and phase of the six OFDM data symbols caused by multipath fading is compensated for.

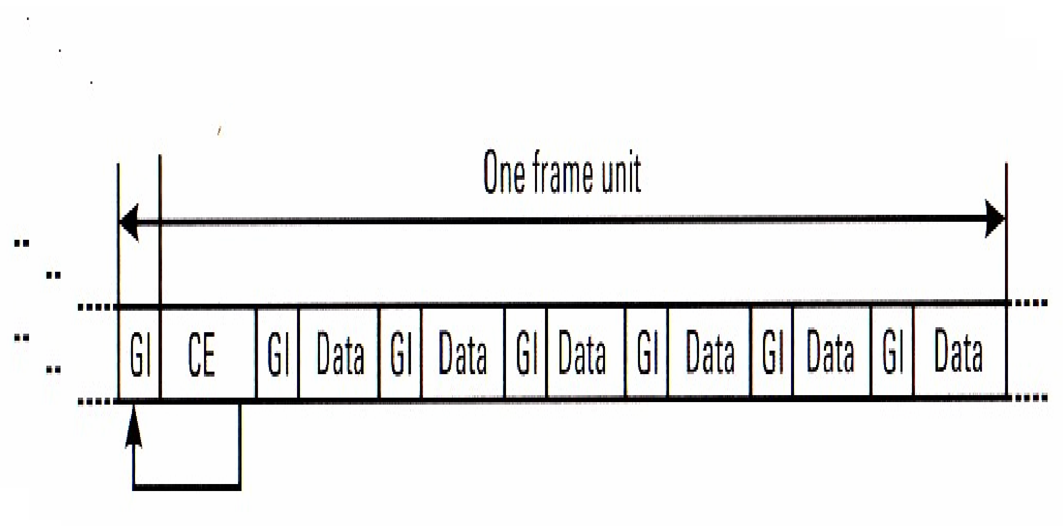

Figure-4-Frame format of the simulated OFDM transmission

Interval of 800 ns, because we must consider using the OFDM based wireless communication system for not only an indoor environment but also in an outdoor microcellular environment.

Sampling rate: The sampling rate (20 MHz) was the same as the input signal rate of the IFFT input signal. This is because we wanted to achieve a total throughput of more than 20 Mbps.

Modulation Scheme: In a WLAN environment, differential encoding and detection-based modulation schemes, such as D8PSK, are used. However according to several standardization committees, the use of a broadband data terminal is possible not only in an indoor environment but also in an outdoor microcellular environment. Therefore, coherent detection-based modulation schemes-such as BPSK, QPSK, 8PSK and 16-QAM-that are used to improve the quality of the transmitted data and preserve robustness against multipath fading not only in an indoor but also in an outdoor environment.

FEC: basically FEC is based on convolutional coding and soft decision Viterbi decoding with R=1/2 and K=7(R=coding rate, K =constraint length). For other coding rates, we use punctured convolutional coding and soft decision Viterbi decoding.

The BER performance is shown in figure-5, where it is compared with theoretical value. The PER performance is shown in fig. In the simulation result for the BER, there was a +0.9691-dB shift from the theoretical value. The shift of the value was caused by the guard interval power for the received signal. It is calculated as follows:

Shifted value=-10log 10(gilen/fftlen2)

Using pilot-symbol insertion, we can estimate the channel characteristics for every symbol. y using the estimated propagation characteristics and we can recover the transmitted data.

The pilot data are random data, and they are inserted only in “Ich”. The data are inserted in the time domain before information OFDM data. By using the formatted transmitted data, ich2 and qch2, we can perform FFT.Then, a cyclic guard signal is inserted and transmitted to the air. After that the transmitted signal is contaminated by multipath fading and AWGN. Then, at the receiver, the inserted guard interval is removed. Subsequently, the removed signal is fed into the FFT circuit.

By using CE symbols, we can then estimate the propagation characteristics. First, we take out the pilot symbols from the received and FFT-performed data ich7 and qch7. In this simulation, the pilot data were located in the first symbol time as shown in fig. At the same time, we prepared pilot data that were used in the transmitter. The relation between (ice1,qce1) and (ice0,qce0) is given by

$$\begin{pmatrix} ice1 \\ qce1 \end{pmatrix} = A \begin{pmatrix} ice0 \\ qce0 \end{pmatrix}$$

Where A is the transition matrix of the fading environment and shown as follows:

$$A = \begin{pmatrix} iv & -qv \\ qv & iv \end{pmatrix}$$

Where

$$iv = \frac{1}{\sqrt{ice1 + qce1}}(ice0 \times ice1 + qce0 \times qce1) \quad ; \quad qv = \frac{1}{\sqrt{ice1 + qce1}}(qce0 \times ice1 - ice0 \times qce1)$$

As fading is a function of a phase rotation and amplitude fluctuation and therefore to compensate for the fading rotation, all the received data have been multiplied by A^{-1}. A^{-1} is given by

$$A^{-1} = \frac{1}{\sqrt{iv^2 + qv^2}} \begin{pmatrix} iv & qv \\ -qv & iv \end{pmatrix}$$

By using iv and qv, two inverse rotation matrices were produced as follows
ieqvi=[iv iv iv iv iv iv iv] ; qeqv1=[qv qv qv qv qv qv qv];

By using the above phase compensation in computer simulation, the BER have been obtained. The BER performance is shown in figure 5, along with the theoretical value. From the BER performance under one-path rayleigh fading, it is found that compensation for the amplitude and phase fluctuations caused by fading will result in a 0.9691-dB shift from the theoretical value. However, without compensation, data can not be recovered.

On the other hand, if we use a *pilot signal-assisted OFDM transmission scheme*, we can obtain a 2-dB shift from the theoretical value. Figure-5 shows the simulated BER performance when there is perfect compensation for the amplitude and phase fluctuation caused by propagation characteristics in a one-path fading environment. For the case of perfect compensation, the value of BER was the same as that obtained in the pilot-assisted OFDM system. Here the BER has been shifted 2 dB compared to the theoretical value. This was because we input pilot data of 1/7 in one frame unit.

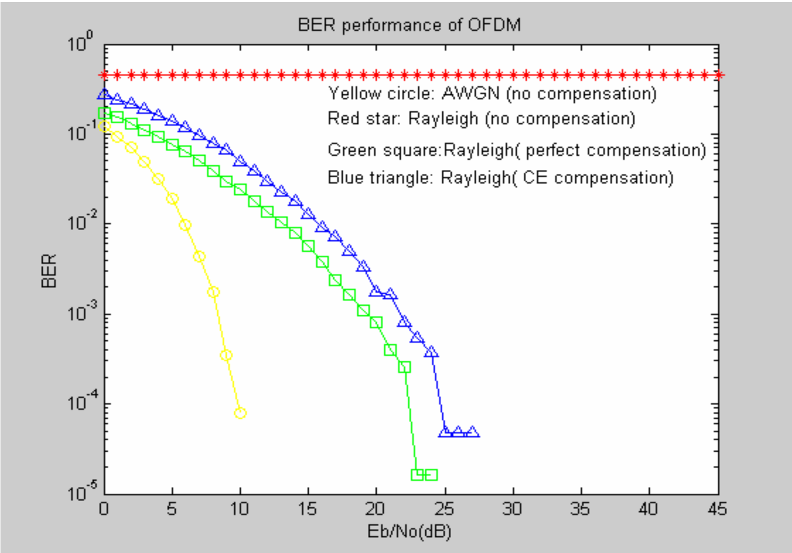

Figure-5- BER performance of OFDM (QPSK modulation) using perfect and CE compensation under AWGN and Rayleigh fading environment of OFDM (QPSK modulation)

5. Comparisons of OFDM Techniques-Results Obtained After Simulation

OFDM Technique	Eb/No	BER
QPSK Modulation with 128 parallel channel with no compensation[1,7,8]	0	4.926563e-001
	5	4.909349e-001
	15	4.927253e-001
	25	4.937591e-001
QPSK Modulation with 128 parallel channel with perfect compensation[1,2,7,8]	0	1.530951e-001
	5	6.467318e-002
	15	6.518229e-003
	25	6.783854e-004
QPSK Modulation with 256 parallel channel with no compensation[1,2,7,8]	0	4.667904e-001
	5	4.624707e-001
	15	4.670475e-001
	25	4.686849e-001
QPSK Modulation with 256 parallel channel with perfect compensation[1,2,7,11]	0	1.456836e-001
	5	5.884115e-002
	15	3.792318e-003
	25	6.184896e-005
Proposed OFDM technique using QPSK modulation under CE(Channel Estimation) compensation with 128 parallel channels	0	2.691026e-001
	5	1.384135e-001
	15	1.791667e-002
	25	**3.685897e-004**
LMS(Least Mean Square) technique using QPSK Modulation with 128 parallel channels[1,2,7,8]	0	4e-001
	5	2e-001
	15	6.5e-002
	25	0.9e-002
LMS technique using BPSK Modulation with 128 parallel channels[1,2,6]	0	3e-001
	5	0.7e-001
	15	2.4e-002
	25	7e-003

Table-4- Comparison of BER performance of different OFDM techniques with proposed in Rayleigh Fading Environment

The proposed OFDM technique using QPSK modulation under CE compensation with 128 parallel channels having Eb/No of 25 , shows that BER is 3.685897e-004,which is very less as compared to other existing models.

6. CONCLUSIONS

This paper proposes through UML constructor the configuration of an OFDM transmitter and receiver. We have justified to configure the OFDM transmitter and receiver by using computer simulation. We discussed the results of our extended simulation of OFDM, where we simulated the broadband WLAN system of the future by using a pilot symbol-assisted OFDM transmission system. We showed the effectiveness of the pilot symbol-assisted OFDM transmission system. If we develop a prototype system, we must simulate the synchronization method for OFDM signals to remove the guard interval at the optimum point. Real time UML can be helpful for developing efficient objects for embedded systems [12, 13].

Communications research and current development of OFDM around the world will certainly provide us with valuable findings in theory and implementation. Further studies should be conducted on the synchronization of OFDM signal, power demand, counter-measures against frequency offset, fading and multiple access.

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