The Performance Simulation of OFDM System Using Hierarchical 16QAM on Multipath Fading Channel

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Abstract

In this paper, we obtained the performance of the OFDM system using hierarchical 16QAM (OFDM/HL-16QAM system) by simulation. The system can provide mobile users with high quality and low quality of data services simultaneously. The wireless channel is assumed to include AWGN and multipath fading. Through simulation we obtained the BER performance of the system and the minimum required mean SNR to satisfy both high quality and low quality of data services. Simulation results show that the proposed system is more effective than conventional OFDM/16QAM system on multipath fading channel in point of required Eb/No to achieve two differenciated target BER performances.

1. Introduction

Recently, there has been an increasing demand for multimedia transmission, such as the transmission of text data, voice and images, in mobile communication systems [1],[2]. In order to provide such multimedia services with high speed transmission and higher bandwidth efficiency OFDM is expected to be the most appropriate scheme.

In OFDM, transmission is carried out in parallel on the different frequencies [3]-[5]. That is, the entire channel is divided into many narrow band subchannels, which are transmitted in parallel, thereby, increasing the symbol duration and reducing the ISI. The carrier spacing is selected such that modulated carriers are orthogonal over a symbol interval. In addition, a guard interval (cyclic prefix) is inserted in order to combat the frequency selectivity of the channel. Therefore, OFDM is an effective technique for combating multipath fading and for high-bit-rate transmission over mobile wireless channels [6],[7].

Hierarchical transmission system was originally proposed to transmit image data for mobile communication [1]. The system composed of hierarchical source coder and corresponding channel coder divides the information into several layers according to their significance, and transmits each layer with different reliability according to their layers. However, it can also be applied to wireless multimedia systems which can support several types of high speed data services having different reliability simultaneously. So we propose an OFDM system using hierarchical 16QAM transmitting both high quality data and low quality data simultaneously.

In this paper, we obtain the BER performance of OFDM system using hierarchical 16QAM (OFDM/HL-16QAM system) by simulation and show that the system is more effective than conventional OFDM/16QAM on multipath fading channel in point of required Eb/No to meet high quality and low quality of data services simultaneously.

This paper is organized as follows. In section 2. the principle of hierarchical 16QAM system is described. Section 3 shows signal representation and the system model of the proposed system. In section 4, simulation results are represented and the paper is concluded in section 5.

2. Hierarchical 16QAM

The constellation diagram of hierarchical 16QAM modulation is shown in figure 1. In this figure, D_1 and D_2 are the minimum distance between clusters and the minimum distance within the cluster, respectively. The first two bits (base layer) determine the one of the four subplanes and the next two bits (refinement layer) determine one of the four constellation points within a cluster, respectively. In this system, by controlling hierarchical modulation parameter ($\lambda = D_2 / D_1$), the performance of each two layered bits can be adjusted. In AWGN, the BER (P_{e1}) of base layer and the BER (P_{e2}) of refinement layer are approximately given by [8],

$$P_{e1} = \frac{1}{4} erfc\left(\sqrt{\frac{\gamma}{4\lambda^2 + 4\lambda + 2}}\right) + \frac{1}{4} erfc\left(\sqrt{\gamma \cdot \frac{4\lambda^2 + 4\lambda + 1}{4\lambda^2 + 4\lambda + 2}}\right) \quad (1)$$

and

$$P_{e2} = \frac{1}{2} erfc\left(\sqrt{\frac{\lambda^2 \gamma}{4\lambda^2 + 4\lambda + 2}}\right). \quad (2)$$

where γ is the CNR at the receiver front end.

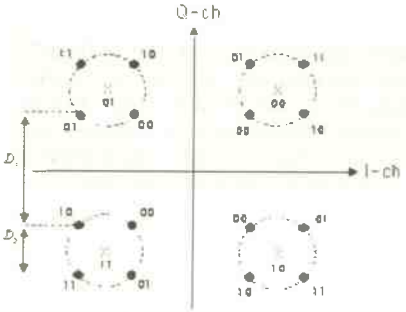


Fig 1. Constellation diagram of the hierarchical 16QAM

3. System Model of OFDM System using Hierarchical 16QAM

In figure 2, the transmitter of OFDM system using hierarchical 16QAM is represented. The N serial hierarchical 16QAM data symbol, spaced by $\Delta t = 1 / f_s$ where f_s is the symbol rate and Δt is symbol duration of serial data, are first converted to parallel form by the serial-to-parallel (S/P) converter and then modulate N subcarriers. The modulated subcarriers are all added, multiplied by the carrier, and then transmitted to the channel. The constellation of the system is represented in figure 1. Practically, the parallel subchannels are performed by a inverse fast Fourier transform, and combined to be upconverted, which is noted as $s'(t)$ in figure 2. The signalling interval is expanded from Δt to $T = N\Delta t$ through the S/P conversion, which makes the system less susceptible to delay spread impairment. In addition, the subcarrier frequencies are separated by multiples of $1/T$ so that, with no signal distortion in transmission, the coherent detection of a signal element in any one subchannel of the parallel system gives no output for the received element in any other subchannel.

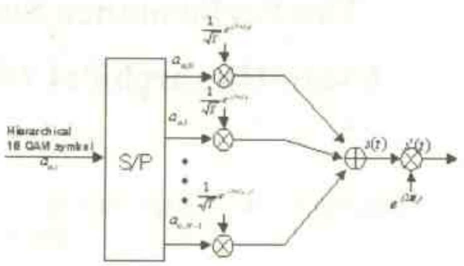


Fig 2. The structure of OFDM transmitter

The generated equivalent complex baseband OFDM signal is written as [9]

$$s(t) = \sum_{n=-\infty}^{\infty} \sum_{i=0}^{N-1} \frac{A}{\sqrt{T}} a_{n,i} e^{j2\pi f_i t} p(t - nT_s), \quad (3)$$

where A is a constant related to the signal power, T_s is the symbol duration, $a_{n,i}$ is the hierarchical 16QAM symbol transmitted to the i-th subchannel in the n-th signaling interval [$nT_s, (n+1)T_s$] and f_i is the frequency of the i-th subcarrier. $p(t)$ is a pulse shaping function expressed as

$$p(t) = \begin{cases} 1, & T_g \le t \le T_s \\ 0, & otherwise \end{cases}, \quad (4)$$

where T_g is a guard interval of OFDM signal. The time difference between the symbol period T_s and the guard interval T_s is the effective symbol interval and represented as

$$T = T_s - T_g. \quad (5)$$

Since the orthogonality condition should be satisfied, f_i is represented as

$$f_i = \frac{i}{T} = \frac{i}{N\Delta t}. \quad (6)$$

The transmitted OFDM signal represented in equation (3) passes through multipath fading channel modeled by two ray model.

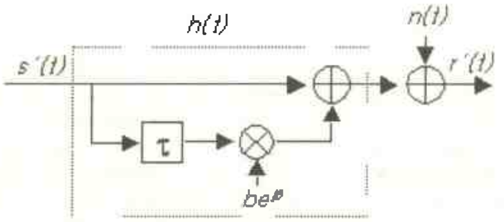


Fig 3. Two ray multipath channel model

This two ray model represented in figure 3 well decribes multipath propagation of VHF/UHF band [10]. The impulse response of this fading channel is expressed as

$$h(t) = \delta(t) + b\delta(t-\tau)e^{j\theta}, \quad (7)$$

where the parameters b, τ, and θ are respectively the amplitude, time of arrival, and random phase of delayed multipath components.

Figure 4 shows the structure of the general coherent OFDM system receiver. At first, the received signal is multiplied by the carrier frequencies, and then passes through a bank of correlators. Finally, the coherently detected symbols are converted to the serial fashion by the parallel-to-serial (P/S) converter.

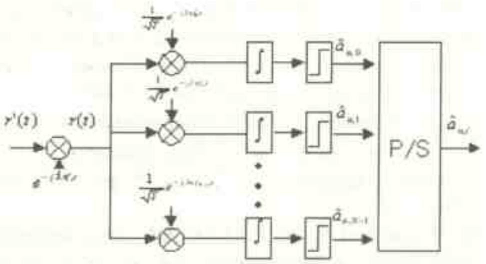


Fig 4. The structure of OFDM receiver

The received signal after passing through multipath channel is represented as

$$\begin{aligned} r'(t) &= s'(t) * h(t) + n(t) \\ &= s'(t) + bs'(t-\tau)e^{j\theta} + n(t) \end{aligned}, \quad (8)$$

where "*" represents a convolution operation and n(t) is the additive white Ganussian noise with the double sided power spectral density of $N_0/2$. In the first part of the OFDM/HL-16QAM receiver, the signal is down converted to the baseband by multiplying it by the carrier frequency.

$$\begin{aligned} r(t) &= r'(t)e^{-j2\pi f_c t} \\ &= y(t) + n(t)e^{-j2\pi f_c t} \end{aligned}, \quad (9)$$

where f_c is the carrier frequency, and $y(t)$ is the signal component of $r(t)$ as to be

$$\begin{aligned} y(t) = &\frac{A}{\sqrt{T}} \sum_{n=-\infty}^{\infty}\sum_{i=0}^{N-1} a_{n,i} e^{j2\pi f_i t} p(t-nT_s) \\ &+ \frac{Ab}{\sqrt{T}} e^{-j2\pi f_c \tau} e^{j\theta} \sum_{n=-\infty}^{\infty}\sum_{i=0}^{N-1} e^{j2\pi f_i (t-\tau)} p(t-\tau-nT_s) \end{aligned} \quad (10)$$

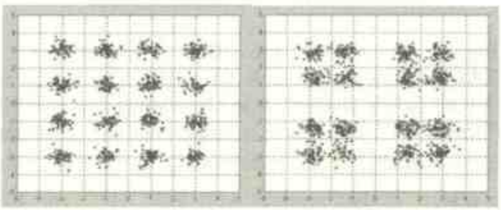
4. Simulation Results

Simulation results on the bit error probability have been obtained on the specific channel condition. The system and channel parameter values used for simulation of OFDM/HL-16QAM system is presented in Table 1. In this simulation, the guard time is not included, so effective OFDM symbol interval is equal to FFT interval in the receiver.

Table 1. Parameters for simulation

Parameters	Values	
Modulation type	Hierarchical 16QAM	
Normalized delay(τ/T)	0.03	
Attenuation coefficient (b)	-6dB	
Number of carrier	64	
Hierarchical modulation parameter (λ)	1	0.5

Figure 5 depicts two constellation diagrams that are derived from simulation of an OFDM/HL-16QAM system with 64 subcarriers, each modulated by using hierarchical 16QAM. Figure 5 (a) and (b) show the constellation for hierarchical modulation parameter (λ=1) and (λ=0.5), respectively. In the case of λ=0.5, first half two bits within a symbol (base layer) are more robust to channel distortion than last half two bits (refinement layer) within it. In these figure, though the center positions of 16 clusters in (a) are different from those of (b), mean signal powers of the two constellation diagram are the same. Therefore, these figures decribe that hierarchical modulation parameter can be changed maintaining mean signal power.



(a) λ=1 (b) λ=0.5

Fig 5. Constellation for the OFDM/HL-16QAM system in two ray multipath channel (Eb/No = 40 dB).

Figures 6 and 7 show the BER performance of OFDM/HL-16QAM system in AWGN and multipath fading chanel, respectively. These figures show that the hierarchical modulator improves the BER of base layer transmission at the sacrifice of refinement layer's BER.

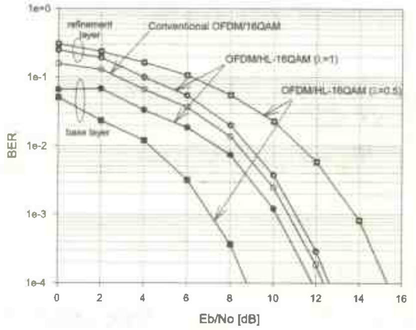


Fig 6. BER performance of OFDM/HL-16QAM system in AWGN channel.

Figure 6 shows the BER performances of OFDM/HL-16QAM system with 64 subcarriers in AWGN channel. It is shown that the BER performances of base layer is improved and refinement layer is degraded as λ is decreased. In this case, when two quality of data services with BER 10^{-2} and BER 10^{-3} are required, conventional OFDM/16QAM system and OFDM/HL-16QAM system with $\lambda=1$ need about 10.7 dB and 10.1 dB in terms of Eb/No, respectively. From this result, it is assured that OFDM/HL-16QAM system is relatively suitable for mobile multimedia communication requiring multi- reliability of data services.

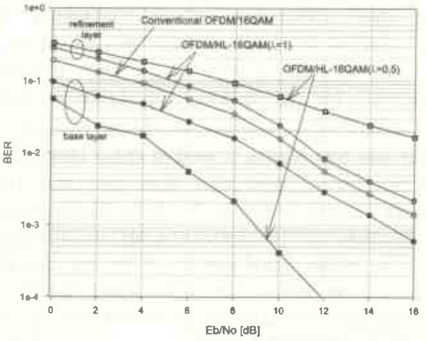


Fig 7. BER performance of OFDM/HL-16QAM System in two ray multipath fading channel.

Figure 7 shows the BER performance of OFDM/16QAM system with 64 subcarriers in two ray multipath fading channel. It is also shown that the BER performance of base layer is improved and refinement layer is degraded as λ is decreased. In this case, when two quality of data services with BER 10^{-2} and BER 10^{-3} are required to be transmitted simultaneously, conventional OFDM/16QAM system and OFDM/HL-16QAM with $\lambda=1$ need about 17 dB and 14.8 dB in terms of Eb/No, respectively.

Therefore, OFDM/HL-16QAM system can be operated with less power compared with conventional OFDM/16QAM when the two target performances are different.

5. Conclusion

In this paper, we have simulated the OFDM/HL-16QAM system and obtained the performance of the system on the multipath fading channel. The effectiveness of the proposed system in mobile multimedia communication is proved by comparing the BER performance of the obtained simulation results of the OFDM/HL-16QAM system with that of conventional OFDM/16QAM system. It has been shown that the proposed system is more effective than conventional OFDM/16QAM on AWGN and multipath fading channel in point of required minimum Eb/No to satisfy multi-reliability of data services simultaneously. Therefore, it is concluded that the proposed OFDM/HL-16QAM system is suitable for mobile multimedia communication requiring multi- reliability of data services.

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