The Performance Simulation of OFDM System Employing Hierarchical 16QAM for Image and Data Transmission in Multipath Fading Channel

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Abstract

In this paper, we have evaluated the performance of an OFDM system using hierarchical 16QAM (OFDM/HL-16QAM) for achieving high quality and high speed data and image transmission in multipath fading channel. The wireless channel for performance evaluation is assumed to include AWGN and two ray multipath fading. Through simulation we have obtained the BER performance of the system according to E_b/N_o, then compared the received image quality of proposed system with that of conventional system. From the result, it is shown that the OFDM/HL-16QAM system is more effective for data and image transmission.

1. Introduction

In the last years, OFDM transmission have received much attention due to its ability of transmitting high data rates even in severe multipath fading channel and higher bandwidth efficiency. These advantage makes the system expected to be the most appropriate scheme for multimedia transmission such as voice, data, and image.

In OFDM, transmission is carried out in parallel on the different frequencies[1]-[3]. 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[4][5].

Hierarchical transmission system was originally proposed to transmit image data for mobile communication[6]. 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. Some source coding schemes, such as DCT (discrete cosine transform), can divide image into several part depending to its importance (high frequency/low frequency). In these source coders, the sensitivity of the channel error varies significantly depending on the importance of the corresponding bits[7]. So, these characteristics of DCT and unequal reliability of transmission depending on importance of image data can be used for effective image transmission.

In this paper, we obtain the BER performance of OFDM system using hierarchical 16QAM (OFDM/HL-16QAM system) by simulation. Then, we show that the system is more effective than conventional OFDM/16QAM on multipath fading channel in point of required E_b/N_o to meet high quality and low quality of data services simultaneously and the system is effective for image transmission by comparing received images of OFDM/HL-16QAM system with OFDM/16QAM system.

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

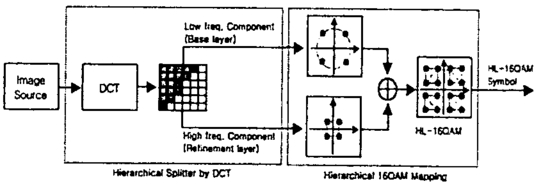


Fig. 1 Block diagram of hierarchical 16QAM system.

The block diagram of hierarchical 16QAM system is shown in figure 2. Image source data are converted to frequency domain by 2 dimensional DCT. After the bits in frequency domain are divided to low frequency component and high frequency component, final output signal is constructed by hierarchical 16QAM mapper.

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.

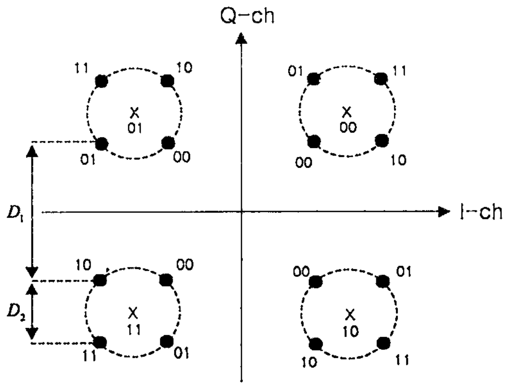


Fig. 2 Constellation diagram of the hierarchical 16QAM.

3. System Model of OFDM System using Hierarchical 16QAM

In figure 3, 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 2. 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 3. 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.

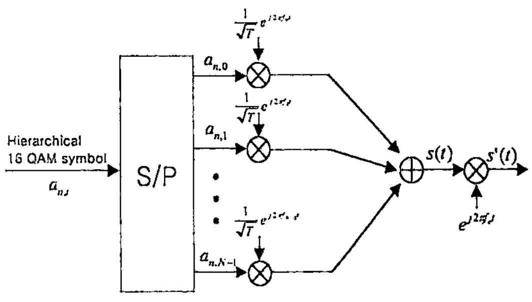


Fig. 3 The structure of OFDM transmitter.

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_g 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 channel.

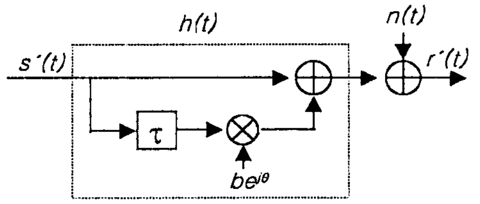


Fig. 4 Two ray multipath channel model.

This two ray model represented in figure 4 well describes 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.

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 Gaussian 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

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

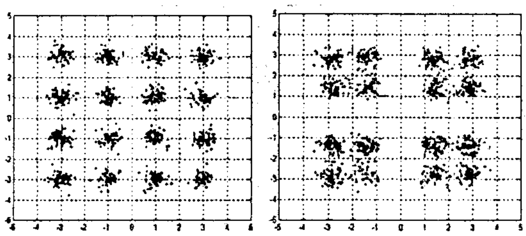
4. Simulation Results

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.



(a) λ=1 (b) λ=0.5

Fig. 5 Constellation for the OFDM/HL-16QAM system in two ray multipath channel (E_b/N_0 = 40 dB).

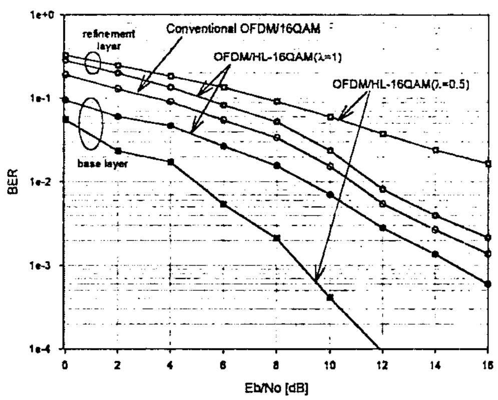


Fig. 6 BER performance of OFDM/HL-16QAM system in two ray multipath fading channel.

Figure 6 shows the BER performance of OFDM/HL-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 λ=1 need about 17 dB and 14.8 dB in terms of E_b/N_0, respectively.

Therefore, OFDM/HL-16QAM system can be

operated with less power compared with conventional OFDM/16QAM when the two target performances are different.

(a) original image ("lena")

(b) OFDM/HL-16QAM (λ=0.5)

(c) OFDM/16QAM

Fig. 7 Simulation result of image transmission in two ray multipath fading channel (E_b/N_o = 10 dB).

Figure 7 shows the simulation result for image transmission. Fig. 7(a) is original image referred as "lena" without channel error. Fig. 7(b) and (c) are received images by OFDM/HL-16QAM system with λ =0.5 and OFDM/16QAM system, respectively. From these figure, it is assured that OFDM/HL-16QAM system is more effective than conventional OFDM/16QAM system.

5. Conclusion

In this paper, we have simulated the OFDM/HL-16QAM system and obtained the performance of the system in the multipath fading channel. Through simulation we have obtained the BER performance of the system according to E_b/N_o and the number of subcarriers, then showed the received image quality. It has been known that the proposed system is more effective than conventional OFDM/16QAM system in the multipath fading channel for satisfying multi-reliability of data services and image transmission with higher quality. Therefore, it is concluded that the proposed OFDM/HL-16QAM system is suitable for data and image transmission.

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