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Design and comparison of new DWT – OFDM with conventional based system

M.Devipriya¹, Dr.R.Kalaivani², P.Sureshkumar³

¹PG Scholar, Department of Electronics and Communication Engineering, Erode Sengunthar Engineering, College, ANNA University, Chennai, Tamilnadu, India. 638-057.

²Professor, Department of Electronics and Communication Engineering, Erode Sengunthar Engineering, College, Erode-Dist, Tamilnadu, India. 638-057

³Assistant Professor, Senior Grade, Department of Electronics and Instrumentation Engineering, Tamilnadu, India.638-057

ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is normally implemented using a Fourier Transform (FT) to create and detect the different subcarriers. This can be efficiently implemented using an Inverse Fast FT / Fast FT (IFFT/FFT). This transform however has the drawback that it uses a rectangular window, which creates rather high side lobes. Moreover, the pulse shaping function used to modulate each subcarrier extends to infinity in the frequency domain this leads to high interference and lower performance levels. A wavelet transform is an operation that filters a signal using wavelet and scaling basis functions. Therefore, we compared the bit error rate (BER), spectral efficiency, and peak to average power ratio (PAPR) performance with the conventional OFDM system through the design of OFDM system based on wavelet transform. In this paper a new wavelet based OFDM system is proposed which uses discrete wavelet transform (DWT) instead of FT. Simulation shows that the use of DTCWT outperforms the use of wavelet packet transform (WPT) and outperforms the use of FT in conventional OFDM system in term of reduction of PAPR. The complementary cumulative distribution function (CCDF) of the PAPR for the OFDM based on DTCWT show about 2 dB improvements over WPM and conventional OFDM.

Keywords: Wavelet Transform, OFDM, PAPR, Spectral Efficiency; Discrete Meyer.

INTRODUCTION

OFDM, which is currently used as a kind of fourth generation mobile communication system, is an MCM system that enables high-speed transmission using a plurality of carriers. In a single carrier method using one carrier, multi-carriers chimes used, and a fast Fourier transform operation is used to map symbols to a plurality of subcarriers. In this way, symbols are mapped to a plurality of subcarriers, where each subcarrier is orthogonal to one another on the time axis and

overlaps on the frequency axis [1]. Therefore, the signal mapped to the subcarrier minimizes the problem using the CP so that inter-symbol interference does not occur in the multipath channel. However, the CP used in OFDM has a problem of wasting power and lower spectral efficiency than existing signals. In addition, the conventional OFDM system has a disadvantage of high PAPR. This has the problem that the signal passes through the amplifier and nonlinear distortion occurs above a certain level [2]. In this

Author for correspondence:

Department of Electronics and Communication Engineering, Erode Sengunthar Engineering College, Erode, Tamil Nadu, India.638-057

paper, we propose a new MCM system to overcome the disadvantages of OFDM. In the proposed system, the symbol is mapped by using IDWT instead of IFFT operation for the OFDM and the symbol recovered by the DWT in the receiver [3, 4]. There have been some studies about the DWT-OFDM [5, 6], but they are not enough. Therefore, we investigate and compare the several performances of OFDM system using IDWT such as spectrum efficiency, BER performance and PAPR distributions together.

WAVELET-OFDMSYSTEM

Wavelet transform

The wavelet transform means that the signal is expanded, decomposed and analyzed by using a basis function according to different wavelets. This signal analysis method is used to analyze transient signal analysis, image analysis, and communication system signals. The difference from the Fourier transform is that signals are generated in the form of transformation and expansion of each wavelet fixed function rather than in terms of trigonometric functions. Therefore, in this study, IDWT operation is performed by using different types of wavelet basis functions, and the performance change is examined, and the performance of the conventional OFDM scheme is compared and analyzed. The following is the IDWT formula used in system operation [4].

$$X(t) = \sum_{n=0}^{A-1} \sum_{a=0}^{O-1} \sum_{O=0}^{T-1} \alpha_n \alpha_a \alpha_O(t - nT_0)$$

$$+ \sum_{n=0}^{A-1} \sum_{a=0}^{O-1} \sum_{O=0}^{T-1} \alpha_n \alpha_a \alpha_O(t - nT_0) \tag{1}$$

Here, w and y are constants corresponding to the scale values, \$ and \$ are specific fixed functions for various wavelets. \$ is a scale function and has various resolutions according to this value. is a wavelet function and is used for signal filtering. In the IDWT operation, the scale function serves as a low-pass filter and the wavelet function serves as a high-pass filter.

Wavelet and scaling functions

The following are the wavelet and scale functions used in the wavelet transform [3]. At first, equations (2) and (3) are the wavelet and scale functions representing the Discrete Meyer wavelets.

$$\psi(m) = \begin{cases} 1 & |m| \leq \frac{2n}{3} \\ \frac{\cos[\pi/2 (|m| - 1)]}{2} & \frac{2n}{3} < |m| \leq 4n \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$\phi(m) = e^{im/2} [\phi(m+2n) + \phi(m-2n)] \tag{3}$$

The following are the scale and wavelet functions of Daubechies wavelets.

$$\phi(t) = \sum_{k=0}^6 a_k \phi(2t - k) \tag{4}$$

$$\psi(t) = \sum_{k=0}^6 b_k \psi(2t - k) \tag{5}$$

The following are the scale and wavelet functions of the Haar wavelet.

$$\phi(t) = \begin{cases} 1 & 0 \leq t \leq 1 \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

$$\psi(t) = \begin{cases} 1 & 0 \leq t < 1/2 \\ -1 & 1/2 \leq t \leq 1 \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

The following shows the wavelet function and scale function of each wavelet.

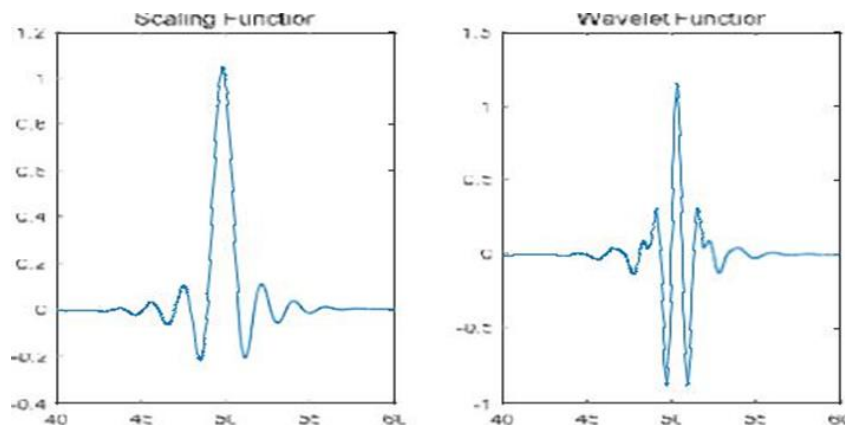


Figure1. Scaling and wavelet function of Discrete Meyer

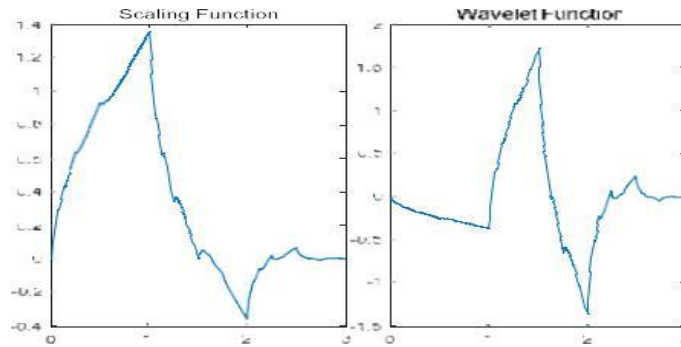


Figure 2. Scaling and wavelet function of Daubechies2.

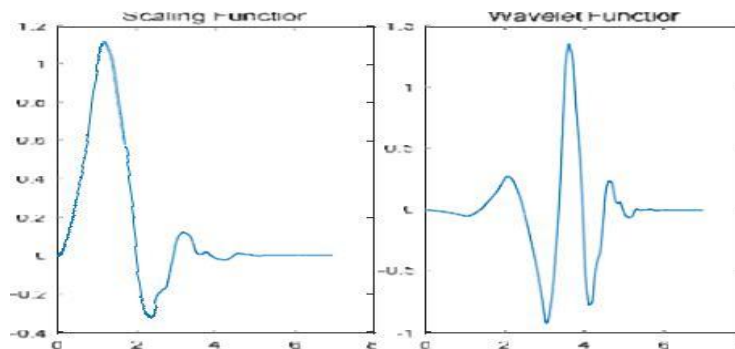


Figure3. Scaling and wavelet function of Daubechies4

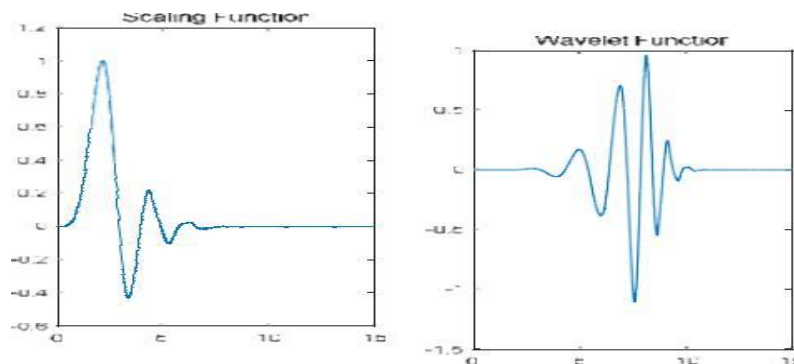


Figure4. Scaling and wavelet function of Daubechies8.

SIMULATION RESULTS AND ANALYSIS

In this paper, we have simulated the proposed Wavelet-OFDM system to analyze and verify the performance of each system model using MATLAB program.

The simulation was performed by specifying the symbol period according to the IEEE 802.11a

standard. The symbol period after the conventional IFFT operation and the symbol period after the IDWT operation are set to 3.2 μ s in the same manner as the standard, and the interval between the bandwidth and the subcarrier is measured. Then, the spectral efficiency according to the simulation result was calculated, respectively.

Table I Simulation parameters

Modulation	64 QAM
FFT size	64
Number of subcarriers	52
CP length	16
Channel	AWGN
Type of wavelet	Discrete Meyer Daubechies2 Daubechies4 Daubechies8 Haar

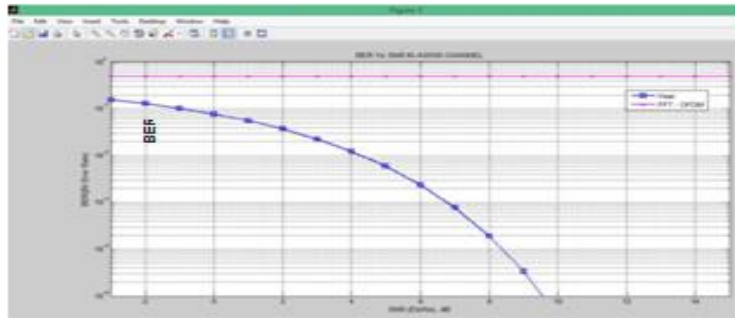


Figure6. BER Comparison between Wavelet OFDM and conventional DFT-OFDM.

Figure 6 shows the BER performances of the conventional OFDM system and Wavelet-OFDM system. As can be seen from the figure, the conventional OFDM system and the OFDM system constructed using various wavelets showed almost

the same BER performance. However, the system using Daubechies8 wavelet among wavelet-OFDM showed some performance degradation compared with other systems.

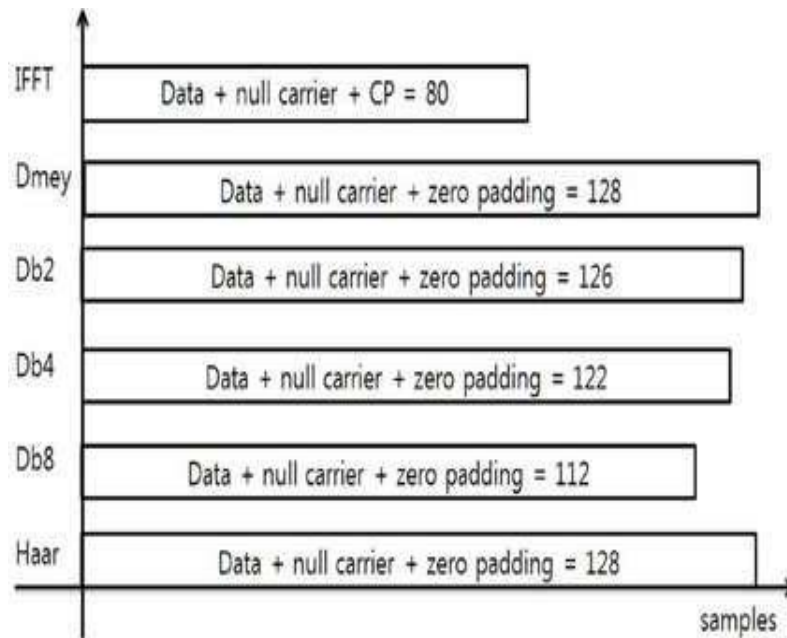


Figure 7. The number of samples that make up one symbol in each system

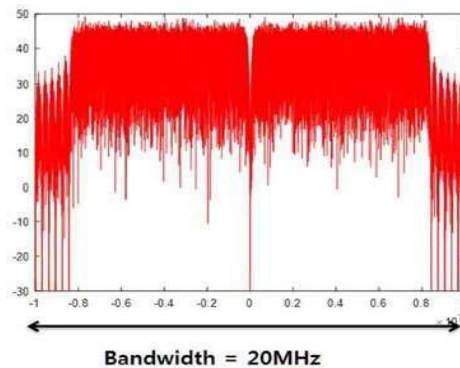


Figure 8. Spectrum of conventional OFDM.

Figure 7 shows the symbol length of a conventional OFDM and Wavelet-OFDM system as a sample. Here, the cycle per symbol is equal to 3.2 μ s. Therefore, the time per sample is different. For example, in OFDM using Discrete Meyer wavelet, 128 samples constitute one symbol and the period of the symbol is 3.2 μ s, so the time per sample is 0.25 ns. In addition, in the conventional OFDM system, since the period of the CP is added by 1/4 of the period of one symbol in addition to the period of one symbol, the period per symbol transmitted in the OFDM system is calculated as 4.0 μ s added with 3.2 μ s and 0.8 μ s do. Therefore, the period per one sample of the OFDM system has a period of 0.5 ns because 80 samples are 4.0 μ s, and the simulation proceeds.

Figure 8 is the spectrum of the existing OFDM system according to the simulation

environment [4]. As shown in Figure 8, the resulting bandwidth was measured at 20 MHz, as in the IEEE 802.11a standard. And we divide the measured bandwidth by the number of subcarrier s and check the subcarrier spacing of each system.

Figure 9 through Figure 13 show the spectrums of wavelet-OFDM constructed using different wavelets. It can be confirmed that the bandwidths are different from each other due to the difference in the number of samples constituting one symbol and the shape of the wavelet function in each wavelet. Among them, the bandwidth of the Wavelet-OFDM system using the Discrete Meyer wavelet is the narrowest, and the out-of-band (OOB) is also lower than that of other wavelets. This seems to be an advantage of improving the frequency efficiency.

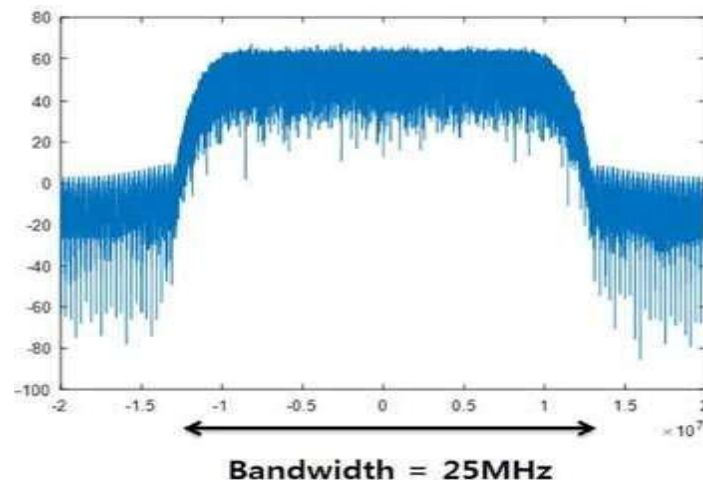


Figure 9. Spectrum of wavelet-OFDM using Discrete Meyer wavelet.

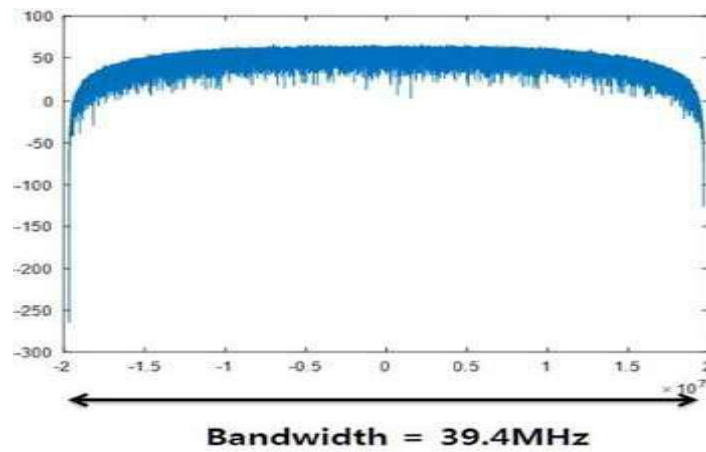


Figure 10. Spectrum of wavelet- OFDM using Daubechies2 wavelet.

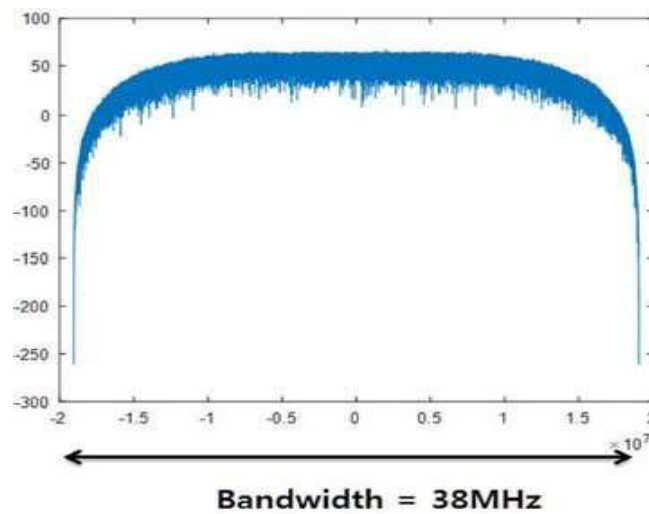


Figure11. Spectrum of wavelet- OFDM using Daubechies4 wavelet.

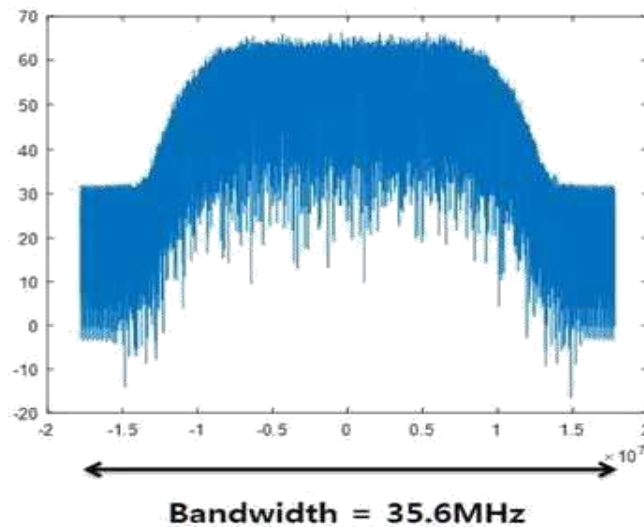


Figure 12. Spectrum of wavelet-OFDM using Daubechies8 wavelet

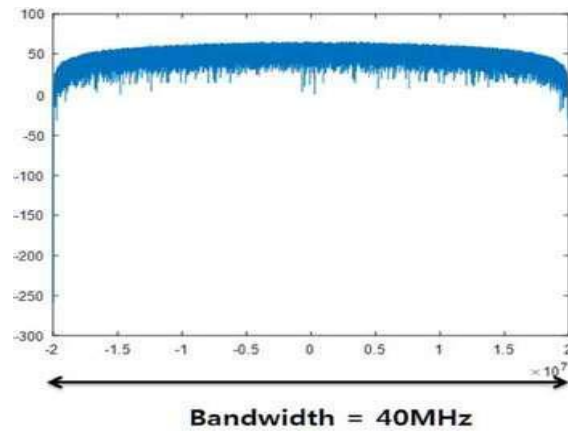


Figure 13. Spectrum of wavelet-OFDM using Haar wavelet

Table 2 summarizes the spectrum efficiency, bandwidth, and spacing between subcarriers for each system. The spectral efficiency of the OFDM system using existing IFFT operation is calculated as 2.7bps/Hz. The wavelet- OFDM system using the Discrete Meyer wavelet has the same spectral

efficiency as the conventional OFDM system. In the case of other wavelets, the spectral efficiency was worse than that of the conventional OFDM due to the difference of the symbol length due to the difference between the iFFT and the IDWT operation and the difference in the bandwidth.

TABLEII .Comparison between BER and SNR in OFDM

Wavelet	Bandwidth(MH)	Subcarrier spacing
FFT	20	312.5
HAAR	40	625

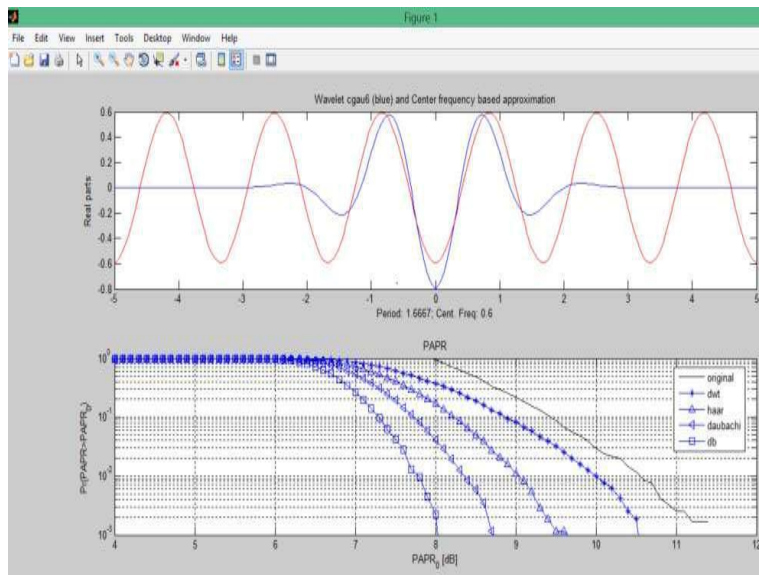


Figure 14. PAPR comparison of conventional OFDM and wavelet-OFDM

The following is a comparison of PAPR performance of conventional OFDM system and wavelet-OFDM system using several wavelets. As shown in Fig. 14, the difference between

wavelet-OFDM and PAPR of existing OFDM becomes clear. The PAPR of the system using Haar wavelet was the lowest.

Table III. PAPR comparison of conventional and wavelet OFDM

Wavelet	BER(dB)	PAPR(dB)
FFT	18.3	9.8
Db	18.5	8.3
Daubechies	18.3	7.9
Haar	18.3	5.8

Table 3 summarizes the three spectral efficiency, BER and PAPR performance of the system. BER performance was measured with SNR of 10^{-4} . As can be seen in the table, wavelet-OFDM system with BER and spectral efficiency most similar to existing OFDM system is a system using Discrete Meyer wavelet. Moreover, OFDM systems using Discrete Meyer wavelets have lower PAPR performance than conventional OFDM, and as shown in the spectrum, having low OOB characteristics is considered to be a great advantage. In the case of other wavelets, the wavelet with the best spectral efficiency is a system using Daubechies8, but the BER performance is different from other wavelet systems and PAPR is higher than other wavelet systems. In addition, the Haar wavelet has the lowest PAPR performance, but the spectral efficiency is also the lowest compared to other wavelets, so it is not suitable to replace the existing OFDM system. Therefore, the OFDM system using the Discrete Meyer wavelet solves the disadvantages of the conventional OFDM system and is considered to be the most suitable as the WCM system.

CONCLUSIONS

In this study, we propose an OFDM system based on IDWT operation as a new MCM scheme and compare its performance with existing OFDM. For more accurate comparison, the OFDM symbol period of the IEEE 802.11a standard is applied equally to all systems. As a result, conventional OFDM systems and wavelet-OFDM systems use Daubechies wavelets. System showed almost similar BER performance. It is confirmed that the length per symbol after IFFT operation and the length per symbol after IDWT operation are expressed by the number of samples. Therefore, when the simulation is performed according to different sample periods, different bandwidths and spectral shapes are shown. However when comparing PAPR performance, wavelet-OFDM using Discrete Meyer wavelet showed lower PAPR performance than conventional OFDM. As a result, the wavelet-OFDM system using the Discrete Meyer wavelet can replace the existing OFDM system based on the iFFT, since the spectral efficiency of the present OFDM system solves the high PAPR problem and the spectrum efficiency shows the same spectral efficiency without using CPIT is thought to be a new MCM method.

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