Wireless images transmission over OFDMA systems: investigation and evaluation

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Published in *The Journal of Engineering*; Received on 25th March 2016; Accepted on 16th August 2016

Abstract: The orthogonal frequency division multiple access (OFDMA) system is a well-known system, which has recently become a preferred choice for wireless communications. This is attributed to its advantages such as the use of frequency-domain equalisers. The issue of the wireless images transmission over the coded and the uncoded OFDMA systems is investigated and evaluated for different wireless channels, different modulation schemes and different subcarriers mapping schemes. Experimental results show that efficient wireless images transmission over OFDMA systems is possible even for mobile channel. Results also show that the coded interleaved OFDMA system provides better performance than the localised OFDMA system, regardless of the wireless channel or the modulation scheme used.

1 Introduction

The goal of recent generation mobile networks is to provide users with a high data rate, and to provide a wider range of services such as voice communications, videophones and high-speed Internet access. One challenge in designing a wireless system is to overcome the effects of the wireless channel, which is characterised as having multiple transmission paths and as being time varying. Multi-carrier code division multiple access (MC-CDMA) and orthogonal frequency division multiplexing (OFDM) have a promising future as new technologies in many wireless communication systems [1]. OFDM overcomes the problem of the large bandwidth requirement imposed by guard bands. It uses a mathematical technique called discrete Fourier transform (DFT) to generate the subcarriers. The subcarriers generated this way do not need additional guard bands and can be placed closer together in the frequency domain. The subcarriers are also orthogonal to each other over the duration of an OFDM symbol. In addition, DFT and its inverse can be efficiently computed, eliminating the need for separate radio-frequency components for separate subcarriers. Whereas OFDM assigns one block (in time) to one user, OFDM access (OFDMA) is a method that assigns different groups of subcarriers (in frequency) to different users. This way, more than one user can access the air interface at the same time [2]. On the other hand, the OFDMA system is a multi-user version of the OFDM system. Each user in an OFDMA system is usually given certain subcarriers during a certain time to communication [3].

Many standards of wireless multi-media transmission systems have adopted OFDM system such as digital audio broadcasting and digital video broadcasting. Image and multi-media transmission with recent wireless technologies has attracted the attention of several researchers [4–10]. Efficient image transmission schemes over MC-CDMA system were proposed and studied in [4–6]. Image transmission over OFDM system has also attracted more attention in the literatures [7–10]. In [7–10], the authors have been suggested several schemes to transmit images over OFDM system.

In the literature, the issue of wireless images transmission over OFDMA system is not studied and it is still a hot topic. Recently, OFDMA system has been adopted in long-term evolution standard [11]. The main objective of this paper is to investigate and evaluate the issue of wireless images transmission over the coded and the uncoded OFDMA systems for different subcarriers mapping schemes, different wireless channels and different modulation schemes. First, the OFDMA system model is derived. Then, the peak-signal-to-noise ratio (PSNR) and the mean square error (MSE) performances of the received image over the OFDMA system are studied and investigated for different wireless channels and different modulation schemes. It is found that the coded OFDMA system greatly enhances the PSNR performance and the MSE performance.

The rest of this paper is organised as follows. Section 2 derives the system model of the OFDMA system. Section 3 briefly introduces the subcarriers mapping schemes. The PSNR and MSE metrics are discussed in Section 4. Experimental results are given and investigated in Section 5. Finally, Section 6 concludes this paper.

2 OFDMA system model

The OFDMA system is a multi-user version of the OFDM system. Each user in an OFDMA system is usually given certain subcarriers during a certain time to communicate. Usually, subcarriers are allocated in contiguous groups for simplicity and to reduce the overhead of indicating which subcarriers have been allocated to each user. The OFDMA system for mobile communications was first proposed in [3] based on MC-FDMA, where each user is assigned a set of randomly selected subcarriers.

The block diagram of the OFDMA system is shown in Fig. 1. One base station and U uplink users are assumed. There are totally M subcarriers and each user is assigned a subset of subcarriers for the uplink transmission. For simplicity, we assume that each user has the same number of subcarriers, N. The transmitter of the OFDMA system uses different subcarriers to transmit information data. At the transmitter side, the encoded data is transformed into a multilevel sequence of complex numbers in one of several possible modulation formats. The resulting modulated symbols are grouped into blocks, each containing N symbols.

The outputs are then mapped to M ($M > N$) orthogonal subcarriers followed by the M-points inverse DFT (IDFT) to convert to a time-domain complex signal sequence. $M = QN$ is the output block size. Q is the maximum number of users that can transmit, simultaneously. Note that the remaining M–N subcarriers may be used by the other users communicating in the cell, thus a promising multi-user access is achieved. Finally, the cyclic prefix (CP) is added. Adding a CP to this signal makes the frequency-domain equalisation (FDE) at the receiver side possible since it converts the linear convolution into circular convolution. Also, CP removes the inter-block interference. After adding a CP of length N_C to the resulting signal, the signal is transmitted through the wireless channel.

In matrix notation, the transmitted signal of the uth user ($u = 1, 2, \ldots, U$) can be formulated as follows

$$\tilde{\boldsymbol{x}}^u = \boldsymbol{P}_{\text{add}} \boldsymbol{F}_M^{-1} \boldsymbol{M}_T^u \boldsymbol{x}^u \tag{1}$$

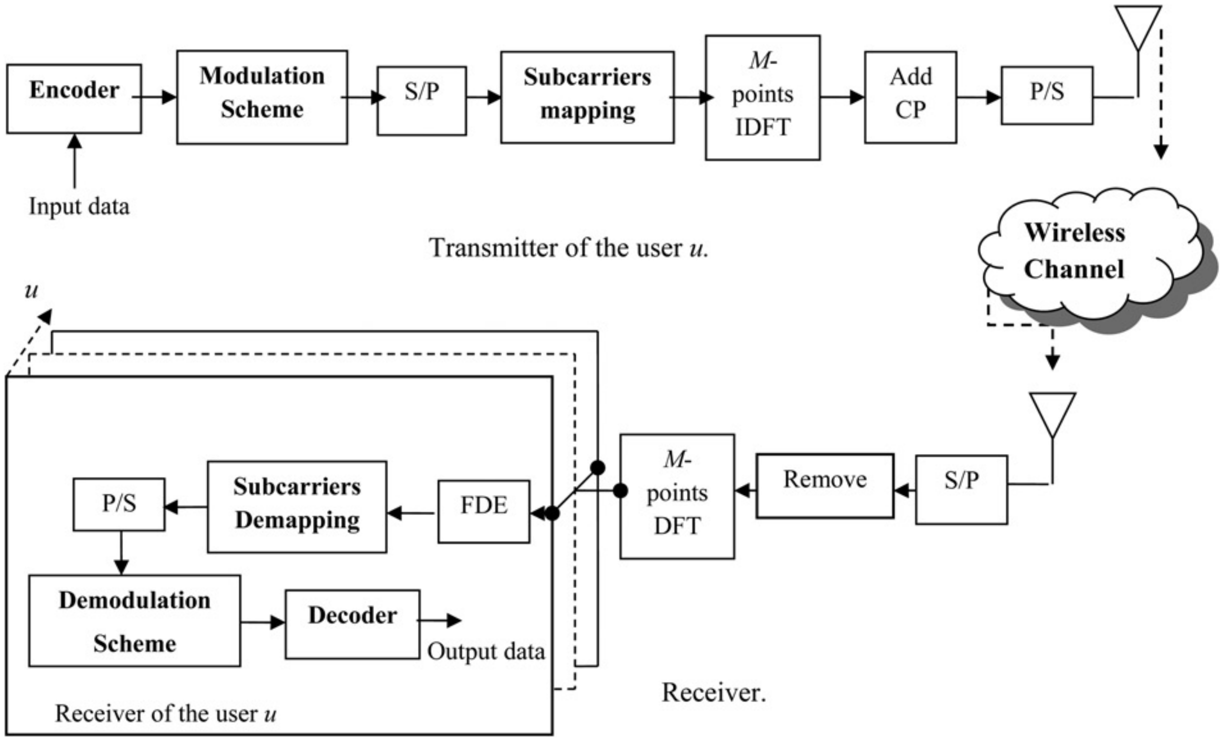

Fig. 1 *Transmitter and receiver structures of the OFDMA system over a frequency selective channel*

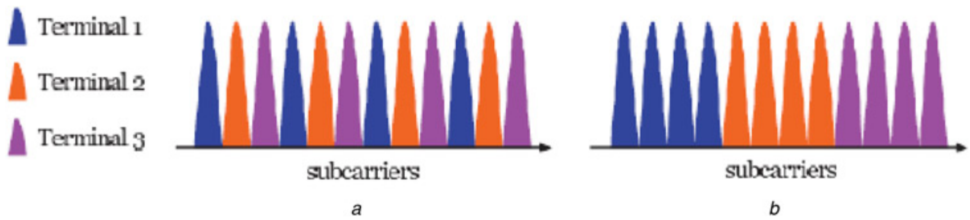

Fig. 2 *Subcarrier mapping methods*
a Interleaved
b Localised

Fig. 3 *Transmitted Cameraman image*

where $\boldsymbol{x}^u$ is an $N \times 1$ vector containing the modulated symbols of the uth user. $\boldsymbol{M}_T^u$ is an $M \times N$ matrix describing the subcarriers mapping of the uth user. $\boldsymbol{F}_M^{-1}$ is an $M \times M$ IDFT matrix. $\boldsymbol{P}_{\text{add}}$ is an $(M + N_C) \times M$ matrix, which adds a CP of length N_C. The entries of $\boldsymbol{M}_T^u$ for both the localised OFDMA (LOFDMA) and the interleaved OFDMA (IOFDMA) systems are given in (2) and (3), respectively [11]

$$\boldsymbol{M}_T^u = [\boldsymbol{0}_{(u-1)N \times N};\ \boldsymbol{I}_N;\ \boldsymbol{0}_{(M-uN)\times N}] \tag{2}$$

$$\boldsymbol{M}_T^u = [\boldsymbol{0}_{(u-1)\times N};\ \boldsymbol{u}_1^{\text{T}};\ \boldsymbol{0}_{(Q-u)\times N};\ \ldots;\ \boldsymbol{0}_{(u-1)\times N};\ \boldsymbol{u}_N^{\text{T}};\ \boldsymbol{0}_{(Q-u)\times N}] \tag{3}$$

where the $\boldsymbol{I}_N$ and $\boldsymbol{0}_{Q' \times N}$ matrices denote the $N \times N$ identity matrix and the $Q' \times N$ all-zero matrix, respectively. $\boldsymbol{u}_l$ ($l = 1, 2, \ldots, N$) denotes the unit column vector, of length N, with all-zero entries except at l. $\boldsymbol{P}_{\text{add}}$ can be represented as follows [11]

$$\boldsymbol{P}_{\text{add}} = [\boldsymbol{C},\ \boldsymbol{I}_M]^{\text{T}} \tag{4}$$

where

$$\boldsymbol{C} = [\boldsymbol{0}_{N_C \times (M - N_C)},\ \boldsymbol{I}_{N_C}]^{\text{T}} \tag{5}$$

Table 1 PSNR values of the received Cameraman image over the uncoded IOFDMA and the uncoded LOFDMA systems when QPSK is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	12.0433	12.1713	13.1638	12.4114	11.7163	11.7376
5	15.2573	15.6255	16.4118	15.3279	14.4059	14.4886
10	19.6336	20.2733	20.4194	19.2161	18.2870	18.2948
15	24.2727	25.3364	24.6958	23.5799	22.8469	23.0097
20	29.5094	30.3592	29.0732	28.4424	27.6328	27.9232
25	34.8772	35.0735	33.1633	33.7812	32.2969	33.2750
30	41.0616	40.1952	38.1207	38.7288	38.2001	38.8362
35	48.4929	46.2845	42.5405	43.6171	42.2133	43.8338

Table 2 PSNR values of the received Cameraman image over the coded IOFDMA and the coded LOFDMA systems when QPSK is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	9.0873	9.0730	10.0581	9.5318	9.3253	8.9351
5	13.8676	14.5231	12.5922	12.5383	12.3593	12.3593
10	23.1538	25.9642	16.5199	18.5928	18.1736	20.1338
15	33.2897	36.8612	22.8933	27.5880	25.8940	30.5828
20	42.5041	48.4880	28.8238	41.7664	37.1680	43.5483
25	51.1411	54.1493	38.4498	49.5165	50.7321	56.5528
30	inf	inf	51.1326	65.8975	55.4008	inf
35	inf	inf	inf	inf	inf	inf

Table 3 PSNR values of the received Cameraman image over the uncoded IOFDMA and the uncoded LOFDMA systems when 16QAM is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	9.6973	9.7750	10.4063	9.7256	9.6153	9.6470
5	11.2527	11.4652	12.5480	11.2996	11.0601	11.1063
10	13.9195	14.4850	16.1985	13.9524	13.4499	13.5008
15	17.7842	19.0273	20.9608	17.7380	16.9794	17.0465
20	22.2257	24.1732	26.2562	22.1553	21.2583	21.2716
25	27.2148	29.5715	31.8249	26.7333	25.8705	26.1574
30	32.8107	34.6425	36.8452	31.1949	30.5454	31.0923
35	39.6131	39.7910	42.8030	37.1830	34.9648	36.2027

At the receiver side, the CP is removed from the received signal and the received signal can be written as follows

$$\boldsymbol{r} = \sum_{u=1}^{U} \boldsymbol{H}_C^u \bar{\boldsymbol{x}}^u + \boldsymbol{n} \tag{6}$$

where $\bar{\boldsymbol{x}}^u = \boldsymbol{F}_M^{-1} \boldsymbol{M}_T^u \boldsymbol{x}^u$ is an $M \times 1$ vector. $\boldsymbol{H}_C^u$ is an $M \times M$ circulant matrix describing the wireless channel between the uth user and the base station. $\boldsymbol{n}$ is an $M \times 1$ vector describing the additive noise. It contains independent identically distributed zero-mean additive white Gaussian noise. $\boldsymbol{H}_C^u$ is given by [11]

$$\boldsymbol{H}_C^u = \begin{bmatrix} h^u[0] & 0 & . & 0 & h^u[L-1] & . & h^u[1] \\ . & h^u[0] & . & & . & . & . \\ . & & . & . & & . & h^u[L-1] \\ h^u[L-1] & & & . & . & & 0 \\ 0 & . & & & . & . & . \\ . & . & . & & & . & 0 \\ 0 & . & 0 & h^u[L-1] & . & . & h^u[0] \end{bmatrix} \tag{7}$$

The circulant matrix $\boldsymbol{H}_C^u$ can be efficiently diagonalised via the DFT and the IDFT. It can be expressed as follows

$$\boldsymbol{H}_C^u = \boldsymbol{F}^{-1} \boldsymbol{\Lambda}^u \boldsymbol{F} \tag{8}$$

where $\boldsymbol{\Lambda}^u$ is an $M \times M$ diagonal matrix containing the DFT of the circulant sequence of $\boldsymbol{H}_C^u$. Now, substituting (8) into (6) and applying the DFT, we get

$$\boldsymbol{R} = \sum_{u=1}^{U} \boldsymbol{\Lambda}^u \boldsymbol{F}_M \bar{\boldsymbol{x}}^u + \boldsymbol{N} \tag{9}$$

where $\boldsymbol{N}$ is the DFT of $\boldsymbol{n}$.

Fig. 1 depicts the OFDMA receiver for the U users. One can see that for each user, a separate detection is performed. So, the detection process for the uth user will be only discussed for the rest of this section. After the DFT, the FDE and the demapping processes are performed to provide the estimate of the modulated symbols as

Table 4 PSNR values of the received Cameraman image over the coded IOFDMA and the coded LOFDMA systems when the 16QAM is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	8.5435	8.5425	8.7317	8.5824	8.5375	8.5377
5	8.8296	8.8166	10.2020	9.0979	8.9135	8.7187
10	10.7973	11.2604	13.0059	11.3628	10.7309	10.2500
15	17.6146	21.7954	16.4083	16.0536	15.0574	16.1511
20	26.5801	34.6660	21.3042	24.3618	21.8778	25.6912
25	38.6153	43.5166	27.0061	34.0754	30.6688	33.4992
30	52.0333	49.1597	33.0160	42.7134	40.9157	44.9179
35	84.2544	inf	41.8266	52.3651	53.8355	inf

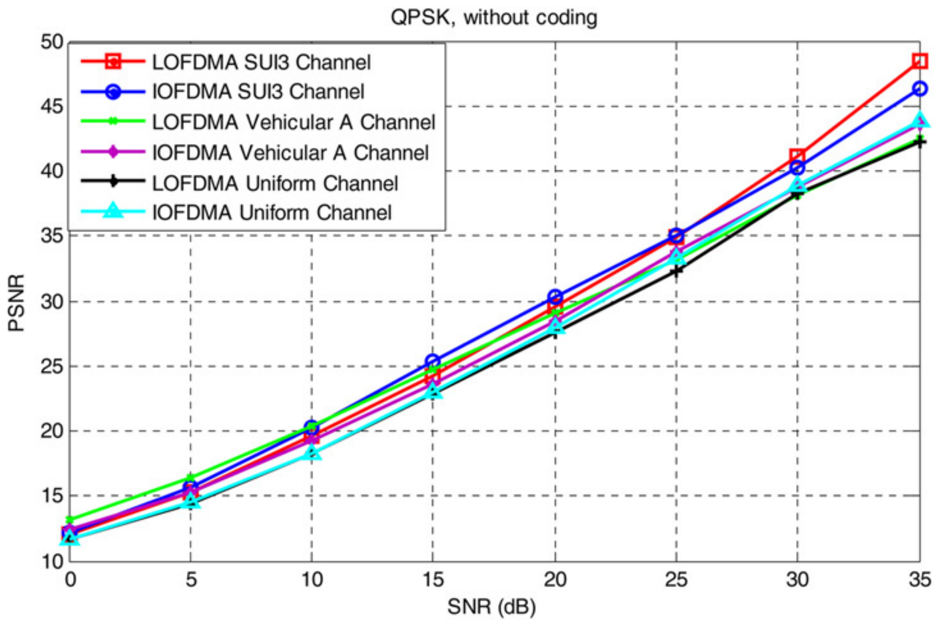

Fig. 4 *PSNR against SNR of the Cameraman image transmission over the uncoded IOFDMA and the uncoded LOFDMA systems when the QPSK is used*

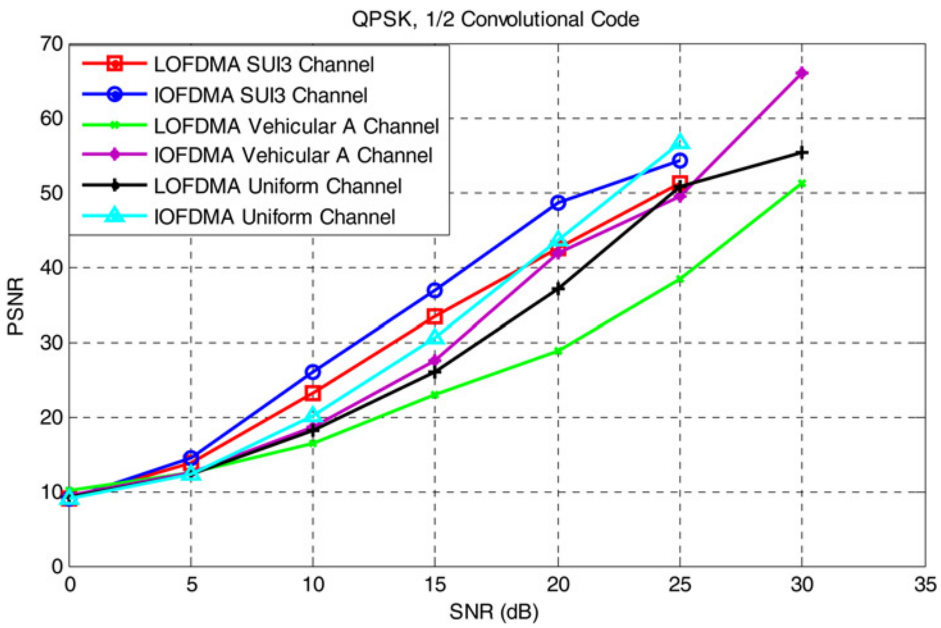

Fig. 5 *PSNR against SNR of the Cameraman image transmission over the coded IOFDMA and the coded LOFDMA systems when the QPSK is used*

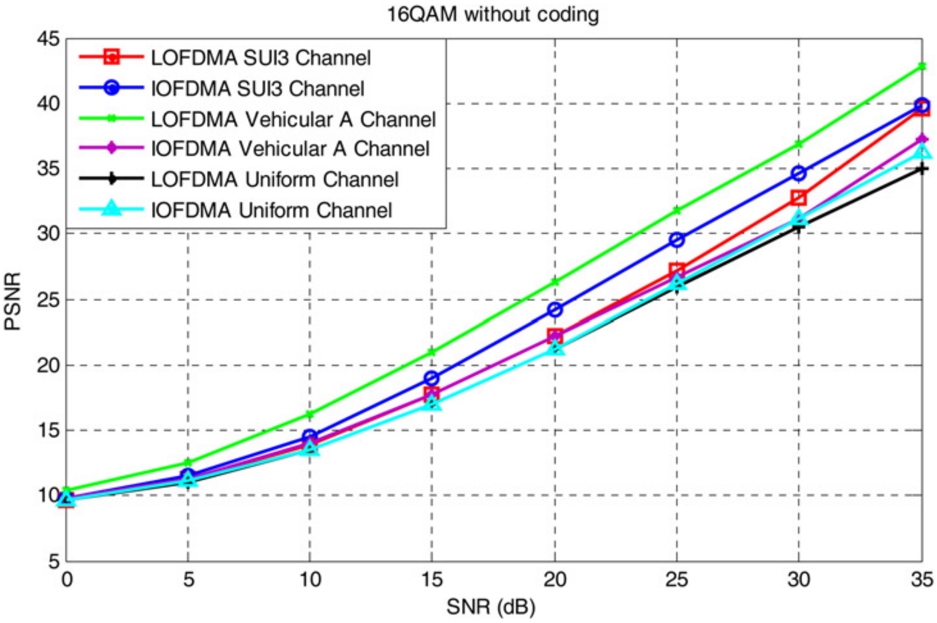

Fig. 6 *PSNR against SNR of the Cameraman image transmission over the uncoded IOFDMA and the uncoded LOFDMA systems when the 16QAM is used*

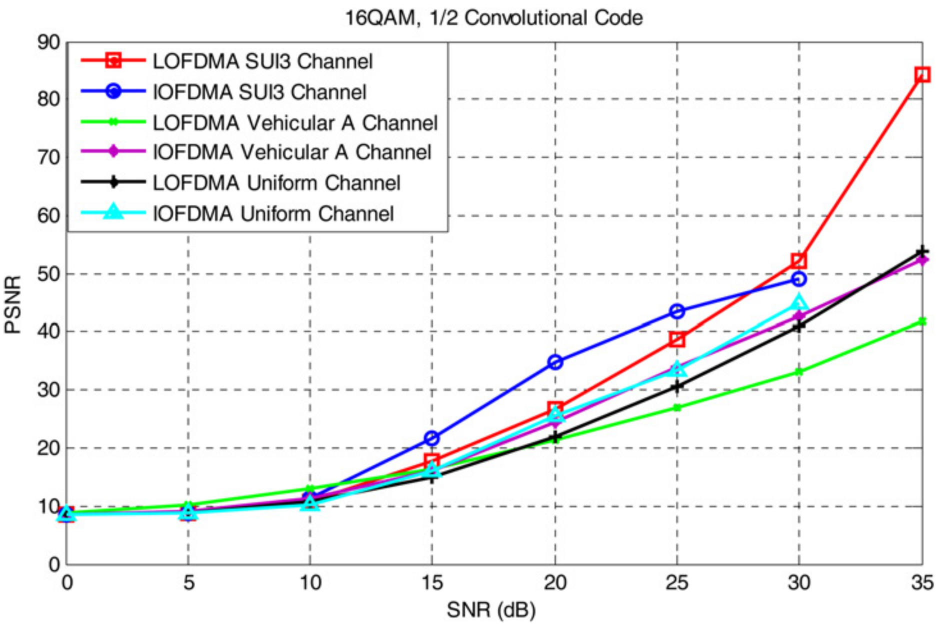

Fig. 7 *PSNR against SNR of the Cameraman image transmission over the coded IOFDMA and the coded LOFDMA systems when the 16QAM is used*

Table 5 MSE values of the received Cameraman image over the uncoded IOFDMA and the uncoded LOFDMA systems when the QPSK is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	0.0625	0.0607	0.0483	0.0574	0.0674	0.0670
5	0.0298	0.0274	0.0228	0.0293	0.0363	0.0356
10	0.0109	0.0094	0.0091	0.0120	0.0148	0.0148
15	0.0037	0.0029	0.0034	0.0044	0.0052	0.0050
20	0.0011	9.206×10^{-4}	0.0012	0.0014	0.0017	0.0016
25	3.253×10^{-4}	3.109×10^{-4}	4.827×10^{-4}	4.186×10^{-4}	5.892×10^{-4}	4.704×10^{-4}
30	7.831×10^{-5}	9.560×10^{-5}	1.541×10^{-4}	1.3400×10^{-4}	1.513×10^{-4}	1.307×10^{-4}
35	1.414×10^{-5}	2.352×10^{-5}	5.571×10^{-5}	4.3480×10^{-5}	6.007×10^{-5}	4.136×10^{-5}

Table 6 MSE values of the received Cameraman image over the coded IOFDMA and the coded LOFDMA systems when the QPSK is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	0.1234	0.1238	0.0987	0.1114	0.1168	0.1278
5	0.0410	0.0353	0.0551	0.0557	0.0581	0.0603
10	0.0048	0.0025	0.0223	0.0138	0.0152	0.0097
15	4.688×10^{-4}	2.060×10^{-4}	0.0051	0.0017	0.0026	8.744×10^{-4}
20	5.618×10^{-5}	1.416×10^{-5}	0.0013	6.658×10^{-5}	1.919×10^{-4}	4.417×10^{-5}
25	7.689×10^{-6}	3.846×10^{-6}	1.429×10^{-4}	1.117×10^{-5}	8.448×10^{-6}	2.212×10^{-6}
30	0	0	7.704×10^{-6}	2.572×10^{-7}	2.883×10^{-6}	0
35	0	0	0	0	0	0

Table 7 MSE values of the received Cameraman image over the uncoded IOFDMA and the uncoded LOFDMA systems when the 16QAM is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	0.1072	0.1053	0.0911	0.1065	0.1093	0.1085
5	0.0749	0.0714	0.0556	0.0741	0.0783	0.0775
10	0.0406	0.0356	0.0240	0.0402	0.0452	0.0447
15	0.0167	0.0125	0.0080	0.0168	0.0200	0.0197
20	0.0060	0.0038	0.0024	0.0061	0.0075	0.0075
25	0.0019	0.0011	6.5691×10^{-4}	0.0021	0.0026	0.0024
30	5.2352×10^{-4}	3.4336×10^{-4}	2.0677×10^{-4}	7.5947×10^{-4}	8.8198×10^{-4}	7.7763×10^{-4}
35	1.0932×10^{-4}	1.0493×10^{-4}	5.2444×10^{-5}	1.9129×10^{-4}	3.1880×10^{-4}	2.3973×10^{-4}

Table 8 MSE values of the received Cameraman image over the coded IOFDMA and the coded LOFDMA systems when the 16QAM is used

SNR, dB	SUI3 channel		Vehicular A channel		Uniform channel	
	LOFDMA	IOFDMA	LOFDMA	IOFDMA	LOFDMA	IOFDMA
0	0.1398	0.1399	0.1339	0.1386	0.1400	0.1400
5	0.1309	0.1313	0.0955	0.1231	0.1284	0.1343
10	0.0832	0.0748	0.0501	0.0731	0.0845	0.0944
15	0.0173	0.0066	0.0229	0.0248	0.0312	0.0243
20	0.0022	3.4150×10^{-4}	0.0074	0.0037	0.0065	0.0027
25	1.3755×10^{-4}	4.4497×10^{-5}	0.0020	3.9126×10^{-4}	8.5727×10^{-4}	4.4676×10^{-4}
30	6.2614×10^{-6}	1.2135×10^{-5}	4.9934×10^{-4}	5.3537×10^{-5}	8.0989×10^{-5}	3.2226×10^{-5}
35	3.7546×10^{-9}	0	6.5665×10^{-5}	5.8008×10^{-6}	4.1347×10^{-6}	0

follows

$$\hat{x}^u = M_R^u W^u R \tag{10}$$

where W^u is the $M \times M$ FDE matrix of the uth user. M_R^u is the $N \times M$ subcarriers demapping matrix of the uth user. The entries of M_R^u for both the LOFDMA and the IOFDMA systems are given by taking the transport of (2) and (3), respectively, that is, $M_R^u = M_T^{u\mathrm{T}}$. Finally, the demodulation and the decoding processes are performed.

On the basis of the minimum MSE (MMSE), the FDE equaliser can be expressed as [11]

$$W_{MMSE}^{\ u} = (\Lambda^{u^H}\Lambda^u + 1/SNR)^{-1}\Lambda^{u^H} \tag{11}$$

Though OFDMA has proved itself as a powerful modulation technique, it has its own challenges [12]

- It has high sensitivity to carrier frequency offsets and phase errors.
- It has a large dynamic signal range with a relatively high peak-to-average power ratio. This tends to reduce the power efficiency of the power amplifier.
- It has sensitivity to the resolution and dynamic range of the digital-to-analogue and analogue-to-digital converters.
- It has a loss in power and spectral efficiency due to the CP application.
- It has a need for an adaptive or coded scheme to overcome spectral nulls in the channel.

3 Subcarriers mapping techniques

The subcarrier mapping technique assigns modulated symbols as the amplitudes of some of the selected subcarriers. Subcarrier mapping techniques can be classified into two types: localised mapping and interleaved mapping. In the localised mapping, the modulated symbols are mapped to a subset of consecutive subcarriers thereby confining them to only a fraction of the system bandwidth. In the interleaved mapping, the modulated symbols of the input data are assigned to subcarriers over the entire bandwidth non-continuously, resulting in zero amplitude for the remaining subcarriers. In this paper, the IOFDMA is abbreviated by IOFDMA

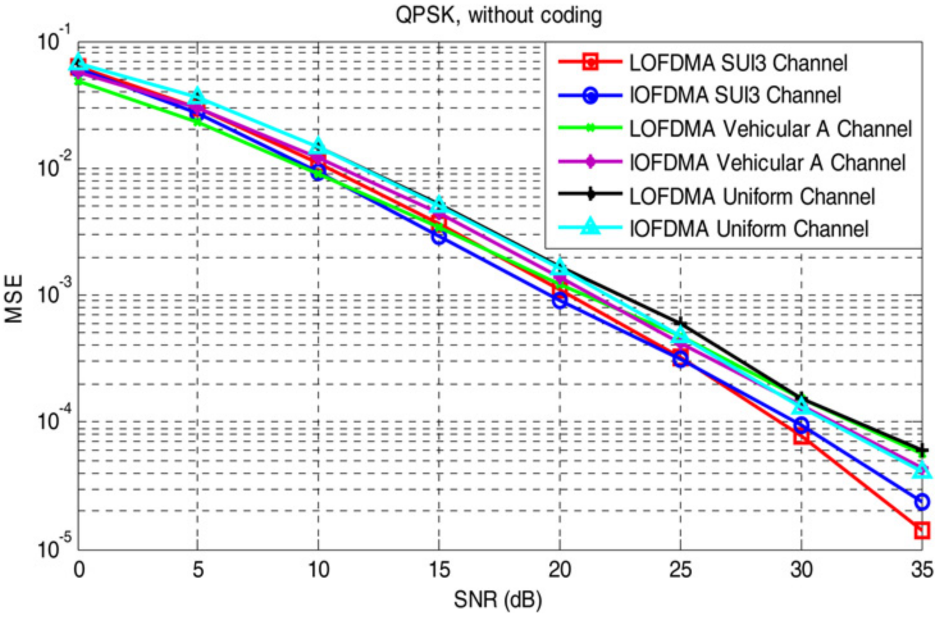

Fig. 8 *MSE against SNR of the Cameraman image transmission over the uncoded IOFDMA and the uncoded LOFDMA systems when the QPSK is used*

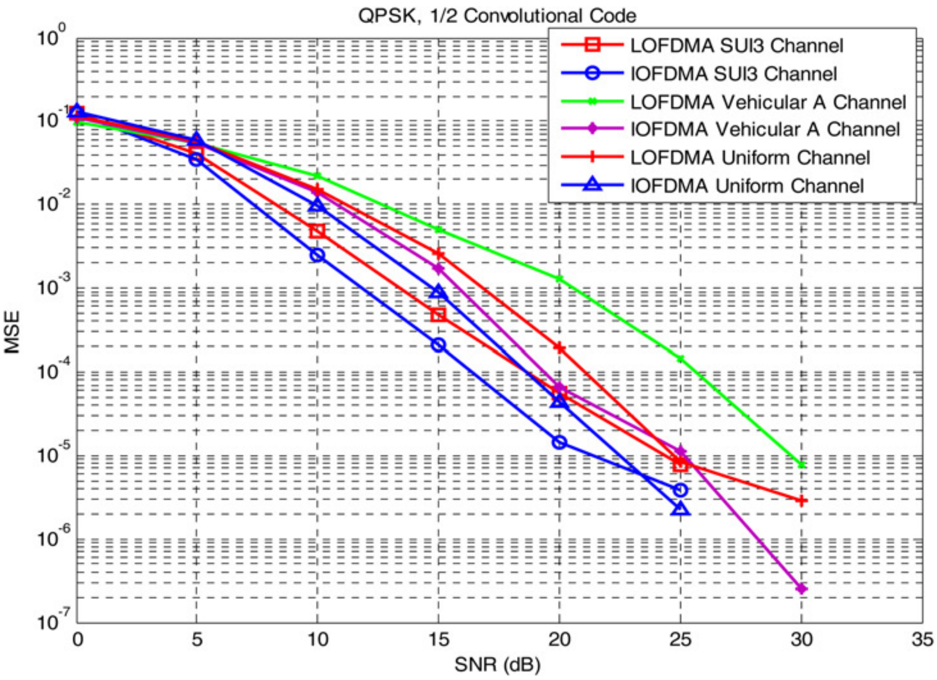

Fig. 9 *MSE against SNR of the Cameraman image transmission over the coded IOFDMA and the coded LOFDMA systems when the QPSK is used*

system and the LOFDMA system is abbreviated by LOFDMA. Fig. 2 is a general picture of the interleaved and localised subcarriers mapping schemes [12].

4 PSNR and MSE metrics

The quality of the reconstructed image compared with the original transmitted image will be measured using two metrics MSE and PSNR. The MSE is defined as follows [4, 6]

$$\text{MSE} = \frac{\sum_{i=1}^{M}\sum_{J=1}^{M}[I_o(i, j) - I_r(i, j)]^2}{M^2} \quad (12)$$

where M^2 is the total number of pixels in the transmitted image, I_o and I_r are the original and the recovered images, respectively.

The PSNR metric is used to measure the quality of the reconstructed image at the receiver. It is defined as the ratio between the maximum possible power of a signal and the power of the corrupting noise that affects the fidelity of this signal. The PSNR can be expressed as [4, 6]

$$\text{PSNR} = 10 \log\left(\frac{f_{\max}^2}{\text{MSE}^2}\right) \quad (13)$$

where f_{max} is the maximum pixel value in the image.

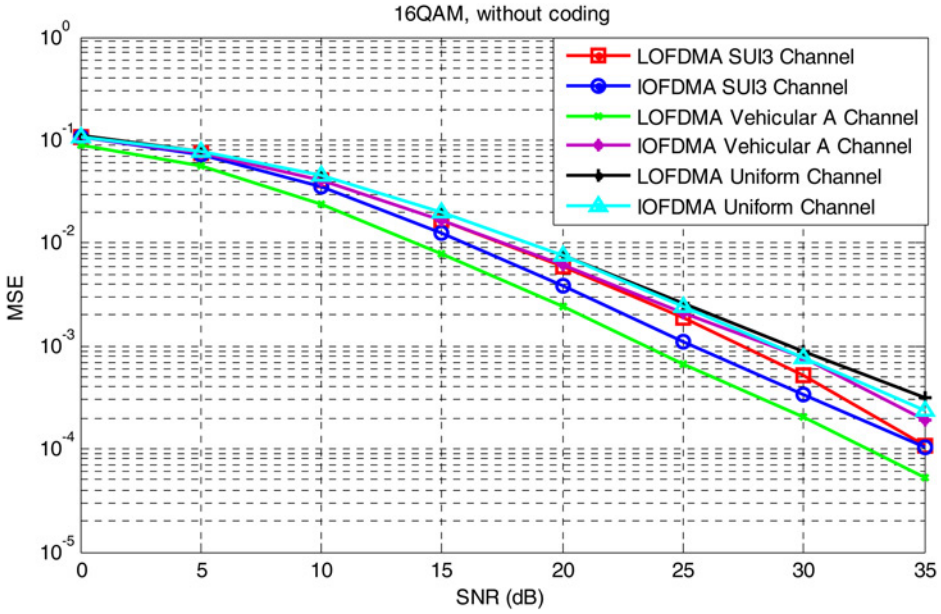

Fig. 10 *MSE against SNR of the Cameraman image transmission over the uncoded IOFDMA and the uncoded LOFDMA systems when the 16QAM is used*

5 Simulation results

5.1 Simulation parameters

Simulations using MATLAB are used to investigate and evaluate the issue of wireless images transmission over OFDMA system. In the simulated OFDMA system, each user occupies 64 subcarriers. The total number of subcarriers $M = 256$ and the number of users $U = 4$. In each simulation, all subcarriers are assigned among all users according to the subcarriers mapping method used. Quadrature phase shift keying (QPSK) and 16 quadrature amplitude modulation (QAM) modulation schemes are used to generate a transmitted block for each user. MMSE equalisation is assumed. The channel models used for simulations are the vehicular A model [13], the SUI3 channel [14] and the uniform channel. A convolutional code with memory length seven and octal generator polynomials (133,171) is chosen as the channel code. The transmitted Cameraman image for all users of size 256 × 256 is shown in Fig. 3.

5.2 PSNR performance

In this section, the Cameraman image of size 256 × 256 has been transmitted over the coded and the uncoded OFDMA systems when the QPSK and the 16QAM are used. The PSNR values of the received image are calculated for different SNR values, SNRs from 0 to 35 dB in 5 dB steps. Different wireless channels and

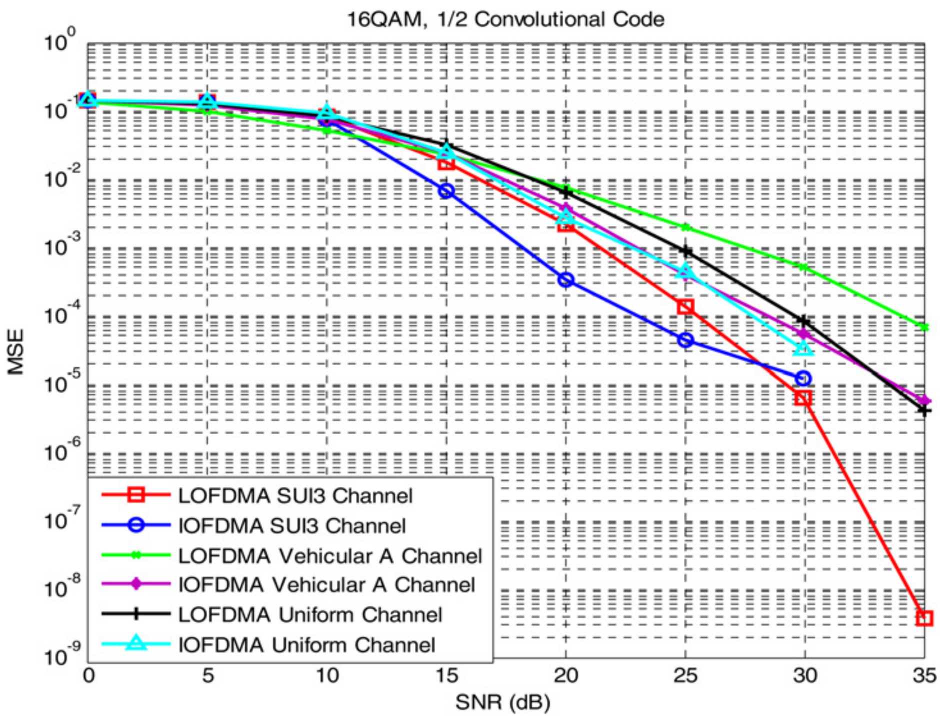

Fig. 11 *MSE against SNR of the Cameraman image transmission over the coded IOFDMA and the coded LOFDMA systems when the 16QAM is used*

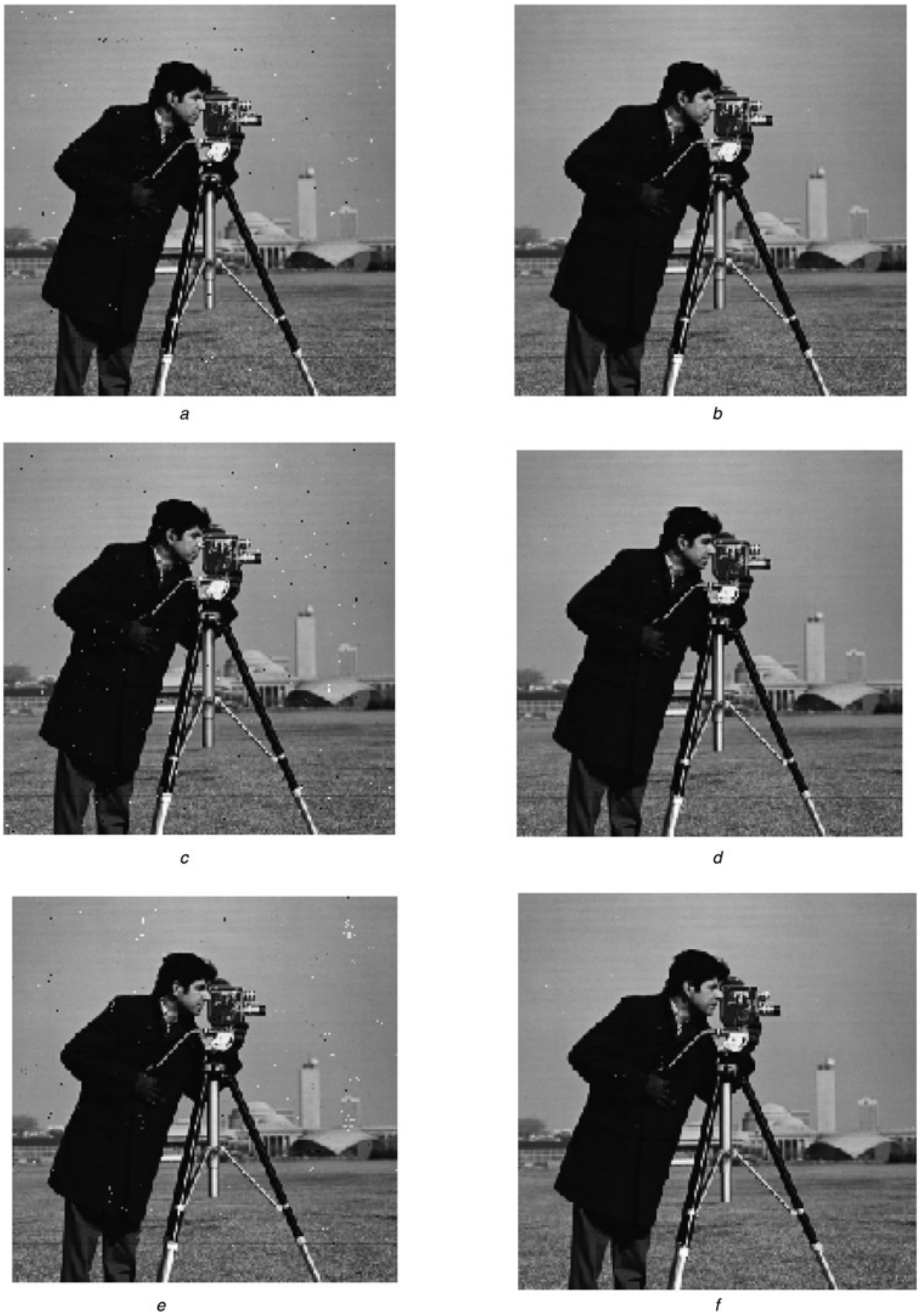

Fig. 12 *Received Cameraman images using the coded and the uncoded IOFDMA systems for different wireless channels, QPSK and SNR = 25 dB*
a Uncoded IOFDMA for SUI3 channel
b Coded IOFDMA for SUI3 channel
c Uncoded IOFDMA for uniform channel
d Coded IOFDMA for uniform channel
e Uncoded IOFDMA for vehicular A channel
f Coded IOFDMA for vehicular A channel

different subcarriers mapping schemes have been considered and compared. The obtained PSNR values are tabulated in Tables 1–4.

Figs. 4 and 5 show the PSNR against the SNR of the received image through the uncoded and the coded OFDMA systems, respectively, for different wireless channels and different subcarriers mapping schemes when the QPSK is used.

The efficiency of image transmission over the coded and the uncoded OFDMA systems is also tested with the 16QAM. Figs. 6 and 7 plot the PSNR against the SNR of the received image through the uncoded and the coded OFDMA systems, respectively, for different wireless channels and different subcarriers mapping schemes when the 16QAM is used. It is clear that the coded IOFDMA system gives the best PSNR performance when compared with the LOFDMA system, regardless of the wireless channel type or the modulation scheme type. This is attributed to the immunity of the interleaved scheme against the burst errors. The obtained results indicate that the uncoded LOFDMA system provides better PSNR performance than the uncoded IOFDMA system for the vehicular A channel. It is also found that the performance of the coded or the uncoded IOFDMA systems for SUI3

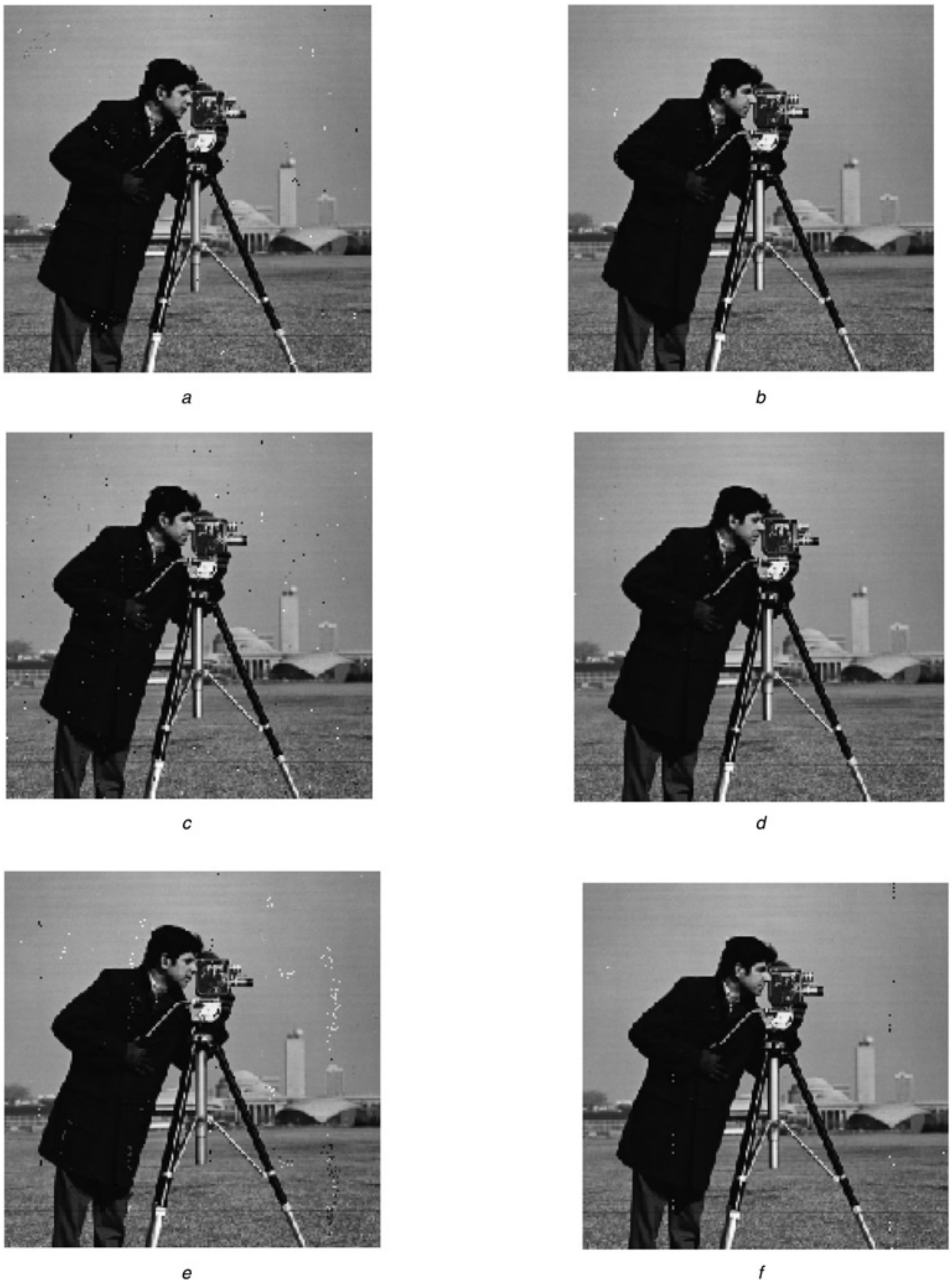

Fig. 13 *Received Cameraman images using the coded and the uncoded LOFDMA systems for different wireless channels, QPSK and SNR = 25 dB*
a Uncoded LOFDMA for SUI3 channel
b Coded LOFDMA for SUI3 channel
c Uncoded LOFDMA for uniform channel
d Coded LOFDMA for uniform channel
e Uncoded LOFDMA for vehicular A channel
f Coded LOFDMA for vehicular A channel

channel is the best as compared with their performance for other wireless channels.

5.3 MSE performance

In this section, several experiments are performed to test and investigate the MSE performance of the received image over the coded and the uncoded OFDMA systems for different wireless channels and different subcarriers mapping schemes when the QPSK and the 16 QAM are used. The obtained MSE values are tabulated in Tables 5–8.

Figs. 8 and 9 indicate the variation of the MSE of the received image with the channel SNR over the uncoded and the coded OFDMA systems, respectively, for different wireless channels and different subcarriers mapping schemes when the 16QAM is used. From these figures, it is clear that the coded IOFDMA system gives the best MSE results as compared with the coded LOFDMA system, regardless of the wireless channel type or the modulation scheme type. The obtained results indicate that the uncoded LOFDMA system provides only better MSE performance than the uncoded IOFDMA system for the vehicular A channel. It is also found that the MSE performance of the IOFDMA system for

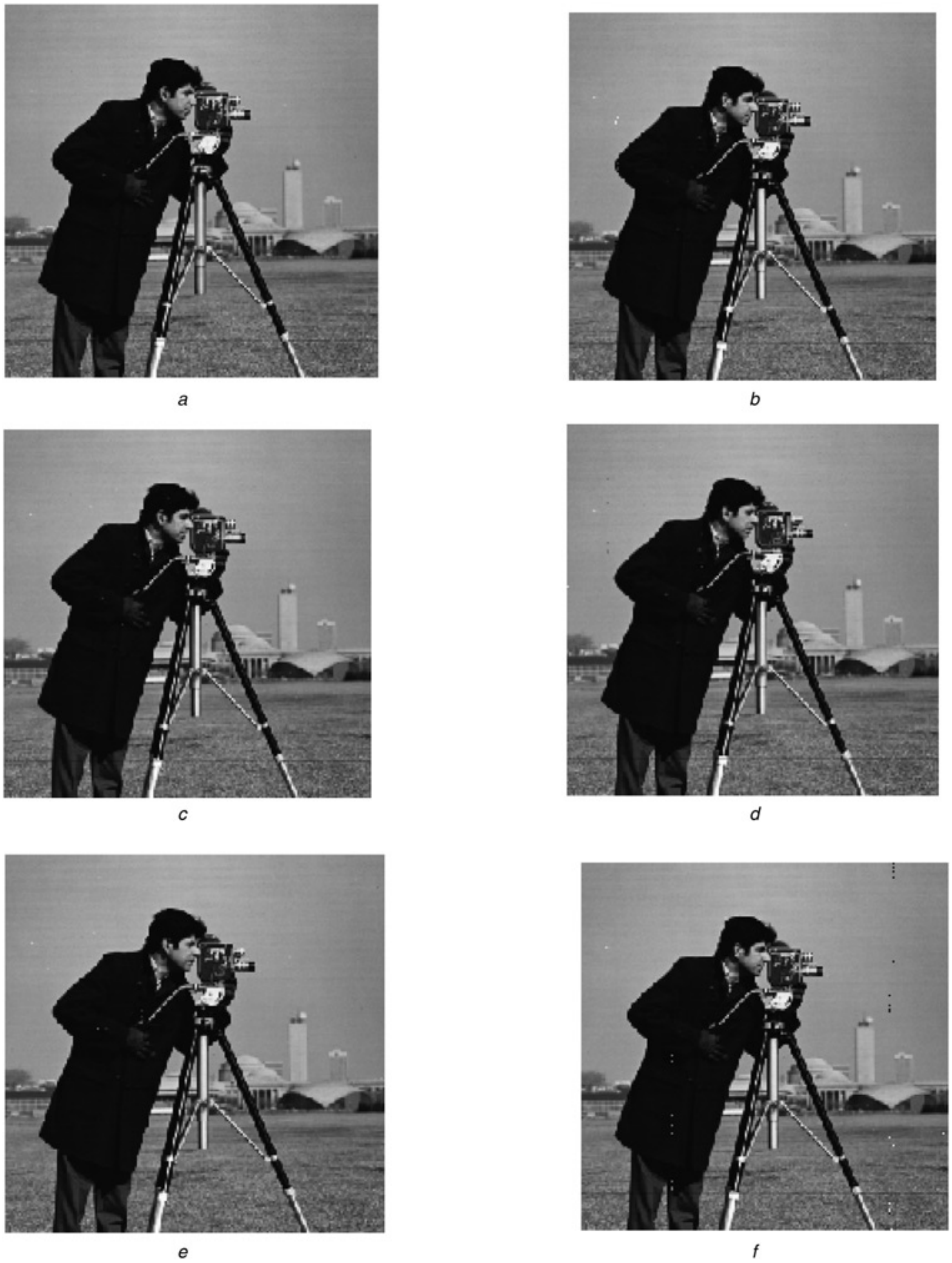

Fig. 14 *Received Cameraman images using the coded IOFDMA and the coded LOFDMA systems for different wireless channels, QPSK and SNR = 25 dB*
a Coded IOFDMA for SUI3 channel
b Coded LOFDMA for SUI3 channel
c Coded IOFDMA for uniform channel
d Coded LOFDMA for uniform channel
e Coded IOFDMA for vehicular A channel
f Coded LOFDMA for vehicular A channel

SUI3 channel is the best as compared with its performance for other wireless channels.

Figs. 10 and 11 show the variation of the MSE with the channel SNR for the image transmission over the uncoded and the coded OFDMA systems, respectively, for different wireless channels. The results reveal the superiority of the coded IOFDMA system to the LOFDMA system.

5.4 *Clarity investigation*

To investigate the clarity of the received images over different wireless channels, the received images at an SNR = 25 dB are selected and shown in Figs. 12–14 when the QPSK is used. Fig. 12 shows the received images of the coded and the uncoded IOFDMA systems over different wireless channels. It is clear that the quality of the received images using the coded IOFDMA system is better than that using the uncoded IOFDMA system.

Fig. 13 shows the received images of the coded and the uncoded LOFDMA systems over different wireless channels. It is clearly seen that adding a coding scheme to the LOFDMA system greatly improves the clarity of the received image for all channels.

In Fig. 14, the received images over the coded IOFDMA system and the coded LOFDMA system are selected and shown for different wireless channels. It is shown that the clarity of the received images over the coded IOFDMA system is better than that over the coded LOFDMA system, especially for the vehicular A channel.

From the obtained results in Figs. 4–14, we can go to a conclusion that the coded OFDMA systems are able to efficiently transmit wireless images over different wireless channels, especially the coded IOFDMA system.

6 Conclusion

In this paper, the issue of wireless images transmission over the coded and the uncoded OFDMA systems has been studied, investigated and evaluated for different subcarriers mapping schemes, different wireless channels and different modulation schemes. The baseband signal model for the OFDMA system has been derived. Simulation results have been shown that the coded IOFDMA system provides better performance than the LOFDMA system, regardless of the wireless channel or the modulation schemes used. Also, results have been shown that the performances of the IOFDMA and the LOFDMA systems for SUI3 channel are better than that for other wireless channels. This indicated that the coded OFDMA systems are able to efficiently transmit images over different wireless communication channels.

7 References

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