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Performance of image transmission over MC-CDMA based on super resolution technique

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Abstract
Multi-carrier code-division-multiple-access (MC-CDMA) is a promising technique to obtain high data rate in wireless communication. Contemplation of medical image transmission for various patient's information using MC-CDMA system through wireless media is discussed. Arnold cat map encryption algorithm is ensured to enhance the image transmission securely. At each mobile station, transmitted bit stream of encrypted images is estimated using minimum-mean-square error (MMSE) algorithm. The picture quality is ensured at the receiver by adopting super resolution through sparse technique. The performance of considered system through stanford channel model specification is illustrated. PSNR metric is also considered for image transmission. From the analysis, it is observed that considered MC-CDMA system with encryption algorithm and sparse based super resolution technique mitigates multi-user interference effects while retaining the quality of individual medical images. Further, it is witnessed that the channel encoded proposed system's performance achieves the promising bit-error-rate for MMSE receiver. Furthermore, from the simulation it is discerned that the computational time for super resolution is minimized using considered sparse technique.

Keywords Arnold cat map (ACM) · Code division multiple access (CDMA) · Integer wavelet transform (IWT) · Orthogonal frequency-division-multiplexing (OFDM) · Rayleigh-fading channel · Super resolution (SR)

1 Introduction

Multi-carrier code division multiple access (MC-CDMA) scheme has been anticipated for the next generation wireless networks owing to its advantages of frequency-diversity, better bandwidth efficiency and high data communication. It combines the advantages of orthogonal frequency division multiplexing and code division multiple access (CDMA). MC-CDMA system has fascinated the research community as the system has high potential to transmit picture, video at high data rate with limited bandwidth irrespective of channel conditions. Multiple-input and multiple-output system can be invoked to obtain higher spectral efficiency. But in the context of downlink communication, the size of the receiver has to be compromised. Further, complex detection algorithm is carried out to nullify the effects of multiple- access-interference (MAI). Furthermore, it has been observed that the desired picture quality can't be obtained at the receiver end due to multi-path channel fading effects. The précised picture quality is essential to study patient information.

While transferring image or video especially a medical reports or medical images, details of the patients are very important and it should be saved from trespassers. To transmit the image securely from trespassers, image has to be encrypted. There are different types of encryptions are available. In this work, arnolds cat map (ACM) is considered. It is an ergodic process and mixing technique. So, for trespassers no-win situation will occur to decrypt them. ACM will shuffle the pixels of the image. The output of the ACM will differ from the given input. Integer wavelet transform (IWT) is taken for compressing the image. The pro of IWT is decompressing (reconstructing) the compressed image is stress-free compared to other compression technique. Resolution and textures are not degraded for the reason that it follows shift and lift procedure.

From the research, it is proved that CDMA [1,2] provides better performance. When it comes to downlink communication, process becomes tedious. Spectral efficiency and

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diversity plays a vital role for downlink communication, when number of user gets increased. To overcome this multicarrier CDMA (MC-CDMA) [3] technique is used. In [4], the authors have analyzed the performance of image transmission with MC-CDMA. In this work, bit error rate (BER) is taken into justification. Multi path fading effect is revealed by space diversity. Comparison of single carrier and multi carrier modulation is evaluated and result has been exposed. Image transmission through wireless medium by interleaving schemes is given [5]. Two interleaving technique are discussed and the authors suggested that for image transmission through wireless medium, MC-CDMA is a promising technique. System performance is discussed with the parameter like PSNR and root mean square error (RMSE). Results exposed that MC-CDMA system affords enhanced performance for image transmission. MC-CDMA consisting of chaotic interleaver with liner minimum mean square error (LMMSE) equalizer system is taken for image transmission [6]. Comparison of LMMSE and zero-forcing (ZF) equalizer is framed and firm up that LMMSE outperforms zero forcing because of its behavior against noise. Performance of coded system is discussed and stated that for downlink (DL) communication MC-CDMA achieves attainable BER [7].

For cancellation of multi-access interference (MAI), discrete sine transform (DST) aided MC-CDMA system is suggested [8]. At the receiver, minimum mean square error (MMSE) is well-thought-out for reckoning the users data initially. They have proposed a new MMSE-PIC (parallel interference cancellation) scheme for eliminating MAI. The measured resulting parameters of this system are BER and PSNR. Image quality level can be increased through JPEG2000 compression technique [9]. When compared to multi-tone CDMA and DS-CDMA, MC-CDMA spreading code is longer. With this as advantage more users can accommodate for transmitting the data (signal). MC-CDMA take over both CDMA and orthogonal frequency division multiplexing (OFDM) features. Image transmission is done through AWGN and also with Rayleigh fading channel [10]. The results have discussed with performance of BER and SNR. Structural similarity index measure (SSIM) is also taken into account for image quality measurement.

In [11], the authors have proposed an algorithm based on IWT-SVD (singular value decomposition). They have considered adaptive Huffman coding and also Graph quantization technique. In order to store an image in digital format, they have considered this technique for secured storage. With this one can achieve better performance with reasonable PSNR. In [12], watermarking scheme is executed by radius-weighted mean (RWM) based on IWT. An invisible watermarking algorithm is proposed in [13]. The authors have defined how IWT-DCT achieves better robustness for statistical attacks than DWT-DCT. With the increase in robustness secret embedding scheme can be performed well. They have also compared the results for DWT-DCT and IWT-DCT. Yang et al. [14] explains in which way IWT works for an image specifically for business planning and control system (BPCS) images. The authors have considered Stenography technique. But for this payload capacity and visible attacks will be high. So, to improve robustness and payload capacity IWT based BPCS image has been taken.

Super resolution is engaged for extracting the details from the image. Many techniques are there for image super resolution. Sparse is one among them. Sparse can be represented as a linear combination of elements termed as atoms. Sparse is a latest and ongoing research technique for super resolution. This technique is carried out with the help of dictionary formation. Dictionary formation is carried out by different types of methods. Online dictionary formation is one among them.

Sparse representation with couple dictionary is one of the best techniques for super resolution. Couple dictionary is formed by framing low resolution (LR) and high resolution (HR) patches [15]. LR dictionary and HR dictionary is constructed by forming patches from images. Both the dictionaries are coupled, this coupled dictionary and sparse coefficient works together for super resolution. In [16], online dictionary learning is proposed. This technique consists of two stages, first dictionary will be generated with sparse coefficients and then it will be updated with the lasted sparse coefficients. Dictionary learning for sparse representation in NP-hard is evaluated [17]. Instead of K-SVD based dictionary, a new algorithm is proposed and it is compared with K-SVD. Single LR image is taken as an input [18]. This is considered as a compression of HR image. Training set consists of different set of images, so the values of dictionary will be high, so what happens with this high values details will be extracted. By this dictionary, HR image is framed with the help of sparse coefficient. For this system, over-complete dictionary [19] is chosen. In [20], dictionary is trained not with the set of random image it is trained with the input image itself. By doing so, details from the same input is extracted for both LR and HR dictionary. To construct dictionary K-SVD algorithm is engaged. Sparse representation is constructed by orthogonal matching pursuit (OMP). Now, by making sparse coefficients persistent and dictionary is restructured. With this restructured dictionary, sparse coefficient is updated [20]. Until it reaches an optimal value both will be updated. In this work, an encryption algorithm is used to transfer the image in a secured manner. To shun burst error in wireless transmission and fight the multi-path fading effects interleaver is taken into account. To increase the bandwidth of the transmission MC-CDMA is considered. With super resolution technique, details form the received image are extracted. By frequency domain equalizer, performance of the system gets benefited.

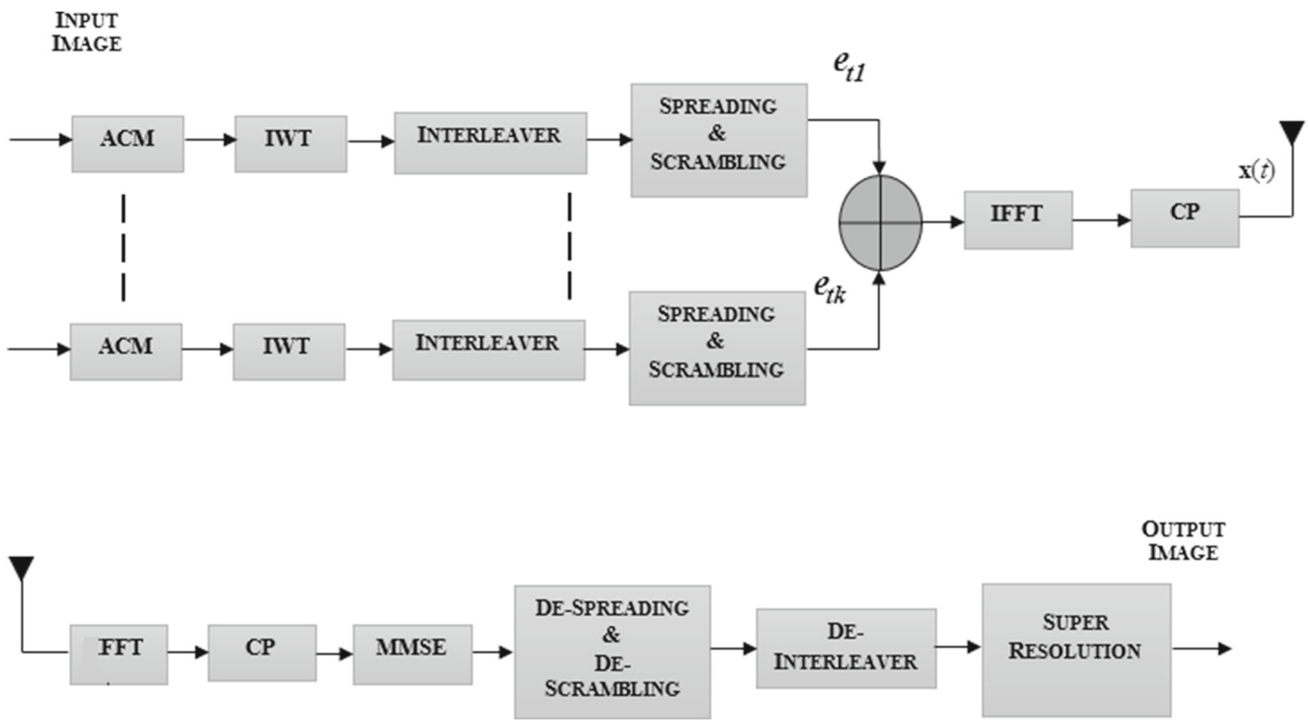

Fig. 1 Transmitter and receiver structure of MC-CDMA with super-resolution

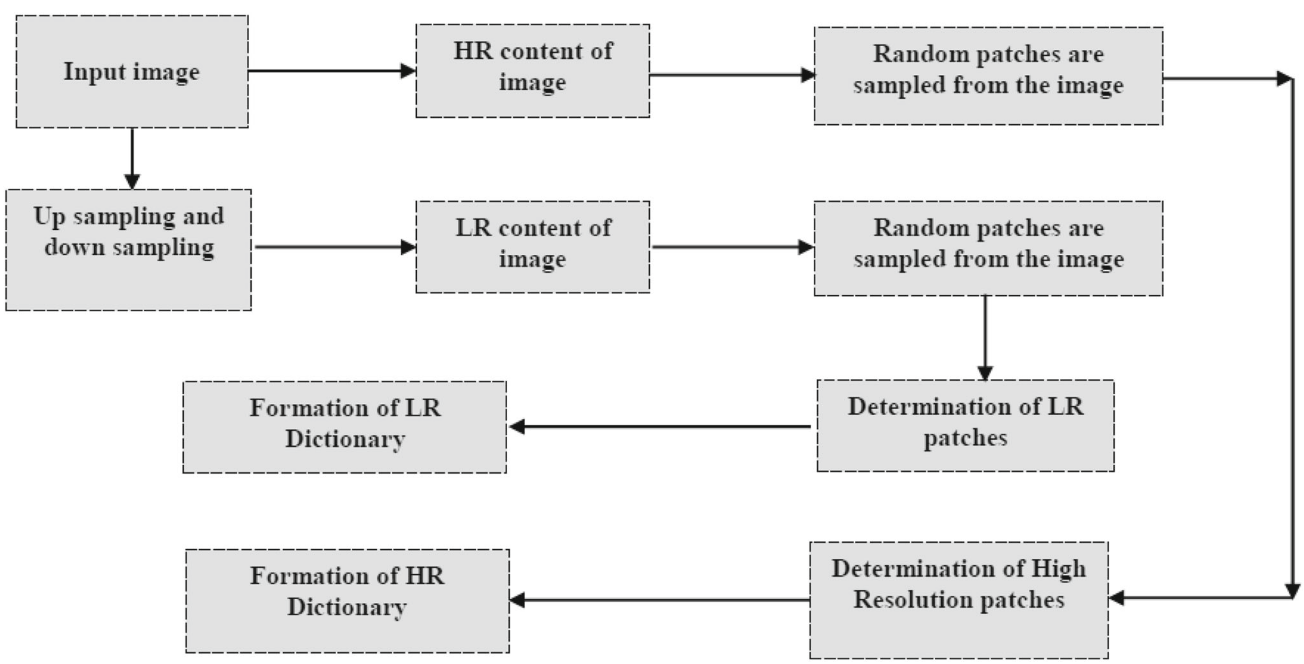

Fig. 2 Dictionary formation

The proposed system consists of: ACM, IWT, random interleaver, spreader & scrambling, OFDM. At the receiver side frequency domain equalizer (FDE) to estimate the data.

2 System model

Single cell multi-user MC-CDMA system can accommodated K DL users. Each DL user is equipped with N_r receive antenna and base station (BS) is equipped with N_t transmit antenna. Each user medical image is encrypted with

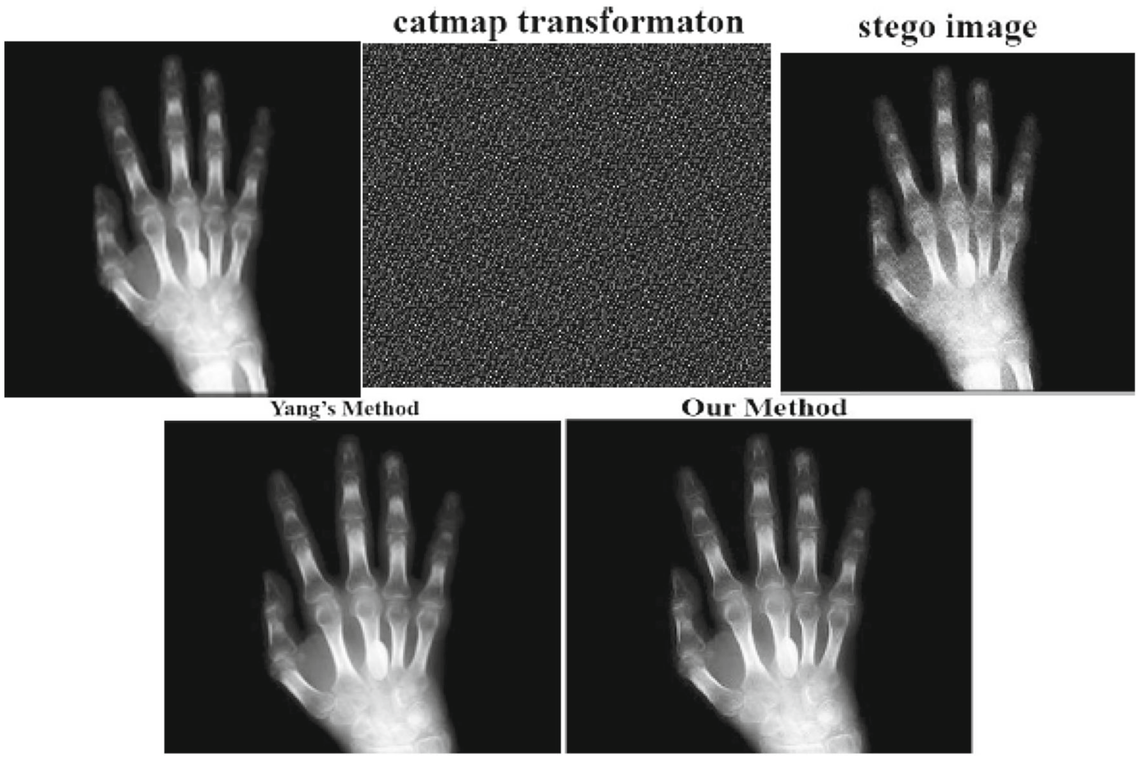

Fig. 3 Image of a left hand with 256×256 dimensional image. Yang's and our method is taken for super resolution for the dimension of 512×512

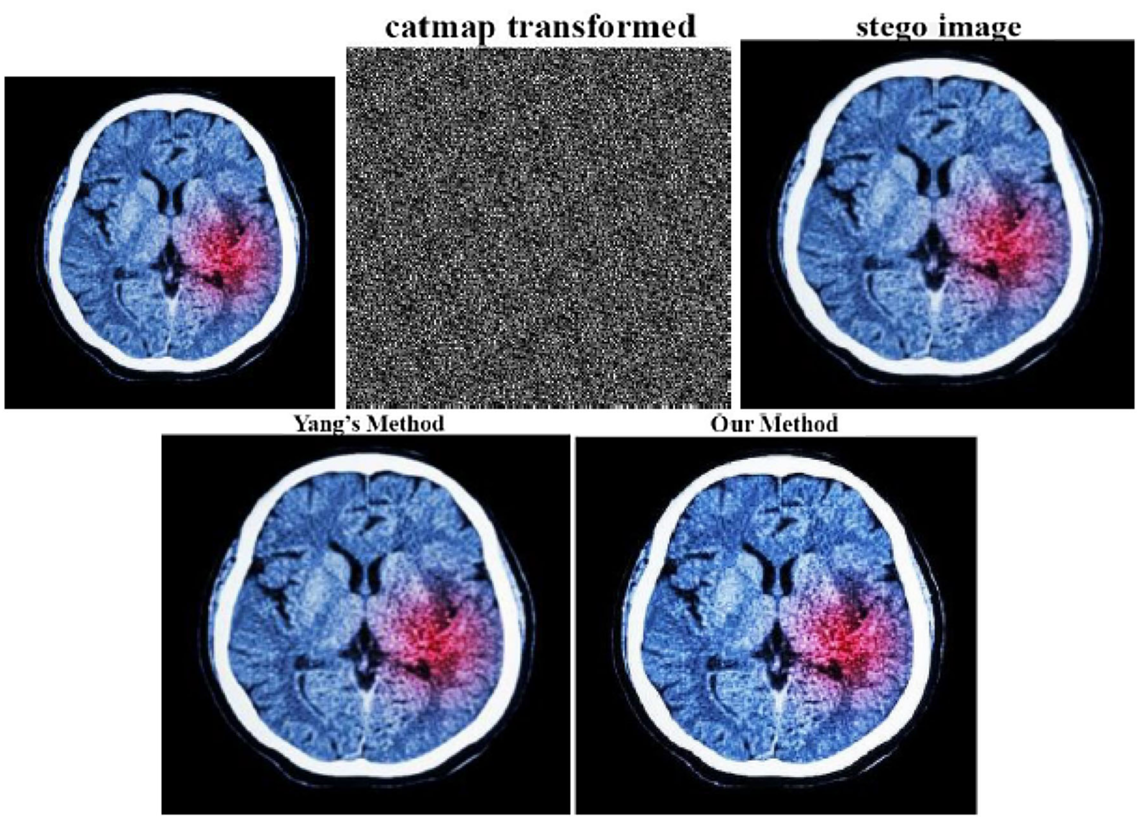

Fig. 4 Image of brain with 256×256 dimensional. Yang's and our method is taken for super resolution for the dimension of 512×512

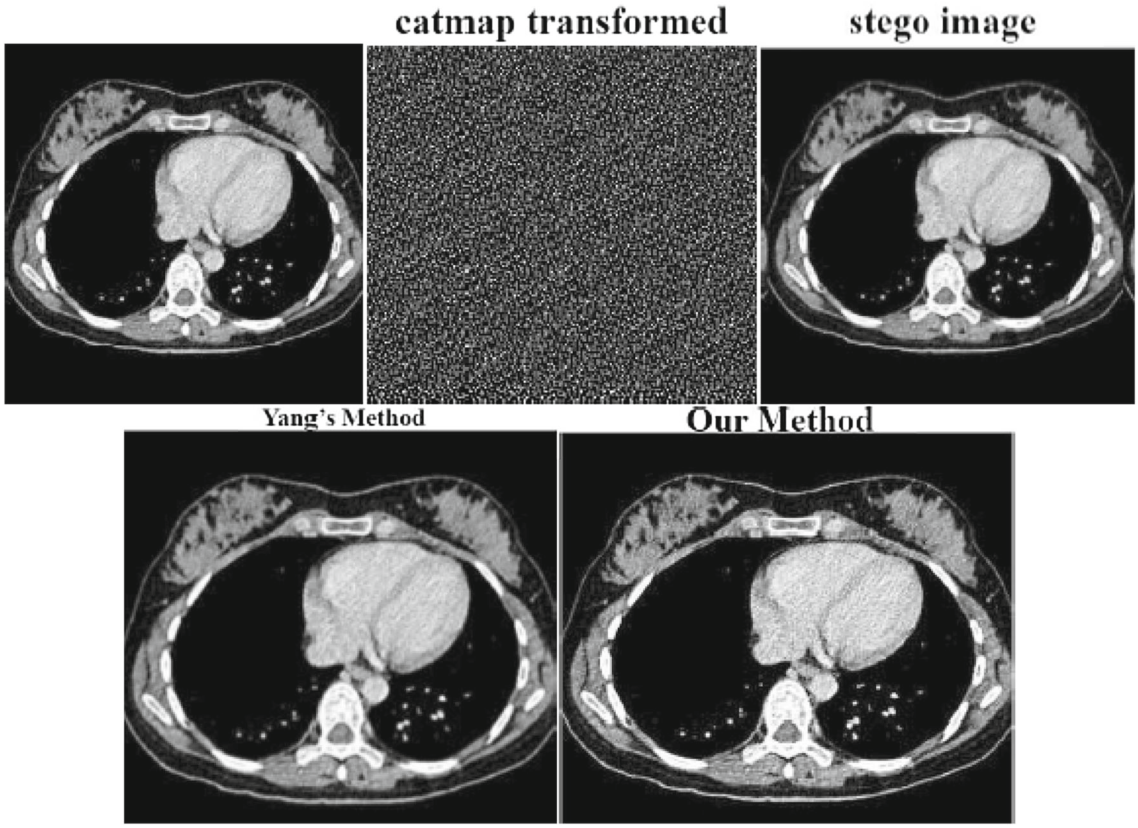

Fig. 5 Image of chest with 256×256 dimensional. Yang's and our method is taken for super resolution for the dimension of 512×512

ACM. Then the encrypted data is compressed with IWT. Consequently, the compressed data is interleaved by desired interleaver to overcome the problem of burst errors. Then the interleaved information of image is spread by user-specific spreader. Now all the encrypted, compressed and spread sequences are summed. Now the sum sequence are multi-carrier modulated using inverse fast fourier transform block. Finally cyclic prefix (CP) are added to obviate the inter-carrier-interference effects. Figure 1 shows the structure of transmitter and receiver of MC-CDMA.

The mathematical description of transmitted sequence is explained as follows.

For the kth user the input data will be $\boldsymbol{i_k}$, it has bit data stream of m

$$\boldsymbol{i_k} = \left[\boldsymbol{i_k^0}, \boldsymbol{i_k^1}, \ldots, \boldsymbol{i_k^m}\right]^{\boldsymbol{T}} \quad \boldsymbol{k = 0, 1, \ldots, K} \tag{1}$$

Now, $\boldsymbol{i_k}$ is encoded and this signal is represented as $\boldsymbol{b}_k$

$$\boldsymbol{b}_k = \left[\boldsymbol{b_k^1}, \boldsymbol{b_k^2}, \ldots, \boldsymbol{b_k^s}\right]^{\boldsymbol{T}}, k = 1, 2, \ldots, K \tag{2}$$

$\boldsymbol{b}_k$ is the encoded bit stream of kth user, where $s = 2m$.

This signal will be interleaved. After that, signal will be spread and scrambled. Spreader has both time (T) and frequency (T) domain (D) so it is called as time frequency domain (TFD)

The FD spread code is denoted by $\boldsymbol{M_{fk}}$, which can be described as

$$\boldsymbol{m}_{fk} = \left[m_f^1, m_f^2, \ldots, m_f^s\right], \quad k = 1, 2, \ldots, K \tag{3}$$

The length of the spreading code be $\boldsymbol{L}$

$$\boldsymbol{M_{fk}} = \frac{1}{\boldsymbol{L}} \begin{bmatrix} m_{f,1}^1 & m_{f,2}^1 & \cdot & \cdot & \cdot & m_{f,s}^1 \\ m_{f,1}^2 & m_{f,2}^2 & \cdot & \cdot & \cdot & m_{f,s}^2 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ m_{f,L}^1 & m_{f,L}^2 & \cdot & \cdot & \cdot & m_{f,L}^s \end{bmatrix} \tag{4}$$

FD spread with the length vector of $\boldsymbol{L}$ is represented as $\boldsymbol{e_{fk}}$ where

$$\boldsymbol{e}_{fk} = \boldsymbol{M}_{fk}\boldsymbol{b}_k, \quad k = 1, 2, 3, \ldots, K. \tag{5}$$

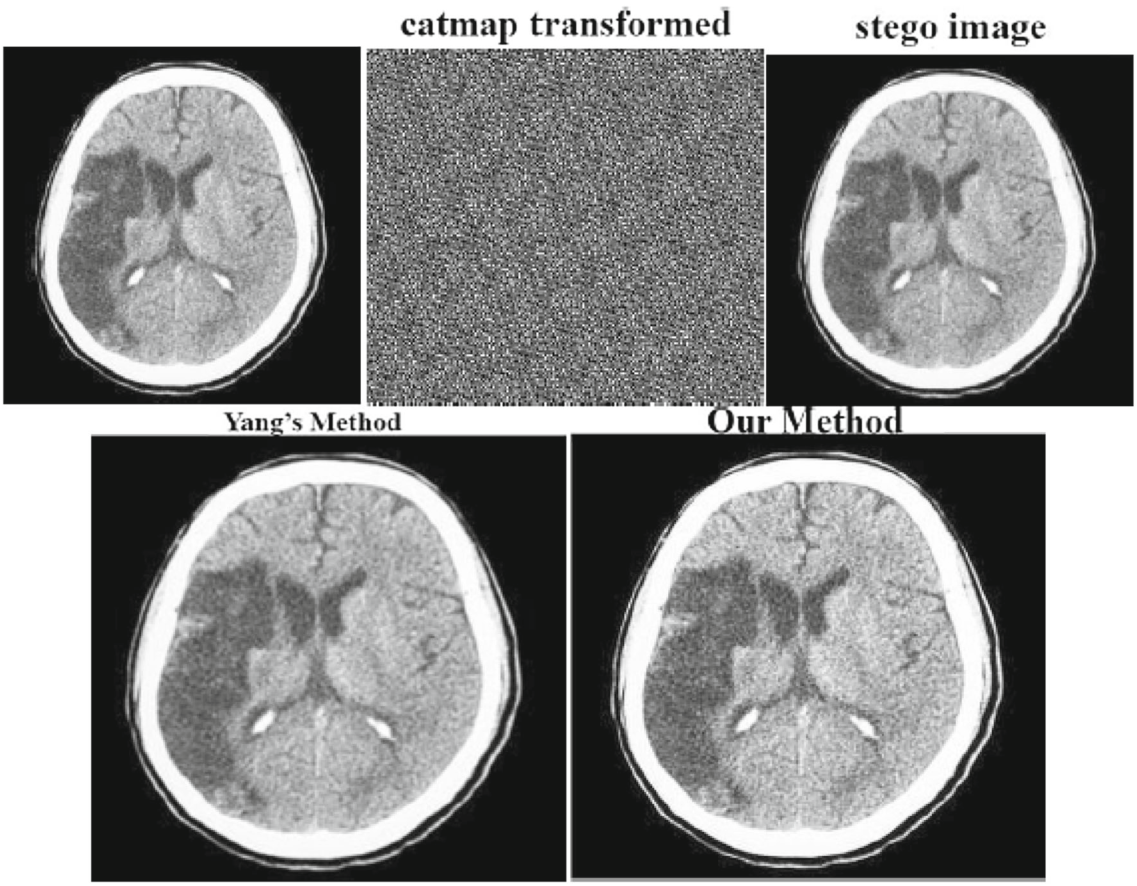

Fig. 6 Image of brain with 256×256 dimensional. Yang's and our method is taken for super resolution for the dimension of 512×512

Now, TD spreading code for kth user is denoted as $\boldsymbol{t}_k$ with the length $\boldsymbol{Q}$. It is expected that $\boldsymbol{LQ} \geq K$.

$$\boldsymbol{t}_k = \frac{1}{\boldsymbol{Q}}\left[t_{k0}, t_{k1}, \ldots, t_{k(Q-1)}\right]^T \tag{6}$$

$$\begin{aligned}\boldsymbol{e}_{tk} &= (\boldsymbol{I}_L \otimes \boldsymbol{t}_k)\boldsymbol{e}_{fk} \\ &= (\boldsymbol{I}_L \otimes \boldsymbol{t}_k)\boldsymbol{M}_{fk}\boldsymbol{b}_k, \quad k = 1, 2, 3, \ldots, K\end{aligned} \tag{7}$$

Now in compact form, this $\boldsymbol{e}_{tk}$ is given by

$$\boldsymbol{e}_{tk} = \boldsymbol{M}_k\boldsymbol{b}_k, \quad k = 1, 2, 3, \ldots, K \tag{8}$$

where $\boldsymbol{M}_k = (\boldsymbol{I}_L \otimes \boldsymbol{t}_k)M_{fk}, \boldsymbol{LQ} \times s$ component matrix. (9)

This is conveyed as

$$\boldsymbol{e}_t = \sum_{k-1}^{K} \boldsymbol{M}_k\boldsymbol{b}_k \tag{10}$$

$$= \boldsymbol{Mb} \tag{11}$$

where

$$\boldsymbol{M} = [\boldsymbol{M}_1, \boldsymbol{M}_2, \ldots, \boldsymbol{M}_K], \boldsymbol{LQ} \times Ks \text{ Component matrix} \tag{12}$$

The signal from IFFT and CP is transmitted to the wireless channel. $\mathbf{x}^k(t)$ is the sequence transmitted to the channel. Inter-symbol-interference effect is reduced by CP.

$$\boldsymbol{rs} = \boldsymbol{Hx} + \boldsymbol{n} \tag{13}$$

$\boldsymbol{H}$ is the channel matrix whose dimension is $\boldsymbol{LQ} \times \boldsymbol{LQ}$. Noise vector $\boldsymbol{n}$ with $\boldsymbol{LQ}$ length. $\boldsymbol{rs}$ is received vector which is served to the detector for estimating the transmitted data.

MMSE algorithm is engaged to estimate the received data. The general equation of MMSE equalizer is

$$\boldsymbol{y} = \left(\boldsymbol{H}^{\mathrm{H}}\boldsymbol{H} + \frac{1}{\mathrm{SNR}}\boldsymbol{I}\right)^{-1}\boldsymbol{H}^{\mathrm{H}} \tag{14}$$

After estimating the data, image is recovered. Now, the recovered image is given to super resolution to carry out super resolution for received image.

3 Dictionary learning

Reconstruction of an image with high dimension will lead to super resolution image. For reconstruction of an image

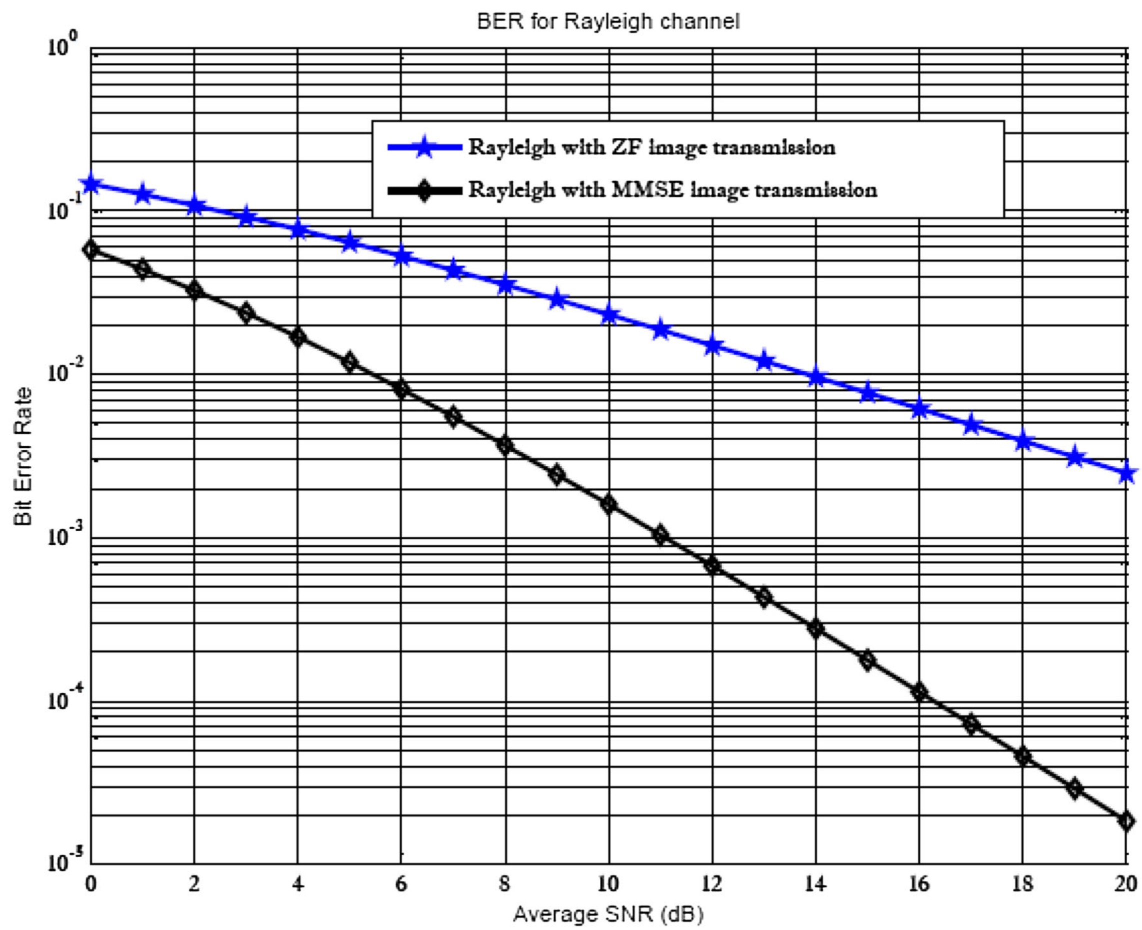

Fig. 7 Performance of MC-CDMA system for Rayleigh channel using ZF detector and MMSE detector

two major component is necessary. Those two components are represented by $\boldsymbol{D_s}$ and $\boldsymbol{\alpha_s}$. $\boldsymbol{D_s}$ is Dictionary and $\boldsymbol{\alpha_s}$ is sparse coefficient. $\boldsymbol{D_s}$ is taken as an over complete dictionary. Construction of the dictionary is discussed in [20].

Dictionary learning [20] is done by (i) making $\boldsymbol{D_s}$ static and restructuring $\boldsymbol{\alpha_s}$ then making (ii) $\boldsymbol{\alpha_s}$ stationary, $\boldsymbol{D_s}$ is restructured. In [19], separate training set is occupied for learning dictionary. In this work (Fig. 2), dictionary is constructed with the same image by online dictionary learning.

Dictionary, $\boldsymbol{D_s} \in \mathbb{R}^{n \times K}$ where k is termed as atoms and this has to be $k >> n$. The received signal is

$$\boldsymbol{D_s} = \arg\min_{\boldsymbol{D_s},\boldsymbol{\alpha_s}} \|X - \boldsymbol{D_s}\boldsymbol{\alpha_s}\|_2^2 + \lambda \|\boldsymbol{\alpha_s}\|_1$$
$$\text{s.t. } \|\boldsymbol{D_s}_i\|_2^2 \leq 1,\ \ i = 1, 2, \ldots, K \tag{15}$$

where
norm ℓ_2 and ℓ_1 is for removing scaling ambiguity and enforce sparsity,

3.1 Pseudo algorithm for dictionary learning

Step 1: $\boldsymbol{D_s}$ Initialize with Gaussian random matrix, and normalize each column

Step 2: $\boldsymbol{D_s}$ remains stationary, $\boldsymbol{\alpha_s}$ is restructured.

$$\boldsymbol{\alpha_s} = \arg\min_{\boldsymbol{\alpha_s}} \|X - \boldsymbol{D_s}\boldsymbol{\alpha_s}\|_2^2 + \lambda \|Z\|_1 \tag{16}$$

Step 3: $\boldsymbol{\alpha_s}$ stands static, until $\boldsymbol{D_s}$ gets efficient.

$$\boldsymbol{D_s} = \arg\min_{\boldsymbol{D_s}} \|X - \boldsymbol{D_s}\boldsymbol{\alpha_s}\|_2^2$$
$$s.t. \|\boldsymbol{D_s}_i\|_2^2 \leq 1, i = 1, 2, \ldots, K \tag{17}$$

Step 4: Repeat until it converge.

4 Sparse coefficient

After building dictionary, sparse coefficient will be updated. orthogonal matching pursuit (OMP) algorithm is used in finding the sparsity matrix. Super resolution will be done

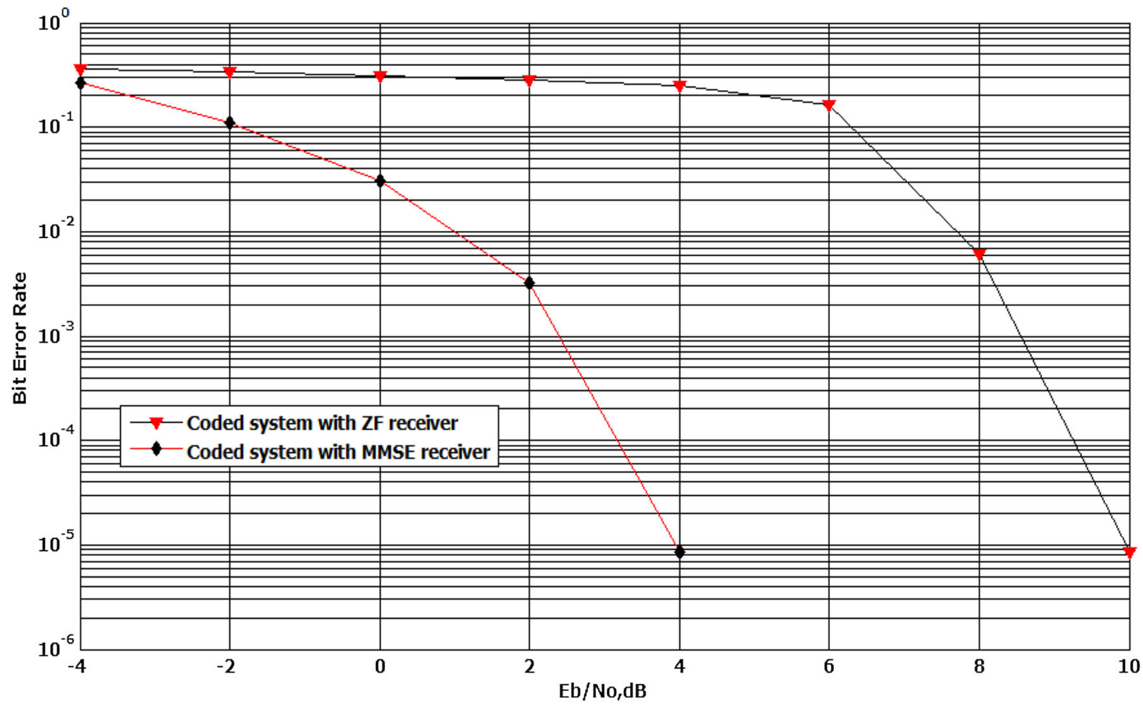

Fig. 8 Performance comparison of coded MC-CDMA system using MMSE receiver and ZF receiver

by either reconstruction constraint or sparsity prior. Stipulation of HR image from LR image is called as reconstruction constraint. If LR image patch is considered for sparse representation, then with sparse technique HR patch is generated. This is for Sparsity prior. For reconstruction constraint, input image has to be downsampled and blurring factor has to be added [19].

$$Y = \Phi \Lambda X \tag{18}$$

Φ is the sampling factor for super resolution. Λ is blurring factor. X is the sparse and dictionary [20].

5 Results and discussions

Medical images like X-Ray, MRI and CT scanned images are taken as an input image. These images are encrypted and the encrypted images are shown as a “cat map transformation”. After that stego image of an input is given. Proposed method is compared with Yang’s method. It clearly shows that the proposed method is good for Super Resolution.

In Figs. 3, 4, 5, 6 medical image is taken as input. Input image is with the dimension of 256 × 256. This is encrypted with ACM algorithm and the transformation is shown in the figure. Then stego image is also attached in the figure. At the receiver, all this process is reversed. Now, the obtained image i.e. received image is taken for Super Resolution. By, changing its dimension from 256× 256 to 512× 512, data’s may get neglected. So, to avoid that, sparse recovery technique is addressed. With this technique, super resolution can be achieved without data losses.

Table 1 Psnr value

Input image	Yang’s method (dB)	Proposed method (dB)
Left Hand	34.890374	36.831495
Brain (colored)	28.053510	30.042801
Chest (dB)	27.759770	29.589260
Brain (dB)	24.796936	25.274548

Comparison of Yang’s method and proposed method is equipped. It clearly shows that proposed method outperforms Yang’s method. For different scanned images, this technique is addressed and the results are given in upcoming figures. Comparison plot for uncoded MC-CDMA system considering ZF and MMSE receivers is given in Fig. 7. The curve shows that MMSE detector outperform ZF detector by means of low SNR.

In Fig. 8, the performance of ZF receiver and MMSE receiver for coded system is compared. The figure illustrates that for the SNR of 3 dB, achieved BER is approximately 10^{-4} for MMSE receiver which is reasonable for image transmission. The PSNR values from Table 1 shows how the proposed method outperforms the conventional super-resolution technique.

6 Conclusion

In this work, secured transmission of image with MC-CDMA is proposed. Spectral efficiency is effectively enhanced by implementing multi-carrier system. System has ensured the security of medical image transmission over wireless media using encryption algorithm while retaining high picture quality using Super Resolution technique. The performance evaluation in terms of BER for system analysis and PSNR for medical image quality metric is presented. Considered MC-CDMA with coded system obtain better BER with less SNR for MMSE receiver while obtaining higher value of PSNR using super resolution technique when transmitting through frequency-selective channel is demonstrated.

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