

Performance Analysis of Wideband MC-CDMA for Wavelet Video with Multilevel UEP Codes over Fading Channels

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Abstract: - Performance analysis of multilevel unequal error protection (UEP) codes with wavelet video compression for wideband multicarrier code division multiple access (MC-CDMA) and Rake receivers over additive white Gaussian noise (AWGN) and Rayleigh fading channels are achieved and evaluated. Wavelets possess a dominant method and high quality for compressing video sequence. A spatially scalable video coding framework of MPEG2 in which motion correspondences between successive video frames is utilized in the wavelet transform domain. The proposed algorithms of the embedded zero-tree wavelet (EZW) coder and the two-dimensional wavelet packet transform (2-D WPT) are investigated. The introduced system of wideband MC-CDMA and Rake receivers is operated for multipath problems. Each Rake receiver is provided for each carrier of MC-CDMA and each level of UEP codes. The wideband is carried with encoded data when transmitting through the AWGN and Rayleigh fading channels.

Key-Words: - Multicarrier Code Division Multiple Access, Multilevel Unequal Error Protection Codes, Rake Receiver, Embedded Zero-Tree Wavelet Transform, Two Dimensional Wavelet Packet Transform, Additive White Gaussian Noise, Rayleigh Fading Channel.

1 Introduction

Wideband MC-CDMA system divides the system bandwidth into several equal narrow subbands that are used to transmit multiple signal waveforms in parallel. A Rake receiver is provided for each subcarrier and the receiver combines the outputs with a maximal ratio combiner. Wideband MC-CDMA technique has received a great deal of attention recently. This is because it can get such advantages as bandwidth efficiency, frequency diversity, lower speed parallel type of signalling processing, and interference rejection capability in high data rate transmission. MC-CDMA system is known to be robust to multipath fading and narrowband interference. In wideband MC-CDMA system, the energy of each information symbol is spread over several subcarriers, which leads to a diversity gain in a broadband fading channel. Wavelet theory treats both the continuous and discrete time cases. The introduction of the embedded zero-tree concept for wavelet-based video compression has generated a significant improvement in performance compared to previous video coding methods [1].

Multilevel unequal error protection and multilevel Rake receivers in wideband MC-CDMA system for different sets of bits in a transmitted symbol over AWGN and Rayleigh fading channels is presented in coding scheme. The wideband is brought with transmitted data when passing through the AWGN and Rayleigh fading channels. The proposed scheme accomplishes multilevel UEP by encoding the data according to the significance of the information and switching between eight codes and eight Rake receivers in wideband MC-CDMA system. The scheme uses the different pseudo-noise (PN) codes of digital matched filter (DMF) synchronizer to make up eight levels of UEP codes and eight levels of Rake receivers in wideband MC-CDMA system. The quality of video sequence increases with enhancing levels of UEP codes. Wavelet video with multilevel UEP codes in wideband MC-CDMA and Rake receiver obtains higher peak signal to noise ratio (PSNR) than wavelet video with multilevel UEP codes in W-CDMA system and Rake receiver [2].

2 Wideband MC-CDMA for Wavelet Video with Multilevel UEP Codes and Rake Receivers over AWGN and Rayleigh Fading Channels

Multilevel unequal error protection codes and Rake receivers in wideband MC-CDMA system with wavelet video compression over AWGN and Rayleigh fading channels are analyzed. Figure 1 illustrates the block diagram of multilevel UEP codes and Rake receivers for wavelet video transmission in wideband MC-CDMA system over AWGN and Rayleigh fading channels Encoder. Figure 2 shows the block diagram of multilevel UEP codes and Rake receivers for wavelet video transmission in wideband MC-CDMA system over AWGN and Rayleigh fading channels Decoder.

2.1 Wideband MC-CDMA System

2.1.1 Transmitter Model

Wideband MC-CDMA transmitter allocates the original data stream over different subcarriers using a given spreading code. The MC-CDMA is a digital modulation technique where a single data symbol is transmitted at multiple narrowband subcarriers with each subcarrier encoded with a phase offset of 0 or π based on a spreading sequence. This modulation scheme is also a multiple access technique in the sense that different users will use the same set of subcarriers but with a different spreading sequence that is orthogonal to the sequence of all other users.

Let $\varphi = 2\pi \frac{Q}{T_b} t$. The MC-CDMA signal at the m -th transmitter can be represented as

$$g_m(t) = \sum_{k=-\infty}^{+\infty} \sum_{i=0}^{N-1} \{c_m[i] a_m[k] pT_b(t - kT_b)\} \cdot \cos\left(2\pi f_c t + 2\pi i \frac{Q}{T_b} t\right) \quad (1)$$

where $c_m[i]$ is a chip from the m -th spreading sequence of length N , $a_m[k]$ is the k -th input data symbol for the m -th user, pT_b is a unit amplitude pulse that is non-zero in the interval of $[0, T_b]$, f_c is a carrier frequency, and Q is the number of subcarriers. Figure 3 illustrates the transmitter in the wideband MC-CDMA system [3].

2.1.2 Receiver Model

Single user direct sequence CDMA Rake receiver includes multiple correlators; each synchronized to a different resolvable path in the received composite signal. Assuming there are M active users and the channel is noiseless, the received signal is

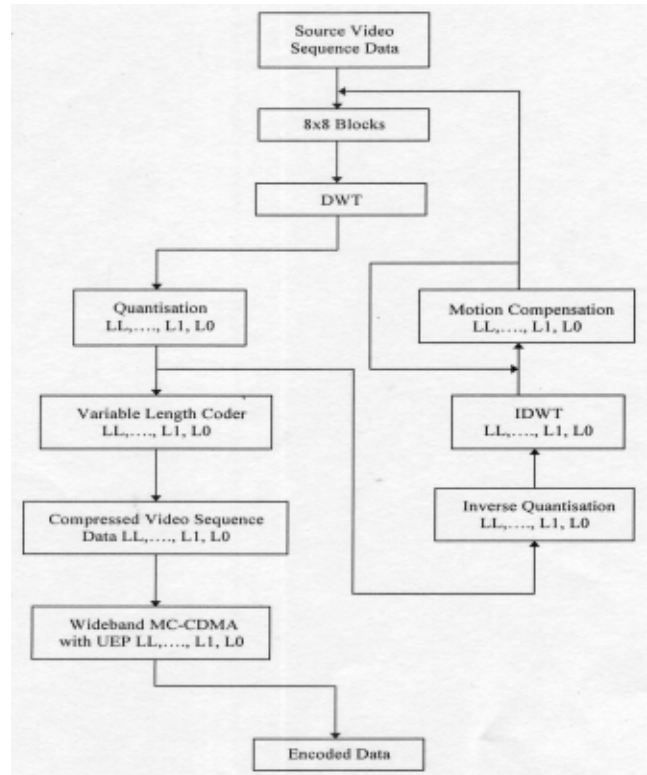


Fig. 1 Block Diagram of Multilevel UEP Codes and Rake receivers for Wavelet Video Transmission in Wideband MC-CDMA system over AWGN and Rayleigh fading channels Encoder

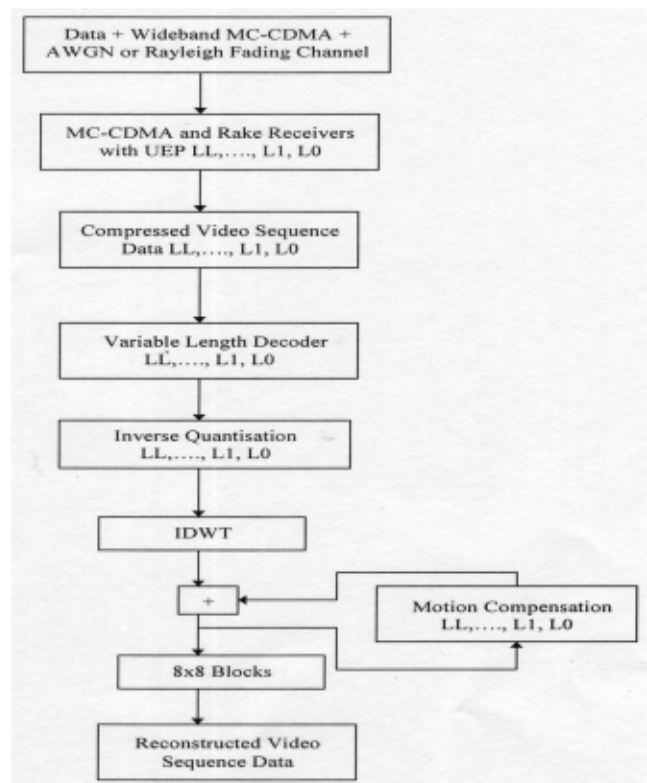


Fig. 2 Block Diagram of Multilevel UEP Codes and Rake receivers for Wavelet Video Transmission in Wideband MC-CDMA system over AWGN and Rayleigh fading channels Decoder

$$h(t) = \sum_{k=-\infty}^{+\infty} \sum_{m=0}^{M-1} \sum_{i=0}^{N-1} \left\{ \frac{c_m[i]a_m[k]}{\sqrt{T_b}} \phi\left(\frac{t-kT_b}{T_b}\right) + \frac{c_m[i]b_m[k]}{\sqrt{T_b}} \psi\left(\frac{t-kT_b}{T_b}\right) \right\} \cdot \cos\left(2\pi f_c t + 2\pi i \frac{Q}{T_b} t\right) \quad (2)$$

Assume that $m=0$ corresponds to the desired signal. In the 0 -th receiver, there are N passband filters with the i -th one corresponding to the frequency f_c+iQ/T_b , so the received signal $h(t)$ is first converted back to the baseband signal in each i -th branch of the receiver:

$$h_i(t) = \sum_{k=-\infty}^{+\infty} \sum_{m=0}^{M-1} \left\{ \frac{c_m[i]a_m[k]}{\sqrt{T_b}} \phi\left(\frac{t-kT_b}{T_b}\right) + \frac{c_m[i]b_m[k]}{\sqrt{T_b}} \psi\left(\frac{t-kT_b}{T_b}\right) \right\} \quad (3)$$

Now the signal $h_i(t)$ is filtered separately by digital matched filters with the impulse responses $\phi\left(\frac{KT_b-t}{T_b}\right)$ and $\psi\left(\frac{KT_b-t}{T_b}\right)$ respectively, where

$T=KT_b$ is the duration of $\phi(t/T_b)$ and $\psi(t/T_b)$, and the filter outputs are sampled at $t=nT_b$, which result in the following variables

$$x_i(nT_b) = h_i(t) * T_b^{-1/2} \phi\left(\frac{KT_b-t}{T_b}\right) \Big|_{t=nT_b}$$

$$x_i(nT_b) = \sum_{m=0}^{M-1} c_m[i]a_m[n-K]$$

and

$$w_i(nT_b) = h_i(t) * T_b^{-1/2} \psi\left(\frac{KT_b-t}{T_b}\right) \Big|_{t=nT_b}$$

$$w_i(nT_b) = \sum_{m=0}^{M-1} c_m[i]b_m[n-K]$$

then $x_i(nT_b)$ is multiplied by $c_o[i]$, and taking summation over i gives

$$d(n) = \sum_{i=0}^{N-1} c_o[i]x_i(nT_b) = a_o[n-K] \quad (4)$$

Similarly we have

$$e(n) = \sum_{i=0}^{N-1} c_o[i]w_i(nT_b) = b_o[n-K] \quad (5)$$

Therefore, we recover the data symbols $a_o[n-K]$ and $b_o[n-K]$ for $n=0, \pm 1, \pm 2, \dots$ [3]. The receiver in the wideband MC-CDMA system is demonstrated in figure 4.

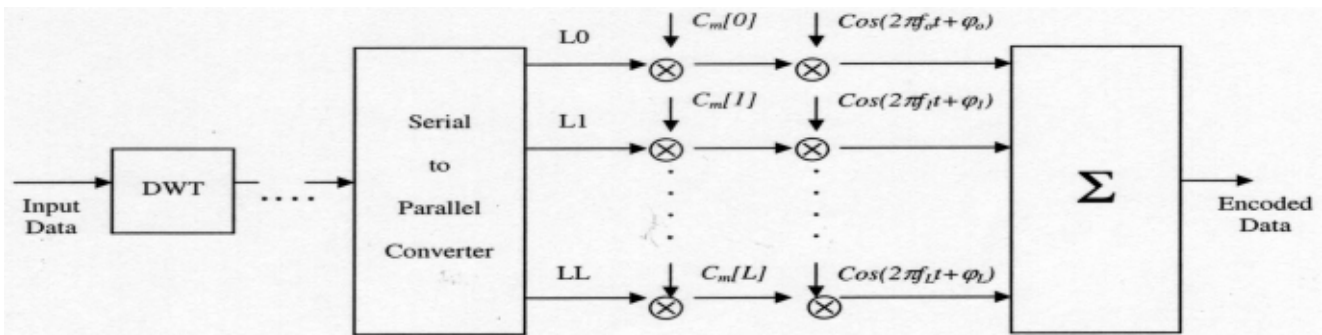


Fig. 3 Transmitter in the wideband MC-CDMA system

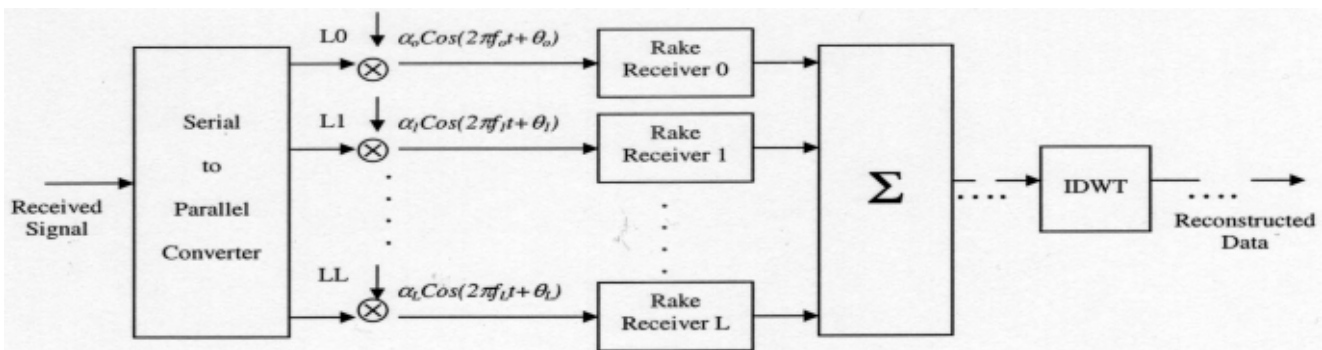


Fig. 4 Receiver in the wideband MC-CDMA system

2.2 Rake Receiver for Wideband MC-CDMA

Rake receiver is a diversity receiver designed expressly to equalize the effect of multipath. A signal propagates from transmitter to receiver over multiple paths with multiple different time delays can be resolved into separately fading signals by cross-correlating the received signal with multiple time shifted versions of the pseudorandom sequence. The structure of Rake receiver is illustrated in figure 5 [4].

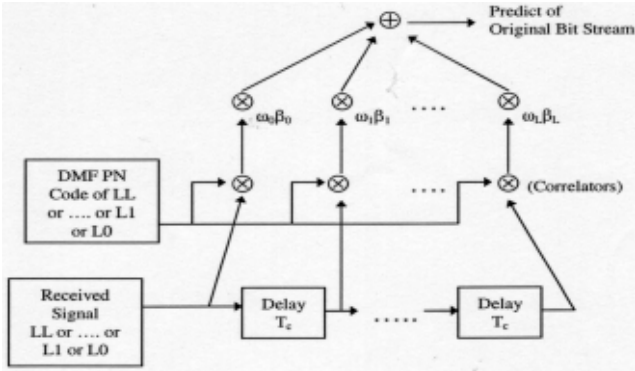


Fig. 5 Structure of Rake Receiver

2.3 Embedded Zero-Tree Wavelet Coding

Embedded zero-tree wavelet algorithm exploits the important hypothesis. After the embedded zero-tree wavelet transform (EZWT) of a video sequence, the important data is concentrated in the upper left corner that corresponds to the low frequency range of the wavelet coefficients. The remaining data in the high frequency domain is not as significant. A wavelet coefficient tree is defined as the set of coefficients from different bands that represent the same spatial region in video sequence. A wavelet video sequence representation can be thought as a tree structured spatial set of coefficients. Figure 6 illustrates three levels wavelet decomposition of the video sequence. The lowest frequency band of the decomposition is represented by the root nodes (top left) of the tree (LL₃), the highest frequency bands by the leaf nodes (bottom right) of the tree, and each parent node represents a lower frequency component than its children. Except for a root node, which has only three children nodes, each parent node has four children nodes, the 2x2 region of the same spatial location in the immediately higher frequency band [5].

2.4 Two-Dimensional Wavelet Packet Transform

Two-dimensional wavelet packet transform of a video sequence is composed of low frequency components and high frequency components. Low frequency components give video sequence its foundation, or character, while high frequency components give video sequence its fine details or nuances. Figure 7 illustrates the wavelet decomposition of the two-dimensional wavelet packet

transform for the video sequence. The output from the low pass filter produces an approximation of the signal based on the low frequency detail coefficients. The output from the high pass filter produces the fine details of the video sequence, that when put together will form the original video sequence. However, these values are down-sampled. This means that the output of either filter has every second coefficient dropped. This effectively halves the number of coefficients from each filter. Nevertheless, at the reconstruction side, this can produce some distortion, but if the filters are chosen carefully then perfect reconstruction can occur. One of the aspects that make wavelets so suited to video coding is that the filtering process can be iterated repeatedly, allowing us to break up a video sequence into various lower resolution versions or multilevel decomposition [2].

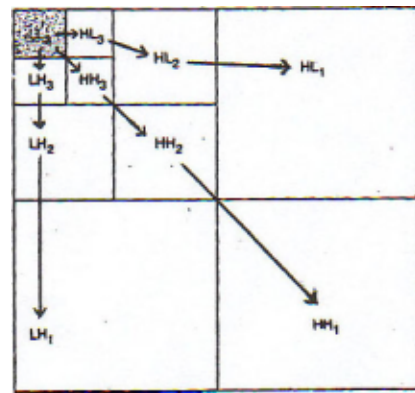


Fig. 6 Three Level Wavelet Decomposition of The Video sequence

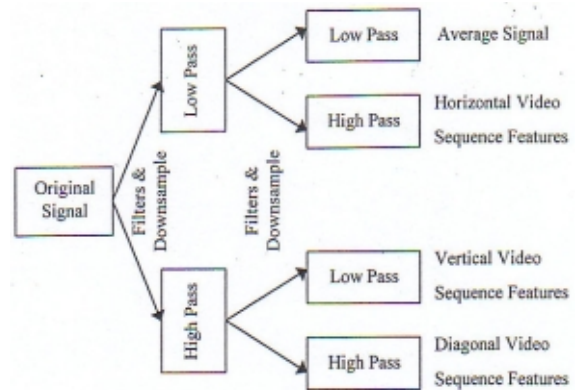


Fig. 7 Wavelet Decomposition of the 2-D Wavelet Packet Transform for the Video sequence

3 Experimental Results

The QCIF video sequences with compression rate of 0.312 bits/pixel are inspected. The wideband MC-CDMA system obtains a bandwidth of 10MHz and will also be in many indoor achievements. The various sections of a compressed video sequence obtain different importance and error sensitivity. The wideband MC-CDMA system over AWGN and

Rayleigh fading channels with Rake receivers of video compression for multilevel UEP codes are considered with eight levels of significance for operating with data stream of information. Each level of UEP code is matched with a different Rake receiver and a different level of DMF PN code. The proposed scheme accomplishes multilevel UEP by encoding the data according to the significance of the information and dividing into eight codes. The coding scheme introduces eight levels of error protection and Rake receivers for different sets of bits in a transmitted symbol functioning wideband MC-CDMA system over AWGN, and Rayleigh fading channels. The proposed scheme applies the different PN codes of DMF synchronizer to construct eight levels of UEP codes and Rake receivers. The functioning estimation of eight UEP codes with Rake receivers in wideband MC-CDMA system over AWGN and Rayleigh fading channels are evaluated.

For EZW coding, the eight levels of UEP codes with eight significant levels of UEP codes and eight different Rake receivers are proposed for this DMF PN code synchronizer scheme. From figure 6, the LL₃ includes level 0 and level 1 is the lowest error protection levels with easiest levels of DMF PN code synchronizer. The HL₃, LH₃, HH₃ comprises level 2 and level 3 is the lower error protection levels with easier levels of DMF PN code synchronizer. The HL₂, LH₂, HH₂ contains level 4 and level 5 is the higher error protection levels with harder levels of DMF PN code synchronizer. The HL₁, LH₁, HH₁ consists of level 6 and level 7 is the highest error protection levels with hardest levels of DMF PN code synchronizer.

For 2-D WPT, the eight levels of UEP codes with eight different levels of multilevel UEP codes and eight dissimilar Rake receivers are designed for this DMF PN code synchronizer scheme. Figure 7 illustrates the Wavelet Decomposition of the 2-D WPT for the video sequences. The average signal contains level 0 and level 1 is the lowest error protection levels with easiest levels of DMF PN code synchronizer. The horizontal video sequence features consists of level 2 and level 3 is the lower error protection levels with easier levels of DMF PN code synchronizer. The vertical video sequence features comprises level 4 and level 5 is the higher error protection levels with harder levels of DMF PN code synchronizer. The diagonal video sequence features includes level 6 and level 7 is the highest error protection levels with hardest levels of DMF PN code synchronizer.

Matlab programs are written to simulate the outcomes of the eight levels of UEP codes with wavelet video compression and Rake receivers in wideband MC-CDMA system over AWGN and Rayleigh fading channels. The PSNR is calculated.

The objective video sequence quality has been evaluated using PSNR, which is defined as follows:

$$PSNR = 10 \times \log_{10} \left(\frac{(PeakSignal\ Value)^2}{MeanSquare\ Error} \right) \quad (6)$$

where, *Peak Signal Value*=255 for an 8 bits/pixel video sequence.

$$MeanSquareError = \frac{1}{(N \times N)} \sum_{ij} (x_{ij} - y_{ij})^2 \quad (7)$$

x_{ij} - y_{ij} =value of pixel (i,j) in the original and reconstructed video sequences respectively.

$N \times N$ =number of pixels in the video sequence.

The table of outcomes of tested Salesman sequences is tabulated in the table 1.

Salesman Sequences in QCIF with Compression rate of 0.312 (bits/pixel)	PSNR (dB) of Eight levels UEP for EZWT	PSNR (dB) of Eight levels UEP for 2-D WPT
Salesman Sequence with Wideband MC-CDMA and Rake Receivers over AWGN Channel	14.29	14.04
Salesman Sequence with Wideband MC-CDMA and Rake Receivers over Rayleigh Fading Channel	36.07	34.72

Table 1: The outcomes of tested Salesman sequences

The original tested Salesman sequence in QCIF (176x144) is illustrated in figure 8.



Fig. 8 (a)

Fig. 8 (b)

Fig. 8 The original Salesman sequence in QCIF (a) Frame number 18 (b) Frame number 25

The results of Salesman sequences in QCIF (176x144) are illustrated in figures 9, 10, 11 and 12.



Fig. 9 (a)

Fig. 9 (b)

Fig. 9 The reconstructed Salesman sequence with Eight levels UEP of EZWT for Wideband MC-CDMA and Rake Receivers over AWGN channel; PSNR=14.29 dB (a) Frame number 18 (b) Frame number 25

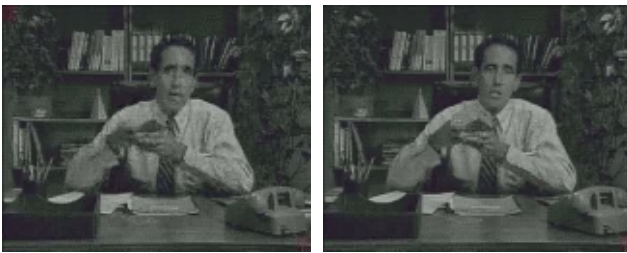


Fig. 10 (a)

Fig. 10 (b)

Fig. 10 The reconstructed Salesman sequence with Eight levels UEP of EZWT for Wideband MC-CDMA and Rake Receivers over Rayleigh fading channel; PSNR=36.07 dB (a) Frame number 18 (b) Frame number 25



Fig. 11 (a)

Fig. 11 (b)

Fig. 11 The reconstructed Salesman sequence with Eight levels UEP of 2-D WPT for Wideband MC-CDMA and Rake Receivers over AWGN channel; PSNR=14.04 dB (a) Frame number 18 (b) Frame number 25

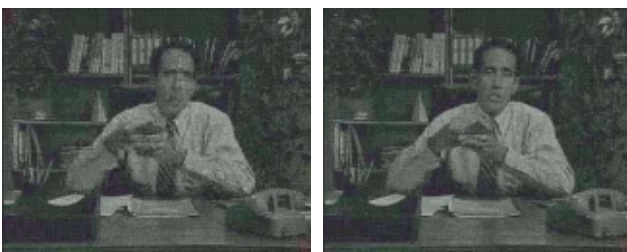


Fig. 12 (a)

Fig. 12 (b)

Fig. 12 The reconstructed Salesman sequence with Eight levels UEP of 2-D WPT for Wideband MC-CDMA and Rake Receivers over Rayleigh fading channel; PSNR=34.72 dB (a) Frame number 18 (b) Frame number 25

4 Conclusion

Performance analysis of wavelet video compression with multilevel UEP codes and Rake receivers in wideband MC-CDMA system over AWGN and Rayleigh fading channels are examined. The EZW algorithm and the 2-D WPT are analysed with multilevel UEP codes and Rake receivers in wideband MC-CDMA system over AWGN and Rayleigh fading channels. The direct sequence signal acquisition in wideband MC-CDMA environment with the proposed DMF synchronizer for fast code acquisition have been presented and analysed. The proposed scheme accomplishes multilevel UEP by encoding the data according to the significance of the information and switching between eight codes and eight different Rake receivers. The scheme uses the different PN codes of DMF synchronizer to make up multilevel UEP codes and different Rake receivers. The Rake receivers for wavelet video with multilevel UEP codes in wideband MC-CDMA system over AWGN and Rayleigh fading channels are operated to improve the video sequence superiority. The video sequence quality improves with extra levels of UEP codes for the EZW coding and the 2-D WPT coding. The EZW transform coding with multilevel UEP codes and Rake receivers have advantages compared to the 2-D WPT coding with multilevel UEP codes and Rake receivers. The Rayleigh fading channels obtain higher PSNR than the AWGN channels. The qualities of QCIF video sequences improve with the progressive increase of the PSNR. The scheme also shows design flexibility so that it is easily modified to accommodate different needs for error protection in various data transmission systems.

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