Asynchronous MC-CDMA System in Wavelet Video and Rake Receiver for UEP Codes over Fading Channels

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Abstract: - Asynchronous multicarrier code division multiple access (MC-CDMA) system and Rake receivers for wavelet video transmission with four levels of unequal error protection (UEP) codes over additive white Gaussian noise (AWGN) and Rayleigh fading channels are performed and evaluated. The deployment of Wavelets has approached a powerful technique and high quality for compressing video sequence. A spatially scalable video coding framework of MPEG2 in which motion correspondences between successive video frames are exploited 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 analysed. The presented scheme of the asynchronous MC-CDMA and Rake receivers is used for multipath problems. Each carrier of asynchronous MC-CDMA system is provided for each Rake receiver and each level of UEP codes.

Key-Words: - Asynchronous Multicarrier Code Division Multiple Access, Video Sequence, Unequal Error Protection Codes, Rake Receiver, Embedded Zero-Tree Wavelet Transform, Two Dimensional Wavelet Packet Transform, Fading Channels.

1 Introduction

An asynchronous MC-CDMA system and Rake receivers for wavelet video transmission with four levels of UEP codes over AWGN and Rayleigh fading channels system is proposed. For asynchronous transmission, the received signal comprises of all active users information whose timings are misaligned with each other. Such asynchronous reception destroys orthogonalities among different subcarriers and spreading codes of different users. Asynchronous 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. 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].

The coding scheme presents four levels of error protection and four levels of Rake receivers in asynchronous MC-CDMA system for different sets of bits in a transmitted symbol over AWGN and Rayleigh fading channels. The proposed scheme accomplishes unequal error protection by encoding the data according to the significance of the information and switching between four codes and four Rake receivers in asynchronous MC-CDMA system. The scheme uses the different pseudo-noise codes of digital matched filter synchronizer to make up four levels of unequal error protection codes and four levels of Rake receivers in asynchronous MC-CDMA system. It was shown that four levels of different error protections were accomplished with the digital matched filter (DMF) pseudo-noise (PN) code synchronizer schemes in asynchronous MC-CDMA system over AWGN and Rayleigh fading channels by providing the coded detection at the Rake receivers. The scheme provides the capability of multi-level error protection without complexity as compared to regular DMF PN code schemes [2].

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

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

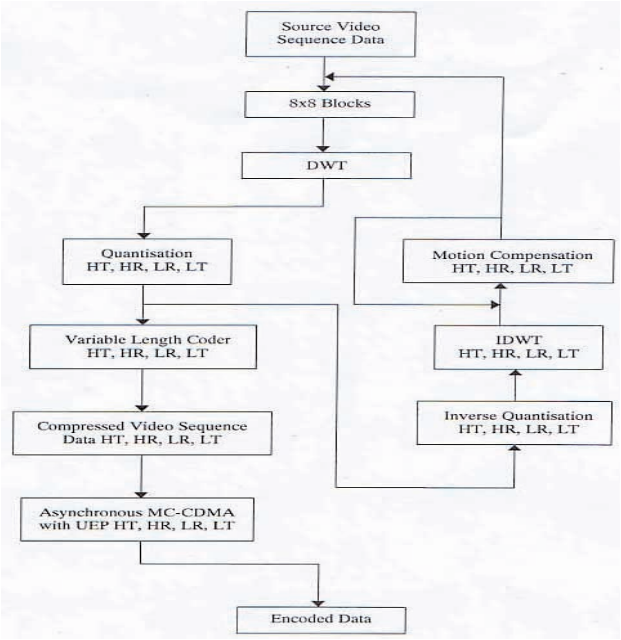

Fig. 1 Block Diagram of UEP Codes and Rake receivers for Wavelet Video Transmission in Asynchronous MC-CDMA system over AWGN and Rayleigh fading channels Encoder

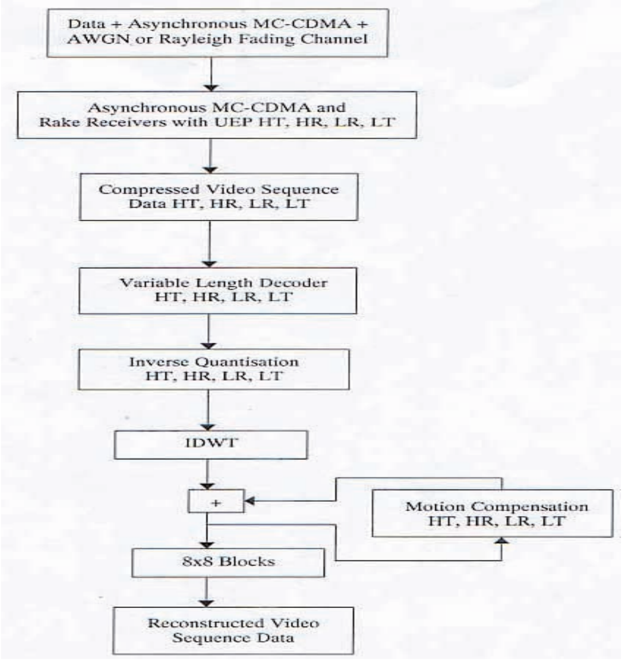

Fig. 2 Block Diagram of UEP Codes and Rake receivers for Wavelet Video Transmission in Asynchronous MC-CDMA system over AWGN and Rayleigh fading channels Decoder

2.1 Asynchronous MC-CDMA System

2.1.1 Transmitter Model

Asynchronous MC-CDMA transmitter distributes the original data stream over dissimilar subcarriers using a given spreading code. 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. Let $\varphi = 2\pi i \frac{Q}{T_b} t$. The MC-CDMA signal at the *m-th* transmitter can be represented as

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

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 an 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 asynchronous MC-CDMA system [3].

2.1.2 Receiver Model

A single user asynchronous MC-CDMA Rake receiver contains 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

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

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:

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

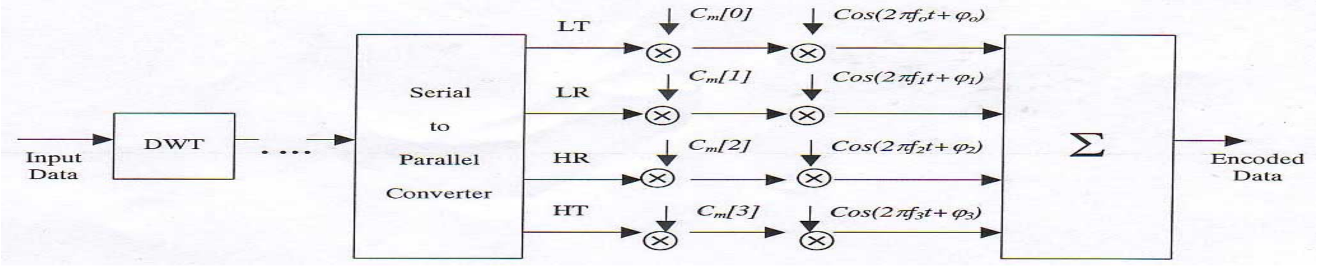

Fig. 3 Transmitter in the asynchronous MC-CDMA system

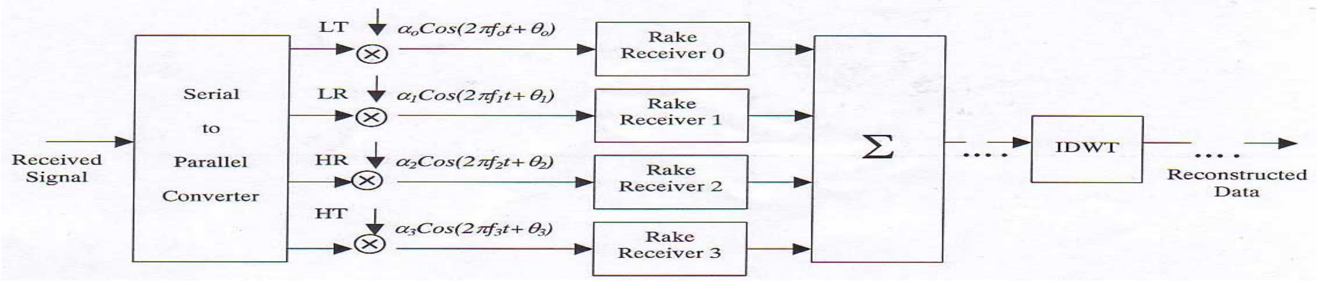

Fig. 4 Receiver in the asynchronous MC-CDMA system

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

$$x_i(nT_b) = h_i(t) * T_b^{-1/2}\phi\left(\frac{KT_b-t}{T_b}\right)\Big| t = nT_b \qquad (4)$$

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

and

$$w_i(nT_b) = h_i(t) * T_b^{-1/2}\psi\left(\frac{KT_b-t}{T_b}\right)\Big| t = nT_b \qquad (5)$$

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

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

$$d(n) = \sum_{i=0}^{N-1} c_o[i]x_i(nT_b) = a_o[n-K] \qquad (6)$$

Similarly we have

$$e(n) = \sum_{i=0}^{N-1} c_o[i]w_i(nT_b) = b_o[n-K] \qquad (7)$$

Therefore, we recover the data symbols $a_o[n-K]$ and $b_o[n-K]$ for $n=0, \pm1, \pm2, \ldots$[3]. The receiver in the asynchronous MC-CDMA system is demonstrated in figure 4.

2.2 Rake Receiver for Asynchronous MC-CDMA System

The Rake receiver was developed in the 1950's as a diversity receiver designed expressly to equalize the effect of multipath. The Rake receiver derives its name from the parallel correlators obtain an alike appearance to the fingers of a garden rake. 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 the Rake receiver is illustrated in figure 5. Each Rake receiver is supplied with different level of DMF PN code for dissimilar level of UEP code. The bandwidth of the PN sequence is denoted as $W=1/T_c$, where T_c is the chip duration. The autocorrelation function of a PN sequence has a single peak of width $1/W$. The phase (ω) and gain (β) regulators are functioned in the receiver for all correlator outputs join constructively. An appropriate delay is introduced into each correlator output so that the phase angles of the correlator outputs are in agreement with each other. The weighting coefficients ω_n are computed in accordance with the maximal ratio.

The linear combiner output is: $r(t) = \sum_{n=1}^{L}\omega_n\phi_n(t)$ (8)

Where $\phi_n(t)$ is the phase compensated output of the n^{th} correlator, and L is the number of correlators in the receiver. Provided we use enough correlators in the receiver to span a region of delays sufficiently wide to encompass all the significant echoes that are likely to occur in the multipath environment. The Rake receiver operates with the binary phase shift keying (BPSK) in performing spread spectrum modulation at the transmitter. Hence, the final performance in the Rake receiver is integrating the linear combiner output $r(t)$ over the bit interval T_b and then determining whether binary symbol 1 or 0 was transmitted in that bit interval [4].

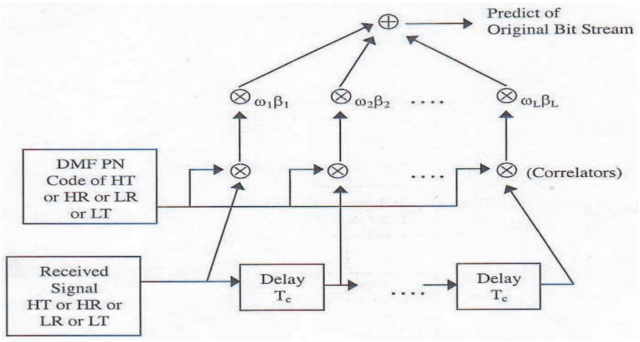

Fig. 5 The Structure of the Rake Receiver

2.3 The Embedded Zero-Tree Wavelet Coding

The 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 the 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 (LL_3), 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].

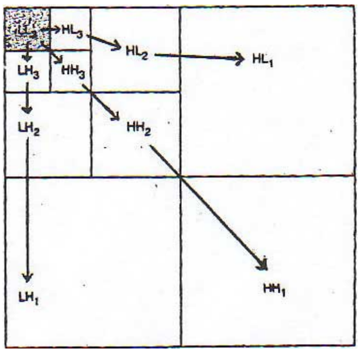

Fig. 6 Three Levels Wavelet Decomposition

2.4 The 2-Dimensional Wavelet Packet Transform

The 2-D wavelet packet transform of video sequence is composed of low frequency components and high frequency components. Low frequency components give a video sequence its foundation, or character, while high frequency components give a video sequence it is 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 and 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. Typically, the way in which this is conducted is by filtering the output of the Low Frequency Decomposing Filter with the same wavelet function. The low frequency coefficients of this output may again be filtered, extracting more information and so on. Now, because there is a down sampling routine done after each filtering process, the theoretical limit that stops us from iterating is until we reach one discrete wavelet transform (DWT) coefficient. In general, the more levels of decomposition we have, the better the compression, although loss of quality [2].

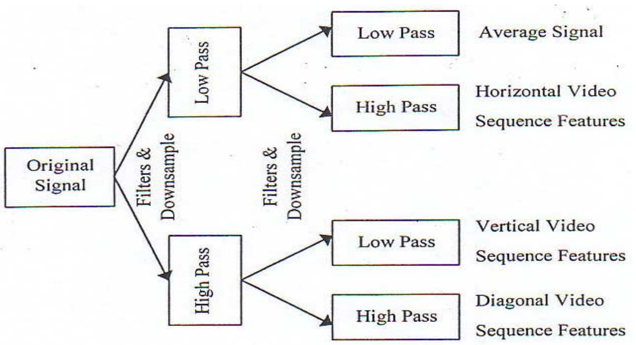

Fig. 7 Wavelet Decomposition of the 2-D Wavelet Packet Transform for the Video Sequence

3 Experimental Results

The QCIF video sequences with compression rate of 0.312 bits/pixel are examined. The various sections of a compressed video sequence obtain different importance and error sensitivity. The asynchronous MC-CDMA system over AWGN and Rayleigh fading channels with Rake receivers of wavelet video compression for unequal error protection codes are considered with four 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 in asynchronous MC-CDMA system. The proposed scheme accomplishes unequal error protection by encoding the data according to the significance of the information and dividing into four codes. The coding scheme introduces four levels of error protection and Rake receivers for different sets of bits in a transmitted symbol functioning asynchronous MC-CDMA system over AWGN and Rayleigh fading channels. The proposed scheme applies the different pseudo-noise codes of digital matched filter synchronizer to construct four levels of unequal error protection codes and Rake receivers in asynchronous MC-CDMA system. The asynchronous MC-CDMA and Rake receivers with timings are misaligned with each other. The asynchronous MC-CDMA reception ignores the orthogonalities between different subcarriers and spreading codes of dissimilar users. The performance of asynchronous MC-CDMA systems utilizes equal gains combining and maximal ratio combiner.

For the Embedded Zero-Tree Wavelet Coding, the four significant levels of unequal error protection codes with four different Rake receivers in asynchronous MC-CDMA system are proposed for this digital matched filter pseudo-noise code synchronizer scheme. From figure 6 the first level or the LL_3 is the lowest error protection level with easiest level of digital matched filter pseudo-noise code synchronizer. The second level or the HL_3, LH_3, HH_3 is the lower error protection level with easier level of digital matched filter pseudo-noise code synchronizer. The third level or the HL_2, LH_2, HH_2 is the higher error protection level with harder level of digital matched filter pseudo-noise code synchronizer. The fourth level or the HL_1, LH_1, HH_1 is the highest error protection level with hardest level of digital matched filter pseudo-noise code synchronizer.

For the 2-D Wavelet Packet Transform, the four different levels of unequal error protection codes with four dissimilar Rake receivers in asynchronous MC-CDMA system are designed for this digital matched filter pseudo-noise code synchronizer scheme. Figure 7 illustrates the Wavelet Decomposition of the 2-D Wavelet Packet Transform for the video sequence. The first level or the average signal is the lowest error protection level with easiest level of digital matched filter pseudo-noise code synchronizer. The second level or the horizontal video sequence features is the lower error protection level with easier level of digital matched filter pseudo-noise code synchronizer. The third level or the vertical video sequence features is the higher error protection level with harder level of digital matched filter pseudo-noise code synchronizer. The fourth level or the diagonal video sequence features is the highest error protection level with hardest level of digital matched filter pseudo-noise code synchronizer.

Matlab programs are written to simulate the outcomes of the four levels of UEP codes with wavelet video compression and Rake receivers in asynchronous MC-CDMA system over AWGN and Rayleigh fading channels. The peak signal to noise ratio (PSNR) is calculated. The objective video sequence quality has been evaluated using PSNR, which is defined as follows:

$$PSNR = 10 \times \log_{10}\left(\frac{(PeakSignal\,Value)^2}{MeanSquare\,Error}\right) \tag{9}$$

where, *PeakSignalValue=255 for an 8 bits/pixel video sequence.*

$$MeanSquare\,Error = \frac{1}{(N \times N)}\sum_{ij}(x_{ij} - y_{ij})^2 \tag{10}$$

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 Lab sequences is tabulated in the table 1.

Table 1: The outcomes of tested Lab sequences

Lab Sequences in QCIF with Compression rate of 0.312 (bits/pixel)	PSNR (dB) of Four levels UEP for EZWT	PSNR (dB) of Four levels UEP for 2-D WPT
Lab Sequence with Asynchronous MC-CDMA and Rake Receivers over AWGN Channel	11.29	11.04
Lab Sequence with Asynchronous MC-CDMA and Rake Receivers over Rayleigh Fading Channel	34.08	32.95

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

Fig. 8 (a) Fig. 8 (b)

Fig. 8 The original Lab sequence in QCIF
(a) Frame number 0 (b) Frame number 80

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

Fig. 9 (a) Fig. 9 (b)

Fig. 9 The reconstructed Lab sequence with Four levels UEP of EZWT for Asynchronous MC-CDMA and Rake Receivers over AWGN Channel; PSNR=11.29dB (a) Frame number 0 (b) Frame number 80

Fig. 10 (a) Fig. 10 (b)

Fig. 10 The reconstructed Lab sequence with Four levels UEP of EZWT for Asynchronous MC-CDMA and Rake Receivers over Rayleigh fading channel; PSNR=34.08dB (a) Frame number 0 (b) Frame number 80

Fig. 11 (a) Fig. 11 (b)

Fig. 11 The reconstructed Lab sequence with Four levels UEP of 2-D WPT for Asynchronous MC-CDMA and Rake Receivers over AWGN channel; PSNR=11.04dB (a) Frame number 0 (b) Frame number 80

Fig. 12 (a) Fig. 12 (b)

Fig. 12 The reconstructed Lab sequence with Four levels UEP of 2-D WPT for Asynchronous MC-CDMA and Rake Receivers over Rayleigh fading channel; PSNR=32.95dB (a) Frame number 0 (b) Frame number 80

4 Conclusion

Asynchronous MC-CDMA and Rake receivers for wavelet video compression with four levels of UEP codes over AWGN and Rayleigh fading channels are investigated. The EZW algorithm and the 2-D WPT are analysed with UEP codes and Rake receivers in asynchronous MC-CDMA system over AWGN and Rayleigh fading channels. The direct sequence signal acquisition in asynchronous MC-CDMA environment with the proposed DMF synchronizer for fast code acquisition have been presented and analysed. The proposed scheme accomplishes UEP by encoding the data according to the significance of the information and switching between four codes and four different Rake receivers in asynchronous MC-CDMA system. The scheme uses the different PN codes of DMF synchronizer to make up four levels of UEP codes and four different Rake receivers in asynchronous MC-CDMA system. The asynchronous MC-CDMA system and Rake receivers for wavelet video with UEP codes over AWGN and Rayleigh fading channels are operated to improve the video sequences superiority. The EZW transform coding in asynchronous MC-CDMA system with four levels of UEP codes and Rake receivers has advantages compared to the 2-D WPT coding in asynchronous MC-CDMA system with four levels of 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 analytical calculation and simulation results demonstrate that the proposed system provides more powerful and robust performance than the conventional MC-CDMA.

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