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

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Abstract. Wideband Multicarrier code division multiple access (MC-CDMA) 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 wideband MC-CDMA and Rake receivers is used for multipath problems. Each carrier of asynchronous wideband MC-CDMA is provided for each Rake receiver and each level of UEP codes.

1 Introduction

An asynchronous wideband MC-CDMA 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. The performance of asynchronous wideband MC-CDMA systems uses identical gains. Asynchronous wideband MC-CDMA system divides the system bandwidth into several equal narrow subbands that are used to transmit multiple signal waveforms in parallel. The wideband is carried with encoded data when transmitting through the fading channels. A Rake receiver is provided for each subcarrier and the receiver combines the outputs with a maximal ratio combiner. Asynchronous 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. 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 wideband MC-CDMA system for different sets of bits in a transmitted symbol over AWGN and Rayleigh fading channels. The proposed scheme accomplishes UEP by encoding the data according to the significance of the information and switching between four codes and four Rake receivers in asynchronous wideband MC-CDMA system. The scheme uses the different pseudo-noise codes of digital matched filter synchronizer to make up four levels of UEP codes and four levels of Rake receivers in asynchronous wideband MC-CDMA system. It was shown that four levels of different error protections were easily accomplished with the digital matched filter pseudo-noise code synchronizer schemes in asynchronous wideband 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 digital matched filter pseudo-noise code schemes [2].

2 Wideband 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 wideband MC-CDMA system with wavelet video transmission over AWGN and Rayleigh fading channels are analyzed. Figure 1 (a) illustrates the block diagram of UEP codes and Rake receivers for wavelet video transmission in asynchronous wideband MC-CDMA system over AWGN and Rayleigh fading channels Encoder. Figure 1 (b) shows the block diagram of UEP codes and Rake receivers for wavelet video transmission in asynchronous wideband MC-CDMA system over AWGN and Rayleigh fading channels Decoder.

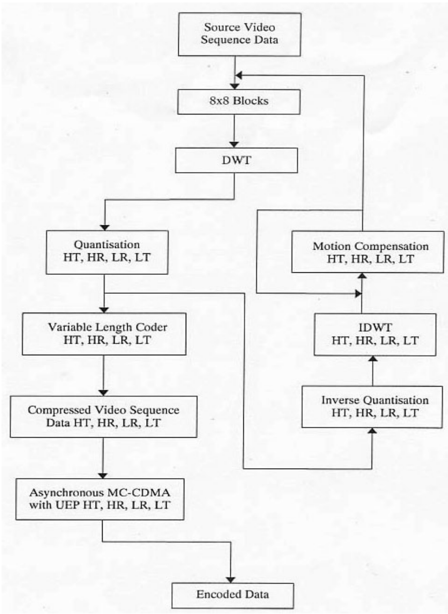

Fig. 1 (a)

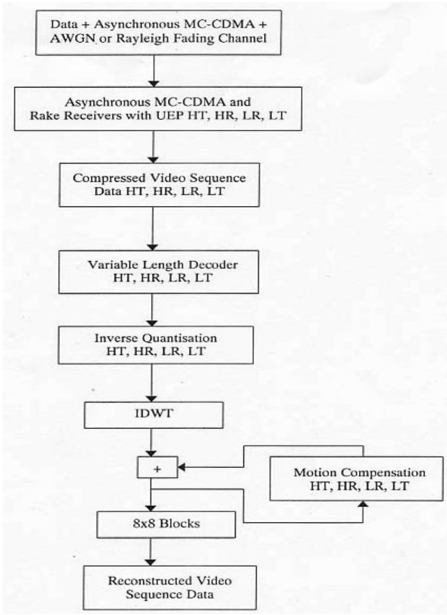

Fig. 1 (b)

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

2.1 Asynchronous Wideband MC-CDMA System

Transmitter Model

In the transmitter model, the asynchronous wideband MC-CDMA transmitter distributes the original data stream over dissimilar 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 $\varphi = 2\pi i \frac{Q}{T_b} t$. The MC-CDMA signal at the *m-th* transmitter can be represented as

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

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 2 (a) illustrates the transmitter in the asynchronous wideband MC-CDMA system [3].

Receiver Model
In the receiver model, a single user of the asynchronous wideband 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

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

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 [3]:

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

The receiver in the asynchronous wideband MC-CDMA system is demonstrated in figure 2 (b).

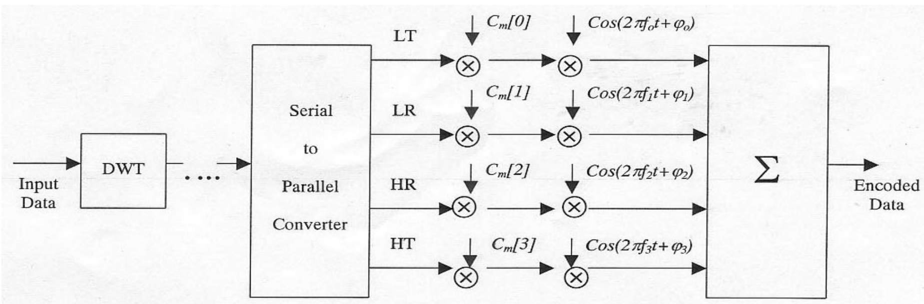

Fig. 2 (a)

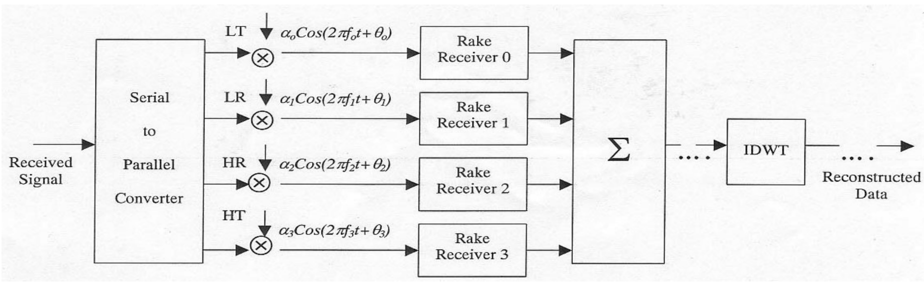

Fig. 2 (b)

Fig. 2. (a) Transmitter in the asynchronous wideband MC-CDMA system
(b) Receiver in the asynchronous wideband MC-CDMA system

2.2 The Rake Receiver for Asynchronous Wideband MC-CDMA

The structure of the Rake receiver is illustrated in figure 3.

The linear combiner output is: $r(t) = \sum_{n=1}^{L} \omega_n \phi_n(t)$ (4)

Where $\phi_n(t)$ is the phase compensated output of the n^{th} correlator, L is the number of correlators in the receiver and ω_n is the weighting coefficients. 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 [4].

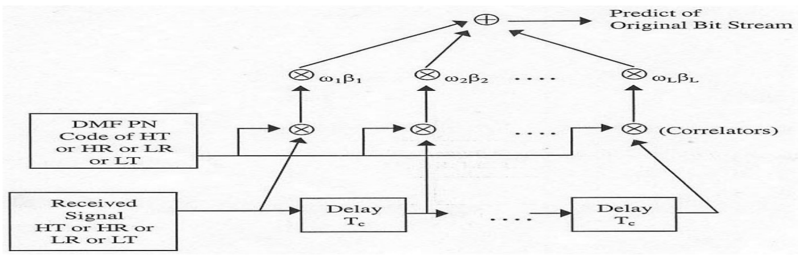

Fig. 3. The Structure of the Rake Receiver

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 4 (a) 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].

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 4 (b) 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].

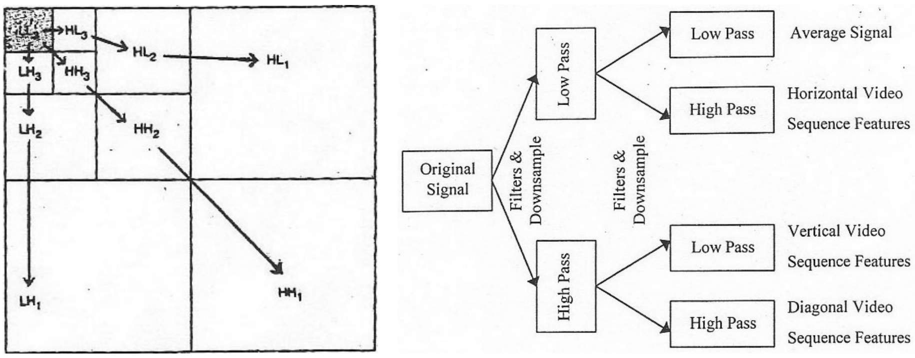

Fig. 4 (a) Fig. 4 (b)

Fig. 4. (a) Three Levels Wavelet Decomposition of the Video Sequence
(b) 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 wideband MC-CDMA system over AWGN and Rayleigh fading channels with Rake receivers of wavelet video compression for UEP 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 wideband MC-CDMA system. The proposed scheme accomplishes UEP 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 wideband 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 UEP codes and Rake receivers in asynchronous wideband MC-CDMA system. The asynchronous wideband MC-CDMA and Rake receivers with timings are misaligned with each other. The asynchronous wideband MC-CDMA reception ignores the orthogonalities between different subcarriers and spreading codes of dissimilar users. The performance of asynchronous wideband MC-CDMA systems utilizes equal gains combining and maximal ratio combiner. The wideband is carried with encoded data when transmitting through the AWGN and Rayleigh fading channels.

For the Embedded Zero-Tree Wavelet Coding, the four significant levels of unequal error protection codes with four different Rake receivers in asynchronous wideband MC-CDMA system are proposed for this digital matched filter pseudo-noise code synchronizer scheme. From figure 4 (a) 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 UEP codes with four dissimilar Rake receivers in asynchronous wideband MC-CDMA system are designed for this digital matched filter pseudo-noise code synchronizer scheme. Figure 4 (b) 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 wideband MC-CDMA system over AWGN and Rayleigh fading channels. The peak signal to noise ratio is calculated. The objective video sequence quality has been evaluated using peak signal to noise ratio, which is defined as follows:

$$PSNR=10*\log_{10}((Peak\ Signal\ Value)^2/Mean\ Square\ Error) \tag{5}$$

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

$$Mean\ Square\ Error=(1/(NxN))\sum_{ij}(x_{ij}-y_{ij})^2 \tag{6}$$

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

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

Table 1. The outcomes of tested Miss America sequences

Miss America 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
Miss America Sequence with Asynchronous Wideband MC-CDMA and Rake Receivers over AWGN Channel	17.25	15.64
Miss America Sequence with Asynchronous Wideband MC-CDMA and Rake Receivers over Rayleigh Fading Channel	38.05	36.12

The original tested Miss America sequence in QCIF (176x144) is illustrated in figure 5.

Fig. 5 (a) Fig. 5 (b) Fig. 5 (c) Fig. 5 (d)

Fig. 5. The original Miss America sequence in QCIF
(a) Frame number 40 (b) Frame number 60 (c) Frame number 80 (d) Frame number 90

The results of Miss America sequences in QCIF (176x144) are illustrated in figures 6, 7, 8 and 9.

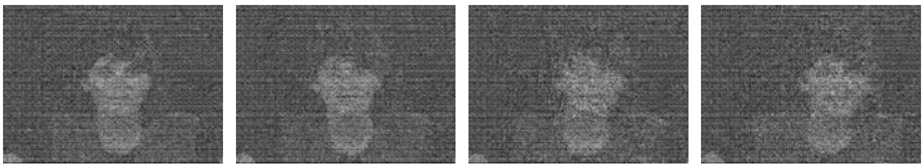

Fig. 6 (a) Fig. 6 (b) Fig. 6 (c) Fig. 6 (d)

Fig. 6. The reconstructed Miss America sequence with Four levels UEP of EZWT for Asynchronous Wideband MC-CDMA and Rake Receivers over AWGN Channel; PSNR=17.25 dB (a) Frame number 40 (b) Frame number 60 (c) Frame number 80 (d) Frame number 90

Fig. 7 (a) Fig. 7 (b) Fig. 7 (c) Fig. 7 (d)

Fig. 7. The reconstructed Miss America sequence with Four levels UEP of EZWT for Asynchronous Wideband MC-CDMA and Rake Receivers over Rayleigh fading channel; PSNR=38.05 dB (a) Frame number 40 (b) Frame number 60 (c) Frame number 80 (d) Frame number 90

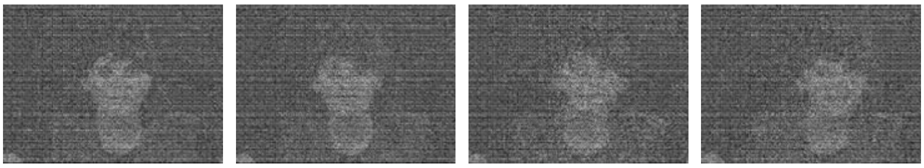

Fig. 8 (a) Fig. 8 (b) Fig. 8 (c) Fig. 8 (d)

Fig. 8. The reconstructed Miss America sequence with Four levels UEP of 2-D WPT for Asynchronous Wideband MC-CDMA and Rake Receivers over AWGN channel; PSNR=15.64 dB (a) Frame number 40 (b) Frame number 60 (c) Frame number 80 (d) Frame number 90

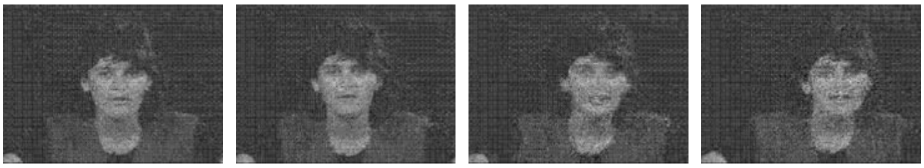

Fig. 9 (a) Fig. 9 (b) Fig. 9 (c) Fig. 9 (d)

Fig. 9. The reconstructed Miss America sequence with Four levels UEP of 2-D WPT for Asynchronous Wideband MC-CDMA and Rake Receivers over Rayleigh fading channel; PSNR=36.12 dB (a) Frame number 40 (b) Frame number 60 (c) Frame number 80 (d) Frame number 90

4 Conclusion

Performance analysis of asynchronous wideband 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 wavelet packet transform are analysed with UEP codes and Rake receivers in asynchronous wideband MC-CDMA system over AWGN and Rayleigh fading channels. The direct sequence signal acquisition in asynchronous wideband MC-CDMA environment with the proposed digital matched filter synchronizer for fast code acquisition have been presented and analysed. 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 different Rake receivers in asynchronous wideband MC-CDMA system. The wideband is passed with encoded data when transmitting through the channels. 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 different Rake receivers in asynchronous wideband MC-CDMA system. The Rake receivers for wavelet video with UEP codes in asynchronous wideband MC-CDMA system over AWGN and Rayleigh fading channels are operated to improve the video sequences superiority. The advantage of the video sequence quality enhances with four levels of UEP codes for the EZW coding and the 2-D WPT coding. The EZW transform coding with four levels of UEP codes and Rake receivers in asynchronous wideband MC-CDMA system has advantages compared to the 2-D WPT coding with four levels of UEP codes and Rake receivers in asynchronous wideband MC-CDMA system. The Rayleigh fading channels obtain higher peak signal to noise ratio than the AWGN channels. The qualities of QCIF video sequences improve with the progressive increase of the peak signal to noise ratio. The analytical calculation and simulation results demonstrate that the proposed system provides more powerful and robust performance than the conventional MC-CDMA. 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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