Performance Analysis of Multilevel UEP Codes for Wavelet Video in W-CDMA over Fading Channels

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Abstract: - Performance analysis of multilevel unequal error protection (UEP) codes with wavelet video compression for wideband code division multiple access (W-CDMA) 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 wideband is carried with encoded data when transmitting through the AWGN and Rayleigh fading channels.

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

1 Introduction

Wavelets in commercial applications were mainly with efficient compression techniques on signals such as voice, image and video. The wavelet functions are developed for harmonic analysis, signal representation, speech and video bandwidth compression, multiresolution signal processing and signal design in various coding and communication applications. This was due to the logarithmic-scale decomposition in frequency, which fits naturally in many of the sound, image and video sequence reconstruction studies. Wavelet theory covers quite a large area. It 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. A refinement of the EZW approach, called set partitioning into hierarchical trees (SPIHT) by Said and Pearlman, is the most well known EZW derivative. While SPIHT enjoys a good rate-distortion performance for video with comparatively low complexity, it is quite fragile against bit errors in noisy communication channels. Direct sequence signal acquisition in W-CDMA environment is estimated. A digital matched filter (DMF) is presented and investigated for direct sequence spread-spectrum systems [1].

The coding scheme presents multilevel error protection for different sets of bits in a transmitted symbol using W-CDMA system over AWGN and Rayleigh fading channels. The proposed scheme accomplishes multilevel unequal error protection by encoding the data according to the significance of the information and switching between eight codes. The scheme uses the different pseudo-noise (PN) codes of digital matched filter synchronizer to make up multilevel unequal error protection codes. It was shown that multilevel error protections were easily accomplished with the digital matched filter pseudo-noise code synchronizer systems over AWGN and Rayleigh fading channels by providing the coded detection at the receiver. The scheme provides the capability of multilevel error protection without complexity as compared to regular digital matched filter pseudo-noise code schemes. Wavelet video with multilevel UEP codes in W-CDMA system obtains smaller peak signal to noise ratio (PSNR) than wavelet video with multilevel UEP codes for wideband MC-CDMA and Rake receiver. However, it requires less complex design and less cost of acquisition. The quality of video enhances with increasing levels of unequal error protection codes [2].

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

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

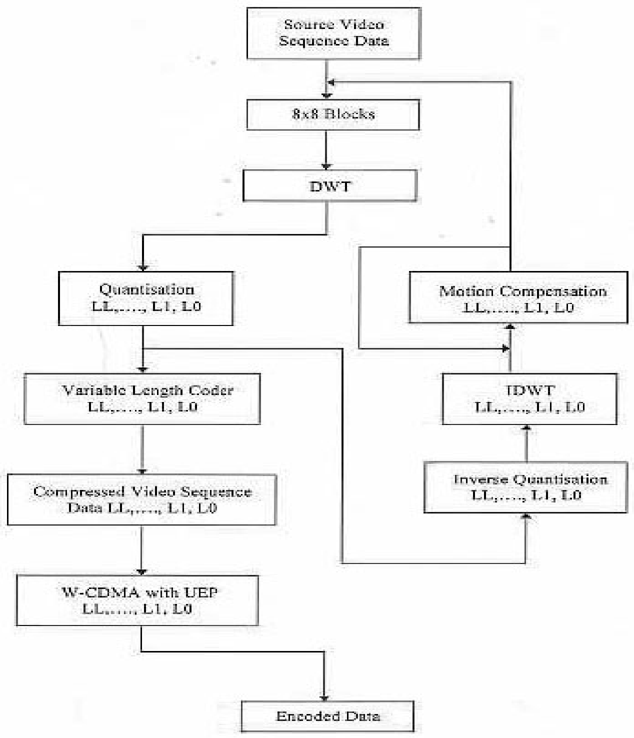

Fig. 1 Block Diagram of Multilevel UEP Codes for Wavelet Video Transmission in W-CDMA system over AWGN and Rayleigh fading channels Encoder

The discrete wavelet transform is described with the generic signal $g(t)$ that can be represented in terms of translates and dilates typically bandpass of a single prototype wavelet $\beta(t)$.

$$g(t) = \sum_{i,j=-\infty}^{+\infty} \alpha(i,j)\, 2^{-i/2} \beta(2^{-i} t - j) \qquad (1)$$

or similarly for some $W>0$

$$g(t) = \sum_{j} \eta(j)\, 2^{-W/2} \theta(2^{-W} t - j) + \sum_{i=-\infty}^{W} \sum_{j} \alpha(i,j)\, 2^{-i/2} \beta(2^{-i} t - j) \qquad (2)$$

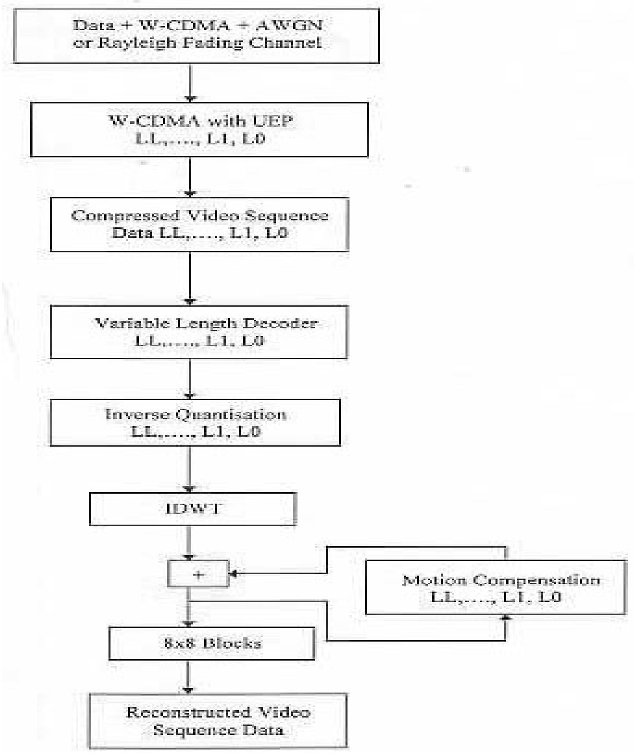

Fig. 2 Block Diagram of Multilevel UEP Codes for Wavelet Video Transmission in W-CDMA system over AWGN and Rayleigh fading channels Decoder

where

$$\alpha(i,j) = \int_{-\infty}^{+\infty} g(t)\, 2^{-i/2} \beta(2^{-i} t - j)\, dt$$

are detail coefficients of wavelet.

$$\eta(j) = \int_{-\infty}^{+\infty} g(t)\, 2^{-W/2} \theta(2^{-W} t - j)\, dt$$

are approximation coefficients or scaling coefficients, and $\theta(t)$ is a low-pass scaling function. The significance is the interpretation of equation (2) as a multiresolution analysis of $g(t)$: i indexes the *scale* or *resolution*, the smaller i the higher the resolution, while j indexes the *spatial* location of analysis. If the mother wavelet is centred at time 0 and frequency f_c, $\alpha(i,j)$ measures the content of around time $2^i j$ and frequency $2^{-i} f_c$, while $\eta(j)$ represents the local mean around time $2^W j$. In this framework, we can think of $g(t)$ as the finest scale (W=0) representation of $g(t)$ itself. The function $\beta(t)$ has to satisfy some critical conditions to ensure that equation (2) holds for any square integrable function $g(t)$. In particular, $\beta(t)$ has to satisfy the two scale equations:

$$\theta(t) = \sqrt{2} \sum_{n} c_o(n) \theta(2t - n) \qquad (3)$$

$$\beta(t) = \sqrt{2} \sum_{n} c_1(n) \theta(2t - n) \qquad (4)$$

where the coefficients $c_i(n)$ can be nonzero only over a finite number of consecutive values of n. Hence,

$$\beta_{i,j}(t) = 2^{-i/2} \beta(2^{-i} t - j)\, ; \; \theta_{i,j}(t) = 2^{-i/2} \theta(2^{-i} t - j)$$

The three orthogonalities constraints require

$$\int \theta_{i,j}(t) \theta_{i,j'}(t)^{*}\, dt = \delta(j - j')$$

$$\int \beta_{i,j}(t)\beta_{i',j'}(t)^* dt = \delta(j-j') = \delta(i-i')$$

$$\int \beta_{i,j}(t)\theta_{i',j'}(t)^* dt = \delta(j-j') = 0$$

The three orthogonalities are satisfied by coefficients $c_i(n)$ those have the following properties:

$$\sum_n c_o(n)c_o(n+2k) = \delta(k)$$

$$c_1(n) = (-1)^n c_o(n)$$

where $c_i(n)$ are the coefficients of a perfect reconstruction two-band or dyadic filter bank with the quadrature mirror reconstruction property. Therefore, the design of wavelets is equivalent to the design of filter banks. Observe that the conditions imposed up until now are not sufficient to construct in practice useful wavelets. Certainly, they can lead to decompositions with not enough regularity. Regularity is imposed requiring a large number of vanishing moments. In practice, $\eta(j)$ and $\alpha(i,j)$ can be computed recursively from $\alpha(i+1,j)$ using the efficient pyramid algorithm proposed by Mallat [3]. It is not necessary to explicitly compute the shape of $\theta(t)$ and $\beta(t)$. The basic applications of wavelets in this paper stems from a multiresolution decomposition of a time-varying multipath response of the form $\tilde{h}(t,\tau)$ at any τ with respect to t are:

$$\tilde{h}(t,\tau) = \sum_j \eta(j,\tau)2^{-W/2}\theta(2^{-W}t-j)$$

$$+\sum_{i=-\infty}^{W}\sum_j \alpha(i,j,\tau)2^{-i/2}\beta(2^{-i}t-j) \quad (5)$$

where $\alpha(i,j,\tau)$ are wavelet coefficients and $\eta(j,\tau)$ are scaling coefficients. If the channel is modelled as deterministic, wavelet and scaling coefficients are considered deterministic, and if the channel is modelled as random, wavelet and scaling coefficients are considered random parameters. The wavelet-based representation will exhibit *global* characteristics of the channel dynamics in the low-resolution coefficients, while retaining *local* rapid transitions in just a few coefficients at higher resolutions. A practical advantage is that the decomposition decouples the variations in time and relegates them in $\beta(t)$ and $\theta(t)$, so that the wavelets coefficients are indeed time invariant for any τ. Subsequently, we will assume discretized responses with resolvable multipath components of the form $\tilde{h}(t,\tau) = \sum_{i=1}^{Q} g_i(t)\delta(\tau-\tau_i)$ [3].

2.1 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 3 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 [4].

2.2 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 4 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 [2].

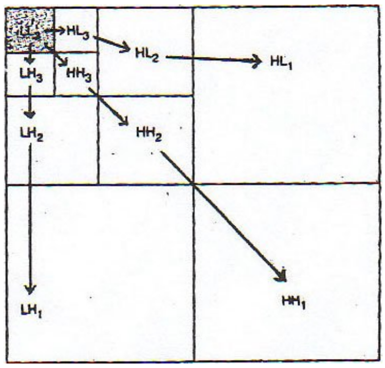

Fig. 3 Three Level Wavelet Decomposition of The Video sequence

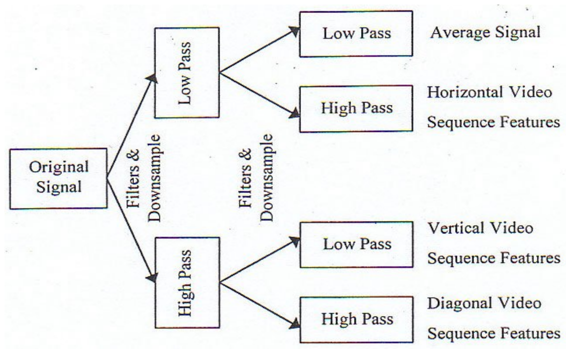

Fig. 4 Wavelet Decomposition of the 2-D Wavelet Packet Transform for the Video sequence

2.3 Wide-Band Code Division Multiple Access Channels

W-CDMA is technique in which users share the channel by employing different spreading codes. In W-CDMA systems, all the users occupy the same frequency band at the same time. This is in contrast to frequency division multiple access (FDMA) and time division multiple access (TDMA) schemes in which the signals occupy the channel at disjoint frequencies or times, respectively. In W-CDMA systems, each transmitter has a different spreading code that is known by the intended receiver. For effective operation, the cross correlation between code used by different users should be minimized so that the despreading process will reject most of the multi-user interference. W-CDMA systems can be implemented using either frequency hopping (FH) or direct sequence (DS) spread spectrum (SS) techniques, although DS is by far the most popular choice. One reason for this is that when multiple approaches is generally more computationally intensive than the synchronous approach. The basis function to be used as the spreading waveform is determined by a pseudo-noise sequence and is allowed to change with each incoming data bit. Since both the transmitter and receiver are assumed to know which spreading function is used, and these codes are known to be orthogonal. Each user is assigned a different spreading code, i.e., transform basis function, and allowed to transmit over the same channel. If all users transmit synchronously, the orthogonality of the spreading waveforms ensures that there is no interference between users. The direct sequence spread spectrum (DSSS) communications systems nominate coherent binary phase shift keying (BPSK) for both the data modulation and the spreading modulation [5]. The encoded DSSS with BPSK signal is provided:

$$y(t)=s(t)x(t)=s(t)b(t)\sqrt{2S}\ cosw_ct \qquad (6)$$

where $x(t)=b(t)\sqrt{2S}\ cosw_ct$, $b(t)$ is the baseband signal at the transmitter output and receiver input, $s(t)$ is the spreading signal, S is the signal power, w_c is the carrier frequency.

Equation (6) represents the modulo-2 addition of $s(t)$ and $b(t)$ as a multiplication because the binary signals, 0 and 1, represent values of 1 and -1 into the modulator. The signal $x(t)$ has a $[(sinx)/x]^2$ spectrum of bandwidth roughly $1/T$ (where T is the periodicity at baseband), while the SS of signal $y(t)$ has a similar spectrum but with a bandwidth of approximately $1/T_c$, where T_c is the periodicity of the spreading signal. The processing gain of the system is $G_p=(B_w/R)=T/T_c$. B_w is the bandwidth in Hertz and R is the information rate. If the interfering signal is represented by $I(t)$, then in the absence of noise, assuming that the interferer limits the system performance. Also, the interferer's power level exceeds the thermal noise power, the signal at the receiver is given as $[r(t)]^*=y(t)+I(t)$. The receiver multiplies this by the PN waveform to obtain the signal:

$$r(t)=s(t)[y(t)+I(t)]=s(t)[s(t)x(t)]+s(t)I(t)=x(t)+s(t)I(t) \qquad (7)$$

From $s(t)^2=1$, $s(t)I(t)$ is the effective noise waveform due to interference. The conventional BPSK detector output is given as: $r=m\sqrt{E_b}+n$, where m is the data bit for the T second interval, E_b is the bit energy, n is the equivalent noise component. The spreading-despreading functions do not affect the signal and do not affect the spectral and probability density function of the noise. For this reason, the bit error probability P_b associated with the coherent BPSK SS signal is the same as with the BPSK signal and is given as [5]:

$$P_b=(1/2)erfc\left(\sqrt{\frac{E_b}{N_o}}\right) \qquad (8)$$

The proposed DMF achieves a mean time to acquisition comparable to that obtained by the conventional matched filter allows an unlimited period of integration without complexity increase and some advantages in terms of probabilities of correct acquisition and false alarm. Since the nature of DSSS signals is digital, DMFs provide a straightforward way of implementing correlation in noncoherent receivers for signals of that kind. Digital concepts provide most flexibility, which is required for easy adaptability to changing waveforms. This can be of paramount importance for the exploitation of the anti-interference and anti-eavesdropping capabilities of such systems. DMF is one of the most critical components incorporated in the VLSI transceiver in terms of power dissipation [6].

3 Experimental Results

The QCIF video sequences with compression rate of 0.312 bits/pixel are inspected. The W-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 W-CDMA system over AWGN and Rayleigh fading channels 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 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 for different sets of bits in a transmitted symbol functioning W-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. The functioning estimation of eight UEP codes in W-CDMA system over AWGN and Rayleigh fading channels are evaluated.

For EZW coding, the eight significant levels of UEP codes are proposed for this DMF PN code synchronizer scheme. From figure 3, the LL_3 includes level 0 and level 1 is the lowest error protection levels with easiest levels of DMF PN code synchronizer. The HL_3, LH_3, HH_3 comprises level 2 and level 3 is the lower error protection levels with easier levels of DMF PN code synchronizer. The HL_2, LH_2, HH_2 contains level 4 and level 5 is the higher error protection levels with harder levels of DMF PN code synchronizer. The HL_1, LH_1, HH_1 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 different levels of multilevel UEP codes are designed for this DMF PN code synchronizer scheme. Figure 4 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 were written to simulate the outcomes of the eight levels of UEP codes with wavelet video compression in W-CDMA system over AWGN and Rayleigh fading channels. The PSNR was calculated. The objective video sequence quality has been evaluated using PSNR, which is defined as follows:

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

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

$$MeanSquareError = \frac{1}{(N \times N)}\sum_{ij}\left(x_{ij} - y_{ij}\right)^2 \qquad (10)$$

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 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
W-CDMA and AWGN Channels	10.27	10.02
W-CDMA and Rayleigh Fading Channels	32.06	30.74

Table 1: Outcomes of tested Salesman sequences

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

Fig. 5 (a)

Fig. 5 (b)

Fig. 5 Original Salesman sequence in QCIF (a) Frame number 10 (b) Frame number 25

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

Fig. 6 (a) Fig. 6 (b)

Fig. 6 Reconstructed Salesman sequence with Eight levels UEP of EZWT over W-CDMA and AWGN channel; PSNR=10.27 dB (a) Frame number 10 (b) Frame number 25

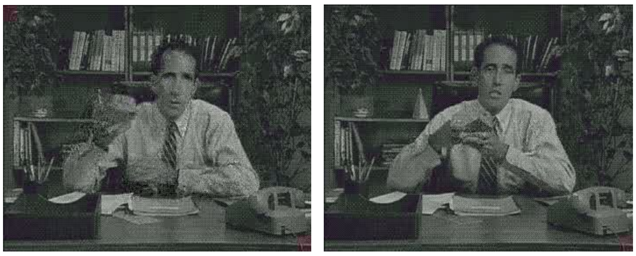

Fig. 7 (a) Fig. 7 (b)

Fig. 7 Reconstructed Salesman sequence with Eight levels UEP of EZWT over W-CDMA and Rayleigh fading channel; PSNR=32.06 dB (a) Frame number 10 (b) Frame number 25

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

Fig. 8 Reconstructed Salesman sequence with Eight levels UEP of 2-D WPT over W-CDMA and AWGN channel; PSNR=10.02 dB (a) Frame number 10 (b) Frame number 25

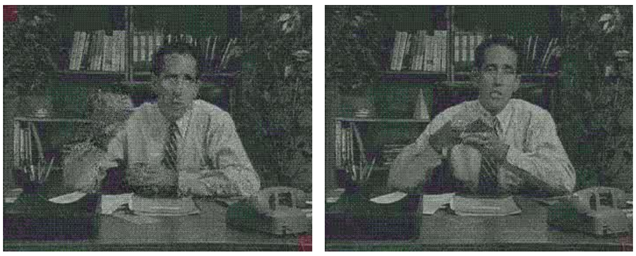

Fig. 9 (a) Fig. 9 (b)

Fig. 9 Reconstructed Salesman sequence with Eight levels UEP of 2-D WPT over W-CDMA and Rayleigh fading channel; PSNR=30.74 dB (a) Frame number 10 (b) Frame number 25

4 Conclusion

Performance analysis of wavelet video compression with multilevel UEP codes in W-CDMA system over AWGN and Rayleigh fading channels are examined. The EZW algorithm and the 2-D WPT are analysed with multilevel UEP codes in W-CDMA system over AWGN and Rayleigh fading channels. The direct sequence signal acquisition in W-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. The scheme uses the different PN codes of DMF synchronizer to make up multilevel UEP codes. Wavelet video with multilevel UEP codes in W-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 has advantages compared to the 2-D WPT coding with multilevel UEP codes. 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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