A NOVEL TRACKING ALGORITHM BASED ON GRAVITY OF ENERGY WINDOWS FOR DS/CDMA SYSTEM*

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Abstract  PN (Pseudo-Noise) code tracking is the most challenging task in a Direct Sequence Spread Code Division Multiplex Access (DS-CDMA) for cellular mobile communication systems. In this paper, the gravity of energy windows (GEW) tracking loop of the time and frequency uncertainty of the received signal is investigated, and the GEW's analytical results in a multi-path fading channel are introduced. GEW tracking loop exploits the inherent multi-path diversity of the channel, and has better performance than single-path one when working in multi-path fading environment.

Key words  PN tracking; DS/CDMA; Energy window

I. Introduction

The most popular land mobile communication systems like the IS'95 and CDMA2000 use Direct Sequence Spread Code Division Multiplex Access (DS-CDMA). Pseudo-Noise(PN) code synchronization is essential for DS-CDMA. Code acquisition is the initial search process that bring the phase of the locally generated code to within a small fraction of chip interval of the incoming code; Code tracking further maintains the PN code generator at the receiver in synchronism with the incoming signal. The commonly used tracking loops for Direct Sequence (DS) spread spectrum signal are the Delay-Locked Loop (DLL) and the Tau-Dither Loop (TDL)[1], DLLs and TDLs have been mainly applied to Additive White Gaussian Noise(AWGN) channel. However, the performance of these code tracking loops for multi-path fading channels is severely degraded. This paper proposes an efficient tracking loop for DS spread spectrum signal on multi-path fading channels.

The receiver operates a search engine which constantly search the channel for separable multi-path components of the desired signal. The search engine, having found the separable multi-path components and ranked them in terms of the energy strength, assigns the top J components (that is referred as energy window) to the Gravity of Energy Window (GEW) tracking algorithm, and produces the code phase error-correcting signal to align the local PN code phase according to the variation of the gravity of neighboring energy windows. The aim of the GEW tracking loop is to assure the RAKE receiver that the sum of the J separable multi-path component energies is maximum, so the receiver system has better performance. The simulating results show that the new tracking loop provides a much better loop performance working in multi-path than DLLs working in single-path.

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II. Analytical Model for PN Code Tracking Loop

Most DS-CDMA systems as IS’95 or CDMA2000 use pilot signal to simplify the system synchronization and to achieve better channel estimates. A pilot channel is transmitted at all times by the base station on each active forward CDMA channel, the pilot channel is an unmodulated spread spectrum signal, the transmitted signals can be given as follows:

\[ s(t) = \text{Re}[p(t)e^{j2\pi f_c t}], \quad \text{BPSK spreading} \]  

where the spreading function \( p(t) = \sum_{n=-\infty}^{+\infty} \alpha_n P_{T_c}(t - nT_c) \), the spreading sequences \( \{\alpha_n\} \) are modeled as mutually independent random sequences taking on the values of +1 and -1, \( P_{T_c}(t) = 1 \) for \( 0 \leq t \leq T_c \) and zero otherwise, and \( T_c \) is the chip duration, the auto-correlation of the spreading function \( R_c(\zeta) = \frac{1}{NT_c} \int_0^{NT_c} p(t)p(t + \zeta T_c)dt \) (\( N \) corresponds to one or more periods of the random sequences) is approximated as

\[ R_c(\zeta) = \begin{cases} 1 - |\zeta|/T_c, & |\zeta| \leq T_c \\ 0, & \text{otherwise} \end{cases} \]

In IS’95A or CDMA2000 system, the bandwidth of signal is very large, the channel delay is normally not exceed 20\(\mu s\), so the channel is frequency-selective. The channel model can be given as follows with a complex base-band equivalent impulse response \( h_c(t) \):

\[ h_c(t) = \sum_{l=1}^{L} a_l \delta(t - \tau_l) e^{-j\theta_l} \]  

where \( a_l \)'s represent the amplitudes of slowly varying independent stationary Rayleigh random processes, \( \theta_l \)'s are i.i.d. random variables uniformly distributed on \((0, 2\pi)\). The \( \tau_l \)'s are the relative delays of the \( L \) separable multi-path components with \( \tau_1 < \tau_2 < \cdots < \tau_L \) and assumed to satisfy \( \tau_{l+1} - \tau_l > T_c \).

The received signal \( r(t) \) can then be written as

\[ r(t) = \text{Re} \left[ \sum_{l=1}^{L} a_l p(t - \tau_l) e^{j2\pi f_c t + \theta_l} \right] + N(t) \]  

where \( N(t) \) is AWGN process with two-sided power spectral density \( N_0/2 \), and \( \tilde{\theta}_l = -(2\pi f_c \tau_l + \theta_l) \mod (2\pi) \).

The GEW tracking loop is shown in Fig.1, the received signal is demodulated into I and Q quadrature base-band components:

\[ r^I(t) = \frac{1}{\sqrt{2}} \sum_{l=1}^{L} a_l p(t - \tau_l) \cos(\tilde{\theta}_l) + N^I(t) \]  

\[ r^Q(t) = \frac{1}{\sqrt{2}} \sum_{l=1}^{L} a_l p(t - \tau_l) \sin(\tilde{\theta}_l) + N^Q(t) \]  

The local PN code \( p(t - \Delta) \) is fed into tapped delay line where \( \Delta \) is an offset which will be used to model the timing error, the \( L \) stage branches are correlated with the quadrature base-band components, after squared and summed, produced the energy of the \( L \) separable multi-path components \( E_m(-\Delta) \) (that is referred to as tracking energy windows). In IS’95A