DS-SS Code Acquisition Based on Simultaneous Search and Verification

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Abstract—**We propose a two-dwell acquisition system with a serial search that operates simultaneously with verification. This system employs two correlation blocks: one for search and the other for verification. The search block continuously searches for the time instants at which the partial correlation value exceeds a time-varying threshold, and at those instants, the verification block is reset and reinitiated until code acquisition is declared by the verification. The time-varying threshold is updated depending on the partial correlation. The mean acquisition time for AWGN and multiple access environment is evaluated by computer simulation and is compared with that of a two dwell system which alternates search and verification modes. The results indicate that the proposed system can perform much better than the conventional one.**

I. Introduction

In direct sequence spread spectrum (DS-SS) systems, the goal of code acquisition is to achieve a coarse time alignment between the received pseudo-noise (PN) code and the locally generated code to an accuracy of a fraction of one PN sequence chip. A popular approach to code acquisition is the serial search techniques [1]-[8] which correlate the received and locally generated code sequences and test the synchronization based on either the crossing of a threshold or the maximum correlation. These techniques can be thought of as a serial realization of a maximum-likelihood (ML) search method [16] and outperform classical sequential estimation techniques [14], [15], especially in multiple access environment. The serial search techniques perform worse than the parallel acquisition in [8]-[13], but the complexity of the latter is often prohibitive.

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In many practical code acquisition systems, to avoid any false alarm, search techniques are often used in conjunction with a verification algorithm [4]-[7], [9]-[12]. The verification process alternates with the search process: it is started whenever acquisition is declared; the search is in rest during verification, and is resumed when false alarm is declared. The verification can reduce the mean acquisition time especially when the probability of false alarm of the search mode is high. An acquisition algorithm employing both the search and verification is called a *two-dwell* system.

In this paper, we make an attempt to improve the performance of a two-dwell acquisition system with a serial search. Specifically, an algorithm that simultaneously operates search and verification is introduced and its performance is examined. It will be shown that the proposed algorithm can perform better than the conventional two-dwell acquisition which alternates search and verification modes.

II. Code Acquisition Using Simultaneous Search and Verification

Simultaneous search and verification requires two correlation blocks, one for search and the other for verification, as shown in Fig. 1. For the search block, either a matched filter (equivalently, a passive correlator) or an active correlator may be employed — in this work, we use a matched filter for fast acquisition. For the verification block, it is sufficient to use an active correlator. The continuous input signal $r_a(t)$ is frequency down converted and sampled with

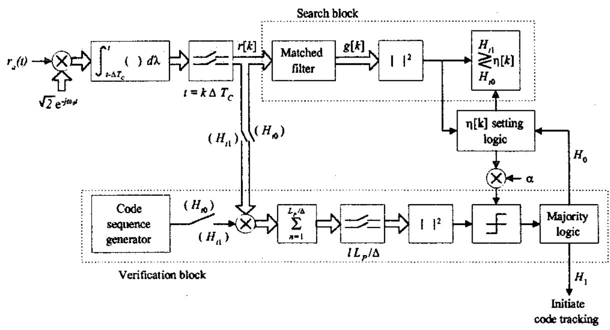

Fig. 1. The proposed code acquisition system.

period ΔT_C where Δ is a constant, typically $\Delta = 2^{-n}$ for a non-negative integer n, and T_C is the chip period. Assuming an AWGN channel, the resulting signal $r[k]$ which is inputted to the correlators is given by

$$r[k] = \sum_{m=1}^{M} \sqrt{S_m} e^{j\theta_m} \int_{(k-1)\Delta T_C}^{k\Delta T_C} d_m(t-\tau_m) \cdot c_m(t-\tau_m)dt + n[k], \quad k = 1, 2, 3, \ldots, \quad (1)$$

where M is the number of multiple access users; S_m is the signal power for the m-th user; θ_m represents the carrier phase offset; $d_m(t)$ and $c_m(t)$ denote the data sequence and the code sequence of length L-chips, respectively; τ_m represents the delay with respect to a time reference; and $n[k]$ is zero-mean Gaussian noise with variance $\sigma_n^2 = \Delta T_C N_0/2$. In the ensuing discussion, we shall assume that $d(t) = 1$ (data are absent) and that $c(t)$ is ± 1-valued (rectangular pulse shape), as in [1].

The output of the matched filter in the search block for the m-th user is given by

$$g[k] = \sum_{i=0}^{L_P/\Delta - 1} r[k-i] c_m[i] \quad (2)$$

where L_P is the partial correlation length and $c_m[i]$ can be obtained by sampling $c_m(t)$ with period ΔT_C, i.e.,

$$c_m[i] = c_m(t)|_{t=i\Delta T_C}. \quad (3)$$

In the search block, the magnitude $|g[k]|^2$ is compared with a variable threshold $\eta[k]$, which is defined as

$$\eta[k] = \begin{cases} \eta_0, & \text{at } k = 1 \text{ and at time instants where false alarm is declared by verification} \\ \max\{\eta_0, \eta[k-1], |g[k-1]|^2\}, & \text{otherwise} \end{cases} \quad (4)$$

where η_0 is the initial threshold which is determined depending on input statistics. This $\eta[k]$ is non-decreasing, unless false alarm is declared by the verification block. The search block declares tentative acquisition, say hypothesis H_{t1}, whenever $|g[k]|^2 > \eta[k]$. Referring to Fig. 2, which shows typical trajectories of $\eta[k]$ and $|g[k]|^2$, the proposed algorithm is described as follows. At $k = k_1$, $|g[k_1]|^2 > \eta[k_1]$. Then H_{t1} is declared and verification is activated. The threshold at k_1+1 becomes $\eta[k_1+1] = |g[k_1]|^2$. For $k > k_1$, both search and verification processes are in motion. The search block continues finding instants at which the threshold is crossed. Suppose that threshold crossing is occurred at $k = k_2$, before the verification is completed. In this case, we reset verification: the verification process is restarted at $k = k_2 + 1$, ignoring the results between $k_1 + 1 \leq k \leq k_2$. This is because $|g[k_2]|^2 \geq |g[k_1]|^2$. In this manner, the search and the verification blocks operate simultaneously until the verification is completed.

The procedure for verification is essentially identical to those in [4]-[7]. The active correlator evaluates the partial correlation at multiples of L_P/Δ time instants, and compares the results with a threshold $\alpha\eta[k]$ for α a constant. False alarm is declared if the majority of partial correlations fail to exceed the threshold.

The proposed code acquisition algorithm is summarized as follows: 1) The search block continuously searches for time instants, say $k_1, k_2, k_3, \ldots (k_1 < k_2 < k_3 \ldots)$ at which $|g[k_j]|^2 > \eta[k_j]$, by serially evaluating partial correlation values, where the time varying threshold $\eta[k]$ is given by (4). 2) At k_1, verification is started; at each k_j, $j \geq 2$, verification is reset and reinitiated. 3) The search and verification continues until code acquisition is declared by the verification block.

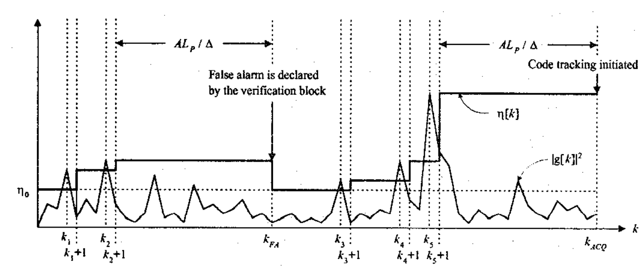

Fig. 2. Typical trajectories of $\eta[k]$ and $|g[k]|^2$ where A is a positive integer. At k_1 and k_3 verification is started, and at k_2, k_4, and k_5 verification is reset and reinitiated.

III. Performance Evaluation

In order to evaluate the performance of the proposed system, its mean acquisition time is obtained by computer simulation and compared with that of a two dwell system in [5], having variable threshold. In the simulation, the Gold code of length $L = 1023$ chips is used; the chip quantization factor $\Delta = 1/2$; the partial correlation length $L_P = 256$ chips; and the initial threshold $\eta_0 = 0$. For verification, the parameter A is set at 4: if at least 2 out of 4 observations in the verification exceed $\alpha\eta[k]$, code acquisition is declared. The time required for the tracking loop to indicate false lock and the acquisition system to resume search is set to 25000 T_C [7]. The mean acquisition time is normalized with LT_C, and denoted by $E\{T_{ACQ}\}/LT_C$.

The normalized mean acquisition time of the proposed algorithm is empirically estimated for various E_C/N_0 and for several values of the parameter α. The results are shown in in Fig. 3. It is seen that $\alpha = 0.3$ exhibits the best performance over the entire range of E_C/N_0. Therefore, α is fixed at 0.3.

For comparison, the normalized mean acquisition time of the method in [5] is also evaluated. In this method, the threshold η_v is given by

$$\eta_v = \gamma\hat{\sigma}^2 \tag{5}$$

where γ is a variable which is determined depending on E_C/N_0, and $\hat{\sigma}^2$ is an estimate of the disturbance variance. The normalized mean acquisition time is obtained both through computer simulation and by numerical integration of the analytical results in [5].

The performances of the two methods are compared in Fig. 4 and 5. Note that for the variable threshold method, the results from the simulation are very close to those from the numerical integration. The proposed method outperforms the variable threshold method in the entire range of E_C/N_0 (Fig. 4) and of the number of users M (Fig. 5). In particular, the former performs considerably better than the latter either when E_C/N_0 is low or when M is large.

IV. Conclusion

A two dwell acquisition system based on simultaneous search and verification was proposed and its performance was examined through computer simulation. The simulation results demonstrate that the proposed method can perform much better than the conventional variable threshold method. The design of the proposed method is simple: regardless of input statistics, its initial threshold η_0 can be set to zero, and the parameter α for verification can be fixed to a constant. On the other hand, determination of the variable threshold requires careful estimation of E_C/N_0. Further work in this direction will be concentrated on the extension of the presented scheme for multipath fading channels.

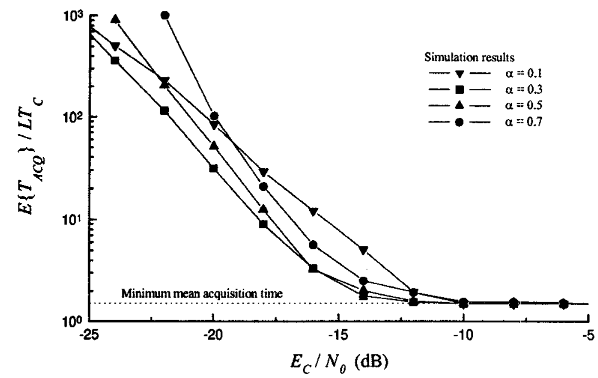

Fig. 3. Normalized mean acquisition time $E\{T_{ACQ}\}/LT_C$ versus E_C/N_0 where α is a scaling factor.

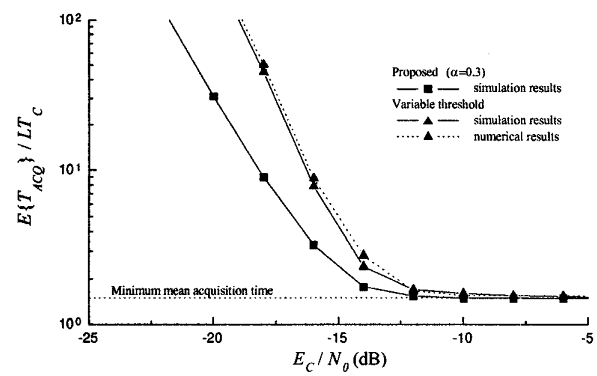

Fig. 4. Performance comparison between the proposed and the variable threshold methods, where number of users $M = 1$.

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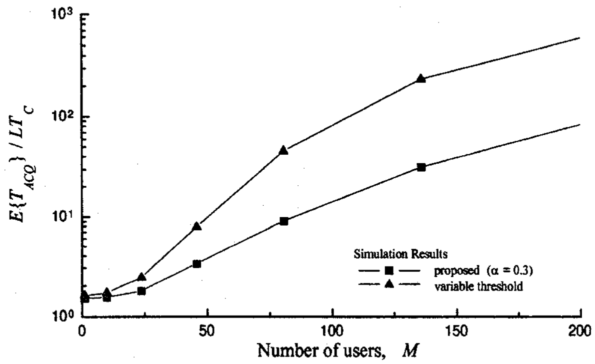

Fig. 5. Performance comparison between the proposed and the variable threshold methods, when $E_C/N_0 = -10$ dB and the number of users is increased.

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