Suboptimal Schemes for Noncoherent Parallel Acquisition of Spreading Sequences in DS/SS Systems

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Abstract — Acquisition is a very important step in DS/SS communications systems. In this paper, we describe several suboptimal schemes for parallel noncoherent acquisition. Simulation results and performance analysis are also summarized.

I. INTRODUCTION

In direct sequence spread-spectrum (DS/SS) communications systems, the transmitter’s signature sequence and the receiver’s replica of this sequence must be synchronized in order to provide enough signal energy for reliable data demodulation. The synchronization has two stages. In the first stage, often referred to as coarse acquisition, the receiver’s sequence is synchronized to within some fraction of the chip duration with the transmitter’s sequence. In the second stage, the receiver accomplishes and maintains fine alignment of the sequences by using a code tracking loop. In this paper, we consider only the coarse acquisition process. Our goal is to find effective acquisition schemes which are also easy to implement.

II. ESTIMATION OF DELAY

In noncoherent parallel acquisition schemes, the receiver first computes, in parallel, the correlation of the received signal with the locally generated in-phase and quadrature RF carrier for each of the phases of the PN sequence. Next, the N complex observations \( Z_i(t) \), where \( i = 0, 1, \ldots, N-1 \), are used to estimate the unknown delay between the local sequence and the sequence in the received signal.

Optimal Estimator The optimal estimation scheme [1] [2] minimizes \( P_e \), the probability that the estimate of the true delay differs from the true delay by more than half a chip interval. \( S_{opt} \) as given in [2] is very intensive computationally and its performance is difficult to evaluate analytically.

Suboptimal Estimators Srinivasan and Sarwate [3] have considered suboptimal estimators in which the delay \( \delta = k + \epsilon \) (where \( k \in [\delta] \)) is estimated in two steps. First, \( k \) is estimated as \( k_{est} = \arg \max_{x \in \{0,1,\ldots,N-1\}} |Z_{x}| \) and then \( \epsilon \) is estimated in the same manner as in \( S_{opt} \) or the coherent version of \( S_{opt} \) [1]. These schemes perform nearly as well as the optimal estimator scheme but analytical evaluation of performances is difficult.

We have studied some two-stage suboptimal schemes that estimate \( k \) as

\[
\arg_{i \in \{0,1,\ldots,N-1\}} \max \left( |Z_i|^2 + |Z_{i+1}|^2 + \text{Re}(Z_i Z_{i+1}^*) \right)
\]

cf. [2], and \( \epsilon \) from the ratio \( |Z_{k_{est}}|/|Z_{k_{est}+1}| \). In particular, \( S_{est} \) uses

\[
\frac{|Z_{k_{est}+1}|^2}{|Z_{k_{est}+1}|^2 + |Z_{k_{est}}|^2}
\]

as the estimate of \( \epsilon \). The computational costs of these schemes are much smaller than the optimal scheme. Moreover, because of the simplicity of the decision statistics, analytical results can be obtained.

III. PERFORMANCE ANALYSIS

We have proved that \( P_e \) for all the suboptimal schemes is bounded above by a function that decreases exponentially with increasing SNR. This implies that \( P_{e,\text{opt}} \), the error probability for \( S_{opt} \) is also an exponentially decreasing function of SNR.

We have studied the performances of the suboptimal schemes by simulation. The figure below compares the error probability performance of the optimal scheme and the four suboptimal schemes. For \( \epsilon = 0.25 \), two of the schemes have performance close to optimal. For other values of \( \epsilon \), other schemes are close to optimal. However, in all cases, \( S_{est} \) is always close to the optimal.

![Figure 1: \( P_e \) for \( S_{opt} \) and four suboptimal schemes.](image)

REFERENCES

