MULTIPLE-DWELL SERIAL-SEARCH CODE ACQUISITION OF SPREAD-SPECTRUM RECEIVER - MEAN ACQUISITION TIME AT FIXED FALSE-ALARM PENALTY

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Abstract

The contribution summarizes the results of the mean code acquisition time calculations of multiple - dwell serial search detector with fixed false-alarm penalty. The repeated calculations enable to choose optimum values of the synchronizer parameters.

Keywords:

1. Introduction

Recovery of information contained in a received direct-sequence spread-spectrum signal (DS-SS) can only be achieved if the receiver eliminates a spreading code modulation, which is the modulation by a periodic digital code signal, the bandwidth of which determines the bandwidth of the resulting spread spectrum signal. When the spreading modulation is synchronous with the data, the period T_{PC} of the code signal is equal to the symbol interval T_o of a digital data signal being transmitted. The spreading elimination, i.e. despreading, is performed by modulation of the received signal by the inverse code signal, which in the case of binary phase shift keying (BPSK) is the replica of the original spreading code signal [1]. The despreading is accomplished, if this replica is aligned with the code modulation of a received signal, i.e., if the time offset between the code modulation and its replica is kept very low in comparison with the chip interval T_c. This mechanism is described in Fig.1. If no information concerning the time position of the spreading code modulation of a received signal is known at the receiver, the uncertainty region of this position is equal to the whole code modulation period and the probability density of the true position has uniform distribution. The more information of this position is known, the closer is the probability density to the δ-distribution which describes the case of the perfect knowledge of the modulation position. As apriori information concerning time position of the code modulation of a received signal is usually very low, we have to find the right position of the code replica within a prescribed uncertainty region and maintain it. This two-step process is referred to as the code synchronization process. Initially, the code replica acquisition to within a prescribed maximum mutual shift of the code modulation and of the replica must be achieved. Typically, this maximum value is a fraction of the chip interval T_c, e.g. $T_c/2$. Then, a fine alignment (tracking) must be maintained.

Initial code acquisition is generally the most difficult operation to be performed in any spread-spectrum system. In a low signal-to-noise ratio environment serial search

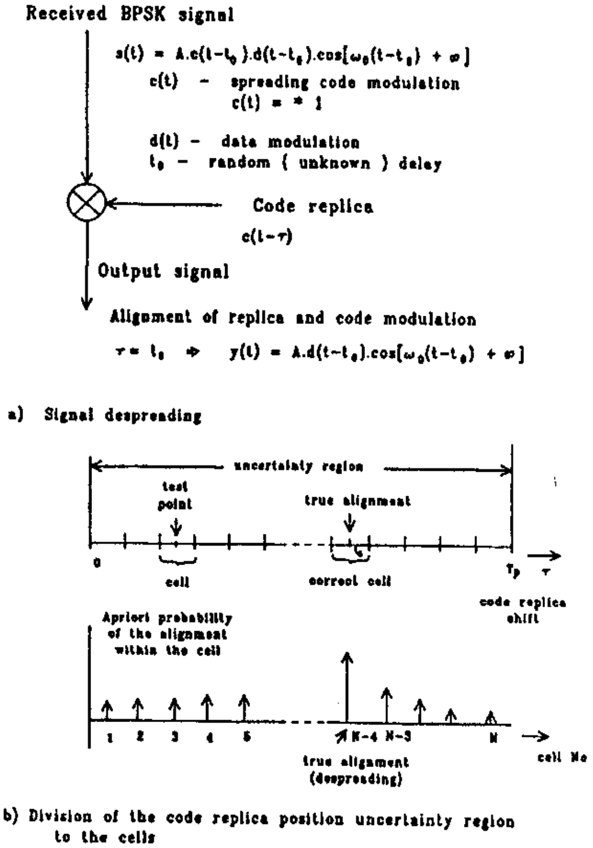

Fig.1
Mechanism of despreading and code replica alignment

usually outperforms other synchronization methods based on matched filter or convolver, sliding correlator or sequential estimator [2], [3]. For the serial search the uncertainty region is divided into cells of an equal width the value of which is constrained by the double of the value of the maximum allowable acquisition error. Each cell is supposed to be observed in its middle point and an observer decides between two alternative hypotheses concerning the elimination of the spreading modulation - signal is despreaded or not. If the signal is despreaded at the tested cell, the replica is aligned and acquisition is reached . The next cell is then tested, if despreading has not been reached. The full description of an acquisition process comprises of the search strategy and the detection rule statement. The search strategy defines the order of cells tested during acquisition. The detection rule is a rule of the decision concerning signal despreading at the tested cell. The decision is based on one or more observations.

The mean time to reach acquisition is generally used as a measure of the system acquisition performance. This is the average time of a search through the region of uncertainty until successful acquisition occurs. In many cases of bursty communication, a more appropriate measure is the probability of successful acquisition within a given time interval.

2. Multiple-dwell acquisition detector

In the contribution, the influence of a detection rule on the mean acquisition time is analyzed. During cell testing, any real detector is subject to detection errors induced by noise. The false-alarm denotes the wrong "signal is despreaded " decision, the wrong "signal is not despreaded" decision is referred to as signal miss. These decision errors cause the mean acquisition time to increase. An attempt to lower this mean time under such circumstances leads to serial-search by the multiple-dwell detector whose decision is based on repeated observations at the tested cell [4]. The final decision concerning the

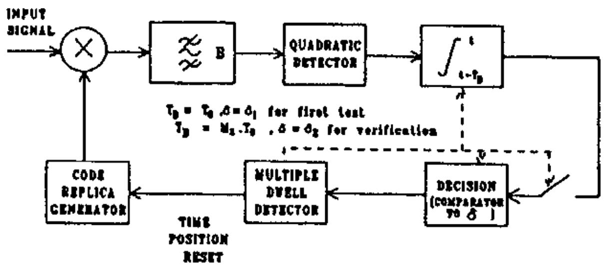

Fig.2
Block diagram of envelope correlator and multiple dwell detector

tested cell is a function of the sequence of individual decisions. This function is referred to as the detector rule.

When the first decision concerning the correctness of the tested cell is positive, this decision is verified by I repetitions of the verification observation and decision. If $I = 0$, the result of the first test is not verified and the multiple-dwell detector is reduced to the single-dwell detector. The length of the first observation interval T_D need not be equal to the length $M_2 \cdot T_D$ of the observation interval of I repetitions of the verification. Equally the first test decision level δ_1 need not be equal to the decision level δ_2 of all verifications. The individual observations are obtainable by means of coherent or quadrature or envelope correlator [1], [7]. A block diagram of the last type is given in Fig.2 . It consists of a chain of intermediate frequency multiplier of a received signal by the code replica (despreading multiplier, Fig.1), a band-pass filter, the pass-band of which is matched to the despreaded signal spectrum bandwidth , a quadratic (envelope) detector and an integrator. The output of this correlator forms the observation of the despreaded signal on the time interval T_D given by the interval of integration. The output of an envelope correlator can be treated as data independent only if the bandwidth B of the correlator band-pass filter fulfils the condition $B \cdot T_0 >> 1$ [5]. SNR is defined as the ratio of signal power to noise power at this predetection filter output.

To simplify calculations, the integrator is often approximated by sampler and a summing circuit. This approximation together with an approximation of the chi-square sample probability distribution by the gaussian distribution is utilized in our analysis.

Let the analyzed acquisition process be defined by the block diagram in Fig.3. The decision rule given there declares the cell to be the correct one, only if all $I+1$ subsequent decisions concerning correctness of a tested cell are positive. Then the synchronizer switches to the tracking mode. This type of detector is referred to as the

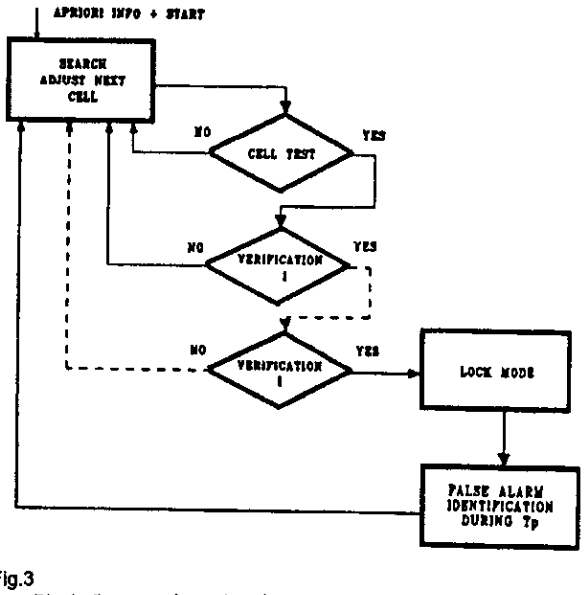

Fig.3
Block diagram of synchronizer

immediate rejection type. But the decision concerning acquisition can result from the chain of $I+1$ false alarms as well. Therefore, the synchronizer has to contain a false alarm detector, which recognizes between false and true acquisition within the shortest time interval. This time interval is random, but a plausible simplification of analysis is reached, if we consider it as the fixed penalty time T_p. This simplification is used during our analysis.

3. Calculations of mean acquisition time

For the mean acquisition time calculation the theory of Markov chains and their representation by signal flow graphs is utilized. A rather complicated derivation of polynomial description of a detector model transfer function will not be given here. The description of the method can be found in [1], the precise derivation of the expression of the mean acquisition time can be supplied by the authors [8]. We would rather describe the results of our analysis in the typical case corresponding to the current applications. Our analysis is confinéd to BPSK spreading as well as data modulation. Both modulation are supposed to be synchronous. The other parameters of a received signal and the envelope correlator synchronizer can be varied during calculation widely.

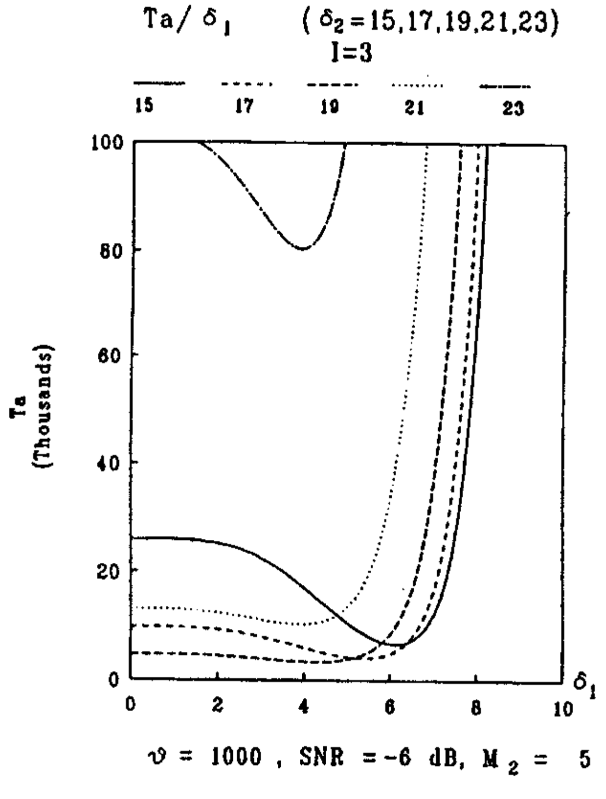

Fig.4
Dependence of T_a on δ_1 and δ_2 for $I = 3$, $\vartheta = 1000$

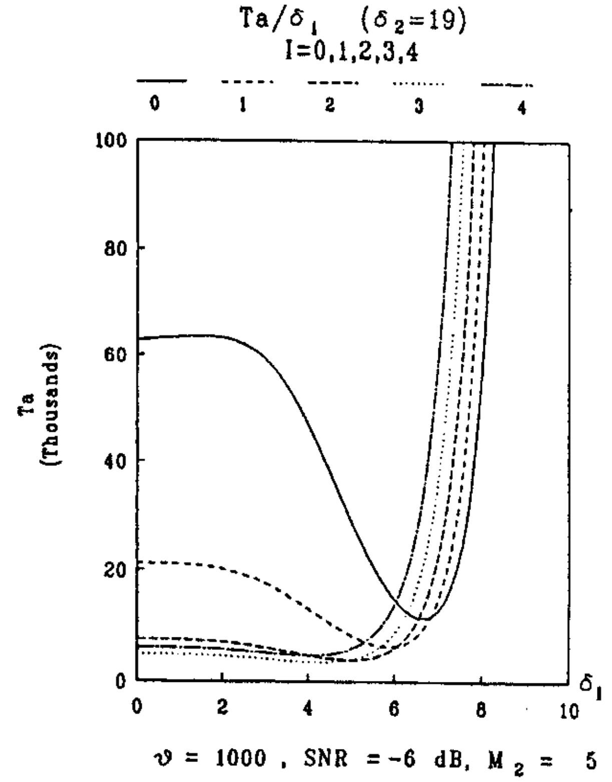

Fig.5
Dependence of T_a on δ_1 and I for $\delta_2 = 19$, $\vartheta=1000$

The aim of our analysis is to express the normalized mean acquisition time $T_a = T_{acq} \cdot T_0^{-1}$ as a function of parameters δ_1, δ_2, I, M_2, SNR, and normalized penalty time $\vartheta = T_p \cdot T_0^{-1}$. By repeated calculations we can find the optimum values of I, δ_1 and δ_2 for given values of SNR, T_D, ϑ and M_2. The code period consists of L chips and the period of the code signal $L \cdot T_c$ equals to the data interval T_0. During analysis the results of which are presented here $L = 63$ and $B \cdot T_0 = 3.15$ are fixed. The code signal is supposed to have the ideal triangular autocorrelation function [1],[3],[6]. The observation interval is $T_D = T_0$ for the first test and $M_2 \cdot T_0$ for each of I verifications.The results are calculated for two values of the normalized penalty time, $\vartheta = 100; 1000$.

It is useful to start our analysis by the proper choice of the verification decision level value δ_2. To find this, the dependence of T_a on the first test decision level δ_1 for various values of δ_2 is calculated for $I = 3$, $M_2 = 5$, $SNR = -6$ dB and $\vartheta = 1000$. The result is given in Fig.4. The chosen values of parameters are supposed to be typical for a code synchronizer. The minimum of T_a is reached for $\delta_2 = 19$. For this value fixed , the normalized mean acquisition time T_a as a function of δ_1 for different number of verifications I is given in Fig.5. The optimum value of $I = 3$ realizes the minimum of T_a. But if the value of normalized penalty time ϑ decreases, the optimum value of I decreases, too. This tendency can be found by comparison of Fig.5 with Fig.6, where the only altered parameter is $\vartheta = 100$. In this case, $I = 2$ is an optimum

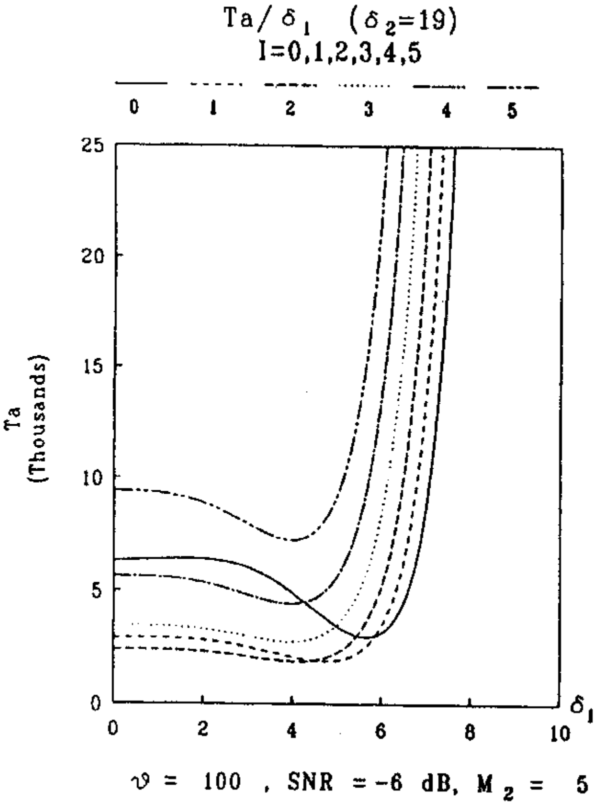

Fig.6
Dependence of T_a on δ_1 and I for δ_2 = 19, ϑ=100

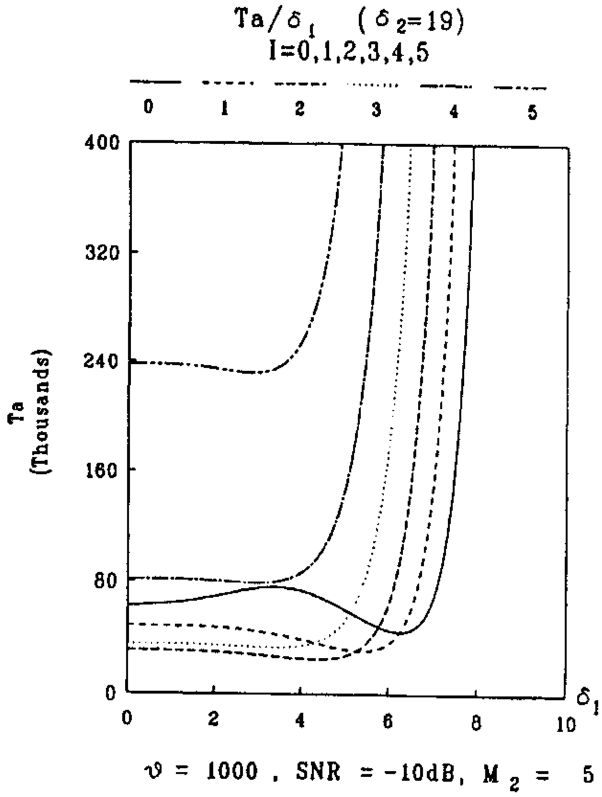

Fig.7
Dependence of T_a on δ_1 and I for δ_2 = 19, ϑ=1000, SNR = -10 dB

value and the resulting normalized mean acquisition time is shorter. Its dependence on the signal to noise ratio *SNR* can be demonstrated by comparison of Fig.5 and Fig.7. Evidently , the lower the *SNR*, the longer is T_a. The optimum value $I = 2$ in Fig.7 differs from the preceding case $I = 3$ in Fig.5. Moreover, the optimum value of δ_2 is *SNR* dependent, therefore, a new optimum of δ_2 for $SNR = -10$ dB should be found. Finally, the influence of verifications increases, if the verification observation time interval $M_2 \cdot T_0$ increases. This is documented by Fig.8. In all cases, the general tendency concerning δ_1 can be found. The normalized mean acquisition time T_a is less sensitive to changes in δ_1 in the region of lower than optimum values. If δ_1 increases above its optimum value, the increase of T_a is very rapid. As a rule, the amplitude of a received signal is not apriori known precisely. Therefore, the lower than expected optimum value of the decision level should be set.

4. Conclusion

In this contribution the serial search code acquisition process of a direct-sequence spread- spectrum receiver is analyzed. The model with fixed false-alarm penalty time is utilized for derivation of the dependence of the normalized mean acquisition time on the values of multiple-dwell acquisition detector parameters. For some parameters fixed, repeated calculations enable to find nearly optimum values of the varied parameters and the locally minimum value of the mean acquisition time. In comparison with the single-dwell detector, this time is remarkably lower but both values are of the same order in the presented case.

The described method can be utilized for the analysis based on an arbitrary model of acquisition detector and numerical results obtained for different detectors could be compared. The method has been utilized not only for the fixed false-alarm penalty model , but for a model containing a specified lock verification detector [9] as well.

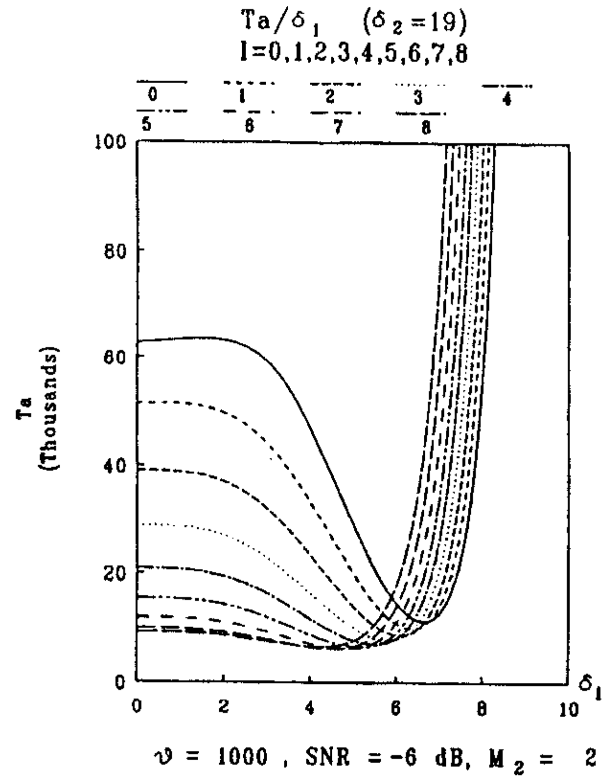

Fig.8
Dependence of T_a on δ_1 and I for δ_2 = 19, M_2 = 109

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