CLPDI ALGORITHM IN UWB INITIAL CODE ACQUISITION WITH SALEH-VALENZUELA MODIFIED CHANNEL MODELS

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ABSTRACT

In this paper the code acquisition in time hopping (TH) ultra wideband (UWB) systems is investigated. A serial search strategy is implemented by a passive code Matched Filter (MF) and then a chip level post detection integration (CLPDI) algorithm is utilized. The aim of this paper is to compare the performance of the code MF with the performance obtained with CLPDI using the modified Saleh-Valenzuela channel models. The results show that the CLPDI algorithm achieves a considerable reduction in terms of mean acquisition time.

I. INTRODUCTION

Spread spectrum (SS) systems advent added a new synchronization duty: the code synchronization. The receiver is forced to adjust its code phase to the received signal code phase in order to recover the transmitted information. In UWB case the signal is already wideband, and therefore the spreading codes are used only for multi-user and spectrum sharpening reasons. CLPDI algorithm has been presented for code acquisition in direct sequence code division multiple access (CDMA) systems [1][2]. The suitability of CLPDI in TH-UWB systems has also been studied in [3] in static multipath AWGN channel. In this work the performances of the algorithm are studied to prove its suitability in realistic UWB channel environments.

The paper is organised as follows. In Section II, TH-UWB system model and channel model are presented. Section III describes the synchronization approach. Section IV and Section V give simulation results and conclusions.

II. SYSTEM MODEL

A. Time Hopping UWB System

TH concept applied to UWB system has been presented in [4]. The data (bit) energy is spread over the data time window using several pulses according to the TH code. The symbol window is divided in N frames and in each frame only one pulse per user can be sent using one of the possible M positions defined by the spreading code. In Fig. 1 T_b is the data duration, T_f is the time frame and T_p is the pulse width. Processing gain (PG) generated by the TH technique can be obtained adding two values in logarithmic scale: one is given by the pulse repetition and one is defined by the low duty cycle inside each frame $T_p/T_f \ll 1$.

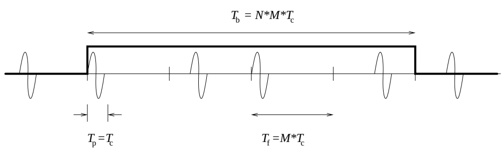

Fig. 1. The TH spread concept applied to UWB.

In this paper binary pulse position modulation (PPM) is used. This means that once the spreading code defines the position inside a frame (chip) where the pulse has to be transmitted, a delay $\tau_\delta = \delta T_p$ is used to distinguish bit '0' from bit '1'. The transmitted signal for a single user system can be presented as

$$s(t) = \sum_{k=1}^{\infty} \sum_{j=1}^{N} w_{tr}(t - kT_b - jT_f - c_j T_c - \tau_\delta d_k) \quad (1)$$

where $w_{tr}(t)$ is the pulse waveform after the antenna at the transmitter side, d_k is the data bit transmitted, c_j is the j^{th} phase code. T_c is the chip time equal to T_p. In this paper orthogonal modulation is used (δ≥1), blocks of bits '0' are transmitted and $w_{tr}(t)$ is the Gaussian monocycle. The signal at the receiver side after the Rx-antenna is given by

$$s_{rc}(t) = \sum_{i=1}^{L} A_i \sum_{k=1}^{\infty}\sum_{j=1}^{N} w_{rx}(t - kT_b - jT_f - c_j T_c - \\ -\tau_\delta d_k - i\tau_l) + n(t) \quad (2)$$

where $w_{rx}(t)$ is the 1st derivative of $w_{tr}(t)$, L is the number of resolvable paths, A_i defines the gain for path i and $n(t)$ is zero mean additive Gaussian noise.

B. Channel model

The CLPDI algorithm performance in TH-UWB in a static multipath channel has already been presented in [3]. In this paper we consider a realistic channel model for UWB transmission. The selected channel model is Saleh-Valenzuela (SV) with a couple of slight modifications proposed in [5]. The path arrivals are described in clusters where the average power decays are exponential. The two modifications made for the original SV-mode are log-normal fading distribution on the path amplitudes instead a Rayleigh distribution and independent fading for each cluster as well as each ray within the cluster.

Four different channel models are considered as they are defined in IEEE 802.15.3a. The first one (CM1) is based on LOS(0-4m) channel measurements and the others (CM2, CM3 and CM4) are based on NLOS channel measurements. Usually complex base-band model is a natural fit for narrowband systems to capture channel behaviour independently of carrier frequency, but this motivation breaks down for UWB systems where only signal inversion due to reflections is considered [5].

III. SYNCHRONIZATION

A. General

The goal of a code acquisition procedure is to aligning the receiver code phase with the incoming signal code phase. In this paper a serial search strategy is considered. The implementation of this strategy is based on code MF.

In TH case the uncertainty region corresponds to the code length and it is divided in a number of cells equal to the number of possible pulse positions presented in a bit interval.

The presence of a multipath channel introduces more than one correct synchronization cells. Once the code synchronization algorithm finds one of the possible synchronization cells, an additional sweep has to be performed to acquire the necessary number of paths. The aim of this initial code acquisition in multipath channel is to find a starting point to reduce the multipath search time.

B. Synchronization schemes

In time hopping system, the code MF combines samples according to the code defined delays between the consecutive pulses. A threshold comparator follows the code MF. Block diagram is shown in Fig. 2. When the threshold is crossed a verification procedure starts to define if the acquisition point is correct or not.

When the CLPDI block is used, m consecutive MF outputs are processed and the sampling rate at the CLPDI output is equal to mT_c. Then the threshold comparison is done after the new CLPDI-block.

The idea of the chip level post detection integration is to take advantage of the diversity created by the multipath channel performing post detection integration at the chip level. Processing independent blocks of m consecutive MF outputs (modified CLPDI [2]) there is an extra gain in two directions: one is that the outputs of the CLPDI block are independent and the other is the reduced number of cells to be tested as it can be seen comparing Fig. 3 and Fig. 4

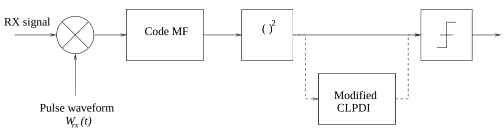

Fig. 2. Synchronization scheme

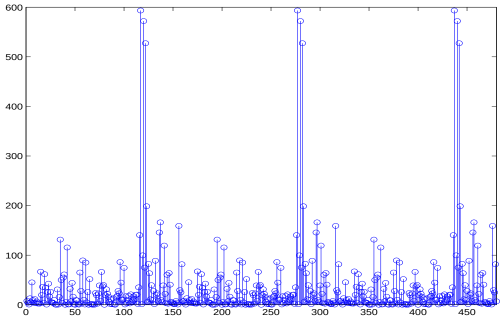

Fig. 3. MF output without noise as function of time in channel model 1, N=10 and M=16.

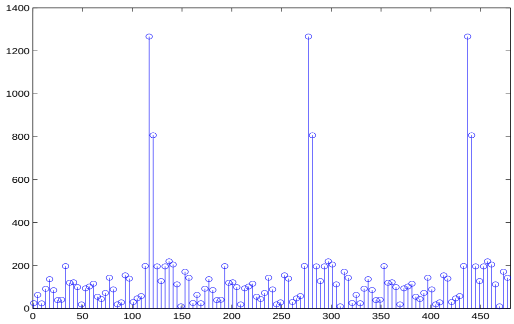

Fig. 4. CLPDI output without noise as function of time in channel model 1, N=10, M=16 and m=4.

IV. SIMULATION

A. Simulation model

The received signal is correlated with the pulse waveform $w_{rx}(t)$. Perfect chip synchronization is assumed. As in a non-coherent approach the output of the MF is squared. In this way all the processed samples in the CLPDI block have positive values. In our study, the threshold setting is done at the beginning of the simulation for each signal to noise ratio (SNR) value using a noise vector and using constant probability of false alarm (P_{fa}) criteria. During the simulation the threshold level is controlled (adjusted) to maintain the desired P_{fa}. Because of the fine path resolution of the UWB channel, the number of resolvable paths is larger than 100. Only the most powerful paths are considered for the code acquisition. The number of cells or chip positions on which the receiver can be considered synchronized is defined by the 20 strongest paths in the MF case. When m-CLPDI is used we make sure that the 20 synchronization positions defined in the MF case are included in the synchronization cells for the m-CLPDI algorithm. Since it is possible that the 20 synchronization cells are non consecutive the number of synchronization cells in the m-CLPDI case can be bigger than $20/m$. Once one of the synchronization cells is found a new acquisition process starts. Verification extra-time is added for each false alarm event occurred during the acquisition process. The acquisition performances are measured as mean acquisition time T_{ma}.

B. Simulation results

The simulations consider four modified Saleh-Valenzuela channel models. The pulse width T_p is fixed to 1ns. The code length is 160, the number of frames per bit is N=10 and the number of possible pulse position in each frame is M=16. The penalty time in the case of false alarm is $T_{fa}=100T_b$ and the required P_{fa}=0.01. The synchronization process is performed over a data packet of 30 bits and the channel is static over each packet. Every time the synchronization is reached or the data packet has been explored without synchronization, a new data block is transmitted.

Figs. 5-8 present the mean acquisition time of the code MF and of the system with the CLPDI block, respectively for m = 4, 10 and 20, versus the SNR, defined as the E_b/N_0 at the receiver side. E_b is the bit energy borne by all the paths composing the channel. Using CLPDI the reduced code acquisition time is evident for all the channel models. In terms of absolute time the mean acquisition time increases fro both MF and CLPDI passing from the CM1 to the CM4. The reason is the reduced energy borne by the 20 strongest paths while moving from CM1 towards CM4. Otherwise passing from the CM1 to the CM4 the performance improvement of CLPDI compared with the MF case increases. This is because moving from the CM1 to the CM4 the channel gets closer to the situation of having path with equal average power that gives best result as it has been showed for data detection using diversity techniques [6]. The extra gain achieved using m = 20 is not remarkable in the CM1. This is due to the reduced CM1 delay spread compared to the other channel models.

V. Conclusions

CLPDI algorithm and MF initial code acquisition performances have been compared in Saleh-Valenzuela channel models. The receiver with CLPDI block showed lower mean acquisition time then the receiver with only the MF for all the different channel scenarios. Using the CLPDI block the reduction of the mean acquisition time increases as the channel delay spread increases. The next step is to define the best number of MF outputs (m) to be processed in the CLPDI block considering the channel delay spread.

VI. References

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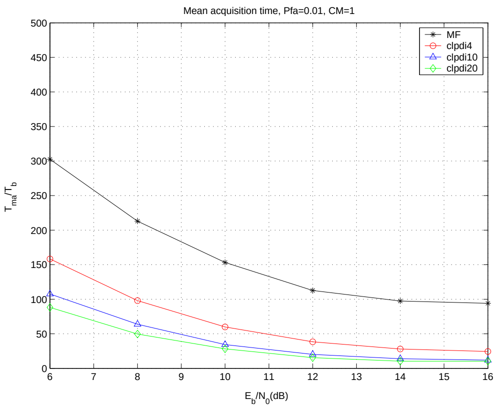

Fig. 5 T_{ma}/T_b as a function E_b/N_0 in channel model 1.

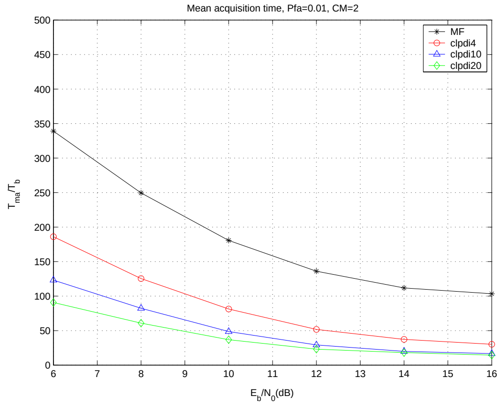

Fig. 6. T_{ma}/T_b as a function of E_b/N_0 in channel model 2.

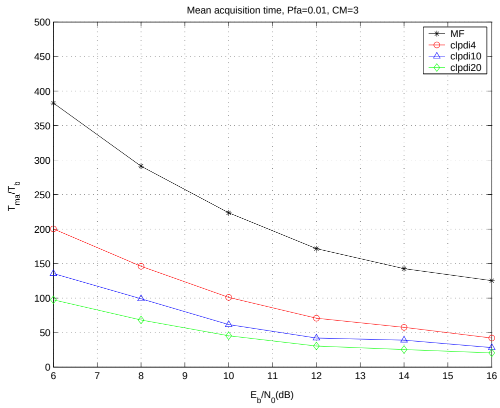

Fig. 7. T_{ma}/T_b as a function of E_b/N_0 in channel model 3.

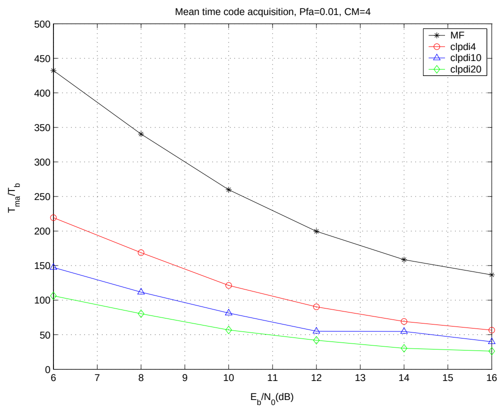

Fig. 8. T_{ma}/T_b as a function E_b/N_0 in channel model 4.