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CODE ACQUISITION WITH DOUBLE CORRELATOR IN DSSS RECEIVERS

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Abstract: *The spread spectrum (SS) communications system, use a pseudo-noise (PN) code to spread the initial bandwidth occupied by data over a bandwidth much wider. In receiver, the SS signal is despread using the same PN code. The most difficult task to achieve in receiver is to synchronize the locally generated PN code with the code existing in the received signal. The purpose of this paper is to present a receiver model for code acquisition that uses two active correlators, method derived from acquisition with active correlator. The method proposes that, in some circumstance, the synchronization of signals to be done by delaying the received signal, not the local PN code,with the advantages in reducing the acquisition time and signal recovery.*

Keywords: *communications, spread spectrum, direct sequence, code acquisition,correlator.*

1. INTRODUCTION

The **spread spectrum** (SS) communication technique use a **pseudo-noise** (PN) code as a waveform to spread the initial bandwidth occupied by data over a bandwidth much wider. In receiver, the SS signal is **despread** using the same PN code used in transmitter.

Direct Sequence Spread Spectrum **DSSS** is a method commonly used for spreading spectrum where the PN code is multiplied with input data [1,2,3].

The most difficult task to achieve in DSSS receiver is to synchronize the locally generated PN code with the code existing in the received signal. This synchronization process is carried out in two stages [1]:

- **Code acquisition** – coarse acquisition process which beings the two PN sequences in the same range of chip;
- **Tracking code** – fine–tune process in order to maintain the synchronization.

In code acquisition, one of the critical elements is during this process.

In order to reduce time acquisition, have been developed various methods, starting from fundamental techniques (with active correlator, with matched filter, serial or parallel search, etc.) to advanced code acquisition techniques [1,6,8].

The purpose of this paper is to present a receiver model for code acquisition that uses two active correlators, method derived from acquisition with active correlator.

2. COMMUNICATION SYSTEM MODEL

2.1 The work environment. Given the complexity of a SS communication system, it is preferable that the experiments for development of new tyle of schemes to be made initially, in a software simulation. For this study, as a working environment for modeling and experiments was used Matlab & Simulink software package.

2.2 System description. The structure of the proposed system is shown in Fig. 1 and consists of:

- The transmitter with: Data Generator, PN Sequence Generator and BPSK modulator;
- Communication channel with AWGN;
- The receiver with double correlator.

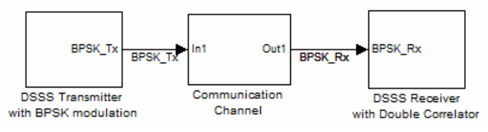

Fig. 1 Block diagram for communication system structure proposed.

Proposed structure for the transmitter shown in Fig. 2 is a simplified version of DSSS transmitter using a Gold Sequence Generator (as PN generator) for spreading spectrum and a BPSK modulator achieved with product operator.

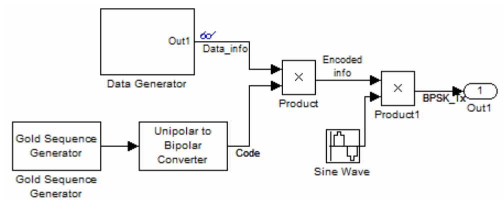

Fig. 2 Block diagram proposed for transmitter with DSSS and BPSK modulation.

For DSSS receiver was designed a model Pentru receptor a fost creat un model whose scheme is shown in Fig. 3. The main blocks of the designed receiver are:

– **BPSK Demod** – a coherent demodulator that extract the signal *Encoded info_Rx* from the BPSK modulated signal present at its input.

– **PN Sequence Generator** which generates local replica of the spreading code used in transmission.

– Two blocks with active correlator, **Delay Counter_LateRx** and **Delay Counter_EarlierRx**.

– Two blocks for delay, one for received signal and one for local code.

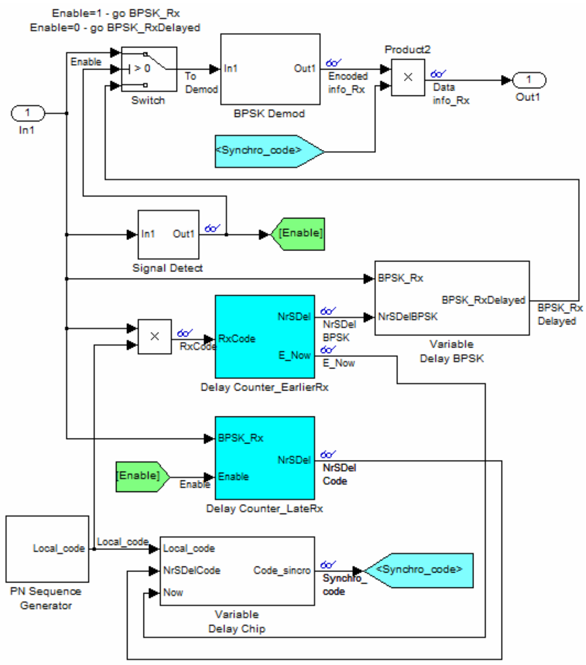

Fig. 3 Block diagram for receiver structure proposed.

The basic idea is to use two correlator blocks that have the role to calculate the phase shift between the received signal and the local code, phase shift counted in number of code bits (chips).

Delay Counter_LateRx calculates the number of chips, *NrSDelCode*, that have delayed the code to align it with the received signal.

Delay Counter_EarlierRx calculates the number of chips, *NrSDelBPSK*, that have delayed the received signal to align it with the code.

Through this mechanism, at the demodulator input is brought or the received signal *BPSK_Rx*, or the received signal delayed with *NrSDelBPSK* chips. There are two possible cases:

1. If the transmitter is turned on later than the receiver (the receiver waiting for the arrival of the signal from the transmitter), becomes operational the **Delay Counter_LateRx** block and is commanded local code delay with *NrSDelCode* chips. On entering the demodulator block is allowed access for the received signal *BPSK_Rx*. The delayed code, *Synchro_code*, is used to

extract the data signal *Data info_Rx* from the *Encoded info_Rx* signal.

2. If the transmitter is turned on earlier than the receiver (begins receiving a signal that it is not known when it started), becomes operational **Delay Counter_EarlierRx** block and the other operation is inhibited with the signal Enable = 0. Is commanded the delay of the received signal *BPSK_Rx* with *NrSDelBPSK* chips and on entering the demodulator block is allowed access for the signal *BPSK_RxDelayed*. In this case, the local code delay is zero, so that the *Synchro_code* signal is in phase (identical) with *Local_code*.

2.3 Experimental studies. The experiments are intended to test the receiver operation in the two cases above described:

1. The later transmission.
2. The earlier transmission.

The structure of the designed receiver allows:

- Delay setting for any of the two signals (*BPSK_Rx* and *Local_code*);
- Pursuit of signal processing at important points;
- Comparing the transmitted data signal to that recovered in the receiver;
- Delay analysis for recovered date signal in reception, due to proposed method.

2.4 The basic parameters of the system. To make visible representation of signal in time diagrams measured at various points, were chosen for system parameters the folowing values:

– The length of a data bit for signal information, $T_b = 0.01$ s;
– The length of PN code obtained from Gold Sequence Generator, $L_c = 63T_{chip}$ (shortened notation used in this paper: $L_c = 63$ chips);
– The length of a chip, $T_{chip} = 1/6300$ s;
– Carrier frequency, $f_c = 18900$ Hz, so that $T_c = T_{chip}/3$ (3 sinusoids/chip);
– Time simulation $T_{sim} = 0.04$ s, corresponding to 4 data bits.

3. EXPERIMENTAL RESULTS

For each of the two cases (as described in 2.2) were chosen two values of delay to be within:

a. $\Delta t < ½ L_c$
b. $\Delta t > ½ L_c$

In this way it may reveal to what amount of delay it is good to make signals alignment by delaying the PN local code or the received signal. PN code length being $L_c = 63$ chips, were chosen $\Delta t = 20T_{chip}$ and $\Delta t = 50T_{chip}$ (shortened notations used in this paper: $\Delta t = 20$ chips and $\Delta t = 50$).

3.1 Ideal case. Its shows diagrams of signals in ideal situation, when there are no delay and the received signal *BPSK_Rx* and *Local_code* are perfectly synchronized.

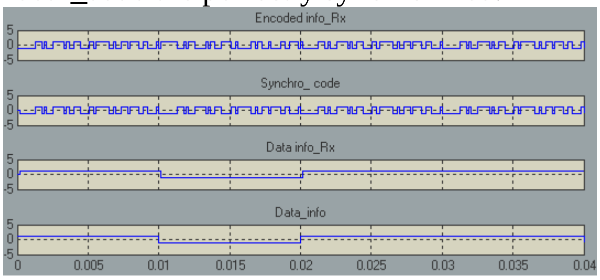

Fig. 4 Waveforms for *Encoded info_Rx*, *Synchro_code* and *Data info_Rx* compared to *Data_info* for ideal case.

If it make a zoom in the diagram of Fig. 4 around to t = 0 (see Fig. 5), can be observe a delay (marked with red) of 1 chip of *Encoded info_Rx* signal, due to signal processing in

BPSK Demod block. This delay has to be compensated by local code delay, in order to correct alignment of both signals. The effect: extract data signal is delayed by one chip towards the transmission.

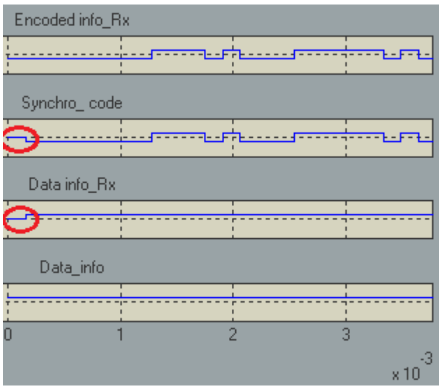

Fig. 5 The delay (of extracted data signal) by one chip towards the transmitted data signal, for ideal case.

3.2 The later transmission.

a. For a delay Δt = 20 chips of *BPSK_Rx* signal towards the local code, **Delay Counter_LateRx** block calculates the delay value and generates the signal *NrSDelCode* = 21, as shown in Fig. 6. The block **Variable Delay Chips** performs local code delay, thus achieving the synchronization of the two signals, *Encoded info_Rx* and *Synchro_code* from which it is recovered *Data info_Rx*.

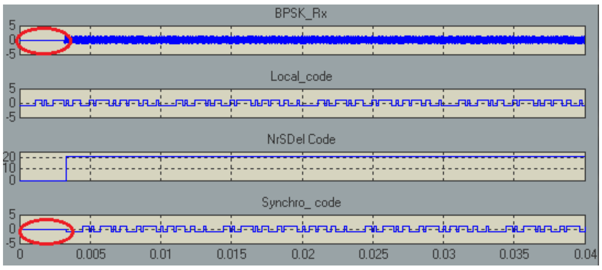

Fig. 6 Waveforms for received signal with 20 chips delay, *Local_code* and *Synchro_code* delayed with *NrSDelCode* chips for later transmission with **Δt = 20**.

On the waveforms shown in Fig. 7 can be seen synchronization of the two signals and a dealy with Δt + 1 = 21 chips of the signal *Data info_Rx*.

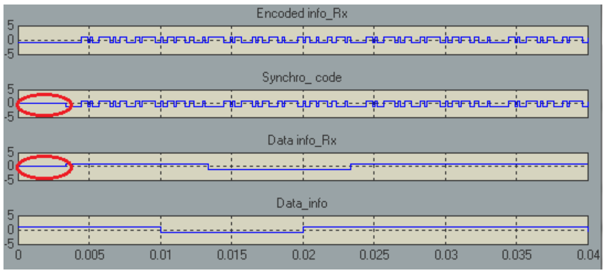

Fig. 7 Waveforms for *Encoded info_Rx*, *Synchro_code* and *Data info_Rx* compared to *Data_info* for later transmission with **Δt = 20**.

b. For a delay Δt = 50 chips of *BPSK_Rx* signal towards the local code, the behavior is similar, **Variable Delay Chips** block performs local code delay with Δt + 1 = 51 chips, to synchronize the signals *Encoded info_Rx* and *Synchro_code*. The waveforms obtained are shown in Fig. 8 and Fig. 9.

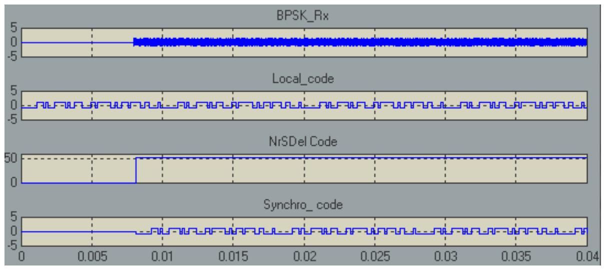

Fig. 8 Waveforms for received signal with 50 chips delay, *Local_code* and *Synchro_code* delayed with *NrSDelCode* chips for later transmission with **Δt = 50**.

In Fig. 9 can be seen synchronization of the two signals and a delay with Δt + 1 = 51 chips for *Data info_Rx* signal.

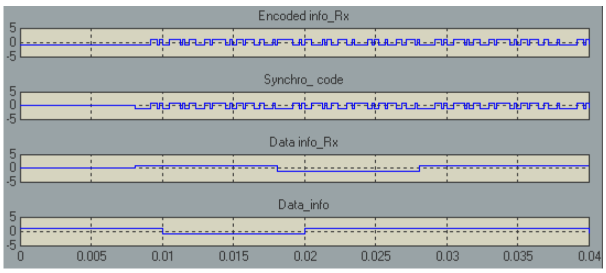

Fig. 9 Waveforms for *Encoded info_Rx*, *Synchro_code* and *Data info_Rx* compared to *Data_info* for later transmission with **Δt = 50**.

3.3 The earlier transmission.

a. For the case of a signal *BPSK_Rx* arrieved earlier with Δt = 20 chips towards the local code, **Delay Counter_LateRx** block calculates the offset value and generates the signal *NrSDelBPSK* = 20 - 1, as shown in Fig. 11. The block **Variable Delay BPSK** performs received signal delay with 19 chips since turning on the receiver (obviously, the part arrived in advance is lost, can not be processed). The movement of the received signal *BPSK_Rx* on the time axis and the loss due to late turning on the receiver are outlined in Fig.10.

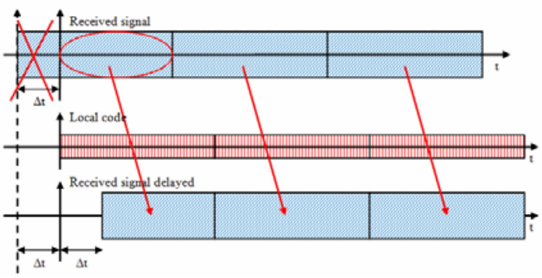

Fig. 10 The delay imposed to received signal to align it with the local code.

When the signal *Enable* = 0 are two effects:

- Is commanded the signal *BPSK_RxDelayed* access to demodulator;
- Is inhibited operation of **Delay Counter_LateRx** block.

The signal *Synchro_code* is, in this case, the same as *Local_code*, because the **Variable Delay Chips block** receives from **Delay Counter_LateRx** block the information *NrSDelCode* = 0.

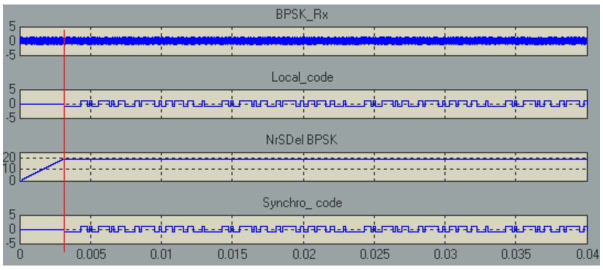

Fig. 11 Waveforms for *BPSK_Rx*, *Local_code*, *Synchro_code* and *NrSDelBPSK* for earlier transmission with **Δt = 20**.

On the waveforms shown in Fig. 11 it can be seen that the signal *Synchro_code* is identical to *Local_code* signal.

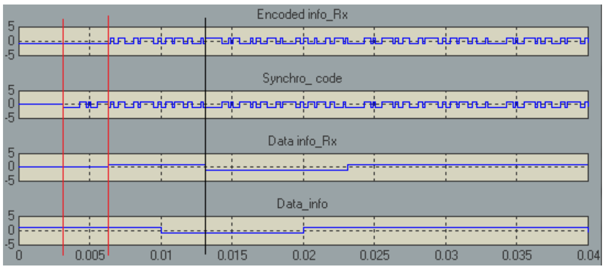

Fig. 12 Waveforms for *Encoded info_Rx*, *Synchro_code* and *Data info_Rx* compared to *Data_info* for earlier transmission with **Δt = 20**.

On the diagram in Fig. 12 was marked with a red line (first from left to right) the moment when the receiver is turned on. The second red line marks the moment until which the receiver delays the received signal to synchronize it with local code. Can be observed the signal *Encoded info_Rx* delay with 2Δt towards time of initiating transmission, namely Δt towards time of turning on the receiver, manner shown in Fig. 10. From the received signal was fully recovered everything that has been received from the receiver turning on. The section between the second red line and the black line is the area of received signal which would be lost with a conventional receiver structure, using code acquisition with active correlator.

Fig. 13 shows the delay of the received signal by Δt = 20 chips towards time of turning on the receiver, respectively 2Δt towards time of initiatind transmission, to the demodulator input being allowed the access for *BPSK_Rx Delayed* signal.

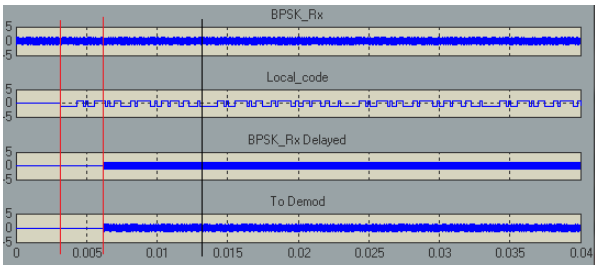

Fig. 13 The delay of the received signal towards time of turning on the receiver, for earlier transmission with **Δt = 20**.

b. If the signal *BPSK_Rx* arrives earlier with Δt = 50 chips towards the local code, the **Delay Counter_EarlierRx** block calculates the offset value and generates the signal *NrSDelBPSK* = 50 - 1, as shown in Fig. 14. The block **Variable Delay BPSK** performs received signal delay *BPSK_Rx* with 49 chips to synchronize the signals *Encoded info_Rx* and *Synchro_code*. The waveforms are shown in Fig. 14 , Fig. 15 and Fig. 16.

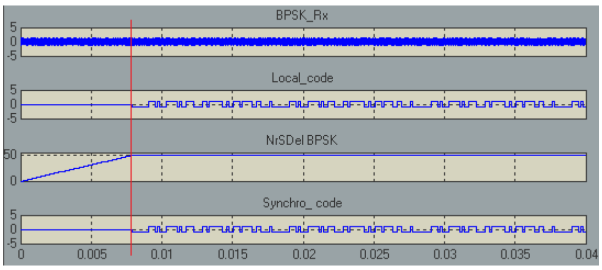

Fig. 14 Waveforms for *BPSK_Rx, Local_code, Synchro_code* and *NrSDelBPSK* chips for earlier transmission with **Δt = 50**.

On the waveforms shown in Fig. 14 it can be seen that the signal *Synchro_code* is again identical to *Local_code* signal.

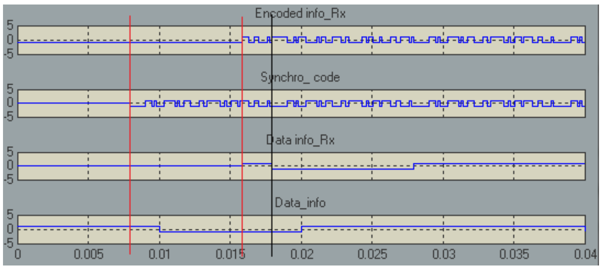

Fig. 15 Waveforms for *Encoded info_Rx*, *Synchro_code* and *Data info_Rx* compared to *Data_info* for earlier transmission with **Δt = 50**.

In Fig. 16 can be seen the delay caused to the received signal, to the demodulator input being allowed the access for *BPSK_Rx Delayed* signal.

Keeping marking convention described above, it can be seen that, area between the second red line and the black line, (representing the first portion of the receved signal recovered) is lower than the case of earlier transmission with Δt = 20.

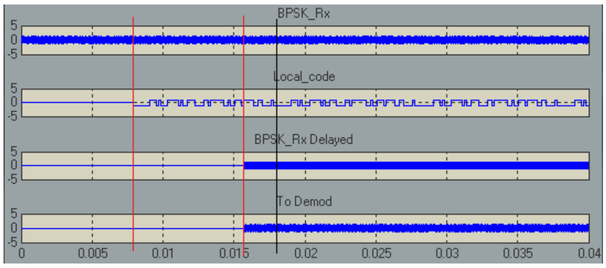

Fig. 16 The delay of the received signal towards time of turning on the receiver, for earlier transmission with **Δt = 50**.

3. CONCLUSIONS

From these experiments it can be deduce some conclusions.

In the case of later transmission, signals synchronization is made by local code delaying and, regardless of the time of initiating the transmission, if the receiver is already turned on, do not lose anything from the received signal. This behavior is identical to the receivers that make code acquisition by one of the methods brief presented in introduction.

The proposed method is advantageous in earlier transmission case, when the synchronization is made by delaying the received signal and not the code. In this way is possible to recover the information contained in the received signal starting right from the moment of turning on the receiver.

The alignment takes Δt chips from the turning on the receiver (interval between the two marks with red line).

If Δt < ½ L_c, the time taken for signals alignment is:

- $t_{synchro}$ = Δt, in case of proposed method in this paper;
- $t_{synchro}$ = L_c – Δt, in case of code acquisition în cazul achiziției by basic method, where is made local code delay.

In other words, proposed method shortens time acquisition if the delay Δt is less than half of length of PN code.

A possibility of extending this benefit is to combine the two methods as follows:

- delaying the received signal, if Δt < ½ L_c;
- delaying the local code, if Δt > ½ L_c.

With the model receiver proposed in Fig. 3, combining those two methods can be done by:

- Using the blocks **Delay Counter_EarlierRx** and **Variable Delay BPSK** for delaying received signal (as in experiments described in 3.3 a.) if Δt < ½ L_c;
- Reactivation of blocks **Delay Counter_LateRx** and **Variable Delay Chips** for delaying local code (as in experiments described in 3.2 a), if Δt > ½ L_c.

This is possible because both blocks with correlator, and **Delay Counter_EarlierRx** and **Delay Counter_LateRx,** counts the necessary delay to align the signals.

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