EFFICIENCY OF SPREADING SPECTRUM IN DSSS SYSTEMS WITH GOLD SEQUENCES

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Abstract: *Using spread spectrum technique provides, in addition to efficient use of frequency bands, protection against eavesdropping, interferences and high noise immunity, remarkable qualities for military applications. The purpose of this paper is to present experimental results for the study of spectral spreading efficiency when using Gold sequences as pseudo-noise generators. Experiments are intended to highlight the spread spectrum and noise immunity (minimum SNR for extracting data correctly) for three code lenghts.*

Keywords: *communications, spread spectrum, Gold sequences.*

1. INTRODUCTION

The **spread spectrum** (SS) communication is a transmission technique in which a **pseudo-noise** (PN) code (independently from the data) is used as a waveform to spread the signal energy over a bandwidth much wider than the initial bandwidth occupied by data. In receiver, the signal is **despread** using a local replica synchronized PN code used in transmitter.

There are several methods for spreading the spectrum, which are distinguished by the place where, in transmission chain, the PN code is inserted. The basics are:

- Direct Sequence Spread Spectrum **DSSS**: PN code is inserted at the level of input data;
- Frequency Hopping Spred Spectrum FHSS: PN code acts on the carrier frequency.

Especially for military applications, the advantages of using the SS communications are particularly attractive:

- Protection against eavesdropping
- High immunity to fading appeared on communication channel;
- Protection against interference with other communications;
- Anti-jamming.

Order to ensure efficient SS communications, PN code has a few rules on length, autocorrelation, crosscorrelation, orthogonality and bits balance. Commonly used PN codes are: Barker, Gold, Walsh-Hadamard. Note that a complex code sequence provides a more robust link, but the price paid is in complex electronics, especially in receiver blocks, to synchronize the local PN code with the received signal, for despread the spectrum.

Gold sequences are a class of codes which provide larger sets of sequences with good crosscorelation properties.

The purpose of this paper is to present experimental results for the study of spectral spreading efficiency when using Gold sequences as PN generators.

2. COMMUNICATION SYSTEM STRUCTURE PROPOSED

2.1 The work environment. To meet the requirements imposed by the complexity of spread spectrum communication system, was used, as a working environment for experiments, 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 Generator and QPSK modulator;
- Communication channel with AWGN;
- The receiver with: QPSK Demodulator, Local PN code generator and Autocorrelator block.

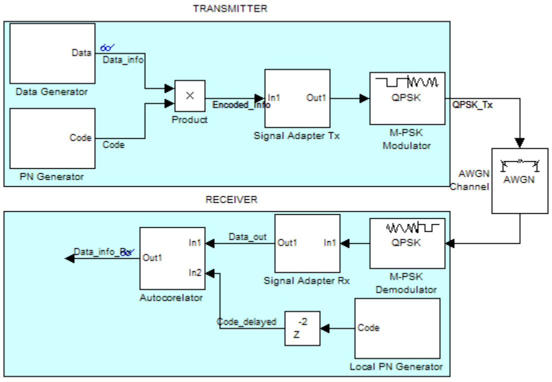

Fig. 1 Block diagram for communication system structure proposed.

Data Generator has been set to generate a random binary number with bit witdh $\mathbf{T_b = 1}$ **ms**, using a Bernoulli Binary Generator from Simulink Library.

Acording [4], a set of Gold sequences with period $N = 2^n - 1$ consisting of $N + 2$ sequences for which, the peak crosscorrelation magnitude q_c and the peak out-of-phase autocorrelation magnitude q_a meet the condition

$$q_c = q_a = t(n), \text{ unde } t(n) = 1+2^{(n+2)/2}$$

PN Generator was achieved with a Gold Sequence Generator for which has been selected three settings of **n**, the degree for generators polynomials. In all three cases, was chosen as **N**, the generated code length, be equal to $\mathbf{T_b}$, duration of a data bit. That means Tc, the width of a code bit will be:

$$T_c = T_b / N$$

According to [1,2], that is the use of a short code, with spreading factor N.

Sience the process of synchronizing the local code PN with the received signal is not the subject of this paper, synchronisation was achieved by introducing a fixed delay covering delay due to signal processing.

2.3 Experimental studies. For bit data witdh $\mathbf{T_b = 1}$ **ms**, spectral components occupies a bandwidth shown in Fig. 2.

Experiments are intended to compare the spread spectrum (generated by multiplying data signal with PN code sequence) for three settings of **n**, respectively for three values of bit code witdh:

a. n = 6 => N = 63 and T_c = 1/63000. Bandwidth will be $B_w = \pm 63$ kHz.

b. n = 7 => N = 127 and T_c = 1/127000. $B_w = \pm 127$ kHz.

c. n = 9 => N = 511 and T_c = 1/511000. $B_w = \pm 511$ kHz.

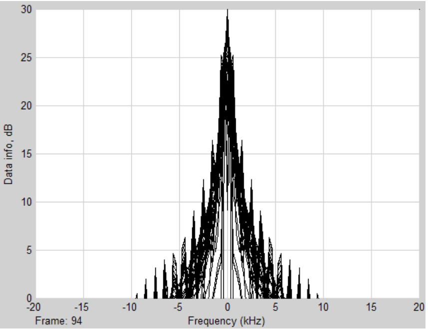

Fig. 2 Spectrum occupied by data signal with T_b = 1 ms and $B_w = \pm 1$ kHz.

In each of these cases, the aim is highlighting the spread spectrum and noise immunity (minimum SNR for extracting data correctly).

3. EXPERIMENTAL RESULTS

In order to study spreading spectrum, experimental measurements were made on the signal *Encoded_info*. As shown in Fig.1, this signal is obtained by the product between digital signal information, named *Data_info*, and the PN code from Gold Sequence Generator, signal named *PN Code*. Waveforms for this three signals are shown in Fig. 3.

To analyze the noise immunity, measurements aim to determine the minimum signal-to-noise ratio (SNR) until which the receiver extracts correctly the transmited data.

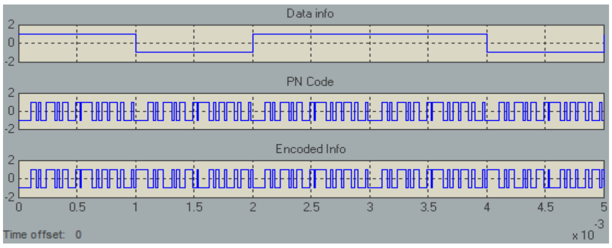

Fig. 3 Waveforms for data, Gold code with N = 63 and their product.

3.1 Spreading spectrum efficiency. In order to compare the three cases, all experiments are made under the same conditions, viewing the spectral components of the signal *Encoded_info* in baseband, between $-1/T_c$ … $1/T_c$ kHz.

a. For a code length N = 63 and T_c = 1/63000 s = 15.8 us, the initial baseband, shown in Fig. 2, is extended between – 63 … 63 kHz, as shown in Fig. 4.

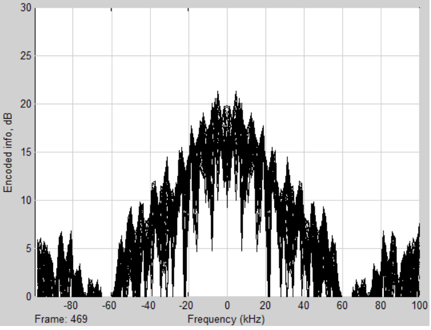

Fig. 4 Spectrum occupied by *Encoded_info* with T_c = 15.8 us

b. For a code length N = 127 and T_c = 1/127000 s = 7.9 us, the initial baseband is extended between – 127 kHz … 127 kHz, as shown in Fig. 5.

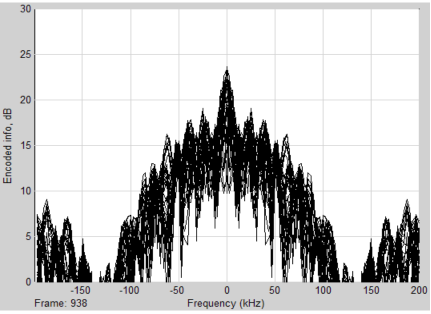

Fig. 5 Spectrum occupied by *Encoded_info* with T_c = 7.9 us

c. For a code length N = 511 and T_c = 1/511000 s = 2 us, initial baseband is extended between – 511 … 511 kHz, as shown in Fig. 6, wider range than in previous cases.

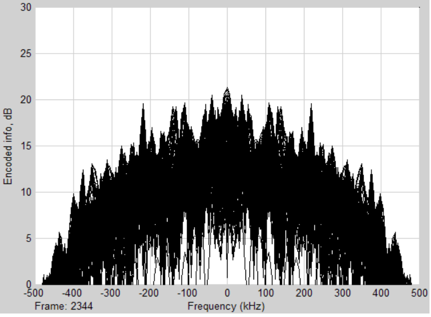

Fig. 6 Spectrum occupied by Encoded_info with T_c = 2 us

3.2 Noise immunity. The modulated signal, at transmitter output, have the spectrum shown in Fig. 7. For a good signal-to-noise ratio, SNR = 10 dB, constellation diagram and signal spectrum at receiver input are shown in Fig. 8 and Fig. 9.

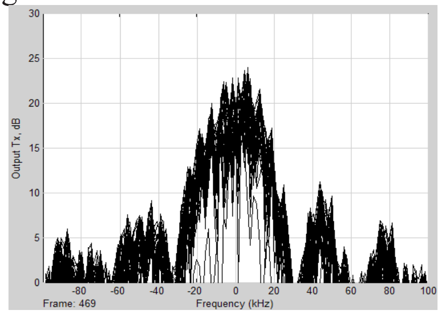

Fig. 7 Signal spectrum at transmitter output (QPSK modulated signal).

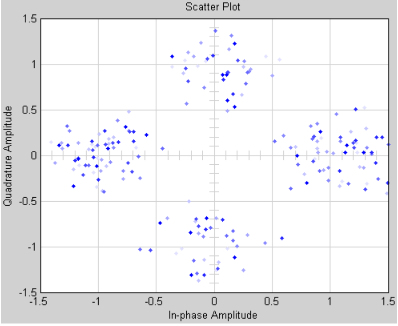

Fig. 8 Constellation diagram at receiver input, for N = 63 and SNR = 10 dB

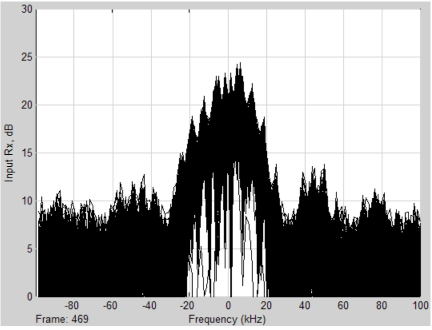

Fig. 9 Signal spectrum at receiver input, for N = 63 and SNR = 10 dB

a. For a code length N = 63 and T_c = 1/63000 s = 15.8 us, the receiver extract correctly the *Data* signal, until **SNR = - 6 dB**. Constellation diagram and signal spectrum at receiver input in this case are shown in Fig. 10 and Fig. 11. From Fig. 11 it can be seen that, for the range – 20 … 20 kHz, certain spectral components exceed the noise level.

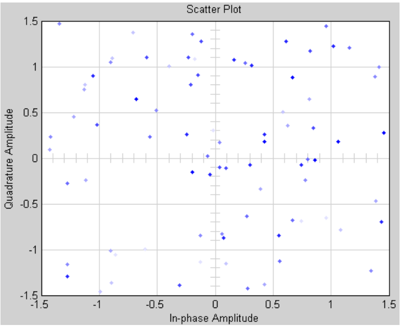

Fig. 10 Constellation diagram at receiver input, for N = 63 and SNR = - 6 dB

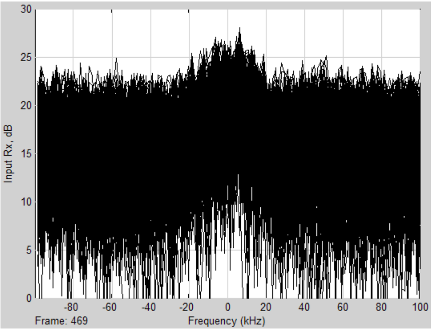

Fig. 11 Signal spectrum at receiver input, for N = 63 and SNR = - 6 dB

b. For a code length N = 127 and T_c = 7.9 us, the receiver extract correctly the *Data* signal, until **SNR = - 11 dB**. Constellation diagram and signal spectrum at receiver input in this case are shown in Fig. 12 and Fig. 13. Now, in Fig. 13 it can be seen that the signal at receiver input is completely covered by noise.

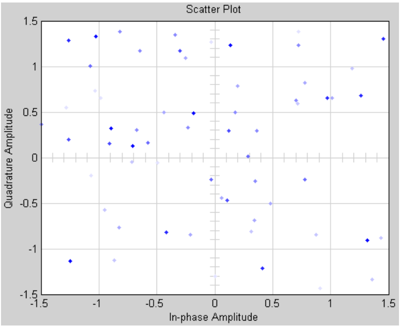

Fig. 12 Constellation diagram at receiver input, for N = 127 and SNR = - 11 dB.

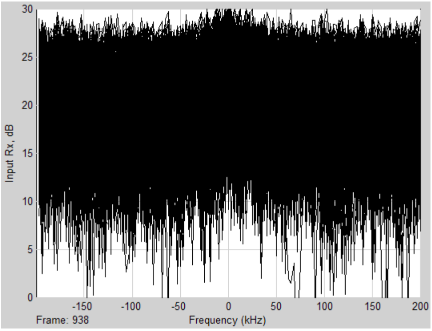

Fig. 13 Signal spectrum at receiver input, for N = 127 and SNR = - 11 dB

c. For a code length N = 511 and T_c = 1/511000 s = 2 us, the receiver extract correctly the *Data* signal, until **SNR = - 16 dB**, what is really remarkable. Signal spectrum at receiver input in this case is shown in Fig. 14. As in previous case, the received signal is completely covered by noise.

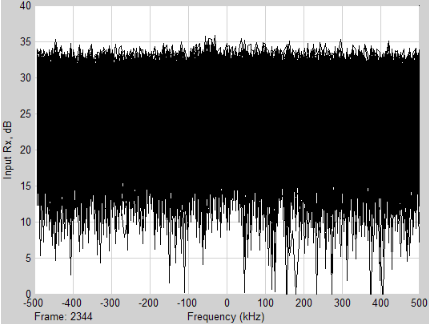

Fig. 14 Signal spectrum at receiver input, for N = 511 and SNR = - 16 dB

This results on noise immunity are summarized in Table 1.

Table 1 Minimul SNR [dB] for different code lengths and bit code widths

Code length, N	**Tc [us]**	**Minimum SNR [dB]**
63	15.8	-6
127	7.9	-11
511	2	-16

3. CONCLUSIONS

If the initial spectral components of the signal *Data* reaches a maximum of 30 dB and were concentrated in a narrow band, in all three cases examined, by multiplying the signal with the PN sequence, are obtained spectral components whose maximum is less than 25 dB, on average, being around 20 dB.

Much more obvious is the difference between the three cases analyzed in terms of noise immunity. It is outstanding the resistance to noise of signal spreaders with Gold sequence having length N = 511. As the code length is larger and code bit narrower, the more is better noise immunity.

All this results related to noise immunity can be improved through the use of error-correcting codes. Even without forward error correction techniques (FEC), the use of spread spectrum communications provides protection from noise (random or not) appeared on the communication channel, more than traditional methods.

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