DESIGN AND IMPLEMENTATION OF A CDMA TRANSMITTER FOR MOBILE CELLULAR COMMUNICATIONS

R. Muraoka, D. Covarrubias, A. Arvizu & J. Mendieta

Centro de Investigación Científica y de Educación Superior de Ensenada,
Km 107 Carretera Tijuana-Ensenada, B.C., México.
Phone: +52(646) 1745050 to 55 Fax: +52(646)1750549,
E-mail: rmuraoka@cicese.mx

Received: April 29th 2001 and accepted September 8th 2001

ABSTRACT

In this work we describe the design and implementation of a CDMA transmitter with application on third generation mobile and personal communication systems. We present several experimental results.

RESUMEN

En este trabajo se describe el diseño e implementación de un transmisor CDMA con una aplicación en sistemas móviles y personales de comunicación de tercera generación. Asimismo, se presentan varios resultados experimentales.

KEYWORDS: CDMA transmitter, Mobile communications, Gold codes, Shift register, PN codes.

1. INTRODUCTION

Code Division Multiple Access (CDMA) is a promising technique for radio access in cellular mobile and personal communication systems. CDMA in cellular systems offers attractive features such as the potential for high spectrum efficiency, soft capacity, soft handover and macro-diversity. This has been claimed and demonstrated in various system design studies, analyses and trials. CDMA techniques are based on spread spectrum communications, which were originally developed for military applications. A simple definition of a spread spectrum signal is that its transmission bandwidth is much wider than the bandwidth of the original signal. In a CDMA communications systems, a unique binary spreading sequence (a code) is assigned for each call to every user. The user's signal is multiplied by the assigned code and "spread" onto a bandwidth much wider. All the active users share the same frequency spectrum at the same time. The signal of each user is separated or "de-spread" from the others at the receiver using a correlator keyed with the associated code sequence. Spreading codes o spreading sequences can be divided into pseudo-noise (PN) codes and orthogonal codes. PN codes are pseudo-random codes generated by a feedback shift register.

In a CDMA transmitter, the information signal is modulated by spreading code, and in the receiver it is correlated with a replica of the same code. Thus, low cross-correlation between the desired and interfering users is important to suppress the multiple access interference. Good autocorrelation properties are required for reliable synchronization and reliably separation on of the multipath components. Having good autocorrelation properties is also an indication of good randomness of a sequence which allow us to connect another important sequence's property: cross-correlation. Many families of codes with such correlation properties are known; for example, Gold code [1].

This paper is focused on a CDMA transmitter design and implementation for third-generation mobile and personal communication systems. We present a step by step design procedure, and a complete characterization of a CDMA transmitter.

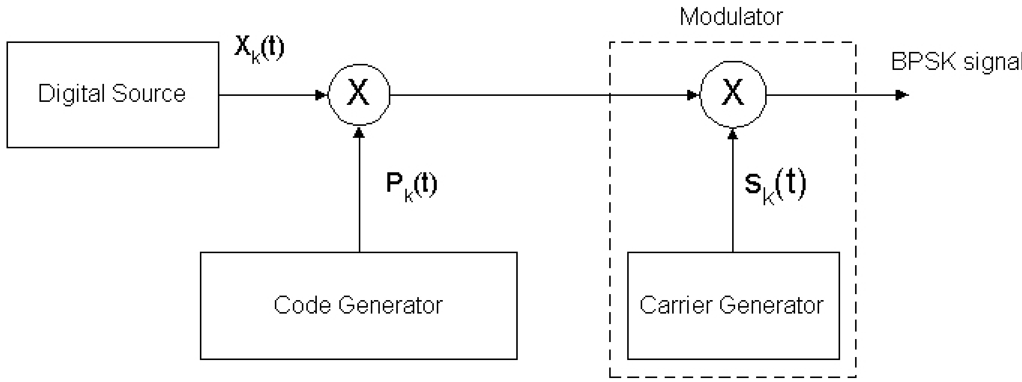


Figure 1. Block diagram of the spread spectrum and BPSK modulation system.

2. CDMA TRANSMITER DESIGN

Figure 1 shows the block diagram of a CDMA transmitter. The input data signal, is multiplied with the output of a Gold pseudorandom sequence generator, in order to obtain an spread spectrum (SS) signal, which is multiplied with the output of a carrier generator in order to have a BPSK signal.

2.1 Multiplier and signal conditioning circuit

The multiplier circuit is implemented using the integrated circuit AD834JN from Analog Devices [9], with a maximum input level of ± 1Vpp. The design of the low-pass filters used in the system, and the conditioning circuits is described below.

A signal conditioning circuit is used to obtain the voltage level required by the multiplier. This circuit is implemented using the op amp LF351N from National Semiconductor in an inverting summing configuration.

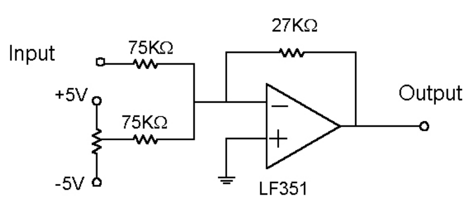


Figure 2. Inverting summing circuit implemented.

The output voltage of the inverting summing circuit is calculated using the following equation[10]:

$$Vout = -\left(\frac{27K\Omega}{75K\Omega} Vin_1 + \frac{27K\Omega}{75K\Omega} Vin_2 \right) \tag{1}$$

2.1.1 Passive low pass filter

A low-pass filter is used to reduce the noise bandwidth of the system. The filter implemented is shown in figure 3.

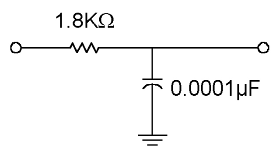


Figure 3. Low-pass filter implemented.

2.2 Pseudorandom Gold sequences generator

The pseudorandom Gold sequences generator is designed using universal shift registers of 4 bits (that divide by itself the preferred pairs of polynomials) and exclusive-or gates. The electrical diagram is shown in figure 4.
The polynomials used are: {5,2}{5,4,3,2}.
The electrical diagram of the spread spectrum (SS) transmitter is shown in figure 5, while in figures 6 and 7 are shown the experimental set-up and block diagram of the system implemented.

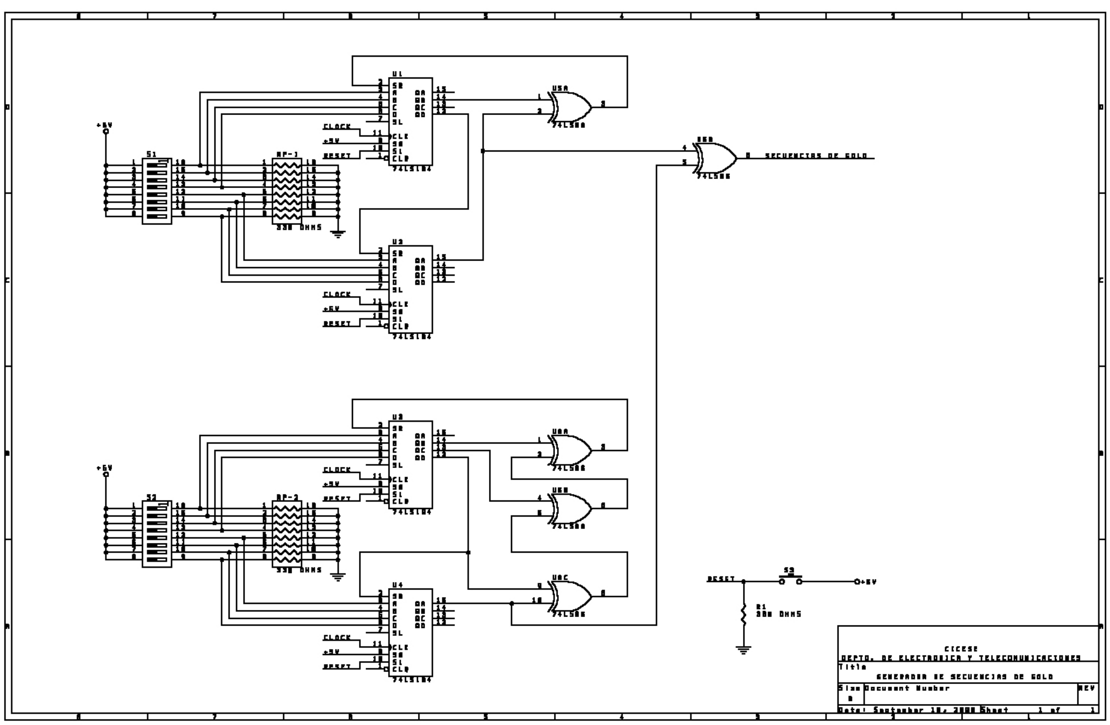


Figure 4. Electrical diagram of the pseudorandom Gold sequence generator.

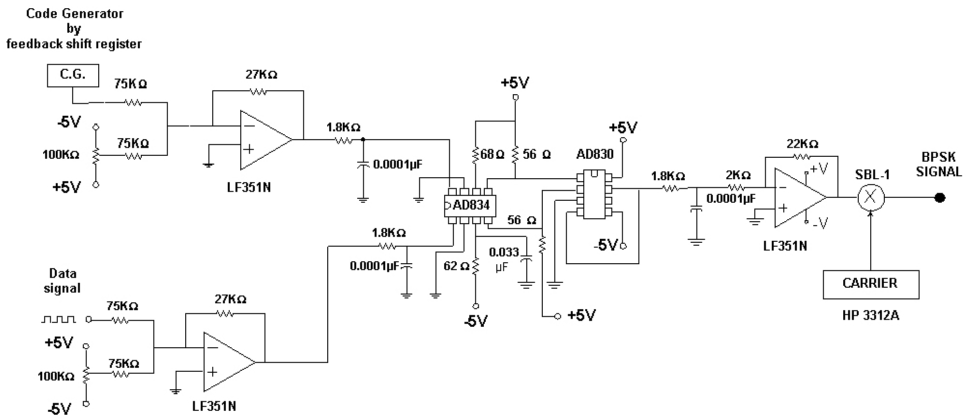


Figure 5. Electrical diagram of the SS circuit and BPSK modulator implemented.

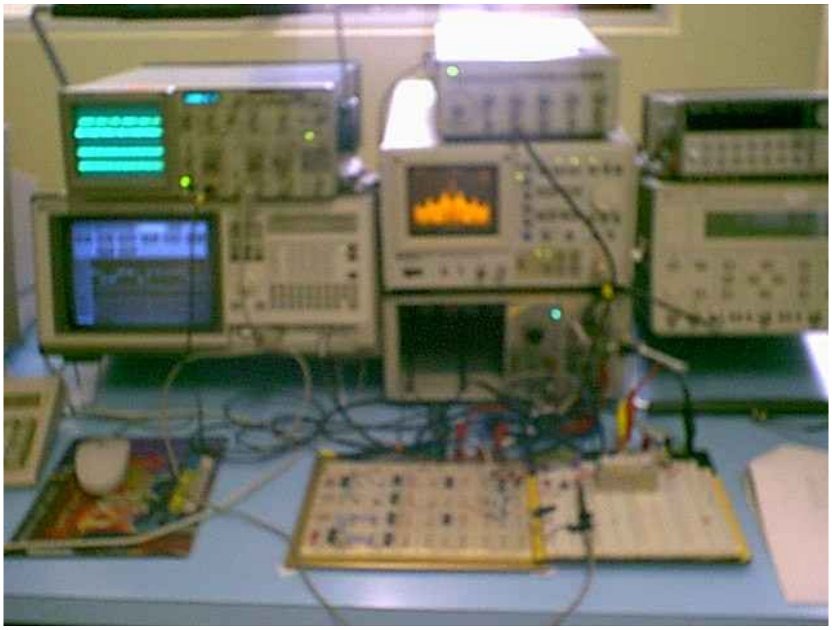


Figure 6. Experimental set-up.

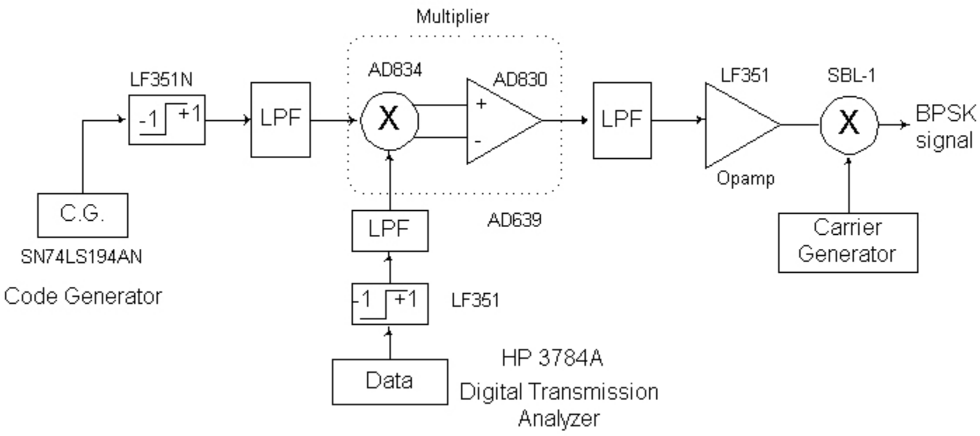
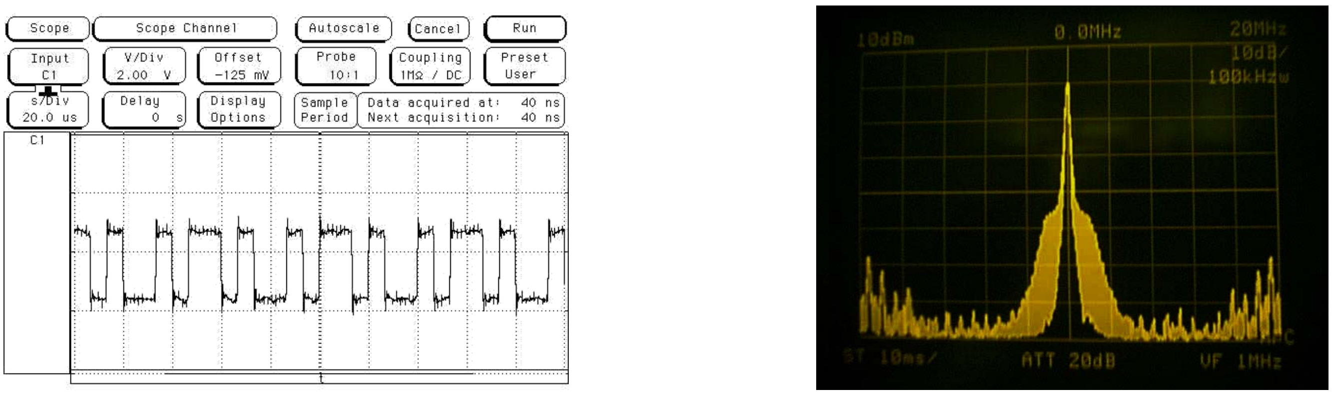


Figure 7. Block diagram of the CDMA transmitter implemented.

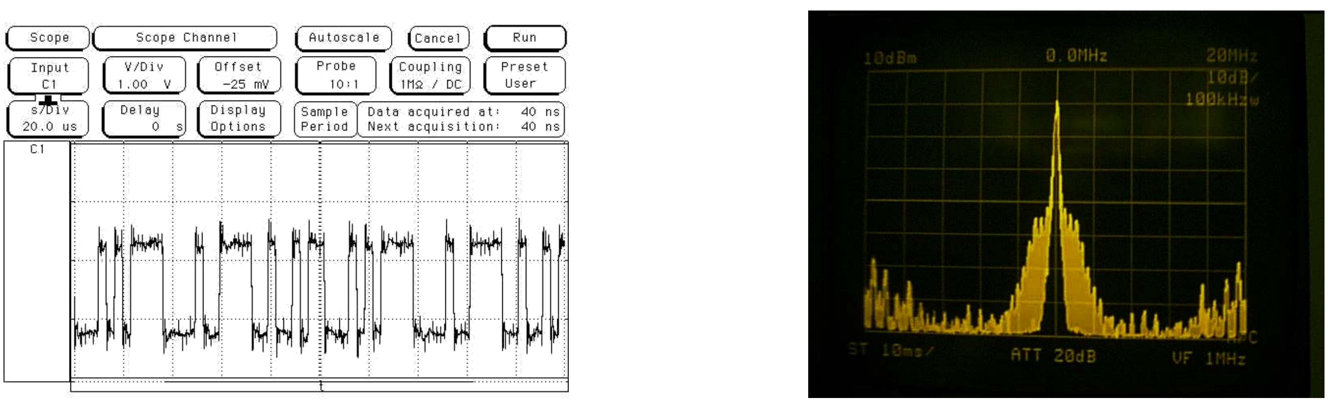
3. CDMA TRANSMITTER TESTS

In figure 8 the data signal is shown both in the time and frequency domains using an 8 bits sequence [10110100], with a clock frequency of 150KHz. As part of the test procedure, the following figures depicts the basic properties of spreading codes used in the CDMA transmitter implemented. Figure 9 shows the time and frequency domain behavior of the Gold sequence. Figure 10 illustrates the spread spectrum signal generated, both on the time and frequency domain.



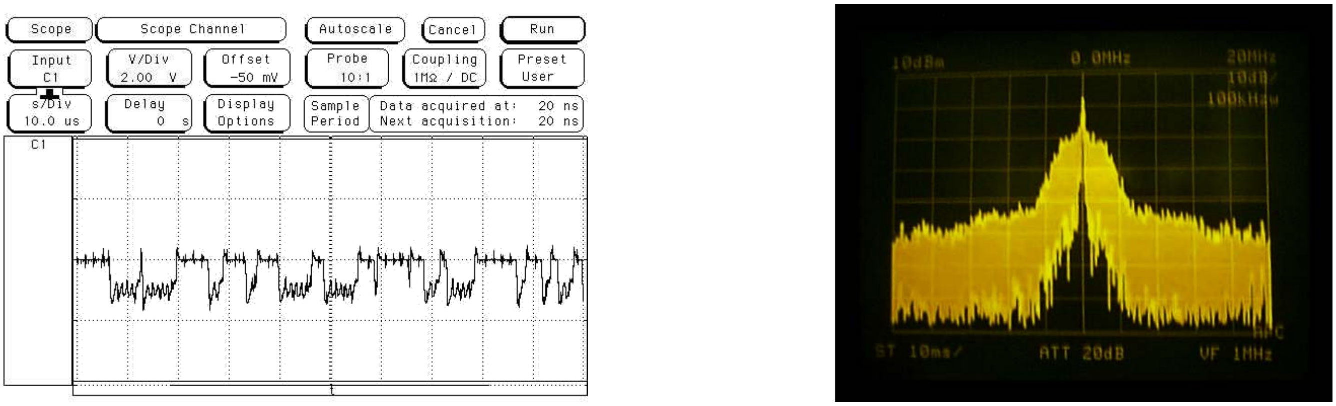
a) *b)*

Figure 8. Data signal on the: a) time domain, (b) frequency domain.



a) *b)*

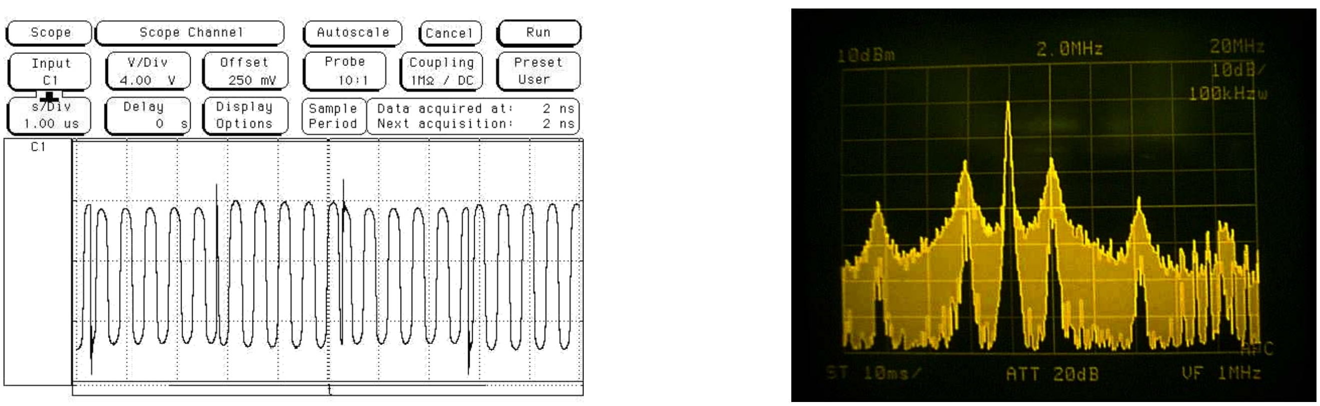
Figure 9. Pseudorandom Gold sequence on the: a) time domain, b) frequency domain.



a) b)

Figure 10. Spread signal on the: a) time domain b) frequency domain.

Finally figure 11 shows the typical BPSK output signal in a CDMA transmitter.



a) b)

Figure 11. BPSK signal on the: a) time domain b) frequency domain.

In figure 12 is shown a Gold sequence generated by the system implemented. This sequence with a length of 2^N-1 consists of 16 “ones” and 15 “zeros” in order to obtain a well balanced code.

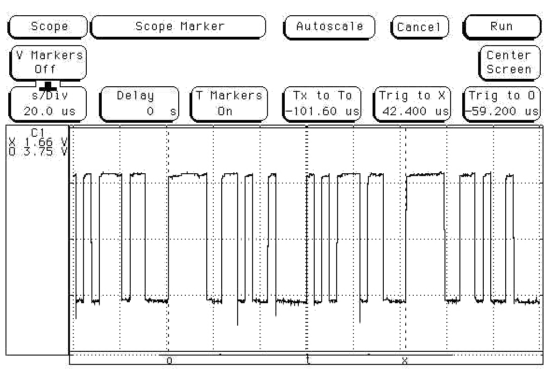


Figure 12. Gold Sequence generated by the system.

3.1 Processing Gain

The processing gain (Gp) is calculated using the following equation [11]:

$$G_P = 10\log (T_b / T_c)$$

with:
T_b : Period of the data signal,
T_c: Period of the spread spectrum code.

For the sequence generated in our case and using an input data signal with a bit rate of 868Hz we have:

T_b = 1.152 ms, T_c = 720 ns
then,

$$Gp = 10\log\left(\frac{1.152ms}{720ns}\right) = 31dB \tag{2}$$

Which agrees with the following equation [11]:

$$G_P(DS) = N_{DS} \tag{3}$$

With N_{DS} =31

4. VERIFICATION OF THE SPREADING CODE PROPERTIES

In order to simulate the cross and autocorrelation functions of the Gold sequences generated, we implemented a function using Matlab that we called "corre".
The function "corre" was implemented based on the correlation function Rx(t) that can be obtained as [5]:

$R_x(\tau)$ = 1/P	Number of agreements less number of discords compared in a complete period of the sequence with a τ displacement one with respect to the other sequence

considering that the PN sequences of maximum length, represent a double-valued periodic autocorrelation with period $(2^N-1)\ T_c$, and T_c is the chip time.

4.1 Gold sequences

In order to analyze the properties of the Gold sequences, two different sequences were generated using the implemented circuit, as is shown in figures 13 and 14.

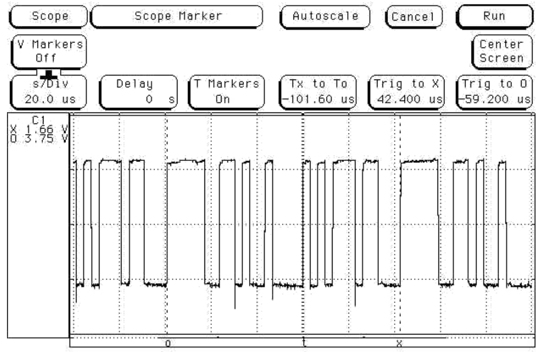


Figure 13. First Gold sequence generated.

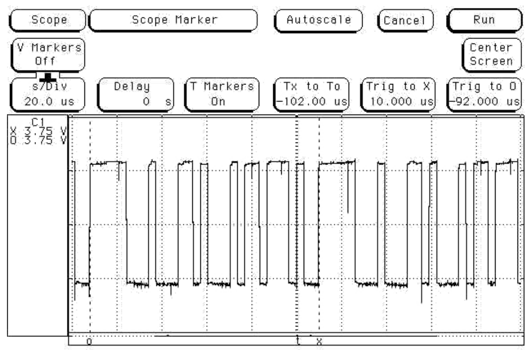


Figure 14. Second Gold sequence generated.

The chip period is 3.3µs, so the inputs used in the function “corre” are;

V_1 = [1 1 1 1 1 0 0 1 1 0 1 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 1 1 0 0 0]

V_2 = [1 1 1 1 1 0 0 0 1 0 0 0 1 1 0 1 0 0 0 1 0 1 1 0 1 1 1 0 1 0 0]

Tc = 3.3µs

Therefore a cross-correlation vector is obtained with a length of:

$(2^N-1) * Tc = (31) * 3.3\mu s = 102\mu s$

This signal has a mean value of 0.2, which can be considered as a small correlation value, however, due to this, the sequences are not completely orthogonal. Figure 15 shows the properties of the cross-correlation of the Gold sequences. The autocorrelation of the vector V_1 is shown in figure 16, which has three values, with the advantage of the possibility of having more users in the system.

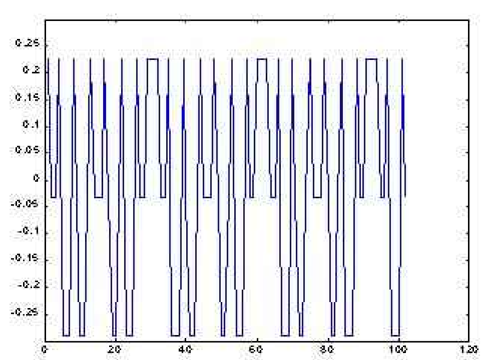


Figure 15. Cross-Correlation of two Gold sequences.

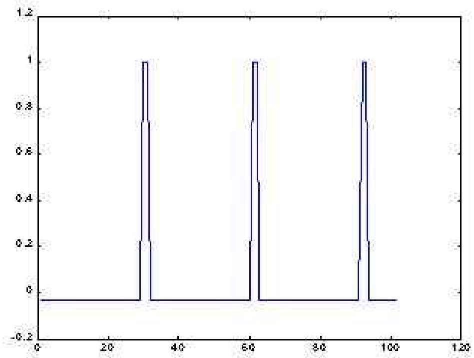


Figure 16. Autocorrelation of Gold sequence.

5. CONCLUSIONS

In this work, we have reported the design, experimental set-up and characterization of a CDMA transmitter. Particularly, we emphasized those effects that have a strong influence on the performance system like the spread spectrum and Gold sequence circuits and the modulation scheme. According to the results obtained, we have found a good CDMA transmitter behavior in terms of auto-correlation and cross-correlation properties, as an indication of good randomness of a Gold sequence required for reliable synchronization. The CDMA transmitter obtained shows a low cross-correlation between the desired and interfering users, which is important to suppress the multiple access interference.

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Authors Biography

Ramon Muraoka

BSEE from the Universidad Autónoma de Baja California, México (Autonomous University of Baja California). Técnico de soporte en el Departamento Electrónico y Telecomunicaciones en el Centro de la Investigación Científica y estudios Superiores de Ensenada B.C., México (Technical support for Electronics & Telecommunications Department of Centre of Scientific Research and Higher Education of Ensenada B.C., Mexico). He has worked in the development of space optical communications systems. Currently is student of a Master of Science degree at CICESE.

David Hilario Covarrubias Rosales

PhD on Telecommunications (Cum Laude) Universitat Politécnica de Catalunya, Barcelona, España. Master on Science on Telecommunications, CICESE, México, and BS on Electronics & Communications Engineer, Universidad Nacional Autónoma de México, (National Autonomous University of Mexico), México. Faculty member of the Electronics & Telecommunications Department, CICESE Research Center, Centro de la Investigación Científica y estudios Superiores de Ensenada B.C., México (Centre of Scientific Research and Higher Education of Ensenada B.C, Mexico), Ensenada, Baja California, México, since June 1984 to date. Research Areas: 3G Mobile Communications Systems and Smart Antenas

Arturo Arvizu

Ph.D. in Telecommunications from the Centre of Centro de la Investigación Científica y Estudios Superiores de Ensenada, B. C., México (Scientific Research and Higher Education of Ensenada, B. C. Mexico). He has a BSEE from the Universidad Nacional Autónoma de México –UNAM- (National Autonomous University of Mexico), and has also obtained an Engineering Master Degree. He a researcher in the CICESE. He has been working mainly in analog, digital and optical communications systems.

Javier Mendieta

Ph.D and M.Sc degrees from the École Nationale Superieure des Télécommunications (ENST) in France. He received a B.SC degree in the Universidad Nacional Autónoma de Mexico (National Autonomous University of Mexico), is a researcher in the Center of Scientific Research and Higher Education of Ensenada (CICESE), and his research areas includig optical coherent communication, free-space communications and space communication systems.