# A Novel Spread Spectrum System using MC-DCSK

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***Abstract*—A new spread spectrum technique using Multi-Carrier Differential Chaos Shift Keying (MC-DCSK) modulation is presented in this paper. The approach explores the properties of chaotic sequences. Chaotic signals are non periodic, wide-band, and more difficult to predict, reconstruct, have good correlation properties and increases transmission security. These properties of chaotic signals make it more difficult to intercept and decode the information modulated upon them and is used as the spreading code in this system. However, many suggested chaos-based communication schemes do not provide spectral efficiency, high data rate and energy efficiency. This paper suggests the solution to the above problems by transmitting multiple modulated data streams over the carriers. Simulation results show that the bit-error rate performance of this system can always outperform the single carrier DCSK system and provide high data rate and improved spectral efficiency.**

***Index Terms*—Chaos communications, differential chaos shift keying (DCSK), Henon map generator, multi-carrier DCSK, multipath Rayleigh fading channel, non-coherent receiver.**

## I. INTRODUCTION

IN the last several years, increasing efforts have been devoted to study the possibility of using chaotic sequences in spread spectrum systems to enhance the security and energy efficiency. This is because of the good correlation properties and non periodic random behavior of chaos, which increases transmission security and the immunity of the system to multipath degradation.

The application of mathematical chaos in communications research has been active for several years and a number of digital chaos-based communication systems [1], [2] have been proposed. The idea behind spread-spectrum communication systems [3], [4] is that a relatively narrow-band information signal can be modulated to a wide-band signal for the long distance transmission. Chaos-based communication systems can be classified into two: systems using coherent receivers and systems using non coherent receivers. In coherent receivers, the chaotic signal is used to spread the data information signal to a wide-band and on the receiver side, code synchronization is necessary in order to demodulate the transmitted bits, which is quite difficult and not robust against channel imperfections [5].But in the case of non-coherent systems no such synchronization is needed, which offer a good performance in multipath channels [6].

Differential Chaos Shift Keying (DCSK) modulation and its constant power derivative, frequency-modulated DCSK (FMDCSK), are almost insensitive to channel distortion and show one of the best bit error rate (BER) performances [6]–[8]. However, the price that they have to pay is low attainable data rate (or bandwidth efficiency), inferior immunity to interception, and weakened information security. For this reason, a permutation transformation has been introduced in [9] so as to offer solution with improved data security but leading to a more complicated system design. To increase data rate in regard to DCSK, quadrature chaos shift keying in [10] and M-ary DCSK in [11] have been investigated as a multilevel version of DCSK at the expense of a fairly higher system complexity. Without sending individual reference signal, correlation delay shift keying (CDSK) in [12] doubles the attainable bit rate and enhances communication security but degrades BER performance in comparison to DCSK. Although the generalized version of CDSK in [13] demonstrates a slightly better BER performance under certain $E_b/N_0$ ratios, the highest hardware requirement still makes its application limited.

The performance of chaos-based digital communication systems under an additive white Gaussian noise (AWGN) environment has been thoroughly studied [13]. In wireless communications, however, the reflecting objects and scatterers in a wireless channel dissipate the signal energy, leading to multiple versions of the transmitted signal arriving at the receiver with different amplitudes, phases, and time delays [14], [15]. These multipath waves combine at the receiver, causing the received signal to vary greatly in amplitude and phase. Such multipath fading limits the performance in wireless applications. It is generally known that spread-spectrum systems perform significantly better than narrowband systems in a multipath environment. Since chaos-based systems are spread-spectrum systems, their performance in multipath environments should be an important practical consideration.

The proposed system is a hybrid of multi-carrier and DCSK modulations which uses a non coherent receiver in which chaotic synchronization is not used on the receiver side to generate an exact replica of chaotic sequence. In the frame, the chaotic reference sequence is transmitted in the first bit duration and then the modulated data sequence is transmitted in the remaining bit slots. This system delivers a good performance in multipath fading channels.

The rest of the paper is organized as follows: In section II a brief description of DCSK system and its demerits are presented. The third section describes the architecture of the proposed system. The block diagrams of the transmitter and receiver is presented and analyzed in this section. The simulation of the proposed system is carried out in Simulink and the simulation results are explained in section IV. Finally, some conclusive remarks are given in Section V.

## II. DIFFERENTIAL CHAOS SHIFT KEYING COMMUNICATION SYSTEM AND THE DEMERITS

The operation of the DCSK modulator and demodulator is illustrated in Fig. 1. For every bit of information, the transmitter $x_i$ outputs a chaotic sequence of length $M$ followed by the same sequence multiplied by the information signal $b_l = \pm 1$, where $l$is the bit counter. Thus, the transmitted signal for a single bit is given by

$$s_i = \begin{cases} x_i, & 0 < i \leq M \\ b_l x_i - M, & M < i \leq 2M \end{cases} \qquad (1)$$

In order to recover the information, the received signal is multiplied by the received signal delayed by $M$. The product is then averaged over the spreading sequence length $M$. Thus, the output of the correlator can be written as

$$S = \sum_{i=1}^{M} r_i r_i + M \qquad (2)$$

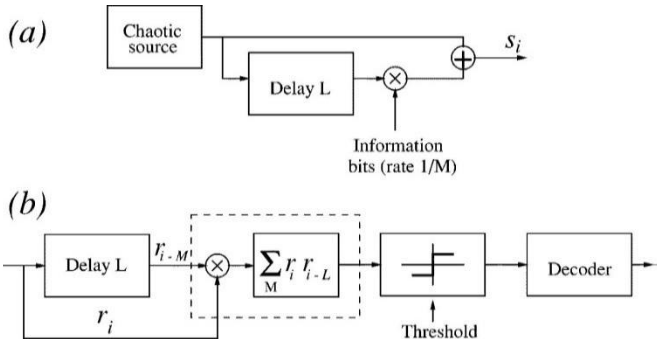


Fig 1. DCSK operation: (a) transmitter, (b) receiver.

The received bits are estimated by computing the sign of the output of the correlator. Decoder decodes the output of the threshold device to get the final output.

The demerits of this system are the following: The non-information-bearing reference is sent in the half bit duration time. Therefore, the data rate of this architecture is seriously reduced, leading to a loss of energy. Half the energy of each bit is dissipated for the reference sequence. The need to transmit the same chaotic sequence twice makes this system prone to interception. Also, the transmitter requires a delay element and a switch, or a generator capable of reproducing the same chaotic sequence. This can lead to technical implementation difficulties. The DCSK system receiver requires a delay line, which is not easy to implement because of the wide bandwidth.

So this paper focuses on solving these demerits and to improve the security, energy efficiency and to provide good performance.

## III.ARCHITECTURE OF SPREAD SPECTRUM SYSTEM USING MC- DCSK

In this section, the architecture of the proposed system is described in detail.

### A. Henon Map Chaotic Generator

The Hénon map is an iterated discrete-time dynamical system that exhibits chaotic behavior. The state equations of the Henon map chaotic generator are given by

$$x_{n+1} = 1 + y_n - a x_n^2 \qquad (3)$$

$$y_{n=1} = b x_n \qquad (4)$$

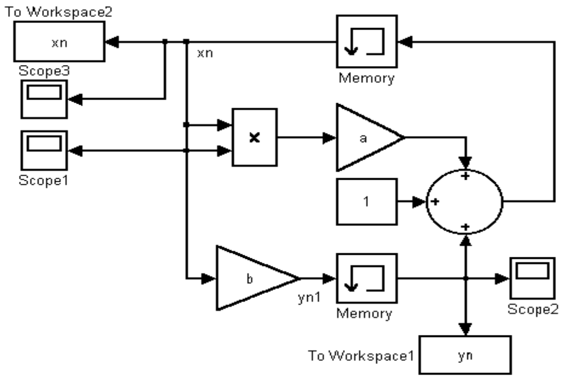


Fig 2. Henon Map Chaotic Generator Model

where a and b are constants and a= -1.4 and b= 0.3. The state equations of the Henon map chaotic generator converts to a Simulink model using the MATLAB®Simulink toolbox are shown in Fig. 2 and the output is controlled by the clock

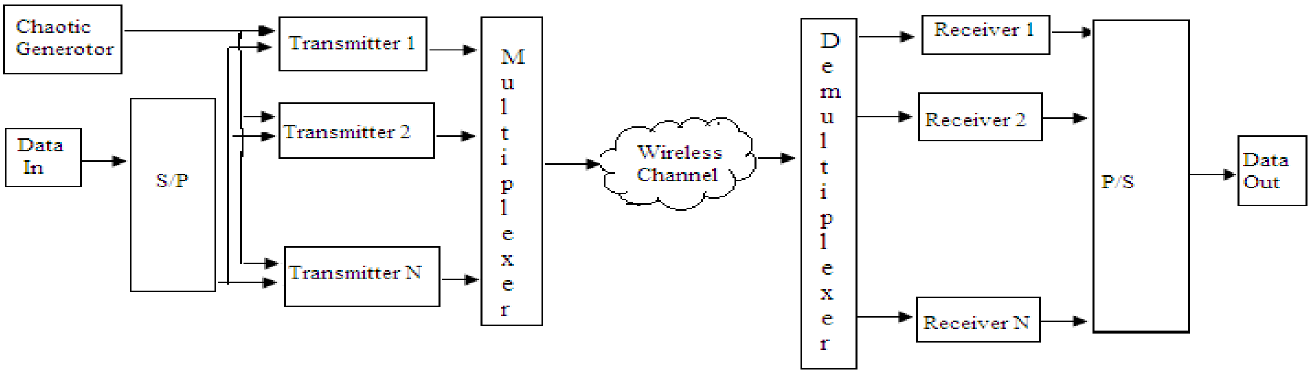
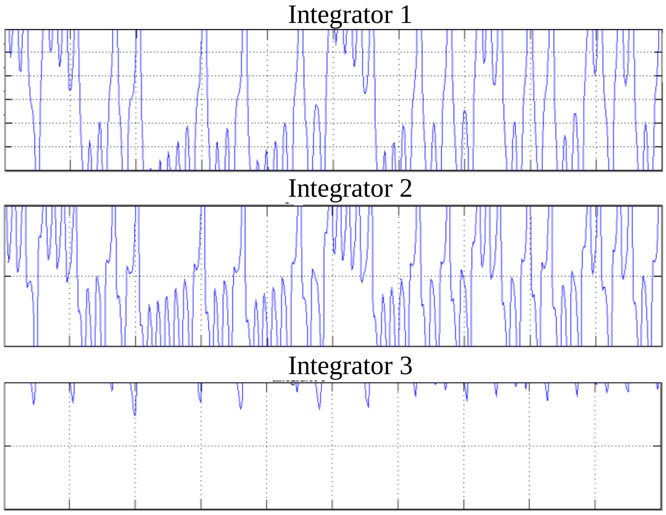


Fig. 3. Block Diagram of Spread spectrum system using MC-DCSK

time which is the step size of the simulation. The simulation result is shown in Fig. 4.


Integrator 1

Integrator 2

Integrator 3

Fig 4. The Henon map chaotic generator simulation results.

The chaotic sequence is used to spread the data sequence into a wide-band.

### B. Modulation Scheme

Multicarrier modulation is currently used in many wireless systems. The basic idea of multicarrier modulation is to divide the transmitted bitstream into many different substreams and sent over the channel. The advantage of multicarrier modulation is that it mitigates the effect of delay spread. As shown in fig. 3, the transmitter section first converts the input binary information into $p$ parallel data sequences $s_p$ for $p$ = 1, 2, ...P.

$$s_p = [s_{p,1}, \ldots, s_{p,i}, \ldots, s_{p,N-1}] \qquad (5)$$

where $s_{p,i}$ is the $i^{th}$ bit of the $p^{th}$ sequence data and $P-1$ is the number of data per $p^{th}$ sequence. After a serial to-parallel conversion, the $N-1$ bits stream of the $p^{th}$ data sequence are spread due to multiplication in time with the same chaotic spreading sequence. The output of N transmitters are given to the multiplexer which multiplexes the signals and the multiplexed signal is given to the wireless channel.

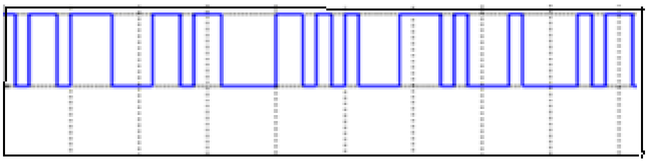
### C. Channel model

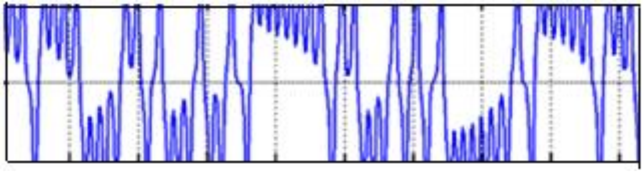
Analysis is carried out in both AWGN and Rayleigh fading channel. The reference sample and data samples are transmitted through the channel. The power spectral density of Gaussian noise channel is given by $S_n(f)=N_0/2$. Then Rayleigh channel model is considered, which is a slow fading multipath channel with $L$ (the number of paths, $L \geq 2$) independent and Rayleigh distributed random variables. In this model, $\lambda_l$ is the channel coefficient and the time delay of the $l^{th}$ path is $\tau_l$. For line-of sight path, $L = 1$ and $\tau_l = 0$.

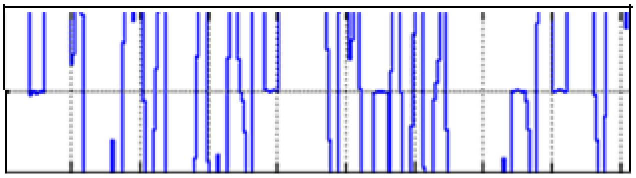
The probability density function of the channel coefficient of the Rayleigh fading channel is given by

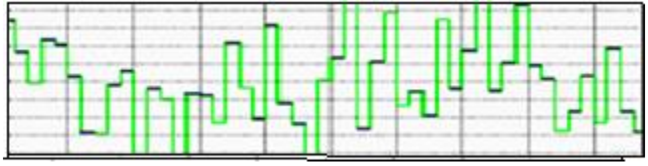
$$f_\lambda(z) = \frac{z}{\sigma^2} e^{-\frac{z^2}{2\sigma^2}} \qquad z > 0 \qquad (6)$$

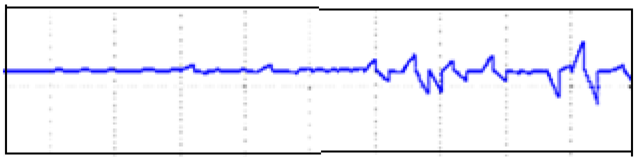
where $\sigma > 0$ is the scale parameter of the distribution. In an case of AWGN channel, the number of path is equal to one ie; $L = 1$ with a unit channel coefficient $\lambda(t) = 1$.Applied to the system over an AWGN or multipath channel ,this method provides the good estimates of the bit error rate (BER) for very large spreading factors. A raised cosine filter can be placed at the output of the channel to reduce ISI. The roll off factor of the filter is selected as 0.2.

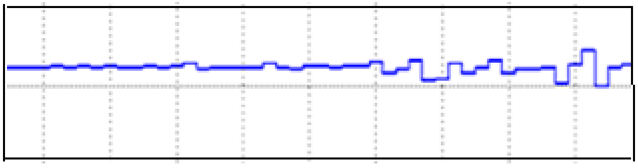

a.Data In

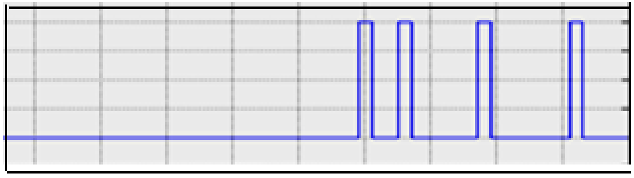

b. Chaotic Sequence


c. Modulator output


d. Channel output


e. Integrator output


f. Output of sample and hold circuit


g. Output of decision device circuit

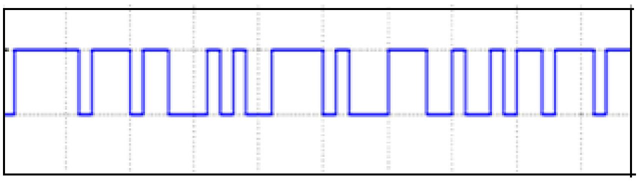

e. Data out

Fig. 5 Signal waveforms of the system in Simulink

### *D. Demodulation Scheme*

The system uses a non-coherent receiver in which chaotic synchronization is not used on the receiver side to generate an exact replica of chaotic sequence. The demultiplexed signal is given to the N parallel receivers which contains a set of matched filters for demodulating the desired signal and then the signals are sampled using a sample and hold circuit and finally given to the decision device circuit. The output of the N parallel receivers is given to the parallel to serial converter which produces the final output which is a replica of the transmitted signal.

## IV. SIMULATION RESULTS

### *A. Performance analysis*

In order to verify the performance, the system with specific parameters is simulated in Simulink. Fig. 5 shows the signal waveforms of the transmitter and receiver section. Fig.5a is the data input which is used to transmit. The sequence is spreaded by the chaotic sequence shown in the Fig. 5b.The modulator has the sampling period of 1μs, gain, k=5.

Fig. 5c shows the modulator output. AWGN channel add white Gaussian noise to the input signal. The parameters of the channel model are the following: signal to noise ratio, $E_b/N_0$=10; number of bits per symbol, $N_b$=1; input signal power, $P_i$=1 watt.

Raised cosine filter is used at the output of the channel in order to reduce the intersymbol interference. Square root raised cosine FIR filter is used here with parameters are input samples per symbol, N=8; Group delay, $g_d$=4; Roll off factor, α=0.2.

AWGN channel output is shown in Fig. 5d. The integrator performs discrete-time integration and its output waveform is shown in Fig. 5e.

The Sample and Hold block acquires the input at the signal port whenever it receives a trigger event at the trigger port. Here a pulse generator output is given as the trigger input. If latch (buffer) input is selected, then it produces a value of the input from the previous time step. The block then holds the output at the acquired input value until the next triggering event occurs.

Fig. 5f, 5g shows the output of the sample and hold circuit and decision device respectively. The output of N parallel receivers is converted into the serial form using the parallel to serial converter and the final data out is shown in fig. 5h.

### *B. BER Performance*

The BER performance obtained from simulation of the system using single carrier DCSK and MC-DCSK in AWGN channel is presented in Fig. 6 and 7. The BER performance of the system using MC-DCSK is better in comparison with that of the other. For instance, at the same BER=$10^{-3}$, the $E_b/N_0$ rates for the DCSK, MC-DCSK are about 350 dB and 45 dB.

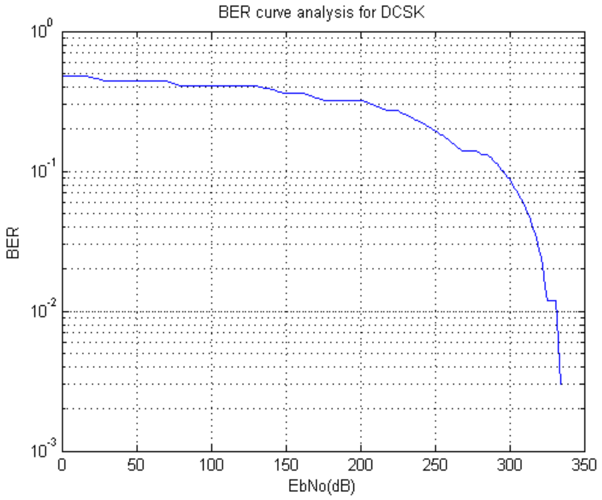


Fig. 6. BER performance of single carrier DCSK in AWGN channel

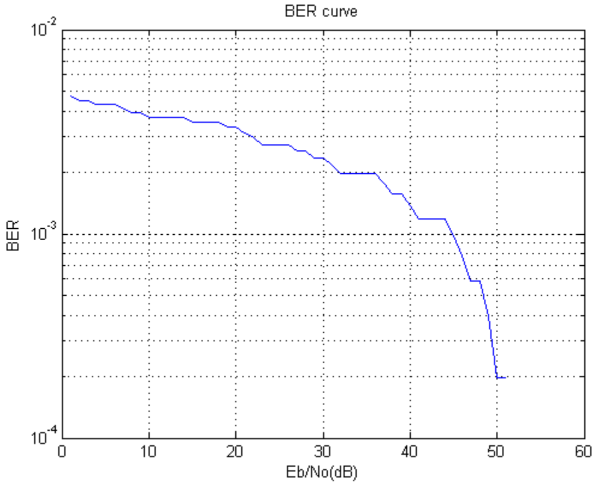


Fig. 7. BER performance of MC-DCSK in AWGN channel

Fig.8 evaluate the effect of the multipath Rayleigh channel on the performance of the system using MC-DCSK. The system's performance is evaluated for number of subcarriers M=2, a spreading factor, β=15 and for two light paths, L=2. The simulation results shows that when the time delays are much less than the bit duration, the effect of ISI can be neglected. This proves that the application of MC-DCSK to spread spectrum communication is feasible.

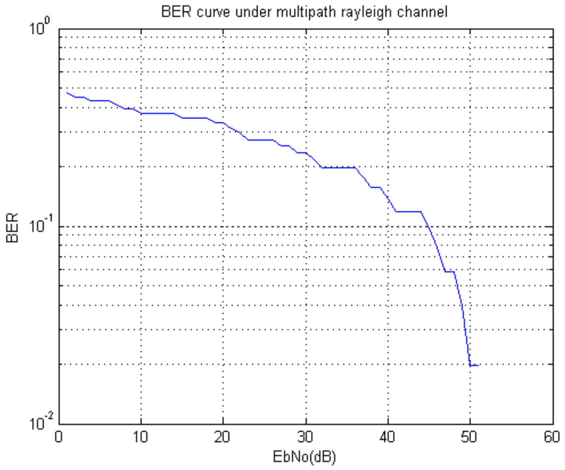


Fig.8. BER performance of MC-DCSK in Rayleigh channel

## V. CONCLUSION

This paper has presented and investigated the application of MC-DCSK scheme for spread spectrum communication which has vital role in military, biomedical applications etc.

It can be seen from the simulation results that the proposed spread spectrum system not only inherits valuable features of the MC-DCSK based methods such as high privacy due to its chaotic behavior and the spectral efficiency; but also achieve a better performance in noise and distortion-affected environments. This makes the spread spectrum method using MC-DCSK become a good candidate for application in security required digital communication systems.

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## REFERENCES

[1] A. Abel and W. Schwarz, *Chaos communications—Principles schemes, and system analysis,‖ Proc. IEEE*, vol. 90, pp. 691–710, May2002

[2] F. C. M. Lau and C. K. Tse, *Chaos-Based Digital Communication Systems*. Heidelberg , Germany: Springer-Verlag, 2003

[3] R. M. Gargliardi, *Introduction to Communications Engineering*. NewYork: Wiley, 1988

[4] B. Sklar, *Digital Communications: Fundamentals and Applications*. Englewood Cliffs, NJ: Prentice-Hall, 1988.

[5] C. C. Chen and K. Yao, "Stochastic calculus based numerical evaluation and performance analysis of chaotic communication systems," *IEEE Trans. Circuits Syst. I, Fundam. Theory Appl.*, vol. 47, no. 12, pp. 1663–1672, Dec. 2000

[6] G. Kolumbán, G. Kis, Z. Jákó, and M. P. Kennedy, “FM-DCSK: A Robust modulation scheme for chaotic communications,” *IEICE Trans. Fundam. Electron. Commun. Comput. Sci.*, vol. E81-A, no. 9, pp. 1798–1802,Oct. 1998.

[7] M. P. Kennedy and G. Kolumbán, “Digital communication using chaos,” in *Controlling Chaos and Bifurcation in Engineering Systems*, G. Chen, Ed. Boca Raton, FL: CRC Press, 2000, pp. 477–500.

[8] L. Wang, C. Zhang, and G. Chen, “Performance of an SIMO FM – DCSK communication system,” *IEEE Trans. Circuits Syst. II, Exp. Briefs*, vol. 55, no. 5, pp. 457–461, May 2008.

[9] F. C.M. Lau, K. Y. Cheong, and C. K. Tse, “Permutation-based DCSK and multiple access DCSK systems,” *IEEE Trans. Circuits Syst. I, Fundam. Theory Appl.*, vol. 50, no. 6, pp. 733–742, Jun. 2003.

[10] Z. Galias and G. M. Maggio, “Quadrature chaos-shift keying: Theory and performance analysis,” *IEEE Trans. Circuits Syst. I, Fundam. Theory Appl.*, vol. 48, no. 12, pp. 1510–1519, Dec. 2001.

[11] S. Wang and X. Wang, “ *M*-DCSK-based chaotic communications in MIMO multipath channels with no channel state information,” *IEEE Trans. Circuits Syst. II, Exp. Briefs*, vol. 57, no. 12, pp. 1001–1005, Dec. 2010.

[12] M. Sushchik, L. S. Tsimring, and A. R. Volkovskii, “Performance analysis of correlation-based communication schemes utilizing chaos,” *IEEE Trans. Circuits Syst. I, Fundam. Theory Appl.*, vol. 47, no. 12, pp. 1684–1691, Dec. 2000.

[13] G. Kolumbán, “Theoretical noise performance of correlator-based chaotic communications schemes,” *IEEE Trans. Circuits Syst. I*, vol. 47, pp. 1692–1701, Dec. 2000.

[14] J. G. Proakis, *Digital Communications*. Boston, MA: McGraw-Hill, 2001.

[15] T. S. Rappaport, *Wireless Communications: Principles and Practice*.Englewood Cliffs, NJ: Prentice-Hall, 1996.