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PERFORMANCE ANALYSIS OF CHAOTIC CHIRP SPREAD SPECTRUM SYSTEM IN MULTIPATH ENVIRONMENT

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ABSTRACT

Wireless channels often include multipath propagation, in which the signal has more than one path from the transmitter to the receiver. Atmospheric reflection or refraction, as well as reflection from the ground or from objects such as buildings may cause this phenomena. The aim of this research is to study the effects of multipath environment on the performance of a proposed chaotic chirp spread spectrum system (CCSSS). The benchmark performance of the proposed system is investigated in term of bit error rate (BER) under multipath environment. A Quadrature Phase Shift Keying (QPSK) modulation scheme and a matched filter based on adaptive threshold decision were used in this work. To assess the performance of this system, simulations were performed to compare the proposed system with the traditional frequency modulation differential chaotic shift keying (DCSK) spread spectrum system. The proposed system may be considered as a well qualified communication system in multipath environment.

Keywords: Chirp, Chaotic, QPSK, Matched filter, Spread Spectrum Systems.

1. INTRODUCTION

Spread spectrum (SS) communication is a kind of communication which spreads the information width in transmitter before going into the channel and compresses the received signal to get the information in receiver. Because of the spreaded information width, the ability to anti interference is strengthened and reliability is improved. There are two kinds of interference in communication system, that is, multipath and multiaddress interferences [1]. Multipath interference results from reflection/refraction in the course of signal transmission. It has been a problem of historical interest. It certainly has adverse effect on the quality of indoor and outdoor mobile communications. In multipath fading channels, however, interferences that result from path delays make it difficult to use high order data modulations and high code rates, thus limiting the capacity of the system [2]. Many techniques have been proposed to cope with multipath interference, e.g. diversity reception, channel equalization, and spread spectrum signaling [3]. The chirp spread spectrum is originated from the fact that the chirp signal uses a spread spectrum and a high correlation gain. Chirp signal, chirp modulation, or linear frequency modulation for digital communication was patented by Sidney Darlington in 1954 with significant work performed by Winkler in 1962. This type of modulation employs sinusoidal waveforms whose instantaneous frequency increases or decreases linearly over time. These waveforms are commonly referred to as linear chirps or simple chirps. Chirp signals have been heavily used in radar and sonar applications but it has been focused on personal wireless communication and localization application recently [4]. The representation of a typical linear chirp waveform is given as:

where T , $a(t)$, $f_o = w_o / 2\pi$: are chirp duration,

$$S(t) = a(t) \ \cos(w_o t \ + \mu \ \frac{t^2}{2}) \quad -\frac{T}{2} \langle \ t \ \langle \ \frac{T}{2} \qquad (1)$$

$$= 0 \quad elsewhere \qquad (1)$$

envelope, and center frequency. μ indicates the rate of change of instantaneous frequency. A chirp with positive μ is considered as "up-chirp", otherwise it is "down-chirp" [5]. It is convenient to define the bandwidth B as the range of the instantaneous frequency, so that $B = |\mu| \ T$. A linear time-invariant (LTI) filter with impulse response h(t) = s(T − t), where s(t) is assumed to be confined to the time interval 0 ≤ t ≤ T, is called the matched filter of the signal s(t). For the matched filter illustrated in Fig. (1), the output y (t) in response to an input signal r (t) is [6]:

$$y(t) = h(t) * r(t) \qquad (2)$$

$$y(t) = \int r(\tau)\ h(t-\tau)\ d\tau$$

$$y(t) = \int r(\tau)\ s(T-t-\tau)\ d\tau \qquad (3)$$

If the received signal is:

$$r(t) = s(t) + n(t) \qquad (4)$$

where n(t) is the noise, then

$$y(t) = \int s(\tau)s(T-t-\tau)d\tau + \int n(\tau)s(T-t-\tau)d\tau \qquad (5)$$

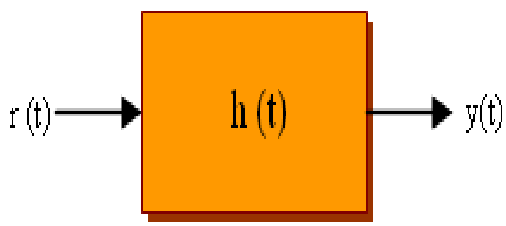


Figure 1. Matched Filter.

and the and the second part is the noise present at the output of matched filter. The signal portion is the time autocorrelation of the signal s(t), which exhibits the maximum possible signal power. Since the noise generally has different properties than the signal, the signal-to-noise ratio is usually much greater at the output of the matched filter than at the input [6]. The impulse response of a matched filter $h(t)$ for a linear chirp signal is again a linear chirp signal but with a chirp rate of opposite sign. If a chirp waveform is fed into its matched filter the output signal typically has a narrow IF peak at the chirp center frequency. Given chirp waveforms with a time domain envelopes and matched filter to be centered at t = 0 then an analytical expression for the output waveform g(t) of the matched filter will be:

$$y(t) = \dot{h}(t) * \dot{s}(t) = \psi_{ss}(t) \qquad (6)$$

where $\psi_{ss}(t)$ is the autocorrelation function of s(t). It can be shown that $\psi_{ss}(t)$ is given by:

$$\psi_{ss}(t) = \sqrt{B.T}\ \frac{\sin\left\{\pi.B.T(1-\frac{|t|}{T}\right\}}{\pi.B.T}\cos(2\pi f_o t) \quad for \quad -T\langle t\ \langle T \qquad (7)$$

The envelope has its maximum at t = 0, and its first zeros at $t \approx \pm 1/B$. It is therefore convenient to specify the pulse width as $1/B$. The ratio of the input and output pulse widths is therefore given by the time- bandwidth product $T.B$ which is known as compression ratio or processing gain [7].

Chaotic communication has recently attracted great interests because of its potential applications in secure communications and spread spectrum communications. Synchronization plays an important role in chaotic communications because it offers a potential advantage over noncoherent detection in terms of noise performance and data rate when the basis functions are recovered from noisy distorted received signals [8]. Chaotic phenomenon has aroused people's attention in recent years. Chaotic system is of very complex nonlinear property, and it is sensitive to the initial value very much. Until 1990, it was found that two chaotic systems can have the completely same chaotic behavior by connecting them properly, namely the drive-response synchronization scheme [9]. Chaotic signals show irregular and a periodic evolution, which are strongly dependent on the initial conditions; they are highly unpredictable and more similar to an ideal white noise source than any other PN source that is currently in use. At the same time, these signals are very easy to generate and control. The very favorable autocorrelation and cross-correlation (AC and CC) properties of chaotic spreading sequences in spread spectrum systems (SSS) make them preferable against competing solutions, like those based on Gold codes [10]. The signal generated by the chaotic generator can be taken from [11].

In this paper, a new scheme of multipath data transmission based on the principle of spread spectrum communication is proposed and investigated. The core of the proposed scheme is the chaotic generator whose output is used to spread the chirp signal. A special feature of the proposed scheme is robustness against multipath fading channel. Moreover, MATLAB/SIMULINK program is written to build the proposed system.

The BER of the proposed scheme is compared with the conventional SSS scheme in the presence of multipath interference conditions.

2. CHANNEL MODEL

The contamination of a transmitted signal can usually be modeled as additive noise at the received end. However, in many realistic situations, modeling transmission channels with additive Gaussian-noise does not precisely describe the transmission phenomena leading to various degradation sources in digital data transmission. Such sources include non-Gaussian noise, radio-frequency interference, and multiple transmission paths. Accordingly, the design of appropriate decision-theory operations becomes challenging due to the characterization of the transmitted signal and the modeling of the communication channel. Fig. (2) illustrates the channel model for multipath transmission where a direct transmission path from the transmitter to the receiver and subchannels corresponding to signals being reflected from the ground plane are included [12].

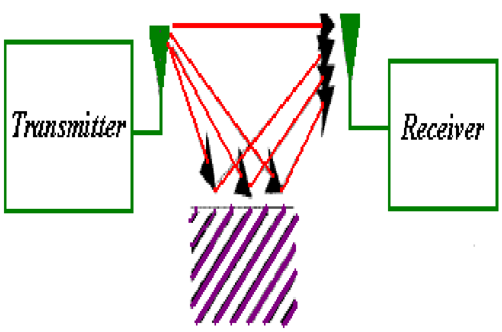


Figure 2. Channel model for multipath transmission

3. MODLE OF MULTIPATH CHANNEL

The tapped delay line model of a time-invariant multipath radio channel having N propagation paths is shown in Fig.(3). The radiated power is split and travels along the N paths, each of which is characterized by a delay T_i and gain K_i, where i=1,2, …,N. If a narrow-band telecommunication system is considered, then in the worst case two paths exist and the two received signals cancel each other completely at the carrier frequency w_c, i.e.,

$$\Delta_{T_{WC}} = (2n+1)\pi, \quad n = 1,2,3. \tag{8}$$

where $\Delta_T = T_2 - T_1$ denotes the excess delay of the second path [6].

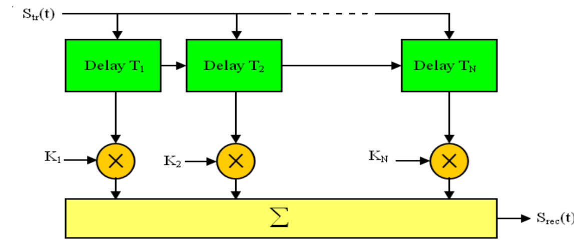
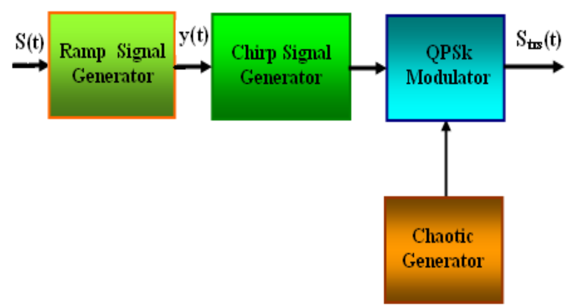


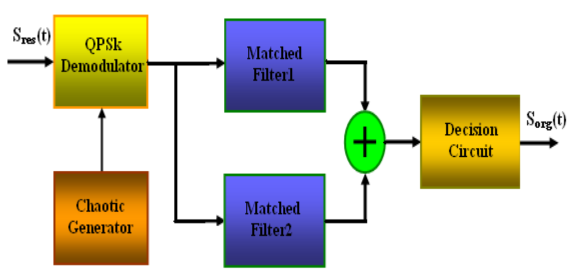
Figure 3. Tapped delay line model of multipath

4. SYSTEM MODEL

A block diagram of the proposed system is shown in Fig. (4).



a-Transmitter



b- Receiver

Figure 4. The proposed system block diagram.

The information signal $s(t)$ is a binary data. It controls a ramp generator whose action is to create a ramp signal. According to the value of $s(t)$ at any given instant t, the ramp generator output $y(t)$ has a ramp signal with positive slope if $s(t)$ is bit '1' and $y(t)$ is a ramp with negative slope if $s(t)$ is bit 'zero'. The signal $y(t)$ is then applied to voltage controlled oscillator (VCO) to produce a chirp signal. The generator of the chaotic signal at the transmitter produces a spreading signal, which is used to modulate the chirp signal, producing a quadrature phase-shift keyed (QPSK) signal. At the receiver, a reference signal, a code replica, which is an identical copy of spreading code, is used in a despread modulator (QPSK demodulator). If the code replica and the received code are the same and in phase, they correlate, and the transmitted data modulation can be restored as it is for data before spreading. In order to enable the detection of transmitted data at the proposed spread spectrum receiver, the code replica generated by the receiver has to be synchronized using the received code as accurately as possible, and the synchronization has to be maintained (signal tracking). The spreading code replica generated in the receiver thus has to be maintained in phase with the spreading code included in the received signal. For this reason, a special synchronization algorithm or unit is required for code synchronization, in addition to regular carrier and data synchronization. The QPSK demodulator output is a chirp signal with positive slope or negative slope depending on the data transmitted, so to recover the original data, two matched filters are used one for compression a chirp with positive slope and the other is used for compression a chirp with negative slope. Matched filters are devices whose outputs are time-reversed replica, a copy of the desired incoming signal, when the input is an impulse. A matched filter calculates the correlation between a known reference signal (chirp with positive slope) and the signal to be measured (chirp with negative slope), and gives a maximum output when the reference signal best corresponds to the incoming signal. For this reason, a matched filter is used for signal acquisition in spread spectrum systems for searching for the right phase of the reference signal generated by a receiver. A matched filter is the optimal way to identify signals from AWGN type of noise. The matched filters output is then fed to a decision circuits to recover the data transmitted, and the synchronization has to be maintained (signal tracking). The spreading code replica generated in the receiver thus has to be maintained in phase with the spreading code included in the received signal. For this reason, a special synchronization algorithm or unit is required for code synchronization, in addition to regular carrier and data synchronization.

5. SMULATION RESULTS

To study the impact of multipath interference performance of the proposed system, a simulator of the transmitter, receiver and a channel model were built. The channel is modeled using a tapped delay line (TDL) allowing the simulation of the proposed system in the Rayleih and Rician environments. The simulation system is built as a Simulink block diagram. The simulation is performed using the

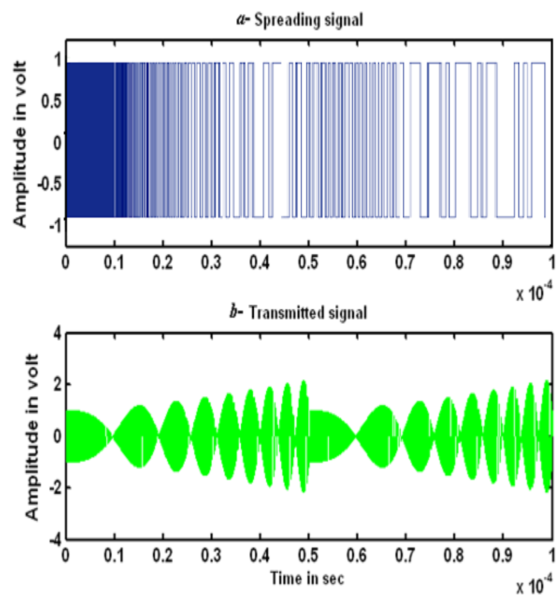


Figure 5. a- Spreading signal , b- Transmitted signal.

following parameters: data signal frequency, chaotic signal frequency, chirp signal frequency and the time band width product. The transmitted signal after spreading is shown in Fig. (5). In that case, there were no errors, so the received signal is identical to the data. Fig.(6) shows the signal sent to the decision circuit. In order to estimate system performance, the probability of error due to the multipath interference must be calculated.

The simulator is designed to estimate the system's BER. In this simulation the number of transmitted information bits is 10^5. The simulation result is given by Fig. (7), where it is easy to see clearly that in the

Rayleigh fading channel, the BER of the system using Hamming window is (the red curve) much better compared with the BER of the system with Taylor window (the green curve).
Fig.(8) shows the system BER in the presence of Rician fading channel. It is clearly that the system performance is much better with Taylor window (the red curve) compared with BER of the system using Hamming window (green curve). Therefore, the Taylor and Hamming windows can be used to enhance the system capacity and the system quality.

6. CONCLUSION

In this paper, a new scheme of data transmission based on the principle of spread spectrum communication can be considered as promising technique to reduce the effects of multipath fading in wireless communications. The proposed system can combine efficiently the chaotic and chirp techniques . This system makes use of a chaotic signal as a spreading signal to spread the chirp signal generated using VCO technology.

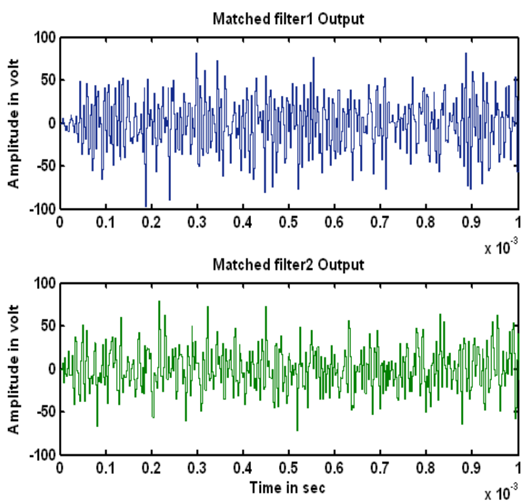


Figure 6. Signal sent to the decision circuit.

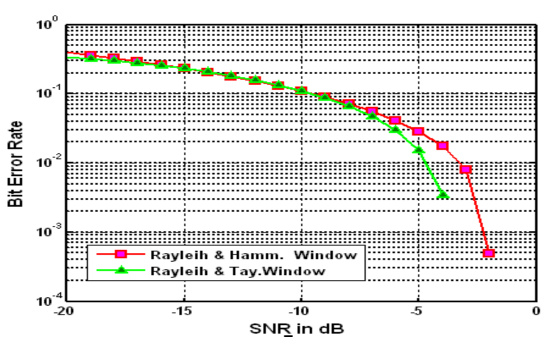


Figure 7. BER in the presence of multipath Rayleigh interference

Matched filters are used as a compression filters to recover the original data. The correctness of model has been verified by a Simulink model. The achieved results show that there are good prospects for chaos in the field of spread spectrum systems. The BER of different multipath fading channel of the proposed system is investigated using Hamming and Taylor windows in term of system capacity and the system quality. The proposed structure has improved the BER in comparison with the conventional one. The proposed system is promising candidate of a data transmission system.

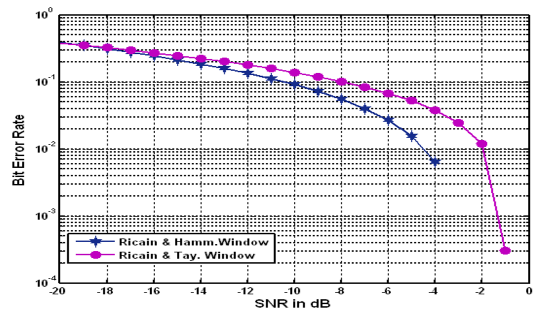


Figure 8. BER in the presences of multipath Racian interference.

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