Indian Journal of Science and Technology, *Vol 9(42), DOI: 10.17485/ijst/2016/v9i42/104647, November 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Rayleigh-Benard Attractor for OFDM

K. V. Sriharsha, R. Abishek Arun, C. Ramanathan, R. Abirami, S. Hamsavaahini, J. N. Saranya, R. Subhathira, K. Kalaiselvan and N. R. Raajan*

Department of Electronics and Communication Engineering, School of Electrical and Electronics Engineering, SASTRA University, Thanjavur - 613401, Tamil Nadu, India; sriharshakv.sastra@gmail.com, arun.abishek1@gmail.com, ramanathan461@gmail.com, abiramirajan30@gmail.com, hamsavino@gmail.com, saran11ms@gmail.com, saipritika@gmail.com, kalaikavithigal@gmail.com, nrraajan@ece.sastra.edu

Abstract

Objectives: Emerging trends in non-linearity has resulted in "Strange Attractors" which is highly chaotic in nature. In this paper the strange attractor – chaotic signal is being applied on the Orthogonal Frequency Divisional Multiplexing (OFDM) system and its performance is measured. **Methods/Statistical Analysis**: The work is divided into two parts– generation of the strange attractor, application of the attractor on the OFDM System. After generating strange attractor from Rayleigh-Bernard System, it is utilized by OFDM with different modulation techniques such as 16-QAM, 64-QAM and QPSK. A chaotic signal in OFDM transmission is seems to be rare combination for secured communication and that gains the novelty in this paper by applying strange attractors to OFDM technique. **Findings:** Performance of the Rayleigh Bernard Attractor with OFDM system has been estimated with BER vs E_b/N_0 plot and its security has been verified by calculating password decoding time. **Application/Improvements:** Rayleigh Bernard Attractor for OFDM system helps in the secured transmission and reception of the signal.

Keywords: Attractors, BER, Chaos, OFDM

1. Introduction

In the recent trends the term "non linearity" is gaining quality due to unpredictable features which have some strange features. This system does not adapt the super position principle which means that it does not hold both linearity and homogeneity. The second one is that the nonlinear systems have multiple multi-isolated equilibrium (where as linear systems have only one). Some of the properties of nonlinear systems are limit-cycle, bifurcation and chaos. Here in this work the construct of chaotic attractor is being applied into an OFDM (Orthogonal Frequency Division Multiplexing) system. The main purpose of employing the chaotic attractor into an OFDM System is to guarantee the secure communication, so that the data sent and data received is safe without being monkeyed by others during transmission[1].

The systems which hire chaotic sequences are essentially computationally complex in nature, difficult to hack, and the system functioning is better when compared with other communication systems. The confinement of chaotic system is that it needs to be precisely synchronized and the trans-receiver circuits need to be monovular in nature to decode it. This travail is the biggest advantage. One of the typical examples that can be given at this context is the working mechanism of Brain. In Brain the Left Brain is responsible for the linear thinking (i.e., logic thinking) and the Right Brain for the non linear thinking. Another example that can be given is the butterfly wings pattern which is highly chaotic in nature. There are several examples of the chaos codes for telecommunications, specified by the Prime Numbers 'P' and their associated primitive roots 'Q'. In literature secured digital communication has been done by using

**Author for correspondence*

chaotic shift keying in existing frequency-hop spread spectrum system[2–4].

2. Theory

2.1 Chaos

The real physical world litigate scan be laid out with the dynamical systems of mathematical systems. Given an apotheosis active system with the available knowledge of finite number of feigning factors, in the present state with the precise conditions of the system, we can predict the future of the system, with the states in the past. Chaos theory research is for understanding the complex systems in such a way that the mysterious unpredictable behavior accurately in precise deterministic form.

The present research says that the nonlinearity systems behave in an unpredictable manner and chaotic manner. The term "chaos" says that it is random in nature or unpredictable. This word creates a massive confusion for the public. The importance of chaos is being appreciated and this concept is helping in tackling wide range of problems existing in the areas like economics, ecology, physics, biology, engineering, fluid mechanics, meteorology and many more. With the varying complexity in the system, there exist a wide number of mappings that show the chaotic behavior. The main problem of the system is the long time prediction becomes difficult as there might be an error at the initial state which increases exponentially with the time. The reconstruction of the data from the dynamic systems becomes difficult without some initial conditions.

The strange attractor tells the behavior of the chaotic system. For a dynamical system the attractor set is closed subset of its phase space with many choices of the initial points in the systems that evolve towards the subset. The analysis of nonlinear dynamical processes data is done with the help of the phase space thus helping in the characterization of the data. Generally the data is wide spread across the transmission bandwidth in Direct Sequence Spread Spectrum (DSSS) communication systems which employ the chaotic sequences and the receiver will despread the spread sequence with the help of time synchronization. When the Direct Sequence Spread Spectrum communication system is compared with non-spread communication systems, DSSS system is computationally complex in nature. But the main advantage in using the DSSS system is the capability of reusing the multi-user spectrum and the multipath mitigation. For a layman the chaotic sequence can be viewed as a random sequence which is complex in nature.

There are basically three fundamental tenets defined for a chaotic system:[5]

- Periodic orbits with dense collection of points.
- Initial conditions and perturbations are highly sensitive.
- Fulfils topologically transitive condition/state.

So these three defined parameters can be used to form the mathematical equations which describe the chaotic system. Chaotic systems generally operate in domain which is continuous and takes every possible value present in the domain range; have non-measurable period which is periodic in nature and provides extremely highly sensitivity[6,7]. It operates recursively on any possible value in the domain to produce the closest possible value chosen in the range. There are many forms of chaotic systems like bifurcation, attractors which can be defined with non linear differential equation. In order to measure the chaotic systems lyupanov exponent is used.

The non-linear differential equations for Rayleigh-Benard attractor is given by:

$$Dx = -\alpha x + \alpha y\,; \tag{1}$$

$$Dy = rx - y - xz\,; \tag{2}$$

$$Dz = xy - \beta z; \tag{3}$$

Definitions:

- $D = d/dt$
- α, r, β – equation parameters
- x, y, z - 3D coordinates
- t– time

Parameters: $\alpha = 9$, $r = 12$, $\beta = 5$

The response of the chaotic Rayleigh-Benard attractor is given in Figure 1.

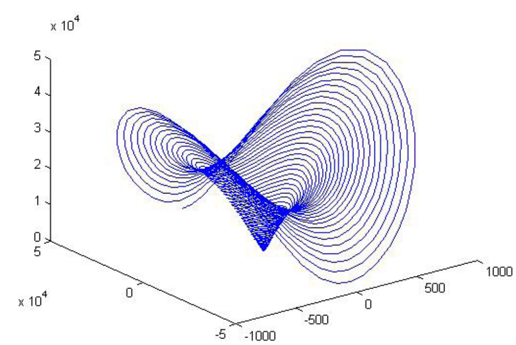


Figure 1. Rayleigh-Benard attractor.

2.2 OFDM

One of the most bully advantages in using the OFDM is that it can be viewed as a technique of modulation or the multiplexing. Narrow band interference and the frequency selective fading can be surmounting by using the OFDM system thus by enhancing the robustness of the system. The single fade or interference can crock up the integral system in the single carrier system. Only small portion of the subcarriers are enticed or struck or unhinged in the multicarrier system. And these erroneous data can be chastised using the ECC. In normal system there will be N frequency sub channels which does not non overlap each other. Separate symbols are used to regulate the sub channels and then frequency multiplexing is done thus warding off the inter-channel interference but it results in inefficient usage of the spectrum. This cause's excessive usage of the bandwidth of spectrum[8–9]. The problem is overcome by using the data which is in parallel form and the Frequency Division Multiplexing (FDM) in the efficient usage of the bandwidth.

The term orthogonal represents the mathematical relation between the subcarriers present in the frequencies. In the Frequency Division Multiplexing system, there will be space in between the carriers such that the signal can be incurred using the demodulators and the ceremonious filters. In frequency domain in between the different carriers guard bands are infixed in receivers. This lowers the spectrum efficiency[10–13]. In order to cater the needs of the OFDM, IEEE 802.11a standard supports different motley of coding schemes and the modulation techniques. This allows the engineers to combine different modulation dodging like QSPK, BPSK and QAM. Some of the advantages of using OFDM are;

- Efficient spectrum usage.
- Uses cyclic prefix thus eliminating the IFI and ISI.
- Resistant against co-channel interference and impulsive noise.
- Protective covering against frequency selective fading.

The modulation techniques in the OFDM uses complex signal processing sets about like (IFFT) Inverse Fast Fourier Transform and (FFT) Fast Fourier Transforms and in the transmitter and receiver sections. Typical Block diagram for the OFDM with Attractor is given in Figure 2.

Steps for generating an attractor for OFDM:

Step 1. Define the non linear differential equation.
Step 2. Define all the parameters in the non differential equation.
Step 3. Define the data parameters.
Step 4. Define the BER parameters.
Step 5. Define the convolution encoder parameters.
Step 6. Define the data mapping sequences.
Step 7. Define the viterbi decoder.

3. Results and Discussions

Various modulation techniques have considered especially QAM and QPSK techniques are used in this context. In QAM Modulation 16-bit and 64-bit are considered. Different types of modulation schemes have been applied for the OFDM System with attractor and its performance are plotted in Figure 3.

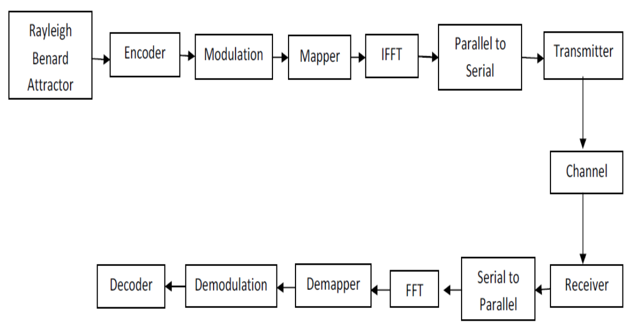
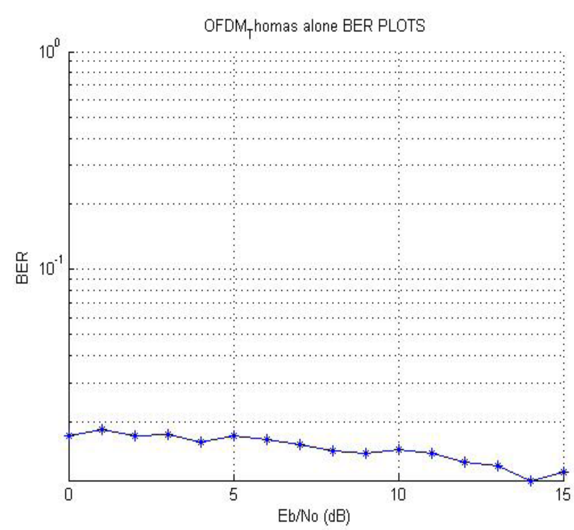
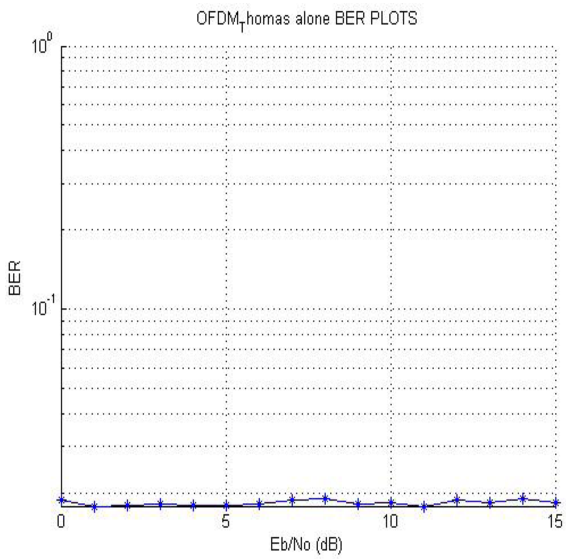


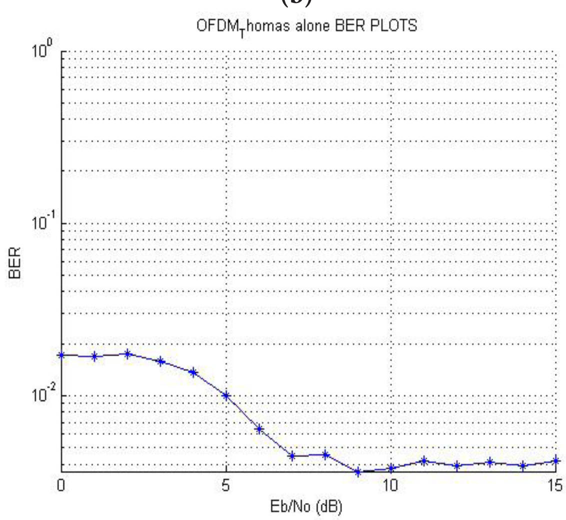
Figure 2. Block diagram for OFDM with Rayleigh-Benard attractor.



(a)



(b)



(c)

Figure 3. BER vs E_b/N_0 plot for OFDM system with Rayleigh-Benard attractor for. **(a)** 16 bit QAM modulation scheme. **(b)** 64 bit QAM modulation scheme. **(c)** QPSK modulation scheme.

Table 1. Time required for decoding the password

Password Length	Keys Per Second	Type of Data	Time Required for Decoding Years:Days:Hours:Min:Sec
16	256	Upper Alphabet	6 trillion:128:12:11:18
32	256	Upper Alphabet	$2.448^{*}10^{35}$:166:1:54:44
64	256	Upper Alphabet	$4.65^{*}10^{80}$:230:13:51:46

3.1 Security Level

In the present context there exists combination 256 keys per second for the input of key sizes of 16, 32, 64 bit key in length. Here combination 16 key bit password and 256 key bit for numeric will take one million years for decoding and if it increases towards 64 bit password, it takes $1.37\,^{*}10^{54}$ years 93 days 19hours 14 minutes 4 seconds and when even increases towards 256 bit key, it takes $1.37\,^{*}10^{246}$ years 152 days 15 hours 51 minutes and 14 seconds. Brute force approach has been considered for the generation of the passwords and its corresponding time required for decoding are tabulated in Table 1.

4. Conclusion

The execution of the system defines security level and the BER plots have been given above are enforced using data encryption that employs the strange attractor for the OFDM System. With the strange attractors the security level is meliorate when compared with other systems for the data.

5. References

1. Raajan NR, Monisha B, Vishnupriya R, Rangarajan N, Jayabhavani GN, Nishanthini C. Chaotic interleaving for secured OFDM. Research Journal of Information Technology. 2015; 5(3):449–55.
2. Kumar RR, Sampath A, Indumathi P. Improving security of communication systems using CHAOS. Indian Journal of Science and Technology. 2011 May; 4(5):561–5.
3. Mohammad SP, Gopal SK. A hybrid technique for BER and paper analysis of OFDM systems. Indian Journal of Science and Technology. 2016 Apr; 9(15):1–5.
4. Manikandan C, Neelamegam P, Divya E. OFDM techniques for MIMO-OFDM System: A review. Indian Journal of Science and Technology. 2015; 8(22).
5. Weisstein E. Chaos. Available from: http://mathworld.wolfram.com/Chaos.html
6. Bartle R. Elements of real analysis. 2nd ed. Wiley; 1976.
7. Debnath L, Mikusinski P. Introduction to Hilbert spaces with applications. 2nd ed. Academic Press; 1998.
8. Chang RW. Synthesis of band limited orthogonal signals for multichannel data transmission. Bell System Technical Journal. 1996 Dec; 45(10):1775–96.
9. Salzberg BR. Performance of an efficient parallel data transmission system. IEEE Transaction on Communication Technology. 1967; 15(6):805–13.
10. Bingham JAC. Multicarrier modulation for data transmission: An idea whose time has come. IEEE Communications Magazine. 1990 May; 28(5):5–14.

11. Cioffi JM. A multicarrier primer. ANSI T1E1.4 Committee Contribution; Boca Raton, FL. 1991 Nov. p. 1–18.
12. Weinstein SB, Ebert PM. Data transmission by frequency-division multiplexing using the discrete fourier transform. IEEE Transactions on Communication Technology. 1971 Oct; 19(5):628–34.
13. Stott J. The effects of phase noise in COFDM. EBU Technical Review; 1998. p. 1–22.