BER PERFORMANCE OF A CHAOS COMMUNICATION SYSTEM INCLUDING MODULATION - DEMODULATION CIRCUITS

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ABSTRACT

In this article, estimation of bit error rate (BER) performance in a general chaos communication system including modulation - demodulation circuits is investigated. We observe influences of modulation - demodulation circuits by both computer simulation and SPICE simulation. BER is calculated by computer simulation. We confirm that nonlinearity of modulation - demodulation and several circuits influence chaos synchronization and also communication quality.

1. INTRODUCTION

Since various chaotic phenomena were discovered in several nonlinear systems, some chaos applications have been considered by many researchers. Especially chaos communication systems attract many researchers' attentions for one of engineering applications. A variety of studies on chaos communication systems have been reported [1][2]. In these systems, chaos synchronization plays an important role [3] and the accuracy of the synchronization directly influences on communication quality. Therefore, it is important to research the effect of noise or nonlinearity of communication channel including transmission terminal. On the other hand, in order to transmit chaotic signals by radio frequency, it is necessary to modulate baseband chaotic signal to radio frequency. It is generally known that real modulation and demodulation circuits have a bad influence on the quality of communication. However, influence of modulation and demodulation circuits in communication systems using chaos synchronization has not been discussed until now.

In this study, we investigate influence of chaos communication systems including modulation and demodulation circuits. Two chaotic systems are connected by modulation - demodulation circuits. We use a simple chaos masking communication system using Chua's circuits [4]. The sum of chaotic signal from Chua's circuit and digital information signal is modulated by amplitude modulation (AM) circuit. The radio-band modulated signal is demodulated at the receiving side. In order to estimate communication quality, BER for various conditions (e.g. carrier frequency, bit rate and information signal voltage are tuned) are obtained by computer simulation.

2. CIRCUIT MODEL

Our communication system consists of a Chua's circuit for generating chaotic signal, a modulation circuit using a transistor, a demodulation circuit, several circuits for transmitting to a demodulation circuit, and reproducing circuit based on a Chua's circuit for reproducing the original chaotic oscillation. Fig. 1(a) shows a well known Chua's circuit including three memory elements, a resistor and nonlinear resistor N_R which is characterized by three segment piecewise-linear as Fig. 1(b). We know that Chua's circuit has two types of chaotic attractors, which are called as single - spiral and double - scroll chaotic attractor as shown in Fig. 2(a) and (b), respectively. A modulation circuit shown in Fig. 3(a) is a typical amplitude modulation system which consists of a transistor and some elements. We model the transistor as the Ebers-Moll model for a computer simulation. The demodulation circuit is constructed by a rectifier, an RC filter and several circuits. Further, two subsystems based on Chua's circuit are interconnected by voltage buffers to reproduce the original chaotic signal as shown in Fig. 3(b).

The circuit parameters of Chua's circuit are given as

- **Setting of Chua's circuit for single-spiral chaotic attractor**

$C_1 = 5.56[nF]$, $C_2 = 50[nF]$, $L = 7.14[mH]$, G = 1/R = 0.7 $[mS]$, $m_0 = 0.241[mS]$, $m_1 = 0.807[mS]$ and $B_p = 1.0[V]$.

- **Setting of Chua's circuit for double - scroll chaotic attractor**

Almost parameters are the same as the single - spiral case. The different parameters are

$C_1 = 5.0[nF]$ and G = $0.75[mS]$.

Two type of chaotic attractors for these parameters are

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shown in Fig. 2 (a) and (b), respectively. We can calculate the natural frequency of the circuit as 8.4[kHz] from the value of C_2 and L in Chua's circuit.

3. SIMULATION

3.1. Influence of Modulation and Demodulation

At first, we consider the case that only chaotic signal obtained from Chua's circuit is modulated. Chaotic signal is modulated by a typical transistor amplitude modulation circuit in Fig. 3(a). Figs. 4 and 5 are computer simulated results in the case of single-spiral and double-scroll chaotic attractors, respectively. (a-1) is attractor obtained from Chua's circuit at the transmitter side, (a-2) shows synchronization between original chaotic signal and reproduced chaotic signal, (a-3) is reconstructed chaotic attractor at the receiver side, (b) is the original chaotic waveform, (c) is modulated chaotic waveform, (d) is demodulated chaotic waveform, and (e) is reproduced chaotic waveform at the receiver side. We can see that the receiver cannot reproduce the original chaotic signal completely, especially for the case of double-scroll attractor. Because it was known that Chua's circuit can achieve chaos synchronization completely without any noise, the synchronization error is due to the modulation-demodulation circuits. We also carried out SPICE simulation of the same system and verified that both results agree well.

Next, we consider the case of transmission of chaotic signal including information signal. The computer simulated results for both of the single-spiral and double-scroll chaotic attractors are shown in Figs. 6 and 7, respectively. (a) is the original chaotic waveform $v(C1)$, (b) is digital information signal v_s, (c) is the sum of original chaotic waveform and digital information signal $v(C1)+v_s$, (d) is demodulated waveform v_x, (e) is reproduced chaotic waveform $v(C1')$, (f) $v_x - v(C1')$, and (g) low-pass filtered signal of $v_x - v(C1')$. We choose suitable circuit parameters for generating best performance. Bit rate is chosen as 2.65×10^3 [bps], namely the bit width is 3.78×10^{-4}[sec]. In Fig. 6, we can almost reproduce original information signals obtained from the receiver circuits by inputting v_s' to the several circuits. In Fig. 7, some bit error was confirmed and modulation-demodulation circuits influence on communication quality.

3.2. Simulation of BER

We calculate BER for the estimation of communication quality including modulation - demodulation circuits. Simulated results of BER are shown in Figs. 8, 9 and 10. Fig. 8 firstly shows BER while carrier frequency f_c is changing, amplitude E of the information signal v_s is fixed at 0.10[V] and bit rate of digital information is fixed as 2.65×10^3[bps]. In the case of single-spiral chaotic attractor, we can confirm that the BER performance is going better as f_c increases. Meanwhile the double-scroll chaotic case, it has only a little transition for contradistinction to the case of single-spiral chaotic attractor. Secondly BER of Fig. 9 shows obtained results while E is changing, f_c and bit rate are fixed as 110[kHz] and 2.65×10^3[bps], respectively. BER of the double-scroll attractor case was decreasing as E increases. However, in the case of single-spiral attractor, we can confirm the best BER performance was at around E=0.10[V]. Other voltages of E cannot produce a better performance of BER. It means bit error was directly affected by voltage E. Fig. 10 shows BER while bit rate is changing. The single-spiral case BER tends to be violently reduced as bit rate decreases, the other way, the double-scroll case BER tends to be slightly reduced.

We can conclude that high voltage E or lower frequency f_c cannot produce a good performance and that especially the double-scroll chaotic case is strongly influenced by modulation-demodulation circuits. They mean that it is important to apply a suitable bit rate or information signal voltage to the chaotic signal and they have been transmitted by high frequency carrier.

4. CONCLUSIONS

In this article, estimation of BER performance in chaos communication system including modulation-demodulation systems have been investigated. We confirmed that nonlinearity of modulation-demodulation circuits influenced chaos synchronization and also communication quality. It is important to design chaos communication systems considering influence of modulation-demodulation.

5. REFERENCES

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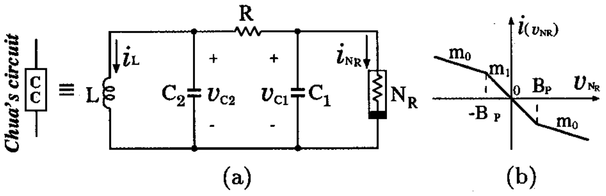
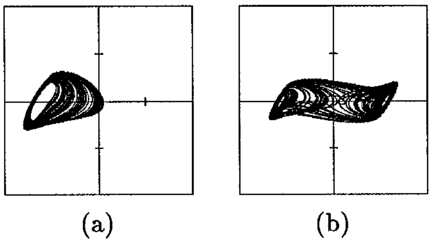


(a) (b)

Figure 1: Chua's circuit.



(a) (b)

Figure 2: (a) Single - spiral chaotic attractor and (b) double - scroll chaotic attractor.

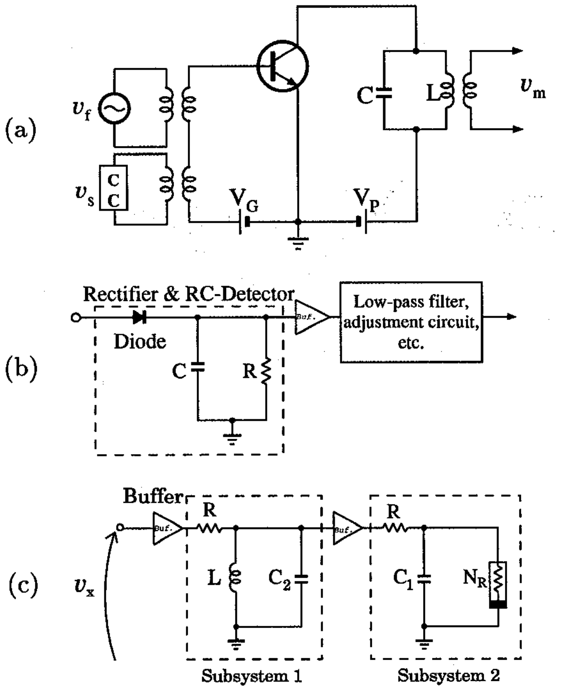


Figure 3: Models of chaos communication system using modulation - demodulation circuits for AM. (a) Transistor modulation circuit for AM, (b) demodulation circuit system, (c) reproducing circuit based on Chua's circuit.

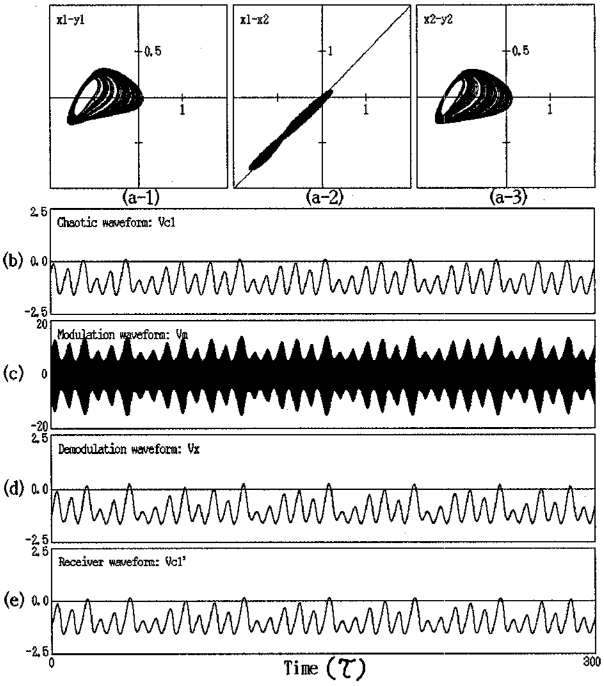


Figure 4: Transmission of only chaotic signal (single - spiral chaotic attractor) for $f_c \simeq 130$[kHz]. Horizontal axis of (b)~(e) is τ ($\tau = (LC_2)^{1/2}$[sec]).

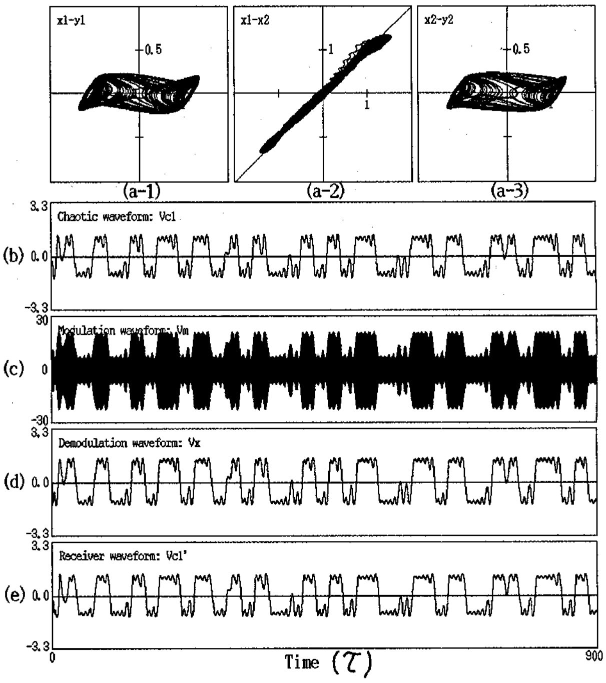


Figure 5: Transmission of only chaotic signal (double - scroll chaotic attractor) for $f_c \simeq 130$[kHz]. Horizontal axis of (b)~(e) is τ ($\tau = (LC_2)^{1/2}$[sec]).

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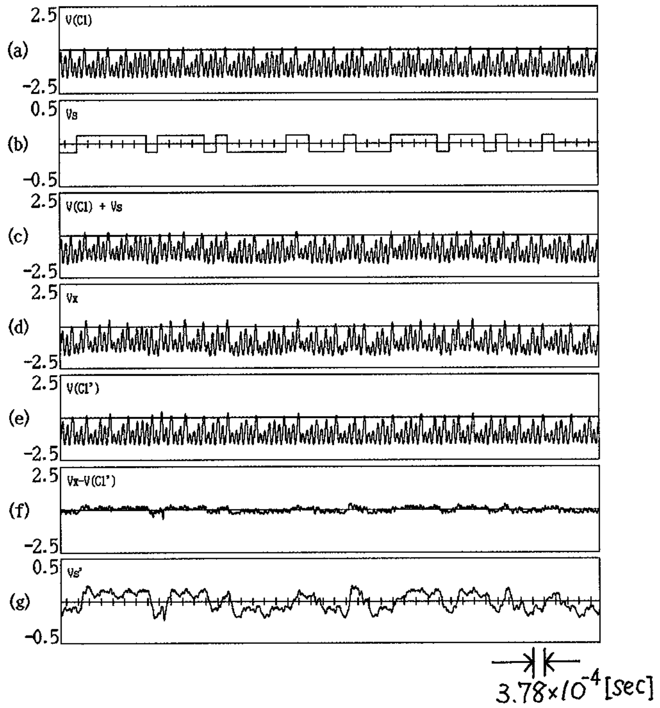

Figure 6: Transmission of chaotic signal (single-spiral chaotic attractor) including digital information signal for $f_c \simeq 130$[kHz].

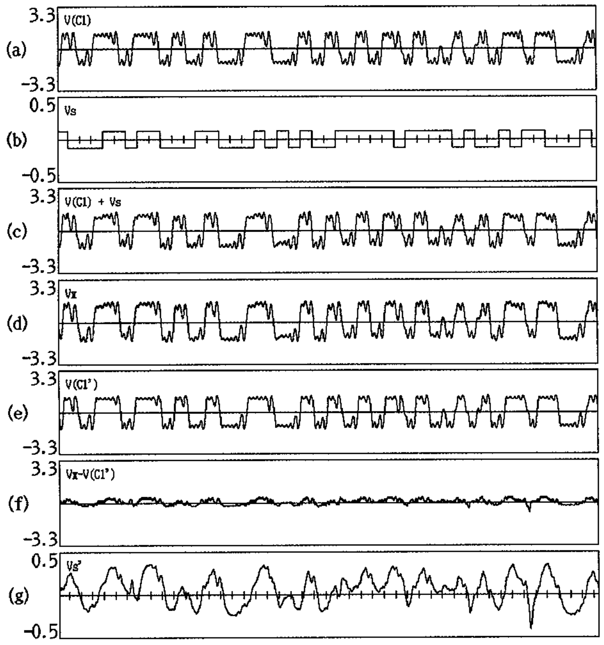

Figure 7: Transmission of chaotic signal (double-scroll chaotic attractor) including digital information signal. for $f_c \simeq 130$[kHz].

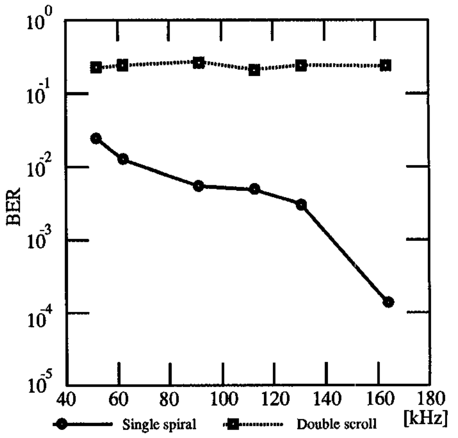

Figure 8: BER vs. carrier frequency f_c[kHz] for E=0.10[V] and bit rate 2.65 × 10^3[bps]. Each BER is simulated by 100000 points of data.

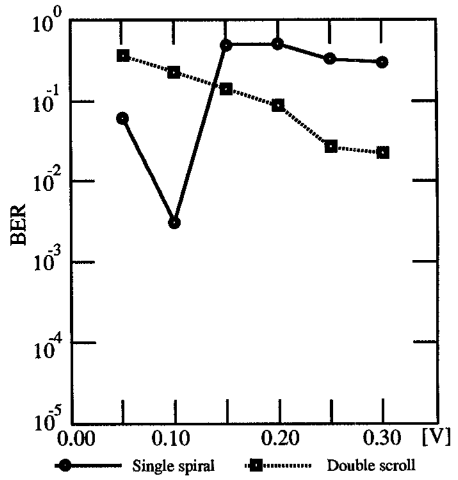

Figure 9: BER vs. information signal voltage E[V] for $f_c \simeq 130$[kHz] and bit rate 2.65 × 10^3[bps]. Each BER is simulated by 100000 points of data.

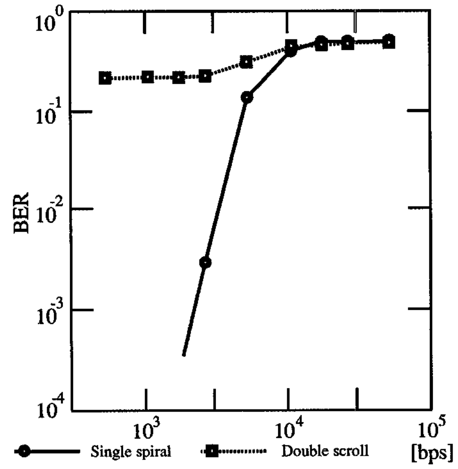

Figure 10: BER vs. bit rate[bps] for $f_c \simeq 130$[kHz] and E=0.10[V]. Each BER is simulated by 100000 points of data.