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# The Performance of Genetic Algorithm for Synchronized Chaotic Chen System in CDMA Satellite Channel

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***Abstract*—**Synchronization is a difficult problem in CDMA satellite communications. Due to the influence of additive noise and fading in the mobile channel, it is not easy to keep up with the attenuation and offset. This paper considers a recently proposed approach to solve the problem of synchronization chaotic Chen system in CDMA satellite communication in the presence of constant attenuation and offset. An analytic algorithm that provides closed form channel and carrier offset estimates is presented. The principle of this approach is based on adding a compensation block before the receiver to compensate the distortion of the imperfect channel by using genetic algorithm.

The resultants presented, show that the receiver is able to recover rapidly the synchronization with the transmitter.

***Keywords*—**Chaotic Chen system, genetic algorithm, Synchronization, CDMA

## I. INTRODUCTION

THUS far, the primary applications of satellite communication have been TV broadcasting, telephony and bundled data trucking, military communications, and data relay for space missions. Satellites can provide services to mobile users as well as fixed ground users while the terrestrial networks (fibre and wireless) can only cover terrestrial users on the ground where there are fibres and wireless infrastructures leaving coverage gaps in sparsely populated areas, over the ocean, and in the air. [1]

Recently, Iridium and Global star utilize low Earth orbital (LEO) satellites for mobile telephone service and limited point-to-point data communications. To varying extents, all these schemes include building a heterogeneous network, which interconnects the satellites with the terrestrial wired wireless networks. [2-3]

The realization of the handover between different satellites and the multiple accesses is very important for a LEO satellite communication system. Both issues can be managed by using DS-CDMA (Direct Spread Code Division Multiple Access) technology. Unfortunately, the performance of a DS-CDMA system degrades with the delay of synchronization. For example, the Global star satellite system is taken as a basic model. Global star is a LEO satellite communication system with CDMA technology, which is already online [4-5]. Recently immediate synchronization has become very pertinent, due to the fact that it improves the system.

Chaotic communications based on the transmission of messages encoded on a chaotic waveform are a subject of great current interest, attracting increasingly intensive research activities [6]-[7]. Compared to conventional communication systems, there are several unique features of chaotic communication systems. Potential benefits of chaotic communications include efficient use of the bandwidth of a communication channel, utilization of the intrinsic nonlinearities in communication devices, large-signal modulation for efficient use of carrier power, reduced number of components in a system, and security of communication by chaotic encryption.

It is possible to implement a chaotic communication system either with or without chaos synchronization. A chaotic communication system based on synchronization has many different features and potentially different applications from one that is not based on synchronization, although both share some common characteristics due to the fact that they are both chaotic systems. [8]-[11] Most of the research activities in chaotic communications so far address systems based on synchronization of chaos between a transmitter and a receiver linked by a transmission channel. For such systems, chaos synchronization is mandatory, while the quality of communication, measured by the bit-error rate (BER) of a decoded message at the receiver, depends crucially on the accuracy and robustness of synchronization.

In this paper, we propose the use the combination of Chen chaotic system synchronization and genetic algorithm to realize the synchronization in CDMA satellite communications. To achieve this result, a compensator is added before the receiver. The genetic algorithm is applied to estimate the attenuation and offset. The resultants presented, show that the receiver is able to recover rapidly the synchronization with the transmitter.

## II. SYNCHRONIZATION OF CHEN SYSTEM

We consider Chen system [12]:

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$$\begin{cases} x_t' = a(y_t - x_t) \\ y_t' = (c-a)x_t - x_t z_t + c y_t \\ z_t' = x_t y_t - b x_t \end{cases} \qquad (1)$$

which is chaotic when $a$ = 35, $b$ = 3, and $c$ = 28, this system is topologically non-equivalent to the Lorenz system and is indeed a *dual* system to the Lorenz system. Fig 1, show the Chen's attractor.

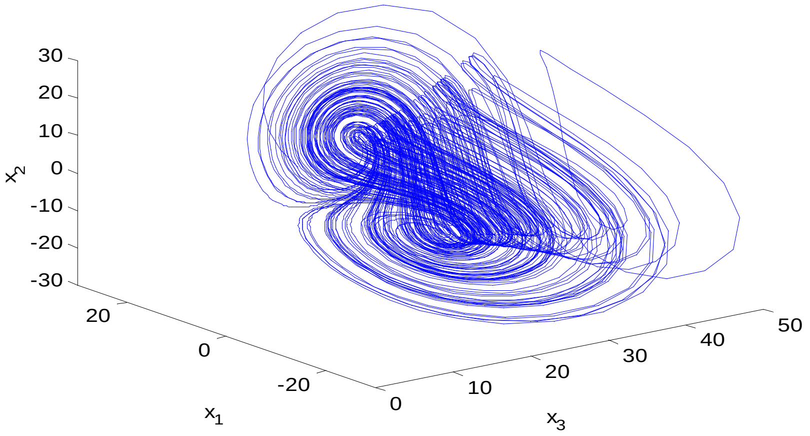

Fig. 1 The typical Chen chaotic attractors

We assume Eq. (1) to be the transmitter and we select its output as:

$$y = y_t = y_r \qquad (2)$$

Then the receiver equations are

$$\begin{cases} x_r' = a(y_t - x_t) \\ y_r' = y_t' \\ z_r' = x_r y_t - b x_r \end{cases} \qquad (3)$$

For this system, the error dynamics system is given by:

$$\begin{cases} e_1' = -ae1 \\ e_2' = y e_1 - b e_2 \end{cases} \qquad (4)$$

where

$$e_1 = x_r - x_t \text{ and } e_1 = z_r - z_t \qquad (5)$$

Notice, however, that

$$e_1(t) = e_1(t_0) e^{-a(t-t_0)}$$

$$e_2(t) = e_2(t_0) e^{-b(t-t_0)} + \int_{t_0}^{t} e^{-b(t-\tau)} y(\tau) e_1(\tau) d\tau \qquad (6)$$

Therefore the criterion given by [12], we can easily verify that both $e_1(t)$ and $e_2(t)$ globally and exponentially converge to zero. Hence, the Chen systems synchronize globally and exponentially.

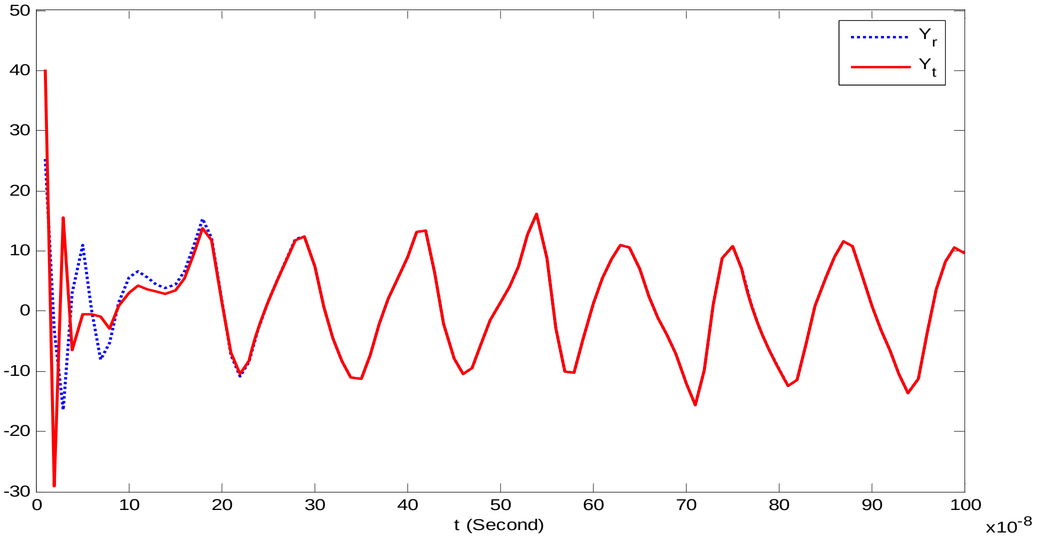

Fig. 2 The synchronizing process and result of two identical Chen's systems

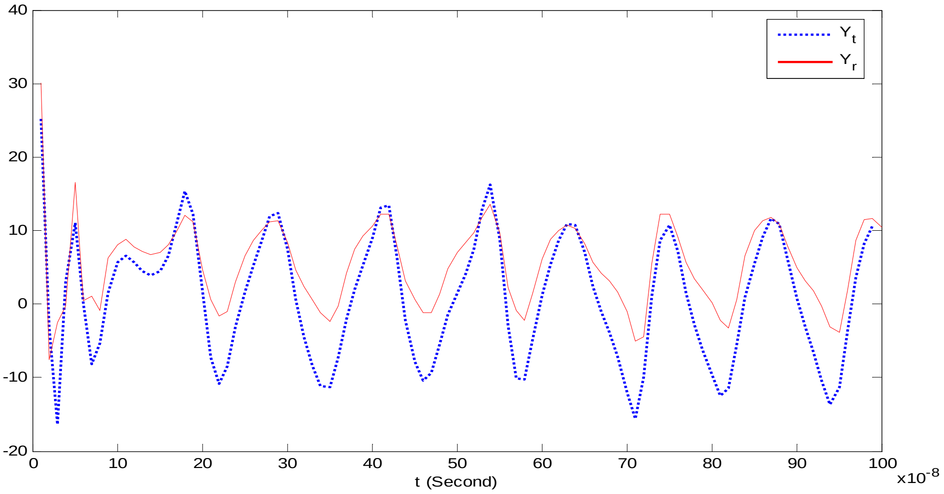

Fig.3. Synchronization between transmitter an receiver in satellite channel with Attenuation A=2 and offset B=6

Fig. 2 shows the synchronizing process and the result of two identical Chen's systems. This simulation result has thus verified the theoretical analysis and condition given above. Likewise, if we choose $\tilde{y}_t$ be a delayed version of $y_t$ (the channel is a time delayed system).

However, if $\tilde{y}_t$ is a distorted version of $y_t$ after passing through a channel, there will be a *synchronization mismatch* between $y_t$ and $y_r$ .

We can quantitatively define the synchronization mismatch (*SM*) as a dimensionless quantity [13]:

The maximum absolute value of the difference between $\tilde{y}_t$ and $y_r$ over the root mean square (rms) value of $y_t$, which is:

$$SM = \frac{\max\limits_{t_c \le t \le \infty} \left| y_r(t) - \tilde{y}_t(t) \right|}{y_{rms}} \tag{7}$$

Where $t_c$ can be chosen to be a time value after which the difference between $\tilde{y}_t$ and $y_r$ becomes less significant for a perfect channel. $u_{rms}$ is the rms value of $y_t$ and defined as

$$y_{rms} = \lim_{t > \infty} \frac{1}{t - t_c} \sqrt{\int_t^t \left| y_t(t) \right|^2 dt} \tag{8}$$

synchronization mismatch defined above may be considered as a signature of the channel. For a perfect channel, SM is very small. However, for an imperfect channel, the distortion from the channel may introduce a considerable SM, or even destroy the chaotic synchronization.

## III. SYNCHRONIZATION RECOVERY IN SATELLITE CHANNEL

The satellite channel is imperfect; the synchronization mismatch may be quite large.

The output $\hat{y}_t$ of the channel is given by $\hat{y}_t = \frac{y_t}{A} + B$ , where A: is the attenuation factor and B: is the offset of the channel. [13]

The values of A and B will affect the synchronization status. We can find that when A is as small as 1.1, the synchronization mismatched can be detected, although it is not significant. However, if A goes up to 5, the mismatch can be considerable. The offset B has the similar effect on the synchronization as the attenuation A factor. When offset B increases from 1 to 5, the mismatch grows up simultaneously. As shown in Fig. 3, when the distortion from the channel is characterized as A =2 and B=6, the synchronization mismatch is very significant and the synchronization can be hardly hold. So it is very clear that the mismatch increases as the attenuation or offset increases. The even worse case is that the synchronization may be totally lost.

In the following, we will show the idea to recover the chaotic synchronization. An intuitive way is to add a compensation system before the receiver as shown in Fig. 4. We can design the compensator to be

$$\tilde{y}_t = (\hat{y}_t - \hat{B}).\hat{A} \tag{9}$$

Therefore,

$$\tilde{y}_t = (\hat{y}_t - \hat{B}).\hat{A} = \frac{y_t}{A}.\hat{A} + (B - \hat{B}) \tag{10}$$

From (10), we can find that if $\hat{A}$ and $\hat{B}$ approach $A$ and $B$ , respectively, $\tilde{y}_t$ will approach $y_t$ , and the synchronization can be recovered by the response system.

Here, the objective is to find the estimation values $\hat{A}$ of and $\hat{B}$ . For obtained these values, we use the genetic algorithm. The cost function used in optimization is the synchronization mismatch between the receiver input and receiver output. $\hat{A}$ and $\hat{B}$ are the approximations of $A$ and $B$ when the value of the cost function approaches zero.

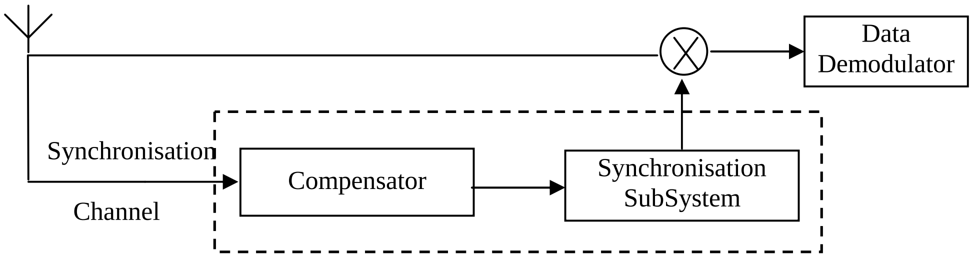

Fig. 4 The synchronization schema with compensator before the receiver

## IV. GENETIC ALGORITHM

GAs inspired by Darwinian Theory, are powerful non-deterministic iterative search heuristics. It has used in many applications in communication systems [14]. Gas operate on a population consists of encoded strings, each string represents a solution. Crossover operator is used on these strings to obtain the new solutions, which inherits the good and bad properties of their parent solutions. Each solution has a fitness value, solutions having higher fitness values are most likely to survive for the next generation.

Mutation operator is applied to produce new characteristics, which are not present in the parent solutions. The whole procedure is repeated until no further improvement is observed or run time exceeds to some threshold.

The operation of the GA is explained as follows:

To start the optimization, GA use randomly produced initial solutions. This method is preferred when a priori knowledge about the problem is not available. After randomly generating the initial population of say *N* solutions, the GA uses the three genetic operators to yield *N* new solutions at each iteration. In the selection operation, each solution of the current population is evaluated by its fitness normally represented by the value of some objective function and individuals with higher fitness value are selected. Different selection methods such as roulette wheel selection and stochastic universal sampling can be used.

The crossover operator works on pairs of selected solutions with certain crossover rate. The crossover rate is defined as the probability of applying crossover to a pair of selected solutions.

There are many ways of defining this operator such as single point crossover, double point crossover, multi-point crossover etc. For example, the single point crossover works on a binary string by determining a point randomly in the two strings and corresponding bits are swapped to generate two new solutions.

Mutation is a random alteration with small probability of the binary value of a string position. This operator prevents GA from being trapped in local minima.

The fitness evaluation unit in GA acts as an interface between the GA and the optimization problem. Information generated by this unit about the quality of different solutions is used by the selection operation in the GA. Next the stopping criteria must be decided. This may be the case when there is no significant improvement in maximum fitness or the maximum allowable time (number of iterations) is passed. At the end of the algorithm, the best solution found so far is returned

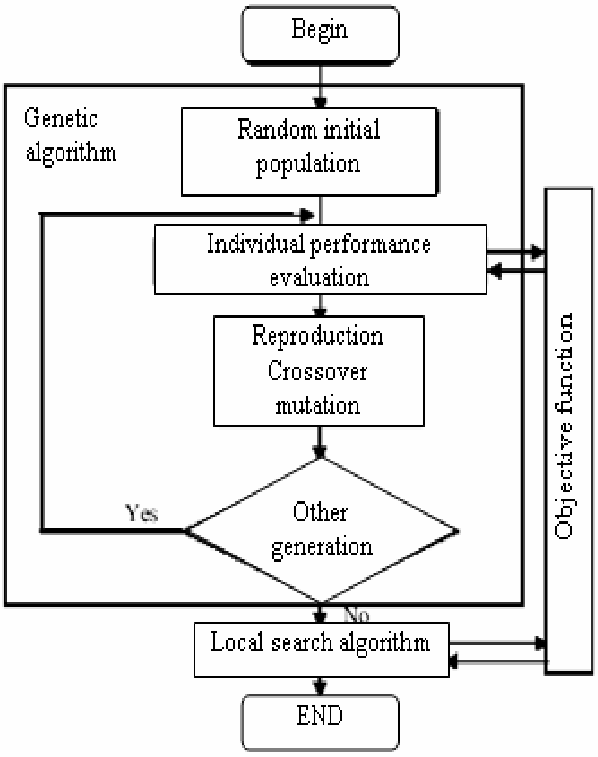

Fig. 5 Flowchart of Genetic Algorithms

## V. NUMERICAL EXAMPLE

Let us consider an example to show the robustness of the approach to recover synchronization. For the systems in (1) and (3), the Chen system parameters are $a = 35$, $b = 3$, and *c* = 28. The distortion from the channel is characterized as A=2 and B=6. As shown in Fig. 2, the synchronization mismatch is very significant and the synchronization can be hardly held.

Using genetic algorithm, the initial guesses are in the range [0,10] $\hat{A}$ and [-15,15] for $\hat{B}$ As shown in Fig. 6.At the meanwhile, $\hat{A}$ and $\hat{B}$ are also varying toward their optimum values. After 100 iterations, the results are: $\hat{A}$ =2.006 and $\hat{B}$ =5.986.

The results are very close to the actual values of A and B, where A=1.5 and B=5. Applying $\hat{A}$ and $\hat{B}$ in (10), the expression of the compensator becomes:

$$\tilde{y}_t = (\hat{y}_t - 5.986) \times 2.006$$

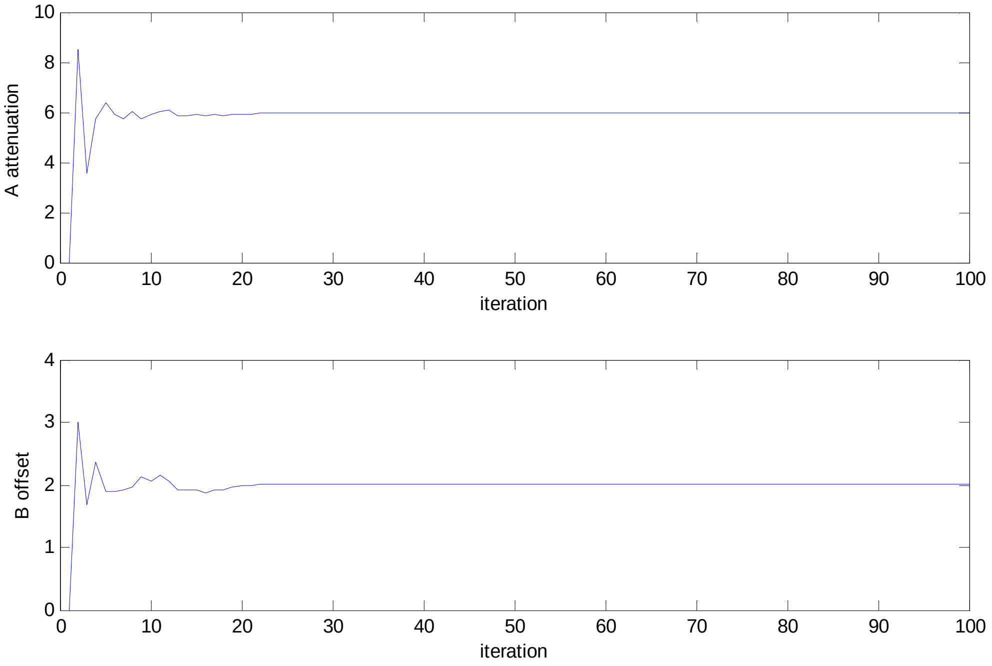

Fig. 6 Estimation the values of attenuation and offset

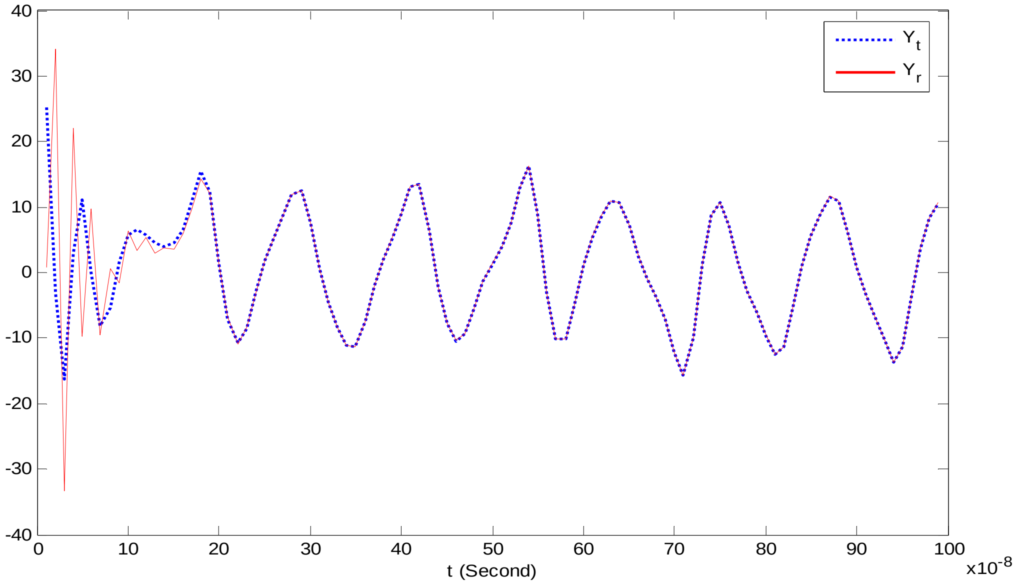

Fig. 7 The synchronization recovery with the compensator

And, as shown in Fig. 4, with the compensator in (10) added before the receiver, the synchronization mismatch has been reduced remarkably. In fig. 7 we can see that the compensator excellently recovers the synchronization

## VI. CONCLUSION

In this paper, we have presented the use the combination of Chen chaotic system synchronization and genetic algorithm to realize the synchronization in CDMA satellite communications. To achieve this result, a compensator is added before the receiver. The genetic algorithm is applied to estimate the attenuation and offset. The resultants presented, show that the receiver is able to recover rapidly the synchronization with the transmitter in CDMA satellite communications.

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