CAPTURE METHOD FOR SPREAD SPECTRUM ALOHA SIGNALS

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ABSTRACT

The concept and model of Spread Spectrum ALOHA (SS-ALOHA), as an important subject to develop dual-purpose satellite system in China, are described in this paper. The new synchronous code format and method for capturing the SS-ALOHA signals are presented and the process of correlation with surface-audio wave (SAW) is shown. The diagram of fast acquisition system and the results of experiment are given.

KEY WORDS

Satellite Communication, Mobile Communication, Spread Spectrum, Random Access

INTRODUCTION

The dual-purpose satellite systems were developed that would handle message and supply positioning information after Professor G. K. O'Neill presented dual-purpose satellite concept in 1982[1]. Radio Determination Satellite Service (RDSS) is coming from that concept. It operates at radio frequencies allocated by the International Telecommunication Union (ITU) and is licensed in the United States by the Federal Communications Commission (FCC). In China, similar system called as communication and positioning based on two satellites (CPTS) has been developed since 1986. The two trials of CPTS system were done in 1989 and in 1995 respectively. The system similar to CPTS have also been developed in other countries[2-4]. CPTS uses the spread spectrum (SS) for measure the distance from the users to two satellites and uses slot-ALOHA protocol to send the response message from users' transceiver according to beginning of the subframe from the center. In this paper, we present a SS-ALOHA multiple-access protocol used for CPTS. SS-ALOHA is the differ from the spread-ALOHA suggested by Dr. N. Abramson in University of Hawaii. SS-ALOHA concept means that a number of users use the same SS-encoding sequences, the same carry frequency and random arrival time with slot-ALOHA access. In SS-ALOHA system, it is not necessary to use the different spreading sequences for different users, but the new synchronous code must be built in order to get identical word of packet and larger processing gain. In this paper, we present to combine concatenated sequence with Barker code for this aim and capture method for synchronous code by means of SAW. The experiment of capture SS-ALOHA signals had been made by using the SAW-MFC in the Lab. A few results of correlating signal of the experiment will be given in next section.

SPREAD SPECTRUM ALOHA ACCESS CONCEPT

The configuration of CPTS is based on construction of RDSS. The space segment has two satellites, and the ground segment of system consists of one controlling and data processing center (also call as center station) and near million users. According to timing protocol of CPTS, users must send their message in beginning of the subframe broadcasting from center. It is the basis of measuring distance from users to two satellites. Gotten distance between users and satellites, the host computer in center can calculate users' altitude and longitude, and then insert position information into the broadcasting superframe to transmit to one of two satellites, and repeat the information to the ground in order to be received by user. If the CDMA scheme is used in the system, the center will be required to build a number of correlators or match filters so that the different users can be captured by using different correlators. Certainly, one programming correlator can be used for many users, but the time of capture will delay for long. So we present to use the same PN sequence for different users' signal. As we know, the packet of user consists of synchronous head, information segment and error-correcting segment. In this paper, only synchronous head is considered. The overlapping of packets does not mean losing packets by using the spread spectrum for users in slot-ALOHA channel. Center can distinguishing the overlapping signal sent by users in different time of arrival. From this point, we find that the signals of users have a packet format in ALOHA channel and have spread spectrum characteristics so that the communication protocol is called as spread spectrum ALOHA.

Spread spectrum ALOHA is differ from the spread ALOHA presented by N.Abramson in 1985. Both of them have similar performance in channel capability. Spread ALOHA show that each bit of packet must be firstly spread in time and then to be modulated by PN sequence, but SS-ALOHA will maintain a data rate and directly modulate by PN. If we use the signal dimension theorem[5], the signal can be presented in $D=2B_DT_D$ signal space. Where B_D is the band of signal and T_D is the time of signal. Signal energy in out of T_D is zero. The same signal can be presented in the high dimension space $n=2B_ST_S$ again and $n>D$, where B is the band and T_S is the time of spread spectrum sequence. Through the low dimension (D- dimension) signal imbedded in a high dimension (n-dimension) space, the processing gain G_A can be gotten, $G_A = 2B_ST_S / 2B_DT_D$. We can find that the same result — large time-band can be obtained by means of spread the signal band or spread time of signal. That is a different point between SS-ALOHA and spread ALOHA.

SYNCHRONOUS CODE FORMAT AND CAPTURE METHOD

The single concatenated sequence, like sequence AAAA... (where A means PN sequence), was chosen as the synchronous code in first trial of CPTS of China in 1989. A synchronous code consists of many m-sequences concatenated simply. That code used in trial, however, it is shown that synchronic time of packet arrival cannot be fixed because that random correlation peak time can be emerged by means of SAW circle adder. The result changes with the different threshold. The old synchronous code cannot be used for radio determination or distance measure. In order to get accurate correlation peak, timing of system and large processing gain, the fixed length synchronous code must be chosen.

Concatenated sequences[6] are defined as combinations of two sequences such that each bit of one sequence is further encoded by another sequence. In this paper, new concatenated sequences consist of three layers encoded sequences. First sequence is designated as an "outer" encoded sequence. The second sequence is used to encode each bit of the first as the "middle" sequence. The third sequence is called the "inner" sequence. To be clear, the process of encoding sequences is shown in Fig.1. "Outer" sequence is $Gd_1Gd_2Gd_3G$ ($d_1 \neq d_2 \neq d_3$, a chip of PN sequence as a unit), "middle" sequence-G made of four sequence-As is Barker sequence and encoding pattern 1 -1 1 1. The "inner" sequence-A is PN sequence. We chose m-sequence in experimental system, in fact that M-sequence, Gold sequence and the other PN sequence can be used for the practical spread spectrum systems. In reference[6], some good suggestions have been given about why to take the shorter sequence rather than the longer one in spread spectrum receiver, but only the processing gain of 60 (17.8dB) has been obtained so that it does not meet needs for CPTS system operating under the low signal-to-ratio. Here we consider the longer L>2048 chips sequence and three layers concatenated sequences. The aim of finding a new concatenated sequence is to obtain the performance of a long sequence in the CPTS system while using the shorter MFC, thus simplifying the receiver implementation and decreasing the time of acquisition. On the other hand, if the long sequence as 2048 chips may be used, it is feasible in theory, but the MFC as 2048 chips is not easy to be made, especially programmable SAW-TDL (Surface Acoustics Wave Time Delay Line). To realize the CPTS system and reduce cost of system, the shorter SAW-MFCs should be used to the practical spread spectrum system. The concatenated sequences presented here are taken as the synchronous code of the SS-ALOHA packet, only a small part of PN signals for the CPTS system. A scheme for generation and acquisition of concatenated sequences is shown in Fig. 2. We choose the SAW-DTL as MFC. The "inner" and "middle" sequences are matched by a few SAW-DTL, then the "outer" encoding sequence is matched by the digital shift registers. The length of the concatenated sequence is as follows:

$$L=(L_1+4)+d_1+d_2+d_3$$

The three processing gains in theory are given by three stage's MFC, they are

$G_1=10\lg L_1$

$G_2=10\lg 4$

$G_3=10\lg 4$

If we let $L_1=255$, $G_1=24$dB, the processing gain in all is 36dB.

AN ACQUISITION SYSTEM

As shown in Fig.3, an experimental system for fast acquiring synchronous code mainly consists of one programmable SAW-DTL, three fixed SAW-DTL, four long digital shift registers (DSR) and local PN codes generator, etc. The signal input to programmable TDL is a bi-phase synchronous code modulated by 70 MHz IF. The local PN code generator generates only sequence-A and $\underline{A}$ (reverse sequence-A) in itself, and keeps it in each tap of programmable DTL. When the concatenated sequences arrive at programmable DTL and a complete "inner" sequence A enters DTL, the auto correlation peak will appear, then it enters the first fixed DTL and the sequence-$\underline{A}$ enters completely programmable DTL, the negative auto correlation peak or reverse phase peak can be obtained. Output of adder is zero, the reason is that negative peak output of programmable DTL adds position peak output of the first fixed DTL. Until the last sequence-A of $A\underline{A}AA$ as "middle" sequence enters completely the programmable DTL, the four auto-correlation peaks simultaneously appear in input of adder and the output of adder is about four times as amplitude as the single peak. The envelope signal of the peak can be obtained by envelope detector. Envelop signal must be compared with threshold level so that the better detection probability P_d and the lower false-alarm probability P_f are obtained. After output signals of detector enter DSR, they will be delayed different time and the output signals of four DSR's taps enter adder into the largest pulse. The output signals are shown in Fig.4-c. The second decision will turn out a synchronous pulse to the local code generator and the tracking loop so that the CPTS realizes synchronization and tracking. The wave forms of each output nod of fast acquisition system are shown in Fig.4. Now we simply discuss if the sequence G is not encoded by Barker sequence rather than sequence $A\underline{A}AA$, what is the result of correlation? The correlating process and auto-correlation peak are shown in Fig.5-a, the largest side peak is three times as amplitude as a single one. The ratio of side-to-main peak is 3/4. If the sequences are encoded by Barker sequence as given above in this paper, the largest ratio of side-to-main peak is 1/4. The correlating process and the auto correlation peak are shown in Fig.5-b.

The reason to choose $d_1 \neq d_2 \neq d_3$ is that the signals always add coherently and the noise adds incoherently, which results in reducing random noise and improving $(S/N)_{in}$ of the receiver of spread spectrum system.

RESULTS

This section gives the used parameters of the experimental system in Fig.3 and the parts of the experimental results. The experimental parameters are given as follows:

The length of m-sequence A is L=255;

$d_1=4$; $d_2=6$; $d_3=2$;

The clock of PN sequence generator is Rc=10MHz;

The medium frequency is Fc=70MHz;

Under the input $(S/N)_{in}$= -15dB, we got the $(S/N)_{in}$ of every output end of experimental system as follows:

$$(S/N)_a = 6.5dB$$

$$(S/N)_b = 11.36dB$$

$$(S/N)_c = 17.37dB$$

The processing gain of every output and the total processing gain G_{total} are as follows:

$$G_a = (S/N)_a - (S/N)_{in} = 21.5dB$$

$$G_b = (S/N)_b - (S/N)_a = 4.86dB$$

$$G_c = (S/N)_c - (S/N)_b = 6dB$$

and

$$G_{total} = G_a + G_b + G_c = 32.36dB$$

The acquisition probability P_d of system is 0.9464, and the false-alarm probability P_f is 0.0091. The acquisition time of the experimental systems T_{ac}=0.80ms.

CONCLUSION

The SS-ALOHA signal, capture method and acquisition system presented above will be used in the CPTS in China. The advantages of it are not limited in the area discussed in this paper, the concatenated sequences can be used to distinguish overlapping PN signals in spread spectrum system for further improving the multiple access ability of system. We believe that the concatenated sequences will be also used for the personal communications network (PCN) and the global mobile communications network (GMCN).

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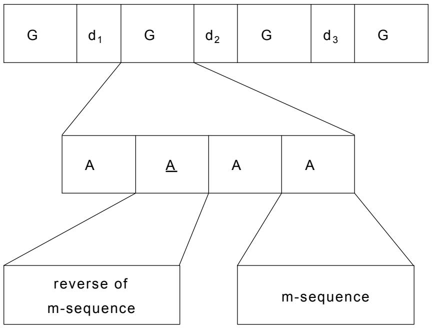

Fig.1 SS-ALOHA synchronous code

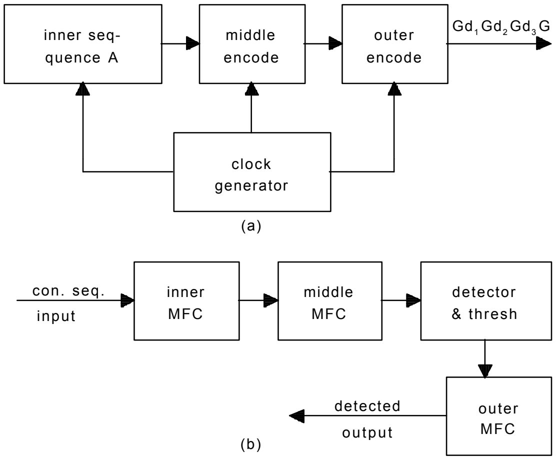

Fig.2 (a) Generator of SS-ALOHA synchronous code
(b) Capture scheme of SS-ALOHA synchronous code

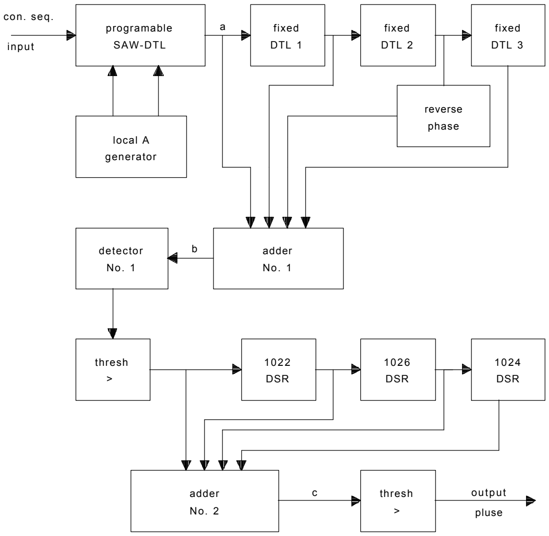

Fig.3 Block diagram of the experimental system fast acquisition of SS-ALOHA synchronous code

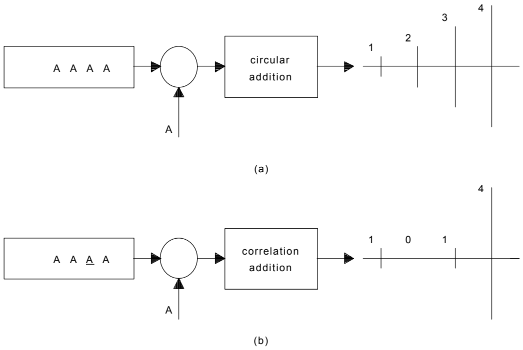

Fig.5 (a) Combining sequences correlation
(b) Barker encoding sequence correlation

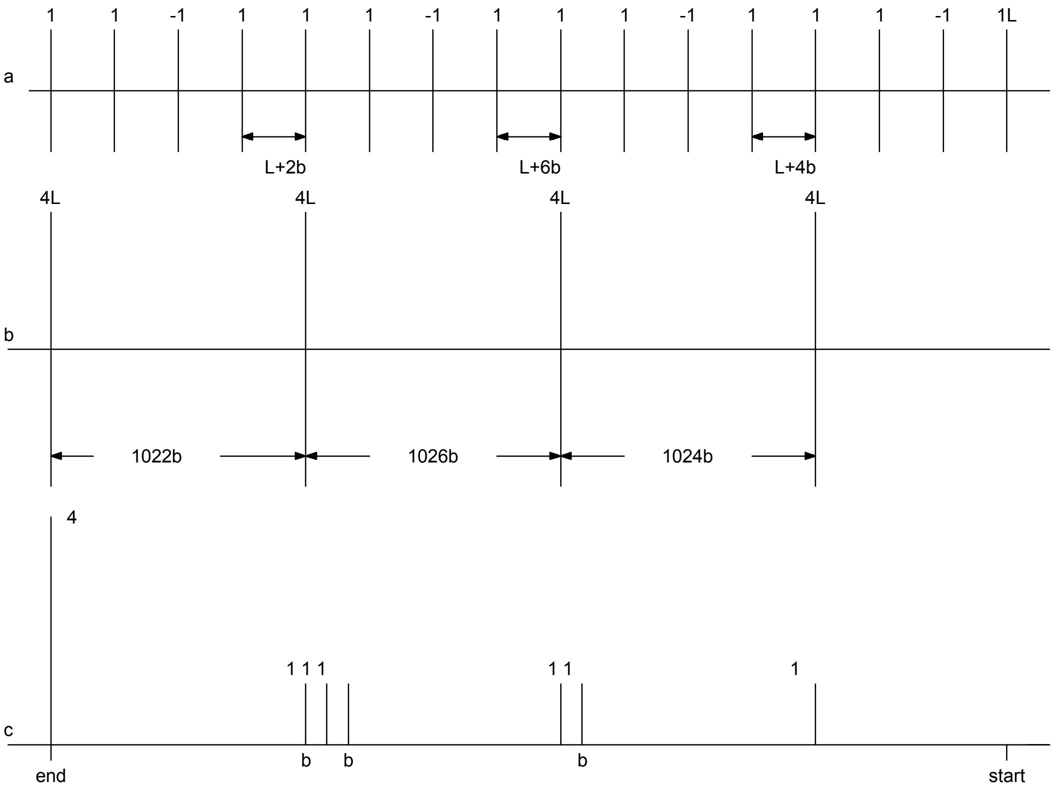

Fig.4 Output wave forms of the experimental system (L=255b, b is a chip of PN sequence)