마이크로 프로세서를 사용한 다이렉트 시퀀스 스프레드 스펙트럼 시스템의 동기회로에 관한 연구

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Synchronization of the Spread Spectrum Systems by Microprocessor

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Abstract

New acquisition method in synchronization of the PN- modulated spread spectrum system is presented. Microprocessor is adopted for its flexibility and the hardware complexity when not used.

1. Introduction

Spread spectrum techniques has been used almost in tactical or ranging equipment because of its information security, jamming immunity, low power density and high ranging resolution.

There are several methods in spread spectrum communications, say, direct-sequence, frequency-hopping, time-hopping, combination of them(hybrid), and especially in rada application, chirp.

Common requirement in the receiver is to acquire the same phase of the locally-generated sequence to the incoming code, and to maintain it. The former is acquisition process, and the latter is tracking process.

In this paper, only the acquisition process is considered. The tracking process is performed by ordinary delay-lock loop.

Also there are several methods in the acquisition of the direct sequence spread spectrum communications. The basic technique is the stepping correlation in which the two code sequences slip in phase with respect to each other. But, when a large amount of phase offset is encountered, examination of all possible phase position is impractical because of the time involved.

Other method, called RASE (Rapid Acquisition by Sequential Estimation) is more rapid acquisition technique. But the acquisition time is highiy sensitive to the input SNR.

Majority-logic decoding which is based on error-correcting is also efficient but requires a significant amount of logic hardware.

In this paper, new acquisition method based on the recognition of initial state, is presented.

2. Algebraic Aspect

Let $A_1 = (a_1, a_2, \ldots\ldots)$ the sequence of linear feedback shift register (LFSR) with period 2^n-1 where n is the number of the register stages. And let $A_2 = (a_2, a_3, \ldots\ldots)$

$$\vdots$$

$$A_p = (a_p, a_1, \ldots\ldots)$$

the replicas of A_1 with phase offset.

Then group $G = (A_0, A_1, \ldots\ldots A_p)$ is Abelian group where $A_0 = (1,1, \ldots\ldots)$ is the identity element and $p = 2^n-1$.

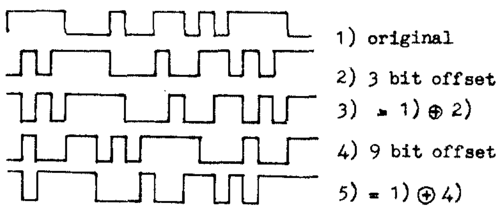
That is, term-by-term multiplication of any two elements in G is still in G and has unique one-to-one correspondence. On the other hand, if

$A_i \times A_j = A_k$ and $A_i \times A_l = A_m$, then $k \neq m$ for $j \neq l$.

For a additive group, multiplication is replaced by addition and $A_0 = (1,1, \ldots\ldots)$ by $A_0 = (0, 0, \ldots\ldots)$.

For example, Fig.1 illustrates this fact when $n = 4$.

Assuming the sequence 1) is the local sequence in spread spectrum receiver and the sequence 5) is correlator output, we know that the relative phase offset is 9 bits from one-to-one correspondence table or the sequences 4) and 5)



a)

offset	1	2	3	4	5	6	7	8	9	10	11	12	13	14
resulting offset	12	9	4	3	10	8	13	6	2	5	14	1	11	7

b)

Fig.1 a) Additive group example when $p = 2^4-1 = 15$
b) One-to-one correspondence table

3. Acquisition Process

As dicussed above, the maximal-length sequence (m-sequence) which has been used in spread spectrum communications has Abelian group properity. This property is applied to the acquisition method to be considered here.

In Fig.2, hardware blockdiagram of the acquisition system proposed is dipicted.

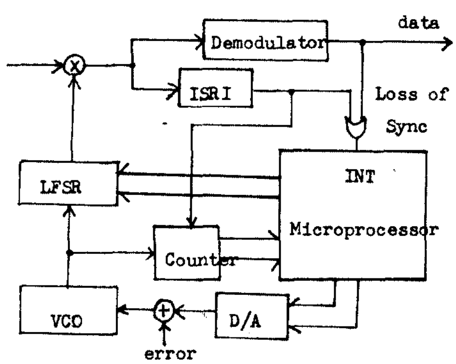


Fig.2 Blockdiagram of acquisition circuit

Given n and C_i where C_i is the coefficient of feedback connections of the LFSR, the sequence is comletely determined by recursion relation

$$a_n = \sum_{i=1}^{n-1} C_i \, a_{n-i} .$$

Because one-to-one correspondence is needed in our acquisition system, it must be calculated and stored before the operation.

In processing and calculating, microprocessor is feasible. So, in our system, above two operations and all the controll operations is performed by the microprocessor.

The operation of this system is as follows;

Step 1. Microprocessor loads the initial state to the LFSR and instructs to run and waits for the interrupt.

Step 2. If there is recognition of the initial state from the Initial State Recognition Indicator, processor reads the contents of the counter which is clock number from initial operation to initial state recognition. the counter is reset as soon as the initial state was recognized.

Step 3. Calculate the phase offset of the received ved and local code sequence.

Step 4. Stopping the operation of the LFSR, calculated value at Step 3. is loaded to the LFSR, and instructs to run.

Because of the noise and ISRI error, there can be several phase step uncertainties in calculated value and also can be several recognition points in one period interval of the sequence.

This problem can be solved by approximate jump to the vicinity of recognition point, and stepping correlation in several bits interval and repetition untill the acquisition is reached.

If acquisition was recognized, tracking process begin.

Loss of sync during the tracking process causes the microprocessor to enter the acquisition process again.

In spread spectrum communications, the input SNR is very low. The reason is that the information energy transmitted was spread over the wideband, hence has very low power spectral density. As a consequence, it may be very diffcult to recognie the initial state at the correlator output.

In our present case, we use a special state which is easy to recognize as a initial one.

4. M-Sequences

Generally, the maximal-length sequence (m-sequence) has been used in spread spectrum communications because it has several remarkable properties. One of them is the impulse shape of its autocorrelation function.

This is illustrated in Fig.3.

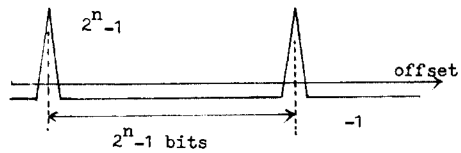


Fig.3 Autocorrelation function

Almost all the synchronization methods utilize this property. Other tow properties which are applied here are the randomness property and the distribution of consecutive elements.

For m-sequence, it is a well-known fact that there are exactly one n 1's consecutive terms, no pure n-1 1's consecutive terms, and 2^{n-r-2} r 1's consecutive terms where $0 < r < n-1$.

From the spectrum point of view, n 1's consecutive terms has the narrowest bandwidth. Because of this, and small number in one period interval, n 1's consecutive terms is selected as a initial state.

5. Initial State Recognition Indicator (ISRI)

The block " initial state recognition indicator " in Fig.2. is proposed in Fig.4. Fig.5 is a example when n 1's consecutive terms was encountered.

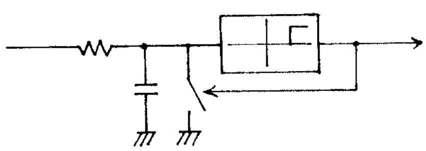


Fig.4 Proposed ISRI

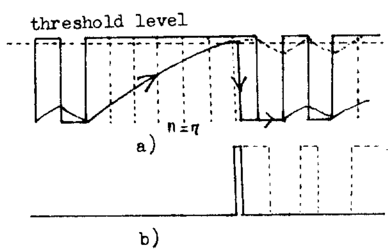


Fig.5 a Low pass filter output when n 1's Consecutive terms is encountered

b) ISRI output

Simple low pass filter has the rising time equal to n/R where R is code sequence rate.

And -3 dB cutoff frequency is 0.35R/n (Hz).

Because the bandwidth of the reveiver input filter is 2R (Hz), noise at the correlator output is spread over the band 4R (Hz).

Consequently, noise rejection ratio is 4n/0.7 and power loss of main lobe is approximately 40 %, and Processing Gain in this case is

$$\text{Processing gain} \doteq 10 \log_{10} \frac{4n}{0.7} \times 0.6$$

$$\doteq 10 \log_{10} 3.4\,n \quad (\text{dB})$$

As seen in Fig.5, it may be possible that there are spurious recognition points after the correct one. In order to prevent from being done so, ISRI also signals the discharging swich after the recognition.

6. Conclusion

Relatively high performance is expected because of the processing gain. During the acquisition or tracking process, other components in the receiver can utilize the microprocessor.

Problems in this system are non-remarkable threshold level and low speed of MOS microprocessor in high speed applications.

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