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Doppler Frequency Shift Tolerance Extension in Burst Spread Spectrum Communication System

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Abstract.A method to extend Doppler frequency discrimination tolerance is proposed for quick acquirement PN-code and Doppler frequency in TDMA burst spread spectrum communication system. According to Doppler's different impacts on the correlation Peak and data demodulation, PN-code is acquired through single channel matched-filters, and parallel multi-channel correlators are used in the data demodulation branch channel. Thus, with using frame head prior information in data channel instead of traditional Cross-Product Automatic Frequency Control (CPAFC), the Doppler frequency shift discrimination tolerance is extended. Simulation and experiment show that frequency and PN-code can be acquired in several data periods, and synchronous time and the resources consumption are effectively reduced.

Introduction

In multi-goal burst spread spectrum digital transmission system, the time of signal acquisition is only a few data symbol periods. As the pseudo-random sequence with the sensitivity of Doppler frequency shift, the receiver must capture received data both in the frequency domain and time domain. In high dynamic burst spread spectrum communications systems, how to implement pseudo-code acquisition quickly and compensation for the Doppler frequency shift caused by characteristic of high dynamic, which are the key technologies in receiver. To be the current common FFT-based algorithms, rapid acquisition includes parallel search in frequency domain [1], parallel search in time domain [2] and matched filter and FFT frequency correction [3]. The first two methods do not use spread spectrum gain, in phase offset estimation, therefore, the performance is poor under small signal environment. Due to the third method only uses of a sub-part energy of pseudo-code matched filter, the performance of anti-noise will be affected. Although the capture algorithm which based on FFT can be synchronized in a short time, it still can not satisfy the system requirements of acquisition time.

Using the characteristic which Doppler frequency shift can reduce the peak value from match filter, the multiple-parallel matched filter can be used to capture pseudo-code. By setting local oscillator with the process of digital down-conversion, the each matched filter can work at the different Doppler frequency, and by comparing to all the correlation peaks output by the matched filters, the fact can be attained that the Doppler frequency of maximum peak value is coarse valuation of frequency during the process of capture. In theory, the method can capture PN code and frequency within a symbol, which is the advantage of the method. However, as pseudo code is longer, the larger resources will be used by matched filter hardware, thus application of this method is limited. Considering hardware resources and speed of capturing, a modulation method which use single matched filter to acquisition pseudo-code and use the parallel multi-correlator to CPAFC is proposed. Moreover, in order to adapt to the larger Doppler shift, the frame header with which priori information will be used to avoid frequency symbolic inversion in CPAFC method, therefore the tolerance of Doppler frequency discriminator can be enhanced to twice.

Impact on System Caused by Doppler Frequency Shift

Figure 1 shows the signal processing flow diagram of single-channel IF de-spread and demodulation in missile spread spectrum transmission system. When received signal contains Doppler frequency shift, and tome synchronization between local pseudo-code and received pseudo-code can be attained, the correlation peak can be modulated by Doppler frequency shift.

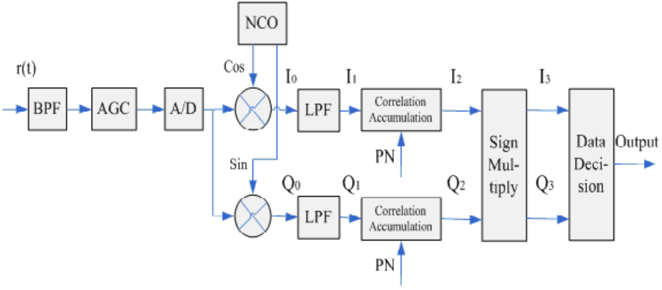

Figure 1 The signal processing flow diagram

Zero-IF quadrature two-channel signal will be taken into correlator:

$$S_1 = I_1 + \mathrm{j}Q_1 = Ad(t)\,\mathrm{PN}(t)\exp[\mathrm{j}(2\pi f_{\mathrm{d}}t + \theta)] \quad (1)$$

Where A is signal amplitude, $d(t)$ is modulated data, $PN(t)$ is pseudo-code, f_{d} is the Doppler frequency shift, θ is initial phase.

Correlation accumulated signal shown as：

$$\begin{aligned} S_2 &= I_2 + jQ_2 \\ &= ANd(nT)R(\tau)\left|\frac{\sin(\pi f_{\mathrm{d}}T)}{\pi f_{\mathrm{d}}T}\right| \\ &\times \exp[\mathrm{j}(2\pi n f_{\mathrm{d}}T - \pi f_{\mathrm{d}}T + \theta + \pi/2)] \end{aligned} \quad (2)$$

Where, $R(\tau)$ is related value of receiving PN(Pseudo noise) code and local PN code in a data chip, N is PN code length，T=40μs denotes correlation accumulated time. The relationship between the peak value and frequency offset as follows:

$$\eta = \left|\frac{\sin(\pi f_d T)}{\pi f_d T}\right| \quad (3)$$

Where η denotes attenuation parameter which affect on correlation peak.

The range of Doppler frequency cause by missile flight is [-3kHz -19kHz]. By pre-setting the oscillator, the residual frequency offset range is [-8kHz +8kHz] after digital down conversion. According to (1), the maximum residual frequency difference corresponding to the normalized correlation peak is 0.8399. Compared to the maximum value, it reduces by 1.5dB, from which, a fact can be attained that the affect on correlation peak caused by Doppler frequency is relatively small, only using the single channel matched filter, the acquisition of pseudo-code can be implemented.

In DBPSK spread spectrum system, taking complex conjugate multiplication with adjacent samplings, the demodulation signal can be attained [4].

$$\begin{aligned} S'(t) &= S_2(t) \times S_2(t+T)^* \\ &= k\exp[\mathrm{j}(2\pi f_{\mathrm{d}}t + \theta_0 + \theta_t)] \\ &\times k\exp[-\mathrm{j}(2\pi f_{\mathrm{d}}t + 2\pi f_{\mathrm{d}}T + \theta_0 + \theta_{t+T})] \\ &= k^2\exp[-\mathrm{j}(2\pi f_{\mathrm{d}}T + d\theta_t)] \end{aligned} \quad (4)$$

Where * denotes conjugate calculation, and $\theta_0=\theta+\pi/2-\pi f_{\mathrm{d}}T$, $k=ANR(\tau)\sin(\pi f_{\mathrm{d}}T)/(\pi f_{\mathrm{d}}T)$. In (4), $\mathrm{d}\theta_t=\theta_t-\theta_{t+T}\in[0, \pi]$ denotes differential modulation signal. Identical phase data and quadrature-phase data can be expressed by (5) and (6).

$$I_3 = k^2\cos[-(2\pi f_{\mathrm{d}}T + d\theta_t)] \quad (5)$$

$$Q_3 = k^2\sin[-(2\pi f_{\mathrm{d}}T + d\theta_t)] \quad (6)$$

By judging identical phase data I_3 is positive and negative, the demodulation data can be attained. However, due to residual frequency offset range is [-8kHz, +8kHz] after digital down conversion, it introduces the additional phase shift is $2\pi f_{\mathrm{d}}\mathrm{T}=2\pi\times 8\mathrm{k}/25\mathrm{k}=0.64\pi$. Therefore, it reduces signal noise ratio of decision value I_3 by about 7.4db, and reverses demodulated data. In order to avoid the impact on demodulation data caused by Doppler frequency shift, it must be estimated and compensated.

The method of CPAFC can be used to estimate Doppler frequency shift in each channel [5,6], follow as: In DBPSK spread spectrum system, the frequency error can be attained by using the (7) and (8),

$$e = \mathrm{sign}(I_3)\times Q_3 \tag{7}$$

Due to $d\theta_t\in[0, \pi]$, $I_3\approx\pm k^2$, $Q_3=\pm k^2\sin(2\pi f_{\mathrm{d}}T)$. Then, the frequency error signal is

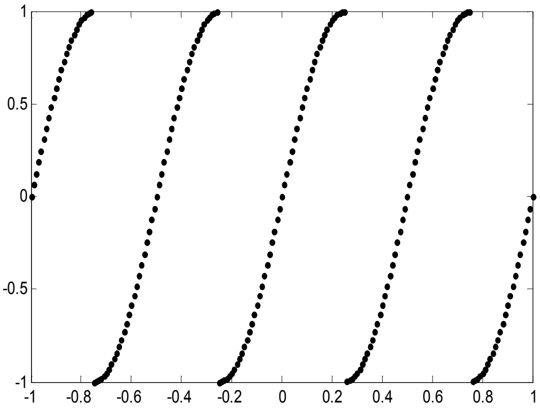

Fig.2 Characteristic of frequency discrimination

$$e = k^4\sin(2\pi f_{\mathrm{d}}T)\approx 2\pi k^4 f_{\mathrm{d}}T \tag{8}$$

Fig.2 shows the frequency discrimination curve of (7). In this figure, the horizontal axis denotes normalized frequency error $f_{\mathrm{d}}T$, the vertical axis denotes frequency error e. We can see from the figure, the range of frequency discrimination is $|f_{\mathrm{d}}T|<1/4$, so $|f_{\mathrm{d}}|<1/(4T)=6.25$kHz. The maximum Doppler frequency shift is $|f_{\mathrm{d}}|=8$kHz, which exceeds the frequency discrimination range.

Doppler Tolerance Extension

In order to expand the range of frequency discrimination of traditional CPAFC methods, a frequency discrimination method which using the known data symbols of frame header replace data symbols of (5) will be proposed. In (5), as $|f_{\mathrm{d}}|<1/(4T)$, the proposed method can effectively avoid to symbol reversal caused by additional phase shift is greater than $\pi/2$. Frequency error is expressed by:

$$e = Q_3\times\mathrm{sign}(\text{frame data}) \tag{9}$$

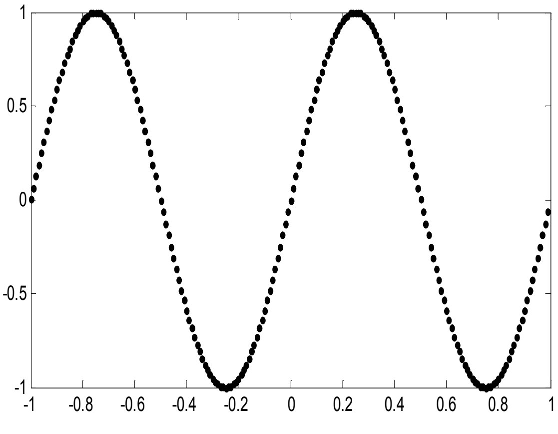

Fig.3 Characteristic of frequency discrimination of channel 1 figure

In (9), due to the corresponding frequency discrimination range is [-T/2, T/2], namely [-12.5kHz, +12.5kHz], Doppler frequency discrimination tolerance will enhance twice. Frequency discrimination curve shown as Figure 3, the abscissa denotes the frequency error $f_d T$, the vertical axis denotes normalized frequency error e.

In order to capture coarse frequency rapidly, taking parallel three-way channels scheme into data demodulation method. Channel 0, 1, 2 corresponding to frequency offset of LO is -16/3kHz, 0kHz, 16/3kHz respectively.

The curve of frequency discrimination of channel 1 shows as Figure 3. Frequency discrimination curves of channel 0 and channel 2 deviate from channel 1 the left and the right about 16/3 kHz respectively. Scheme of Rough estimate of frequency follow as: firstly, by using (9), the sign of frequency discriminator error can be decided, if the sign is positive, comparing the absolute value of the minimum frequency error of channels 1 with channel 2. If not, comparing the absolute value of the minimum frequency error of channels 1 with channel 0, the minimum corresponding to frequency offset of LO is the coarse estimates of frequency. By using the three-way parallel channels to demodulation, the absolute value of frequency estimation error is less than 2.67kHz. The most additional phase shift brought by identical phase data: $2\pi f_d T=0.21\pi$, reduction of SNR: $20\times\lg(\cos(0.21\pi))$=-2db.

Therefore, taking parallel three-way channel scheme into data demodulation method, polarity reverse of data can be avoided, and deterioration extent of SNR can be reduced.

Conclusion

In this paper, using frame header, a frequency discrimination scheme is proposed. It can extend Doppler frequency discrimination tolerance, and suit for the spread spectrum system. Simulation shown that the scheme consumption of resources is small, simple hardware, fast acquisition time, low false alarm probability.

References

[1] LI Ju, CHEN He, WU Siliang, HE Peikun, “Rapid Acquisition for Direct Sequence Spread-Spectrum Signals,” Transact ions of Beijing Institute of Techno logy. vol. 25, no. 10, 2005, pp. 905–908.

[2] WANG Jun, AN Jianping, SONG Shujuan, “Rapid Code Acquisition for High Dynamic DSSS Receiver,” Transact ions of Beijing Institute of Technology. vol. 24, no. 5, 2004, pp. 439–441.

[3] Spillard C.L., Spangenberg S.M., Povey G.J.R, “A serial-parallel FFT correlator for PN code acquisition from LEO satellites,” Spread Spectrum Techniques and Applications. 1998. Proceedings. 1998 IEEE 5th International Symposium on . 1998, vol.2, pp. 446-448.

[4] Sascha M.Spangenberg, Iain Scott, Stephen McLaughlin, “An FFT-Based Approach for Fast Acquisition in Spread Spectrum Communication Systems,” Wireless Personal Communications, 2005, vol. 13, pp. 27–55.

[5] DONG Yuan-wen, GUAN Hong-yun, HU Hui, “GPS Code-track Research And Simulation. Journal of System Simulation,” 2006, 11, vol. 18, no. 11, pp. 3209–3216.

[6] Hui hu,Luchao Xu, “GPS Carrier Tracking Research and simulation, 2008 International Symposium on information Science and Engieering,” pp.414–416.