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Research on the Strategy and Distance Precision of Mordenized GPS M-code Signal

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Abstract—M code signal by the BOC modulation will be the military signal in the plan of GPS modernization. In the paper, M code military signal strategy is analyzed, the modulation principal, the auto-correlation function of the signal are analyzed and simulated. The specialty of the spectrum-apart, the increased signal power level and the structure of navigation message indicate the improvement of anti-jamming performance for M code as compare with P/Y code signal, the simulation result of code tracking loops accuracy testify the higher measurement precision of M code compare with P/Y code signal.

Keywords-GPS;M code; BOC modulation;auto-correlation function;power spectrum

1. Introduction

In the modern plan of GPS, the military signal on the L1 and L2 will be designed into M-code signal for the future military signal system, which is the big change to the GPS. In this paper, the strategy of M-code signal is analyzed firstly, function of M-code signal is described and in this foundation the performance in distance measurement of the signal is analyzed and simulated. the conclusion is that GPS M-code signal improve the capability of anti-jamming and precision of distance measurement as compared with P/Y-code used presently. The M-code design of GPS will be used for reference to the other GNSS systems including the Chinese BEIDOU system.

2. Strategy of the GPS M-code

Based the plan of GPS modernization[1],the M-code signal is started from the BlockⅡR-M satellite launched in 2003-2006,and the IOC of M-code is realized in 2009,the FOC will be fulfill in 2012 and the high-power M-code FOC will be realized in 2018, it is concluded that the M-code signal will be the future military signal system without question.

The M-code signal added on L1 and L2 is one part of NAVWAR(NAVigation WARfare) plan of GPS. In war field, to prevent the enemy from using the GPS C/A signal, the USA army would interfere with the

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C/A signal, but frequence spectrums of C/A and P/Y are superposed so the interference to C/A signal would influence P/Y military signal seriously, which is the reason to design and add the M-code in GPS signal.

Based the power spectrum of modern GPS signal[2],the spectrum of the M-code signal is separated with that of the C/A signal. The simulation result of GPS signal power spectrum is described in the figure1,the center of the M-code signal modulated by BOC（10,5）is at the interval of ±10MHz with the carrier frequence, where is the zero in the C/A power spectrum, comparatively ,the center of the power spectrum of C/A code signal is just at the zero of that of M-code, which is proved the separate of the military M-code with the civilian C/A signal. by contrast with the past satellite navigation message, the M-code signal message[3],[4] is grouped by the regimentation of information, the message is encrypte and the FEC is used in the message.

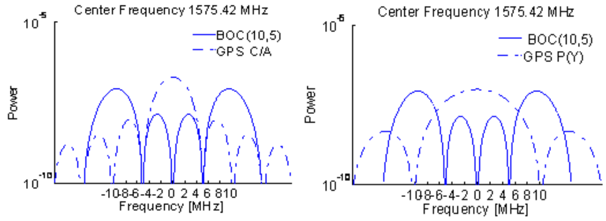

Fig.1. Power spectrum of M-code ,C/A and P/Y

3. Essential of GPS M-code Signal

3.1. The modulating mode of the signal

In contrast with the BPSK modulating mode of the present milaitary P/Y-code signal,the BOC mode is used in the M-code signal,BOC means Binary Offset Carrier. the simple procedure is described in figure 2.

BOC modulated signal is commonly presented into BOC(α , β). It means the frequency of the sub carrier is fs= α ×1.023MHz and the rate of PRN modulated by data code fc= β ×1.023MHz.

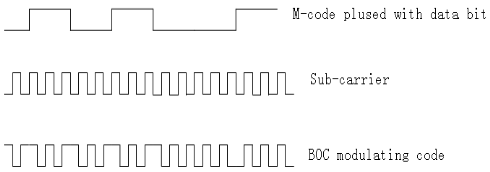

Fig.2. The procedure of BOC modulating

3.2. Eigenfunction of M-code signa(The auto-correlation function)

GPS M-code signal use the BOC(10,5) modulation, based the principle of BOC ,the M-code signal can be described as below[5]:

$$S_m(t)=\sqrt{2P_T}D_m(t)P_m(t)T_{sc}(f_{sc})\cos(\omega t+\varphi_0) \tag{1}$$

In (1) P_T means the signal power ,$D_m(t)$ means the data code of the satellite message ,$P_m(t)$ means the M-code PRN and $T_{sc}(f_{sc})$ means the sub carrier signal.

In the basis of the (1) formula ,the auto-correlation function of the BOC(α , β) can be reckoned as below (2)[6]:

$$R(\tau)=(-1)^{k+1}nT_s[(2k+1)(1-\frac{|\tau|}{nT_s})-\frac{2k(k+1)}{n}],\tau\in[-nT_s,nT_s] \tag{2}$$

$$R(\tau)=0,\tau\in others$$

According the (2) auto-correlation function BOC(10,5) and BOC(8,4) can be simulated to the result descibed in fig3.

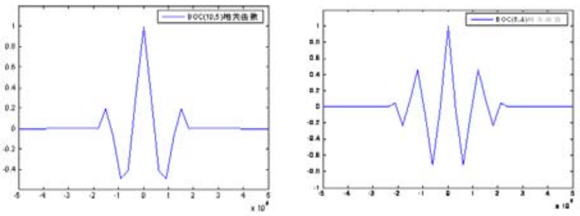

Fig.3. The simulation result of auto-correlation function BOC(10,5) and BOC(8,4)

3.3. Eigenfunction of M-code signa (power spectrum density function)

In the basisi of formula (1),the power spectrum density function of M-code signal BOC(f_s,f_c) is calculated as below foumula (3) and (4):

$$G(f)=\frac{1}{nT_s}\left[\frac{\sin(\pi fT_s)\sin(n\pi fT_s)}{\pi f\cos(\pi fT_s)}\right]^2 = f_c\left(\frac{\tan(\frac{\pi f}{2f_s})\sin(\frac{\pi f}{f_c})}{\pi f}\right), n=\frac{2f_s}{f_c}=2k,$$
$$k = \text{positive whole number} \tag{3}$$

$$G(f)=\frac{1}{nT_s}\left[\frac{\sin(\pi fT_s)\sin(n\pi fT_s)}{\pi f\cos(\pi fT_s)}\right]^2 = f_c\left(\frac{\tan(\frac{\pi f}{2f_s})\cos(\frac{\pi f}{f_c})}{\pi f}\right), n=\frac{2f_s}{f_c}=2k+1, \tag{4}$$
$$k = \text{positive whole number}$$

In the basisi of foumula (3) and (4) ,simulation is made to present the function of BOC(10,5) as figure3.

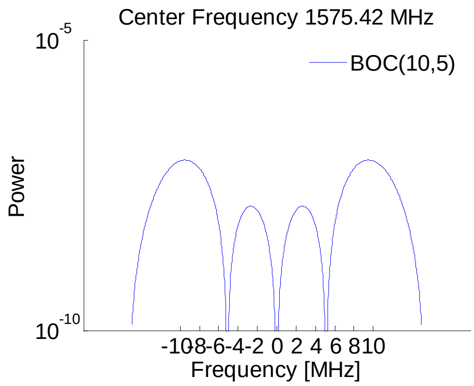

Fig.4. power spectrum of BOC(10,5)

4. Distance Measurement Precision Analyze of the M-code Signal

From the auto-correlation function chart described in figure3 ,it is stated that the peak width of the BOC(10,5) function is narrower than traditonal signal,so the higher precision in code track can be realized and since the precision in code track is direct correlative with distance precision,so the M-code is concluded the higher distance measurement precision.

For expressing by quantum,the square difference of M-code distance measurement can be presented in foumula (5):

$$\sigma=\sqrt{\frac{B_N\tau}{2(2n-1)C/N_0}\left(1+\frac{1}{[1-(n-1/2)\tau T_B C/N_0}\right)} \tag{5}$$

in the foumula (5) , $n=\frac{2f_s}{f_c}$, τ means chip length

C/N_0 means rate of signal carrier to noise , B_N means bandwidth of noise

T_B means accumulate time.

And square difference of distance measurement of the same rate of BPSK modulation signal and be presented in foumula (6):

$$\sigma = \sqrt{\frac{B_N \tau}{2C/N_0}\left(1+\frac{1}{[1-(1-\tau/2)T_B C/N_0}\right)} \qquad (6)$$

In the enactment that B_N =4Hz， τ =1/6 chip, T_B =10 second, the precision of the BOC and BPSK can be compared in the simulation result as presented in figure 5.

Based the figure5 ,it is concluded that the code track precision of BOC signal is higher than BPSK signal.

5. Conclusion

Modernized GPS will apply the BOC(10,5) for the military M-code signal, from the chart of power spectrum of M-code,C/A and P/Y,it is realized that M-code signal's spectrum apart with the C/A signal ,which will improve the NAVWAR ability of military M-code signal, by analyzing the signal auto-correlation and the simulation result conclude that the M-code signal can provide higher precision in code track than BPSK. It is sure that the M-code signal modulated in BOC mode will be the main structure of the military signal of GPS ,which can be used for reference to other GNSS.

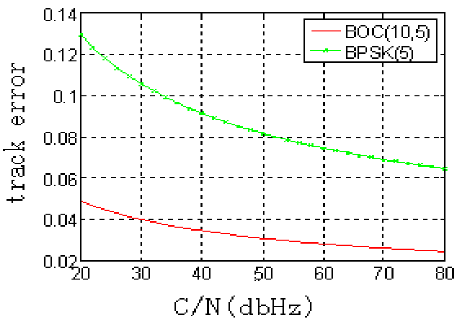

Fig.5. the track error of the BOC and BPSK with C/N_0

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