Advances in Engineering, volume 126
5th International Conference on Machinery, Materials and Computing Technology (ICMMCT 2017)

Research on tracking and demodulation of FM signal

Su Yonghe, Yu Wei
China Satellite Maritime Tracking and Control Department, Jiangyin, 214431, China

Keywords: Diversity synthesis; tracking; link delay

Abstract. The delay difference of the link has an effect on the diversity performance of the FM mode diversity, and may even cause the system to demodulate abnormally and can not stably track. Based on the diversity of FM mode and the principle of angular error demodulation, this paper analyzes the influence of link delay on the performance of synthesis gain and angular error randomness, and puts forward the improvement of tracking demodulation system by introducing delay correction.

Introduction

The S-band unified monitoring and control system in the monitoring and control system, FM mode to support diversity synthesis function, the use of single-pulse dual-channel tracking system, the downlink to receive left-handed and right-handed and left-handed, right-handed difference of four signals. In this paper, we study the effect of link delay difference on diversity gain and angular error in FM mode.

FM mode of operation

FM mode diversity synthesis principle.

FM receiver uses the maximum pre-detection ratio polarization diversity synthesis technology, can effectively improve the impact of signal fading, and improve the received signal quality and reliability. The diversity synthesis module uses the signal-to-noise ratio weighting method to determine the weighting coefficients, and achieves the maximum-ratio synthesis of the left-right and the right-hand rotation signals.

Diversity synthesis consists of two key components: common mode and differential mode. Wherein the common mode part is used for tracking the common frequency and phase change of the input signal, the differential mode part is used for tracking the frequency and phase change between the two input signals and symmetrically controlling the corresponding local oscillation NCO frequency of the two input signals And phase, to ensure continuity of the track, to avoid the deep fading of the signal caused by data loss.

Two synthetic quadrature baseband signals are digitally discriminated and filtered in the FPGA to obtain the common-mode error of the local carrier and the input signal. Thus, by adding the differential mode signal and the common mode error signal together, the output frequency of the numerically controlled oscillator is jointly controlled so that the two signals inputted to the diversity synthesizer are always in phase with each other and fall in the designed filter with a center frequency.

After the diversity of the signal into the carrier wave receiver module. The demodulation of the FM signal is completed in the carrier receiving module.

FM demodulation module to receive left and right rotation and road signals, the time domain expression:

$$s_{FM}(t) = A_0 \cdot \cos[\omega_0 t - \int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau]$$

The received signal and the digital local oscillation signal are subjected to orthogonal mixing and low-pass filtering,(T), QL (t), and IR (t), QR (t), respectively, of the left and right quadrature baseband signals,

$$I_L(t) = A_L \cos(\int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau + \theta_L)$$

$$Q_L(t) = A_L \sin(\int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau + \theta_L)$$

$$I_R(t) = A_R \cos(\int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau + \theta_R)$$

$$Q_R(t) = A_R \sin(\int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau + \theta_R)$$

Left and right rotation orthogonal baseband signal to the maximum score set, then, the combined quadrature baseband signals Ic (t), Qc (t),

$$I_C(t) = A_C \cos(\int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau + \theta_C)$$

$$Q_C(t) = A_C \sin(\int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau + \theta_C)$$

The quadrature baseband signal contains all the information of the input signal, and is fully capable of expressing the amplitude and phase characteristics of the input signal. The synthesized quadrature signal is processed by phase discrimination to obtain the instantaneous phase of the modulated signal:

$$\theta_m(t) = arctg \frac{Ic(t)}{Qc(t)} = \int_{-\infty}^{t} k_f \cdot A_m \cdot m(\tau) d\tau + \theta_c$$

Instantaneous phase and then by differential processing, to obtain instantaneous frequency, which contains the local carrier and input carrier frequency difference and modulation signal. When the carrier synchronization is normal, the frequency difference component can be ignored, that is, the original modulation signals to complete the FM demodulation.

Differential-mode ring closed-loop using the input error signal for the left and right hand signal phase difference:

$$\Delta\theta = I_L(t)Q_R(t) - I_R(t)Q_L(t) = A_L A_R \sin(\theta_L - \theta_R) \approx A_L A_R(\theta_L - \theta_R)$$

After the loop filter, differential-mode error control voltage is obtained, used to adjust the left and right NCO, eliminating the left and right hand signal frequency difference and phase difference.

Common-mode loop to complete the input differential after the instantaneous frequency signal filtering, filtering out the modulation signal components and the signal mutation and jitter caused by high-frequency components, common-mode error control voltage. Used to eliminate the local carrier and input carrier frequency difference, the mixed signal falls after the design of the filter passband center frequency.

FM Mode Angle Error Demodulation Principle.

FM mode in the diversity synthesis module, the input of the left and right-handed digital IF signal to the orthogonal mixing, into the differential mode and common-mode ring for closed-loop. Two differential mode outputs are always guaranteed to be in phase with the left and right hand signals, respectively, to achieve tracking of the two signal carriers.

FM baseband angular error demodulation using dual-channel monopulse tracking system. The signal form of the double channel monopulse system is:

$$\sum IF = A\cos(\omega_c t + f(t))$$

$$\Delta IF = A(\Delta A\cos(\omega_c t + f(t) + \theta) + \Delta E \sin(\omega_c t + f(t) + \theta))$$

The difference channel receiver receives the difference signal inputted by the front channel, and the intermediate frequency receiving module of the channel provides the carrier reference signal to complete the demodulation of the azimuth and pitch angle error signals. The angular error demodulation result, the AGC control voltage and the lock indication are sent to the antenna control unit via the analog port.

The local reference signal of the quadrature mixer of the differential channel is derived from the received signal of the intermediate frequency and the local signal of the channel. It is used to compensate the synchronous delay caused by the transmission of the difference channel and the local reference signal sent by the channel. Phase correction by the phase correction unit to ensure that the difference between the input signal and the local reference signal in phase with the same frequency.

Analysis of Link Delay Difference

Influence of Link Delay Difference on Diversity Synthesis.

In the polarization synthesis method, the composite coefficient is calculated by the signal-to-noise ratio of the left and right hand signal symbols. Since the signal-to-noise ratio of the left-right signal is calculated by the same symbol timing pulse, of the two signals will increase the signal to noise ratio difference. When the signal-to-noise ratio difference between the two signals exceeds the specified range, the diversity combining mode is exited, and only one signal with a strong SNR is subjected to single-rotation reception demodulation; when the SNR difference does not exceed the prescribed range, the reception solution is received according to the synthesis mode Tone. In the synthesis mode, if the code rate is high and the left and right delay is large, the NCO of the output of the diversity synthesis module can not track the carrier frequency and phase of the received signal in real time. If the delay difference is large, When the effective signal offset each other, resulting in decreased or even negative for the composite gain phenomenon. In the case of the same time delay difference, the higher the bit rate is, the more the phenomenon of deterioration is caused by canceling each other.

In order to verify the effect of left-right delay difference on the demodulation of FM mode diversity reception, a pre-test data of 5MbpsFM test task is played back, demodulated by baseband FM, and then saved. When the baseband has 127ns delay, the SNR of baseband demodulation is smaller than that of left and right spin, and even many times of flashover.

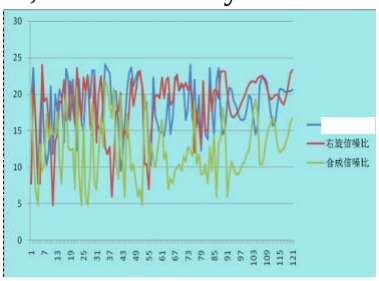

Figure 1. Signal-to-noise ratio for baseband without compensation for time-delay difference

Left and right hand signals are about 127ns delay difference, FM code rate of 5Mbps plus TPC coding, the symbol period is 155ns, left and right hand delay time difference of 81.9% of the symbol period, more than half a symbol period, resulting in this time The left and right signals cancel each other in the diversity synthesis, and the synthesis gain is negative. The angular error voltage of the differential output also fluctuates greatly, resulting in the system working abnormally.

Effect of Link Delay Difference on Tracking Performance.

The left and right rotation difference signals are respectively quadrature mixed with the local oscillation signal supplied from the channel, and the right and left rotation orthogonal difference signals are diversity-synthesized according to the weighting coefficients provided by the channel and filtered by the digital narrowband filter to obtain the digital components of the azimuth and pitch errors , By the zero value, the slope correction unit processing, the high precision D / A output sent to the servo subsystem to complete the antenna tracking angle.

And the difference of 127ns delay time delay link, the phase curve glitch phenomenon, and the results of repeated school repeatability is poor, as shown in Figure 2, the phase can not be completed after the stability of the output azimuth, pitch error voltage.

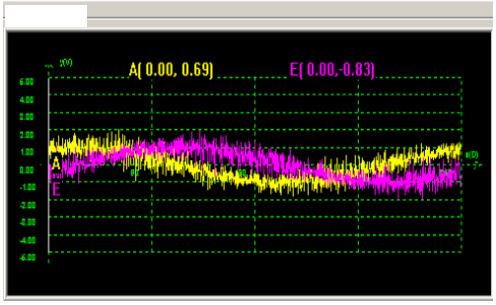

Figure 2. 5Mbps bit rate and differential delay of 127ns phase curve

System modification of introducing delay compensation.

From the receiver diversity synthesis principle can be seen, the maximum score set can be adjusted and road left and right spin phase, to meet the requirements of left and right rotary phase synchronization, when there is a large road and road delay difference, the data transition, There will be a case where the gain of the synthesis is decreased, or even a negative gain occurs.

Since the same signal timing pulse is used to calculate the signal-to-noise ratio of the left-right signal, when the left-right rotation delay is larger than 5% of the timing pulse, the calculated signal-to-noise ratio will exceed the range of the diversity synthesis mode, and performs diversity combining tracking demodulation. It can be seen from the above test that the high bit rate FM baseband does not match the difference of the delay difference between the left and right input signals and the actual delay difference of the left and right input signals of the tracking link at 5Mbps, resulting in baseband diversity synthesis reception abnormality, Stable tracking. When the left and right spin delays are the same, the synthesized signal-to-noise ratio is kept substantially larger than that of the left and right hand spin-offs, as shown in Fig. 3. The synthesized signal-to-noise ratio (SNR) Is significantly larger than the first case of the composite signal to noise ratio, see Figure 4.

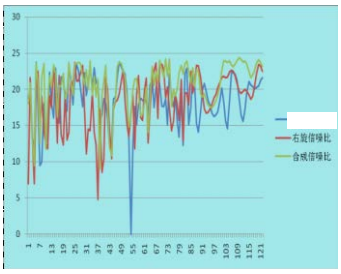

Figure 3. Compensation baseband signal-to-noise ratio when delay difference

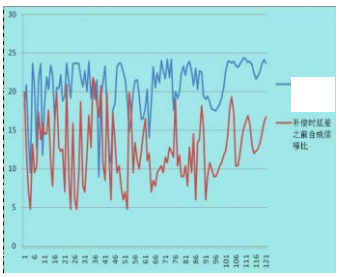

Figure 4. Comparing the base-band synthesized signal-to-noise ratio before and after compensating the time delay difference

A set of measurement and control system channel link stability after the link delay is a certain value, the delay depends on the size of the system link electrical characteristics [4]. Through the radio frequency signal ranging can be achieved by the length of the electrical calibration, and thus converted to link delay value.

Summary

From the analysis we can see that there is a large link delay will affect the diversity of performance and differential signal normal demodulation. At present most of the FM signal data symbol rate in the 2 ~ 10Mbps / s, can be symbol width 100 ~ 500ns between. For a stable measurement and control system, the delay of the left and right links should be controlled at 5% of the symbol period, and the difference signal link delay should be controlled at 10% of the symbol period to ensure that the diversity synthesis gain And tracking accuracy. With the passage of time, S-band uniform measurement and control system equipment, device performance, aging, will introduce a certain link delay difference may lead to diversity synthesis anomalies, school anomalies and other issues, it must introduce delay compensation to be amended.

Reference

[1] CCSDS.RADIO FREQUENCY AND MODULATION SYSTEMS [M] .401 (2.4.11) B-1 .2012.

[2] Wu Youxing et al .. Digital baseband measurement and control technology [M] .2011.

[3] Zhu Xiaolong et al .. Digital Communication Technology [M] .2012.