Analysis on GNSS Receiver with the Principles of Signal and Information

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Abstract. In the paper, principles of signal and information were introduced to the design of GNSS receiver. Analyze Antenna and radio frequency (RF) front-end with the perspective of transmission link, Understand the baseband processing though signal modulate and demodulate, design the navigation calculation utilized the information pick-up and disposal, and research the receiver system by the inherent connection between signal and information. New ways and means would be developed though these researches.

Introduce

Utilizing the relationship between distance and Doppler frequency shift to obtain pseudorange information, and according to spherical intersection principle to calculation the position information are basic principles of the satellite navigation system. Based on these, the technologies of electronics, communications, control and other modern means are used in the design and development of the receiver, thus providing real-time, accurate, reliable service. To comprehensive view, the receiver is the product of multi-technology integration. As the literature [1] mentioned, the receiver is a complex art. With inspiration of literature [2], this article attempts to seek the benefit of satellite navigation receiver design experience from the signal and information processing mechanisms, including (1)explaining the receiver antenna and RF front-end design using signal power amplification and loss in transmission link, (2)analyzing the related art of the baseband processor with the mechanism of modulation and demodulation of signal, (3)understanding the basic principle of synchronization from the information extract and convert, (4) parsing receiver system development using the nature of the signal and the information.

Explaining the receiver antenna and RF front-end design using signal power amplification and loss in transmission link

For purposes of the satellite navigation system, the basic communication link comprises a satellite signal transmitting apparatus, the signal receiving apparatus, the transmitting and receiving antenna, and the propagation path between the two antennas, as shown in Figure 1.

In 2005, the power of emitting CA code signal in the L1-carrier of the GPS satellites is 27W, equivalent 14.3dBW. Assuming satellites located in the zenith, the gain of the antenna of the satellite is approximately 10.2dB, the equivalent power of the transmitting signal is about 24.5dBW. In this case the distance between the satellite and the receiver is approximately 20190km, the corresponding path loss of approximately-157.1dB. Through transmission loss, the signal power is only-154.5dBW when the transmitted signals reach the ground. Received satellite signal is extremely weak, including the natural noise of the outside of the receiver, the thermal noise within the receiver, the reflected signal, other GNSS signal, human disturbance, and so on. According to the above analysis, the design requirements of the receiver antenna having a weak signal reception capability, the higher the antenna gain, the appropriate poloidal, and anti-jamming capability.

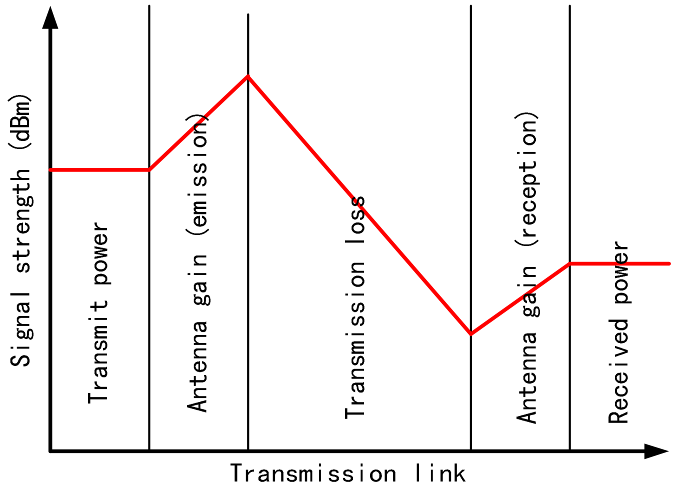


Fig. 1 The signal strength of the communication link

In the basic RF front-end of receiver, the weak signal would be processed by filtering, amplification, frequency conversion and analog to digital conversion, then convert into proper type for subsequent baseband processing [3, 4]. Treatment of such weak signals, the RF front-end should have a high amplification gain, a lower noise introduced, to minimize the introduction of the deterioration of the signal quality.

Power amplifier in the receiver often utilizes a multi-stage LNA. The series more front, the impact on noise coefficient greater, so the first LNA performance is critical for coefficient greater. The noise, power consumption, gain, stability, frequency, and linearity problems should be considered.

The receiving signal of antenna includes satellite signal, other unnecessary signals, such as a television transmitter signal, the mobile telephone signals and other interfering signals, and its mirror image. Thus increasing the filter in RF front-end can be attenuation band signal and improve the anti-jamming capability of the receiver.

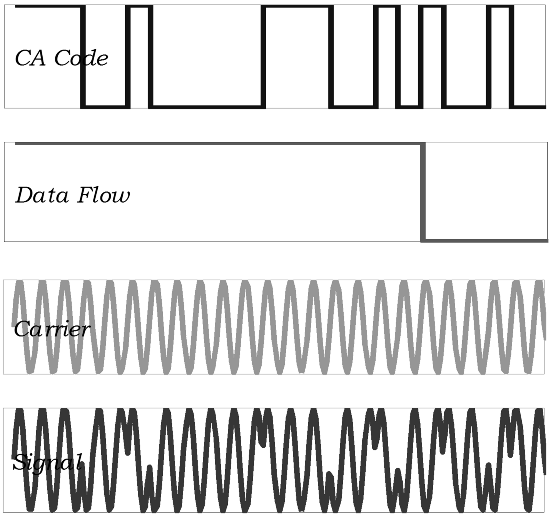
Down-conversion is as a part of the RF front-end. The implementation is completed by mixing with satellite signal and frequency synthesizer. This convert will lower the difficult of receiver hardware design, to meet the requirements of the digital processing.

Sampling and quantization are important parts of the analog-to-digital conversion, and also inevitably bring signal loss. For sampling, the sampling frequency should meet the conditions of bandpass sampling. The higher sampling frequency will improve SNR, reducing the sharpness of the anti-aliasing analog filter before sampling, equivalently to extend the dynamic range of the ADC (resolution rate). However, it will bring the ADC power consumption, and increases the computation of the subsequent digital signal processing.

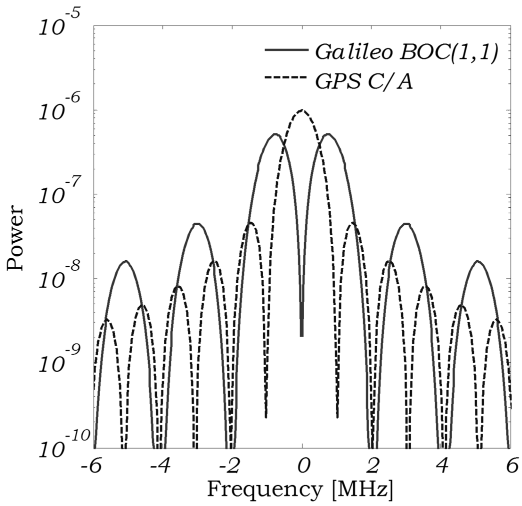
For quantization, more bits of ADC will reduce quantization error, and reduce the loss of sensitivity. Assuming that bandwidth is unlimited, 1bit quantization will bring 1.96dB loss, 2 bit quantization will bring 0.55dB loss, 3bit quantization will bring 0.16dB loss, and higher than 4 bit quantization will no longer significantly reduce the quantization loss. Increasing the number of quantization bits will increase the complexity of ADC design, and cost more. Therefore, the choice of frequency and the bits should comprehensively consider the difficulty, follow-up treatment, and other factors.

Analyzing the related art of the baseband processor with the mechanism of modulation and demodulation of signal

The spread spectrum signal is the carrier of the satellite transmission of information, and the mean to improve the SNR, which often constitute by the pseudo-code signal, the data bits and the carrier, as shown in figure 2. BPSK modulation are mostly applied in GPS L1 signal, BOC modulation scheme are mostly selected in Gallieo signal, and the MBOC form will be applied in future satellite signal. For the design of the receiver, they are same are to separate code signal and the data from the carrier signal, that is, acquisition and tracking process.



(a) Modulation of the satellite signal



(b) The spectrum of the satellite signal

Fig. 2 The form of satellite signals

Signal acquisition and tracking process are actually closely linked to each other [3, 5]. Even the acquisition would be assigned to tracking flow. As shown in figure 3, the digital IF signal will processed by waiting, capture, confirm, pull-in and tracking.

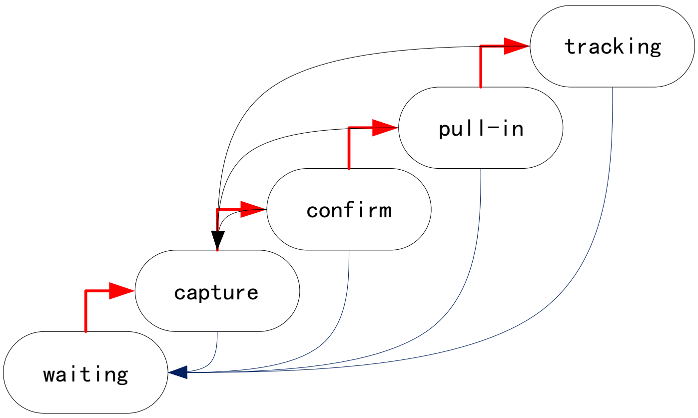


Fig. 3 Receiver channel state transitions

The most important indicators of the signal processing are processing time and processing accuracy. For time, an effective means is to comprehensively apply matched filtering and time-frequency conversion. For precision, the affecting factors include thermal noise, dynamic stress, the clock errors, vibration error, etc., so the good loop design is to seek the most excellent filter, discriminator, and treatment programs with the constraint of error condition.

Understanding the basic principle of navigation calculation from the information extract and convert

Literature [2] defines the meaning of information extracting and processing with the perspective of radar. Extracting is to find one-dimensional, two-dimensional or fewer number data in interest signal. Processing is based on extracting, to further estimate, judgment and achieve troubleshooting process. For satellite navigation receiver, especially navigation solution process, information extraction and processing are given new meanings.

Signal extraction is originated from the navigation message, obtaining the desired information by bit synchronization, including the number of visible satellites, pseudorange, correction parameters, and so on. Of course, the extracted information is depending on the subsequent processing.

In the receiver, information processing is utilized obtained pseudorange, carrier information, and navigation message to calculate the position and velocity. It is noteworthy that dilution of precision (DOP) has a critical influence on the positioning result, as shown in figure 4. The error range of the positioning is different, but good DOP value does not represent good positioning results. It will also be related to the measurement error of pseudorange.

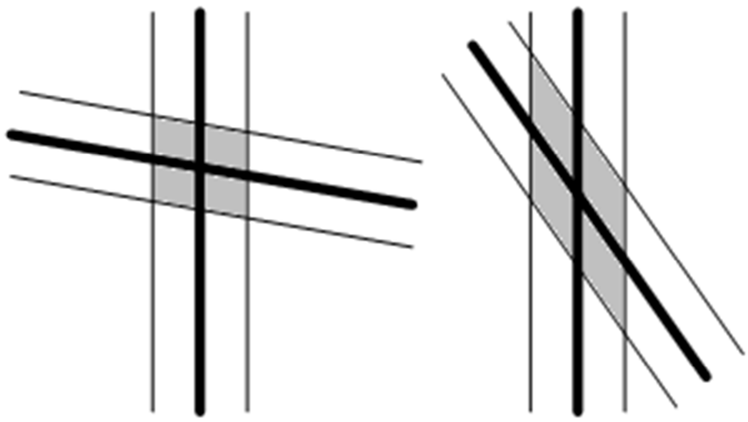


Fig. 4 The positioning precision with DOP

The pseudorange will be got by code information or carrier information. Relatively, position with carrier will obtain better positioning results, but it is difficult to solve the problem of ambiguity. For improving the navigation accuracy, one side is to improve the pseudorange measurement precision, and the other side is to select appropriate information.

Parsing receiver system development using the nature of the signal and the information

In literature [2], the relationship between signals and information is detailed analyzed. In satellite navigation, the signal is considered as the carrier of information. More close correspondence relationships are existed, which is verified in the vector tracking receiver. As shown in figure 5, a vector structure [6] makes full use of the relationship between the signal tracking and information processing.

Improvement of navigation and positioning promote the development of integrated navigation. The pleasant surprise is the emergence of deep integration, which breaks the limitations of information fusion’s level in loose integration. Deep integration perfectly explains the combination between the signal and the information. Positioning accuracy and anti-jamming are improved with thorough form.

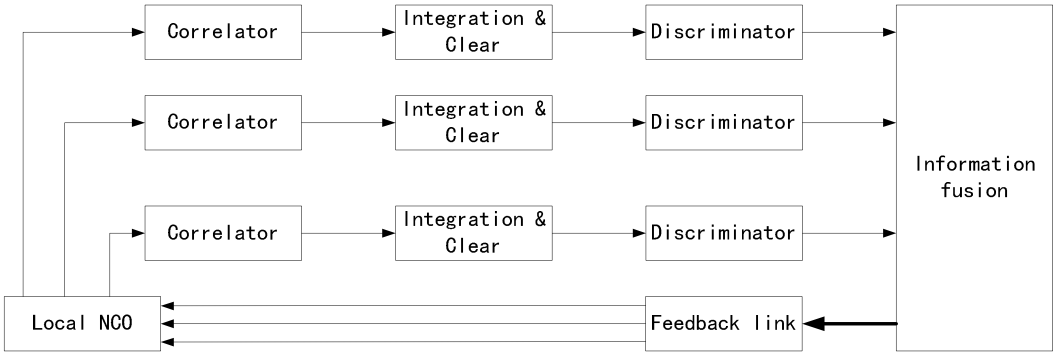


Fig. 5 Structure of vector tracking receiver

Conclusion

In this paper, the signal processing and information fusion are utilized to open the understanding of satellite navigation receiver and clear the designing needs. Research the corresponding relations in order to bring new design ideas and research methods.

Acknowledgments

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