Design of Multi-mode GNSS Vehicle Navigation System

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Abstract. As the Beidou System (BDS) and Galilei Positioning system gradually improve, people intend to make use of more satellites to offer location service for vehicle and other mobile terminal. A kind of multi-mode vehicular positioning system is proposed, the whole framework can be divided into three parts as XN647-8 positioning module, signal processing module and the antenna. XN647-8 is a high-performance, low-cost single-chip GNSS receiver module. Its signal processing module includes a high gain, low noise amplifier chip XN114 and surface acoustic wave (SAW) filter circuit. Through a oscilloscope and analyzer, BDS/GPS antenna is measured and calibrated. So multimode receiver can actually receive satellite signal strength indication close to the theoretical value. The experimental results show that the receiver have a so good performance that it can achieve real-time location tracking well.

Keywords: GNSS · Vehicle navigation · Positioning and tracking · Multi-mode satellite positioning

1 Introduction

The accuracy of satellite positioning system has been increased substantially after a long term development. However, the more accurate positioning requirements is proposed when the GNSS-based vehicular positioning system is used in new application of the Internet of Vehicles (IoT) [1–3]. The positioning accuracy and the user experience should be improved substantially. Improving positioning accuracy not only is target for mainstream navigation services vendor, who make arduous efforts abidingly, but also is the important technical support which will be extended to a variety of consumer electronics products [4, 5]. But now it is also difficult to satisfy the full range of application requirements depending on a single satellite positioning system technology [6].

DBS is growing very rapidly. For example, a new generation Beidou satellite is launched successfully which is a landmark of the building of 2020 Global Network. DBS entered into the “3.0 times”. Global networking will be realized gradually. The same change is happening on Galileo Navigation Satellite System. This means that the traditional GPS is transferring into the GNSS [7–10]. The availability, interference, etc. of GNSS are better than GPS’s. Its multi-mode receiver has higher cost performance than the single GPS receiver. Multimode-compatible receiver is the inevitable direction

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of future development. This paper will describe the building of GNSS positioning system based on multi-mode chip XN647-8.

2 BDS/GPS Multimode Satellite Receiver Framework

GNSS positioning system is divided into three parts, XN647-8 positioning module, signal processing modules (low-noise amplifier module with SAW filter modules) and antennas. The system framework is shown in Fig. 1.

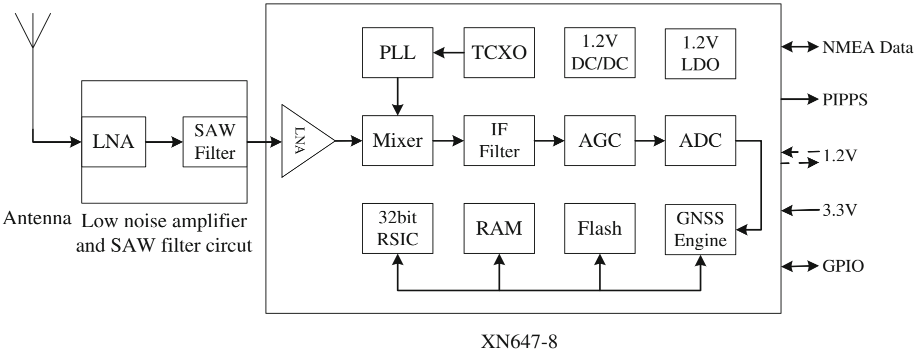


Fig. 1. The block diagram of GNSS positioning system

XN647-8 is a high-performance, low-cost single-chip GNSS satellite navigation receiver module with low power consumption, high sensitivity, small size and other characteristics. It can be received in parallel multimode satellite navigation signals. XN647-8 highly integrated system solutions. Its components include Integrated RF receiver unit, Baseband processing unit, a temperature-compensated crystal oscillator (TCXO/0.5 ppm), low dropout linear regulator (LDO) and some passive components (resistors, capacitors, inductance). Only a few external resources are used to integrate the mobile terminals and handheld devices.

XN647-8 has a strong ability to capture weak signals and a short first position time. Correlating signal parameter search engine base with internal dedicated to quickly capture the available satellites, and can receive a weak signal. Even in harsh environments, advanced tracking engine is also capable of weak signal tracking and positioning.

Its main features: ① small multimode GNSS receiver module, support for multiple satellite positioning system; ② high sensitivity, cold start sensitivity: –148 dBm; tracking sensitivity: –165 dBm; ③ fast start-up time, cold start requires 29 s, hot start only need 1 s; ④ positioning accuracy of 2.5 m; ⑤ easy programming, support for external SPI flash memory data record. According to the instructions and circuit requirements XN647-8 chip, design positioning module circuit diagram is shown in Fig. 2.

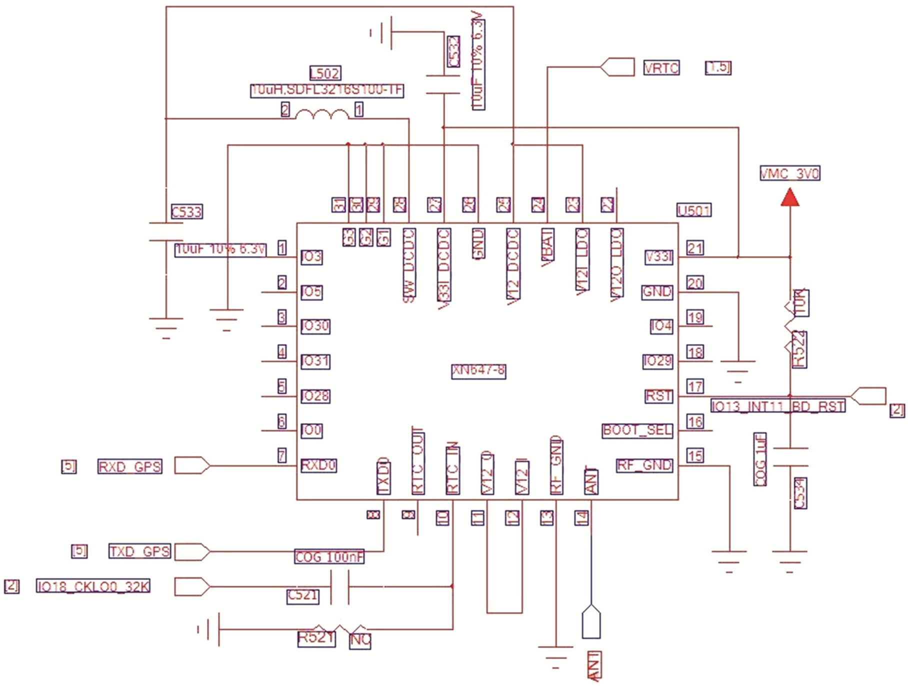


Fig. 2. Low noise amplifier and surface acoustic wave filter circuit schematic diagram

3 Low Noise Amplifier and Surface Acoustic Wave Filter Circuit

XN114 is a chip which is usually be applied to a low noise amplifier receiver. It is designed with BiCMOS technology, with high gain and low noise characteristics, the conditions under 18 dB of gain, noise figure reached 0.8 dB. The chip is applied to the receiver front end, which can effectively improve the receiving sensitivity of the receiver and expand the scope of application of the receiver. XN114 can work in +1.8 V~+ 3.3 V supply voltage while current consumption is only 5.5 mA. In shutdown mode the current

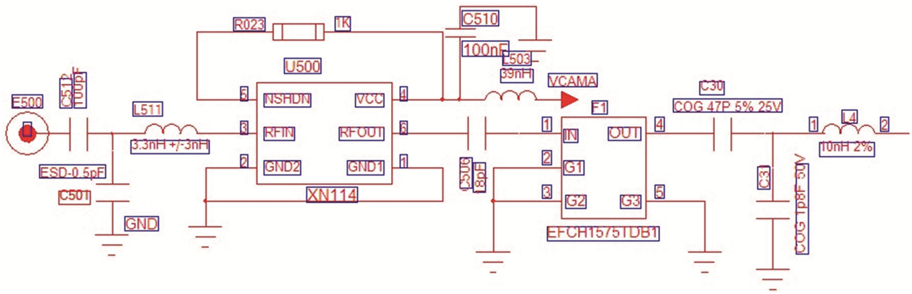


Fig. 3. Low noise amplifier and surface acoustic wave filter circuit schematic diagram

consumption is less than 10μA. It is packaged with 6-pin LGA form, which size is 1.5 mm × 1.0 mm × 0.75 mm. Recommended operating conditions: power supply voltage1.8 V~3.3 V, Operating temperature −40 °C~85 °C. According to The circuit chip demand and user guidance, we designed low noise amplifier and sound table filter circuit. The schematic diagram shown in Fig. 3.

4 Measurement and Calibration of BDS/GPS Antenna

BDS/GPS antenna is defined as a kind of antennas which is used in the satellite positioning system for receiving the positioning or navigation signals used. BDS antennas work at the center frequency of 1561.098 MHz while GPS L1 works at a center frequency of 1575.42 MHz. Signal power is generally about −166 DBM, belongs weak signal. BD/GPS antenna has four important parameters: gain, voltage standing wave ratio (VSWR), noise figure (Noise figure), the axial ratio.

Signal generally about −166 DBM, belongs to a weak signal. BDS/GPS antenna has four important parameters: Gain, standing wave ratio, noise figure, the axial ratio.

BDS/GPS antenna performance is measured by a oscilloscope and analyzer (HP 8752A). Measurement procedure is as follows:

1. Use calibrations to correct network analyzer by single port mode.
2. Connecting the test antenna to the network analyzer.
3. Measuring the reflection coefficient (S11), return loss and other relevant parameters.

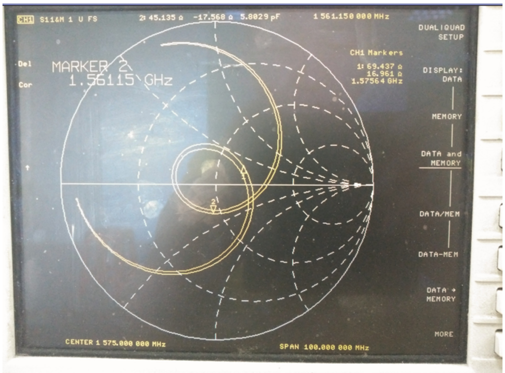


Fig. 4. The smith chart of BDS/GPS antenna

BDS/GPS antenna sizes are 25 mm × 25 mm × 4 mm. According to measurement procedures relevant graphical data is obtain obtained. Figure 4 is a Smith chart of the antenna while Fig. 5 is the VSWR diagram.

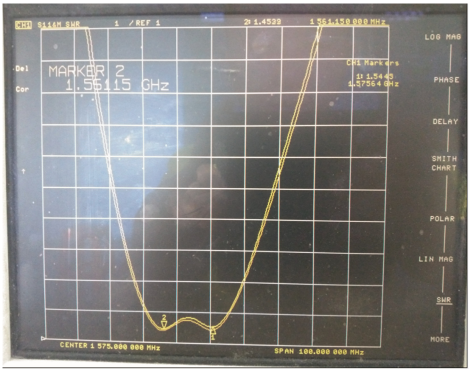
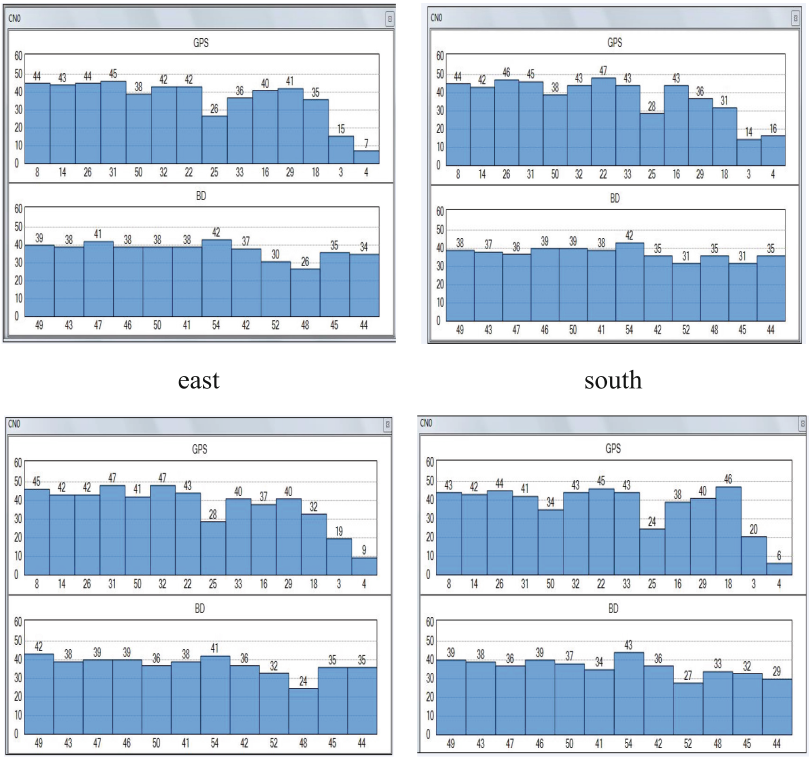


Fig. 5. Standing wave chart of BDS/GPS antenna



east south

west north

Fig. 6. The block diagram of onboard positioning

Figure 6 give the machine actually received satellite signal strength value when it is put different orientations at outdoor occasions: the east, south, west and north. Figure 5 shows good BDS/GPS antenna performance. Actually received satellite signal strength values of the machine is close to the theoretical value.

5 GNSS Positioning Module Satellite Capture Test

First needs of GNSS receiver is to capture the satellite signal. The minimum signal strength required to complete capture is named capturing sensitivity. After the capture, the satellite signal tracking sensitivity is very important parameter. It is defined as the minimum signal strength to maintain the continuous tracking.

Performance positioning module for positioning the circuit to be tested. Positioning chips collected by BDS/GPS antenna satellite system signal. After amplification filter circuit, the satellite signal is sent to XN647-8 Monolithic GNSS satellite navigation receiver module. Then the data changed to output by the ADC and internal operations according to NMEA protocol.

Overall performance test results of GNSS positioning system shown in Figs. 5, 6 and 7. The figure includes the first positioning time, TTFF different protocol selection, RTC, receiver sensitivity, and satellite location data. As can be seen, the vehicle

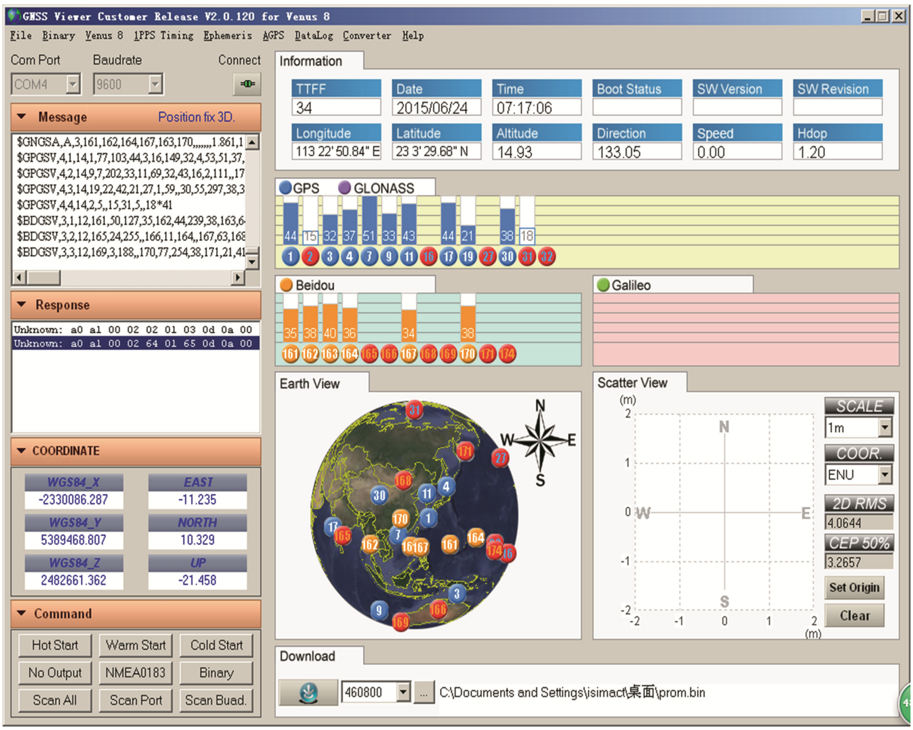


Fig. 7. The overall performance comprehensive test of GNSS positioning system

networking intelligent terminal receives 9 GPS satellite signals and 6 BDS signals. The specific satellite position is also can be identified. Vehicle networking intelligent terminal device owns good positioning performance that can achieve real-time location tracking.

6 Conclusion

This design improved GNSS-based vehicle positioning system. System hardware framework and integrated control terminal are designed to improve the integration of the system. Overall performance test results showed that: vehicle networking intelligent terminal can successfully receive signals from multiple GPS satellites and BD satellites, can be a good vehicle to achieve real-time location tracking.

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