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Design and Implementation of BDS RTCM SSR Message

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Abstract. Based on the real-time differential positioning system of Beidou wide area, a set of Beidou high-precision differential information transmission protocol is studied and designed. After the system generates satellite precise orbit and clock difference products, it needs to be sent to the users in a certain data format through C band GEO communication satellite. The transport protocol should be designed according to the data volume and update rate of the system. At the same time, it is necessary to combine the signal system, satellite resources and the restriction and restriction of the receiver implementation technology. It refers to the relevant fields and international similar systems of technology and standards to design. This paper establishes a set of technical indicators which can measure the pros and cons of differential message organization and broadcasting strategy. Through modeling, simulation and actual test, this paper makes a comprehensive comparison of different strategies. Finally, a transmission protocol design scheme which has good performance and meets the system service requirements is presented.

1. Introduction

In order to realize the harmonization of different receiver differential data formats to facilitate the exchange and processing of differential data, the International Maritime Radio Technical Committee (RTCM) has developed a differential global navigation system service standard. According to the age of development, it is divided into two stages, second and third[1]. Each stage consists of a series of message structures and content standards similar to the content of the message (referred to as the RTCM 10402.X series and the RTCM 10403.X series). It has been widely used in the field of satellite navigation [4]. RTCM 10403.x and RTCM 10402.x in the message structure, teletext length, calibration methods are not the same, the latest standard is RTCM 10403.2 It supports high bandwidth, broadcast and point to multipoint communications, and also supports the following high precision land, sea and air applications [2]:

1. Single frequency, dual frequency and multi frequency RTK applications. Can get better than the sub-level real-time positioning accuracy;
2. RTK applications in single GNSS mode or multiple GNSS modes. Can get better than the sub-level real-time positioning accuracy;
3. Network RTK applications in single GNSS mode or multiple GNSS modes. Can be better than the

sub-level positioning accuracy;

4. SSR (state space representation) applications in single GNSS mode or multiple GNSS modes. You can get real-time positioning accuracy of the sub-meter level.

In the satellite navigation and positioning, satellite orbit and clock error, ionospheric delay and other errors are independent of the location of users. These error sources together form the state space of satellite navigation and positioning.

Precision single point positioning (PPP) mainly uses accurate satellite orbit and clock parameters (calculated by the global IGS tracking network data) and the global atmospheric model to achieve single station precision positioning. By providing the user with the above-mentioned state space information, the observation error is corrected to improve the user positioning accuracy. On a global scale, the use of dual-band receivers can achieve the accuracy of the sub-meter or even sub-meter scale. This method is called in the RTCM standard state space representation, also known as wide-area difference.

2. BDS RTCM SSR transmission protocol

In this paper, the definition of the Beidou System State Space Information (BDS SSR) is based on the RTCM V3.2[3]. Data is defined in order to better broadcast, so in the definition of BDS SSR message format first need to determine the message type.

Beidou wide area differential message broadcast information includes the following five types: orbit correction, clock correction, code deviation, user ranging accuracy and fast clock correction. The data volume and update interval for each type of information are shown in Table 1.

TABLE 1. BDS SSR message type table.

Message Type	Message Name	The number of bytes	Bytes Update interval (s)	Description
1235	orbit correction	4.125+16.625*Ns=236.875	30	
1236	clock correction	4.125+9.25*Ns=133.625	10	
1237	code deviation	4.125+0.875*Ns+2.125*Ns*6=194.875	1800	Ns=Number of satellites
1238	ura	4.125+1.25*Ns=21.625	2	
1239	High speed clock correction	4.125+3.25*Ns=49.625	2	

To 14 satellites, each satellite 6 signal calculation.

1) The orbit correction information is: 4.125 + 16.625 * 14 = 236.875 bytes, rounded 237 bytes, or 1896 bits.

2) The clock correction information is: 4.125 + 9.25 * 14 = 133.625 bytes, rounded up to 134 bytes, that is, 1072 bits

3) The code offset is 4.125 + 0.875 * 14 + 2.125 * 14 * 6 = 194.875 bytes, rounded up to 195 bytes, or 1560 bits.

4) URA information is occupied as: 4.125 + 1.25 * 14 = 21.625 bytes, rounded 22 bytes, that is, 176 bits.

5) The High speed clock correction information occupies: 4.125 + 3.25 * 14 = 49.625 bytes, rounds up to 50 bytes, that is, 400 bits.

According to the parameters of the update rate can be calculated in one second at the same time broadcast all the parameters of the amount of 744bit information.

3. Coding scheme

Beidou wide area real-time differential positioning system uses GEO satellite to broadcast differential information, while receiving signals can also be received by a large number of common terminals. Therefore, the transmission scheme is designed to require an original differential information rate of up to 744bps and a bit error rate of less than 10^{-7}.The downlink constraints must be taken into account. Corresponding major system performance constraints can be summarized as shown in Table 2.

TABLE 2. The main control parameters of the system.

Message Type	Restrictions
Carrier synchronization signal - to - noise ratio requirements	≥4dB
Satellite EIRP	39dBW
Satellite output back	4dB
Terminal antenna gain	0dBi
Polarization Mismatch Loss	3dB
Power stability	0.5dB/Day

The quality of the satellite downlink is a bottleneck that constrains system performance. By satellite equivalent EIRP and terrestrial terminal reception capacity constraints, satellite downlink quality is poor. To meet the system performance indicators, it need to use a special error correction coding technology. Based on the construction theory of cyclic permutation matrix, the QC-LDPC code with code length of 992 and bit rate of 3/4 is constructed according to the requirements of the actual system. The main method is to construct multiplexing the cyclic permutation matrix A new parity check matrix is obtained, and the required QC-LDPC code is reconstructed[6].

For QC-LDPC codes with a code length of 992, we take L = 62, and the parity check matrix is

$$\mathbf{H}=\begin{bmatrix} I(p_{1,1}) & I(p_{1,2}) & \cdots & I(p_{1,16}) \\ I(p_{2,1}) & I(p_{2,2}) & \cdots & I(p_{2,16}) \\ \vdots & \vdots & \ddots & \vdots \\ I(p_{4,1}) & I(p_{4,2}) & \cdots & I(p_{4,16}) \end{bmatrix} \quad 1)$$

We follow the following steps to eliminate the ring in H [7].

1. Initialize the cyclic shift value of all the 1 elements in the base matrix X corresponding to its check H_b, that is, set it to zero.

2. In the base matrix H_b, from the first column, up to the 16th column, select the current column one by one. In the current column, from the line 1 to the last, select the current 1 element, the order of one by one optimization. That is, by adjusting the shift value of the current 1 element while keeping the shift value of 1 element has been traversed, the loop with any length of 2g contained in the current 1 element satisfies the loop constraint condition. The current column divides the matrix into left and right parts. The current 1 element divides the current column into upper and lower parts.

3. Find the ring contained in the current 1 element in the range above the current column and the current 1 element and create a ring constraint list.

4. Eliminate the extended loop by setting the shift value of the current element. The value of the shift value corresponding to the current 1 element is [0,61] [8]. I If the current 1 element corresponds to the shift value, the contained ring cannot satisfy the constraint condition, The shift value corresponding to the current 1 element is increased at tolerance 1 until the current 1 element corresponds to the shift value. So that all the rings contained satisfy the ring constraint.

After the above steps we can get the check matrix H. We use Matlab to simulate its performance. Through the AWGN channel, the log domain and product decoding algorithm are used [11]. The decoding is iterated 30 times. The bit error rate performance shown in Figure 1.

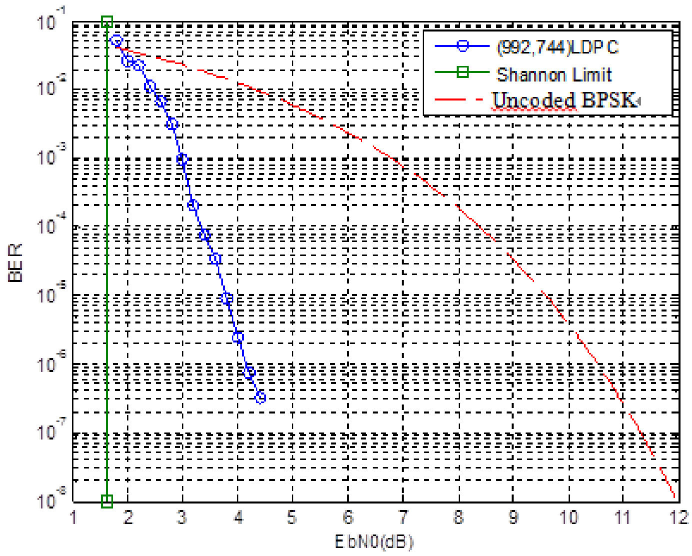

FIGURE 1. (992,744)LDPC coding bit error rate performance curve.

As can be seen from the above figure, the (992, 744) LDPC coded bit error rate performance can meet the bit error rate requirements. When the bit signal to noise ratio exceeds 5 dB, it is possible to obtain a bit error rate of less than10^{-7}.

The bit-to-noise ratio and the bit-to-noise ratio and coding gain required for coding the BPSK system at different bit error rates are shown in Table 3.

TABLE 3. The coding gain at different bit error levels ((992,744) LDPC codes).

Bit Error Rate Level	**Not Encoded Required Signal to Noise Ratio (dB)**	**Required Signal to Noise Ratio (dB)**	**Encoded Gain (dB)**
10^{-5}	9.59	3.79	5.8
10^{-6}	10.53	4.15	6.38
10^{-7}	11.31	4.6	6.71

As can be seen from the above table, LDPC coding using 3/4 rate can achieve a coding gain of 6.5 dB or more at a bit error rate of 10^{-7}, at a cost of 4/3 times the transmit power. If LDPC encoding is not used, there is no coding redundancy, and the gain is only 1.25dB gain due to 4/3 power, which is much smaller than the gain caused by LDPC coding.

In fact, due to the relatively poor situation of the downlink, it is impossible to achieve the desired original information rate close to 750 bps (744 bps) without using the LDPC encoding. As can be seen in the link budget described below, the receiver can obtain an encoded bit signal to noise ratio of about 5 dB at which the LDPC decoder can achieve an error rate level of less than 10^{-7}. In this link condition, if the LDPC coding is not used, the receiver can obtain the bit signal to noise ratio of about 8dB. The bit signal to noise ratio can only support about 2×10^{-4} bit error rate level, can not reach the system Claim.

4. Frame structure design

In this paper, the 3/4 rate LDPC code is used as the error control code, and the LDPC code belongs to the block code. The decoder at the receiving end needs to determine the head of a coded packet to start the decoding process [5]. Therefore, it is necessary to add a header flag for each coded bit group.

Since the system requires the original differential information rate of 744bps, and from the system to meet the bit error rate requirements.This paper also selected 3/4 rate of LDPC coding. Therefore, this time within 1 second 744 original differential information bits Encoding, get 992 encoded bits. For the sake of convenience, it is desirable that the final frame length is 1000 bits, and therefore 8 bits are available as the header indication of the coded packet[10]. Due to the basis of frame synchronization LDPC decoding, the header indication flag must have a very high detection accuracy rate. In order to achieve this goal, this paper uses a good self-correlation characteristics of the Barker code as a coded packet header. The 7-bit Barker code of the currently known maximum length is used to search for the packet header by correlating the received signal with the local signal. And further adds one padding bit to form a data frame having a length of 1000 bits.

5. BDS RTCM SSR message structure

Based on the above research basis, the final message structure is designed as follows.

C1 frequency of the I-channel broadcast fast clock correction and code offset information, the information rate of 250 bps, 2 seconds into the message once, each injection 500 bits.C2 frequency I branch broadcast track correction and URA information, information rate 200 bps, 2 seconds into the message once, each time 400bits. In the case of the design of the message, the orbit correction, code offset, URA, fast clock correction information were 30 seconds, 128 seconds, 2 seconds, 2 seconds a complete broadcast time,.It fully meet the requirements of data updates.

The detailed message is as follows.

1. C1 I message

C1 I Road message broadcast Fast clock correction with code offset information. The message structure is a frame containing 64 subframes. Each subframe 500 bits, 2 seconds to generate a subframe, a total of 32000 bits, with 128 seconds to complete the broadcast. The information rate of 250bps. The structure of each message subframe is consistent and the fast clock correction information appears once every subframe. The code offset information is broadcast once through 64 subframes.

2. C2 I message

C2 I message broadcast track revision and URA information. The complete data unit is a frame containing 15 subframes. Each subframe 400 bits, 2 seconds to generate a subframe, a total of 6000 bits with 30 seconds to complete the broadcast. The information rate of 200bps. The structure of each message subframe is consistent and the URA information is presented once every subframe. The track correction information is broadcast once through 14 subframes (the corresponding position of the 15th subframe is left blank).

6. Conclusions

In order to adapt to the development of new systems (especially BDS and Galileo), there have been system upgrades (such as new L2C and L5 signals) and regional wide area differential enhancement systems[9]. In this paper BDS RTCM and SSR messages are designed according to the standard of data volume and update rate of Beidou wide area real-time difference system. It refers to the technology and RTCM standards of international similar systems. It also combines the C band signal system, satellite resources and the restriction and restriction of the receiver implementation technology.

The new message protocol design provides a strong support for the construction of stable and reliable high-precision enhanced information broadcasting means. The use of space-based broadcast will provide high-precision differential products to provide high-precision users to use, covering the "one side" area of advanced performance, Continuous and reliable, reliable service Beidou satellite navigation system High-precision civilian service system, and other domestic service system for the " One belt One road " area to provide seamless BeiDou high-precision navigation location services.

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