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Satellite Communication and Navigation Integrated Signal

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Abstract

Under the rapid development of satellite communication systems and satellite navigation systems, there is an urgent need to combine the two together in order to achieve location-based services, etc. Despite the long relationship history of navigation and communication, the two satellite systems are basically independent of each other. As a result, terminal size tends to be relatively large, and difficult to be miniaturized. This article puts forward a novel idea that satellite navigation and satellite communication functions are integrated together in the signal level, and gives four types of the integrated navigation and communication signal structures which are composed of message, spreading code and carrier. It lays a technical foundation for the in-depth development of the integration of navigation and communication systems in signal level.

Keywords*: satellite communicaton, satellite navigation, integration, singal structure*

1. Introduction

The relation between navigation and communication has a long history. From a brief review of satellite navigation technology development, it can be seen that navigation and communication have been closely connected [1-3]. In fact, communication technology is the cornerstone of navigation, and navigation is a special application of communication technology. If communication function can be reserved in navigation system, you can make the single user positioning information exchanged in time between users and user centers. In this way, navigation and positioning information becomes more active and creates greater application value. Furthermore, navigation has been developed from single carrier navigation into user group navigation, realizing monitoring and control, commanding, assessment, assistance, operational optimization and effective management. A majority of navigation users are on the mobile carrier, which determines that terrestrial mobile communication (such as GSM, CDMA, 3G, etc.) will be the main methods can be used. Although the terrestrial mobile communications network is very popular, its coverage area is less than 20% and it is still difficult to communicate in remote areas, desert areas and on the ocean. Especially when natural disaster occurs, terrestrial mobile communication network will be destroyed. At this time, only satellite communication can be used. Therefore, as no "gap" coverage and emergency use, satellite communication still remains indispensable, or satellite communication is a complement and extension of terrestrial mobile communication system. As the satellite transmission channel with high quality, high reliability, long transmission distance and larger coverage, it is still very popular.

Existing satellite navigation and communication integration approaches are mainly in the system level, such as the combination of Global Positioning System (GPS) [4] and mobile communication, or GPS and Inmarsat. GPS receivers are used to obtain user's location information, and then information of location, time, status etc. is transmitted via mobile network or satellite communication system to be exchanged. However, in the "highly sophisticated global positioning system (HI-GPS) project" [5], the second generation of GPS-assisted signal has been transmitted through the Iridium satellite constellation successfully, by upgrading enhanced narrow-band software on-board computer of Iridium satellite communication systems, which makes it faster and more accurate to realize GPS positioning. In the HI-GPS program, it has been implemented to transmit satellite navigation signal by satellite communication system,

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which is a combination in the system level. If you want to truly achieve the integration of navigation and communication functions, it should be in a system, even by the same link. In this paper, four novel satellite communication and navigation integrated signal strucutres are put forward.

2. Satellite Communication and Satellite Navigation Integration Principle

All of the satellite navigation systems, such as GPS, GLONASS, Galileo, COMPASS, etc., adopt pseudo-code spreading spectrum singal system [6-8]. Spreading codes is used as the ranging codes. In the navigation message, there are time scale, orbital parameters, as well as various types of error corrections. In general satellite communication system, the message is the communication message, and the communication message are directly modulated onto a carrier. However, therer is one kind of satellite spreading spectrum communication technology, which is similar to the navigation spreading process. It multiplyies the baseband signal d(t) with a high-speed pseudo code signal c(t) in the time domain to abtain a spreading code stream to be sent to the satellite channel. Since the spreading code rate is much higher than the information rate, the process of multiplying the baseband signal and spreading code is equivalent to make convolution of the frequency spectrum in the frequency domain. As a result, signal spectrum is widened. So that the power spectral density is greatly reduced. However, the IF (short for “intermediate frequency”) signal bandwidth after despreading is very narrow so that interference and noise power is reduced and demodulator input signal-to-noise ratio is improved. System interference suppression capability is raised. At the same time, there are many advantages of spreading spectrum communication, such as anti-interception, anti-monitoring, good resistance to fading, anti-multipath, and multiple access communication ability. Now we can make a conclusion that present satellite spreading spectrum communiation and satellite navigation spreading spectrum technology are interlinked. So that we can take advantage of the spreading pseudo-code in the satellite communication system, such as satellite positioning system applications, not only as a spreading spectrum code, but also as a ranging code. And if some simple parameters with information related to the positioning, such as the necessary time scale, satellite orbit, delay error in the transmission pathway caculation relevant parameters, we can finish pseudorange measurement and solving measurement equations to achieve positioning.

Navigation and communication integrated singal is capable of not only communication, but also pseudo range measurement, positioning and timing service, through a single link. Thereby, system can be simplified [9-10]. This research can lay a technical foundation for the in-depth development of navigation and communication integration. It will promote the integration of navigation and communication, create a new platform for the time-and location-based services, and explore new ideas for satellite space utilization of resources.

3. Satellite Communication and Navigation Integrated Signal Structures

3.1. The First Signal Structure—I and Q Slips

The first integrated navigation and communication signal structure is shown in Figure 1. It is made up of one I slip and one Q slip, which are orthogonal. The signal structure of each slip is composed of consecutive super-frames where each super-frame consists of several sub-frames and each sub-frame contains frame signs, a sub-frame number, an identification number, the main message, check bits and the frame’s end. For the I slip, the data rate is low, and its message provides mainly time signal, location information and satellite orbit information. Short code benefits capture and recapture. The Q slip adopts long codes, which have the advantage of longer coherent integration time, higher ranging precision, better security performance and anti-interference ability. It can play an important role in tracking and precise measurement of time delay. The communication message is modulated in the Q slip. In this signal structure, a combination of the I slip and Q slip signals uses the direct sequence spread spectrum (DSSS). The transmission signal can be expressed as:

$$S(t) = A_c C_c(t) D_c(t) \sin(2\pi f_{sc} t + \varphi_c) + A_p P(t) D_p(t) \cos(2\pi f_{sp} t + \varphi_p) \quad (1)$$

where A_c is the amplitude of the communication spread spectrum code; C_c (t) is the spreading code for communication; D_c (t) is communication data; f_{sc} is carrier frequency for the communication information; φ_c is communication carrier phase; A_p is amplitude spreading code for the navigation and positioning; P (t) is spreading code for the navigation and positioning; Dp (t) is the navigation and positioning message; fsp is carrier frequency of navigation and positioning information; φ_p is carrier phase for navigation and positioning. Because the system can provide continuous and stable ranging and navigation signals as well as communication signals, this signal can provide continuous real-time navigation and positioning like a GPS positioning system.

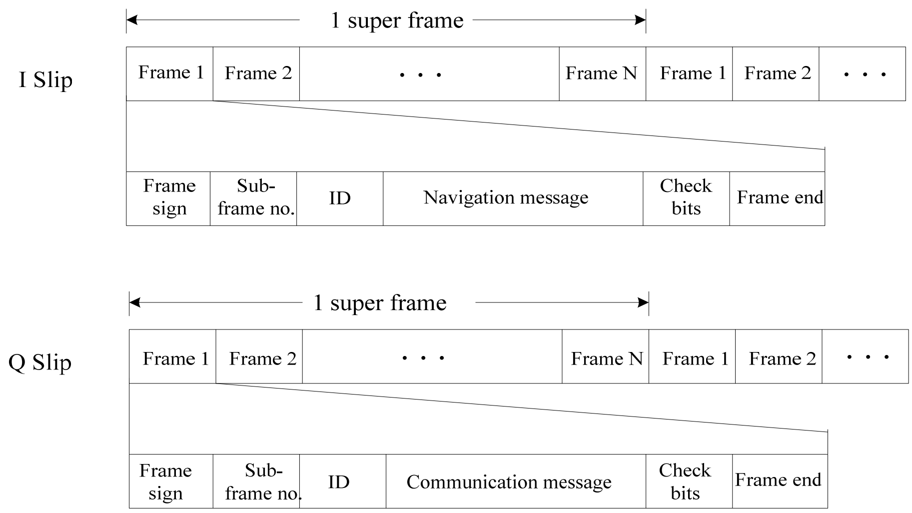

Figure 1. First Integrated Navigation and Communication Signal Structure

3.2. The Second Signal Structure Single Slip

The second signal structure is shown in Figure 2. The former part is the navigation section, and the latter is the communications segment. The two segments are transmitted alternately. The main function of the former part is to capture and transmit navigation-related information, including user ID, message length, time information, and so on. In this capture section, a short code is used for rapid acquisition. The latter, is the track section which is mainly to achieve transmission of information and precision ranging. The communication message is also modulated on the latter part, too. The communication message length can be fixed or variable. Long code is used in the tracking section, which will help improve the measurement accuracy and make it difficult to decipher, and will provide better anti-jamming capability. Capturing of the latter segment is led by the former, or assisted by the preceding paragraph to re-capture.

The message modulated is a combination of an alternating communication and navigation short message. This combination message is modulated onto the ranging PN code, and then modulated to the carrier. It consists of navigation and communication information, so it has a dual function of communication and positioning. The pseudo-code of the navigation section and the communication section can be the same or different. In this signal structure, the signal transmission format is expressed as:

$$S(t) = AP(t)D(t)\sin(2\pi f_s t + \varphi), \quad (2)$$

where A is the spreading code amplitude; P(t) is the spreading code; D(t) is the navigation and communication message; fs is the carrier frequency; φ is the phase.

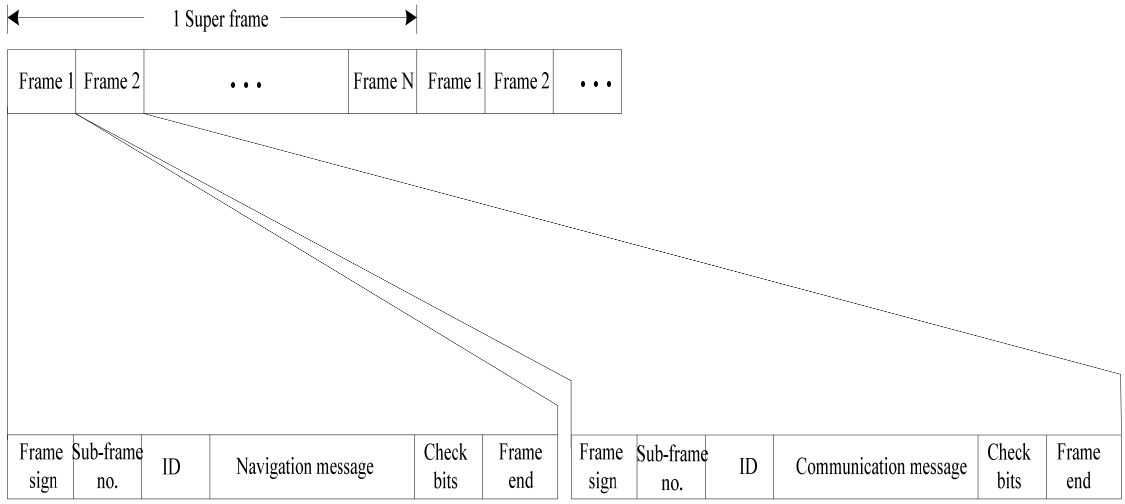

Figure 2. The Second Integrated Navigation and Communication Signal Structure

3.3. The Third Signal Structure Plug-in

The third signal structure is produced by inserting the navigation message into the pilot frame of the communication signal to achieve the integration of navigation and communication. For example, one can use the CMMB broadcast signals' pilot signal frame directly, as shown in Figure 3, which is one second per frame. Each frame is divided into 40 time slots, and each slot delay is 25 ms, which includes a beacon sub-frame and 53 OFDM sub-frames. The beacon sub-frame structure is shown in Figure 4.

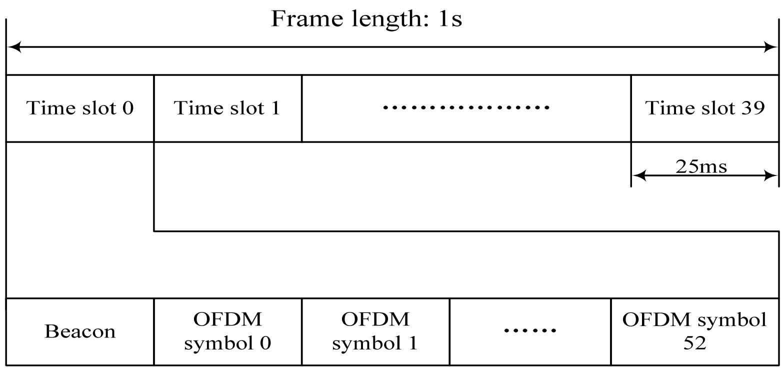

Figure 3. Frame Structure Diagram

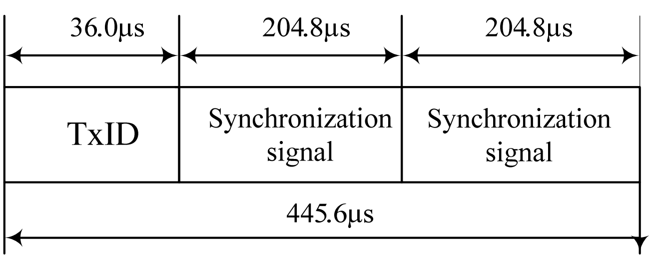

Figure 4. Schematic Diagram of the Beacon Signal Sub-frame

As the beacon signal is the band-limited (12.5MHz) part of the pseudo-random spread-spectrum signal, it can be used to achieve accurate ranging. The beacon signal is made up of the transmitter identification (TxID) and two synchronous signals. TxID consists of a cyclic prefix T1 (10.4μs) and data volume T0 (25.6μs). The data volume can be used to send time information, satellite orbital information and other relevant information so that it can constitute a navigation and time service message. The data length of the spreading code of each beacon is 191, and it can send 1-bit information. Each pilot frame contains 40 slots, so the message content that can be transmitted per second is: 1bits×40 = 40bps. Information which can be transmitted may be slightly less than the GPS navigation data message. However, some information can be reduced, so that 40bps is adequate for the transmission positioning timing message of one satellite (GPS information transmission rate is 50 bps, and the amount of super-frame information transmitted in GPS can be 1500 bits in 30 seconds). The beacon length is 445.6μs, including TxID duration of 36.0μs, which has a 191-bit PN spreading code with the spreading gain of 22.8dB.

As shown in Figure 5, the respective time slots before the beacon section 136μs CMMB data segment (including 36μs TxID and synchronization signal 100μs) is replaced to be the gold code of a code length of 511, used for capture, tracking and demodulation. 104.8μs is reserved synchronization signal as a guard interval, does not affect synchronization and channel estimation.

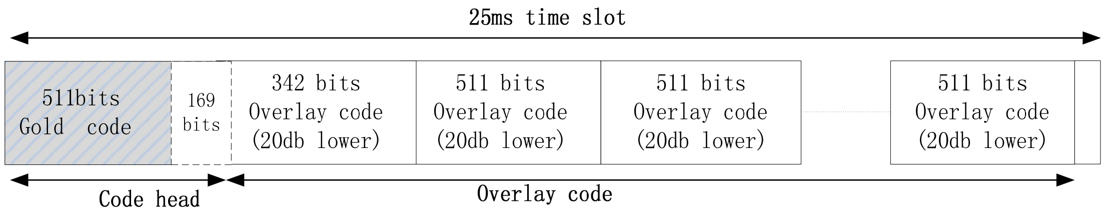

Figure 5. The Beacon Part Inserted with Spreading Code Schematic Diagram

3.4. The Fourth Signal Structure—code Division

In the CDMA communication system, one of the communication code channels is selected for navigation purposes, and the other code channels are still used for communication.

4. Conclusion

Integrated navigation and communication signal structure includes many types. Which of these four kinds of signal structures will be used depends on the transmission capability of the system. If system power (or the carrier to noise ratio) is enough to bear both I slip and Q slip transmission, the first kind of signal transmission format is recommended. If the power (or the carrier to noise ratio) is limited and cannot bear the transmission of two slip signals, the second signal transmission format is suggested, transmitting a single slip.

Because the integrated navigation and communication signal needs to complete precise distance measurement, it should adopt a broadband spread-spectrum, or a special wideband spread-spectrum system. In this way, we can get high spreading gain, so that the signal can be buried under the noise background during transmission, and so that the signal transmission has good anti-interference capability. If the system has multiplex capabilities, we can use the fourth signal structure, in which a code channel is used for navigation and positioning, and the other code is still used for communication. In the satellite broadcasting signals, due to the presence of a spread-spectrum pilot frame, we can use the spreading code for ranging. If other empty frames are added with orbit and time parameters, these information can serve as a navigation message. Multiplex transmission is redundant in distance ranging, which can improve the ranging accuracy.

Acknowledgements

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