Pseudolite seamless indoor and outdoor positioning is developing rapidly in China

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Abstract—In modern society, there is a growing need for positioning navigation, especially in a variety of complex environments, such as scenic spots, airport halls, exhibition halls, warehouses, supermarkets, libraries, underground parking lots, etc., the satellite navigation signal loses the navigation service capability in the above-mentioned places due to the shielding effect. In order to solve the problem of indoor and outdoor navigation signal coverage, the navigation pseudolite is easy to install and possess the technical advantages of GNSS receiver hardware[1]. It can realize the GNSS positioning module of the personal mobile terminal to receive the pseudolite signal inside and outside the room, thus realize seamless navigation and location services. China's indoor and outdoor pseudolite seamless positioning technology has developed rapidly, it consists of direct and forward pseudolite positioning system outdoors, and array pseudolite positioning system indoors; Pseudolite signal design uses space navigation satellite navigation signal system and message, and the corresponding positioning system is put forward according to the actual application scenario, including the location based on the signal, based on the signal strength, based on ranging information, based on carrier phase measurement and other positioning mode; Finally, this paper introduces the application of pseudolite positioning system in the typical area of the mall and so on, and makes an analysis and prospect of its development prospect.

Keywords- pseudolite; indoor positioning; seamless positioning system;

I. INTRODUCTION

Satellite navigation system can provide high-quality location services for outdoor personnel and vehicles in the environment, space satellite because of its location and signal system constraints, can not cover the serious effect of the indoor environment to achieve high-precision seamless location services[2]. Pseudolites can achieve a wide range of indoor navigation signal coverage and seamless switching of indoor and outdoor location services due to their flexible deployment advantages, and can be combined with other indoor positioning technology to further improve the positioning of the rate and accuracy. Indoor and outdoor location service is China's modern mobile Internet industry next high ground, the most urgent need for its core is a stable and accurate indoor and outdoor positioning technology for support, and pseudolite technology which meets this demand, can be used as indoor and outdoor positioning Infrastructure, and promote the development of China's indoor and outdoor location services industry.

Pseudolite technology originated in the United States Baisha test field, in response to the seamless location service market, the EU has proposed the Galileo Local Technology Program (GILT) in the Galileo project, specializing in indoor and outdoor Galileo pseudolite applications. Japan attaches great importance to promote support for GPS signal of the indoor pseudolite positioning system IMES, and ublox, Broadcom and other navigation chip manufacturers also introduced the corresponding GNSS / IMES navigation chip, the IMES signal interface has been written IS-QZSS-1.4; LOCATA pseudolites meet the automatic control, mining, port precision positioning, indoor positioning and other areas of ad hoc network users, its horizontal positioning accuracy can reach centimeter level; CETC 54 as the representative of China’s pseudolite technology, its military pseudolite technology has been used in the theater navigation enhanced, UAV landing and other fields to carry out the application, and is actively promoting the development and application of civilian pseudolite system, part of the BD outdoor pseudolite products have been successfully in Jiuzhaigou scenic mountain road navigation enhancement applications, in the national PNT system and Xihe plans, pseudolite network is one of the important components and important research direction.

In this paper, the system consists of the pseudolite indoor and outdoor seamless positioning network are introduced, including the outdoor pseudolite system and the indoor pseudolite system. Secondly, the pseudolite signal system similar to BD and GPS is designed and analyzed. The pseudolite positioning mode and its principle are briefly described. Finally, the application and development trend of the pseudolite indoor and outdoor seamless positioning system are analyzed and predicted.

II. PSEUDOLITE INDOOR AND OUTDOOR SEAMLESS POSITIONING SYSTEM

Pseudolite indoor and outdoor seamless positioning system consists of pseudolite outdoor positioning system and pseudolite indoor positioning system, ensure that the existing satellite navigation receiver does not make hardware changes, only to upgrade the IP soft core to receive the solution pseudolite navigation signal. As shown in Figure 1, the

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outdoor pseudolite is divided into direct pseudolite system and forwarding pseudolite system, forwarding pseudolite system adopts multi-channel homologous transmission, its brings a good time synchronization accuracy, outdoor pseudolite positioning system accuracy is up to 0.2m; indoor pseudolite using array pseudolite, positioning accuracy is up to sub-meter level.

A. Outdoor pseudolite positioning system

1) Forwarding pseudolite positioning system

The forwarding pseudolite system consists of a multi-channel transmitting base station, an L-C up-conversion unit and a C-L down-conversion unit. The multi-channel base station is mainly responsible for the generation of the multi-channel navigation signal and the pilot signal. The signal is then converted into a C-band signal by LC and sent by the directional antenna to each forwarding unit. Finally, the transponder unit realizes its own PLL under pilot signal guidance Lock frequency, and through the lock signal to C-band signal into L-band navigation signal to the coverage area to provide navigation services.

B. Indoor pseudolite positioning system

Indoor pseudolite positioning system using array pseudolite, array pseudolite system by the array of pseudolite host and array antenna composed of two parts. Array pseudolites using low-cost crystal drive, to achieve small and low power consumption structural design. The indoor array of pseudolites can provide carrier phase difference positioning to the user receiver, allowing the user to calculate floor information and relative height based on the message information of the indoor array of pseudolites.

III. SIGNAL PROPERTIES

In order to enable the GNSS receiver or chip to receive the pseudolite signal, the pseudolite signal parameters are shown in Table 1, it can be seen: pseudolite signal center frequency, code rate, code length, information rate, polarization are the same as the BD and GPS, but the pseudolite spread code uses GNSS navigation system expansion code specified in the Interface Control Document, pseudolite modulation using "pulse + BPSK" way to solve the far and near effect problem.

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>BD</th>
<th>GNSS pseudolite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>GPS</td>
</tr>
<tr>
<td>Center frequency (MHz)</td>
<td>1.575</td>
<td>1.561</td>
<td>1.575</td>
</tr>
<tr>
<td>PRN ID</td>
<td>1-32</td>
<td>1-32</td>
<td>33-37</td>
</tr>
<tr>
<td>code chip rate (MHz)</td>
<td>1.023</td>
<td>1.023</td>
<td>1.023</td>
</tr>
<tr>
<td>code length (1 ms)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Information rate (bps)</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>modulation</td>
<td>BPSK</td>
<td>BPSK</td>
<td>pulse+BPSK</td>
</tr>
<tr>
<td>polarization</td>
<td>RHCP</td>
<td>RHCP</td>
<td>RHCP</td>
</tr>
</tbody>
</table>

The pseudolite uses the pseudolite pulse modulation scheme recommended by the Committee in RTCM SC -104. The pulse duration is defined as 1/11 of the code period, and for the pseudolite spread code with code length of 1023 chips (1 ms), 93 chips are sent every millisecond and 2 pulses are
sent every 10 cycles to provide 10% average duty cycle PDC.

The pseudolite signal navigation format is shown below. The navigation message is transmitted by pseudolite via the L1 and B1 channels at a rate of 50 bits per second.

<table>
<thead>
<tr>
<th>BCD-17</th>
<th>header-8</th>
<th>received-2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>WN-10</td>
<td>precision-4</td>
<td>Toc-10</td>
<td>P</td>
</tr>
<tr>
<td>Toc-6</td>
<td>Af1-14</td>
<td>Af0-4</td>
<td>P</td>
</tr>
<tr>
<td>Af0-18</td>
<td>X-6</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>X-6</td>
<td>Y-16</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Y-16</td>
<td>Z-6</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Z-6</td>
<td>received-18</td>
<td>P</td>
<td></td>
</tr>
</tbody>
</table>

Fig 4. Pseudolite signal message format(L1)

IV. POSITIONING SYSTEM

A. Based on location notification

Pseudolites are deployed in the application environment. Each pseudolite has its own ID, and the exact location of the pseudolite is recorded in the database corresponding to the ID. The location-based notification is based on the pseudolite ID identification at the mobile station reception at the pseudolite network. The pseudolite broadcast message contains information such as its own ID, the attenuation factor of the environment, and when the mobile user enters the coverage of the specific pseudolite signal, the mobile station receiver receives and demodulates the pseudolite signal, obtains the pseudolite ID, the ID is then retrieved in the database, returning the pseudolite position and the possible positioning range. If no other information is available, the user location is assumed to be the pseudolite location.

B. Based on received signal strength

The positioning method based on location notification is simple and easy to locate, but the positioning accuracy is relatively low, the error can reach the signal coverage of single pseudolite. It is possible to quickly improve the positioning accuracy based on the method of received signal strength after quickly determining the possible range of the mobile station by the pseudolite ID identification. Positioning algorithm based on the received signal strength is to calculate the difference between the signal strength of the pseudolite and the intensity of the signal received by the mobile station, and see the value of the signal as the path transmission loss, and then use the appropriate signal fading theory or empirical model to calculate the signal transmission distance, and then according to the known pseudolite position information, and the calculated pseudolite to the mobile station distance, calculate the location of the mobile station.

C. Based on ranging information

The pseudolite positioning system based on ranging information is a regional positioning system that simulates GPS/BD positioning system, as shown in Fig7. It is similar to GPS / BD, four or more pseudolites can be used as signal sources to transmit pseudolite ranging signals. Pseudolite independent coordinate system and time base can be established according to the situation. GPS/BD compatible receiver receives the signal and extracts the relevant information such as pseudorange, carrier phase and so on, and obtains the receiver position through the positioning solution.

D. Based on carrier phase measurement

Figure 5 shows the principle of sub-level indoor positioning based on carrier phase difference. The BD/ GPS ground pseudolite broadcasts four navigation signals, which are broadcast by four-channel array antenna, respectively. The distance between the array antenna elements is \( L \), and \( L \) is less than half the wavelength. Since the two signals are generated by the same PLL, the frequency and wavelength of the signal are consistent, and there is no need to consider the difference between the two signals. At the same time in the measurement process of receiver measurement, because there is no problem of ambiguity, the effect of the receiver clock error can be effectively eliminated when the two signals are subtracted.

![Fig 5. High Precision Positioning Schematic of Indoor Pseudolite Network](image)

V. THE DEVELOPMENT AND APPLICATION OF PSEUDOLITE INDOOR AND OUTDOOR SEAMLESS POSITIONING SYSTEM

A. The application of pseudolite indoor and outdoor seamless positioning
Indoor and outdoor positioning in the consumer and enterprise market have strong market demand, with the gradual application of Internet of things, indoor and outdoor seamless positioning industry is expected to get rapid development. Pseudolite indoor and outdoor seamless positioning applications include smart home, precision marketing, emergency rescue, personnel management. The following figure is a typical scenario - the application of shopping malls.

Pseudolite are placed at high points of the buildings or base stations for equipment reuse, which can ensure signal coverage while further reduce the cost. Through the relevant deployment optimization software to ensure that the signal coverage and availability in the demonstration area, the user can enjoy high-quality seamless positioning navigation services both in the outdoor and indoor area.

B. Development trend of pseudolite indoor and outdoor seamless positioning

1) Pseudolites are combined with other positioning means

Due to the complexity and variability of the indoor application environment, a single pseudolite positioning method cannot guarantee the real-time continuous positioning service. The integration with the multi-sensor is the main trend of seamless positioning, and greatly improves the use of the positioning accuracy and reliability. Cost and compatible with more equipment.

2) Under the opportunity of internet of things + 5G boom

When the 5G network is everywhere, positioning technology can be embedded in any device when the city's form will be changed, large data, artificial intelligence and the combination of things, human living environment will have the ability to perceive. Increasing yearly indoor and outdoor positioning applications require more people to focus on indoor and outdoor positioning technology, and also meet many of the Internet of Things applications on the indoor and outdoor positioning of this feature requirements. The deep integration of pseudolite + 5G network + Internet + Internet of Things will provide a technology and platform basis for seamless space-time tags to drive indoor location services.

3) Large data cloud positioning is indispensable

The cloud platform database stores the sensed information from a variety of sensors, and combines the pseudolite with a variety of indoor and outdoor positioning technology, the depth of fusion of multi-sensor data, map data and network data, in order to achieve optimal positioning performance.

VI. CONCLUSION

With the urgent increase in demand for indoor and outdoor location services, pseudolite indoor and outdoor seamless positioning system has been rapid development, both as a satellite navigation system to enhance the supplement, but also a independent positioning navigation in the space where satellite signal is sheltered. This paper systematically introduces the system composition, signal structure, positioning system and application mode of the pseudolite indoor and outdoor seamless positioning system, and analyzes and prospects the development trend of the pseudolite. Pseudolite indoor and outdoor seamless positioning system integration of a variety of positioning means used in shopping malls, airports and other large service areas, in line with today's world of all things mainstream trend, has a good application prospects.

REFERENCES
