International Symposium on GNSS 2015
Kyoto, Japan.
November 16-19, 2015.

Zone Based Indoor Location Using GNSS Simulators

Lisa Perdue[1], Hiro Sasaki[2], and John Fischer [3]

1Spectracom Corp., USA, lisa.perdue@spectracom.orolia.com
2 Spectracom Corp., USA, hiro.sasaki@spectracom.orolia.com
3 Spectracom Corp., USA, john.fischer@spectracom.orolia.com

Abstract Signals from Global Navigation Satellite Systems (GNSS), such as the Global Positioning System (GPS), are very weak and usually cannot be seen indoors or underground. A common method to overcome the problem of receiving GNSS signals indoors or underground is to use a GPS/GNSS repeater with an antenna located outdoors to receive the GNSS signals and an amplifier/antenna to re-transmit the signal indoors. However, there are two limitations to this approach. First, the repeater will only transmit the position of the receiving antenna point (outdoors), not the desired indoor point. The transmitted location can be hundreds of meters away or more. Second, a low-loss coaxial cable and signal amplification are required to bring the signal from the outdoor point to an indoor space and running this special cable can be prohibitively expensive.

The Intelligent Repeater System addresses these issues. The system contains a GPS receiver unit that receives the live sky signal, synchronizes to the exact time and captures the navigation and almanac data in real-time. Then the receiver transmits this data across any existing network connection to any number of GPS simulators. Each simulator is configured to transmit GPS signals corresponding to a location within its zone. The system allows the use of any standard GPS device across boundaries between live sky and GPS denied environments to calculate position to within the resolution of zones defined by the number of simulators deployed. No special receiver or software is required to operate with the system.

This paper describes the technologies and methods for creating such a system including time synchronization at the nanosecond, microsecond, and millisecond levels, how each synchronization level affects the overall system and methods for achieving each, power level considerations including power level requirements between zones and how they affect transitions from one zone to another, data transfer and example system configurations. While GPS is primarily demonstrated and tested, the possibility for adding other GNSS constellations such as QZSS, BeiDou, Galileo, and GLONASS are also presented.

Keywords Synchronization, QZSS, repeater, GPS, indoor location

1. Introduction

Indoor positioning is highly desired for many applications, including personnel tracking for safety in normally unmanned locations. There are several methods and technologies available to achieve accurate indoor position and location but the majority relies on dedicated, specialized equipment or modifications to achieve this goal. With the growing number of devices that contain GPS receivers it is practical to develop a system that will allow indoor positioning using these already available receivers.

GPS repeaters are typically used as a solution to bring GPS signals indoor. A traditional repeater consists of installing a GPS antenna outdoor along with an amplifier, and running a loss low coaxial cable to the indoor space with a radiating antenna or using a leaky-coaxial cable to transmit the signal to a wider area. There are several issues with this approach. The first is that any GPS receiver that receives the repeated signal will believe that it is in the location of the outdoor antenna, not the actual indoor position. This can make it difficult to locate people, especially if they are underground or if the indoor position is far away from the outdoor GPS antenna location. Secondly, if the system is using a leaky cable to supply the signal to the user, the signal will be strongest near the antenna amplifier which is typically located in an outdoor location, and could disrupt GPS for users in the local area.

The Intelligent Repeater System overcomes these issues. An outdoor antenna is installed anywhere with a clear view of the sky. Rather than attaching the antenna directly to an amplifier and antenna system in a traditional repeater system, the antenna in an Intelligent Repeater System is attached to a data collection and synchronization unit. The information about the live sky signals is collected and accurate 10MHz and 1PPS signals are produced. These signals can be used by a GNSS simulator to recreate the live sky signals, but instead of generating signals that would correspond to the outdoor antenna location, the generated location can be programmed to simulate a position anywhere in the world into the indoor zone.

Using the Intelligent Repeater System, personnel or equipment can be located within a given zone, making critical response times shorter, improving safety, and providing more accurate information than a traditional repeater system.

This paper describes the data collection, the synchronization methods, and the GNSS RF signal generation capability of the Intelligent Repeater System.

2. Intelligent Repeater System

The Intelligent Repeater System consists of a Spectracom SecureSync® for the data collection and synchronization signals, and multiple Spectracom GSG Simulators for the GNSS RF signal generation. Working together these components form a system to deliver zoned-based indoor location that any GPS receiver can use for indoor positioning in GPS-denied environments.

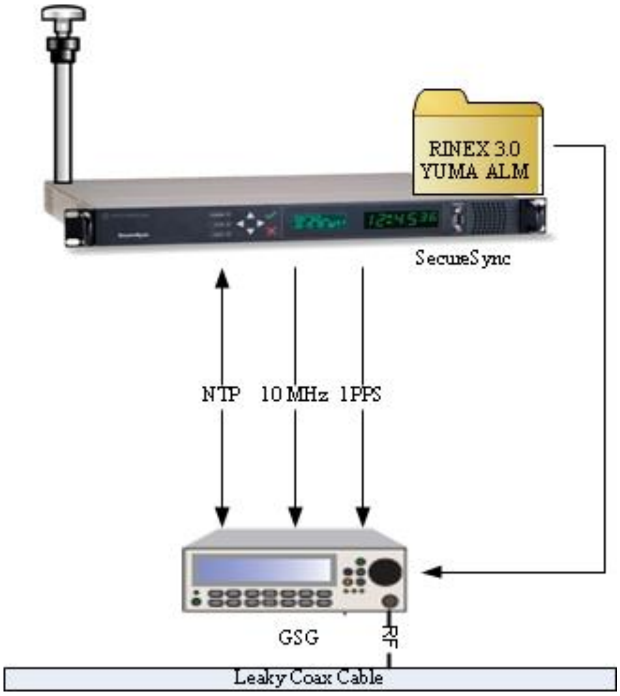

Fig. 1 Intelligent Repeater System – Single Zone

2.1 Data Collection

In order to re-generate the GNSS signals accurately the GNSS simulator needs to have information about the live signals. This information includes precise orbital information for the satellites in view (ephemeris data) and the almanac information for the entire constellation. The system also needs information about the leap second, the satellite clocks, and all the data contained in the NAV message for the constellation. This complete re-generation of the signals allows for seamless transition between the live sky signal and the signals generated within the zones.

This data is collected by the SecureSync. The receiver in the SecureSync receives the ephemeris and almanac information from the satellites in view and the SecureSync software generates ephemeris data files in RINEX 3.0 format and almanac data in YUMA format. These files are updated with current data at a user configurable rate. For the Intelligent Repeater System, the files are updated once every 10 minutes. The station name and the record duration are also configurable.

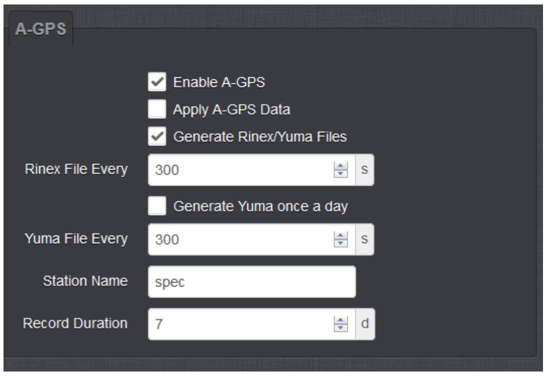

Fig. 2 SecureSync Data Generation Settings

The files are stored in the SecureSync memory and can be retrieved manually by a user or automatically by a GSG Simulator using HTTP Wget.

2.2 Synchronization

It is important that the re-generated signals are synchronized to the live sky signals. This synchronization is done by transferring UTC Time from the SecureSync using NTP and a 1PPS signal. The GSG Simulator gets the current time to the nearest second, loads the simulation scenario, and uses NTP to align to the precise current time. The GSG Simulator is set into ARM’ed mode, where it will open the arming window when the set NTP time has been reached. The SecureSync allows the 1PPS to be time aligned to the rising or falling edge and also allows for an offset to be added compensating for additional system delays. In this system the SecureSync 1PPS is set to align to the falling edge and an offset of 40ns is applied to compensate for internal delays in the simulator. The first falling edge detected from the 1PPS signal once the arming window is opened starts the RF generation in precise alignment with the live GNSS signals.

When the SecureSync is synchronized using GNSS directly with the NTP and 1PPS signal generated from that unit, the difference between live sky time and simulated time can be brought to < 1ns. When the SecureSync is connected to GNSS for data collection and timing is located in a remote location, local SecureSync units can be used to provide the 1PPS signal to the GSG Simulators. Time transfer between the local SecureSync receiving GNSS signals and the remote SecureSync can be done using IP based timing (PTP or NTP) or directly using coaxial cables (IRIG or 1PPS signals). Network timing can provide synchronization as low as 100’s of nanoseconds to millisecond time differences.

The affect the difference in timing has on the system varies. With nanosecond level of timing, the system allows for transitions between live sky and indoor zone, or between indoor zone and indoor zone with no reset or loss of signal during transition, effectively providing a seamless rapid transition for the user. With microsecond and millisecond levels of time synchronization, it will take a longer time (up to 1 minute) for the receiver to transition between live sky and indoor zone. It may also require a loss of the live sky signals completely for the receiver to transition over to the indoor zone position. Indoor zone transitions (between zones) will still be very fast though because the zones will be < 1ns synchronized to the each other, the offset due to timing variations will only occur for the live sky to indoor zone case.

2.3 RF Generation

The GSG Simulator is used to generate the GNSS RF signals for transmission within each zone. Multiple GSG Simulators can utilize data and timing signals from a single SecureSync, so the number of outdoor antennas needed for the system is minimal. A single SecureSync can be configured with enough outputs to support up to 20 GSG Simulators, each representing a different zone. An unlimited number of GSG Simulators can receive the time using NTP and access the collected data of a single SecureSync, and multiple SecureSync unitss can be slaved to provide the 10MHz and 1PPS signals. This makes the system scalable and able to accommodate many zones for large deployments. Figure 3 illustrates an example deployment.

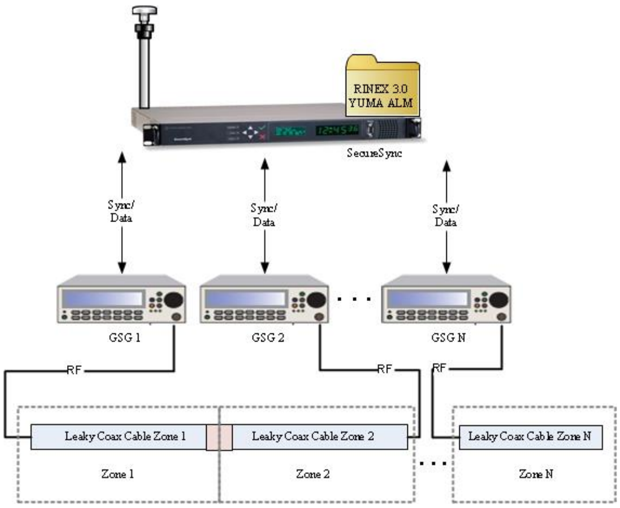

Fig. 3 Example Deployment

The GSG Simulator generates the GPS/GNSS signals by utilizing the available RINEX 3.0 and YUMA almanac files. The satellite orbits are determined using the RINEX 3.0 data, and the NAV message is filled using the data from the RINEX and YUMA files. This is a standard function of the GSG Simulator and therefore no special firmware or customization of the simulator software is needed. Both the SecureSync and the GSG Simulator are COTS products configured for use in the Intelligent Repeater System.

The sources for both the NTP server and the Download server in the GSG Simulator can be selected. Both of these can be set to a SecureSync or to an internet server. Figure 4 shows the NTP and Download server configuration.

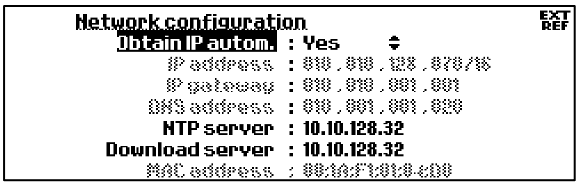

Fig. 4 GSG Simulator Server Settings

When the SecureSync has a multi-GNSS receiver installed, it can simultaneous collect the data from multiple constellations simultaneously. GSG Simulators can then generate signals for any and all constellations that have been received by the SecureSync, enabling multi-frequency, multi-constellation signal re-generation for multiple indoor zones. Currently these constellations include GPS, GLONASS, BeiDou, and QZSS. In the future the system will support Galileo as well.

3. Zones

Careful planning, installation and commissioning is required to ensure the appropriate power levels within each zone. If the signals are too strong, users transitioning to adjacent zones will be difficult, and the generated signals could leak out of the indoor areas into the outdoor locations where users are utilizing live sky signals. The users in this proximity could be negatively and unexpectedly affected. On the other hand, if the signals are too weak, the user receiver might not pick up the indoor positioning signals in some areas of the zone, or the transition from zone to zone may take longer than expected or desired. Planning the zones based on the leaky cable or antenna deployment is absolutely necessary. During installation, a known receiver can be used to measure the received signals within the zones. Using this information it is possible to adjust the power levels from each GSG Simulator so that the power level of the first zone is 2dB less than the power level of the second zone at the transition point between zones. This will allow the receiver to move from zone to zone with quick transition times, avoiding the situation where the receiver would have to completely lose the signal from one zone before picking up the next zone’s signal. Using GSG Simulators allows the power to be adjusted with a 0.1 dB resolution in each zone, so the power levels can be carefully configured and optimized during installation and commissioning.

The Intelligent Repeater System can be deployed to provide GNSS coverage into areas that do not normally receive GNSS signals. By creating zones in an underground area or within a building to differentiate floors or rooms, it is possible to locate personnel and assets to within a certain zone. Zone sizes can be set based on the area to be covered and the number of GSG Simulators deployed.

4. System Monitoring

4.1 In-Zone Monitoring

A GNSS receiver can be placed in each zone and monitored for the correct power level and position. This will allow for complete monitoring of the system from the signal generation to the signal distribution and transmission. The receivers in the zone can be monitored wirelessly or with an existing network. With large deployments, this option could become cost prohibitive and may be difficult to monitor but many of the functions could be automated to assist the user

4.2 Equipment Monitoring

The SecureSync and the GSG Simulators in the system can also be monitored for status and errors over network connections. A monitoring software can be installed on a network computer and can check the status of the SecureSync synchronization, data generation and NTP status remotely. The same monitoring software can also verify the GSG Simulator uptime, power level set, and the satellites generated. Remotely rebooting the SecureSync and GSG Simulator is also possible, to simplify maintenance procedures.

When the system is installed on individual local networks without LAN connection, network monitoring cannot be used. In this case the SecureSync can check the basic status of the GSG Simulators and report any errors using a single sum alarm via an installed relay card that can be sent to a local monitoring system.

5. Conclusion

Bringing GNSS signals indoors is a common solution to indoor positioning. A traditional GNSS repeater system can be used for this purpose but comes with several significant limitations. By dividing the coverage area into zones, personnel and assets can be located to the resolution of the zones. However, a traditional repeater system has several drawbacks. The need for an outdoor antenna for each zone indoor can rapidly drive up the system costs. Additionally, in some installations, it may not be possible to get permissions or licenses from landowners to install antennas in convenient locations above ground. Furthermore, the re-radiated position could be several hundred meters away from the actual position. On the other hand, the Intelligent Repeater System uses COTS products that can overcome these issues and still provide a reliable alternative that works with any GNSS receiver. By deploying the Intelligent Repeater System in an environment that does not normally receive GNSS signals, the safety of responders and maintenance personnel in the area is greatly improved, especially in the situations where they need to be located quickly and accurately. The flexibility and reliability of the Intelligent Repeater System make it a practical solution that can be deployed as part of building or underground infrastructure either during initial construction or as an addition to the area.

Biographies

Lisa Perdue is an Applications Engineer at Spectracom and a Subject Matter Expert (SME) in GNSS simulation. She has more than 15 years of navigation and RF systems experience, including 10 years of Naval Service.

Hironori Sasaki is the Director of Solutions Architecture at Spectracom. He has over 12 years of experience in system design, business development, and business management in government, military and other commercial applications requiring high-reliability systems. An innovator at heart, he is always seeking new and innovative solutions to drive business improvement for his customers. He excels at translating complex business improvement concepts into simple and actionable tasks. Prior to joining Spectracom, Hironori worked at Harris Corporation for 11 years. He holds an MBA from the University of Rochester and a Bachelor’s of Science in computer and systems engineering from Rensselaer Polytechnic Institute.

John Fischer is Spectracom’s Chief Technology Officer. For more than a decade, John has been at Spectracom working with global navigation satellite systems (GNSS), wireless, positioning navigation and timing (PNT) and specialized systems for customers. Prior to joining Spectracom, he specialized in wireless telecom as a founding member of two startups: Aria Wireless in 1990 and Clearwire Technologies in 1997. At Clearwire, he served as Chief Technology Officer in creating wireless broadband equipment for Internet connectivity. Early in his career, John worked as a systems engineer in radar, EW and command and control systems at Sierra Research and Comptek Research. He graduated with a Master’s and Bachelor’s of Science in Electrical Engineering and Computing Engineering from the State University of New York at Buffalo.