

GPS-Tag for Indoor location Information and Additional User Information Providing

M.H. PARK*, W.H. KIM**, S.J. LEE*, H.C. KIM***

*ETRI (Electronics and Telecommunications Research Institute), KOREA

**UST (University of Science & Technology), KOREA

***OCube CO., LTD., KOREA

E-mail: mano@etri.re.kr

Today the number of smartphone users is rapidly increasing and smartphone market is expected to reach 26% of total mobile phone market in 2011. Also the number of LBS (Location-based service) providers grew more than ten times over the year in South Korea, reflecting rising demand for LBS-based applications on smartphones.

User can have relatively good locationing performance with the built-in GPS receiver of Smartphones, which is one of major resource for location information in outdoor environments. However, user can't get a fine LBS service in indoor environment because the GPS system does not work reliably since its signal suffers from the attenuation, reflection and refraction from buildings and walls.

This paper presents a novel method to provide location information and user defined additional information with the GPS-tag to a smartphone whose built-in GPS receiver is idling in indoor and shows a signal structure and system design aspects of GPS-tag.

Keywords— Pseudolites, GPS-tag, indoor, LBS

I. INTRODUCTION

Many IT Market Reports predicted LBS to become the killer application of mobile commerce with the rapid growth of smartphone market. They expect the smartphone market to reach a quarter of total mobile phone market in 2011 and predict the LBS (Location Based Service) market size to grow exponentially from 2006 to 2010. During this period, Asia's LBS market size is expected to increase from \$291.7 million to \$447 million, Europe's market from \$191 million to \$622 million, and the U.S. market from \$150 million to \$3.1 billion [1]. Before the developments of smartphone, user can have only restricted level of LBS service due to the low h/w performance of feature phone, the lack of the service infrastructure, and immature technology developments but now can have high quality LBS service with the smartphone's versatile sensors, such as magnetometers, accelerometers, gyroscopes, built-in GPS (Global Positioning System) receiver and the help of network infrastructure. Among those method, GPS-based positioning service is the most widely used for the LBS in the world because the smartphone equipped with GPS receiver can constantly provide the user with information about the user's position in outdoors with in tens of meters accuracy.

However, the GPS receiver has a major weakness, user must have location information from GPS in indoor environments because GPS signal suffers from the attenuation,

reflection and refraction from buildings and walls so GPS system can't work consistently and reliably at inside building or underground. So many researches have been done to overcome this shortcoming and one of those solutions is Pseudolites or Pseudo-Satellites (PL's) which are designed to send GPS-like signals with the purpose to increase accuracy, integrity and availability of the system[2] [3].

We introduce a novel service for providing indoor location information and additional user information based on PL system and present the signal structure to accommodate these services.

II. GPS OVERVIEW AND ITS APPLICATION

A. GPS overview

The GPS is a 3D navigation system based on a constellation of multiple satellites. GPS utilizes the concept of TOA range measurement to calculate the user position. In order to get the its location, a GPS receiver has to measure the time from at least four different satellites it takes for a signal transmitted by emitter at a known location to reach a GPS receiver. The distance between the emitter and receiver is obtained by multiplying the signal propagation time and the speed of the signal. By measuring the propagation times from multiple satellites at known position, the GPS receiver can calculate its position. But the receiver must maintain its lock on each satellite's signal for a period of time enough to receive the information encoded in the transmission as the navigation message. Locking on more than four satellite signals simultaneously and consistently is difficult because GPS signal's frequency is very high (ex. 1575.42MHz for L1) and its high directivity prevents bend around or pass through solid objects in the signal's path. For this reason, user can't have GPS services indoors, undergrounds and outdoors, tall building, dense foliage, or terrain that stands between a GPS receiver and a satellite will block the satellite's signal.

B. GPS Signal

GPS signal utilize the CDMA (Code Division Multiple Access) Technique, in which all the satellites share the same bandwidth. All the satellites have a unique PRN (Pseudo Random Noise) code assigned to them which is used by the GPS receiver to de-spread and recover the satellite signal from the background noise. The GPS signals are transmitted on two radio frequencies, referred to as L1 (1575.42MHz) and L2 (1227.60MHz). The signals are composed of three parts -

carrier, Navigation Message, Spreading Sequence or PRN code. The Navigation Message contains the information regarding satellite orbits. The navigation data have a bit rate of 50 bps and the message consists of words of 30 bits so it takes 0.6s to read one navigation message word.

Each satellite has two unique PRN codes - C/A (Coarse/Acquisition) code and encrypted precision code (P(Y)) - and C/A code is the standard code used for free open access service for civilian users. The C/A code is a sequence of 1023 chips (or bits) and the code is repeated each ms giving a chipping rate of 1.023MHz and modulated onto the L1 carrier. Figure 1 is a block diagram describing the GPS signal generation and the signal transmitted from satellite k is given by

$$S_k(t) = \sqrt{2P_c}(C_k(t) \oplus D_k(t)) \cos(2\pi f_{L1}t) \quad (1)$$

P_c : The powers of signals with C/A code

C_k : The C/A code sequence of satellite number k

D_k : The navigation data sequence

f_{L1} : The carrier frequencies of L1

The spreading codes used as GPS codes are a kind of Gold code, referred to as pseudo-random sequences or PRN sequence. PRN codes for the GPS satellites are deterministic sequences with noise-like properties. The C/A codes generated using a tapped LFSR (Linear Feedback Shift Register) and defined uniquely as a string of 0s and 1s with the required autocorrelation properties, i.e., Nearly no cross correlation and nearly no correlation except for zero lag[4].

There are 36 legacy C/A code for satellites and an additional set of 173 C/A PRN sequences for future GPS satellites, future augmentation systems and other applications like Pseudolites [5].

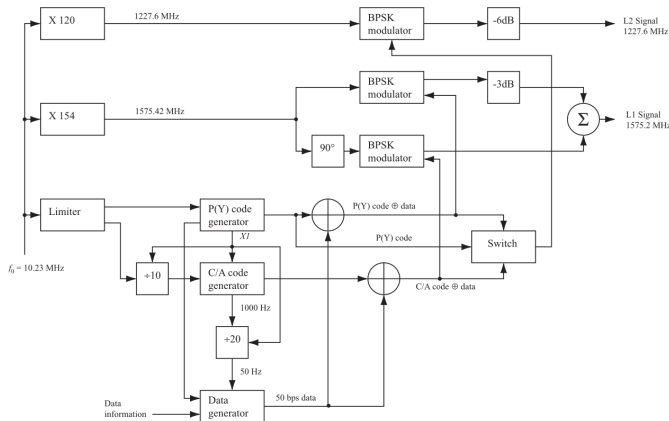


Figure 1. Block diagram of GPS signal generation

C. Pseudolites

Because indoor spaces and some outdoor spaces like urban with narrow streets surrounded by tall buildings make a typical environment where GPS can't work due to GPS signal degradation, Ground-based transmitters, Pseudolites have been used to complement the satellites by improving navigation availability and geometry for navigation. These auxiliary ground-based transmitters can augment existing GPS navigation and positioning techniques by providing valuable

ranging information in areas where the normal satellite constellation does not have sufficient availability and by serving as a backup system if one or more satellites signal failures happen unexpectedly. Another benefit of Pseudolites is a significant improvement in vertical position accuracy [6][7]. The typical application of a vertical position accuracy improvement is the aircraft applications in airport areas, improving all the vertical DOP (Dilution of Precision) that allows aircraft to approach and land precisely and safely. Because the satellites are always above the aircraft while Pseudolites are below the aircraft and this constellation can decrease the VDOP and increase the vertical position accuracy by operating a Pseudolites at carefully chosen location. Recently lots of variations of Pseudolites have been studied to give Pseudolites more flexibility and functionality with the advent of enhanced signal characteristic and modifications of signal structure.

D. IMES

A typical example of Pseudolites applications is the Japan's IMES (Indoor Messaging System) that designed to provide a user seamless indoor and outdoor positioning service with a GPS-enabled Phone, receiver or other portable device and some useful information by modification of GPS navigation message format. IMES is designed to provide accurate positioning indoors where GPS and other type of GNSS signal aren't available or unreliable. By slight modification of GPS receiver firmware with the navigation message decoding block and no hardware modification, this application is able to have GPS interoperability and meant to pick up where GPS fails, in a seamless way - using satellite signals outside in the usual way, while using signals from IMES transmitter indoors, where satellite signal quality is reduced.

IMES transmitter sends an RF signal similar to that of GPS and the Japanese QZSS (Quasi-Zenith Satellite System), providing the position of the center of its cell coverage zone and additional information by predefined message type configuration [8]. The position and additional information in the IMES navigation message is periodically broadcasted instead of the ephemeris data, clock corrections, and so on contained in the GPS message. The IMES uses the same L1 frequency and modulation method with ordinary GPS and utilizes the dedicated spread code from the same family of GPS codes, PRN code 173-182 from the C/A code allocation. Those codes are used for the IMES-compatible GPS receiver to de-spread the spread spectrum modulation and to decode the navigation message. Not like ordinary GPS system, IMES directly provides the designated position of IMES transmitter to user so pseudo-ranging or time determination is not necessary. IMES defines four different types of message. Two of these messages are used for delivering location information like latitude, longitude, and height or altitude and the rest for sending identifier to address additional data, such as maps and route guidance.

Although IMES can provide user with location information and additional information using GPS-compatible receiver, its ability and feasibility are quite restricted. For example, if a user wants to receive the location information of IMES

transmitter then user must remain in IMES transmitter's cell area for relatively long time. In the best case scenario of Message type 0 which use 3 words to convey the location information, it takes 1.8 second to get whole location information and in worst cast, it takes about 3.6 second to complete message reception.

III. GPS-TAG SYSTEM

A. overview

As mentioned earlier, GPS signal use the PRN code for spreading and de-spreading the navigation message. By the orthogonal property of PRN code, satellites can transmit its signal simultaneously and receiver can identify each GPS signal and reconstruct the message from the mixed signals that are below the noise floor. We utilized this property to send more information to user instantaneously and designed more efficient Pseudolites application, GPS-Tag to provide user location information in a shorter time than other application and to support a various type of information exploiting the functionality of information service provider system.

The signal transmitted from a GPS-Tag which use n channels to send to send data simultaneously is given by

$$S(t) = \sqrt{2P_c}(\sum_{i=1}^n C_i(t) \oplus D_i(t)) \cos(2\pi f_{L1}t) \quad (2)$$

Figure 2 shows the correlation properties example of the GPS-Tag which uses 5 channels and we can verify that multi-channel GPS-Tag signal holds the auto- and cross-correlation properties of the C/A code.

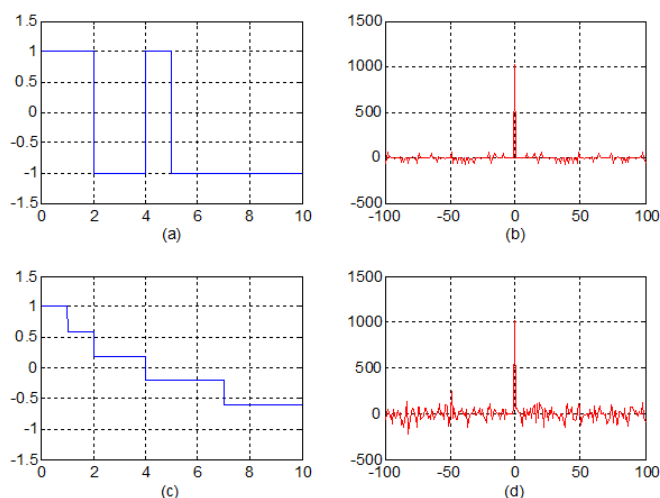


Figure 2. The Correlation Properties example of GPS-Tag

(a) PRN1 first 10 chips, (b) PRN1 ⊗ PRN1,

(c) sum{PRN1:PRN5} first 10 chips, (d) sum{pm1:pm5} ⊗ PRN1

B. GPS-Tag Design

The key idea of GPS-Tag system is multi-channel transmission and combination of user message construction method. GPS-Tag signal structure is basically similar to that

of GPS satellites signals except for the handling of the navigation message. Therefore user might use same GPS receiver both indoor and outdoor. Table 1 shows signal properties of GPS-Tag. The RF characteristics of GPS-Tag are the same with GPS L1 C/A code. The same carrier frequency (1575.42 MHz) is used for transmitting and the same modulation scheme is applied. GPS-Tag will use PRN code 159- 210 of GPS PRN code allocations for spreading and dispreading the data.

Table 1. GPS-Tag signal properties

Item	GPS-Tag
Carrier Frequency	1575.42 MHz
PRN Code	159-210
PRN Chip Rate	1.023 MHz
PRN Chip Length	1 ms
Data Rate	50 bps × No. Ch.
Modulation	BPSK

GPS-Tag signal accommodates multi-channel slotted structure to have shift messaging ability and extended information service functionality. The slot consists of word of 32 bits to have the consistency with the character-based representation and improve the messaging efficiency. So if GPS-Tag use 5 channels to send message then user can have 160 bits (20 bytes) in 0.64s, which is relatively high data rate for GPS based application. Depend on user configuration. GPS-Tag frame can be composed of multiple slots – up to 4 slots in our configuration and periodically broadcast the GPS-Tag frame to give user a various information service. Figure 3 is the example of GPS-Tag frame with 4 slots plus 5 channels allocation providing ordinary message information and location information.

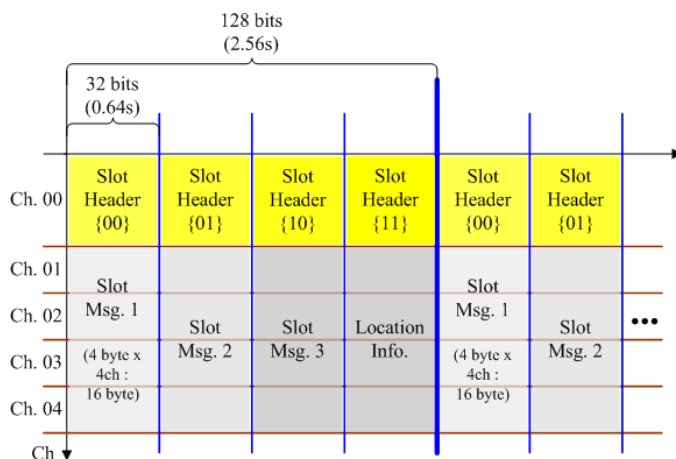


Figure 3. GPS-Tag signal structure

Among the multiple channel information, the first channel information is used for GPS-Tag slot header, which holds information about the slot and figure 4 shows the example of GPS-Tag slot header configuration and content. In our design, GPS-Tag slot header includes frame sync, GPS-Tag frame and slot info, user data index to upgrade messaging capability,

location information flag, and so on. Slot Message Frame consists of the others and delivering GPS-Tag service provider's message –text messages, Location information, link for further information, etc. - in parallel transmission scheme.

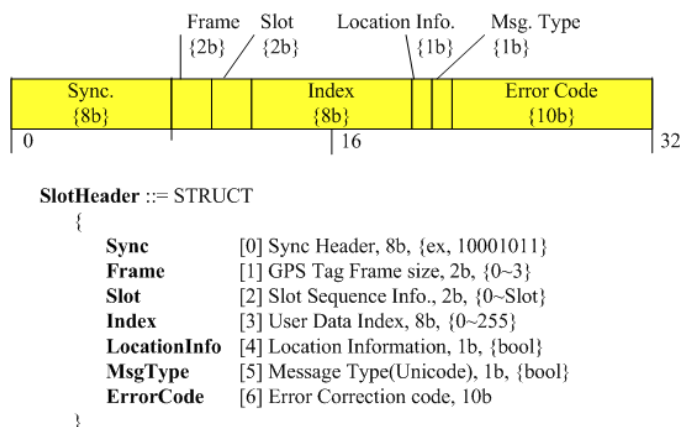


Figure 4. GPS-Tag Slot Header

The first 8 bits of header are always set and user can search though the Slot Header channel message for the first occurrence of the frame sync. GPS-Tag frame field hold the number of slots that compose the whole frame and the slot field indicates which slot is currently transferring. The 8 bits long User Data Index is adopted to improve the messaging efficiency.

Index	Message
000	Big Chance!!!
	⋮
100	Welcome to {blank}!
	⋮
255	{blank}

- User Data Index : 100, "Welcome to {blank}!"
- Slot Message : "My World"
- Final Service Message : Codebook message + Slot Message, "Welcome to My World!"

Figure 5. Message combination example

Even though multi-channel scheme could increase the GPS-Tag's data rate, it could provide only 8 Unicode per slot, which is much lower than performance of other information services. We solved this constraint of GPS-Tag system by utilizing user data index in GPS-Tag slot header with adaptation of codebook based messaging method used in telegraph system. We allocated in our experimental design 8 bit user data index and could indicate 256 predefined long messages which are allocated by service provider in advance as a message codebook and distributed to smartphone user when GPS-Tag related application is installed and updated.

After GPS-Tag compatible receiver completely receive an individual slot then decode the user data index. The long

message in the message codebook is retrieved by index value and combined with 8 Unicode message of the Slot Message Frame then makes whole and upgraded service message for GPS-Tag service provider. Figure 5 shows an example of proposed message service.

IV. CONCLUSIONS

In this paper, we presented a new system GPS-Tag for indoor location information providing and upgraded additional user information service. We introduced parallelized transmission architecture to increase total information bitrate of GPS-Tag system by utilizing the orthogonality of PRN codes. Also we enhanced the feasibility of message system by combination message method, which blends long predefined codebook message with service provider's short slot message then produce whole and effective message for service provider.

We will continue our research, update the GPS-Tag design, implement GPS-Tag system, and demonstrate experiments in a real environment so that GPS-Tag system becomes widely used and powerful method for indoor locationing.

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