Next Generation Software-based GPS Receiver for Real-World Applications

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BIOGRAPHY

Francis Yuen has over 20 years of extensive experience in GPS product design and business development. Francis is the founder and CEO of Baseband Technologies Inc., a company that specializes in software based GPS receiver design for consumer electronics. Francis possesses two engineering degrees in Microelectronics and an MBA from Richard Ivey School of Business.

Zhe Liu has worked in the GPS and INS navigation research and development field since 1994, he is the senior GNSS specialist at Baseband Technologies Inc.. He obtained a Master degree at University of Calgary, a Master degree and a Bachelor degree at Beijing University of Aeronautics & Astronautics.

ABSTRACT

This paper introduces a next generation software-based GPS receiver technology that is capable of providing meters level accuracy, independent raw measurements and PVT (position, velocity, time) solutions using as little as 1-2ms (millisecond) of I/Q samples. This unprecedented performance is based on a revolutionary patent pending technology called Deep-R™.

Unlike conventional software based processing techniques, Deep-R™ does not require an initial position. Initial time tag can be provided by an external time source with errors up to 10's of minutes.

Deep-R™ does not employ the use of tracking loops, as a result, the problems with maintaining lock in the tracking loops are completely eliminated. When used in streaming mode, Deep-R™ is capable of generating 500Hz of independent raw measurements and PVT solutions.

Deep-R™ provides a low-cost solution for GPS positioning without the need for significant processing power and expensive hardware. Instead of using a dedicated baseband processor, Deep-R™ employs only a low-cost RFIC to extract, down-convert and demodulate GPS signals. Processing is performed in software using a general purpose processor such as a microprocessor or a digital signal processor. This flexible approach significantly reduces power consumption and is therefore ideal for modern consumer electronics.

INTRODUCTION

Software based GPS receiver technology is a concept where the GPS baseband processor is replaced by software that runs on a computer or an embedded processor (e.g. ARM9, XScale etc.). One of the principal benefits is to lower component cost. Additionally, with the convenience of software upgrades, software based GPS receivers can frequently be improved with algorithmic enhancements and added functionalities.

Unfortunately, conventional software based GPS receiver technologies require extensive CPU and memory resources to implement. As a result, they all failed to meet the demanding nature of real world consumer electronics in fast position fix, minimizing component costs and achieving the lowest possible power consumption.

Developed by Baseband Technologies Inc., Deep-R™ is a next generation software based GPS receiver technology to specifically address these problems.

SYSTEM ARCHITECTURE

With the recent advancements in microelectronics, consumer electronics such as personal navigation devices (PND) and mobile phones etc. typically implement GPS functions using a GPS chipset (see Figure 1).

Software based GPS receiver essentially replaces the GPS chipset with a low cost RFIC and baseband processing algorithm that runs on the microprocessor of the host system (see Figure 2). The RFIC is used solely to extract, down-convert and demodulate GPS signals and output in digital I/Q formats.

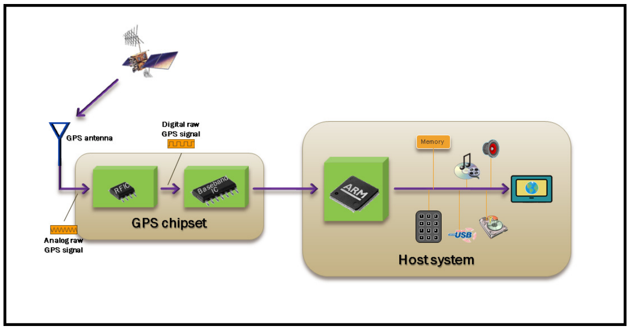

Figure 1: Hardware based GPS receiver

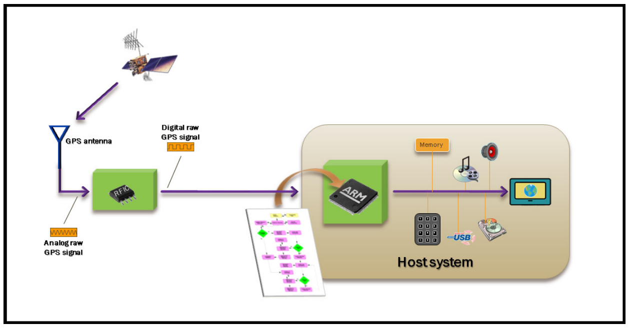

Figure 2: Software based GPS receiver

Conventional software based receivers acquire, track and decode GPS navigation message in real-time. The purpose of acquisition is to identify all satellites visible to the receiver. In order for traditional receivers to compute PVT, it requires real-time navigation message data. When the signal is properly tracked, the C/A code and the carrier wave are removed, leaving only the navigation message data bits for decoding. By decoding the navigation message, traditional GPS receivers can determine the GPS time tag by using the Z-count to align the locally-generated signals with the received signals. Subsequently, using the time tag, or the Z-count, embedded in the navigation message, the exact time of when the navigation message was transmitted from the satellite can be determined.

Once the navigation message is decoded, the ephemeris data (used later to compute the position of the satellite at the time of transmission), or the almanac data, for the satellite will be available. Other useful information such as Ionospheric correction parameters for single-frequency users and satellite clock corrections parameters can also be decoded for later use. Finally, pseudoranges are computed based on the time difference between the satellite transmitted time and the receiver received time.

Assuming the satellite signal is strong, the process of searching for and acquiring GPS signals, reading the ephemeris data for multiple satellites and computing the location of the receiver from this data is very time consuming and often requires from 10's of seconds to a few minutes for "Cold Start".

The Deep-R™ software based receiver technology uses a radically different approach in that it does not continuously track and decode navigation messages. Instead, it requires only 2ms of I/Q samples and an ephemeris file to process a PVT solution. In the case of real-time application, the ephemeris file contains predicted orbits and clock states that can be used up to 28 days. For post mission application, an ephemeris file with historic satellite orbits and clock states can be downloaded on demand.

UNIQUE DEEP-R™ FEATURES

a. Data throughput

One of the most unique features of Deep-R™ is its ability to capture a position within 2ms of I/Q samples. At a sampling rate of 4.092 MHz using 2-bit I, 2-bit Q data format, the amount of I/Q data required to transfer from the RFIC to the microprocessor is only 4KB for Deep-R™. Compare this with conventional software based receiver technologies, the data transmission rate is 2MB/sec. for a few seconds to minutes depending on the time it requires for "cold start" (see Table 1).

	Traditional SW GPS	***Deep-R™ SW GPS***
Sampling Frequency	4.092 MHz	4.092 MHz
Raw GPS signal needed	5 - 60 sec.	0.002 sec.
# of samples	4,092,000 per sec.	8,184 per 0.002 sec.
Data Format (raw data)	2-bit I, 2-bit Q	2-bit I, 2-bit Q
Data Size	2,000 KB/sec. (16 Kb/sec.)	4 KB (32 Kb)

Table 1: Data size comparison

b. Initial position

There is no requirement to provide an initial position for Deep-R™ prior to processing. This feature is especially important for consumer based products that are aimed for today's highly mobile international travelers.

For applications where reliable position information is available, Deep-R™ is capable of accepting independent position input to speed up the positioning process.

c. Initial time tag

Deep-R™ requires a rough time tag attached to the 2ms I/Q samples. The accuracy of the time tag, however, can be quite loose as long as 10's of minutes. As a large majority of today's consumer electronics are likely built with a real-time clock that exceeds this requirement, initial time tag requirement should be easily met.

d. Independent raw measurements and PVT solutions

In addition to PVT solutions, Deep-R™ is capable of outputting raw measurements such as Doppler and Code Phase information. In addition, since raw measurements and PVT solutions are generated using only the 2ms I/Q samples, each 2ms sample is independently processed and has no correlation with any 2ms samples before or after it.

e. Ultra high 500Hz in streaming mode

With using only 2ms of I/Q samples to compute raw measurements and PVT solution, when operated in real time streaming mode, it gives rise to a unique ability for Deep-R™ to output at an ultra fast rate of 500Hz of independent raw measurements and PVT solutions. This capability is perhaps the highest output rate for unaided GPS receivers known in the industry to date.

f. No tracking loop design

In order to precisely track code and carrier, conventional receivers typically employ the use of tracking loops. Depending on the design, tracking loop bandwidth may have adverse effects on the dynamic range of a receiver. Tradeoffs are often made to optimize tracking loop bandwidth between receiver performance and noise rejection.

Deep-R™ has a unique no tracking loop design, as a result, the problems with maintaining lock in the tracking loops as well as the dilemma to tradeoff between receiver performance and noise rejection are completely eliminated. Deep-R™ is therefore suitable for very high dynamic applications.

g. Ultra low power

In order for Deep-R™ to operate, the RFIC (≈10 mA) must be turned on for 2ms. In addition, if Deep-R™ is to operate in real time mode, the microprocessor (≈50 mA) and the SDRAM (≈250 mA) must be activated long enough to process the 2ms I/Q samples. The total current consumption is therefore around 310 mA with the majority of the power used in the SDRAM.

Assuming a CR123 camera battery has a capacity of 700mAh, it can power the RFIC/CPU/RAM for 2.25 hours continuously.

Assuming further that it takes 100ms for Deep-R™ to compute a PVT solution, a CR123 battery has potential to compute 80,000+ PVT solutions on one single charge. The level of performance exceeds the typical power requirements of most, if not all, consumer applications.

h. Position Accuracy

Deep-R™ requires minimum of 5 satellites with relatively good DOP's for processing. Typical errors caused by ionosphere, troposphere, multipath and receiver noise etc. contribute to the overall error budget.

Typical position accuracy with 8-10 satellites in open sky is around meters level.

i. Work flow

Deep-R™ is a collection of four utilities:

- StoreGPS: Collects I/Q samples (2ms default)
- VerifyGPS: Verifies sample files for sufficient number of satellites
- GetOrbitInfo: Retrieves satellite orbit data and clock correction information
- ProcessGPS: PVT processing engine

Deep-R™ can be configured to operate in real time or in post processing modes. Prior to operating in real time mode (see Figure 3), a small file containing satellite orbits and clock states can be downloaded to predict up to 28 days into the future.

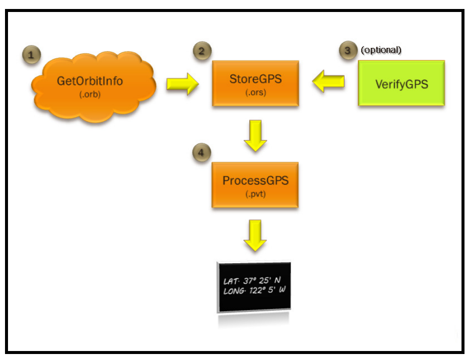

Figure 3: Deep-R™ in real time mode

For operating in post process mode (see Figure 4), a small file containing historic satellite orbits and clock states is downloaded at the time of PVT processing.

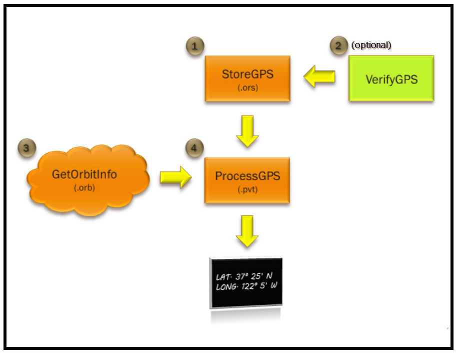

Figure 4: Deep-R™ in post process mode

EVALUATION KIT

Deep-R™ was designed specifically for high volume consumer electronics products. For evaluation purpose, some users may prefer to test Deep-R™ in an independent and proven embedded environment. An ARM9 based evaluation board was developed (see Figure 5) to provide users with an ideal platform for rapid data collection, testing and experimentation.

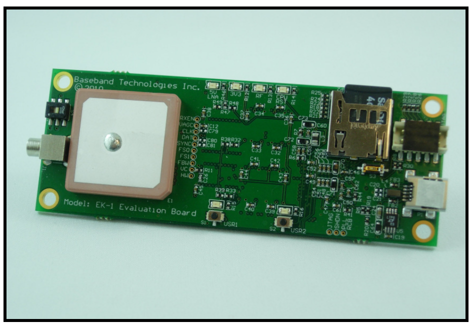

Figure 5: EK-1 Evaluation Kit

CONCLUSION

In this paper, a patent pending next generation software based receiver technology called Deep-R™ was presented.

Deep-R™ is capable of providing meters level accuracy, independent raw measurements and PVT (position, velocity, time) solutions using as little as 1-2ms I/Q samples. When used in streaming mode, Deep-R™ is capable of providing 500Hz of independent raw measurements and PVT solutions.

Designed for today's highly mobile international travelers in mind, Deep-R™ does not require an initial position prior to operation and needs only a rough initial time tag from an external time source.

Deep-R™ employs a unique no tracking loop design to completely eliminate the problems with maintaining lock in the tracking loops as well as the dilemma to tradeoff between receiver performance and noise rejection that exists in conventional receivers. As a result, Deep-R™ technology can support ultra high dynamic applications.

Deep-R™ provides a low-cost solution for GPS positioning without the need for significant processing power and expensive hardware.

ACKNOWLEDGMENTS

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