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DATA BOUNDARY AWARE BASE STATION ASSISTED POSITION LOCATION METHOD

G00002

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to position location. More particularly, the present invention relates to a novel and improved method and apparatus for performing position location in wireless communications system.

II. Description of the Related Art

Both government regulation and consumer demand have driven the demand for position location functionality in cellular telephones. The global positioning system (GPS) is currently available for performing position location using a GPS receiver in conjunction with a set of earth orbiting satellites. It is therefore desirable to introduce GPS functionality into a cellular telephone.

Cellular telephones, however, are extremely sensitive to cost, weight and power consumption considerations. Thus, simply adding additional circuitry for performing GPS location is an unsatisfactory solution for providing position location functionality in a cellular telephone. Thus, the present invention is directed to providing GPS functionality in a cellular telephone system with a minimum of additional hardware, cost and power consumption.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and apparatus for performing position location in wireless communications system. One embodiment of the invention comprises a method for performing position location on a subscriber unit in a terrestrial wireless telephone system using a set of satellites each transmitting a signal, the terrestrial wireless telephone system having base stations, including the steps of transmitting an aiding message from the base station to the subscriber unit, said aiding message containing information regarding a data boundary for each signal from the set of satellites, applying correlation codes

to each signal yielding corresponding correlation data and accumulating said correlation data over an first interval preceding a corresponding data boundary yielding a first accumulation result, and a second interval following said corresponding data boundary yielding a second accumulation result.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

Fig. 1 is a block diagram of the Global Positioning System (GPS) waveform generator;

Fig. 2 is a highly simplified block diagram of a cellular telephone system configured in accordance with the use of present invention;

Fig. 3 is a block diagram of a receiver configured in accordance with one embodiment of the invention;

Fig. 4 is another block diagram of the receiver depicted in Fig. 3;

Fig. 5 is a receiver configured in accordance with an alternative embodiment of the invention;

Fig. 6 is a flow chart of the steps performed during a position location operation;

Fig. 7 is a block diagram of a DSP configured in accordance with one embodiment of the invention;

Fig. 8 is a flow chart illustrating the steps performed during a search performed in accordance with one embodiment of the invention;

Fig. 9 is a time line illustrating the phases over which fine and coarse searches are performed in one embodiment of the invention;

Fig. 10 is a time line of the search process when performed in accordance with one embodiment of the invention;

Fig. 11 is a diagram of search space.

Fig. 12 is a block diagram of a receiver in accordance with another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A novel and improved method and apparatus for performing position location in wireless communications system is described. The exemplary embodiment is described in the context of the digital cellular telephone system. While use within this context is advantageous, different embodiments of the invention may be incorporated in different environments or configurations. In general, the various systems described herein may be formed using software controlled processors, integrated circuits, or discreet logic, however, implementation in an integrated circuit is preferred. The data, instructions, commands, information, signals, symbols and chips that may be referenced throughout the application are advantageously represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or a combination thereof. Additionally, the blocks shown in each block diagram may represent hardware or method steps.

Fig. 1 is a block diagram of the Global Positioning System (GPS) waveform generator. The circle with a plus sign designates modulo-2 addition. In general, the GPS constellation consists of 24 satellites: 21 space vehicles (SVs) used for navigation and 3 spares. Each SV contains a clock that is synchronized to GPS time by monitoring ground stations. To determine a position and time, a GPS receiver processes the signals received from several satellites. At least 4 satellites must be used to solve for the 4 unknowns (x, y, z, time).

Each SV transmits 2 microwave carriers: the 1575.42 MHz L1 carrier, which carries the signals used for Standard Positioning Service (SPS), and the 1227.60 MHz L2 carrier, which carries signals needed for Precise Positioning Service (PPS). PPS is used by governmental agencies and allows a higher degree of accuracy in positioning.

The L1 carrier is modulated by the Coarse Acquisition (C/A) code, a 1023-chip pseudorandom code transmitted at 1.023 Mcps that is used for civil position location services. (The Coarse Acquisition code should not be confused with the coarse and fine acquisitions described herein, which both involve the use of the C/A codes.) Each satellite has its own C/A code that repeats every 1ms. The P code, which is used for PPS, is a 10.23 MHz code that is 267 days in length. The P code appears on both carriers but is 90 degrees out of phase with the C/A code on the L1 carrier. The 50Hz navigation message, which is exclusive-ORed with both the C/A code and P

code before carrier modulation, provides system information such as satellite orbits and clock corrections.

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Each satellite has a different C/A code that belongs to a family of codes called Gold codes. Gold codes are used because the cross-correlation between them are small. The C/A code is generated using two 10-stage shift registers as shown below in figure 1.4-2. The G1 generator uses the polynomial $1+X^3+X^{10}$, while the G2 generator uses the polynomial $1+X^2+X^3+X^6+X^8+X^9+X^{10}$. The C/A code is generated by exclusive ORing the output of the G1 shift register with 2 bits of the G2 shift register.

Fig. 2 is a highly simplified block diagram of a cellular telephone system configured in accordance with the use of present invention. Mobile telephones **10** are located among base stations **12**, which are coupled to base station controller (BSC) **14**. Mobile switching center MSC **16** connects BSC **14** to the public switch telephone network (PSTN). During operation, some mobile telephones are conducting telephone calls by interfacing with base stations **12** while others are in standby mode.

As described in copending US patent application serial no. 09/040,051 entitled "SYSTEM AND METHOD FOR DETERMINING THE POSITION OF A WIRELESS CDMA TRANCEIVER" assigned to the assignee of the present invention and incorporated herein by reference, position location is facilitated by the transmission of a position request message containing

"aiding information" that allows the mobile telephone to quickly acquire the GPS signal. This information includes the ID number of the SV (SV ID), the estimated code phase, the search window size around the estimate code phase, and the estimated frequency Doppler. Using this information, the mobile unit can acquire the GPS signals and determine its location more quickly.

In response to the aiding message, the mobile unit tunes to the GPS frequency and begins correlating the received signal with its locally generated C/A sequences for the SVs indicated by the base station. It uses the aiding information to narrow the search space and compensate for Doppler effects, and obtains pseudo-ranges for each satellite using time correlation. Note that these pseudo-ranges are based on mobile unit time (referenced from the CDMA receiver's combiner system time counter), which is a delayed version of GPS time.

Once this information is calculated, the mobile unit sends the pseudo-ranges for each satellite (preferably to 1/8 chip resolution) and the time the measurements were taken to the base station. The mobile unit then retunes to CDMA to continue the call.

Upon, receipt of the information, the BSC uses the one-way delay estimate to converts the pseudo-ranges from mobile unit time to base station time and computes the estimated position of the mobile unit by solving for the intersection of several spheres.

Another parameter provided by the aiding message is the frequency Doppler or Doppler offset. The Doppler effect manifests as an apparent change in the frequency of a received signal due to a relative velocity between the transmitter and receiver. The effect of the Doppler on the carrier is referred to as frequency Doppler, while the effect on the baseband signal is referred to as code Doppler.

In the GPS case, frequency Doppler changes the received carrier frequency so the effect is the same as demodulating with a carrier offset. Since the base station's GPS receiver is actively tracking the desired satellite, it knows the frequency Doppler due to satellite movement. Moreover, the satellite is so far away from the base station and the mobile unit that the Doppler seen by the mobile unit is effectively the same as the Doppler seen by the base station. In one embodiment of the invention, to correct for the frequency Doppler value, the mobile unit uses a rotator in the receiver. The frequency Doppler ranges from –4500Hz to +4500Hz, and the rate of change is on the order of 1 Hz/s.

The effect of the code Doppler is to change the 1.023Mhz chip rate, which effectively compresses or expands the width of the received C/A code chips. In one embodiment of the invention, the mobile unit correct for code Doppler by multiplying the frequency Doppler by the ratio 1.023/1575.42. The mobile unit can then correct for code Doppler over time by slewing (introducing delay into) the phase of the received IQ samples in 1/16 chip increments as necessary.

Fig. 3 is a block diagram of the receiver portion of a cellular telephone (wireless subscriber unit) configured in accordance with one embodiment of the invention. The received waveform **100** is modeled as the C/A signal c(n) modulated with a carrier at frequency $w_c + w_d$, where w_c is the nominal carrier frequency 1575.42 MHz, and w_d is the Doppler frequency created by satellite movement. The Doppler frequency ranges from 0 when the satellite is directly overhead, to about 4.5kHz in the worst case. The receiver analog section can be modeled as demodulation with a carrier at frequency w_r and random phase θ, followed by low pass filtering.

The resulting baseband signal is passed through an A/D converter (not shown) to produce digital I and Q samples, which are stored so that they may be repeatedly searched. The samples are generated at two times the C/A code chip rate (chipx2) which is a lower resolution than necessary to perform the fine search algorithm, but which allows 18 ms of sample data to be stored in a reasonable amount of memory. In general, it is desirable to perform the searching over something greater than 10ms in order to allow acquisition in most environmental conditions, with 18ms being a preferred integration period. These environmental conditions include being inside or not having a direct view to the satellite.

During operation, the samples are first rotated by rotator **102** to correct for the Doppler frequency offset. The rotated I and Q samples are correlated with various offsets of the satellite's C/A sequence and the resulting products are coherently integrated over Nc chips by integrators **104**. The coherent integration sums are squared and added together to remove the effect of the unknown phase offset θ. To augment the hypothesis test for a particular offset, several coherent intervals are non-coherently combined. This despreading is performed repeatedly at various time offsets to find the time offset of the satellite signal. Rotator **102** removes the frequency Doppler created by satellite movement. It uses the Doppler frequency specified by the base station (preferably quantized to 10Hz intervals) and rotates the I and Q samples to remove the frequency offset.

In one embodiment of the invention, the rotation is continuous only over the coherent integration window. That is, the rotator stops in between coherent integration periods of, for example, 1 ms. Any resulting phase difference is eliminated by the square and sum.

Fig. 4 is another block diagram of a receiver configured in accordance with one embodiment of the invention, where the rotator portion of the receiver is depicted in greater detail.

Fig. 5 is a receiver configured in accordance with an alternative embodiment of the invention. This internal embodiment of the invention takes advantage of the ability to stop the rotator between coherent integration periods by rotating the locally generated C/A sequence instead of the input samples.

As shown, the C/A sequence c(n) are rotated by application to the sinusoids $\sin(W_d n T_C)$ and $\cos(W_d n T_C)$ and then stored. The rotation of the C/A sequence only needs to be done once for each satellite. Thus, rotating the C/A sequence reduces the amount of computation required. It also saves memory in the DSP used to perform this computation in one embodiment of the invention.

Another significant impairment that degrades the performance of the position location algorithm is the frequency error in the mobile units internal clock. It is this frequency error which drives the use of short coherent integration times on the order of 1 ms. It is preferable to perform coherent integration over longer time periods.

In an exemplary configurations, the mobile's free running (internal) local oscillator clock is a 19.68MHz crystal that has a frequency tolerance of +/-5ppm. This can cause large errors on the order of +/- 7500 Hz. This clock is used to generate the carriers used for demodulation of the GPS signals, so the clock error will add to the signal acquisition time. Because the time available to search is very small, error of this magnitude due to the frequency tolerance are not tolerable and must be greatly reduced.

To allow longer coherent integration times, in one embodiment of the invention, the CDMA receiver corrects for local oscillator error by using timing acquired from the CDMA pilot, or any other source of timing information available. This produces a control signal that is used to tune the local oscillator clock to 19.68MHz as closely as possible. The control signal applied to the local oscillator clock is frozen when the RF unit switches from CDMA to GPS.

Even after the correction is performed using the timing information from the bases station (or other source), however, some additional clock error

remains. In one embodiment of the invention, the resulting frequency uncertainty after correction is +/- 100Hz. This remaining error still reduces the performance of the receiver, and in general prevents longer coherent integration times. In one embodiment of the invention, the remaining error simply avoided by performing non-coherent integration for duration of more than 1ms which reduces performance.

As also shown in **Fig. 1**, the 50Hz NAV/system data is also modulated onto the L1 carrier. If a data transition (0 to 1 or 1 to 0) occurs between the two halves of a coherent integration window, the resulting coherent integration sum will be zero because the two halves will cancel each other out. This effectively reduces the number of non-coherent accumulations by one in the worst case. Although the data boundaries of all the satellites are synchronized, they do not arrive at the mobile unit simultaneously because of the differences in path delay. This path delay effectively randomizes the received data phase.

In one embodiment of the invention, the problem of different data phases on different signals is to include the data phase in the aiding information sent from the base station to the mobile unit. Since the base station is demodulating the 50Hz data, it knows when the data transitions occur for each satellite. By using knowledge of the one-way delay, the base station can encode the data phase in, for example, 5 bits (per satellite) by indicating which one millisecond interval (out of 20) the data transition occurs on.

If the coherent integration window straddles the 50Hz data boundary the coherent integration is divided into two (2) sections. One section preceding the data boundary and one section following the data boundary. For example, if En1 is the coherent integration sum over the window preceding the data boundary the first half of this window and En2 is the coherent integration sum over the window following the data boundary, the mobile unit then selects the maximum (in magnitude) of (En1 + En2) (in case the data stayed the same) and (En1 – En2) (in case the data changed) to account for the phase change. The mobile unit also has the option of performing non-coherent combining of the two halves over this data window or avoiding this data window completely.

In an alternative embodiment of the invention, the mobile unit attempts to find the data transitions without the aiding information from the base station by comparing the magnitude squared of the sum and difference in 1 ms coherent integration.

In one embodiment of the invention, a firmware-based DSP (Digital Signal Processor) approach is used to perform the GPS processing. The DSP receives I and Q samples at a chipx2 (2.046 MHz) or chipx8 (8.184 MHz) rate, and stores a snapshot of 4-bit I and Q samples in its internal RAM.

In the exemplary embodiment, the DSP generates the C/A sequence, performs rotation to eliminate frequency Doppler, and correlates over the search window provided by the base station for each of the satellites. The DSP performs coherent integration and non-coherent combining and slews an IQ sample decimator as necessary to compensate for code Doppler.

To save computation and memory, the initial search is performed using _ chip resolution and a finer search to obtain 1/8 chip (higher) resolution is performed around the best index (or indexes). System time is maintained by counting hardware-generated 1ms interrupts (derived from local oscillator).

Additionally, in one embodiment of the invention, the fine search is performed by accumulating the chipx8 samples (higher resolution) over the duration of one chip at various chipx8 offsets. The correlation codes are applied to the accumulated values yielding correlation values that vary with the particular chipx8 offset. This allows the code offset to be determined with chipx8 resolution.

Fig. 6 is a flow chart illustrating the steps performed to correct for the local oscillator error during a position location procedure when performed in accordance with one embodiment of the invention. At step **500**, it is determined whether the local oscillator has been corrected recently. If not, then the pilot is acquired from the base station, and error of the local oscillator is determined by comparing to the pilot timing at step **502** and a correction signal generated based on that error.

The flow then leads to step **504**, where the correction signal is frozen at the current value. At step **506**, enters GPS mode and performs the position location using the corrected clock. Once the position location has been performed, the mobile unit leaves GPS mode at step **508**.

Fig. 7 is an illustration of a DSP receiver system configured in accordance with one embodiment of the invention. The DSP performs the entire searching operation with minimal additional hardware. DSP core **308**, modem **306**, interface unit **300**, ROM **302** and Memory (RAM) **304** are coupled via bus **306**. Interface unit **300** receives RF samples from an RF unit (not shown) and provides the samples to RAM **304**. The RF samples can be stored at coarse resolution or fine resolution. The DSP core **308** processes the samples stored in memory using instruction stored in ROM **302** as well

as in memory **304**. Memory **304** may have multiple "banks" some of which store samples and some of which store instructions. Modem **700** performs CDMA processing during normal mode.

Fig. 8 is a flow chart of the steps performed during a position location operation. A position location operation begins when the aiding messaging is received, and the RF systems is switched to GPS frequencies at step **600**. When the RF is switched to receive GPS, the frequency tracking loop is fixed. The DSP receives aiding information from the phone microprocessor and sorts the satellites by Doppler magnitude.

At step **602**, the coarse search data is stored within the DSP RAM. The DSP receives a few hundred microseconds of input data to set an Rx AGC. The DSP records the system time and begins storing an 18ms window (DSP memory limitation) of chipx2 IQ data in its internal RAM. A contiguous window of data is used to mitigate the effects of code Doppler.

Once the data is stored, a coarse search is performed at step **604**. The DSP begins the coarse (chipx2 resolution) search. For each satellite, the DSP generates the C/A code, rotates the code based on the frequency Doppler, and correlates over the search window specified by the base station, via repeated application of the C/A code to the stored coarse search data. Satellites are processed over the same 18ms data window and the best chipx2 hypothesis that exceeds a threshold is obtained for each satellite. Although a 2ms coherent integration time (with 9 non-coherent integrations) is used in one embodiment of the invention, longer coherent integration times can be used (for example 18ms), although preferably where additional adjustments are made as described below.

Once the coarse search is performed, a fine search is conducted, at step **606**. Before beginning the fine search, the DSP computes the rotated C/A code for each of the satellites. This allows the DSP to process the fine search in real-time. In performing the fine (chipx8 resolution) search, the satellites are processed one at a time over different data.

The DSP first slews the decimator to compensate for code Doppler for the given satellite(s). It also resets the Rx AGC value while waiting for the next 1ms boundary before storing a 1ms coherent integration window of chipx8 samples.

The DSP processes 5 contiguous chipx8 resolution hypotheses on this 1ms coherent integration window, where the center hypothesis is the best hypothesis obtained in the coarse search. After processing the next 1ms window, the results are combined coherently and this 2ms sum is combined non-coherently for all Nn iterations.

This step (starting from slewing the decimator) is repeated on the same data for the next satellite until all the satellites have been processed. If the code Doppler for 2 satellites is similar in magnitude, it may be possible to process both satellites over the same data to reduce the number of required data sets. In the worst case, 8 sets of 2*Nn data windows of 1ms are used for the fine search.

Finally, at step **608**, the results are reported to the microprocessor and the vocoder process is restarted within the DSP so that the call can continue. The DSP reports pseudoranges to the microprocessor, which forwards them to the base station. After the microprocessor redownloads the vocoder program code into the DSP memory, the DSP clears its data memory and restarts the vocoder.

Fig. 9 is a diagram illustrating the fine search performed after the coarse search. After isolating the best chipx2 phase in the coarse search, the DSP performs a fine search around this phase to gain chipx8 resolution.

The 5 phases to compare in the fine search are shown enclosed by a rectangle. The best chipx2 phase is evaluated again so that comparisons can be made over the same set of data. This also allows the coarse search and fine search to use different integration times. The fine search is performed separately for each satellite because each satellite may have a different value for code Doppler.

Fig. 10 provides a time line of the search process when performed in accordance with one embodiment of the invention. The overall processing time (coarse + fine search) is performed in about 1.324 seconds in one embodiment of the invention, which does interrupt the call, but still allows the call to continue once the search is performed. The total search time of 1.324 seconds is an upper bound, because it assumes that the DSP needs to search all 8 satellites and each satellite has a search window of 68 chips. The probability that the entire 1.324 seconds will be necessary is small, however, due to the geometry of the satellite orbits.

During the first 18ms **80**, IQ sample data is collected at the GPS frequency. During the period **82**, a coarse search is performed internally which could last up to 1.13 seconds, but which will probably terminate early when the satellite signals are identified. Once the coarse search is performed, the C/A codes are computed during time period **84**, which takes 24 ms. During time periods **86** the slew value is adjusted for code Doppler and the Rx AGC is further adjusted. During time periods **88**, fine searches are performed on the IQ data samples, with continuous adjustment performed during time periods **86**. The use of 18 ms integration times

allows code Doppler to be neglected because the received C/A code phase will be shifted by less than 1/16 of a chip. Up to eight sequences of adjustments and fine searches are performed for the up to eight satellites, at which time the position location procedure is complete.

Additionally, in some embodiments of the invention, the phone continues to transmit reverse link frames to the base station while the position location procedure is performed. These frames may contain null information simply to allow the base station to remain synchronized with the subscriber unit, or the frames may contain additional information such as power control commands or information request. The transmission of these frames is preferably performed when GPS samples are not being gathered when the RF circuitry is available, or while the GPS samples are gathered if sufficient RF circuitry is available.

Although the use of 18ms integration time avoids the effects of code Doppler, the transmission of data over the GPS signals at 50Hz rate can cause problems if a data change occurs within the 18ms processing span (as described above). The data change causes the phase of the signal to shift. The 50Hz data boundaries occur at different places for each satellite. The phase of the 50Hz transitions for each satellite have been effectively randomized by the varying path lengths from each satellite to the phone.

In the worst case, if the data bit was inverted in the middle of a coherent integration interval, the coherent integration could be completely wiped out. For this reason, in an alternative embodiment of the invention, the base station must communicate the data transition boundaries for each satellite to the phone (also described above). Preferably, the data transmission boundary is also included in the aiding message transmitted from the base station (such as in a set of five bit messages indicating the millisecond interval during which the transition occurs for each satellite). The phone uses this boundary to split the coherent integration interval for each satellite into 2 pieces and decide whether to add or subtract the coherent integration sums in these 2 intervals. Thus, by also including the data boundary of each GPS signal, the reliability of the location procedure is increased.

In the exemplary embodiment of the invention, any frequency uncertainty creates a loss in Ec/Nt that increases with the coherent integration time. For example, uncertainty of +/-100Hz, the loss in Ec/Nt increases rapidly as the coherent integration time is increased, as shown in Table I.

Nc	Loss in Ec/Nt
1023 (1ms)	0.14 dB
2046 (2ms)	0.58 dB
4092 (4ms)	2.42 dB
6138 (6ms)	5.94 dB
8184 (8ms)	12.6 dB

Table I.

As also noted above, there is always some unknown frequency offset of the local oscillator in the mobile unit. It is this unknown frequency offset that prevents longer coherent despreading and integration from being performed. Longer coherent would improve processing if the effects of the unknown frequency offset could be reduced.

In one embodiment of the invention, this unknown frequency offset is accounted for by expanding the search space to 2 dimensions to include frequency searches. For each hypothesis, several frequency searches are performed, where each frequency search assumes the frequency offset is a known value. By spacing the frequency offsets, one can reduce the frequency uncertainty to an arbitrarily small value at the expense of added computation and memory. For example, if 5 frequency hypotheses are used, the resulting search space is shown in **Fig. 10**.

For a +/-100Hz frequency uncertainty, which is the typically operating specification of a mobile unit, this configuration reduces the maximum frequency offset to 20Hz (one hypothesis must be within 20Hz of the actual frequency offset). With a 20ms coherent integration time, the loss in Ec/Nt with a 20Hz frequency offset is 2.42 dB. By doubling the number of frequency hypotheses to 10, the frequency uncertainty can be reduced to 10Hz, which causes an Ec/Nt loss of .58dB. However, adding additional hypotheses widens the search space, which increases both the computation and memory requirements.

One embodiment of the invention computes the frequency hypothesis by lumping the frequency offset in with the frequency Doppler, and computing a new rotated PN code for each frequency hypothesis. However, this makes the number of frequency hypotheses a multiplicative factor in the total computation: 5 frequency hypotheses would mean 5 times as much computation.

Alternatively, since the frequency uncertainty is small compared to the frequency Doppler, the rotation phase can be considered to be constant over a 1ms interval (8% of a period for an 80Hz hypothesis) in another embodiment of the invention. Therefore, by dividing the coherent integration interval up into 1ms subintervals, the integration sums of the subintervals are rotated to reduce the added computations needed to compute the frequency searches by three orders of magnitude. The result is that longer coherent despreading can be performed, and performance improved.

Fig. 12. is a block diagram of a receiver configured in accordance with the use of longer coherent despreading approach. The first set of multipliers **50** compensates for the frequency Doppler by correlating the IQ samples with a rotated C/A code. This is equivalent to rotating the IQ samples before correlation with the unmodified C/A code. Since the frequency Doppler can be as large as 4500Hz, the rotation is applied to every chip. After coherently integrating over a 1ms interval (1023 chips) using accumulators **52**, the second set of multipliers **54** rotates the 1ms integration sums (Σ_I and Σ_Q) to implement the frequency hypothesis. The rotated sums are then added over the whole coherent integration interval.

Recall that the frequency Doppler rotation was only computed on 1023 chips to save memory and computation. For coherent integration times longer than 1ms, each coherent integration sum are multiplied by a phase offset to make the phase of the rotation continuous over time. To show this mathematically, the 1ms coherent integration sum with frequency Doppler rotation can be expressed as:

$$S_1 = \sum_{n=1}^{1023} [I(n) + jQ(n)]c(n)e^{-jw_d nT_c} \quad \text{with } \Sigma_I = \text{Re}\{ S_1 \} \text{ and } \Sigma_Q = \text{Im}\{ S_1 \}$$

where I(n) and Q(n) are the input samples received on the I and Q channels respectively, c(n) is the unrotated C/A code, w_d is the frequency Doppler, and T_c is the chip interval (.9775us). A 2ms coherent integration sum can be expressed as:

$$S(2ms) = \sum_{n=1}^{2046} [I(n) + jQ(n)]c(n)e^{-jw_d nT_c}$$

$$= \sum_{n=1}^{1023} [I(n) + jQ(n)] c(n) e^{-jw_d nT_c} + e^{-jw_d (1023) T_c} \sum_{n=1}^{1023} [I(n+1023) + jQ(n+1023)] c(n) e^{-jw_d nT_c}$$

$$= S_1 + e^{-jw_d (1023) T_c} S_2$$

Here, S_1 is the first 1ms integration sum and S_2 is the second 1ms integration sum computed using the same rotated C/A values that were used to compute S_1. The term $e^{-jwd(1023)Tc}$ is the phase offset that compensates for using the same rotated values. Similarly, a 3ms coherent integration sum can be expressed as

$$S(3ms) = S_1 + e^{-jw_d (1023) T_c} S_2 + e^{-jw_d (2046) T_c} S_3$$

So to extend the integration time while using the same 1023-element rotated C/A sequence, the (n+1) 1ms integration sum should be multiplied by $e^{-jwdn(1ms)}$ before being added to the whole sum. Since this is a rotation of 1ms integration sums, we can combine this operation with the frequency search to avoid having to perform 2 rotations. That is, since

$$e^{-jw_d n(1ms)} e^{-jw_h n(1ms)} = e^{-j(w_d + w_h) n(1ms)}$$

we can multiply the (n+1)th 1ms integration sum by $e^{-j(wd+wh)n(1ms)}$ to search a frequency hypothesis and account for the frequency Doppler phase offset.

Note that the frequency search can be reduced after acquiring one satellite, because the frequency uncertainty is not dependent on the satellite. A much finer frequency search can be performed if a longer coherent integration is desired.

In the exemplary embodiment of the invention, the fine search is performed in similar manner the coarse search with 2 differences. First, the integration intervals are always added coherently instead of squaring and adding noncoherently. Second, the rotation to remove the frequency uncertainty (which should be known after the coarse search) is combined with the frequency Doppler phase offset and used to rotate the 1ms coherent integration intervals before adding them together.

In an alternative embodiment of the invention, the coherent integration window of chipx2 data is integrated for integration times longer

than 18ms. This embodiment is useful were additional memory is available. For coherent integrations longer than 18ms, the 50Hz data boundaries are treated the same as with shorter integration periods. The base station indicates where the boundaries are for each satellite and the DSP decides whether to add or subtract the sum of 20 1ms coherent integration intervals to or from its running sum.

However, because the product of the frequency uncertainty and the integration time constant affects the loss in Ec/Nt, the frequency uncertainty must be reduced to very small levels for long coherent integration intervals. Since a 20ms integration with a 20Hz frequency uncertainty resulted in a loss in Ec/Nt of 2.42 dB, maintaining the same loss with an integration time of 400ms requires that the frequency uncertainty be reduced to 1Hz. To correct for this problem, the frequency uncertainty is reduced down to 1Hz in a hierarchical manner. For example, a first frequency search reduces the uncertainty from 100Hz to 20Hz, a second search reduces the uncertainty to 4 Hz, and a third search reduces the uncertainty to 1Hz. The frequency search will also compensate for errors in the frequency Doppler obtained from the base station.

Additionally, to perform longer integrations only satellites with similar Doppler are searched over the same data for long integration times, since the code Doppler is different for each satellite. The DSP computes how long it takes to slip 1/16 of a chip and slews the decimator as it collects a coherent integration data window. Additionally, multiple data windows are taken in this embodiment.

Thus, a method and apparatus for performing position location in wireless communications system has been described. The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

CLAIMS

1. A method for increasing the sensitivity of a receiver, comprising the steps of: receiving in the receiver a first signal having at least one data boundary from an external source; receiving in the receiver, from a second source, an aiding message containing information regarding at least one of the data boundaries within the first signal; applying correlation codes to the first signal to yield correlation data; accumulating the correlation data yielded by applying the correlation codes over a first interval preceding a first one of the data boundaries for which information was received from the second source yielding a first accumulation result; and accumulating the correlation data over a second interval following the first one of the data boundaries for which information was received from the second source yielding a second accumulation result, the timing of the first and second interval being based upon the knowledge of the timing of the at least one data boundary ascertained from the aiding message.

2. The method as set forth in claim 1, further comprising the steps of: adding the first accumulation result and the second accumulation result yielding a first full accumulation result; subtracting the first accumulation result from the second accumulation result yielding a second full accumulation result; selecting the first full accumulation result when larger in magnitude then the second full accumulation result; and selecting the second full accumulation result when larger in magnitude then the first full accumulation result.

3. A mobile unit capable of receiving signals from a first and second source, the mobile unit comprising a coherent integrator adapted to receive a data phase signal from the first source and a content-bearing signal from a second source, wherein the data phase information is used to coherently integrate the content-bearing signal over time.

4. The mobile unit of claim 3, further comprising a first receiving section adapted to receive the data phase information and a second receiving section adapted to receive

the content-bearing signal, the first and second receiving sections being coupled to the integrator.

5. The mobile unit of claim 4, wherein the first receiving section is adapted to receive signals from a terrestrial station and the second receiver is adapted to receive signals from a satellite.

6. The mobile unit of claim 5, wherein the terrestrial station is a base station within a communications network and the satellite is a global positioning satellite.

7. The mobile unit of claim 3, wherein the data phase information is information indicative of the timing of data boundaries in the content-bearing signal.

8. The mobile unit of claim 3, wherein the data phase information can assume a plurality of values, each value representing a particular timing of the data boundaries of the content-bearing signal.

9. A tangible data storage medium comprising executable data capable of causing a programmable device to perform the steps of:

(a) receiving data phase information from a first source;

(b) receiving a content-bearing signal from a second source; and

(c) using the data phase information to perform coherent integration on the content-bearing signal.

10. A tangible data storage medium comprising executable data capable of causing a programmable device to perform the steps of:

(a) receiving a first signal having at least one data boundary from an external source;

(b) receiving from a second source a second signal an aiding message containing information regarding at least one of the data boundaries within the first signal;

applying correlation codes to the first signal to yield correlation data;

accumulating the correlation data yielded by applying the correlation codes over a first interval preceding a first one of the data boundaries for which information was received from the second source yielding a first accumulation result; and

(c) accumulating the correlation data over a second interval following the first one of the data boundaries for which information was received from the second source yielding a second accumulation result, the timing of the first and second interval being based upon the knowledge of the timing of the at least one data boundary ascertained from the aiding message.