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(54) Title: GPS RECEIVER AND MOBILE UNIT INCORPORATING THE SAME
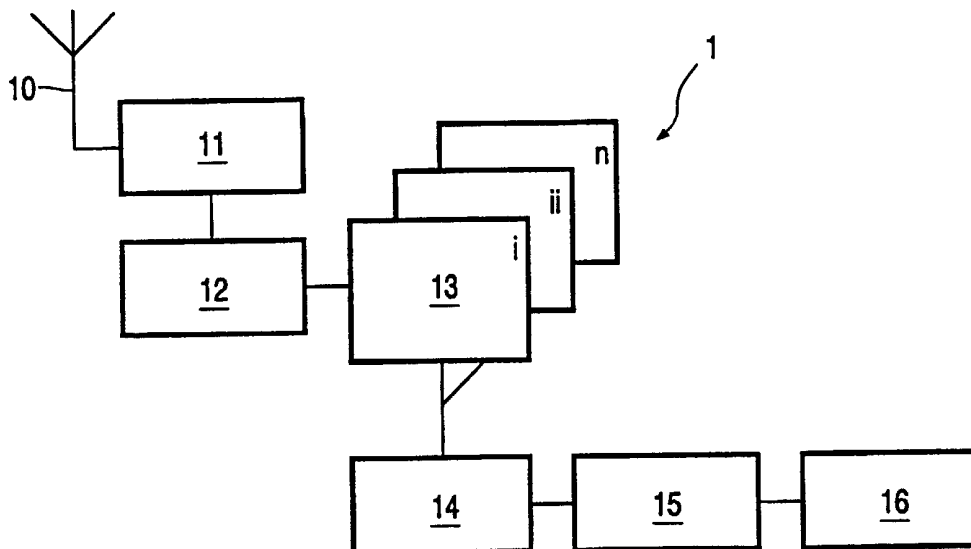
(57) Abstract: GPS receiver (1) is disclosed together a mobile unit especially in the form of a mobile cellular telephone (30) incorporating the same. The GPS receiver (1) comprises a GPS signal antenna (10) for receiving externally transmitted GPS signals; an analogue-to-digital converter (11) coupled to the antenna for sampling the received GPS signals; a memory (12) for storing the GPS signal samples; and a digital GPS signal processor (13, 14) for retrieving pseudorange information from the GPS signal samples stored in the memory (12). The receiver (1) has a dormant mode of operation in which received GPS signals are sampled and stored in the memory (12) but the signal processor (13, 14) is not operative for retrieving pseudorange information, and an active mode of operation in which the signal processor (13, 14) is operative for retrieving pseudorange information. Also, the receiver (1) is arranged to change from the dormant mode to the active mode in response to a instruction received from external to the receiver (1) and made whilst the receiver (1) is operating in the dormant mode.

DESCRIPTION

GPS RECEIVER AND MOBILE UNIT INCORPORATING THE SAME

This invention relates to a GPS receiver comprising a GPS signal antenna for receiving externally transmitted GPS signals; an analogue-to-digital converter coupled to the antenna for sampling the received GPS signals; a memory for storing the GPS signal samples; and a digital GPS signal processor for retrieving pseudorange information from the GPS signal samples stored in the memory, wherein the receiver has a dormant mode of operation in which received GPS signals are sampled and stored in the memory but the signal processor is not operative for retrieving pseudorange information, and an active mode of operation in which the signal processor is operative for retrieving pseudorange information.

The invention further relates to a mobile unit incorporating such a GPS receiver and, in particular but not exclusively, to a mobile cellular telephone adapted to provide information corresponding to its position to the base station with which it is registered in the event of an emergency call being made.

At present, GPS is most notably associated with the Navigation System with Time and Ranging (NAVSTAR) GPS, an all weather, spaced based navigation system developed and operated by the US Department of Defense, however, the general principles underlying GPS are universal and not merely limited to NAVSTAR. Accordingly, GPS hereafter refers to any global positioning system comprising a plurality of radio transmitters at different locations and a receiver which determines its location based on the time of arrival and / or time difference of arrival of the transmissions of the radio transmitters.

As is well known, a GPS receiver having a digital GPS signal processor may implement a pseudorandom noise (PRN) code tracking loop in which early (E), prompt (P) and late (L) replica codes of satellite PRN codes are

continuously generated, and compared to the incoming satellite PRN codes as received by the receiver. Assuming carrier phase lock, a linear code sweep should eventually result in the incoming PRN code being in phase with that of the locally generated replica and therefore, if detected, code acquisition. Once the code is acquired, the pseudorange information may be retrieved and using conventional navigation algorithms, the position of the receiver calculated.

Recently, as an alternative to the above early-late correlation method, it has become known to use fast convolution methods and in particular, involving Fast Fourier Transforms (FFTs), in order to acquired the PRN codes. Such convolution methods are particularly suited to where fast PRN code acquisition is required and are further described in US patent 5,781,156 which is incorporated herein by reference.

Notwithstanding which of the aforementioned techniques is used for code acquisition, the power consumption during signal acquisition and also during the position calculation process can be significant, up to approximately 1 watt. The problem is particularly relevant to handheld, battery powered GPS receivers which by their nature have a limited capacity and similarly to mobile telephones incorporating such receivers. In addition, with respect to mobile telephones, the problem is further compounded by the fashion for their miniaturisation for both aesthetic and ergonomic reasons.

An important reason for integrating GPS functionality in a mobile cellular telephone is that it has been proposed as a means to enable operators of cellular telephone networks to determine the location from which a call is made and, in particular, for an emergency call to the emergency services. Indeed, in the US, the Federal Communications Commission (FCC) has become the first regulatory authority to require operators to be able to do so. In the case of an emergency call, it is desirable for the positional information to be available as soon as possible, however, from a "cold start" where the GPS receiver does not have access to up to date ephemeris data or even worse from a "factory cold start" where the GPS receiver does not have an up to date almanac, the time to first fix (TTFF) can be anywhere between 30 seconds and 5 minutes.

Of course, the problems of cold starts can be eliminated if the GPS receiver is operative to provide a position fix continuously but this is undesirable for the aforementioned reasons relating to power consumption. Also, a user may simply wish to turn their telephone off yet may later wish to make an emergency call immediately after power up.

It is therefore an object of the present invention to provide a GPS receiver capable of the prompt and power efficient retrieval of pseudorange information from received GPS signals.

It is a further object of the invention to provide a mobile unit such as a mobile cellular telephone incorporating the same.

According to a first aspect of the present invention, a GPS receiver of the type described above is provided characterised in that the receiver (30) is arranged to change from the dormant mode to the active mode in response to a instruction received from external to the receiver (30) and made whilst the receiver (30) is operating in the dormant mode.

Such a GPS receiver, upon receiving an appropriate instruction, is able to immediately commence processing the signal samples stored in the memory in order to retrieve the pseudorange information and determining its current position. Furthermore, as receiving, sampling and storing the externally transmitted GPS signals are low power processes relative to the operation of the signal processor for retrieving pseudorange information, the overall power consumption of the GPS receiver remains relatively low.

To ensure that the most up to date GPS signal samples are stored in the memory, in the dormant mode, the received GPS signals may be sampled and stored in the memory continuously.

Alternatively, in the dormant mode, the received GPS signals may be sampled and stored in the memory periodically. This reduces the power consumption of the receiver whilst still enabling the processing of the stored signal samples to commence immediately in order to retrieve pseudorange information.

During use, there is no guarantee that the latest set of GPS signal samples stored in the memory will contain the necessary pseudorange information in order to calculate the position of the receiver. It may be that at the time the last sample set was taken, the GPS signals were received under

5   circumstances of poor signal reception and /or that there were insufficient GPS satellites in view from which to retrieve the necessary pseudoranges. For example, when caused by the GPS receiver being surrounded by tall buildings or foliage.

To mitigate the effects of this problem when the received GPS signals

10   are sampled and stored in the memory periodically, the memory store may contain at least two separate sets of GPS signal samples, one separated in time from another. By doing so, it is more likely that at least one sets of samples will be of sufficiently strong GPS signals with a sufficient number of satellites in view. In short, the likelihood of retrieving pseudorange information

15   without having to resample the GPS signals is increased.

In addition, by taking signal samples at different times, it is possible to double-check the determined position and also, if the signal samples are time-stamped, to identify and measure movement of the GPS receiver.

Operation in the dormant mode may be commenced in response to

20   power up of the GPS receiver or, if the receiver comprises a user interface, in response to an instruction received from a user via the user interface.

Also, where the GPS receiver comprises a user interface and is already operating in the dormant mode, the change from the dormant mode to the active mode may be in response to an instruction received from a user via the

25   user interface. This would enable the user to retrieve pseudorange information only when desired.

According to a second aspect of the present invention, a mobile unit is provided comprising a transmitter and a receiver adapted for two-way communication with a base station, and a GPS receiver according to the first

30   aspect of the present invention.

The mobile unit may be arranged to change from the dormant mode to the active mode in response to an instruction received by the mobile unit from

a base station. Also, the mobile unit may be further arranged to transmit positional information from the mobile unit to the base station.

In additional, the mobile unit may be a mobile cellular telephone for use with a cellular radio transmission system in the form of a plurality of base stations adapted for two-way radio communication and situated at respective geographical locations to define a corresponding plurality of overlapping service areas constituting one or more regions.

Such a mobile telephone would enable operators of cellular telephone networks to promptly determine the location of a mobile unit from which a call is made. NB. positional information includes not only direct expressions of the position of the mobile unit but also information from which this could be derived, for example, pseudorange information.

Furthermore, by sampling the GPS signal prior to activation of the active mode, say in response to an emergency call, the risk of signal interference and drowning of the GPS signal is reduced. Such signal interference and drowning may be caused by the mobile unit's transmitter transmitting encoded voice or other data to a base station and perhaps also the mobile unit's receiver receiving base station replies.

Operation in the dormant mode may commence upon the mobile telephone's recognition of an emergency call being made and then to change to active mode in the event of a request being made by the emergency services operator. This would reduce power consumption whilst ensuring the sampled data was still available when required.

Alternatively, when operating in the dormant mode, to change from the dormant mode to the active mode may occur in response to recognition by the mobile telephone of an emergency call being made. This would enable the positional information to be available more quickly, possibly even in advance of connection of the mobile cellular telephone to the emergency services operator.

Recognition by the mobile telephone of an emergency call being made may include recognising when a user enters the first one or more digits of the

emergency call telephone number, for example, by typing on a keypad or alternatively using speech recognition.

Operation of the dormant mode may also be in response to a change in the strength of the signals received from a base station of a cellular radio transmission system, e.g. indicative of the mobile telephone being removed from a pocket or briefcase; in response to detected movement of the mobile telephone, e.g. when detected by an accelerometer located in the mobile telephone; or in response to the retracting of a cover on the mobile telephone, e.g. in the case of a mobile telephone with a sliding cover protecting the key pad, by retracting the cover, or in the case of a "flip top" mobile telephone, by flipping the cover.

According to a third aspect of the present invention, a method of operating a GPS receiver of the type described above is provided comprising the steps of (i) in a dormant mode of operation, sampling and storing received GPS signals in the memory whilst the signal processor for retrieving pseudorange information is not operative; and (ii) in response to a instruction received from external to the GPS receiver, changing from the dormant mode to an active mode of operation in which the signal processor for retrieving pseudorange information becomes operative.

In the dormant mode, the received GPS signals may be sampled and stored in the memory continuously or alternatively periodically. Where they are stored periodically, the memory store may contain at least two separate sets of GPS signal samples, one separated in time from another. Also, where the GPS receiver further comprises a user interface, the transition from the dormant mode to the active mode may occur in response to an instruction received from a user via the user interface.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows, schematically, a GPS receiver according to the present invention;

Figure 2 shows, schematically, the receiver channels and receiver processor of the GPS receiver of figure 1 in greater detail;

Figure 3 shows a "flip-top" mobile cellular telephone incorporating the GPS receiver of figure 1;

Figure 4 shows, schematically, the workings of the mobile cellular telephone of figure 3.

In the drawings, corresponding features in different embodiments have been identified using the same reference numerals.

Figure 1 shows, schematically, the architecture of a GPS receiver 1 according to the present invention. NAVSTAR SPS GPS signals are received by an antenna 10 and pre-processed in a pre-processor 11; typically by passive bandpass filtering in order to minimise out-of-band RF interference, preamplification, down conversion to an intermediate frequency (IF) and analog to digital conversion. The resultant, digitised IF signal remains modulated, still containing all the information from the available satellites, and is fed into a first in-first out (FIFO) memory 12. From the memory, the samples may be fed at any time later into each of a series of parallel receiver channels 13. The satellite signals are acquired and tracked in respective digital receiver channels in co-operation with the receiver processor 14 for the purpose of acquiring pseudorange information. Such methods for acquisition and tracking are well known, for example, see chapter 4 (GPS satellite signal characteristics) & chapter 5 (GPS satellite signal acquisition and tracking) of GPS Principles and Applications (Editor, Kaplan) ISBN 0-89006-793-7 Artech House. Using acquired pseudorange information and the time of arrival of the transmissions, the navigation processor 15 calculates the position of the receiver using conventional algorithms and that position is displayed on a display 16 to the user.

Figure 2 shows, schematically, the receiver channel co-operating with the receiver processor in greater detail. In order to retrieve pseudorange information from the signal samples stored in the memory 12, a carrier wave must be removed and this is done by the receiver generating in-phase (I) and

quadrature phase (Q) replica carrier wave signals using a carrier wave generator 21. A carrier wave phase lock loop (PLL) is normally employed to accurately replicate the frequency of the received carrier wave. In order to acquire code phase lock, early (E), prompt (P) and late (L) replica codes of the PRN sequences are continuously generated by a code generator 22. The replica codes are then correlated with the I and Q signals to produce three in-phase correlation components (I_E, I_L, I_P) and three quadrature phase correlation components (Q_E, Q_L, Q_P), typically by integration in an integrator 23 over substantially the whole of the PRN code. In the receiver processor 14, a code phase discriminator is calculated as a function of the correlation components and a threshold test applied to the code phase discriminator. A phase match is declared if the code phase discriminator is high and if not, the code generator produces the next series of replicas with a phase shift. A linear phase sweep will eventually result in the incoming PRN code being in phase with that of the locally generated replica and thus code acquisition.

The pre-processor 11 will be typically implemented in the form of front end analogue circuitry with the digital receiver channels 13, the receiver processor 14 and the navigation processor 15 implemented in the form of a general purpose microprocessor or a microprocessor embedded in a GPS application specific integrated circuit (ASIC).

In one example, downconversion of received L1 C/A GPS signals is from the carrier broadcast frequency of 1575.42 MHz to an IF in the region of 5MHz. The IF signal is sampled at a rate of 25MHz with 4-bit quantisation and stored in an 8 Megabyte FIFO memory 12. This makes it possible to store samples of 0.64 seconds worth of GPS signal, which equates to approximately 640 L1 C/A Gold code repetitions. This is normally sufficient to acquire the GPS signals in even poor conditions. In good reception conditions, a smaller memory for storing samples from a smaller snapshot of GPS signal sample would be sufficient and, conversely, a larger memory may enable weaker code signals to be acquired. A lower IF, sampling rate and level of quantisation may enable the memory to be used more efficiently, however, inevitably at the expense of the quality of the subsequent correlation.

The GPS receiver 1 has two modes of operation. First, a dormant mode of operation which is effected automatically upon power up and in which every five seconds, a 0.64 second GPS signal extract is received, pre-processed, sampled and stored in the memory 12. In the dormant mode, the digital receiver channels 13, the receiver processor 14 and the navigation processor 15 are powered down, i.e. no baseband processing is performed. Secondly, the GPS receiver has an active mode of operation in which the pre-processing, sampling and sample storage in the memory 12 store of GPS signals is suspended and samples stored in the memory processed in the digital receiver channels 13 and receiver processor 14 in order to retrieve pseudorange information. Upon retrieval of the pseudorange information, the navigation processor 15 calculates the position of the receiver which is displayed to the user on a display 16. A user is able to effect the transition from dormant mode to active mode for the purpose of displaying the current position by pressing a button on a keypad (not shown) of the GPS receiver.

As previously stated, the pre-processing, receiver channel and receiver processor will be typically implemented in the form of front end analogue circuitry combined with either a general purpose microprocessor or a microprocessor embedded in a GPS application specific integrated circuit. Implementation of a method of GPS receiver operation according to the present invention, including the example as described below, may be accomplished by appropriate analogue circuitry design and / or microprocessor programming. Of course, such design and programming is well known and would be accomplished by one of ordinary skill in the art of GPS and CDMA communication without undue burden.

A "flip-top" mobile cellular telephone 30 according to the present invention is shown schematically in figure 3. The telephone comprises a communication processor 31 having a central processing unit 32 and memory 33. The communication processor is coupled to an antenna 34 via a transmitter / receiver 35, to speakers 36 of which one is for use with the telephone ear piece and the other for user notification, to a microphone 37, to a keypad 38, to a display 39. The mobile cellular telephone is powered by a

battery (not shown) and further incorporates a GPS receiver 1 of the type shown in figure 1.

The "flip-top" telephone 30 is shown pictorially in figure 4. A flip cover 41 is attached by a hinge 42 to the body 43 of the mobile telephone on which is further mounted the keypad 38 and the display 39. Also visible on the outside of the telephone is the antenna 37 and perforations in both the flip cover 44 and body 45 of the mobile telephone which allow passage of sound waves from the ear piece speaker located within the flip cover 36 and to the microphone 37 located within the body of the mobile phone respectively.

The mobile cellular telephone 30 is suitable for use with a cellular radio transmission system (not shown) in the form of a plurality of base stations adapted for two-way radio communication and situated at respective geographical locations to define a corresponding plurality of overlapping service areas constituting one or more regions. Of course, such cellular radio transmission systems and their signalling protocols are well known and will not be elaborated upon here further.

When the mobile telephone is powered up, the GPS receiver 1 of the mobile cellular telephone 30 operates in dormant mode, periodically sampling GPS signals. This remains the case until a user makes an emergency call to an emergency service operator (the US version being a 911 public safety answer point, PSAP). From the emergency service operator, an automated request is sent to the mobile cellular telephone for information relating to its position and upon receiving the request, the GPS receiver 1 changes from dormant mode to active mode whereby the position of the GPS receiver is determined. This position is provided to the communication processor 31 and transmitted to the operator via the base station of the cellular radio transmission system with which the mobile cellular telephone is registered (not shown) and thereafter the appropriate emergency service. Alternatively, pseudorange information may be provided to the base station and the position derived from this, remote from the mobile cellular telephone.

In the above example, the transition from dormant to active mode is made in response to a request from the base station. Alternatively, by the user

entering the number for the emergency services ("999" in the UK, "911" in the US), the mobile telephone may itself recognise an emergency call is being made, perhaps from the first few digits of the appropriate telephone number, and effect the transition from dormant to active mode accordingly.

Also, as an alternative to commencement of operation in the dormant mode upon power up, commencement may be in response to flipping the flip cover, indicative of the phone being prepared for use.

US patent 5,841,396 discloses a GPS receiver of the conventional type to which the invention relates. It describes a mobile unit comprising a GPS antenna for receiving GPS signals, an RF to IF converter for downconverting the received GPS signals to an IF, an analogue to digital converter for digitising the IF signals, a "digital snapshot memory" for storing the digitised samples and a digital signal processing (DSP) microprocessor for processing the digitised samples in order to determine the position of the mobile unit. At lines 49 to 64 of column 6, it states that upon receiving a command, the RF to IF converter, analogue to digital converter and "digital snapshot memory" are activated in order to store a set of data in the memory corresponding to between 100ms and 1s of GPS signal. It further states from lines 11 to 22 of column 7 that this is done whilst keeping the DSP microprocessor in a low power state and then the DSP microprocessor is activated to process the signals during which time the RF to IF converter and analogue to digital converter may be powered down in order to minimise power consumption. The present invention distinguishes over this mobile unit in that its RF to IF converter, analogue to digital converter and "digital snapshot memory" are activated upon receiving a command such as from a base station, and that the DSP microprocessor is merely activated sequentially thereafter. Activation of the DSP is not in response to an instruction received whilst the RF to IF converter, analogue to digital converter and "digital snapshot memory" are activated.

At the time of writing, the applicant is not aware of the FCC having prescribed a maximum time limit in which to obtain a location fix, but it is

believed the general consensus amongst mobile telephone vendors and the 911 PSAP is that it will be set at about five seconds.

One way in which this can be achieved is using base station assistance. Such assistance includes the provision by the base station to the receiver of a precision carrier frequency reference signal for calibrating the local oscillator used in the GPS receiver and also up to date satellite almanac and ephemeris data in order to calculate the approximate frequency shift for satellites in view. This assistance is further described in US patents 5,841,396 and 5,874,914 which are incorporated herein by reference.

Although described with reference to early-minus-late correlation techniques, the invention is equally applicable to convolution methods including involving Fast Fourier Transforms (FFTs). Also, base station assistance is equally applicable to either correlation architecture, i.e. for using both early-minus-late correlation and convolution methods.

From a reading of the present disclosure, other modifications will be apparent to the skilled person skilled and may involve other features which are already known in the design, manufacture and use of GPS receivers and component parts thereof and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present application also includes any novel feature or any novel combination of features disclosed herein either explicitly or implicitly, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same problems as does the present invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

CLAIMS

1.   A GPS receiver comprising:

a GPS signal antenna for receiving externally transmitted GPS signals;

an analogue-to-digital converter coupled to the antenna for sampling the received GPS signals;

a memory for storing the GPS signal samples; and

a digital GPS signal processor for retrieving pseudorange information from the GPS signal samples stored in the memory,

wherein the receiver has a dormant mode of operation in which received GPS signals are sampled and stored in the memory but the signal processor is not operative for retrieving pseudorange information, and an active mode of operation in which the signal processor is operative for retrieving pseudorange information, characterised in that the receiver is arranged to change from the dormant mode to the active mode in response to a instruction received from external to the receiver and made whilst the receiver is operating in the dormant mode.

2.   A GPS receiver according to claim 1 wherein, in the dormant mode, the received GPS signals are sampled and stored in the memory continuously.

3.   A GPS receiver according to claim 1 wherein, in the dormant mode, the received GPS signals are sampled and stored in the memory periodically.

4.   A GPS receiver according to claim 2 or claim 3 wherein, in the dormant mode, the memory contains at least two separate sets of GPS signal samples, one separated in time from another.

5. A GPS receiver according to any preceding claim arranged to commence operation in the dormant mode in response to power up of the GPS receiver.

6. A GPS receiver according to any preceding claim further comprising a user interface, wherein the receiver is arranged to commence operation in the dormant mode in response to an instruction received from a user via the user interface.

7. A GPS receiver according to claims 1 to 6 further comprising a user interface, wherein the receiver is arranged to change from the dormant mode to the active mode in response to an instruction received from a user via the user interface.

8. A GPS receiver substantially as hereinbefore described with reference to the figures 3 and 4.

9. A mobile unit comprising a transmitter and a receiver adapted for two-way communication with a base station, and a GPS receiver according to any preceding claim.

10. A mobile unit according to claim 9 arranged to change from the dormant mode to the active mode in response to an instruction received by the mobile unit from a base station.

11. A mobile unit according to claim 9 or claim 10 arranged to transmit positional information from the mobile unit to the base station.

12. A mobile unit according to claims 9 to 11 in the form of a mobile cellular telephone for use with a cellular radio transmission system in the form of a plurality of base stations adapted for two-way radio communication and

situated at respective geographical locations to define a corresponding plurality of overlapping service areas constituting one or more regions.

13.   A mobile unit according to claim 12 arranged to commence operation in the dormant mode in response to recognition by the mobile telephone of an emergency call being made.

14.   A mobile unit according to claim 12 arranged, when operating in the dormant mode, to change from the dormant mode to the active mode in response to recognition by the mobile telephone of an emergency call being made.

15.   A mobile unit according to claim 13 and claim 14 wherein recognition by the mobile telephone of an emergency call being made occurs when a user enters one or more digits of the emergency call telephone number.

16.   A mobile unit according to claim 12 arranged to commence operation in the dormant mode in response to a change in the strength of the signals received from a base station of the cellular radio transmission system.

17.   A mobile unit according to claim 12 arranged to commence operation in the dormant mode in response to detected movement of the mobile telephone.

18.   A mobile unit according to claim 12 further comprising a retractable cover and arranged to commence operation in the dormant mode in response to a user retracting the cover.

19.   A mobile unit substantially as hereinbefore described with reference to figure 4.

20.   A method of operating a GPS receiver comprising a GPS signal antenna for receiving externally transmitted GPS signals; an analogue-to-digital converter coupled to the antenna for sampling the received GPS signals; a memory for storing the GPS signal samples; and a digital GPS

5   signal processor for retrieving pseudorange information from the GPS signal samples stored in the memory, the method comprising the steps of:

(i) in a dormant mode of operation, sampling and storing received GPS signals in the memory whilst the signal processor for retrieving pseudorange information is not operative; and

10   (ii) in response to a instruction received from external to the GPS receiver, changing from the dormant mode to an active mode of operation in which the signal processor for retrieving pseudorange information becomes operative.

15   21.   A method according to claim 20 wherein, in the dormant mode, the received GPS signals are sampled and stored in the memory continuously.

22.   A method according to claim 21 wherein, in the dormant mode,
20   the received GPS signals are sampled and stored in the memory periodically.

23.   A method according to claim 22 wherein, in the dormant mode, the memory store contains at least two separate sets of GPS signal samples, one separated in time from another.

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24.   A method according to claims 20 to 23 wherein the GPS receiver further comprises a user interface; and wherein the transition from the dormant mode to the active mode occurs in response to an instruction received from a user via the user interface.

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25.   A method of operating a GPS receiver substantially as hereinbefore described with reference to figures 3 and 4.
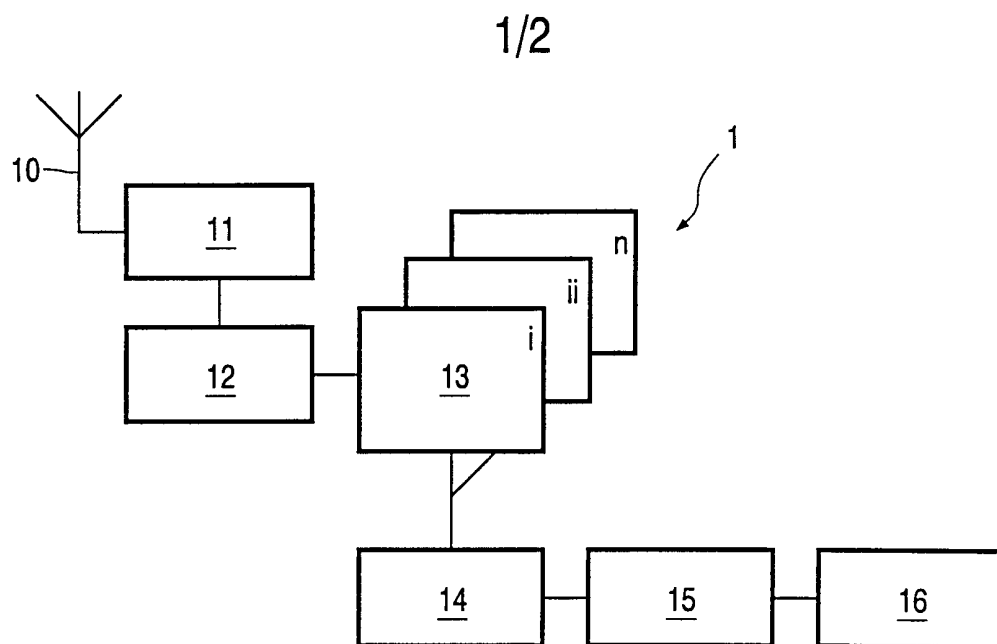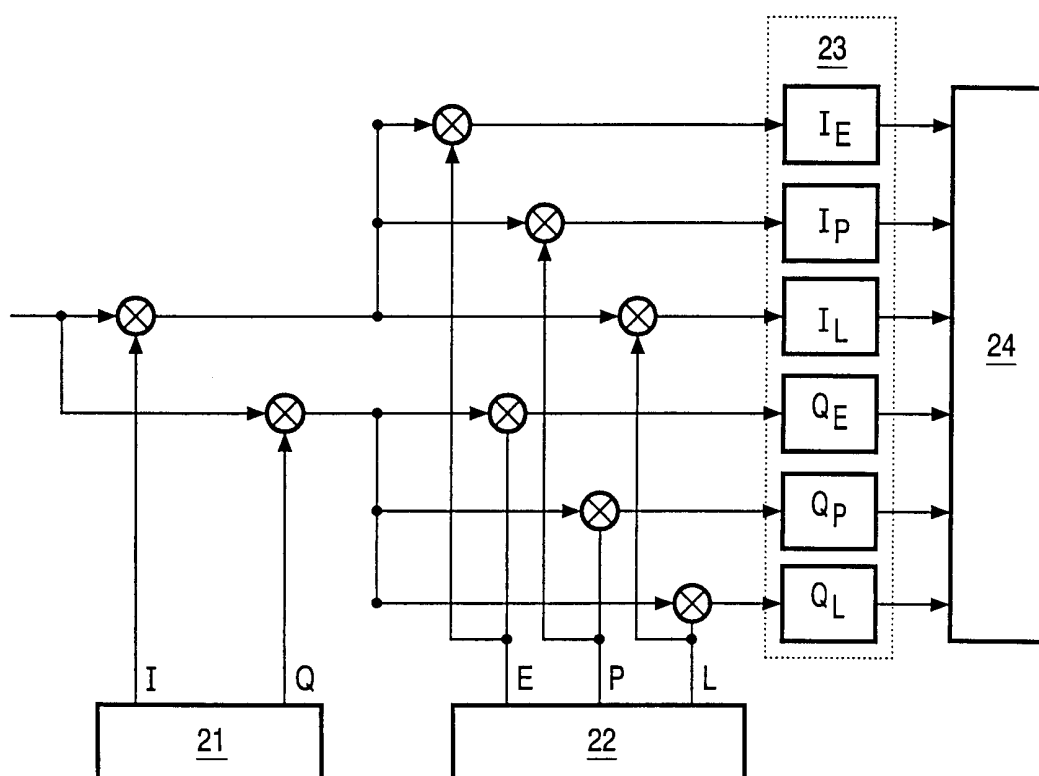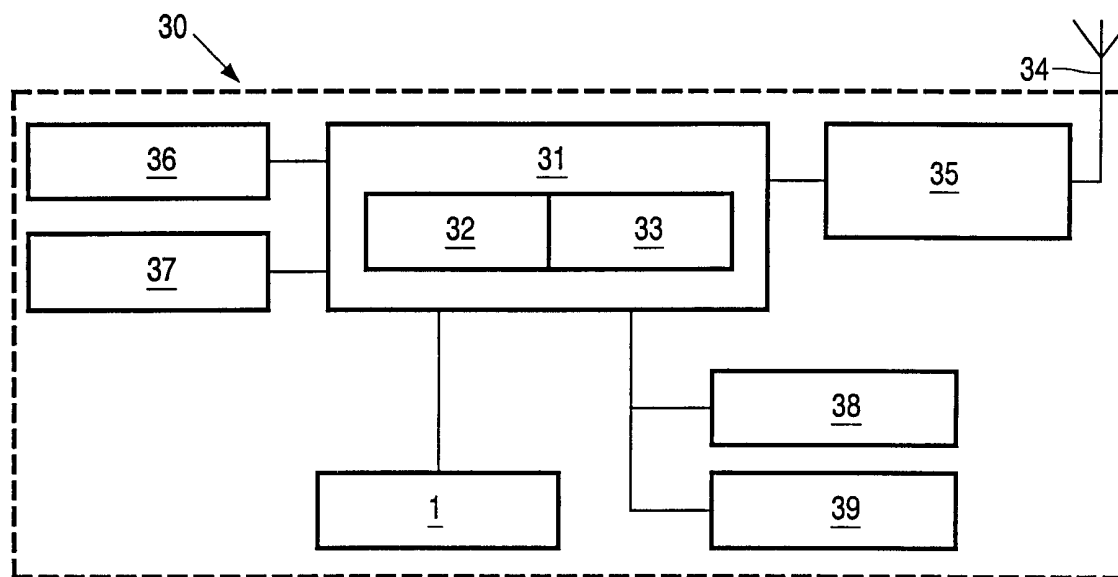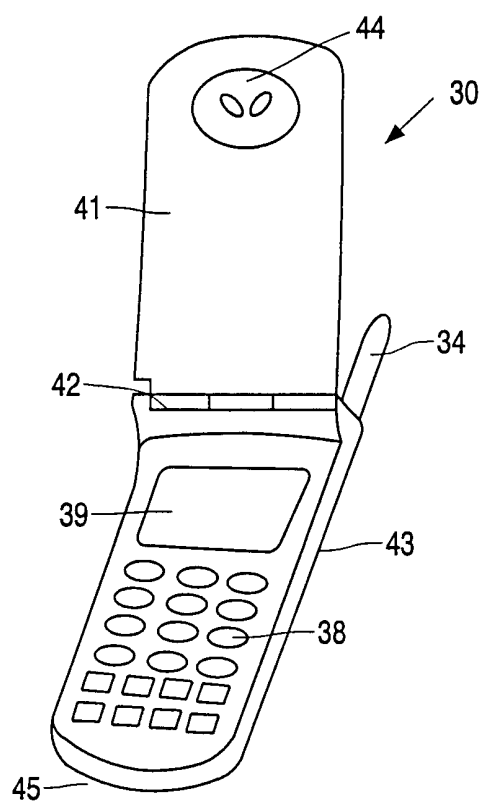
FIG. 1

FIG. 2

FIG. 3

FIG. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   G01S5/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 592 173 A (LAU CHUNG Y ET AL) 7 January 1997 (1997-01-07) abstract; figures 1,2 column 5, line 63 -column 6, line 26 column 7, line 35 -column 8, line 4	1,20
A	US 5 841 396 A (KRASNER NORMAN F) 24 November 1998 (1998-11-24) cited in the application column 6, line 49 -column 7, line 29	1,20
A	US 6 028 887 A (HARRISON DANIEL DAVID ET AL) 22 February 2000 (2000-02-22) abstract; figure 3 column 10, line 13 - line 30	1,20

☐ Further documents are listed in the continuation of box C.   ☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 April 2001	04/05/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Niemeijer, R

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5592173	A	07-01-1997	NONE		
US 5841396	A	24-11-1998	US	5874914 A	23-02-1999
			AU	2070297 A	22-09-1997
			AU	5587698 A	29-06-1998
			AU	5588898 A	29-06-1998
			EP	0885492 A	23-12-1998
			EP	0950194 A	20-10-1999
			EP	0941487 A	15-09-1999
			JP	2000506348 T	23-05-2000
			WO	9733382 A	12-09-1997
			WO	9825157 A	11-06-1998
			WO	9825158 A	11-06-1998
			US	6064336 A	16-05-2000
			US	6133874 A	17-10-2000
			US	6150980 A	21-11-2000
			US	6208290 B	27-03-2001
			US	5945944 A	31-08-1999
			AU	723615 B	31-08-2000
			AU	7662096 A	30-04-1997
			BR	9611701 A	28-12-1999
			CA	2230841 A	17-04-1997
			CN	1211324 A	17-03-1999
			EP	0855039 A	29-07-1998
			JP	11513787 T	24-11-1999
			WO	9714049 A	17-04-1997
			US	6111540 A	29-08-2000
			US	6002363 A	14-12-1999
US 6028887	A	22-02-2000	AU	3815797 A	09-02-1998
			CA	2258692 A	22-01-1998
			EP	0910805 A	28-04-1999
			WO	9802758 A	22-01-1998
			AU	3739497 A	09-02-1998
			AU	3814097 A	09-02-1998
			AU	3814297 A	09-02-1998
			AU	3815897 A	09-02-1998
			AU	3896797 A	09-02-1998
			AU	3965397 A	09-02-1998
			AU	4046397 A	09-02-1998
			CA	2258673 A	22-01-1998
			CA	2258674 A	22-01-1998
			EP	0910901 A	28-04-1999
			EP	0910902 A	28-04-1999
			EP	0939906 A	08-09-1999
			EP	0912947 A	06-05-1999
			EP	0910903 A	28-04-1999
			JP	2001502129 T	13-02-2001
			WO	9802972 A	22-01-1998
			WO	9802984 A	22-01-1998
			WO	9802973 A	22-01-1998
			WO	9802974 A	22-01-1998
			WO	9802975 A	22-01-1998
			WO	9802759 A	22-01-1998
			WO	9802830 A	22-01-1998
			US	6118808 A	12-09-2000
			US	6151353 A	21-11-2000
			US	5896304 A	20-04-1999

Form PCT/ISA/210 (patent family annex) (July 1992)

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6028887 A		US 6028883 A	22-02-2000
		US 6009118 A	28-12-1999
		US 5987059 A	16-11-1999
		US 5982811 A	09-11-1999

Form PCT/ISA/210 (patent family annex) (July 1992)