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(71) Applicant (*for all designated States except US*): **CELL-GUIDE LTD.** [IL/IL]; Beit Tamar, Entrance A, Hamada Street 12, 76703 Rehovot (IL).

(71) Applicant (*for TJ only*): **FRIEDMAN, Mark, M.** [US/IL]; Alharizi Street 1, 43406 Raanana (IL).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **NIR, Joseph** [IL/IL]; Hanasi Harishon Street 36, 76302 Rehovot (IL). **SHAYEVITS, Baruch** [IL/IL]; Ben Eliexer Street 12, 75229 Rishon Lezion (IL). **COHEN, Hanoch** [IL/IL]; Eilon Street 5, 75286 Rishon Lezion (IL).

(74) Common Representative: **FRIEDMAN, Mark, M.**; c/o Castorina, Anthony, Suite 207, 2001 Jefferson Davis Highway, Arlington, VA 22202 (US).

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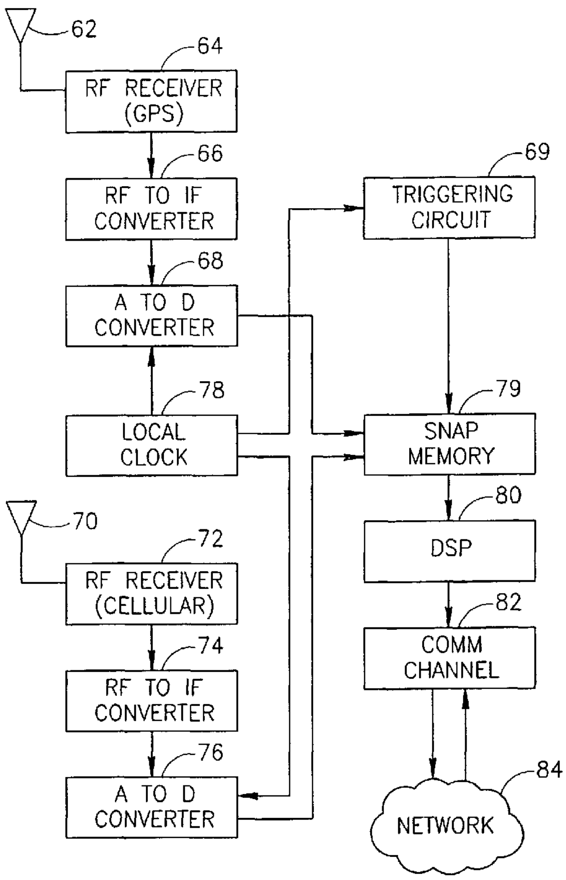
[Continued on next page]

(54) Title: REFERENCE UNIT FOR A LOCATION SYSTEM OF A CELLULAR NETWORK



(57) Abstract: A system is described which provides a timing reference for a plurality of BTSs (base transceiver stations), of an unsynchronized cellular network. The system receives and processes two types of radio sources, namely BTSs signals and navigation satellite signals. It employs internal triggering for snap starts. One embodiment of the system incorporates commercial GPS receiver (65) for executing some of the tasks otherwise performed by the processor and triggering circuit. A local clock (78) determines the rate at which signals of the radio sources are sampled. In the method of the invention, regular satellite positioning is performed out of which local clock bias is calculated, and local clock drift is calculated by the ratio between observed Doppler offset and calculated Doppler offset. Mutual BTSs signals are matched, providing mutual synchronization by referencing the timing of identifiable timing structures of each BTSs to the snap start. The BTSs signals are also referenced to satellite system time in order to facilitate the use of hybrid navigation techniques.

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REFERENCE UNIT FOR A LOCATION SYSTEM OF A CELLULAR NETWORK

FIELD OF THE INVENTION

The present invention relates generally to location systems of mobile transceivers. More specifically, the invention is in the field of location systems for mobile units of unsynchronized cellular systems.

BACKGROUND OF THE INVENTION

Ranging methods based on radio channels measure the time it takes for a radio signals to travel from a radio source to a receiver. The longer it takes for the signal to travel the way, the farther the receiver is displaced from the emitter. A set of radio sources emitting signals received by a receiver, can potentially provide enough physical information of time of travel for such a receiving unit to determine its own location relative to the radio stations. Practically however, the speed of light being extremely high, about 3 X 10^8 m/sec, requires compatible clock for providing meaningful measurements of the time of arrival of the respective signals to the receiver of the radio sources. There are additional requisites that must be fulfilled in order to make the ranging technique practical. The emitted signals of the radio sources must be structured in such a way as to facilitate timing references of the signal to be clearly discerned by the receiver. Base stations of the GSM network do not supply time of emission of signals, which complicates the process for determination of location. A way to overcome the lack of data as incicated earlier is by providing timing references which mutually synchronize base stations. In WO – 99- 21028, the contents of which are incorporated herewith by reference, is disclosed a method for calculating a location of a mobile receiver (MU) in which at least one extra receiver of the unsynchronized cellular network is employed in order to provide time reference to base stations. Another method, disclosed in WO – 99 – 61934 uses navigation satellite ranging signals, in addition to base station signals.

GSM cellular networks operate along the principles of the TDMA (time division multiple access) and FDMA (frequency division multiple access) technology and associated standards. The time division principle allows many subscribers to use the radio channel concomitantly by occupying each a small portion of the time resources available for the communication medium. To achieve that, the mobile stations (MUs) communicating with a certain base station (BTS), are rendered mutually synchronized. The BTSs communicates with each mobile unit by sending a sequence of discrete structures called time slots, allocated exclusively for data bits to or from the active subscriber, uplink or downlink oriented.

GSM and other unsynchronized cellular network systems do not provide however mutual base station synchronization. This implies that whereas each MU is fully synchronized with the BTS with which they are actively engaged, there is no concomitant synchronization of a mobile station with other base stations of the same network. This lack of mutual time synchronization among the BTSs of a network, precludes the possibility of a

MU to synchronize with signals originating in BTSs other than the one within the cell boundary of which it is operative. Accurate ranging methods for locating mobile units based on network radio channels, cannot be sustained under these circumstances unless a synchronization element mutually synchronizing base stations is made operative to that effect. A network element called LMU (location measurement unit) is such a GSM network elements that synchronizes between different BTS (ETSI MOBILE NEWS, SPECIAL EDITION – 2000 GSM WORLD CONGRESS). With regards to the reference methods, the LMUs are classified into two classes: first, a class containing mutually synchronizing BTS signals on a real time basis, in that the correlation between identifiable timing structures of the different BTS signals are made in real time furnished by the real time clock of the LMU. A second LMU class, correlates the received identifiable timing structures of the BTSs with the GPS timing structures. A GPS – correlating LMU is inherently more accurate than a non GPS correlating LMU. The reason for that stems from the fact that a GPS system clock has a much higher stability (10^{-12} sec/sec deviation) as compared to network clock stability (10^{-8} sec/sec deviation).

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method for mutually time - synchronizing signals of BTSs. According to the method of the invention, all available BTSs of a cellular network are received by a NRU (network reference unit) of the invention. The respective signals of the BTSs are processed in a single snap. They are digitized, and the individual discrete frames are discerned. Identifiable timing frames of each respective BTS signal are matched with the equivalent timing frames of all other BTS signals, thus providing mutual calibration. Navigation satellites (typically of the GPS system) are received, providing for bias corrections to be made to the local clock of the NRU. Code periods of the satellite system are digitized and matched with the BTS frames in the same snap indicate earlier.

A further object of the present invention is to provide a system for time – synchronizing signals of individual BTSs (base transceiver stations) of an unsynchronized cellular network with the time system of the GPS system of navigation satellites. The system of the invention contains receiving circuits for satellite navigation signals and for BTS signals. The system contains sufficient DTA (digital to analog devices to facilitate fast parallel sampling of all received signals, the rate of which is set by a local clock, and the resulting digital numbers are stored in a snap memory preferably capable of storing two snaps.

The system of the invention provides for a triggering circuit and a communication line for receiving and transferring data to and from the network.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a block diagram illustrating the main functional elements of a prior art LMU of a GSM cellular network;

Fig. 1B is block diagram illustrating the interconnectivity of the functional elements of a prior art LMU as in Fig. 1A;

Fig. 2A is a block diagram illustrating schematically the architecture of a NRU (network reference unit) in accordance with a preferred embodiment of the invention.

Fig. 2B is a block diagram illustrating schematically the architecture of a NRU (network reference unit) having additional GPS receiver unit.

Fig. 3 is a schematic illustration of the sequence of events performed for achieving mutual synchronization of BTSs.

Fig. 4 is a graphic illustration describing the timing signal structures of the satellite with respect to the BTS signals within the frame work of a single snap in the processor.

Fig. 5. is a graphic illustration describing the timing signal structures of the satellite with respect to signals of two BTSs as being matched in the processor, mutually and with respect to the satellite time system.

Fig. 6 is a block diagram classifying the groups of data which contribute to the synchronization process of the invention.

Fig. 7 is a schematic illustration describing the sequence of events of calculating the local clock bias with respect to satellite system clock.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

GPS referenced commercial LMUs employed in GSM networks contain the functional components as are illustrated schematically in **Fig. 1A**, to which reference is now made. A fully operational GPS receiver **14** is coupled to a time measuring circuit **16**. The data obtained is sent to the BTS through a link **18**. A precise clock **15**, of better stability characteristics than mobile unit clock, provides frequency for the ATD (analog to digital) circuit of the cellular receiver **20,** and timing reference to the TMC (time measuring circuit) **16.** The TMC measures time between the precise trigger pulse supplied by the GPS receiver **14** and one or more identifiable timing references of the of the BTSs received. The timing references are sent to the BTS through a link **18** to network. The present invention relates also to third generation networks, for example UMTS networks, that are scheduled to succeed the GSM networks.

In Fig. **1B** such an LMU is described in more details and in reference to the functionality thereof. GPS antenna **13** is connected to a fully operational GPS receiver **14** that sends a triggering pulse, known as 1PPS (one pulse per second) to the TMC (time measurement circuit) **16**. The GPS receiver can also send system time data to the TMC. An RF receiver **22** receives BTS signals through antenna **33**, the signal is downconverted by a circuit **36** to IF, and burst periods extracted. Analog to digital converter **34** demodulates the signal and frames of the BTS signals are then extracted. The TMC **16** calculates the time difference between the triggering pulse and the reception of the identifiable time references of the BTSs, typically SCHs (synchronization channels). The time difference between the triggering pulse and the timing references may be long enough to cause deterioration of the timing accuracy, which necessitates the employment of a high quality clock **42**. Communication channel **44** sends to the network respective time matching data of each of the BTS signals as referenced to the 1PPS pulse, through a physical A-bis connection or through wireless connection. Controller **48** regulates the output link with the network.

Optionally, Ancillary data, obtained by the GPS receiver, from the individual satellites (ephemeris) or system time are also transferred to the network through any of the two links, A – bis **46**, or wireless transmitter **38**.

In **Fig. 2A** to which reference is now made, is described in general the architecture of a NRU (network reference unit), in accordance with a preferred embodiment of the invention. RF receiver **64,** receives through antenna **62** at least one **GPS** satellite navigation signals. The signal is downconverted in circuit **66**, and the resulting IF signal is digitized by the ATD (analog to digital) converter **68**. Triggering circuit **69** triggers the snap memory which sets off a data collection and processing stage as will be elaborated later on. The sampling rate is determined by local clock **78**. In a parallel circuit, triggered by the same triggering signal as above, cellular BTSs are received through antenna **70**, which may be the same as antenna **62**, and the received signal is downconverted in circuit **74**. IF signal is sampled in ATD converter **76**, the sampling rate of which is set by local clock **78**. When sampling is finished, snap memory **79** transfers the information into signal processor **80**. Signal processor **80** receives therefore a digitized output of digitizers **68** and **76** collected in one snap, and processes the signals.

Processor **80** sends the resulting data to communication channel **82**. The transmission is carried out by wireless link, or by a physical A -bis link to the network **84**. In another embodiment of the invention, described generally in **Fig 2B** to which reference is now made, a commercial GPS receiver **65** is integrated into a network NRU of the invention, for performing several tasks. A first task is obtaining satellite ephemeris data independently, and another reason is for triggering the snap through the 1PPS mentioned above. Other tasks of the adjunct GPS receiver will be discussed later on. The adjunct receiver **65** is optionally connected to the existing antenna **62** at the front end, and to the processor **80**.

Mutually synchronizing the BTS signals

To achieve the end of mutual synchronization of cellular BTSs signals and their common reference to the GPS system time, the following steps are followed, as depicted generally in **Fig. 3** to which reference is now made. In accordance with the present invention, a trigger is set off at a predetermined rate and for a predetermined period of time, typically for 0.1 second every 30 seconds. The trigger sets off a process which aims at achieving mutual synchronization of cellular BTS signals and a reference to the GPS system time.

Snap is triggered at step **108**, collecting data from both a plurality of GPS system satellites and a plurality of BTSs, in step **110**. Data processing begins in step **112** within reception of enough data to start a procedure, as will be explained later on. In step **114** the BTSs are mutually synchronized and referenced to the GPS system time.

The processor of a NRU of the invention performs the necessary calculations for calibrating the local clock. The principles of the calibration procedure for the local clock are explained with reference to **Fig. 4**. The local clock time axis is indicated in the figure by arrow **120**. When triggered, a snap start designated by arrow **122** occurs receiving the two signals: satellite and BTS. In the processing stage, two respective repetitive signal structures are discerned, one of each radio source. The contiguous repetitive GPS code periods are discerned, by correlating the received signal code with a stored replica code within the processor. Discrete GSM frames are discerned by identifying specific burst periods, such that the total number of frames is calculated until a synchronization frame is identified. In more detail, a first beginning of a GPS code period **130**, marked by arrow **118** is measured in local clock time terms. When the first synchronization frame **124**, hereinafter referred to as s.frame of a certain BTS signals is encountered, the processor calculates the number of frames having been counted since snap start **122**. The method of the invention takes into consideration measurement elements much shorter than GSM frames, and the example portrayed in **Fig. 4** puts line **126** in a frame start, for convenience of illustration but sub- frame structures, i.e. time slots, bits and sub- bit accuracy can be attained.

Two calculation results are subsequently obtained, in local clock terms: A. $T_{satreference} - T_{snap\ start}$ and B. $T_{s\cdot frame\ start} - T_{snap\ start}$. The local clock is used only for the short period of time between snap start and the GPS code period, and s.frame, whichever comes last. For this short period of time it is required to compensate the measurement system for inaccuracies cause by the local clock bias and drift. This compensation is effected by using the timing and Doppler data derived from the GPS system with reference to the local clock.

In **Fig. 5** to which reference is now made, the synchronization of two cellular BTS channels are described schematically. A snap start designated by arrow **160** indicates, on the local clock time axis and on the satellite time axis, the initiation of data collection and loading into the snap memory. Collected are frames of a first BTS signal **162**, and of a second BTS **164**. In addition, the code periods of GPS navigation transmission **166** are collected. S.frames of the BTSs, such as frame **170** of BTS **162** are shadowed to distinguish them from other frames. Thus, when a s.frame is encountered, it is identified by its internal structure, and the identification number it bears is registered, then, the number pf frames elapsed between this frame and the snap start (arrow **160**) are counted, including fractions of a frame), thereby finding the time between the snap start and the s: frame, in sub-frame resolution. The same is performed for the signal of BTS **164**, until all available BTSs have mutually correlated their timing, referencing to the same snap start. It should be noted that this entire process is performed with corrected local clock bias. The compensation for drift is implemented for every sample in the snap, assuming a linear drift model.

Compensating for local clock bias

In each snap, data is collected in order to provide a set of parameters required for repeatedly correcting the measurements performed using the local clock as a reference. Data from optional sources are collected and submitted for processing by a processor of the unit of the invention in. In **Fig. 6** to which reference is now made, the data collected for providing to processor **240** of the

NRU of the invention are classified into three groups. Group **242** is the information related to the satellite system. This group includes:

1. Ephemeris data for each satellite received
2. Differential correction parameters for each satellite received is optionally provided.
3. Satellite system time (TOW)

Group **244** contains the location parameters of the NRU itself, in units and terms compatible with the geographical notation used by the unit. This Information need not be updated once the unit is positioned, but should be updated if the unit is moved. Group **246** contains the information carried by the signals of the BTSs, which include the transmitted signals of all available BTSs, at preset frequencies.

Table 1 describes the above information types and the alternative sources for their acquisition.

Table 1.

Information type	Possible Information source
Ephemeris for each received satellite.	1. Locally received and processed satellite navigation signals. 2. Network system.
Differential correction parameters	1. Network
Satellite system time	1.Locally processed
Location parameters	1. Network 2. NRU processor
BTS signals	1. Locally received BTSs

In accordance with a preferred embodiment of the invention, the sequence of events leading to calibration of the local clock begins with determining the location of the NRU. Such can be achieved by either obtaining the information from a data base within the network or by calculating within the NRU, based on received satellite data. Within the NRU, the determination can be carried out by the processor of the unit, or by the adjunct receiver, if present. In **Fig. 7** to which reference is now made, the steps for determining the described are described. In step **250**, the receiver locks on to every available satellite, extracting from each of them navigation information, which allows in step **252** to calculate ranges to each of the available satellites. In step **254**, from the range parameters calculated for each satellite, the local clock bias for each satellite, as will be explained later on. Bias obtained for each satellite, in step **256** a mean is calculated with respect to all of the satellites.

The functional relationship between local clock bias and the range is explained as follows. The difference in time of transmission (T_{tr}) from the satellite and the time of reception of a signal (T_{re}) is the time it takes to a signal to pass the distance from the satellite to a receiver. Theoretically , this time, multiplied by the speed of light (C) is the distance (Range) between the two objects. Theoretically:

1. $(T_{tr} - T_{re})XC = R$

In reality, this range is not absolute because the parameter T_{re} is measured by a relatively inaccurate local clock, and the measured distance is called therefore pseudorange (PR). In real world therefore:

2. $(T_{tr} - T_{re})XC = PR$

A parameter representing the local clock bias is inserted in the equation as follows:

3. $(T_{tr} - T_{re} - clock\_bias) X C = R$

From a set of equations formed by the measurements performed with respect to each satellite, R given as distance between the geographical location of the NRU, and the satellite's position as derived from the ephemeris data, T_{tr} extracted, T_{re} provided, clock_bias is calculated. Clock bias is thus calculated for each satellite received, and a mean is calculated. The clock bias obtained is used for correcting the local clock bias at the snap start (advance or retard).

As regards the clock drift, Doppler frequency is used in the assessment of the variable. The local clock drift is calculated as follows:

$$Local\_clock\_drift = \frac{measured\_Doppler\_offset - calculated\_Doppler\_offset}{Nominal\_frequency}$$

Compensating for satellite clock bias

Within the ephemeris of the satellite navigation message, there is contained information for compensating for satellite clock offset and drift. This information is used for correcting the system time synchronization, and local clock bias and drift.

Determining BTS clock drift

The transmitter in each BTS contains a clock that provides a reference for the production of the discrete signals subsequently received by the individual mobile receivers localized within the particular cell. Although the clock of the BTS is more stable than that of the NRU, the procedure of the invention includes determining the clock drift of each BTS timing signals received, with reference to the more stable satellite system clock. In order to determine a BTS clock drift, two separate snaps are executed, registering in each snap a nominal of a synchronization frame, matched to a snap start. The entire procedure for determining BTS clock drift is explained schematically by reference to **Fig. 5**, to which reference is again being made. BTS signal **162** is digitized and synchronization frame **170** is identified, its identity registered. Arrow **112** designates the point in time on the local clock's time axis at which a first period start is encountered. Thence, the start time of synchronization frame **170** with respect to arrow **112**, is registered as ΔTsnap1. In other words, the difference in time (corrected local clock time), between code period start and synchronization frame start is registered. Subsequently, in the consecutive snap, the same procedure is repeated, registering ΔTsnap2.

The difference ΔTsnap1- ΔTsnap2, for a given nominal time difference between the respective snap starts, is considered a function of the BTS clock drift. The resulting parameter is used by mobile units for calculating location, based on ranging to BTSs.

Synchronizing BTSs clocks with satellite system time

The purpose of this aspect of synchronization of the BTSs is to correlate between their timing and the GPS system time. This procedure is implemented mainly for facilitating so called hybrid location procedures, involving pseudoranging to satellites as well as to BTSs. The C/A code used for regular pseudoranging positioning tasks of GPS receivers is transmitted in code periods as explained above. Each code period lasts exactly 1 msec (millisecond) and repeats itself perpetually and contiguously. Each sequence of 20 code periods is structured into a data bit and each 30 bits are structured into a word. The entire navigation data message of the satellite is a 30 seconds long entity, divided into 5 sub-frames. Each sub-frame divides into 10 words each one 600 msec long, the first of which in a cycle is a telemetry message (known as TLM) which is an identifiable timing structure. Following the TLM word is a HOW (hand over word) that contains the TOW (time of week) information. There exists a synchronization between a beginning of a data bit and a beginning of a code period. A more elaborate explanation is found in UNDERSTANDING GPS: PRINCIPLES AND APPLICATIONS, Elliott D. Kaplan, ed., Artech House Publications, Boston – London.1996, pp. 186 – 189, the contents of which are incorporated herein by reference. In order to keep the system of the invention synchronized with the system time, the snap must be performed at such a time as the HOW word, containing the TOW data is received. This is performed by orderly scanning of the navigation message, until such a time as identification of a TLM word is achieved.

Reference is again made to **Fig. 5**, now describing schematically in a snap performed during a HOW word, BTSs signals and satellite code periods are received. A snap start designated by arrow **160** indicates, on the local clock time axis and on the satellite time axis, the initiation of data collection and loading into the snap memory. Collected are frames of a first BTS signal

162, and of a second BTS **164**. In addition, the code periods of GPS navigation transmission **166** are collected. Synchronization frames of the BTSs, such as frame **170** of BTS **162** are shadowed to distinguish them from other frames. Thus, when a synchronization frame is encountered, it is identified by its internal structure, and the identification number it bears is registered, then, the number pf frames elapsed between this frame and the snap start (arrow **160**) are counted, including fractions of a frame, thereby finding the time between the snap start and the synchronization frame, in sub-frame resolution. The arrow **112** indicates the first code period start encountered during since snap start. This timing indicator is also registered with respect to snap start 160 so all BTSs synchronization frames are also registered with respect to code periods of the satellite.

CLAIMS

1. A network reference unit for providing time reference for unsynchronized cellular network, wherein identifiable time references of respective signals of a plurality of BTSs (base stations) are mutually synchronized, comprising:
    - a receiver for receiving a plurality of BTS signals,
    - at least one receiver for GPS satellite navigation signals,
    - a local clock for providing rate for sampling said BTS signals and said GPS satellite navigation signals,
    - at least one ATD (analog to digital) converter for each receiver;
    - a snap memory for storing BTS and satellite data of at least one snap, and
    - a processor for processing data received at least from said snap memory.

2. A network reference unit for providing time reference for unsynchronized cellular network as in claim 1, comprising two receivers for GPS signals.

3. A method for mutually synchronizing respective signals of a plurality of BTSs of an unsynchronized cellular network, and for synchronizing said plurality of BTS with GPS system time, whereby a reference unit receives said plurality of BTSs and

matches identifiable timing references of said signals, comprising the steps of:

- receiving signals of said plurality of BTSs signals in a single snap,
- receiving identifiable timing references of at least one GPS navigation satellite signal in said snap,
- compensating a local clock of said reference unit for offset and drift with respect to GPS clock,
- sampling simultaneously said at least one satellite signal and said plurality of BTSs signals,
- measuring time difference between identifiable timing references of each respective signal and a snap start, and
- matching between said identifiable timing references and satellite system time.

4. A method for mutually synchronizing signals of a plurality of BTSs of an unsynchronized cellular network, as in claim 3, and wherein at least ephemeris data for calculating said compensating of said local clock is obtained from said cellular network.

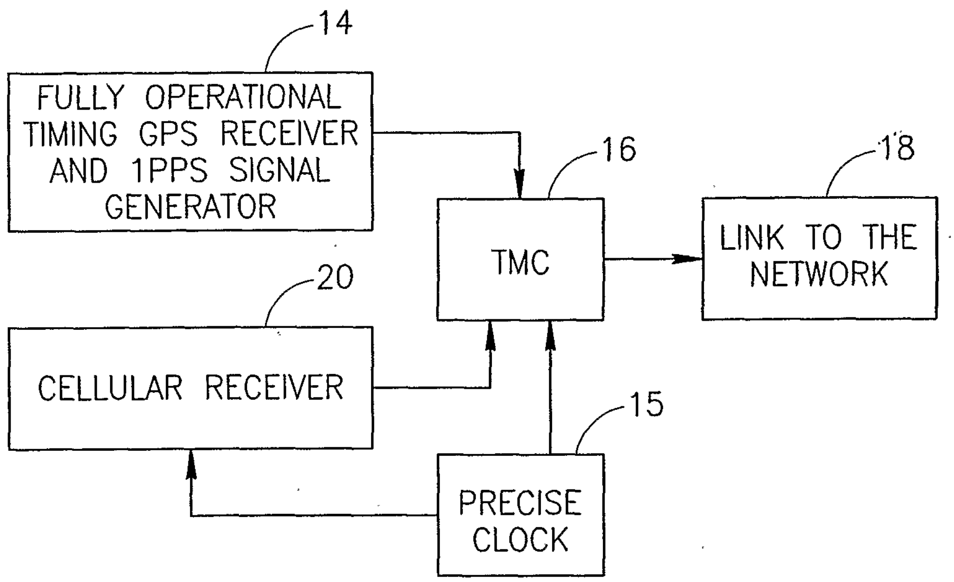

FIG.1A
PRIOR ART

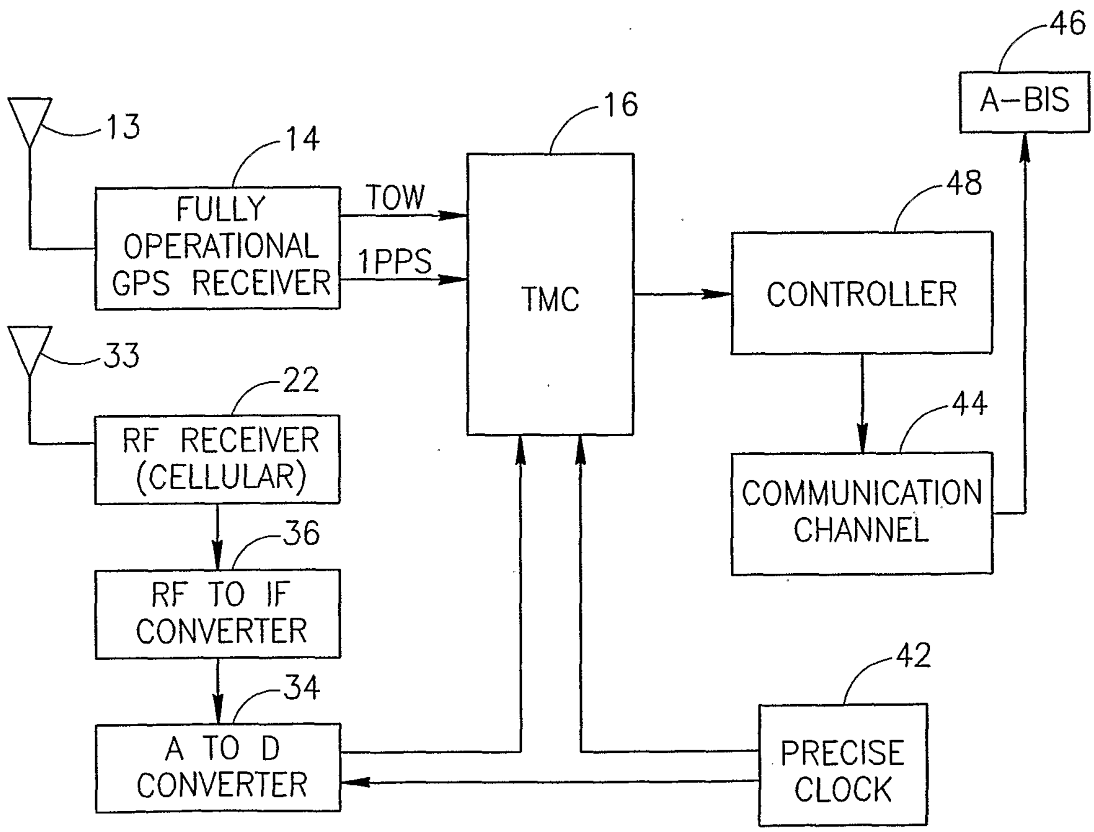

FIG.1B
PRIOR ART

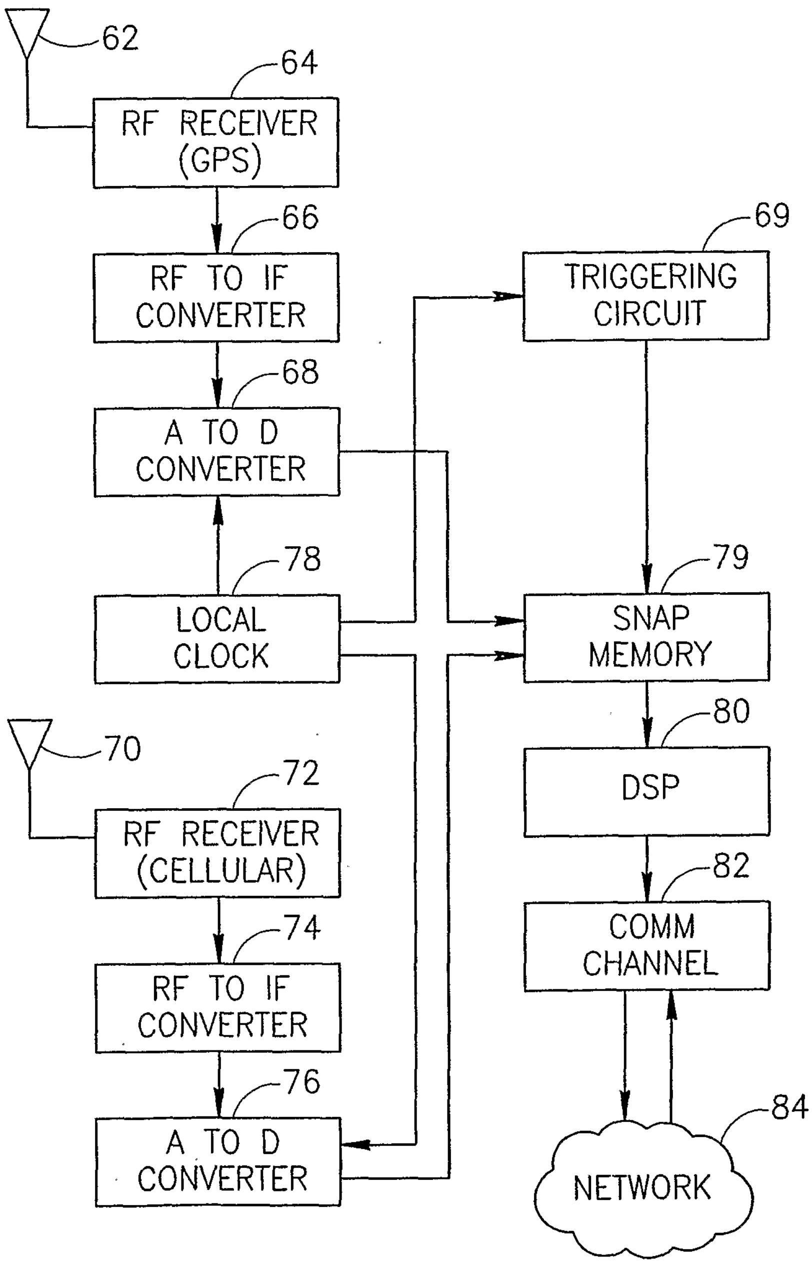
62
64
RF RECEIVER (GPS)
66
RF TO IF CONVERTER
68
A TO D CONVERTER
78
LOCAL CLOCK
70
72
RF RECEIVER (CELLULAR)
74
RF TO IF CONVERTER
76
A TO D CONVERTER
69
TRIGGERING CIRCUIT
79
SNAP MEMORY
80
DSP
82
COMM CHANNEL
84
NETWORK

FIG.2A

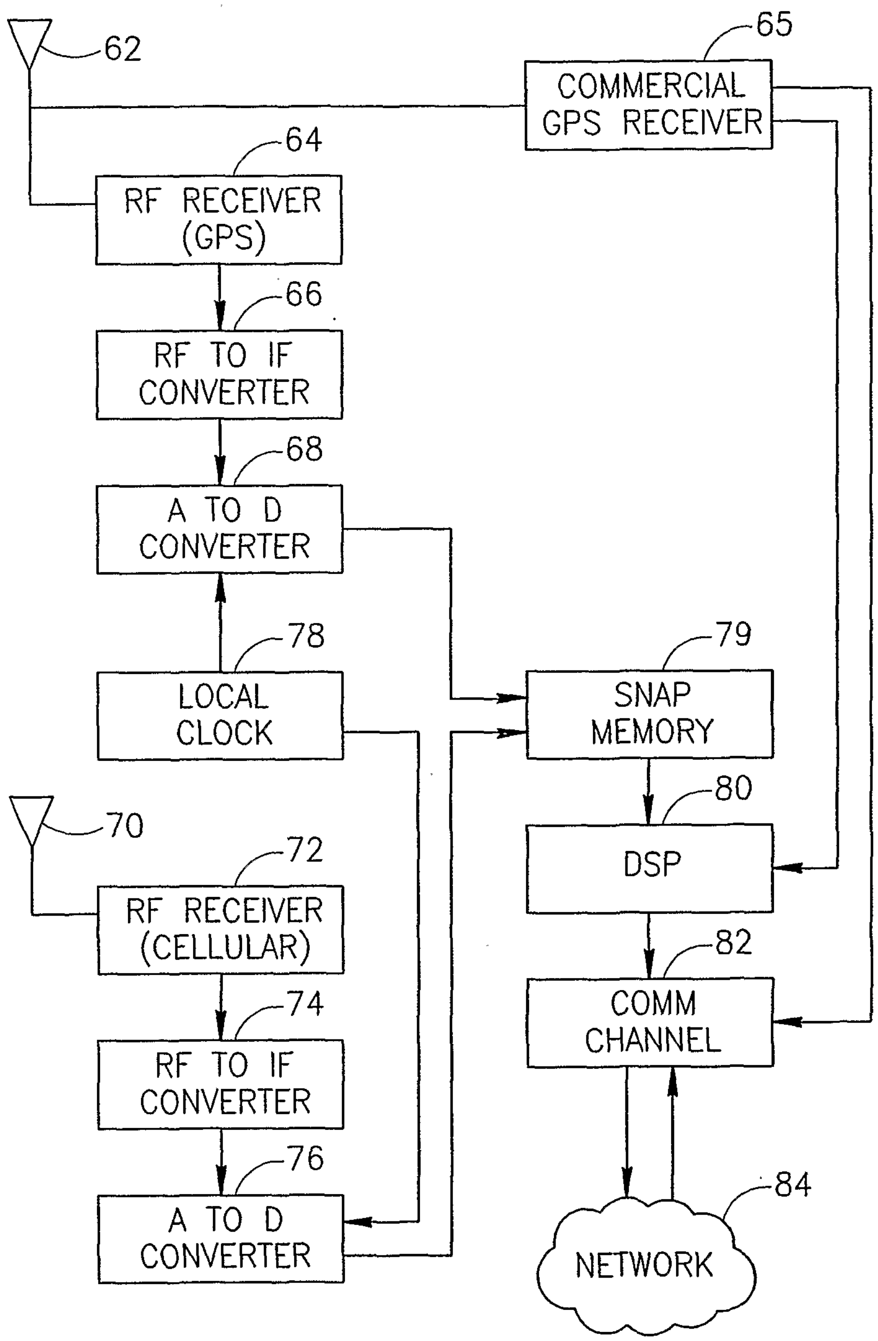
62
65
COMMERCIAL GPS RECEIVER
64
RF RECEIVER (GPS)
66
RF TO IF CONVERTER
68
A TO D CONVERTER
78
LOCAL CLOCK
79
SNAP MEMORY
80
DSP
70
72
RF RECEIVER (CELLULAR)
82
COMM CHANNEL
74
RF TO IF CONVERTER
76
A TO D CONVERTER
84
NETWORK

FIG.2B

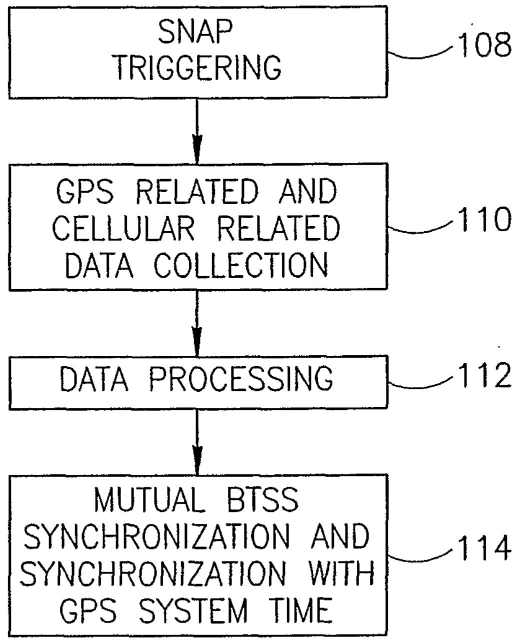
SNAP TRIGGERING
108
GPS RELATED AND CELLULAR RELATED DATA COLLECTION
110
DATA PROCESSING
112
MUTUAL BTSS SYNCHRONIZATION AND SYNCHRONIZATION WITH GPS SYSTEM TIME
114

FIG.3

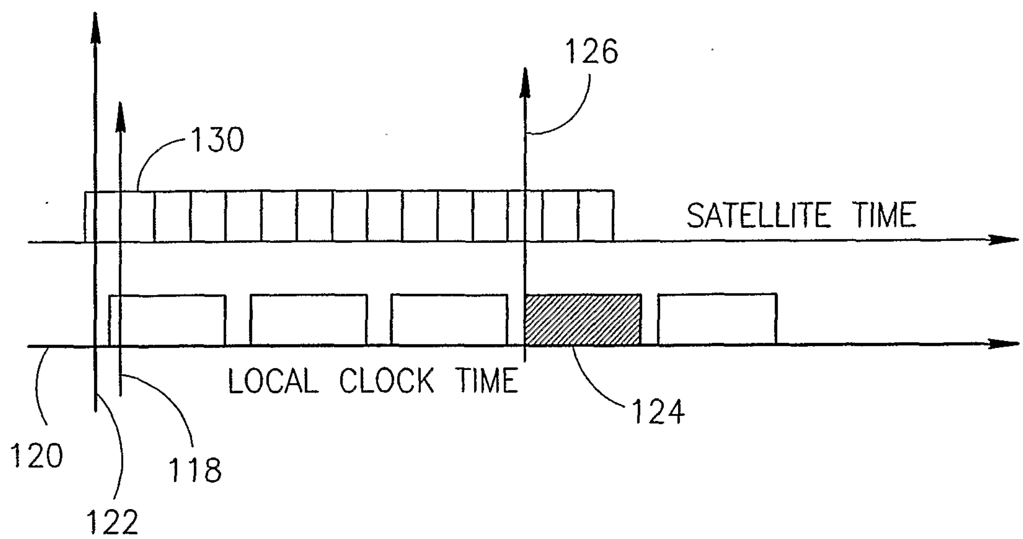
126
130
SATELLITE TIME
LOCAL CLOCK TIME
124
120
118
122

FIG.4

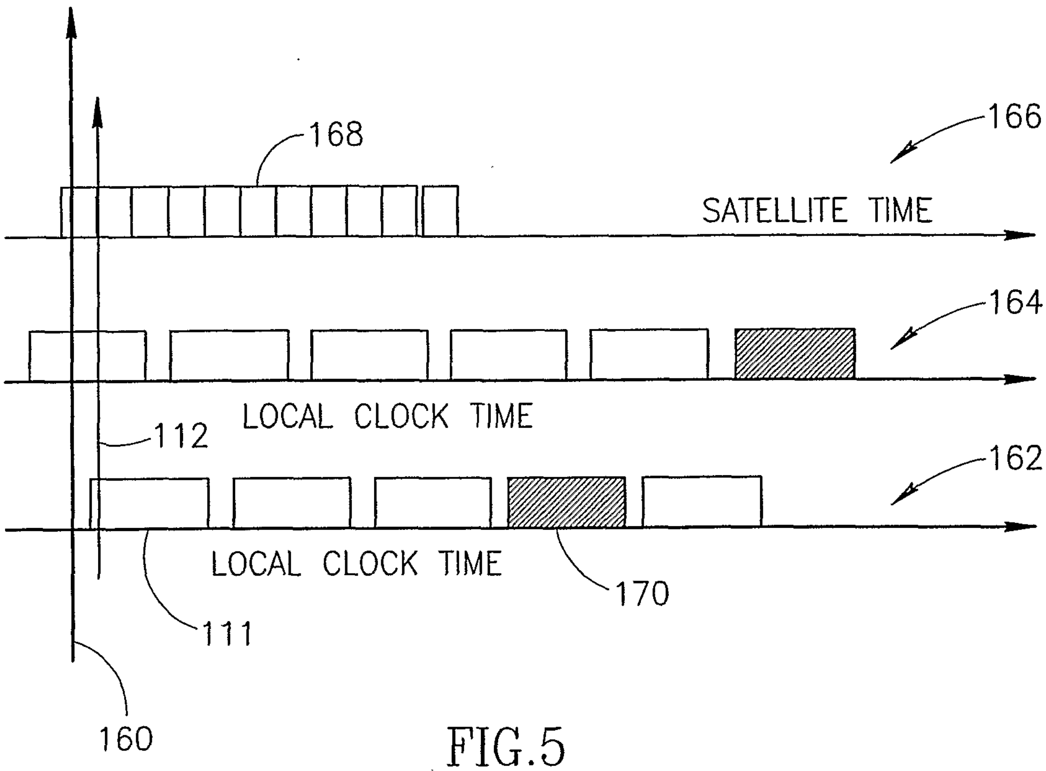
168
166
SATELLITE TIME
164
LOCAL CLOCK TIME
112
162
LOCAL CLOCK TIME
170
111
160

FIG.5

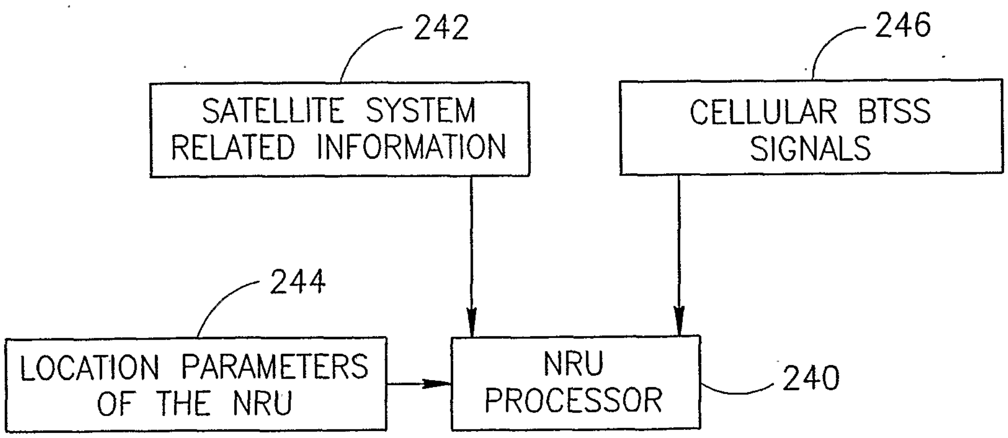
242
SATELLITE SYSTEM RELATED INFORMATION
246
CELLULAR BTSS SIGNALS
244
LOCATION PARAMETERS OF THE NRU
NRU PROCESSOR
240

FIG.6

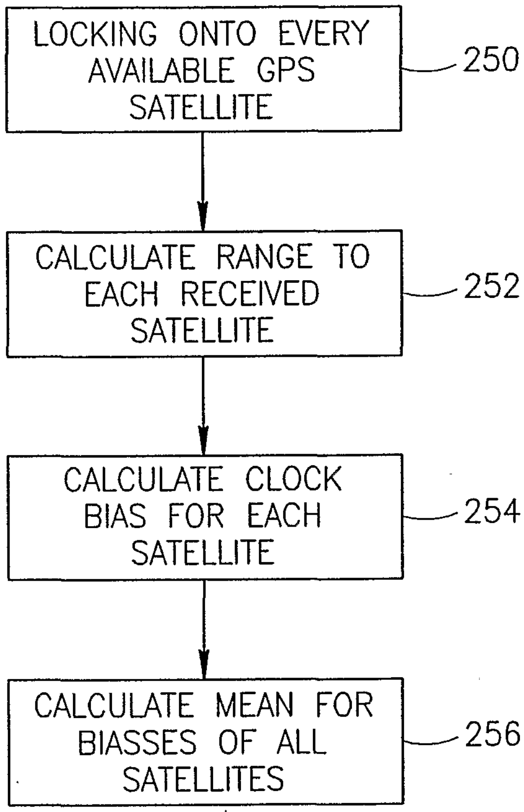
LOCKING ONTO EVERY AVAILABLE GPS SATELLITE
250
CALCULATE RANGE TO EACH RECEIVED SATELLITE
252
CALCULATE CLOCK BIAS FOR EACH SATELLITE
254
CALCULATE MEAN FOR BIASSES OF ALL SATELLITES
256

FIG.7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/08557

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/26

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 H04B H04Q 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	WO 98 52376 A (NOKIA TELECOMMUNICATIONS OY ;RANTALAINEN TIMO (FI); SILVENTOINEN M) 19 November 1998 (1998-11-19) abstract page 1, line 28-34 page 2, line 8 -page 3, line 10 page 5, line 31 -page 6, line 11 page 11, line 35 -page 12, line 13 claims	1-4
A	EP 0 803 994 A (ITALTEL SPA) 29 October 1997 (1997-10-29) abstract column 4, line 35-59 column 5, line 22-41 column 6, line 51 -column 7, line 54 claims	1-4

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[X] Further documents are listed in the continuation of box C.

[X] 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

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"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
7 September 2001	20/09/2001

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	Dejonghe, O

1

Internati   ıplication No
PCT/US 01/08557

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 23785 A (DRANE CHRISTOPHER R ;MACNAUGHTAN MALCOLM D (AU); SCOTT CRAIG A (AU) 3 July 1997 (1997-07-03) abstract page 2, line 27-36 page 3, line 10-25 page 7, line 22-30 page 10, line 4 -page 11, line 35 claims ---	1-4
A	WO 99 21028 A (CAMBRIDGE POSITIONING SYS LTD ;DUFFETT SMITH PETER (GB); HANSEN PA) 29 April 1999 (1999-04-29) the whole document -----	1-4

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 01/08557

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9852376	A	19-11-1998	AU	2895997	A	08-12-1998
			EP	1008269	A	14-06-2000
			NO	995452	A	08-11-1999
EP 0803994	A	29-10-1997	IT	MI960785	A	22-10-1997
WO 9723785	A	03-07-1997	AU	708505	B	05-08-1999
			AU	1133297	A	17-07-1997
			US	6275705	B	14-08-2001
			US	2001004601	A	21-06-2001
WO 9921028	A	29-04-1999	AU	9549898	A	10-05-1999
			BG	104363	A	31-01-2001
			BR	9814614	A	03-10-2000
			CN	1276876	T	13-12-2000
			EP	1025453	A	09-08-2000
			HR	20000240	A	28-02-2001
			HU	0004241	A	28-04-2001
			NO	20002068	A	19-04-2000
			PL	340056	A	15-01-2001
			SK	5792000	A	09-10-2000
			TR	200001096	T	21-08-2000
			TW	425797	B	11-03-2001