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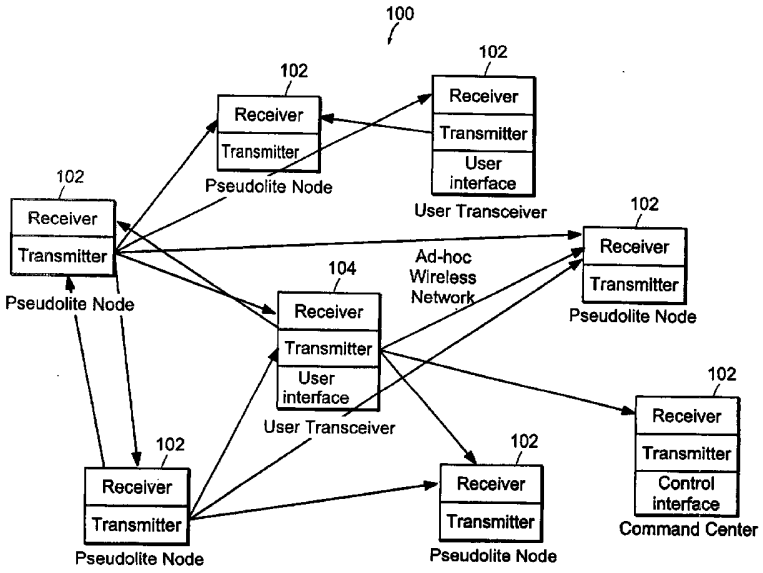
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[Continued on next page]

(54) Title: RECONFIGURABLE GEOLOCATION SYSTEM



(57) Abstract: A portable reconfigurable geolocation system is provided. The system includes a portable user node and one or more portable pseudolite nodes in communication one another and with the user node. Each of the user nodes and pseudolite nodes includes a transmitter that generates a signal on one or more carrier frequencies. Each signal is modulated with digital signals necessary to establish distances between the nodes and to convey data between the nodes. Each node also includes a receiver for receiving and demodulating the signals transmitted between the nodes, and a processor for receiving the demodulated signals, extracting data values and derived values from the demodulated signals and determining a three-dimensional position of each node in the system.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Reconfigurable Geolocation System

Technical Field

The present invention relates to global positioning systems, and more particularly to apparatus and methods for providing a reconfigurable geolocation system.

Background Art

One of the most hazardous jobs firefighters and other emergency personnel must do is to enter a burning building. In this situation, the building floor plan may be unknown (and may change), visibility is impaired, and the locations of equipment and personnel may change. Combining this situation with a limited air supply and potentially obstructed escape paths results in an extremely dangerous environment.

In such an environment, there are strict limits on the amount of time a firefighter may be inside a burning building due to limitations imposed by the limited air supply and on increasing fire and smoke intensity. Additional challenges result as a consequence of the complete or partial failing of the building, which may result in the destruction of escape paths.

Pseudo-satellites, or pseudolites, are commonly known in the art as devices which transmit a GPS, or GPS-type signal, but which are located in relatively close proximity to the ground. When using pseudolites to provide navigation in an indoor, underground or obstructed environment, there is a concern that nearby pseudolites will negatively impact the ability of a receiver to track all of the available pseudolites. This problem, known as the "near-far" problem, is a consequence of limited dynamic range. Some techniques for solving this problem, such as modifying the pseudolite duty cycle or synchronizing the pseudolite transmissions have been previously proposed.

A system for locating emergency personnel in a building has been discussed in "A System of Tracking and Locating Emergency Personnel Inside Buildings" presented by Progri et al. at the Institute of Navigation (ION GPS 2000, 19-22 September 2000, pp. 560-568). Similarly, techniques for dealing with the "near-far" problem have been discussed in "Techniques for Reducing the Near-Far Problem in Indoor Geolocation Systems" presented by Hill et al., at the Institute of Navigation (ION NTM 2001, 22-24

January 2001, pp. 860-865). The above referenced publications and presentations are hereby incorporated herein, in their entirety, by reference.

Summary of the Invention

In a first embodiment, a portable reconfigurable geolocation system is provided. The system includes a portable user node and at least three portable pseudolite nodes in communication with one another and with the user node. Each of the user nodes and pseudolite nodes includes a transmitter that generates a signal on one or more carrier frequencies. Each signal is modulated with signals necessary to establish distances between the nodes and to convey data between the nodes. Each of the nodes also includes a receiver for receiving and demodulating the signals transmitted between the nodes, as well as a processor for receiving the demodulated signals, extracting data values and derived values (such as range and phase) from the demodulated signals and determining a three-dimensional position of each node in the system.

In accordance with a related embodiment, each user node optionally includes a user interface. In accordance with another related embodiment, communication between the nodes may be wireless. In accordance with further related embodiments, signals generated by the user node and the pseudolite nodes may be modulated by at least two digital signals. The at least two digital signals may establish at least two communication channels that are substantially orthogonal to one another. Similarly, at least one digital signal may provide signal selection for a particular signal frequency, interference resistance, or bit synchronization resolution. The processor may be configured to optimize ranging and communications topology of the system, verify the integrity of information transmitted in the system, and/or provide dynamic reconfiguration of the system in the event of node failure.

In accordance with another embodiment of the invention, a method of locating a communication node in an area is provided. The method includes distributing a plurality of portable nodes within the area; each of the nodes including a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor. Communication is established between the nodes, and signals generated by the nodes are modulated with signals necessary to establish distances between the nodes and to convey data between the nodes. A three-dimensional position of each of the nodes is determined using the

modulated signals.

In accordance with a related embodiment, modulating signals generated by the nodes may include establishing at least two communication channels that are substantially orthogonal to one another. In accordance with a further related embodiment, establishing communication between the nodes may include establishing wireless communication between the nodes. In accordance with a further related embodiment, modulating signals generated by the nodes may include modulating the signals by at least two digital signals, and at least one digital signal may provide signal selection for a particular signal frequency. Similarly, at least one digital signal may provide interference resistance and/or bit synchronization.

In accordance with another embodiment of the invention, a portable pseudolite node includes a transmitter that generates a signal on one or more carrier frequencies. Each of the signals is modulated with digital signals necessary to establish distances between the nodes and to convey data between the nodes. The pseudolite node also includes receiver for receiving and demodulating the signals transmitted between the nodes. The pseudolite node also includes a processor for receiving the demodulated signals, extracting data values and derived values (such as range and phase) from the demodulated signals and determining a three-dimensional position of each node in the system.

In accordance with a further embodiment of the invention, a method for locating a human in an area includes providing the human with a portable user node. The user node includes a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor. A plurality of portable pseudolite nodes are distributed within the area. Each of the pseudolite nodes includes a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor. Signals generated by the user node and the pseudolite nodes are modulated with digital signals to establish communication among the user node and the pseudolite nodes and to convey data among the user node and pseudolite nodes. A relative position of the user node and the pseudolite nodes is determined using the modulated signals, and a relative position of the human is determined using the relative position of the user node and the pseudolite nodes. In accordance with a related embodiment, providing the human with a portable user node includes providing the human with a portable user node that includes a user interface. In

accordance with a further related embodiment, providing wherein providing the human with a portable user node includes providing the human with a portable user node that includes an input/output device.

Brief Description of the Drawings

The foregoing features of the invention will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram illustrating a reconfigurable geolocation system in accordance with an embodiment of the invention;

Fig. 2 is a block diagram illustrating a pseudolite node of the reconfigurable geolocation system of Fig. 1;

Fig. 3 is a flowchart illustration a method for locating the position of a communication node in an area in accordance with another embodiment of the invention; and

Fig. 4 is a flow chart illustrating a method for locating a human in an area in accordance with a further embodiment of the invention.

Detailed Description of Specific Embodiments

The present invention provides users with the ability to accurately navigate in environments where access signals from the Global Positioning System is unavailable and where radio navigation aids are either unavailable or of insufficient accuracy and/or reliability.

In Fig. 1 is shown a block diagram illustrating a portable reconfigurable geolocation system in accordance with an embodiment of the invention. The system **100** employs a plurality of portable pseudolite nodes **102** as well as one or more portable user nodes **104.** The user nodes **104** may be identical to the pseudolite nodes **102** and augmented with an ability to interact in a more sophisticated manner with a user, such as through a user interface and/or data input and output devices.

As shown in Fig. 2 each portable pseudolite node **102** contains one or more transmitters **206** and one or more receivers **208** as well as appropriate antennae and batteries (not shown). Each pseudolite node **102** also includes a computing element or

processor **210** which performs any necessary data processing, signal processing, and general control operations to support the operation of the node **102**. Each portable user node **104** includes one or more transmitters **216**, one or more receivers **218**, appropriate antennae and batteries, a processor **220**, and a user interface **222**. Each user interface **222** may be configured for a particular user. For example, the interface **222** may be part of a hand-held portable device for one user, such as a firefighter or other human being in a building. Similarly, the interface **222** may be a conventional CRT for a user at a command and control center, and the user node may be provided with other input and output devices **224** such as keyboard and mouse, modem, monitor, facsimile and/or printer.

Every pseudolite signal is modulated by three known pseudo random codes at a rate commonly known as the chipping rate and the bandwidth of the resulting signal is proportional to the chipping rate. The first pseudo random code is shorter and is used only to select the appropriate signal from a given channel. The second pseudo random code is identical for every signal and it is used to resolve the bit synchronization and, at the same time, to improve the signal auto-correlation properties. The third pseudo random code is much longer and provides better jammer/interference resistance due to its auto-correlation and cross-correlation properties. Examples of apparatuses and methods that may be used to modulate the pseudolite signals are described in co-pending patent application entitled "Adaptive Spatial Temporal Selective Attenuator with Restored Phase" filed on the same day of the present application (June 11, 2003) and bearing attorney docket number 2627/104, which is hereby incorporated by reference.

The transmitted signal is typically modulated in such a way that both an in-phase channel and a quadrature-phase channel are formed. Typically, the code sequences used on the in-phase and quadrature-phase channels are orthogonal or near orthogonal. In general, the data transmitted between nodes **102, 104** (pseudolite or user) can be modulated on one or the other or both of these channels. Further, the data modulated on the in-phase channel can be different from the data modulated on the quadrature-phase channel. To improve system performance by further increasing the system dynamic range, the transmitted signal can also be modulated by an additional code sequence. Such a code sequence may be applied to resolve bit synchronization and provide timing information on both or either of the in-phase and quadrature-phase channel(s).

The number of channels supported by the transmitters and receivers may or may not be the same as the number of pseudolite nodes **102**. The only issue associated with the number of channels that are supported is that a sufficient number of channels should be available to avoid any near-far problem that exists in the deployment area. The architecture of each channel is similar to that of an ordinary Global Positioning System receiver, with the exception that every channel must optionally track a different carrier.

Although each pseudolite node **102** can operate on a single frequency (as is the case with the Global Positioning System), the system **100** also permits the use of multiple frequencies. Such multiple frequencies would typically be equally spaced by integer multiples of π multiplied by the chipping rate. When multiple frequencies are used, a significant improvement in receiver dynamic range results, which eliminates the so-called "near-far" problem that reduces the effectiveness of single frequency systems.

In accordance with the embodiment of Fig. 1, the pseudolite nodes **102** are distributed in an ad-hoc manner, the only restriction being that each pseudolite node **102** must be able to make contact with one or more other pseudolite nodes **102** in the system **100**. On initialization, the pseudolite nodes will exchange information to allow them to determine both the achievable connectivity of the network and the distance to each pseudolite node **102** having a direct communication path. As a result of this information, both the physical configuration and the network paths to each node in the system **100** can be determined. Using signals received from a known location, the specific geographic location of each pseudolite node **102** in the system **100** can be determined using, for example, the same kinds of algorithms which are commonly used in current GPS receivers. A similar process allows determining the location of user node **104** in the system **100**.

In accordance with another embodiment, the pseudolite nodes **102** may be arranged in specific locations, eliminating the need to automatically determine the geographic locations and network paths in the system **100.**

Fig. 3 is a flowchart illustration a method for locating the position of a communication node in an area in accordance with another embodiment of the invention. A plurality of portable nodes are distributed **301** within the area. Each of the nodes includes a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor. In process **302**, communication between the nodes is

established, and signals generated by nodes are modulated **303** with signals necessary to establish distances between the nodes and to convey data between the nodes. A three-dimensional position of each of the nodes is determined **304** using the modulated signals. Modulating signals generated by the nodes may include establishing at least two communication channels that are substantially orthogonal to one another.

Fig. 4 is a flow chart illustrating a method for locating a human being such a firefighter or rescue worker, in an area in accordance with another embodiment of the invention. The person is provided with a portable user node in process **401**. The user node includes a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor. The user node may also include a user interface, as well as other input and output devices.

A plurality of portable pseudolite nodes are distributed **402** within the area. Each of the pseudolite nodes includes a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor. Signals generated by the user node and the pseudolite nodes are modulated **403** with digital signals to establish communication among the user node and the pseudolite nodes and to convey data among the user node and pseudolite nodes. A relative position of the user node and the pseudolite nodes is determined **404** using the modulated signals, and a relative position of the firefighter or other person is determined **405** using the relative position of the user node and the pseudolite nodes.

In order to ensure that both positioning and communications among the user and pseudolite nodes are reliable, certain features may be included to ensure that the integrity of the system is preserved. In the case of communications information, integrity can be enhanced by encoding the signals in such a way that transmission errors may be detected and/or corrected. Commonly known methods of providing this form of integrity include techniques such as Viterbi coding or the inclusion of forward error correction ("FEC") codes. The reliability of position information may be enhanced using receiver autonomous integrity monitoring ("RAIM") techniques such as those commonly used in GPS receivers.

Further discussion related to indoor geolocation systems and integration systems related thereto may be found in "A DSSS/CDMA/FDMA Indoor Geolocation System" presented by Progri et al. at the Institute of Navigation (ION GPS 2002, 24-27 September

2002, Portland, OR, pp. 155-164) and "GPS/Pseudolite/SDINS Integration Approach for Kinematic Applications" presented by Lee at the Institute of Navigation (ION GPS 2002, 24-27 September 2002, Portland, OR, pp. 1464-1473) Further disclosure relating to pseudolite signal structure may be found in "The Impact of Proposed Pseudolite's Signal Structure on the Receiver's Phase Code Error" presented by Progri and Michalson at the Institute of Navigation (ION 57th Annual Meeting/CIGTF 20th Biennial Guidance Test Symposium, 11-13 June 2001, Albuquerque, NM, pp. 414-422) and "An Investigation of the Pseudolite's Signal Structure for Indoor Applications" presented by Progir et al. at the Institute of Navigation (ION 57th Annual Meeting/CIGTF 20th Biennial Guidance Test Symposium, 11-13 June 2001, Albuquerque, NM, pp. 453-462). Further disclosure relating to the "near-far" problem for indoor geolocation systems may be found "An Alternative Approach to Multipath and Near-Far Problem for Indoor Geolocation Systems" presented by Progri and Michalson at the Institute of Navigation (ION GPS, 2001, September 11-14, 2001, Salt Lake City, UT, pp. 1434-1443). All of these documents and presentations are hereby incorporated herein, in their entirety, by reference.

While the invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification. This application is intended to cover any variation, uses, or adaptations of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which invention pertains.

What is claimed is:

1. A portable reconfigurable geolocation system comprising:

a portable user node; and

at least three portable pseudolite nodes in communication with one another and with the user node;

the user node and pseudolite nodes each having:

a transmitter that generates a signal on one or more carrier frequencies, each signal being modulated with digital signals necessary to establish distances between the nodes and to convey data between the nodes;

a receiver for receiving and demodulating the signals transmitted between the nodes;

a processor for receiving the demodulated signals, extracting data values and derived values from the demodulated signals and determining a three-dimensional position of each node in the system.

2. A system according to claim 1, wherein the user node further comprises a user interface.

3. A system according to claim 1, wherein communication between the nodes is wireless.

4. A system according to claim 1, wherein signals generated by the user node and the pseudolite nodes are modulated by at least two digital signals.

5. A system according to claim 4, wherein the at least two digital signals establish at least two communication channels that are substantially orthogonal to one another

6. A system according to claim 4, wherein at least one digital signal provides signal selection for a particular signal frequency.

7. A system according to claim 4, wherein at least one digital signal provides interference resistance.

8. A system according to claim 4, wherein at least one digital signal provides bit synchronization resolution.

9. A system according to claim 1, wherein the processor optimizes ranging and communications topology of the system.

10. A system according to claim 1, wherein the processor verifies the integrity of information transmitted in the system.

11. A system according to claim 1, wherein the processor provides dynamic reconfiguration of the system in the event of node failure.

12. A method of locating a communication node in an area, the method comprising:

distributing a plurality of portable nodes within the area, each of the nodes including a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor;

modulating signals generated by the nodes with digital signals to enable communication between the nodes and to convey data between the nodes; and

determining a relative three-dimensional position of each of the nodes using the modulated signals.

13. A method according to claim 12, wherein modulating signals generated by the nodes includes establishing at least two communication channels that are substantially orthogonal to one another.

14. A method according to claim 12, wherein establishing communication between the nodes includes establishing wireless communication between the nodes.

15. A method according to claim 12, wherein modulating signals generated by the nodes includes modulating the signals by at least two digital signals.

16. A method according to claim 12, wherein modulating signals generated by the nodes includes modulating the signals by at least one digital signal that provides signal selection for a particular signal frequency.

17. A method according to claim 15, wherein modulating signals generated by the nodes includes modulating the signals by at least one digital signal that provides interference resistance.

18. A method according to claim 15, wherein modulating signals generated by the nodes includes modulating the signals by at least one digital signal that provides bit synchronization resolution.

19. A portable pseudolite node comprising:

a transmitter that generates a signal on one or more carrier frequencies, each signal being modulated with digital signals necessary to establish distances between the nodes and to convey data between the nodes;

a receiver for receiving and demodulating the signals transmitted between the nodes;

a processor for receiving the demodulated signals, extracting data values and derived values from the demodulated signals and determining a three-dimensional position of each node in the system.

20. A method for locating a human in an area, the method comprising:

providing the human with a portable user node, the user node including a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor;

distributing a plurality of portable pseudolite nodes within the area, each of the pseudolite nodes including a transmitter that generates a signal on one or more carrier frequencies, a receiver, and a processor;

modulating signals generated by user node and the pseudolite nodes with digital signals to establish communication among the user node and the pseudolite nodes and to convey data among the user node and pseudolite nodes;

determining a relative position of the user node and the pseudolite nodes using the modulated signals; and

determining a relative position of the human using the relative position of the user node and the pseudolite nodes.

21. A method according the claim 20, wherein providing the human with a portable user node includes providing the human with a portable user node that includes a user interface.

22. A method according to claim 20, where providing the human with a portable user node includes providing the human with a portable user node that includes an input/output device.

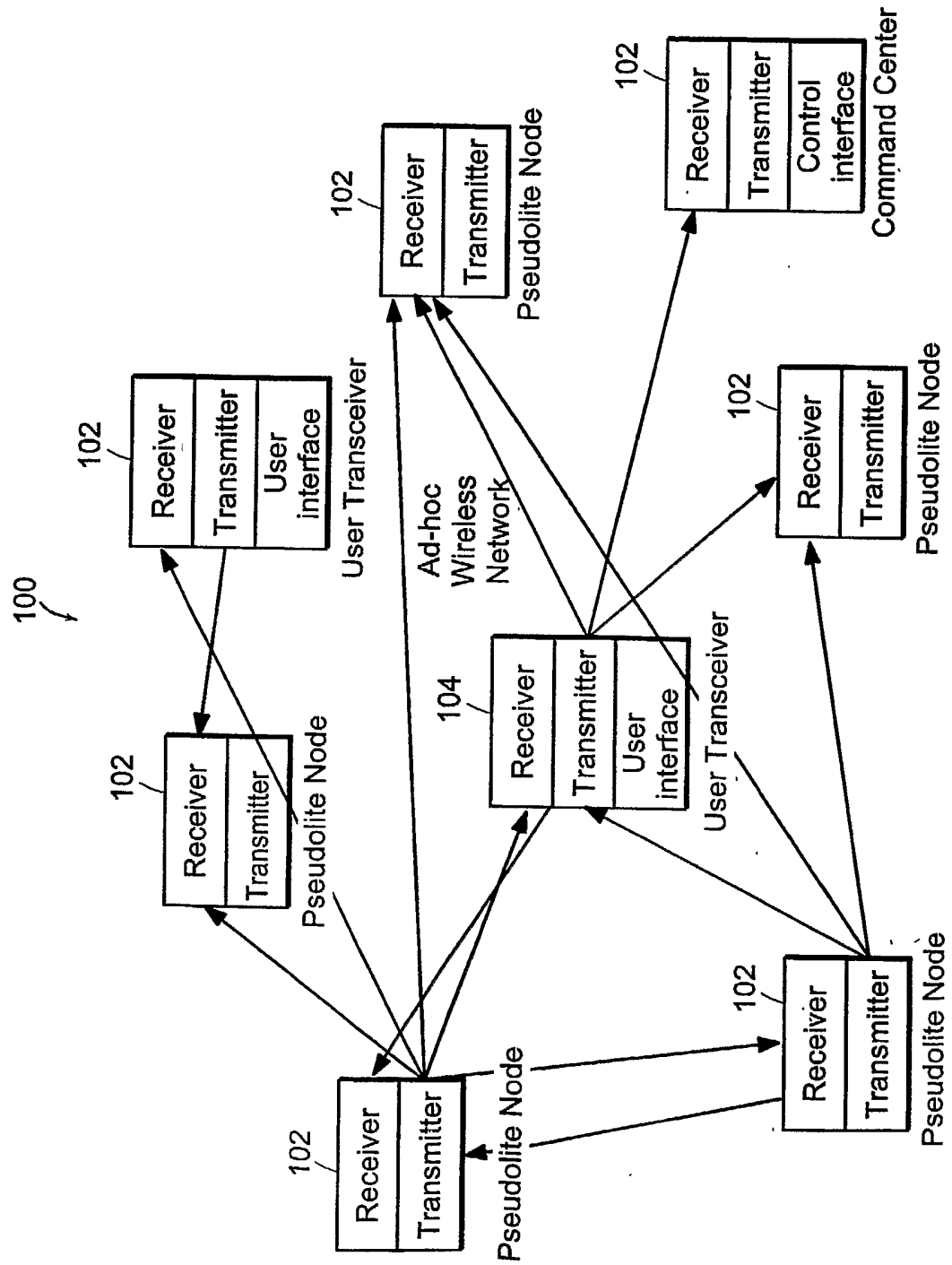

100
102
Receiver
Transmitter
User interface
User Transceiver
Ad-hoc Wireless Network
Pseudolite Node
Control interface
Command Center
104

FIG. 1

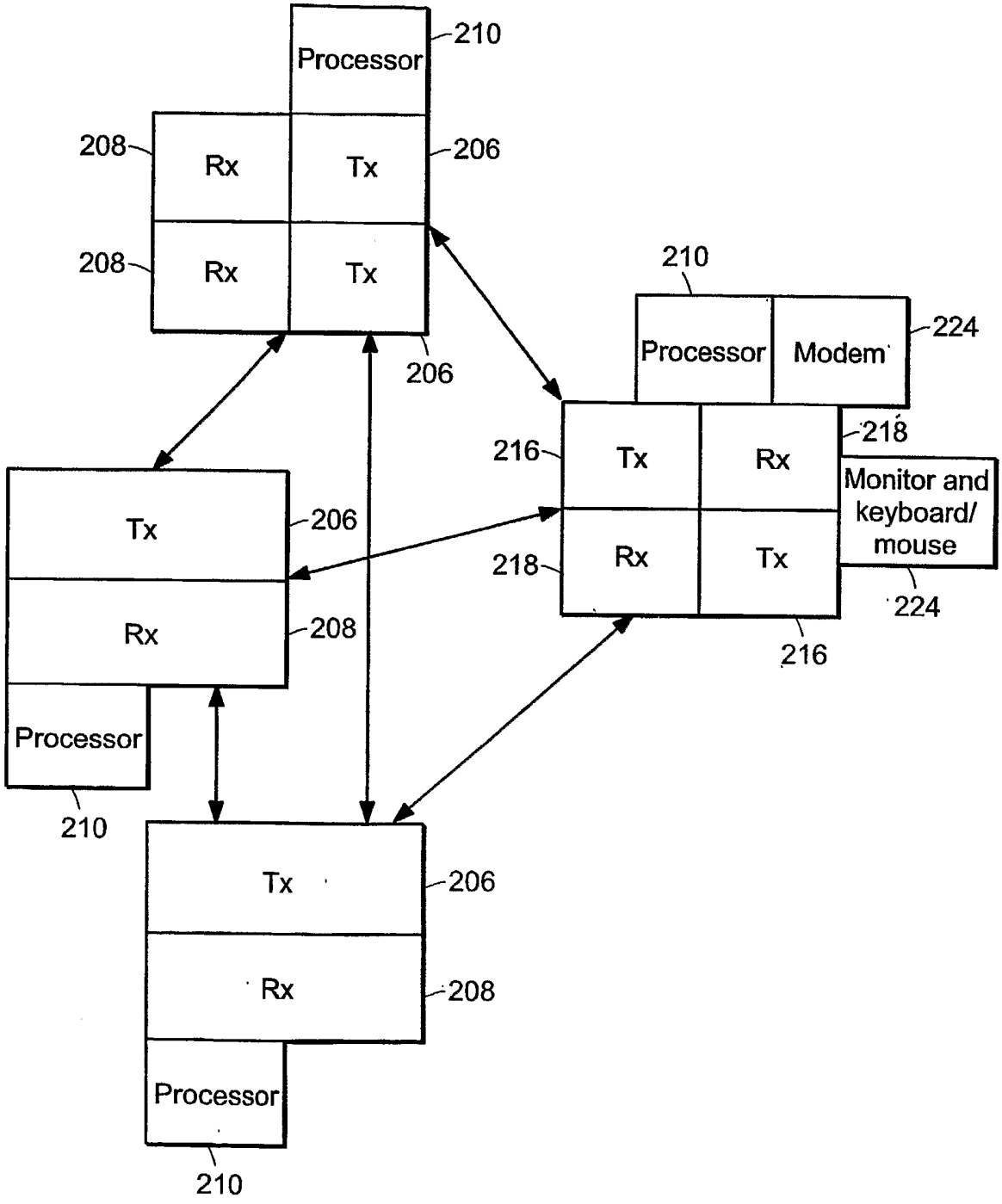

Processor
210
208
Rx
Tx
206
208
Rx
Tx
206
210
Processor
Modem
224
218
216
Tx
Rx
Monitor and keyboard/ mouse
218
Rx
Tx
224
216
Tx
206
Rx
208
Processor
210
Tx
206
Rx
208
Processor
210

FIG. 2

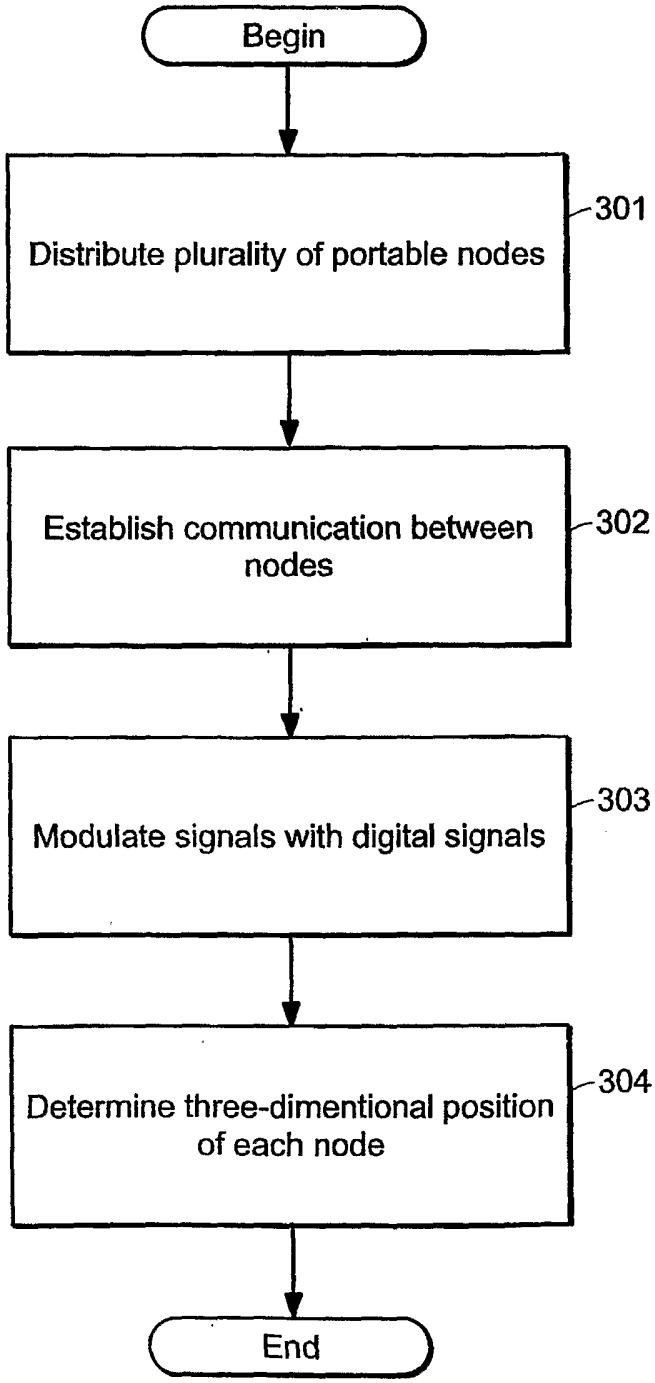

Begin
Distribute plurality of portable nodes
301
Establish communication between nodes
302
Modulate signals with digital signals
303
Determine three-dimentional position of each node
304
End

FIG. 3

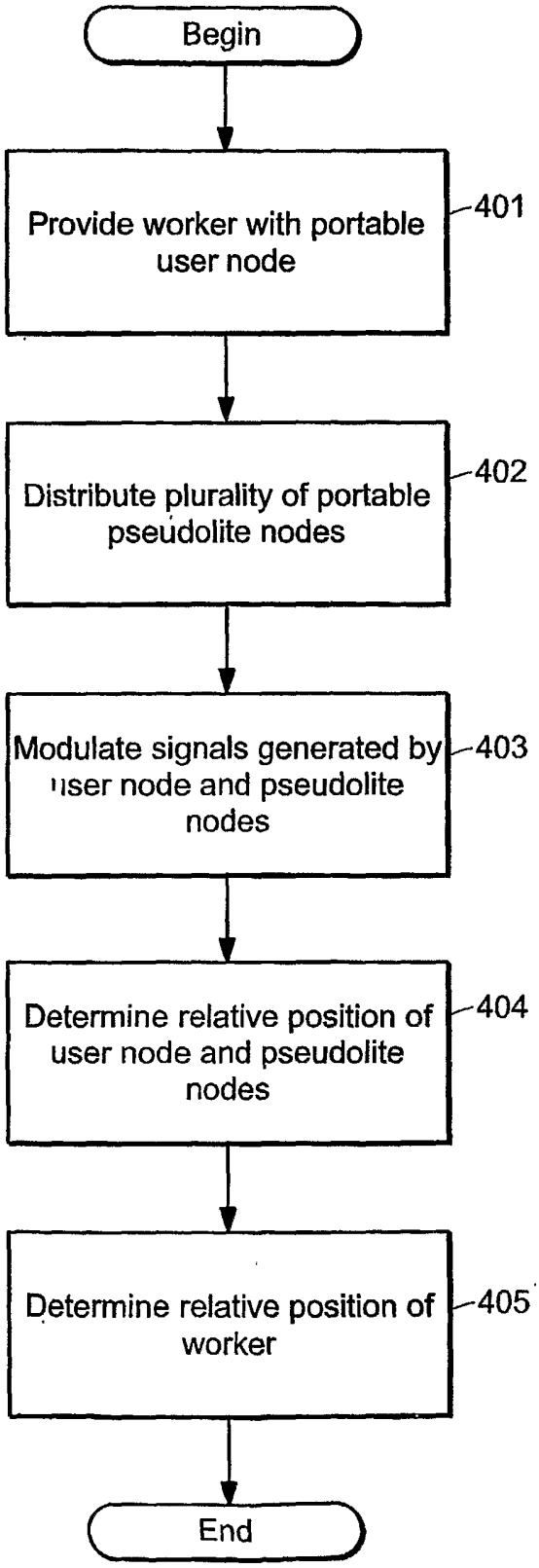

Begin
Provide worker with portable user node
401
Distribute plurality of portable pseudolite nodes
402
Modulate signals generated by user node and pseudolite nodes
403
Determine relative position of user node and pseudolite nodes
404
Determine relative position of worker
405
End

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/18268

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S1/68 G01S5/02 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 99 63358 A (SMALL DAVID ;COMMUNICATIONS PTY LTD Q (AU)) 9 December 1999 (1999-12-09) page 11, line 16 -page 13, line 11; figures 4-8 page 19, line 3 -page 20, line 22 ---	1-22
X	PATWARI N ET AL: "RELATIVE LOCATION IN WIRELESS NETWORKS" VTC 2001 SPRING. IEEE VTS 53RD. VEHICULAR TECHNOLOGY CONFERENCE. RHODES, GREECE, MAY 6 - 9, 2001, IEEE VEHICULAR TECHNOLGY CONFERENCE, NEW YORK, NY: IEEE, US, vol. 2 OF 4. CONF. 53, 6 May 2001 (2001-05-06), pages 1149-1153, XP001067140 ISBN: 0-7803-6728-6 page 1149 -page 1153 --- -/--	1,12,19, 20

[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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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 September 2003	17/09/2003

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	Fanjul Caudevilla, J

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

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/18268

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02 03091 A (HAMDI MAHER ;CAPKUN SRDAN (CH); ECOLE POLYTECH (CH); VETTERLI MART) 10 January 2002 (2002-01-10) abstract; figure 1 page 8, line 19 -page 11, line 4	1,12,19, 20
X	CAPKUN S ET AL: "GPS-FREE POSITIONING IN MOBILE AD-HOC NETWORKS" , PROCEEDINGS OF THE ANNUAL HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES, XX, XX, PAGE(S) 1-10 XP008001836 page 1 -page 7	1,12,19, 20
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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