

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



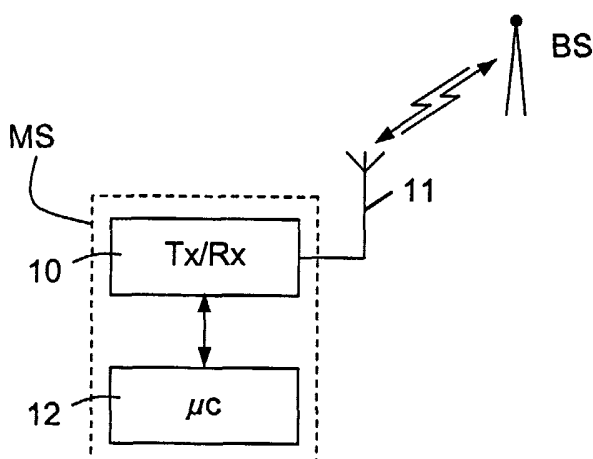
(43) International Publication Date
1 May 2003 (01.05.2003)

PCT

(10) International Publication Number
WO 03/036833 A1

- (51) International Patent Classification⁷: **H04J 3/06**
- (21) International Application Number: PCT/IB02/03844
- (22) International Filing Date:
18 September 2002 (18.09.2002)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
0125600.7 25 October 2001 (25.10.2001) GB
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- (81) Designated States (*national*): CN, JP, KR.
- (84) Designated States (*regional*): European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR).
- Published:**
— with international search report
- 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.

(54) Title: METHOD OF OBTAINING TIMING INFORMATION AND METHODS OF RANGING USING SAID TIMING INFORMATION



(57) Abstract: A method of obtaining timing information between first MS and second BS devices is disclosed together with methods of ranging using said timing information and devices for the same. The method of obtaining timing information comprising the steps of transmitting a timing signal from the first device MS to the second device BS at a time t1 relative to the local clock of the first device MS and measuring the time of arrival t2 of that signal at the BS second device relative to the local clock of the second device BS; transmitting a timing signal from the second device BS to the first device MS at a time t3 relative to the local clock of the second device BS and measuring the time of arrival t4 of that signal at the first device MS relative to the local clock of the first device MS; and assembling the values of t1, t2 and t4 in one of the devices.

WO 03/036833 A1

DESCRIPTION

**METHOD OF OBTAINING TIMING INFORMATION AND METHODS
OF RANGING USING SAID TIMING INFORMATION**

5

This invention relates to a method of obtaining timing information between first and second devices and to methods of ranging between the two devices using said timing information.

10 In particular, the invention relates to a method of obtaining timing information comprising the steps of transmitting a timing signal from the first device to the second device at a time t_1 relative to the local clock of the first device and measuring the time of arrival t_2 of that signal at the second device relative to the local clock of the second device; and transmitting a timing signal from the second device to the first device at a time t_3 relative to the local clock
15 of the second device and measuring the time of arrival t_4 of that signal at the first device relative to the local clock of the first device.

Such a method is known from the section "Protocols for co-operating localisers to determine range" of the report entitled "Low-Power, Miniature,
20 Distributed Position Location and Communication Devices Using Ultra-Wideband, Nonsinusoidal Communication Technology" prepared by Æther Wire & Location Inc. for the US Advanced Research Projects Agency / Federal Bureau of Investigation (Contract J-FBI-94-058) in July 1995. At the time of writing, this report is available from the website of Æther Wire & Location Inc.
25 at url http://www.aetherwire.com/PI_Report_95/pi_rep95.html.

In this report, a method of ranging between two devices is suggested in which timing information is obtained as above, and then the second device transmits the difference (Δtime) between t_2 and t_3 to the first device. The first device is then able to determine the range r between the two devices as:

30
$$r = \frac{c}{2}(t_4 - t_1 - \Delta\text{time})$$

where c is the speed of light. In effect, the range is determined as a function of

the round trip delay less the time elapsed between the second device receiving a timing signal and transmitting a return timing signal.

It is an object of the present invention to provide an alternative and improved method of obtaining timing information as described above with which the timing information obtaining can be readily used for, amongst other purposes, quantifying the lack of synchronicity and ranging between the two devices.

In accordance with the present invention, such a method is provided in which the values of t1, t2, t3 and t4 are assembled together, ideally in one of the two devices although conceivable in a third device. In the case of the former, this may be done by transmitting values t2 and t3 from the second device to the first device and where this is the case, the values t2 and t3 may be transmitted in the timing signal transmitted at a time t3. Alternatively, the values t1, t2, t3 and t4 may be assembled in the second device by transmitting values t1 and t4 from the second device to the first device.

In either case, the difference between the local clocks (ΔClock) of the two devices, the lack of synchronicity, may be readily determined in one of the devices using the values of t1, t2, t3 and t4. For example:

$$\Delta\text{Clock} = \frac{t1 - t2 - t3 + t4}{2}$$

Further in accordance with the present invention, the range r between the two devices may be readily determined in one of the devices using the values of t1, t2, t3 and t4. For example, the range may be determined as:

$$r = \frac{c}{2}(t4 - t1 - t3 + t2)$$

where c is the speed of light

Alternatively, after determining the difference between the local clocks (ΔClock), the range r may be determined by transmitting a further timing signal from one of the devices at a time t5 relative to the local clock of that device and measuring the time of arrival t6 of that signal at the other device relative to

the local clock of that device; and determining the range r between the two devices using the values of t_5 , t_6 and ΔClock . In this case, the range r may be determined as:

$$r = \frac{c}{2}(t_6 - t_5 - \Delta\text{Clock})$$

5 and, again, optionally transmitted to the other device.

Also provided in accordance with the present invention is a corresponding combination of first and second devices as claimed in claims 13 and 14, and corresponding devices in isolation as claimed in claims 15 to 27.

10 The present invention will now be described, by way of example only, with reference to following figures in which:

Figures 1 and 2 show, schematically, a mobile cellular telephone MS ranging with to a nearby cellular telephone network base station BS.

15 Figure 1 shows, schematically, a mobile cellular telephone MS in accordance with the present invention and registered with a nearby cellular telephone network base station BS facilitating voice and data communication with that base station and the corresponding cellular telephone network (not shown). Such data communication may include text messaging using, for
20 example, the short message service (SMS) protocol and accessing the internet using, for example, the wireless application protocol (WAP). The telephone is shown comprising a communications transmitter (Tx) and receiver (Rx) 10 connected to a communications antenna 11 and controlled by a communications microprocessor (μc) 12.

25 Figure 2 shows, schematically, the base station BS with which the telephone MS of figure 1 is registered. The base station also comprising a communications transmitter (Tx) and receiver (Rx) 20 connected to a communications antenna 21 and controlled by a communications microprocessor (μc) 22.

30 As the design and manufacture of such telephones and base stations for two-way communication within a cellular telephone network are well known,

those parts which do not directly relate to the present invention will not be elaborated upon here further.

As is known, in the event of the user of mobile cellular telephone MS making an emergency call, a position fix may be determined in the mobile cellular telephone and transmitted from mobile cellular telephone MS back to the base station and then on to the emergency services operator, termed the Public Safety Answer Point (PSAP) in the US. In order to obtain a position fix, the mobile telephone MS must range to at least 3 base stations of known location (only 1 shown).

In accordance with the present invention, each range r is obtained as described in steps described below:

- telephone MS transmits a signal to base station BS at a time t_1 relative to the telephone's local clock
- base station BS measures the time of arrival t_2 of the signal transmitted by telephone MS relative to the base station's local clock
- base station BS transmits a signal to telephone MS at a time t_3 relative to the base station's local clock wherein the signal comprises the values of t_2 and t_3
- telephone MS measures the time of arrival t_4 of the signal transmitted by base station BS relative to the telephone's local clock and extracts from the signal values of t_2 and t_3 ; and
- telephone MS calculates its range to basestation BS as:

$$r = \frac{c}{2} (t_4 - t_1 - t_3 + t_2)$$

where c is the speed of light

Ideally, times t_1 , t_2 , t_3 and t_4 are measured to nanosecond resolution if ranging within a few metres is to be done. Telephone MS may also calculate the difference (ΔClock) between the local clocks of the telephone and base station as:

$$\Delta\text{Clock} = \frac{t_1 - t_2 - t_3 + t_4}{2}$$

which enables telephone MS to make future measurements of range by

receiving only a signal from base station BS, until the difference between clocks of the telephone and base station drifts as described above. This difference may be transmitted to the base station.

Once 3 ranges have been obtained, the distances are resolved with the known positions of the base stations and a position fix determined. Of course, ranging to more than three base stations results in an overdetermined set of equations which can be resolved by a best fit type, iterative method to provide a position fix with improved accuracy and tolerance to error. Also, the first timing signal transmitted by the telephone MS may be received and measured by all three base stations.

This position fix is then transmitted to the base station with which the telephone is registered for the purposes of voice and data communication, and subsequently forwarded onwards to the emergency services operator thereby enabling the user of the telephone to receive prompt, location specific assistance.

Whilst the method of the present invention has been described with reference ranging in a cellular telephone context, it will be appreciated that this could have applied to other devices such as those that might be present in an in-home network or a local, say factory based positioning system.

Also, specific methods for measuring the time of transmission and reception of timing signals are well known and have not been greatly elaborated on in this disclosure. However, it is noteworthy that delays may occur in the transmitter and receiver owing to filters, delays with A to D converters etc. which will appear as part of the time-of-flight measurement and it may be necessary to measure these delays to remove them (for example, by factory calibration). If the delays transmitting from one device and receiving by another are the same the other way around, then the equations for ΔClock will still be valid although the values obtained for range r are strictly speaking pseudoranges until these delays have been subtracted.

CLAIMS

1. A method of obtaining timing information between first and second devices comprising the steps of:
 - 5 - transmitting a timing signal from the first device to the second device at a time t_1 relative to the local clock of the first device and measuring the time of arrival t_2 of that signal at the second device relative to the local clock of the second device;
 - transmitting a timing signal from the second device to the first device
10 at a time t_3 relative to the local clock of the second device and measuring the time of arrival t_4 of that signal at the first device relative to the local clock of the first device; and
 - assembling the values of t_1 , t_2 , t_3 and t_4 in a single device.
- 15 2. A method accordingly to claim 1 wherein the values t_1 , t_2 , t_3 and t_4 are assembled in the first device by transmitting values t_2 and t_3 from the second device to the first device.
- 20 3. A method according to claim 2 wherein the values t_2 and t_3 are transmitted from the second device to the first device in the timing signal transmitted at a time t_3 .
- 25 4. A method according to claim 1 wherein the values t_1 , t_2 , t_3 and t_4 are assembled in the second device by transmitting values t_1 and t_4 from the second device to the first device.
- 30 5. A method according to any of the preceding claims further comprising the step of determining, using one of the devices, the difference between the local clocks (ΔClock) of the two devices using the values of t_1 , t_2 , t_3 and t_4 .
6. A method according to claim 5 wherein the difference between

the local clocks (ΔClock) is determined as:

$$\Delta\text{Clock} = \frac{t_1 - t_2 - t_3 + t_4}{2}$$

7. A method according to claim 5 or claim 6 wherein the difference
5 between the local clocks (ΔClock) determined by one of the devices is
transmitted to the other device.

8. A method of ranging between first and second devices
comprising the steps of:

- 10 - obtaining timing information between the two devices by a method
according to any of the preceding claims; and
- determining, using one of the devices, the range r between the two
devices using the values of t_1 , t_2 , t_3 and t_4 .

15 9. A method according to claim 8 wherein the range r is determined
as:

$$r = \frac{c}{2}(t_4 - t_1 - t_3 + t_2)$$

where c is the speed of light.

20 10. A method of ranging between first and second devices
comprising the steps of:

- obtaining timing information relating to the difference between the local
clocks (ΔClock) of the two devices by a method according to any of claims 5
to 7
25 - transmitting a further timing signal from one of the devices at a time t_5
relative to the local clock of that device and measuring the time of arrival t_6 of
that signal at the other device relative to the local clock of that device; and
- determining the range r between the two devices using the values of
 t_5 , t_6 and ΔClock .

11. A method according to claim 10 wherein the range r is determined as:

$$r = \frac{c}{2} (t_6 - t_5 - \Delta \text{Clock})$$

where c is the speed of light.

5

12. A method according to any of claims 8 to 11 wherein the range r is determined by one of the devices and transmitted to the other device.

13. A combination of first and second devices, each of which is adapted for two way communication with the other and has a local clock which is unsynchronised with respect to the other wherein the combination of devices are mutually adapted to obtain timing information between each other by a method in accordance with any of claims 1 to 7.

14. A combination of first and second devices, each of which is adapted for two way communication with the other and has a local clock which is unsynchronised with respect to the other wherein the combination of devices are mutually adapted to range between each other by a method in accordance with any of claims 8 to 12.

20

15. A device adapted comprising a transmitter, receiver and processor adapted to receive and measure the time of arrival t_1 relative to its local clock of a timing signal transmitted by another device; to transmit at a time t_4 relative to its local clock a timing signal to the other device; and to transmit values t_1 and t_4 to the other device.

25

16. A device according to claim 15 wherein the device is adapted to transmit its timing signal only after receiving the other timing signal.

17. A device according to claim 16 wherein the timing signal transmitted by the device contains the values of t_1 and t_4 .

30

18. A device adapted comprising a transmitter, receiver and processor adapted to transmit at a time t_1 relative to its local clock a timing signal to another device; to receive and measure the time of arrival t_4 relative to its local clock of a timing signal transmitted by the other device; and to receive and store values from the other device which are relative to the local clock of the other device and correspond to the time of arrival t_2 at the other device of the timing signal transmitted at time t_1 and to the time of transmission t_3 at the other device of the timing signal received at time t_4 .

10

19. A device according to claim 18 wherein the timing signal received by the device contains the values of t_2 and t_3 .

20. A device according to claim 18 or claim 19 further adapted to determine the difference between its local clock and the local clock of the other device (ΔClock) using the values of t_1 , t_4 , t_2 and t_3 .

21. A device according to claim 20 wherein the difference between the local clocks (ΔClock) is determined as:

20
$$\Delta\text{Clock} = \frac{t_1 - t_2 - t_3 + t_4}{2}$$

22. A device according to claim 20 or claim 21 wherein the difference between the local clocks (ΔClock) is transmitted to the other device.

23. A device according to any of claims 18 to 22 further adapted to determine the range r to the other device using the values of t_1 , t_4 , t_2 and t_3 .

24. A device according to claim 23 wherein the range r is determined as:

30
$$r = \frac{c}{2} (t_4 - t_1 - t_3 + t_2)$$

where c is the speed of light.

25. A device according to any of claims 20 to 22 further adapted to receive and measure the time of arrival t_6 relative to its local clock of a further timing signal transmitted by the other device; to receive and store a value from the other device which is relative to the local clock of the other device and corresponds to the time of transmission t_5 at the other device of that further timing signal; and to determine the range r to the other device using the values of t_5 , t_6 and ΔClock .

10

26. A device according to claim 25 wherein the range r is determined as:

$$r = \frac{c}{2}(t_6 - t_5 - \Delta\text{Clock})$$

where c is the speed of light.

15

27. A device according to any of claims 23 to 26 wherein the range r is transmitted to the other device.

FIG. 1

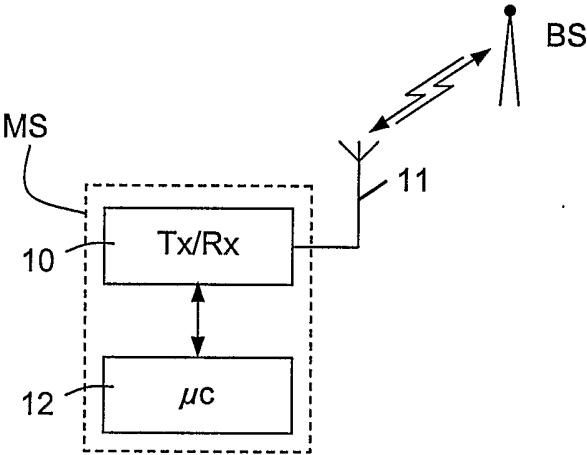
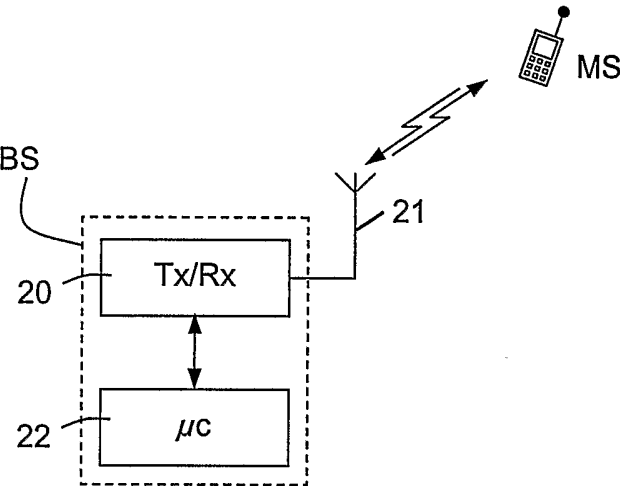


FIG. 2



INTERNATIONAL SEARCH REPORT

Int onal Application No

PCT/IB 02/03844

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04J3/06

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 H04J 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>FLEMMING ROBERT, KUSHNER CHERIE : "Low-power, miniature, distribution position location and communication devices using ultra-wideband, nonsinusoidal communication technology" SEMI-ANNUAL TECHNICAL REPORT PREPARED BY AETHER WIRE & LOCATION, INC. FOR US ADVANCED RESEARCH PROJECTS AGENCY (CONTRACT J-FBI-94-058), 'Online! July 1995 (1995-07), page 1-32 XP002223000 Retrieved from the Internet: <URL:www.aetherwire.com/PI_Report_95/pi_re p95.html> 'retrieved on 2002-11-29! cited in the application page 7, line 1 -page 8, paragraph 1 --- -/--</p>	1-27



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

29 November 2002

Date of mailing of the international search report

02/01/2003

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 02/03844

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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