



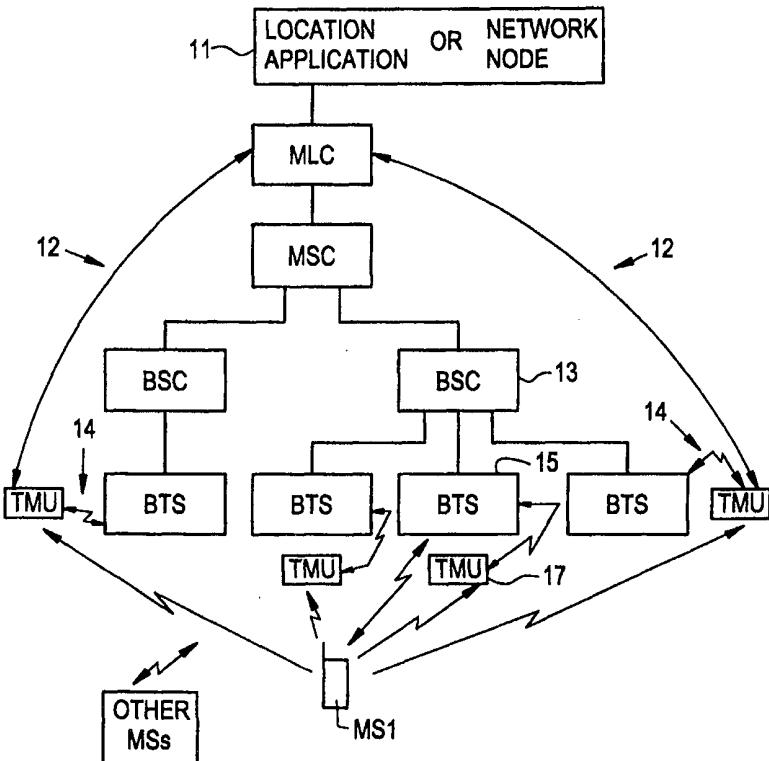
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : <b>H04Q 7/38, G01S 5/06</b>	A1	(11) International Publication Number: <b>WO 00/07404</b> (43) International Publication Date: 10 February 2000 (10.02.00)
(21) International Application Number: PCT/SE99/01307		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 23 July 1999 (23.07.99)		
(30) Priority Data: 09/123,201 27 July 1998 (27.07.98) US 09/162,079 28 September 1998 (28.09.98) US		
(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE).		
(72) Inventors: LARSSON, Erik; Helsingörsgatan 50 nb, S-164 44 Kista (SE). KANGAS, Ari; Ruddansvägen 43, 6 trp, S-114 21 Stockholm (SE). FISCHER, Sven; Rollnerstrasse 134, D-90408 Nürnberg (DE). LUNDQVIST, Patrik; 106 Ashley Glenn Drive, Cary, NC 27513 (US).		
(74) Agent: ERICSSON RADIO SYSTEMS AB; Common Patent Dept., S-164 80 Stockholm (SE).		

## (54) Title: IMPROVEMENTS IN MAKING TIME OF ARRIVAL MEASUREMENTS

## (57) Abstract

A time of arrival measurement apparatus is (TMU) used to measure the time of arrival of a radio signal (30) transmitted by a mobile communication station (MS) operating in a wireless mobile communication network. The apparatus is provided with information indicative (36) of a predetermined point in time at which the radio signal is to be transmitted. The time of arrival measurement apparatus monitors for arrival of the radio signal only during a period of time after the predetermined point in time. The time of arrival measurement apparatus also receives information (BSIC, HRN) from which it can determine an informational content of the radio signal.



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

## IMPROVEMENTS IN MAKING TIME OF ARRIVAL MEASUREMENTS

5 This application is a continuation-in-part of copending U.S. Serial No. 09/123,201 (Attorney Docket No. 34645-424) filed on July 27, 1998. This application discloses subject matter related to subject matter disclosed in copending U.S. Serial No. 09/131,150 (Attorney Docket No. 34645-423) filed on August 7, 1998, which is hereby incorporated herein by reference.

10 **FIELD OF THE INVENTION**

The invention relates generally to locating the position of a mobile communication unit in a wireless communication network and, more particularly, to uplink time of arrival measurements.

15 **BACKGROUND OF THE INVENTION**

20 The ability to locate the position of a mobile communication unit operating in a wireless communication system provides many well known advantages. Exemplary uses of such position locating capability include security applications, emergency response applications, and travel guidance applications. Among several possible techniques for providing position locating capability, uplink time of arrival (TOA) techniques are attractive because they normally do not require any changes to the mobile communication units.

25 One example of an uplink time of arrival approach will now be described with respect to the Global System for Mobile Communication (GSM), which is exemplary of a wireless communication system in which uplink time of arrival techniques are applicable. When an external application (or the GSM network itself) decides to locate the position of a mobile unit (also referred to as mobile station), a Mobile Location Center forces (via a base station controller) the mobile unit to perform a conventional intracell handover, whereupon the mobile unit transmits up to 70 uplink access bursts, one burst per TDMA

frame (i.e., one burst every 8 timeslots). The mobile unit transmits the access bursts in an attempt to comply with the intracell handover command.

5        The Mobile Location Center (MLC) orders a number of TOA Measurement Units (TMUs) to capture the access bursts and measure the time of arrival of each burst at each TMU. The TMUs then provide the MLC with their time of arrival measurements and reliability estimates for these measurements. In order to compute the position of the mobile station, the MLC uses the time of arrival values and corresponding reliability parameters, the geographic location coordinates of the TMUs, and information regarding time differences among the respective internal time bases of the TMUs. For example, each TMU can be  
10      provided with an absolute time reference (e.g., a Global Positioning System (GPS) clock), in which case the TMUs are all synchronized together, so that relative time differences among the TMUs are not a factor in the MLC's calculation of the position of the mobile station.

15      However, if the TMUs do not include an absolute time reference, then the relative differences among their respective local time references can be determined, for example, by having each TMU measure the time of arrival of an uplink burst from a stationary reference mobile station positioned at a known location in the network. The time of arrival information for the reference mobile station is then transmitted from the TMUs to the MLC. The MLC can use these time of arrival measurements to compute the relative differences in the timing  
20      references of the respective TMUs, also referred to as inter-TMU time differences (ITTDs).

25      More specifically, because the MLC knows the location of the reference mobile station and also knows the locations of the TMUs, the MLC can easily calculate the expected difference (in absolute time) between the time of arrival of the burst at a first TMU and the time of arrival of the burst at a second TMU. Then, when the MLC receives the time of arrival information as actually observed at the first and second TMUs, it can compare the difference between observed arrival times to the expected difference as previously calculated. By this comparison, the actual time difference between the local time references of the first and second TMUs (the ITTD of the first and second TMUs) can be readily determined. Time of arrival measurements on the reference mobile station can be

-3-

made periodically by the TMUs, and provided to the MLC for use in determining the ITTDs, so that MLC can maintain an updated record of the ITTDs.

In addition to the technique described above, other conventional techniques are also available for determining the ITTDs.

5 Because the MLC knows the ITTDs (or alternatively knows that the TMUs are all synchronized by a GPS system), it can calculate an estimate of the position of a given mobile station from the time of arrival information provided by the TMUs, using conventional Time Difference of Arrival (TDOA) techniques.

10 One problem with the above-described uplink time of arrival techniques is that the TMUs do not know when they should expect, or begin to monitor for, the access bursts from the mobile station. This has the following disadvantages. The sensitivity of conventional time of arrival measurement algorithms decreases as the uncertainty in the a priori knowledge of the arrival time increases. This is due to the fact that more noise and interference is received if the receiver does not know when the "meaningful" data is coming. 15 Also, the TMU must monitor for a long time in order to be sure that it captures the desired bursts. Thus, the utilization efficiency of the TMU hardware is disadvantageously degraded.

20 Furthermore, in a frequency hopping system such as GSM, the access bursts are transmitted on a frequency hopped channel. In this situation, not only does the TMU not know when to begin monitoring for the access bursts, but it also does not know which frequency it should monitor. Thus, not only is an undesirably long monitoring time possible, but the TMU would also be required to include a receiver for each frequency in the hop sequence so that all possible frequencies could be monitored.

25 It is therefore desirable to provide time of arrival measuring devices with information indicative of when the access bursts can be expected to arrive, and which frequency will be used to transmit the access bursts. According to the present invention, such information is provided to time of arrival measuring devices, thereby avoiding the aforementioned problems associated with conventional time of arrival techniques.

Also, for positioning purposes, time of arrival measurements are sometimes performed on radio links having a signal-to-noise and interference ratio (SN IR) far below

-4-

zero. Especially indoors and in rural environments, sensitivity can become a problem. Also, the TMUs that will perform the time of arrival measurements must be selected before the actual measurements are performed, when no information on SN<sub>IR</sub> is available. Thus, it is unavoidable that the radio links between at least some of the selected TMUs and the selected mobile unit will have a very poor SNR. Prediction simulators indicate that every dB that can be won in the measurement is valuable. This is especially true with respect to TMUs implemented without antenna diversity, in which case several dB are lost. This of course degrades the system performance significantly.

It is therefore desirable to provide the TMUs with enhanced sensitivity to the signaling from the mobile unit. This is achieved according to the present invention by providing the TMUs with information from which the TMUs can determine in advance certain encrypted bits in the uplink access burst that will be transmitted by the mobile unit.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a block diagram of an exemplary wireless communication system including uplink time of arrival capability according to the present invention.

FIGURE 2 illustrates an example of the mobile location center of FIGURE 1 in greater detail.

FIGURE 3 illustrates an example of the TOA measurement units of FIGURE 1 in greater detail.

FIGURE 4 is a flow diagram which illustrates example operations of the structure of FIGURES 1-3 to implement uplink time of arrival techniques according to the present invention.

FIGURE 5 illustrates how an example monitoring window is determined according to the invention.

FIGURE 6 illustrates another example of the mobile location center of FIGURE 1.

FIGURE 7 illustrates another example of the TOA measurement units of FIGURE 1.

-5-

FIGURE 8 is a flow diagram which illustrates example operations of the structure of FIGURES 1, 6 and 7 to implement uplink time of arrival techniques according to the present invention.

FIGURE 9 illustrates sensitivity enhancement achieved by the invention in the TMUs of FIGURE 1.

#### DETAILED DESCRIPTION

FIGURE 1 illustrates one example of a pertinent portion of a wireless communication system including the uplink time of arrival capability according to the present invention. The invention is implemented in a GSM network in the example of FIGURE 1. As shown in FIGURE 1, a GSM mobile switching center MSC is coupled for communication with a plurality of GSM base station controllers BSCs, which are in turn coupled to communicate with one or more GSM base transceiver stations BTSs. The base transceiver stations are capable of radio communication with a plurality of mobile stations MSs via the air interface. Communication from the MSC to the MSs via the BSCs and the BTSs is well known in the art.

FIGURE 1 also includes time of arrival measurement units TMUs which communicate with respective base transceiver stations via radio signaling through the air interface. A mobile location center MLC is coupled to communicate with the mobile switching center MSC using conventional GSM signaling protocol. In FIGURE 1, the MLC can receive a request to locate the position of a mobile station MS1. Such a request can be received from a node within the network itself, or from an external location application as illustrated at 11 in FIGURE 1. In response to this request, the MLC interrogates the MSC to thereby determine the serving BTS 15 (i.e., the serving GSM cell) and to receive from the serving BSC 13 (via MSC) all available physical channel parameters associated with the serving cell, including all frequency hopping parameters. The MLC decides which TMUs should be involved in the uplink time of arrival measurements, and initiates a conventional intracell handover command (via MSC and BSC 13), which intracell handover command is then to be transmitted to the mobile station MS1 by BTS 15.

-6-

5        The intracell handover command in GSM includes starting frame and time slot information which directs the mobile station to begin the conventional access burst (responsive to the intracell handover command) at a specified TDMA time slot in a specified TDMA frame. When initiating the intracell handover command via communication with BSC 13, the MLC either specifies to BSC 13 the frame number and time slot number, or receives from BSC 13 the frame number and time slot number that have been specified by BSC 13.

10      Communications between the MLC and the TMUs can occur, for example, via cable connections between the MLC and the TMUs (see, e.g., 12 in FIGURE 1), or via the air interface between the TMUs and BTSs (see, e.g., 14 in FIGURE 1) and the network communication path from BTS through BSC and MSC to MLC.

15      The TMUs periodically monitor the broadcast control channels of the respective base transceiver stations with which they communicate. Each TMU provides the MLC with the frame structure timing of its associated BTS relative to the TMU's own local time reference. This frame structure timing information can be transmitted from the TMUs to the MLC via, for example, conventional Short Message Service utilizing the air interface between the TMU and the MLC. This frame structure timing information can be updated periodically by the TMUs and sent to MLC periodically. Thus, when the MLC initiates the intracell handover command, which specifies the frame number and time slot number for the access burst from the mobile station, the MLC also knows the frame structure timing currently used by the mobile station MS1 in communication with its serving base transceiver station 15.

20      Moreover, the MLC also knows any inter-TMU timing differences (ITTDs) among the TMUs selected to make the uplink time of arrival measurements on the mobile station MS1. As described above in detail, the TMUs can all include a conventional absolute time reference, or the MLC can calculate the inter-TMU time differences among the TMUs using uplink time of arrival measurements made by the TMUs on a stationary reference mobile station located in a known position. The MLC can therefore determine the frame structure timing according to the local time reference of any TMU by simply translating the frame

structure timing measurement from the local timing of the TMU that made the frame structure timing measurement (TMU 17 in the example of FIGURE 1) to the local timing of any of the TMUs selected to make TOA measurements on MS1. Thus, when the MLC requests an intracell handover command specifying a frame number and time slot number of the access burst, the MLC can also communicate to the selected TMUs the frame number, the time slot number and the frame structure timing of the serving BTS (and thus the mobile station also) relative to the local timing of each respective TMU. Now, each TMU will know, relative to its own local timing reference, precisely when the mobile station will begin transmitting the first access burst.

In addition, the mobile location center can request from the base station controller 13 the conventional hopping sequence parameters associated with the serving base transceiver station 15. These parameters can also be transmitted from MLC to the TMUs along with the frame number, time slot number and frame structure timing. With knowledge of the conventional hopping sequence parameters and the frame and time slot numbers, the TMUs can then calculate the hopping sequence in conventional fashion. Thus, the TMUs will all know when (frame and time slot numbers), and on which frequency, to begin monitoring for the arrival of the access burst from the mobile station.

The MLC may also compute a monitor window beginning at the starting time as specified by the frame number and time slot number in the intracell handover command, and 20 extending for a time period determined as shown in the example of FIGURE 5. FIGURE 5 illustrates one example of how monitoring windows can be established for the TMUs of FIGURE 1. The example of FIGURE 5 illustrates determination of a monitoring window for a TMU 57 that is substantially cosited with a base transceiver station designated as BTS2. The TMU illustrated in FIGURE 5 will make time of arrival measurements on bursts received from a mobile station currently being served by the base transceiver station 25 designated as BTS1. In this situation, the longest transmission time before the burst arrives at the TMU will occur when the mobile station is located at 51, namely on the boundary of serving cell 53 opposite the TMU 57. If  $T_0$  designates the starting time of the access burst (as defined by the frame number and time slot number received by the mobile station in the

-8-

intracell handover command), then the access burst from the mobile station will actually arrive at BTS1 at the starting time T0 due to the fact that the mobile station is synchronized to the serving BTS1. This operation is conventional in, for example, GSM systems.

Due to the aforementioned synchronization, the access burst will have already arrived at BTS1 at time T0, so the total transmission time to the TMU will be  $T0 + d_{12}/c$ , where  $d_{12}$  is the distance between BTS1 and the TMU 57, and  $c$  is the speed of light. On the other hand, the shortest transmission time between the mobile station and the TMU will occur when the mobile station is located at 52, namely on the cell boundary of cell 53 nearest to the TMU. With the mobile station located at 52, the access burst will have reached point A at time T0, so that the total transmission time to the TMU will be given by  $T0 + (d_{12} - 2r)/c$ , where  $r$  is the radius of the serving cell 53. Thus, the monitoring window for the TMU 57 of FIGURE 5 would begin at time  $T0 + (d_{12} - 2r)/c$ , and would extend until time  $T0 + d_{12}/c$ . This monitoring window is easily calculated by the MLC which has stored therein or available thereto the cell radius information of all cells covered by the MLC, and either the distances between all base transceiver stations (in the case of TMUs cosited with the base transceiver stations) or the geographic coordinates of all base transceiver stations and all TMUs (to accommodate architectures wherein the TMUs are not necessarily cosited with base transceiver stations).

Rather than using the cell radius  $r$  to calculate the search window, the MLC could alternatively use the current Timing Advance (TA) value, which is conventionally available from the serving BTS. The TA value gives a rough estimate of the distance between the mobile station and the serving BTS. Because the TA value will correspond to a distance less than or equal to the cell radius  $r$ , use of the TA value can often reduce the search window by locating the beginning point of the window later in time than it would be if the cell radius  $r$  were used.

FIGURE 2 illustrates one example of the mobile location center MLC of FIGURE 1 in greater detail. In the example of FIGURE 2, the MLC includes a position locator 21 which receives the location requests from the location application or network mode at 11 in FIGURE 1. The position locator is coupled to a geographic storage portion 24 for storing

5 therein, for example, the geographic coordinates of the TMUs, the geographic coordinates of the base transceiver stations, and the cell radius of each cell covered by the MLC (or current TA value of any mobile station that is being located). The position locator includes an input 23 where time of arrival information (and associated reliability estimate) from the TMUs is received. The position locator 21 implements well-known time difference of arrival techniques in response to the time of arrival information.

10 For example, position locator 21 can operate to solve the equation  $OTD = GTD + ITTD$  where OTD is the observed time difference (difference between TMU-measured times of arrival), GTD is geographic time difference (difference between times of arrival in absolute time). Thus, the observed time differences differ from the geographic time differences due to ITTD as described above. When MLC is locating a mobile station, OTD and ITTD are known, so the equation is solved for GTD, and when MLC is determining the ITTDs using a stationary reference mobile, OTD and GTD are known, so ITTD can be calculated. When the position of the mobile station has been located by the position locator, 15 the position locator outputs the position location information to the requesting node (network or external) from which the original location request was received. Position locator 21 can determine the ITTDs from time of arrival measurements made by TMUs on a stationary reference mobile station. The ITTDs are stored in storage portion 29.

20 The position locator also outputs an intracell handover request (HO) to BSC, in which the position locator can specify the desired starting frame and time slot numbers.

25 The MLC further includes a window determiner 25 which determines the monitoring window for each TMU, for example, in the manner described above with respect to FIGURE 5. The window determiner has an input 27 for receiving the starting time (frame number FN and time slot number TSN) from the BSC 13 (via MSC). Window determiner 25 is also coupled to geographic storage portion 24 to permit access to geographic location information needed to compute the monitoring windows. A timing translator 26 receives frame structure timing information for each BTS from the associated TMU assigned to measure that BTS, and uses the ITTDs stored at 29 to translate the frame structure timing information into the timing reference of every other TMU. Frame structure timing

-10-

information for every BTS relative to every TMU's local timing reference is stored in storage portion 20.

The MLC includes a further input for receiving the hopping sequence information from the BSC 13(via MSC). The MLC provides as output a positioning measurement command to the selected TMUs (via MSC, BSC and BTS), the command including (1) monitoring window information and the frame number FN and time slot number TSN from window determiner 25, (2) hopping sequence information as received at MLC from BSC, and (3) localized frame structure timing from storage portion 20.

FIGURE 3 illustrates an example embodiment of the TMUs of FIGURE 1. The TMU of FIGURE 3 includes a frame structure monitor 31 including an input 32 for monitoring the broadcast control channel (or other channel suitable for determining frame structure timing) of the associated base transceiver station of FIGURE 1, and an output 34 for providing the frame structure timing information to the MLC (via BTS, BSC and MSC). The frame structure monitor receives its timing from the TMU's local clock 33. As discussed above, the frame structure monitor receives the broadcast control channel of the associated BTS and determines the frame structure timing of the BTS relative to the TMU's local clock. This frame structure timing information is then transmitted to the MLC at 34.

The TMU of FIGURE 3 further includes a time of arrival monitor 35 which includes an input 30 for receiving the access bursts from a mobile station, and a further input 36 for receiving the positioning measurement command information provided by MLC as described above. The time of arrival monitor also includes an output 37 for providing time of arrival information (and associated reliability estimates) to the MLC. The time of arrival monitor 35 can monitor the input 30 for access bursts during the window as defined by the received window information. The window information and starting frame and time slot numbers (FN and TSN) are interpreted by the TOA monitor 35 in conjunction with the localized frame structure timing information, so the monitoring window is properly adjusted to the local clock timing of the TMU.

The time of arrival monitor also uses the hopping sequence information, in conjunction with the starting frame and time slot numbers to compute the hopping sequence

-11-

used by the mobile station and its serving base transceiver station. Such computation of a frequency hopping sequence is a well known conventional procedure. Thus, the TMU will advantageously monitor the access bursts on the correct frequency and during a limited window of time which includes the arrival time of the access bursts. The window is of course easily re-used to measure subsequent access bursts in the (potentially) 70 burst sequence. Even without receiving the window information, the monitor would still know the burst starting time from FN, TSN and the localized frame structure timing, and thus could alternatively monitor for a predetermined default window time beginning at the known starting time.

FIGURE 4 illustrates exemplary operations of the wireless communication system portion of FIGURE 1, including the uplink time of arrival techniques of the present invention. At 61, the MLC receives a request to locate the position of a particular mobile station. At 62, the MLC determines the serving cell, obtains transmission parameters of the mobile station (including hopping sequence parameters), and selects which TMUs should be involved in the time of arrival measurement. At 63, the starting frame number and time slot number for the first access burst is specified, either by MLC or from BSC. At 64, the MLC computes the monitoring window for each selected TMU. At 65, the MLC sends the monitoring windows and hopping sequence information to the selected TMUs along with the starting frame and time slot numbers and the localized frame structure timing information. At 66, the selected TMUs compute the hopping sequence. At 67, the intracell handover command is sent to the mobile station, and the mobile station transmits the access burst in response thereto. At 68, the TMUs record the time of arrival of the access burst within their respective monitoring windows. At 69, the TMUs send the time of arrival information to the MLC. At 70, the MLC computes the position of the mobile station and relays the position information to the requesting node.

As mentioned above, the MLC receives from each TMU the frame structure timing of the associated BTS relative to the TMU's own local time reference. This information, when combined with conventional downlink time of arrival measurements made on BTSs by a stationary reference mobile station, permits the MLC to calculate the ITTDs. If the

-12-

reference mobile station makes time of arrival measurements on two BTSs, for example, by monitoring the broadcast control channel of each BTS, then the MLC can receive this information (e.g., via BTS, BSC and MSC) and calculate the timing difference between the 5 BTSs. Because the MLC also knows the timing of each BTS's broadcast control channel frame structure relative to the associated TMU, the MLC can easily calculate the ITTD between the two TMUs associated with the two BTSs measured by the reference mobile station. This technique for determining the ITTDs according to the present invention advantageously permits the reference mobile station simply to monitor existing downlink 10 signals from the BTSs, rather than transmit uplink signals to be measured by the TMUs, thus requiring no additional traffic in the network for performing ITTD determinations.

The intracell handover command in GSM conventionally includes a Handover Reference Number (HRN) associated with the particular handover. When initiating the intracell handover command via communication with BSC 13, the MLC can receive from 15 BSC 13 the BSIC of the BTS that is the intended handover target and the Handover Reference Number that has been specified for the handover by BSC 13. The MLC can then communicate to the selected TMUs the BSIC and the Handover Reference Number.

The BSIC and the Handover Reference Number are used in GSM to produce 36 encrypted bits that are included along with a 41 bit training sequence in the conventional access bursts transmitted by the mobile station. Thus, when the TMUs are provided with 20 the BSIC (6 bits) and the HRN (8 bits), the TMUs can utilize a well known algorithm in the GSM standard to produce from the BSIC and HRN bits the 36 encrypted bits of the access burst (see e.g., Draft prETSI 300 575 (GSM 05.03 version 4.5.0); July 1997, page 23).

By knowing all 77 information bits (36 encrypted bits plus 41 known training bits) of the access burst in advance, rather than knowing only the 41 bit training sequence as in 25 the prior art, the sensitivity at the TMUs is directly enhanced, as shown by the simulation example of FIGURE 9. In FIGURE 9, the horizontal axis corresponds to SNIR and the vertical axis corresponds to the standard deviation of the time of arrival estimate,  $\sigma_{TOAE}$ . Knowledge of the additional 36 bits permits the TMUs to achieve, in a far noisier environment, the same accuracy as could be achieved using only the 41 training bits in a less

-13-

noisy environment. This enhances the time of arrival measurements made by the TMUs, reduces the risk of measurement errors, and reduces the time required to make the necessary measurements.

5 FIGURE 6 is similar to FIGURE 2 but shows an MLC receiving the BSIC and HRN from the BSC, and also shows the MLC transmitting the BSIC and HRN to the TMUs.

FIGURE 7 is similar to FIGURE 3, but shows a TOA monitor 35A receiving the BSIC and HRN as inputs from MLC.

10 FIGURE 8 illustrates an example modification of the operations of FIGURE 4 to include the above-described use of the BSIC and HRN. In particular, blocks 63, 65 and 66 from FIGURE 4 are shown modified at 63A, 65A and 66A, respectively, to illustrate the use of the BSIC and HRN. In particular, at 63A, the BSC specifies the BSIC and HRN in addition to the other information illustrated at 63 in FIGURE 4. At 65A, the MLC sends the BSIC and HRN to the selected TMUs along with the additional information illustrated at 65 in FIGURE 4. At 66A, the TMUs compute the encrypted bits of the access bursts in addition to computing the hopping sequence illustrated at 66 in FIGURE 4. In the example of FIGURE 8, operations other than at 63A, 65A and 66A in FIGURE 8 can be 15 the same as disclosed in FIGURE 4.

20 It should be understood that the above-described use of BSIC and HRN to compute encrypted bits can be implemented together with or separately from the above-described use of monitor windows, burst starting times and frequency hopping calculations.

Although exemplary embodiments of the present invention have been described above in detail, this does not limit the scope of the invention, which can be practiced in a variety of embodiments.

-14-

WHAT IS CLAIMED IS:

1. A method of using a time of arrival measurement apparatus to measure the time of arrival of a radio signal transmitted by a mobile communication station operating in a wireless mobile communication network, comprising:

5 providing the time of arrival measurement apparatus with information indicative of a predetermined point in time at which the radio signal is to be transmitted; and

using the time of arrival measurement apparatus to monitor for arrival of the radio signal only during a period of time after said predetermined point in time.

10 2. The method of Claim 1, wherein said providing step includes expressing the predetermined point in time relative to a time base of the time of arrival measurement apparatus.

15 3. The method of Claim 2, including determining a relative timing relationship between the predetermined point in time and the time base of the time of arrival measurement apparatus.

20 4. The method of Claim 3, wherein said determining step includes monitoring a radio communication channel used by the mobile station and determining therefrom a relationship between communication timing of the mobile station and the time base of the time of arrival measurement apparatus.

25 5. The method of Claim 4, wherein the radio communication channel is a control channel of a fixed-site transceiver serving the mobile station, and the communication timing is frame structure timing of the fixed-site transceiver.

6. The method of Claim 1, including specifying the information to a node in the network, and thereafter communicating the information from the node to the mobile station.

-15-

7. The method of Claim 1, including communicating the information from a node in the network to the mobile station, and also communicating the information from the node in the network to a further node in the network that performs said providing step.

5 8. The method of Claim 1, including calculating the period of time based on the information indicative of the predetermined point in time and based on geographic characteristics of the network, the period of time including a predetermined beginning point in time and a predetermined ending point in time, and providing to the time of arrival measurement apparatus information indicative of the period of time.

10

9. The method of Claim 8, wherein the beginning point in time of said period of time is separated by a further period of time from the predetermined point in time at which the radio signal is to be transmitted.

15

10. The method of Claim 1, including providing to the time of arrival measurement apparatus information indicative of a frequency at which the radio signal is to be transmitted, and using the time of arrival measurement apparatus to monitor the frequency for arrival of the radio signal.

20

11. The method of Claim 10, wherein the information indicative of the frequency at which the radio signal is to be transmitted includes the information indicative of the predetermined point in time at which the radio signal is to be transmitted, along with further information indicative of frequency hopping parameters used by the mobile station, and including determining the frequency based on the information indicative of frequency hopping parameters and the information indicative of the predetermined point in time at which the radio signal is to be transmitted.

25

12. The method of Claim 1, wherein said providing step includes providing the information to a plurality of time of arrival measurement apparatuses, and wherein the

-16-

information provided to each time of arrival measurement apparatus expresses the predetermined point in time relative to a time base of that particular time of arrival measurement apparatus.

5           13.     The method of Claim 12, including receiving from a first time of arrival measurement apparatus information indicative of a timing relationship between a time base of the first time of arrival measurement apparatus and communication timing used by the mobile station, and determining from the timing relationship a plurality of other timing relationships between the communication timing used by the mobile station and the  
10           respective time bases of the other time of arrival measurement apparatuses.

14.     The method of Claim 13, including determining differences among the time bases of the respective time of arrival measurement apparatuses.

15           15.     The method of Claim 1, wherein the wireless communication network is a  
GSM network.

16.     An apparatus for use in locating a mobile station in a wireless communication network, comprising:

20           a plurality of time of arrival monitors, each said time of arrival monitor for monitoring an air interface to determine when a radio signal transmitted by the mobile station has arrived at said time of arrival monitor;

25           each said time of arrival monitor including an input for receiving first information indicative of a predetermined point in time at which the mobile station is to transmit the radio signal, wherein said first information received at each time of arrival monitor expresses said predetermined point in time with respect to a local time base associated with that particular time of arrival monitor; and

              each said time of arrival monitor including an output for providing second information indicative of a time of arrival of the radio signal at that time of arrival monitor.

-17-

17. The apparatus of Claim 16, wherein each said time of arrival monitor includes an input for receiving third information indicative of frequency hopping parameters used by the mobile station.

5 18. The apparatus of Claim 17, wherein each said time of arrival monitor is responsive to said first information and said third information for calculating a frequency at which the radio signal will be transmitted by the mobile station, and each said time of arrival monitor is operable to monitor the calculated frequency for arrival of the radio signal.

10 19. The apparatus of Claim 16, wherein each said time of arrival monitor includes an input for receiving second information indicative of a period of time during which said time of arrival monitor is to monitor the air interface for arrival of the radio signal, wherein said period of time is separated from said predetermined point in time by a further period of time.

15 20. The apparatus of Claim 16, including a plurality of timing monitors respectively associated with said time of arrival monitors, each of said timing monitors coupled to the air interface for monitoring a radio channel used by the mobile station and determining therefrom a timing relationship between communication timing used by the mobile station and the local time base of the associated time of arrival monitor, each of said timing monitors including an output for outputting third information indicative of said timing relationship.

25 21. The apparatus of Claim 20, wherein the radio communication channel is a control channel of a fixed-site transceiver serving the mobile station, and the communication timing is frame structure timing of the fixed-site transceiver.

22. The apparatus of Claim 16, wherein the wireless communication network is a GSM network.

-18-

23. An apparatus for use in locating a mobile station in a wireless communication network, comprising:

an input for receiving a request to locate the mobile station;

an output for indicating that a radio signal is to be transmitted from the mobile station

5 for use in locating the mobile station; and

an output for providing to a plurality of time of arrival measurement devices first information indicative of a predetermined point in time at which the radio signal is to be transmitted by the mobile station.

10 24. The apparatus of Claim 23, including an input for receiving second information indicative of a timing relationship between communication timing used by the mobile station and a time base used by a selected time of arrival measurement device.

15 25. The apparatus of Claim 24, including a translator responsive to said second information for determining further timing relationships between the communication timing used by the mobile station and respective time bases used by other time of arrival measurement devices, and an output for outputting the further timing relationships to the respective time of arrival measurement devices.

20 26. The apparatus of Claim 23, including a position locator having an input for receiving second information indicative of time difference relationships between time bases of the plurality of time of arrival measurement devices and having an input for receiving third information from the plurality of time of arrival measurement devices indicating the time at which the radio signal from the mobile station arrived at each time of arrival measurement device, said position locator responsive to said second and third information for determining 25 the position of the mobile station.

-19-

27. The apparatus of Claim 23, including an output for providing to the time of arrival measurement devices second information indicative of hopping sequence parameters used by the mobile station.

5 28. The apparatus of Claim 23, wherein the wireless communication network is a GSM network.

10 29. The apparatus of Claim 23, including a window determiner having an input for receiving said first information and for receiving second information indicative of geographic characteristics of the network, said window determiner responsive to said first and second information for determining window periods of time during which the respective time of arrival measurement devices are to monitor for arrival thereat of the radio signal, said last-mentioned output further for providing information indicative of said window periods of time to the time of arrival measurement devices.

15 30. A method of determining a time base difference between time of arrival measurement units used in locating a mobile station in a wireless communication network, comprising:

20 using a stationary reference mobile station to determine a first relationship between time bases of a pair of stationary transceivers in the network;

25 using a first time of arrival measurement unit to determine a second relationship between the time base of one of the stationary transceivers and a time base of the first time of arrival measurement unit, and using a second time of arrival measurement unit to determine a third relationship between the time base of the other of the stationary transceivers and a time base of the second time of arrival measurement unit; and

30 determining a time base difference between the first and second time of arrival measurement units in response to the first, second and third relationships.

-20-

31. The method of Claim 30, wherein the wireless communication network is a GSM network.

32. The method of Claim 1, including providing to the time of arrival measurement apparatus information from which an informational content of the radio signal can be determined but which information does not itself reveal the informational content of the radio signal, and the time of arrival measurement apparatus determining the informational content of the radio signal in response to the information, and the time of arrival measurement apparatus using the informational content to measure the time of arrival of the signal.

33. The apparatus of Claim 16, wherein each said time of arrival monitor includes an input for receiving fourth information from which an informational content of the radio signal can be determined but which information does not itself reveal the informational content of the radio signal.

34. The apparatus of Claim 33, wherein each said time of arrival monitor is responsive to said fourth information for determining the informational content of the radio signal and for using the informational content of the radio signal to measure the time of arrival of the radio signal at that time of arrival monitor.

35. A method of locating the position of a mobile communication station in a wireless communication network, comprising:  
the mobile communication station transmitting an uplink radio signal;  
obtaining from the wireless communication network information from which an informational content of the radio signal can be determined but which information does not itself reveal the informational content of the radio signal;  
determining the informational content of the radio signal in response to the information; and

using the informational content of the radio signal to measure the time of arrival of the radio signal at a plurality of predetermined locations.

5       36.      The method of Claim 35, wherein said uplink radio signal is a signal requesting a handover of the mobile communication station to a predetermined fixed-site transceiver.

10       37.      The method of Claim 36, wherein said information includes information indicative of said fixed-site transceiver.

15       38.      The method of Claim 37, wherein the communication network is a GSM network, and wherein the information indicative of said fixed-site transceiver includes a base station identity code (BSIC) which identifies a base station in the GSM network.

20       39.      The method of Claim 36, wherein said information includes information identifying the handover.

25       40.      The method of Claim 39, wherein the communication network is a GSM network, and wherein the information identifying the handover is a handover reference number.

41.      An apparatus for use in locating the position of a mobile communication station in a wireless communication network, comprising:

25       a plurality of time of arrival monitors, each said time of arrival monitor for monitoring an air interface to determine when a radio signal transmitted by the mobile communication station has arrived at said time of arrival monitor;

each said time of arrival monitor including an input for receiving information from which an informational content of the radio signal can be determined but which information does not itself reveal the informational content of the radio signal; and

-22-

each said time of arrival monitor responsive to said information for determining the informational content of the radio signal and using the informational content to measure the time of arrival of the radio signal at that time of arrival monitor.

5           42.     The apparatus of Claim 41, wherein said radio signal is a signal requesting a handover of the mobile communication station to a predetermined fixed-site transceiver.

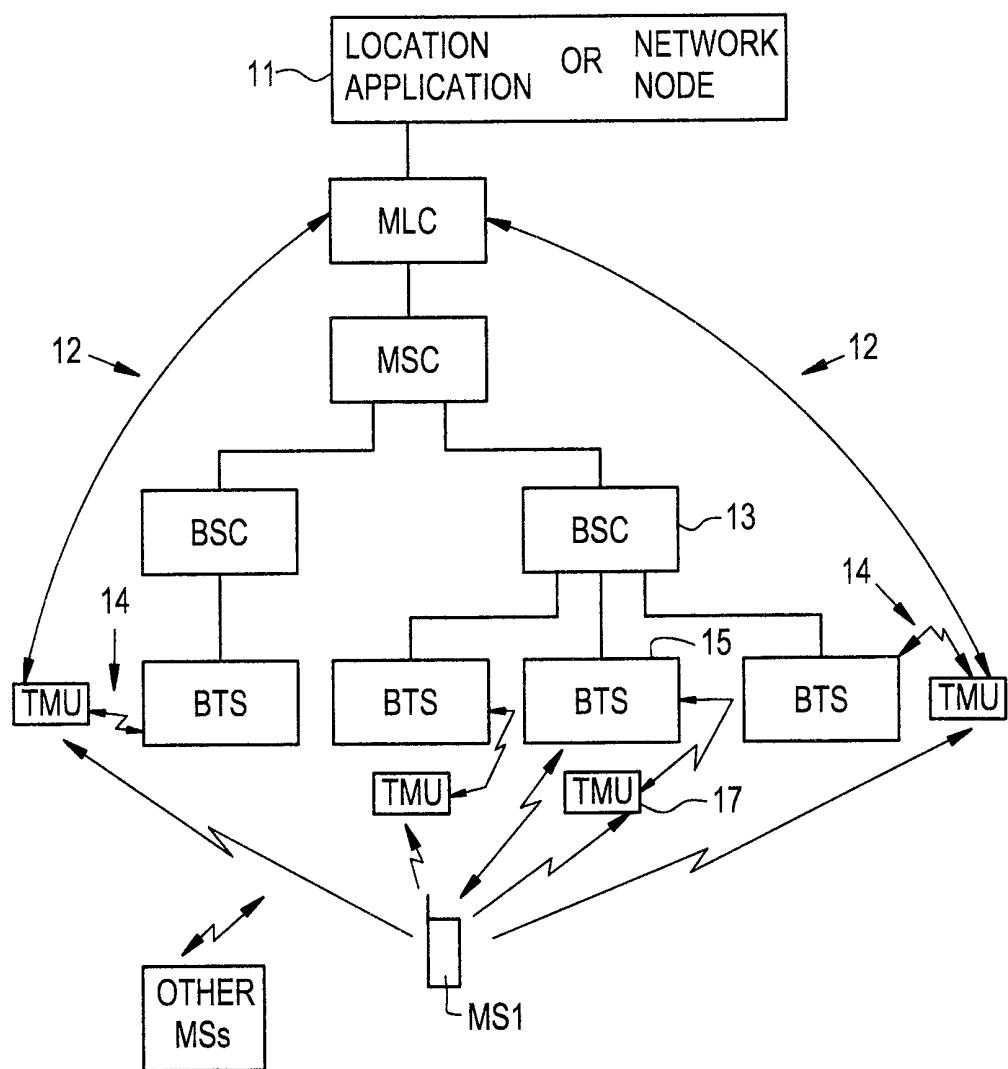
43.     The apparatus of Claim 42, wherein said information includes information indicative of said fixed-site transceiver.

10           44.     The apparatus of Claim 43, wherein the communication network is a GSM network, and wherein the information indicative of said fixed-site transceiver includes a base station identity code (BSIC) which identifies a base station in the GSM network.

15           45.     The apparatus of Claim 42, wherein said information includes information identifying the handover.

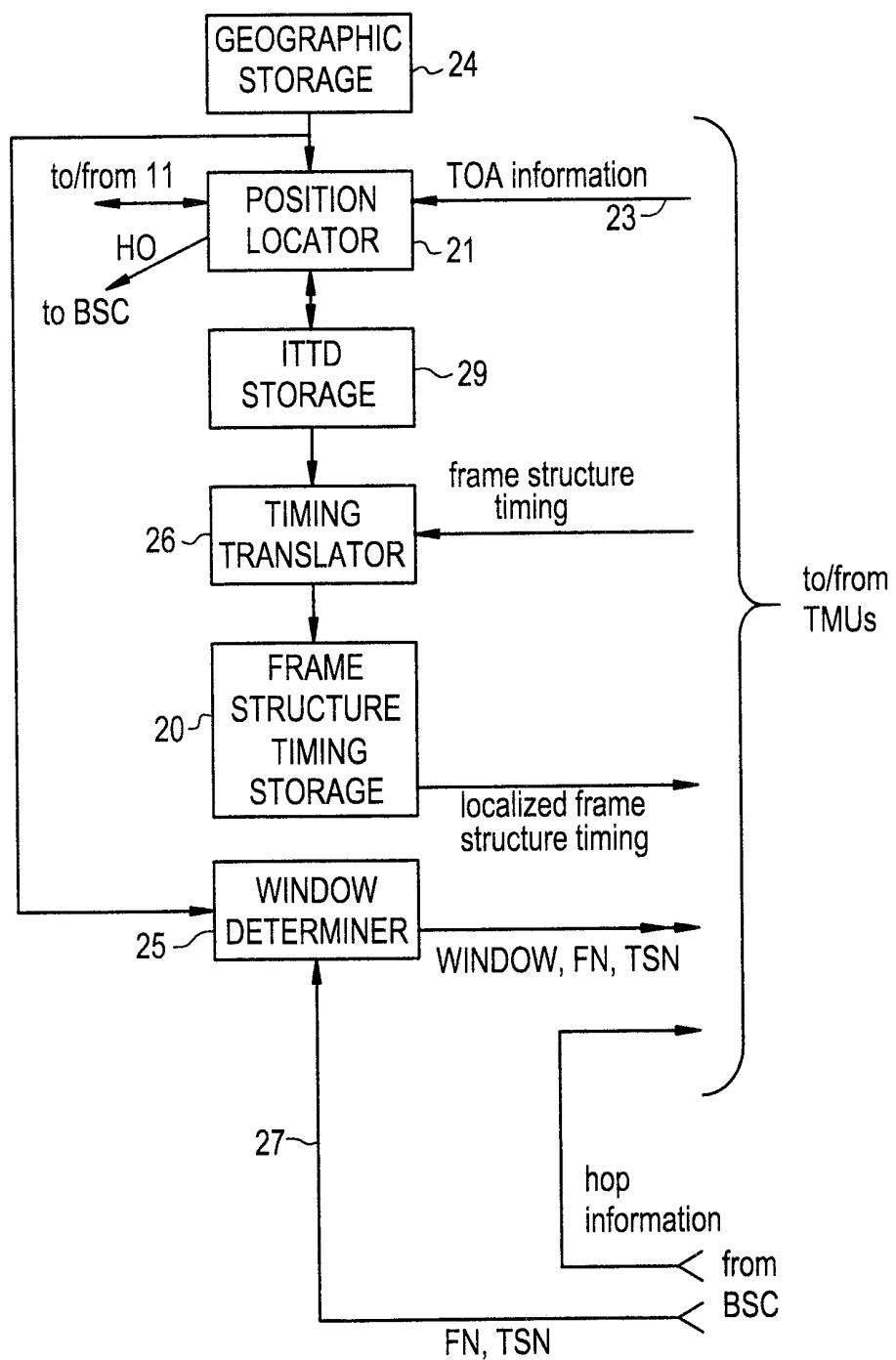
20           46.     The apparatus of Claim 45, wherein the communication network is a GSM network, and wherein the information identifying the handover is a handover reference number.

FIG. 1



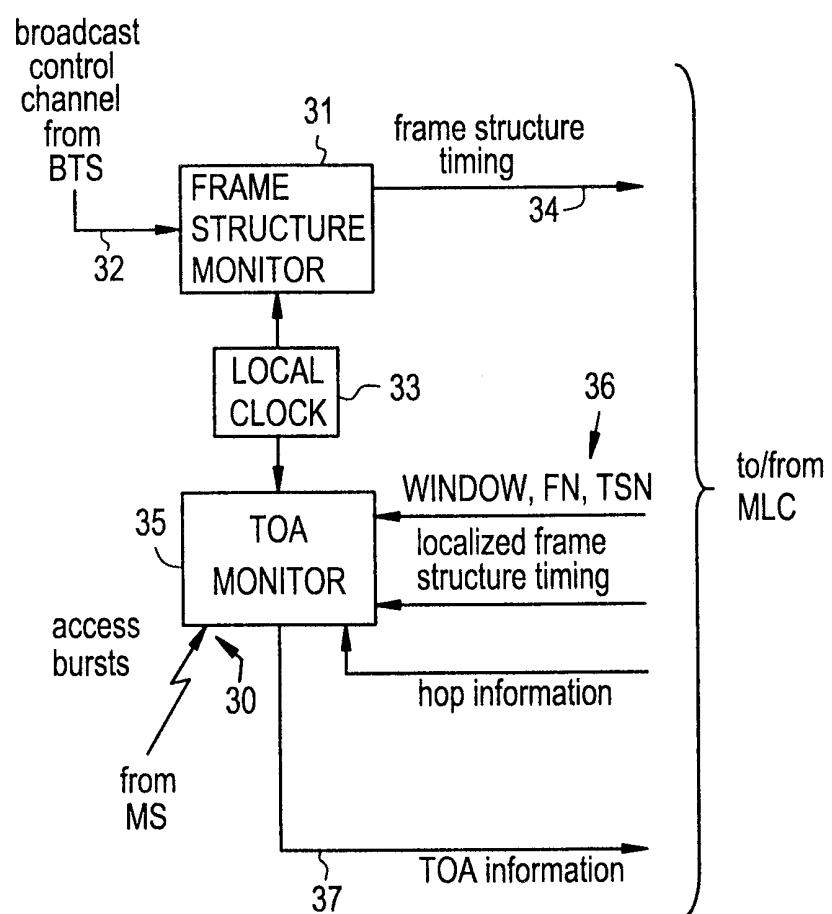
2 / 9

FIG. 2



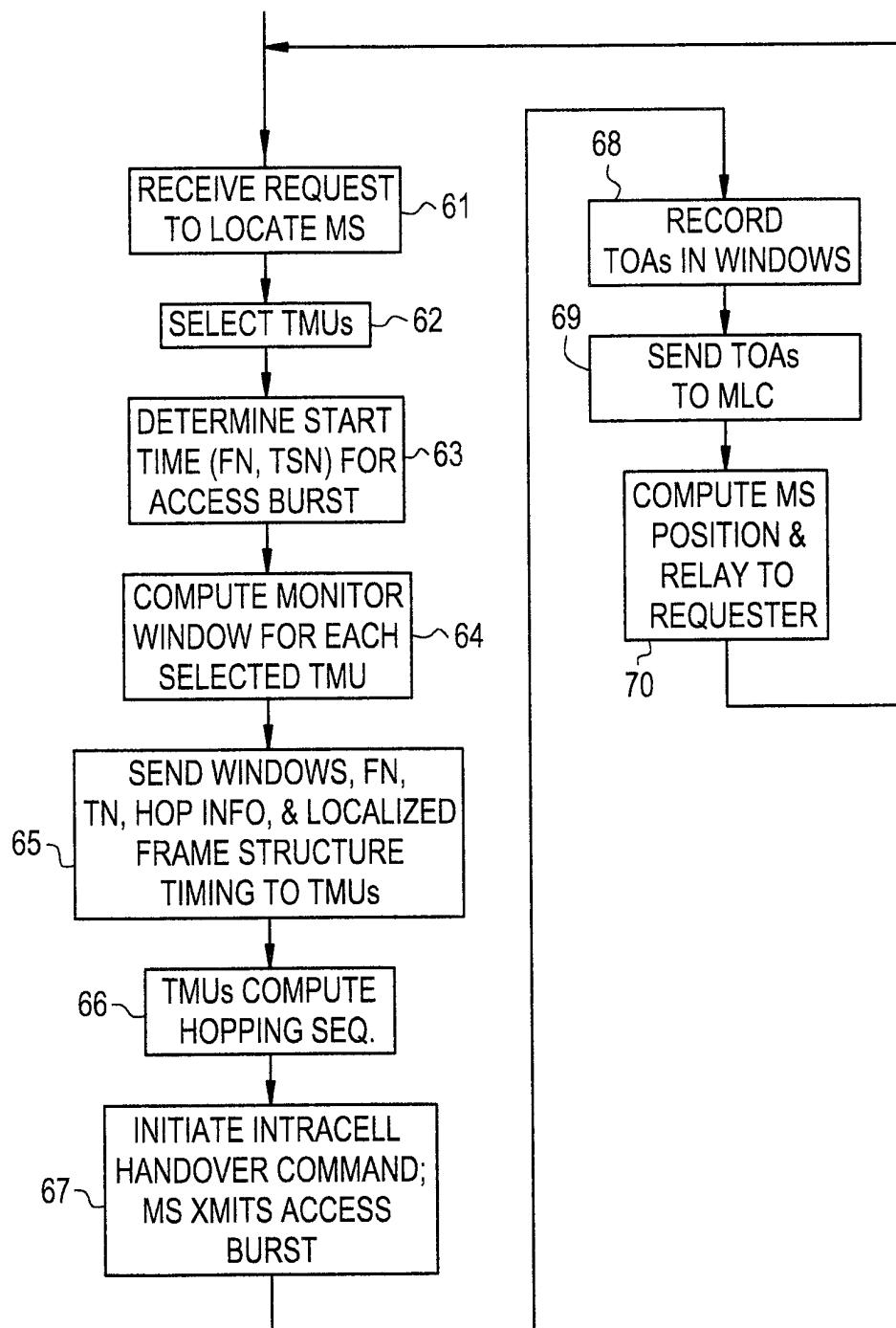
3 / 9

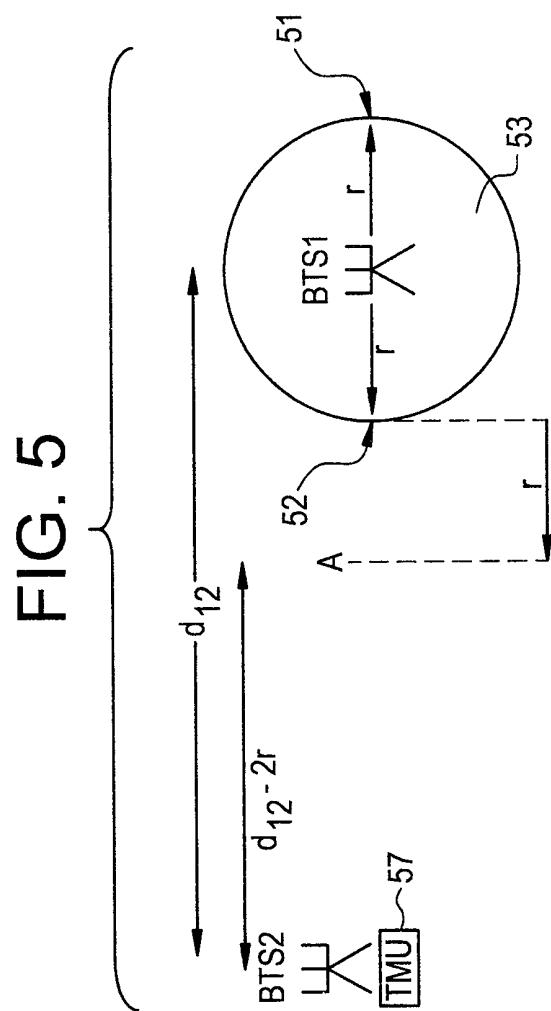
FIG. 3



4 / 9

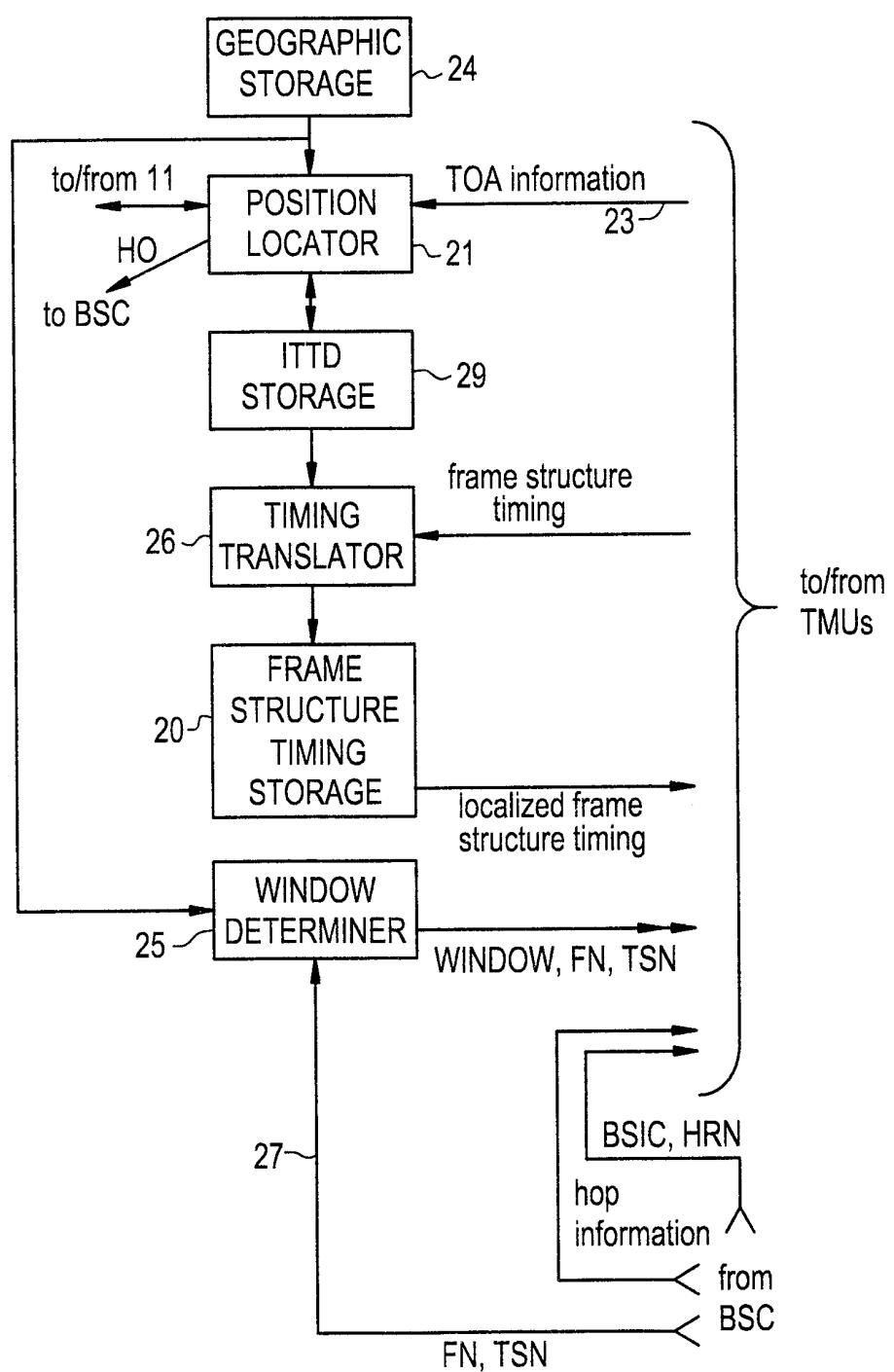
FIG. 4





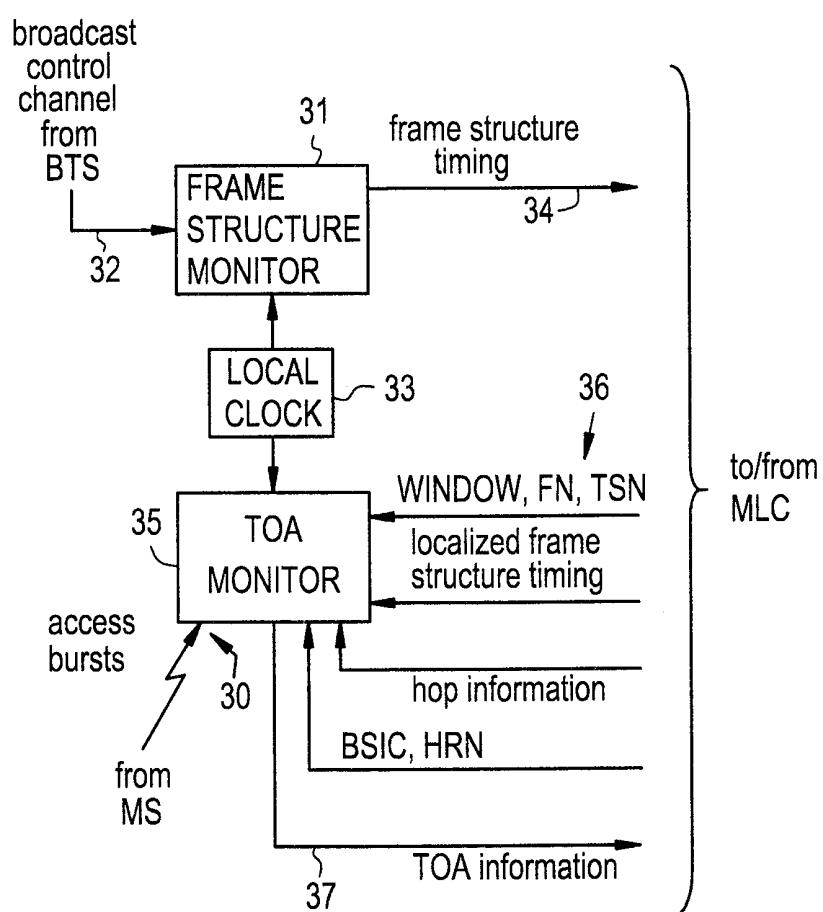
6 / 9

FIG. 6



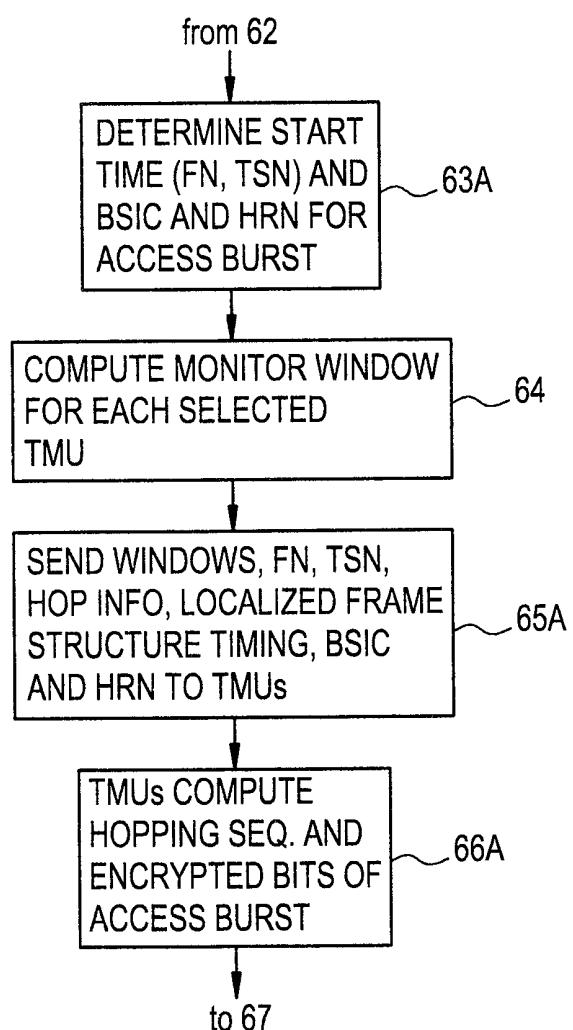
7 / 9

FIG. 7



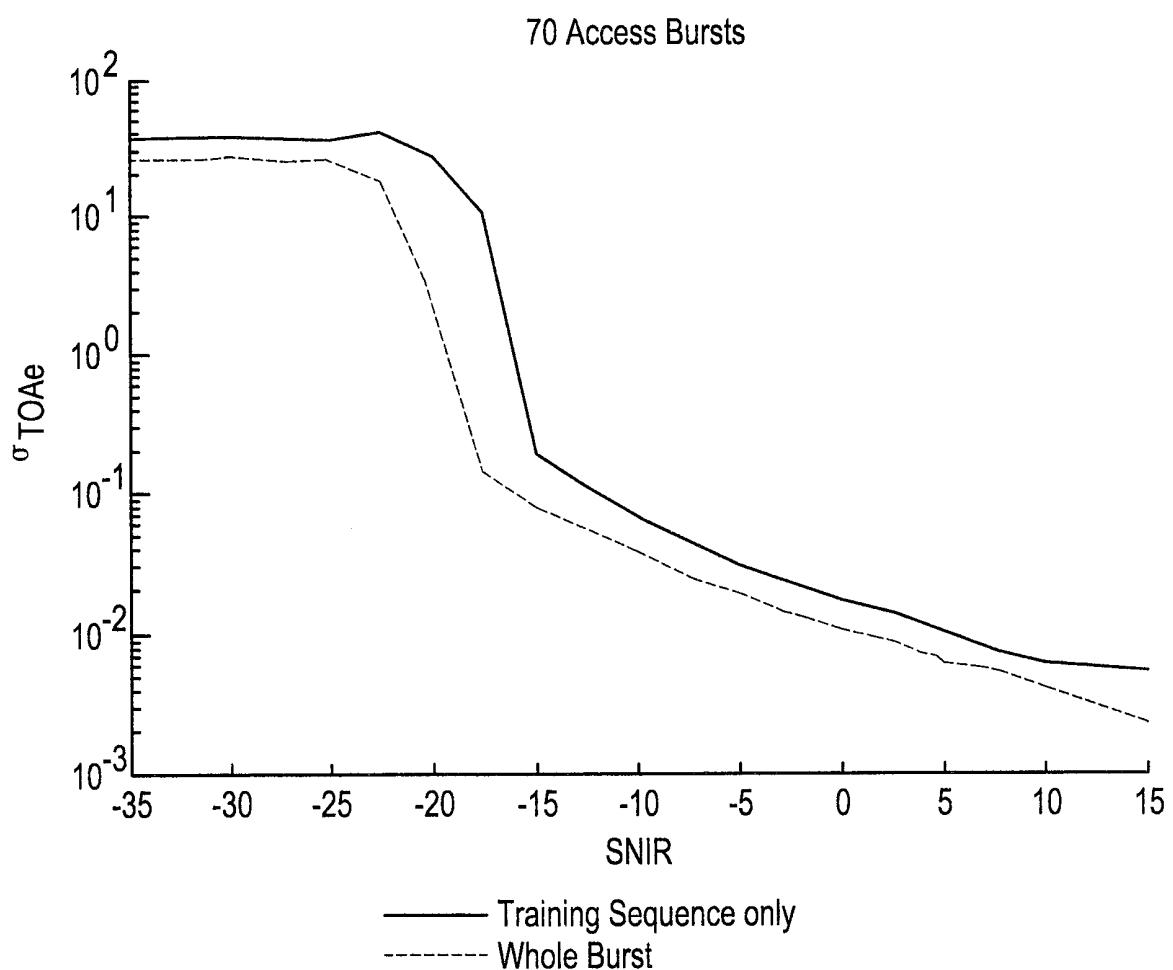
8 / 9

FIG. 8



9 / 9

FIG. 9



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/SE 99/01307

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 7 H04Q7/38 G01S5/06

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 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)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 26510 A (QUALCOMM INC) 5 October 1995 (1995-10-05)	23,28
A	page 11, line 9 -page 12, line 18 ---	1,16
P, X	WO 99 09778 A (ERICSSON TELEFON AB L M) 25 February 1999 (1999-02-25)  page 12, line 13 -page 19, line 18 ---	30,31, 35-37, 39-46
A	DE 44 09 178 A (SIEMENS AG) 21 September 1995 (1995-09-21) the whole document ---	1,16,23, 30,35,41
A	US 5 327 144 A (STILP LOUIS A ET AL) 5 July 1994 (1994-07-05) column 8, line 23 -column 9, line 38 column 14, line 46 -column 16, line 2 -----	1,16,23

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
16 December 1999	28/12/1999
Name and mailing address of the ISA  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	Authorized officer  López-Pérez, M-C

# INTERNATIONAL SEARCH REPORT

## Information on patent family members

International Application No

PCT/SE 99/01307

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO 9526510	A 05-10-1995	AU 2188195	A 17-10-1995	A
		BR 9507174	A 02-09-1997	
		CA 2186378	A 05-10-1995	
		CN 1149339	A 07-05-1997	
		EP 0752113	A 08-01-1997	
		FI 963833	A 25-09-1996	
		JP 10500771	T 20-01-1998	
WO 9909778	A 25-02-1999	US 5952969	A 14-09-1999	
		AU 8893698	A 08-03-1999	
DE 4409178	A 21-09-1995	NONE		
US 5327144	A 05-07-1994	AT 165169	T 15-05-1998	
		AU 677292	B 17-04-1997	
		AU 6094094	A 12-12-1994	
		AU 6820694	A 12-12-1994	
		BR 9406463	A 30-01-1996	
		CA 2161333	A,C 24-11-1994	
		DE 69409645	D 20-05-1998	
		DE 69409645	T 06-08-1998	
		EP 0700525	A 13-03-1996	
		HK 1010461	A 17-06-1999	
		JP 2843951	B 06-01-1999	
		JP 8508381	T 03-09-1996	
		SG 48730	A 18-05-1998	
		WO 9427160	A 24-11-1994	
		WO 9427161	A 24-11-1994	
		US 5608410	A 04-03-1997	
		ZA 9401019	A 25-08-1994	