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(71) Applicant *(for all designated States except US)*: KARBASI, Amir, Kiumars [IR/FI]; Jousenkaari 11 A 20, FIN-02120 Espoo (FI).

(71)(72) Applicant and Inventor: VAZVAN, Behruz [FI/FI]; Jämeräntaival 11 B 53, FIN-02150 Espoo (FI).

(74) Agent: OY HEINÄNEN AB; Annankatu 31-33 C, FIN-00100 Helsinki (FI).

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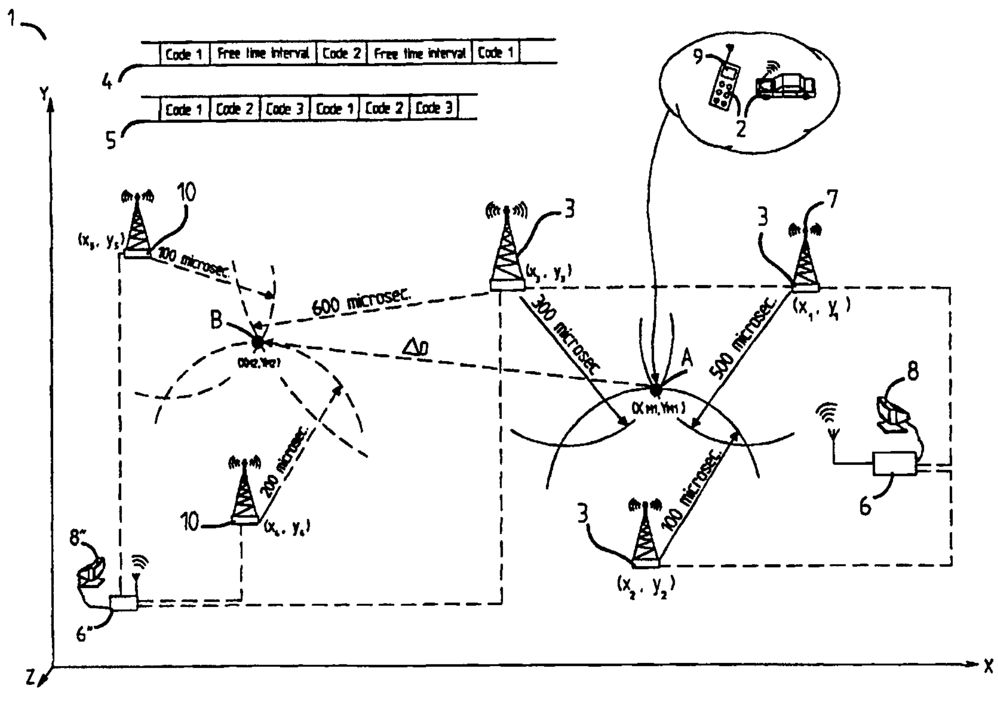
(57) Abstract



A cellular positioning system (1) and a mobile terminal (2), where a unique code, the predefined free time intervals (4) or the time period of other code slots (5) located between any transmitted or received pair of code (4, 5), the arrival time of each pair of codes, the timing advances defined either in mobile terminal or in three or more base stations (3, 10), and an area map transmitted by the base stations are used in order to compute and define the exact position, speed and direction of the mobile terminal (2) continuously or whenever required, either in the computing unit (6) or in the mobile terminal (2) itself, either when the mobile terminal is in active mode or in idle. In the present invention at least three base stations (3, 10) communicate with the mobile terminal (2) in order to define its position, speed and direction by measuring the distances between the base stations (3 or 10) and the mobile terminal (2) and computing the intersection points (A, B), of three or more distance measurements. The continuous location positioning method presented in this cellular positioning system also enables the network to compute the moving speed and direction of the mobile terminal by taking into computation the change (Δ_D)) in the coordinates of its position and the time (t) passed during this change. Furthermore, three inventive applications: 1-Teleparking system (Fig. 2), 2-Teleradar system, 3-Theft detection system, are presented in the inventive cellular positioning system.

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CELLULAR POSITIONING SYSTEM (CPS)

The present invention is a cellular positioning system (CPS) and a mobile terminal, where an unique code, the predefined free time intervals or the time period of other code slots located between any transmitted or received pair of code, the arrival time of each pair of codes, the timing advances defined either in mobile terminal or in three or more base stations, and an area map transmitted by the base stations are used in order to compute and define the exact position, speed and direction of the mobile terminal, continuously or whenever required either on the system infrastructure side or in the mobile terminal itself. The present invention is characterized in that at least three base stations communicate with the mobile terminal in order to define its position, speed and direction by measuring the distances between the base stations and the mobile terminal and computing the intersection points of three or more distance measurements. The continuos location positioning method presented in this cellular positioning system also enables the network to compute the moving speed and direction of the mobile terminal by taking into computation the change in the coordinates of its position and the time passed during this change. Furthermore, three inventive applications: 1- Teleparking system, 2- Teleradar system, 3- Theft detection system, are presented in the inventive cellular positioning system.

The most common and known positioning system is the Global Positioning System (GPS). wherein GPS-terminal receives from four satellites their transmitted codes and clock time and information about each satellite's position in space. After this the GPS terminal starts to produce the same code in its processors. The time for code processing in GPS-terminal and the propagation time of the codes from satellites to the GPS-terminal are computed for positioning purposes. Besides the GPS satellites' clocks use different time reference (Universal Time Clock; UTC) than clock time used on the earth. Furthermore, the clocks installed in satellites are atomic clocks and very expensive. In the GPS and other satellite positioning system a GPS-like terminal must exactly know the position of satellites, in addition to other information, in order to define its location. In general, location positioning by GPS-like satellite systems is not quite exact because of: ionospheric delay, tropospheric delay, ephemeris error, satellite clock error, and selective availability. Besides, the satellite constellations of GPS system do not configure a cellular configuration and furthermore the location positioning is defined only in GPS's user terminal. Therefore, the satellite system is not aware of the position of the

GPS-terminal. At the moment for all land or sea positioning purposes mostly GPS satellites and GPS receivers are used.

On the other hand, at the present cellular communication systems there is no exact location positioning system. In these systems the location of each mobile is defined only at the level of cell area in which the base station reports to the system about a mobile being under its coverage. Therefore the exact position of the mobile terminal is not considered.

The present invention provides a positioning system wherein the position and moving speed of a mobile terminal, which may be a hand-set or vehicle-mounted terminal or any other kind of mobile telephone, can be exactly and continously defined anywhere under the coverage of a mobile cellular communication system, either in the mobile terminal or in the base stations. This is achieved with an inventive positioning system called Cellular Positioning System (CPS) having the characteristic features set forth in the following claims.

The invention will now be described in more detail with reference to an inventive cellular positioning system (CPS) illustrated schematically in the accompanying drawings.

FIG. 1 presents the cellular positioning system (CPS)
FIG. 2 presents the teleparking system as one of the applications of the CPS.

In the inventive cellular positioning system **1** a mobile terminal **2** transmits an unique code, which may be its user's subscriber number or equipment identity number or any other signals transmitted by mobile terminal, continuously after any predefined free time interval, to the three or more cells' receivers **3** which may be the base stations of any cellular mobile telecommunications system. Alternatively, codes can be transmitted by at least three base stations **3** to the mobile terminal **2**. The base stations **3** or mobile terminal **3** after reception of each pair of code, record their arrival times and compute the distances between the mobile terminal and the base stations, which will result in an intersection point **A** of three or more distance measurements. The length of the free time intervals **4** may be either predefined or the length information may be transmitted together with codes. The codes can be any signal transmitted in a time division order by the base stations or mobile terminal. For example, when the mobile terminals or base stations send their codes in a time division order, then the free time intervals located between each code sequence **4** may be replaced by the code slots allocated for other terminals referred as to code1, code2, code3 **5** which belong to the three different mobile terminals. On the network side the distances of the base stations **3** relating to each other are fixed and known, therefore one of them, or any other point, can be considered as the point of origin used for distance measurements. The distance coordinates of the mobile terminal can be then defined in the computing unit **6** resulting in an intersection point **A** having two or three quantities which indicate the plain and space coordinates of the mobile terminal which may be located either on the ground or in some altitude over the land. For instance when the mobile terminal is located somewhere in a high building, the height of the base stations antenna **7** from the ground is also taken into account. The intersection point **A** which is defined in the computing unit **6** can be monitored **8** on an area map where the mobile terminal is located. The computing unit **6** can be connected to the base stations **3** either via cable or wireless communications. Alternatively, the computing unit **6** may be integrated into each base station separately. In this case each base station, also, receives from the other neighbour base stations the codes of mobile terminal being transmitted to them. Furthermore, each three or more base stations involved in positioning measurements are synchronized accordingly, depending on either the position computation is based on the timing advances or the arrival time of each pair of codes and the free time intervals between them. However, the codes can be sent from the base stations to the mobile terminal and the distances can be computed in the mobile terminal as well. The distances between the base stations and mobile terminal are computed as follows:

$$D_{BS1} = c.(t_{A1} - t_{A2}) - \varepsilon$$
$$D_{BS2} = c.(t_{A1} - t_{A2}) - \varepsilon$$
$$D_{BS3} = c.(t_{A1} - t_{A2}) - \varepsilon$$

having three distances defined by the above equations, the coordinates of the mobile terminal can be driven from the following equations:

$$D_{BS1} = \sqrt{(X_{BS1} - X_M)^2 + (Y_{BS1} - Y_M)^2 + (Z_{BS1} - Z_M)^2}$$
$$D_{BS2} = \sqrt{(X_{BS2} - X_M)^2 + (Y_{BS2} - Y_M)^2 + (Z_{BS2} - Z_M)^2}$$
$$D_{BS3} = \sqrt{(X_{BS3} - X_M)^2 + (Y_{BS3} - Y_M)^2 + (Z_{BS3} - Z_M)^2}$$
$$\vdots$$
$$D_{BSn} = \sqrt{(X_{BSn} - X_M)^2 + (Y_{BSn} - Y_M)^2 + (Z_{BSn} - Z_M)^2}$$

Where:

D:	The distance between the base stations and the mobile terminal,
c:	The speed of radio waves ≈ 300 000 km/s,
t_{A1}:	Time of arrival of the first code,
t_{A2}:	Time of arrival of the second code,
D_{BS}:	The distance between each base stations with the mobile terminal,
X_{BS}, Y_{BS}, Z_{BS}:	The coordinates of the base stations,
X_M, Y_M, Z_M:	The coordinates of the mobile terminal.

ε: The length (of the free time interval) between each pair of codes, measured in time. For example if the mobile terminal is programmed in order to send its codes to a base station every 200μs but the base station receives them every 400μs, then ε=200μs. This means that the mobile terminal is 200μs far from this base station.

Alternatively the base stations **3** may at any required time request the mobile terminal **2** to send its codes and/or null timing advances in order to be positioned. In this case at least three base stations **3** will be synchronized. Then they record the departure time of their signals to the mobile terminal **2** and the arrival time of the signals returned back from the mobile terminal. On the other hand the user of mobile terminal may send or request the codes and/or null timing advances, to or from three or more base stations for positioning purposes, by using a function which is defined in his/her mobile terminal for positioning purposes.

Moreover, the intersection point **A** and the coordinates of mobile terminal **2** relating to the base stations **3** can be computed in the mobile terminal independently after receiving the codes from three or more base stations **3**. Then, mobile terminal **2** computes its position by taking into account the arrival time of the first code and the period of the free time interval which is between the arrival time of the first and the second code **4**. In this case the base stations **3** do not need to be synchronized because the length of the time interval between a pair of codes is either fixed and predefined and known by the mobile terminal or the length information can be sent to the mobile terminal **2** in conjunction with the code transmission. Alternatively, the mobile terminal **2** after that has defined its position, can send its position information back to the network if required.

Furthermore, the base stations **3** provide the mobile terminal with the information indicating their geographical position. The base stations **3** also send to the mobile terminal **2** an area map or a partial map of the area where the mobile terminal is located. In mobile terminal **2** this area map will be monitored **9** and the position of mobile terminal can be shown on the map for its user. The area map is be continously updated: the old map is replaced with a new one as mobile terminal is moving from a cell or a service area to the other one. Therefore, additional information like CD-ROM discs including city or road maps, which necessitates a different device dose not need to be used or integrated into the mobile terminal separately.

In the inventive cellular positioning system the location positioning can be carried out continously. The continuos changes in the coordinates of a mobile terminal **2** and its moving speed is defined all the time while it is moving from point **A** to the point **B**. This is achieved when mobile terminal sends its codes, continuously, in a predefined time schedule for example every 200-300μs or 1ms to the three or more base stations **3** in the view. When mobile terminals moves toward point **B**, new base stations **10** take the role of the previous ones accordingly, so that the position of the mobile terminal is defined and followed in the computing unit **6** all the time while the mobile terminal is moving. In any case, the codes can be sent by mobile terminal independently or the base stations **3** or **10** may request from the mobile terminal to send its codes. Alternatively, the speed of mobile terminal can be computed in the mobile terminal and be sent to the base stations.

The moving speed of the mobile terminal is defined by having the travelled distance Δ_D, which is the change in the coordinates of the position of mobile terminal and the time passed (t) during this change. The Δ_D can be easily derived from computed intersection points **A** and **B**. Therefore the speed of mobile terminal is defined as follows:

$$V_M = \frac{\Delta_D}{t}$$

$$V_M = \frac{\sqrt{(X_{M1} - X_{M2})^2 + (Y_{M1} - Y_{M2})^2 + (Z_{M1} - Z_{M2})^2}}{t}$$

Where:

V_M:	The speed of mobile terminal,
Δ_D:	The distance which mobile terminal has travelled during the time t,
t:	time,
X_M, Y_M:	The coordinates of mobile terminal.

Having the moving speed and the continuos position of the mobile terminal, its moving direction can be easily followed and monitored **8** in the computing unit **6** or in the screen of the mobile terminal **2**. The information of continuos location positioning can be sent back to the mobile terminal for its user information if required. Furthermore, handover requirements and decisions, both in the mobile terminal and base stations, can be made more accurately and in time, when the speed and direction of mobile terminal is known. Also fast fading, resulted from fast moving speed of the mobile terminals, can be overcome by knowing the speed and direction of the mobile terminals and defining more accurate transmission and reception schedule.

The present invention can be applied to the TDMA systems like GSM, where the time slots belonging to the different mobile terminals can play the role of *free time intervals* and therefore be used for distance measurements. Alternatively, the timing advances defined in the base stations or in the mobile terminal can be used for positioning purposes. In GSM for example, the time division multiplexing scheme used on its radio path is such that the BTS (Base Transceiver Station) must receive signals coming from different mobile terminals very close to each other. In order to reach this goal despite the propagation delay incurred by the return trip from BTS to mobile terminal, and taking into account that guard times between bursts have been chosen very small for spectral efficiency, a mechanism to compensate for the propagation delay is necessary. Therefore the mobile terminal should advance its transmission time relative to its basic schedule, which is derived from the reception of bursts, by a time indicated by the infrastructure, which is referred as to the *timing advance*, and is used as a parameter in the inventive cellular positioning system to define the position of mobile terminals operating in GSM network.

In GSM, once a dedicated connection has been established, the BTS continuously measures the time offset between its own burst schedule and the reception schedule of mobile terminal bursts. Based on these measurements, it is able to provide the mobile terminal with the required timing advance and dose that on the SACCH (Slow Associated Control Channel) at the rate of twice per second. The timing advance can take values from 0 to 233 microsecond, which is enough to cope with cells having a radius of up to 35km without any other special scheme and given the speed of light. In the present invention these time offsets and timing advance are used to define the position of mobile terminal. The value of timing advance can be computed when the mobile terminal or base station advances its emission relatively to its reception by a time compensating the to and fro propagation delay. In GSM timing advance can be assessed both by mobile terminal and the BTS, which indeed happens upon subsequent assignment. In GSM the mobile terminal is required to send some bursts to the base stations with a null timing advance. When the base station receives such a burst, the reception instant is a measure of a double propagation time and the base station can drive the value of the timing advance, which it sends to the mobile station. But this procedure takes place only between one base station and the mobile terminal. In general, in TDMA systems there is no mechanism to synchronize at least three base stations so that mobile terminal could initialize its timing advance with them. In the inventive cellular positioning system **1** at least three base stations **3** to whom the mobile terminal can has access at the same time, are synchronized so that when mobile terminal sends its null timing advance to each base station, they assess their own timing advances and send them either to the computing unit **6,** to define the position of mobile terminal at the network side, or to the mobile terminal **2** for position computing in the mobile terminal itself. When mobile terminal **2** receives the timing advances assessed in the base stations **3**, it dose not need to measure the propagation delay which is indeed equal to the distance between the mobile terminal and each base station, since it has been once measured by each base station separately and this information has been sent to the mobile terminal: *timing advance = distance.* Therefore three values of timing advances represent the distances between each base station **3** and mobile terminal **2**, measured in time. As mobile terminal moves on, in this case toward the base stations **10**, it again sends a null timing advance to the most optimal (e.g. the nearest) base stations and receives their computed timing advance accordingly.

Alternatively base stations **3** or mobile terminal itself may send to the new base stations **10** the latest timing advance which was defined between the previous base station and the mobile terminal. This is actually used in TDMA systems when handover is required but only between two base stations, which are not enough for positioning purposes. But in the inventive cellular positioning system three base stations **3**s, **10**s are involved and synchronised so that the timing advances defined between them and the mobile terminal can be used to define the position, speed and the moving direction of the mobile terminal continously or every now and then. Furthermore, when the base stations **3** broadcast their geographical position information and an area map, then mobile terminal **2** would be able to monitor its position for its user as mentioned already. Alternatively, the null timing advance can be requested from the mobile terminal by three synchronized base stations and the position of mobile terminal can be defined on the network side whenever required.

The inventive cellular positioning system can be utilized in any terrestrial cellular system or in any future satellite cellular communication systems, whose cellular configuration provide a mobile network. The cells of the inventive cellular positioning system may be configured of the cells of one terrestrial or satellite cellular mobile communication system or they may be a combination of the cells of the both terrestrial and satellite cellular telecommunication systems which are interworking or are integrated in order to configure one universal telecommunication system.

Comparing to other available positioning systems, the present invention provides a considerably more economic, accurate and effective positioning system, which can be utilized anywhere under the coverage of a cellular telecommunication system. Several applications can be created using the advantages of the inventive cellular positioning system. For example, three inventive applications are presented in this invention:

1- The present invention provides the municipality **11** an inventive mobile teleparking system (FIG. 2). Having parked the vehicle in the parking space **16**, the driver **12** dials on his/her vehicle or hand-held mobile telephone an especial telephone number (which can be entered to the memory of the mobile terminal) which is allocated for a parking charging system of a municipality **11**, in which the subscriber number of calling person is immediately, at its arrival time, recorded to the database **13**. After this, the exact place of the vehicle, in which the mobile terminal is located is positioned by the inventive cellular positioning system and also this information is forwarded to the parking database **13**. In the parking database **13**, in accordance with each subscriber number, the user and her/his car number and other required information are recorded already. When the driver collects the vehicle from the parking space, she/he again telephones to the parking system, whereupon the database **13** records that the parking period has been terminated. In this case the mobile terminal can be also a hand-held one, which can be taken along with user while his/her car is parked and recorded in the system.

As an full automatic alternative, the exact location and distance of the parking spaces to the base stations are once measured, calibrated and recorded to the database **13** of the municipality. When a vehicle with a vehicle-mounted mobile terminal, whose position is continuously defined either in the idle or active mode, arrives to or leaves from the municipality parking space, its location would change accordingly. Because the parking space belongs to the municipality, therefore this change in location can be sent to the parking database **13** via the inventive cellular positioning system. This can be achieved because the location of the parking places are already positioned and the measured data, including the coordinates of the parking place are already recorded in the database **13** of the municipality **11**. Therefore the driver dose not need to do any action. The parking charges can be accounted and invoiced either separately or be added to the driver's telephone bill. In this alternative mobile terminal transmits continuously, for example every minute, an unique code which can be comprised of for example its user subscription number or the equipment number of the mobile telephone etc. to the three or more base stations of the inventive cellular positioning system.

When location of the parking spaces are exactly defined by the inventive cellular positioning system, then different parking place-related tariffs can be also recorded and applied to each parked vehicle in different parking places. Municipality's parking inspector **14** can use a hand-held inspecting device **15**, which is connected to the teleparking system so that she/he can easily check if the relevant parking space is occupied legally or not. This means that the vehicle's register number or further information dose not need to be entered into the inventive inspecting device **15**. The parking space is considered legally-occupied when the driver has telephoned to the teleparking system or the changes in the position of his/her vehicle are reported to the teleparking system through the inventive cellular positioning system. Since the parking database **13** can be considered as a telephone subscribers database used in any mobile communication network, and since the parking charges can be added to the telephone bills, therefore any mobile operator would be able to provide the inventive teleparking system to the municipalities. Subsequently, the inventive teleparking system is a global system which uses telephone subscriber numbers as the subscriber numbers for parking services of any municipality.

2- The present invention provides also an inventive mobile teleradar system by positioning the location of the mobile terminal continuously. This is achieved, as mentioned already, by taking into account the continuos code transmission from a mobile terminal **2** to the base stations **3** or **10** for example every 200 or 300μs. Since the inventive cellular positioning system provides the possibility to define the moving speed and direction of the mobile terminal, it can be used for police force to define the speeds of vehicles which drive over the allowed speed in speed-limited areas. If each vehicle is equipped with a fixed mobile terminal in it, when the it is driven over the allowed speed in the speed-limited areas, it's speed is recorded in a speed database which is integrated into the inventive cellular positioning system. Therefore, the driver can be fined in the case of speed violation. The fines can be also added to his/her telephone bills, if required.

3- The present invention provides also an inventive theft detection systems. This system can be used to find the stolen vehicles immediately. If each vehicle is equipped with a mobile terminal (which can be hidden somewhere inside the vehicle) which transmits continuously, after any predefined free time interval, an unique code allocated for that vehicle, or its register number together with the unique code to the inventive positioning system, then when the vehicle is stolen, its location can be exactly positioned in the network. If anyone, by any means, interrupts the communications between the mobile terminal and the network illegally, then the system immediately informs the police force about this and the latest location where the vehicle was positioned. This can be achieved when the code transmission of the mobile terminal to the network is in a continuos mode. Alternatively, the code transmission in such mobile terminal used for theft detection can be requested by the base stations of the inventive cellular positioning system whenever required. Even when a mobile telephone is stolen, it can be easily found by using the inventive cellular positioning system.

CLAIMS

1. A cellular positioning system (1) and a mobile terminal (2), **c h a r a c t r i z e d** in that. an unique code, the predefined free time intervals (4) or the time period of other code slots (5) located between any transmitted or received pair of code (4), (5), the arrival time of each pair of codes, the timing advances defined either in mobile terminal or in three or more base stations (3), (10), and an area map transmitted by the base stations are used in order to compute and define the exact position, moving speed and direction of the mobile terminal (2), continously or whenever required, either in the computing unit (6) or in the mobile terminal (2) itself, either when the mobile terminal is in active mode or in idle; and that:

- the said unique code may be comprised of the subscriber number or/and the equipment number of the mobile terminal or any other code allocated for the communications between the mobile terminal and the base stations, which is sent to or received from the three or more cells' receivers (3), (10) of the cellular positioning system (1) wherein the arrival time of said codes are recorded, which after the exact position and/or moving speed and direction of said mobile terminal is defined in the computing unit (6) or in the mobile terminal (2) itself, resulting in an intersection point A or B, taking into computation the said predefined free time intervals, the speed of light, the arrival time of said codes to the said base stations (3), (10) or mobile terminal (2), and the timing advances defined either by mobile terminal (2) or at least three synchronized base stations (3), (10);

- the said unique code may be any signal which is transmitted in any time division or frequency division or code division order, either by mobile terminal (2) or the base stations (3), (10);

- the said codes of a mobile terminal (2) may be requested, simultaneously by at least three or more base stations (3), (10) of the said cellular positioning system (1) or alternatively they may be transmitted by the base stations (3), (10) all the time or whenever the mobile terminals (2) request it;

- at least three base stations (3), (10) are synchronized so that when the mobile terminal (2) sends its null timing advance to each base station, they define their own timing advances and send them either to the computing unit (6) or to the mobile terminal (2); and that the defined timing advances may be used in both either the mobile terminal (2) or the base stations (3), (10) to define the position and moving speed and direction of the mobile terminal (2);

- the information of the positioned location, defined by said computing unit (6) can be sent back to the mobile terminal (2) and be monitored for its user information;

- the base stations (3), (10) of the inventive cellular positioning system (1) send to the mobile terminal (2) whenever required an area map which is updated while mobile terminal (2) is moving form a cell area or a service area to the other; and that the said area map can be monitored on the screen (9) of the mobile terminal (2) where the position of the mobile terminal (2) is shown;

- the cells of said cellular positioning system may be comprised of the cells of a terrestrial or a satellite cellular mobile communication system or they may be a combination of the cells of both terrestrial and satellite cellular telecommunication system which are integrated or interworking;

- the mobile terminal can be any kind of hand-held or vehicle-mounted mobile terminal or telephone capable of communicating with a mobile communication system;

2. A cellular positioning system (1) as claimed in claims 1, **charactrized** in that the moving speed of said mobile terminal (2), can be defined both in the mobile terminal and the base stations (3), (10) by measuring, continuously, the distances between the base stations (3), (10) and the mobile terminal (2), at any predefind time schedule, taking into computation the change (Δ_D) in the coordinates of the mobile terminal relating to the base stations (2), (10) and the time (t) passed during this change.

3. A cellular positioning system (1) as claimed in any one of preceding claims, **charactrized** in that it can be used to determine the locations of the parking places (16) where the mobile users (12) are located, or to find the stolen vehicles equipped with a mobile terminal capable of transmitting and receiving a unique code continuously at every predefined or required time interval, or whenever requested by the said cellular positioning system.

4. A mobile terminal (2) as claimed in claim 1 **c h a r a c t r i z e d** in that it is equipped with means for transmitting and receiving an unique code at every predefined or required time interval to or from the inventive cellular positioning system (1) in order to be positioned; and that:

- the said mobile terminal (2) is capable to receive from the base stations (3), (10) the computed location information together with an area map which can be monitored on the screen (9) of the mobile terminal (2);

- the said mobile terminal (2) is capable to define its position by sending some bursts in a time division order which may include an unique code allocated for the mobile terminal (2) with a null timing advance to the three or more base stations (3), (10) of the said cellular positioning system (1) and to receive a new value of the timing advance computed by each base station, and that the values of three timing advances which indicate the distances between the each base station (3), (10) and the mobile terminal (2) are used to define the position of the mobile terminal resulting in an intersection point A or B;

5. A positioning system (1) as claimed in any one of preceding claims **c h a r a c t r i z e d** in that its name: Cellular Positioning System (CPS) can be used only in conjunction with this invention.

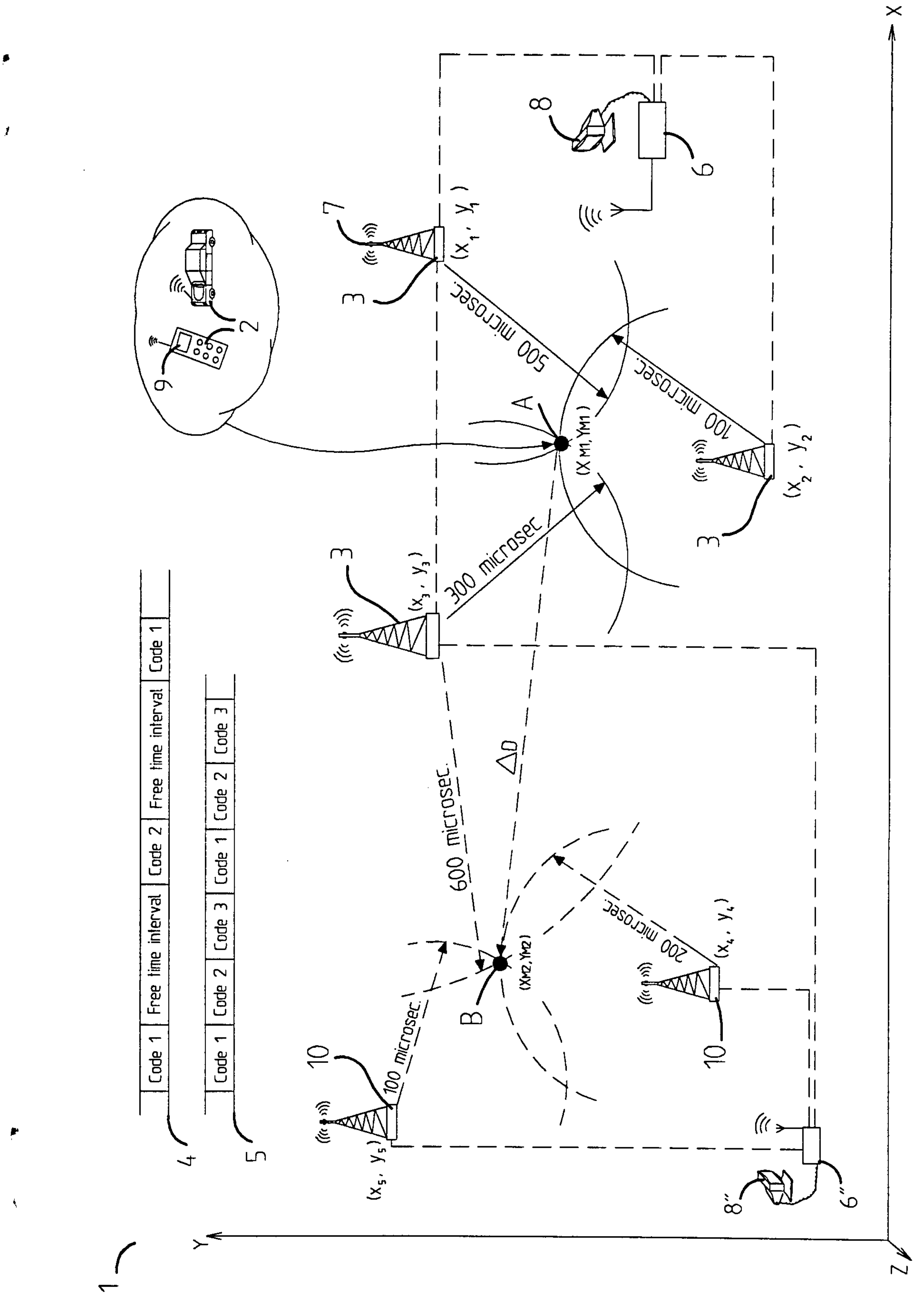
500 microsec.
100 microsec.
300 microsec.
600 microsec.
200 microsec.
100 microsec.
Code 1
Free time interval
Code 2
Free time interval
Code 1
Code 1
Code 2
Code 3
Code 1
Code 2
Code 3
A
B
X
Y
Z

FIG 1

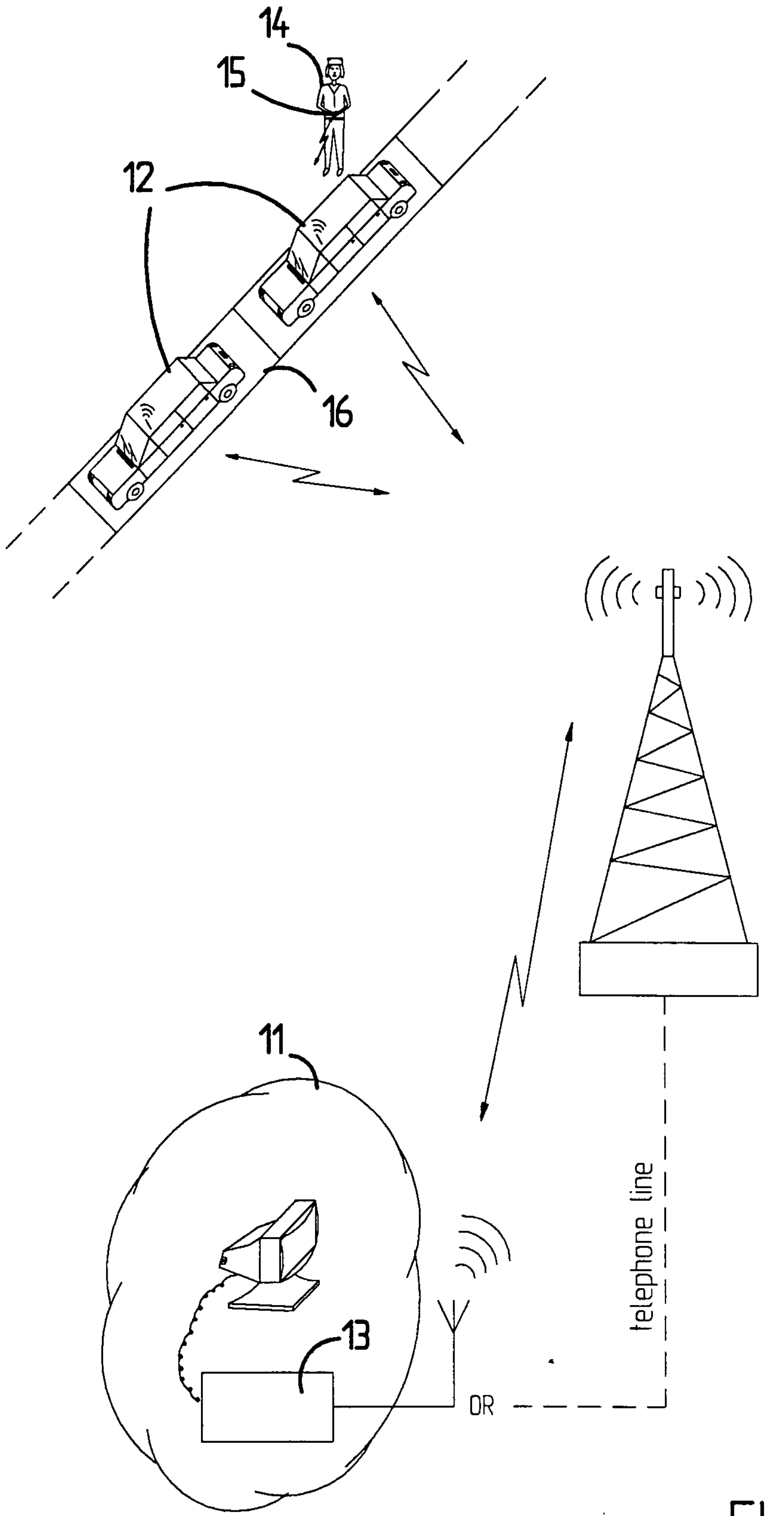

FIG 2