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FIG. 1

(57) **Abstract:** The proposed solution includes the use of four reference bases (A,B,C,D) on the ground at known positions, with a coded time signal transmitted by one of them which is retransmitted by the repeater station and received by each of the reference bases. Using two distinct sets of three reference bases it is possible to calculate the differences between two positions for the repeater station (R), assigning to the later changes in time, phase or frequency as well as temporal changes due to the signal propagation in the medium, for the respective elevation angles found for the repeater. It can be then identified which values attributed to the temporal changes produces a minimum difference between the two respective positions of the repeater station (R). The identified temporal change can be used for the correct determination of the repeater station and its use on pertinent applications.

"PROCESS AND SYSTEM TO DETERMINE TEMPORAL CHANGES IN RETRANSMISSION AND PROPAGATION OF SIGNALS USED TO MEASURE DISTANCES, SYNCRONIZE ACTUATORS AND GEOREFERENCE APPLICATIONS"

Field of invention

The present invention addresses to a process and a system to determine changes in time, phase and frequency at a signal repeater station located at a remote and inaccessible site, being operatively associated to a set of ground-based transmitting and receiving bases, at known geodetic positions, as well as to determine temporal changes due to the signals propagation in the medium, to obtain distance measurements, navigation and geographic positioning, relative to the inaccessible repeater, and to obtain time synchronization through measurements corrected for the changes in frequency (phase delays) and in time at the remote signal repeater. This proposal provides an innovative solution for the remote determination of time changes and of signal transit times in the process of being received and retransmitted by repeater stations or transponders operating at inaccessible conditions and of the additional time changes caused by the signal propagation in the medium where the system operates.

Antecedents of the invention

The echo obtained of a signal sent forward and retransmitted is used to measure distances of remote objects. The precision of the determinations depends entirely on the knowledge and the correction of the temporal effects that occur at the repeater, caused by four principal factors: (a) velocity of propagation in the medium, (b) propagation in the cables and instruments during transmission, (c) propagation in the cables and instruments at the final reception, and

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(d) in the retransmission by the remote object (repeater) which distance is to be determined.

The models describing (a) are, in general, well known for propagation in different media (terrestrial ionosphere and troposphere) as well as in space (J.W. Marini, "Correction of satellite tracking data for an arbitrary tropospheric profile", Radio Sci., 7, 223-231, 1974; J.A. Klobuchar, "Design and characteristics of the GPS ionospheric time delay algorithm for single frequency users", em PLANS '86 - Position Location and Navigation Symposium, Las Vegas, NV, Nov. 4-7, 1986, Record (A87-41351 18-17), New York, Institute of Electrical and Electronics Engineers, 1986, pp. 280-286, 1986; S.M. Hunt et al., "Equatorial atmospheric and ionospheric modeling at Kwajalein missile range", Lincoln Laboratory Journal, vol. 12, pp. 45-64, 2000; S.M. Honma,Y. Tamura e M.J. Reid, "Tropospheric delay calibrations for VERA", Publ. Astron.Soc. Japan, vol. 60, pp. 951-960, 2008; T.S. Radovanovic, "Adjustment of satellite-based ranging observations for precise positioning and deformation monitoring", PhD dissertation, Department of Geomatics Engineering, University of Calgary, Canada, UCCGR Reports Nr. 20166, 2002, and references therein). After the adequate model selection, the effect of propagation on the temporal changes need to be calculated as a function of the distance and of the angle of elevation through which the repeater is seen, which are parameters also not known in advance

Factors (b) and ·(c) are measured directly, experimentally with high precision.

Factor (d), however, is undetermined, since the remote object is inaccessible for direct measurements and it undergoes to changes in its internal signal propagation characteristics, which can change with

time, or for each sequence of signals utilized to
determine its distance. In addition other temporal
alterations due to Doppler effects and those predicted
by relativity may become important for repeaters
transported by satellites or spacecrafts moving
rapidly in relation to a reference frame containing he
points from which the distances from the remote object
are intended to become determined. Other temporal
changes may be considered as caused by relativistic
effects when the satellite (the remore object) moves
along different gravitational potential in relation to
the geoid (Ashby, N., "Relativity and the global
positioning system", Physics Today, 55, pp. 41-47,
2002; Larson, K.M. et al., "An assessment of
relativistic effects for low Earth orbiters: the GRACE
satellites", Metrologia, 44, pp. 484-490, 2007).
On the other hand, when using meteor as reflecting
transponders, phase delays can be caused by the signal
scattering on the ionized trails (Wislez J.-M.,
"Forward Scattering of Radio Waves of Meteor Trails",
Proceedings of the International Meteor Conference,
Brandenburg, Alemanha, pp.99-117, 1995).
Electromagnetic signals, such as the radio signals,
can be sent to great distances by mean of transmission
links. These links receive the transmission, detect
it, amplify it, or not, and retransmit the radio
signals o the directions of interest.
There technologies are well known and of public
domain, and for this reason they will not be described
here. Distant wireless transmission of information is
accomplished by well known technologies using
electromagnetic waves (e.m.w.) as carriers. Radio
electromagnetic waves are the most widely utilized.
Currently the e.m.w. wireless techniques extend to
frequency bands corresponding to the infrared,

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visible, ultraviolet and X-rays.

Links are used for telecommunications on longer distances. The links receive and retransmit the signals, at the same frequency, or at different frequencies. The links can be natural, such as the reflections of radio e.m.w. in terrestrial ionosphere, or by scattering on ionosphere or troposphere inhomogeneities and by reflection on ionized meteor trails in the upper atmosphere, among others.

An innumerable number of artificial links options have been implemented and utilized, namely a variety of repeaters, retransmitters, generically designated as transponders, installed on ground or in space, on board of a platform at an artificial satellite. At retransmission links the e.m.w. undergo phase delays caused by the electronic devices through which the signal propagates. For many applications this effect does not bring serious consequences to the signals that are being transported. They are delayed all together, for fractions of time, independently from the user. This is the case of wireless retransmissions of audio and video.

However, in intercommunication applications, such as in mobile cell phone, digital telecommunications, the signal synchronism of signals are required at the links. Reference time and frequency standards must be common and synchronized at every link of a wireless telecommunication network. The use of atomic frequency and time standards at every link would be a solution. This option, however might not be always practical, being certainly expensive.

The modern solution for such link synchronization is obtained by time standards referred to GPS satellites, or to similar constellations of geopositioning satellites. The are known as GPS clocks, that provide

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accuracy and stability of the order of hundred of nanoseconds, that means, at a sufficient level to assure the reference for the electronic circuits operated at the links (T.A. Clark and R.H. Hambly,

5   "Improving the performance of low cost GPS timing receivers", 38th Annual Precise Time and Time Interval (PTTI) Meeting, Reston, Virginia, USA, 7 December, 2006).

The calculations needed to determine distances based
10   on echoes of signals transmitted and received are necessarily associated to the accurate knowledge of the phase delays, or of the temporal changes, that occur at the links, as well as the delays caused by the propagation media, in order to obtain the signals
15   propagation time corrections transported from their origin to their destination, going through the retransmission link.

The remote determination of temporal changes at the repeaters and those due to the signal propagation in
20   the media are conditions essentially required to make viable the use of systems and processes for geographic and space positioning using reference transmitters and receivers on the ground and transponders in space, as described analytically in the article byP. L. Kaufmann
25   et al., "Non recursive algorithm for remote geolocation using ranging measurements", Math. Problems in Engineering, v. 2006, pp. 1-9, Article ID79389, DOI:10.1155/MPE/2006/79389, 2006.

The determination of temporal changes at the repeater
30   and the changes due to propagation effects is essential to make viable the correct operation of the concepts exposed in the Patent of Invention PI9101270-8, "System and process of geographic positioning and navigation", granted September 30, 1997 and in its
35   Addition Certificate" C19101270-8, filed 17.05.2002;

in the Patent of Invention PI03003968-4, "System and process of geographic and space positioning" filed 8 October 2003, corresponding to PCT/BR2004/000190, "Geographic and space positioning system and process",

5   filed 4 October 2004, which resulted, up to this date, in the following granted patents: US752877B2, on 05/05/09; RU2635934C2 on 27/08/09; and AU 2004277511, on 26/11/2010.

The phase delays caused by links components,

10 converters, cables and electronics, in the transmission and reception of signals at the ground, can be accurately measured in laboratory and adopted for the data retransmitted by the link. However the continuous use and the remote and inaccessible

15 location of a defined link as, for example, in a satellite, jeopardizes the maintenance of the delays previously determined and makes impossible its updating correction. In the case of transponders in satellites, the relativistic temporal effects will

20 depend on their position in space. In the case of repetition by retransmission in meteor trails, the temporal effects will depend on the direction they occur in the sky. On the other hand many transponders carry internal processors which cause signal

25 retardations, which can be distinct for each sequence of retransmitted signals. The difficulties become aggravated when adding imponderable signal phase changing physical effects - such as effect due to temperature variations in the electronic circuits at

30 the repeater.

In satellites it must also be considered Doppler effects and other caused by relativity and by the gravitational potential. Thee unpredictable phase variation effects must be taken into account to assure

35 the distance determinations by signal reflection (or

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by retransmission). Time changes caused by signal propagation in the media may become significant and will depend on the adopted models and of the angles of sight of the repeaters, to be determined. The

5   determination of these changes is a necessary condition to make feasible the application of geopositioning, navigation and time dissemination systems and processes using ground references and transponders in space, as mentioned above.

10   Summary of the invention

Taking into account the operational requirements of wireless signal transmission systems using a remote and inaccessible repeater station, and also the need of the usual accurate and instantaneous determination

15   of the geographic positioning of the referred remote station, the present invention has the objective to define and provide a process and a system, relatively simple to be implemented and economically feasible, to provide the correct and instantaneous determination of

20   the temporal changes, phase delays and frequency shifts, in the signals retransmission and propagation, which can contain audio, video and other information, such as coded time signals, related to a remote and inaccessible repeater station, generally moving in

25   space.

According to the solution proposed by the present invention it is possible to determine, in any instant, the correct geographic and spatial positioning and the adjustment of time indication of a repeater station,

30   remote and inaccessible, from the determination of time changes in retransmission and propagation of signals that the remote station, located at great distance and having a transponder (transceiver or repeater), receives from a stationary transmitter of

35   signals, located at a known and accessible site.

According to the invention the process to determine
temporal changes and phase delays at a signal repeater
station, remote and inaccessible, and time delays due
to signal propagation, comprises one first step to
5   install four reference bases on the ground, at known
geographic positions and visible from the repeater
station. The following step consists in emission, at a
reference instant and by a transmitting device
provided in one of the above referred reference bases,
10   here designated as the central base, of a coded time
signal, containing the identification of there
reference base that is emitting it and of the instant
of emission; and the step to receive, by a receiving
device installed at each one of the four bases of
15   reference, the coded signal, which was received and
retransmitted by the repeating station.
After completed the steps above mentioned, the process
continues with the calculation of the difference of at
least two positions for the repeater station for the
20   same transmitted coded signal, which calculation is
done utilizing at least two distinct sets of three
reference bases, being known that the above mentioned
difference dependent from a value of the alteration in
time, phase or frequency, attributed to the repeater
25   station. Different values for the temporal changes are
then attributed systematically and arbitrarily, and
calculated, for each of these values adopted,
different values for the differences between the two
positions. Once the above referred differences between
30   every two respective positions for the repeater
station, it is possible to identify which value,
attributed to the temporal changes at the repeater,
produce a minimum difference for the two positions
calculated for the repeater station. The calculations
35   involved in this phase of the process are performed in

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iterative   form,   for   example,   by   successive
approximations,   adopting   various   values   for   the
temporal changes that might have happen in the signal
passage by the repeater station, until a value is
5   identified for which the difference between two
calculated positions for the repeater becomes minimum.
This value defined the variation in time, frequency or
phase, at the repeater station, deduced from the
minimum found for the difference in positions for the
10   repeater. The distances of the four bases to the
repeater can now be corrected, adopting the temporal
change that has been determined. The value of the
temporal change can now be used to determine the
correct position of the repeater. The same iterative
15   process can include other temporal changes due to the
velocities   of   propagation   of   the   signals
characteristics of the medium, adopted according to
known propagation models and using the elevation
angles the repeater is seen from the bases, found
20   using the same iterative procedure.
In one possible application of the process, another
step is further provided to determine the coordinates
of the repeater station with correction of the change
in time, frequency or phase for the referred instant.
25   In another process application, the time signals are
disseminated to other points on the ground, with known
geographic positions, in order to synchronize their
respective clocks.
Brief description of the figures
30   The present invention will be described with reference
to the attached figures, provided with the scope to
illustrate, namely:
Figure 1 is a schematic perspective view, illustrating
the space positioning off a signal repeater, remote
35   and inaccessible in relation to four bases installed

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on the ground at known geographic positions, with at least one of them containing a coded signals transmitter to be received and retransmitted by the repeater station in space, with the four bases
5   containing receivers of the signals retransmitted by the repeater station, and where the position labeled by P indicates a target which coordinates are known or are to be determined, depending on the application that will be described ahead.
10   The four bases have their own means of communication to the central processing station, to where they send the time differences between the time signal retransmitted by the repeater and their respective clocks. For simplicity, the central processing station
15   could be the same reference base where the time signals are transmitted.
     Figure 2 represent a schematic view in perspective, illustrating the system of coordinates, spherical and Euclidean, used to equate the space positioning of the
20   repeater station, illustrated in figure 1; and Figure 3 represent the four distinct positions for the repeater station, in two coordinate systems, one referred to x,y,z and another referred to u,v,w, utilized to find the position of the target P, which
25   coordinates are to be determined.
     Description of the invention
     As mentioned before, and illustrated in the attached figure 1, the invention provide a process and a system for wireless transmission of signals, as for example
30   digital audio or video signals, or even analog signals, with the use of a repeater station R, remote and inaccessible, which may be represented by a satellite platform or of another object or repeater device of any kind, capable to receive and retransmit,
35   in predetermined directions, the coded time signals.

The invention here presented utilizes four reference
bases A, B, C, and D, every three of them not
collinear, installed on the ground (see figure 1) at
known geographic positions with each one of the bases
5   containing signal receiving devices, such as radio
frequency signals, modulated digitally, for example,
in audio or video, and received and retransmitted by
the repeater station R in space. Time coded signals
are transmitted by one of the reference bases A, B, C
10   and D and retransmitted by the repeater station R in
space back to the reference bases A, B, C, and D.
According to the proposed system one of the four
reference bases A, B, C, D contains one coded time
signal transmitter T and one receiver REC of the
15   signals retransmitted by the transponder provided at
the remote repeater station R. To simplify the
description the transmitter is associated to base A.
The four reference bases A, B, C, D have receivers to
receive the time coded signals retransmitted by the
20   remote transponder at the repeater station R. With
exception of base A which contains the transmitting
mean T, the other bases have means to transmit the
respective differences between the coded time signal
received from the remote transponder and time coded
25   signal generated in each one of them, to a central
processing base E. To simplify, the reference base A
(herewith called central base) can be the same base
that transmits the time signals. At the central base
the coded time signal received from the remote
30   transponder is compared to the coded time signal
generated at the same reference base. The four
reference bases have their own precision clocks RL
each one synchronized to each other.
The four reference bases A, B, C, D have their own
35   precision clocks RL and means to compare the time

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signal retransmitted by the remote transponder to the time generated locally. The reference bases process their local differences in time, and transmit them to the central base E which, for simplicity can be the same reference base A, which also have emitted the original signal transmission. The local differences in time will be transmitted to the central base by some mean of communication such as, for example, commercial telecommunication, or making use of the same remote repeating station for data communication.

The correct position for the spatial repeater station R will depend on the knowledge of the temporal changes and/or phase delay at the repeater station R and those caused my the signal propagation in the medium, needed to correct the time differences measured in relation to each three over four reference bases A, B, C, and D. The good performance of the system requires the knowledge of phase delays undergone by the signals being transmitted, in all segments and, in particular, in the coded time signal transit by the repeater station (transponder) R and those caused by propagation.

The present invention resolves the current difficulties to determine correctly and by economically feasible means, the temporal change measurements, or the phase delays, for example, undergone by the signal in the retransmission link at a repeater station R, remote and inaccessible, and in their propagation in the media involved, such as the in the terrestrial atmosphere and ionosphere, as it occurs for stations located in space, in satellite platforms.

With the adoption of four reference bases there are several possible forms to determine the temporal variation on the signal received and retransmitted by

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the repeater station, or by the transponder. It can be used, for example, a more general procedure with great accuracy to determine the time changes at the repeater station R, which to not depend on the disposition of
5   the planes containing the four reference bases A, B, C and D.
It is possible to adopt the same spherical and euclidean coordinate systems utilized by P.L. Kaufmann et al. (2006), illustrated in figure 2, which
10   algorithm permits to equate the repeater R coordinates obtained with the reference bases A, B, C and D.
The measurements obtained by the system provide the following data, according to the nomenclature defined below:
15   $AR(\delta_R) = (\Delta t_A - \delta_{At} - \delta_{Ar} - \delta_R)\ (c/2) - 2\Delta_{pdAR}$
        (1)
$BR(\delta_R) = (\Delta t_B - \delta_{At} - \delta_{Br} - \delta_R)\ c - AR(\delta_R) - \Delta_{pdBR} - \Delta_{pdAR}$
$CR(\delta_R) = (\Delta t_C - \delta_{At} - \delta_{Cr} - \delta_R)\ c - AR(\delta_R) - \Delta_{pdCR} - \Delta_{pdAR}$
$DR(\delta_R) = (\Delta t_D - \delta_{At} - \delta_{Dr} - \delta_R)\ c - AR(\delta_R) - \Delta_{pdDR} - \Delta_{pdAR}$
20   Where $AR(\delta_R)$, $BR(\delta_R)$, $CR(\delta_R)$ and $DR(\delta_R)$ are the distances from bases A, B, C and D to the repeater R position, respectively, expressed s a function of the temporal changes of · the signals transiting by the repeater, δ_R, to be determined; Δt_A, Δt_B, Δt_C and Δt_D are
25   the time differences effectively measured at bases A, B, C and D, respectively; δ_{At} is the time change caused by the signal passage by circuits and cables when being transmitted from base A, previously measured and known; δ_{Ar}, δ_{Br}, δ_{Cr} and δ_{Dr} are the time changes caused by
30   the signal passage by circuits and cables when being received at bases A, B, C and D, respectively, previously measured and known; and c is the speed of the electromagnetic waves transporting the time coded signals, as for example radio waves, in vacuum, and
35   Δ_{pdAR}, Δ_{pdBR}, Δ_{pdCR} and Δ_{pdDR} are the distance errors of

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the segments AR, BR, CR and DR are temporal delays
caused by the propagation of signals in the physical
media (atmosphere, ionosphere).

The errors in distance above described, caused by
5   temporal deviations due to propagation in the medium
are added to the distance deviation due to the time
change of the signal at the repeater, δ_R, which is
the same for the four segments AR, BR, CR and DR. The
coordinates for the repeater station R, as determined
10   for bases A, B and C are expressed by the algorithm
already developed by P. L. Kaufmann et al.(2006), in
the reference system illustrated in figure 2, in
relation to axis x, y and z, as a function of the
signal when transiting by the repeater, δ_R, to be
15   determined:

$$x_R(\delta_R) = \{[AR(\delta_R)]^2 - [BR(\delta_R)]^2 + AB^2\}/2AB$$
        (2)

$$y_R(\delta_R) = \{\{[r_1(\delta_R)]^2 - [r_2(\delta_R)]^2\}/2y_c\} + y_c/2$$

$$z_R(\delta_R) = \{[r_1(\delta_R)]^2 - [y_R(\delta_R)]^2\}^{1/2}$$

20   where

$$[r_1(\delta_R)]^2 = [AR(\delta_R)]^2 - [x_R(\delta_R)]^2$$
        (3)

$$[r_2(\delta_R)]^2 = [CR(\delta_R)]^2 - [(x_c - x_R(\delta_R)]^2$$

IF needed to express the result in spherical
25   coordinates, latitude, longitude and altitude for the
repeater, these can be deduced by a simple inverse
analytical procedure. On the other hand, with the use
of the measurements obtained with the use of base D,
we obtain:

30   $x_R'(\delta_R) = \{[AR(\delta_R)]^2 - [BR(\delta_R)]^2 + AB^2\}/2AB$ (igual
$_R(\delta_R)$) (4)

$$y_R'(\delta_R) = \{\{[r_1'(\delta_R)]^2 - [r_2'(\delta_R)]^2\}/2y_D\} + y_D/2$$

$$z_R'(\delta_R) = \{[r_1'(\delta_R)]^2 - [y_R'(\delta_R)]^2\}^{1/2}$$

where

35   $[r_1'(\delta_R)]^2 = [AR(\delta_R)]^2 - [x_R'(\delta_R)]^2$ (igual a $[r_1(\delta_R)]^2$)

(5)

$$[r_2 (\delta_R)]^2 = [DR(\delta_R)]^2 - [(x_D - x'_R(\delta_R)]^2$$

The two systems of equations permit to formulate the discrepance in the repeater's position as a function
of the temporal intended to be determined, according to the following expression:

$$f(\delta_R) = |[x_R(\delta_R) , y_R(\delta_R) , z_R(\delta_R)] - [x'_R(\delta_R) , y_R'(\delta_R) , z_R'(\delta_R)]|^2 =$$

$$= [x_R(\delta_R) - x_R'(\delta_R)]^2 + [y_R(\delta_R) - y_R'(\delta_R)]^2 +$$

$$+ [z_R(\delta_R) - z_R'(\delta_R)]^2 \qquad\qquad (6)$$

Utilizing known numerical calculation methods, such as iterative procedures, for example, by successive approximations, adopting various values for the temporal changes that might have happened in the signal passage by the repeater station, in Will be found the value of the phase delay δ_R at the repeater station R, for which the function $f(\delta_R)$ assumes a minimum value, which will be close to the searched value, needed for the utilization by the system considered in this invention. This procedure can be done with the simultaneous use of data from the other two sets of reference bases A,B,D and A,C,D, adopting base A as the transmitter and improving the accuracy of δ_R determination.

The iterative described above can include the corrections of the time changes due to the propagation velocities, distinct from c, of the signals that transport the coded time information in the media represented by the low and high terrestrial atmosphere. These velocities are distinct from the speed of light c in vacuum, and its effect correspond to delays in phase of in time causing an apparent larger distance for the measured segments, as described by the equations of system (1). The respective time or phase delays correspond to

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deviations in the respective segments, which can be calculated at the same time by the iterative process described before, with the determination of the elevation angles from the repeater H, as see from the

5   bases A, B, C and D, and adopting a model to describe the respective segments deviations (as for example described by S.M. Hunt et al., "Equatorial atmospheric and ionospheric modeling at Kwajalein missile range", Lincoln Laboratory Journal, vol. 12, pp. 45-64, 2000;

10 S.M. Honma,Y. Tamura e M.J. Reid, "Tropospheric delay calibrations for VERA", Publ. Astron.Soc. Japan., vol. 60, pp. 951-960, 2008). The process calculations are repeated adopting the deviations for the respective segments, due to propagation effects in the

15 terrestrial atmosphere added to systems of equations (1), obtaining the correction for the time transit at the repeater added to the correction of correction for signal propagation times at all segments, allowing the calculation of the searched coordinates with great

20 accuracy. The process and system proposed by the invention allows the remote determination of the temporal changes at the link defined by the signal repeater station and the temporal changes due to the propagation of signals in the medium, simultaneously

25 to measurements of distance, navigation, clock synchronization and geographic positioning, for every discrete temporal sequence utilized in the procedure. To calculate the corrected distances, geographic coordinates of the repeater and of the targets and

30 applications in time .synchronization it will be used the analytical procedures described in the article of P. L. Kaufmann et al., "Non recursive algorithm for remote geolocation using ranging measurements", Math. Problems in Engineering, v. 2006, pp. 1-9, Article

35 ID79389, DOI:10.1155/MPE/2006/79389, 2006.

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The phase delays corresponding to the references bases
A, B, C and D can be well determines "in loco" and are
assumed as fixed and well known data, considering that
such reference bases are fixed and accessible to all
5   procedures for verifying measurements.
The solution proposed by the present invention makes
the economically possible, with high degree of
accuracy, the determinations of phase delays and
temporal changes in the passage of time coded signals
10   by the repeating station R (in reception and
retransmission), at a remote and inaccessible
location, as well as the time changes caused by
propagation effects in the medium.
The temporal effects in the time coded signals in
15   their passage by the repeater station R, and those
caused the signal propagation at different elevation
angle, are unknown and cannot be determined with only
three bases of reference in the system, which defini
only one position for the repeater R.
20   The process here proposed can also include steps to:
emit, from the above indicated reference base at
successive instants, coded signals and to obtain
successive coordinates for the repeater station R,
corrected in function of changes in time, phase and
25   frequency, in the retransmission of the above said
successive coded signal, in order to allow the
navigation of the repeating station R, making the
calculations of coordinates for the repeater shown
before with system of equations (2), to which it will
30   be introduced the time changes (δ_R) and Δ_{pdAR}, Δ_{pdBR},
Δ_{pdCR} and Δ_{pdDR} determined according to the present
invention; retransmit, by the repeater station R, the
coded time signals to other targets which geographic
coordinates are well known (one of them represented in
35   this application by point P in figure 1); determine

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the difference between the time coded signal that
arrives at target P and the time generated by its own
clock, Δ'_p allowing the correction of synchronism,
following the equation (P.L. Kaufmann et al., 2006):

5     $\Delta'_p = (AR/c) + (PR/c) + \delta_{At} + \delta_{Pr} + \delta_R + \Delta_{pdPR} + \Delta_{pdAR}$
        (7)

where AR and PR are the measured segments, δ_{At} and δ_{Pr}
are the temporal changes previously determined and
known at the transmitter and at the target P with

10   known position, respectively, δ_R and Δ_{pdPR} are the time
changes determined by the present invention. The
synchronization or time correction will be $\Delta'_p - \Delta_p$
where Δ_p is the time difference predicted
theoretically for position P.

15   The other possible step is to retransmit, by the
repeater station R, the time coded signals, to the
other targets with unknown position (similarly
represented by the point P in figure 1), with their
clocks synchronized to the clocks installed at the

20   four reference bases, A,B,C,D; to obtain the distances
from the repeater station R to the other targets,
corrected for temporal changes at retransmission and
in propagation; and determine the coordinates for the
targets in at least three successive instants,

25   adopting the corrections in time, frequency and phase.
It is therefore possible to calculate the distance
Of the repeater station R to the reference bases
A,B,C,D and to the targets with positions to be
determined, with corrections of the time changes at

30   retransmission and in propagation, at repeater   R
positions in four different instants, which positions
are not in a straight line in space, defining,
univocally, in any coordinate system in space, through
four successive measurements, the spatial position of

35   the target, as it has been proposed to determine. The

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analytical solution to perform these calculations can follow, for example, the algorithm published by P.L. Kaufmann et al. (2006) repeating the procedures expressed by equations (1), (2) and (3) in relation to

5   one set of three reference bases that include base A where the transmitter is located, for four instants above referred, obtaining four spheres with distinct radii, all of them centered on the repeater, at positions and instants distinct, respectively. The

10   interception of spheres will give the position of target P, which coordinates become determinate. The practical procedure is illustrated in figure 3 (after P.L. Kaufmann et al., 2006) where a target P, with position to be determined (A, x, y, z) is located in

15   relation to the four distinct positions of the repeater R_1, R_2, R_3 and R_4, being the last position na option when the surface of the planet itself cannot be used as a fourth reference. The operations are made by adding another system of reference as a function of

20   the repeater's positions in R_1, R_2, R_3 and R_4 (see figure 3), (R_1, u, v, w), where the target's coordinates u, v and w constitute the solution for the system. It has been shown by P.L. Kaufmann et al. (2006) that for three repeater's positions two

25   solutions are found:

$$u_P = (PR_1^2 - PR_2^2 + R_1R_2^2)/2R_1R_2$$

(8)

$$v_P = [(\rho_1^2 - \rho_2^2)/2 \; v_{R3}] + v_{R3}/2$$

$$w_P = \pm (\rho_1^2 - v_P^2)^{1/2}$$

30   where $\rho_1^2 = PR_1^2 - u_P^2$ e $\rho_2^2 = PR_3^2 - (u_{R3} - u_P)^2$.

The uncertainty in the signal of w_P is eliminated by adopting a fourth sphere to define only one position. This can be the interception with the planet's surface, taken as the fourth reference surface, or by

35   adding one fourth position for the repeater station R_4

(see figure 3), generating a respective fourth sphere with radius PR_4.

The position solution found, using known analytical procedures, can be converted into the (A,x,y,z) system

5 by determining the position of P (x_P, y_P, z_P) in this coordinate system. In the case there are interest in expressing the results in spherical coordinates (latitude, longitude, altitude of the repeater's station), these can be found using well known

10 analytical procedures, deduced from simple known operations.

The technical solution proposed by the present invention permits to choose the time or the hour of reference to perform the measurements, provided there

15 is synchronism between the clocks provided at the reference bases and/or at the targets with positions are to be determined.

The technical solution proposed allows: the determination of geographic and spatial positions of

20 targets located at distances which are within the visibility line as seen from the repeater R in space; the prediction for the adoption of a larger number of fixed reference bases A, B, C, D, covering larger geographic extensions with the use of the same

25 repeater R in space; the prediction the adoption of more than one repeater station R in space, extending the area on the terrestrial surface to become surveyed, to define targets geopositioning; to calculate the targets geographic position with four

30 transponders in space, separated at a distance from each other, with one single time signal interaction; and to allow the accomplishment of hundreds of successive measurements per minute of time, of one or more targets, fixed or mobile, with the use of a

35 single repeater station R in space.

The process and system here presented can be applied to any kind of transponders or repeaters of electromagnetic waves in general in space, being artificial or natural, active or passive.

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CLAIMS

1. Process to determine temporal changes in retransmission and propagation of signals, to measure distances, synchronize actuators, and georeferencing, 5 characterized by the fact of comprehending the steps of:

a- installing four reference bases (A,B,C,D) on the ground, every three of them not collinear, at known geographic positions and visible from the repeater 10 station (R);

b- emitting, at a reference instant and from a transmitter device (T) provided a tone of the above mentioned reference bases, one time coded signal containing the identification of the emitting reference 15 base and of the instant of emission;

c- receiving, in a receiver device (REC) installed at each one of the four reference bases (A,B,C,D) the coded signal, received and retransmitted by the repeater station (R);

20 d- attributing, systematically, different arbitrary values to the change in time, phase or frequency, to the repeater (R) and ·calculate, for each one of the attributed temporal change, one respective position difference for the repeater station (R) obtained with 25 the use of two distinct sets of three reference bases (A,B,C and A,B,D; A,B,C and B,C,D; A,B,D and B,C,D);

e- identifying which one of the attributed values for the temporal changes at the repeater (R) results in a minimum difference between the two positions of the 30 repeater station (R), obtained using two distinct sets of three reference bases (A,B,C and A,B,D; A,B,C and B,C,D; A,B,D and B,C,D); and

f- utilizing the temporal change found in "e" to determine the position·of the repeater (R).

35 2. Process, according to claim 1, characterized by the

fact that the difference positions for the repeater (R) station are calculated algebraically attributing certain values to the so said temporal change, in sufficiently high number of values enough to identify

5 the so called minimum value of the comparative differences.

3. Process, in agreement with claim 2, <u>characterized</u> by the fact that the realization of the iterative calculations of the differences between positions of

10 the repeater station include and correct effect caused by temporal changes due to the signal propagation characteristic of the medium in which the system operates, adopting known propagation models, and using elevation angles for the repeater station (R) as seen

15 from the different bases (A,B,C,D) to determine the accurate and definitive position of the repeater station (R).

4. Process, in agreement with claim 3, <u>characterized</u> by also including another step: the determination of the

20 repeater station (R) coordinates with corrections for changes in time, frequency or phase, for a given instant of reference.

5. Process, in agreement with any of claims 3 or 4, <u>characterized</u> by also including another step to

25 disseminate time signals to other points on the ground, with know geographic positions, for synchronization of the respective clocks.

6. Process, in agreement with any of the claims 3 or 4, <u>characterized</u> by also including the following steps:

30 - emit, from the said reference base and at successive instants, coded signals and to obtain successive coordinates for the repeater station (R), corrected taking into account the time, frequency or phase changes in retransmission and propagation of Said coded

35 time signals in order to determine the navigation of

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the repeater station (R);

- retransmit, by the repeater station (R), the coded time signals to other targets with unknown geographic positions, each one with their own clocks synchronized

5   to clocks installed at the four reference bases (A,B,C,D);

- obtain distances from the repeater station (R) to the other targets, corrected for the time changes on retransmission and on the propagation in the medium;

10 and

- determine targets' coordinates by measuring time differences at least three successive instants, with the adoption of changes in time, phase or frequency.

7. Process, in agreement with claim 6, <u>characterized</u>

15 by also comprehending the step of:

- calculate the distance from the repeater station (R) to the reference bases (A,B,C,D) and to the targets with geographic positions to be determined, with corrections for the time changes at the repeater

20 station (R) and those caused by the signal propagation in the medium, for repeater station (R) positions at four different instants, which positions are not along a single straight line, defining univocally, at a given arbitrarily selected coordinate system in space,

25 through four successive measurements, the spatial positioning of the targets, which location are searched.

8. System to determine temporal changes in retransmission and propagation of signals, addressed

30 for measurement of distances, synchronize actuators and georeferencing, from a remote and inaccessible repeater station (R), containing a transponder, being such system <u>characterized</u> by the fact of comprehending:

a- four reference bases (A,B,C,D) on the ground, every

35 three of them not collinear, at known geograghic

positions and visible from the repeater station (R);

b- one transmitting device (T) provided a tone of the bases (A) capable to emit, at a reference instant, a time coded signal containing the identification of the

5 reference transmitting base (A) and of the instant of emission;

c- one receiving device (REC) installed at each one of the four reference bases (A,B,C,D) capable to receive the time coded signal, emitted by the transmitting

10 device (T) and received and retransmitted by the repeater station (R);

d- precision clocks (RL) each one installed at every one of the four reference bases (A,B,C,D);

e- one central processing station (E) that receives the

15 coded time signal, retransmitted by the by the repeater station (R), comparing it to the coded time signal generated at the emitting reference base (A) and assigning different arbitrary values for the changes in time, phase or frequency, to the repeater station (R)

20 calculating, for each of the assigned temporal changes, a respective difference between positions for the repeater station (R), obtained with use of two distinct sets of three reference (A,B,C and A,B,D; A,B,C and B,C,D; A,B,D and B,C,D), identifying which value

25 assigned to the temporal change at the repeater (R) results in a minimum difference between the two positions found for the repeater station (R), and processing the corresponding temporal change to determine the position of the repeater station (R); and

30 f- one transmission mean or device (MT) provided at each of three reference bases (B,C,D), distinct from that transmitter that generates the coded time signal, with each transmission mean or device (MT) forwarding to the central processing station (E) the time

35 difference between the coded time signal received from

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the transponder at the repeater station (R) and the respective coded time signal generated at each one of the referred three reference bases (B,C,D).

9. System, according to claim 8, <u>characterized</u> by the fact that the central processing station (E) is defined at the emitting reference base (A), provided with a transmitter (T).

10. System, according to claim 8, <u>characterized</u> by the fact that the central processing station (E) is able to calculate algebraically the differences between positions of the repeater station (R), assigning certain values for the temporal changes, in sufficient number of assignments to allow the identification of the minimum value for the comparative differences.

11. System, according to claim 10, <u>characterized</u> by the fact that the repetition of the iterative calculations of differences between positions of the repeater station (R), processed by the central processing station (E), include the signal propagation velocities characteristics to the medium where they propagate, obtained from known models, and the elevation angles of the repeater station (R) as seen from the different reference bases (A,B,C,D).

12. System, according to claim 11, <u>characterized</u> by the fact that the central processing base (E) determine the coordinates of the repeater station (R) with correction of changes in time, frequency or phase, for the given instant of reference.

13. System, according to any one of claims 11 or 12, <u>characterized</u> by the fact of also include other points on the ground, with known geographic positions, for which the time signals are disseminated, for synchronization of the respective clock systems.

14. System, according to any one of claims 11 or 12, <u>characterized</u> by the fact of also include other targets

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with unknown geographic positions and having their own clocks synchronized to the clocks installed at the four reference bases (A,B,C,D), with reference base (A) emits, at successive instants, coded time signals, with
5   the central processing base (E) providing successive coordinates for the repeater station (R), corrected for the changes in time, phase or frequency occurred in retransmission and due to propagation of the said time coded signals, determining the navigation of the
10   repeating station (R); with the said other targets receiving the coded time signals retransmitted by the repeater station (R) with the said central processing station (E) obtaining the distances from the repeater station (R) to the other targets corrected for the
15   temporal changes in retransmission and in propagation in the medium, and determining the target coordinates by measuring the differences in time at least three successive instants, adopting the corrections for temporal changes in time, phase or frequency and for
20   propagation in the medium.

15. System, according to claim 14, characterized by the fact that the central processing station (E) calculate the distance of the repeater station (R) to the reference bases (A,B,C,D) and to the targets with
25   geographic positions to be determined, with corrections for temporal changes at the repeater station (R) and those caused by propagation in the medium, at positions of the repeater station (R) in four different instants, which positions are not in a same straight line,
30   defining univocally, in any coordinate system in space, the searched spatial position of the target, through four successive measurements.
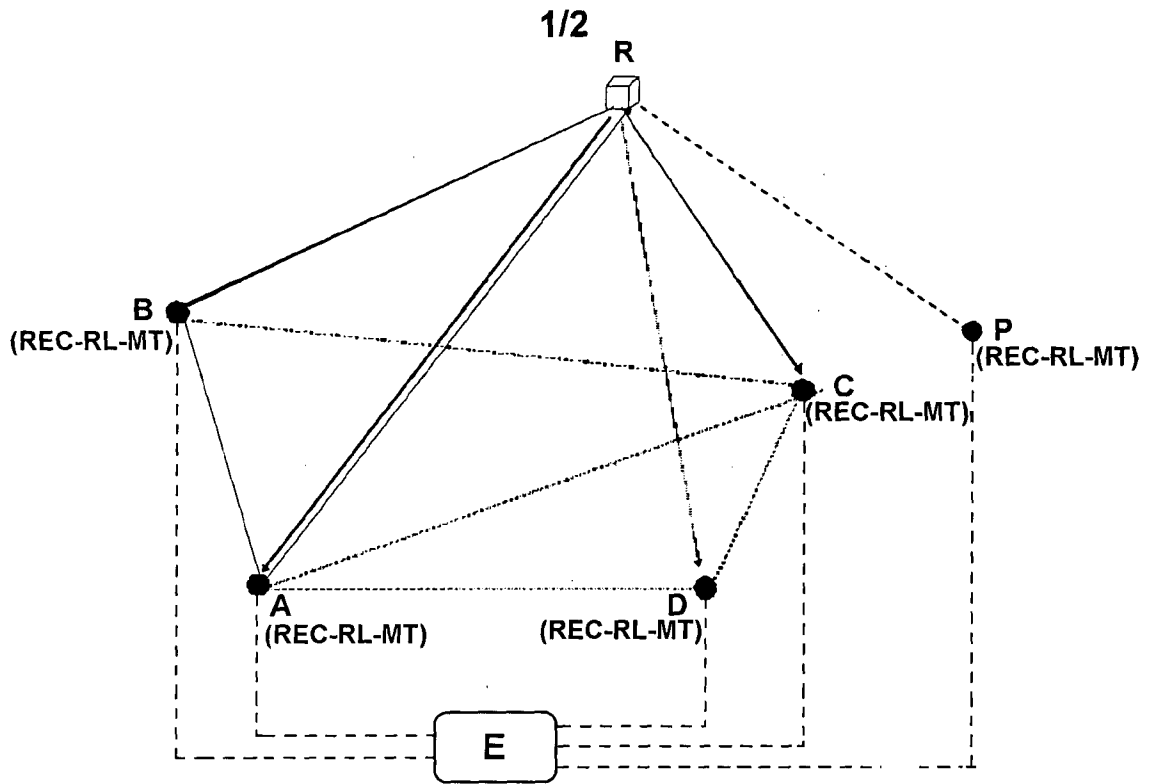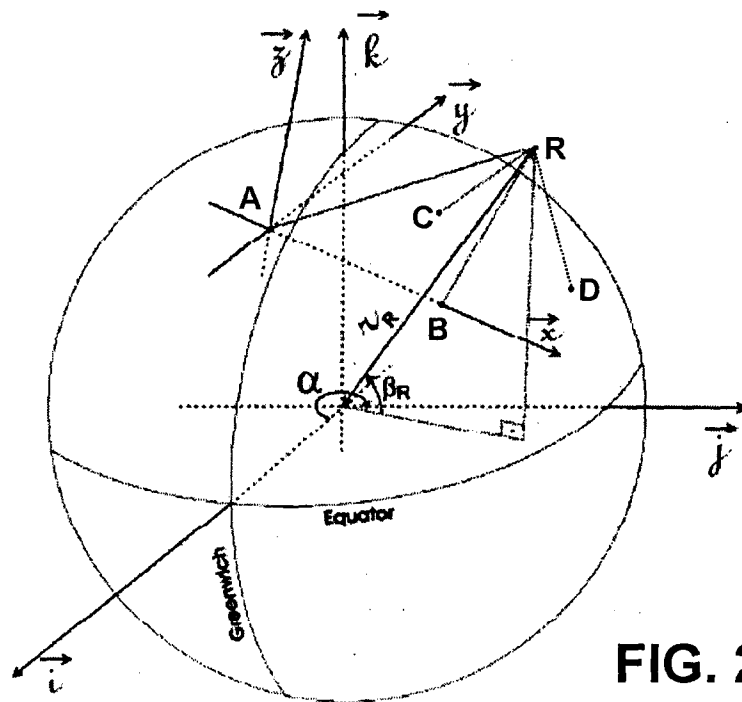
FIG. 1

FIG. 2

FIG. 3

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S5/02   G01S13/87
ADD.

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)

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 7 822 427 B1 (HOU JIONGKUAN [US]) 26 October 2010 (2010-10-26) abstract; figure 2 column 13, line 40 - column 15, line 25 -----	1,8
A	US 2004/219930 A1 (LIN IE-HONG [US]) 4 November 2004 (2004-11-04) abstract paragraph [0011] - paragraph [0015] paragraph [0064] - paragraph [0077] -----	1,8

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
16 July 2012	23/07/2012

| Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016 | Authorized officer López de Valle, J |

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INTERNATIONAL SEARCH REPORT

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