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Experimental Positioning Results of the Repealite Based Indoor Positioning System

Preliminary 2D results

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***Abstract*— The continuity of the positioning service, mainly achieved outdoors with satellite navigation systems, is clearly a fundamental aspect for the development of location based applications and services. Indoors, many techniques are proposed but yet no definitive answers have been given. Our proposition for indoor positioning is a new pseudolite-based system: the repealites. A single GNSS-like signal is transmitted from all the repealites (typically 4 for 3D positioning) in order to simplify both the synchronization process (between transmitters) and the interferences between repealites. In addition, in order to avoid intentional multipath, the signals from different repealites are shifted in time by a few chips.**

The paper describes the set up and the results of an experimental campaign of measurements carried out in our premises in Evry, France, a few kilometers south of Paris. The main advantage of the repealite approach is the possibility to carry out both code phase and carrier phase measurements with a simplified transmission scheme. These two measurements allow us to carry out many different computations and hence comparisons. Among the most important ones, we can cite the direct code phase based positioning associated with a large impact of multipath on the positioning accuracy. The next step is then to carry out carrier phase measurements and to compute relative displacement positioning through Doppler shifts analysis. We also discuss real world performance of a positioning that combines code and carrier phase measurements through the implementation of a Kalman filter intended to provide a smoother and more accurate positioning.

Details concerning the receiver and the associated algorithms will be given, together with the really obtained accuracies and experiment contexts.

Indoor positioning, Pseudolites, Repealites, Code phase, Carrier phase, Continuity of positioning.

I. INTRODUCTION

The main goal of this paper is to describe the current state of the so called repealite based indoor positioning system. A repealite is a sort of pseudolite associated with some specific features described below. The complete system, including a local infrastructure of repealites to be deployed, aims at providing continuity of the GNSS based positioning to a typical user, i.e. a human being equipped with a Smartphone (although this is not the only target), in all environments. Thus, indoors and outdoors are covered with the same piece of electronics, the GNSS receiver.

II. DESCRIPTION OF THE SYSTEM

The proposed system is based on the use of specific pseudolites, called repealites. Thus, a local infrastructure is required and must be deployed in the considered building. The main advantage of using a GNSS approach is the very high sensitivity of the receivers, allowing us, with a reduced transmitted power, to reach a typical range of several tens of meters indoors.

A. Origin of the concept

The original idea of using pseudolites in order to achieve indoor positioning is based on the concept of local constellation. In other words, the principle is to create a constellation of transmitters of GNSS signals in a similar way GNSS works outdoors with satellites [1], [2]. Thus, each pseudolite transmits its own signal. The main advantage of this approach is clearly the similitude with outdoor GNSS and the possibility to implement almost all the satellite navigation techniques with minor modifications. Unfortunately, the indoor environment is quite different and although some physical phenomena are easier to deal with, some others are much more difficult. Among a few others, let us mention the near-far problem, the synchronization aspects and multipath.

A repeater based approach [3] was then designed in order to simplify the problem of near-far by implementing time division transmissions. Unfortunately, this sequential approach is almost incompatible with carrier phase measurements, needed in order to efficiently cope with multipath and to provide accurate positioning. An original approach also consisted in transmitting the same signal for all the repeaters, reducing the interference problem [4].

The idea of repealites then proposes to keep the most interesting features of the repeater including the unique signal, but with a continuous transmission scheme. In order to avoid the intentional interference, we decided to delay the various transmissions by a few chips. Carrier phase measurements are now possible and will help the classical code phase measurements: the goal is to reach sub-meter accuracy in real indoor environments with a good reliability.

B. Main description of the system

The system consists of an infrastructure where the signal is generated and the delays implemented. The various repealites are connected to the main signal generator with optical fibers in order to reduce both the size and the signal attenuation of the system. A second part consists of various algorithms implemented on a GNSS software receiver in order to cope with the specific signal processing required. Fig. 1 shows the infrastructure part and Fig. 2 the repealite itself.

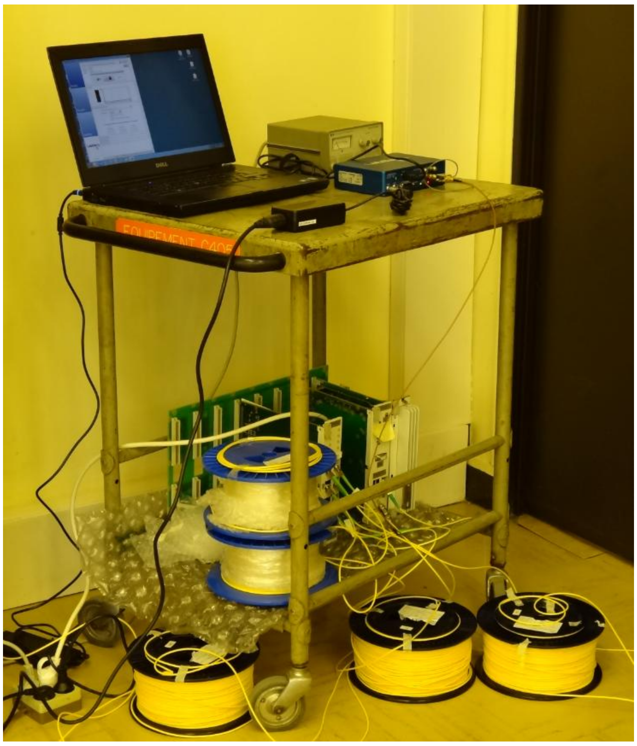

Figure 1. Infrastructure part of the proposed system

The system consists of a signal generator (in dark blue on the top of the trolley) driven by a computer, a radio over fiber sub-system that converts the radio signal to optical signal (various electronics connected to the green card), fiber coils allowing to implement the delays between repealites (the blue coils at the bottom of the trolley) and another set of fiber coils to link the antennas of the repealites (the yellow coils on the floor). Note that there are only three repealites in the current assembly (for 2D positioning), hence two “delay” coils and three “link” coils.

One can notice that the signal transmitted to the repealite is an optical one and the conversion to radio has to be carried out before the antenna. Thus, the repealite (see Fig. 2) includes an electronic converter, associated with radio amplifiers in order to feed the antenna.

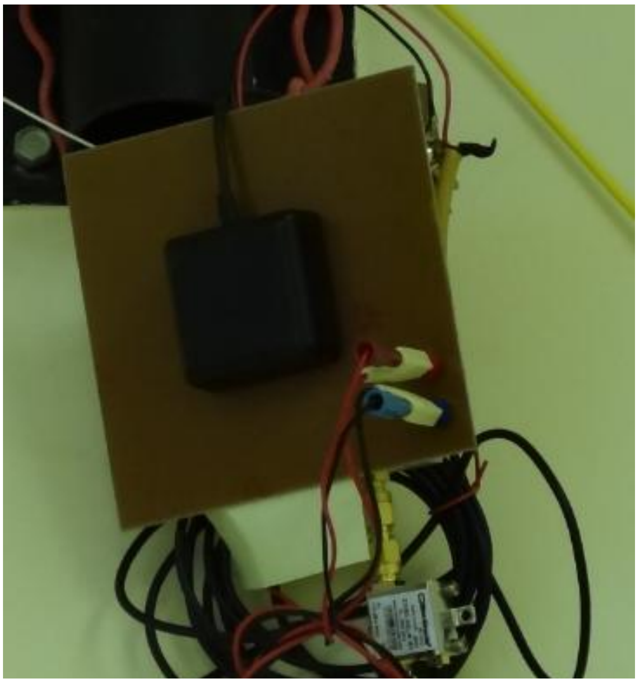

Figure 2. A repealite antenna

The indoor receiver used is an IFEN SX-NSR and the indoor receiving antenna is a very classical automotive one mounted on a remote control car (see Fig. 3).

III. POSITIONING RESULTS

We carried out two types of experiments: 2D relative displacement in a large classroom and absolute positioning (2D) in the entrance hall of our institute. 3D positioning is planned but has not yet been implemented: an additional repealite antenna is required and new fiber coils. This is scheduled for the end of this year.

Relative displacement is based on a known initial position and carrier phase measurements from the three repealites: this is a kind of GNSS based inertial system. By measuring the Doppler shifts (equivalent to carrier phase), it is possible to compute the velocity vector of the displacement and thus to estimate the displacement itself. We carried out straight line and circular trajectories with the receiving antenna mounted on a remote control car, as shown in Fig. 3. Our current user interface is not sufficient in order to carry out a direct time stamped comparison of the positioning but post-processing allows us to compare the trajectories shown in Fig. 4 (this deployment is the one considered for all the results provided in this paper).

For the straight line, the estimation of the maximum difference between the real trajectory and the computed one is in the range of a few decimeters, as shown in Fig. 5. Note that in such a configuration and considering the limitations of our receiver, the near-far effect appears sometimes. We developed, a few times ago, a specific technique for eliminating this effect but it has not yet been implemented.

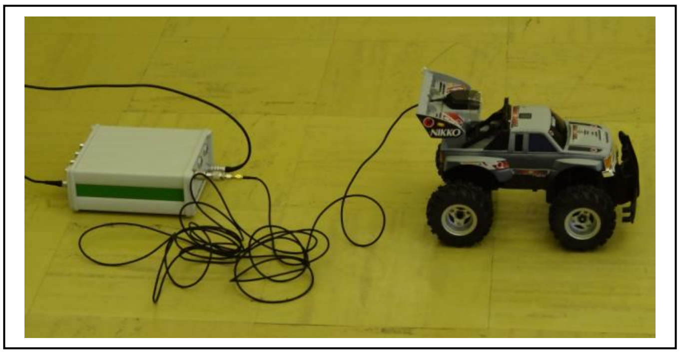

Figure 3. The receiving antenna mounted on a remote control car

For the circular trajectory, the same approach was carried out. Nevertheless, some difficulties appeared when the carrier phase is lost at some point during the displacement. Our current implementation of the various algorithms is not well adapted to this situation since the acquisition process has to be restarted when all the three carrier phases are no longer available. Improvements are currently investigated. Results are provided in Fig. 5 and are comparable to the ones obtained for the straight line displacement. The dashed lines in Fig. 4 and 5 are the real trajectories.

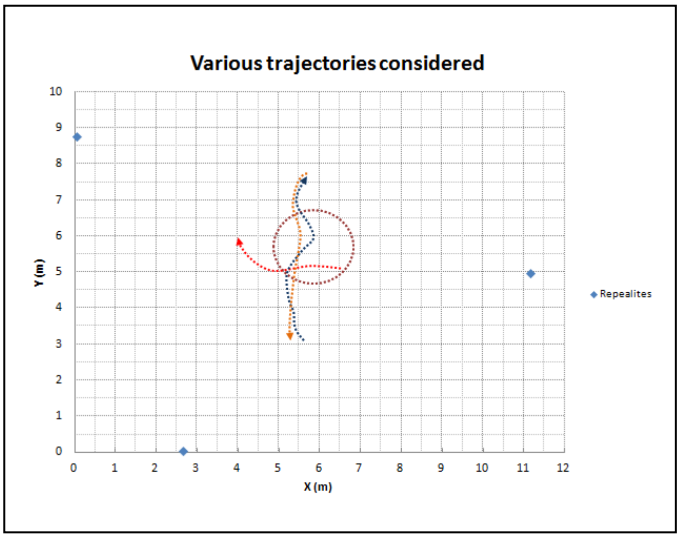

Figure 4. Locations of the repealites and relative displacement trajectories

Concerning the absolute positioning, the typical approach is based on a combination of code phase and carrier phase measurements (using a simple Kalman filter already described in [5]). The smoothed pseudoranges thus obtained are then computed through a classical positioning resolution algorithm. Note that since there is no redundancy at all, measurements errors have a direct impact on the resulting positioning. Further developments are already planed in order to increase the number of repealites of the system.

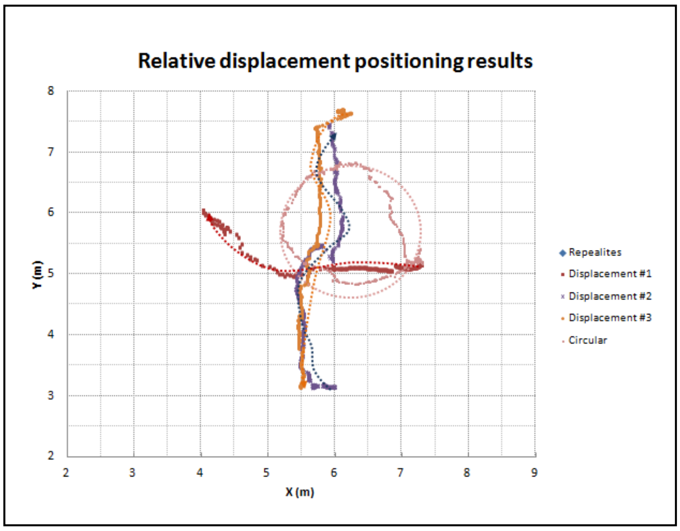

Figure 5. Absolute positioning results for a few static locations

We carried out static positioning as well as displacements. Fig. 6 shows the results obtained for a few static locations using carrier phase measurements.

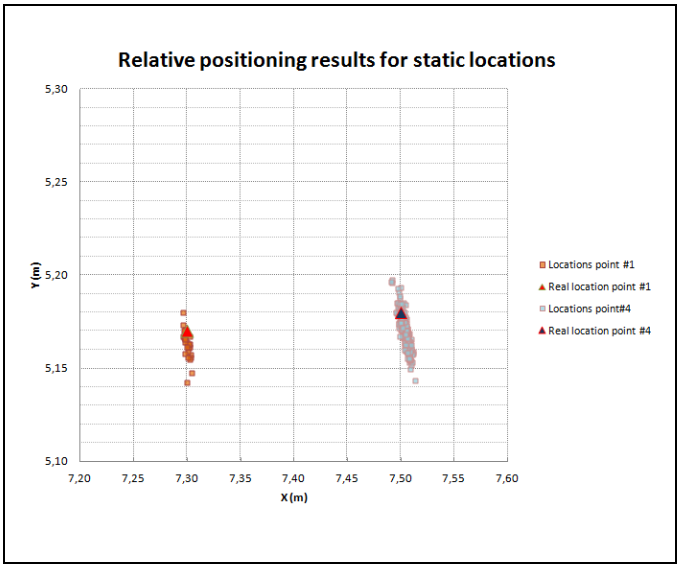

Figure 6. Comparison between absolute and relative positioning for a straight line displacement

As can be seen, the typical accuracy obtained for the tested points is in the range of less than ten centimeters, as expected.

The shape of the obtained locations suggests that there is a drift somewhere, either in the DOP values or in the clocks of the receiver or the signal generator: this has to be investigated further.

Absolute positioning using code phase measurements have also been carried out. Fig. 7 shows the various results obtained for a significant location. For comparison purposes, the carrier phase positions are also plotted. Two sets of “code” locations are available: the first one is the raw set, including all the calculated locations using the standard features of the IFEN receiver. There are about 180 locations calculated for a static time of about 15 seconds. The second set is a filtered subset of the raw set. The filtering approach consists in having a threshold in the possible change of the X and Y coordinates for two consecutive locations. The threshold considered here is 2 meters for 0.06 second: note that this constraint is quite acceptable in real life!

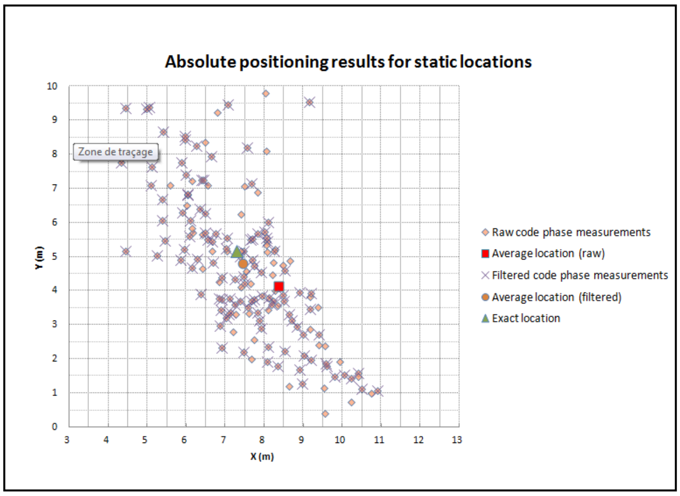

Figure 7. Absolute positioning first results

The average distance errors are 4.2 meters for the raw set and 2.4 meters for the filtered set, but the averaged locations are much more accurate to 1.5 meter and 0.4 meter respectively for the raw and filtered sets. Thus, we consider that even if there is still the need for real-time code positioning improvements (currently under consideration), the filtered approach seems quite good in providing the carrier relative displacement approach an initial location. Of course, it requires the user to wait for about 15 seconds …

IV. Discussion

These preliminary results will probably be improved in the coming months since no multipath mitigation or near-far effect reduction techniques were implemented.

Another important point is certainly to consider that these first results have shown that redundancy is almost compulsory if one wants to obtain a really deployable system. For example, it is quite important to still have three carrier phase measurements available for relative displacement positioning. Thus, a minimum of four or five is required.

Some difficulties remain in our current implementation, such as the fact that pseudorange measurements are drifting regularly. The implementation of a Kalman filter combining code and carrier measurements reduces the impact of this drift, but investigations are still required to remove this effect. In addition, the uncertainty concerning the real delays induced by the fibers, typically one to two meters is another concern.

V. Synthesis and Future Works

These preliminary results are encouraging in order to reach a really deployable system using GNSS techniques with the goal of less than one meter of accuracy in real environments, since some problems have been identified. Solutions exist, either in the positioning computations at the receiver end or in a better initial calibration of the system. The continuity of the positioning service seems to be possible. Nevertheless, a lot of work is still needed for this approach to run efficiently: near-far [6], multipath [7], redundancy, combination of measurements and estimation of the real delays between repealites have to be implemented or improved.

Acknowledgment

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References

[1] Kee C, Jun H, Yun D, (2003), “Indoor Navigation System using Asynchronous Pseudolites”, *Journal of Navigation*, 56, pp 443-455.

[2] Rizos C., Barnes J., Wang J., Small D., Voigt G. and Gambale N., (2003), “LocataNet: Intelligent Time-Synchronised Pseudolite Transceivers for cm-Level Stand-Alone Positioning”, *11th IAIN World Congress*, Berlin, Germany.

[3] Im S-H, Jee G-I, Cho YB., (2006), An indoor positioning system using time-delayed GPS repeater. *ION GNSS 2006*, Forth Worth, (TX).

[4] Anca Fluerasu, Alexandre Vervisch-Picois, Nel Samama, "Repeater based Indoor Positioning - Summary of experimental campaigns of measurements", ENC-GNSS2011, Londres, Novembre 2011, UK.

[5] A. Vervisch-Picois, N. Samama, “First Experimental Performances of the Repealite Based Indoor Positioning System”, ISWCS 2012, Paris, August 2012, France.

[6] A. Vervisch-Picois, N. Samama, "Interference Mitigation In A Repeater And Pseudolite Indoor Positioning System", IEEE Journal of Selected Topics on Signal Processing, October 2009, Vol. 3, N°5, PP. 810-820.

[7] Jardak N., Samama N., (2010), "Short Multipath Insensitive Code Loop Discriminator", *IEEE Trans. on Aerospace and Electronic Systems*, Vol. 46, PP.278-295.