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Software Defined Radio Implementation of a Non-synchronized Indoor Positioning System Using Dual-antenna Pseudolites

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Abstract: *The main objectives of our work are to implement an indoor positioning system using "Grin-Locs", a kind of pseudolite with dual transmitting antennas, and to evaluate its performance, using Software Defined Radio (SDR). "Grin-locs" architecture allows to perform measurements of the carrier phase without the need to synchronize the various pseudolites, and to obtain a typical positioning accuracy of a few decimeters. The first implementation uses GNSS signals, but the use of an SDR is likely to allow a change in the frequency bands used, in ISM bands for example. The paper describe the SDR choices and the way we implement both the transmitters and the receivers, also using SDR.*

1. Introduction

Indoor Position, Localization and Navigation is a very well-known issue, widely studied in the literature. The possible applications of an indoor positioning system are large: military, medical, industrial or even marketing applications. There are also applications that for optimal use require indoor positioning, as indicated by El-Seimy *et al.* [4], for instance, fully autonomous driving and location, or Mobility as Service (MaaS) allowing even the safety of travelers and reduce the carbon footprint. It is worth noting that for applications that require high precision, face the problem of equipment cost and in many cases also installation cost. For this reason is very difficult the scalability of Indoor Position technologies.

The technologies used to implement an indoor positioning system are very diverse, for instance, HD maps, Lidar, RADAR or UWB or even Inertial Navigation System (INS). These technologies also use different methodologies to know the position. for instance, radio technologies are broadly based on two techniques; Time of arrival (ToA) and Angle of Arrival (AoA). The technologies base on ToA, or its variant TDoA (Time Difference of Arrival, use the transmission time to deduce the position. This technique need the position knowledge of the base stations and need also the synchronization among them. The technologies, based on AoA, use the measurement of signal angles of arrival in the receiver antenna, but indoor positioning is a very complex environment where problems such as multipath and interference increase, making it

difficult to use this technique. In addition to these techniques, to treat the signals and sometime use undesirable effect as multipath, different algorithms are used, such as the one based on fingerprint [5].

In this paper, we use "Grin-locs" architecture proposed in [2], that allows to perform measurements of the carrier phase without the need to synchronize the various pseudolites, and to obtain a typical positioning accuracy of a few decimeters. Our goal is to implement this architecture using SDR in order to test if a low-cost implementation could work properly. This allows us to give a first response to the possibility of creating indoor positioning systems at a reasonable cost and that may be scalable in the future. The use cases are varied and range from sports venues or exhibition centers to closed structures such as parking lots, hangars or tunnels. More structured buildings, such as office buildings, are less targeted because signal propagation is then much more complex and can seriously degrade positioning performance.

The remaining sections are structured as follows. Section 2 proposes a dual-antenna pseudolites implementation using SDR. Section 3 presents the results of the measurements carried out. Section 4 concludes the paper.

2. Dual-antenna Pseudolites implemented by SDR

This paper uses the "Grin-locs" architecture proposed in [2]. This architecture has, as main characteristic, the ability to use only the carrier phase measurement to carry out the absolute positioning. Another no less important feature of this architecture is that the synchronization between the transmitters is not necessary. Figure 2 shows a possible implementation, where depends on the number of transmitters, it is possible to obtain, for instance, 2D or 3D positioning. As shown in the figure, for this architecture, each transmitter is made up of 2 antennas separated by one wavelength. It is worth noting that the signals transmitted by both antennas are generated by the same oscillator that ensures their synchronization. In addition, each antenna transmits a signal with a different code, in our implementation we use the PRN (Pseudorandom Noise) codes of GPS, more specifically, the codes PRN 10 and PRN 20. Regarding the characteristics of the receiver, this can be a standard receiver, which uses the measurement of the phase difference of the two signals sent by the receiver, allowing the determination of the Angle of Arrival (AoA) of the signals. To determine the Angle of Arrival, it is worth noting the importance to know the location of the transmitter. As indicated in [2], it is possible to calculate a fixed point by means of geometric intersections of straight lines, using two or three Grin-Loc transmitter.

To implement the aforementioned architecture with SDR technology, we carry out an exhaustive analysis of SDR devices existent in the market. Among the different existing SDR devices, we have chosen the USRP SDR from National Instruments (NI) for this implementation. More specifically, the USRP B210 (or USRP-2901) device for implementing the transmitters, since it is a MIMO 2x2 RF device, and the USRP B200 (or USRP-2900) for implementing the receiver (SISO RF device). This choice allows us, on one hand, having high oscillator stability in the receiver, a measurement error less than 1 ppb. That means, high accuracy of GPS signals received

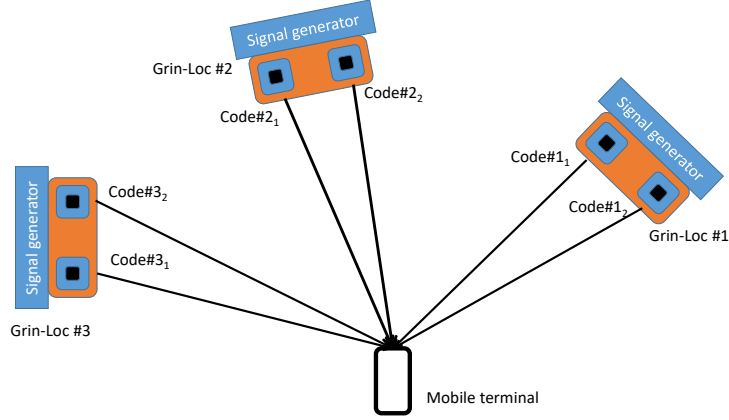


Figure 1: Grin-Loc positioning system

and position; and on the other hand, to build a system with tight synchronization requirements in the transmitters, using the GPSDO for USRP (GPS-Disciplined OCXO).

The implementation to carry out the aforementioned architecture using SDR devices consists of: 1) transmitters with two output signals (dual-antenna) which send two different synchronized signals (two different pseudorandom noise (PNR) codes (as mentioned previously, in the implementation, we have used the codes PRN 10 and PRN 20), implemented using GNURadio and Python). It is worth noting that the transmitter antennas are separated by a distance of λ between them; and, 2) receivers, which recover the carrier phase of received signals to obtain the phase difference between the two coded signals received. This difference between the carrier phases allows carrying out a calculation of the angle of arrival of the signal or of positioning. To recover the carrier phase and the PNR associated as well as timestamps of these received signals (from USRP's clock), to compute the position, we have used and modified for our architecture the GNSS-SDR code propose in [3]. GNSS-sdr code, is a code implemented for SDR devices that allows receiving the different GNSS signals and calculate the position. The modification made to this code for our tests is related to reading the navigation message, which we do not send. In the next section, we will analyze the results obtained in a first analysis with wired connection.

3. Results

Figure 2 shows the first test carried out with a wired transmitter-receiver system, used to test the aforementioned implementation. In this implementation, a USRP B210 is the transmitter and a USRP B200 is the receiver. Both USRP are connected by a power splitter (2 way (-3 dB) power combiner) with lead two transmitter signals to the receiver.

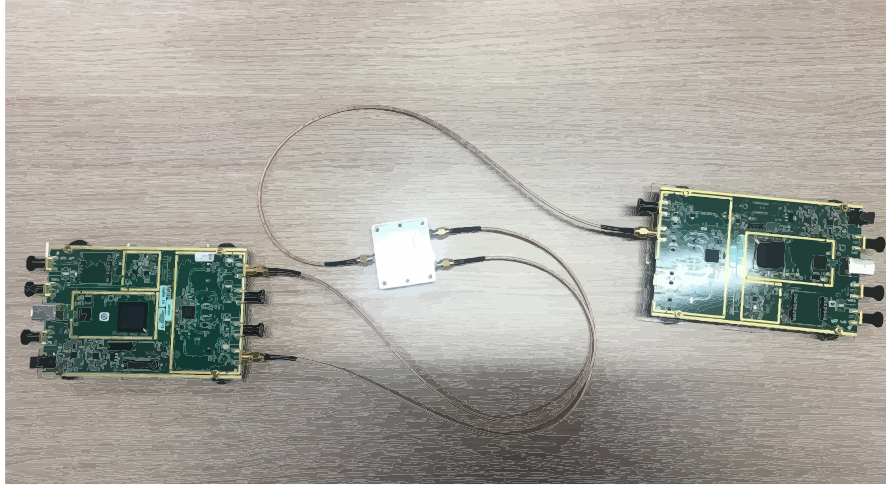


Figure 2: Wired transmitter-receiver system connection.

The first test carried out with the previous set-up has been to verify the correct transmission and reception of the PRN 10 and PRN 20 codes, generated synchronously and sent from the transmitter to the receiver. Subsequently, the accumulated phase belonging to each received signal has been recovered in order to verify the possibility to calculate the carrier phase difference between both signals and the accuracy of this measurement. To carry out this verification, we have made two tests:

- First: We have sent both signals to the receiver, and we have analyzed the carrier phase of each signal (noted by phase in figures), and the difference of carrier phase between two signals generated in the transmitter at the same time.

Figure 3 shows the carrier phase of the two transmitted signals (a signal carrying the PRN 10 code and a signal carrying the PRN 20 code). And Figure 4, shows the difference of carrier phase between two above-mentioned signals. Analyzing the results, we note a difference of carrier phase constant, as expected. With these results, we can conclude that both signal have only a different initial phase, and both signals come from the same transmitter, leading to determine the angle of arrival of the signal from this transmitter.

- Latter: We have induced a phase difference in the carrier of one of the signals to analyze its behavior at the receiver.

Figure 5 shows the carrier phase of the two transmitted signals (the signal carrying the PRN 10 code and the signal carrying the PRN 20 code) with an induced modification of

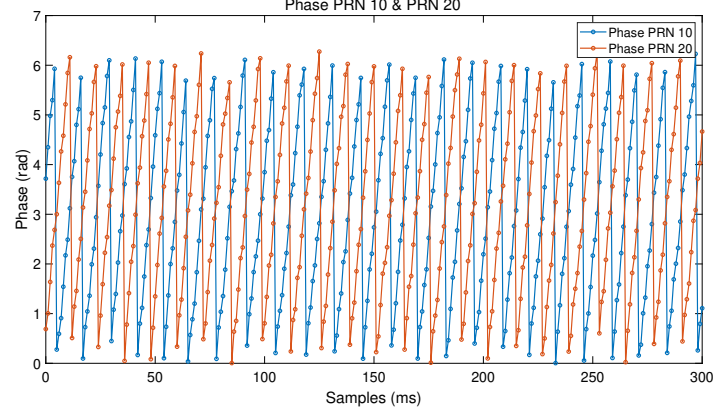


Figure 3: Carrier phase of incoming signals of output 1 and 2 respectively, of a Grin-Loc on the receiver

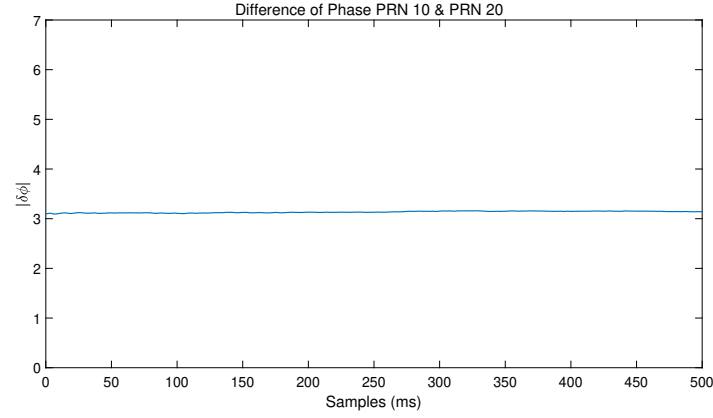


Figure 4: Difference of carrier phases between incoming signals of output 1 and 2 respectively, of a Grin-Loc on the receiver

0.5 Hz in the carrier of the signal which carries the PRN 10 code. And Figure 6, shows the difference of carrier phase between two above-mentioned signals for different induced modification of the carrier ($[0.5; 0.3; 0.2; 0.05]$ Hz). After analyzing the results, we note that, on the one hand, the phase shift changes over time in the reception as expected. And, on the other hand, the evolution of the difference of carrier phase over time is not so far to the theoretical evolution for a first test. This allows us to indicate that our system could discriminate the signals coming from different receivers and calculate the angle of arrival of each transmitter with an SDR implementation of the system. That allows us to follow our investigation to implement the system presented in [2], using SDR technology.

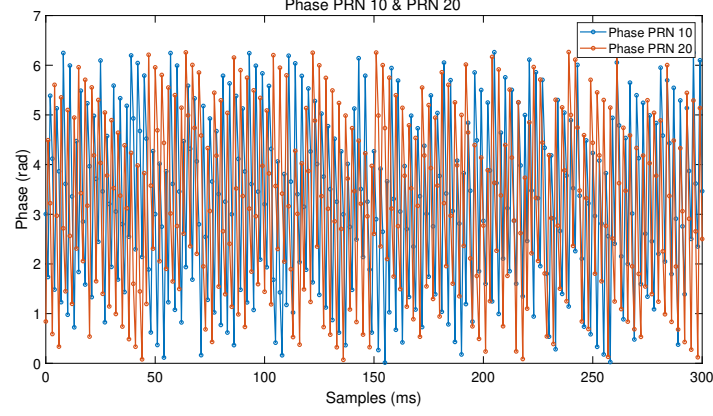


Figure 5: Carrier phase of incoming signals of output 1 and 2 respectively, of a Grin-Loc on the receiver, with an induced carrier phase shift of 0.5Hz

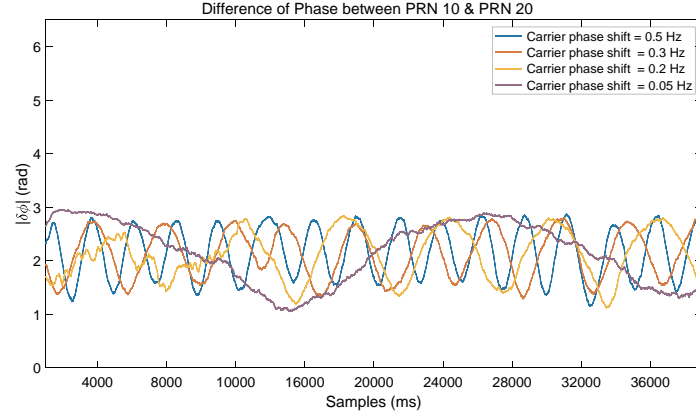


Figure 6: Difference of carrier phases between incoming signals of output 1 and 2 respectively, of a Grin-Loc on the receiver (with different induced carrier phase shift [0.5, 0.3, 0.2, 0.05]Hz)

4. Conclusion

In this paper, we show an implementation of Grin-Loc architecture positioning system using SDR technology. We also present some result using a wired connection between a transmitter and a receiver, with hopeful results. However, there are still many points to verify and improve to conclude that the positioning system architecture can work using SDR technology. Points such as improve performance to measurements of the carrier phase. In addition, the future work is to test the system (wireless) in an anechoic chamber so as not to cause any interference with the outside world. The objective is clearly to estimate the real achievable performances: the test in such a chamber is probably not very significant because in a very confined environment, but once the principle validated, we could then make measurements in authorized frequencies outside the chamber.

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