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Indoor LOS Positioning Comparison Between UWB and Pseudo-Lite Technology

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Abstract

Nowadays, positioning technique such as GNSS is limited by the indoor structure and environment. From this context, pseudo-satellite and ultra-wideband technologies for improving the quality of indoor positioning are provided. In this paper, the performance of UWB and pseudo-lite for indoor positioning simulation scenarios are evaluated. Based on the same set of positioning accuracy, while using different MATLAB codes and mathematical model simulation, comparison of the two technologies of system complexity is processed.

Keywords

Indoor Positioning; Ultra-wideband; Pseudo-Lite; System Complexity.

1. Introduction

As outdoor positioning technology has already been matured, indoor positioning situations still own the growing demand of improvements. For recent researching techniques, advanced Ultra-wideband and Pseudo-lite techniques are becoming popular for improving indoor positioning. To compare these two techniques, modulations of models need to be set. Essentially, two precedent conditions need to be consistent to get proper comparison within models: LOS condition and Multipath effect. LOS is line-of-sight, only indoor obstructions within visual range are considered. Because most environments are within LOS range, LOS condition is taken here for both two models. For multipath effect, when radio signals are transmitted between antennas, signals will be divided into different multiple paths causing the worst impact of signal fading and phase shifting.

To better compare UWB and Pseudo-lite, channel fading models need to choose individually. For UWB, systems such as IR-UWB, DS-UWB and MB-OFDM are commonly used. IR-UWB system owns lower energy consumption and better multipath resistance, so it is chosen. For Pseudo-lite, it can send messages in the same format as GNSS, which can be received by mobile phones. If the broadcast signal is continuously carried out, the system paragraph problem can be handled better and the power consumption is very high. As the pseudo-lite is more flexible to adjust its settings, the model of pseudo-lite is designed uniquely with random sequences and proprietary anti-multipath algorithm.

In the work, two models are decided, details need to set into MATLAB codes to get more practical emulation of real indoor condition. When the models are ensured, algorithms need to be taken to process the settled fading effect to try to improve the results of the positioning accuracy.

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2. UWB process and models

For UWB process and models, it will be introduced by the sequence of System, Signal Pulse Generation, Modulation, Channel Model and Range Calculation & Positioning respectively.

2.1 System

UWB positioning system is constructed by hardware part and the software part. For the hardware part, the target will carry the signal source to send message and conclude ID information or time message. Besides, there are a few base stations receiving the signal. Between them, two different connections are wireless and wire connections. Wireless connection is cheaper, but its system delay can be 0.25ns, while wire system only has 0.1ns. The software is mainly about the algorithm to calculate positioning results. Based on UWB system, four methods are used to locate the target: TOA, TDOA, AOA and RSS. According to the accuracy and simplicity of the system, TDOA is used in this paper. RSS has a worse accuracy than others. AOA needs the antenna array that is complex for indoor. TOA requires the accurate time synchronization between target and base stations. However, it is difficult to achieve because of the limitation of the single clock on the target. To be compared, TDOA has a more satisfied accuracy with keeping time of base stations the same easier.

2.2 Signal pulse generation

As for signal pulse generation, this system needs the peak of Gaussian Pulse to carry message, but with higher order of the derivative, it gets higher number of peaks. In this case, the signal may be covered by the noise, which is difficult to distinguish the message. Accordingly, the second derivative Gaussian Pulse for communication is picked.

The formula of the second derivative of Gaussian pulse is listed below:

$$f(t) = \frac{1}{\sqrt{2\pi\sigma^3}}[1 - \left(\frac{t}{\sigma}\right)^2]e^{-\frac{t^2}{2\sigma^2}} \tag{1}$$

In order to do the Normalization, the formula is changed into the way:

$$= \frac{4\pi}{\alpha^4}(-\alpha^2 + 4\pi t^2)e^{-\frac{2\pi t^2}{\alpha^2}} \tag{2}$$

The parameters are as follows:

Time duration of the pulse: 2ns;Bit rate: 1Mbps;Duty cycle: 0.002;Periodical duration: 1000ns;

In MATLAB:

Sampling frequency: 200hz;σ=0.714

Because of the low duty cycle and long interval between each two pulses, the message can effectively resist the multipath fading.

2.3 Modulation

In the UWB system, target needs to send message to base stations. According to the TDOA system, the set target only needs to send ID message. After modulation, Gaussian Pulse can carry ID message. Comparing four mainly used methods below, and BPM is picked to modulate the pulse.

-PAM/OOK		high BER
-PPM		complicated system & serious SIS interference
-BPSK/BPM	√	better than OOK -about 3dB
-PSM		complicated system

A function to simulate this part is generated, it requires to input two parameters. The digit of the ID is set to be 4 and 6, set the period is 100ns and 1000ns.

[1 1 0 1 1 0] with 1000ns

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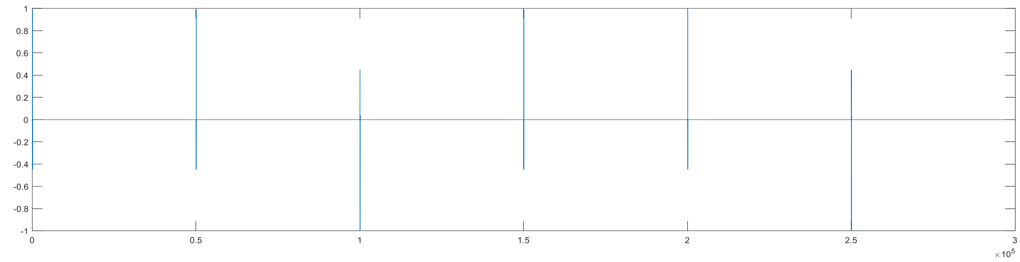

Fig. 1 Simulation of 6 digits ID

2.4 Channel Model

The channel model was contrasted to outline of the design, which includes eight rough institutions of the transmitters and the receivers. IEEE.802.15.4a is close to the real situation when the Gaussian Pulse is transmitting. The specific parameters can be consulted in a form which includes CM1 to CM8. CM1 is selected in this paper as it corresponds to the indoor LOS environment. According to the standard of IEEE 802 Committee and some relative papers, the IEEE.802.15.4a model is mainly composed by three parts. [1][2]

Path Loss and Shadow Fading formular:

$$PL(d) = PL_0 + 10n\,log_{10}(\frac{d}{d_0}) + s \tag{3}$$

Multipath Fading based on S-V model:

$$h_{discer}(t) = \sum_{l=0}^{L}\sum_{k=0}^{K}\beta_{k,l}\exp(j\Phi_{k,l})\delta(t - T_l - \tau_{k,l}) \tag{4}$$

Small scale fading based on Nakagami Distribution:

$$pdf(x) = \frac{2}{\Gamma(m)}(\frac{m}{\Omega})^m x^{2m-1}\,exp(-\frac{m}{\Omega}x^2) \tag{5}$$

Some main parameters used in model:

PL0(one-meter pathloss)=43.9

n(pathloss exponent)=1.79

s (shadow fading) =2.22

Cluster arrival rate(GHz)=0.047

Ray arrival rate(GHz)=1.54,0.15,0.095

Cluster decay factor=22.61

Fig.2 shows the response of generated impulse

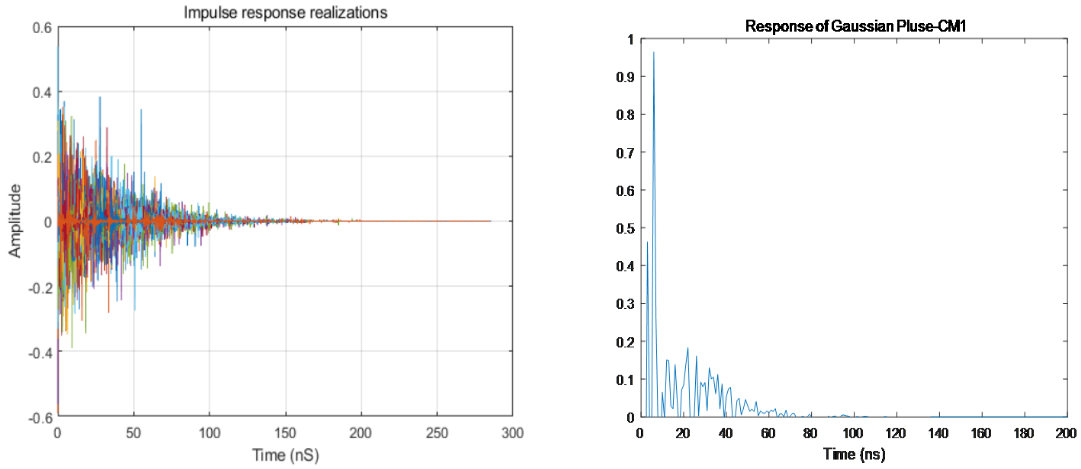

Fig. 2 Response of impulse

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2.5 Range Calculation & Positioning

Next step is to build a physical model to simulate the positioning. First establish a square flat with size of 100m *100m. And the range of the coordinate axis is from 0 to 100m. Then three constant points:[0,0] [100,0] [50,50√3] are set as the base stations. These three points get a regular triangle. The third step is to give a random point as the target.

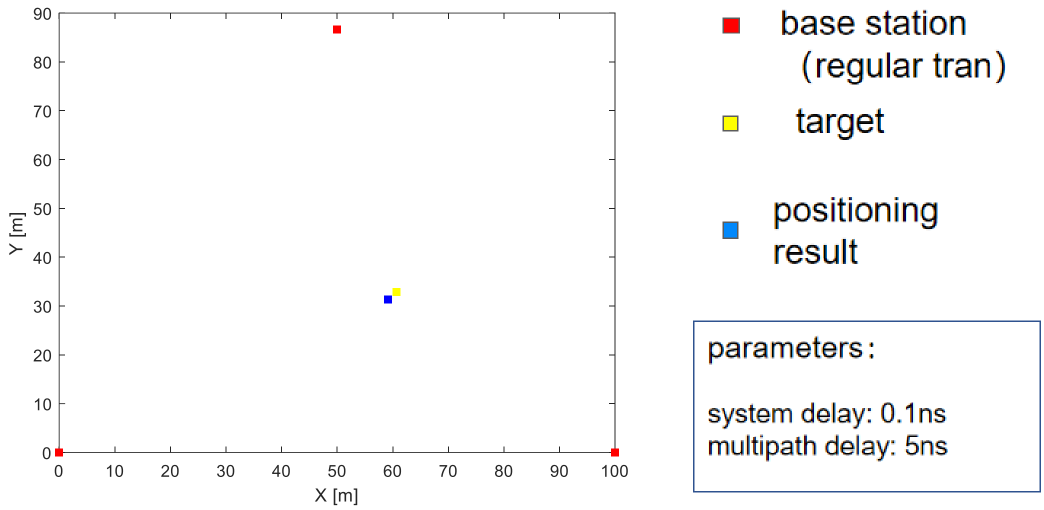

Fig. 3 Creation of a random point as the target

The algorithm used here is TDOA [3], the coordinate of target is set as (X, Y). Then the coordinate of 'antenna i' is (Xi,1 ,Yi,1) and (Xi,2 ,Yi,2). i=1, 2, 3… N. 'N' is the number of the base stations. The time difference for each station is set as Δti. 'c' is the speed of light. In this system the number of stations is 3.

$$\begin{cases} \sqrt{(x-x_{1,1})^2+(y-y_{1,1})^2}-\sqrt{(x-x_{1,2})^2+(y-y_{1,2})^2}=c\widehat{\Delta t}_1 \\ \sqrt{(x-x_{2,1})^2+(y-y_{2,1})^2}-\sqrt{(x-x_{2,2})^2+(y-y_{2,2})^2}=c\widehat{\Delta t}_2 \\ \sqrt{(x-x_{3,1})^2+(y-y_{3,1})^2}-\sqrt{(x-x_{3,2})^2+(y-y_{3,2})^2}=c\widehat{\Delta t}_3 \end{cases} \tag{6}$$

The number of needed equations depends on that of available stations. However, there are always some limitations and errors in real world.

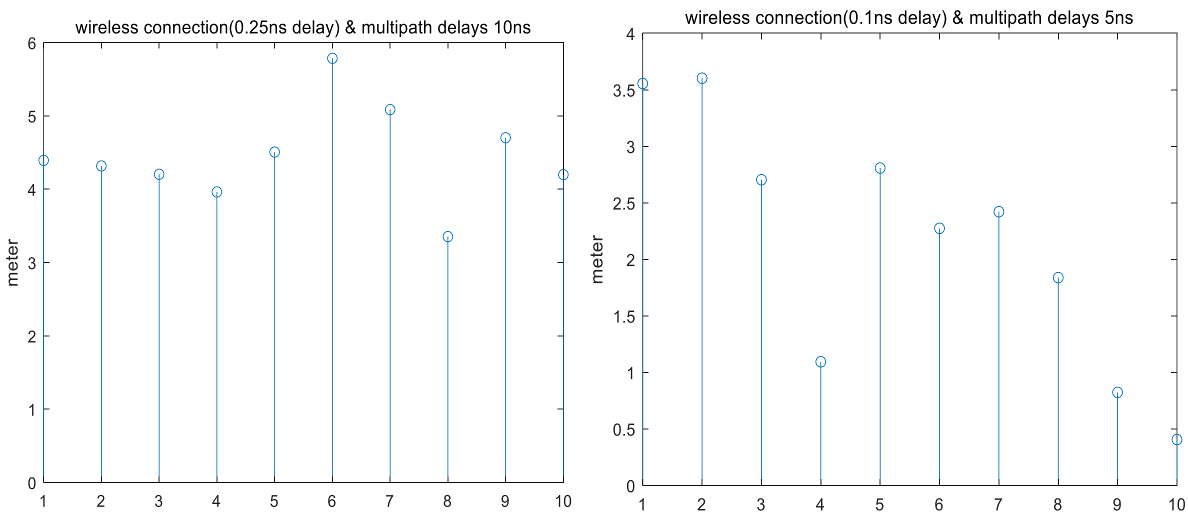

Fig. 4 Positioning errors by continuously positioning

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After these, first calculate the positioning in different situations without AWGN based on TDOA and get the results. In the wire system, the positioning errors were distributed from 0.5m to 2m. In the wireless system, the errors were mostly distributed form 1m to 4m.

Then we add the AWGN (30dB) to the system and repeated the positioning. The errors of the wire connection system with 5ns time delay increased into about 5 meters, and errors of the wireless part increased into about 10 meters.

Obviously, results are not satisfied. In this case, another step is added. Continuously positioning is taken the same target for ten times. Because of the short period, the system can realize it below about 10^-5 seconds. Averaging them and get a new one.

According to results, errors for both two system are lowered. Though it still has some difference compared with the result without AWGN, it is very close to the expectation of the results.

3. Pseudo-lite process and models

The whole simulation process for the pseudo-lite model is mainly divided into seven part, which are given as follows:

3.1 Step1: PRN code generation

The first step is to generate PRN code, which is based on Direct Sequence/Spread-band signal (DS/SS) technology, which considers the compatibility of pseudo-satellite positioning system with widely used GNSS. To use similar type of PRN code used in GNSS system as BPSK modulation is chosen, PRN code rate as 1.023MHz, code length as 1023 and digital sampling rate as 40 times of code rate.

3.2 Step2: Model design

Large-scale fading (path loss and shadow fading):

Both path loss and shadowing are two main large-scale fading that need to consider, and since these fading effects could not cause severe positioning error, small-scale fading is mainly focus on.

Small-scale fading (multipath and doppler effect):

(1) Multipath effect:

The second step is to build a channel mode for pseudo-satellite system. There are two major effects considered: large-scale and small-scale fading. More precisely, path loss and shadow fading belonging to the former one and multipath effect included the later one. As only stationary receiver is discussed, doppler effect is not considered.

It is addressed that large-scale channel fading mainly has influence on the value of the receiving signal, which is not the main part of channel mode. And as it is relatively easy to solve this problem, assume that the gain from transmitter and receiver side plus the demodulation gain could exceed the effect of large-scale channel fading and noise to guarantee that small-scale fading. More precisely, multipath effect is the main fading that needed to be considered.

Furthermore, in order to proof the generalization of anti-multipath algorithm which are expected to be mentioned in following part, a random multipath is used.

(2) Doppler effect:

In this paper, only stationary object is detected, so Doppler effect is no need to consider.

3.3 Step3: Correlation patterns generation

The third step is important to generate a series of correlation patterns. According to PRN codes and BPSK modulation, the correlation patterns of receiving codes and local code are a series of triangle. Most positioning receivers have three correlators: one early code, one late code correlator and one exact code correlator as the intervals between them are half PRN code chip length and the key to get stable positioning result is to let the results of advanced and delay correlators equal, leading to lock on of DLL, simultaneously PLL locks on. It is obvious that the existence of multipaths damages the

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correlation pattern, leading that the locked position of DLL shifts, which means a pseudo-distance error.

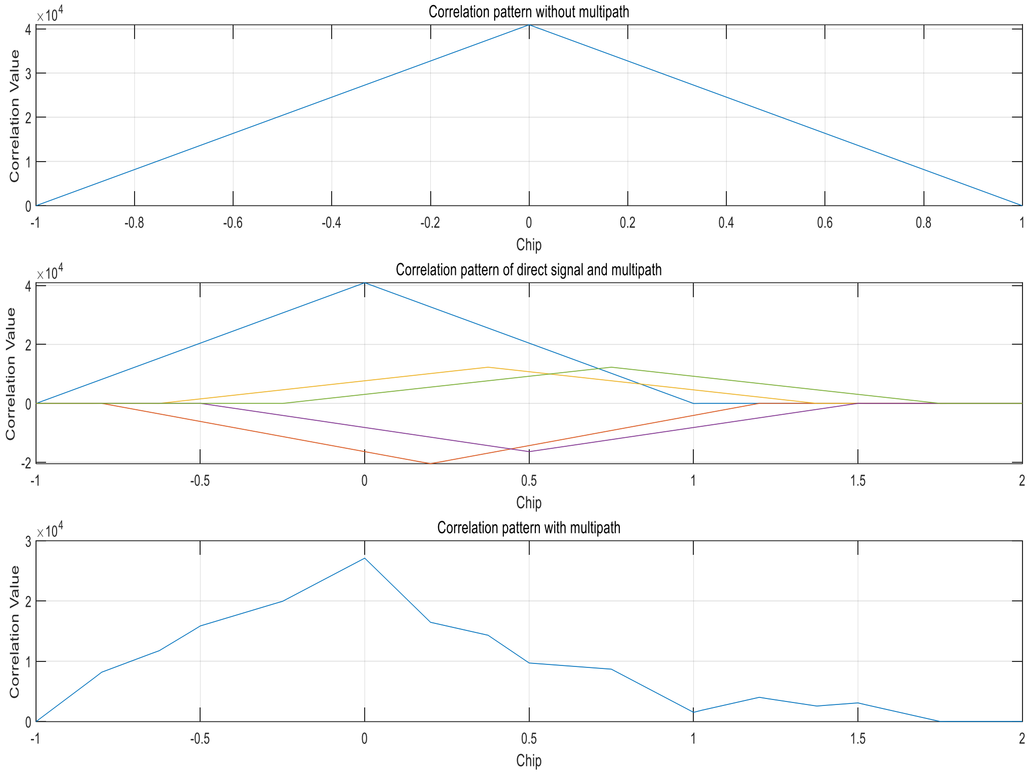

Fig. 5 Correlation pattern with / without multipath or direct signal plus multipath

3.4 Step4: Multipath mitigation algorithm

There are many ways to reduce pseudo-distance error caused by multipath. One of the multipath mitigation techniques is narrow correlator [4], another one is Multipath Estimation Technology (MET) [5]. However, both of them do not consider the error of carrier phase in PLL. Although, MEDLL [6] is an optional approach to this problem, it requires a number of correlators for the estimation, and consumes a lot of hardware resources.

An adaptive filter based multipath mitigation technique [7] is taken. The basic principle is to use this adaptive filter to separate receiving signal with multipath into a series of individual path with designed time delay (0.05 chip length), which means that direct signal and multipaths are divided, and if it subtracts the multipath, the correlation pattern can only be generated from direct signal.

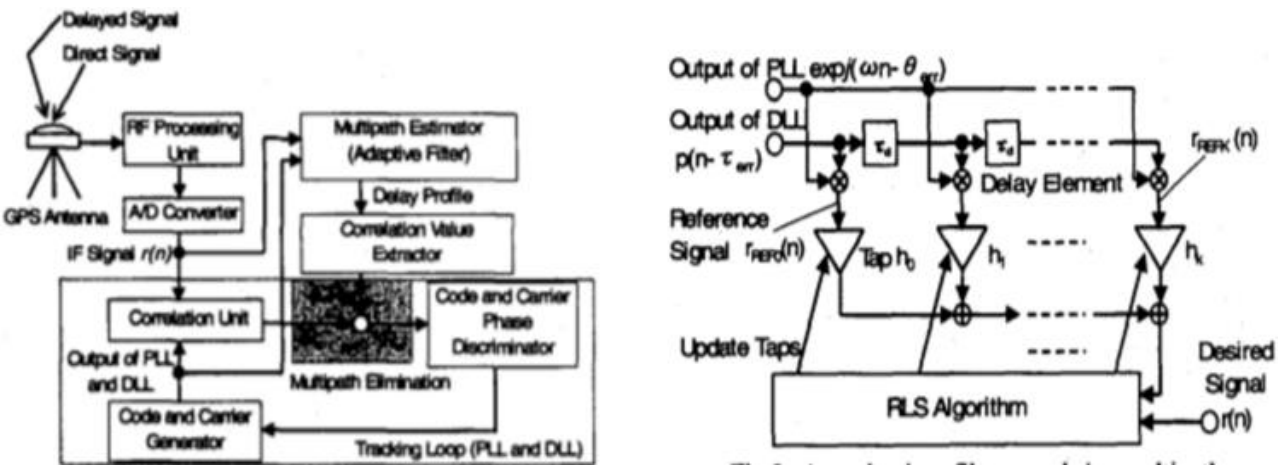

Fig. 6 Main parts of an adaptive anti-multipath algorithm (From Reference [7])

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3.5 Step5: Test and verify for multipath mitigation algorithm

This step is about testing and detailed code and algorithm, the results will be focus here. (Fig.7&8)

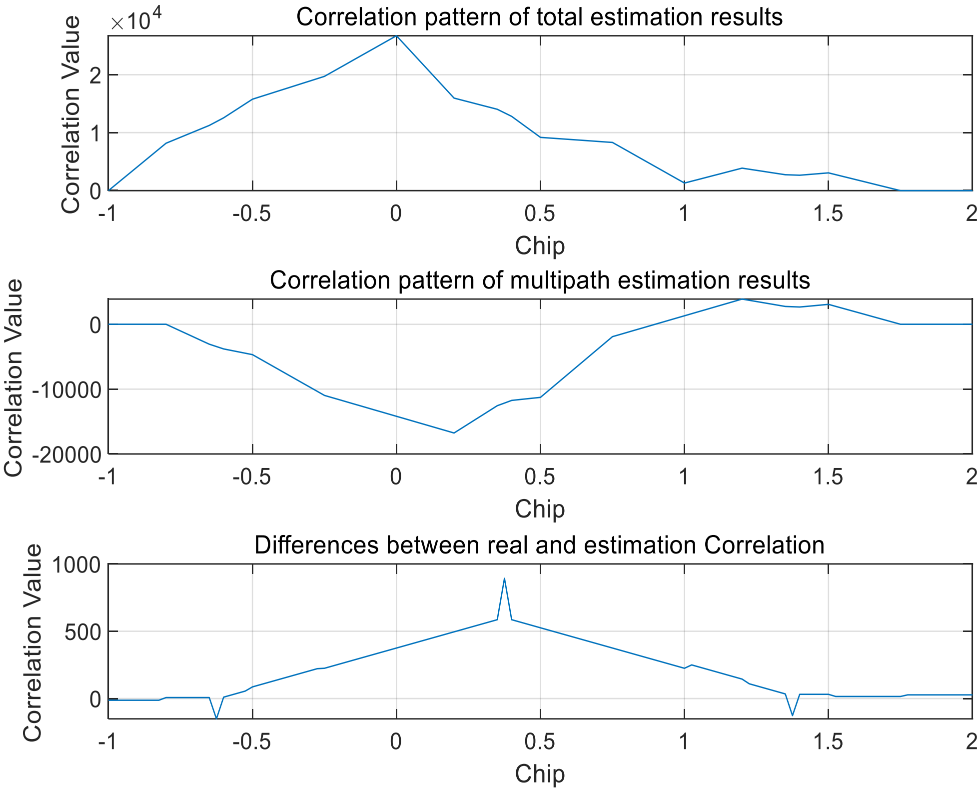

Fig. 7 Correlation pattern and differences of synthetic signal

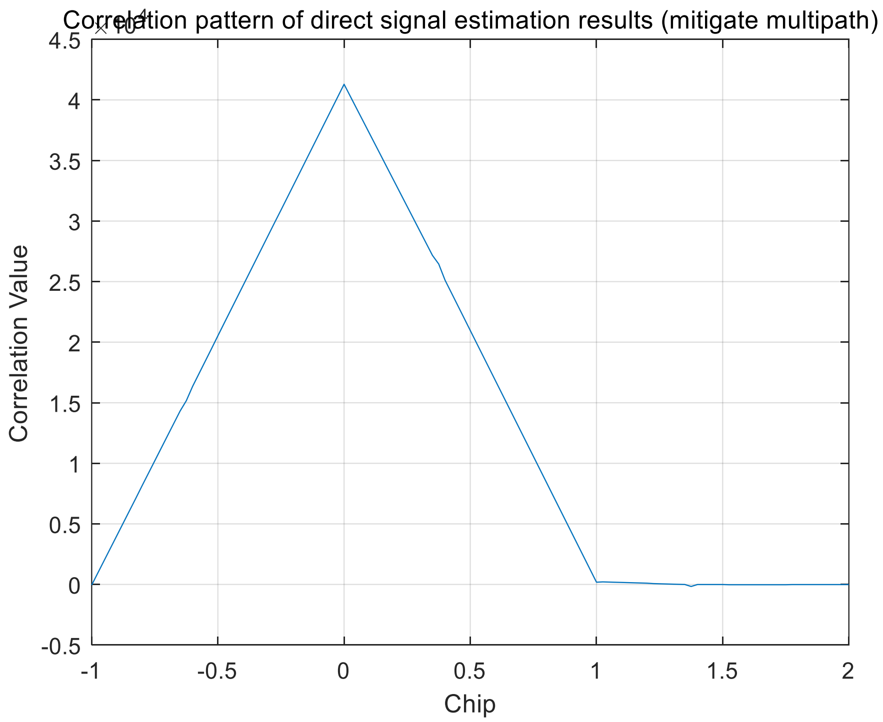

Fig. 8 Correlation pattern after anti-multipath algorithm

3.6 Step6: Comparison of time delay distributions and distance errors

The next step is to use the pseudo-distance from anti-multipath receiver with the ideal one, which is obvious that the pseudo-distance error of multipath become very small, according to further calculation, it's about 1/40 chips, which is about 7m in physical world, which could fit the requirement mentioned in the background of the project. If without that anti-multipath, error will be approximately 1/10 chips, which is about 30m. Results above are just based on the precondition that there is no other significant error effect. If it considers more kinds of error effects, results will not be that great.

3.7 Step7: Design of more pseudo-lite nodes

The final design is that more pseudo-satellite nodes are required in real application. Because there are still some barriers at indoor environment, and not all nodes are LOS for receivers. Therefore, try to add more nodes in the environment to let most positions have enough LOS pseudo-satellite nodes where may need channel estimation algorithm to evaluate the quality of pseudo-satellite nodes and only choose data from LOS nodes.

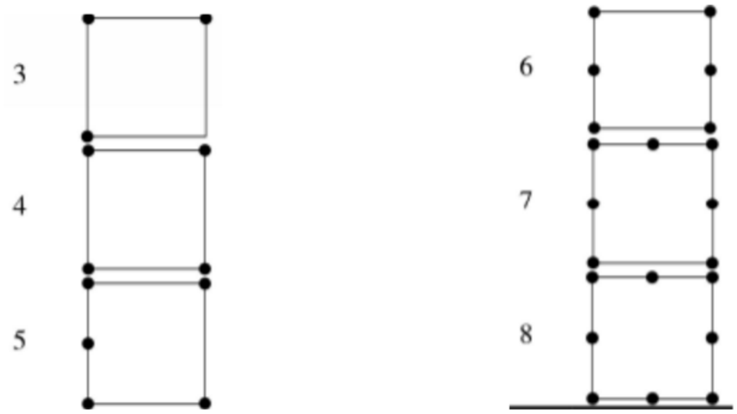

Fig. 9 Design of trying to set more nodes of pseudo-lite

4. Conclusions

According to the whole process of this project, two models for simulating UWB and Pseudo-lite indoor positioning with LOS condition and multipath effect are designed in MATLAB respectively. By following their own designs of process, multipath effect is set to simulate the environment as practical as possible, and different algorithms and filtering solutions are employed. In this case, positioning accuracy and error eliminating results of two simulating systems are produced individually.

For IR-UWB positioning system, it shows a good ability to resist multipath effect, and it can realize the accurate positioning. However, due to the time delay and AWGN there are still errors in the system. In fact, the time delay caused by the connection of base stations has little interference to the result and the error is close to 0.03m. In order to improve the multipath delay and AWGN, the average of multiple results is used.

For pseudo-lite, it is mainly considered about the multipath effect. And an adaptive anti-multipath filter is set to separate and extract direct signal and multipath signals, leading that the result of positioning is improved significantly. However, there are still several other effects causing positioning error, and more practical system may not achieve such accuracy generated in the result of this paper.

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Three writers of this article own the equal contributions to the essay, which means the first author is shared by all of three.

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