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Accurate Spot Positioning Technology for Indoor Hybrid Navigation

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Abstract— **Simple and accurate spot positioning technology is proposed and experiments were carried out at 315 MHz frequency band. The positioning station employs 2 element array antennas. The array antenna radiates two different patterns alternatively. A mobile user detects his/her position by using the transition data of the receiving level from the array antenna. The accurate position is detected when the mobile user crosses the front line of the array antenna. Measured average positioning error was less than 0.7 m even the antenna is attached on the human body.**

Combining proposed positioning algorithm with autonomous positioning technology, positioning error can be improved with keeping low installation cost.

Keywords — **Indoor Positioning; Range Free; Hybrid Navigation**

I. Introduction

Positioning technologies in the indoor area were investigated in many papers [1]. For the indoor positioning system, both accurate positioning capability and low system installation cost are required.

Autonomous positioning technology is applicable for this purpose. The change of the relative position is detected by using a directional sensor such as terrestrial magnetism sensor and a step counter (Fig.1) [2].

Figure 2 shows an experimental result of the autonomous navigation at the underground pavement in the Shinjuku station, Tokyo Japan. PointMan (GyroDRM^{TM} Gyro-Stabilized Dead Reckoning Module, made by Point Research Corporation) is used. Around 50 m positioning error was observed during the 800 m distance walking. This error is due to the terrestrial magnetism tolerance caused by the surrounding metal materials. This directional drift must be corrected by an additional positioning system.

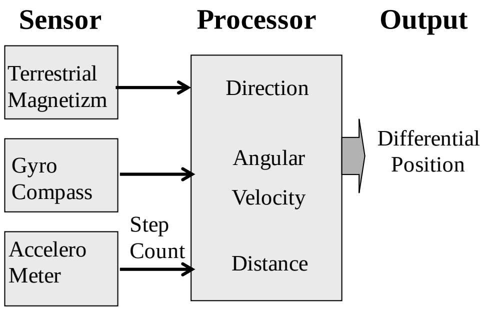


Figure 1 Autonomous Positioning System for Pedestrian

"Hybrid navigation system" (Fig.3), that employs a spot positioning (discrete positioning), technology with the autonomous positioning technology, is the promising technology to improve the accuracy [3]. Absolute location of the user is detected by the spot positioning stations occasionally, and the autonomous positioning interpolates the location of the user which is located between spot positioning stations. Hybrid navigation system enables wide area coverage without increasing the installation cost because not many spot positioning stations are necessary by the aid of the autonomous navigation.

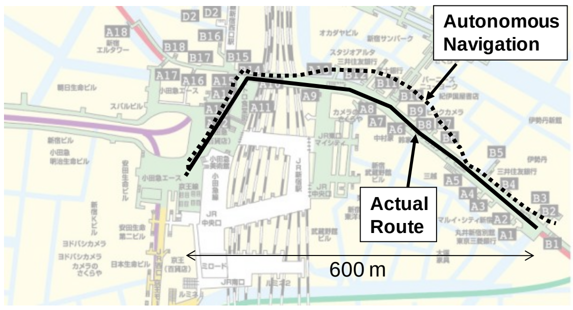


Figure 2 Autonomous Navigation in the Shinjuku Station Underground Pavement

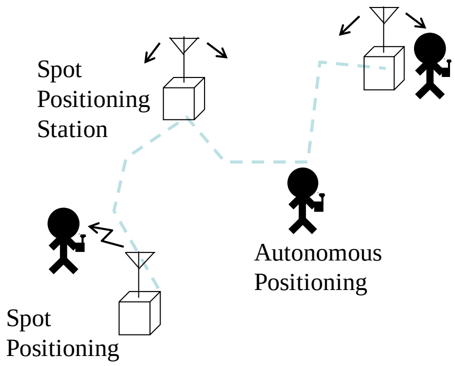


Figure 3 Hybrid Navigation System for Pedestrian

The "spot" positioning is achieved either by range based positioning or range free positioning. Usually, wireless technology is applied to these positioning. Range based positioning, such as triangulation is preferable for the accuracy point of view. However, since at least 3 positioning stations are required for each spot, the system becomes complex and installation cost becomes high.

On the other hand, range free positioning is simple and installation cost is lower [4]. However, accuracy is low because the user receives the same position information wherever he/she is within the coverage of the transmitter. For instance, if the coverage is 10 meters radius, accuracy is also 10 meters.

In this paper, simple and accurate spot positioning is proposed and experiments verified its effectiveness [5].

II. Basic Principle

Figure 4 shows the image of the proposed positioning technology. An array antenna with two radiating elements is employed. The transmitter sends signals using two different antenna radiation patterns, alternately. Radiation pattern A is a pencil beam which is formed by exciting two radiating elements in the same phase. Radiation pattern B has dual peak which is formed by exciting two radiation elements at out of phase (180 degrees).

During the user passes in front of the array antenna, the user terminal measures the receiving levels of the two radiation patterns A and B. Simulated receiving field distributions are shown in Fig. 5. The field distribution of the radiation pattern B gives very narrow dip on the front line of the transmitting array antenna. By using this dip, a time and the user position is detected very precisely when the user crosses the front line.

The receiving level for the radiation pattern A is decreasing along with the distance on the front line of the transmitting array antenna. The distance is estimated using the relationship between the receiving level and the distance.

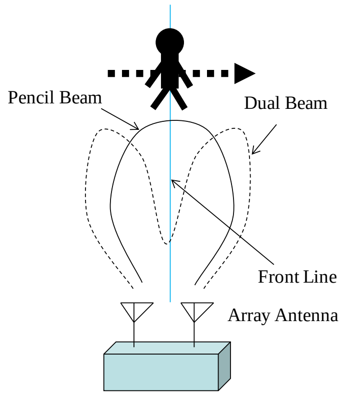
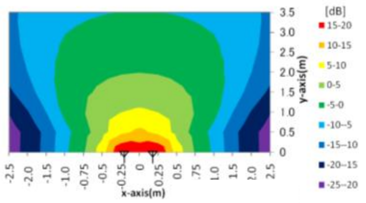
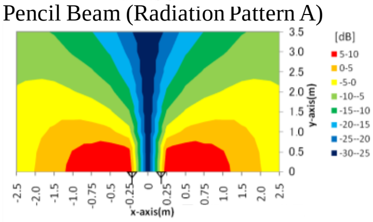


Figure 4 Antenna Patterns of the Transmitter



(a) Pencil Beam (Radiation Pattern A)



(b) Dual Beam (Radiation Pattern B)

Figure 5 Estimated Receiving Level Distribution

Based on the proposed principle, the user location is determined accurately. Although the user position is identified only when the user crosses the front line of the transmitting array antenna, it is enough for the hybrid navigation.

III. Experiments

Experiments were carried out at 315 MHz. Figure 6 shows the experimental system. A network analyzer is used to measure the receiving level. An inverted F type antenna is used for the transmitter and a sleeve antenna is used for user terminal as shown in Fig. 7.

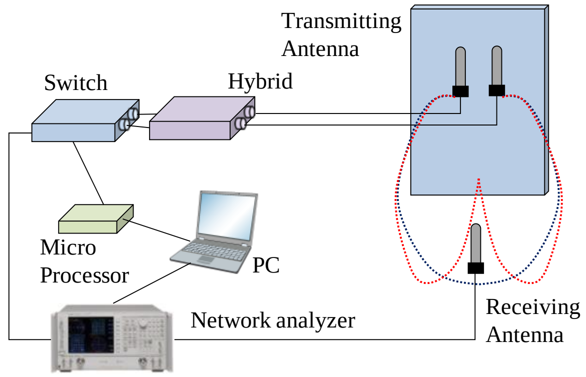
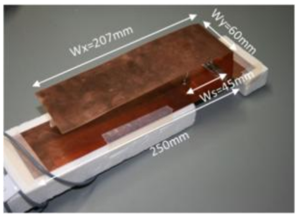


Figure 6 Experimental Spot Positioning System



(a) Transmitting Antenna

(b) Receiving Antenna

Figure 7 3.15 GHz Antennas for Experiments

A. *Experiment in Gym*

Experiments were carried out in the gym in the University of Electro-Communications. Figure 8 shows the experimental site. Figure 9 shows measured receiving level distributions. Figure 9 (c) is a difference of the field distribution in dB between the pencil beam and the dual beam. The timing and the position when the user crosses the front line of the transmitter is accurately identified by detecting the peak level in Fig. 9 (c).

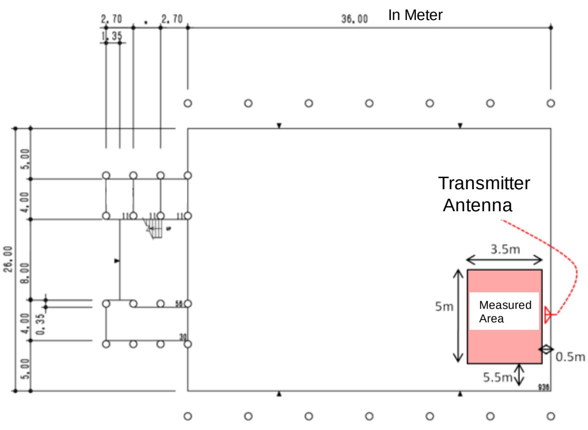
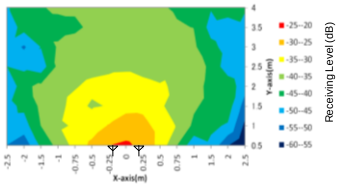


Figure 8 Experimental Environment (Gym)

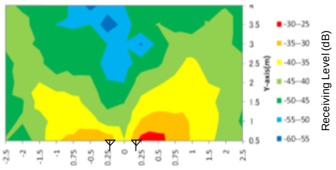
If the pencil beam is applied, the accuracy will be degraded because the receiving level distribution is almost flat around the front line. This is a reason why the dual beam is used.

Distance of the user terminal from the transmitter antenna is estimated using the equation written in Fig. 10.

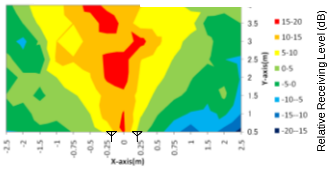
Table 1 shows actual positions, estimated positions and estimation errors when the user passes in front of the transmitter at various distances from 0.5 to 4 m. Maximum estimated error was 0.77 m and the average error was 0.3 m. If pencil beam is applied for estimation, the error may be several meters or more.



(a) Pencil Beam



(b) Dual Beam



(c) Pencil Beam – Dual Beam

Figure 9 Field Distribution in Gym.

Table 1 Estimation Error (Free Space)

Actual Pos.(x,y)	Estimated(x,y)	Error (m)
(0 , 0.5)	(0 , 0.15)	0.35
(0 , 1)	(0 , 1)	0.00
(0 , 1.5)	(0 , 1.7)	0.20
(0 , 2)	(0 , 2.08)	0.08
(0 , 2.5)	(0 , 2.67)	0.17
(0 , 3)	(0.25 , 3.34)	0.43
(0 , 3.5)	(-0.25 , 3.55)	0.25
(0 , 4)	(-0.5 , 3.42)	0.77

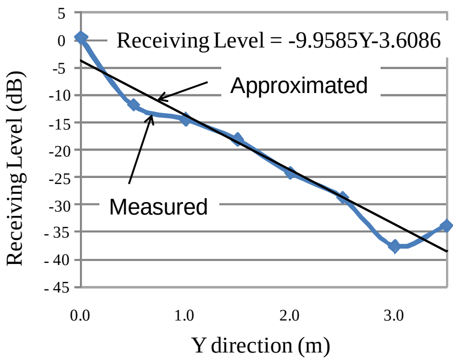


Figure 10 Approximated Receiving Level vs. Distance

B. *Body and Multipath Effects*

Experiments were carried out under the condition that there is no obstacle around the receiving antenna. But a body effect must be taken into consideration for simulating actual environments.

Next experiments were carried out under the condition that the receiving antenna was attached at the waist http://www.isabelconference.com/ad_for_special_issue_wearable_technology.pdf of the user as shown in Fig. 11. In the case of "Position A", the antenna is attached at the right hand side of the person. This corresponds to the LOS (line of sight) condition. For "Position B", the antenna is attached at the left hand side of the person. This corresponds to the NLOS (non line of sight) condition.

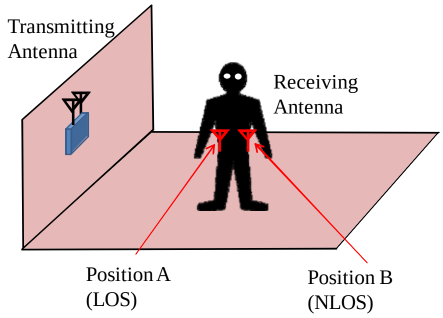
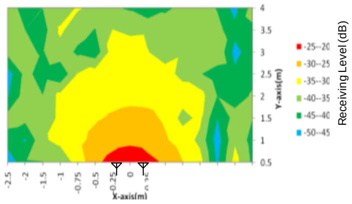
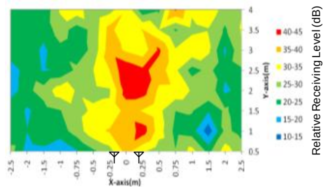


Figure 11 Receiving Antenna Position

Figure 12 and Table 2 show the experimental results for "Position A" (LOS). Field distributions were not deformed comparing with Fig. 9. Maximum and average position errors were 0.87 m and 0.4 m. Accuracy was kept high.



(a) Pencil Beam



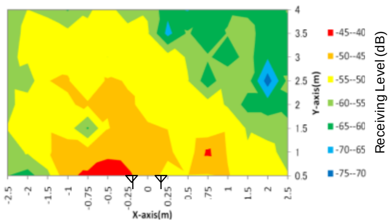
(b) Pencil Beam – Dual Beam

Figure 12 Field Distribution at Position A (LOS)

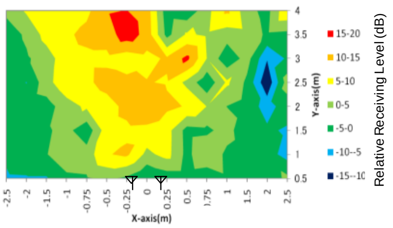
Table 2 Estimation Error (LOS)

Actual Pos.(x,y)	Estimated(x,y)	Error (m)
(0 , 0.5)	(0 , 0.07)	0.43
(0 , 1)	(-0.25 , 0.96)	0.25
(0 , 1.5)	(-0.25 , 1.64)	0.29
(0 , 2)	(0 , 2.14)	0.14
(0 , 2.5)	(0.25 , 2.51)	0.25
(0 , 3)	(-0.5 , 3.02)	0.50
(0 , 3.5)	(-0.25 , 4.33)	0.87
(0 , 4)	(0 , 3.54)	0.46

Figure 13 and Table 3 show the experimental results for "Position B" (NLOS). Field distributions were deformed due to the body effect. Maximum and average errors were 4 m and 1.15 m. Worst error happened in the vicinity of the transmitting antenna (0.5 m distance : Table 3). Excluding the worst point, Maximum and average errors were 1.24 m and 0.7 m, which is satisfactory for the navigation purpose.



(a) Pencil Beam



(b) Pencil Beam – Dual Beam

Figure 13 Field Distribution at Position B (NLOS)

Table 3 Estimation Error (NLOS)

Actiual Pos.(x,y)	Estimated(x,y)	Error (m)
(0 , 0.5)	(2.5 , 3.63)	4.00
(0 , 1)	(-0.25 , 0.15)	0.88
(0 , 1.5)	(-0.25 , 0.97)	0.58
(0 , 2)	(0 , 1.98)	0.02
(0 , 2.5)	(-0.5 , 1.36)	1.24
(0 , 3)	(0.5 , 4.07)	1.18
(0 , 3.5)	(-0.25 , 3.17)	0.41
(0 , 4)	(-0.25 , 4.86)	0.90

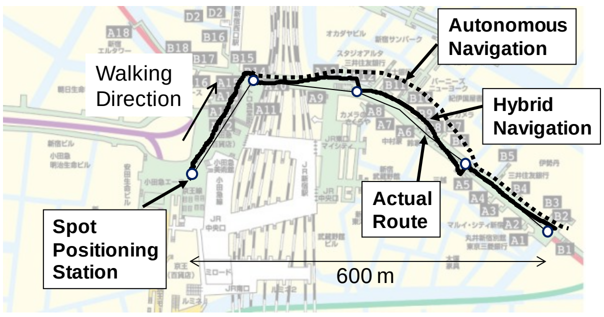


Figure 14 Hybrid Navigation in the Shinjuku Station Underground Pavement

With the proposed spot positioning technology, accuracy of the pedestrian navigation is improved remarkably comparing the autonomous positioning as shown in Fig.14. In this case, the error of the autonomous positioning is corrected every 200m. Maximum error is improved from 50 m to 10 m.

IV. CONCLUSION

A simple and accurate spot positioning system was proposed and investigated experimentally. The positioning station employs 2 element array antennas. The user terminal estimates its location using two different antenna patterns. Experimental frequency is 315 MHz. Average positioning error was 0.3 m in the case that there is no obstacles around the receiving antenna. Whereas, when the receiving antenna was attached on the human body, the average errors were 0.3 m and 0.7 m, at LOS and NOS conditions, respectively. These positioning errors are small enough for human navigation application. If the dual beam antenna were not applied, the error would be several meters or more.

Combining the spot positioning and autonomous positioning technologies, low cost, precise and wide indoor area coverage human navigation service will become realistic.

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