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Position Location using OFDM signal in LCX Linear Cell MIMO System

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***Abstract*—This paper proposes a new scheme of position location for radio terminals using MIMO-OFDM signal. First, this paper describes on a system configuration of LCX linear cell MIMO system and its research issues. Second, to observe channel responses depending on the terminal location, impulse responses are measured in the anechoic chamber. Third, principle of operation for positioning the radio terminals using multiple antennas and its signal processing using OFDM are described. The 2x2 spatial division multiplexing is successfully carried out using 2-port LCX as a transmitting antenna. Time difference of arrival (TDOA) is estimated at receiver by using its channel estimation function. From the experiments, the validity of averaging operation between estimated TDOAs are found to enhance positioning precision.**

***Keywords*—position location, MIMO, LCX, Linear cell, WiFi**

I. Introduction

The demand for broadband wireless communication has increased year by year. In Japan, the data traffic for mobile internet access grows up by more than twice per year. Especially, low connectivity at densely populated are such as large station, large shopping mall, and underground city becomes serious problem. The causes of low connectivity in terms of wireless radio communication technology are considered as a lot of radio dead spots. The Leaky Coaxial Cable (LCX) is widely used for radio communication systems as an antenna in tunnels. Although the LCX was previously used for lower frequency bands, some LCXs have been developed for higher frequency such as 2.4 GHz ISM band [1] and higher band.

In this paper, a new configuration of wireless cell using LCX to establish broadband wireless hot spots is proposed. For this purpose, multiple-input multiple-output (MIMO) technique is applied to LCX.

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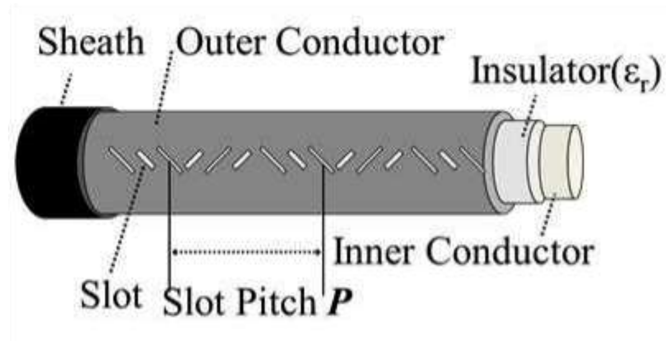

Figure 1. LCX Linear cell MIMO system and its technical issue.

Currently, 8 by 8 MIMO had been standardized in the 3rd Generation Partnership Project (3GPP). However, conventional LCX system requires more than two LCXs to support MIMO. Some experimental studies of this type of MIMO system were reported, e.g., in [2]. We focus on the effective combination of LCX antenna and MIMO technology [3]. The LCX [4] can make relative small cell, but frequency channels can be repeatedly used the other cell. Therefore, the LCX contributes the improvement of spectral efficiency.

Figure 1 shows the configuration of LCX. An LCX has two characteristics as a feeder and an antenna. Radio wave is radiated from slots that are periodically located along the outer conductor in LCX. Elemental waves are interfered with each other, there are some peaks in terms of antenna gain. Typical coupling loss is around 60 dB, typical cell coverage is limited near around cable. Moreover, LCX typically has two feeding ports, one is usually terminated in order to suppress the reflection, the other is used for feeding point. In other word, LCX has naturally capability of 2 by 2 MIMO transmitting and receiving antenna.

The proposed cell configuration using the combination of LCX linear cell and MIMO, and describes its research issues. Position location is one of required function to perform seamless handover among cells. The terminal position information in linear cell is required. Rest of this paper is organized as follows. Section II describes on the LCX linear cell MIMO system and its challenging issues. Section III describes on the experiment to obtain specific channel response depending on mobile terminal position. Section IV describes on precision evaluation on computer. This story is summarized in section V.

II. LCX Linear cell MIMO system

Figure 2 shows an LCX linear cell MIMO system. An LCX plays role of antenna and feeder, and it makes radio coverage at area along cable. This type of cell is called the Liner cell. Base station equips modulator and demodulator and LCX is connected.

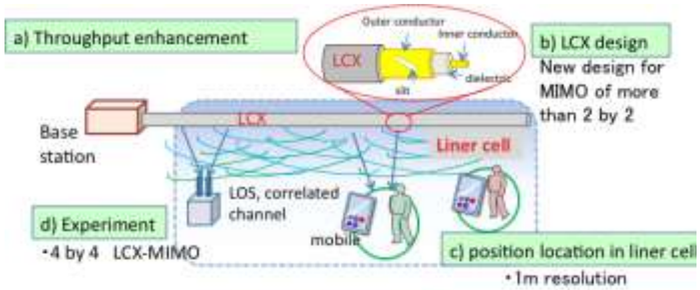

Figure 2. LCX Linear cell MIMO system and its technical issue.

In our project, four research issues are focused on. a) throughput enhancement, b) LCX design, c) position location, and d) experiment.

In a), LCX typically makes LOS path for wireless communication, and spatial streams go through path with difference length. Technical solutions are required to combat correlated MIMO channel. In b), new design is required in order to increase the number of spatial streams more than two. In c), position location is required to perform handover seamlessly [5-8]. The d) means the feasibility inspection for more than two spatial streams multiplexing transmission.

III. Experiment

This section describes on experiment. The purpose of the experiment is to measure the channel response between mobile terminal and LCX. Two omni-directional antennas are simulated as a mobile terminal that equips multiple antennas. All experiments are carried out in anechoic chamber.

A. *Setup*

Figure 3 shows the schematic view of measurement. The LCX is horizontally located in x-axis. Figure 4 shows the view in the anechoic chamber. The distance between center of LCX and omni-directional antennas is set to be 1.5 m.

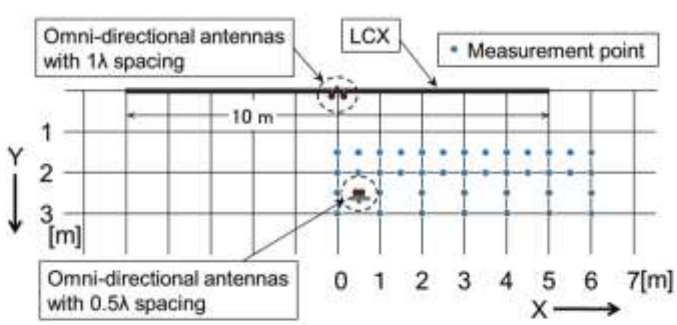

Figure 3. LCX Linear cell MIMO system and its technical issue.

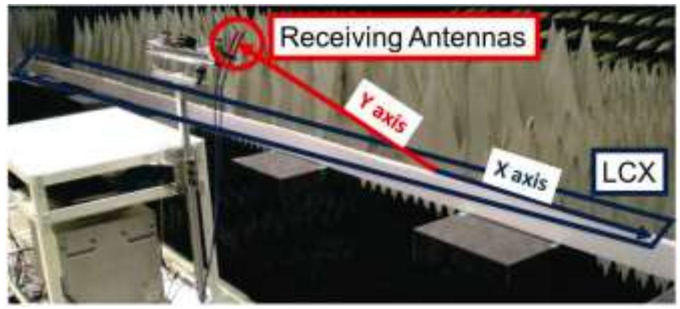

Figure 4. View in the anehoic chamber

B. *Parameters*

Table I shows the experimental parameters. Four ports network analyzer is used for channel estimation between mobile terminal and LCX. Since the radio coverage is almost symmetry to x-axis centered at origin, measurement for left area can be omitted.

TABLE I. EXPERIMENTAL PARAMETERS

Center frequency [GHz]	3.25
Bandwidth [MHz]	500
Resolution BW [MHz]	1.25
Length of LCX [m]	10
Distance between MT and LCX [m]	1.5

C. *Results*

Figure 5 and 6 show the experimental results in cases of terminal locations are (1, 1.5) and (2, 1.5). Impulse response can be obtained from measured frequency response by using IFFT operation. You can see that direct paths are clearly observed. The number of sweep is one, responses are not averaged.

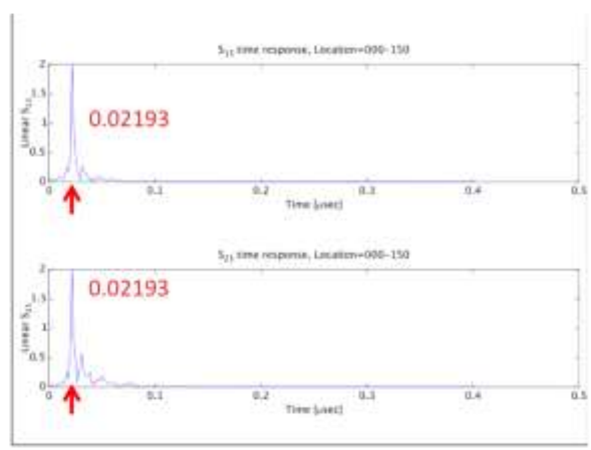

Figure 5. Measured impulse resoponse (x,y)=(0,1.5).

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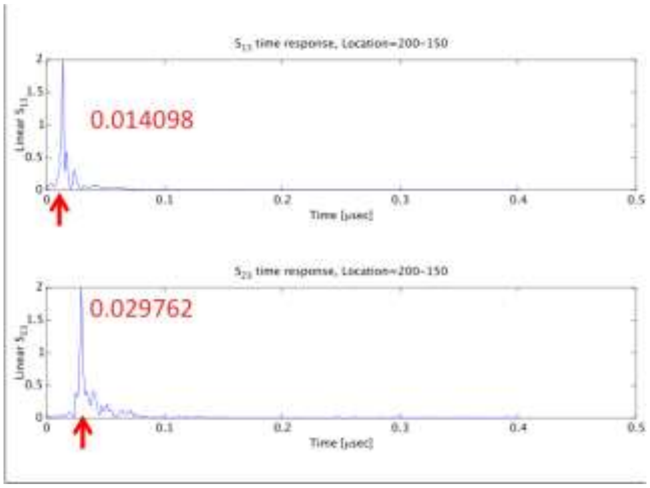

Figure 6. Measured impulse resoponse (x,y)=(2,1.5).

IV. System evaluation

This section describes on location precision evaluation. Evaluation is carried out by using computer. Channel response data obtained in the experiments are used in this analysis. Since the bandwidth of measurement is 500 [MHz], time resolution is equivalent to 2 [nsec].

A. Configuration

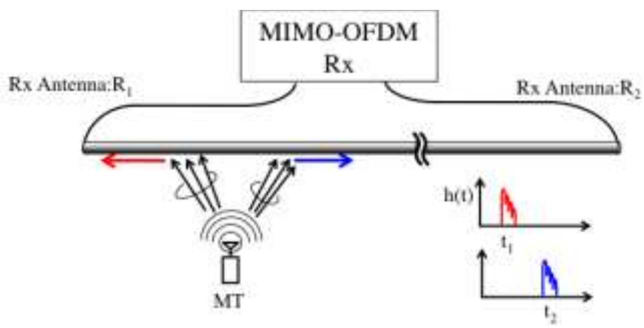

Figure 7. Principle of operation for positioning (uplink 1 by 2 type).

Figure 7 shows the principle of operation of positioning. OFDM signal with pilot sequence is transmitted from MT. Delay time of each signal received at R1 and R2 are estimated by using channel. The estimated position at x-axis can be calculated from TDOA[9,10] as, $2x/v = t_1 - t_2$, where v is group velocity of RF signal in LCX. Channel response is easily estimated by using pilot sequence. For instance in WiFi [11] system, Long Training Sequence (LTF) is used.

Figure 8 shows configuration of receiver. Received two RF signals are independently processed. After the symbol synchronization, FFT is carried out. Frequency domain equalization is performed is employed in many wireless systems using OFDM signal. After the channel estimation, delay time is estimated using phase response, because the slope of phase response is equivalent of delay time of its channel. This method can estimate delay time and their difference

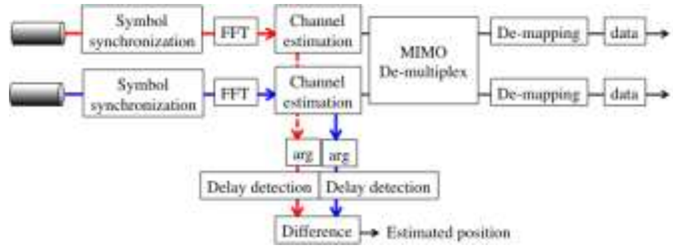

Figure 8. Receiver configuration[12].

B. Parameter

Table II shows simulation parameters for positioning precision evaluation using computer. An OFDM signal is assumed as transmitting signal [10,11].

TABLE II. SIMULATION PARAMETERS[13]

Channel Bandwidth [MHz]	500
Tx signal bandwidth [MHz]	20
FFT size	64
Channel estimation sequence	LTF
Subcarrier bandwidth [kHz]	315

C. Results

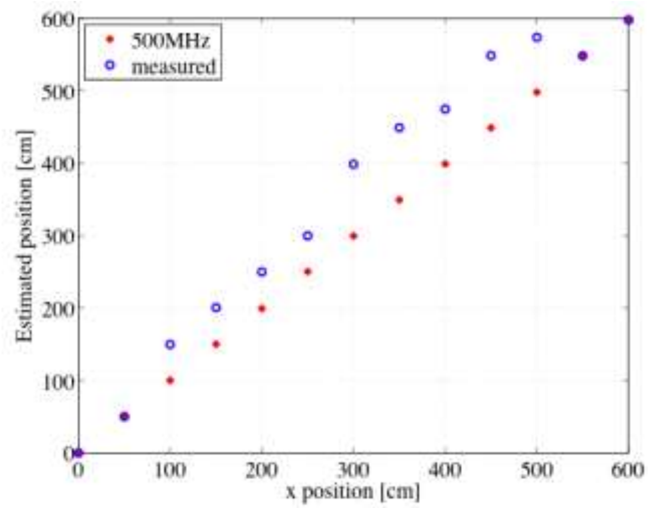

Figure 9. Relasionship between MT position and estimated position.

Figure 9 shows relationship between MT position and estimated position. Error between ideally estimated position and estimated position using measured response. At most 1[m] resolution can be achieved. Since this analysis does not include additional noise, it is considered that additional noise deteriorates the precision. Some solutions are required to suppress noise affection.

V. Summary

This paper described on an LCX liner cell MIMO system. Proposed system combines LCX liner cell and MIMO technology. Research issues are summarized. In this system, position location of radio terminals is one of required function to perform seamless handover among cells. To observe channel responses depending on the terminal location, impulse responses are measured in the anechoic chamber. Finally, principle of operation for positioning of radio terminals using multiple antenna, 2-port LCX and signal processing using OFDM signal are described. As a result of experiment, about 1 [m] precision is obtained. Since analysis assumes the channel has no additive noise, some technical solutions to combat noise and fading are required to real time tracking for moving terminals.

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References

[1] F. Suzuki, A. Niwa, K. Takano, "Thin Leaky Coaxial Cable LCX- 5D," IEICE General Conference 2012, B-1-156, March 2012.

[2] J. Medbo, A. Nilsson, "Leaky Coaxial Cable MIMO Performance in an Indoor Office Environment," IEEE 23rd International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2012), pp. 2061–2066, Sep. 2012.

[3] S. Tsukamoto, S. Ano, T. Maeda, S. Sonobe, H. Ban, K. Kobayashi, "A Feasible Study of 2×2 MIMO System with Single Leaky Coaxial Cable," IEICE General Conference 2013, B-1-220, March 2013.

[4] J. H. Wang; K. K. Mei, "Theory and analysis of leaky coaxial cables with periodic slots," IEEE Transactions on Antennas and Propaga- tion, vol.49, no.12, pp.1723–1732, Dec 2001.

[5] Samer S. Saab, Zahi S. Nakad," A Standalone RFID Indoor Positioning System Using Passive Tags, " IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, vol.58, no.5, pp.1961-1970, May. 2011.

[6] Ali Asghar Nazari Shirehjini, Abdulsalam Yassine, Shervin Shirmohammadi," An RFID-Based Position and Orientation Measurement System for Mobile Objects in Intelligent Environments, " IEEE TRANSACTION ON INSTRUMENTATION AND MEASUREMENT, vol.61, no.6, pp.1664-1675, Jun. 2012.

[7] Angus F. C. Errington, Brian L. F. Daku, Arnfinn F. Prugger,"Initial Position Estimation Using RFID Tags: A Least-Squares Approach, "IEEE TRANSACTION ON INSTRUMENTATION AND MEASUREMENT, vol.59, no.11, pp.2863-2869, Nov. 2010.

[8] Hao Ni, Guangliang Ren, Yilin Chang," A TDOA Location Scheme in OFDM Based WMANs, "IEEE TRANSACTIONS ON CONSUMER ELECTRONICS, vol.54, no.3, pp.1017-1021, Aug. 2008.

[9] Nishikawa K., Higashino T, Tsukamoto K, Komaki S,"Two dimentional position detection method using bi-directional leaky coaxial cable based on TDOA, "2009 IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, pp.2167-2170.

[10] Shiranaga H, Ogawa S, " Positioning Algorithm, " IEICE Technical Report, ITS2008-2, Japan, vol.108, no.42, pp.9-14, May 2008.

[11] IEEE, IEEE Std 802.11-2007:Part11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Orthogonal frequency division multiplexing (OFDM) PHY specification for the 5 GHz band, 2007.

[12] Matsuyama T, Higashino T, Okada M, Tsukamoto K, Komaki S, " An Error Evaluation of Position Detection using OFDM Signal and LCX, " ICESIT2013 vol.1, no.1, pp49-54, 14 Jan. 2013

[13] Rohde & Schwarz," 802.11ac Technology Introduction, h White Paper, 1MA192, pp5-9, Mar. 2012

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