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A new position detection method using leaky coaxial cable

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Abstract: Position detection services tend to be important in ubiquitous wireless communication systems. A new position detection method which utilizes an LCX (Leaky CoaXial cable) is proposed. Proposed method is based on a TOA (time of arrival) of both direct wave and reflected wave from the end of LCX. Position detection error is experimentally investigated.

Keywords: LCX, position detection, TOA

Classification: Microwave and millimeter wave devices, circuits, and systems

References

[1] J. Kwon, B. Dundar, and P. Varaiya, "Hybrid algorithm for indoor positioning using wireless LAN," *VTC2004-Fall*, vol. 7, pp. 4625–4629, Sept. 2004.

[2] M. Kawabata, M. Aso, T. Saikawa, and T. Hattori, "Performance evaluation of TDOA system based on the maximum Likelihood location estimation in cellular system," *IEICE Trans. Commun. (Japanese Edition)*, vol. J87-B, no. 7, pp. 285–291, Feb. 2004.

[3] M. Takashima, D. Zhao, K. Yanagihara, K. Fukui, S. Fukunaga, S. Hara, and K. Kitayama, "Location estimation using received signal power and maximum likelihood estimation method in wireless sensor network," *IEICE Trans. Commun. (Japanese Edition)*, vol. J89-B, no. 5, pp. 742–750, May 2006.

[4] K. Inomata and T. Hirai, "On measuring the position of target for wide-area perimeter surveillance sensor with leaky coaxial cables," *IEICE Technical Report*, vol. 105, no. 618, SANE2005-101, pp. 29–34, Feb. 2006.

[5] K. Inomata, T. Hirai, K. Sumi, K. Tanaka, H. Yamada, and Y. Yamaguchi, "A fundamental study of two-dimensional targets detection technique with leaky coaxial cables," *IEICE Technical Report*, vol. 106, no. 329, SANE2006-100, pp. 13–18, Oct. 2006.

[6] J. H. Wang and K. K. Mei, "Theory and analysis of leaky coaxial cables with periodic slots," *IEEE Trans. Antennas Propagat.*, vol. 49, pp. 1723–1732, Dec. 2001.

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1 Introduction

Recently, the demand on position detection system using IEEE802.11 WLAN (Wireless Local Area Network) [1] and cellular phone [2] have been appeared. Car navigation system and 3 G cellular phone use GPS(Global Positioning System) for position detection. However, it is impossible to use GPS underground because GPS signal cannot be received due to obstacles. Therefore, many position detection methods to use at narrow area have been proposed [3, 4, 5]. A method in [3] is a method using wireless sensor nodes. At the underground, the LCX(Leaky CoaXial cable) is considered as a preferable infrastructure, because LCX has already been constructed in the underground shopping center. Another position detection methods [4, 5] use LCX. In [4], LCX performs as an intruder sensor by using two parallel LCXs are located. But it cannot detect two-dimensional position. A method in [5] can detect two-dimensional position. But two kinds of RF-band and two LCXs are required.

In this letter, a new position detection method using one kind of RF-band and one LCX is proposed. Proposed method utilizes two TOA (time of arrival) parameters which are direct wave from the feeding point and reflected wave from the end of LCX. Two-dimensional position could be estimated from two propagation delay time.

2 Proposed method

2.1 Radiation characteristic of LCX

Fig. 1 (a) shows configuration of LCX and its directivity. Radio signal is radiated from slots which are periodically located along the LCX axis. A set of periodical slot consists of sub slots. There are set of three slots that tilt at the same direction. Another set of three slots tilt another direction. Each set of slots is adjacent and all slot are align. The time of radiation from each slot is delayed according to the slot position. It results from the constructive and destructive interference between multiple waves reaching wireless terminal from the feeding point of the LCX. As a result, radiation angle, θ_m is given by [6]

$$\theta_m = \sin^{-1}\left(\sqrt{\varepsilon_r} + \frac{m\lambda_{RF}}{P}\right), \qquad (m = -1, -2, \cdots) \tag{1}$$

where m is an order mode of LCX, ε_r is relative permittivity of the insulator in LCX, λ_{RF}[m] is wavelength of the electric wave, and P[m] is an interval of the slot. In general, radiation field is most strong in case of $m = -1$.

2.2 Principle of position detection

Fig. 1 (b) shows a diagram of the proposed position detection method. Proposed method utilizes an LCX and one RF-band. It enables to two-dimensional positioning by using two TOA parameters. At the wireless terminal, direct wave is received through LOS(Line Of Sight) path which is constructed by LCX transmission line and free space with their lengths are A[m] and B[m],

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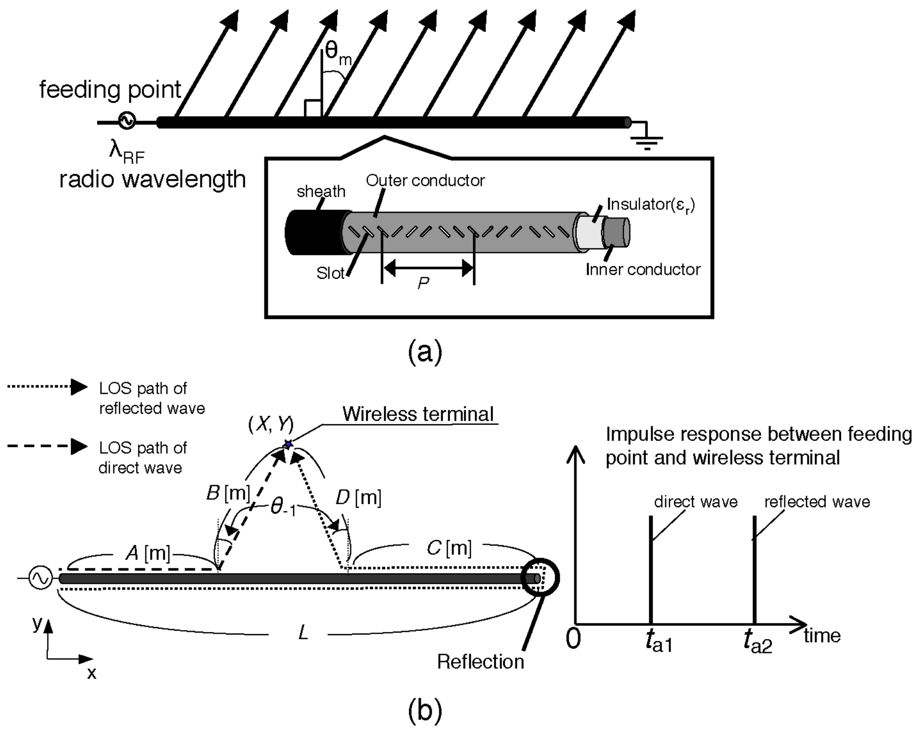

Fig. 1. (a) Configuration of LCX and radiation characteristics and (b) Principle of position detection

respectively. Total propagation delay, t_{a1} can be approximated as

$$t_{a1} \simeq \frac{A}{v} + \frac{B}{c}, \tag{2}$$

where v and c are propagation velocity in LCX and free space, respectively. Proposed method makes transmitting radio signal reflection at the end of LCX on purpose. Radio reflection can be achieved by not getting on termination at the end of LCX. Reflected wave is received through another LOS path which is constructed by LCX transmission line and free space with their lengths are $L+C$[m] and D[m], respectively. Total propagation time, t_{a2} can be approximated as

$$t_{a2} \simeq \frac{L+C}{v} + \frac{D}{c}. \tag{3}$$

As shown in Fig. 1 (b), the origin of coordinates is set the feeding point of LCX. The x-axis denotes longitudinal direction, and the y-axis denotes radial direction. The position of wireless terminal is set to (X, Y). A, B, C, and D can be represented by using the position (X, Y) as

$$A = X - Y\tan\theta_{-1}, \tag{4}$$

$$B = D = \frac{Y}{\cos\theta_{-1}}, \tag{5}$$

$$C = L - X - Y\tan\theta_{-1}. \tag{6}$$

Assigning Eq. (4)–(6) to Eq. (2), (3), estimated position $(X, Y) = (\tilde{x}, \tilde{y})$ can

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Table I. Characteristic of LCX and omnidirectional antenna

LCX	Transmission loss@2.4 GHz	0.78 [dB/m]
	Coupling loss@2.4 GHz	64.3 [dB]
	VSWR@2.4 GHz	≤ 1.25
	Interval of slot (P)	0.24 [m]
	Group velocity (v)	2.63×10^8 [m/s]
	Radiation angle (θ_{-1})	39 [degree]
Omnidirectional antenna	Frequency band	1.9∼2.4 [GHz]
	VSWR@2.4 GHz	≤ 1.3009
	Antenna gain@2.4 GHz	2.6 [dBi]
Velocity of the light (c)		3.0×10^8 [m/s]

be derived

$$\left\{ \begin{array}{rcl} \tilde{x} & = & \left\{ \frac{2L}{v} - (t_{a2} - t_{a1}) \right\} \frac{v}{2} \\ \tilde{y} & = & \left\{ \frac{2L}{v} - (t_{a1} + t_{a2}) \right\} \xi(v, \theta_{-1}) \\ \xi(v, \theta_{-1}) & = & \left\{ 2 \left(\frac{\tan\theta_{-1}}{v} - \frac{1}{c\cos\theta_{-1}} \right) \right\}^{-1} \end{array} \right. . \tag{7}$$

In this letter, position detection error in two-dimensional space, e is defined as

$$e = \sqrt{(X - \tilde{x})^2 + (Y - \tilde{y})^2}. \tag{8}$$

In addition, position detection error of direction x, e_x and position detection error of direction y, e_y are defined as

$$e_x = \sqrt{(X - \tilde{x})^2}, \tag{9}$$

$$e_y = \sqrt{(Y - \tilde{y})^2}. \tag{10}$$

3 Experiment and discussion

Table I shows the characteristics of antennas used in the experiment. LCX and omnidirectional antenna was used as a transmission antenna and a receiving antenna, respectively. The LCX length is about 5 m. The height of the both antenna was 1.4 m.

Fig. 2 (a) shows block diagram of the experiment system. Since directivity of antenna of mobile terminals is omnidirectional, this experiment uses omnidirectional antenna as a wireless terminal. Port 1 of network analyzer is connected to the feeding point of LCX, and Port 2 is connected to the omnidirectional antenna. In this experiment, band-limited rectangle impulse of electric wave are transmitted, with its frequency and bandwidth of 2.4 GHz and 1 GHz, respectively. These electric wave are transmitted from Port 1, and then electric wave is received by network analyzer in frequency domain through Port 2. Next, we compute the inverse Fourier transform of the frequency domain response to get time domain response.

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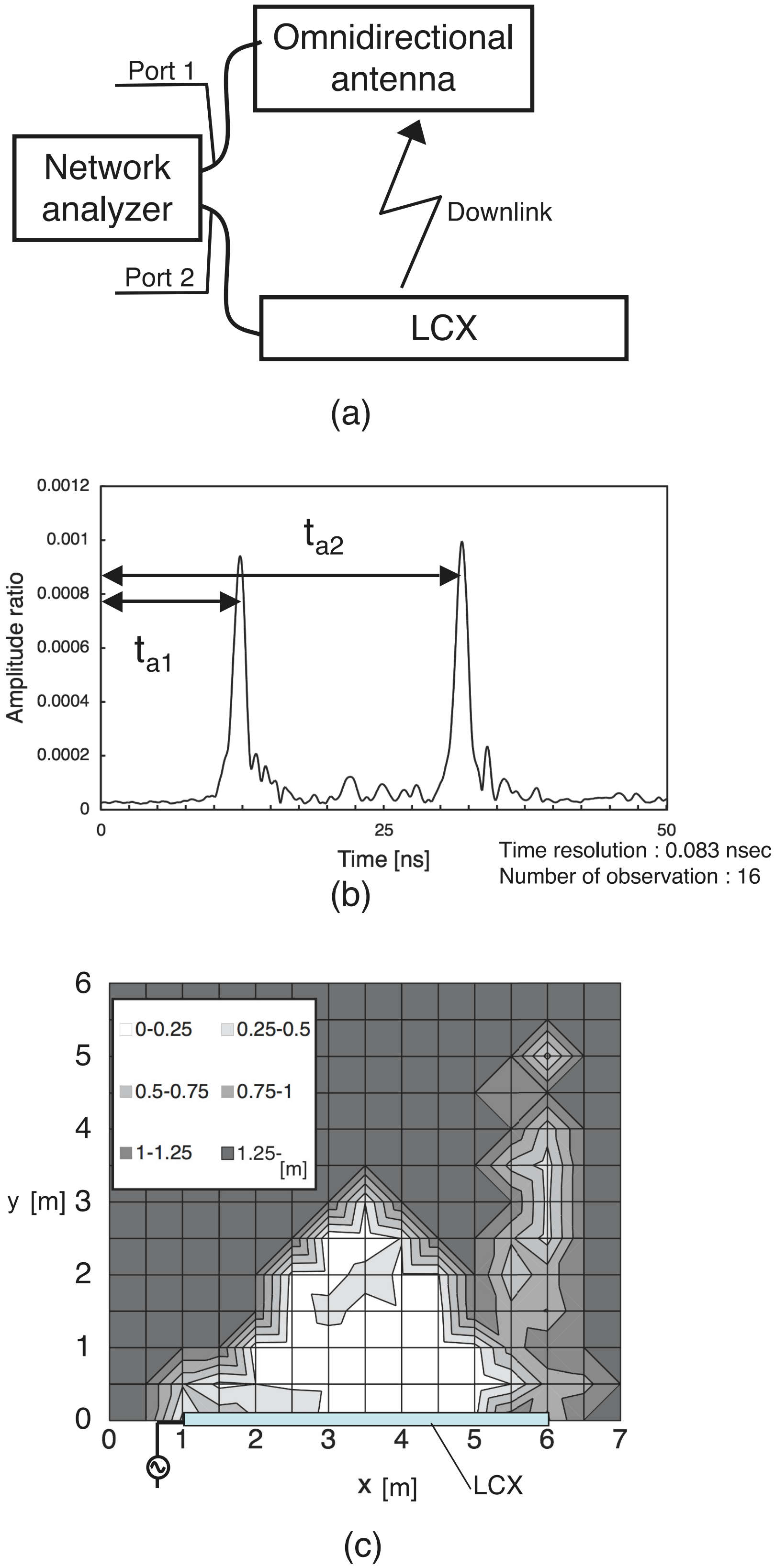

Fig. 2. (a) Block diagram of the experiment system, (b) A measured impulse response and (c) Position detection error

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Fig. 2 (b) shows measured impulse response between the feeding point and omnidirectional antenna. Amplitude ratio mean the value of (received power)/(input power). In Fig. 2 (b), the signal level of reflected wave higher than that of direct wave. Signal level of First peak is −30.26 dB and of second peak is −30.02 dB. The difference of two peaks is 0.24 dB. But this difference is occurred by nonuniform gain of omnidirectional antenna, there is no essential influence for the proposed method. Amplitude ratio represents a linear value of downlink from LCX to omnidirectional antenna. Both of direct wave and reflected wave are clearly observed.

Fig. 2 (c) shows that two-dimensional position detection error e. In the area where the direct wave and reflected wave overlap, position detection error achieves less than 0.25 m. Position detection error of the area where is far from LCX is wrong, because direct wave and/or reflected wave cannot be measured.

Time resolution of the omnidirectional antenna is considered as an important parameter to decide an accuracy for positioning. In the actual situation, measured TOA parameters have error, and it degrades accuracy. The coefficients of both $v/2$ and $\xi(v, \theta_{-1})$ can be considered as a sensitivities to resultant spatial resolution for positioning. In addition, the ratio defined as $v/2\xi(v, \theta_{-1}) \simeq 0.32$ stands for a difference of sensitivities between e_x and e_y. It is found that there is about 3 times sensitivity difference. Assume that $v/2$ and $\xi(v, \theta_{-1})$ have equality, both sensitivity of position detection of direction x and y are equal. The resolution for accuracy reduction due to the multipath components which are generated in the free space propagation at the far from LCX is considered as a farther study.

4 Conclusion

A new position detection method which utilizes an LCX and one RF-band is proposed and its accuracy is experimentally investigated. Proposed position detection is based on two TOA parameters which are one the direct wave and reflected wave from end of LCX. When the signal for the detection are transmitted by downlink, proposed method can detect multiple wireless terminal, because each wireless terminal received electric wave which radiated from LCX and calculates position in the terminal. When the signal for the detection are transmitted by uplink, since wireless LAN terminals use CDMA for transmission method, multiple terminals are recognized and are detected about position to use identification code. Unfortunately, this experiment cannot distinguish multiple terminals, beacuse terminal isn't distinguished from another terminal.

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