Wideband CTL cell to measure operating range of UHF RFID

Jaehoon Yun[✉], Yongchae Jung, David R. Novotny and Jeffrey R. Guerrieri

A wideband coupled transmission line (CTL) cell to measure the operating range of an UHF RFID (ORUR) is presented. Also, an ORUR test system is proposed to increase the isolation to more than 55 dB. It is shown that the ORUR measured by this proposed cell agrees well with the measured data using a fully anechoic chamber.

Introduction: Tranverse electro-magnetic (TEM) cells can be divided into two kinds, a single waveguide and a double waveguide. The double waveguide has input and output ports on opposite sides of the cell, such as the symmetric TEM cell [1] and the single coupled transmission line (SCTL) cell [2]. These models are restricted in frequency range up to the first resonant frequency. The single waveguide, such as the GTEM cell [3] and the double polarisation cell [4], has more wideband characteristics. Among the double waveguides, the SCTL cell is useful for measuring backscattering because it has two input and output ports with the same polarisation on one side as shown in Fig 1*a*. The cell is a useful facility for testing the operating range of an UHF RFID (ORUR), especially as its reader has two separated input and output antennas (bistatic). However, this model is still restricted in frequency range up to the first resonant frequency and is limited by the isolation between the input port (Tx) and the output port (Rx). To extend the frequency range, we propose a wideband coupled transmission line (WCTL) cell as shown in Fig. 2. To increase the isolation between Tx and Rx, an ORUR test system with co-channel feedback interference cancellation is also proposed in this Letter.

Results of designed WCTL cell: We have calculated a structure of a WCTL cell with impedance matching using the Newton-Raphson method mixed with the moment method [2] (characteristic impedance = 50 Ω). We have designed a WCTL cell illustrated as in Figs. 1*a*, *b* that has a uniform area (UA) large enough to test a large majority of UHF RFID (UR) tags (size of 0.1 m). The calculated w is 0.325 m when a is 0.5 m, b is 0.6 m, h is 0.3 m and d is very thin (≈ 0 m).

The field uniformity in the UA is 1.6 dB in the TEM mode as shown in Fig. 1*b*. The VSWR of the designed cell has been measured to be from 40 kHz to 2 GHz with a network analyser. The VSWR at port 1 is also shown in Fig. 2. The other port exhibits nearly the same result. The VSWR at each port is less than about 1.5 up to 2 GHz.

We can see that the designed cell has good impedance matching. The electric field at the centre of the cell is a constant value in the TEM mode. However, we cannot provide the same field information at the frequency above the higher-order mode (HOM) cutoff. Hence, we define an effective height, h_e, to correct the electric field at the centre over the frequency of the HOM as follows:

$$h_e = (h \cdot E_t)/E_m \qquad (1)$$

where h is the height between the inner conductors as shown in Fig. 1*a*, E_t ($\approx V/h$) is the electric field calculated at the centre in the TEM mode and E_m is the electric field measured at the centre with the HOM. When the input power at the WCTL cell is 31 dBm, the measured electric fields, at three test points of the designed cell in Fig. 1*b*, are as shown in Fig. 1*c*. It is shown that the HOM have asymmetric characteristics, unlike the TEM mode of Fig 1*b*, in the frequency range of the Korean UR, 908.5–914 MHz. We can see that the field uniformity at the three test points inside the UA is <±2.0 dB within this band. The calculated effective heights from (1) are also presented in Fig. 1*c*. We find that the average of effective heights, h_e, is about 0.556 m in the Korean UR band.

Results of designed ORUR test system: We propose an ORUR test system with a WCTL cell as shown in Fig. 3. We used two variable attenuators to calculate the ORUR, similar to the isolation antenna method in a small anechoic chamber [5]. We also used an interference cancellation radio frequency (RF) circuit (ICRFC) to increase the isolation between Tx and Rx [6]. It is shown that the isolation is more than 24 dB in an ICRFC and 31 dB using the WCTL cell as shown in Fig. 4. We can see that the total isolation of the proposed ORUR test system is more than 55 dB. We can calculate the ORUR from the maximum attenuation value (MAV) to operate a tag inside the WCTL cell. When the gain of the transmit antenna of the UR reader is 6 dBi, the equation of the ORUR is obtained from the total attenuation α at Tx as

$$R = 1.55 h_e / \sqrt{\alpha} \qquad (2)$$

where R is the operating range of the UR tag with a bistatic reader, not a monostatic reader [7]. We used the same UR reader and tags as in [5].

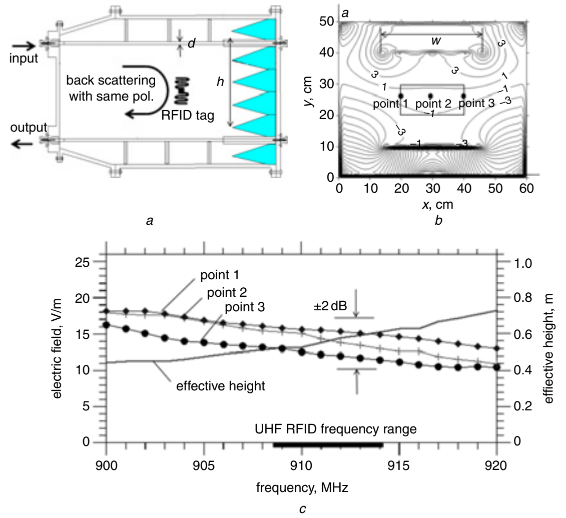

Fig. 1 *Front cross-section of WCTL cell and electric field distribution inside WCTL cell*

a Front cross-section of WCTL cell
b Electric field dB distribution inside WCTL cell in TEM mode
c Measured electric field and effective height inside WCTL cell

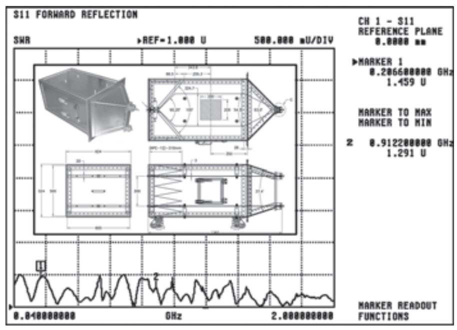

Fig. 2 *Measured VSWR of designed WCTL cell up to 2 GHz*

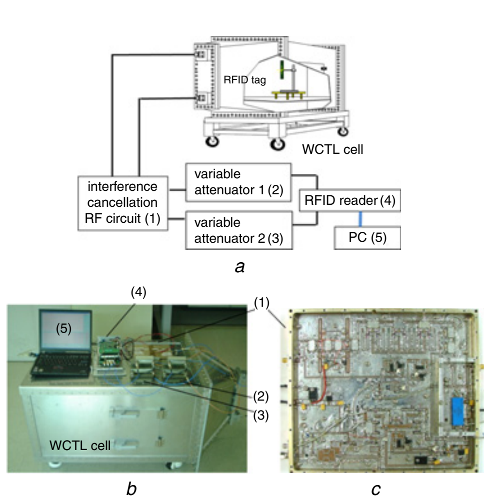

Fig. 3 *ORUR test system with interference cancellation RF circuit*

a Structure of ORUR test system
b Photograph of designed ORUR test system
c Photograph of RF module on interference cancellation [6]

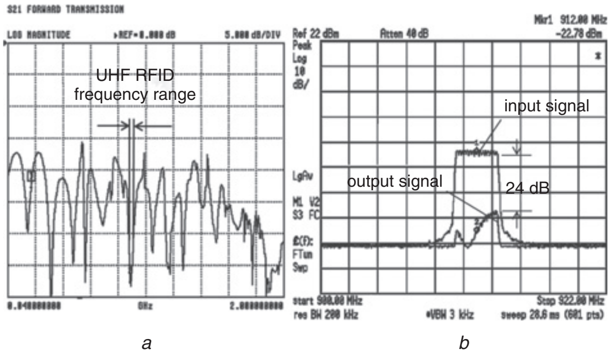

Fig. 4 *Measured isolation of ORUR test system*

a Measured isolation of WCTL cell
b Measured isolation of RF module on interference cancellation

The MAV at Tx is about 8 dB as shown in Table 1. The input cable loss, including the two attenuators, is about 2 dB. Therefore, α is calculated to be 10 dB. We can calculate that the ORUR of the tags is about 2.73 (±0.16) m from (2). The directly measured result inside a fully anechoic chamber is 2.7 (±0.1) m. It is shown that the measured ORUR by the WCTL cell also agrees approximately with the test results in [5] when using the same UR system. We can see that the compact WCTL cell shielded from environmental RF noise is useful for ORUR testing.

Table 1: Measured attenuation for readable identification of tags

RFID tag 1		RFID tag 2	
Tx (dB)	Rx (dB)	Tx (dB)	Rx (dB)
0	0–21	0	0–23
2	0–18	2	0–20
4	0–17	4	0–18
6	0–9	6	0–11
8	0–3	8	0–2

Conclusion: A WCTL cell to measure the ORUR has been presented in this Letter. We also propose an ORUR test system with co-channel feedback interference cancellation to increase the total isolation to more than 55 dB. We can see that the ORUR measured by this proposed cell agrees well with the measured data using a fully anechoic chamber. We will include an estimation of the measurement uncertainty to characterise the accuracy of this system in a future publication.

Acknowledgments: This work was supported by the Guest Research Program of NIST and the ICT R&D programme of MSIP/IITP. The authors thank M.-S. Kwon and J.-K. Lee for obtaining the measurement data [Development of RF energy Transmission under 100 Watts and Harvesting Technology].

13 October 2014
doi: 10.1049/el.2014.3359
One or more of the Figures in this Letter are available in colour online.

Jaehoon Yun (*Radio Science Section, ETRI, Taejon 305-350, Republic of Korea*)

✉ E-mail: jhyun@etri.re.kr

Yongchae Jung (*Department of Electronics and Information and Engineering, Chonbuk University, Chonju 561-756, Republic of Korea*)

David R. Novotny and Jeffrey R. Guerrieri (*Electromagnetics Division, NIST, Boulder 80305-3337, USA*)

References

1 Crawford, M.L., and Workman, J.L.: 'Asymmetric versus symmetric TEM cell for EMC measurements'. IEEE Symp. on EMC, Atlanta, GA, USA, June 1978, pp. 368–375
2 Yun, J., Lee, H., and Hwang, H.: 'Straight coupled transmission-line cell for generating standard electromagnetic fields', *IEEE Trans. Electromagn. Compat.*, 2002, **44**, pp. 515–521
3 Konigstein, D., and Hansen, D.: 'A new family of TEM cells with enlarged bandwidth and optimized working volume'. Proc. 7th Int. Symp. on EMC, Zurich, Switzerland, March 1987, pp. 127–132
4 Yun, J., Cho, I., Moon, J., and Kim, S.: 'A new single waveguide cell with double polarisations to generate standard electromagnetic fields', *Electron. Lett.*, 2012, **48**, (4), pp. 208–209
5 Kwon, M., and Yun, J.: 'RFID tag range measurement system using isolation antenna'. 37th European Microwave Conf., Munich, Germany, October 2007, pp. 230–233
6 Choi, H., Jeong, Y., Kim, C., and Yun, J.: 'Digital controlled co-channel feedback interference cancellation system with broadband cancellation'. 1st European Wireless Technology Conf., Amsterdam, The Netherlands, October 2008, pp. 194–197
7 Kuester, D.G., Novotny, D.R., Guerrieri, J.R., Ibrahim, A., and Popovic, Z.B.: ' Simple test and modeling of RFID tag backscatter', *IEEE Trans. Microw. Theory Tech.*, 2012, **60**, pp. 2248–2258