Accurate Impedance Measurement and Implementation of a Folded Dipole Antenna for RFID Tags

#Dongsu Kim[1], Tae Wan Koo[1, 2], Jong-In Ryu[1], Jong-Gwan Yook[2], and Jun Chul Kim[1]

[1] System Packaging Research Center, Korea Electronics Technology Institute
#68 Yatap-dong, Bundang-gu, Seongnam-si, Gyeonggi-do, 463-816, South Korea
[2]Department of Electrical and Electronics Engineering, Yonsei University
#262 Seongsanno, Seodaemun-gu, Seoul 120-749, South Korea

1. Introduction

Radio Frequency Identification (RFID) has become very popular in various applications such as parcel and document tracking, animal tracking, distribution logistics, and so on. Among several elements in an RFID system, a tag, which contains digital information, is one of the most critical elements. An RFID tag is mainly composed of a tag chip and a tag antenna. In order to realize a high-performance RFID tag, an accurate impedance measurement of a tag antenna is one of the key design issues because the tag performance is heavily dependent on conjugate matching characteristic between a chip and an antenna. In other words, the antenna has a conjugate impedance of the chip in order to deliver maximum power from the antenna to the chip which has very high capacitive characteristic. Several research groups have proposed the methods of measuring the impedance of a balanced antenna which is the most common RFID antenna configuration. By employing a balun or imaging method, we can obtain the impedance of a balanced antenna [1],[2]. However, accuracy relies heavily on the balun characteristic and the size of the ground plane. Other methods to use the measured *S*-parameter have been proposed recently [3]-[5] by employing microstrip lines or coaxial cables as test fixtures.

In this paper, we present the accurate measurement method of differential mode impedance for a balanced antenna with the test fixture. Based on an accurate impedance of a commercial tag strap, the meander-line folded dipole antenna in UHF band is designed and implemented on a PET film.

2. Impedance Measurement

The two-port impedance model shown in Figure 1 is proposed by [3]. V_1 and V_2 are balanced excitation voltages, and Z_a, Z_b, and Z_c represent the antenna impedances. Even though the difference between Z_a and Z_b accounts for unbalance of the tag antenna, Z_a is equal to Z_b in this symmetrical dipole antenna structure.

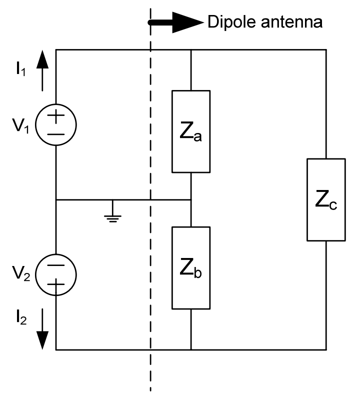


Figure 1: Two-port impedance model [3].

Palmer *et al*. presented this broadband network analyzer technique for measuring balanced antenna and derived the common mode and differential mode impedance [3]. The differential mode impedance of the balanced antenna is given by

$$Z_{diff} = \frac{Z_c(Z_a+Z_b)}{Z_a+Z_b+Z_c} \tag{1}$$

where Z_a, Z_b, and Z_c are the impedance at Fig. 1. In case of symmetrical structure, Z_a is equal to Z_b, and thus the equation (1) can be simplified by

$$Z_{diff} = \frac{2Z_aZ_c}{2Z_a+Z_c} \tag{2}$$

Z_a, Z_b, and Z_c can be calculated through the following equation.

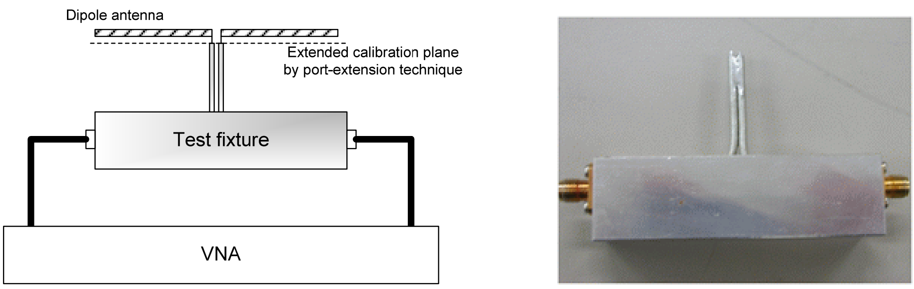
$$Z_a = \frac{1}{Y_{22}+Y_{21}} = \frac{1}{Y_0}\frac{(1+S_{11})(1+S_{22})-S_{12}S_{21}}{(1+S_{11})(1-S_{22})+S_{12}S_{21}-2S_{21}} \tag{3}$$

$$Z_c = -\frac{1}{Y_{21}} = \frac{(1+S_{11})(1+S_{22})-S_{12}S_{21}}{2Y_0S_{21}} \tag{4}$$

The differential mode impedance can be extracted by the *S*-parameters directly through the following equation.

$$Z_{diff} = \frac{2Z_0\left[(1+S_{11})^2-S_{21}^2\right]}{1-S_{11}^2+S_{21}^2+2S_{21}} \tag{5}$$

Figure 2 illustrates two-port test fixture for measuring balanced devices. Two SubMiniature version A (SMA) connectors are placed at one end, whereas the small extension of inner conductor of the semirigid cables is open in order to directly connect the antenna. After standard two-port Short-Open-Load-Through (SOLT) calibration is done, the calibration plane is shifted from the test cables to the small extension by port-extension function of VNA, as shown in Figure 2 (a). Then the differential mode impedance of the antenna can be extracted by the equation (5).



(a) (b)

Figure 2: Two-port test fixture. (a) Configuration. (b) Photograph.

3. Antenna Design

Figure 3 shows the proposed folded dipole antenna. Due to the size limitation for most RFID tag, the proposed antenna has meandered structure. In order to provide very high inductive reactance, the antenna has T-matching structure as shown in Figure 3. By adjusting m_1, m_2, m_3, and m_4 of the T-matching structure, we can fulfil the conjugate matching between the strap and antenna. The dimension of the proposed antenna is presented in Table 1. The proposed antenna is realized on a thin flexible PET substrate (ε_r = 3.4) with a thickness of 0.07 mm. The Ag is printed on the PET substrate as a conducting material. Figure 4 shows the photograph of the implemented RFID tag using the proposed antenna and the Alien Higgs-2 microchip.

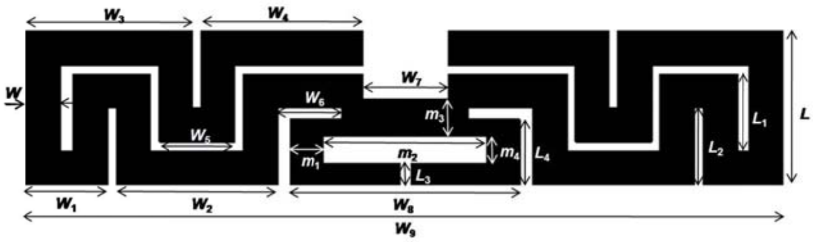


Figure 3: Proposed meander-line folded dipole antenna.

Table 1: Antenna dimension

w	4 mm	L	10 mm
w_1	9.5 mm	L_1	9 mm
w_2	19 mm	L_2	9 mm
w_3	19.5 mm	L_3	2.5 mm
w_4	19 mm	L_4	7.7 mm
w_5	9 mm	m_1	3.9 mm
w_6	7.5 mm	m_2	19.2 mm
w_7	10 mm	m_3	4.3 mm
w_8	27 mm	m_4	3.2 mm
w_9	89 mm		

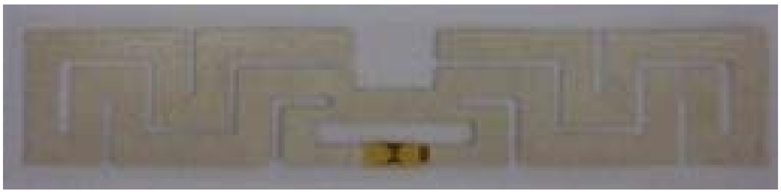
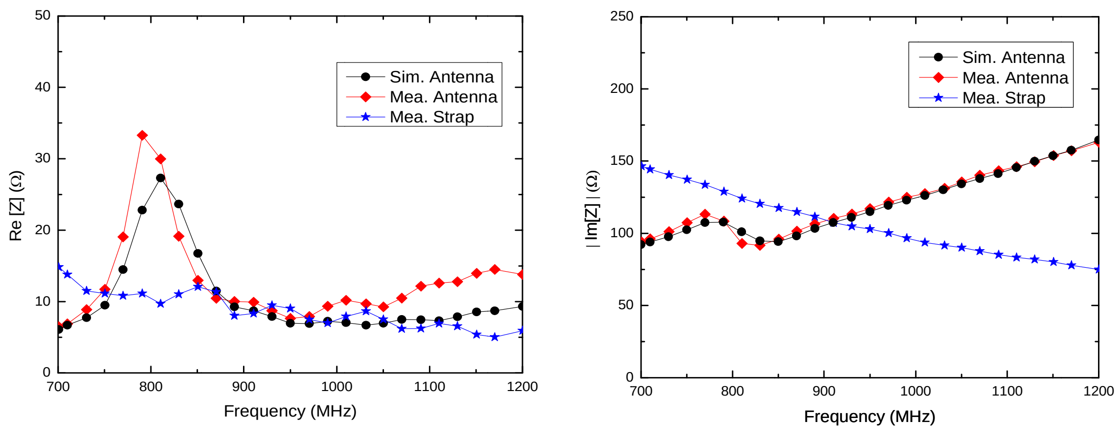


Figure 4: Photograph of the implemented RFID tag with the proposed antenna.



(a) (b)

Figure 5: Measured and simulated input impedance of the proposed folded dipole antenna with the measured impedance of the strap. (a) Real part. (b) Imaginary part.

Figure 5 illustrates the simulated and measured impedance of the proposed antenna in the frequency range of 700 MHz ~ 1200 MHz. The measured impedance of strap is also plotted in this figure in order to check the conjugate matching characteristic. The measured result is in good agreement with the simulated result. The simulated and measured S_{11} is shown in Figure 6. It provides the frequency bandwidth of the proposed antenna is from 890 MHz to 947 MHz for $S_{11} < -10$ dB. The reading distance of the implemented tag at an anechoic chamber is measured, resulting in about 5 ~ 6 m with almost omnidirectional radiation pattern, as shown in Figure 7.

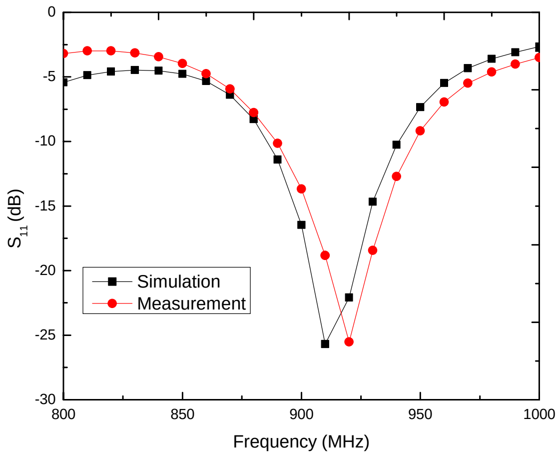


Figure 6: Measured and simulated S_{11}.

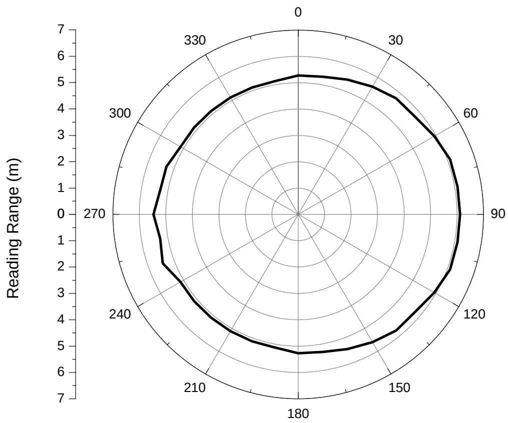


Figure 7: Measured reading distance.

4. Conclusion

An accurate impedance measurement and implementation of a folded dipole antenna for UHF RFID tags have been described. Based on the measured two-port *S*-parameter with the manufactured test fixture, the accurate differential mode impedance of the balanced antenna was obtained. By using this method, the folded dipole antenna has been designed and implemented, resulting in relatively large bandwidth and long reading distance with small size in UHF band.

References

[1] K. S. Leong, M. L. Ng, and P. H. Cole, "Investigation of RF cable effect on RFID tag antenna impedance measurement,"IEEE Antennas and Propag. Symp., pp. 573-576, 2007.
[2] D. M. Dobkin and S. M. Weigand, "Environmental effects on RFID tag antennas," IEEE MTT-S Int. Microw. Symp. Dig. pp. 135 - 138, 2005.
[3] K. D. Palmer and m. W. Rooyen, "Simple broadband measurements of balanced loads using a network analyzer," IEEE Trans. on Instrument and Measurement, vol. 55, No. 1, 266-272, 2006.
[4] S. –K. Kuo, S. –L. Chen, and C. –T. Lin, "An accurate method for impedance measurement of RFID tag antenna," Progress In Electromagnetics Research, PIER 83, pp. 93-106, 2008.
[5] X. Qing, C. K. Goh, and Z. N. Chen, "Impedance characterization of RFID tag antennas and application in tag co-design," IEEE Trans. on Microwave Theory and Techniques, vol. 57, No. 5, pp. 1268-1274, 2009.