Investigation of RF Cable Effect on RFID Tag Antenna Impedance Measurement

Kin Seong Leong*, Mun Leng Ng, and Peter H. Cole
School of Electrical and Electronic Engineering
The University of Adelaide, SA, Australia.
Email: {kleong, mng, cole}@eleceng.adelaide.edu.au

1 Introduction

The performance of a passive Radio Frequency Identification (RFID) tag depends on the antenna, the chip efficiency of the tag, and also on the matching between the antenna and the chip. The design of the tag antenna often involves the measurement of its impedance. There is no literature which explicitly discusses the measuring methods of the performance of an RFID tag antenna. The closest literature on the measurement of small antennas is either antenna on a mobile handset, mobile radio [1, 2] or antenna in a 50 Ω system [3]. This paper investigates the RF cable effect on the measurement of the RFID tag antenna impedance. Measurement results obtained through several different RF cables are compared with simulation results. Discussions on minimizing measurement error and on how measurement of antenna impedance can assist the design of tag antenna are presented.

2 Settings and Connection

An RFID tag antenna is normally made of thin copper tracks on an adhesive sheet. This is to make an RFID tag easily and readily attached to an object. However, for convenience, our prototype tag antenna is fabricated on a solid dielectric material to have a strong foundation. The material chosen is FR4. An SMA connector is then used as the feed point of the Antenna Under Test (AUT) in order to connect the AUT to a network analyzer for measurement. Measurement results are then compared with the simulated results obtained through Ansoft HFSS simulation software. Three types of coaxial cable configurations are used for testing purposes: **(1)** Using RG223 coaxial cable. **(2)** Using RG223 coaxial cable with ferrite sleeve. **(3)** Using Gore GMCA 190-1 (now known as G2) coaxial cable.

Two types of antenna are tested using some or all of the coaxial configurations stated above: **(1)** A balanced bow tie antenna, as shown in Fig. 1(a). The feed point of the antenna (an SMA connector) is from the back and through the FR4 material as shown in Fig 1(a) (i). **(2)** Half of the balanced bow tie antenna on ground plane is one half of the balanced bow tie antenna shown as Fig. 1(a), and attached on a ground plane (Fig. 1(b)). This unbalanced version of the bow tie antenna is soldered on a SMA connector, which is mounted on a ground plane. The idea is to combine the unbalanced bow tie antenna with its image created by the ground plane, to simulate a complete balanced bow tie antenna. It has been proven in theory that a half unbalanced bow tie antenna on a ground plane will have half of the input impedance of a complete balanced bow tie antenna [4].

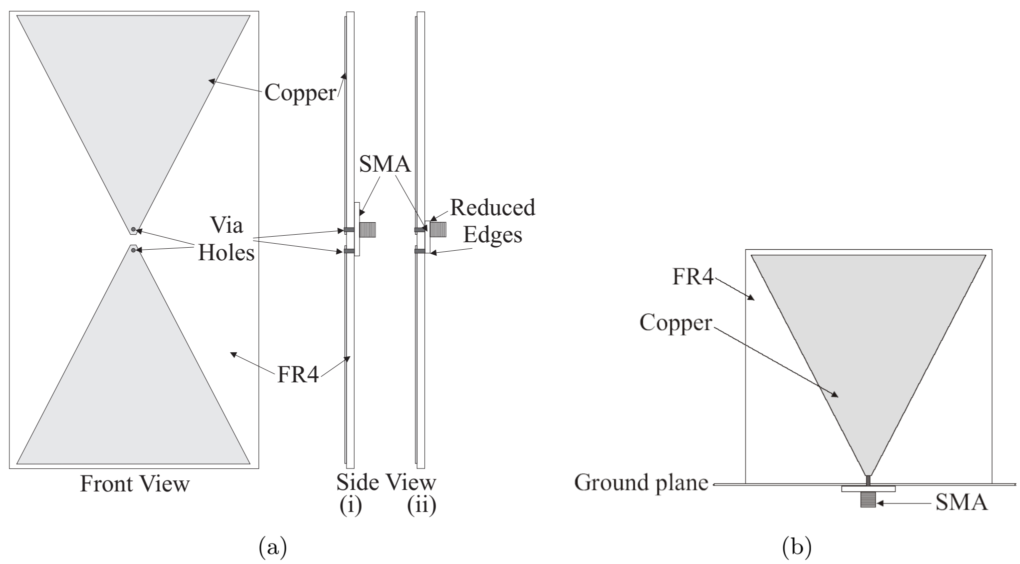


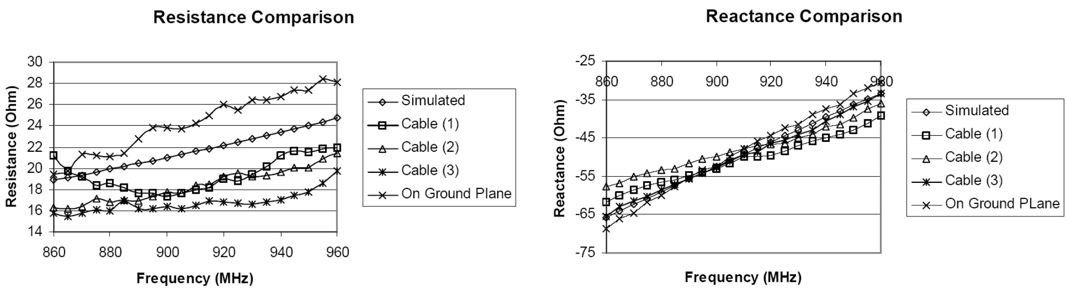
Figure 1: (a) A bow-tie antenna on FR4: Side view (i) With SMA connector (ii) With modified SMA connector to enhance measurement results. (b) Half bow-tie antenna on ground plane

The effect of SMA connector of the balanced bow-tie antenna on the measurement results was observed through a comparison between the simulated and measured reactance of a simple bow tie antenna. As the edges of the SMA connector overlap with part of the AUT, extra capacitance is added. The solution is to minimise the edge of the SMA connector as shown in Fig 1(a) (b). In this paper, all the experiments were carried out with a modified SMA connector, unless otherwise stated.

3 Testings and Results

For a balanced bow tie antenna, the inaccuracy of measurements done using Cable (1), Cable (2) and Cable (3) are on average similar as shown in Fig. 2(a) and Fig. 2(b). However, by touching with hand both of the cables and monitoring the impedance of the AUT, it is confirmed that Cable (1) and Cable (3), without the addition of ferrite sleaves, are more susceptible to environment effects. For a half bow-tie antenna on ground plane, it is observed that the ground plane with the AUT mounted provided sufficient shielding between the cable and the AUT. The results obtained using any of the cables shows negligible difference.

In all comparisons and graphs presented in this paper, measured values for a half balanced bow tie antenna on ground plane has been doubled for the reason explained in previous section to enable easy comparison. In comparison of resistance values, the measured results are consistently higher than the simulated results. This is mostly due to the finite ground plane effect. A quick simulation confirmed this claim. Nonetheless, in comparison of the reactance values, the measured results are slightly better than all the results obtained on a balanced bow-tie antenna, with the exception of Cable(3), which is a high quality shielded coaxial cable. Hence, the



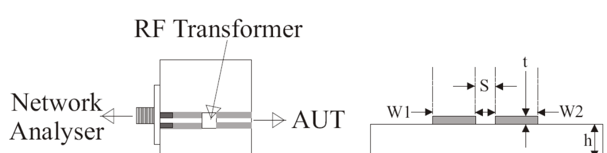
(a) (b)

Figure 2: (a) Simulated and measured resistance of AUT. (b) Simulated and measured reactance of AUT.

ground plane has effectively shielded the cable and the measuring instrument from any unwanted coupling. The challenge in using this method is that the AUT must be symmetrical in nature, which is not always the case for an RFID tag antenna. Also, the distance of the half bow-antenna from the ground plane must be half of the distance between the two feed points of a balanced bow tie antenna.

4 Discussion and Improvement

Ccoaxial cable with high shielding improves the measurement results by reducing the coupling between the cable and the AUT. Not all errors can be eliminated as inaccuracy may be introduced by the balanced to unbalanced issue. Hence a Balun is designed by using coplanar strips with an RF transformer (Fig. 3 (a)). The model of the chosen commercial RF transformer is TC1-1-13M with with characteristic impedance of 50 Ω and with operating frequency range of 4.5 to 3000 MHz. From [5], the impedance of coplanar strips is physically limited to above 45 Ω. Even for a 50 Ω coplanar strips, the fabrication process is extremely difficult. As the AUT is small, the track size W1 and W2 cannot be too wide (W1 and W2 < 5 mm). To obtain 50 Ω coplanar strips with W1 and W2 less than 5 mm, the width of separation, S, has to be around 0.05 mm for FR4 material with ε_r equals 4.4. The final design uses a more expensive composite dielectric, consists of polytetraflouroethylene (teflon) and ceramic, with ε_r of 10.2. W1 and W2 are both 2 mm in width and the separation is 0.12 mm. The calculated characteristic impedance is 49.35 Ω.



(a) (b)

Figure 3: **A Balun:** (a) The use of balun to connect a balanced load to unbalanced coaxial cable (b) The design parameters of coplanar strips.

It can be seen in Table 1 that with the use of Balun, the measurement of resistance is the best, though not much better, than the rest. On the other hand, a high quality co-axial cable provides the best results for reactance measurement. It is inconclusive which measurement method is the best among all, as a direct measurement using a normal coaxial cable offers comparably acceptable results. Note that the result is only applicable for small RFID antennas. Big scaled antenna, such as a half-wave dipole, will most certainly required a Balun or ferrite sleeve for proper measurement. Also, in all our comparison, simulated results are used as the standard values. We are assuming that with proper fabrication process, an actual antenna with similar characteristics with the modeled antenna, can be obtained.

Table 1: Average Error and Highest Error

	Average Error (Ω)		Highest Error (Ω)	
	Re	Im	Re	Im
Cable (1)	2.55	3.38	3.72	6.49
Cable (2)	3.29	3.64	3.96	8.03
Cable (3)	4.91	0.59	6.38	1.62
With Ground Plane	2.62	1.63	4.04	2.91
With Balun	2.35	4.12	3.9	5.26

5 Conclusion

The investigation of the RF cable effect on an RFID tag antenna impedance measurement exposes the difficulties in getting accurate measurements and obtaining the best match between AUT and the chip. The inaccuracy may be caused by the effect of the RF cable and the coupling between the AUT and the environment. In actual RFID tag design, it is best to:

(1) Design by simulation. Adjust the dimension of the antenna so that the input impedance equals to the conjugate of the chip impedance.
(2) Fabricate the designed antenna. Measure the antenna input impedance.
(3) Attach tag chip on antenna. Fine-tuning the antenna, such as reducing the dimension of certain part of the antenna, while monitoring the read range.

6 References

[1] Y. L. Chow, K. F. Tsang, and C. N. Wong, "An accurate method to measure the antenna impedance of a portable radio," *Microwave and Optical Technology Letters*, vol. 23, no. 6, pp. 349–352, 1999.

[2] C. Icheln, M. Popov, P. Vainikainen, and S. He, "Optimal reduction of the influence of RF feed cables in small antenna measurements," *Microwave and Optical Technology Letters*, vol. 25, no. 3, pp. 194–196, 2000.

[3] J. Thaysen, K. B. Jakobsen, and J. Appel-Hansen, "A wideband balun - how does it work?" *Applied Microwave & Wireless*, vol. Technical Feature, 2000.

[4] C. A. Balanis, *Antenna theory: analysis and design*, 3rd ed. John Wiley and Sons, 2005.

[5] R. C. Johnson, and H. Jasik, *Antenna engineering handbook*, 3rd ed. McGraw-Hill, 1993.