Miniaturization of Dual Frequency RFID Antenna with High Frequency Ratio

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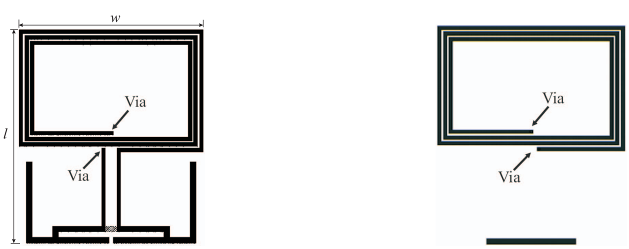
Introduction

This paper presents a novel design of a miniaturized dual frequency Radio Frequency Identification (RFID) antenna, which can support both the HF (13.56 MHz) and UHF bands (860-960 MHz). Discussions presented in [1–3] have suggested that neither HF nor UHF is superior to the other; in general, a UHF RFID system can offer a longer read range while an HF RFID system can read better in a liquid environment. Hence, it is desirable to have an RFID tag which can respond in both the HF and the UHF bands. Frequency ratio is obtained through the division of the higher frequency by the lower frequency and is always > 1. Dual frequency antennas with a frequency ratio within 1.8 - 4.9 are common [4]. Frequency ratio of a dual frequency antenna for our intended RFID application (operating in both HF and UHF bands) is around 70.

Previous Work

A novel dual frequency RFID antenna with high frequency ratio is presented in [2] and is as shown in Fig. 1. The dimensions of this antenna are 114 mm (l) by 98 mm (w), giving a total area of 11172 (mm)^2. It has a resonant point at HF and has an impedance match to an RFID UHF chip impedance (17-150j Ω at 915 MHz).



(a) Front view (b) Rear view

Figure 1: Previous antenna design [2].

Improved Novel Design

The new design is to relocate the UHF electric dipole antenna inside the HF coil antenna to reduce the overall size as shown in Fig. 2. The new dimensions are 81 mm (l_{hf}) by 58 mm (w_{hf}), giving a total area of 4698 (mm)^2. This new design retains the characteristics from previous design: **(1)** a HF and a UHF antenna are merged together with a single feed; The HF antenna used is an HF coil antenna and has

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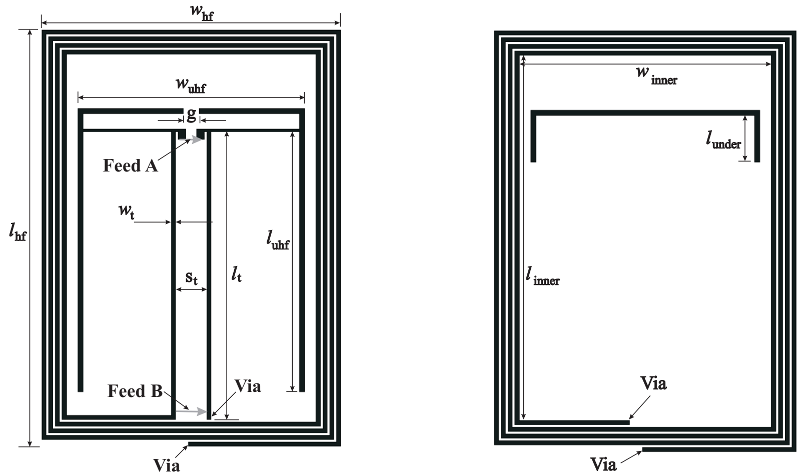


(a) Front view (b) Back view

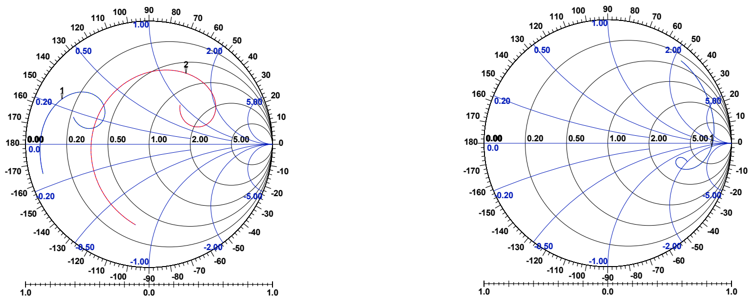
Figure 2: New antenna design with design parameters. The final prototype has the following design values in mm: $l_{\mathrm{hf}} = 81$; $w_{\mathrm{hf}} = 58$; $l_{\mathrm{inner}} = 70$; $w_{\mathrm{inner}} = 48$; $l_{\mathrm{uhf}} = 37$; $w_{\mathrm{uhf}} = 44$; $g = 3$; $w_{\mathrm{t}} = 0.8$; $s_{\mathrm{t}} = 6$; $l_{\mathrm{under}} = 9$.

resonance point at 13.56 MHz. The UHF antenna chosen is a UHF electric dipole with a matching network. **(2)** A transmission line (with length l_{t} in Fig. 2(a)) is used to link the HF and the UHF antenna together with a single feed point, while preventing the HF antenna from affecting the UHF antenna. **(3)** The antenna is double sided. The HF coil on the top overlaps with the HF coil on the bottom to provide enough capacitance in order to obtain a resonant point at HF. **(4)** A series capacitor is added at the matching network of the UHF antenna (the gap provided by g in Fig. 2(a)). This capacitor prevents the UHF antenna from shorting the HF antenna.

Major changes and modifications were carried out to reduce the size and to improve the overall performance of the previous design.

1. *Miniaturization of HF coil and UHF dipole*

   Since the overall size of the dual frequency antenna in the new design is determined by the size of the HF coil, the new HF coil is reduced from 98 mm by 65 mm to 81 mm by 58 mm. To maximize the total inductance (including self inductance and mutual inductance) of a HF coil antenna, the dimension of the interior area ($w_{\mathrm{inner}} \times l_{\mathrm{inner}}$) is to maximized. With the reduction of the size of the HF coil, inductance is reduced and resonance frequency is increased. This can be solved introducing an additional loop into the HF coil as shown in Fig. 2 as compared to Fig. 1. To fit both the transmission line and the UHF antenna within the HF coil antenna, the HF coil antenna is rotated 90 degrees from the previous design (compare Fig. 1 and Fig. 2). The impact on the size limitation of the UHF dipole antenna is significant. The w_{uhf} is shortened from 95 mm to 44 mm. Although we can design this dipole antenna to be matched in impedance, its simulated directivity drops from 2.9 to 2.2. This is a trade-off between size and performance.



(a) (b)

Figure 3: Impedance transformation in Smith Chart where all the traces cover from 860 to 960 MHz: (a) Trace 2 is the reflection coefficient of the impedance of the antenna normalized to 50 Ω while Trace 1 is the reflection coefficient of the impedance of the antenna renormalized with respect to 290 Ω. (b) Trace of the reflection coefficient when Trace 1 in (a) is transformed using a $\frac{\lambda}{4}$ transmission line.

2. *HF not affecting UHF over a broader bandwidth*

   The HF antenna is not exactly a short circuit for the entire band of UHF as shown in Fig. 3(a). The idea is to design a transmission line with high characteristic impedance, Z_0, by changing w_t and s_t. A coplanar strips (CPS) has a theoretical physical limit on the lowest and highest Z_0 of 45 and 280 Ω respectively when ε_r is 10 [5]. The highest Z_0 limit can be increased by reducing the ε_r value. The effect of higher Z_0 is shown in Fig. 3(a), and with the impedance transformation of the $\frac{\lambda}{4}$ CPS, the HF coil impedance is plotted as Fig. 3(b). It can be seen that the HF coil behaves like a high impedance for most of the UHF band of interest.

   The final design of our transmission line linking the HF and the UHF antenna together has the following dimensions (Refer Fig. 2(a)): $s_{\mathrm{t}} = 6$ mm, $w_{\mathrm{t}} = 0.8$ mm and $\varepsilon_r = 4.4$, resulting a $Z_0^{new} \approx 290$ Ω. The effective dielectric constant value, ε_{eff} is approximately 2.12. Using $l_{\mathrm{t}} = \frac{\lambda}{4\times\sqrt{\varepsilon_{eff}}}$, l_{t} is is approximately 0.056 m at 920 MHz.

3. *The coupling effect between UHF and HF antenna*

   In the previous design, the UHF dipole antenna is located beside the HF coil. Although the overall size is larger, the coupling between the HF and UHF antennas is not significant. In our new design, the UHF dipole is relocated within the HF coil to reduce overall size. The coupling between the antennas changes the UHF dipole impedance quite significantly and we no longer have a impedance match between the UHF dipole and the UHF chip at UHF. A fine tuning was carried out by readjusting g, l_{uhf} and l_{under}.

Testing

The prototype of the designed dual frequency antenna was tested and found to be resonating at 13.56 MHz while having reasonable impedance match with a generic

RFID tag chip at UHF. However, there is no tag chip available that would work on both HF and UHF. Though our intention is to have a single feed system, for the purpose of testing, we used an UHF RFID C1G1 chip and a Tag Talk First HF chip.

Referring to Fig. 2(a), we first put both the HF and UHF chip at position A. In HF operation, the read range is limited by the size of the reader antenna [6]. Our dual frequency RFID tag offers a maximum possible read range at HF when using a fixed size reader antenna. However, the HF chip affects the UHF chip significantly and a poor read range of only 0.3 m is observed at UHF. The HF chip is then moved to the B position in Fig. 2(a), so that it is transformed to a very high impedance at UHF by the transmission line. A read range of more than 2 m is observed at UHF while a maximum possible read range at HF is maintained. Although the final prototype dual frequency RFID tag has two chips and has two feed points, we believe that our prototype will work with equivalent efficiency in both HF and UHF bands when a single dual frequency chip is used on a single feed.

Conclusion

We have presented a novel design for dual frequency RFID antenna with high frequency ratio. This antenna works well in both the HF and UHF bands for RFID operation with a single feed. Comparisons between the new design and the previous design are made and the new design is shown to be less than half of the size of the previous design while offering almost the same performance. A functioning dual frequency RFID tag proves that having a dual frequency RFID system is feasible. Although no dual frequency RFID chip is available at the moment, we hope that this successful design of a compact dual frequency RFID antenna will catalyze the development of a dual frequency RFID chip.

1 References

[1] Philips Semiconductor, TAGSYS, and Texas Instruments Inc., “Item-level visibility in the pharmaceutical supply chain: a comparison of HF and UHF RFID technology,” July 2004 2004. [Online]. Available: http://www.tagsysrfid.com/modules/tagsys/upload/news/TAGSYS-TI-Philips-%White-Paper.pdf

[2] K. S. Leong, M. L. Ng, and P. H. Cole, “Dual-frequency antenna design for RFID application,” in *21st International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2006)*, Chiang Mai, Thailand, 2006.

[3] S. Lewis, “A basic introduction to RFID technology and its use in the supply chain,” Jan 2004. [Online]. Available: http://www.printronix.com/library/assets/public/case-studies/rfid-laran%-white-paper-english.pdf

[4] K. L. Wong, *Compact and broadband microstrip antennas.* John Wiley and Sons, 2002.

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

[6] Texas Instruments, “HF antenna design notes,” *Technical Application Report*, 2003.