Systematic Design of High-Performance Smart Card with HF/UHF Dual-Band RFID Tag[1]

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Abstract

Recently, there have been widely conducted researches on dual-band radio frequency identification (RFID) tag based on 13.56 MHz (HF) and 900 MHz (UHF). Most dual-band RFID tag has been implemented so that each antenna is separated in a different inlay sheet respectively, which makes the resulting smart card impractically thick, and the typical drawback of dual-band RFID tags incorporated in one inlay is a mutual frequency interference phenomenon due to the fabrication of the HF antenna and the UHF antenna on the same sheet. In this paper, we introduce a novel design of high performance smart card with HF/UHF dual-band RFID tag to overcome the frequency interference problem. Firstly, we have design and tested a UHF RFID tag using a simulation software system. In the smart card hardware design stage, we connect a HF antenna and a UHF antenna and place them in one inlay sheet. Using a spectrum analyzer, we systematically adjust the antenna pattern to detect the optimal patterns that fit the impedance of the RFID chip.

Keywords: *Dual band RFID Tag; HF/UHF*

1. Introduction

Radio frequency identification (RFID) is one of the basic technologies for the realization and implementation of ubiquitous and pervasive computing. For the design of high performance RFID technology, we primarily need to research and invest on technologies for the design of RFID antennas [1]. For the last several years, numerous studies have been conducted on the design and implementation of RFID [2, 3, 4]. Especially, there have been intensive researches on the implementation of 13.56MHz RFID antennas and on the commercialization of RFID tag products with different types and functions [5, 6, 7].

One of popular commercial configurations in contemporary RFID card products is a financial IC chip. It is equipped with RFID and does not contain a USB-type memory. The IC chip is used for the authorization and authentication for secure financial transaction, and the separate USB-type memory can also be used for the memory function of public certificate, which is widely used in South Korea. Another typical example of contemporary RFID card products is a transit card for public transportation. There have been various commercial RFID-based transit cards designed to maximize the functional usage and efficiency of USB memories inside the cards. Additionally, there have observed remarkable changes in transit card development including the evolution to a general-purpose multi-functional card for the application to diverse domains. For instance, RFID cards are applied to the security of

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personal computers and business/enterprise-level security hub by utilizing the memories inside the cards.

2. Design of Dual Band RFID Tag

There have been many researches to utilize heterogeneous RFIDs in one card. However, there are a fundamental difference between those previous researches and our research in terms of the structure of inlay and design procedure. In most of those previous researches, they embed each antenna on a different layer according to its frequency. In our research, we propose a RFID tag embedded with two different frequency bands on one layer to construct inlay. Also, for the previous researches of dual band RFID tags stored in one inlay, our design usually outperforms the tags in terms of accuracy and size.

To understand the basic principle and to minimize the frequency interference and impedance mismatching among antennas, it is necessary to understand the product which the antennas are to be applied.

Before the explanation, we would like to explain a few fundamental concepts for RFID tag design. In designing RFID tag, we bond antenna and RFID chip for actual functioning. Impedance is a measure of opposition to electric current in an electric circuit. Therefore, an impedance of RFID chip characterizes the RFID chip for its proper functioning and operation. For example, if the impedance level of a RFID chip is 50.0Ω, we need to design the antenna to be attached to the RFID chip so that the impedance level of the antenna to be 50Ω for proper operation of the resulting RFID tag.

To begin with, we briefly summarize the design and optimization procedure discussed in this section as follows:

- We determine the shape, size and position of the UHF antenna pattern to design a UHF RFID tag. We design and test the UHF RFID tag using a simulation software system. Ansoft's HFSS™ is used for this purpose.
- We analyze Smith chart to fit the antenna to the impedance level of RFID chip. Please note that we use the simulation software for UHF antenna only, because there is no system that can simulate antennas with different frequency levels in one inlay design.
- In the smart card hardware design stage, we connect a HF antenna and a UHF antenna and place them in one inlay sheet to resolve the interference problem. Since we only have adjusted the UHF antenna to the RFID chip in the design stage using the simulation software, the combined antennas naturally will not fit to the impedance level of the RFID chip, which result in malfunction or no operation.
- To solve this impedance mismatching problem, we use a spectrum analyzer to systematically adjust the antenna pattern to detect the optimal patterns that fit the impedance of the RFID chip. We repeat this step for every pattern adjustment until we obtain an antenna pattern that fits in the impedance level of the RFID chip. We consider a trade-off between size and recognition range of the antenna pattern during this adjustment.
- We evaluate the performance of the resulting smart card with standard RFID testers.

Now, let us explain the procedure in more detail. As shown in Figure 1, we need to decide which the size, shape and position of the combined antenna (UHF and HF) to optimize the interaction with RFID chips. To decide the positions that minimize the interference problem, we firstly estimate frequency functions of active power and reactive power to measure mutual interference of different frequency bands. From the obtained frequency functions, we identify amplitude and phase of frequency element of each sine wave.

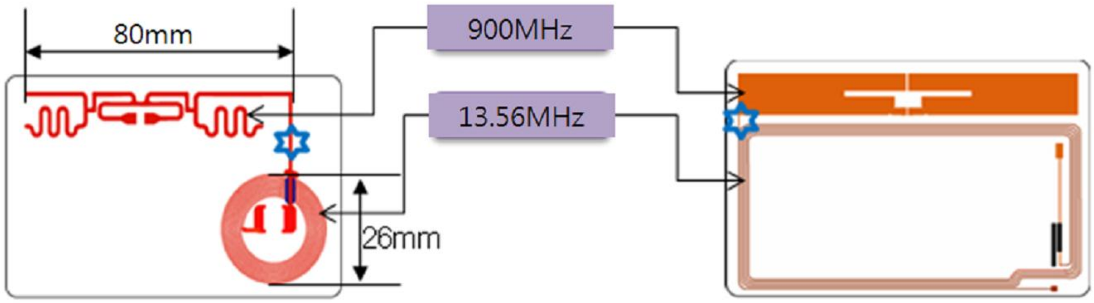


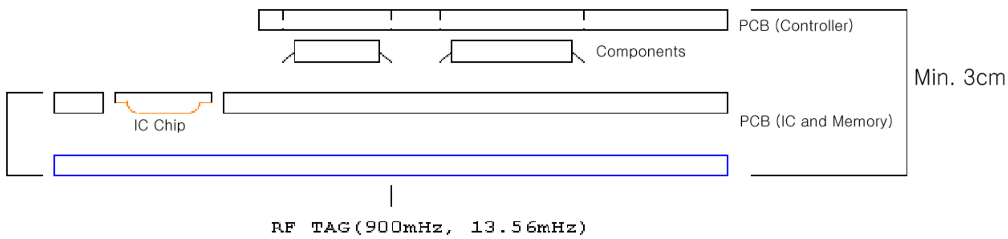
Figure 1. Configuration of one-sheet inlay RFID tag antenna in a smart card. Note that both antennas are singly connected (denoted by a blue star in the figure). That is, they are connected by etching

After we identify the amplitude and phase of each frequency band, to optimize the electricity usage for each band, we solve the impedance mismatching problem by strategically changing antenna pattern, position, and antenna shape for each band. However, if both antennas are not connected or both antennas are not designed with the consideration of their mutual interference, this trial-and-error based step-by-step change cannot completely solve the interference problem. For instance, in actual implementation, communication failure between the antenna and the reader can happen. And the failure can result in modification of reading speed and frequency priority, which affects the interaction between the antenna and the RFID reader.

To solve this interference problem, we propose and implement an inlay antenna design as shown in figure 1 to effectively distribute active resonance current. Note that the proposed antenna works in integrated and connected mode, instead of independent mode. That is, as shown in Figure 1, we connect HF(13.56MHz) antenna and UHF(900MHz) antenna. This connection can cause impedance mismatching problem, which causes marginal performance degradation of HF(13.56MHz) antenna, however overall performance turns out to be enhanced.

As for the related work on RFID design technologies [8], there have been many research work conducted. In this research, we basically use an antenna pattern program (Ansoft's HFSS™) and equipments to design and implement RFID tag antenna as shown in the Figure 2. However, according to our knowledge, there are no antenna pattern tools available to assist generating antenna patterns for the antennas with different frequency bands on one sheet. That is why we have to adopt step-by-step trial-and-error based approach in this research. However, there are a few considerations to be maintained for the dual-band RFID tag design for smart card. Because the smart card should be portably used, the size of the card is strictly limited, and we know that if the antenna is bigger, its recognition range is farther. We consider this size vs. recognition range trade-off during the antenna adjustment step.

From the structural diagram of the card in Figure 2(a), it can be seen that we stack a tag containing both antennas (HF and UHF) at the bottom, a PCB board containing IC chip and memory in the middle, and a controller with other components on the top of the card. Note that HF antenna and UHF antenna are on the same inlay, though we present them separately in Figure 2(b) and 2(c) for easier understanding of readers.



(a) Structure of the card

(b) HF(13.56MHz) RFID Tag

(c) UHF(900MHz) RFID Tag

Figure 2. Design of Smart Card with Dual Band RFID Tag

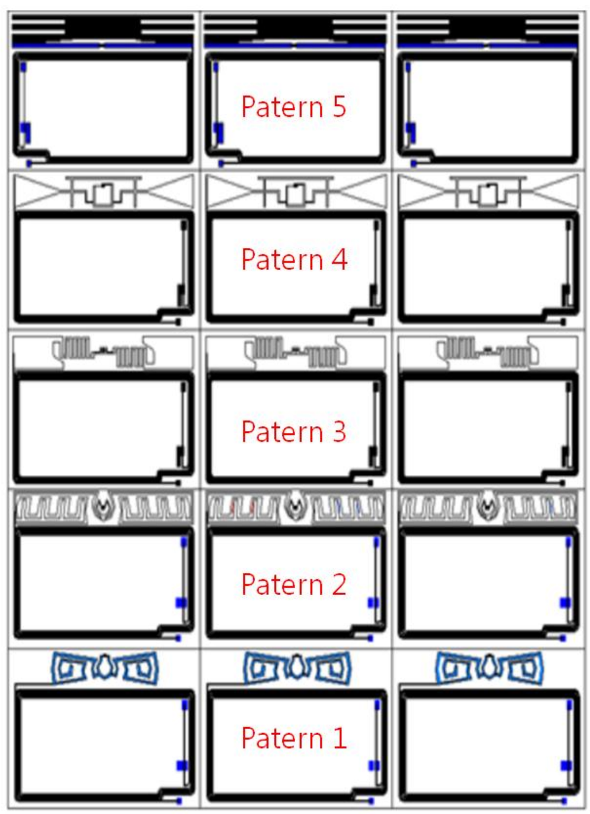


Figure 3. Detected Patterns of Dual Band RFID Tag Antenna

In terms of antenna implementation, there have been many studies conducted [9], and several products of different types and functions have been commercialized including access cards, various membership cards, smart cards, transportation cards, and e-money cards. In this research, we need to design an antenna that maximizes efficiency when multiple antennas are used together for RFID on the same sheet and a financial IC chip with a memory on a different inlay sheet (as shown in the Figure 2).

For this purpose, we have detected and developed five inlay patterns to minimize frequency interference. In terms of RFID tag usage per frequency band, we use Philips's ISO14443A-type chip for 13.56MHz RFID and Impinj's Gen2™ chip for 900MHz RFID.

As for UHF(900MHz) RFID, we have changed the contact point considering the impedance of the chip. In figure 3, it can be seen that we apply single-ended connection (i.e. both antennas are connected by etching) for the contact point design, which is different from the case when we design UHF(900MHz) RFID tag alone. As mentioned, we have integrate two antennas with different frequency bands in a way to minimize frequency interference and to maximize the amplitude for the response signal.

3. Conclusion

We introduce a novel design of high performance smart card with HF/UHF dual-band RFID tag to overcome the frequency interference problem.

Firstly, we have design and tested a UHF RFID tag using a simulation software system. In the smart card hardware design stage, we connect a HF antenna and a UHF antenna and place them in one inlay sheet. Using a spectrum analyzer, we systematically adjust the antenna pattern to detect the optimal patterns that fit the impedance of the RFID chip. We evaluate the performance of the resulting smart card with standard RFID testers. The experiments show that our proposed RFID tag outperforms other dual-band RFID tags, and maintains itself in a reasonable size. By solving technological problems step-by-step in each stage until the prototype products, and by evaluating the performance of the tag prototype in several environments where next-generation memory/IC chip cards can be used, we see high potential for the proposed tag's commercial value in the smart card market.

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References

[1] Y. Lee, “Antenna circuit design for RFID applications”, MICROCHIP App. Notes 710 **(2003)**.

[2] I. J. Park, “Production control system based on RFID”, The Journal of IWIT (The Institute of Webcasting, Internet and Telecommunication) 9 **(2009)** pp. 25-31.

[3] Y. S. Hong, C. Kim, E. J. Yoon and C. Jung, “Intelligence e-learning system”, The Journal of IWIT (The Institute of Webcasting, Internet and Telecommunication) 10 **(2010)** pp. 137-144.

[4] K. Lee and S. Park, “Patient classification scheme for patient information management in hospital u-healthcare system”, The Journal of IWIT (The Institute of Webcasting, Internet and Telecommunication) 10 **(2010)** pp. 131-137.

[5] G. Huault, “How did they do that? play tag with RFID manufacturers, retailers, shipping companies, and even government officials are either using or implementing the use of RFID tags to better identify, track, and manage products, we show you how RFID tags work”, Smart Computing 15 **(2004)**.

[6] D. S. Currier, “RFID manufacturers advised to roll out RFID tags now”, Computer Weekly 62 **(2004)**.

[7] C. Kim, K. H. Yang and J. Kim, "A strategy for third-party logistics systems: A case analysis using the blue ocean strategy", Omega 36 **(2008)** 522-534 Special Issue on Logistics: New Perspectives and Challenges.

[8] J. Kang, H. Yoo and S. Lee, "Novel process methodology of smart combi card (SCC) manufacturing for RFID/USN", Lecture Notes in Computer Science / Ubiquitous Convergence Technology 4412 **(2007)** pp. 90-99.

[9] C. H. Loo, K. Elmahgoub, F. Yang, A. Z. Elsherbeni, D. Kajfez, A. A. Kishk, T. Elsherbeni, L. Ukkonen, L. Sydanheimo, M. Kivikoski, S. Merilampi and P. Ruuskanen, "Chip impedance matching for UHF RFID tag antenna design", Progress In Electromagnetics Research 81 **(2008)** pp. 359-370.

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