Parallel-fed Multiple Loop Antenna for 13.56MHz RFID Reader

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Abstract

In this paper, we suggest a new antenna structure for RFID(Radio Frequency IDentification) reader. Conventional RFID reader uses a loop antenna. The central area of a loop antenna shows a low magnetic field strength especially for the case of a large loop antenna diameter. We propose a parallel-fed multiple loop antenna. Simulation results and measured results show that we can adjust field distribution with the number of turns and diameter of an inner loop antenna to obtain a longer reading distance. Simulation results for the specific case of a proposed antenna structure show that at the center point of a proposed parallel-fed multiple loop antenna, the typical card area averaged magnetic field strength is 2.53A/m, which is higher than the case of a conventional type single loop antenna of 0.44A/m and the case of a series-fed multiple loop antenna of 0.96A/m when we drive with same source signal. We realized the antenna for the case of 13.56MHz RFID reader and the performance of reading distance was much more improved than the case of a conventional antenna.

Key words: RFID reader, parallel-fed, multiple loop antenna, magnetic field strength.

1. INTRODUCTION

An RFID(Radio Frequency IDentification) card system is used mainly in fare collection system of public transport in Korea, and the application range has expanded increasingly in access control, fare collecting, electronic money, health card areas. Also, its practical usage expanded in the field of a huge market such as physical distribution information system with low cost and technology development of general RFID system[1].

Nationwide supplied RFID system in the country adopts ISO (International Standardization Organization) / IEC (International Electrotechnical Commission) 14443 standard which use 13.56MHz signal. The operating power of inductively coupled PICC(Proximity IC Card) is provided by the magnetic alternating field of a reader at a transmission frequency of 13.56MHz[2]. According to ISO/IEC 14443 standard, RFID reader antenna should generate the magnetic field strength within the range of $1.5\text{A/m} < H < 7.5\text{A/m}$[3]. In the field of wireless identification card, one of the most important concerning topics is the identification range maximization.

In this paper, we propose a parallel-fed multiple loop antenna to guarantee long and stable identification range[4,5]. Simulations by using 2.5D simulation program, IE3D, for the conventional single loop antenna, series-fed multiple loop antenna and proposed parallel-fed multiple loop antenna will be carried out. Measurement and comparison for implemented antennas will be made.

At first, proposed parallel-fed multiple loop antenna structure is described in the chapter 2 and we will analyze simulation results and measured results of actually implemented antennas in the chapter 3. At last in the chapter 4, we reach a conclusion.

2. PARALLEL-FED MULTIPLE LOOP ANTENNA

2.1. Parallel-fed multiple loop antenna

Generally a closed loop whose maximum dimension is less than about a tenth of a wavelength is called a small loop antenna. If the length of loop circumference is electrically small, the radiation of the small loop is the maximum in the loop surface direction, because the current around the loop has constant amplitude and phase. The radiation fields of small loops are independent of the loop shape and depend only on the area of the loop[6]. Usually, RFID reader and transponder adopt loop antenna for communication. Conventional system mostly uses a single loop antenna. Sometimes, a serially connected multiple loop antenna is used.

In the case of a single loop antenna, to interrogate at a long distance, we should increase radius R of an antenna. As the radius R increases, the field strength at a long distance($z>R$) is becoming stronger than that of an antenna with small radius. If the radius R of the transmitter antenna is varied at a constant distance z from the transmitter antenna under the simplifying assumption of constant coil current I in the transmitter antenna, then field strength H is found to be at its highest at a certain ratio of distance z to antenna radius R[2].

$$R = z \cdot \sqrt{2} \qquad (1)$$

In the case of a single loop antenna, the magnetic field strength is maximum in the vicinity of loop and minimum at the center of loop. If the antenna radius is too great, the field strength H is too low even at a distance $z = 0$ from the transmission antenna. In this paper, to reinforce field strength at the central area of an antenna, we propose a parallel-fed multiple loop antenna.

Fig. 1 depicts a special case of a proposed antenna. A small loop antenna is connected in parallel to outer loop antenna. Both inner loop and outer loop wind in the same direction. In this way, the directivity of the antenna is improved which results in the extended identification range of RFID reader. The inductance of a parallel-fed multiple loop antenna is lower than the inductance of each loop, inner loop and outer loop. Also the inductance of a parallel-fed multiple loop antenna is lower than that of a single loop antenna with outer loop only. If we want to maintain same inductance value of a single loop antenna, we can increase the number of turns for the proposed antenna.

Fig. 1 shows two windings case. The number of windings can variously be organized in accordance with size of an antenna and application purpose.

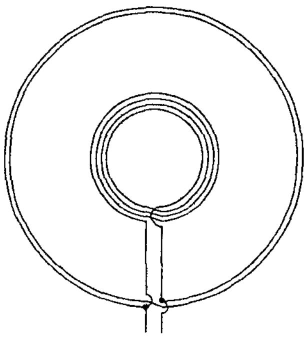


Fig. 1. The structure of a parallel-fed multiple loop antenna.

2.2. Parallel-fed multiple loop antenna design

We designed a parallel-fed multiple loop antenna to identify a tag at a long distance. Suggested antenna shows the structure that an inner loop is connected to an outer loop in parallel and represents structure which reinforces magnetic field strength at the central area by inner loop.

Fig. 2 shows a parallel-fed multiple loop antenna modeled by simulation program IE3D. A parallel-fed multiple loop antenna, in this case, has an outer loop of two turns with outside diameter 180mm and an inner loop of four turns with outside diameter 80mm.

Fig. 3 shows the equivalent circuit of a parallel-fed multiple loop antenna. Because an inner loop is connected to an outer loop in parallel, mutual influence can be reduced when a tag is approaching a reader antenna.

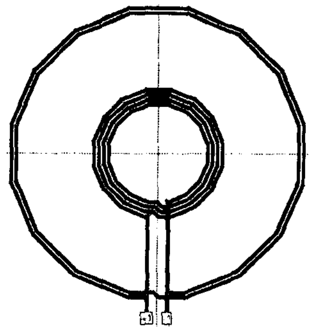


Fig. 2. Design of a parallel-fed multiple loop antenna.

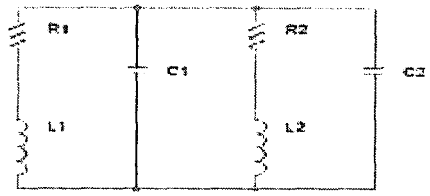


Fig. 3. Equivalent circuit.

3. SIMULATION AND MEASUREMENT RESULTS

Two conventional and proposed types of antennas are designed with simulations. Simulations of antennas are executed by IE3D, and the implemented antennas are measured by HP4195A network analyzer.

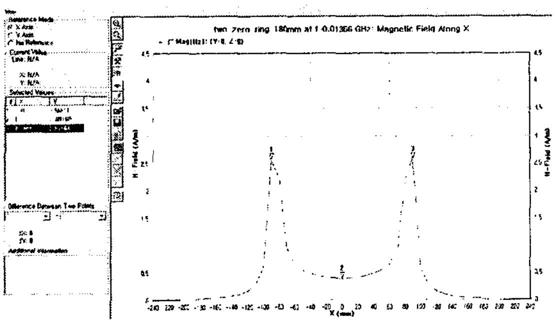
3.1. Simulation

A single loop antenna has two turns with outside diameter 180mm in the shape of circle. The width of copper wire is 2mm and the space between copper wires is 1mm. In the case of a series-fed multiple loop antenna, the number of windings is two. So, an additional inner loop of outside diameter 80mm of one turn is connected to a same single loop antenna in series. The proposed parallel-fed multiple loop antenna has same parameter with Fig. 2. Same magnitude of source is applied to three types of antenna simulations.

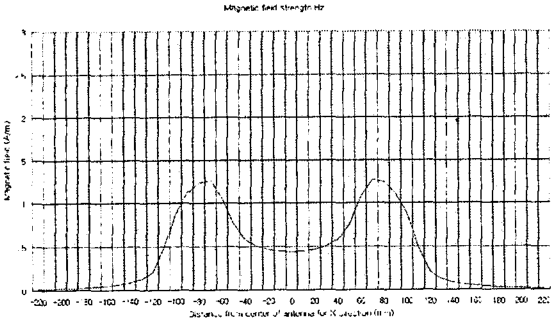
Fig. 4 shows simulation results for a single loop antenna. From Fig. 4(a), we can see the magnetic field strength near the loop coil is high and the field strength at the center of an antenna is low. Fig. 4(b) shows typical card area averaged magnetic field strength. Perpendicular direction magnetic field strength at the center is approximately 0.44A/m in comparison with 1.26A/m at both loop upsides in the Fig. 4(b). Fig. 4(c) shows magnetic field strength distribution for z direction.

Fig. 5 shows simulation results for a series-fed multiple loop antenna. From Fig. 5(b), we can see the typical card area averaged magnetic field strength for z direction is more uniform than that of Fig. 4. Perpendicular direction magnetic field strength at the center is approximately 0.96A/m in comparison with 0.44A/m in Fig. 4(b).

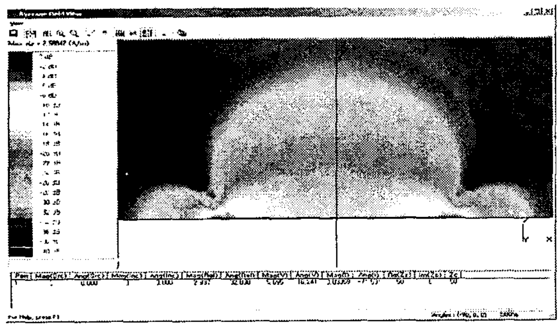
Fig. 6 shows simulation results for a parallel-fed multiple loop antenna. From Fig. 6(b), we can see the typical card area averaged magnetic field strength for z direction at the center is 2.53A/m which is higher value



(a)

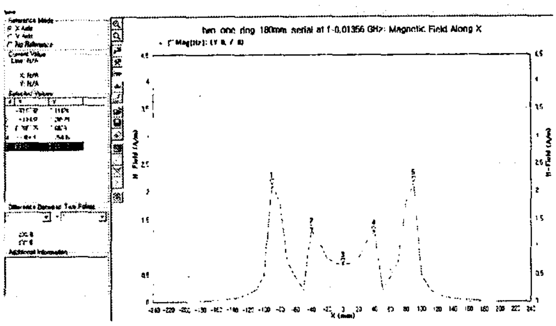


(b)

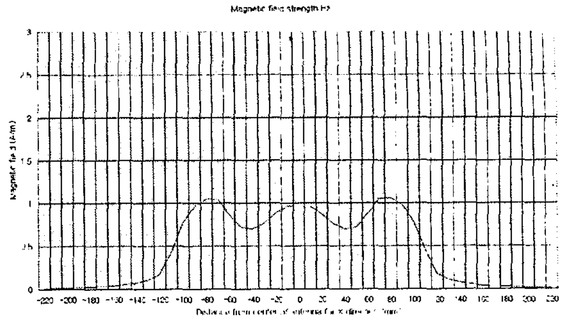


(c)

Fig. 4. Simulation results of a single loop antenna.
(a) Magnetic field strength,
(b) Typical card area averaged magnetic field strength,
(c) Magnetic field strength distribution for z direction.



(a)



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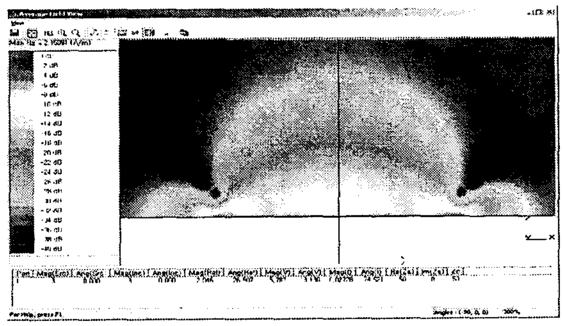
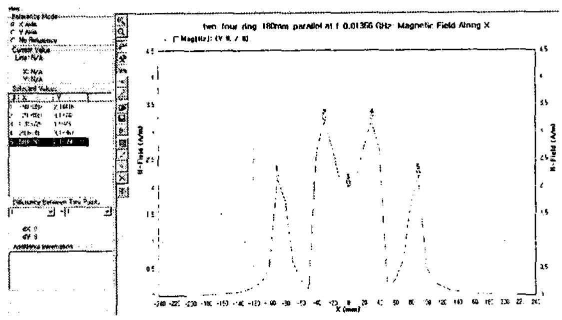


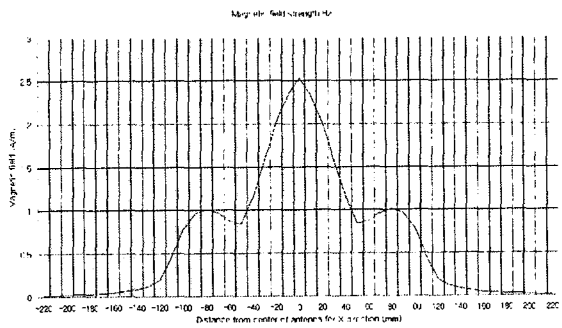
(c)

Fig. 5. Simulation results of a series-fed multiple loop antenna.
(a) Magnetic field strength,
(b) Typical card area averaged magnetic field strength,
(c) Magnetic field strength distribution for z direction.

than the cases of a single loop antenna and series-fed multiple loop antenna. Fig. 6 shows that the magnetic field at the center of an antenna is reinforced, which results in reading distance extension.



(a)



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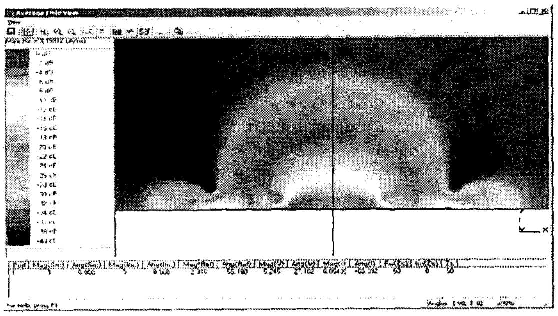


(c)

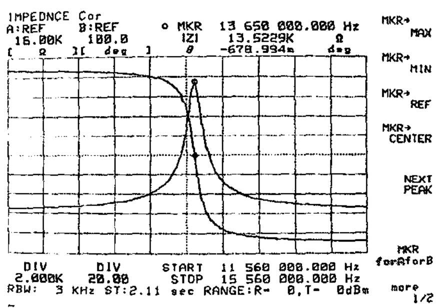
Fig. 6. Simulation results of a parallel-fed multiple loop antenna.
(a) Magnetic field strength,
(b) Typical card area averaged magnetic field strength,
(c) Magnetic field strength distribution for z direction.

3.2. Measurement results

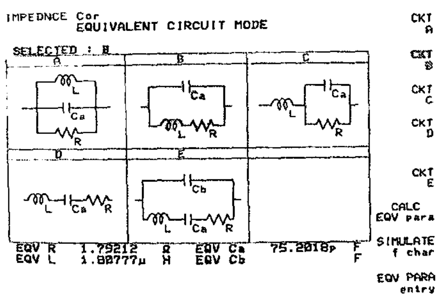
Implemented antennas are measured by using HP4195A network analyzer. Fig. 7, 8, 9 show impedance curves and equivalent circuits for the implemented antennas. Before measurement, tunning capacitor is connected to each antenna to have resonance frequency of 13.56MHz.

From the equivalent circuits, we can see the inductance value of a parallel-fed multiple loop antenna is minimum.

If we adjust the number of turns and external capacitance we can vary inductance value for a parallel-fed multiple loop antenna while maintaining same resonance frequency.

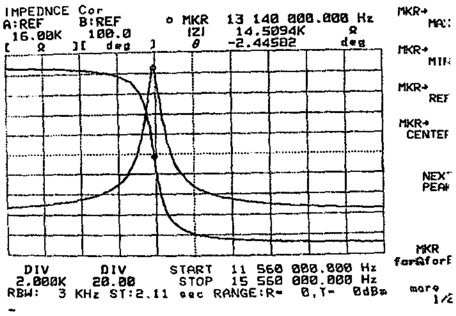


(a)

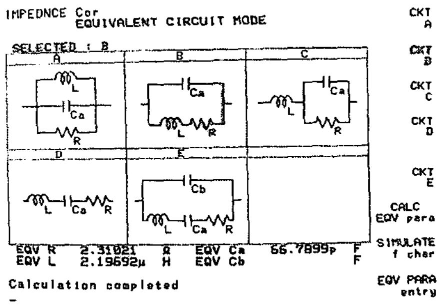


(b)

Fig. 7. Measured results of a single loop antenna.
(a) Impedance curve,
(b) Equivalent circuit model.

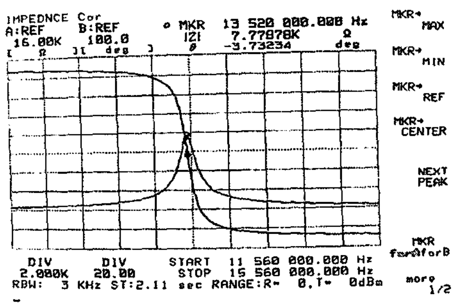


(a)

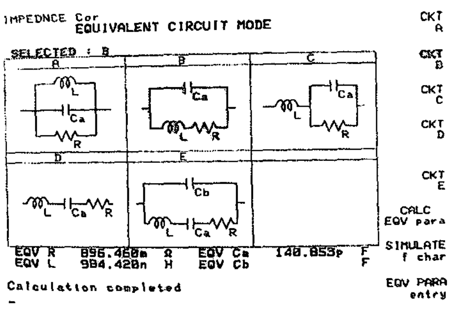


(b)

Fig. 8. Measured results of a series-fed multiple loop antenna.
(a) Impedance curve,
(b) Equivalent circuit model.



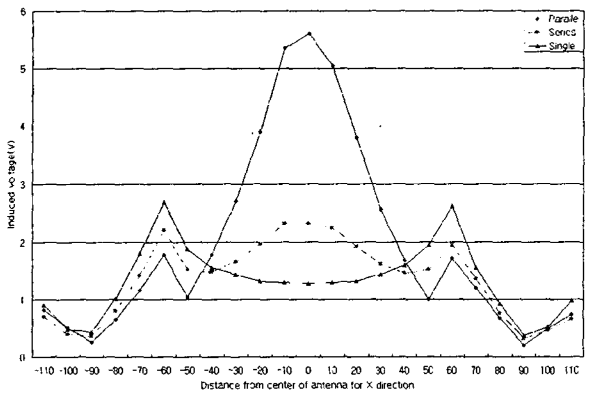
(a)



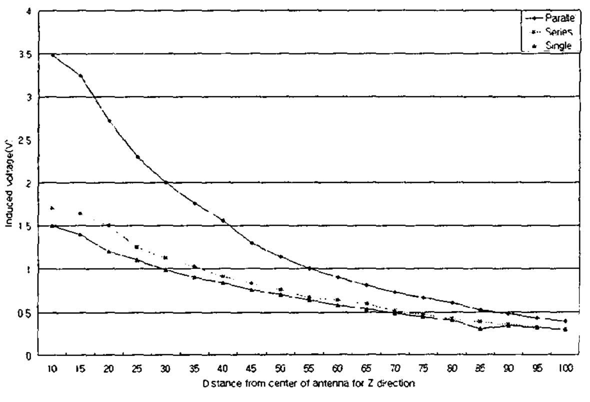
(b)

Fig. 9. Measured results of a parallel-fed multiple loop antenna.
(a) Impedance curve,
(b) Equivalent circuit model.

Fig. 10 shows the induced voltage in a 79mm × 48mm measurement tag. Peak to peak of $20V_{p-p}$ signal source is applied to an antenna via 50ohm series resistor. Measurement tag simulates actual RFID transponder card. The area of 79mm × 48mm is similar to actual antenna area of RFID card. Fig. 10(a) shows induced voltage in a measurement tag while we move the tag along x direction on the reader antenna surface. It corresponds to typical card area averaged magnetic field strength. In the case of a single loop antenna, the induced voltage at the center portion of an antenna is low since magnetic field strength at the center of an antenna is low. Though a series-fed multiple loop antenna induces relatively constant voltage over the antenna area, it can't induce high voltage. But in the case of a parallel-fed multiple loop antenna, we can confirm that magnetic field is reinforced at the center portion of an antenna which results in high induced voltage. Fig. 10(b) shows induced voltage while we move the tag along z direction which is perpendicular to an antenna surface. From the Fig. 10(b), we can see the induced voltage for a parallel-fed multiple loop antenna is higher than those of other types of antennas. That results in a longer reading distance. Directional characteristic can be adjusted by tunning the number of turns and radius of an inner antenna.



(a)



(b)

Fig. 10. Measured induced voltage for each antenna.
(a) x direction with distance z=0,
(b) *z* direction.

4. CONCLUSION

In this paper, we proposed a new antenna structure for RFID reader which is a parallel-fed multiple loop antenna. As an example, we simulated and implemented three types of antennas for specific case of 13.56MHz RFID system.

From the simulation results, typical card area averaged magnetic field strength at the center portion of a parallel-fed multiple loop antenna is 2.53A/m which is higher value than 0.96A/m of a series-fed multiple loop antenna and 0.44A/m of a single loop antenna. Also from the measured results, we can confirm the simulation results. The identification range and properties of a parallel-fed multiple loop antenna were superior to other types of antennas.

Proposed antenna is expected to be widely used with increasing demand of an RFID system.

ACKNOWLEDGEMENT

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