Split Ring Resonator Based Chipless RFID Tags

Madhavan.S[#1], S.Dinesh Dass[#2],

[#] *Department of ECE, Thiagarajar College of Engineering, Madurai, TN, India.*

[1]madhavan.sriram@gmail.com,[2]deenesh2005@gmail.com,

I. INTRODUCTION

RFID has, in the recent years, become a revolution in both the supply chain industry and the commercial sector. However, cost has become a factor that is undermining its growth. This paper deals with the implementation of chipless tags using RFIDs using Split Ring Resonators (SRR). SRRs are used in order for the tag to be tuned at multiple frequencies over the band we have selected. This chipless RFID can be used in the replacement of passive RFIDs which are the most commonly used RFID chips used nowadays.

The passive RFID works on the method of reflecting the signal sent to it from the reader. The reader sends a signal to the surrounding RFIDs and when such a signal is received the passive antenna gets energized. The antenna sends out the serial number present in the microcontroller to the reader. All the energy for this operation is derived from the RF signal transmitted to the tag.

The problem in the above method is that a microcontroller makes the tag bigger and more expensive. By using chipless tags, i.e. tags without microcontroller, their cost can be minimized. The SRRs are the integral part of the chipless tag.

II. SPLIT RING RESONATOR(SRR)

The resonator, an RF component which tunes at particular frequencies can be designed by several means but the closed ring structure is considered to be effective and easier to implement. We have taken one such structure, the Split ring resonator. This structure is obtained by making cuts in the ring structure. For obtaining multiple frequency tunings we use an array of SRRs. The array can be formed by placing SRRs at a particular distance from each other. The resonating frequencies for these resonators can be adjusted by varying certain parameters like the split width (d), gap distance (t), width of the inner and outer rings (w) and the addition of dielectric medium in the gap of the Split Ring Resonator.

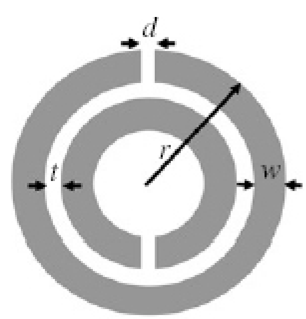


Figure 1: SRR Structure

Micro-fabrication techniques can be used to bring the size of the SRRs to about 100µm to 5µm, thus boosting the frequency range upto few THz. We can thus use this large frequency range for future RFID applications.

In the setup, we use periodic arrays of Split Ring Resonators. Therefore, there will be no variations in the resonating frequencies even if the distance of the tag varies from the reader.

The Split Ring Resonators can be designed by using Pendry's Formula. The design Equation is given below

$$v_0 = \frac{1}{2\pi}\sqrt{\frac{3dc_0^2}{\pi^2 r^3}} < v_{mp} = \frac{v_0}{\sqrt{1-\pi r^2/ab}}$$

Where $c0$ is the speed of light *in* vacuum and the rest of the parameters are shown in the Figure below.

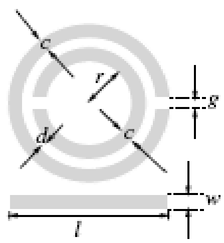


Figure 2: Design of SRR

A. EFFECT OF SPLIT WIDTH(d)

The split width plays a major role in the tuning of the resonators. The splits along with the metals on either side form a virtual capacitor. Charges accumulating on the metal plates provide a capacitance effect with the air medium in between acting like the dielectric. Thus,

$$C = \frac{\epsilon A}{d}$$

From the equation, we can see that the capacitance is inversely proportional to the distance between the metal faces .Thus, by varying the distance, the capacitance can be also varied. This change in capacitance directly affects the reactance which in turn affects the frequency as shown below

$$X_c = \frac{1}{2\pi f C}$$

While all other parameters are kept constant and only the split width varies we can obtain our required characteristics.

B. EFFECT OF GAP DISTANCE(t)

The Gap distance has an indirect influence on the frequency of resonation. The Gap distance when varied, changes the reactance by the influence of Mutual Capacitance and Mutual Inductance. The Mutual Inductance is given by,

$$M = K\sqrt{L_1 L_2}$$

The coupling factor K decreases as the gap distance increases. The Mutual Capacitance also changes in the same manner. This change in Mutual inductance and Mutual Capacitance has an inverse effect on the frequency. Thus, the frequency characteristics can be adjusted or varied using gap distance.

C. EFFECT OF METAL WIDTH

The Metal Width is one of the characteristics which have a profound influence on the frequency characteristics. The width of the outer and inner rings are varied Increasing the metal width will decrease the mutual inductance and mutual capacitance. Therefore, SRRs made of thinner rings will have smaller resonant frequencies. Thus, the SRRs can be made to change the frequency characteristics by varying the metal width too.

D. EFFECT OF DIELECTRIC IN GAP

The addition of dielectric medium in the gaps can affect the overall capacitive effects. The introduction of high dielectric materials in the gap provides an additional capacitive effect to that of the air medium. This structure appears like two capacitors are placed parallel to each other. Thus, the overall capacitance C is

$$C = C_1 + C_2$$

Where C_1 & C_2 are the capacitances induced with dielectric and air as medium. The overall capacitance increases and this directly affects the frequency component.

III. SRRS IN RFID TAGS

We have seen the various effects of the SRR with certain geometric and physical variations. These variations are used in the design of the chipless tags. The SRRs are designed in such a manner that the chipless tag thus developed is able to be tuned at several frequencies.

The chipless tag doesn't work in the exact manner as the chipped RFIDs do and their operation varies. The reader transmits a similar RF signal to the tags and the tag corresponds back to the reader by reflecting the energy back. The individual response to the reader from each tag is unique as each tag is made to be tuned at several frequencies whose order is unique to itself.

An illustration of the working of the chipless tag is given below. Suppose there are 70 different frequencies that are used to be tuned by the tags. Therefore a total of 2^{70} combination of RFIDs can be developed. Each tag is made to be tuned in a permutation of frequencies and thus each tag is unique.

The reader reads the reflected signal from the RFID tag and checks the Return loss or Reflection Parameters, thus obtaining an accurate and inexpensive solution for the RFID industry.

IV. SIMULATION RESULTS

The Simulation Results help us to understand the working of the RFIDs practically. The tags are embedded with SRRs as shown below. These periodic structures are embedded in RFID tags and have the frequency characteristics as shown in the figure

In the simulation 1, a 2×2 SRR matrix is taken and simulated for output characteristics. The output simulation is shown in simulation 3.It can be seen that there are four dips in the frequency response corresponding to the design of the SRR structure. Similarly, in simulation 2, a linear array of SRR structures are placed periodically and their output response is obtained. By simulation, we can deduce that there are dips at three frequencies corresponding to the design of the above parameters explained in the previous section. Thus, from the simulations performed in HP Advanced Design System 1.1, we can conclude that multiple frequencies, even in higher orders can be tuned. RFID tags can be produced in large quantities by permuting the frequencies randomly by varying the above parameters. Thus, a large number of unique RFID tags can be obtained from SRR configuration.

V. CONCLUSION

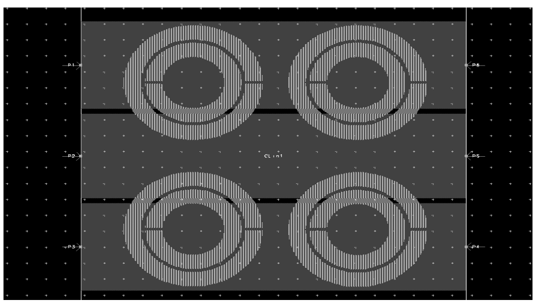
RFIDs are now playing an important role in our day to day life. Supply chain management is one of the most important areas in which the RFIDs can be used. The cost of RFIDs has always been a factor that the industry has always contended with. By forging ahead with chipless tags, the cost can be drastically reduced. These SRR configuration rings can be used to replace the microcontroller-based chipped RFID tags as a large number of such small tags can be produced in an inexpensive manner.

REFERENCES

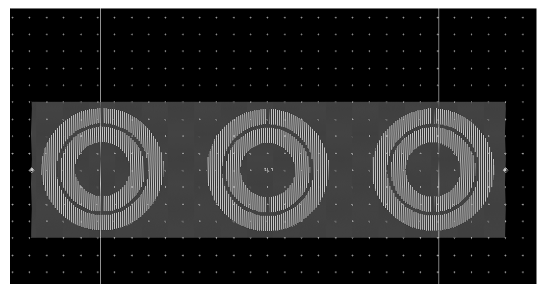
[1] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J.Stewart, IEEE Trans. Microwave Theory Tech. **47**, 2075 (1999).

[2] C.A.Balanis, *Antenna Theory,* 3rd edition, Wiley Interscience, 2005.

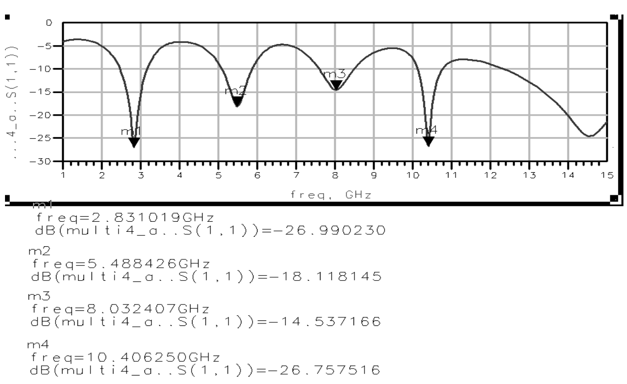
[3] Philippe Gay-Balmaz and Olivier J. F. Martin, Journal Of Applied Physics "Electromagnetic resonances in Individual and coupled split-ring resonators"



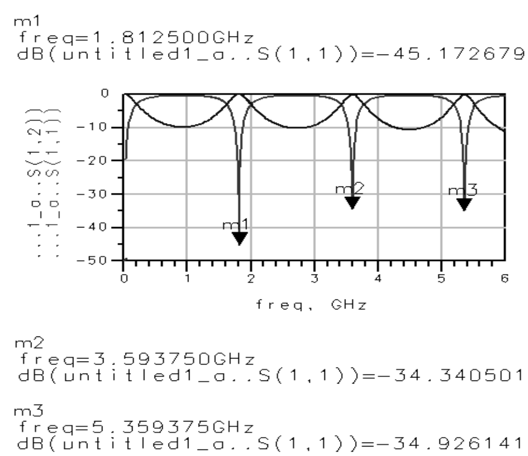
Simulation 1



Simulation 2



Simulation 3



Simulation 4