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REVIEW ON MULTI-RESONATOR BASED CHIP-LESS RFID SYSTEM

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ABSTRACT

This paper analyzes how Chip-less RFID works. Here, frequency domain technique of encoding and decoding is shown. Also the advantages, disadvantages of chip-less RFID are presented along with applications and future scopes for developing better tags. This literature portrays a possible design calculation expression for multi-resonator spirals. From a review perspective, this study emphasizes that chip-less RFID can be a promising solution for costly chip based RFID.

KEYWORDS: Chip-Less, Reader, Transponder, Multi-Resonators, Spiral.

INTRODUCTION

Radio Frequency Identification technique uses radio waves for capturing data without contact from long distance, and automatically identifies objects using those radio signals. It allows data transmission in faster and efficient way, without line-of-sight [2,5,8]. It is an emerging technology which can be used for identification, tracking and sensing applications [5,8,10].The data transmission occurs between an RFID transponder and an interrogator, better known as reader. RFID technology has been utilized for low-cost implementation, but for using in large amount of paper or plastic items, the price is high due to on-chip Application Specific Integrated Circuit (ASIC) [2,8]. So, the demand for low-cost RFID system is increasing which has resulted in generation of on-chip passive tags [1].

Some successful implementations of chip-less RFID tags are Surface Acoustic Wave (SAW) tags, space-filling curves and capacitive tuned dipoles. But the most efficient printable solution for chip-less transponders utilizes multi-resonators and cross-polarized ultra-wideband (UWB) monopole antennas [2]. The multi-resonator circuit utilizes integrated passive components like resistors, inductors and capacitors which are easy to model. Inductors have been practically implemented using planar spiral structure like square, hexagonal, octagonal and circular structures. Of these square spirals are preferred for their easier layout. These spiral structures can be implemented using lumped circuits, and requires proper expressions for accuracy [1,6].

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Multi-turn spiral particles are better than SRR (split-ring resonators) because of reduced size for higher frequency range such as 1-5 GHz [4]. These spiral resonators are used for data encoding and changing the dimensions of each resonator changes its frequency [1,5,7,8].

RFID systems are application specific and used in different bands [2]. There are mainly four frequency bands where RFID system ranges, Low Frequency (LF): 125 kHz, High Frequency (HF): 13.56 MHz, Ultra High Frequency (UHF): 860-960 MHz and microwave: 2.45 GHz. Of these, UHF RFID technology is broadly used [5].

This paper is organized as follows. Section II presents the literature surveys of different papers. A brief theory about chip-less RFID system is presented in section III. Section IV describes a possible design parameter calculation for multi-resonator spirals. Section V, VI, VII and VIII convey the advantages, disadvantage, application and future scopes of chip-less RFID system respectively followed by a conclusion in section IX.

LITERATURE SURVEY

Mohan *et al.* discussed aboutmany types of spiral resonators (square, hexagonal, octal and circular) and expressions for inductance of these resonators [1].

Preradovic *et al.* introduced a fully printable chip-less RFID system for low-cost item tracking and also discussed the concept of multi-resonators and frequency signature technique in this regard [2].

Hadi *et al.* represented the designing procedure and fabrication of a coaxial-fed rectangular spiral microstrip antenna for Wi-Fi application and analysis of various parameters of the antenna like return loss, S11, voltage standing wave ratio, line impedance and radiation pattern [3].

Nemer *et al.* discussed about the spiral with multi-turns which has reduced surface area in comparison to other resonant particles at the resonance frequency. To model the resonant frequency of a multi-turn spiral the non-uniformity of the current on the spiral is taken in concern [4].

Mostafa *et al.* presented a model of a spiral RFID antenna along with a method of estimating the peak current and resonance frequency of the antenna [5].

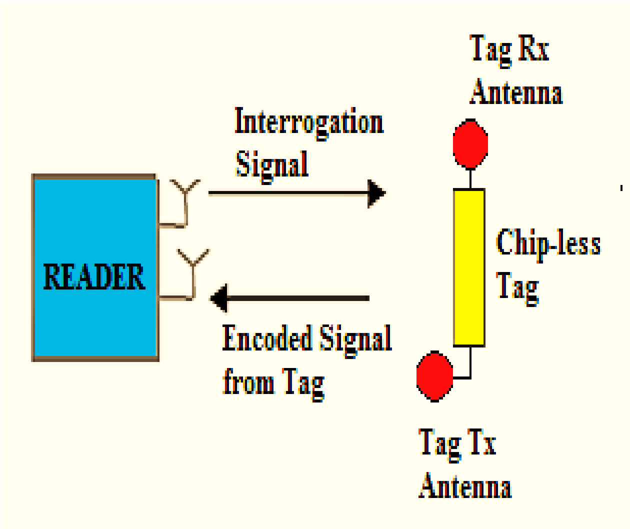

Figure 1.Block Diagram of Chip-less RFID System

Ellstein *et al.* discussed about circuit model of a single layer and a double layer spiral which can predict some of the higher resonant frequencies of the spiral resonators [6].

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Santos-Souza *et al.* represented a numerical study to demonstrate the frequency guard band impact in the design of spiral resonators coupled in 50Ω microstrip line for encrypting Chip-less RFID Tags in S-band [7].

Habib *et al.* discussed about fully printable chip-less RFID tag for encoding data and it can be integrated with a sensor to make it suitable for use in sensing applications [8].

Ammouri *et al.* presented a spiral planar inductor based physical model along with its characteristics in time and frequency domain and analyzed the parameters like inductances and capacitances of the model [9].

Manekiya *et al.* discussed about quantile regression algorithm to correctly retrieve the tag information under different noise conditions for improving detection capabilities of a chip-less RFID system [10].

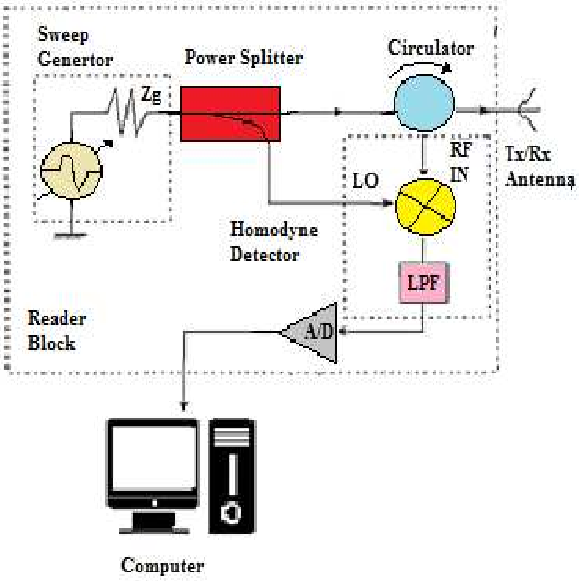

Figure 2.Block Diagram of Reader Section

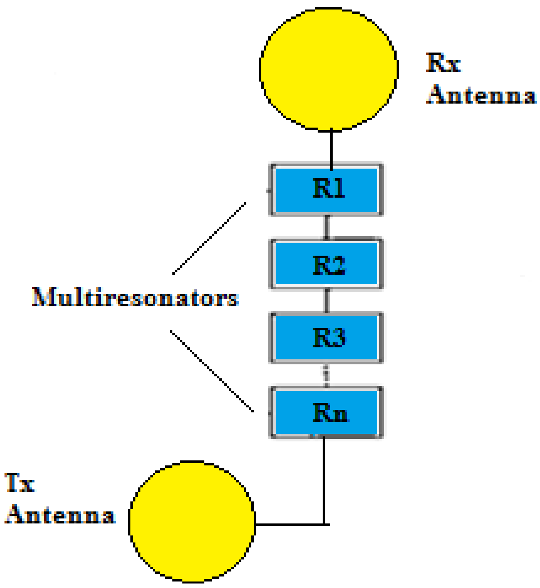

Figure 3.Block Diagram of Tag Section

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THEORY

In chip-less RFID system, there are two major sections which take important part.

- Reader Section
- Tag Section

The tag will be powered by a portion of the energy radiated by the reader section. To transmit the information it contains, it will create an amplitude modulation or phase modulation on the carrier frequency. From reader to tag, the process is symmetric. The reader transmits data by modulating the carrier. The modulations are analyzed by the chip and digitized [5]. A block diagram of a chip-less RFID system is illustrated in Fig. 1.

READER SECTION

The reader contains a sweep signal generator, a power splitter, a circulator, a mixer, a low pass filter, and an analog to digital converter. The mixer mixes the decoded RF signal, and a low pass filter eliminates the high-frequency components. This mixer with the low-pass filter implements a homodyne detector mandatory to retrieve the signal correctly [10]. A block diagram of reader section is presented in Fig. 2.

When the RF signal impinges on the receiving tag antenna and propagates further towards the resonating circuit, cascaded spiral resonators produce phase frequency jumps at particular frequencies of the spectrum, which encode the data bits. Later, when the signal has been passed through the resonating cascade resonators, the unique spectral signature of the tag is transmitted back by means of the transmitter antenna tag [10]. The spectral signature is achieved by cross-examining the tag by a multi-frequency interrogation signal by the reader. The tag thus retransmits the received interrogation signal and encrypts the information into the frequency spectrum in both amplitude and phase [2]. This re-transmitted encrypted signal is detected and offered to the reader [10]. This allows the reader to use two criteria for data decoding-amplitude and phase [2]. The reader receives this data and converts them into binary (0 or 1)[5].

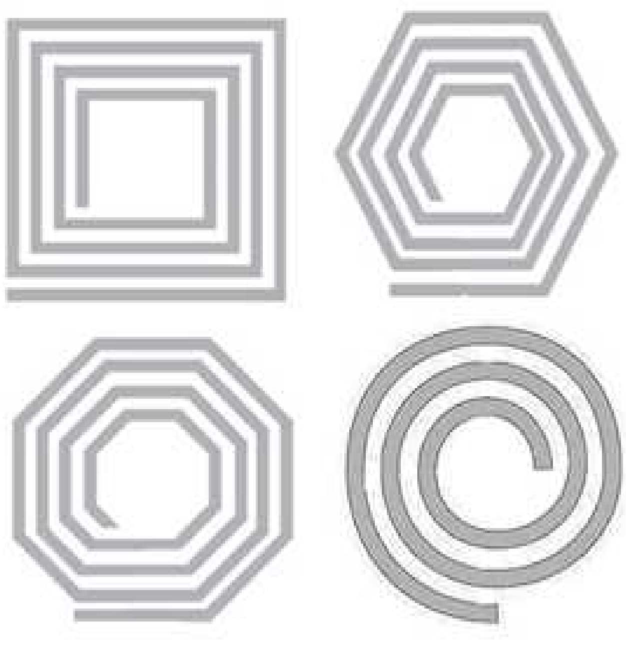

Figure 4.Designs of Different Spirals

TAG SECTION

A tag section comprises two main elements, spiral resonators, and two antennas. Multiple spiral resonators are used to encode data where each resonator corresponds to one bit [2, 7, 10]. All the resonators are in cascade form and they are connected with circular polarized antennas. The distance between the reader and tag is defined as the operative range at which information is correctly retrieved from the tag by the reader [10]. A typical block of tag section is given in Fig. 3.

The interrogating signal by the reader is used to excite the tag. The data is encoded in the desired frequency spectrum by the tag using multi-resonator structure. Resonators produce phase frequency jumps or stop bands at particular frequencies of the spectrum, which encode the data bits [2, 10]. Hence the multi-resonator circuit works as a multi-stop band filter [2]. Thus the chip-less transponder shows a unique ID and yields a spectral signature in particular frequencies [2]. The tag then retransmits the received interrogation signal which holds the encoded data in the frequency spectrum in both amplitude and phase [2]. The reader then detects attenuation and phase ripple introduced in the transmitted interrogation signal due to the stop bands and identify the corresponding encoded bits. In order to provide isolation between the transmitting and receiving signals, the reader and tag antennas are cross-polarized [2].

There are four famous designs of spiral resonator. Those are-square, hexagonal, octagonal and circular [1, 9]. The designs are given in Fig. 4.

POSSIBLE TAG DESIGN

The Tag For Chip-Less RFID Can Be Designed Using Different Mechanisms. Different Spiral Resonators Can Be Used As Multi-Stopband Filter. Some Popular Designs Are Presented In Fig. 4.

To design a tag, we need to take account for a feed line and a set of multi-resonators [2]. The feed line is fed by the circularly polarized antenna. Then the feed line couples the resonators by electromagnetic coupling. For this to happen efficiently, the feed line should have characteristic impedance of 50Ω [7]. Then the particular resonator resonates about a particular frequency depending on the total length of the spiral. So, multiple resonators have distinct lengths.

Most of the designs are done with rectangular spirals as it is simple and can be fabricated easily [10]. A design of a single resonator with feed line is given in Fig. 5.

The notations on the Fig. 5 denote different design parameters. The width of the microstrip line is W_0, $D_{gap}$is the gap between the resonator and feeding line, and the width of the spiral conductor is W_{sp}. The separation between the spiral conductors is D_{sp}, the length of the spiral resonator isL_{sp}. L_1 and L_2 are the distance between the resonator and ports [10].

The design parameters and the layout calculation of the microstrip spiral resonator are defined as follows.

$$L_{tot} = \frac{\Psi + 1}{2} L_{sp} + \frac{\Psi - 1}{2} D_{sp} \quad (\Psi\ Odd)$$

$$L_{sp} \approx \frac{\lambda_m - (\Psi - 1) D_{sp}}{\Psi + 1}$$

$$f_{res} = \frac{c_0}{[(\Psi + 1) L_{sp} + (\Psi - 1) D_{sp}] \sqrt{\varepsilon_e}}$$

Where, L_{tot}=Total length of spiral, Ψ=Number of the spiral resonators sides, λ_m=Wavelength, c_0=Velocity of light in free space, ε_e=Effective Dielectric constant of substrate, f_{res}=Resonant frequency [10].

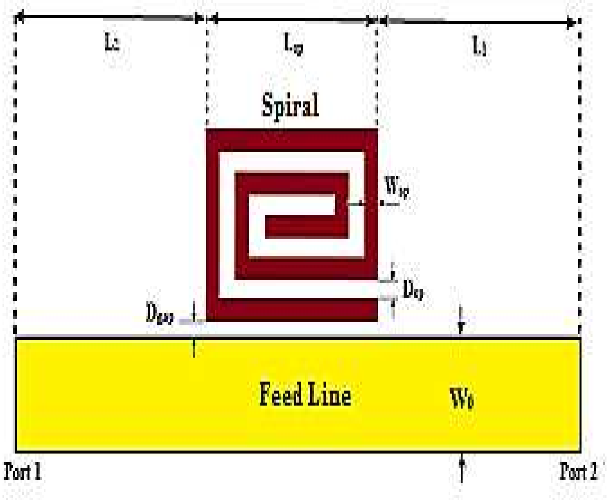

Figure 5.Design of Single Resonator with Feed Line

ADVANTAGES

- Chip-less RFID tags and transponders use passive components, which leads to low manufacturing cost [1,2,5,8,10].
- They can be easily implemented on low-cost materials such as paper, plastic and others [2].
- Radio Frequency Identification technology is much faster and efficient than other identification technologies [5,10].
- UHF RFID provides greater range and high data rate [5].
- No line of sight is required for detection [8].

DISADVANTAGE

One of the disadvantages for chip-less RFID design could be the occurrence of spurious resonances which are undesirable. This could cause error while reading the unique ID. To avoid this situation, it is necessary to establish a minimum frequency guard band value between the resonances for each type of chip-less RFID Tag [7].

APPLICATIONS

- Chip-less RFID tags can be used on banknotes, tickets, postage stamps, envelopes as cost is low [2].
- It can be used in radio technologies and wireless networks such as Wi-Fi [3].
- It can be used for identification purpose such as contactless smartcard, parking and building access control, highway tolls, etc. [5, 8].
- Radio Frequency Identification (RFID) system can also be used for tracking purpose like human monitoring, health monitoring, goods tracking in shops and supermarkets, library books tracking [8,10].
- It can also be implemented in different sensors for sensing applications such as temperature and humidity sensors, moisture and gas detectors, strain sensor, light sensors, metal crack detector [8,10].
- RFID is also useful for Internet of Things (IoT) applications [10].

FUTURE SCOPES

- Future research will be focused on better accuracy of reading and RFID reader development with anti-collision protocols [2].
- In future, to reduce the ultimate cost of RFID system, the tag can be implemented using flexible plastic substrates [2, 8].

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- Further, better process detection of peaks in noisy environments will be implemented by the designers [10].
- Number of bits can be increased in future by further optimization of design. Also, bandwidth utilization can be made more efficient [8].

CONCLUSION

In this paper we have portrayed a chip-less RFID system, which can be used for tracking items such as note bills, envelopes and other products. The operating system uses multi-resonators to encode data into spectral signature. In case of resonance frequency, the use of multi-turn spirals reduces the surface area occupied by the resonant particle. The issue in adopting RFID technology was its cost but with the advancement of 'GREEN ELECTRONICS', the use of passive chip-less RFID tags in various applications have increased rapidly.

Currently we are working on such chip-less RFID design using spiral resonators and substrates as plastics, paper etc.

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REFERENCES

[1]. Sunderarajan S. Mohan, Maria del Mar Hershenson, Stephen P. Boyd, and Thomas H. Lee, "Simple Accurate Expressions for Planar Spiral Inductances," IEEE Journal Of Solid-State Circuits, Vol. 34, No. 10, pp. 1419-1424, October 1999.

[2]. Stevan Preradovic, Isaac Balbin and Nemai Chandra Karmakar, "Multiresonator-Based Chipless RFID System for Low-Cost Item Tracking," IEEE Transactions On Microwave Theory And Techniques, Vol. 57, No. 5, pp. 1411-1419, May 2009.

[3]. N. H. Abdul Hadi, K. Ismail, S. Sulaiman and M. A. Haron, "Design of a Rectangular Spiral Antena for Wi-Fi Application," International Conference on Advanced Communication Technology, pp. 30-34, February 2011.

[4]. S. Nemer, B. Sauviac,B. Bayard, C. Nader, J. Bechara, and A. Khoury, "Modelling Resonance Frequencies of a Multi-turn Spiral for Metamaterial Applications," Progress in Electromagnetics Research C, Vol. 20, pp. 31-42, February 2011.

[5]. Makroum El Mostafa, Rifi Mounir, Latrach Mohamed and Benbassou Ali, "Simplified Design Approach of Rectangular Spiral Antenna for UHF RFID Tag," Recent Researches in Telecommunications, Informatics, Electronics and Signal Processing, pp. 17-23, May 2011.

[6]. David Ellstein, Bingnan Wang, and Koon Hoo Teo, "Accurate Models for Spiral Resonators," European Microwave Conference, pp. 787-790, October 2012.

[7]. Gilberto T. Santos-Souza, Andreia Ap. de C. Alves, Leonardo L. Bravo-Roger and Hugo E. Hernandez-Figueroa, "Numerical Determination of Frequency Guard Band Resonances for Chipless RFID Tags, IEEE Brasil RFID, pp. 10-12, September 2014.

[8]. Ayesha Habib1, M. Ali Afzal, Haleema Sadia, Yasar Amin and Hannu Tenhunen, "Chipless RFID Tag for IoT Applications," IEEE 59th International Midwest Symposium on Circuits and Systems, pp. 1-4, October 2016.

[9]. Aymen Ammouri, Tarek Ben Salah and Herve Morel, "A Spiral Planar Inductor: An Experimentally Verified Physically Based Model for Frequency and Time Domains," International Journal of Numerical Modelling: Electronic

Networks, Devices and Fields, pp. e2272, June 2017.

[10]. Mohammedhusen Manekiya, Massimo Donelli, Abhinav Kumar and Sreedevi K. Menon, "A Novel Detecion Technique for a Chipless RFID System Using a Quantile Regression," MDPI Journals, Vol. 7, Issue. 12, Art. 409, December 2018.

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