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PARAMETRIC STUDY ON UWB IMPULSED INTERROGATION BASED CHIPLESS RFID TAG

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ABSTRACT

The ultra-wide band passive RFID system is receiving a great consideration for the researchers with the aim of substituting the conventional barcode system. The dimension of the chipless tag still rests as a big question that makes the use of tagging the object difficult as well as costly. Different backscattered signal with time delay can successfully be read which is generated from the conventional UWB chipless tag by impulse interrogation signal instead of continues chirp signal. This approach can reduce the dimension of the tag, but it is still challenging to obtain a useful size by reducing further and to make comparable to cost of a barcode. In this paper, approaches have been made to find out the proper dimension of the tag with the help of CST MWS. The relation between the patch length and the substrate length has been established and hence the tag dimension is determined as 81.4mm × 81.4mm.

Keywords: UWB, RFID, barcode, CST MWS.

INTRODUCTION

The term RFID is a kind of technology that uses the radio frequency (RF) for the objects' identification. An RFID system mainly consists of two prominent parts: the tag and the reader that is mainly on the basis of the type or nature of the tag. On the basis of the power supply, the tag can be divided into three types: i) Active, ii) semi-active/passive and iii) passive. The active type tags have a battery on board to power it and acts like a bacon. The semi-active/passive types also have battery on board, only to power the chip/memory circuitry but need the reader interrogation signal power to transmit back the signal. The passive types have no battery on board, and fully dependent on the reader's signal to transmit the interrogated signal to the reader for identification. The passive type can either have a chip on board or can be chipless.

The RFID systems have few dedicated ISM bands for tag- reader communication [1]. The current necessity of very high speed tracking of the items for toll collection purpose and auto-surveillance systems encouraging the researchers for using the Ultra Wide Band (UWB) range (3.1 GHz-10.7 GHz) which is well-defined by FCC. This frequency band for communication in RFID is under research and not commercially deployed yet. There are few methods that have been proposed for the detection of chipless UWB tags in the recent years: CWT (Continuous Wavelet Transform) based tags, Micro strip Resonator tags and SAW (Surface Acoustic Wave) tags [2-4]. All those proposed methods are on the basis of the backscattered modulation in which, the tag receives the reader's interrogation signal, alters some properties of that received interrogation signal and reflects back that altered signal to the reader to identify object or products.

Research on chipless RFID tags can be broadly classified into two main categories: time-domain reflectometry (TDR)-based chipless RFID and frequency-signature-based chipless RFID. In TDR-based tags, the RFID reader transmits an ultra-wideband (UWB) RF interrogation pulse and listens to the reflections or echoes coming back from the tag [5-10]. By varying the structural properties of the tag, the time of arrival of these echoes can be controlled, providing a method for passive data storage in the tag. In frequency-signature-based chipless RFID tags [11-12], the frequency spectrum of the interrogation signal sent by the RFID reader is transformed by the tag to represent data bits. Most of the researchers on these frequency signature or frequency-spectra-based tags use planar microwave circuits to realize these transformations in the amplitude or phase spectra of the backscattered signals. In this approach the reader sends a continuous linear chirp signal with constant amplitude and receives the backscattered signal from the tag with dips in amplitude or phase corresponding with the tuned resonating frequencies.

In [13], authors have proposed a new tag which includes multiple patch antennas instead of multi-resonator. They have used the UWB impulsed interrogation technique to read the UWD tag. The system is described below in Figure-1,

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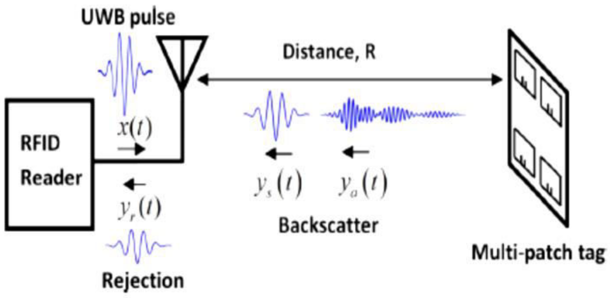

Figure-1. Multi-patch tag-reader system.

From Figure-1 it can be seen that the reader sends an UWB interrogation pulse to the multi-patch tag. When the reader antenna gets the tag's back scattered signal, at first the antenna rejection y_r (t), the second received signal is the backscattered signals from the tag that consists of two different backscattered signal; structural mode, y_s (t) and tag antenna mode, y_a (t). The total received signal can be written as the Equation (1).

$$y(t) = y_r(t) + y_s(t) + y_a \quad (1)$$

The antenna rejection is not relevant for the analysis because this is due to the mismatch profile of the reader antenna. Also, y_s (t) is not relevant since it only contains the structure information of the tag. The last received signal y_a(t) contains the antenna mode information of the tag (that comprises four patch antennas). From the time domain representation it is impossible to extract any information from the tag but if the signal is represented in the frequency domain by using Fourier Transform there will be as many picks as there the numbers of patch antennas on the tag and with the number of picks, the number of bits can be extracted.

Though the tag detection method is well described and understood, the dimension of the tag is not well described, only the patch dimensions are given in [13]. In this paper an approached has been made to make a parametric study on the multi-patch tag.

PARAMETRIC STUDY

Referred to [13] the designed tag has four patch antennas tuned in different frequencies, 4.64GHz, 5.16GHz, 5.8 GHz and 6.2 GHz, shown in Figure-2.

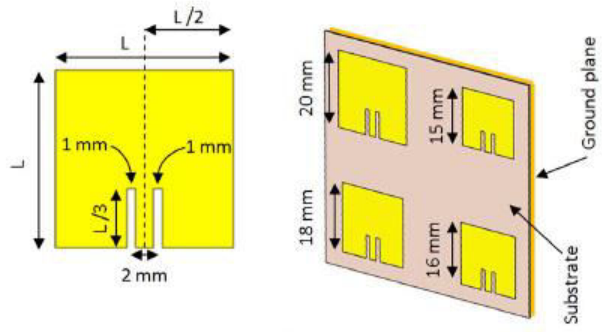

Figure-2. Multi-patch tag.

Though the dimensions of the patches are stated properly but the total size (width and length) of the tag is not stated. So, at first each of the antennas is re-designed and simulated is CST MWS. The layout of the patch antenna in the simulator is shown in Figure-3.

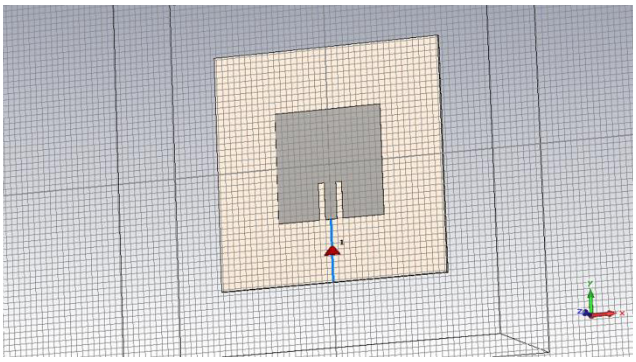

Figure-3. Layout of the patch antenna tag in the simulator.

The antenna is considered as a PEC (perfect electrical conductor) with a thickness of 0.035mm. The substrate is Taconic TLX-8 with $\varepsilon_r = 2.66$ and the thickness is 0.5mm. A ground plane is also placed under the substrate as PEC with the thickness of 0.035mm.

The width (W) and the length (L) are kept the same as the parametric sweep is performed with the simulator. The width and the length have been changed arbitrarily until the best possible S_{11} results have been attained. Table-1 summarizes the suitable values of width and length of the patch tag, for the specific frequency.

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Table-1. Dimensions of the patch and substrate.

Frequency (GHz)	**Patch** (W or L)	**Substrate** (W or L)	**Ratio** (K)	S_{11}
4.64	20.1	44	2.19	-33.7dB
5.16	18.1	39.1	2.17	-37 dB
5.8	16.075	34.75	2.16	-30.1dB
6.2	15	32.65	2.18	-31.6dB

Table-1 discloses the proper dimensions of the single patch tag in different frequencies. It can be seen that the ratio between substrate (W or L) and patch (W or L) is fairly constant regardless of the change in the tuned frequencies. If the ratio is kept for any UWB single patch tag, the best possible S_{11} results can be obtained. Any deviation of that value can cause comparatively bad S_{11} response.

Since the goal is to find the proper dimension of the multi-patch tag, all the four different single patch tags are needed to be integrated in a single tag to make it multi-patch tag with four bits. Figure-4 shows the layout of the multi-patch tag in the simulator and Figure-5 shows the S_{11} response of the design.

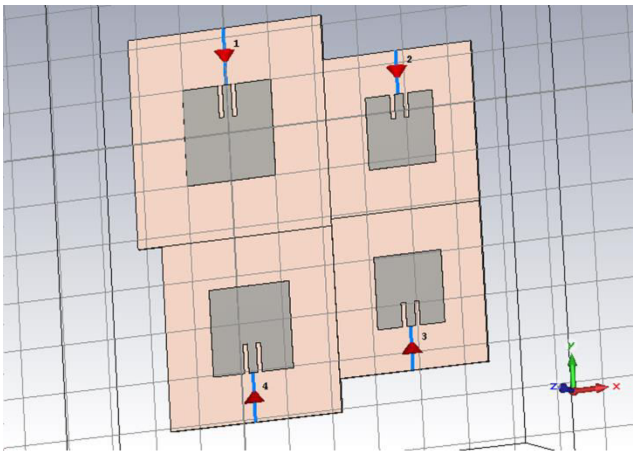

Figure-4. Layout of the multi-patch tag in the simulator.

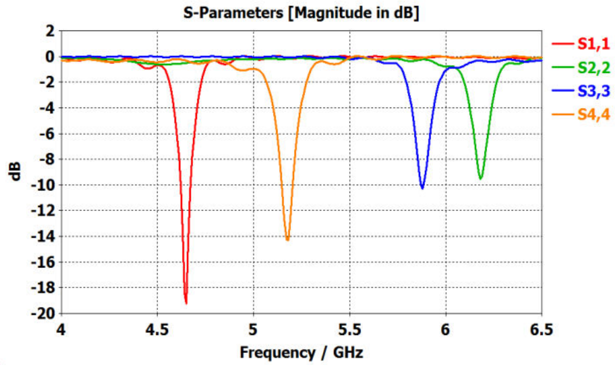

Figure-5. S-parameter results of the multi-patch tag.

As it can be seen from Figure-4, the single patch tags are added together to form the multi-patch tag. The dimensions are kept the same as Table-1. Four different ports have been introduced in the simulator to get four different S- parameter results for different frequencies and are shown in Figure-5. It can be seen that there are four resonances in the plot at 4.64, 5.16, 5.8 and 6.2 GHz. If the dB values of the S-parameter response of the tag are compared with Table-1, it can be seen that there is big difference for the tuned frequencies. This is because when the individual antennas are added together the ratio of the width and length is deviating from its constant value and mismatch occurred. To determine the proper dimensions of the tag another parametric sweep is needed to be done. To do so another variable has been declared as, 'd' which is the distance between the patches. Figure-6 illustrates the scenario.

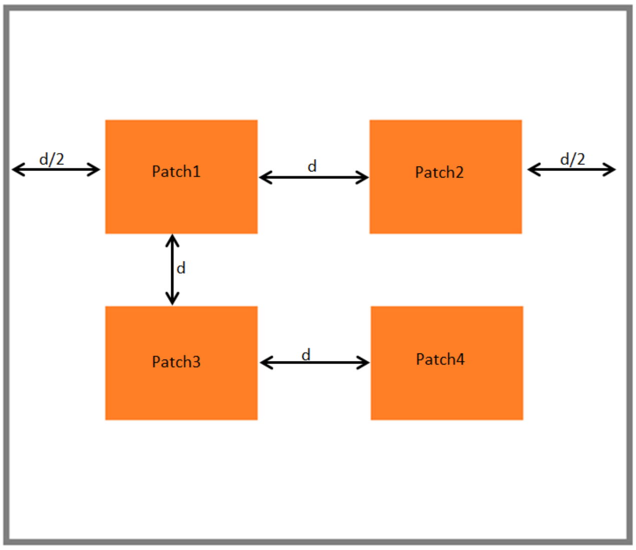

Figure-6. The Significance of the variable 'd'.

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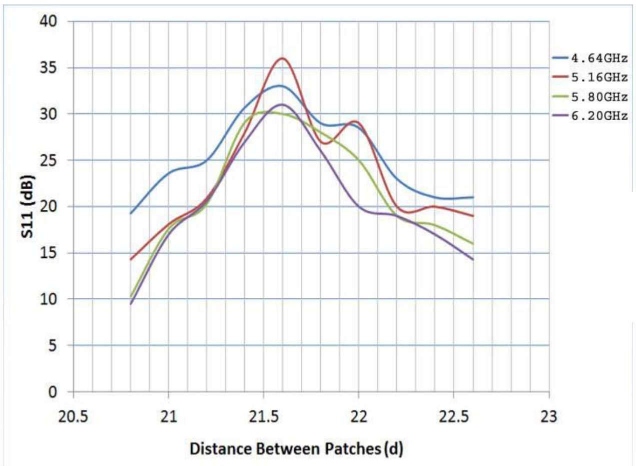

Figure-7. S-parameter Vs distance (d) between the patches for different frequencies.

In the Figure-7, the horizontal line is the distance (d) between the patches and vertical line corresponds to the S_{11} response. After given different parametric sweep, it can be seen from the Figure-6 that for d = 21.6 mm the S_{11} response is comparatively better than other d values. The S_{11} results for the d=21.6mm is shown in Figure-8.

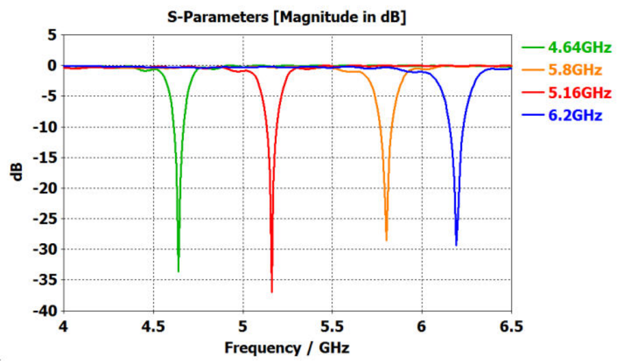

Figure-8. S_{11} response for d = 21.6 mm.

From Figure-8, it can be seen that the results of the S_{11} are very close to the Table-1 values. Therefore, it can be concluded that with the distance of 21.6 mm of the patches from each other gives the optimum response for the tag's S_{11} response (matching). So, with this distance the tag dimension becomes 81.4mm × 81.4 mm (by following Figure-6).

CONCLUSIONS

Two different types of analysis with a single patch tag and a multi-patch tag have been successfully carried out. In the single patch, the S_{11} response remains unchanged and optimum for a ratio if the ratio between the dimensions of the substrate and the patch is constant (~2.17). It is also found that for the multi patch, the distance between the different patches has been swept to get the optimum S_{11} response. The distance of 21.6 mm gives the optimum S_{11} response and hence the tag dimension has been determined as 81.4 mm × 81.4 mm for the 4-bit impulsed interrogation based tag.

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