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Rectangular Microstrip Patch Antenna Array for RFID Application Using 2.45 GHz Frequency Range

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Abstract- In this paper ,a microwave frequency band 2x2 microstrip phased antenna array is designed for an RFID reader system. The main focus will be on optimizing of dimensions of patch antenna for RFID application with resonance frequency of 2.45 GHz. In this paper we discuss the microstrip patch antenna, feeding techniques and phased array antenna with their advantage and disadvantages over conventional microwave antennas. The phased antenna array is used as the receiving antenna in a commercial reader system; experimental results indicate that the coverage of the RFID system with the phased array antenna is superior to with a conventional broader beamwidth microstrip patch antenna. Different parameters of antenna like VSWR, return loss and radiation pattern are calculated using MATLAB coding and hence their graphs are plotted in accordance with the simulated results using SONNET software. Moreover the antenna achieved and measured demonstrates a good agreement between simulation and typical results.

Index Terms- Microstrip Phased Array antenna, Microwave-band, RFID, Microstrip Patch Antenna, SONNET Simulate

I. Introduction

The Radio Frequency Identification (RFID) technique is supported by Wal-Mart and is becoming one of the most popular wireless communication techniques in the world. RFID has several benefits relative to traditional bar-code technique such as non-contact reading, longer reading range, anti-pollution property, longer lifetime and larger carrying information capacity. In general, RFID systems can be classified into three different types by operating methods which are passive, semi-active and active system. There are different operation frequency and standards in different countries. The common operation frequencies include 125 kHz in LF band, 13.56MHz in HF band, 915MHz in UHF band, 2.45GHz and 5.8GHz in microwave frequency. The RFID technology is a means of gathering data about a certain item without the need of touching or seeing the data carrier, through the use of inductive coupling or electromagnetic waves. The data carrier is a microchip attached to an antenna (together called transponder or tag), the latter enabling the chip to transmit information to a reader (or transceiver) within a given range, which can forward the information to a host computer. In order to extend the coverage area of the RFID system, one may implement many readers and antennas with small reading ranges to cover the monitoring area, or use high gain phased array antenna system for extended reading range of an RFID reader for a smaller number of total reader deployments. In this paper, a phased antenna array system is proposed for extending coverage range of an RFID system.

The microstrip patch antenna is one of the most useful antennas for low cost and compact design for RFID applications and wireless systems. The major drawback of microstrip patch antenna is the narrow bandwidth. An individual microstrip patch antenna has a typical gain of about 6 dBi.

In single element antenna, the radiation pattern is usually very broad and the directivity is relatively low. This problem can be solved by enlarging the size of the element thus increasing the directivity. Another way to enlarge the antenna without changing the size of the individual elements is to assemble the radiating elements in a geometrical configuration known as an “array”.

II. Microstrip patch antenna

A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photoetched on the dielectric substrate. Arrays of antennas can be photoetched on the substrate, along with their feeding networks.

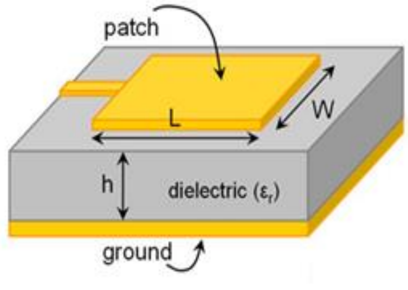

Figure 1 : A Typical Microstrip Patch Antenna

A.Feeding Method

There are many methods of feeding a microstrip antenna. The most popular methods are: Microstrip Line, Coaxial Probe (coplanar feed), Proximity Coupling, Aperture Coupling. Table-l shows different properties of different feeding mechanisms. Based on the properties in Table-l and also on the heritage, Line Fed in combination with Co-axial fed probe is used for design purpose since it provides better matching and wide bandwidth and low feed radiations.

Table I: Microstrip Feeding Mechanisms Properties

Characteristic	Line Feed	Probe Feed	Aperture Coupled Feed	Proximity Coupled Feed
Feed Radiation	Less	Less	Less	Minimum
Reliability	Better	Good	Good	Good
Ease of Fabrication	Easy	Soldering Required	Alignment Required	Alignment Required
Impendence Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	2-5%	13%

B.Phased Array Antenna

Phased array antenna is a multiple-antenna system.In order to achieve higher directivity and additional gain, antenna elements can be arranged to form linear or planar arrays.Consist of multiple antennas (elements) 'collaborating' to synthesize radiation characteristics not available with a single antenna.They are able to match the radiation pattern to the desired coverage area and to change the radiation pattern electronically through the control of the phase and amplitude. In addition, they are used to scan the beam of an antenna system, increase the directivity, and perform various other functions which would be difficult with any one single element. The elements can be fed by a single line or by multiple lines in a feed network arrangement. There are three types of array;liner array,planner array and conformal array.

III. DESIGN STEPS OF MICROSTRIP PATCH ANTENNA

A.Substrate Selection

Dielectric constant (εr) is in the range from 2.2 to14.εr of air, polystyrene ,dielectric honey comb is in the range from 0 to 2. εr of fiber glass reinforced teflon is in the range from 2 to 4. εr of ceramic,quartz,alumina is in the range from 4 to 10.Dielectric constant should be less than 4($\varepsilon r<4$) in order to get higher radiation efficiency and directivity.Heigh should be h<1.5mm for operating frequency less than 10 GHz. So the proposed system selects 1.5mm.

B.Calculate The Width Of The Patch

The selected parameters for the antenna design are as follows:

F_o = Operating frequency = 2.45GHz

ε_r = Dielectric Constant of the substrate

(here ε_r = 2.2 for duroid 5880 substrate)

h = substrate height = 1.5mm

$$W = \frac{c}{2F_0\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

Where, W =width of the patch

C =free-space velocity

ε_r =dielectric constant

C.Calculate The Length Of The Patch

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{h}{w}]^{-\frac{1}{2}}$$

$$L_{eff} = \frac{C}{2\, f_r \sqrt{\varepsilon_{reff}}}$$

$$\Delta L = 0.412h\frac{(\varepsilon_r + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_r - 0.258)(\frac{W}{h} + 0.8)}$$

$$L = L_{eff} - 2\Delta L$$

Where, ΔL = effective increase in length due to fringing effects
L =the actual length of the patch
L_{eff} =effective length of the patch
ε_{reff} = effective dielectric constant

By using the above equations, MATLAB GUI is created for patch dimensions calculation. Fig. 2 demonstrates the calculated parameters of rectangular microstrip patch using MATLAB GUI.

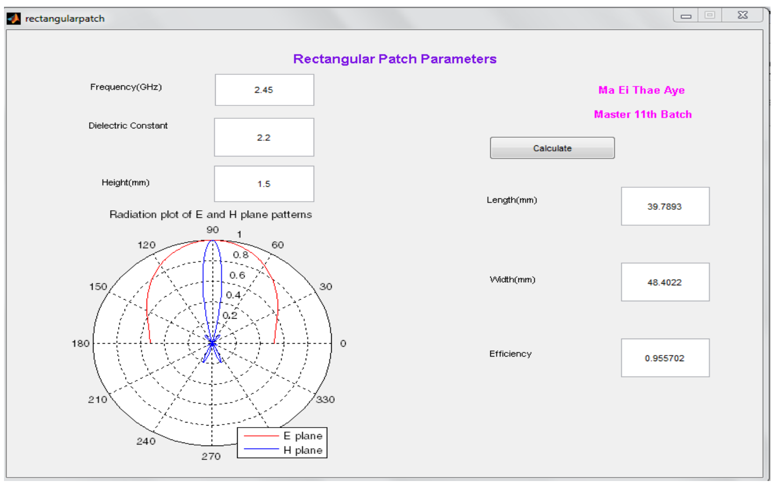

Figure 2: Matlab GUI for Patch Element Design Calculation

The parameters of Rectangular Microstrip Patch Antenna (RMSA) are calculated using MATLAB and the following table is obtained.

Table II:Parameters of Rectangular Microstrip Patch Antenna

Parameters	**Values**
Substrate Material	Duroid 5880
Relative Permittivity of the substrate	2.2
Thickness of the dielectric	1.5mm
Operating Frequency	2.45GHz
Length	39.7893mm
Width	48.4022mm
Efficiency	0.955702

IV. SIMULATED RESULTS AND DISCUSSION

The simulated results were obtained by considering an equivalent circuit of rectangular microstrip patch antenna using MATLAB for calculating various parameters. The designed parameters are utilized on SONNET software.

A. Return Loss

The S11 parameter for the proposed antenna was calculated and the simulated return loss results are shown in Figure 3. The value of return loss is -31.5224 dB in this proposed antenna. The achieved return loss value is small enough and frequency is very closed enough to the specified frequency band for 2.45 GHz RFID applications. The value of return loss i.e. -31.5224 dB shows that at the frequency point i.e. below the -10 dB region there is good matching. A negative value of return loss shows that this antenna had not many losses while transmitting the signals.

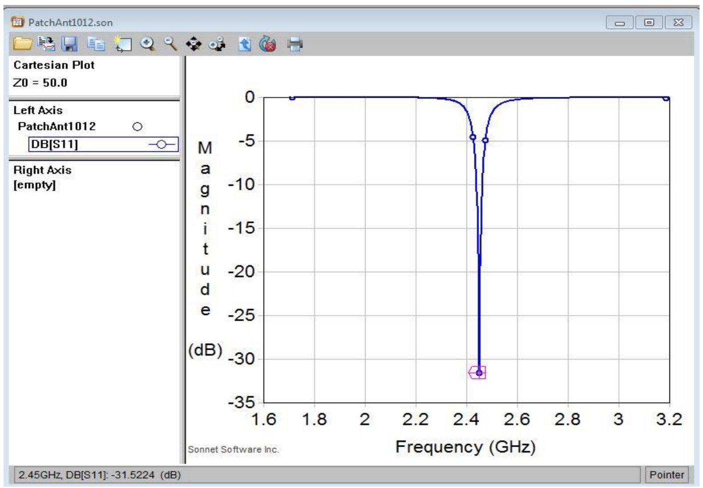

Figure 3:Return Loss

B. VSWR

The value of voltage standing wave ratio(VSWR) should be in the range between 1 and 2. The acceptable VSWR is 1.5. Fig. 4 shows that the value of VSWR is close to the ideal value of 1 and 2:1 VSWR Bandwidth = 0.89796 with the measurements that are provided.

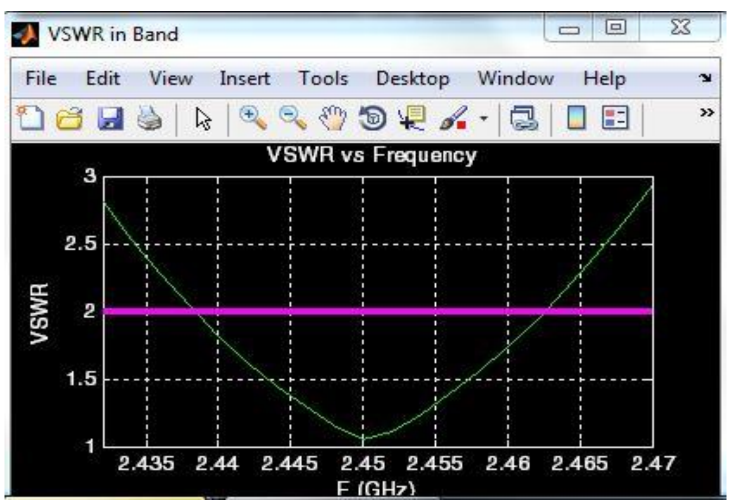

Figure 4: VSWR in Band

C.3D Gain

Radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. The antenna should not have the side lobes and back lobes ideally. We cannot remove them completely but we can minimize them. Microstrip antennas can provide directivity in the range of 6-9dBi. Figure 5 shows the simulated 3-D radiation pattern with directivity of 8.31 dBi for proposed antenna configuration at the resonating frequency of 2.45 GHz. 3-D radiation pattern with directivity of 8.31 dBi for proposed antenna is agreement with the typical value of the directivity in the range of 6-9dBi.

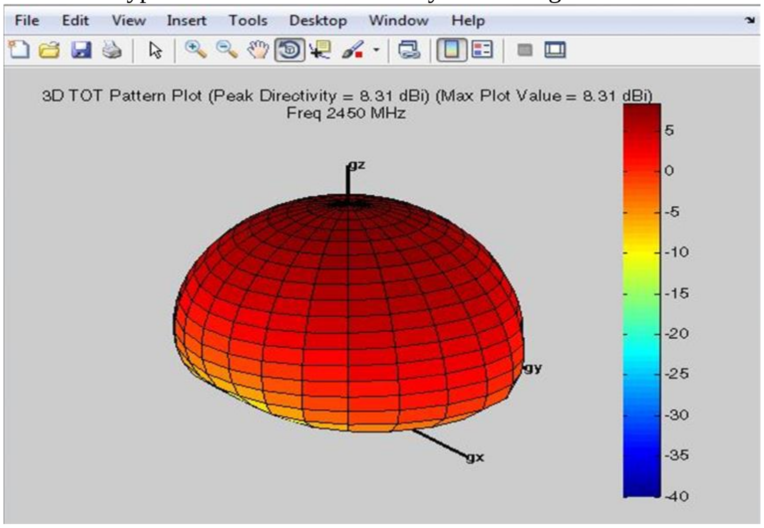

Figure 5: 3D Directivity and Gain

D.Antenna Spacing Pattern Of The Antenna Array

The element spacing has a large influence on the array factor as well. If element spacing is greater than 0.5λ ,the side lobe is big and grating lobes occur. A grating lobe is another unwanted peak value in the radiation pattern of the array. If element spacing is less than 0.5λ ,mutual coupling effects occur. To avoid grating lobes and mutual coupling effects, the patch spacing for this design was chosen as 0.5λ. In this paper ,a microwave frequency band 2x2 microstrip phased antenna array is designed for an RFID reader system.

E.Compare With 3D Directivity And Gain Of 0.5λ Spacing And 0.6 λ Spacing

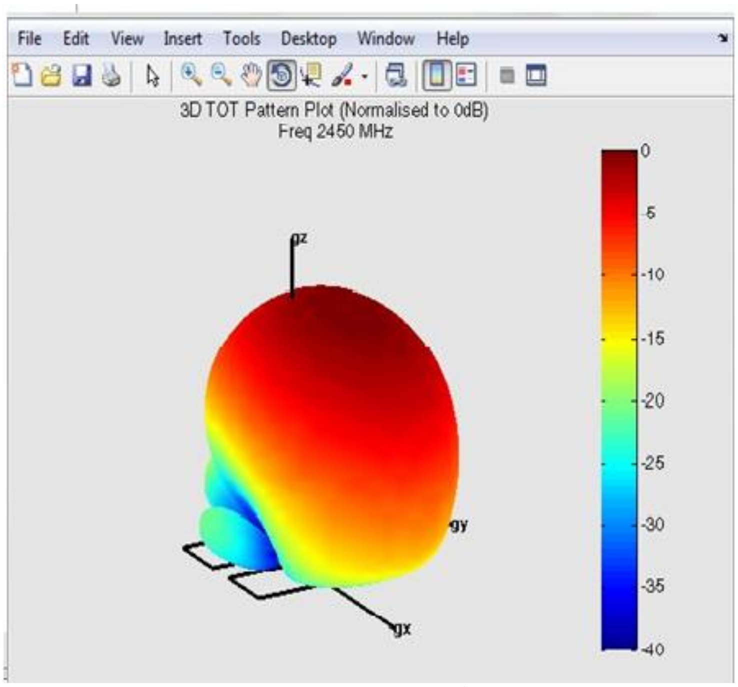

Figure6:3D Directivity Gain Using 0.5λ Spacing

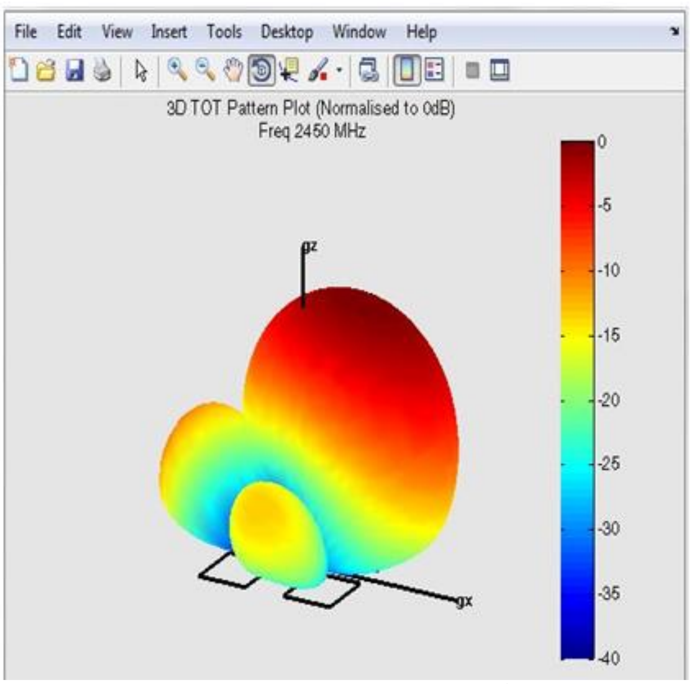

Figure7:3D Directivity Gain Using 0.6λ Spacing

In figure6,we find that if the patch spacing for this design was chosen as 0.5λ,we can avoid the occurance of grating lobes and the side lobes. In figure7,we find that if element spacing is greater than 0.5λ ,the side lobe is big and grating lobes occur.

F. Compare With Rectangular Plot Of 0.5λ Spacing And 0.6λ Spacing

If the side lobe level is less than -10dB or -15dB,the antenna performance is good. In figure8, we find that the side lobe level is -15dB. So the antenna performance is good. In figure 9, we find that the side lobe level is greater than -10dB.So the antenna performance is not good.

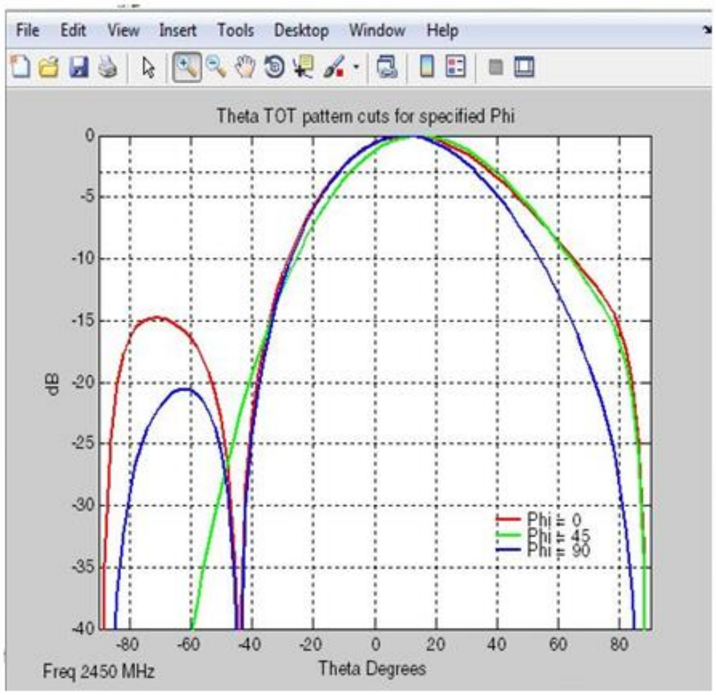

Figure8:Rectangular Plot of 0.5λ Spacing

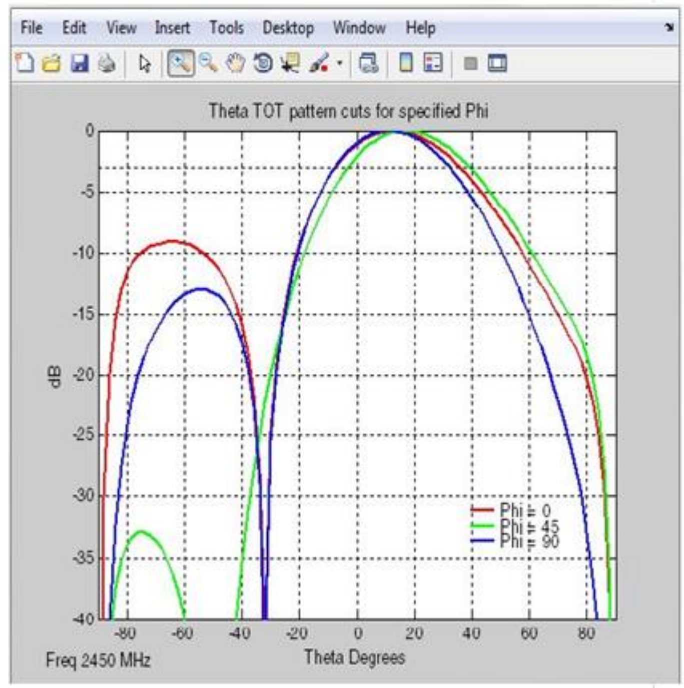

Figure8:Rectangular Plot of 0.6λ Spacing

V. Conclusion

This paper has been presented the design and performance analysis of Microstrip Phased Array Antenna for RFID system. Physical patch dimensions were calculated in MATLAB and SONNET antenna simulator software was used to implement the performance of the patch. The selected patches were arranged in planner array form for RFID application. 4 patch elements were selected to achieve high gain and good efficiency. This proposed antenna model is cost effiective, high efficiency and impact design for the applications in 2.45GHz frequency range. The optimum design parameters (dielectric material=Duroid 5880, height of the substrate=1.5 mm, operating frequency=2.45GHz) were used to achieve the compact dimensions and high radiation efficiency. It provides a gain of 8.31 dBi, 95.5702 percent efficiency and VSWR < 2 is achieved over the complete frequency band with linear polarization of antenna in the desired part of the beam.

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