Dual Polarized Reader Antenna Array for RFID Application

S. K. Padhi [1] N.C. Karmakar[2] and C.L Law[2]

1: Molecular Science Division, CSIRO, Bayview Avenue, Clayton, Melbourne, Australia, Email: shantanu.padhi@csiro.au

2: School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore

Abstract —This paper presents the design and development of a compact dual linearly polarized aperture coupled microstrip patch antenna array at S-band for RFID reader applications. The 2x2 array uses two symmetric *dog-bone* shaped coupling aperture. The prototype array yields 14.6 dBi peak gain, 36° half-power beam width (HPBW) in both E and H-planes, 28 dB cross-polarization levels and an isolation better than 35 dB between the two polarization at the designed frequency bandwidth. These performances make the antenna very much suitable for RFID reader applications.

Introductions: Now a days, there is a phenomenal growth in demand for wireless RF systems such as wireless local area network (WLAN), RFID and point-to-point communications systems. RFID systems are gaining popularity in manufacturing units, purchase departments, logistics and transportation etc., where identification is a prime concern. At present, some RFID systems operating at S-band (2.45 GHz) are commercially available; RFID systems operating in the next higher ISM band (around 5.8 GHz) are under active development [1]. There is a great commercial demand for RFID applications near 2.4 GHz. In these applications dual polarized shared-aperture antennas are preferred to reduce cost, size and complexity. For RFID application, it is desirable to have an isolation of more than 25 dB between the orthogonal ports. A good isolation also contributes in achieving a good axial ratio if the antenna is used to produce circular polarization. For microstrip patch antennas, aperture coupling [2-4] is preferred to other feeding mechanisms as it offers greater design flexibility such as compact size, less complexities and reduction in overall cost.

This paper presents the design and development of a shared aperture dual polarized aperture coupled microstrip patch antenna and array at C-band (5.8 GHz) and S-band (2.4 GHz) respectively. Two coupling apertures are placed in right angle under the radiating patch to generate two orthogonal modes. To obtain optimum return loss (RL) bandwidth and isolation the positions of the slots are varied. Upon achieving the desired performance the antenna was fabricated and tested in an anechoic chamber. The antenna design and its performances are presented in following sections. The unit antenna element can be used as a circular polarized antenna in RFID tag using an external polarizer as described in [5]. In this work, more emphasis was given to improve the isolation between the two orthogonal polarization (Tx and Rx).

Antenna Design: Initially, a shared-aperture dual polarized square patch antenna is designed, optimised and characterized at 5.8 GHz. A circularly polarized version of the antenna can be used as RFID tag antenna at 5.8 GHz. Having satisfied with the performance of the antenna a scale down model is used to design the 2x2 array for reader application at lower frequency. The design layout of antenna array is shown in Fig. 1. A corporate feed network is designed for the 2x2 array using two-stage Wilkinson power dividers to divide the power equally to each element. The configuration of the 2x2 antenna array is shown in Fig 1 (b). The array is designed in

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multilayer structures. As can be seen, the radiating elements (square patches) are etched on the top substrate and dual orthogonal apertures (dog-bones shaped) and feed lines are etched on top and bottom sides of the bottom substrate, respectively The parameters of the substrate materials are as follows: the patch and feed substrates are 0.79 mm thick TLX with dielectric constant (ε_r) of 2.45 and loss tangent ($\tan\delta$) of 0.0019. An air gap of height 3.00 mm ($\varepsilon_{r:}$: 1.00) is maintained in between the top (patch) and bottom (feed) layers. The thickness of air-gap, the length and positions of the coupling apertures are the prime parameters to determine the amount of power coupled to radiating elements. These parameters are optimised such that both radiating patch and the apertures resonate at close frequency. To increase the isolation between the two polarizations (Rx and Tx) both orthogonal apertures are pushed off vertically with respect to centre position. A corporate feed network is designed to make the (2x2) array. The inter-element spacings are chosen to be $d_x=d_y=0.72\lambda o$ to obtain the optimum gain and mutual coupling between the elements. The design and simulation of the structure are performed on Ensemble platform. After achieving satisfactory input impedance, return loss (RL), isolation, radiation patterns and gain, a prototype model is fabricated with the help of Quick Circuit milling machine.

Measurements and Discussions: The impedance characteristics of the array are measured with HP8510C Vector Network Analyzer (VNA). The far field radiation patterns and gain were measured in an anechoic chamber equipped with HP 8530A Microwave Receiver.

A. Return Loss:

The prototype design layouts of the unit antenna element and the array are shown in Fig. 1 (a-b). The width of 50-Ω transmission line used in the feed network is 2.27 mm. The ground plane size for the unit antenna element is (80x 80) mm^2. The antenna resonates close to 5.8 GHz with an impedance bandwidth (10 dB RL) of 15 % at 5.8 GHz. Similar resonance curve is obtained for both Rx and Tx polarizations. The isolation between the two polarizations is better than –35 dB in the frequency band. The measured S-parameter of the array is shown in Fig 2. As can be seen the array resonates at 2.42 GHz for both Rx and Tx polarization. The impedance bandwidth (10 dB RL) covers the frequency range from 2.38 GHz to 2.5 GHz (~5 % at 2.42 GHz) for both Tx and Rx polarization. The isolation between the two ports is better than 35 dB over the frequency band. These antenna performances are more than sufficient for any RFID application at S-band.

B. Radiation Pattern

The measured broadside co-polar and cross-polar E-pane and H-plane radiation patterns of the array for both polarizations (Tx and Rx) are shown in Fig.3 (a-b). The radiation patterns are directive and symmetric in both E- and H-planes. The measured radiation patterns agree well with the simulated ones. The measured cross-polar levels are 28 dB lower than the co-polar levels. Back radiations are also found as the coupling aperture radiates in backwards. The measured worst-case front-to-back ratio of the co-polar radiation patterns is around 10 dB. The back radiation can be suppressed with a metallic shield placed at a distance of quarter wavelength from the feed line. The 3-dB beamwidth (HPBW) of both E-pane and H-plane radiation patterns is approximately 36°.

C. Gain:
The gain measurement is performed on a HP-8530A Microwave Receiver with the similar set up for radiation pattern measurements in the anechoic chamber. The measured gain of the array is 14.4 dBi and 14.1 dBi for both Rx and Tx polarizations, respectively compared to calculated gain of 14.7 dBi and 14.56 dBi for both Rx and Tx polarizations. The simulated gain data for both array and unit element is shown in fig 4. The maximum variation of 0.5 dBi in gain is obtained in the frequency range of 2.4 to 2.5 GHz for the array, which is used for data communication. Similarly a variation of less than 0.4 dBi in gain is obtained in case of unit antenna element, in the vicinity of 5.6 to 5.9 GHz. The gain bandwidth is reasonable good for both unit antenna element and array in the respective frequency band.

D. Field Trial:
The array was incorporated in the reader module of *in-house* developed RFID tag set and a series of field tests was carried out to optimise the read/write range of tag set. A maximum range of 10 meters was obtained by using a passive tag.

Conclusion: The papers presents the design and development of a shared aperture coupled dual polarized square microstrip patch antenna and array for 5.8 GHz and 2.4 GHz frequency band. Two symmetric dog-bone shaped coupling apertures are used to excite two orthogonal modes. The array exhibited a maximum of 5% impedance bandwidth for both polarizations. A high isolation between the two orthogonal ports (Tx and Rx) of the order of 35 dB was observed over the frequency band of interest (2.4 to 2.5 Ghz). The measured radiation patterns are presented and the array yields the maximum gain of 14.4 dBi, 36° 3-dB beamwidth (HPBW) and 10 dB front-to-back ratio. The cross polar components are on average 28 dB below the co-polar level. The array was satisfactorily tested with an in-house developed RFID module. The read/write range was approximately 10 meter when used with a passive tag. High gain and high isolation between the two input ports make the array very much suitable candidate for RFID reader module for 2.4 GHz band.

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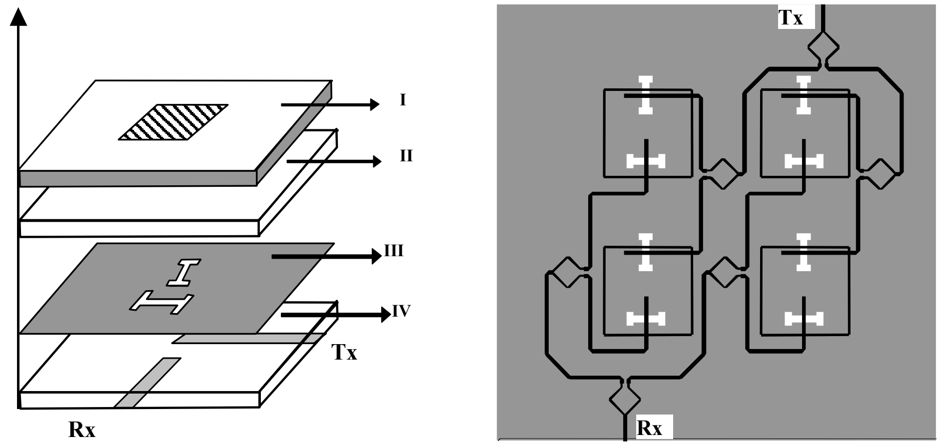


(a) (b)

Fig 1 (a) The geometry of unit element of array, (b) The top view of array. Dimensions: I: Patch (50x50) mm^2, II: Air gap h_2=3.5 mm, III: Ground plane, slot (R_x=T_x): (22x4) mm^2, slot width at edges: 8 mm, slot offset: 15 mm (R_x) and 23 mm (T_x), IV: bottom substrate, feed line width: 2.27 mm, Inter element spacing : d_x=d_y=0.72λo.

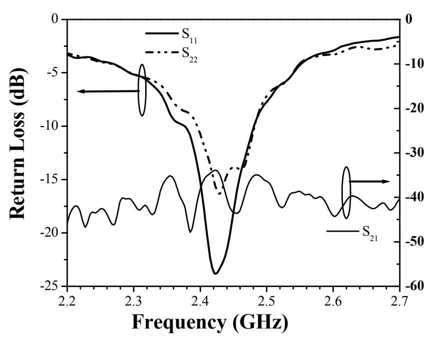


Fig 2

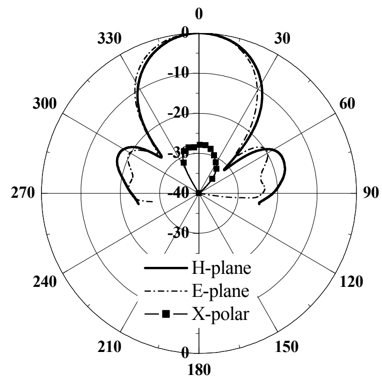


Fig 3(a)

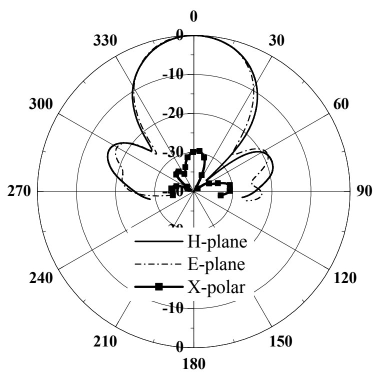
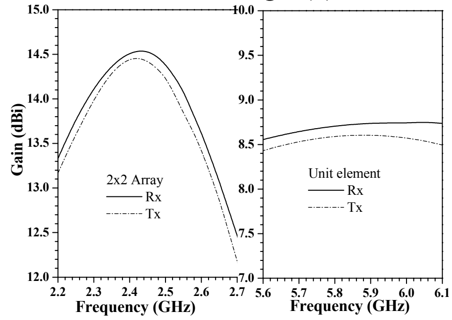


Fig. 3(b)



(a) (b)

Fig. 4

Fig. 2 Measured S-parameter of 2x2 array. Fig. 3. Measured co-polar and cross-polar radiation pattern in H- and E-plane: (a) for Tx polarization aand (b) for Rx polarization. Fig 4: Calculated gain of (a) 2x2 array and (b) unit antenna element.