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Gain Enhancement of Microstrip Patch Antenna Array with Rectangular Dielectric Resonator Antenna

Mohith N Raate.[1], Shushrutha K S.[2]

[1]Student, *Dept of ECE*
RV College of Engineering
Bangalore, India

[2] Associate Professor, *Dept of ECE*
RV College of Engineering
Bangalore, India

Abstract: A 2X1 Rectangular Microstrip Patch Antenna Array (RMPAA), operating in C-band is proposed and extended to form 4X2 array to reduce the number of feed elements power divider structure is employed. The array performance is investigated with Rectangular Dielectric Resonator Antenna (RDRA). The material selection for RDRA design is curtail so as to increase the gain. In this work very low loss tangent material is considered for the design. This paper presents a systematic design procedure RMPAA integrated with RDRA and simulation is carried out in ANSYS HFSS software. The designed structure provides high gain, return loss < -15dB and PSLL < -17dB, which best suits for WIFI and radar applications.

Keywords: Rectangular Microstrip Patch Antenna Array, RDRA, Bandwidth, Gain, Return Loss.

1. INTRODUCTION

Due to WIFI 6/7 there is a need for compact antenna operating in C-band, the ese of design of microstrip patch antenna and ese of fabrication of DRA has led to the development of RMPA with DRA. Microstrip patch antennas have many advantages like low weight, low cost, low profile, conformability and can be easily fabricated [1]. Arrays can be used to achieve higher gain, to give path diversity (also called MIMO) which increases communication reliability, to cancel interference from specific directions, to steer the radio beam electronically to point in different directions, and for radio direction finding (RDF).

Power dividers are passive RF components that are commonly used to split and distribute power in various proportions to different components of networks. Two major areas for power divider applications are (1) distribution of input signal to amplifiers and (2) distribution of RF signal to antenna arrays. A circularly polarized (CP) multiple-input-multiple-output (MIMO) antenna is investigated in [2]. The MIMO antenna consists of two identical dielectric resonator antennas (DRAs), which use the same feeding cross slots to generate the same CP fields. Four metal strips are printed on the lateral sides of each DRA to change the rotation direction of the E-field coupled in the passive (coupled) DRA, vary its polarization property, and thus make it opposite (orthogonal) to that of the active (driven) DRA. The slots that are feeding the DRA's are the feed lines which is a series power divider. The idea is to increase the radiations from the side walls of the DRA compared to that of its top wall by engraving grooves on the side walls is described in [3]. A mixed breed double band dielectric resonator antenna with parasitic opening encouraged by microstrip feed line, to realize dual frequency service for WLAN applications is discussed in [4]. Single circular patch antenna design introduced with U-slot operating in multiple bands is described in [5] which is not radiating as desired when fabricated in all the bands of frequencies desired but sure did increase the gain when a DRA was placed over it.[6] describes a Circularly Polarized Dielectric Resonator Antenna Based on Quasi-Self-Complementary Meta surface antenna that has realized the linear-to-circular polarization transformation in millimeter frequency band without additional substrate. The various techniques of feeding, addition of lens, DRA's which result in the enhancement of gain are described in [7-9]. A single layer dual-polarized, microstrip patch antenna with dual port is discussed in [10] which has a phase shift of 180 degree.

Adding to all the previous works here a 4x2 RMPAA is designed with power divider from which one feed, feeds two patches at a time therefore making it a four-feed network which feeds the entire 8 patches in the array. In addition to this a RDRA is placed on top of the array to enhance the gain of the RMPAA.

In this paper the design of gain enhanced RDRA antenna for cellular applications. A brief literature survey of the previous research is presented in this section followed by a detailed procedure for designing patch antenna and array with power divider network, construction of RDRA is discussed in II. In section III simulation results of this research work is presented and summarized in the last section.

2. DESIGN OF MICROSTRIP PATCH ANTENNA ARRAY

The rectangular microstrip patch antenna is designed using the empirical equations from [4] for which the obtained gain of 8.1dB and a return loss of -37.09dB with a 10dB bandwidth of 180MHz the design specifications are shown in table I. The antenna is excited using an inset feed using lumped port, extending from the ground plane to the patch. The design specifications of the single element include: Operating frequency in C Band, f = 5GHz and Substrate dielectric constant $\epsilon_r = 2.2$.

A preliminary RMPA is designed to function in C-band, with optimal bandwidth, low return loss and high gain. The design equations used for the RMPA are already described in [9]. The MPA is designed on Rogers R T Duroid 5880 substrate, with a loss tangent tanδ of 0.0009 and a dielectric constant of ε_r = 2.2. As bandwidth is directly proportional to thickness, the dielectric substrate thickness (h) used is 0.1575cm. The detailed schematic sketch of designed antenna element is shown in Fig.1. A Smaller size, lower weight, repeatability and reliability of fabrication process further reinforces the advantageous benefits of a RMPA structure.

$$\boldsymbol{Z1 = \sqrt{Z_2 Z_0}} \quad (1)$$

$$\boldsymbol{L1 = \frac{\lambda_g}{4}} \quad (2)$$

$$\boldsymbol{\lambda g = \frac{\lambda_0}{\sqrt{\varepsilon_r}}} \quad (3)$$

$$\boldsymbol{\lambda o = \frac{c}{f_0}} \quad (4)$$

where Z1 is the impedance of the power divider structure, L1 is the length of the power divider, f_0 is the operating frequency.

The power divider is designed using the equations (1-4) which has given us the length to be 0.84815 cm and the width to be 1.011 cm by calculations whereas the optimized values to achieve the required specifications as gain increment with stable bandwidth, by optimizing the obtained values, the optimized values to achieve the required specifications are 0.794cm for length and 1.069cm for width which are mentioned in Table I.

TABLE I. POWER DIVIDER RMPA SPECIFICATION

Figure 1 **Parameters** **Figure 2**	**Figure 3** **Optimized** **Figure 4** **Values**
Figure 5 Patch Width (W)	**Figure 6** 2.28cm
Figure 7 Patch Length (L)	**Figure 8** 1.93cm
Figure 9 Substrate width (W_P)	**Figure 10** 4.2cm
Figure 11 Substrate length (L_P)	**Figure 12** 5.1cm
Figure 13 Substrate thickness (h)	**Figure 14** 0.1575cm
Figure 15 Dielectric constant (ε_r)	**Figure 16** 2.2
Figure 17 Inset distance (I_d)	**Figure 18** 0.45cm
Figure 19 Inset gap (I_g)	**Figure 20** 0.17cm
Figure 21 Feed width (F_w)	**Figure 22** 0.25cm
Figure 23 Feed length (F_l)	**Figure 24** 0.58cm
Figure 25 Power divider length (P_l)	**Figure 26** 0.794cm
Figure 27 Power divider width (P_w)	**Figure 28** 1.069cm

2.1 A 1X2 sub array with power divider MPA

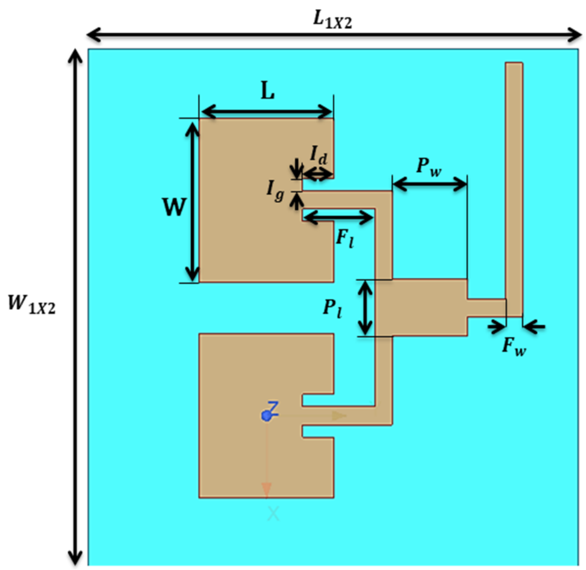

Fig. 1: 2X1 RMPA sub-array Schematic

The design, simulation and optimization of 2x1 sub array, 4x2 RMPAA are carried out using ANSYS HFSS software, which has powerful methods for effectively addressing large antenna arrays.

Using the empirical equations, a 2x1 MPA is designed and simulated. The power divider is designed to Array element is simulated using Ansys HFSS.

To provide a match, the transformer characteristic impedance Z1 should be $Z_1 = \sqrt{R_{in} Z_0}$,where Z_0 is the characteristic impedance of the input transmission line. The feeding line has a 90-degree rotation as shown in the Fig 1. The rotation is given so as to reduce the array size matching the phase differences between them.

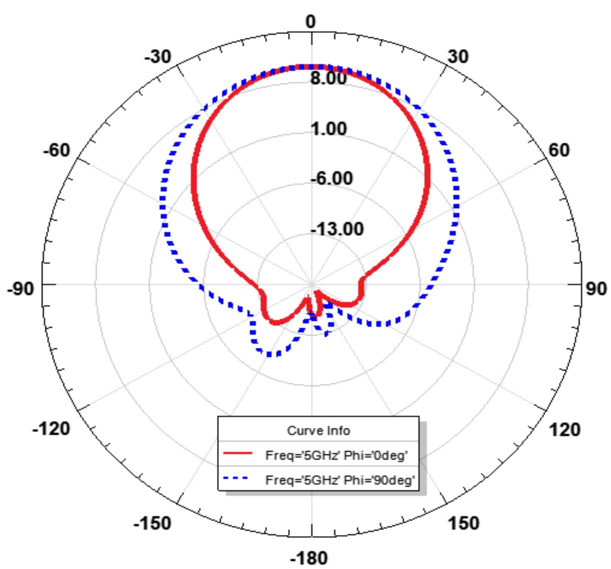

Fig. 2: Radiation pattern of 1X2 sub-array with power divider

The width (W_{array}) and length (L_{array}) of array is 7 cm and 7.3 cm, the schematic of the 1X2 sub-array array is presented in Fig. 1. The return is -45.43 dB with bandwidth of 180 MHz. The sub-array alone has a gain of 10.13dB with Half Power Beam width (HPBW) of 51.63° in E-plane and 71.41° in H-plane are achieved respectively as shown in Fig 2.

2.2 Design of Microstrip Patch Antenna Array

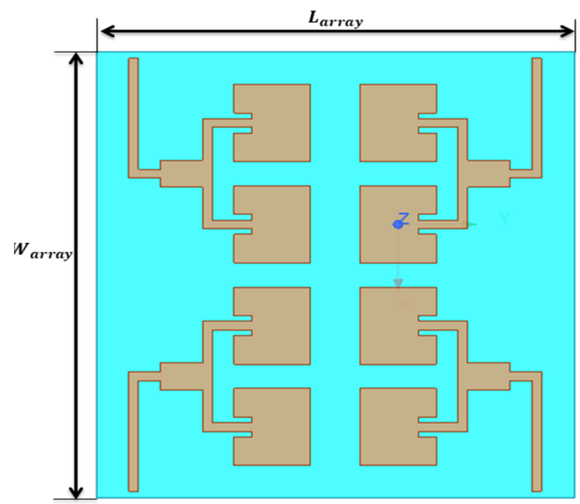

Fig. 3: 4X2 RMPA array Schematic

Array structure is simulated using Ansys HFSS. The width (W_{array}) and length (L_{array}) of array is 12.08 cm x 13.2 cm and schematic of the 4X2 array is presented in Fig. 3. The return loss with respect to reference element obtained is -33.63 dB with bandwidth of 190 MHz. The array has a high gain of 15.79dB with Half Power Beam width (HPBW) of 24.91° in E-plane and 37.72° in H-plane are achieved respectively as shown in Fig 4. The RMPAA is a 4X2 array which has 8 elements and 4 feeds, resulting to which the array had an increment of 5.74dB in gain. Which has a PSLL of -13.56dB.

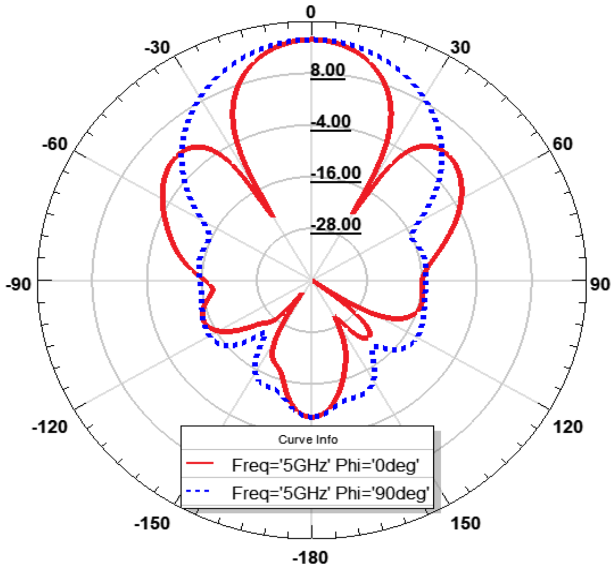

Fig. 4: Radiation pattern of 4x2 MPAA with power divider

3. Design of Microstrip Patch Antenna Array with DRA

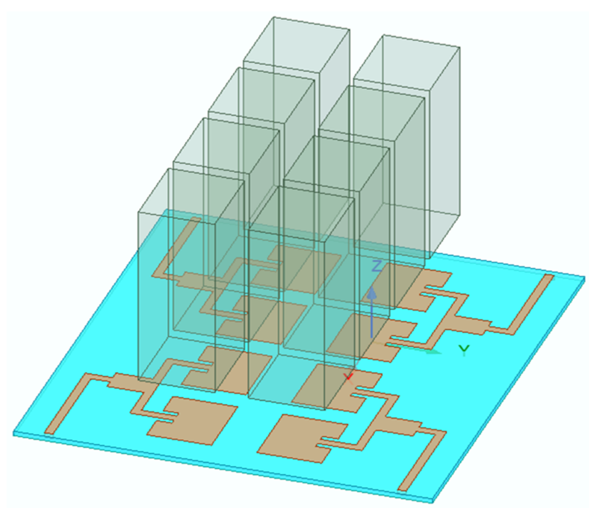

Fig. 5: 4x2 RMPA array with RDRA Schematic (isometric view)

A dielectric resonator antenna is a radio antenna mostly used in radio frequencies and higher, that consists of a block of ceramic material of various shapes and sizes as per requirement, the DRA is mounted on the metal surface, aground plane. Radio waves are introduced into the inside of the resonator material from the transmitter circuit and bounces back and forth between the resonator walls, forming standing waves. The walls of the resonator are partially transparent to radio waves, allowing the radio power to radiate into space. These antennas can have lower losses and be more efficient than metal antennas at higher frequencies. As we have designed the microstrip antenna to radiate in 5GHz frequency, it makes it easy for us to mount the DRA on top of the antenna as the radiating frequency is not higher. Based on the availability of materials polypropylene material is used which has a low loss tangent od 0.001 and relative permittivity of 2.25.

The array is introducer with a RDRA structure per individual patch which is designed for this antenna array which has the dimensions as specified, length of 2.2 cm (DRA_l), width of 2.6cm (DRA_w) and has a height of 6 cm (DRA_h) which is placed at a distance of 2 cm (DRA_d) from the RMPAA. Array structure is simulated using HFSS which provides a quick and accurate solution to a finite array simulation. The width (W_{array}) and length (L_{array}) of array is 12.08 cm x 13.2 cm and schematic of the 4X2 array is presented in Fig. 5. The return loss with respect to reference element obtained is -27.03 dB with bandwidth of 190 MHz. The array has a high gain of 17.89dB with Half Power Beam width (HPBW) of 21.66° in E-plane and 26.36° in H-plane are achieved respectively as shown in Fig 6. There is an increment of 2.01 dB of gain when DRA is introduced to the RMPAA which had a gain of 15.79dB, after the DRA was introduced, the gain increased to 17.89dB. which has PSLL of -17.3dB.

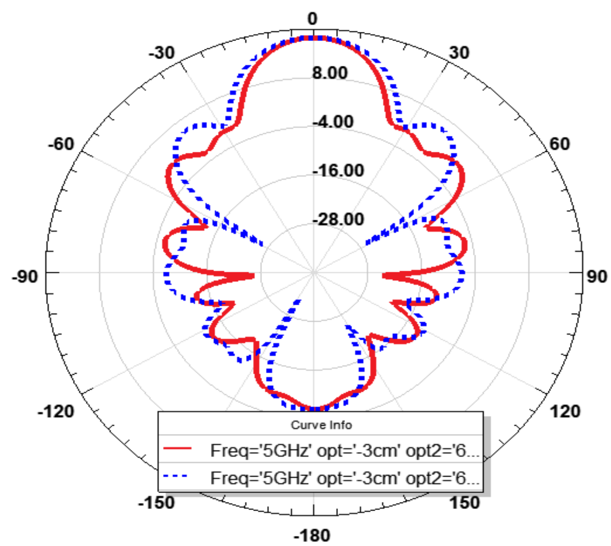

Fig. 6: Radiation pattern of 4x2 MPAA with power divider

4. Conclusion

In this paper, a Rectangular Microstrip patch antenna array is discussed. The design procedure of single RMPA element is presented along with simulation results followed by the design of power divider which feeds two elements. The designed antenna element was extended to 4x2 array. The 4x2 array shows the high gain performance when the DRA is added. Existing literature is used to validate the design technique and the simulated results show that these array antennas can be used for a variety of applications like WIFI and base stations in 5G wireless cellular systems.

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