Design of Partially Reflective Surface Antennas for Wireless Applications

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***Abstract*——---Recently Partially Reflective Surface (PRS) antennas have received significant attention due to their compact structure and ease of achieving high directivity. A multiband partially reflective surface (PRS) antenna specifically employed for X-band (radar communication) and WLAN applications is presented. RT- Duroid 5880 is used as a substrate with thickness of 20 mils and relative permitivity of 2.2. The prototype initially consists of a microstrip patch as the source antenna, PEC ground plane and PRS surface employed with 2x4 radiators which operated at 1.799GHz and (5.104-5.833) GHz used for WLAN applications. Further the design was enhanced with 2x2 radiating elements which operated at dual band such as 9.275GHz and 11.16GHz suitable for X-band applications. Antenna exhibits omni-directional radiation patterns with reasonable gain on all operating frequency bands. Analysis and simulation of prototype was performed using Agilent Advanced Design System (ADS).**

Keywords--- GSM ,Partially reflective surface, WLAN,radiation pattern, microstrip patch array, X-band.

I. INTRODUCTION

PRS antennas usually employ a microstrip antenna acting as the radiating source and a metallic or metallo-dielectric periodic array, located approximately half a wavelength above the radiator to enhance the directivity. Generally, the centre–fed PRS antenna provides a broadside beam. Wireless technologies require compact and low-profile components for communication systems. The characteristic parameters of antenna mainly depend upon the size of radiating element which is approximately one-half of a free-space wavelength. This implies a trade-off between the size of antenna and operating frequency. Recently, Partially Reflective Surface (PRS) antennas have received significant attention due to their compact structure and ease of achieving high directivity.

A multiband partially reflective surface (PRS) antenna specifically employed for X-band (radar communication) and WLAN applications is presented in this paper. RT-Duroid 4003 is used as a substrate with thickness of 20 mils and relative permitivity of 2.2. The prototype initially consists of a microstrip patch as the source antenna, PEC ground plane and PRS surface employed with 2x2 radiators which operated at 1.8GHz and 5.375GHz (5.042GHz-5.689GHz) used in GSM and WLAN (IEEE 802.11a) applications. A cavity was created between the dielectrics to improve the radiation pattern

Then, the research was further extended by increasing the number of radiating elements to enhance the operating frequency .The design was enhanced with 6x6 radiating elements which operated at 5.498GHz and 7.535GHz suitable for X-band applications. Antenna exhibits omni-directional radiation patterns with reasonable gain on all operating frequency bands. Analysis and simulation of prototype was performed using Agilent Advanced Design System (ADS). The rest of the paper is organised as follows. The concept of PRS antenna is described in section II. Section III presents the overall design methodology of the proposed PRS antenna with varying number of reflectors. Discussions on various simulated results are provided in section IV. Finally some conclusions are drawn in section V.

II. CONCEPT OF PRS ANTENNA

The schematic model of a conventional PRS antenna is shown in Fig.1.It is composed of a source antenna(exciter) embedded between a ground plane and a dielectric superstrate employed as the PRS. The PRS is placed at a distance Lr above the ground plane with a reflection coefficient

$$\Gamma=R.\exp(j\varphi). \qquad (1)$$

The electromagnetic waves radiating from the source experience multiple reflections and transmissions within the cavity. According to the ray theory, a maximum directivity at the broadside is obtained when the condition below is satisfied

$$\varphi-\pi-\frac{4\pi Lr}{\lambda}=2N\pi,\quad N=0,\pm1,\pm2.. \qquad (2)$$

where, λ is the free space wavelength at the resonant frequency.

Hence, the antenna profile is determined by

$$Lr=\left(\frac{\varphi}{\pi}-1\right)\frac{\lambda}{4}+N\frac{\lambda}{2},\ N=0,\pm1,\pm2. \qquad (3)$$

Partially reflective surface (PRS) antennas have attracted a significant attention due to their compact structure and high diretivity.The directivity of the PRS antenna depends on the PRS reflectivity

$$D=Dsource.\frac{1+R}{1-R} \qquad (4)$$

Dsource is the directivity of the source antenna, and R is the PRS reflection coefficient magnitude. It is also known that a center-fed PRS antenna can radiate a broadside pattern.The typical PRS antenna is shown in Fig.2. PRS reflection coefficient, written for a plane wave is $\Gamma = R.\exp(j\psi)$

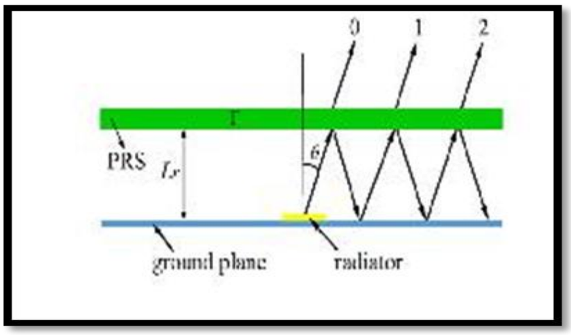


Fig.1. Schematic model of a conventional PRS antenna

III. PROPOSED DESIGN METHODOLOGY

The proposed PRS antenna is designed by initially beginning with a microstrip square patch acting as the source (exciter) with a length of 36.7mm using the below equation:

$$L = \frac{c}{2fr\sqrt{\varepsilon r}} \qquad (5)$$

where c is the speed of light(3x10^8 m/s), fr is the operating frequency and εr is the dielectic permitivity of the substrate (2.2). The patch antenna is etched on a 20mil-thick Rogers4003 substrate (εr=2.2) and simulated in Advanced Design System.The cavity length Lr =29mm which is approxmiately half a wavelength is created. Finally, the PRS surface employing radiators are designed using microstrip array elements etched on the same Rogers 5880 substrate.The number of the radiating elements is increased to enhance the operating frequency. Table I illustrates the dimensions of the proposed antenna as shown below.

TABLE I

DIMENSIONS OF THE PROPOSED ANTENNA

S.NO	DIMENSIONS OF SOURCE ANTENNA		
	LENGTH	WIDTH	FEED
1	37.5mm	37.5mm	L=13mm,W=1mm
	DIMENSIONS OF RELECTOR ANTENNA		
2	10mm	10mm	Array spacing: 24mm
3	20mm	20mm	Array spacing: 35mm

Initially, the PRS antenna was designed using (2x4) array i.e, 8 radiating elements. The length of each square patch is L1=10mm and L2=20mm and the periodicity between the two adjacent patches is 24mm as shown in Fig.3. The simulated results of this antenna provided high directivity and a broadside radiation pattern. This antenna operated in multi-band such as 1.799GHz and 5.4GHz (5.104GHz-5.833GHz) band suitable for GSM and WLAN applications as shown in Fig4. Having achieved this, the research was further extended by simplifying the antenna making it suitable for wireless applications. The radiators are simple structures consisting of simple square patches of different dimensions.The compactness of the antenna makes it applicable for wireless domain.

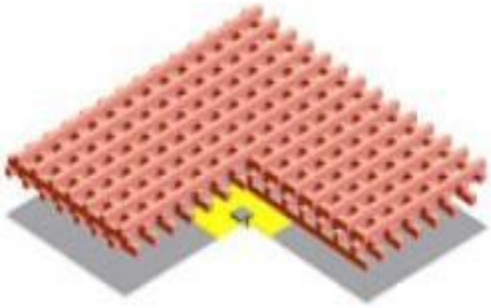


Fig.2.Typical PRS antenna

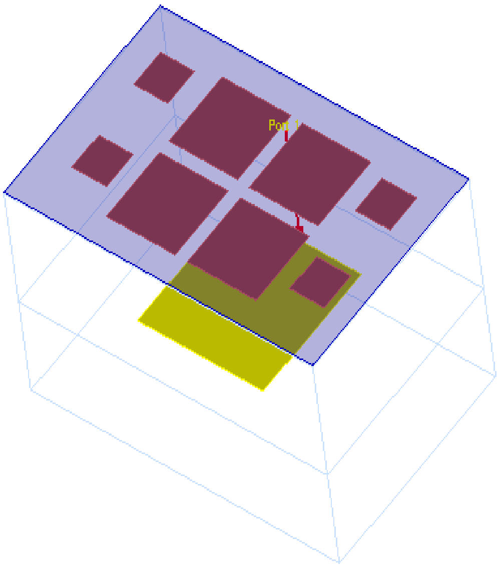


Fig.3. PRS antenna with 2x4 radiators

Further the PRS antenna theory was tried with 4x1 radiators but it was not efficient and did not provide us with good results.So, the design was tried with 2x2 array elements as shown in Fig.4. The above mentioned PRS antenna was designed with the same microstrip patch of length L=36.7mm as the exciter but the radiators with increased number of elements i.e 4 elements. The PRS surface of the antenna illustrated in the Fig.4. is made simple by simply employing 4 radiators. The cavity length and the periodicity between the patches are considered as same to the previous case.Simulated results of this antenna as shown in Fig.6 was efficient than the previous case. The modifications introduced two new bands at higher frequencies (X-band) i.e, 9.275GHz and 11.16GHz respectively. The directivity and radiation pattern were also improved. The proposed antenna is mainly aimed for radar communications.Also, the compact structure makes it suitable for wireless applications.The center feed source antenna improves the radiation efficiency.

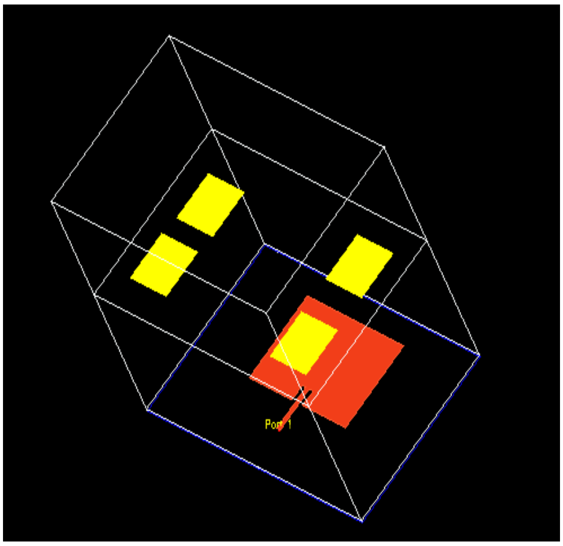


Fig.4. PRS antenna with 2x2 radiators

IV.SIMULATION RESULTS

The following simulation results were obtained in ADS with an array of four microstrip patch antennas as radiators for a source placed at a cavity length of Lr=29mm.

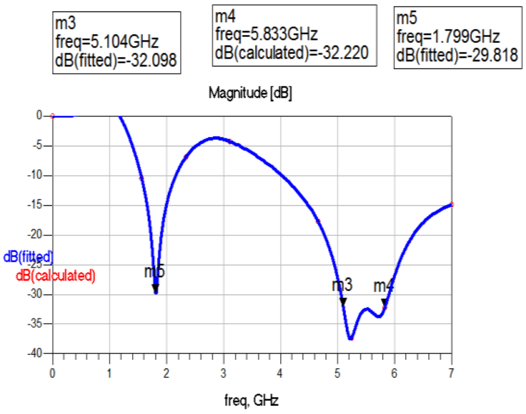


Fig.5. Simulated results of 2x4 PRS antenna

The above designed antenna operated at 1.799GHz and 5.4GHz (5.104GHz-5.833GHz) with a return loss of -29dB and -35dB respectively. The operating frequency is improved by increasing the number of elements. The research was further extended to 4x1 array which did not provide good results..Finally a PRS antenna was designed witth an array of 4 (2x2) microstrip patches with two different dimensions.The cavity length and source antenna was considered from the previous case.This configuration achieved a significant rise in the operating frequency and operated at 9.275GHz and 11.16GHz (X-Band Radar communication) respectively.The center-fed PRS antenna also achieved a broad side radiation pattern as shown in Fig.7.The return loss was found at -20dB and -21dB. The directivity achieved was 10.4351dB with realized gains over 10.4241 dBi.

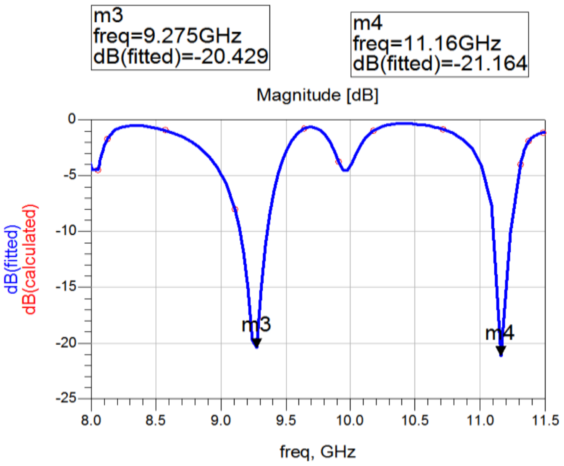


Fig.6. Simulated results of 2x2 PRS antenna

The radiation pattern of the proposed antenna is shown as follows which reveals radiation in all directions i.e omni-directional radiation pattern. Hence suitable for X-band radar applications. The gain and directivity of the designed antenna is shown in Fig.8.

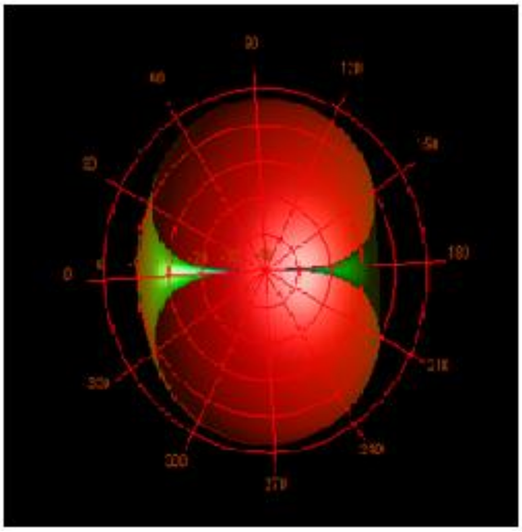


Fig.7. Radiation pattern of 2x2 PRS antenna

The proposed antenna due to its compact structure was mainly applicable in WLAN and X-BAND radar communications. The fast rising demand for compact and surface antennas have made the designed antenna to draw a significant attention. The antenna losses are reduced by employing minimal loss dielectric such as RT-DUROID4003 in comparison to the antennas reported in the literature.

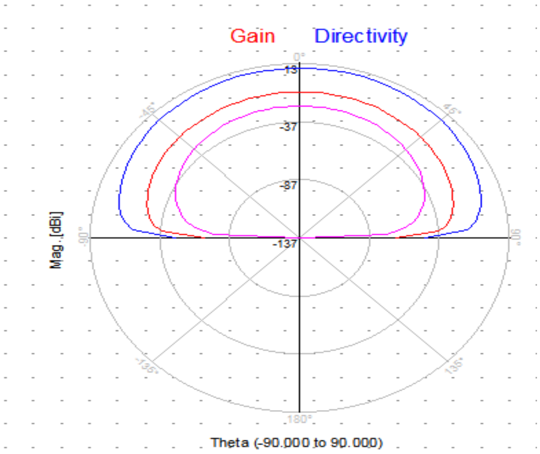
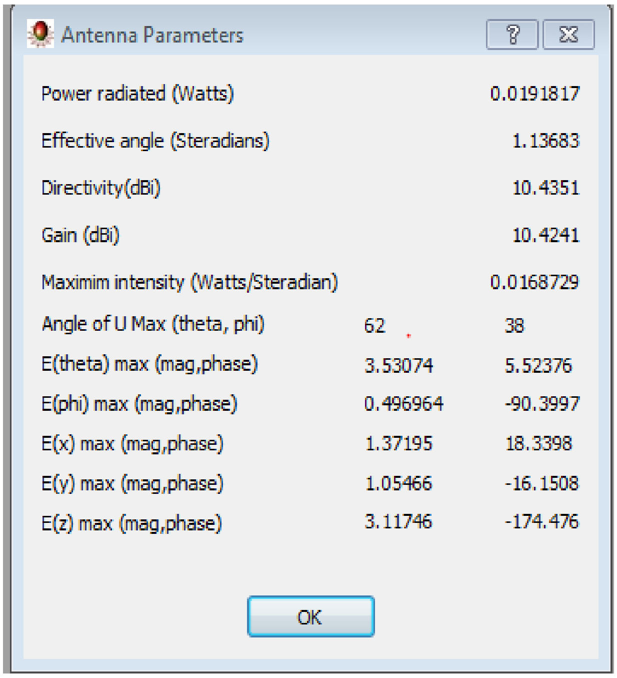


Fig.8.Gain and Directivity measurement

The proposed antenna is simulated and the desired parameters is obtained as shown in Fig.9.



Power radiated (Watts)		0.0191817
Effective angle (Steradians)		1.13683
Directivity(dBi)		10.4351
Gain (dBi)		10.4241
Maximim intensity (Watts/Steradian)		0.0168729
Angle of U Max (theta, phi)	62	38
E(theta) max (mag,phase)	3.53074	5.52376
E(phi) max (mag,phase)	0.496964	-90.3997
E(x) max (mag,phase)	1.37195	18.3398
E(y) max (mag,phase)	1.05466	-16.1508
E(z) max (mag,phase)	3.11746	-174.476

V.CONCLUSION

A compact multiband PRS antenna has been proposed in this paper. Compared to some of the PRS antennas that have been reported in the literature, the proposed antenna was simple in its structure with enhanced directivity in relatively wide frequency range.

VI. FUTURE SCOPE

The research is further extended to design reconfigurable PRS antenna by employing pin diodes. The Wilkinson power divider mechanism is used for biasing. The reconfigurable antenna is also aimed for beem steering applications. In order to increase the tilt range, a phased array antenna is employed as the source (exciter) for the PRS antenna. To obtain phase shifts between the array elements, reconfigurable defected microstrip structure (RDMS)-based phase shifters are incorporated in the feed network. The feed network is comprised of two phase shifters etched on each branch of a Wilkinson power divider. Each phase shifter consists of three identical RDMS units.

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