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Elliptical Ring Patch Antenna for X-Band Radar

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***Abstract*— This paper presents a simulated design of high performance elliptical ring Microstrip patch antenna at resonant frequency of 8 GHz for radar. Owing to its intrinsic geometry elliptical ring patch is found to be suitable candidate for designing high power, large gain and better efficiency conformal antennas for radar at X-band or even higher frequencies. Simulated antenna shows very high average gain of 7.5 dB for entire bandwidth of 340MHz i.e. 4.25% impedance bandwidth. Simulated results shows very good return loss performance, S11 parameter is -42.5 dB at resonant frequency. Roger Ultralam 2000 substrate is used to design the antenna. Average radiation efficiency of antenna is very high (97.9%). Design show great promise for radar application with no side lobes, high directivity of 7.71 dB at 8 GHz & very high front to back ratio. Comparative study of recent works in X-Band and our design is presented & variation of return loss with dielectric height is also elaborated in paper.**

Keywords—Elliptical Ring , Radar, X-band, High performance, high gain,Patch Antenna.

I. INTRODUCTION

Microstrip patch Antenna date backs about four decades when it was first coined by Munson, since then lot of research has been done to exploit properties like low profile, compatibility, conformability to shaped surfaces.

Missiles telemetry, aircraft and chopper's altimeters and for rockets these antenna has proved great advantage. Due to capability of being integrated to surface of Aerodynamic structures, without deteriorating the Aerodynamic drag performance [1].

Nevertheless patch antenna has broad regime of applicability from military to civilian communication, to other extent from agriculture sensors to biomedical sensors.

Traditional Radars are very bulky and need a separate carrier and a maintenance crew. Introducing patch antenna design for radar application is in recent trend of research. Low weight high efficiency radar for L, S, and C band is developed in [2], C and K band reflector array in [3].Similar design is presented [4-6] for radars at lower frequency bands. X band is very prominent band for radar application like Anti-collision, Automatic Turret Control, Fire Control, Surveillance, Perimeter Surveillance [7].

A. Problem Statement

Radar is backbone of military defence system, lot of research work and technology upgradation is done in this area since the First World War.

Military operations are carried out in harsh terrain and varied atmospheric condition so large and vehicle carried radars are obsolete for such operations since there are lower on mobility factor. Rain and other atmospheric condition degrade the reception of reflected signals which lowers the RCS (radio cross section).RCS is parameter which is measure of the detectability of any object by radar and every radar has it threshold RCS i.e. a minimum value of RCS that it can measure so if weather conditions like frost and rain by varying the dielectric constant of medium reduce the RCS below the threshold then the objects will not be detected. So the major drawbacks in existing traditional radar are bulkiness and high threshold RCS.

Existing printed technology is implemented in antenna design of radar to make it less bulky but at cost of gain, poor efficiency. To mitigate the problem of gain, complex array of antenna is developed which uses Microstrip line feed, drawback of which is spurious radiation, i.e. the feed line also radiates thus leading to side lobes in antennas radiation pattern which can cause multiple detection of same objects called false alarms. Basic requirement for Radar antenna at higher frequencies is to have side lobes level <-20dB since side lobes leads to false alarms, high directivity for better scanning, higher radiation efficiency and gain.

B. Solution

We propose a special geometry for patch antenna i.e. elliptical which is not much used in other applications like in communication because of comparatively larger patch dimension then square and circle for same frequency but have 2 to 3 dB higher gain then its counterparts. Not much of work is done in literature on elliptical ring antenna for radar so far. The patch antenna design parameters like feeding, dielectrics and patch geometry are implemented to make it exclusively for radar application.

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II. ANTENNA CONFIGURATION

The configuration of antenna illustrated in fig.1.

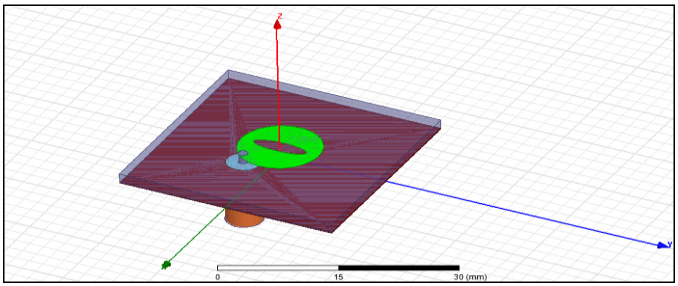

Fig. 1 Model of simulated Antenna

Dimension of patch is calculated from [9]

$$a = p/f_r\,(\mu_{eff}*\epsilon_{eff})^{1/2} \qquad (1)$$

μ_{eff} is effective permeability which is assumed unity in this case. ϵ_{eff} is effective permittivity calculated from 2. P is empirical constant varies from 0.27 to 0.29[9].

$$\epsilon_{eff} = (\epsilon_r+1)/2 + (\epsilon_r-1)/2(1+12h/W)^{1/2} \qquad (2)$$

ϵ_r is dielectric constant of substrate.

A. Dielectric

The patch is fabricated on Roger Ultralam 2000 substrate which has relative permittivity of 2.5 and thickness of 1.5mm and loss tangent of 0.0019 and overall dimension is 30X30 (in mm).Lower dielectric needs larger dimensions and have lesser gain but elliptical patch mitigates the problem of gain and increase in aperture size enhance the directivity of antenna. For larger frequencies losses are high [10] as dipole in dielectric materials oscillates producing heat, this heat generation intensity is directly proportional to the frequency of oscillation, so we preferred lower dielectric material since emphasis was more on radiation efficiency and return loss than bandwidth.

B. Patch dimensions

Patch is fabricated on 30X30 (in mm) ground plane of height 0.1mm.

TABLE 1

Patch Dimension			
major axis(a)		b/a ratio	
Inner	Outer	Inner	Outer
3.63mm	5.6mm	0.30	0.975

C. Feed Point

F(x y) = (3.45,-3.45) probe feed dimension is of 50Ω commercially used SMA connector [11]. Probe feed gives freedom of feeding anywhere in xy plane but leads to reduced bandwidth. Probe feed immune to spurious radiation because the feed is engulfed in an insulator coating so the problem side-lobes and false alarms is curbed out but it comes out at cost of reduced bandwidth but bandwidth can be further enhanced using aperture coupling or proximity feeding, but with increased complexity.

III. SIMULATION RESULTS

Table 2 and Table 3 highlight the figure of merits of antenna for the resonant frequency at 8 GHz. Model is simulated on Ansoft HFSS 13.0 and results are shown in Fig.2-7 to complement the data in table.

TABLE 2

Resonant Frequency (f_r) (GHz)	Avg. gain	Directivity (at 8 GHz)	Front to Back ratio (at 8 GHz)
8	7.5dB	7.71 dB	25dB

Fig.2 shows variation of return loss with frequency, curve dip at 8 GHz, the optimized resonant frequency. Radiation efficiency of antenna is quite high, 97% for entire radiating bandwidth as shown in Fig.3 which is outcome of elliptical ring and lower dielectric materials, size of aperture and its geometry is always an important parameter for deciding the radiation efficiency and gain of antenna.Fig.4 shows radiation pattern of antenna with larger main lobes and no front side lobes an excellent candidate for radar antenna. High directivity of antenna will lead to better detection of RCS for longer range.

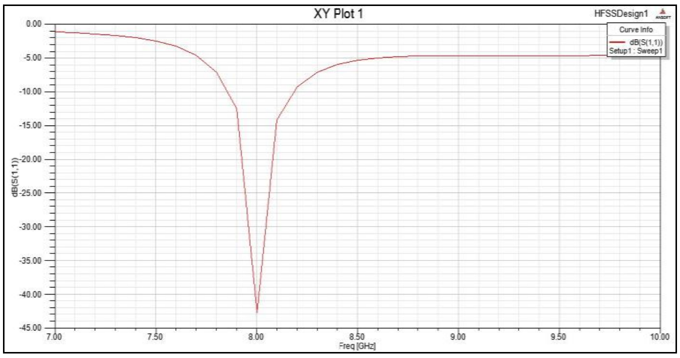

Fig.2 Return Loss vs Frequency

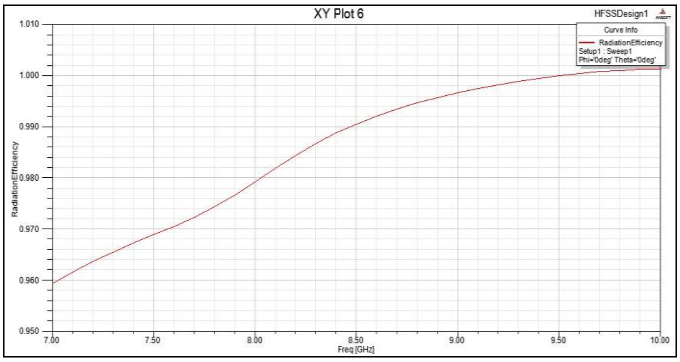

Fig.3 Radiation Efficiency vs. Frequency

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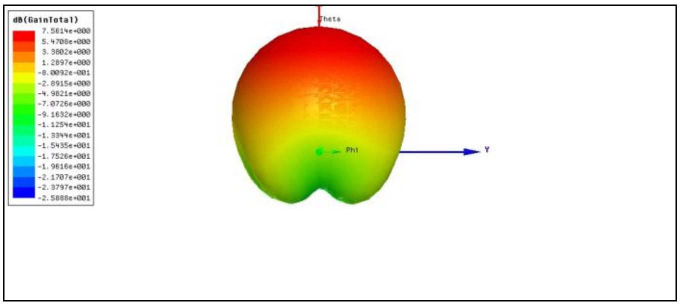

Fig.4 Radiation Pattern

Radiation pattern is unidirectional with some back lobes but front to back ratio is very high. Average gain is produced in Fig. 5 for entire bandwidth gain is almost even i.e. for entire bandwidth gain >7dB.

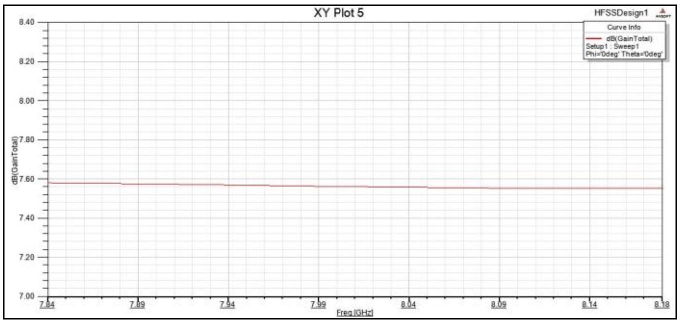

Fig.5 Gain vs Frequency

IV. COMPARISON

Increasing height of dielectric increases bandwidth but at cost of reduced performance as depicted in Fig.6 & Fig.7. S11 parameter degrades as increasing dielectric height increases the dielectric resistance leading to losses. As the height of dielectric increased from 1.5mm to 1.9 mm the S11 minima shifted from very low value of -42.59 dB to about just below -10dB

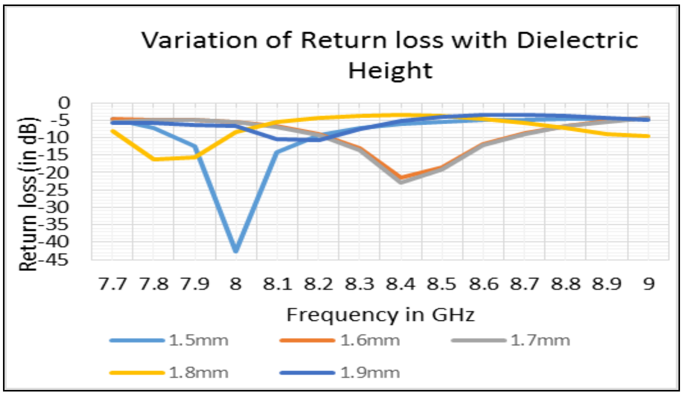

Fig.6 Variation of S11 parameter with dielectric height

Height of dielectric and bandwidth must show linear variation but as deduced from variation graph in Fig.7 it follows linearity for h=1.7mm further increasing height degrade both bandwidth and return loss. Main reason for such behavior can be considered to be change in overall impedance of antenna that leads to mismatch of feed point.

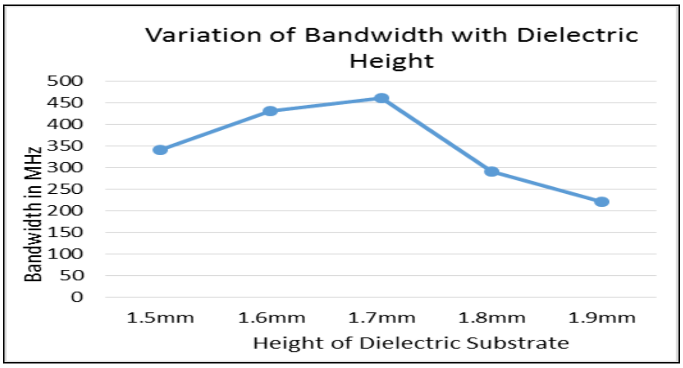

Fig.7 Variation of bandwidth with dielectric height

A comparative study of results for different geometries of patch for X-band at different resonating frequency is detailed in Table 3, table also limelight on better performance of our antenna over other fabricated designs.

TABLE 3

S.No	Resonant frequency (f_r)	Bandwidth (%)	S1 parameter(at f_r)
1	8.0 GHz	4.56	-42.59 dB
2	9.2 GHz	4.34	-15 dB
3	9.5 GHz	4.73	-22 dB
4	10.74 GHz	5.58	-47.13 dB

First result shown in table is our results and others are from [12-14].All are recent designs using circular patches and rectangular patches but with higher dielectric values degrading the efficiency. Last result outperform our design's figure of merit above mentioned parameters but it comes at cost of lower efficiency (0.85) for resonant frequency in compare to our 0.97 at the resonant frequency.

V. CONCLUSION

An elliptical ring patch antenna is simulated and results are overwhelming for radar application in X-band especially for ATC, Fire control, perimeter surveillance and many other military applications. Striking feature of antenna is excellent return loss and very high gain and radiation efficiency for entire radiating band. This patch element can be developed in phased array for military application replacing the existing large, bulky Radar Antennas.

There is huge scope in elliptical patch geometry which has intrinsic property to produce circular polarization with single feed as elliptical geometry inherits asymmetry to excite orthogonal modes. Circular polarization is important aspect in radar antenna which can make radar more robust in any weather and terrain by reducing orientation mismatch losses.

REFERENCES

[1] Chopra, P.; Bhandari, M.; Beenamole, K.S.; Saxena, S., "Design of an X-band conformal antenna using microstrip patches," in *Signal Processing and Integrated Networks (SPIN), 2015 2nd International Conference on* , vol., no., pp.83-87, 19-20 Feb. 2015

[2] K S Beenamole "*Micostrip antenna design for radar application*" published in DRDO Science Spectrum , March 2009 ,pages 84-89.

[3] Chulmin Han, Christopher Rodenbeck, John Huang and Kai Chang "*A C/Ka Dual Frequency Dual Layer Circularly Polarized Reflectarray Antenna With Microstrip RingElements*" published in IEEE Transactions on antenas and Propagationa, vol .52, No. 11, November, 2015

[4] Burshe, G.V.; Khobragade, S.V.; Anitha, V.R., "Dual fed circularly polarized microstrip patch array antenna for radar application," in *Electronics Computer Technology (ICECT), 2011 3rd International Conference on* , vol.1, no., pp.251-253, 8-10 April 2011

[5] M.Venkata Narayana1, Govardhani Immadi, K. Rajkamal, M.S.R.S Tejaswi "*Microstrip Patch Antenna for C-band RADAR applications with Coaxial fed*" published in IJERA,Vol 2,Issue 3 May-Jun 2012,

[6] Kishore, K.V.; Rajesh, G.S.; Kumar, V.; Srinivasulu, P., "Design of 0.71λ, spacing 8-element microstrip patch antenna linear array for 0.43GHz wind profiling radar," in *Emerging Technology Trends in Electronics, Communication and Networking (ET2ECN), 2014 2nd International Conference on* , vol., no., pp.1-6, 26-27 Dec. 2014

[7] Joseph P Camaco "*Federal Radar Spectrum Requirements*" NTIA Special Publication 00-40,U.S Dept. of Commerce May 2000.

[8] Bhattacharyya, A.K.; Garg, R., "Generalised transmission line model for microstrip patches," in *Microwaves, Antennas and Propagation, IEE Proceedings H* , vol.132, no.2, pp.93-98, April 1985

[9] Liang Shen, "The elliptical microstrip antenna with circular polarization," in *Antennas and Propagation, IEEE Transactions on* , vol.29, no.1, pp.90-94, Jan 1981.

[10] Carver, Keith R.; Mink, J., "Microstrip antenna technology," in *Antennas and Propagation, IEEE Transactions on* , vol.29, no.1, pp.2-24, Jan 1981

[11] Constantine A.Balanis ,*Antenna Theory Analysis and Design*,John Wiley & Sons, 2005.

[12] Kumar Deb, P.; Moyra, T.; Bhowmik, P., "Dual band multilayer E-shape microstrip patch antenna for C-band and X-band," in *Signal Processing and Integrated Networks (SPIN), 2015 2nd International Conference on* , vol., no., pp.30-34, 19-20 Feb. 2015.

[13] Tomas Zalabsky, Pavel Bezousek, David Matousek *"Patch Antenna Array for X-band FMCW Sensor"* .The described research was supported by the Internal Grant Agency of University of Pardubice, the project No. SGSFEI_2015004 by the Technology Agency of the Czech Republic research project No. Ta 0301548.

[14] Yisheng He; Arichandran, K., "The design of X band dual feed aperture coupled patch antenna for microsatellites," in *Geoscience and Remote Sensing Symposium, 2001. IGARSS '01. IEEE 2001 International* , vol.6, no., pp.2784-2786 vol.6, 2001