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Design and Analysis of a tuned circular patch antenna for satellite communication application in C band

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Abstract: In this paper a novel design approach of a probe feed circular microstrip patch antenna with four tuning arms on the radiation element for the dual-frequency operation is proposed. The cavity model is used for the parameter computation of the antenna. The circular antenna resonates at 4 GHz and 5.8 GHz which enables it to operate in standard C band which is used by communication satellites. TM110 is the dominant mode for this proposed antenna. The designed antenna provides 11 % bandwidth at 5.8 GHz (200 MHz) and the S[1 1] value is -42 dB whereas it provides 5.75 % bandwidth at 4 GHz (700 MHz) and the S[1 1] value is -16 dB. The absolute values of VSWR at 4 GHz is reported as 1.06 and at 5.8 Ghz is 0.08. A further modification is done on the proposed patch and a comparison of the designs are reported.

Keywords: Coaxial feed , circular microstrip patch antenna, C band , tuning arms, satellite communication.

I. INTRODUCTION

With the rapid advancement in the field of Satellite communications and wireless communication the demand of Microstrip patch antenna is also increased due to its compact , low profile structure. K.L Wong has discussed different types of Microstrip patch antennas in his book " compact and broadband microstrip antennas" New York: J.Wiley and sons,2002[4]. Das and Das has also cited many of such designs and process where multiband operations can be achieved [1]. Hala Elsadek, Member, IEEE, and Dalia M. Nashaat has discussed a V shaped patch antenna which gives multiband and UWB operation at the same time.[5].Dr. Ramesh Garg has discussed many theoretical aspects of bandwidth increment and multi frequency operations in circular patch antenna along with simulations[2].

The proposed antenna in this paper is designed using Ansoft HFSS 14 which works on the Finite Element Method. First the antenna is analyzed using cavity model then by using this software a model is designed to get the desired dual frequency response. The designed antenna resonates at two frequencies 4Ghz and 5.8 Ghz which are the Receiving and Transmitting Frequencies of standard C band respectively[7]

II. ANTENNA CONFIGURATION

The geometry of the proposed antenna is as shown in Fig.1. Here Two semicircular slots were cut on the radiating circular patch. Then 4 tuning arms are added to achieve better frequency matching and a good agreement between the S[11] and Bandwidth of the antenna.

The resonant frequency of excitation can be given as [3]

$$f_r = \frac{x'_{nm} \times c}{2\pi a\sqrt{\varepsilon_r}} \qquad \text{.................(1)}$$

for a physical radius = *a*. After considering the fringing extension modified resonance frequency becomes

$$f_{rTM_{nm0}} = \frac{x'_{nm} \times c}{2\pi a_{eff}\sqrt{\varepsilon_r}} \qquad \text{...........(2)}$$

where m=0,1,2,3,………number of half cycle variation along , and n=1,2,3,…… number of half cycle variation along ϕ. ρ Here the fringing effect is taken into account by using an effective radius [3]

$$a_{eff} = a[1 + \frac{2h}{\pi a \varepsilon_r}\left\{\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right\}]^{0.5} \qquad \text{.... (3)}$$

Here in the proposed antenna the circular patch radius is 19.4 mm. FR_4 epoxy is the dielectric material used here with dielectric constant ε_r = 4.4. and the substrate height (h) is 1.6 mm Here, Lp and Wp are the length and width of the connecting rectangular slot which gives the patch a phi shape. The values are Lp= 30.8 mm and Wp = 5mm . A , B , C , D are the tuning arms which were added to the patch to obtain best matching and agreement between return loss and Bandwidth. The all over with of the circular ring is 5 mm. The dimension of tuning arm A is

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length 5 mm(L1) and width 5 mm (W1); the length(L2) and width(W2) of tuning arm B are 5 mm both . W3 = 3.6 mm and L3 = 5 mm which are the width and length of the tuning arm C . The length (L4) of tuning arm D is 5 mm and width (W4) is 3.6 mm . The positions of the arms with respect to each other is decided through trial and error method. The distance between two tuning arms in each side is maintained as 4 mm.

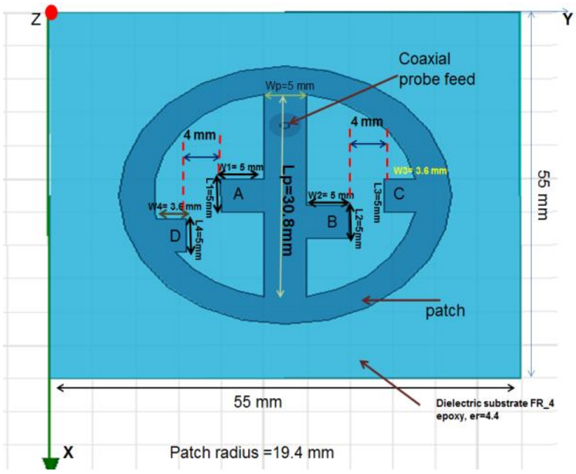

Fig1 :Design 1 : Configuration of the proposed tuned Circular Microstrip Patch Antenna with four tuning arms

Though after varying the distance between the tuning arms of each side pair (Fig.2) the results changes including the change in bandwidth.

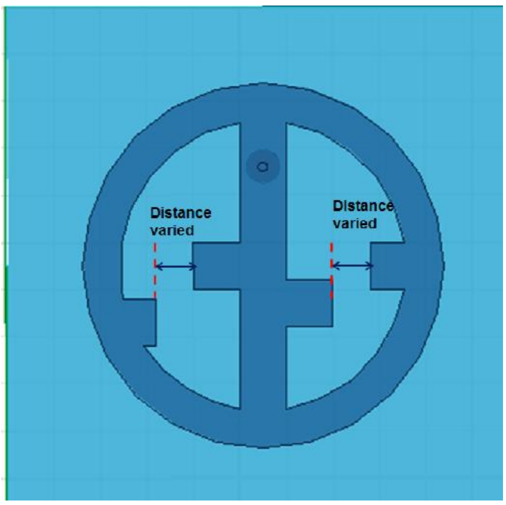

Fig 2 . The distance between the two tuning arms in each side is varied by 0.5 mm keeping all other parameters same.

III.RESULTS AND DISCUSSION

First let us optimised a design by the below mentioned comparative study between the different designs. After comparing the results obtained from different designs, design 1 is been chosen as the optimised one. Below is a comparative study between the designs is given. The comparison is done based on the variation between the distance of two tuning arms on each side.

Table 1 : Discussions on Results of the optimised design (design1)

Distance between two tuning arms on each side	Resonant Frequency	S11	VSWR (abs)	Bandwidth	Remarks
4 mm	4 GHz 5.5 GHz 5.8 GHz	-16 dB -27 dB -42 dB	1.2 0.89 0.6	5.75 % 11%	Best matching along with wide bandwidth
4.5 mm	4.04 GHz 5.5 GHz 5.9 GHz	-14.8 dB -35 dB -27 dB	1.6 0.78 0.9	5.6 % 11 %	Though bandwidth response is good but the matching of 4.04 GHz frequency is very poor
5 mm	4.04 GHz 5.5 GHz 6.09 GHz	-14 dB -27 dB -35 dB	1.6 0.9 0.8	5.4% 4.36 % 5.4 %	Matching of 4.04 is poor. Bandwidth is distorted and poor
5.5 mm	4.04 GHz 5.5 GHz 6.09 GHz	-15 dB -19 dB -21 dB	1.3 1.2 1	5.44 % 3.7 % 6.5 %	Bandwidth is not acceptable

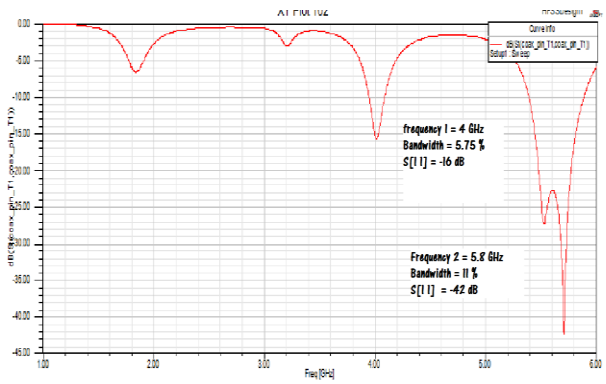

Fig.3 : S[11] in dB vs Frequency in GHz for design1

Table 2 : The report obtained from the simulation of Frequency Vs S [1 1] of Design 1

	Resonant Frequency 1 = 4 GHz	Resonant Frequency 2 = 5.5 GHz & 5.8 GHz
S [1 1]	-16 dB	-42 dB
Bandwidth	5.75 %	11 %
VSWR	1.2	0.08

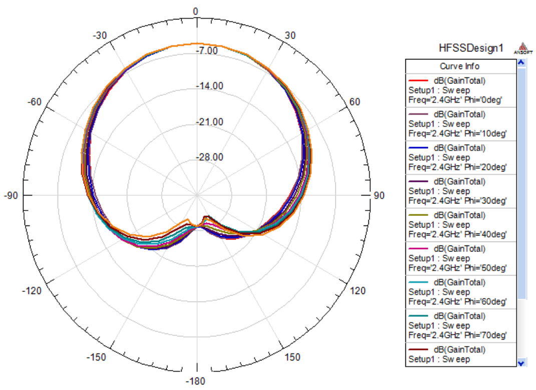

Fig. 5 : Radiation pattern for Design 1

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After comparing the radiation patterns it is seen that all are identical. So we observed the surface current distribution on the optimised patch design i.e design 1

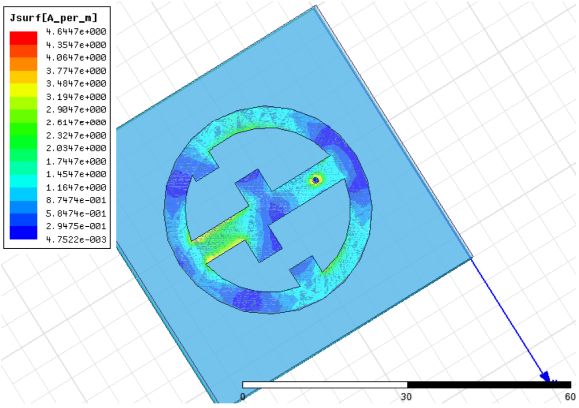

Fig 6 : Surface current distribution on the radiating patch (magnitude)

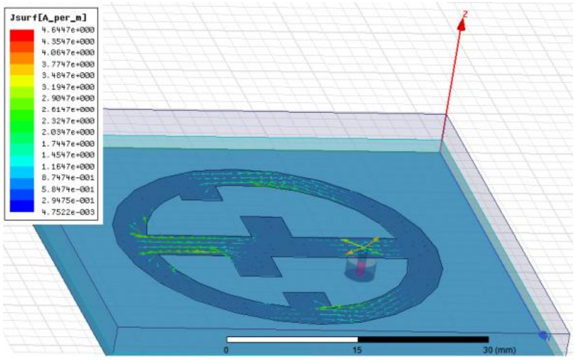

Fig 7 : Surface current distribution on the radiating patch (vector)

The hardware simulation :

Fig. 8 : The hardware design of the proposed antenna

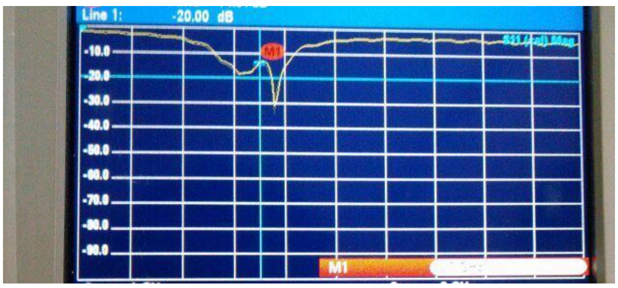

Fig 9 : R & S antenna analyser response of hardware Measurement

IV. CONCLUSION

A multi frequency and wideband circular patch antenna is designed and investigated in this paper. Due to little loss in the system which is not taken into account in the simulation and modeling (the losses occurred due to little human error) the hardware result did not match exactly point to point but they were in good agreement which was shown in Fig 9. The circular patch antenna is embedded with 4 tuning arms to achieve better matching .

The study revealed that just by adjusting the tuning arm positions and distance between them the result can be altered. To prove this a comparison study between design 1 and design 2 is being provided here. In the designs the distance between the two tuning arms are varied by 0.5mm and it was observed that the S[1 1] parameter changes to a great extent though the radiation pattern and the surface current distribution remains identical.

Hence just by altering the tuning arm positions the resonant frequency of the antenna can be configured. After comparing the designs, design 1 was optimized . It gave proper resonance at 4 GHz and 5.8 GHz , the standard C band transmitting and receiving frequency with a higher bandwidth of 11 %. The size of the tuning arms can be changed to obtain higher bandwidth response. So the proposed antenna can well be used in Satellite communication applications

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Annapurna Das obtained M.Sc. degree in physics from University of Calcutta, M.Tech degree in Microwave Electronics and Ph.D degree in Electrical Engineering from the University of Delhi. She worked in the Department of ECE, Anna University during 1985-2007 as Professor. Presently she is Director of GNIT, Kolkata. She is the author of Engineering Text Book “Microwave Engineering”, published by Mc-Graw Hill, USA, Singapore and India and co-author of the text book “Antenna and Propagation”, and published by Mc-Graw Hill Education.She is the life member of Society of EMC Engineers (India) and ISTE. Her current interests are microwaves, EMI/EMC and Microstrip Antenna.