Design of S-band and C-band Modified Plus Shaped Slotted PIFA Antenna for Radar Application

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Abstract— **The objective of this paper is to design a modified plus shaped slotted PIFA antenna which operates in S-band and C-band. This antenna focused on the low cost, minimal weight and low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. These antennas have frequency ranges in IEEE bands. S band cover the frequencies of 2GHz to 4GHz. C band cover the frequencies of 4GHz to 8GHz. These antenna simulations performed by using CADFEKO V5.5. Simulation results are presented in terms of Resonant Frequency Return Loss, VSWR, Radiation Pattern, antenna Gain and Directivity. PIFA antennas have wide range of applications, however in this paper following applications like Medium power Radar[MPR], Hughes Air Defense Radar[HADR], Airfield Surveillance Radar, Tracking, Navigation, Weather Radar, Ship Radar and Space Communication are present.**

Keywords— FEKO, PIFA, HADR, MPR, C-Band, S-Band, Radar.

I. INTRODUCTION

In high performance applications like Aircraft, Radar Systems, Space Communication Systems, missile, Mobile Radio and Wireless Communication Systems size, cost, weight, ease of fabrication, ease of installation offer constraints. PIFA antenna can perform well in Microwave applications as particular of interest like Space Communication and Radar Communication in S-Band and C-Band.

In radar and space communication applications patch antennas have attracted much interest due to their compactness and dual-frequency operation. They are inexpensive to fabricate, light in weight, and can be made conformable with planar and non planar surfaces.

By cutting a slot on the rectangular patch, both compactness and dual frequency operation can be achieved . By loading a pair of narrow slots parallel and close to the radiating edges of a bow-tie patch dual-frequency operation with tunable frequency-ratio can be achieved .A circularly polarized, dual-frequency, slotted square patch with probe feeding mechanism is reported to operate as the telemetry, telecommand and control (TT&C) antenna for satellite spacecrafts.

S-band radar is the atmospheric attenuation is higher than in D-Band. Radar sets need a considerably higher transmitting power than in lower frequency ranges to achieve a good maximum range. As example given the Medium Power Radar (MPR) with a pulse power of up to 20 MW. In this frequency range the influence of weather conditions is higher than in D-band. Therefore a couple of weather radars work in E/F-Band, but more in sub tropic and tropic climatic conditions, because here the radar can see beyond a severe storm. Special Airport Surveillance Radars (ASR) are used at airports to detect and display the position of aircraft in the terminal area with a medium range up to 50…60 NM (≈100 km). An ASR detects aircraft position and weather conditions in the vicinity of civilian and military airfields. The designator S-Band (contrary to L-Band) is good as mnemonic rhyme as smaller antenna or shorter range.

C-band radar are some specialized Radar sets developed for this frequency band (300 MHz to1 GHz). It is a good frequency for the operation of radars for the detection and tracking of satellites and ballistic missiles over a long range. These radars operate for early warning and target acquisition like the surveillance radar for the Medium Extended Air Defense System (MEADS). Some weather radar-applications e.g. wind profilers work with these frequencies because the electromagnetic waves are very low affected by clouds and rain. The new technology of Ultra wideband (UWB) Radars uses all frequencies from A- to C-Band. UWB- radars transmit very low pulses in all frequencies simultaneously. They are used for technically material examination and as Ground Penetrating Radar (GPR) for archaeological explorations.

II. ANTENNA DESIGN

The geometry of the proposed S-band and C-band modified plus shaped PIFA antenna with slit in ground is shown in Fig. 1.The total antenna size of 60x50 mm and patch size of antenna is 35x25 mm This basic patch is designed on a FR4 substrate of thickness 1.4 mm, relative permittivity(ε_r) of 3.38 and loss factor(tan δ) of 2.4e-9.

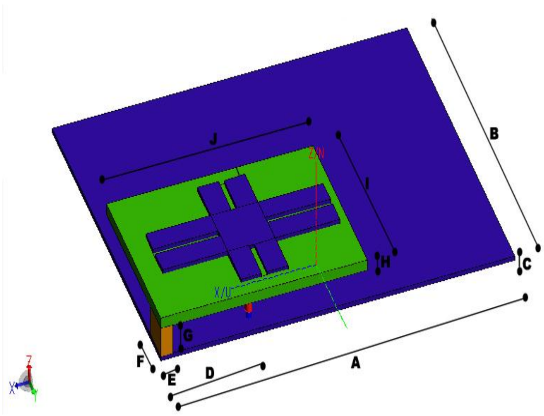
The calculation of the initial physical parameters of PIFA antenna pattern is presented here. This equation has been used to determine the all necessary dimensions of the PIFA antenna.

Patch width: $$W = \frac{1}{2f(\sqrt{\varepsilon_0\mu_0})}\sqrt{\frac{2}{\varepsilon+1}}$$

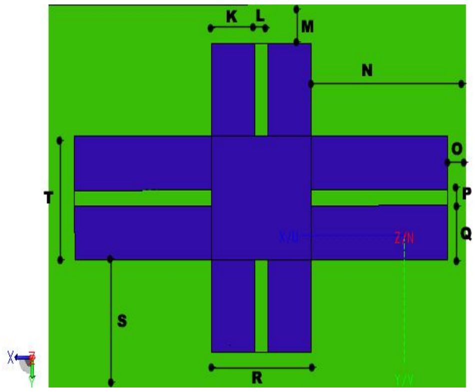
Patch length extension: $$\Delta L = 0.142h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}+0.258)\left(\frac{W}{h}+0.8\right)}$$

Patch length: $$L = \left(\frac{1}{2f(\sqrt{\varepsilon_{eff}}\sqrt{\varepsilon_0\mu_0})}\right) - 2\Delta L$$

Effective patch length: $$Le = L + 2\Delta L$$



(a)



(b)

Fig. 1. GEOMETRY OF PROPOSED ANTENNA. (a) 3D VIEW
(b) TOP VIEW

The optimal dimensions of this proposed dual band antenna are listed in Table 1.

TABLE 1: THE GEOMETRIC PARAMETERS

Antenna Parameters	**A**	**B**	**C**	**D**	**E**	**F**
Values (mm)	60	50	0.5	17	2	5
Antenna Parameters	**G**	**H**	**I**	**J**	**K**	**L**
Values (mm)	3.5	1.4	25	35	3.5	1
Antenna Parameters	**M**	**N**	**O**	**P**	**Q**	**R**
Values (mm)	2.5	13.5	2.5	1	3.5	8
Antenna Parameters	**S**	**T**				
Values (mm)	8	8				

A modified plus shaped is embedded on the centre of the substrate and fed through a matching 50Ω probe feed. A square ground layer of 60x50 mm is connected to patch through a stub, and shorting pin placed on the lower left patch corner. An industry-standard simulation tool CADFEKO has been used to model and simulate the proposed antenna.

III. RESULTS AND DISCUSSIONS

This section describes the simulation results of proposed S-Band and C-Band PIFA antenna. Discussion on the results is also provided in this section. The resonant frequencies observed according to the 3 dB bandwidth criteria.

The Fig.2 shows the simulation results of S-Band. The Radar resonates at the three frequency bands one is at 2.6GHz with a return loss of -9.84dB, second at 3.2GHz with return loss -5.90dB and third at 3.97GHz with return loss -11.07dB.

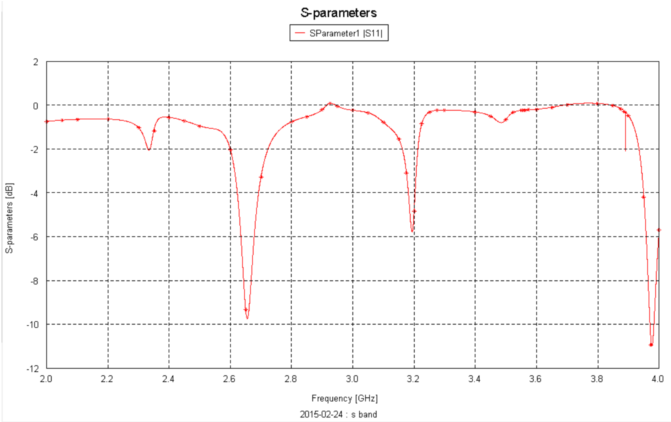


Fig. 2. S-BAND RETURN LOSS.

The Fig.3 shows the simulation results of C-Band. The Radar resonates at the three frequency bands one is at 4.03GHz with a return loss of -5.06dB, second at 6.21GHz with return loss -5.12dB and third at 7.65GHz with return loss -24.21dB.

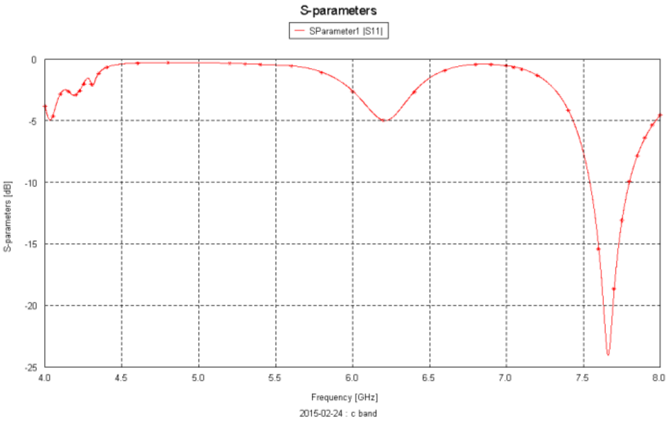


Fig. 3. C-BAND RETURN LOSS.

The Smith Chart is plotted on the complex reflection coefficient plane in two dimensions and is scaled in normalized impedance (the most common), normalized admittance or both, using different colors to distinguish between them. These are often known as the Z, Y and YZ Smith Charts respectively. Normalized scaling allows the Smith Chart to be used for problems involving any characteristic impedance or system impedance, although by far the most commonly used is 50 ohms. The Smith Chart plot represents that how the antenna impedance varies with frequency. Smith Chart for S-Band and C-Band is shown in Fig.4 and Fig.5.

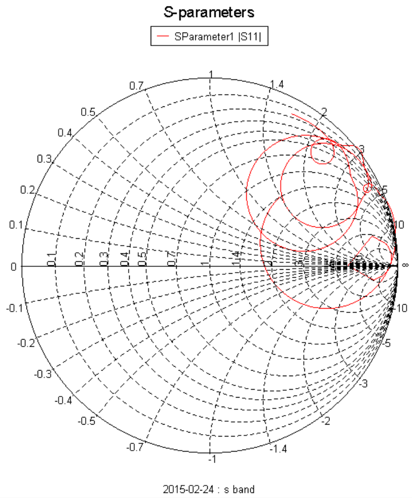


Fig. 4. S-BAND SMITH CHART.

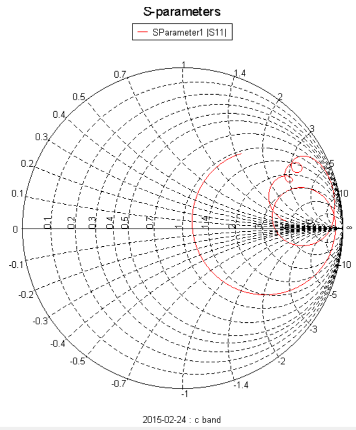


Fig. 5. C-BAND SMITH CHART.

VSWR (Voltage Standing Wave Ratio),is a measure of how efficiently radio-frequency power is transmitted from a power source, through a transmission line, into a load. The resulting pattern is an oscillating pattern is obtained as Fig. 6 and Fig .7.

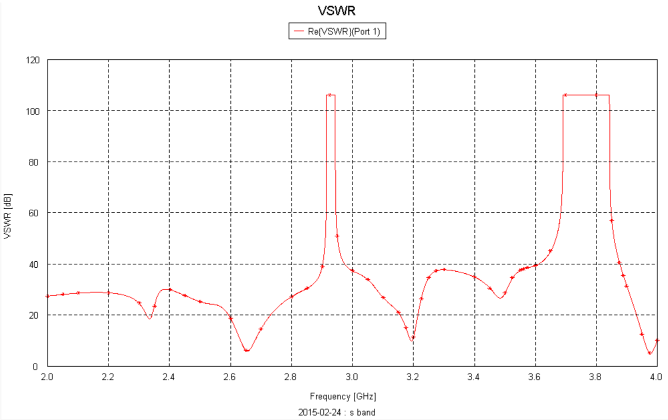


Fig. 6. S-BAND VSWR

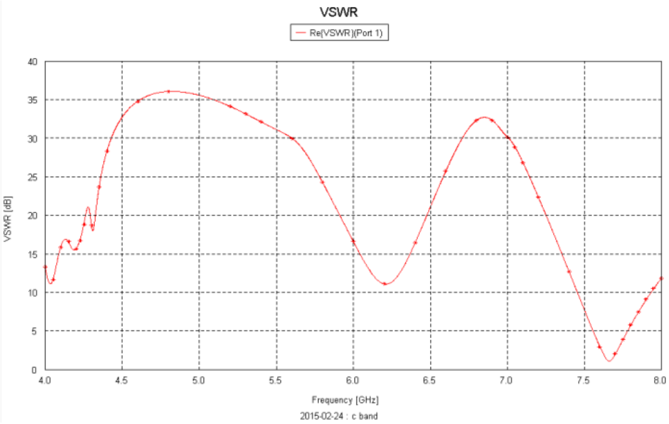
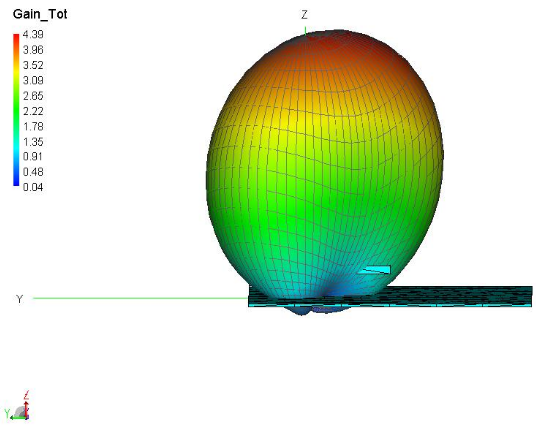
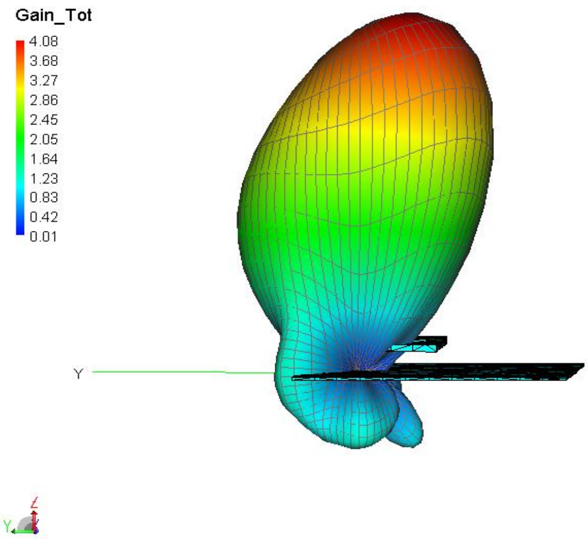


Fig. 7. C-BAND VSWR

The ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. Fig.8 and Fig.9 shows the antenna gain and Directivity in 3D patterns. The gain and Directivity of proposed S-Band and C-Band slotted antenna above 3dB is acceptable.

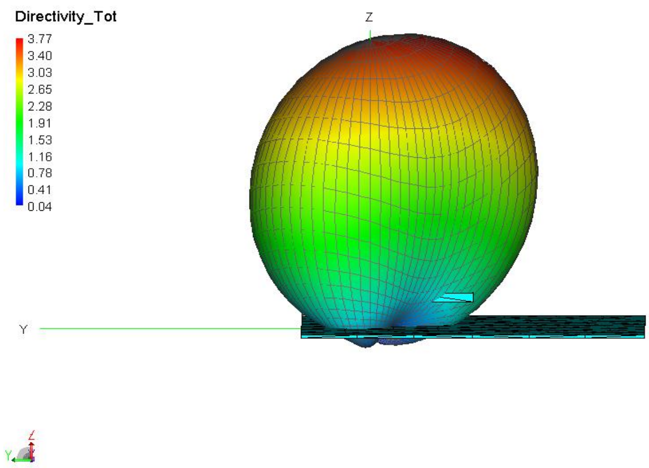


(a)

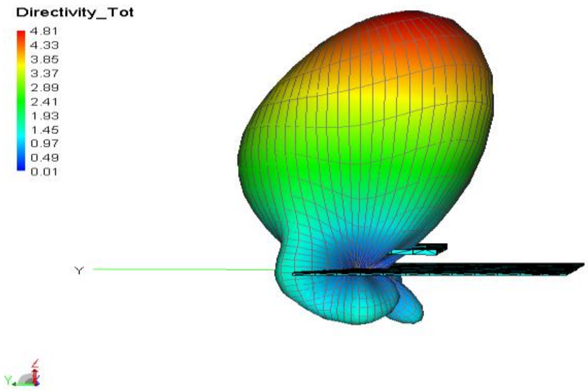


(b)

Fig. 8. ANTENNA GAIN (a) S-BAND (b) C-BAND



(a)



(b)

Fig. 9. ANTENNA DIRCTIVITY (a) S-BAND (b) C-BAND

Table.2 and Table.3 shows the Return loss, bandwidth, Gain and Directivity values of S-band and C-band antenna.

TABLE 2: S-BAND Simulated return loss, bandwidth, Gain and Directivity

Band	S-Band		
Resonating Frequency (GHz)	2.66	3.19	3.97
Bandwidth (GHz)	0.100	0.030	0.060
Return Loss (dB)	-9.84	-5.90	-11.07
Gain(dB)	-3.9	8.0	5.6
	6.4(Overall S-Band)		
Directivity(dB)	5.6	6.3	6.2
	5.8(Overall S-Band)		

TABLE 3: S-BAND Simulated return loss, bandwidth, Gain and Directivity

Band	C-Band		
Resonating Frequency (GHz)	4.03	6.21	7.65
Bandwidth (GHz)	0.090	0.340	0.660
Return Loss (dB)	-5.06	-5.12	-24.21
Gain(dB)	3.7	6.5	4.4
	6.1(Overall C-Band)		
Directivity(dB)	6.9	7.2	5.4
	6.8(Overall C-Band)		

IV. CONCLUSION

The S-band and C-Band Modified plus shaped slotted PIFA antenna has been designed and simulated by CADFEKO. The PIFA antenna has been designed to meet the RADAR applications. Simulation results for both S-band and C-Band is achieved. The radiation pattern shows an omnidirectional pattern.The antenna gain of S-Band and C-band is 6.4 dB and 6.9 dB respectively. The performance properties are analyzed and the proposed antenna works well at the required S- band and C-band.

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