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X-Band Dual Polarized Rectangular Patch Antenna Design For Microwave Imaging Application

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Abstract:-*In our paper rectangular patch antenna has been designed for microwave imaging application. Patch antenna is a linearly polarized antenna, with single polarization echoes from the images are not adequate to reproduce the 3D image effectively. Hence dual polarization is required for imaging application.*

Key words: Edge feed, Gap coupled feed, Microstrip antenna, Gain, Bandwidth.

1. Introduction

In present trends microwave imaging technique is widely used for capturing terrain images and other objects on ground. Microwave imaging is superior than other imaging techniques like optical, laser imaging, etc techniques because it can work day & night and in all weather conditions [9]. It can be for satellite platform for geographical images or it can be placed in UAVs or Aircrafts for military application to obtain images of suspicious objects on earth like tanks, bunkers, etc. Synthetic aperture radar (SAR) use microwave imaging technique too.

2. Selection of antenna element

Table.1 Comparisons between different types of antenna elements

Antenna Type	Advantages	Disadvantages
Waveguide or Cavity back antenna	i. Moderate to higher band width ii. Higher power handling	i. Lack of performance repeatability ii. Bulky with higher weight
PCB antenna	i. Good performance above UHF band ii. Low weight and ease of implementation iii. Performance repeatability in production	i. Difficult to design small and efficient PCB antennas below UHF band ii. 60% to80% Efficiency iii. Lower power handling

Antennas can be broadly classified into various categories depending on our requirement

I. Waveguide or cavity backed antenna.

II. Planar or printed element antenna, ex: - patch antenna.

From various antenna elements we can select the following types which can meet the desired

requirements and suitable for various environmental conditions like heavy rain, smog etc [7&11].,

From list of design requirements, antenna element need to be selected which will be suitable for imaging application. The design requirements are Antenna Gain, Bandwidth, directivity, polarization, beam width, power handling and etc[1&10]. Since most of imaging applications are space borne or Airborne, size with appropriate performance are the most important factors when choosing an antenna. From the above comparisons we can conclude that for X-band miniaturized and low weight antenna, PCB based (Patch) antenna can be right choice.

3. Characteristics of substrate materials

S.no	Substrate material	Relative permittivity (ε_r)	Loss tangent
1	Duroid 5880	2.2	0.0009
2	Duroid 6010	10.2	0.0023
3	Copper	1	0
4	Teflon	2.1	0.001

4. Design analysis

i. Width of the patch [1]

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

ii. Effective dielectric constant

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{[1 + 12\frac{h}{w}]}} \qquad (2)$$

iii. Extended incremental length of a patch

$$\frac{\Delta L}{h} = (0.412) \frac{(\varepsilon_{eff} + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{w}{h} + 0.8)} \qquad (3)$$

iv. Actual length of the patch

$$L = \frac{C}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta L \qquad (4)$$

v. Effective length

$$Le = L + 2\Delta L \qquad (5)$$

vi. Calculation of inset distance y_0

$$R_{in}(y = 0) = \frac{1}{2(G_1 \pm G_{12})} \cos^2(\frac{\pi}{L} y_0) \qquad (6)$$

vii. Inset gap [4]

$$g = \frac{v_0}{\sqrt{2 \varepsilon_{eff}}} \frac{4.65 \times 10^{-12}}{f} \qquad (7)$$

5. Implementation of dual polarized antenna

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i. Rectangular patch antenna is being selected to obtain omni-directional radiation pattern with higher cross polarization level [5&6].

ii. Common radiating patch is used for both polarizations.

iii. For vertical polarization, Edge feed patch antenna is used to obtain better bandwidth [12].

iv. For Horizontal polarization, Aperture Coupled patch is used to obtain lower cross polarization level w.r.t Vertical [8].

6. Schematic of Dual polarized antenna

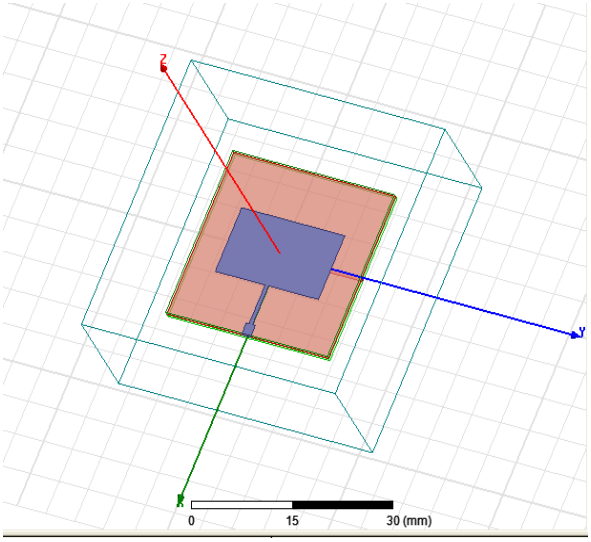

Fig.1: Dual polarized rectangular patch antenna

7. Result optimizations

Table.2 Final results after optimization

S.no	Lp	Wp	Ls	Ws	F	B.W	Gain	S_{11}
1	10.2	8.2	8.7	2	9.1	212	-17	8.9
2	9.8	24.8	8.7	2	9.4	173	-15	8.9
3	9.8	24.8	8.9	2	9.4	174	-12	8.9

Lp, Wp, Ls, Ws – units are in mm

F – GHz, B.W- MHz, Gain & S_{11} - dB.

8. Simulation Results

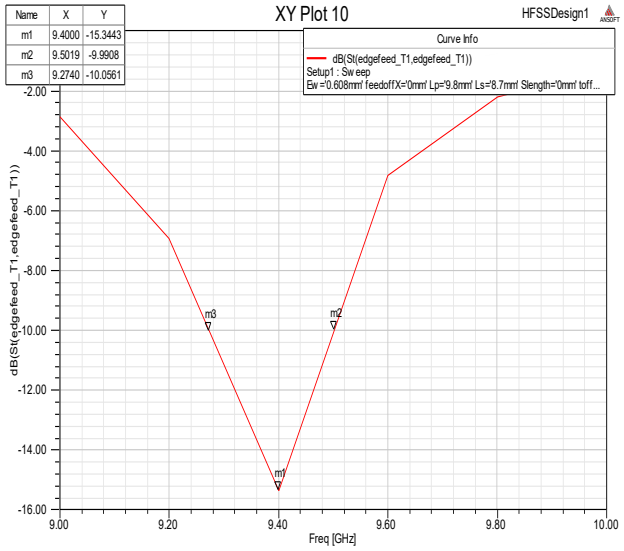

Fig.2: Return loss

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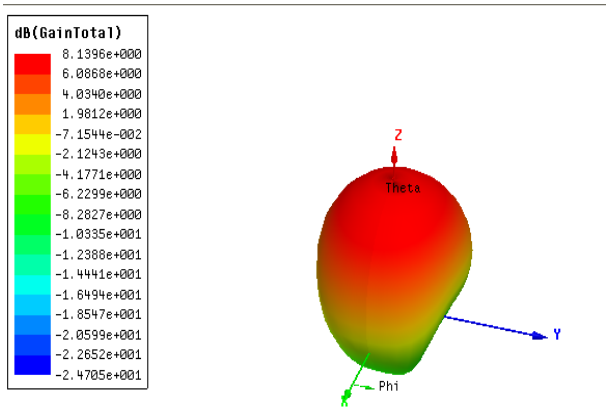

Fig.3: Gain total

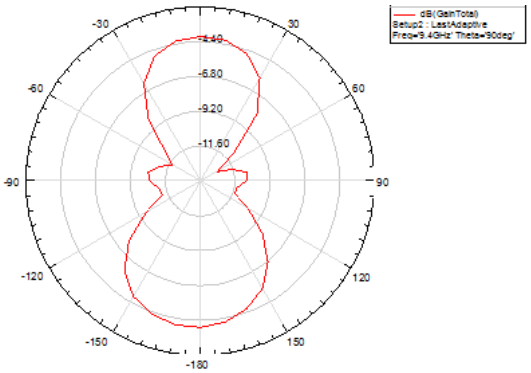

Fig.4: Radiation pattern when θ constant

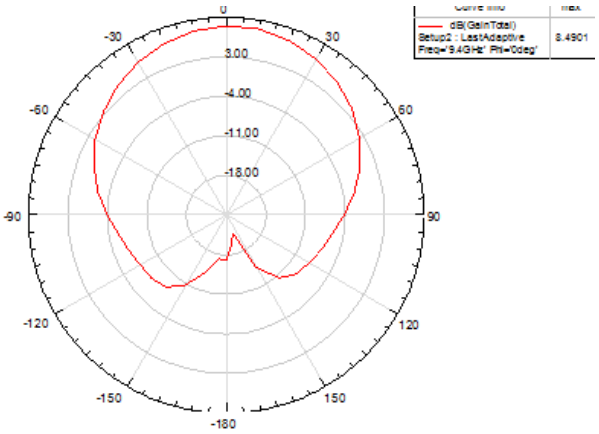

Fig.5: Radiation pattern when ϕ constant

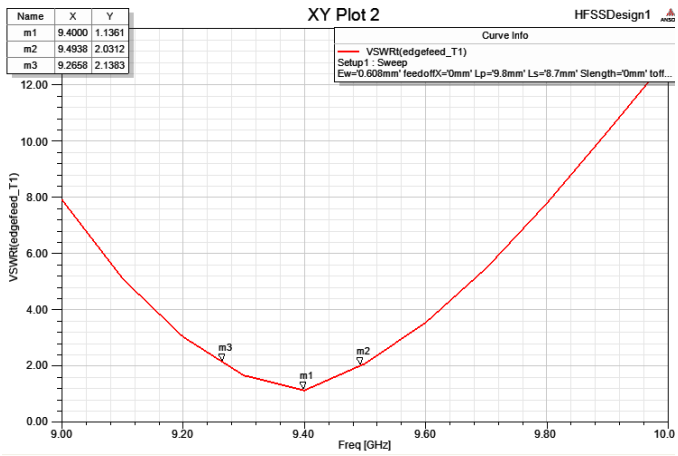

Fig.6: VSWR

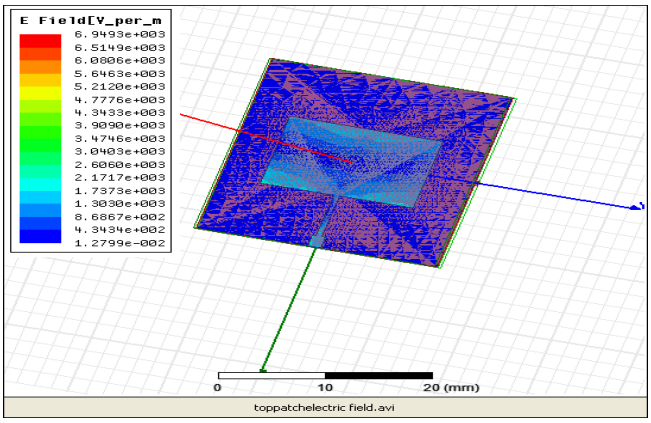

Fig.7: E-field variation

9. Conclusion

Antenna element is a critical module in the imaging radar which affects the overall performance of the radar. Dual polarization antenna with high gain, wide bandwidth, low weight and suitable for airborne application were the scope of the project and have been achieved successfully. Never the less, this dual polarization antenna element suitable for any type of linear and planar array and based on gain requirement the antenna array size can be decided.

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