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Wideband Cavity Backed Patch Antenna for Air Surveilance Radar Application

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Abstract— **This paper describes a compact rectangular patch antenna design for achieving the required bandwidth. The antenna is a probe fed micro strip antenna printed on a RT Duroid 5880 layer (Ɛr=2.2,thickness=1.6 mm) enclosed in a cavity. In the design process, the effect of cavity on the impedance bandwidth of the antenna is first studied and then an additional loading to cavity structure is added such that it resonates at the required frequency band of interest. The antenna is working for 400 MHz bandwidth (>12%) with return loss <-10 dB in S-band and with an antenna element gain of more than 7.2 dB. This design is simulated in FEM based 3D-EM simulator HFSS.**

Keywords—Cavity patch antenna, probe feed , patches, Loading.

I. INTRODUCTION

Micro strip antennas are used for numerous applications because of advantages like low profile, ease of fabrication, low weight etc., But as these antennas are resonant they are limited in bandwidth. Various techniques are available to improve the bandwidth both impedance bandwidth and pattern bandwidth. These techniques include different feed techniques, stacked patches, adding parasitic ,etc.,

It is shown that bandwidth can be increased to 60% by using special techniques. Another basic advantage of micro strip patch antenna is that dual frequency operation is easily achieved and if the resonances are brought closer to each other, these resonance merge to give a wider bandwidth.

In this paper, design is carried out by using a cavity backed probe fed rectangular patch antenna. Cavity backed patch antennas are widely used in today's applications as they possess inherent advantages like reduced sizes, suppressed surface waves and hence low mutual coupling in array configurations. But adding cavity to a patch antenna limits the bandwidth as cavities are considered to be resonant structures. Micro strip patch with loaded cavity are used to characterize and improve the bandwidth for the required frequency of operation.

II. DESIGN AND WORKING PRINCIPLE

The antenna uses three different configurations namely probe feeding and cavity backing and loading. Probe feeding is used in the patch geometry as feeding in presence of cavity is relative easy and also coupling to the patch is better because of direct transfer of energy. The antenna configuration is shown below

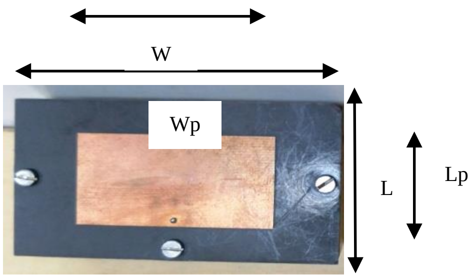

Fig. 1. Cavity patch antenna configuration (top).

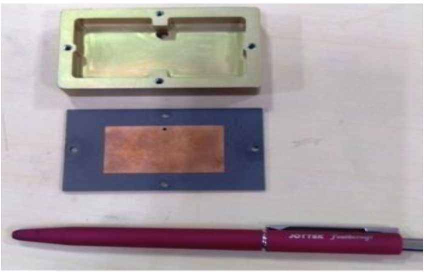

Fig.2.Cavity patch antenna configuration (sideview)

Fig. 3. Cavity patch antenna configuration (Top view)

W=68.4mm; Wp=41.1mm; L=39.3mm; Lp=22.6mm; D=9.8mm ; Depth of cavity Dc=7.6mm ; Position of probe pin from edge of patch is xo=1.7mm;

The coupling of energy to probe fed antenna is given by

$$\boldsymbol{Coupling} \quad \alpha\, \boldsymbol{Cos}\left(\frac{\pi * x_0}{L_p}\right) \text{.............(1)}$$

Effective dielectric constant for different layers is calculated using [1]:

$$\boldsymbol{\varepsilon_r'} = \frac{2\varepsilon r_e - 1 + A}{1 + A} \text{...................................(2)}$$

h- denotes the height of patch.

$$\mathbf{A} = \left(\mathbf{1} + \frac{\mathbf{12}h}{\mathbf{W_p}}\right)^{-1/2} \text{...(3)}$$

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Design steps are as follows:

1. Calculation of resonant frequency assuming dominant TM10 mode :

$$f_r = \left(c/_{2L_p}\right) * \left(1/_{(1+\Delta)}\right) * \left(\varepsilon_r'/_{\sqrt{\varepsilon r_e(L_{p1})\, \varepsilon r_e(W_{p1})}}\right) \text{ ....(4)}$$

where L, Δ empirical correction factor εr_e are as per [1].(Ch.4,page:267).

2. The effect of cavity on patch resonance is given by [3]. It is observed that effective dielectric constant changes due to the proximity of cavity walls on the patch which in turn changes the patch resonance. Initial design is carried without a cavity and resonant length (L_{p1}) is determined as per resonant frequency (f_r) . Now cavity is introduced and a shift in the patch resonance to lower frequency is observed. Hence the patch resonant frequency(fr) is re-optimized with new length (L_p). Since effective dielectric constant is increase s by an amount equal to Eq.5 the length (L_p) less than (L_{p1}).

$$\varepsilon_{efff}(cavity) = K * \varepsilon_{efff} \text{ ....(5)}$$

K is determined by using [3].

3. Coupling between the patch and loaded cavity is best understood from the electric field distributions on different surface planes as shown in (fig.4, fig.5 and fig. 6).

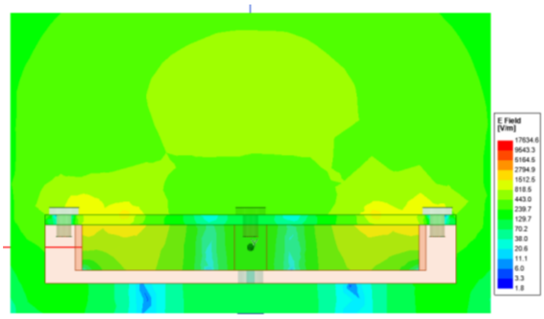

Fig. 4. Electric Field pattern in(XZ- Plane)

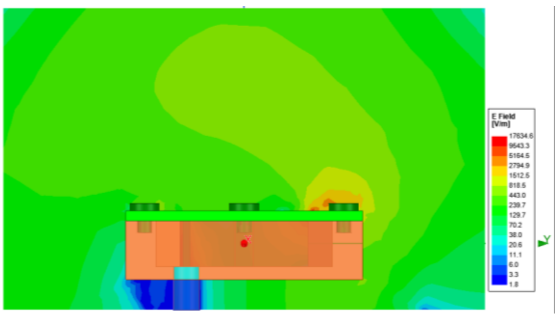

Fig. 5. Electric Field pattern in(YZ- Plane)

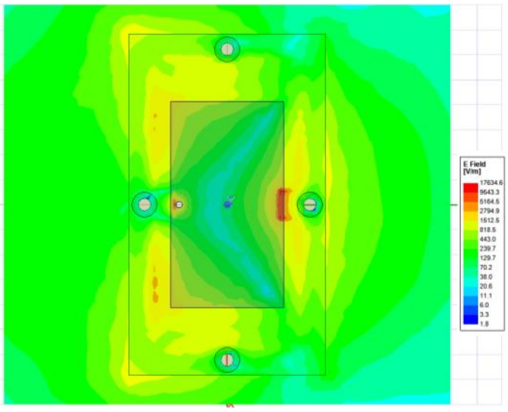

Fig. 6. Electric Field pattern in(XY- Plane)

Energy coupling between the patch and cavity is strongly influenced by the loading structures in cavity. The structure is simulated and optimized in 3D EM simulator ANSYS HFSS.

III. RESULTS AND DISCUSSIONS

The antenna is optimized in the frequency range of 3.1 to 3.5 GHz (400 MHz). The fig.7. represents the simulated and measured results of Return loss. The return loss is observed to better than 10 dB over the full bandwidth.

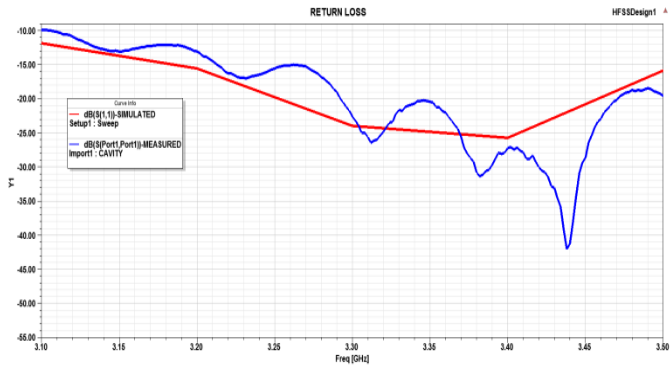

Fig. 7. Simulated & Measured Return loss in dB.

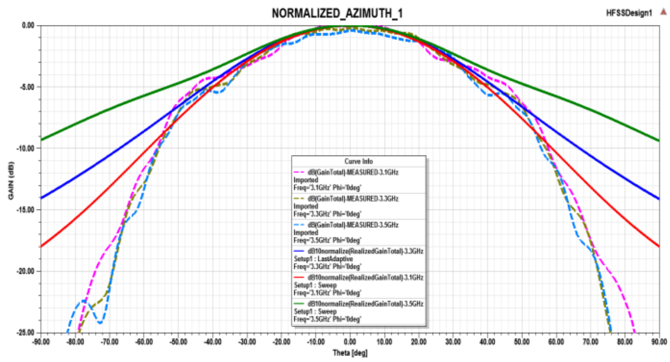

Fig. 8. Simulated & Measured Azimuth Radiation pattern

Measured and simulated Azimuth radiation patterns is shown in fig. 8.The simulated gain is > 7.1 dB and beam width is varying from (60.7 deg. to 70.4 deg.). The measured gain is > 7.2 dB and beam width is varying from (58.4 deg. to 63.8 deg.).

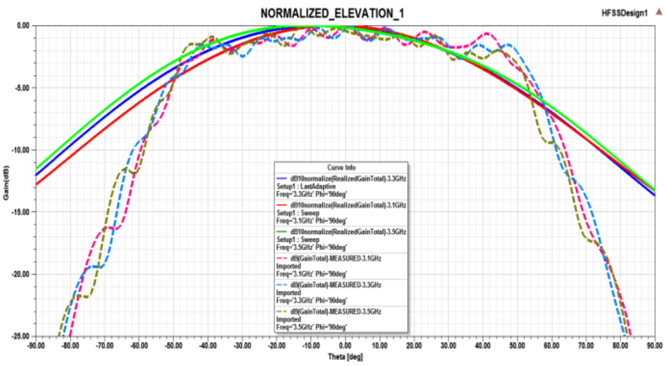

Fig. 9. Simulated & Measured Elevation Radiation patterns

In the above fig. 9 Measured and simulated Elevation radiation patterns is depicted. The simulated gain is > 7.3 dB and beam width is varying from (78.5 deg. to 88.5 deg.). The measured gain is > 7.2 dB and beam width is varying from (95.2 deg. to 98.1 deg.).

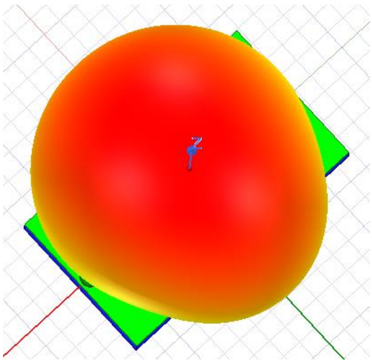

Fig. 10. Simulated 3D radiation pattern

Fig.10 depicts 3d-radiation pattern of compact rectangular patch antenna with loaded cavity .

Comparison	**Measured**	**Simulated**
Az-Gain(dB)	**7.2 - 8.5**	**7.1 - 8.6**
El-Gain(dB)	**7.2 - 8.5**	**7.3 - 8.6**
Az-Beam width(deg.)	**58.4 - 63.8**	**60.7 - 70.4**
El-Beam width(deg.)	**95.2 - 98.1**	**78.5 - 88.5**

TABLE I Simulated/Measured Radiation Pattern Comparison

The measured and simulated antenna parameters are summarized in the table. 1 above.

IV. CONCLUSION

A compact rectangular patch with loaded cavity backed antenna is designed for required bandwidth and detailed study of the effect of cavity on patch resonances is observed. The antenna has a very useful application as a phased array since cavities prevent the surface wave propagation thus eliminating scan blindness. The scan loss can be made lesser by varying the available degrees of freedom. There is close coherence between simulated and measured results.

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